

# **MAINSTREAMING DISASTER RISK REDUCTION IN HOUSING SECTOR**



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Table of Contents

PREFACE ..... i

EXECUTIVE SUMMARY..... iv

1. INTRODUCTION..... 1

    1.1 Statement of The Problem (Impacts of Hazards On The Housing Sector)..... 1

        1.1.1 Earthquake ..... 1

        1.1.2 Flood..... 2

        1.1.3 Cyclone..... 2

        1.1.4 Landslides..... 3

        1.1.5 Building Fires ..... 4

    1.2 Housing..... 5

        1.2.1 Building ..... 5

        1.2.2 Shelter ..... 5

        1.2.3 Housing Sector ..... 6

    1.3 Definition Of Disaster-Related Terms..... 8

    1.4 Disaster Risk Reduction (DRR)..... 8

    1.5 Mainstreaming DRR..... 9

    1.6 Object And Scope of The Guidelines ..... 9

2. Housing Typology In India..... 12

    2.1 House Types As Per Census of India 2001-Housing Series ..... 12

        2.1.1 Wall Types ..... 13

        2.1.2 Roof Types ..... 13

    2.2 Housing In Geo-Climatic Zones of India..... 16

    2.3 The Northern Mountain ..... 17

        2.3.1 Western Himalaya ..... 17

        2.3.2 Central Himalayas: Fig. 2.4..... 18

        2.3.3 Eastern Himalayas..... 18

    2.4 Western Arid Zone And Desert ..... 19

    2.5 Peninsular Coastline ..... 20

        2.5.1 Saurashtra Coastal Area ..... 20

        2.5.2 South Gujarat Coastal Belt ..... 21

        2.5.3 Konkan: The west coast from the city of Mumbai to Goa..... 21

        2.5.4 East Coast ..... 23

    2.6 Central Plateau ..... 25

2.6.1 Peninsular Plateau.....	26
2.7 Peninsular Plateau – Eastern Hills – Bengal & Bihar Hills .....	28
2.7.1 Rural (Purulia district, W. Bengal): Fig. 2.32 .....	28
2.7.2 Shillong Plateau: Detached Block Of Peninsula .....	28
2.8 Gangetic Plain & The Extension Of Its Trough.....	30
2.8.1 Main Indo-Gangetic plain, plains of Punjab.....	30
2.8.2 Gujarat plain .....	30
2.8.3 Assam Valley, Arunachal Pradesh.....	31
2.9 Vulnerability of Various House Types .....	31
2.10 Damage Risk Levels .....	33
2.10.1 Damage Risk Levels For Earthquakes .....	33
2.10.2 Damage Risk Levels For Windstorms.....	34
2.10.3 Damage Risk Levels For Floods.....	34
2.11 The Housing Risk Tables .....	35
2.12 Earthquake-Safe Traditional Construction Practices In India .....	37
3. Framework of Mainstreaming DRR In Housing Sector.....	39
3.1 Guidelines By International Organisations .....	39
3.2 Governance .....	39
3.3 Risk Assessment/Risk Identification .....	40
3.4 Knowledge Management .....	41
3.5 Risk Management And Vulnerability Reduction .....	43
3.6 Disaster Preparedness For Effective Response .....	46
3.7 Disaster Risk Reduction In The Project Cycle Management.....	46
3.8 Awareness, Sensitisation & Capacity Building .....	47
3.9 Targets, indicators and level of attainments.....	49
3.9.1 Institutional Capacity.....	49
3.9.2 Institutional Blockages .....	49
3.9.3 Levels of Achievement.....	52
4 Mainstreaming DRR In Housing Schemes .....	56
4.1 Housing Schemes In India .....	56
4.2 Jawaharlal Nehru National Urban Renewal Mission (JNNURM).....	57
4.2.1 Hazard Proneness of Cities Under JNNURM .....	57
4.2.2 Housing Sector Projects Under JNNURM .....	59
4.2.3 Redevelopment Of Inner (old) City Areas: .....	59



4.2.4 New Buildings Under Various Sectors .....	60
4.2.5 Comments .....	61
4.3 Indira Awas Yojana (IAY) .....	61
4.3.1 Target Group .....	63
4.3.2 Strategy For The Implementation of The Programme.....	63
4.3.3 Unit Assistance For Construction of lay Houses And Upgradation .....	63
4.3.4 Location Of Indira Awas Yojana Dwelling Units .....	64
4.3.5 Appropriate Construction Technologies And Local Materials.....	64
4.3.6 House Design .....	64
4.3.7 Comments .....	65
4.4 Rajiv Awas Yojana (RAY) .....	65
4.4.1 Urban Planning .....	65
4.4.2 Housing & Infrastructure .....	66
4.4.3 Scope of RAY .....	66
4.4.4 Comments .....	67
4.5 Mainstream DRR In Housing Schemes.....	67
4.5.1 General Information of The Project.....	68
4.5.2 Nature / Type of Project.....	68
4.5.3 Hazard Proneness of The Project Site.....	68
4.5.4 Hazards Risk To The Project .....	68
4.5.5 Mitigation/Reduction of Risk: .....	69
4.5.6 Use of the Vulnerability Atlas of India* .....	69
5. Mainstreaming DRR In Housing Projects .....	75
5.1 Uses of Buildings .....	75
5.2 Disaster safety issues in housing projects .....	76
5.3 Working tool for designing & review of buildings .....	76
5.4 Working Tool For Technical Audit .....	78
5.5 DRR in Project Cycle Management.....	78
5.6 Capacity building of officials and professionals.....	80
6. Assessment of Hazard Safety Of Existing Housing.....	87
6.1 Building Types Considered .....	87
6.2 Grades of Damageability.....	87
6.3 Relationship of Seismic Intensity, Building Type & Damage Grade .....	87
6.4 Building attributes enhancing earthquake risk.....	96



6.4.1 Liquefiable condition .....	96
6.4.2 Landslide-prone area .....	96
6.4.3 Irregular buildings .....	96
6.4.4 Falling hazard .....	97
6.4.5 Type Of Foundation Soil .....	97
6.5 Form for Vulnerability Assessment.....	98
6.6 Other Natural Hazards .....	99
6.6.1 Flood Hazard .....	99
6.6.2 Cyclonic Wind Hazards.....	99
6.6.3 Landslides.....	99
6.6.4 Building Fires .....	99
7. Rehabilitation And Retrofitting of Existing Unsafe Buildings.....	101
7.1 Classification of building in India .....	101
7.1.1 Non-engineered building construction .....	101
7.1.2 Engineered Constructions Including Buildings And Infrastructure .....	101
7.1.3 Risk of Damage To Buildings In Earthquake Disaster .....	101
7.2 Prioritisation of Buildings And Structures .....	102
7.3 Need For Restoration And Retrofitting .....	102
7.4 Repair & Restoration - Definitions .....	103
7.4.1 Repair .....	103
7.4.2 Restoration .....	103
7.4.3 Seismic Strengthening/Retrofitting.....	103
7.5 Retrofitting Considerations.....	103
7.5.1 Minimum Seismic Resistance (MSR).....	103
7.5.2 Remaining Useful Life of Building .....	103
7.5.3 Available Seismic Resistance (ASR) .....	104
7.5.4 Factors To Determine Type of Intervention.....	104
7.5.5 Intervention .....	105
7.5.6 Type of intervention .....	105
7.6 Retrofitting of Masonry Buildings .....	106
7.6.1 Masonry Arches.....	106
7.6.2 Reinforcing Large Opening .....	106
7.6.3 Seismic Belts .....	107
7.6.4 Vertical Reinforcing.....	108

7.6.5 Splint And Bandage Strengthening Technique .....	109
7.7 Reinforced concrete buildings .....	110
7.7.1 General principles .....	110
7.7.2 Typical damage in RC buildings columns .....	111
7.7.3 Deficiencies in RC buildings .....	111
7.7.4 Building structural safety survey .....	111
7.7.5 Quality of Construction/Defects .....	112
7.7.6 Design of Retrofitting .....	113
7.8 Rehabilitation of Inner City Areas.....	114
7.8.1 Inner City Areas And Heritage Sites .....	114
7.8.2 Heritage Sites .....	114
7.9 Concluding Remarks.....	115
7.10 Some Retrofitting Details of RC Elements .....	115
8. Seismic Safety Consideration In School Buildings .....	120
8.1 Introduction .....	120
8.2 Damage Observed In Schools In Past Earthquakes .....	120
8.2.1 Various Materials Used In School Buildings In India.....	121
8.2.2 Disaster Risks To Schools .....	121
8.3 Planning And Design of School Buildings .....	123
8.3.1 Design recommendation under Sarve Siksha Abhiyan (SSA) .....	123
8.3.2 Recommendations under National Building Code 2005 .....	124
8.3.3 Planning of school buildings .....	125
8.4 Construction of Civil Works Of Schools (as per SSA Guidelines) .....	126
8.5 Maintenance And Repair.....	126
8.6 State-Level Actions (Suggested).....	126
8.7 Existing schools .....	127
9. Disaster safety of hospitals .....	128
9.1 Structural & non-structural elements .....	128
9.2 What happens during an earthquake? .....	129
9.3 Seismic intensities.....	129
9.4. Importance of non-structural elements safety .....	130
9.5 Reducing "Non-Structural" Hazards In Hospitals .....	132
9.6. Non-Structural Mitigation.....	132
9.6.1 Understanding Earthquakes And Safety Requirements.....	133

9.6.2 Earthquake hazard identification in hospital.....	134
9.6.3 Reducing non-structural hazard.....	134
9.7 Hazard Survey And Prioritisation .....	136
9.8 Implementation of Priorities.....	138
9.9 National Rural Health Mission (2005-2012) .....	139
9.10 Suggestions for mainstreaming DRR.....	140
10 Safety Guidelines For Multistoried & Special Buildings.....	142
10.1 Introduction .....	142
10.2 Causes of The Collapse of RC Frame Buildings And Recommendations.....	142
10.3 Some Important Codal Provisions.....	149
10.3.1 The Earthquake Load .....	149
10.4 Strong Column-Weak Beam Design .....	151
10.5 Seismic Design of Flat Slab Special Structures .....	151
10.6 Concluding Remarks.....	152
11 Implementation of Techno-Legal Regime To Promote DRR In Housing & Building Sector	154
11.1 The Context .....	154
11.2 Existing Technical Legal Framework.....	155
11.3 Lack of Compliance And Laxity In Enforcement of Techno-Legal Measures .....	155
11.4 Zoning Regulations For Flood Hazard .....	156
11.4.1 Prioritisation of Structures In Floodplain Zoning .....	157
11.4.2 Recommended Amendments In Byelaws For Buildings In Flood-Prone Areas	158
11.5 Amendment In Development Control Regulations .....	158
11.5.1 No land shall be used as a site for the construction of building .....	159
11.5.2 Grant or refusal of the permission for development .....	160
11.6 Open spaces.....	161
11.7 Model development control and building regulations including safety.....	161
provisions in rural areas .....	161
11.7.1 Context.....	161
11.7.2 Capacity building of officials and professionals of local authorities .....	162
11.7.3 Scrutiny of Designs And Building Permissions.....	163
12 Techno-Financial Regime .....	165
12.1 Impact of Past Disasters In India .....	165
12.2 Current Practice Of Banks To Fund Construction-Related Projects.....	165



12.2.1	Sanction of Loans .....	165
12.2.2	Disbursement of Loan.....	167
12.3	RBI Guidelines .....	167
12.3.1	Construction Activities Eligible For Bank Credit As Housing Finance .....	167
12.3.2	Advisories Issued By RBI.....	168
12.4	Important Suggestions For Guidelines .....	170
12.4.1	Techno-Financial Regime For Urban And Rural Areas.....	170
12.4.2	Role Of Insurance Sector In DRR .....	171
12.4.3	Self-Contained User-Friendly Guidelines.....	171
12.5	Pro Forma For Assessment of Natural Hazard Impact.....	172
12.5.1	General Information of The Project.....	172
12.5.2	Nature/Type of Project.....	172
12.5.3	Hazard Proneness of The Project.....	173
12.5.4	Hazards Risk To The Project .....	173
12.5.5	Mitigation/Reduction of Risk: .....	173
12.5.6	Relevant References To Standard Codes/Guidelines .....	174
13.	Multi-Hazard-Resistant Construction Of Houses -A Case Study .....	176
13.1	Statement of the problem.....	176
13.2	Approach to multi-hazard safety of new houses .....	176
13.3	House Types Included In Reconstruction Programme.....	176
13.4	Site Soil Conditions .....	181
13.5	Building Materials.....	182
13.6	Provisions For Multi-Hazard Safe Construction .....	183
13.6.1	Considerations For Site Selection.....	183
13.6.2	Safety Provisions Required For Foundation And Plinth .....	183
13.7	Brick walls .....	185
13.7.1	Brick Bonding.....	185
13.7.2	Seismic bands in brick walls .....	186
13.7.3	Openings in brick walls .....	187
13.7.4	Placement of Reinforcement Bars .....	187
13.7.5	Reinforced Concrete Lintels And Slabs .....	187
13.8	Safety Provisions Required For Bamboo Superstructure.....	188
13.8.1	Posts.....	188
13.8.2	Walling Lattice (Wattle And Daub).....	191

13.8.3 Attic-Level Floor (Fig. 13.5).....	191
13.8.4 Pitched Roofs .....	192
13.9 A Few Examples Of Earthquake And Wind-Resistant Bamboo Constructions .....	193
13.9.1 School at Mizoram .....	193
13.9.2 Picnic Hut At Dcs Office Kolasid Mizoram .....	194
14. Checklists For Ensuring Disaster Safety of Building Projects.....	197
14.1 Housing proposals .....	197
14.2 Data To Be Submitted With A Building Project .....	197
14.3 Review Of Building Design.....	197
14.4 Inspection And Technical Audit.....	197
15 The Checklist For Stakeholders .....	209
15.1 Does The Goals Of The Disaster Management Act 2005 Support The Concept Of DRR – And Indicates A National Commitment? .....	209
15.2 Project, Programme & Planning.....	209
15.3 Project Preparation For Submitting The Proposal For Development Permission.....	210
15.4 Taking Cognisance of Correct Information/Data On Hazards, Vulnerabilities, Risks And Capacities To Cope .....	212
15.5 Planning, Design And Construction of Critical (Life Line) Facilities – School And Hospital Buildings .....	213
15.6 Critical Factors For Successfully Integrating DRR In Housing Projects: Responsibility Of Project Owners.....	213
15.6.1 Incorporating Design Checks, Enforcement And Quality Control.....	213
15.6.2 Consultation With Hazard And Construction Experts.....	214
15.6.3 Land-Use Planning And Incorporating Building Codes .....	214
15.6.4 Improving Construction And Implementation Practices .....	214
15.6.5 Guidelines For Performance – Based Design of Structures With Respect To Natural Hazards.....	214
15.6.6 Current Status Of Buildings Byelaws, Development Control Rules, Land .....	214
15.7 The Municipal Corporations, Development Authorities .....	214
Annexure – 1 - Some Examples of Building Damage During Recent Earthquakes In India .	216
Annexure-2- Definitions of Disaster-Related Terms .....	220
Annexure-3- Msk 1964 Intensity Scale (Extract) .....	224
Annexure-4 - Relevant References To Standard Codes / Guidelines .....	227

## **PREFACE**

The Consultancy Project titled “**Mainstreaming Disaster Risk Reduction in Housing Sector**” was assigned to the undersigned by the Executive Director, National Institute of Disaster Management on October 5, 2010 with the following scope of the assignment.

- a) The concept of ‘Housing’ and ‘Mainstreaming’ shall conform to the internationally accepted definitions as adopted by the UN-Habitat and the UN-ISDR respectively.
- b) The concept of DRR shall include every element that would contribute to reduction of risks of disasters in the housing sector, with particular reference to earthquakes, floods, landslides, cyclones and building fires.
- c) The proposed strategies/guidelines/tools for mainstreaming DRR in housing sector shall be comprehensive in nature and shall cover the whole gamut of issues for the housing sector as outlined in the National and State Housing Policies in India.
- d) This would include (i) mainstreaming the strategic issues of DRR in housing policies, (ii) development of guidelines for mainstreaming DRR in housing programmes and (iii) development of tools for mainstreaming DRR in housing projects.
- e) The housing programmes shall include all existing and forthcoming programmes of both the Central and State Governments on rural and urban housing in public, private, public-private, cooperative and individual sectors.
- f) This would further include various sectoral housing programmes for the BPL/SC/ST/OBC/fishermen/weavers/workers/slums, etc.
- g) This would include both engineered and non-engineered houses and shall cover safety issues of both existing and new houses.
- h) The strategies/guidelines/tools shall recommend modifications required in the existing techno-legal regimes in the housing sector, with particular reference



to zoning and building bylaws for housing designs, constructions, retrofitting, etc.

- i) The strategies/guidelines/tools shall further recommend modifications required in the existing techno-financial regimes in the housing sector, with particular reference to housing credit, insurance, etc.
- j) The guidelines shall take into consideration issues of affordable housing based on local environment and geo-climatic considerations, locally available building materials as well as indigenous knowledge of disaster-safe house construction in hazard-prone areas.
- k) The strategies/guidelines/tools shall recommend (i) an implementation plan, (ii) institutional mechanism, (iii) capacity building and (iv) awareness generation for mainstreaming DRR in housing sector.
- l) A check-list on mainstreaming shall be developed for easy guidance of the stakeholders.

An inception report of the project was submitted to NIDM on November 12, 2010 and brainstorming session was organised by NIDM on November 30, 2010 in which the scope of consultancy was enlarged in terms of the following topics:

- The guidelines shall provide detailed typologies of housing in rural and urban India under different geo-climatic zones and examine the risks that each type of house faces from natural disasters like earthquake, flood, cyclone, etc., and manmade disasters like fire, etc.
- The guidelines shall provide the tools and methodologies for reducing the risk of disasters at every stage, i.e., planning, designing, construction, maintenance, upgradation, retrofitting, etc. While the guidelines shall refer to the approved standards and codes (such as BIS, NBC, etc.), it shall explain the basics of such standards in simple designs understandable to all stakeholders.
- The guidelines shall have a separate chapter on school and hospital safety and suggest practical steps for integrating such safety measures in the

planning, designing, construction and maintenance of buildings under Sarva Shiksha Abhiyan (SSA) and National Rural Health Mission (NRHM).

As a result of the enhanced coverage of assignment, the duration of the project was suitably extended.

In compliance with the contract, this draft final report was submitted for validation by NIDM. Subsequently, the final report is being submitted after incorporating necessary modifications suggested by NIDM.

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## **EXECUTIVE SUMMARY**

This report has been prepared in response to the assignment given by the National Institute of Disaster Management to develop strategies/guidelines/tools for mainstreaming Disaster Risk Reduction in the housing sector in India. The report covers the whole gamut of issues of the housing sector. The concerns relating to planning, designing, constructing and maintenance of housing and surrounding elements of built environment, including school and hospital buildings, as part of housing have been addressed.

The report has 15 chapters and 4 annexures.

### **Impacts of Hazards On The Housing Sector**

The report recognises that historically India is prone to frequent natural hazards like earthquakes, cyclones and floods which, in the past have caused heavy losses to life and property and disrupted socio-economic life in affected communities, particularly due to high vulnerability of its human settlements, where nearly 80% of housing stock comprise non-engineered constructions with least capacity of the inhabitants to respond to disasters.

### **Objectives of Mainstreaming DRR**

To ensure that all the development programmes and projects:

- Are designed with full consideration for potential disaster risks and to reduce loss of life, livelihoods and property and to safeguard development gains impact.
- Do not inadvertently increase vulnerability to disaster in all sectors, i.e., social, physical, economic and environmental.
- Are designed to contribute to developmental aims and to reduce future disaster risk.
- Aim at increasing the capacity of local communities and organisations to prevent, prepare for and respond to the impact of disasters through necessary changes in National and State policies and practices.



- Adhere to techno-legal and techno-financial regimes for ensuring the disaster safety of all new constructions and actions for enhancing safety of existing old and unsafe constructions.
- Expanding risk reduction measures for reducing the scale of future disaster impacts, in the context of pressures of population explosion, urbanisation and global climate change.

### **Housing Typologies In India**

The Table 2.2 indicates that total number of buildings in the country as per 2001 Census is 24,90,55,869. Classification of houses is based on materials used in construction of roofs, walls and floors. From the point of view of disaster, the appropriate grouping for the whole country is given in this Table wherein the wall and roofing groups are categorised according to MSK Earthquake Intensity Scale (Annex 3).

### **Housing In Geo-Climatic Zones In India**

The built forms of housing are outcome of the interaction between geo-climatic characteristics of the region, lifestyles and culture of people, locally available materials, construction practices and their performance as experienced in the past. These have resulted in a large variety of building typologies in traditional housing forms in different geo-climatic regions of India.

With reference to seismic zones of the country, it is noted that several earthquake safe construction practices have evolved historically by incorporating necessary elements in the house construction. Few examples of good construction techniques and their type designs (Table 2.4) from different regions have been selected which are not only quite famous globally but have also demonstrated their durability.

### **Framework of Mainstreaming - Suggested Strategies By International Agencies**

Mainstreaming framework as evolved by UN-ISDR for better understanding and agreed fundamental principles at the global level. The UN framework lays responsibility for reducing the impact of disasters on 'policymakers', 'communities', 'non-governmental organisations (NGOs)' and the 'private sector'. This framework provides a functional mechanism which operates under the following thematic areas:

- Governance

- Preparedness and emergency management
- Risk identification/risk assessment
- Knowledge management
- Risk management and vulnerability reduction

**Governance:** Local bodies such as Municipal Corporations, Development Authorities, Municipal Councils, Nagar Panchayats, Cantonment Boards, etc., are the most important institutions which through their 'governance model' can greatly help in reducing social, physical and economic vulnerability for communities by proper planning and ensuring adherence to the approved land uses, building bylaws, regulations and promoting disaster safety in construction activities happening in their areas.

**Disaster Preparedness For Emergency Response:** The Yokohama strategy and UNISDR both emphasise that emergency preparedness programmes and contingency plans for effective response should be supported by national legislation, adequate resources and National, State and local level coordination mechanisms, involving all stakeholders.

**Risk Assessment:** To arrive at precise risk assessment for an area, the data needed includes information about location, impact and frequency of hazard events. Capacity building of project planners is necessary for analysis and validating data and information from past large events, studies, etc., which need to be so formatted as to guide decision making for housing programmes and projects.

**Knowledge Management:** It is universally recognised that proper knowledge management is essential for supporting correct decision making in planning and designing of projects. "Hyogo Framework for Action 2005-2015" inter alia emphasises use of knowledge, innovation and education to build a culture of safety and resilience.

**Risk Management And Vulnerability Reduction:** ISDR recognises 'Disaster Risk Management' (DRM) as a professional practice, requiring trained professionals, experience and culture. Hyogo Framework also emphasises that it is necessary to develop "sector-specific Risk Reduction Plans" by integrating DRR in national plans and programmes of every sector. In housing programmes and projects, risk from natural hazards can be addressed by preventive measures such as (a) avoiding

location in floodplains, (b) building disaster resistant buildings, (c) building strong regulatory mechanisms like strict adherence to codes/standards through a strong governance structure at local bodies/authorities, (d) monitoring and early warning, (e) availability of response measures to manage extreme events and (f) risk transfer policies and insurance products to cope with unavoidable impacts.

### **Awareness, Sensitisation & Capacity Building**

To ensure successful implementation of DRR strategies following actions are important.

- **Awareness creation:** a) improving understanding of hazard status and threats, b) preparing public on how to organise themselves before, during and after disasters and c) equipping professional groups on technical strategies.
- **Sensitisation:** a comprehensive awareness and sensitisation campaign needs to be institutionalised to emphasise periodically about hazard risk and role of individual stakeholders.
- **Capacity building:** tailor-made training programmes to be developed and implemented by experts for intense training of the professionals (architects, engineers, design groups, consultant, municipal engineers and all those dealing with building construction projects).

### **Mainstreaming DRR In Housing Schemes**

Most development schemes of Government of India and those of the States include a housing component and provide great opportunity in practising Disaster Risk Reduction through designing and construction of projects at various sites. A review of these schemes from disaster safety point of view shows that the schemes have failed to address the concerns about the safety of building projects under various hazards to which they may be subjected in their varied locations. A sample guideline has therefore been suggested (4.5.1 ..... 4.5.5) for preparation of DPRs for construction projects under these schemes.

### **Disaster Risk Reduction In The Project Cycle Management**

Four distinct phases that need consideration for integrating risk reduction in the entire project cycle, include: i) project identification, ii) project preparation, iii) project implementation, iv) project evaluation.

For ensuring the safety and minimising disaster risk to housing projects in various States and UTs which are subject to earthquakes, cyclones, floods mostly acting separately but sometimes in combination, the best approach will be to plan, design, construct and monitor the projects in accordance with the relevant BIS standards, codes, guidelines and handbooks. A brief list of most applicable codes and guidelines is given in Annexure 4.

The vulnerability atlas of India prepared by BMTPC (refer para 4.5.6) indicate earthquake, wind storm and flood hazard maps which are drawn for each State and UT separately. Various district boundaries are clearly shown for easy identification of the hazard risk-prone areas. The intensities of earthquakes on MSK scale and intensity of wind hazard related with wind speed are drawn on the maps to show various intensity zones. Flood-prone areas are categorised in terms of unprotected and protected areas combined. Capacity building of officials and professionals is a major issue for successful management of the projects.

### **Assessment of Hazard Safety Of Existing Housing**

The seismic vulnerability of the different building types depends on the choice of building materials and construction technology adopted. The building vulnerability is generally highest with the use of local materials without engineering inputs and lowest with the use of engineered materials and professional skills.

Damageability range for buildings has been indicated for each building type considering different factors affecting its likely performance. Table 6.1 presents the different masonry building types and Table 6.2 presents the framed RC and steel buildings. The likely damages to buildings have been categorised in different grades depending on seismic intensity impact on the strength of the building. Five grades of damageability G1 to G5 are specified in MSK and European Intensity Scales as presented in Tables 6.3 and 6.4 for masonry and RCF/SF buildings respectively.

The following building attributes enhance earthquake risk: liquefiable condition; landslide-prone area; irregular buildings – which include plan irregularities and vertical irregularities; **falling hazard** and softness of foundation soil.

The paragraph 6.5 provides a method for seismic vulnerability assessment of masonry or reinforced concrete or steel frame buildings for determining seismic safety.

### **Rehabilitation And Retrofitting of Existing Unsafe Buildings**

Risk of damage to earthquake disaster for various building types in the country have been given in Table 7.1. Guidelines given in this chapter indicate type of intervention needed to adequately strengthen different types of non-engineered buildings. Guidelines also include methods for building structure survey to assess existing safety levels, quality of construction defects, design of retrofitting, including selection of techniques and materials as well as type and configuration of the intervention needed.

### **Disaster Safety In Hospital Buildings**

The safety, extent of damage and loss of life in hospital buildings are critically related to ‘structural elements’, ‘non-structural elements’ and ‘building contents’. The most important aspect of safety in a hospital building is that its functioning after an event like earthquake should not get adversely impacted.

During an earthquake, building contents and parts of the building that are not fixed are severely shaken. Serious dangers are caused by falling, sliding and crashing objects that can crush, pierce and cut or spill dangerous chemicals. Thus, “non-structural risk reduction” measures are critical for safety of hospital facilities, which can be achieved by simple steps as suggested.

In view of this, a non-structural vulnerability assessment and implementation of mitigation measures in hospitals is essentially required. Table 9.1 shows non-structural elements which need to be considered for vulnerability assessment of hospital facilities.

### **Seismic Safety Consideration In School Buildings**

Mostly existing schools in different parts of India are constructed traditionally using stone/burnt brick walls, wooden or un-engineered reinforced concrete frames. These are usually highly vulnerable to damage by floods, earthquakes, cyclones.

Experience in Bhuj and J&K earthquakes show that the school buildings were not designed to be resistant to earthquake impacts, hence resulted in loss of thousand of school rooms and lives of pupils.

**Planning And Design Of School Buildings:** Under Sarva Shiksha Abhiyan (SSA), a large number (more than 100) building designs have been developed for selected districts. It is recommended that States may use designs already developed under DPEP/Lok Jumbish Project in their specific local context taking care of earthquake safety provisions.

**Seismic Safety of Hospital And School Buildings:** As per NBC of India and IS Code 1893-2002, those buildings should be designed with higher factor of safety. Accordingly, higher seismic coefficient by 50% and higher wind forces are required to be considered for structural design.

Following considerations are essentially to be taken into account while planning and designing the buildings:

- i) For safety against flood damage, the foundations of the building should be taken deeper to avoid erosion of the foundation.
- ii) If the soil is sandy with high water table, the soil may liquefy under an earthquake of Intensity VII and higher, the foundation should be taken to stiffer strata below the liquefaction level under the earthquake intensity.
- iii) The building superstructure must be designed for applicable earthquake and wind forces.
- iv) In storm surge-prone coastal areas, either the whole school or the roof of the school made accessible through staircases should be kept higher than the estimated maximum inundation under storm surge/tsunami.



- v) For earthquake safety and cyclonic wind pressure, where applicable, the masonry walls should be strengthened by using reinforced concrete bands as specified in IS 4326-1993. Also, vertical reinforcing bars have to be embedded at the corners of the rooms as per that standard.

### **Safety Guidelines For Multistoried & Special Buildings**

The seismic safety of a multistoried reinforced concrete building will primarily depend upon the initial architectural and structural configuration of the total building, the quality of structural analysis made, design and reinforcement detailing of the building frame to achieve ductility of elements under serious severe loading. Proper quality of construction and stability of the infill walls and partitions are additional safety requirements of the structure as a whole.

Based on behaviour of a large number of reinforced concrete multistoried frame buildings which were heavily damaged in Bhuj earthquake in 2001 normally unexpected of RC frame buildings in MSK Intensity VIII and VII areas, specific recommendations have been made for structural engineers and architects on critical aspects:

- (i) Indian standards and codes should be essentially referred.
- (ii) Specific recommendations on the special features like a) softness of base soil, b) soft-first story, c) intermediate soft story, d) bad structural system, e) heavy water tanks on the roofs, f) lack of earthquake resistant design, g) improper dimensioning of beams and columns, h) improper detailing of reinforcement, i) short column detailing, j) torsional failures, k) pounding damage of adjacent buildings, l) lack of stability of infill walls, m) poor construction quality.

### **Implementation of Techno-Legal Regime**

High vulnerability of built elements in urban and rural settlements is mainly the result of buildings built without compliance to standards, codes and regulatory requirements for safety, even ignoring the mandatory ones. Migration of large number of families from rural to urban settlements is resulting in the growth of slums,

squatter settlements which in many cases are located on unsafe land and built with very inadequate construction techniques using fragile materials.

Despite the fact that appropriate building codes and standards for structural safety are in place, compliance and correct application in design and construction is one of the major causalities in the Country. Floodplain zoning is needed to regulate land use in the floodplains to restrict the damage caused to human life and buildings by floods.

**No Land Shall Be Used As A Site For The Construction Of Building:** i) if the site is found to be liable to liquefaction, ii) if the competent authority finds that the proposed development falls in the area liable to storm surge during cyclone, iii) in hilly terrain, the site plan should include location of landslide-prone areas, if any, on or near the site, detected during reconnaissance, iv) the site plan on a sloping site may also include proposals for diversion of the natural flow of water coming from uphill.

**Model Development Control And Building Regulations Including Safety Provisions In Rural Areas:** Considering that nearly 750 million people live in rural settlements in about 177 million housing units constructed with large variety of materials and construction techniques are under threat viz, earthquakes, cyclones, floods and landslides, the Ministry of Home Affairs prepared the Model Development Control and Building regulations for health and safety of the people, including safety against natural hazards in the form of simplified guidelines. These suggested guidelines are to be followed by Panchayats but necessary directions need to be issued by the respective State and UT Governments.

**Capacity Building of Officials And Professionals of Local Authorities:** Urban Local Bodies, numbering nearly 5,100 in the country, are the largest owners of lifeline buildings, structures and infrastructure networks. Action plan has been recommended for capacity development in ULBs. (i) Periodic awareness meets at regional level for Mayors/Corporators, lying in seismic regions, (ii) regular training programmes for town planners, architects, engineers and plan approving officials for regulating seismic safety (iii) ULBs must collaborate with academic institutions of excellence and eminent professionals to provide training to their staff and practicing

local engineers and architects in structural safety methods. Under the para 5.6 of the report model syllabi have been proposed for tailor-made training programmes for civil engineers, architects related to the projects in earthquake-prone, flood-prone, cyclone-prone, high wind velocity-prone and landslides-prone areas.

### **Techno-Financial Regime**

Damage or destruction of bank funded assets not only result in adverse economic consequences but may also compromise the lending institutions financial security due to the drastic reduction in asset values following their damage or destruction.

**Advisories Issued By RBI:** Reserve Bank of India (RBI) has issued several proactive advisories to banks for verifying disaster safety and planning issues while granting loans for any building construction. In this regard, RBI's circular of March 1, 2006, asking banks to ensure prior permission from government/local governments/other statutory authorities for the project, wherever required, while giving loans to real estate sector is to be noted. Similarly, again emphasising importance to safety of buildings especially against natural disasters, RBI issued advisory to all banks on June 12, 2006 for adherence of National Building Code, 2005, while approving loans for any building's construction.

**Techno-Financial Regime For Urban And Rural Areas:** A techno-financial regime of banks and other lending institutions extending loans for buildings should take care in regulating all construction as *disaster resilient construction* in the country. The loan delivery mechanism needs to be considered as an opportunity for financial institutions to introduce appropriate disaster resistance in constructions in building sector. The regime should be applicable to both new constructions as well as additions or alterations to full or part of existing constructions.

**Role Of Insurance Sector In DRR:** To integrate Disaster Risk Reduction with the policies, programmes and projects in housing sector and cut down on the mounting economic costs of natural disasters, insurance has been used as a strong policy tool for disaster management in several developed countries. It is treated as a public-private partnership strategy for disaster risk sharing. Insurance companies are

expected to address the twin problems of reducing losses at community level resulting from disasters and providing financial protection to individual families.

### **Multi-Hazard-Resistant Construction of Houses – A Case Study**

In India there are more than 300 districts which are in the multi-hazard-prone category.

A case study from four districts of Bihar is presented in which floods of 2008 in Kosi had destroyed a large number of houses. In these districts safety of reconstructed houses had to be ensured against *future floods, earthquakes as well as high wind speeds*.

Safety against floods is achieved by the safety of foundations up to plinth level of the house. The depth of foundation is kept deep enough to avoid scour sinking by floodwaters and to remain stable if the soil gets liquefied under earthquake. The masonry walls are reinforced by seismic bands and vertical steel bars. Sloping roof with sheet covering are secured by use of J-bolts against wind uplifts.

### **Checklists For Ensuring Disaster Safety of Building Projects**

Considering that the disaster safety of building projects depends upon the appropriate use of building codes in their design, a tabulated checklist along with references to the building code clauses have been prepared and presented in Chapter 14. Table 14.1 gives the expression of safety concerns and data presentation in regard to building schemes and Tables 14.2 to 14.5 cover the details of structural design basis of the building project. Finally, Table 14.6 is added for during-and post-construction technical audit purposes of the building project.

### **DRR Recommendation For Stakeholders**

Critical factors for successfully integrating DRR in housing projects are:

- Consultation with hazard and construction experts.
- Land-use planning and incorporating building codes.
- Improving construction and implementation practices.
- Guidelines for performance-based design of structures with respect to natural hazards.

- Enforcement of building bylaws, development control rules, land-use zoning regulations and incorporating design checks, enforcement of quality control.
- Widespread dissemination of the regulations and capacity building of all stakeholders, including professionals.

## 1. INTRODUCTION

### 1.1 Statement of The Problem (Impacts of Hazards On The Housing Sector)

Historically, India has been prone to the occurrence of damaging earthquakes, floods, cyclones and landslides in different parts of the country, which have resulted in damage or total loss of more than 12 lakh housing units on an average every year. Given both the population explosion and increased need of developmental activities exposure, the scale and impact of natural hazards have increased considerably in the past three-four decades.

These events, coupled with underdevelopment and changing poverty profiles in most urban centres, lead to catastrophic situations for vulnerable sections of society and the housing stock, both in urban and rural settlements. Housing sector is the most commonly affected in any disaster, be it earthquake, flood, cyclone, tsunami or landslides. The main reason for 'housing sector' to be most vulnerable is that a majority of housing stock in India (like most developing countries) comprise non-engineered category of constructions with least capacity of the inhabitants to respond to disaster. High vulnerability of housing settlements is also the result of government policies which do not strictly prohibit occupation of flood-prone areas and expansion of residential pockets (authorised and most often unauthorised) in other risk-prone areas in the absence of clearly laid down land-use policies.

Specifically, the disaster risk in India may be described briefly as follows:

#### 1.1.1 Earthquake

India's high earthquake risk and vulnerability is clear from the fact that about 59 per cent of India's land area could face moderate to severe earthquakes in seismic III, VI and V. Between 1990 and 2006, more than 23,000 lives were lost in India due to six major earthquakes, which also caused enormous damage to buildings and public infrastructure. These earthquakes include the Uttarkashi earthquake of 1991, the Latur earthquake of 1993, the Jabalpur earthquake of 1997 and the Chamoli earthquake of 1999 followed by the Bhuj earthquake of January 26, 2001, and the Jammu & Kashmir earthquake of October 8, 2005. Annexure 1 gives some examples of building damages during recent earthquakes and main reasons identified thereof. The occurrence of several devastating earthquakes even in Zone III area indicates



that the built environment in the country is extremely fragile. All these major earthquakes established that the casualties were caused primarily due to the collapse of buildings. However, similar high intensity earthquakes in the United States, Japan, etc., do not lead to such enormous loss of lives as the structures in these countries are built with structural mitigation measures and earthquake-resistant features. This emphasises the need for strict compliance of town planning bylaws and earthquake-resistant building codes in India.

### **1.1.2 Flood**

Floods have been a recurrent phenomenon in India and cause huge losses to lives, housing, properties, livelihood systems, infrastructure and public utilities. India's high risk and vulnerability is highlighted by the fact that 40 lakh hectares out of a geographical area of 3,290 lakh hectares are prone to floods. On an average every year, 75 lakh hectares of land is affected, 1,600 lives are lost and 12 lakh houses are damaged due to floods. The maximum number of lives (11,316) were lost in 1977. The frequency of major floods is more than once in five years. Floods have also occurred in areas, which were earlier not considered flood-prone.

Eighty per cent of the precipitation takes place in the monsoon months from June to September. The rivers bring heavy sediment load from the catchments. These, coupled with inadequate carrying capacity of the rivers, are responsible for causing floods, drainage congestion and erosion of riverbanks. Cyclonic circulations and cloudbursts cause flash floods and lead to huge losses. Continuing large scale loss of lives and damage to public and private buildings due to floods indicate that we are still to develop an effective disaster reduction strategy.

### **1.1.3 Cyclone**

A long coastline of about 7,500 km of flat coastal terrain, shallow continental shelf, high population density, geographical location and physiological features of its coastal areas make India extremely vulnerable to cyclones and its associated hazards like storm tides (the combined effects of storm surge and astronomical tide), high velocity wind and heavy rains. The impact on the east coast of India is relatively more devastating. This is evident from the fact that in the last 270 years, 21 of the 23 major cyclones (with a loss of about 10,000 lives or more) worldwide occurred over

the area surrounding the Indian subcontinent (India and Bangladesh). This is primarily due to the storm-tides effect in the area.

Thirteen coastal States and Union Territories (UTs) in the country, encompassing 84 coastal districts, are affected by tropical cyclones. Four States (Tamil Nadu, Andhra Pradesh, Orissa and West Bengal) and one UT (Puducherry) on the East Coast and one State (Gujarat) on the West Coast are more vulnerable to hazards associated with cyclones.

About 8% of the area in the country is prone to cyclone-related disasters. Recurring cyclones account for large number of deaths, loss of livelihood opportunities, loss of public and private buildings and severe damage to infrastructure.

A rough assessment of the population at risk suggests that an estimated 32 crore people are vulnerable to cyclone-related hazards.

#### **1.1.4 Landslides**

Landslides constitute a major natural hazard, which accounts for considerable loss of life and damage to communication routes, human settlements, agricultural fields and forest lands. Their widespread and frequent occurrence causes great damage because of unpredictability in space and time, innumerable types and mechanisms of slope failure involved. Removal of vegetation and toe erosion also triggered slides. Torrential monsoon on the hill slopes, with the vegetation cover removed, has been the main causative factor in the Peninsular India namely in the Western Ghats and Nilgiris. Human intervention by way of slope cutting has added to this effect.

The Indian subcontinent, with diverse physiographic, seismo-tectonic and climatologic conditions is subjected to varying degrees of landslide hazards. The Himalayas, including Northeastern mountain ranges, being the worst affected, followed by a section of the Western Ghats, Eastern Ghats and the Vindhyas. Depiction and portrayal of various levels of these geo-hazards and their determination is a prerequisite for (a) projecting damage scenarios, (b) reliable risk analysis, (c) planning and execution of any environment-friendly developmental activity and (d) mitigation of hazard-related miseries.

Landslide disaster, in general, is far less dramatic than those due to earthquakes, but their debilitating impact on the national economy is no less severe. With growing population and human interventions in terms of developmental activities, landslides like other natural hazards pose constant threat to growth of human settlements. Large-scale deforestation along with faulty management practices have led to high vulnerability to landslides in many regions of the country. These often occur in conjunction with severe precipitation on slopes, or in association with ground-shaking caused by earthquakes.

Recognising the imminent need to bridge the existing gaps in the above backdrop, the Building Materials and Technology Promotion Council (BMTPC) and the Centre for Disaster Mitigation and Management (CDMM) joined hands for preparing a Landslide Hazard Zonation Atlas (2003).

### **1.1.5 Building Fires**

The poor housing conditions in India, particularly in rural areas, and squatters and low income neighbourhoods in urban areas force people to live huddled together in a single room in which they cook, light fire often by burning a lot of biomass. A vast majority of the poor in India have inadequate space with hardly any ventilation and they cannot afford materials of construction which could be classified as safe. Additionally, they are exposed to the hazards of smoke and gaseous pollutants that are released on burning biomass for cooking and for keeping themselves warm during the winter months. The living conditions of the poorer sections of the Indian population in general are highly unsatisfactory from the point of haphazard storage and the use of excessive quantities of combustible materials, presenting entirely different social and economic conditions, thereby, exposing people to much greater fire hazards than in developed countries.

India performs poorly in terms of fire costs, property losses and fire deaths. There appears to be no basic culture or any urgent thinking as the nation is already behind in the public awareness schedule, information on the fire behaviour of materials and building elements, in legal requirements, or in compulsion to builders and architects to use only fire safe materials.

National Building Code 2005, Part IV (currently under revision) deals with safety of occupants from fire, smoke, fumes and panic during the time period necessary for escape.

During the last 50 years, many organisations have been reposed with various responsibilities pertaining to their areas of activities. These institutions are Central Building Research Institute (CBRI), Roorkee, Defence Institute of Fire Research (DIFR), New Delhi, National Fire Service (NFS) College, Nagpur, Loss Prevention Association of India Ltd. (LPA), Mumbai, Bureau of Indian Standards, New Delhi, and various fire services of the different States. Each one is contributing towards the same cause that of safety of buildings and of human life from the 'killer' fire.

## **1.2 Housing**

The term housing considered in these guidelines is in generic form and akin to the term building as defined in Census 2001 and as adequate shelter defined in habitat agenda stated here below:

### **1.2.1 Building**

A 'building' is generally a single structure on the ground. Sometimes it is made up of more than one component unit which are used or likely to be used as dwellings (residences) or establishments such as shops, business houses, offices, factories, workshops, worksheds, schools, places of entertainment, places of worship, godowns, stores, etc. It is also possible that buildings which have component units may be used for a combination of purposes such as shop-cum-residence, workshop-cum-residence, office-cum- residence, etc.

### **1.2.2 Shelter**

The habitat agenda that emerged from second United Nations conference on human settlements (Habitat II) addressed "Adequate Shelter" defined as below:

Adequate shelter means more than a roof over one's head. It also means adequate space, physical accessibility, adequate security, security of tenure, structural stability and durability, adequate lighting, heating and ventilation, adequate basic infrastructure such as water supply, sanitation and waste management facilities, all of which should be available at an affordable cost. Adequacy should be determined

together with the people concerned, bearing in mind the prospect for gradual development. Adequacy often varies from country to country since it depends on specific cultural, social, environmental and economic factors. Gender-specific and age-specific factors, such as the exposure of children and women to toxic substances, should be considered in this context.

### **1.2.3 Housing Sector**

We may consider housing sector comprising *all* buildings as per Census 2001 - the housing series, where buildings are classified in different ways “**Rural And Urban**”, based on “**Functional Uses**” and as “**Permanent Semi-Permanent Or Temporary**”. These are defined below:

a) Rural-urban areas

The unit of classification is ‘town’ for urban areas and ‘village’ for rural areas. The definition of urban area adopted is as follows:

- i) All places with a municipality, corporation, cantonment board or notified town area, etc.
- ii) A place satisfying the following three criteria simultaneously:
  - a minimum population of 5,000;
  - at least 75 per cent of male working population engaged in non-agricultural pursuits; and
  - a density of population of at least 400 per sq km.

**For Identification of Places That Would Qualify To Be Classified As ‘Urban’, All Villages, Which, As Per The 1991 Census, Satisfied The Above Criteria, Were So Chosen.**

Apart from these, the outgrowths (OGs) of cities and towns have also been treated as urban under ‘Urban Agglomerations’: Examples of outgrowths are railway colonies, university campuses, port areas, military camps, etc., that may have come up near a statutory town or city but within the revenue limits of a village or villages contiguous to the town or city. Thus, the town-level data, wherever presented, also includes the data for outgrowth of such towns.

Towns with population of 1,00,000 and above are called cities.

**b) Uses of Census Houses**

The different uses of census houses were standardised and grouped into 10 categories as shown below:

**Residence:** This category includes houses that were used exclusively for residential purpose.

**Residence-Cum-Other Use:** Such as residence-cum-grocery shop, residence-cum-workshop (book binding), residence-cum-boarding house, etc.

**Shop/Office:** Census houses exclusively used as shops and offices were covered under this category.

**School/College, etc.:** All types of educational institutions and training centres *without* lodging facilities or any residential use.

**Hotel/lodge/guesthouse, etc.:** Used exclusively for temporary stay or stay in transit and where no person lives for a period of three months or more.

**Hospital/Dispensary, Etc.:** Used as hospitals, dispensaries, nursing homes and other such health or medical institutes.

**Factory/Workshop/Workshed, etc.:** Exclusively used for running a factory or a workshop of manufacturing, production, processing, repairing or services, etc.

**Place of Worship:** Such as temples, gurudwaras, mosques, churches, prayer halls, etc.

**Other Non-Residential Use:** Used as places of entertainment and community gathering and all other non-residential miscellaneous uses not covered under any of the above categories, used as cattle shed, godown, garage, petrol pump, power station, pump house, tubewell room, cinema house, museum, stadium, etc.

**Vacant:** Found vacant, under construction or not being used for any other non-residential purpose.



**c) Type of Census Houses**

These have been classified according to the types of material used in the construction of wall and roof of the house. The basis of their classification is described here:

**Permanent Houses:** Houses, the walls and roof of which are made of permanent material. The material of walls can be any one from the following, namely, galvanised iron sheets or other metal sheets, asbestos sheets, burnt bricks, stones or concrete. Roof may be made of from any one of the following materials, namely, tiles, slate, galvanised iron sheets, metal sheets, asbestos sheets, bricks, stones or concrete.

**Temporary Houses:** Houses in which both walls and roof are made of materials, which have to be replaced frequently. Walls may be made from any one of the following temporary materials, namely, grass, thatch, bamboo, plastic, polythene, mud, unburnt bricks or wood. Roof may be made from any one of the following temporary materials, namely, grass, thatch, bamboo, wood, mud, plastic or polythene.

**Semi-Permanent Houses:** Houses in which either the wall or roof is made of permanent material and the other is made of temporary material.

**Serviceable Temporary Houses:** Temporary houses in which wall is made of mud, unburnt bricks or wood.

**Non-Serviceable Temporary Houses:** Temporary houses in which wall is made of grass, thatch, bamboo, plastic or polythene.

**1.3 Definition Of Disaster-Related Terms**

The terms which are commonly used in relation to hazards and disasters are defined in Annexure 2.

**1.4 Disaster Risk Reduction (DRR)**

DRR is defined as follows:

**Disaster Risk Reduction:** Technical, social or economic actions or measures used to reduce direct, indirect and intangible disaster losses. The expression 'disaster risk

reduction' is now widely used as a term that encompasses the two aspects of a disaster reduction strategy: **Mitigation and Preparedness.**

**Mitigation:** Measures aimed at reducing the risk, impact or effects of a disaster or threatening disaster situation.

**Preparedness:** The state of readiness to deal with a threatening disaster situation or disaster and the effects thereof.

The other terms related to disaster risk reduction are defined in Annexure 2.

### **1.5 Mainstreaming DRR**

**Mainstreaming:** Mainstreaming risk reduction describes a process to fully incorporate disaster risk reduction into relief and development policy and practice. It means expanding and enhancing disaster risk reduction so that it becomes normal practice, fully institutionalised within an organisation's development agenda. Mainstreaming has three purposes:

#### **To Make Certain That All The Development Programmes and Projects That Originate From or Are Funded By A Public or Private Organisation:**

- Are designed with full consideration for potential disaster risks and to resist hazard impact.
- Do not inadvertently increase vulnerability to disaster in all sectors: social, physical, economic and environment.
- Are designed to contribute to developmental aims and to reduce future disaster risk.

The related terms are defined in Annexure 2.

### **1.6 Object And Scope of The Guidelines**

The objectives of the guidelines include the discussion and presentation of the following issues:

- i) The primary objective of vulnerability reduction is to reduce avoidable loss of life, livelihoods and property and to safeguard development gains.

- ii) To increase the capacity of local communities and organisations to prevent, prepare for and respond to the impact of disasters through necessary changes in National and State Policies and Practices.
- iii) To develop performance targets and indicators to assist development organisations so as to *mainstream* risk reduction into relief and development planning.
- iv) To identify and prioritise methods of mainstreaming risk reduction into institutional practice.
- v) Pressures such as population expansion, urbanisation and global climate change make the country increasingly unsafe under natural hazards. It, therefore, becomes essential to expand risk reduction measures for reducing the scale of future disaster impacts.

The scope of the guidelines includes the following main items:

- i) Framework of mainstreaming *disaster risk reduction* (DRR) in housing sector, initially at the policy decision by the authorities.
- ii) Mainstreaming DRR into housing programmes and projects undertaken by the State or other organisations.
- iii) Development of tools for achieving disaster safety in new as well as old city areas.
- iv) Development of tools for undertaking disaster safety in new as well as existing housing.
- v) Developing procedures for ensuring disaster safety in schools and hospitals which are considered critical to the safety of disaster-affected population.
- vi) To highlight the importance of techno-legal and techno-financial regimes for ensuring the disaster safety of all new constructions and actions for the safety of existing old and unsafe constructions.

**References:**

- 1.1 NDMA: National Disaster Management Guidelines: Management of Earthquakes, 2007
- 1.2 NDMA: National Disaster Management Guidelines; Management of Floods; Jan 2008.
- 1.3 NDMA, National Disaster Management Guidelines; Management of Cyclones; April 2008.
- 1.4 NDMA: National Policy on Disaster Management, 2009.
- 1.5 Census of India 2001-Housing Series, Registrar Census, Govt. of India.
- 1.6 Vulnerability Atlas of India, by Expert Group, Published by (BMTPC), 1997, revised and updated, 2006.

## 2. Housing Typology In India

### 2.1 House Types As Per Census of India 2001-Housing Series

The housing series (2001 Census of India) gives the following details of houses based on materials of construction for roofs, walls and floors.

a) Type of roof:

- i. **Pitched or Sloping** including tiles, slate, corrugated iron, zinc or other metal sheets, asbestos cement sheets, plastic polythene, thatch, grass, leaves, bamboo, etc.
- ii. **Flat**, including brick, stone and lime, reinforced brick concrete and reinforced cement concrete.

b) Type of wall:

- i. Mud, unburnt bricks, stone laid in mud or lime mortar
- ii. Burnt bricks laid in cement, lime or mud mortar
- iii. Cement concrete
- iv. Wood or Ekra walling
- v. Corrugated iron, zinc or other metal sheets
- vi. Grass, leaves, reeds or bamboo or thatch, plastic polythene and others

c) Type of flooring:

Various types like mud, stone, concrete, wood or bamboo, mosaic floor tiles, etc. The distribution of houses based on predominant materials of roof and wall over whole of India according to 2001 Census is shown in Table-2.1. From the point of view of vulnerability to the earthquake, wind, flood or tsunami hazards, it is seen that the type of flooring has hardly any significance and that the roof types and wall types could not be grouped together. The appropriate grouping for the whole of India is shown in Table 2.2, wherein the wall and roofing groups are categorised according to MSK earthquake intensity scale presented in Annexure 3 for ready reference. Only intensities VI, VII, VIII and IX which form the basis of seismic zones II, III, IV and V respectively are described.

### **2.1.1 Wall Types**

Category-A: Buildings in field stone, rural structures, unburnt brick houses, clay houses

Category-B: Ordinary brick building, buildings of the large block and prefabricated type, half-timbered structures, building in natural hewn stone

Category-C: Reinforced building, well-built wooden structures

Category-X: Other materials not covered in A,B and C. These are generally light shelter huts.

### **2.1.2 Roof Types**

Category - R1: Light weight (grass, thatch, bamboo, wood, mud, plastic, polythene, GI metal, asbestos sheets, other materials)

Category - R2: Heavy weight (tiles, slate)

Category - R3: Flat roof (brick, stone, concrete)



**Table**  
**Houses By Material of Roof In India (Census of India 2001 – Housing Data)**

	Total census houses	Grass, Thatch, Bamboo, Wood, Mud, etc.		Plastic, Polythene		Tiles		Slate		G.I., Metal, Asbestos sheets		Brick		Stone		Concrete		Any other material	
		No. of houses	%	No. of houses	%	No. of houses	%	No. of houses	%	No. of houses	%	No. of houses	%	No. of houses	%	No. of houses	%	No. of houses	%
<b>Rural</b>	17,75,37,513	4,88,12,470	27.5	6,69,815	0.4	6,29,35,397	35.4	23,64,095	1.3	1,86,65,296	10.5	99,27,250	5.6	1,19,06,910	6.7	2,10,61,294	11.9	11,94,986	0.7
<b>Urban</b>	7,15,58,356	45,73,534	6.4	5,03,956	0.7	1,25,91,573	17.6	4,44,565	0.6	1,18,21,919	16.5	41,47,242	5.8	52,46,952	7.3	3,17,77,933	44.4	4,50,682	0.6
<b>Total</b>	24,90,95,869	5,33,86,004	21.4	11,73,771	0.5	7,55,26,970	30.3	28,08,660	1.1	3,04,87,215	12.2	1,40,74,492	5.7	1,71,53,862	6.9	5,28,39,227	21.2	16,45,668	0.7

**Houses By Material of Wall In India**

	Total census houses	Grass, Thatch, Bamboo, Wood, Mud, etc.		Plastic, Polythene		Mud, Unburnt brick		Wood		G.I., Metal, Asbestos sheets		Burnt Brick		Stone		Concrete		Any other material	
		No. of houses	%	No. of houses	%	No. of houses	%	No. of houses	%	No. of houses	%	No. of houses	%	No. of houses	%	No. of houses	%	No. of houses	%
<b>Rural</b>	17,75,37,513	2,21,62,932	12.5	4,77,498	0.3	6,58,07,212	37.1	23,63,200	1.3	8,76,677	0.5	6,27,15,919	35.3	2,03,47,899	11.5	22,53,979	1.3	5,32,197	0.3
<b>Urban</b>	7,15,58,356	25,74,189	3.6	2,44,278	0.3	79,91,950	11.2	8,33,792	1.2	11,22,001	1.6	4,91,75,710	68.7	51,33,918	7.2	42,86,359	6	1,96,159	0.3
<b>Total</b>	24,90,95,869	2,47,37,121	9.9	7,21,776	0.3	7,37,99,162	29.6	31,96,992	1.3	19,98,678	0.8	11,18,91,629	44.9	2,54,81,817	10.2	65,40,338	2.6	7,28,356	0.3

Table 2.2

Distribution of Houses by Predominant Materials of Roof and Wall and Level of Damage Risk

INDIA

Wall / Roof		Census Houses		Level of Risk under									
		No. of Houses	%	EQ Zone				Wind Velocity m/s				Flood Prone Area in %	
				V	IV	III	II	55 & 50	47	44 & 39	33		
				Area in %				Area in %					
<b>INDIA</b>				10.9	17.3	30.4	41.4	5.0	40.2	48.0	6.7	7.9	
<b>WALL</b>													
<b>A1 - Mud &amp; Unburnt Brick Wall</b>	Rural	65,807,212	26.4										
	Urban	7,991,950	3.2										
	<b>Total</b>	<b>73,799,162</b>	<b>29.6</b>	VH	H	M	L	VH	H	M	L	VH	
<b>A2 - Stone Wall</b>	Rural	20,347,899	8.2										
	Urban	5,133,918	2.1										
	<b>Total</b>	<b>25,481,817</b>	<b>10.3</b>	VH	H	M	L	H	M	L	VL	VH	
<b>Total - Category - A</b>		<b>99,280,979</b>	<b>39.9</b>										
<b>B - Burnt Bricks Wall</b>	Rural	62,715,919	25.2										
	Urban	49,175,710	19.7										
	<b>Total</b>	<b>111,891,629</b>	<b>44.9</b>	H	M	L	VL	H	M	L	VL	H/M	
<b>Total - Category - B</b>		<b>111,891,629</b>	<b>44.9</b>										
<b>C1 - Concrete Wall</b>	Rural	2,253,979	0.9										
	Urban	4,286,359	1.7										
	<b>Total</b>	<b>6,540,338</b>	<b>2.6</b>	M	L	VL	VL	L	VL	VL	VL	L/VL	
<b>C2 - Wood wall</b>	Rural	2,363,200	0.9										
	Urban	833,792	0.3										
	<b>Total</b>	<b>3,196,992</b>	<b>1.2</b>	M	L	VL	VL	VH	H	M	L	H	
<b>Total - Category - C</b>		<b>9,737,330</b>	<b>3.9</b>										
<b>X - Other Materials</b>	Rural	24,049,304	9.7										
	Urban	4,136,627	1.7										
	<b>Total</b>	<b>28,185,931</b>	<b>11.4</b>	M	VL	VL	VL	VH	H	M	L	VH	
<b>Total - Category - X</b>		<b>28,185,931</b>	<b>11.3</b>										
<b>TOTAL BUILDINGS</b>		<b>249,095,869</b>											
<b>ROOF</b>													
<b>R1 - Light Weight Sloping Roof</b>	Rural	69,342,567	27.8										
	Urban	17,350,091	7.0										
	<b>Total</b>	<b>86,692,658</b>	<b>34.8</b>	M	M	L	VL	VH	VH	H	M	VH	
<b>R2 - Heavy Weight Sloping Roof</b>	Rural	65,299,492	26.2										
	Urban	13,036,138	5.2										
	<b>Total</b>	<b>78,335,630</b>	<b>31.4</b>	H	M	L	VL	H	M	L	VL	H	
<b>R3 - Flat Roof</b>	Rural	42,895,454	17.2										
	Urban	41,172,127	16.5										
	<b>Total</b>	<b>84,067,581</b>	<b>33.7</b>	Damage Risk as per that for the Wall supporting it									
<b>TOTAL BUILDINGS</b>		<b>249,095,869</b>											

Housing Category : Wall Types

- Category - A :** Buildings in field-stone, rural structures, unburnt brick houses, clay houses
  - Category - B :** Ordinary brick building; buildings of the large block & prefabricated type, half-timbered structures, building in natural hewn stone
  - Category - C :** Reinforced building, well built wooden structures
  - Category - X :** Other materials not covered in A,B,C. These are generally light.
- Notes :**
1. Flood prone area includes that protected area which may have more severe damage under failure of protection works. In some other areas the local damage may be severe under heavy rains and choked drainage.
  2. Damage Risk for wall types is indicated assuming heavy flat roof in categories A, B and C (Reinforced Concrete) building
  3. Source of Housing Data : Census of Housing, GOI, 2001

Housing Category : Roof Type

- Category - R1 -** Light Weight (Grass, Thatch, Bamboo, Wood, Mud, Plastic, Polythene, GI Metal, Asbestos Sheets, Other Materials)
  - Category - R2 -** Heavy Weight (Tiles, Slate)
  - Category - R3 -** Flat Roof (Brick, Stone, Concrete)
- EQ Zone V : Very High Damage Risk Zone (MSK > IX)  
 EQ Zone IV : High Damage Risk Zone (MSK VIII)  
 EQ Zone III : Moderate Damage Risk Zone (MSK VII)  
 EQ Zone II : Low Damage Risk Zone (MSK < VI)
- Level of Risk : VH = Very High; H = High;  
 M = Moderate; L = Low; VL = Very Low

## 2.2 Housing In Geo-Climatic Zones of India

The built forms in housing are an outcome of the interaction between the geo-climatic zones, lifestyles & culture and locally available materials & construction practices. India is a vast country with regional and sub-regional variations in climate and topography. Historically this has molded the lifestyles and micro-culture. Lack of means of communications in earlier days contributed to development of local language systems and local identities and aspirations. This has led to the development of “Typological Systems” in traditional housing forms that are distinct in various regions and sub-regions. Local skills and micro-climate made some local variations also despite the uniform pattern over the regional and sub-regional levels. Overall, within the Indian subcontinent, substantial variations in the geo-climatic factors have contributed to the typological development in the built form of traditional housing. Therefore, the understanding of the geo-climatic factors that have also added to the occurrences of disasters of various types is necessary.

India is a country that extends over 3,000 sq km in North-South and East-West directions. Climate basically identified as the “Tropical Monsoon” in global context has local variations from extreme cold with snow in the Himalayan mountain ranges in the north, to the dry and arid deserts in the west and major river systems such as the Ganges and Brahmaputra in the northern plains of the country. Besides, southern Indian Peninsula is a “Plateau” with the Western and Central hill ranges and coastal plains along the southern seas. These have resulted in six primary geo-climatic regions. While each of this has sub-regions, there is a clear linkage of these regions with the climatic zones. This linkage can be seen below:

<b>Geographical Zones</b>	<b>Climatic Zones</b>
1) The northern mountains	Cold & sunny and cold & cloudy
2) The desert & western arid zone	Hot and dry
3) Peninsular coastline in east and west	Warm and humid
4) Central plateau	Composite and partly hot & dry
5) Peninsular plateau	Hot and dry
6) The Gangetic plain and its extension	Composite climate

The following building types may be considered as indicative examples of the various geo-climatic zones of India.

### 2.3 The Northern Mountain

#### 2.3.1 Western Himalaya

##### (i) Rural (Semi-Nomadic): Fig. 2.1

Front & back rooms used as barriers to the external climate, used as storage and animal space respectively. Central area, warm and cosy, used as habitable space. Lighting and smoke outlet is through the roof.

Wooden columns as load bearing structure, mud walls plastered with cow dung & mud. Thatch and soil used for roof supported over timber frame strong enough to support snow load.

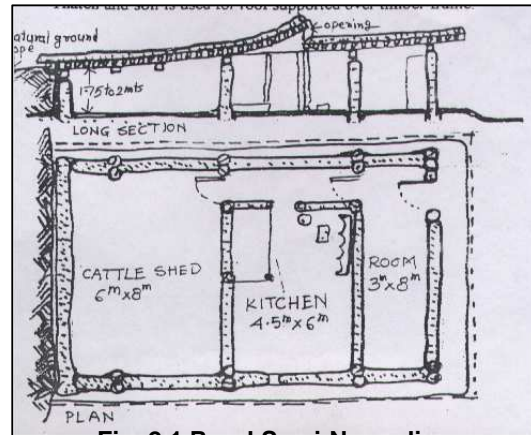


Fig. 2.1 Rural Semi-Nomadic

##### (ii) Rural: A Typical Rural House: Fig. 2.2

A two-room house on two levels with a large room on first floor for summer occupation and smaller rooms on ground floor for winter. Stone and bricks for wall. Mud-plastered and whitewashed walls. Triangular timber trusses with thatch roof. Stone for flooring.

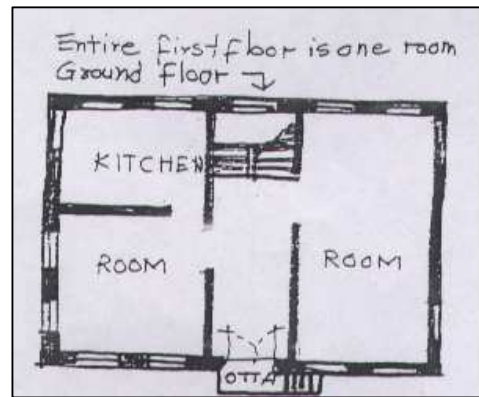


Fig. 2.2 Typical Rural

##### (iii) Urban: (Srinagar, J&K): Fig. 2.3

Rectangular in plan, width more than depth, smaller rooms on lower floors, large rooms above.

Walls with timber frame and brick infill, timber supports for stone roof, stone flooring.

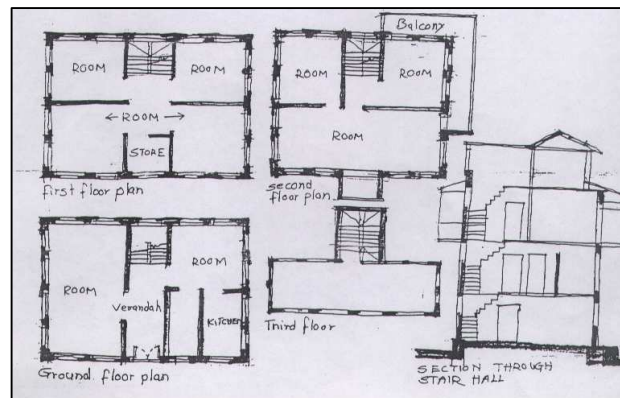


Fig. 2.3 Urban (Srinagar)

(iv) Leh (Ladakh)

High altitude desert area, Himalayan rain shadow, linear settlement form, South orientation, rectangular in shape with longer side facing the sun, two-level house – lower floors warm, walls made of mud brick with mud plaster, roof of mud bricks and stone, stone flooring.

2.3.2 Central Himalayas: Fig. 2.4

(i) Rural (Himachal Pradesh, Garhwal, Kumaon)

Dwellings in a row on narrow terrace spaces, linear house form, less depth, more width, Usually two-storied, ground floor for cattle and store, living habitat on upper floor, walls of stone and brick plastered with mud, whitewashed, triangular timber trusses for tiled roof, stone floor.

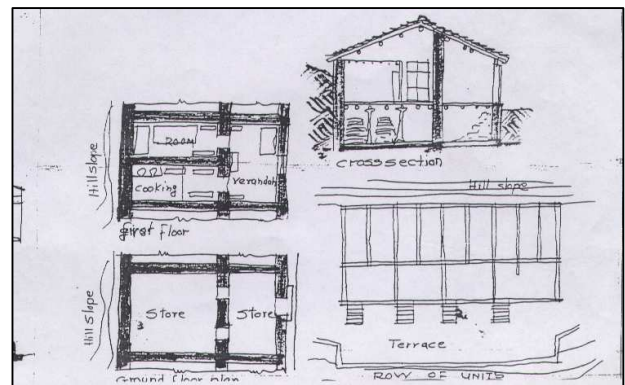


Fig. 2.4 Rural (HP, Uttarakhand)

2.3.3 Eastern Himalayas: (Northern Sikkim, Arunachal Pradesh): Fig. 2.5

(i) Buildings located on ridge or hill flanks facing south, two-storied structure, main room is square with a balcony and kitchen on the first floor, ground floor for cattle and storage, heavy stone masonry walls heavier at bottom and tapering upwards, walls plastered and whitewashed, nipped roof with CGI sheets on timber supports, stone floor.

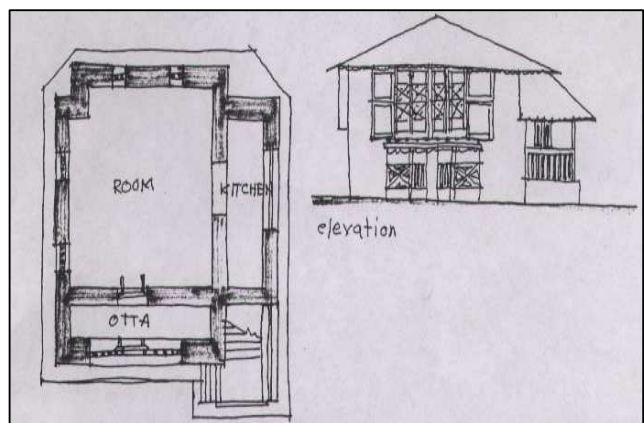


Fig. 2.5 Rural (Sikkim, Arunachal)

## 2.4 Western Arid Zone And Desert (Rajasthan Plain & Kutch in Gujarat)

### i) Bikaner – Urban: Fig. 2.6

Courtyard as a key element, need for privacy, entry through a central bay with rooms on either side, innermost bay occupied by women which is the most private part of the house, two-storied structure, thick stone walls, unplastered, flat roof of stone slabs and stone flooring.

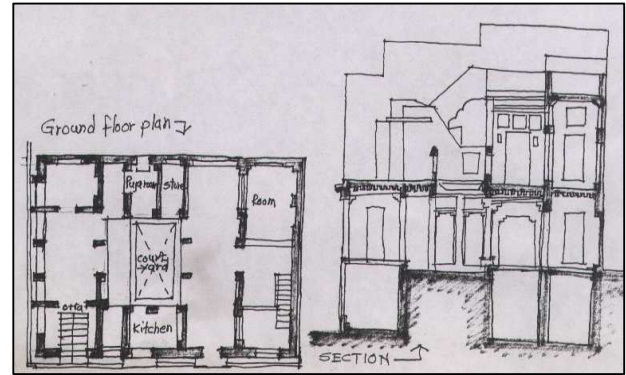


Fig. 2.6 Urban (Kane)

### ii) Urban Jaisalmer

House of introvert nature for climate protection and a strong of privacy, high plinth and baffle wall at the entrance, ground floor has no openings on the street except the entrance door, house form is more open from the inside particularly on the upper floor with terraces, All openings are small and have stone screen, an open court privacy, light and ventilation, also maximises the circulation space, heavy walls of stone and unplastered, stone slabs are used for the roof and floor is also of stone,

### iii) Rural: (Village near Jaisalmer town): Fig. 2.7

Houses clustered having common walls, protected from sand stones, cluster comprises closely knit dwellings introvert in character, central courtyard is the focal point into which the surrounding rooms open, interiors have a variety of storage elements elaborately and elegantly designed such as wooden chests, clay granaries, shelves, etc., walls

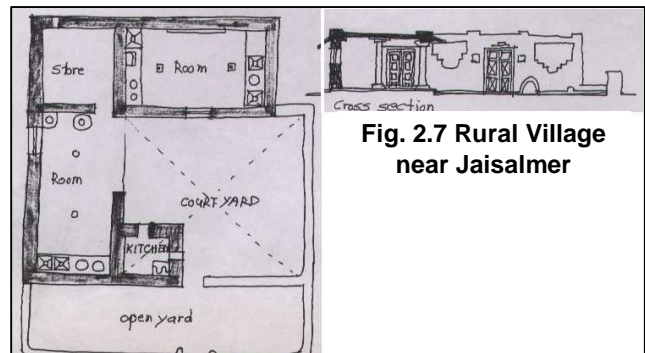


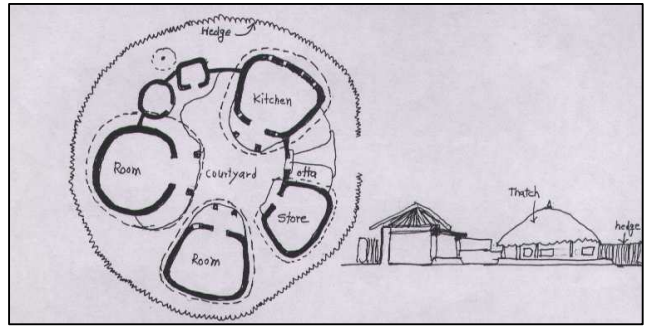
Fig. 2.7 Rural Village near Jaisalmer

of the house are made of mud and stone with mud plaster, thatched roof is spanned by wooden members, mud is used for floor finish.



**iv) Rural (Village near Barmer town): Fig. 2.8**

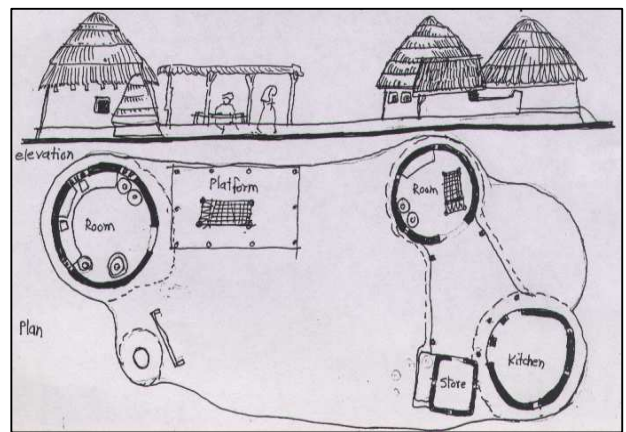
Houses formed using rectangular & circular shaped rooms around a courtyard, grass leaves, reeds and wood used for roofing, Circular huts called Zompas with conical roof. Rectangular houses have pitched roofs.



**Fig. 2.8 Rural near Jaisalmer**

**v) Village in Kachchh: Fig. 2.9**

Village organically grown without conventional streets, decorated walls make the clusters visually attractive, rooms are round in shape built of mud walls, two or three rooms are encircled by a mud platform called Otala used for sit out, each separate circular room used as kitchen, store, verandah or a living room, conical thatched roof is supported by the wooden shafts radiating from the apex of the cone, walls are plastered with mud.



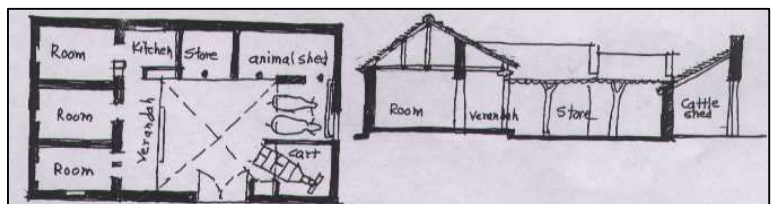
**Fig. 2.9 Rural in Kachchh**

**2.5 Peninsular Coastline**

**2.5.1 Saurashtra Coastal Area**

**(i) Village (On southern coast): Fig. 2.10**

Organically grown village has narrow winding streets, Rectangular shaped houses organised around a courtyard, external surfaces are plain without

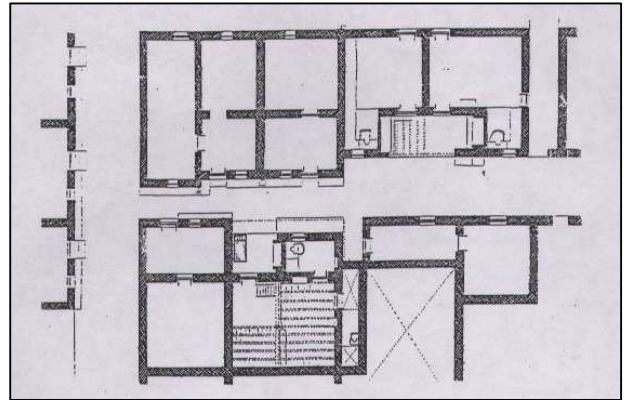


**Fig. 2.10 Saurashtra Coast**

any windows, internal courts are the source of the light & ventilation, main entrance in the courtyard, strong notions of privacy, courtyard the hub of activity with verandahs as transitional space secured by a large gate, walls of stone plastered with cement, pitched sloping clay tiled roof with timber supports, thatch and clay as roofing material alternatively, flooring of mud or plain cement.

**Urban (Western coast of the Saurashtra) : Fig. 2.11**

Well-defined streets with construction up to the edge of the streets, clusters on the basis of casts, houses have identical facades, entrance verandah directly on the street, One room and kitchen house without courtyard, stone walls with lime plastered, clay tile or thatch roof over wooden supports for a pitched roof, stone or plain cement floor.

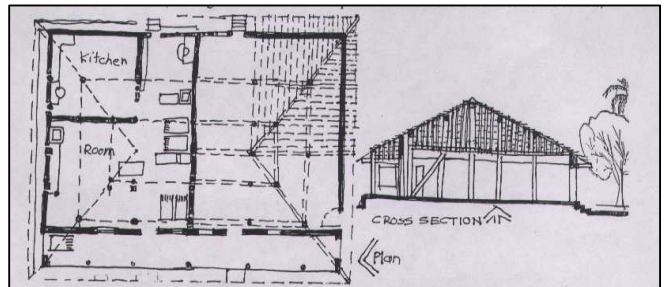


**Fig. 2.11 Urban, Saurashtra Eastern Coast**

**2.5.2 South Gujarat Coastal Belt**

**(i) Rural (village on the coast north of Mumbai in the State of Gujarat) Fig. 2.12**

House takes the form of a single large space covered by hipped end roof, divided functionally as kitchen, living and sleeping areas by arranging storage or furniture, house has two independent systems, one to support the loft and other to support the roof, Frontage of the house has a deep verandah ideal for the warm & humid climate.

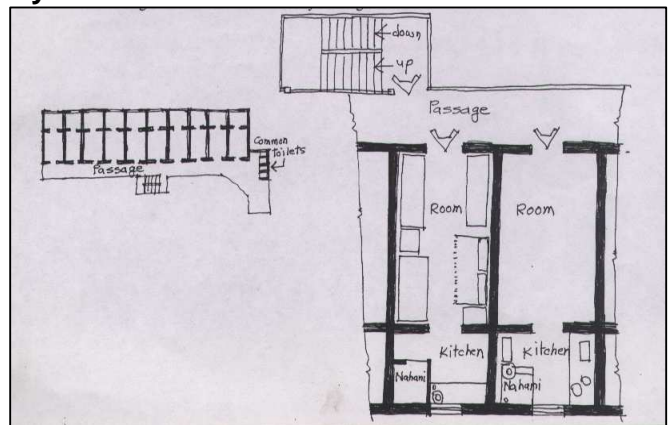


**Fig. 2.12 Rural Cambay Gulf Coast**

**2.5.3 Konkan: The west coast from the city of Mumbai to Goa**

**(i) Chawl (City of Mumbai): Fig. 2.13**

Low income housing, a unique housing typology, one room tenements with cooking areas and common toilets, one or two room tenements are often arranged along a long passage linked to a single staircase in two to five-story buildings.

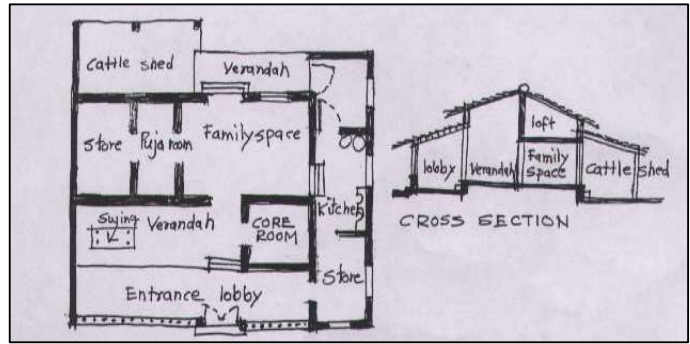


**Fig. 2.13 Chawl, Mumbai**



**(ii) Village (Near Ratnagiri City): Fig. 2.14**

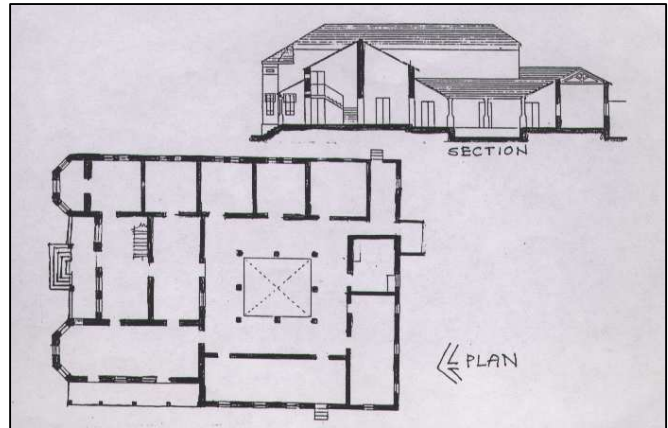
Located on the undulating terrain on the land sloping towards the creek, central rectangular rooms with a loft for storage are surrounded by lean to verandah with a plinth lower than the central rooms, rear verandah space with no plinth is used to keep domestic animals, side verandahs covered and enclosed are used as a storage or kitchen, walls are constructed of thick unplastered laterite stone, timber rafters and purlins support the tiled roof, floor is of cow-dung plaster.



**Fig. 2.14 Rural near Ratnagiri**

**(iii) Goa (Urban) : Fig. 2.15**

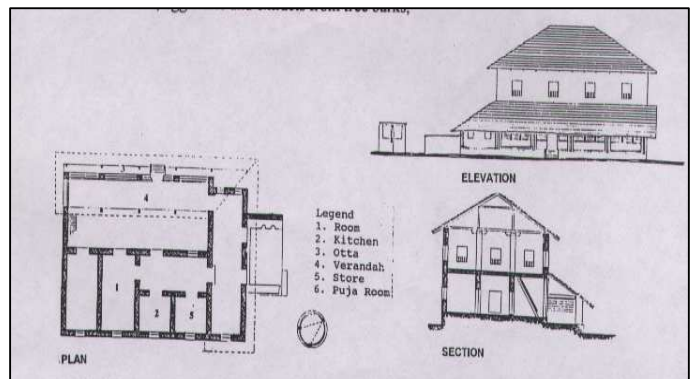
Smaller houses having a front porch or a verandah are similar to houses seen in Konkan villages. Larger houses have the courtyard as main element around which different rooms are grouped. Two-storied houses are constructed of locally quarried laterite stones, walls are plastered and painted white to reflect oppressive humid heat. Tiled roof is supported over timber trusses and purlins, stone or red oxide mixed cement floor is normal.



**Fig. 2.15 Urban in Goa**

**(iv) Village North Karnataka : fig. 2.16**

Houses are similar to those seen on the Konkan coast. No separate spaces for men and women, size and the functional organisation is based on bare necessities principle, walls are of locally quarried laterite stone plastered and painted, tiled roof is supported over timber trusses, black floor is typically local made from the

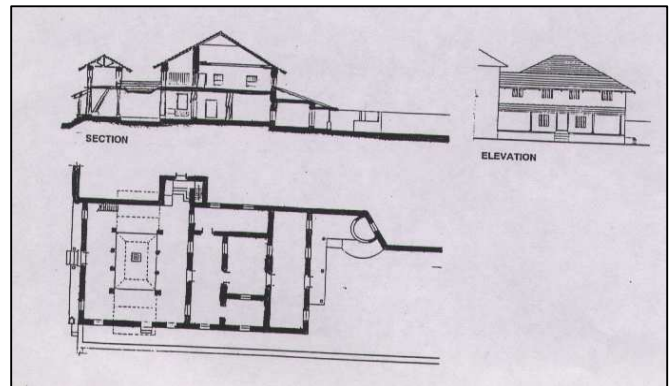


**Fig. 2.16 Rural in Karnataka**

charcoal obtained from the burnt coconut shell, egg white and extracts from tree barks,

**Urban (Mangalore): Fig. 2.17**

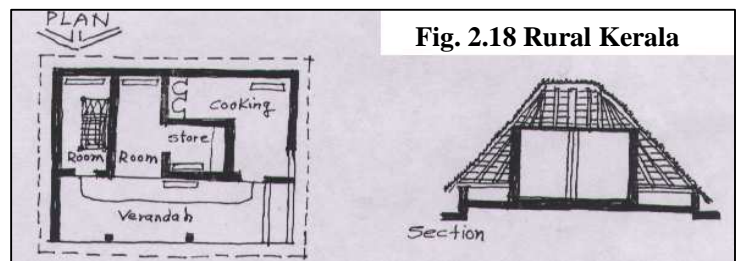
A courtyard with semi-enclosed spaces around in the form of verandah. These spaces are forming the front entrance to the two-storied house.



**Fig. 2.17 Urban Mangalore**

**(v) Village (Kerala): Fig. 2.18**

Linear settlement. Central area of the rectangular house has high plinth. Low plinth semi-open verandahs around central high space. Coconut leaf panel pitched roof supported on coconut trunks. Walls are of laterite stone, lime plaster, lime-levelled floor.

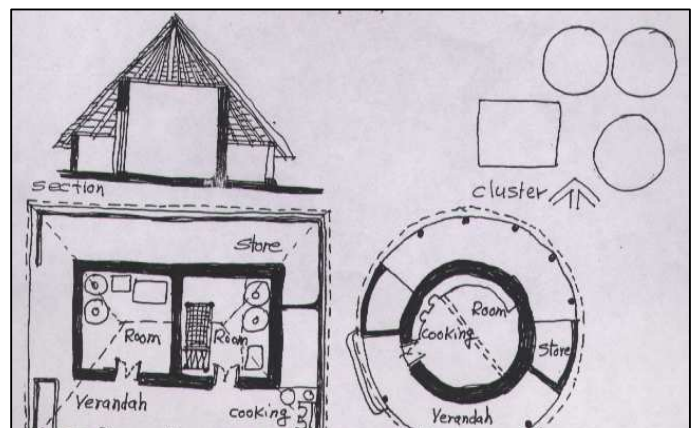


**Fig. 2.18 Rural Kerala**

**2.5.4 East Coast**

**(i) Village (Andhra coast): Fig. 2.19**

Houses in organic clusters without a defined street except the access to the village. Front yards of five to six houses form a common cluster court, paved or asphalted for its use as spillover household activities. Extremely low high-pitched conical roof, just about 15 cm above ground. Lack of light & ventilation, roof pattern is a direct outcome of the high cyclonic winds, 15 to 20 cm high plinth, circular or rectangular form of the house with a core of the same shape surrounded by verandah that account for subsidiary functional spaces. Round houses are used by nuclear small families. Indoor dark

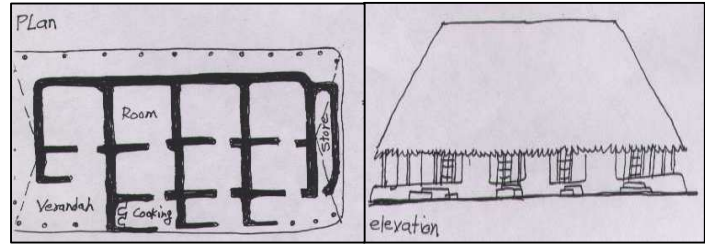


**Fig. 2.19 Village (Andhra coast)**

spaces are mainly used for storage except for rainy season. Walls are of mud, roof of coconut palms.

**(ii) Village (Andhra coast): Fig. 2.20**

Rectangular row houses facing each other at a distance of **about ..... Metres space** forming narrow streets. About four houses under a single dominant high-pitched sleeping roof of coconut leaves supported on middle gable walls & bamboo purlins, attic made of bamboo poles and mat, mud walls. Each household has a room and kitchen.



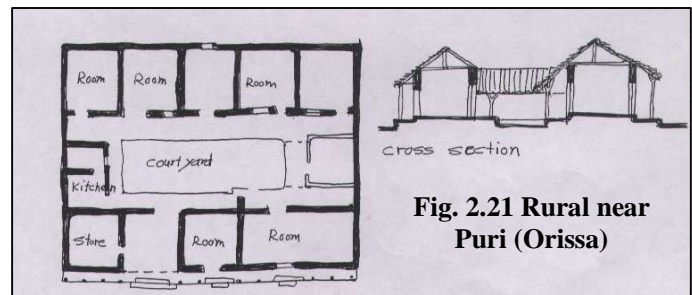
**Fig. 2.20 Rural, AP Coast**

**(iii) Village (Puri District, Orissa)**

Houses are arranged in clusters along the street. Deeper houses with one or two courtyards and have shared walls of 1 to 3 m wide, platforms with plinth of 0.5 m high, single-storied houses with sloping roofs, ornamented doors. Walls made of laterite stone blocks, mud mortar, un plastered exteriors with inside mud plaster, wooden rafters and purlins supporting thatch or asbestos roof, mud floor.

**(iv) Village (Near Puri town): Fig. 2.21**

Houses with internal courtyard and rooms surrounding it. Small covered otala (platform) about 1 m or less wide used as sit on the periphery of the house, mostly no windows, mud or burnt brick walls, partition walls of bamboo with mud & cow-dung plastered. Thatched or tiled roof on bamboo or wooden supports.



**Fig. 2.21 Rural near Puri (Orissa)**

## 2.6 Central Plateau

### (i) Urban (Nathdwara town): Fig. 2.22

Rectangular house with four bays or narrow span. Courtyard as a focal point of activity. Around the courtyard, toilet, kitchen and staircase is located, lime plastered walls are of thick stone, narrow spans are to support the roof/floor by the available length of stone slabs, walls have niches for storage.

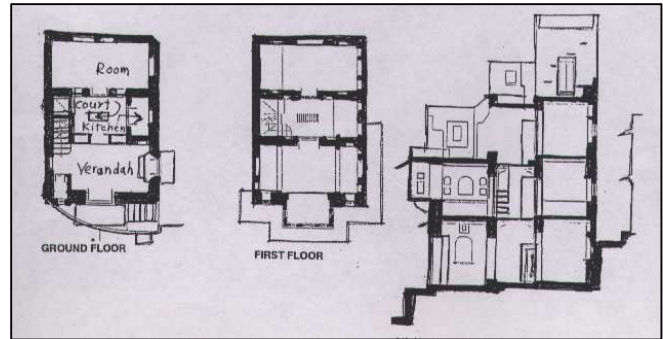


Fig. 2.22 Urban, Nathdwara

### (ii) Village (Malawa & Vindhya Hills): Fig. 2.23

Dispersed locations, elevated living area with a cattle shed below and to protect from heavy rains and water, walls are made of bamboo posts and bamboo mats. Mat porosity gives good ventilation and light, gently sloping roof of clay tiles supported over timber/bamboo.

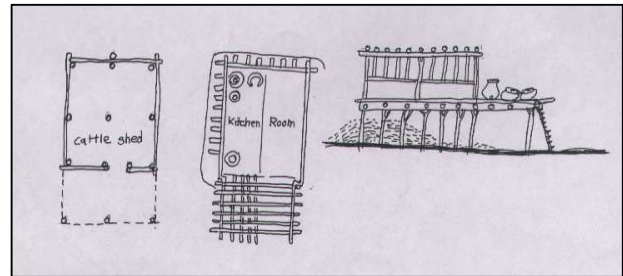


Fig. 2.23 Rural Malwa

### (iii) Village (Central Plateau-Narmada, Dang region): Fig. 2.24

Circular or elliptical houses, thatched conical roofs supported over bamboo rafters. Walls are of bamboo or wooden frames, bamboo mats and mud plaster.

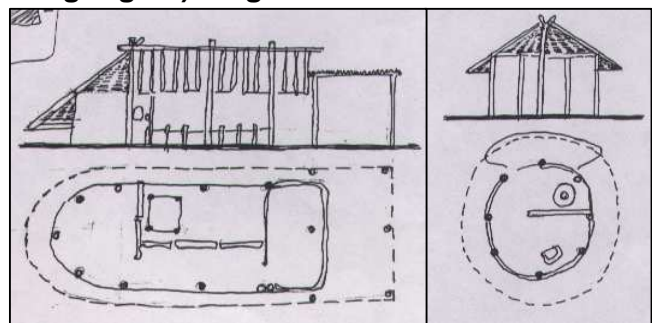


Fig. 2.24 Rural, Dang Region

### (iv) Urban – Central Plateau: Fig. 2.25

Two-roomed G+1-storied houses. A courtyard in front adjacent to verandah, load bearing brick walls lime plastered, country tiled roof supported on timber rafters.

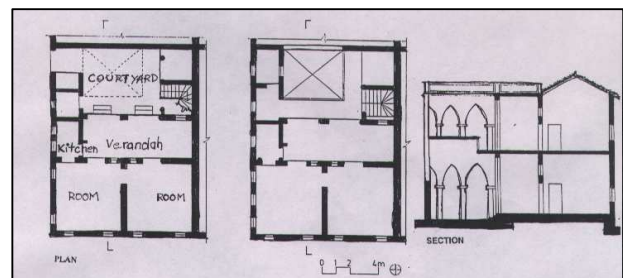


Fig. 2.25 Urban, Dhoraji Town



### 2.6.1 Peninsular Plateau

#### (i) Urban (Nasik Town): Fig. 2.26

Large house around courtyard surrounded by a semi-open verandah is the main source of light & ventilation. Larger the house, more the courtyards. Outer courts have offices or shops, inner courts are residential quarters with a well or a Tulsi plant as a focal point, upper floors are used as living quarters, narrow staircases accommodated in thick walls, wooden column framework with brackets supporting wooden beams for intermediate floor and sloping roof of clay tiles, stone plinths and cement floors, interiors plastered and whitewashed.

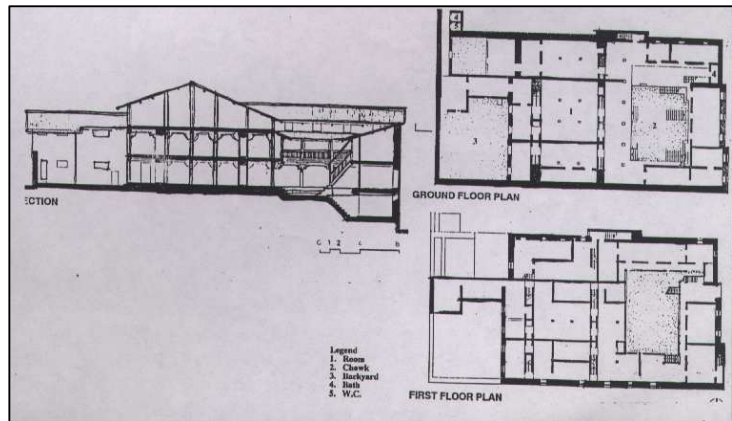


Fig. 2.26 Urban, Nasik Town

#### (ii) Villages (in Latur district): Fig. 2.27

Houses with a central courtyard and an ornate door, have series of rooms with the courtyard in front of verandah. Two-storied, flat roof of timber joists and planks with infill of bricks or earth, thick walls of stones with the cavity filled by earth or rubble.

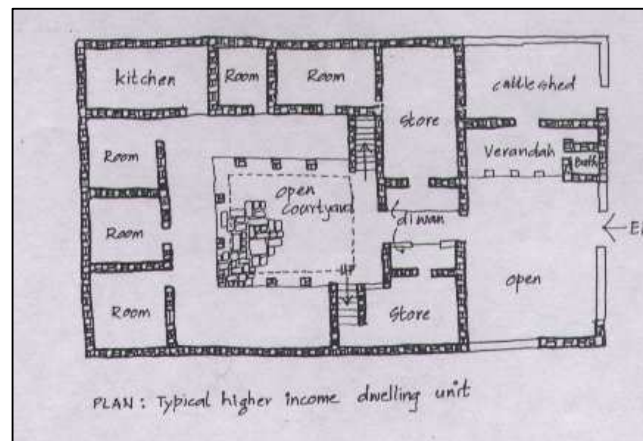


Fig. 2.27 Rural, Latur Distt.

#### (iii) Village (Nilgiri Hills, Near Ootacamand) : Fig. 2.28

Nomadic Toda tribes with buffalo herding as the occupation move from village to village, abandoning some and occupying others, oval shaped house, low and arched to keep the cold and rain out, 2.5 m high in the centre, raised platform to be used as a sleeping place inside the house, no

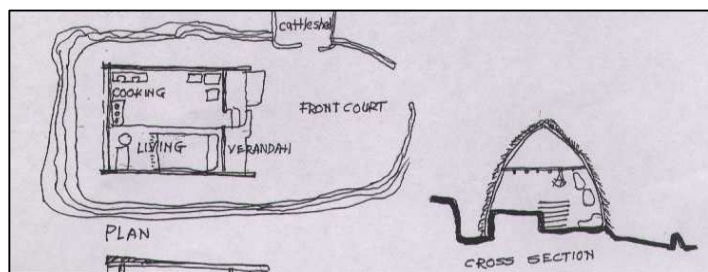
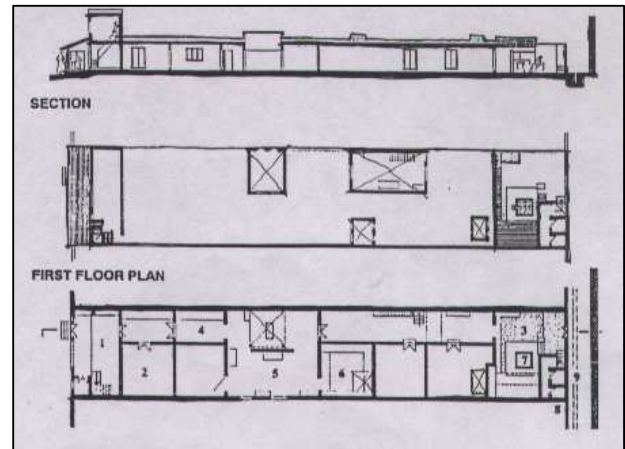


Fig. 2.28 Rural Nilgiri Distt.

internal partitions in a 4x5 m house, no windows or openings except for the door, a braced conical roof starting almost from ground is reinforced from inside with bamboo and wood to resist lateral forces of stormy winds and rains, entrance doorway is low, just 0.75 m high located within the front wall of planking.

**(iv) Urban (Srirangam Town: Deccan Plateau): Fig. 2.29**

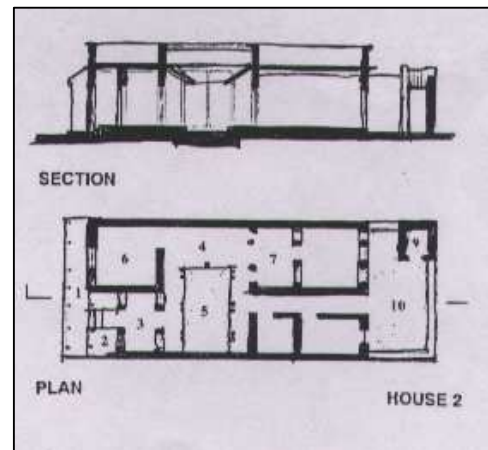
Deep row houses of 1:8 ratio located on either of the narrow street, sublet for multi-family occupation, cool but dimly lit interiors, water channel is connected along wall to the kitchen for filling of water from outside, toilets at the rear along a service lane for use by scavengers, straight alignment of the doors in one line and clear story windows allow light and ventilation, walls are of mud, plastered and whitewashed, flat wooden roof with a lean to roof with Mangalore tiles for the front verandah. Cement or mud floor.



**Fig. 2.29 Urban, Srirangam Town**

**(v) Urban (Pondicherry Town): Fig. 2.30**

Wide straight roads and white buildings, walkway in front of the house is often covered and is used to keep buffalo or to rent it as a shop. Beyond a verandah is a transient space between public road and private house, inner courtyard forms the focal point of the house around which all household activities take place. Brick walls plastered and painted white support an R.C.C. roof.



**Fig. 2.30 Urban, Pondicherry Town**

**(vi) Urban (Mahabalipuram Town): Fig. 2.31**

Residential structures line the main & secondary streets, no specific formation in terms of housing clusters, dense urban fabric, introvert houses looking into an internal courtyard, single-storied with sloping roof, street front has a verandah, load bearing walls are of brick & plastered from inside as well as outside. Sloping clay tiled roof supported on timber trusses, cement floor.

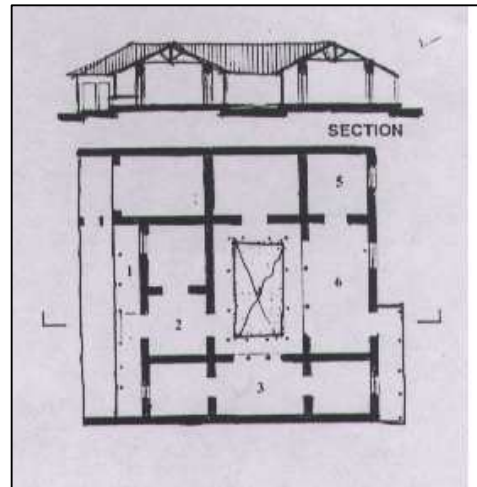


Fig. 2.31 Urban, Mahabalipuram Town

**2.7 Peninsular Plateau – Eastern Hills – Bengal & Bihar Hills**

**2.7.1 Rural (Purulia district, W. Bengal): Fig. 2.32**

Houses are grouped in a cluster and consist of three to five separately built single spaces forming a courtyard. A couple of rooms, a kitchen & a cattle shed complete the house. Thick mud walls, each built space is rectangular in shape and has an entry through a verandah. Cattle shed is semi-covered, walls are plastered with mud and cow dung. Sloping roof is of thatch supported over unfinished wooden members, no purlins but strings and ropes are used for tying the thatch as well as timber members.

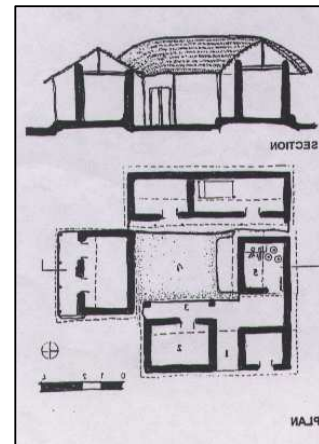


Fig. 2.32 Rural, Purulia Distt.

**2.7.2 Shillong Plateau: Detached Block Of Peninsula**

**(i) Rural village (Near Cherapunji town): Fig. 2.33**

Oval shape of the house originates from their religious beliefs. House takes the form of a truncated oval with front being narrow and round and rear somewhat rectangular, steeply sloping roof with ridge parallel to the long side walls. Roof resembles an upturned boat. House

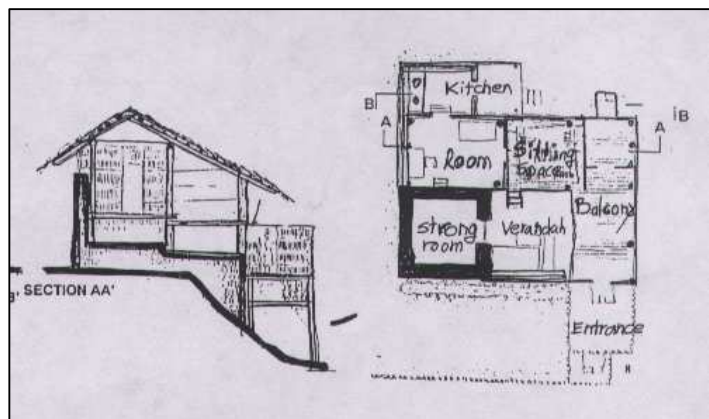


Fig. 2.33 Rural near Cherapunji Town

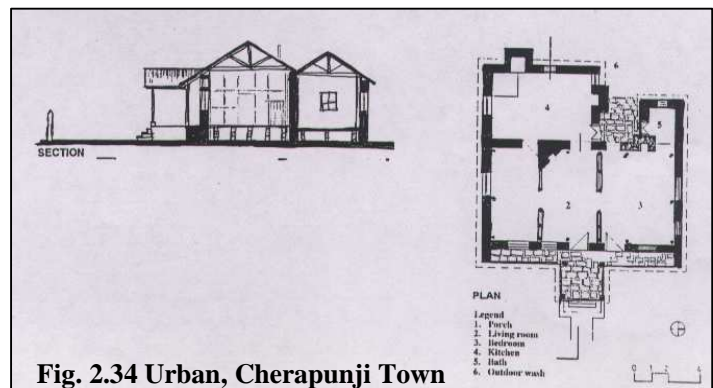
is divided in four parts (entrance room, main living hall, sleeping area & outdoor wash) not by walls but by level changes. Flight of stairs leads to main living area having wooden floor raised (1.2 m) on locally available limestone pillars. Hearth is a part of living space used for dining. Sleeping area is between the side walls and central wooden supporting the roof ridge. Wooden planks for walls painted with tar from inside, thatch or tin sheet roof over wooden members, flooring is also of wood.

**(ii) Rural Village (On Hill Slope)**

Houses are on slopes with fronts resting on pillars while the back rests on the hill slopes, entrance to the houses is through a verandah or a semi-open space, orientation is south-east to north-west along the longer side as dictated by the hill slopes, (at right angle to the hill slope), rectangular house consists of a living space raised on piles, a bedroom, a kitchen and a store, bamboo railings are used, kitchen is on a wooden platform nearer to the bedroom accessible from it, stone is used for the load bearing walls, partitions are of bamboo or reeds, windows are absent, interiors are painted with tar, thatch & palm tree leaves for roof covering supported over bamboo rafters, earth plastered flooring.

**(iii) Urban (Cherapunji Town): Fig. 2.34**

Houses show a strong colonial influence, located on either side of the main road, have common compound walls of stone. Houses have a front margin of 5 metres, stone walls with wooden columns located close to the walls to support the roof. Traditional hearth becomes a colonial fireplace with a chimney. Wood is used for flooring and for partitions. Porch and verandah are a part of the house system, regular windows, false ceiling below the CGI sheet roof.



**Fig. 2.34 Urban, Cherapunji Town**



## 2.8 Gangetic Plain & The Extension Of Its Trough

### 2.8.1 Main Indo-Gangetic plain, plains of Punjab

#### (i) Rural village: Fig. 2.35

Activity spaces are grouped around a courtyard which is entered directly from the street. Houses have an attic generally used as storage, openings are few and small, mud walls plastered with cow dung on either side support a sloping country tiled roof on timber rafter and purlins, eaves of the roof are high and ornamented.

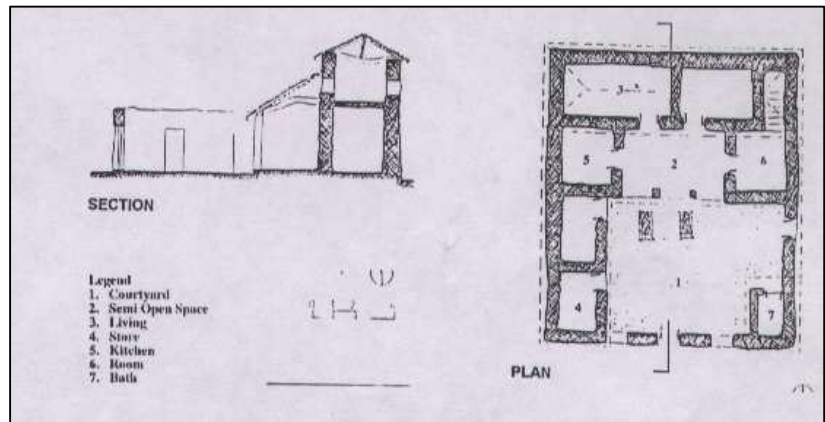


Fig. 2.35 Rural Indus - Ganga Plain

#### (ii) Urban (Banaras): Fig. 2.36

Settlement is structured on the mohalla (neighbor hood) concept with a temple or a lake as nucleus. Houses are multi-level, three- or four-storey, central courtyard is a feature, lower floors are used for services and storage while upper floors are used as living spaces, windows and balconies are used as features. Bricks are used for load bearing walls, cement plaster, flat roof as well as floors on wooden rafters.

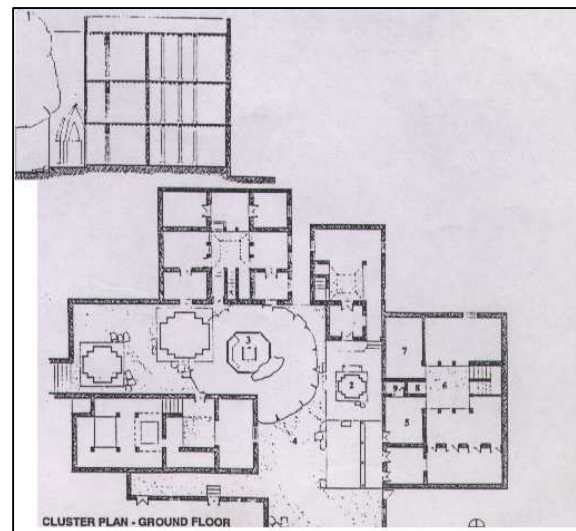


Fig. 2.36 Urban Banaras Town

### 2.8.2 Gujarat plain

#### (i) Rural village: Fig. 2.37

Houses on deep plots with front open space, two-roomed linear house with kitchen at rear opening on to a backyard, front yard is used for keeping cattle, most activities take place in open yards.

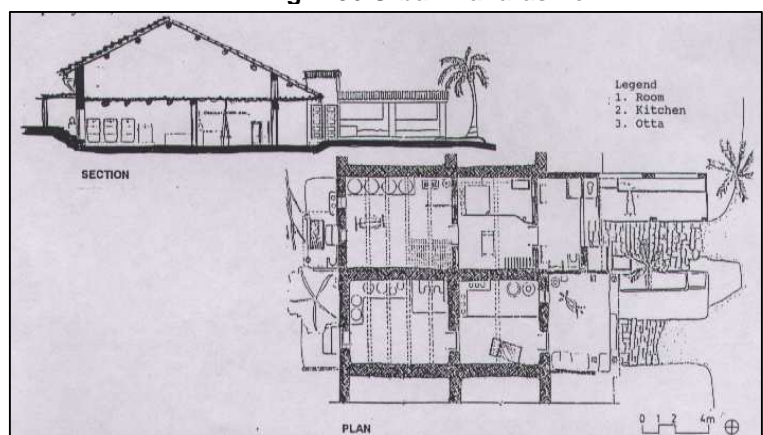


Fig. 2.37 Rural Gujarat Plain

### 2.8.3 Assam Valley, Arunachal Pradesh

#### (i) Rural Village in Arunachal Pradesh: Fig. 2.38

Evergreen and hilly region, houses are randomly sited as per flat contours available. Long houses stretching up to 30 m max. Houses are on stilts with all living spaces on upper floor, longer walls have bamboo screen with verandahs on shorter sides. Upper living space has 3 or 4 **huts** spread at equal distance in the centre, traditionally these are joint family houses, rear verandah

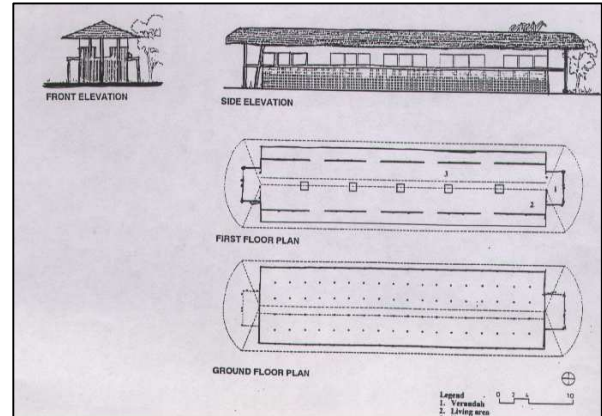


Fig. 2.38 Rural, Assam Plain

is used for cooking & washing, lower floors are for cattle, bamboo is used extensively for walling, flooring, door & window shutters and roof supports.

### 2.9 Vulnerability of Various House Types

With these groupings, the vulnerability of each subgroup could be defined separately for any given intensity of earthquake, wind or flood hazard. The risk levels of the various categories of houses for the three hazards are explained in the following sections. In the 1991 Census of housing, roof and wall combinations were available for each house type. Therefore, the combined vulnerability of the complete house was indicated which is not possible for the data available in Census of housing 2001. For convenience of reference to those who may be studying existing houses taking wall and roof together, reference may be made to Vulnerability Atlas of India 1997.

The damage risk to various house types is based on their average performance observed during past occurrences of damaging events. In view of numerous variations in the architectural planning, structural detailing, quality of construction and care taken in maintenance, the performance of each category of houses in a given event could vary substantially from the average observed. The Intensity Scale as given in Annexure 3 represents average observations. For example, under seismic occurrence, the following observations have been made in many cases:

(a) All masonry houses in categories A and B

- Quality of construction comes out as a major factor in the seismic performance, particularly under intensities MSK VII to IX. Good quality constructions perform much better than poor quality constructions in any category. Appropriate maintenance increases durability and maintains original strength.
- Number of stories in the house and the story height are other factors. Higher the story and more the number of stories, greater is the observed damage.
- Size, location and number of door and window openings in the walls also determine seismic performance since the openings have weakening effect on the walls. Smaller and fewer openings and located more centrally in the walls are better from seismic performance viewpoint.
- Architectural layout, particularly in large buildings, that is, shape of building in plan and elevation, presence of offsets and extended wings also play important role in initiation of damage at certain points and its propagation as well. More symmetrical plans and elevations reduce damage and unsymmetrical ones lead to greater damage.
- Where clay/mud mortar is used in wall construction, its wetness at the time of earthquake is very important factor in the seismic performance since the strength of fully saturated mortar can become as low as 15% of its dry strength.

(b) Wooden houses

- Quality of construction, that is, seasoning of wood and the joinery are important in seismic and cyclonic wind performance. Better the quality, better the performance.
- Wood decays with time due to dry rot, insect and rodent attack, etc. Therefore, the joints tend to become loose and weak. The state of maintenance of the wooden building will determine its performance during earthquake, high wind, as well as flooding.

- In houses with sloped roofs, a shallow angle for the roof, extended eaves projection and reentrant corners lead to higher damage.
- In light roofs, pressures often exceed the dead weight leading to blowing-off of roofs.

(c) Reinforced concrete houses

- Multi-story RC frame buildings resting on soft soils and having soft first storey unconnected wall panels and floating columns in the superstructure collapsed even in Seismic Zone III.
- Besides bad quality of configuration planning and structural design, poor quality of construction lead to total collapses of 5- to 10-storeyed RC frame buildings.
- In reinforced concrete construction, good structural design and detailing and good quality construction only would ensure excellent performance. Carelessness in any of these can lead to poor behaviour, both under earthquakes and cyclones.

Now the average risk levels to various categories of houses for various hazards and their intensities are defined here below for use in the house vulnerability assessment.

## **2.10 Damage Risk Levels**

### **2.10.1 Damage Risk Levels For Earthquakes**

The damage risk to various house types is defined under various seismic intensities on MSK scale (see Annexure 3). The following damage risks are defined based on this Intensity Scale.

**Very High Damage Risk (VH):** Total collapse of buildings.

**High Damage Risk (H):** Gaps in walls, parts of buildings may collapse, separate parts of the building lose their cohesion and inner walls collapse.

**Moderate Damage Risk (M):** Large and deep cracks in walls fall of chimneys on roofs.

**Low Damage Risk (L):** Small cracks in walls, fall of fairly large pieces of plaster, pantiles slip-off, cracks in chimneys, part may fall down.

**Very Low Damage Risk (VL):** Fine cracks in plaster, fall of small pieces of plaster.

### **2.10.2 Damage Risk Levels For Windstorms**

For damage risk to buildings from windstorms, there appears no universally accepted scale like the seismic intensity scale. The following damage risk scale has been proposed by Vulnerability Atlas Expert Group (BMTPC), for developing the house vulnerability tables.

**Very High Damage Risk (VH):** Generally similar to “High Risk” but damage is expected to be more widespread as in the case of cyclonic storms.

**High Damage Risk (H):** Boundary walls overturn, outer walls in houses and industrial structures fail, roofing sheets and tiles or whole roofs fly, large-scale destruction of lifeline structures such as lighting and telephone poles, a few transmission line towers/communication towers may suffer damage and non-engineered/semi-engineered constructions suffer heavy damage.

**Moderate Damage Risk (M):** Loose tiles of clay fly, roofing sheets fixed to battens fly, moderate damage to telephone and lighting poles, moderate damage to non-engineered/semi-engineered buildings.

**Low Damage Risk (L):** Loose metal or fibre cement sheets fly, a few lighting and telephone poles go out of alignment, signboards and hoardings partially damaged, well-detailed non-engineered/semi-engineered buildings suffer very little damage.

**Very Low Damage Risk (VL):** Generally similar to “Low Risk” but expected to be very limited in extent.

### **2.10.3 Damage Risk Levels For Floods**

No detailed building damage reports under flooding appear to have been worked out as yet. Also flood intensities in terms of depth of water, velocity of flow or time duration of inundation are not yet defined. In the absence of such data, no definite recommendation about damage risk levels could be made. The following damage risks have been drafted by the BMTPC expert group based on understanding of material behaviour under submergence.

**Very High Damage Risk (VH):** Total collapse of buildings, roof and some walls collapse, floating away of sheets, thatch, etc., erosion of foundation, severe damage to lifeline structures and systems.

**High Damage Risk (H):** Gaps in walls, punching of holes through wall by flowing water, parts of buildings may collapse, light roofs float away, erosion of foundation, sinking or tilting, undercutting of floors, partial roof collapse.

**Moderate Damage Risk (M):** Large and deep cracks in walls, bulging of walls, loss of belongings, damage to electric fittings.

**Low Damage Risk (L):** Small cracks in walls, fall of fairly large pieces of plaster.

**Very Low Damage Risk (VL):** Fine cracks in plaster, fall of small pieces of plaster.

### **2.11 The Housing Risk Tables**

Now correlating the house types, the hazard intensities on the hazard zoning maps and the damage risk levels as above, the housing damage risk tables have been generated: For the country as a whole, for each State and Union Territory, also for each district in India (see Vulnerability Atlas of India 2006. For example, see Table 2.3 for the district Kendrapara, in Orissa.

Each table also gives at the top of each column of hazard intensities, the per cent of total area of the district covered by the Table, lying under the various hazard intensities. Thus, the administrative or professional authority concerned can visualise the extent of damage risk existing to any hazard at one time or the other in the future. As an example, refer to Table 2.3. District Kendrapara of Orissa. It is seen that 89.2% area of the district lies in seismic intensity VII zone (Zone III) and 100% area in the 50 m/s wind zone. Also 35.5% of its area is flood-prone. The probable maximum 24 hours precipitation is 600 mm, that is, quite a high figure.

According to 2001 Census, there are 3,54,771 housing units in the district, 77.3% of which are of category A (very weak type), 18.8% of category B (moderate strength) and only 1.30% of category C (the strong types). Also 2.7% houses are of bamboo, thatch, grass, leaves type indicating the poverty condition of the people. The risk of damage from earthquakes to Category A houses is 'medium', and to Category B (18.8% of total) it is 'low'.



## Mainstreaming Disaster Risk Reduction In Housing Sector

The example district lies in the cyclone-prone area of the Orissa coast and has very high risk to 77.1% housing units; hence the life and property of this population living in the district is at great cyclone risk. The district has also great risk of flooding, storm surges & tsunami. Hence serious attention has to be paid to the district with cyclone, tsunami & storm surge disaster prevention, mitigation and preparedness points of view. Other hazards can similarly be analysed with the help of the table.

**Distribution of Houses by Predominant Materials of Roof and Wall and Level of Damage Risk**

Table No. : OR 10		State : ORISSA		KENDRAPARA									
Wall / Roof		Census Houses		Level of Risk under									
		No. of Houses	%	EQ Zone				Wind Velocity m/s				Flood Prone Area in %	
				V	IV	III	II	55 & 50	47	44 & 39	33		
		Area in %		Area in %									
<b>WALL</b>						89.2	10.8	100					35.5
<b>A1 - Mud Unburnt Brick Wall</b>	Rural	266,645	75.2										
	Urban	6,906	1.9										
	<b>Total</b>	<b>273,551</b>	<b>77.1</b>			M	L	VH					VH
<b>A2 - Stone Wall</b>	Rural	593	0.2										
	Urban	35	-										
	<b>Total</b>	<b>628</b>	<b>0.2</b>			M	L	H					VH
<b>Total - Category - A</b>		<b>274,179</b>	<b>77.3</b>										
<b>B - Burnt Bricks Wall</b>	Rural	55,783	15.7										
	Urban	10,826	3.1										
	<b>Total</b>	<b>66,609</b>	<b>18.8</b>			L	VL	H					H/M
<b>Total - Category - B</b>		<b>66,609</b>	<b>18.8</b>										
<b>C1 - Concrete Wall</b>	Rural	585	0.2										
	Urban	13											
	<b>Total</b>	<b>598</b>				VL	VL	L					L/VL
<b>C2 - Wood wall</b>	Rural	3,264	0.9										
	Urban	584	0.2										
	<b>Total</b>	<b>3,848</b>	<b>1.1</b>			VL	VL	VH					H
<b>Total - Category - C</b>		<b>4,446</b>	<b>1.3</b>										
<b>X - Other Materials</b>	Rural	8,889	2.5										
	Urban	648	0.2										
	<b>Total</b>	<b>9,537</b>	<b>2.7</b>			VL	VL	VH					VH
<b>Total - Category - X</b>		<b>9,537</b>	<b>2.7</b>										
<b>TOTAL BUILDINGS</b>		<b>354,771</b>											

ROOF													
<b>R1 - Light Weight Sloping Roof</b>	Rural	297,744	83.9										
	Urban	12,052	3.4										
	<b>Total</b>	<b>309,796</b>	<b>87.3</b>			L	VL	VH					VH
<b>R2 - Heavy Weight Sloping Roof</b>	Rural	2,201	0.6										
	Urban	465	0.1										
	<b>Total</b>	<b>2,666</b>	<b>0.7</b>			L	VL	H					H
<b>R3 - Flat Roof</b>	Rural	35,814	10.1										
	Urban	6,495	1.8										
	<b>Total</b>	<b>42,309</b>	<b>11.9</b>										
<b>TOTAL BUILDINGS</b>		<b>354,771</b>											

Probable Maximum Precipitation at a Station of the district in 24 hrs is 600 mm

**Housing Category : Wall Types**

**Category - A :** Buildings in field-stone, rural structures, unburnt brick houses, clay houses

**Category - B :** Ordinary brick building; buildings of the large block & prefabricated type, half-timbered structures, building in natural hewn stone

**Category - C :** Reinforced building, well built wooden structures

**Category - X :** Other materials not covered in A,B,C. These are generally light.

**Notes :** 1. Flood prone area includes that protected area which may have more severe damage under failure of protection works. In some other areas the local damage may be severe under heavy rains and choked drainage.

2. Damage Risk for wall types is indicated assuming heavy flat roof

in categories A, B and C (Reinforced Concrete) building

3. Source of Housing Data : Census of Housing, GOI, 2001

**Housing Category : Roof Type**

**Category - R1 -** Light Weight (Grass, Thatch, Bamboo, Wood, Mud, Plastic, Polythene,

GI Metal, Asbestos Sheets, Other Materials)

**Category - R2 -** Heavy Weight (Tiles, Slate)

**Category - R3 -** Flat Roof (Brick, Stone, Concrete)

EQ Zone V : Very High Damage Risk Zone (MSK > IX)

EQ Zone IV : High Damage Risk Zone (MSK VIII)

EQ Zone III : Moderate Damage Risk Zone (MSK VII)

EQ Zone II : Low Damage Risk Zone (MSK < VI)

Level of Risk : VH = Very High; H = High;

M = Moderate; L = Low; VL = Very Low

## **2.12 Earthquake-Safe Traditional Construction Practices In India**

The traditional construction practices are greatly influenced by local climatic conditions and availability of building material in the area. The building materials used in construction of such houses are categorised as primary (like mud, stone, timber, bamboo, grass, etc.) and secondary (like bricks, cement, steel, etc.) types. Every region has its own supply of locally available building materials. In the Himalayan region of north India, stone, mud/clay, along with timber/wood are the common building materials used for house construction. Similarly, in north east India, bamboo and wood are found in abundance. Naturally, these constitute the primary building materials, along with stone and clay/mud, etc.

To combat the impact of repeated earthquakes in high seismic zones of the country, earthquake in high seismic zones of the country, earthquake-safe house construction practices have evolved by incorporating the necessary elements in the house construction. A few of such techniques which are quite famous globally are summarised in Table 2.4. The durability of such traditional house construction practices during recent and past earthquake had been found to be excellent.

There is a need to document, validate and disseminate the successful examples of disaster resistant construction techniques based on indigenous technologies.

**Table 2.4 Distribution of Earthquake-Safe Traditional Construction Practices In India**

<b>Construction Practice</b>	<b>Typical feature</b>	<b>Regional distribution</b>	<b>Famous earthquakes in the region</b>
Thatch Houses	Thatch and bamboo houses	North East India	Shillong Assam M8.7 (1897), Assam M 8.6 (1950)
Assam Type Houses	Timber frame with Ekra infill		
Nawari Houses (Nepal)	Timber with adobe infill and mud mortar	North Bihar / Nepal	North Bihar M 8.3 (1934)
Kat-ki Kanni	Stone and timber houses	Kullu Valley (Himachal Pradesh)	Himachal Pradesh M8.0 (1905)
Pherols / Sumers	Multi-storey timber/stone structure	Garhwal Region (Uttarakhand)	Chamoli M6.9 (1999), Uttakashi M6.4 (1991)
Dhajji Dewari	Wooden tie beams with adobe infill and mud mortar	Kashmir Valley (Jammu and Kashmir)	Kashmir M6.3 (1885) Kashmir M7.6 (2005)
Taq system	Load bearing masonry piers with adobe infill and timber runners		
Bhonga	Mud houses, circular in shape	Kutch District (Gujarat)	Kutch M8.0 (1819)

*Source: Amir Ali Khan*



**References:**

- 2.1 Census of India 2001-Housing Series, Registrar Census, Govt. of India.
- 2.2 Joglekar MN and Arya A.S., Housing Typology for Disaster Mitigation Study Sponsored by BMTPC, Ministry of Urban Development, GoI, (Report including study by CEPT, Ahmedabad, sponsored by NBO & MoUD, Govt. of India).
- 2.3 Vulnerability Atlas of India, by Expert Group, Published by (BMTPC), 1997, revised and updated, 2006.

### 3. Framework of Mainstreaming DRR In Housing Sector

#### 3.1 Guidelines By International Organisations

The UN-ISDR defines Disaster Risk Reduction as “the systematic development and application of ‘policies’, ‘strategies’ and ‘practices’ to minimise vulnerabilities and disaster risks throughout a society, to avoid (prevention) or to limit (mitigation and preparedness) the adverse impact of hazards, within the broad context of sustainable development”.

The mainstreaming framework provides a functional way to build collaboration between stakeholders in order to reduce the impact of natural disasters by integrating disaster risk reduction measures into development policies. This framework lays responsibility for reducing the impact of disasters on ‘policymakers’, ‘communities’, non-governmental organisations’ and ‘the private sector’. The objective is to ‘develop a way of capturing progress qualitatively and quantitatively in each thematic area that contributes to reduction of ‘identified risks’. The 5 thematic areas include ‘Governance’, ‘Preparedness and Emergency management’, ‘Risk Identification’, ‘Knowledge Management and Risk Management Application’ (Vulnerability Reduction).

Thus, the approach of ISDR to ‘Mainstreaming DRR’ is to establish some agreed fundamental principles at the global level that could be applied to specific circumstances as well as to regional, national and local contexts.

It thus appears relevant to study and put the mainstreaming guidelines under each of the thematic area in the context of housing sector in India.

#### 3.2 Governance

According to the World Disaster Report, effective and accountable Local Body Authorities namely Municipal Corporations, Development Authorities, Municipal Councils, Nagar Panchayats, Zila Panchayats, Rural Panchayats, Cantonment Boards, etc., are the most important institutions and their “governance structure” is most critical for reducing the toll/impact of natural and human-induced disasters in human settlements whether urban or rural.

The governance model in a local body is largely responsible for policies, planning and implementation of regulatory systems which, if taken care of properly, can help in

reduction of social, physical and economic vulnerability for the communities, housing and infrastructure in the areas under their control. The local bodies can achieve this by proper planning and by ensuring adherence to approved land uses, building bylaws, regulations and promoting construction activities which address disaster safety aspects adequately. Disaster risk reduction has to be considered as a local priority for which local bodies should strengthen their institutional base and build internal capacities for properly utilising the disaster risk information while approving project proposals submitted with them.

Yet another factor where our governance models fail is the multiplicity of agencies operating and regulating at local level. There is, therefore, a need to establish an inter-agency coordinating mechanism which would strengthen governance. This has also been recommended by ISDR.

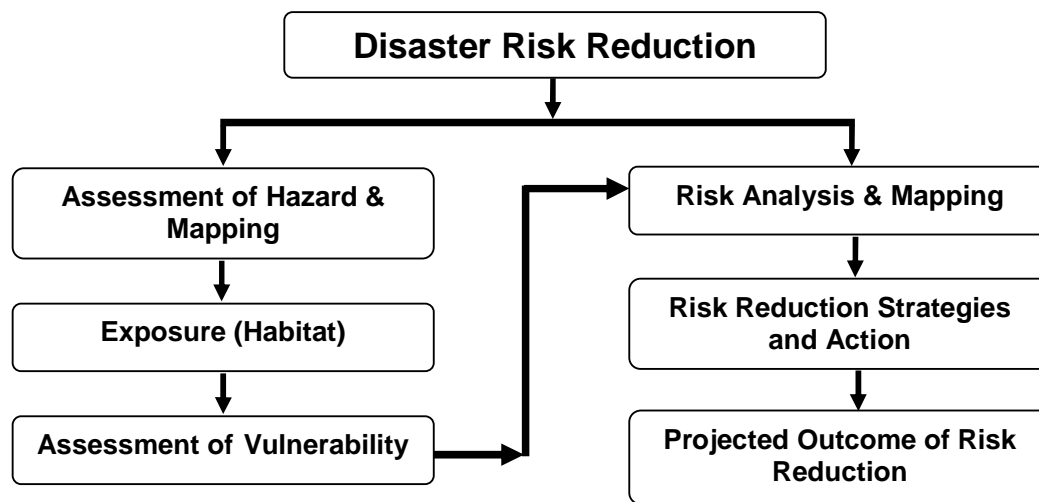
### **3.3 Risk Assessment/Risk Identification**

Collating and validating information from past large events, loss studies and developing geographically precise risk data is a major challenge for those responsible for “Risk Assessment”. Quality of data and information (processed or raw) is important for assessment of risks. A high level of accuracy and detail is generally possible through maps, remote sensing and GIS. In many countries, (India, for example) carrying out new studies may not be necessary in every case as adequate information is available on maps obtainable from remote sensing organisations and hazard zoning maps prepared by BIS, GSI, IMD, etc., available in public domain, though obtaining right scale of maps, may sometimes be time-consuming, expensive and requiring a number of permissions. Sometimes simulations and scenarios can also be useful in assessing how the proposed project might accentuate or mitigate hazards in the project area. Cataloguing hazards can be complicated where primary hazard such as a cyclone triggers secondary hazards such as floods and an earthquake triggers landslides.

Thus, obtaining quality data, information about location, impact and frequency of hazard events is very important for proper assessment of risks in a particular area of interest. Some other recommended information providers, suggested by ProVention Consortium in their report titled “Tools for Mainstreaming Disaster Risk Reduction: Guidance Notes for Development Organisations”, include:

- i) Vulnerable communities and other local stakeholders.
- ii) State Relief and Disaster Management Agencies, planning organisations, etc.
- iii) National and international scientific research and monitoring institutions.
- iv) International development and disaster management organisations.
- v) Other non-state agencies such as NGOs, libraries, media, R&D institutions, insurance companies, etc.

Capacity building of project planners is necessary for information collection and its analysis so that collected information leads to proper 'risk assessment' and is so formatted as to guide decision making for the housing programme and project. The cost and time needed for assessments must also be taken into account while planning and budgeting.



**Fig. 3.1 Process of Disaster Risk Reduction**

### **3.4 Knowledge Management**

Natural hazards information helps project planners in many ways, i.e., recognise and understand hazards in the areas, identify knowledge gaps, identify risks to the project from natural hazards now and in future and make decisions about how to deal with those risks.

“Hyogo Framework for Action 2005-2015: Building the resistance of nations and communities to disasters” (World Conference on Disaster Reduction Jan 2005, Kobe, Japan, agreed by 168 Governments and endorsed by the UN General Assembly) sets out strategies for reducing disaster risks through the following five priorities for action:

1. Ensure that DRR is a national and local priority.

2. Identify, assess and monitor disaster risks and enhance early warning.
3. Use knowledge, innovation and education to build a culture of safety and resilience.
4. Reduce the underlying risk factors.
5. Strengthen disaster preparedness for effective response.

In the first paragraph of this section, it was mentioned that the hazards information helps project planners in identifying “Knowledge gaps”. In several cases studied globally, it is seen that there may be serious consequences by using few and neglecting some aspects (due to lack of knowledge and skills). A study in 2003 examined factors influencing coastal erosion along a 60-km coastline in a Union in the Philippines. Due to results and findings of this study, municipal authorities decided to relocate settlements and schools and redesign seafront structures and rehabilitate mangroves. It is a good example of using risk data coupled with analysis and knowledge.

In another case, a report (1987) to the Govt. of Caribbean island of Montserrat highlighted the risks from the Soufriere Hills Volcano to the Country’s Capital, but the report was ignored and development continued. But due to devastations caused by Hurricane Hugo in 1989 and series of eruptions beginning 1995 (when large areas were affected), three quarters of the remaining population and most critical facilities had to be relocated permanently. Today, more than 60 per cent of this land area is officially designated as unsafe for human habitation.

From these two examples, it is evident that knowledge management is necessary for supporting correct decision-making in planning and designing of projects. If the threat is not regarded as significant, changes to project design may be unnecessary, if it is severe, planners may decide not to go ahead in that location. In this context the Tearfund Report 2005, rightly suggests that “Mainstreaming also necessitates maintaining open Communication Channels on and between all levels of the organisation and facilitating the flow of knowledge and learning”. The report further suggests that skills, knowledge and training are crucial to increasing understanding to risk reduction. Thus, a better knowledge management is essentially needed to identify past, present and potential hazards and their effects.

### **3.5 Risk Management And Vulnerability Reduction**

In the absence of any universally agreed definition of “disaster risk reduction” some authors hint that ‘risk reduction is often apparently seen as being equivalent to vulnerability reduction and at times ‘risk and vulnerability are seen as synonyms and not separate realities’. However, there seems to be consensus in the expression given by Inter-Agency Task Force on Disaster Reduction which emphasises the need to “recognise at all levels that disaster reduction is a strategic concept, which results in reduction of loss of human lives, livelihoods and property as well as social, economic (and environmental) setbacks that result from natural disasters”.

In view of the statement made above, ISDR recognises that ‘Disaster Risk Management (DRM) is a set of processes, planning actions, policies and legal and institutional arrangements aimed at managing and eventually reducing the effects of hazardous events (natural or man-made) on the human and physical assets of a community and minimising the impacts of these hazards on the delivery of essential services to the population.’

Disaster Risk Management should also be recognised as a professional practice, requiring its own processes, trained professionals, experience and culture. In most developing countries it is an emerging practice often in need of experience, investment and capacity development.

The five priorities for action recommended in Hyogo Framework emphasise that it is necessary to develop ‘Sector-specific risk reduction plans’ by integrating national plans and programmes of every sector and area of development. In the housing sector probably, area like land-use planning, the location of critical infrastructure, the management of natural resources, the protection of key assets appear to be important to ensure that risk is identified and reduced at all stages from planning to implementation.

Risk management, therefore, needs to be seen as systematic approach and practice of managing uncertainty and potential losses, involving risk assessment and analysis and the development of strategies and specific actions to control and reduce risks and losses.

Risk from natural hazards in the housing sector most often, can be addressed by preventive measures, such as avoiding settlement in floodplains and building disaster resistant buildings, monitoring, early warning and response measures to manage extreme events and risk transfer, including insurance to cope with unavoidable impacts.

Risk management can be accomplished through three distinct steps i) an analysis of risk elements-starting from risk identification, assessment and analysis to vulnerability (human, material and institutional) assessment, ii) developing policies, strategies and planning process for management of risks including inter-coordination mechanisms for implementation of these policies and resulting programmes, iii) communication and understanding of the risk and risk management practices to the public and various institutions and organisations that serve public.

**Vulnerability Reduction** needs to be seen as an important tool to achieve risk-reduction targets. According to Guidance Note 9 of ProVention Consortium Report “Tools for Mainstreaming DRR” vulnerability reduction has to be achieved by integrating Vulnerability Capacity assessment and Analysis (VCA) into the project planning process and adequately factoring natural hazards and disasters into the process. VCA considers a wide range of environmental, economic, social, cultural, institutional and political pressures that create vulnerability. Table 3.1 illustrates the range of factors that may be relevant in a specific situation.

**Table 3.1 Hazard-related vulnerabilities and capacities of different sectors**

<b>Sector</b>	<b>Vulnerabilities</b>	<b>Capacities Assessment</b>
<b>Social</b>	Occupation of unsafe areas	Social capital
	High-density occupation of sites and buildings	Coping mechanisms
	Lack of mobility	Adaptive strategies
	Low perceptions of risk	Memory of past disasters
	Vulnerable occupations	Good governance
	Vulnerable groups and individuals	Ethical standards
	Corruption	Local leadership
	Lack of education	Local non-governmental organisations
	Poverty	Accountability
	Lack of vulnerability and capacity analysis	Well-developed disaster plans and preparedness
	Poor management and	

<b>Sector</b>	<b>Vulnerabilities</b>	<b>Capacities Assessment</b>
	leadership	
	Lack of disaster planning and preparedness	
<b>Physical</b>	Building at risk	Physical capital
	Unsafe infrastructure	Resilient buildings and infrastructure that cope with and resist extreme hazard forces
	Unsafe critical facilities	
	Rapid urbanization	
<b>Economic</b>	Mono-crop agriculture	Economic capital
	Non-diversified economy	Secure livelihoods
	Subsistence economies	Financial reserves
	Indebtedness	Diversified agriculture and economy
	Relief/welfare dependency	
<b>Environmental</b>	Deforestation	Natural environmental capital
	Pollution of ground, water and air	Creation of natural barriers to storm action (e.g., forests recovering from fires)
	Destruction of natural storm barriers (e.g., mangroves)	Natural environmental recovery process (e.g., forests recovering from fires)
	Global climate change	Biodiversity
		Responsible natural resource management

VCA is mainly used as:

- i) A diagnostic tool to understand problems & causes.
- ii) A planning tool to prioritise and sequence actions and inputs.
- iii) A risk assessment tool to help assess specific risks.
- iv) A tool for empowering and mobilising vulnerable communities.

In the development projects (like housing and infrastructure), its main purpose is to provide analytical data to support project design and planning decisions, particularly to ensure that risks to vulnerable people are reduced as a result of the execution of the project. One critical step for vulnerability reduction as suggested by most international agencies is to integrate risk information into formal land-use planning process, the building regulatory mechanisms, construction codes and actual strengthening of governance structures through capacity development, promoting knowledge sharing



opportunities and promoting well-informed construction services delivery systems. Thus, data obtaining from hazard and risk studies, VCA and community-level initiatives to protect from impact of hazards are all aimed at vulnerability reduction. Besides, reducing the vulnerability of existing building stock is to be considered as one of the most complex risk management and vulnerability reduction issues. Urban renewal programmes aimed at enhancing economic and social potential of old neighborhood's should be used as opportunities for risk and vulnerability reduction by incorporating structural and non-structural mitigation measures.

### **3.6 Disaster Preparedness For Effective Response**

The Yokohoma strategy and that of ISDR, both emphasise that strengthening local resilience and capacity to prepare and respond to natural hazard events is essential, it will need to be supported by national humanitarian assistance, such as the medical and, water, shelter and other forms of technical and logistical support.

The Hyogo Framework for Action 2005-2015 provides the international foundation for reducing disaster risks as agreed by Governments at the World Conference on Disaster Reduction in Jan 2005, sets out Five Priorities for Action. The ISDR system in their specific proposals to advance design and implementation of adaptation of framework actions have inter alia laid emphasis on i) promoting community participation in disaster risk reduction, ii) recognising the differing vulnerabilities and capacities of disadvantaged and disabled sections of population, iii) conducting assessments of changing hazards, vulnerabilities, risk and capacities to provide priorities for intervention, iv) strengthening of early warning systems to ensure that warnings reach all populations and enabling people's preparedness to respond to emergencies, v) updating emergency preparedness programmes and contingency plans for effective response to disasters, supported by legislation, resources and coordination mechanisms and vi) the national adaptation plans should include inter alia setting up of strong inter-ministerial and multi-stakeholder platforms or committees/mechanisms to address emergency response by communities besides addressing various other issues for disaster risk reduction.

### **3.7 Disaster Risk Reduction In The Project Cycle Management**

There are four distinct phases considered in the management of the total project cycle as described in detail in 5.5 and stated briefly below:

**Phase 1: Project Identification:** This phase involves the starting idea of the project, consideration of disaster proneness of the project location and conducting quick risk appraisal of the project. If the risk appraisal is found satisfactory, the project preparation is undertaken. If the quick appraisal is not found satisfactory, more detailed assessment of the risks will have to be carried out.

**Phase 2: Project Preparation:** In this stage, disaster risk reduction measures are worked out and cost thereof estimated. The steps to be taken for reducing the risk are detailed in the plan.

**Phase 3: Project Implementation:** In this stage, the project is taken up for implementation and execution. The resilience of the various project components under the stipulated hazard occurrences has to be checked continuously.

**Phase 4: Project Evaluation:** At the completion of the project, it needs to be evaluated if the targets of disaster risk reduction have been met and the project will not have any adverse disaster impacts on the communities and the environment.

### **3.8 Awareness, Sensitisation & Capacity Building**

Implementation of disaster risk reduction policies, strategies and guidelines can be successfully accomplished through concerted efforts on the part of all stakeholders of housing and human settlements development sector and construction industry. The list of stakeholders, though not exhaustive, includes general public, building owners, engineers, architects, developers, builders, contractors, building managers, functionaries of government department concerned, fire and police departments, local bodies and managers of lifeline buildings and facilities. The other group of stakeholders includes policymakers (elected representatives) and bureaucrats at higher levels of decision-making and governance.

**Awareness:** The important measures required for creating awareness among stakeholders include (i) improving understanding of hazards status and threats in their area, (ii) preparing the general public on how to organise themselves before, during and after disasters and (iii) equipping the professional groups on technical strategies for developing, upgrading and maintaining disaster resistant built environment.

It is the responsibility of the National, State and Local Governments to continuously inform and upgrade/update information on disaster safety aspects. The city governments should also utilise print and electronic media (radio, television, internet) to communicate with the population and strengthen the awareness campaign.

**Sensitisation:** It is a common observation that many groups in civic society do not even understand the hazards status and threats to their settlements. Thus, a comprehensive awareness and sensitisation campaign should be institutionalised to emphasise periodically about the prevalent hazard risk of their area and role of individual stakeholders to address the same in his area of professional work. Widespread availability of information relating to different facets of natural hazards, their potential impact on built environment, socio-economic life of community is to be organised with the help of media. All sections of general public and professional groups in disaster-prone regions and urban and rural settlements must be adequately sensitised about the problems of hazards and about the issues concerning the disaster safety.

It is also useful to undertake sensitisation programmes by State and Local Governments in schools on the lines the Government of NCT of Delhi has carried out. The programme in Delhi helped in identifying and linking the schools with the relevant government departments (fires, police, hospitals, etc.). A target for total number of schools to be covered should be set and each school should be asked to submit its emergency plan.

Sensitising the general public should be done carefully and with sensitivity. Services of professional media companies should be sought to develop mass media sensitisation tools. Such a programme has been recently introduced in a TV channel by NDMA.

**Capacity Building:** Once the group of engineers and architects has been sensitised, programmes need to be developed for training them in the basic concepts of safety against hazards in the design and construction should be organised with the help of expert faculty. Tailor-made training programmes could be developed by experts for intense training of these professionals. Such short-term training programmes for practising architects, engineers, design groups/consultants, municipal engineers and those from public sector departments and companies (PSUs) who are dealing with

building construction projects should be conducted by professional organisations like Indian Institute of Architects (IIA), Institution of Engineers (IE), Construction Industry Development Council (CIDC), National Institute of Disaster Management (NIDM), Building Materials and Technology Promotion Council (BMTPC) and academic institutions like IITs, etc.

The training programmes for above mentioned professionals should be designed to cover various aspects. **(i) Design, construction and supervision of new structures.** The contents of these programmes should focus on topics related to concepts, design basis calculation and detailing of new buildings of varying heights and constructed with different materials. Adequate exposure should be provided on practical situations through analysis of case studies and tutorials on selected topics (concerning the type of hazard or multi-hazard relevant to area where course is being organised), **(ii) Existing buildings.** The course should include seismic/safety evaluation and strengthening of existing buildings, behavior of buildings during hazard events, reconstruction, restoration, retrofitting of buildings constructed with different materials, behaviour of non-engineered dwellings and disaster-safe houses built using traditional methods and wisdom, RC and steel frame buildings and infrastructures.

### **3.9 Targets, indicators and level of attainments**

#### **3.9.1 Institutional Capacity**

The need for 'institutional capacity' to support the mainstreaming process cannot be overestimated. Sufficient ownership, skills and knowledge and financial resources will be crucial if an organisation (Ministry, Departments or Undertaking) is to be successful in mainstreaming.

#### **3.9.2 Institutional Blockages**

Usually the following hurdles are experienced which need to be overcome to build the institutional capacity:

- i) **STAFF** 'Acceptances of responsibility for ownership' of both risk reduction and the process of mainstreaming will be key to attaining 'full integration' of both actions into the normal functioning of the institution. Mainstreaming risk reduction will be totally dependent on enthusiastic and well-informed staff to continually promote it. Once staff accepts risk reduction as their responsibility, it has an excellent chance of becoming sustainable within the organisation.

- ii) **WORKLOAD** Staff may be concerned that an additional issue to be mainstreamed is likely to result in a considerable amount of extra work for them when they are already likely to be very busy. Many organisations have already witnessed the process where other concerns, such as caste and gender awareness or environmental sustainability have been incorporated into development planning with significant pressure on the operating staff to expand their perceptions to take care of this concern, the organisation should recognise that the process of incorporating risk reduction at all levels and in all sectors will require considerable additional work and wider responsibility. Therefore, support may be needed to employ additional staff to cope with the increased demands.
- iii) **LACK OF LEADERSHIP** A risk reduction enthusiastic expert in the organisation is important to promote disaster risk reduction internally. Without such a person, the issue will struggle to gain visibility in the short term and it may be difficult to achieve coordination and monitoring of progress across the organisation. It will be equally important later on to develop the good leadership of line departments who are, in the long run, in the best position to facilitate the engagement of their staff in the tasks. An important and effective combination of leadership will be an institutional expert and line managers who take ownership and can then facilitate and encourage ownership in those whom they manage.
- iv) **CONTROL WITHOUT ACCEPTANCE** Staff resentment can arise when DRR targets are built into work plans without proper consultation and acceptance. By fully involving relevant staff in the process of developing targets, there is an opportunity for the targets to be reached and maintained. Therefore, the aim must be to inform and educate staff in the objectives of mainstreaming and ultimately to rely on trust rather than control to achieve the goals.
- v) **LACK OF SKILLS AND KNOWLEDGE** Ownership of the process of mainstreaming DRR can only be achieved if staff understands the relevance of risk reduction for their own work. Building staff skills and knowledge is crucial to increasing understanding and efficiency. Skills, knowledge and understanding can be developed through, management briefings, training materials, regular courses for development staff and regular communication between relief and development staffs in 'lessons learnt' exercises following major disasters. It is

important to recognise that building staff capacity for risk reduction will take time.

### **Targets of attainment**

The institution/organisation may fix the following targets to be achieved for mainstreaming of DRR in its functioning in a satisfactory manner:

- The risk reduction 'policy' is fully endorsed by senior management.

The risk reduction 'policy' is reflected in internal and external documents, e.g., documents outlining the organisation's vision, mission, approach, values and priorities.

- The organisation has a comprehensive mainstreaming strategy based on the conceptual framework and policy:
  - The strategy is fully endorsed by senior management. The strategy is reflected in internal and external documents.
- The organisation recognises that it must develop appropriate capacity, including sufficient resources, to support the process of mainstreaming risk reduction.
- There is an ongoing analysis of the disaster environment in any given location (i.e., assessment of hazards, disaster impact, vulnerabilities and risks). This analysis involves the perspectives of local communities, NGOs and other stakeholders.
- Appropriate risk reduction strategies are developed on the basis of the above and integrated into new geographical plans as a matter of course.
- Where the national organisation focuses on direct budgetary support, it seeks the inclusion of disaster risk assessment and risk reduction in the planning frameworks of disaster-prone States/districts.
- Project cycles routinely incorporate disaster risk reduction in planning, implementation and evaluation recommendations arising from monitoring and evaluation inform project re-design.



- Where explicit disaster risk reduction programmes are established, these are linked to the organisation's humanitarian/development programmes.
- The organisation supports, enables and invests in capacity development for risk reduction within its implementing partners.
- Institutional capacity is to be sufficient to support all the processes:
  - Financial resources.
  - Skills and knowledge (e.g., staff training and development, materials and appropriate technical support).
- There are strong links between HQ and field staff, who have access to services and exchange of information.

### **3.9.3 Levels of Achievement**

The following levels may be used to evaluate the achievements in the targets fixed:

#### **i) Level 1: Awareness**

- The organisation has little or no awareness of the need to consider disaster risks within geographical planning.
- The organisation has little or no understanding of the importance of addressing hazards, risks and vulnerabilities within project cycle management.
- Where the organisation undertakes disaster risk reduction, it works independently and has little or no awareness of the need to collaborate with others.
- The organisation has little or no capacity to mainstream disaster risk reduction and little or no recognition of the need to increase/develop its financial or human resources for this purpose.

#### **ii) Level 2: Sensitisation of The Responsible Staff**

- There is general awareness within the organisation of the significance of disasters for its relief and development work, including the extent of the threat that disasters pose to the organisation's long-term development goals and objectives.

- The organisation recognises that ad hoc decision-making for disaster risk reduction is inadequate.
  - There is an understanding of the disaster-risk-vulnerability relationship at relevant geographical levels and of the impact of disasters on the organisation's work in a given geographical area.
  - There is widespread understanding of the need to apply policy commitment to risk reduction within geographical planning.
  - The organisation recognises a need for reducing disaster risks within every aspect of project cycle management, for the dual purpose of:
    - protecting projects from disaster impact
    - ensuring that new projects do not increase disaster risks or enhance vulnerability.
  - The organisation recognises that it cannot act alone in the field of disaster risk reduction.
  - The organisation recognises that it must develop appropriate capacity, including sufficient resources, to support the process of mainstreaming risk reduction.
- iii) Level 3: Activities Towards The Target, Including Capacity Building**
- The organisation has a conceptual framework for disaster management which recognises vulnerability as contributing to the risk of disasters.
  - A wide cross-section of staff are engaged in a consultative process to develop a strategy which mainstreams risk reduction within the organisation's development operations and ensures that mainstreaming disaster risk reduction is a component of the organisation's existing strategy framework.
  - The organisation is developing a process to ensure that all planning frameworks include disaster risk reduction.
  - The organisation is developing an approach to ensure hazards, risks and vulnerabilities are addressed within project planning, implementation and evaluation according to the local context.
  - All relevant stakeholders, including implementing partners and collaborating bodies, are being identified through a 'stakeholder analysis'.

- Linkages are being made with key stakeholders at local and national levels to raise awareness of the organisation's risk reduction policy and strategy, to develop collaborative work and to learn from others' approaches/researches.
- Plans are being made to develop a supportive institutional environment for mainstreaming disaster risk reduction.
- Tools are being developed to assess the organisation's progress with mainstreaming.

**iv) Level 4: Comprehensive Action Taken As Found Necessary**

- The organisation has a 'policy' on disaster risk reduction with realistic, achievable goals for mainstreaming. This is understood and accepted across the organisation.
- The organisation's risk reduction 'policy' commits it to addressing three critical issues:
  - Ensuring that development programmes/projects supported by the organisation are protected through disaster risk reduction elements.
  - Ensuring that disaster relief and rehabilitation programmes/projects are managed in a developmental manner.
  - Ensuring that development and rehabilitation programmes/projects do not increase people's vulnerability to disasters.

**References:**

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- 3.4 Thomas Michell, *An Operational Framework for Mainstreaming Disaster Risk Reduction*; Benfield Hazard Research Centre; Disaster Studies Working Report, Paper 8, Nov. 2003.

## 4 Mainstreaming DRR In Housing Schemes

### 4.1 Housing Schemes In India

Most development schemes of the Government of India and those of the States include the housing component and should provide a great opportunity in practising Disaster Risk Reduction through the construction of building projects at various sites. Some of the Central Government schemes are mentioned below:

- (i) Jawaharlal Nehru National Urban Renewal Mission (JNNURM)
- (ii) Indira Awas Yojana (IAY)
- (iii) Samagra Awas Yojana (SAY)
- (iv) Rajiv Awas Yojana

Besides the Central Government schemes, a number of State Governments have also started housing schemes for the poor people living in States such as:

- (i) Birsa Munda Awas Yojana in Jharkhand
- (ii) Atal Awas Yojana in Chhattisgarh
- (iii) Kanshiramji Shahri Garib Awas Yojana in Uttar Pradesh
- (iv) Sardar Patel Awas Yojana in Gujarat
- (v) Credit/Cum-subsidy Scheme for rural housing in Bihar
- (vi) Housing for BPL and middle class families in Andhra Pradesh

The Disaster Mitigation and Management Act, 2005, recognises the need to consider Disaster Mitigation Measures and Strategies as an integral part of all development activities in the country, specifically the Act provides as follows:

- Section 11 (3)(b) states that the National Plan shall include measures to be taken for the integration of mitigation measures in the development plans and
- Section 23(4)(c) states that the State plan shall include the manner in which the mitigation measures shall be integrated with the development plans & projects.

More than 59% of the landmass is prone to earthquakes of moderate to very high intensity, over 40 million hectares (12% of land) is prone to floods and river erosion, close to 5,700 km long coastline is prone to cyclones and tsunamis. Further, hilly areas are also at risk from landslides and avalanches.

It is, therefore, necessary that all investment going for creation of physical infrastructure as a part of this national development scheme (JNNURM) takes cognisance of the likely adverse impact of natural hazards on the assets proposed to be created in the cities falling in the disaster-prone regions. The losses of life and property could be minimised in the future projects to be sanctioned/implemented in the cities (which lie in the disaster-prone regions of the country), if the guidelines/recommendations enclosed for each area are incorporated in all the stages of project formulation, sanction, implementation and monitoring.

A review of these schemes from disaster safety point of view shows that the schemes have failed to address the concern about the safety of the building projects under the various hazards to which they may be subjected in their locations. For example, three schemes namely JNNURM, IAY and RAY are reviewed below in this regard.

#### **4.2 Jawaharlal Nehru National Urban Renewal Mission (JNNURM)**

The mission will cover 65 cities consisting of 7 major cities, 28 million-plus cities and 28 other identified cities with less than 1 million population. The Urban Renewal Mission, envisaging an investment of Rs. 55,000 crore, covering 65 cities, inter alia, provides a great opportunity for improving safety of our cities with respect to natural hazards which often tend to become disasters as experienced in the recent past. It needs to be considered that each project, when sanctioned particularly in disaster-prone region, should include a component for assessment of impact of natural hazards that may occur in the area and likely damage it may cause to life and assets to be built in the scope of the project.

##### **4.2.1 Hazard Proneness of Cities Under JNNURM**

###### **(i) Earthquake Proneness**

- (a) From the earthquake hazard proneness point of view, the following eight cities fall in Seismic Zone V with *very high damage risk*, with the highest intensity considered MSK IX or higher. (example of such an earthquake in recent times is Kachchh earthquake of January 26, 2001):

**Guwahati, Itanagar, Imphal, Shillong, Aizwal, Kohima, Agartala & Srinagar (J&K).**

- (b) The following 14 cities are classified in Seismic Zone IV considered high damage risk zone with MSK Intensity VIII considered probable (recent



example of such an earthquake is that occurred in Uttarkashi 1991 and Chamoli earthquake of 1999):

**Delhi, Patna, Faridabad, Ludhiana, Amritsar, Meerut, Jammu, Shimla, Gangtok, Dehradun, Nainital, Chandigarh, Mathura and Haridwar.**

(c) The following selected 28 cities fall in Seismic Zone III, i.e., moderate damage risk zone with MSK Intensity VII considered probable (recent example of such an earthquake is that occurred in Jabalpur in 1997):

(d) **Greater Mumbai, Ahmedabad, Chennai, Kolkata, Lucknow, Nashik, Pune, Cochin, Varanasi, Agra, Vadodara, Surat, Kanpur, Coimbatore, Jabalpur, Asansol, Vijaywada, Rajkot, Dhanbad, Indore, Panaji, Thiruvananthapuram, Bhubaneswar, Puri, Porbandar and Tirupati.**

(e) Other selected cities are in Seismic Zone II that is low damage risk zone with MSK Intensity VI considered probable

**(ii) Cyclone proneness**

(a) The following nine coastal cities may be affected by very high cyclonic wind velocities causing severe damage to tall flexible & sheeted residential & industrial structures are:

**Chennai, Kolkata, Vishakapatnam, Bhubaneswar, Agartala, Puri, Pondicherry, Porbandar and Tirupati.**

(b) Other five cities which can also be affected by cyclonic winds are:

**Greater Mumbai, Vadodara, Surat, Goa & Thiruvananthapuram.**

**(iii) Landslide proneness**

a) The following cities are located *in severe to high landslide-prone areas*:-

**Coimbatore, Shimla, Imphal, Shillong, Aizwal, Kohima, Gangtok, Dehradun, Nainital & Srinagar (J&K).**

From the foregoing discussion it will be seen that while most cities are prone to earthquake damage of varying intensities, some cities have multi-hazard proneness. The cities in hill areas are additionally liable to landslide damage which can be further intensified due to the earthquakes or severe monsoon rains. Low-lying areas in all cities may be subjected to flooding during high 24-hour rainfall.

#### **4.2.2 Housing Sector Projects Under JNNURM**

The housing sectors which are to be covered under the JNNURM are:

- (i) Redevelopment of inner (old) city areas, Heritage Buildings Preservation.
- (ii) Buildings for Water supply (including desalination plants) and sanitation.
- (iii) Buildings, if any, under Urban Transportation including roads, highways, MRTS and Metro projects.
- (iv) Buildings, if any, under parking lots and spaces on PPP basis.
- (v) Development of heritage areas, including the heritage buildings.

**4.2.3 Redevelopment Of Inner (old) City Areas:** Including widening of narrow streets, shifting of industrial and commercial establishments from non-conforming (inner city) areas to conforming (outer city) areas to reduce congestion:-

The core area of a city is one of the most vulnerable areas as far as natural hazard like earthquake is concerned. This is primarily due to:

- (i) Presence of narrow streets (which will be a major constraint in conducting rescue & relief operations).
- (ii) Existence of old buildings and structures which were not designed/constructed keeping in mind earthquake safety.
- (iii) Poor infrastructure facilities like exposed electric poles with hanging electric wires.
- (iv) Choked sewers, drains, etc.

From the past earthquakes, we have seen that the narrow streets get blocked as the houses on both the sides of the road collapse killing the people moving on (*More than 300 children and teachers were crushed to death in Anjar during Kachchh earthquake of 2001 due to buildings collapsing on them from both sides. In Kobe, city fire tenders could not go on streets which were filled with fallen facades, display boards, etc.*)

For safety of lives & property in the core areas, following measures are recommended:

- The most important issue is the safety of vulnerable buildings from the impact of earthquakes. The following Indian Standards have already been developed to deal with these issues:

- It may be noted that most inner city areas are composed of masonry buildings of various types consisting of brick and/or stone. The information given in IS:4326, IS:13828 and notably IS:13935 will be found most important in this regard.
- In order to safeguard against the collapse of buildings on to narrow streets, reinforced concrete or steel frames of special designs could be erected to provide lateral support to the buildings on both sides. States may be advised to establish panels of earthquake experts to carry out studies in this regard and help develop the safety systems for such areas.
- If such areas consist of burnable wooden buildings, special precautions against fire safety may be carried out for protection.
- Where new structures are proposed for improvement of civic facilities, all such structures should be designed to be earthquake resistant as per the above BIS Codes and properly designed formulations.

#### **4.2.4 New Buildings Under Various Sectors**

- (i) The city areas having high water table and sandy soils should be studied for determination of liquefaction potential under seismic conditions, particularly in Seismic Zone IV & V areas, and the soil condition improved as found necessary while laying the transportation routes.
- (ii) The multi-storied parking lots need to be designed using the appropriate BIS Codes for earthquake and cyclone safety as listed in Annexure 4.
- (iii) Most of the India's cultural heritage is located in active seismic zones, which accelerate the vulnerability of these constructions. These constructions should be preserved over time, including its fabric and structure mainly against earthquake, which now constitutes the most devastating phenomenon.
- (iv) All heritage buildings & structures need to be protected from the impact of natural hazards, namely earthquakes. Two issues will need consideration: first, the buildings will have to be retrofitted for safety against collapse and sever damage using the earthquake codes. Secondly, the valuable contents of these buildings, such as museum artifacts, will have to be stabilised against falling or sliding to prevent damage even if the buildings do not collapse.

#### **4.2.5 Comments**

The guidelines of the schemes show that it does not make reference to disaster safety requirements in the project components and no reference is made to the National Building Code 2005 or the other Indian Standards related to safety from earthquakes, cyclones, floods or landslides. As such, all new building projects under JNNURM scheme may not at all be designed to achieve safety from natural hazards. If the building projects show the weaknesses against the natural hazards, it will be a great tragedy and the schemes will add to the existing stock of unsafe buildings in the country.

#### **4.3 Indira Awas Yojana (IAY)**

The genesis of Indira Awas Yojana (IAY) can be traced to the programmes of rural employment, which began in the early 1980s. Construction of houses was one of the major activities under the National Rural Employment Programme (NREP), which began in 1980 and the Rural Landless Employment Guarantee Programme (RLEGP), which began in 1983. There was, however, no uniform policy for rural housing in the States. For instance, some States permitted only part of the construction cost to be born from NREP/RLEGP funds and the balance was to be met by beneficiaries from their savings or loans obtained by them. On the other hand, others permitted the entire expenditure to be born from NREP/RLEGP funds. Further, while some States allowed construction of only new dwellings, others permitted renovation of existing houses of beneficiaries. As per the announcement made by the Government of India in June 1985, a part of the RLEGP fund was earmarked for the construction of houses for SC/STs and freed bonded labourers. As a result, Indira Awas Yojana (IAY) was launched during 1985-86 as a sub-scheme of RLEGP. IAY, thereafter, continued as a sub-scheme of Jawahar Rozgar Yojana (JRY) since its launch in April 1989. Six per cent of the total JRY funds were allocated for implementation of IAY. From the year 1993-94, the scope of IAY was extended to cover below the poverty line non-SC/ST families in the rural areas. Simultaneously, the allocation of funds for implementing the scheme was raised from 6% to 10% of the total resources available under JRY at the national level, subject to the condition that the benefits to non-scheduled castes/scheduled tribes poor should not exceed 4% of the total JRY allocation. IAY was de-linked from JRY and made an independent scheme with effect from January 1, 1996.

Since 1999-2000, a number of initiatives have been taken to improve the Rural Housing (RH) Programme by making provision for upgradation of unserviceable kuttcha houses and by providing credit with subsidy for certain sections of the poor. Emphasis has also been laid on use of cost-effective, disaster-resistant and environment-friendly technologies in rural housing.

#### **4.3.1 Target Group**

The target groups for houses under the IAY are below poverty line households living in the rural areas, belonging to scheduled castes/scheduled tribes, freed bonded labourers, minorities in the BPL category and non-SC/ST BPL rural households, widows and next-of-kin to defense personnel/paramilitary forces killed in action residing in rural areas (irrespective of their income criteria), ex-servicemen and retired members of paramilitary forces fulfilling the other conditions.

#### **4.3.2 Strategy For The Implementation of The Programme**

The programme will be implemented through the Zila Parishads/DRDAs and houses will be constructed by the beneficiaries themselves. The beneficiaries should be involved in the construction of the house. To this end, the beneficiaries may make their own arrangements for procurement of construction material, engage skilled workmen and also contribute family labor. The beneficiaries will have complete freedom as to the manner of construction of the house. Zila Parishads/DRDAs can help the beneficiaries in acquiring raw material on control rates, if they so desire or request the Zila Parishads/DRDAs in this regard. This will result in economy in cost, ensure quality of construction, lead to greater satisfaction and acceptance of the houses by the beneficiary. The responsibility for the proper construction of the house will thus be on the beneficiaries themselves. A committee may be formed, if so desired, to coordinate the work. The Committee shall be sensitised to incorporate hazard-resistant features in the design of the houses.

#### **4.3.3 Unit Assistance For Construction of Iay Houses And Upgradation**

The ceiling on grant of assistance per unit cost under the Indira Awas Yojana for construction of a new house and up gradation of an unserviceable kuttcha house is given as under:

		Plain Areas	Hilly/Difficult Areas
(a)	Construction of house, including Sanitary latrine and smokeless Chulha	Rs. 45,000/-	Rs. 48,500/-
(b)	Up gradation of unserviceable households	Rs. 15,000/-	Rs. 15,000/-



In addition to assistance provide under the IAY, an IAY beneficiary can avail a loan of up to Rs. 20,000/- per housing unit under differential rate of interest (DRI) scheme at an interest rate of 4% per annum.

#### **4.3.4 Location Of Indira Awas Yojana Dwelling Units**

The Indira Awas Yojana dwelling units should normally be built on individual plots in the main habitation of the village. The houses can also be built in a cluster within a habitation so as to facilitate the development of infrastructure such as internal roads, drainage, drinking water supply, etc., and other common facilities. Care should always be taken to see that the houses under the IAY are located close to the village and not far away, so as to ensure safety and security, nearness to work place and social communication. To the extent possible, the site should not be located in disaster-prone areas, for example, frequently floodable areas.

#### **4.3.5 Appropriate Construction Technologies And Local Materials**

Effort should be made to utilise to the maximum possible extent local materials and cost-effective, disaster-resistant and environment-friendly technologies developed by various institutions. Zila Parishads/DRDAs should contact various organisation/institutions for seeking expertise information on innovative technologies, materials, designs and methods to help beneficiaries in the construction/upgradation of durable, cost-effective houses and disaster-resistant houses.

#### **4.3.6 House Design**

No type design should be prescribed for the IAY dwelling units, except that the plinth area of the houses should not be less than 20 sq.mt. The layout, size and design of the IAY dwelling units should depend on the local conditions and the preference of the beneficiary, the desire of the beneficiaries, keeping in view the climatic conditions and the need to provide ample space, kitchen, ventilation, sanitary facilities, smokeless chulha, etc., and the community perceptions, preferences and cultural attitudes. In areas frequented by natural calamities such as fire, flood, cyclones, earthquakes, etc., incorporation of disaster-resistant features in design should be encouraged.

Life Insurance Corporation (LIC) of India has Insurance Policies called Janshree Bima for rural BPL families and Aam Aadmi Bima for the benefit of rural landless families. DRDAs will furnish the particulars of all the willing IAY beneficiaries every month to the respective Nodal Agency which is implementing the Janshree Bima and Aam Aadmi

Bima in the district so that all willing IAY beneficiaries derive the benefits available under these insurance policies.

#### **4.3.7 Comments**

In its present guidelines of IAY, there is a requirement that the concerned DRDA/local committee and the beneficiary should consider hazard safety aspects in selecting the site and designing the buildings. However, there is a need to give specific guidelines as to what must be provided in the project design and implementation to achieve the stipulated safety from hazards.

#### **4.4 Rajiv Awas Yojana (RAY)**

Rajiv Awas Yojana (RAY) for the slum dwellers and the urban poor envisages a “Slum-free India’ through encouraging State/Union Territories to tackle the problem of slums in a definitive manner. It calls for a multi-pronged approach focusing on:

- Bringing existing slums within the formal system and enabling them to avail of the same level of basic amenities as the rest of the town:
- Redressing the failures of the formal system that lie behind the creation of slums: and
- Tracking the shortages of urban land and housing that keep shelter out of reach of the urban poor and force them to resort to extra-legal solutions in a bid to retain their sources of livelihood and employment.

An outline of the broad policy issues that need to be addressed by State/UTs under RAY is given below:

Some Key Policy issues

##### **4.4.1 Urban Planning**

City master plans follow an exclusionary model that reserves land for housing for high and middle income groups, commercial, institutional, recreational and other uses, with no earmarking for Economically Weaker Sections and Low Income Groups. These plans are not in consonance with the income distribution structure of cities and towns. The norms of planning, including density and development controls, favour the comparatively better-off sections. These factors, coupled with sky-rocketing urban land price, have squeezed the urban poor out of formal urban land markets. Slums are an

inevitable outcome of this deficiency in urban policy and planning. It is necessary that the master plans make provision for EWS/LIG categories by treating them as distinct segments for the purpose of land use and urban planning. There is also a need for 'small lot zoning' in layouts for housing approved by city authorities, creating EWS and LIG plots along with MIG and HIG. The population density norms also require a re-look, not only to rationalise them across cities, but, in understanding of the basic tenet that the poor are deprived of housing where land values are high, to enable better utilisation of valuable land by building vertically on it. It is necessary to catalyse and assist the review of these issues with capacity building and expertise.

#### **4.4.2 Housing & Infrastructure**

Affordable housing and provision of basic infrastructure in urban areas, especially slums, would generally require the intermediation of civil society, government and private entities that can engage the community, undertake planning, reconfigure slums to enable cost-effective provision of infrastructure facilities and construct group housing colonies. Given the massive needs for affordable housing and the capacity constraints faced by public agencies like housing boards, urban development authorities and municipalities to take up group housing on a large scale, it is necessary to involve private sector entities in the creation of affordable housing stock on ownership, rental or rental-cum-ownership basis and in scaling up the programme to the desired scale. There is also a need for resource mobilisation and earmarking of resources by public agencies to meet the cost of affordable housing, civic infrastructure and services for the urban poor where the private sector participation is not possible.

#### **4.4.3 Scope of RAY**

The scope of RAY envisaged projects involving:

- a. Integrated development of all existing slums, notified or non-notified, i.e., development of infrastructure and housing in the slum/rehabilitation colonies for the slum dwellers/urban poor, including rental housing.
- b. Development/improvement/maintenance of basic services to the urban poor, including water supply, sewerage, drainage, solid waste management, approach and internal road, lighting, community facilities such community toilets/baths, informal sector markets, livelihoods centres, etc., and other community facilities like pre-schools, childcare centres, schools, health centres to be undertaken in convergence with programmes of respective Ministries.

- c. Convergence with health, education and social security schemes for the urban poor and connectivity infrastructure for duly connecting slums with city-wide infrastructure facilities/projects, and
- d. Creation of affordable housing stock, including rental housing with the provision of civic infrastructure and services, on ownership, rental or rental-purchase basis.

#### **4.4.4 Comments**

In the guidelines of the scheme, there is no suggestion that the various building projects to be undertaken with funding from the scheme should be made disaster-resistant in the first instance by proper site selection, soil investigation and foundation design and structural design to follow the Bureau of Indian Standard Codes. There are number of cases where slums have come up in the path of natural drainage system or in low-lying areas which are likely to be flooded. Under the scheme, these should be relocated to safer sites and this aspect to be examined at the time of sanctioning of funds. As such all new building projects under the RAY scheme may not at all be designed to achieve safety from natural hazards. It will be a great tragedy if that happens since all new buildings under the scheme will add to the existing stock of unsafe buildings.

#### **4.5 Mainstream DRR In Housing Schemes**

The framework of mainstreaming DRR in housing sector has been presented in Chapter 3. So far as housing schemes such as the above are concerned, some specific suggestions are included here below:

The Ministries and Departments of the Governments need to be sensitised for incorporating the Disaster Safety concerns in all schemes such as IAY, JNNURM and RAY when they are formulated. The concerns should also be conveyed to various levels of the government functionaries for proper implementation and capacity building of various officials and assistances involved in the execution of the scheme not only in the Central Government but also the State Government concerns. Inter-Ministerial or inter-Departmental coordination committees are recommended to ensure that DRR is integrated in all the schemes. The schemes should include guideline for including

disaster safety provisions in the DPRs to be prepared for the various construction projects. Sample guidelines are included in Table 4.1 of Chapter 14. The main aspects are stated here below:

#### **4.5.1 General Information of The Project**

This should include address of the scheme. Name of the Project; State; and District. More exact information about the site of the scheme may also be presented, namely Location of Project Site, its Latitude and Longitude. The height above mean sea level may also be obtained from Survey of India and given in the DPR.

#### **4.5.2 Nature / Type of Project**

All the projects of the nature/type mentioned below are liable to damage by natural disasters and inadequacies of design or any of their components: *Communications*: towers, building; *Transportation*: Bus/Railway Stations; *Power*: Powerhouses, substations; *Habitations*: township-planning; *Water supply and sanitation projects*: Pump Houses; and *Building projects*.

#### **4.5.3 Hazard Proneness of The Project Site**

- 1) Earthquake Zone (Any known geological fault near by may be listed)  
Flood Proneness & Vulnerability: Past history of floods in the area, observed highest flood level, frequency, depth and duration of flooding.
- 2) Cyclone Proneness (If within about 50km of sea coast): Frequency and Intensity; Wind speed zone; Distance of site from sea coast; and Record of past storm surge/tsunami.
- 3) Landslide Proneness & Vulnerability: Location of hill slope vis-à-vis the project's location; Past history of landslides; and Possibility of mudflows/rock falls/snow avalanches etc.

#### **4.5.4 Hazards Risk To The Project**

- Risk needs to be evaluated under the action of the natural hazards stated above. Besides, the soil liquefactions should be investigated under various earthquake intensities.

#### **4.5.5 Mitigation/Reduction of Risk:**

There are specific codes, manuals, guidelines, etc., developed by Bureau of Indian Standards, for siting, design and construction of various types of buildings.

- The relevant BIS codes and guidelines are to be complied with.

#### **4.5.6 Use of the Vulnerability Atlas of India\***

**A)** The Atlas presents the hazard maps of Earthquakes, Cyclones and Floods. The monitoring of hazards and their mapping is carried out by the following most important organisations in the country:-

Seismic occurrence and cyclone hazard monitoring is carried out by Indian Meteorological Department (IMD) and flood monitoring by the Central Water Commission. In addition noteworthy contributions are made by Geological Survey of India and the Department of Earthquake Engineering, University of Roorkee (now Indian Institute of Technology Roorkee) in this regard. The Bureau of Indian Standards Technical Committees on Earthquake Engineering and Wind Engineering publishes the Seismic Zoning Map and the Wind Velocity Map, including cyclonic winds, for the country. The Seismic Zoning Map was revised in 2002. The Central Water Commission has a Flood Atlas of India. The Expert Group, Ministry of Housing and Urban Poverty Alleviation, has used these hazard maps to prepare 1:2 million scales maps by superposing the above available data on digitised Survey of India map as the base map. The earthquake, wind storm and flood hazard maps are drawn for each State and UT separately. Various district boundaries are clearly shown for easy identification of the hazard risk prone areas. The intensities of earthquakes on MSK scale and intensity of the wind hazard-related with wind speed are drawn on the maps to show various intensity zones. Flood prone areas are categorised in terms of unprotected and protected areas combined.

#### **B) State-wise Hazard Maps**

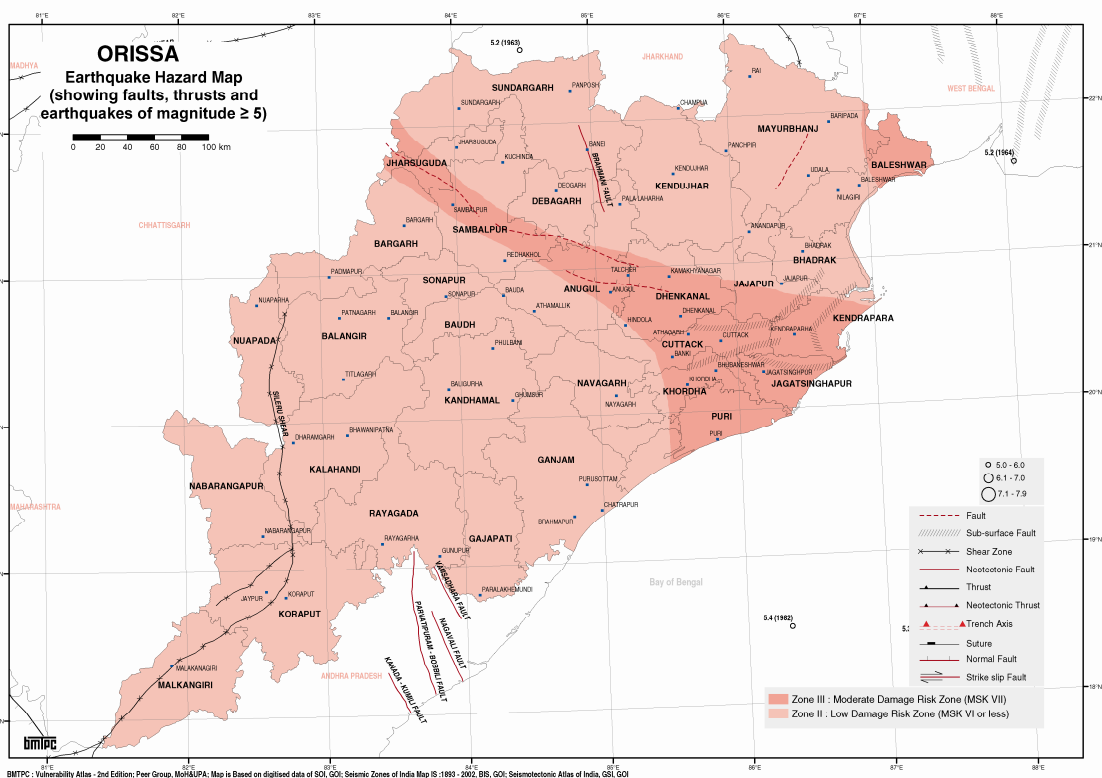
- State-wise hazard maps (including Union Territories) cover the Maps drawn at 1:2 million scale using digitised Survey of India maps as base.
  - Earthquakes



- Cyclones
- Floods
- In every State Map, each administrative district boundary is clearly marked with hazard intensity

(i) Earthquake Hazard Maps

- These are based on Seismic Zoning map of India given in IS 1893:2002. Four Seismic Zones V, IV, III and II are shown imposed on the basic Survey of India map.
- The Seismo-tectonic features are marked as per Seismo-Tectonic Atlas published by Geological Survey of India (GSI).
- Epicentres and years of occurrence of earthquakes of Magnitude ( $\geq 5.0$ ) are

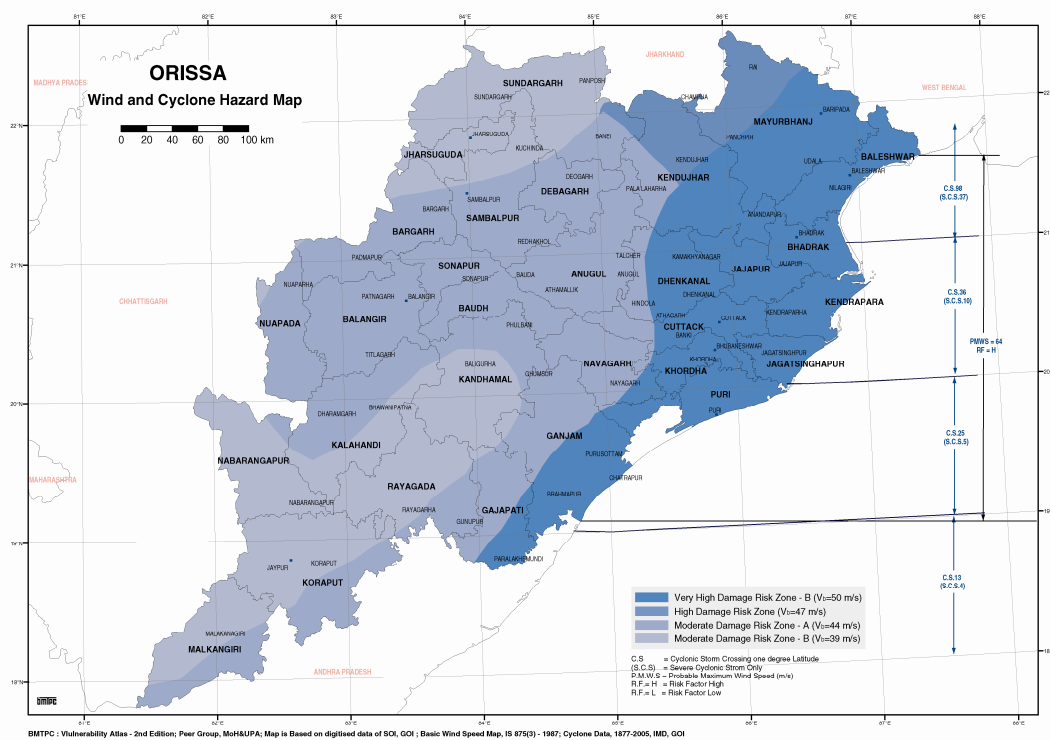


\* Published by BMTPC, Ministry of Housing & Urban Poverty Alleviation (M/o HUPA), Govt. of India, 2006

shown), as per IMD catalogue of earthquakes up to 2005.

**(ii) Wind & Cyclone Hazard Maps**

- These are based on wind speed maps given in IS 875 (Part III) 1987. The wind speed zones are based on wind speeds of 55, 50, 47, 44, 39 and 33 m/s and plotted on basic maps of Survey of India.
- Along with design wind speed, the number of cyclones which have crossed each

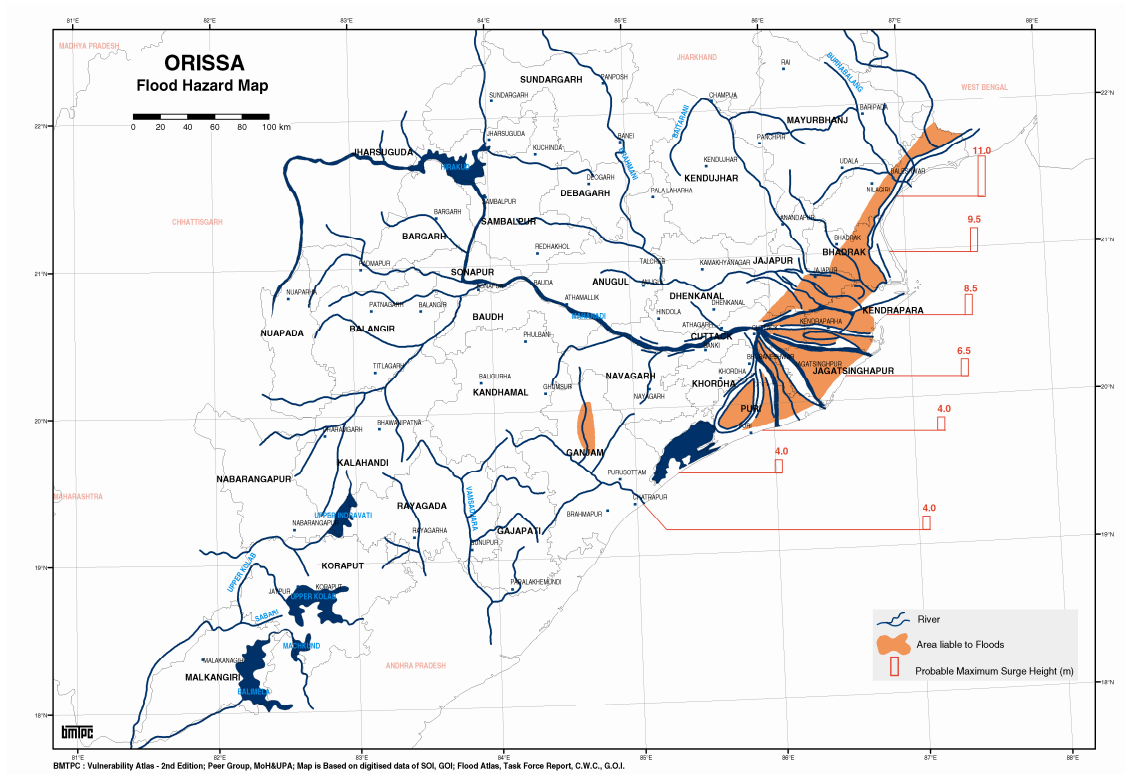


latitude of the sea coast in the past is also marked.

**(iii) Flood Hazard Maps**

- These are based on the revised Flood Atlas of India prepared by the Central Water Commission, Govt. of India. The flood-prone areas in various river plains are shown in each river basin.

- Other low-lying areas outside river floodplains (which are also flooded during



heavy rains due to choked drainage path) could not be plotted because of lack of data, which has to be collected by each state or district administration.

### C) Tables of Damage Risk in the Districts

Numbers of housing units of various types classified by wall material and roof type in Census of Housing 2001 are presented for each State and UT as a whole as well as for each district separately.

Distribution of Houses by Predominant Materials of Roof and Wall and Level of Damage Risk

Table No. : OR 10

State : ORISSA

KENDRAPARA

Wall / Roof		Census Houses		Level of Risk under								Flood Prone Area in %
		No. of Houses	%	EQ Zone				Wind Velocity m/s				
				V	IV	III	II	55 & 50	47	44 & 39	33	
				Area in %				Area in %				
						89.2	10.8	100				35.5
<b>WALL</b>												
<b>A1 - Mud Unburnt Brick Wall</b>	Rural	266,645	75.2									
	Urban	6,906	1.9									
	<b>Total</b>	<b>273,551</b>	<b>77.1</b>			M	L	VH				VH
<b>A2 - Stone Wall</b>	Rural	593	0.2									
	Urban	35	-									
	<b>Total</b>	<b>628</b>	<b>0.2</b>			M	L	H				VH
<b>Total - Category - A</b>		<b>274,179</b>	<b>77.3</b>									
<b>B - Burnt Bricks Wall</b>	Rural	55,783	15.7									
	Urban	10,826	3.1									
	<b>Total</b>	<b>66,609</b>	<b>18.8</b>			L	VL	H				H/M
<b>Total - Category - B</b>		<b>66,609</b>	<b>18.8</b>									
<b>C1 - Concrete Wall</b>	Rural	585	0.2									
	Urban	13	-									
	<b>Total</b>	<b>598</b>	<b>0.2</b>			VL	VL	L				L/VL
<b>C2 - Wood wall</b>	Rural	3,264	0.9									
	Urban	584	0.2									
	<b>Total</b>	<b>3,848</b>	<b>1.1</b>			VL	VL	VH				H
<b>Total - Category - C</b>		<b>4,446</b>	<b>1.3</b>									
<b>X - Other Materials</b>	Rural	8,889	2.5									
	Urban	648	0.2									
	<b>Total</b>	<b>9,537</b>	<b>2.7</b>			VL	VL	VH				VH
<b>Total - Category - X</b>		<b>9,537</b>	<b>2.7</b>									
<b>TOTAL BUILDINGS</b>		<b>354,771</b>										
<b>ROOF</b>												
<b>R1 - Light Weight Sloping Roof</b>	Rural	297,744	83.9									
	Urban	12,052	3.4									
	<b>Total</b>	<b>309,796</b>	<b>87.3</b>			L	VL	VH				VH
<b>R2 - Heavy Weight Sloping Roof</b>	Rural	2,201	0.6									
	Urban	465	0.1									
	<b>Total</b>	<b>2,666</b>	<b>0.7</b>			L	VL	H				H
<b>R3 - Flat Roof</b>	Rural	35,814	10.1									
	Urban	6,495	1.8									
	<b>Total</b>	<b>42,309</b>	<b>11.9</b>									
<b>TOTAL BUILDINGS</b>		<b>354,771</b>										

Probable Maximum Precipitation at a Station of the district in 24 hrs is 600 mm

Housing Category : Wall Types

Category - A : Buildings in field-stone, rural structures, unburnt brick houses, clay houses

Category - B : Ordinary brick building; buildings of the large block & prefabricated type, half-timbered structures, building in natural hewn stone

Category - C : Reinforced building, well built wooden structures

Category - X : Other materials not covered in A,B,C. These are generally light.

- Notes: 1. Flood prone area includes that protected area which may have more severe damage under failure of protection works. In some other areas the local damage may be severe under heavy rains and choked drainage.  
2. Damage Risk for wall types is indicated assuming heavy flat roof in categories A, B and C (Reinforced Concrete) building  
3. Source of Housing Data : Census of Housing, GOI, 2001

Housing Category : Roof Type

Category - R1 - Light Weight (Grass, Thatch,

Bamboo, Wood, Mud, Plastic, Polythene,

GI Metal, Asbestos Sheets, Other Materials)

Category - R2 - Heavy Weight (Tiles, Slate)

Category - R3 - Flat Roof (Brick, Stone, Concrete)

EQ Zone V : Very High Damage Risk Zone (MSK > IX)

EQ Zone IV : High Damage Risk Zone (MSK VIII)

EQ Zone III : Moderate Damage Risk Zone (MSK VII)

EQ Zone II : Low Damage Risk Zone (MSK < VI)

Level of Risk : VH = Very High; H = High;

M = Moderate; L = Low; VL = Very Low

The percentage area of the district likely to be subjected to a particular intensity of hazard is shown at the top of each District Table. Besides the damage *risk* to buildings is indicated as Very High (VH), High (H), Medium (M), Low (L) and Very Low (VL) for each hazard.

The damage risk terms have been clearly explained in the Atlas.

Sample map for one State, viz. Orissa and Damage Risk Table for its district Kendrapara, are shown on next page for illustration.

#### **D) Use of Atlas**

The project authorities may refer to the hazard maps in the Vulnerability Atlas of India for determining the hazard proneness of the area where the project building will be situated. They can have a preliminary idea of the building type being proposed regarding the risk of damage the building will have if disaster safety elements are not incorporated in the design and can choose the method of safety elements required to be provided as per the relevant Indian Standard Codes. This approach may be used for all constructions under IAY, JNNURM, RAY programmes as well as any other housing programme to be undertaken either by the Central Govt. or by State Govt. as well as by private undertakings.

#### **References:**

- 4.1 Jawahar Lal Nehru, National Urban Renewal Mission (JNNURM), Ministry of Housing and Urban Poverty Alleviation, Govt. of India, Dec. 2005.
- 4.2 JNNURM: Provision of Hazard Safety Aspects in Project Eligible for JNNURM Assistance, by A.S. Arya, Ministry of Home Affairs, GoI-UNDP, DRM Programme.
- 4.3 Indira Awas Yojana (IAY) [Effective from 01.04.2004], Government of India, Ministry of Rural Development, Department of Rural Development.
- 4.4 Rajiv Awas Yojana (RAY): Guidelines for Slum-free City Planning, Government of India, Ministry of Housing & Urban Poverty Alleviation.

## 5. Mainstreaming DRR In Housing Projects

### 5.1 Uses of Buildings

The different uses of census houses were standardised and grouped into 10 categories, as shown below:

**Residence:** This category includes houses that were used exclusively for residential purpose.

**Residence-cum-other use:** such as residence-cum-grocery shop, residence-cum-workshop (book binding), residence-cum-boarding house, etc.

**Shop/Office:** Census houses exclusively used as shops, and offices were covered under this category.

**School/College, etc.:** All types of educational institutions and training centers *without* lodging facilities or any residential use.

**Hotel/Lodge/Guest House, etc.:** Used exclusively for temporary stay or stay in transit and where no person living for a period of three months or more.

**Hospital/Dispensary, etc.:** Used as hospitals, dispensaries, nursing homes and such other health or medical institutes.

**Factory/Workshop/Work Shed, Etc.:** Exclusively used for running a factory or a workshop of manufacturing, production, processing, repairing or services, etc.

**Place of Worship:** Such as temples, gurudwaras, mosques, churches, prayer halls, etc.

**Other non-residential use:** Used as places of entertainment and community gathering and all other non-residential miscellaneous uses not covered under any of the above categories; used as cattle shed, godown, garage, petrol pump, power station, pump house, tube well room, cinema house, museum, stadium, etc.

**Vacant:** Found vacant, under construction or not being used for any other non-residential purpose.

Construction of Disaster unsafe buildings under the above schemes will be increasing the number of vulnerability building stock in the country. It will then be a great lost opportunity to demonstrate the disaster safety aspects of all new buildings.

## **5.2 Disaster safety issues in housing projects**

For ensuring the safety and minimising disaster risk to housing projects in various States and UTs in India, which are subject to earthquakes, cyclones, floods and landslides acting mostly separately but sometimes in combination of two of them, the best approach will be to plan, design, construct and monitor the projects in accordance with the relevant BIS standard codes, guidelines and handbooks. A brief list of most applicable codes on Guidelines is given in Annexure '4'. These will cover the issues of siting of the projects, soil properties and foundations, structural design of load bearing masonry buildings, reinforced concrete frame buildings, steel frame buildings, wooden houses or bamboo huts and clay wall houses.

## **5.3 Working tool for designing & review of buildings**

A detailed pro forma has been developed in four parts 1 to 4 as shown in Chapter 14 Tables 14.2 to 14.5 which cover the following main topics:

### *Part 1. General Building and Design Data*

- Address of the building
- Names, Postal Address and Phones
- The building
- Type of building structure
- Soil data
- Foundation data
- Dead loads (Unit waves adopted)
- Imposed (live) loss
- Natural hazards (Cyclone, Earthquake, Flood, Landslide)

### *Part 2. Load-Bearing Masonry Buildings*

- Building Category
- Wall Masonry
- Type and mix of mortar
- Size and position and opening



- Horizontal seismic band
- Vertical reinforcing bar
- Integration of pre fab roofing/flooring elements
- Horizontal basis in pitched trusts

*Part 3. Reinforced Concrete Frame Building*

- Type of Building
- Horizontal Floor System
- Grades of Concrete used in different parts
- Frame analysis
- Base shear
- Distribution of seismic forces – along the height of the building
- Soft ground story
- Clear minimum cover provided
- Ductile detailing of RC frame

*Part 4. Buildings in Structural Steels*

- Type of building
- Proposed material
- Floor construction
- Roof construction
- Horizontal force resisting system
- Structural connection
- Adopted methods of design
- Slenderness ratios maintained
- Member deflection limited to
- Structural members
- Minimum metal thickness for corrosion protection
- Minimum fire rating

The format is to indicate the relevant information sought which is to be provided by the owner/builder/architect or structural designer of the project in the space provided in the form. For convenience of the user or checker/reviewer, reference Indian Standard Code is cited in line with the question in the next column of the Table in Chapter 14. The last column is provided for checking/ reviewing comments.

#### **5.4 Working Tool For Technical Audit**

For carrying out technical audit of a construction project, a pro forma is developed as given in Chapter 14, Table 14.6.

#### **5.5 DRR in Project Cycle Management**

There are four distinct phases in the Project Cycle as shown in figure 5.1 and briefly described below:

##### Phase 1: Project Identification

This phase involves the starting idea of the project, consideration of disaster proneness of the project location, and conducting quick risk appraisal of the project. If the risk appraisal is found satisfactory, the next step of project preparation is undertaken. If the quick appraisal is not found satisfactory, more detailed assessment of the risks will have to be carried out or the site of the project to be shifted.

##### Phase 2: Project Preparation

In the stage of project preparation, disaster risk reduction measures are worked out and cost thereof estimated. The steps to be taken for reducing the risk are detailed and implemented as worked out in the plan. An evaluation also needs to be carried out to check if the measures are proceeding in the right direction.

##### Phase 3: Project Implementation

In this stage the project is taken up for implementation and execution and the resilience of various project components under the stipulated hazard occurrences has to be checked continuously. It needs to be checked that no harmful aspects develop during the execution.

##### Phase 4: Project Evaluation

At the completion of the project, it needs to be evaluated if the targets of disaster risk reduction have been met, and the project will not have any adverse disaster impacts nor it will have harmful impacts on the communities and the environments.

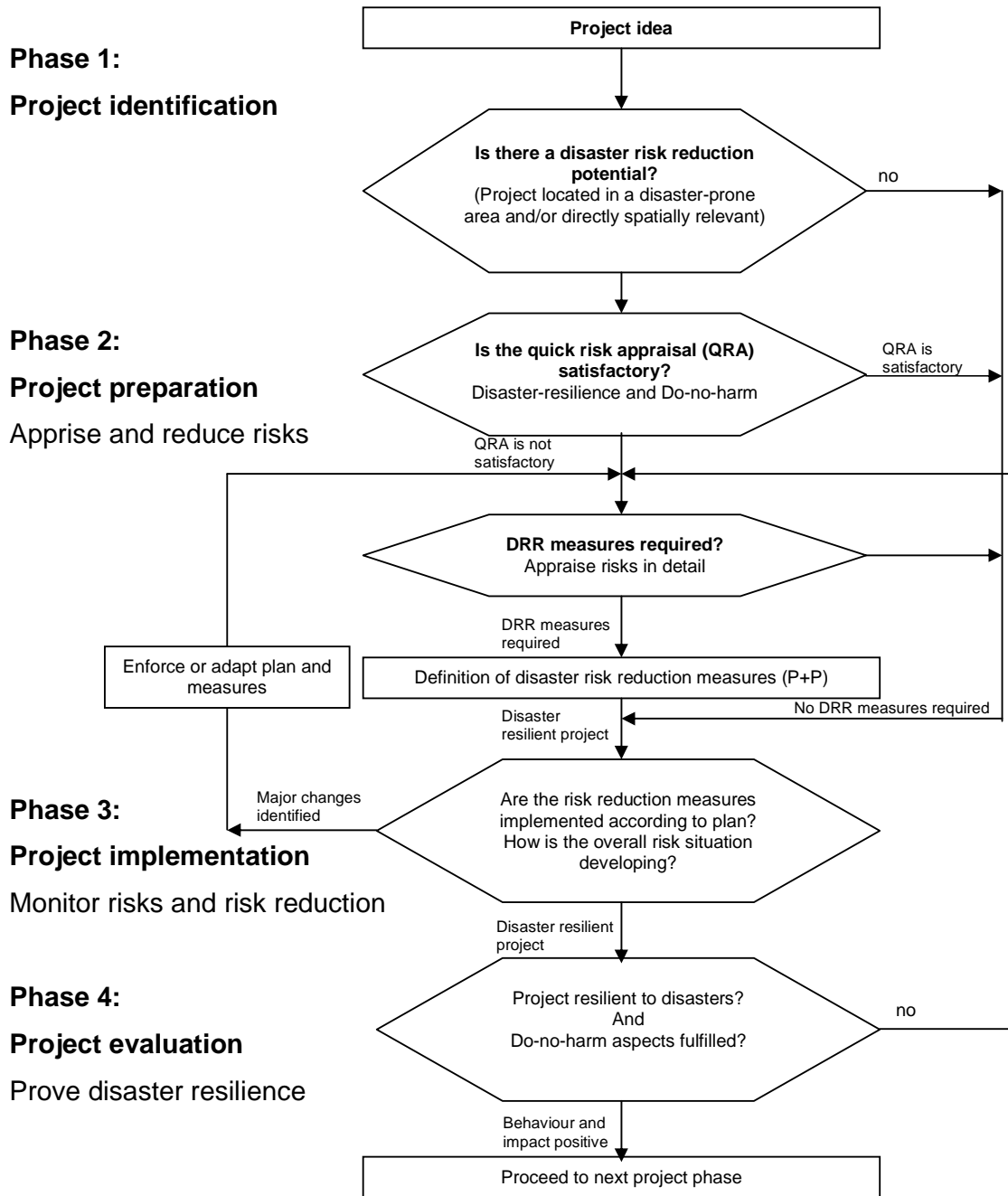


Fig. 5.1 DRR in Project Cycle Management

## **5.6 Capacity building of officials and professionals**

Application and understanding of relevance of Disaster Risk Reduction essential for all stakeholders of housing sector. They need to be sensitised about potential importance of examining and integrating DRR in their respective areas contributing to sustainable growth of housing activities. Such understanding of the relevance of DRR is more critical on the part of governmental organisations who are dealing with concerning, planning, designing and implementing housing projects in varying situations.

Adequate capacities, institutional structures, empowerment for governance and enforcement of DRR-related regulatory framework have to be available within the Municipal Corporations and Councils, Development Authorities, Nagar, rural and Zila Panchayats, all Govt. Departments and Public Sector Undertakings for ensuring adherence to guidelines, regulations, provisions in codes and sound construction practices for achieving disaster-resistant housing construction and usage of land use zoning plans based on full information relating to locations/siting, soil conditions, liquefaction potential and characteristics like erosion, wave and wind action in coastal regions, slope stability history in hilly regions, etc. All implementing institutions and professionals should be adequately trained to take well-informed decisions while undertaking their technical, administrative and regulatory roles for disaster-resistant housing and related building construction which have considerable influence on the safety of total built environment in any urban or rural settlement be in plain, hilly and coastal regions.

There is a need to develop syllabus for the training programmes for professionals and officials. Syllabus development may not be very easy. Number of organisations like NIDM, CIDC, IE(I), BMTPC, etc., have been engaged in running large number of Training and/or Executive Development Programmes on various subjects relating to safety aspects of buildings and other structures in response to impact of natural hazards. It is suggested that a group of experts may study the contents and syllabus of these training programmes and through a participatory approach involving the faculty members of such ongoing programmes and develop few implementable “modules” for short-term training courses ranging from 2/3 days to 2/3 weeks.

Following is the list of possible specialised topics/courses relating to earthquakes, cyclones, floods, landslides and fires. It is important that all the topics to be covered in the training programmes related to various hazards should be strengthened by adding specific case studies of successes and failures.

**I Related to earthquake-safe structures**

- A. New Buildings with RC frame Construction (Two modules for Civil Engineers & Architects – Refer Chapter 14)
- B. Masonry Buildings – Critical issues concerning disaster safety – Standards and Codes
- C. Impact of earthquake on different types of buildings – focusing on Case Studies
- D. Regulatory Frameworks, Provisions for Safety in Standards and Codes for design and construction of earthquake-resistant buildings
- E. Strategies and Methods of upgrading structural strength of existing buildings
- F. Vulnerability Assessment and Retrofitting for existing engineered and non-engineered buildings
- G. Special course in design of earthquake-safe buildings for architects

**A-1 For Civil Engineers**

1. **Introduction** - This will focus on the behavior of RC frame buildings (which exist in very large numbers in Urban Areas) under earthquake forces. The other areas to be covered under the training of engineers are given in following sub-heads.
2. **Conceptual design and planning considerations**
  - Building shape
  - Non-symmetric layout
  - Masonry infill walls
  - Out-of-plane seismic resistance of masonry infills*

Short and captive columns  
Modifications of existing buildings  
*Alterations*  
*Vertical additions*  
Adjacent buildings: pounding effect  
Soft and weak stories  
*How to avoid soft stories*  
Strong beam – weak column failure

**3. Detailing considerations**

On ductility  
Beams  
Failure modes  
Location and amount of horizontal rebars  
Stirrups  
Columns  
Failure modes  
Vertical rebars  
Horizontal ties  
Beam-column Joints  
Masonry infill walls  
Non-structural elements

**4. Construction considerations**

Material quality  
Selection and control of materials  
Preparation, handling and curing of concrete  
Selection and control of steel  
Workmanship  
Inspection

**5. Alternatives to RC frames with infills in regions of high seismic risk**

Why are the alternatives needed

The alternatives

Confined masonry buildings

Background

Advantages

RC frame buildings with RC shear walls

Background

Advantages

## **6. Retrofitting RC frame buildings**

Introduction

Vulnerability assessment to determine if structural retrofitting necessary

Ways to strengthen existing masonry in fills

Installation of new RC shear walls or steel braces to minimise torsion effects

Jacketing for increasing ductility of columns; use of fiber reinforced Polymer (FRP) overlays to strengthen existing masonry in fills.

Strengthening of existing masonry in fills

RC frame buildings with open ground floor

Short-term goal = prevent collapse

Long-term goal = ensure good earthquake behavior

How seismic retrofit affects structural characteristics

Retrofitting RC frames with masonry in fills: implementation challenges

### **A-2 For architects**

What causes earthquakes?

How the ground shakes?

What are magnitude and intensity?

Where are seismic zones in India?

What are the seismic effects on structures?

How architectural features affect buildings during earthquakes?

How buildings twist during earthquakes?



What is the seismic design philosophy for buildings?  
How to make buildings ductile for good seismic performance?  
How flexibility of building affects their earthquake response?  
What are the Indian Seismic Codes?  
How do brick masonry houses behave during earthquakes?  
Why should masonry buildings have simple structural configuration?  
Why are horizontal bands necessary in masonry buildings?  
Why is vertical reinforcement required in masonry buildings?  
How to make stone masonry buildings earthquake resistant?  
How do earthquake affect reinforced concrete buildings?  
How do beams in RC buildings resist earthquakes?  
How do columns in RC buildings resist earthquakes?  
How do beam-column joints in RC buildings resist earthquakes?  
Why are open-ground story buildings vulnerable in earthquakes?  
Why are short columns more damaged during earthquakes?  
Why are buildings with shear walls preferred in seismic regions?  
How to reduce earthquake effects on buildings?

## **II Related to floods**

- A. Assessment of flood risk and vulnerability of the areas, flood risk mitigation measures and their effect on safety of the built environment.
- B. Guidelines for siting of buildings in flood-prone settlements/regions; technical specifications for making new and existing buildings flood-proof.
- C. State-level training of elected representatives at ATIs. Participants to include MPs, MLAs, and Counselor's, Members at the District, Taluka, City and Village levels, administrative personnel from all Central Ministries, Departments and State Governments.
- D. Training in disaster management for Police Force, Civil Defence, Home Guards, School Teachers and NGOs.
- E. Floodplain zoning regulations to guide construction in flood-prone areas.
- F. Bylaws for buildings in flood-prone areas.

Guidelines on Management of Floods issued by NDMA recommend that (a) CWC and NIDM may in collaboration with ATIs and Technical Institutions develop comprehensive curriculum related to flood mitigation management. (b) NIDM will in consultation with reputed knowledge institutions, develop comprehensive programmes and a national plan for creating a pool of trainers from trained faculty members of engineering and architecture colleges and also among professionals.

### **III Related to cyclones, coastal storm surge and high-velocity wind**

- A. Training of supervisory engineering staff for construction of buildings in coastal area. (Multi-hazard situation includes earthquakes, cyclonic wind, storm surge, flooding by incessant rain tsunami)
- B. Approach towards multi-hazard safety measures in coastal areas – design criteria for multi-hazard mitigation
- C. Action required in coastal areas for protection against tsunami and cyclones.
- D. Tsunami effects and design solutions
- E. Design criteria for school-cum-cyclone shelter – structural and architectural considerations.
- F. Introduction to relevant Indian Standards for wind loading – with emphasis on effect of wind loading on the shape and layout of buildings
- G. Wind loading on structures with focus on
  - Wind characteristics
  - Wind flow around buildings
  - Opening in buildings
- H. Guidelines for planning of buildings in cyclone-prone areas – including location, group housing schemes, non-engineered, semi-engineered and engineered buildings.
- I. Recommended improvements to reduce damages due to cyclones for,
  - building layouts
  - roofs and walls of buildings
  - thatched roofs and mud walls

- tiled/AC sheet roofs
- Construction with concrete block masonry
- Connection details and bracings for roof trusses

J. Structural and architectural design requirements under the impact of high velocity and cyclonic winds

#### **IV Related to land slides**

A. Introducing landslide hazard zonation of India

B. Main forces (gravity, seepage, seismic) causing the instability of slopes – evaluating the suitability of land for location of buildings in landslide prone area.

C. Rainfall/earthquake-induced landslides and their impact on siting of buildings

D. Guidelines (dos and don'ts) for expansion of human settlements in landslide-prone regions

E. Assessment and mitigation of landslides in the Himalayas

F. Geotechnical considerations of hill slope stability and landslides

#### **V Related to fire safety**

A. Fire behaviour characteristics of materials and structural elements

B. Fire safety requirements in residential buildings – with different heights and occupancy patterns

C. Assessment of fire-load in buildings and with varying occupancies

D. Reinforcement and compliance of fire safety regulations

#### **References:**

- 5.1 National Housing & Habitat Policy 2007, Govt. of India Ministry of Housing and Urban Poverty Alleviation New Delhi
- 5.2 Expert Committee Chaired by A.S. Arya, Techno Legal Regime Vol., I, Vol. IA, Vol. I.B. for Rural Panchayats, printed by BMTPC, 2006-2009.

## 6. Assessment of Hazard Safety Of Existing Housing

### 6.1 Building Types Considered

A wide variety of construction types and building materials are used in urban and rural areas of India. These include local materials such as mud, bamboo and wood, semi-engineered materials such as burnt brick and stone with different dressings, and engineered materials such as concrete and steel. The seismic vulnerability of the different building types depends on the choice of building materials and construction technology adopted. The building vulnerability is generally highest with the use of local materials without engineering inputs and lowest with the use of engineered materials and professional skills.

The *basic vulnerability* class of a building type is based on the average expected seismic performance for that building type. All buildings have been divided into type **A** to type **F** based on the European Macro-seismic Scale (EMS-98) recommendations. The buildings in type **A** have the highest seismic vulnerability while the buildings in type **F** have the lowest seismic vulnerability. A building of a given type, however, may have its vulnerability different from the *basic class* defined for that type depending on the condition of the building, presence of earthquake-resistant features, architectural features, number of stories etc. It is, therefore, possible to have a damageability range for each building type considering the different factors affecting its likely performance. Some variations in building type are, therefore, defined by the author as **A, A+, B, B+** etc. Masonry buildings are presented in Table 6.1 and framed RC and steel buildings in Table 6.2. The likely damages to buildings have been categorised in different grades depending on the seismic intensity impact on the strength of the building.

### 6.2 Grades of Damageability

Five grades of damageability from **G1** to **G5** are specified in MSK and European Intensity Scales as described in Tables 6.3 and 6.4 for Masonry and RCF/SF buildings respectively.

### 6.3 Relationship of Seismic Intensity, Building Type & Damage Grade

Tables 6.5 and 6.6 provide guidance based on MSK Intensities regarding likely performance of the masonry and RCF/SF buildings respectively in the event of occurrence of the earthquake intensity postulated in the seismic hazard zones, III, IV and V.

This information has been used for assessing the seismic vulnerability of the building it can be used to identify need for retrofiting, and to recommend simple retrofiting techniques for ordinary buildings.

The Indicative quantities **Few**, **Many** and **Most** as defined in European Intensity Scales are as follows:

Few: Less than  $(15\pm 5)$  %; Many: Between  $(15\pm 5)$  and  $(55\pm 5)$  %; Most: Between  $(55\pm 5)$  and 100%

As per MSK Intensity scale the average values of these terms may be taken as

About single, Few: 5%                      Many: about 50%                      Most: about 75%

**Table 6.1: Masonry Load Bearing Wall Buildings**

Building Type	Description
A	a) Walls constructed using clay on ground with shallow foundation
A+	b) Rubble (field stone) in mud mortar or without mortar usually with sloping wooden roof. c) Un coursed rubble masonry without adequate 'through stones'. d) Masonry with round stones. e) Un burnt brick wall in mud mortar
B	Semi-dressed, rubble, brought to courses, <b>with</b> <i>through</i> stones and long <i>corner</i> stones; unreinforced brick walls with country type wooden roofs; unreinforced CC block walls constructed in mud mortar or weak lime mortar.
B+	a) Unreinforced brick masonry in mud mortar with vertical wood posts or horizontal wood elements or wooden seismic band (IS: 13828)* b) Unreinforced brick masonry in lime mortar.
C	a) Unreinforced masonry walls built from fully dressed (Ashler) stone masonry or CC block or burnt brick using good cement mortar, either having RC floor/roof or sloping roof having eave level horizontal bracing system or seismic band. b) As at B+ with horizontal seismic bands (IS: 13828)*
C+	Like C(a) type but having horizontal seismic bands at lintel level of doors & windows (IS: 4326)*
D	Masonry construction as at C(a) but reinforced with bands & vertical reinforcement, etc (IS: 4326), or <i>confined</i> masonry using horizontal & vertical reinforcing elements of reinforced concrete.
D+	Reinforced burnt brick masonry walls

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

IS:4326-1993, "Earthquake Resistant Design and Construction of Buildings – Code of Practice BIS 2005

**Table 6.2: Reinforced Concrete Frame Buildings (RCF) And Steel Frames (SF)**

Frame Type	Description
C	a) RC beam post buildings without ERD or WRD, built in non-engineered way. b) SF without bracings having hinge joints. c) RCF of ordinary design for gravity loads without ERD or WRD. d) SF of ordinary design without ERD or WRD.
C+	a) MR-RCF/MR-SF of ordinary design without ERD or WRD. b) Do, with unreinforced masonry infill. c) Flat slab framed structure. d) Prefabricated framed structure.
D	a) MR-RCF with ordinary ERD without special details as per IS: 13920*, with ordinary infill walls (such walls may fail earlier similar to C in masonry buildings). b) MR-SF with ordinary ERD without special details as per Plastic Design Handbook SP:6(6)-1972*.
E	a) MR-RCF with high level of ERD as per IS: 1893-2002* & special details as per IS: 13920*. b) MR-SF with high level of ERD as per IS: 1893-2002* & special details as per Plastic Design Handbook, SP:6(6)-1972*.
E+	a) MR-RCF as at E with well-designed infills walls. b) MR-SF as at E with well-designed braces.
F	a) MR-RCF as at E with well-designed & detailed RC shear walls. b) MR-SF as at E with well-designed & detailed steel braces & cladding. c) MR-RCF/MR-SF with well-designed base isolation.

IS:13920-1993, "Ductile Detailing of Reinforced concrete structures subjected to seismic forces-Code of Practice" ,BIS.2002".

\*IS:1893(Part-I) 2002, "Criteria for Earthquake Resistant Design of Structures", BIS 2007.

SP:6(6)-1972, "Plastic Design of Steel Structures—Handbook", BIS.1972.

Notes: RCF = Reinforced concrete column-beam frame system

SF = Steel column-beam frame system

ERD = Earthquake Resistant Design

WRD = Wind-Resistant Design

MR = Moment Resistant jointed frame



**IMPORTANT NOTE:**

Buildings having severe vertical irregularity e.g. open plinth, stilt floor called soft storey & those having floating columns resting on horizontal cantilever beams are not covered in the above table & will require special evaluation.

**Table 6.3: Grades of damageability of masonry buildings**

Grade 1: Negligible to slight damage (no structural damage, slight non-structural damage)	
<i>Structural:</i>	Hair-line cracks in very few walls.
<i>Non-structural:</i>	Fall of small pieces of plaster only. Fall of loose stones from upper parts of buildings in very few cases.
<b>Grade 2: Moderate damage (slight structural damage, moderate non-structural damage)</b>	
<i>Structural:</i>	Cracks in many walls, thin cracks in RC* slabs and A.C.* sheets.
<i>Non-structural:</i>	Fall of fairly large pieces of plaster, partial collapse of smoke chimneys on roofs. Damage to parapets, chhajjas. Roof tiles disturbed in about 10% of the area. Minor damage in under structure of sloping roofs.
<b>Grade 3: Substantial to heavy damage (moderate structural damage, heavy non-structural damage)</b>	
<i>Structural:</i>	Large and extensive cracks in most walls. Widespread cracking of columns and piers.
<i>Non-structural:</i>	Roof tiles detach. Chimneys fracture at the roof line; failure of individual non-structural elements (partitions, gable walls).
<b>Grade 4: Very heavy damage (heavy structural damage, very heavy non-structural damage)</b>	
<i>Structural:</i>	Serious failure of walls (gaps in walls), inner walls collapse; partial structural failure of roofs and floors.
<b>Grade 5: Destruction (very heavy structural damage)</b>	
	Total or near total collapse of the building.

\* RC = Reinforced Concrete; AC = Asbestos Cement

**Table 6.4: Grades of damageability of RCC buildings**

<p><b>Grade 1: Negligible to slight damage (no structural damage, slight non-structural damage)</b></p> <p>Fine cracks in plaster over frame members or in walls at the base. Fine cracks in partitions &amp; infills.</p>
<p><b>Grade 2: Moderate damage (slight structural damage, moderate non-structural damage)</b></p> <p>Cracks in columns &amp; beams of frames &amp; in structural walls. Cracks in partition &amp; infill walls; fall of brittle cladding &amp; plaster. Falling mortar from the joints of wall panels.</p>
<p><b>Grade 3: Substantial to heavy damage (moderate structural damage, heavy non-structural damage)</b></p> <p>Cracks in columns &amp; beam column joints of frames at the base &amp; at joints of coupled walls. Spalling of concrete cover, buckling of reinforced rods. Large cracks in partition &amp; infill walls, failure of individual infill panels.</p>
<p><b>Grade 4: Very heavy damage (heavy structural damage, very heavy non-structural damage)</b></p> <p>Large cracks in structural elements with compression failure of concrete &amp; fracture of rebar's; bond failure of beam reinforcing bars; tilting of columns. Collapse of a few columns or of a single upper floor.</p>
<p><b>Grade 5: Destruction (very heavy structural damage)</b></p> <p>Collapse of ground floor parts (e.g. wings) of the building.</p>

- \* The grades of damage in steel and wood buildings will also be based on non-structural and structural damage classification (shown in bold print in above Table 7.4). Non-structural damage to infills would be the same as indicated for masonry building in the above table. Structural damage grade in steel & wooden elements still needs to be defined.

**Table 6.5: Damageability Grades Of Masonry Buildings**

<b>Type of building</b>	<b>Low intensity MSK VII (Zone III)</b>	<b>Moderate intensity MSK VIII (Zone IV)</b>	<b>High intensity (MSK IX or More) (Zone V)</b>
A and A <sup>+</sup>	<i>Most of grade 3 Few of grade 4 (rest of grade 2 or 1)</i>	<i>Most of grade 4 Few of grade 5 (rest of grade 3, 2)</i>	<i>Many of grade 5 (rest of grade 4 &amp; 3)</i>
B and B <sup>+</sup>	<i>Many of grade 2 Few of grade 3 (rest of grade 1)</i>	<i>Most of grade 3 Few of grade 4 (rest of grade 2)</i>	<i>Many of grade 4 Few of grade 5 (rest of grade 3)</i>
C and C <sup>+</sup>	<i>Many of grade 1 Few of grade 2 (rest of grade 1, 0)</i>	<i>Most of grade 2 Few of grade 3 (rest of grade 1)</i>	<i>Many of grade 3 Few of grade 4 (rest of grade 2)</i>
D and D <sup>+</sup>	<i>Few of grade 1</i>	<i>Few of grade 2</i>	<i>Many of grade 2 Few of grade 3 (rest of grade 1)</i>

**NOTE:**

1. As per MSK scale, Few, Many and Most may be taken as: Few: 15%, Many: 50% and Most: 75%.
2. While selecting the damageability grade for ordinary residential building, the grade may be taken as indicated for Many, for Schools and Hospital building the highest grade may be chosen even if indicated for Few.
3. Buildings having vertical irregularity may undergo severe damage in seismic Moderate & High Intensity zones MSK (VIII and 'IX or more') if not specifically designed. Hence they will require special evaluation. Also buildings sited in liquefiable or landslide prone areas will require special evaluation for seismic safety.
4. Buildings having plan irregularity may undergo a damage of one grade higher in the Low, Moderate and High Intensity zones MSK VII, VIII & IX and higher. The surveyor may recommend re-evaluation if damageability grade G4 or more is indicated.

5. Masonry buildings of three-story height may have a damage grade one unit higher, as also buildings founded on soft soil.

**Table 6.6: Damageability Grades of RCC Buildings**

<b>Type of building</b>	<b>Low intensity MSK VII (Zone III)</b>	<b>Moderate intensity MSK VIII (Zone IV)</b>	<b>High intensity (MSK IX or More) (Zone V)</b>
C and C <sup>+</sup>	<i>Few</i> of grade 2 (rest of grade 1 or 0)	<i>Many</i> of grade 2 <i>Few</i> of grade 3 (rest of grade 1)	<i>Many</i> of grade 3 <i>Few</i> of grade 4 (rest of grade 2)
D and D <sup>+</sup>	<i>Few</i> of grade 1	<i>Few</i> of grade 2	<i>Many</i> of grade 2 <i>Few</i> of grade 3 (rest of grade 1)
E and E <sup>+</sup>	-	-	<i>Few</i> of grade 2 (rest of grade 1 or 0)
F	-	-	<i>Few</i> of grade 1

**NOTE:**

1. As per MSK scale, Few, Many and Most may be taken as: Few: 15%, Many: 50% and Most: 75%.
2. While selecting the damageability grade for ordinary residential building, the grade may be taken as indicated for Many, for schools and hospital building the highest grade may be chosen even if indicated for Few.
3. Buildings having vertical irregularity may undergo severe damage in seismic Moderate & High Intensity zones MSK (VIII and 'IX or more') if not specifically designed. Hence they will require special evaluation. Also buildings sited in liquefiable or landslide prone areas will require special evaluation for seismic safety.
4. Buildings having plan irregularity may undergo a damage of one grade higher in the Low, Moderate and High Intensity zones MSK VII, VIII& IX and higher. The surveyor may recommend re-evaluation if damageability grade G4 or more is indicated.
5. Frame buildings of more than four stories founded on soft soil may have a damage grade one unit higher.

## 6.4 Building attributes enhancing earthquake risk

There are some special hazardous conditions to be considered:

**6.4.1 Liquefiable condition:** Normal loose sands submerged under high water table are susceptible to liquefaction under **moderate** and **high** ground accelerations; building founded on such soils will require special evaluation and treatment.

**6.4.2 Landslide-prone area:** If the building is situated on a hill slope which is prone to landslide/ landslip or rock-fall under monsoon and/or earthquake, special geological & geotechnical evaluation of the site and treatment for the building will be needed.

### 6.4.3 Irregular buildings:

Irregularities in buildings are defined in the building codes under the following sub-heads:

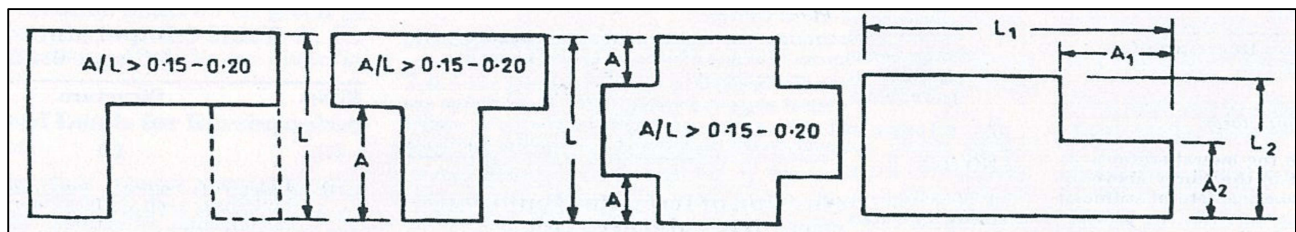
*i. Plan irregularities:*

These are generally defined as follows:

- a) Torsion irregularity
- b) Re-entrant corners
- c) Diaphragm discontinuity
- d) Out of plane offsets
- e) Non-parallel systems

The geometric irregularities in building plans which can be easily identified are shown in Fig.6.1

These irregularities enhance the overall damage by one grade (increased grade of damage e.g. at re-entrant corners). Such a building may be recommended for detailed evaluation, or for retrofiting.



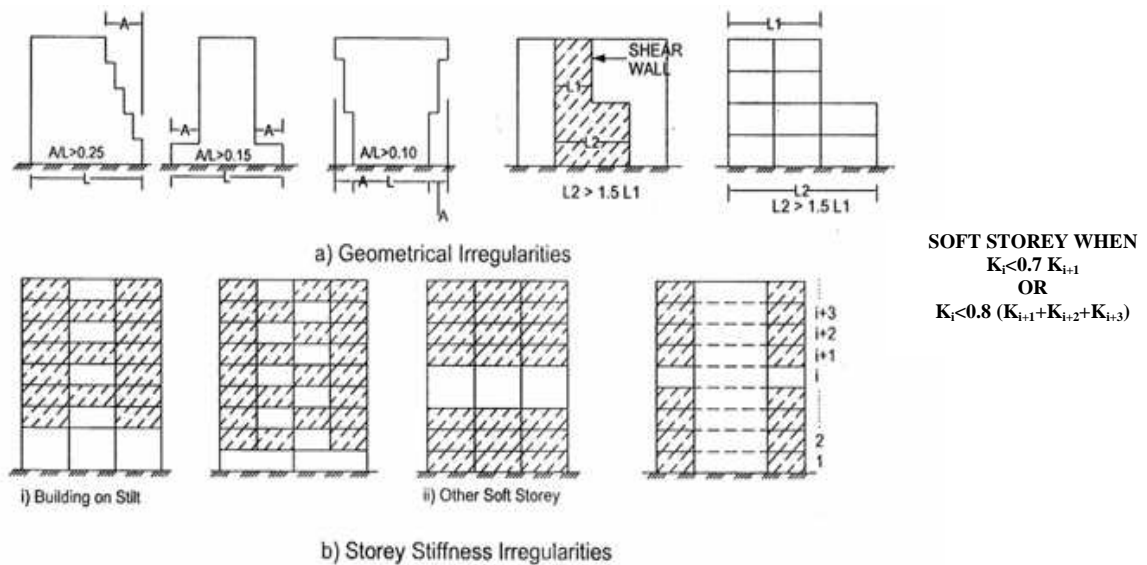
3B Re-entrant corner

Fig. 6.1 Plan irregularities

ii. Vertical irregularities:

The following vertical irregularities may be seen in masonry buildings (see Fig. 6.2).

- a) Mass irregularity
- b) Vertical geometric irregularity
- c) In-plane discontinuity in vertical elements resisting lateral forces.



If any of these irregularities are noticed, the building may undergo much more severe damage even up to Grade 4 or 5 and a Grade of damage by two units higher may be specified.

**6.4.4 Falling hazard:** Where such hazards are present, particularly in high-intensity zones, the risk is enhanced.

**6.4.5 Type Of Foundation Soil:** Normally earthquake resistant building codes define three soil types hard/stiff, medium & soft.

No effect of these is seen in the design spectra of short period buildings, i.e. having  $T < 0.4$  second, covering practically all masonry buildings, hence the soil effect may be considered not so significant in masonry buildings, but it will be prudent to specify one unit higher grade of damage for soft soil condition.



### 6.5 Form for Vulnerability Assessment

Besides the information about the building, its name & location, name of owner etc., information has to be collected for classifying the types of building as given in tables 6.1 & 6.2 & the seismic zone in which the building is situated. Now the vulnerability of the building in general can be estimated from the following table.

**Table 6.1 Probable Risk of Damage Grades In Masonry Building.**

Building Types	A/A+	B/B+	C/C+	D	D+
MSK Intensity VII	G4	G3/ G2	G2/ G1	G1	Nil
MSK Intensity VIII	G5	G4/ G3	G3/ G2	G2	Nil
MSK Intensity	G5	G5/ G4	G4/ G3	G3/G2	G1

SOFT STOREY WHEN  
 $K_i < 0.7 K_{i+1}$   
 OR  
 $K_i < 0.8 (K_{i+1} + K_{i+2} + K_{i+3})$

As mentioned in text there are some additional attributes which enhance the vulnerability of the building. The information about them is also to be collected and entered into the following table.

### 6.2 Photograph/Sketch Plan with Length & Breadth

<p><b>Special Hazard</b></p> <ul style="list-style-type: none"> <li>• High water table (within 3m below ground level) &amp; if sandy soil, then liquefiable site indicated. Yes <input type="checkbox"/> No <input type="checkbox"/></li> <li>• Landslide-prone site Yes <input type="checkbox"/> No <input type="checkbox"/></li> <li>• Severe vertical irregularity Yes <input type="checkbox"/> No <input type="checkbox"/> (<i>Increase damageability grade by 2 units</i>)</li> <li>• Severe plan irregularity Yes <input type="checkbox"/> No <input type="checkbox"/> (<i>Increase damageability grade by 1 unit</i>)</li> </ul>
<ul style="list-style-type: none"> <li>• <b>Non-structural Components*:-</b> Whether the following non-structural elements has been properly anchored/fastened keeping into consideration the potential damages from earthquake</li> <li>• <b>Falling Hazards</b> (<i>Brick wall/wooden partitions, Façade elements, False Ceilings, Parapets, Chimneys, Signs, display boards etc.</i>) Yes <input type="checkbox"/> No <input type="checkbox"/></li> </ul>

It will be helpful if a sketch plan of the building as well as a few photographs taken from the outside of building are attached along with the address of the building.

In this way, all buildings constructed in masonry or reinforced concrete or steel frames can be covered for assessing the seismic safety of the building.

## **6.6 Other Natural Hazards**

Such systematic simple vulnerability assessment methods are not available as for the seismic hazards detailed above. Some general comments can be made in the following.

### **6.6.1 Flood Hazard**

The flood hazard destroys the simple huts of the poor people constructed using bamboo or other biomass materials. Also huts made from clay mud are easily dissolved in standing or flowing water. The substantial masonry and concrete buildings have the risk of damage under floods created by storm surges or tsunamis due to the incursions of the foundation soils.

### **6.6.2 Cyclonic Wind Hazards**

The light weight buildings like bamboo huts and those made from the biomass are the most vulnerable since the roofs can fly off and the walls destroyed or tilted to the ground. Substantial buildings of masonry or reinforce concrete or steel frames having heavy roofs have no danger from the incidence of high wind velocities but masonry buildings having sheeted roofs are found weak in terms of the roofs sheeting and roofs structure which gets torn down by the wind gusts if not properly fixed using adequate bolts and nuts.

### **6.6.3 Landslides**

The building by itself may be affected by rock falls and badly damaged but the real destruction occurs when the land on which buildings stand slides totally towards the khad or ravine takes the building along with. There is no safety measure for the building against the rock falls or landslides. The only precaution could be to prevent the slide from occurrence by appropriate geotechnical preventive steps.

### **6.6.4 Building Fires**

The assessment of buildings against fire hazards is a specialised topic to be carried out by fire specialists. Assessment will include the type of material use in the construction of the building, for example, its structure, cladding, partitions etc., and the furnishings. All are to be checked under fire rating provisions in the Fire Codes given in Chapter 4 in the National Building Code 2005. Besides, the fire load present in the

building, the presence or absence of the fire extinguishing equipment in the building and the fire exists provided for safe evacuations of the occupants. Another issue to be assessed will be the electric current capacity of the power lines to take the increasing load of air conditioners, bathroom geysers and heaters used during winters, which lead to start of fire due to short circuiting.

**Reference:**

- 6.1 Vulnerability Atlas of India, by Expert Group, Published by (BMTPC), 1997, revised and updated, 2006.
- 6.2 “Improving Earthquake Resistance of Buildings – Guidelines” by Expert Group, pub. by Building Material and Technology Promotion Council (BMTPC), 1999, revised and updated by A.S. Arya 2010.
- 6.3 “Improving Flood Resistance of Housing – Guidelines” by Expert Group, pub. by Building Material and Technology Promotion Council (BMTPC), 1999, revised and updated by A.S. Arya 2010.
- 6.4 “Improving Wind/Cyclone Resistance of Housing – Guidelines” by Expert Group, pub. by Building Material and Technology Promotion Council (BMTPC), 1999, revised and updated by A.S. Arya 2010.
- 6.5 Rapid Visual Screening of Masonry buildings, by A.S. Arya, Assisted by Ankush Agrawal, under Gol-UNDP Disaster Risk Management Programme website: [www.ndmindia.nic.in](http://www.ndmindia.nic.in).
- 6.6 Rapid Visual Screening of Reinforced Concrete buildings, by A.S. Arya, Assisted by Ankush Agrawal under Gol-UNDP Disaster Risk Management Programme, website: [www.ndmindia.nic.in](http://www.ndmindia.nic.in).
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## 7. Rehabilitation And Retrofitting of Existing Unsafe Buildings

### 7.1 Classification of building in India

#### 7.1.1 Non-engineered building construction

Non-engineered buildings are those which are spontaneously and informally constructed in various countries in the traditional manner.

Such buildings involve field stone, fired brick, concrete blocks, adobe or rammed earth, wood or a combination of these traditional locally available materials.

#### 7.1.2 Engineered Constructions Including Buildings And Infrastructure

The *engineered constructions* include reinforced concrete and steel buildings and structures, which are normally designed by Architects and Engineers working together or Civil Engineers working in various Govt. Departments or consulting organisations.

#### 7.1.3 Risk of Damage To Buildings In Earthquake Disaster

**Table 7.1 Level of Damage Risk To Various Building Types In India**

Wall Type	Number of Housing Units				Damage Vulnerability in MSK Intensity		
	Census 1991		Census 2001		VII	VIII	IX
	Millions	% of Total	Millions	% of Total			
Earthen walls (mud, unburnt brick)	74.7	38.29	73.80	29.63	M	H	VH
stone walls	21.7	11.10	25.48	10.23	M	H	VH
Burnt Brick walls	68.60	35.18	111.89	44.93	L	M	H
Concrete walls	3.96	2.03	6.54	2.62	VL	L	M
Wood & Ekra walls	3.12	1.60	3.19	1.28	VL	L	L
GI & Other metal sheets	1.01	0.52	1.99	0.80	VL	VL	L
Bamboo, thatch, leaves etc.	21.63	11.09	26.18	10.51	VL	VL	L

\* Census of Housing 1991, total housing units = 195 million.

Census 2001, total housing units = 249 million

R= Rural, U= Urban, VH= Very High, H= High, M= Moderate, L=Low, VL= Very Low

## **7.2 Prioritisation of Buildings And Structures**

### **(A) Important Buildings**

*The following and others to be identified:*

- (i) Hospitals including wards, dispensaries, clinics, etc.
- (ii) Instructional, laboratory and library buildings of educational institutions (schools, colleges, institutes and universities).
- (iii) Congregation halls, temples, churches, cinemas, theatres, etc.
- (iv) Residences of VIPs and top administrative officers in the districts (Collector, SP, CMO and the like needed for immediate response).

### **(b) Service buildings**

*The following among others:*

- (i) Water towers.
- (ii) Telephone exchanges, fire stations, water supply pump houses.
- (iii) Electric power houses and substations.
- (iv) Monuments, heritage buildings, museums.
- (v) Critical and hazardous industries.
- (vi) Railway stations, airport buildings and towers.

Priority may be given in order of Zones V, IV & III.

## **7.3 Need For Restoration And Retrofitting**

- Buildings damaged in Grades G1,G2,G3- need restoration & retrofitting
- Existing weak unsafe buildings
- Buildings not designed to codes
- Upgrading of code-based seismic design forces
- Upgrading of seismic zone
- Deterioration of strength on aging of the structure
- Modification of the existing structures affecting its strength adversely
- Change in the use of the building increasing the floor loads

All such buildings need be upgraded by retrofitting.

## **7.4 Repair & Restoration - Definitions**

### **7.4.1 Repair**

Means the repairing of *non- structural elements*, such as plumbing, electrical works and cosmetic touch-up.

### **7.4.2 Restoration**

Means action taken to restore the structure to its original strength. It is limited to damaged structural elements. It includes repairs of wall cracks, stitching of walls, and grouting of cracks in masonry walls and RCC elements, etc.

### **7.4.3 Seismic Strengthening/Retrofitting**

Retrofitting means action taken to upgrade the seismic resistance of an existing building so that it achieves intended seismic performance level. It includes:

- addition of new members, shear walls, bracings,
- reducing load,
- strengthening of structural elements and
- increasing ductility of members, etc.

## **7.5 Retrofitting Considerations**

### **7.5.1 Minimum Seismic Resistance (MSR)**

MSR as per - IS: 1893 of 1962, 1970, 1984, 2002

- IS: 4326 of 1976, 1993

- IS: 13920 of 1993

Epochs of time for Buildings  $\leq$  1947-62 before the earthquake codes

### **Design basis**

Once-in-life earthquake intensity should not result in the total collapse of the building, which has been the basis of IS:1893 all through.

### **7.5.2 Remaining Useful Life of Building**

The retrofitting level can be determined through probabilistic relationship:

$$R_{str} / MSR = (T_{rem} / T_{des})^{0.5}, \quad \text{but } \geq 0.7 \text{ in any case}$$

Rstr = Seismic force for redesign of the building for strengthening,

Trem = Remaining life, and

Tdes = Design Life of the Building.

### **7.5.3 Available Seismic Resistance (ASR)**

ASR- the earthquake force under which the first of the columns of any building storey will reach its ultimate limit strength, when the remaining structure remains in the undamaged state.

ASR found less than MSR due to.

- i. The design provisions not fully implemented during construction of the building (quantity of reinforcement, quality of concrete & detailing)
- ii. Structure was built on the basis of design seismic actions less than those of the Codes *revised* after construction of the building.
- iii. The usage of the buildings has been changed, and therefore the gravity loads have been increased.
- iv. Environmental attacks, such as corrosion of the reinforcing steel bars, caused a decrease in load-carrying capacity of members.

Interventions of global type, so that overall structural behaviour of the building is improved. Increase Available Seismic Resistance (ASR) to the Minimum Seismic Resistance 'MSR' or to a predefined percentage of MSR which may be related to the remaining useful life of the building.

### **7.5.4 Factors To Determine Type of Intervention**

In case of an existing undamaged structure before an earthquake, the retrofitting be based on ASR/MSR ratio so as remove the deficiency of design and construction based on the best estimated value of ASR.

- i) ASR more than 80% of MSR: Retrofitting taken as 'not needed'.
- ii) Ratio ASR/MSR in the range 0.8 to 0.5: Needs to be retrofitted.
- iii) ASR less than half of MSR: The safety of the structure is unsatisfactory, retrofitting required for upgrading the strength as well as ductility.



### **7.5.5 Intervention**

The following approach may have to be adopted:

- i. In buildings with light damage, of local nature, intervention may be limited to 'restoration'.
- ii. In buildings with extended or heavy damage, of the global type, intervention should include strengthening of the structure besides restoration.

Criteria for Restoration or Strengthening

If  $ASR = MSR$  no damage expected

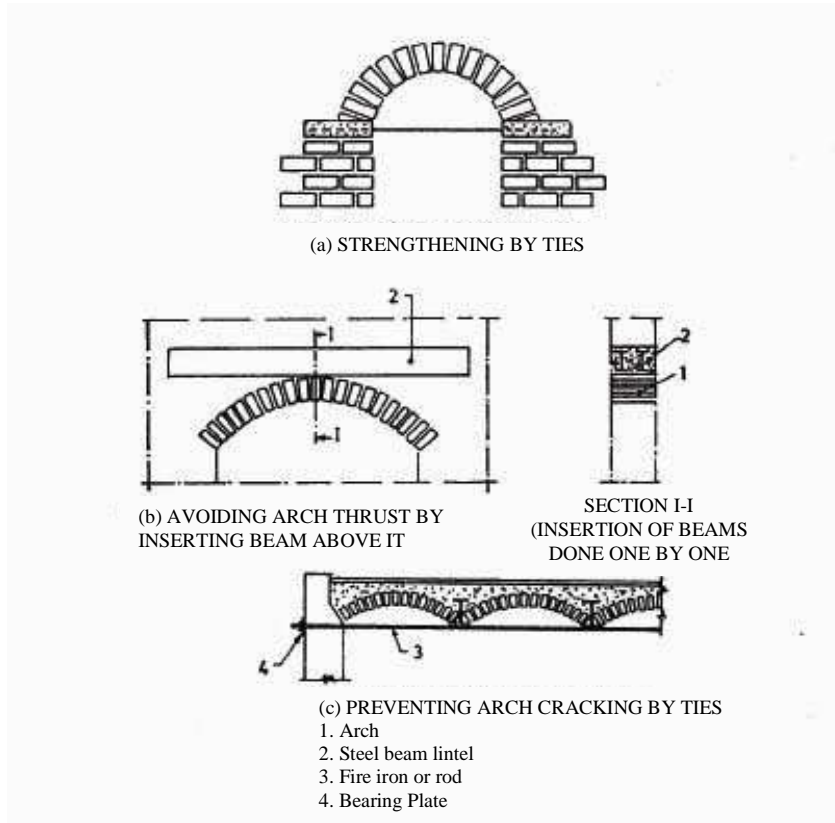
IF  $ASR \ll MSR$  severe damage expected

### **7.5.6 Type of intervention**

- no intervention at all;
- restriction or down graded change of use of the building;
- local or global modification of damaged or undamaged elements;
- possible upgrading of existing non-structural elements into structural ones;
- modification of the structural elements aiming at stiffness regularity, elimination of vulnerable elements, or a beneficial change of the natural period of the structure by base – isolation;
- storey or mass reduction;
- addition of new structural elements (e.g. bracings, infill walls);
- full replacement of inadequate or heavily damaged elements;
- addition of damping devices at appropriate parts of the structure;
- partial demolition.

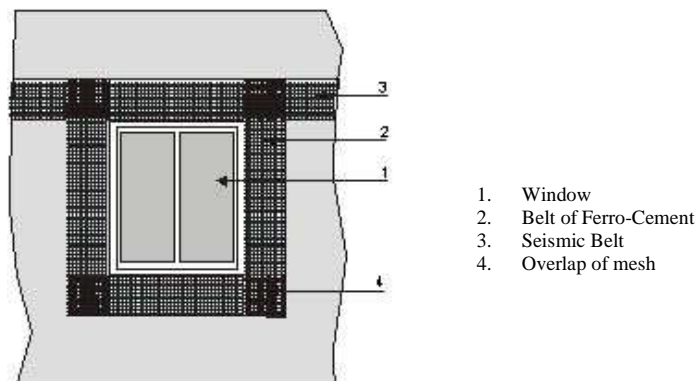
## 7.6 Retrofitting of Masonry Buildings

### 7.6.1 Masonry Arches



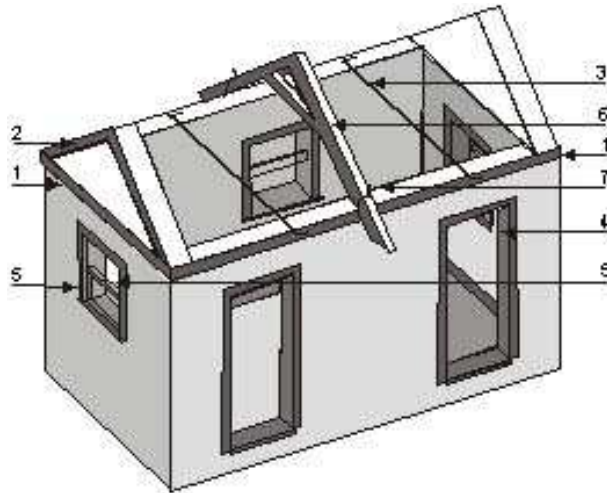
### 7.6.2 Reinforcing Large Opening

Mesh of gauge 13 with wires @ 25 mm in a belt width of 250 mm may be used around the opening.



### 7.6.3 Seismic Belts

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



1. Seismic belt above opening and below roof at eave level
2. Seismic belt on gable wall
3. Tie at eave band level
4. Door
5. Window
6. Rafter with collar tie
7. Tying of rafter with band

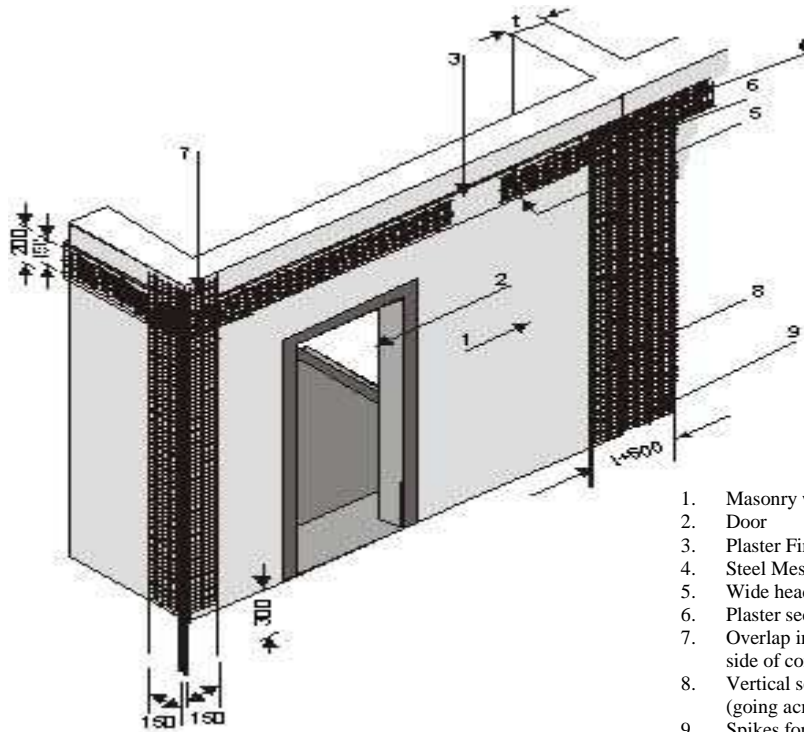
**Table 7.2 Mesh Reinforcement In Seismic Belts In Various Seismic Zones**

Length of wall m	Zone III			Zone IV			Zone V		
	Gauge	N	H	Gauge	N	H	Gauge	N	H
≤ 5.0	g 13	9	250	g 12	9	250	g 10	10	280
6.0	g 12	9	250	g 10	10	280	g 10	14	380
7.0	g 10	10	280	g 10	14	380	g 10	18	460
8.0	g 10	14	380	g 10	18	460	g 10	23	580

1. Gauges: g10=3.25 mm, g11=2.95 mm, g12=2.64 mm, g13=2.34 mm, g14=2.03 mm.
2. N = Number of made longitudinal wires in the belt at spacing of 25 mm.
3. H = Height of belt on wall in micro-concrete, mm.
4. The transverse wires in the mesh could be spaced up to 150 mm.
5. The mesh should be galvanized to save from corrosion.

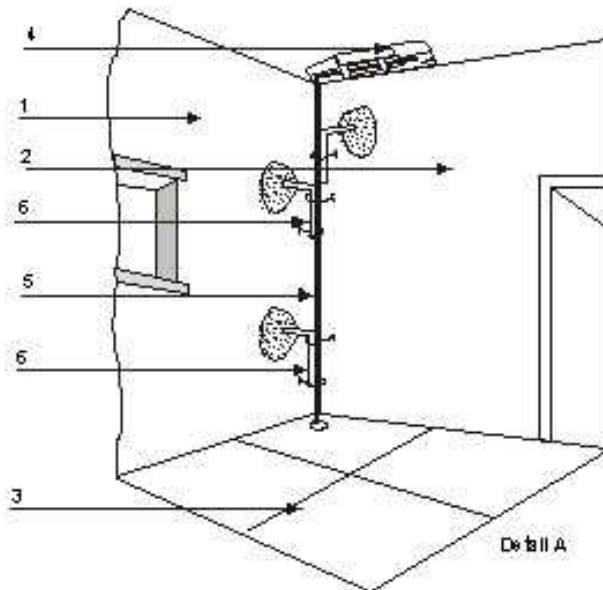
### 7.6.4 Vertical Reinforcing

#### (a) Seismic Band At Corner & Junctions



1. Masonry wall
2. Door
3. Plaster First Layer
4. Steel Mesh in Belt
5. Wide head nail 150 long
6. Plaster second layer
7. Overlap in steel mesh, 200 mm each side of corner
8. Vertical seismic belt at junction (going across horizontal belt)
9. Spikes for fixing mesh

#### (B) Vertical Bar At Inside Corner (Alternative Reinforcing)



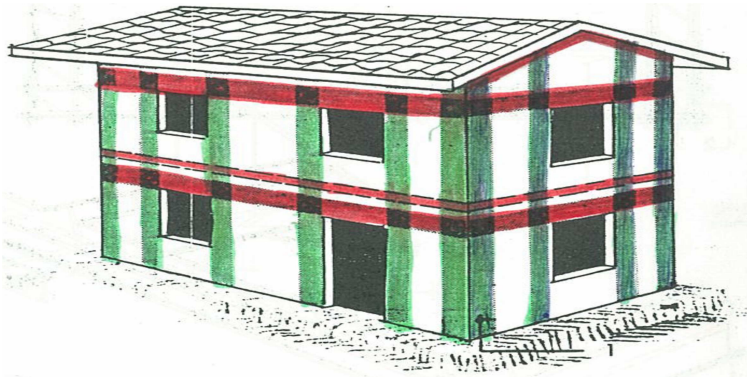
- 1 - Wall
- 2 - Perpendicular wall
- 3 - Floor
- 4 - Slab
1. Wall
2. Perpendicular Wall
3. Floor
4. Slab
5. Vertical Bar
6. Dowel

**Table 7.3 Vertical Bar or Mesh Reinforcement In Vertical Belt At Corners of Rooms**

No. of Storey's	Storey's	Zone III			Zone IV			Zone V		
		Single Bar, mm	Mesh (g10)		Single Bar, mm	Mesh (g10)		Single Bar, mm	Mesh (g10)	
			N	B		N	B		N	B
One	One	-	-	-	10	10	300	12	14	400
Two	Top	-	-	-	10	10	300	12	14	400
	Bottom	-	-	-	12	14	400	16		
Three	Top	10	10	300	10	10	300	12	14	400
	Middle	10	10	300	12	14	400	16	25	650
	Bottom	12	14	400	12	14	400	16	25	650

1. Gauge 10 (3.25 mm dia) galvanized mesh with 25 mm spacing of wires shall be used.
2. Single bar, if used, shall be HSD or TOR type. If two bars are used at a T-junction, the diameter can be taken as follows. For one of 10 or 12 mm take 2 of 8 mm, and for one of 16 mm take 2 of 12 mm.
3. N = Number of longitudinal wires in the mesh.
4. B = Width of the micro concrete belt, half on each wall meeting at the corner or T-junction.
5. The transverse wires in the mesh could be at a spacing up to 150 mm.

**7.6.5 Splint And Bandage Strengthening Technique**



**1- Wire mesh with width  $\geq 400$  mm.**

## **7.7 Reinforced concrete buildings**

### **7.7.1 General principles**

Rational feasible approach for selected buildings:

- i. Detailed examination of the damaged or seismically weak buildings.
- ii. Analysis of the causes of the damages and noting the deficiencies.
- iii. Development of alternative rehabilitation schemes.
- iv. Examination of the technical and cost feasibility of implementing each scheme and selection of the optimum solution.
- v. Rehabilitation design, reanalysis, final design.

### **7.7.2 Typical damage in RC buildings columns**

- Cracking in the tension zone.
- Diagonal cracking in the core.
- Loss of concrete cover.
- Concrete core breaking into lumps by reversed diagonal cracking.
- Stirrups bursting outwards.
- Buckling of main reinforcement.
- Bond failure, particularly in zones under high cyclic stresses in the concrete.
- Shear failure of short columns.

### **7.7.3 Deficiencies in RC buildings**

- Majority of structures not designed for any lateral forces.
- The column to beam junctions assumed as 'hinge' connection.
- RCC shear walls not used in multi-storey buildings.
- Use of floating columns leading to sudden discontinuity in stiffness.
- Use of small width of columns (150 to 200 mm).
- Open parking floor acting as a soft storey.
- Poor connection (inadequate rigid floor diaphragm action) of staircase and RCC lift well to the rest of structure.
- Structural planning and design-deficient engineering practice
  - Use of long cantilevers,
  - Beams cantilevering out from cantilever beams,
  - Walls resting directly on slab without any beams,
  - Slabs having  $l_y/l_x$  ratio  $< 1.5$  also designed as one way slab.

### **7.7.4 Building structural safety survey**

- Detailed structural layout with schedule and reinforcement detailing (if drawings not available, then do as built drawings with the help of NDT).
- Load path and lateral load resisting system.
- Relative size- slenderness ratio (height divided by least lateral dimension) & aspect ratio (length divided by width, in plan).
- Weak storey- the strength of the lateral force resisting system in any storey having less than 80% of the strength in an adjacent storey.



- Soft storey- the stiffness of the lateral force resisting system in any storey having less than 70% of the stiffness in an adjacent storey or less than 80% of the average stiffness of the three stories above or below.
- Geometry- no change in horizontal dimension of the lateral force resisting system of more than 30% in adjacent storey.
- Mass- there shall be no change in effective mass more than 50% from one storey to the next.
- Torsion- distance between the storey centre of mass and storey centre of stiffness not more than 20% of the building width in either plan dimensions.
- Diaphragm continuity- no sudden discontinuity, large cut outs in the diaphragm (i.e., slab). A typical example a building with two wings connected only by staircase ('H'-shaped building).
- Plan irregularities- the complicated plans shapes (L,T,H,U) where both projections of the structure beyond re-entrant corner greater than 15% of its plan dimension.
- Redundancy- structure should have large indeterminacy, i.e., multi-storey moment resistant building with many columns and beams.
- Strong column-weak beam- the sum of the moment capacity of the columns shall be 20% more than that of beams at the frame joint.

#### **7.7.5 Quality of Construction/Defects**

- Type of construction
- Type of infill wall and their connection to the frames
- Quality control test results of construction material used.
- Type of flooring and its thickness.
- Original constructional defects, if any.

**Testing of Elements**, may be carried by non destructive testing and by core cutting

Non- destructive testing

Rebound hammer test, ultrasonic testing,

Other testing

Core cutting, load tests.

**Foundation**, Investigation to be carried out to determine potential for the following:

- Liquefaction
  - During the violent shaking there is possibility that the building may sink down, tilt or ultimately collapse down where resting on water bearing non-cohesive soils due to liquefaction.
- Elastic displacement
  - During strong shaking large elastic displacements may occur in soft soils affecting the piles, underground pipelines, and culvert-type structures.
  - Separate column footings in soft soils could have relative vertical and horizontal displacements.

#### **7.7.6 Design of Retrofitting**

Conceptual design

- i) Selection of techniques and materials, as well as the type and configuration of the intervention;
- ii) Preliminary estimation of dimensions of additional structural parts;
- iii) Preliminary estimation of the modified stiffness of the strengthened elements;
- iv) Preliminary estimation of the appropriate behaviour factor in relation to the local and global ductility of the modified structural system.

Reanalysis

- i) Identification of the non-seismic loads and actions;
- ii) Selection of the seismic coefficients and actions;
- iii) Determination of the action effects taking into account the modified stiffness, and possible unfavorable redistribution of load effects due to heavy damage (i.e. column damage, deviations from the vertical axis;)
- iv) Implementation of the simplified modal response spectrum method of analysis.

*Safety verification*

- i) Selection of the behavior model of restored/retrofitted element;
- ii) Selection of material partial safety factors; (See IS:456-2000)
- iii) Calculation of design resistance;

- iv) Verification of the safety inequalities regarding seismic and non-seismic loads and actions, for both the ultimate limit state (ULS) and the serviceability limit state (SLS).

## **7.8 Rehabilitation of Inner City Areas**

### **7.8.1 Inner City Areas And Heritage Sites**

Majority of migrant and underprivileged families move into inner city areas where buildings are old and in poor maintenance conditions, including aging infrastructure, with very narrow access roads. These old, partly dilapidated buildings constitute a constant threat to their occupants from hazards such as fires, floods, and earthquakes. A large proportion of urban dwellers in most mega and large cities live and work in these highly vulnerable buildings existing in inner city areas and neighbourhoods. Most of these buildings are at high risk from multiple hazards. Lanes are so narrow that even access for emergency vehicles, fire tenders, etc., is often difficult and can be completely obstructed by building and/or hoardings debris in case of a seismic hazard event.

Thus the problem of inner city areas, from disaster safety point of view, is largely due to the high social and very high physical vulnerability. It is commonly seen in most old cities that solution to reduce social and physical vulnerabilities are politically, socially and financially very difficult. It continues to be a formidable challenge to the authorities. Not many case studies are available, where rehabilitation and retrofitting of existing unsafe buildings in inner city areas have been carried out successfully, except in the city of Bhuj where after the destruction of certain old city areas during the earthquake of Jan 26, 2001, the streets were widened by relocating the affected in fresh locations just outside the city.

### **7.8.2 Heritage Sites**

Heritage sites is another area where safety against hazards particularly earthquakes has been of great concern. Archeological survey of India (ASI) is responsible for maintenances upkeep and structural strengthening of historic monuments. The ASI takes the help of experts from academic and other engineering institutions to carry out diagnostic assessment studies at some of the sites where existing structures have shown signs of distress and then necessary retrofitting measures for strengthening are implemented. Some scientists from CBRI have undertaken studies to collect Micro-

Tremor data in few heritage buildings (Qutub Minar) and Sun Temple (In Uttarakhand) by using Digital Triaxial Strong Motion Accelerograph (SMA). Based on some of their studies, they recommend that if natural frequency of the whole monument is same and it is different from the surrounding ground frequency, then it is a good sign. However it is recommended that detailed investigations for other parameters of safety should be carried out to assess the health of monuments definitively.

### **7.9 Concluding Remarks**

- The restoration of a seismically damaged building is a much more difficult task than the original design and construction.
- Difficulties arise during inspection, design and the execution of the intervention.
- A basic factor for the successful outcome of the whole operation is the correct diagnosis of the causes of damage, the level of intervention (restoration or retrofitting or both).
- Design of restoration must aim at providing the structure with the stiffness, strength and ductility that it had *before* the earthquake.
- The design of the retrofitting must aim at providing the structure with the strength, stiffness and ductility required by the current Codes.
- For the choice of the techniques, the economic conditions and the feasibility of application of the chosen technique in every particular case must be taken into account.
- The outcome of the retrofitting depends to a large degree on the quality control of the design and construction.
- The restoration of the heavily damaged infills and connections with the structural frame is very important to the structure before retrofitting.

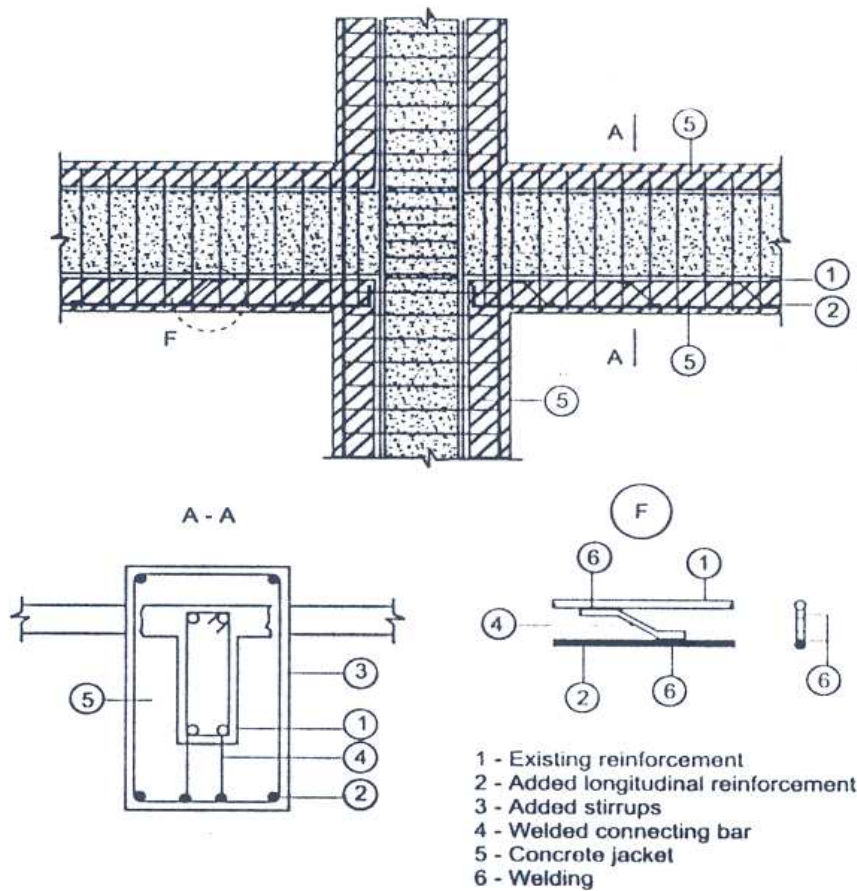
Finally, it has to be stressed that the structural rehabilitation and retrofitting must have the proper combination of strength, stiffness and ductility.

### **7.10 Some Retrofitting Details of RC Elements**

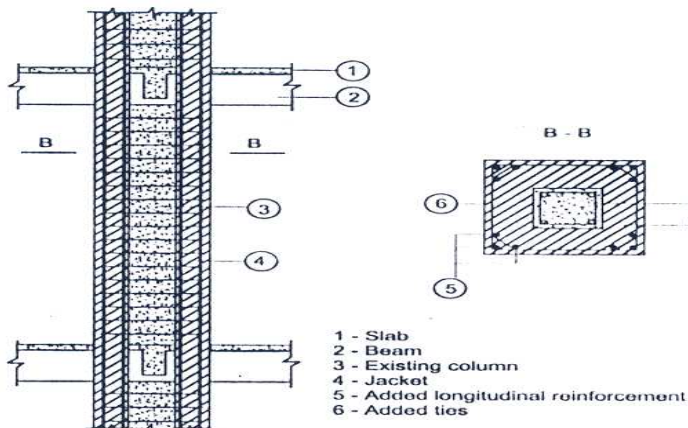
See the figures as mentioned below:

- (a) Typical jacketing scheme of column when beam & beam column strengthening is necessary
- (b) Typical jacketing scheme of column when beam & beam column joint need not be strengthened

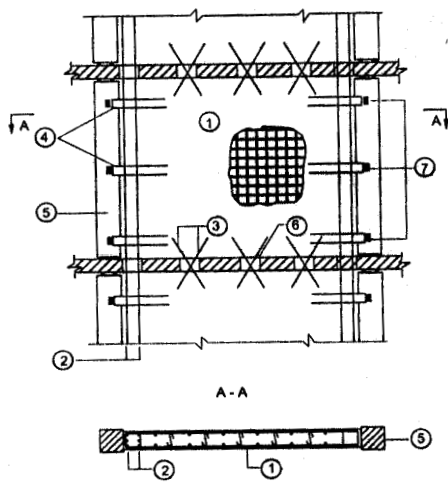
- (c) Typical connection detail of new shear wall with existing structural elements
- (d) Typical jacketing scheme with dowel bars
- (e) Stiffening/strengthening by bracing members
- (f) Typical detail of strengthening of foundation
- (a) Typical Jacketing Scheme of Column When Beam & Beam Column Strengthening Is Necessary**



- (b) Typical Jacketing Scheme of Column When Beam & Beam Column Joint Need Not Be Strengthened**



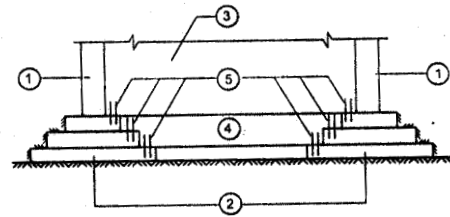
(c) Typical Connection Detail of New Shear Wall With Existing Structural Elements



(a) Connection with existing slab column/beam

Legend for (a)

1. Shear Wall
2. Reinforcement
3. Dowel Bars
4. Connection Reinforcement
5. Existing Column
6. Door Opening
7. Welding with Column Bar

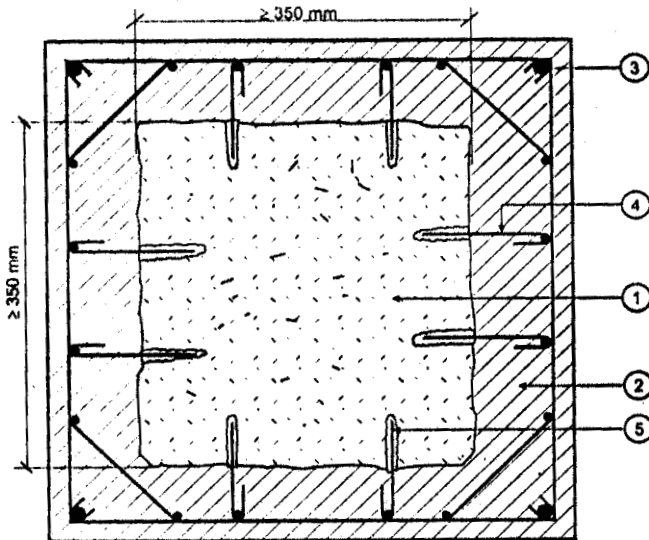


(b) Connection with existing foundation

Legend for (b)

1. Existing Columns
2. Existing Column Bases
3. New Shear Wall
4. New Shear Wall Base
5. Anchorage Bars

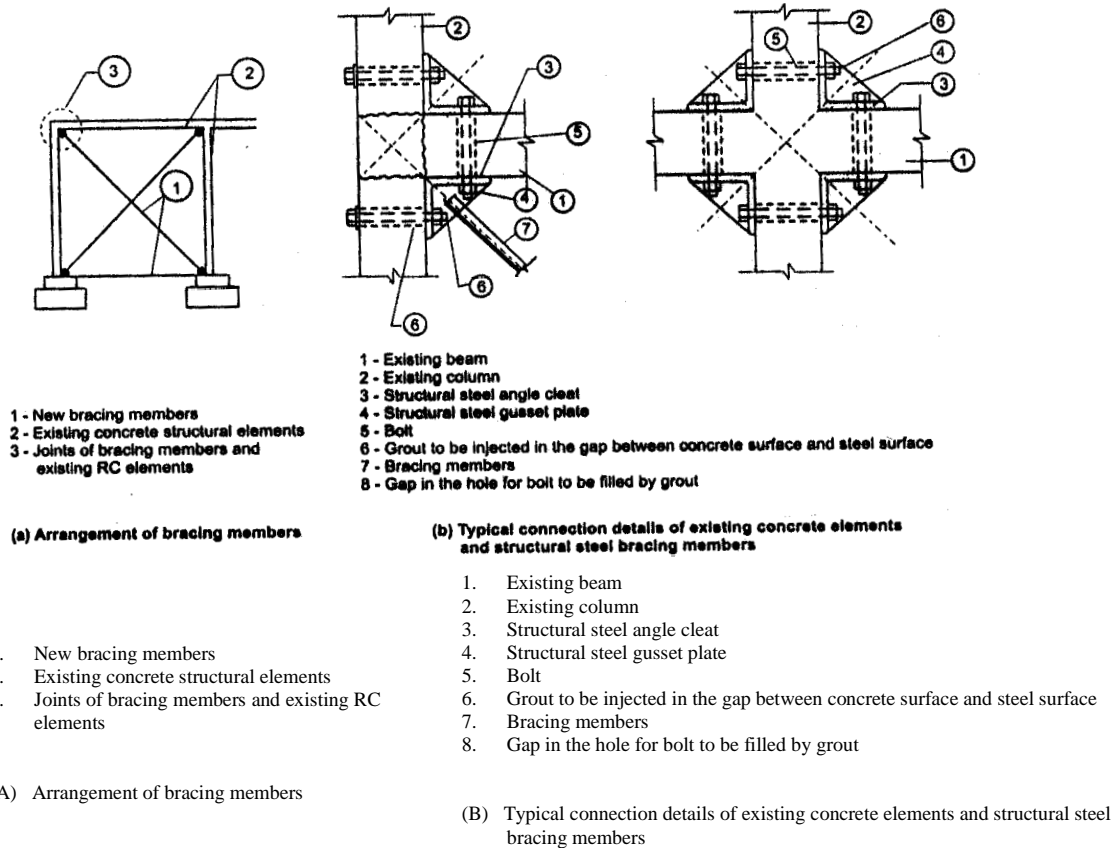
(d) Typical Jacketing Scheme With Dowel Bars



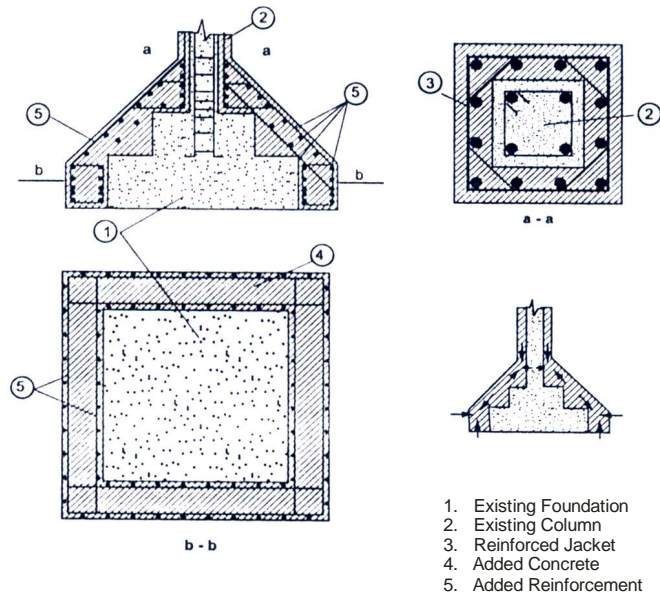
1. Existing Column
2. Jacket
3. Additional Longitudinal Reinforcement
4. Dowel Bars to be inserted into existing concrete up to a depth of full anchoring length
5. Pocket of Dowel Bar to be field with grout



(e) Stiffening/Strengthening By Bracing Members



(f) Typical Detail of Strengthening of Foundation





**References:**

- 7.1 IS: 13935-1993 “Repair and Seismic Strengthening of Buildings-Guidelines” B.I.S. November 1993.
- 7.2 “Improving Earthquake Resistance of Buildings – Guidelines” by Expert Group, pub. by Building Material and Technology Promotion Council (BMTPC), 1999, revised and updated by A.S. Arya 2010.
- 7.3 Arya A.S. et al, Earthquake Resistant Non-Engineered Construction, Monograph pub. by International Association for Earthquake Engineering, 1980, Revised 1986. (translated into Spanish for use in various Spanish countries).
- 7.4 Condition assessment of existing reinforced concrete buildings, by A.S. Arya, Assisted by Ankush Agrawal, under Gol-UNDP Disaster Risk Management Programme, website: [www.ndmindia.nic.in](http://www.ndmindia.nic.in).

## 8. Seismic Safety Consideration In School Buildings

### 8.1 Introduction

Among all the public facilities, children in schools are the most vulnerable during natural disasters, namely any earthquake, landslide, tsunami, cyclone, storm surge or high flood. A large number of schools managed by the education departments of the State as well as by private organisations operate in various urban and rural areas. Experience shows that rarely school buildings are designed to be resistant to disaster impacts. In the earthquake of 26<sup>th</sup> January 2001 in Gujarat, more than 42,000 school rooms were destroyed or severely damaged showing the inherent seismic weakness of school buildings. Thousands of children perished due to collapse of schools in this and Muzaffarabad earthquake (Jammu & Kashmir) in 2005.

School buildings, wherever found safe either in earthquake, cyclone or flood disaster, are used for accommodating the homeless persons as *temporary shelter*. After the Kobe earthquake in Japan, the Ministry of Construction adopted a policy of upgrading all the school buildings to be used as shelters by retrofitting the unsafe buildings and upgrading the kitchen and drinking water facilities for that purpose. Hence, school buildings are considered of higher importance and designed for 50% higher seismic force (as per IS:1893-2002).

### 8.2 Damage Observed In Schools In Past Earthquakes

Table 8.1 shows damages observed in schools in past earthquakes in different countries and the following types of damage can be seen:

- i) Slumping of the foundation soil causing severe damage to the school.
- ii) Failure of masonry walls due to poor mortar and improper connectivity between outside walls and internal partition walls.
- iii) Failure of masonry schools due to severe shaking of the ground.
- iv) Part collapse of reinforced concrete buildings.
- v) Failure of RC columns resulting in the sagging of the heavy roof.
- vi) Weak lateral resisting elements were shattered.
- vii) Prefabricated concrete floors collapsed since these were poorly connected with the structural frame.

### **8.2.1 Various Materials Used In School Buildings In India**

Most existing schools in different parts of India are constructed traditionally using stone walls, burnt brick walls, wood frames or reinforced concrete frames. Some school buildings in rural areas may even be using clay mud and unburnt brick walls. These are usually highly vulnerable to damage by floods, tsunamis, earthquakes and cyclones.

The most damaging to school buildings is the earthquake shock. A summary of the life losses and physical structure damages in Bhuj Earthquake of January 26, 2001, are presented in Table 8.2

### **8.2.2 Disaster Risks To Schools**

The risk to school during future disasters will include the following items:

- i) Damage to or collapse of buildings,
- ii) Damage and loss of furnishing, equipment and building contents,
- iii) Death and injury to students, teachers and the school staff,
- iv) Disruption of educational programmes and school operation.

**Table 8.1: Earthquake Damage In Schools**

<b>S. No</b>	<b>Name of School</b>	<b>Earthquake</b>	<b>Observed Damage</b>
1.	High School at Three Forks, Montana, USA	Helena, Montana USA, June 27, 1925	Badly damaged. Brick walls in lime mortar bulged on all sides.
2.	School at Manhattan, Montana, USA	Helena, Montana USA, June 27, 1925	Partition walls separated from outside walls since no ties between them.
3.	Schools in Long Beach, USA	Long Beach Earthquake, March 10, 1933	70 destroyed, 420 damaged with 120 seriously (mostly masonry)
4.	Helena High School, Montana, USA	Helena Earthquake Oct. 31, 1935	Part of school collapsed (reinforced Concrete Frame, floors and roof)
5.	School in Alaska, USA	Prince William Sound Alaska, March 27, 1964	The school split in two due to slumping of ground
6.	Govt. Hill Elementary School, USA	Prince William Sound, Alaska, March 27, 1964	School destroyed due to ground slumping
7.	Classroom at Agriculture University	Oct. 3, 1974 in Lima, Peru	Column failure caused sagging of roofs (heavy roof structure on concrete frame)
8.	High School Building, Turkey	Earthquake of Sep. 6, 1975, Lice, Turkey	All lateral resisting elements shattered in west wall
9.	Juan Montalvo School, Ecuador	Earthquake of April 9, 1976, Emeralds Ecuador	Sever damage to exterior structural elements
10.	College Mining Institute, Tangshan, China	Earthquake of July 27, 1976, Tangshan China	Collapse of classroom and laboratory (Note: 2000 students killed in dormitories)
11.	Schools in EL, Asnam Algeria	Earthquake of Oct. 12, 1980, EL Asnam, Algeria	85 schools collapsed including modern schools
12.	Dawson Elementary School Library	Earthquake of May 2, 1983, Coalinga, CA, USA	Pendant light fixtures failed and fell down
13.	Elementary School Dzhrashen, Spitak	Earthquake of Dec. 7, 1988, Spitak, Armenia	Precast Concrete Floors Collapsed (poor ties with the Frame)

**Table 8.2: Summary Of Life Loss And Academic Institutions  
In Bhuj Earthquake, Jan 26, 2010.**

<b>Sector</b>	<b>No. of institutions affected</b>
Primary education	
School buildings	9,593
Teachers' training institutes	42
Kitchens for Midday Meal programme	1,871
Secondary/higher secondary education	
Government schools	127
Grant-in-aid schools	1,913
Higher education (universities & colleges)	47
Technical education (polytechnics & engineering colleges)	58
Government schools	51
Grant-in-aids schools	
Teachers	31
Students	971

(Source: Department of Education, Government of Gujarat)

### **8.3 Planning And Design of School Buildings**

#### **8.3.1 Design recommendation under Sarve Siksha Abhiyan (SSA)**

A large number of (more than 100) building designs for schools have been developed in DPEP districts. These designs, apart from being attractive, are child-centred, functional and in tune with the new pedagogical concepts. The publication called "Building rural primary schools" published by the EdCIL and the building construction manuals developed by the Lok Jumbish Project may be utilised by all the States/districts to develop their civil works plan. The States may make use of designs already developed under DPEP/Lok Jumbish Project in their specific local contexts.

Incorporation of child-friendly internal and external elements will be mandatory in all the new construction and repair works.

### **8.3.2 Recommendations under National Building Code 2005**

According to the National Building Code of India 2005 and IS Code 1893-2002, school buildings are considered to be of higher importance as compared with residential/office buildings so far as their structural safety is concerned. Hence, school buildings are designed with higher factor of safety. Accordingly, higher seismic co-efficient by 50% and higher wind forces are considered for structural design.

The following considerations have to be taken into account while planning and designing the school buildings:

- i) For safety against flood damage, the foundations of the building should be taken deeper to avoid erosion of the foundation by flowing water and the plinth level should be kept at least 15 cm above the known highest flood level at the site which should also be at least 45 cm above the existing ground level.
- ii) If the soil is sandy with high water table, the soil may liquefy under an earthquake of Intensity VII and higher, the foundation should be taken to stiffer strata below the liquefaction level under the earthquake intensity.
- iii) The building super - structure must be designed for applicable earthquake and wind forces. The design parameters should be included in the Structural Design Basis Report (Chapter 14, Table 14.2 to 14.3 in this guideline).
- iv) In storm surge-prone coastal areas, either the whole school or the roof of the school made accessible through staircases should be kept higher than the estimated maximum inundation under storm surge/tsunami.
- v) For earthquake safety and cyclonic wind pressure, where applicable, the masonry walls should be strengthened by using reinforced concrete bands as specified in IS: 4326 1993. Also vertical reinforcing bars have to be embedded at the corners of the rooms as per that standard.

### 8.3.3 Planning of school buildings

- i) The various room sizes and their numbers, namely classrooms, laboratories, computer labs, etc., should be adopted as laid down by the various State Boards of Education.
- ii) *Toilet norms for urban areas (NBC 2005, part 3 to 3.1):-*
  - Minimum floor area of water closet should be 1.1 sq.m. with a minimum width of 0.9 m.
  - Minimum floor area of bath should be 1.8 sq.m. with a minimum width of 1.2 m.
  - Every bath or water closet shall have window or ventilator, opening to a shaft or open space, of area not less than 0.3 sq.m. with side not less than 0.3 m.
  - The height of a bathroom or water closet measured from the surface of the floor to the lowest point in the ceiling (bottom of slab) shall not be less than 2.1 m.

- iii) *Toilet norms for rural areas (NBC 2005, part 3, p. 58):-*
  - Minimum floor area of water closet should be 0.9 sq.m. with a minimum width of 0.9 m.
  - Minimum floor area of bath should be 1.2 sq.m. with a minimum width of 1.0 m.

**iv) No. of toilet fixtures required in school buildings**

<b>Fixtures</b>	<b>Boys</b>	<b>Girls</b>
Water closet	1 per 40 pupils or part thereof	1 per 25 pupils or part thereof
Urinals	1 per 20 pupils or part thereof	-
Drinking water fountain or taps	1 per 50 pupils or part thereof	1 per 50 pupils or part thereof



#### **8.4 Construction of Civil Works Of Schools (as per SSA Guidelines)**

SSA will encourage use of local construction materials and low-cost technologies. This would require a large amount of capacity building, including training of engineers and masons in these technologies. Apart from the Technical Resource Group of DPEP, assistance of resource institutions, like HUDCO, may also be sought for this purpose.

There will be a civil work innovation fund of Rs 50 lakh in each State. This will be used for civil works innovations, demonstration buildings, and capacity building.

Civil works under SSA should start with a proper assessment of the infrastructure requirements for each district. There need to be a school-wise compilation of physical and monetary requirements. The attempt should be to find out the minimum money required to provide adequate infrastructure to each school, including repairs, toilets, drinking water, boundary wall, etc. Provision of additional classrooms is to be considered only after exploring possibility of repairs and double shifts. Once the total requirement for the district is obtained, one needs to find out how much of this requirement can be funded through ongoing schemes and, therefore, what the gap is, that is required to be funded through SSA.

There should be a single agency in each district to manage all funds related to school construction. Ideally, it should be an engineering cell in the district team. All school infrastructure works should be executed by the single agency.

#### **8.5 Maintenance And Repair**

Each State must formulate a strategy for repair. The Rs 5,000 per year available to a school for regular maintenance and repair could be used to create a maintenance corpus in a school. The money will be credited to the VEC and the VEC could decide to use only part of the funds and use the rest to create a corpus. Community involvement is a must if the school infrastructure has to be well maintained.

#### **8.6 State-Level Actions (Suggested)**

- 1) Field Act of California after 1933 Long Beach earthquake may be studied and proper guidelines be adopted for safety of schools against various hazards.
- 2) Japanese Ministry of Construction Resolution regarding strengthening of schools to act as post-disaster shelters, may be adopted with local modifications.

- 3) South California State Board Regulation on Student & School Safety, USA, requires State to develop a Model Safe School Checklist to assess buildings and grounds.
- 4) NBC & other State documents should specify safety planning norms for schools.

**Role of educational authorities**

- i) Develop comprehensive policies for public and private schools to be ready are preparedness, mitigation and response plans.
- ii) Increase communication and interaction among education and emergency management agencies.
- iii) Ensure compliance with school safety planning regulations.
- iv) The Headmaster/Principal of school should be provided special training in maintenance and simple repair needed if any distress is noticed in critical elements, which may endanger in the long run the safety of building. Responsibility should be given to the Headmaster for reporting to higher authorities about any distress noticed in the building.

**8.7 Existing schools**

- What can be done to reduce natural disaster risk in existing vulnerable school buildings?
  - Replace or retrofit.
  - Single stage retrofit – cost & disruption.
  - Incremental retrofit – reduce cost & disruption(Sequential operation over a few years combined with annual maintenance).

**References:**

- 8.1 Sarva Shiksha Abhiyan: Guidelines, Ministry of Human Resource Development, Govt. of India.
- 8.2 National Building Code of India 2005, B.I.S. Govt. of India
- 8.3 Arya A.S. Construction of Educational Buildings in Seismic Areas, Digest No. 13, pub. by UNCSCO, Bangkok, 1987 (translated into Persian for use in Iran).
- 8.4 Model School Design for Construction in various seismic zones in India, by A.S. Arya, Assisted by Ankush Agrawal, under GoI-UNDP Disaster Risk Management Programme, website: [www.ndmindia.nic.in](http://www.ndmindia.nic.in).

## 9. Disaster Safety of Hospitals

### 9.1 Structural & Non-Structural Elements

The "structure" is the part of the building that is designed to carry the weight of the building (dead load), its contents and people (live load), and the impact of wind and ground-shaking (dynamic load). The "structural elements" differ in each type of building, but generally they include the foundation, columns, slabs, beams, and "load-bearing" walls. The biggest danger of damage during the hazard occurrence is to those buildings that have not been designed, constructed, or maintained to withstand expected hazard impacts.

Among the various natural hazards, earthquakes are the most disastrous to most buildings consisting of adobe, masonry, concrete or steel structures.

The non-structural building elements includes the stairways, doors, windows, chimneys, lighting fixtures, heating ducts and pipes, wall cladding, and false ceilings. These are most vulnerable to earthquake ground vibrations.

The "building contents" includes all of those items that users bring into a building; furniture, appliances, electronics, equipment, coolers and air-conditioners, stored items, and so forth.

When a building is totally damaged and collapsed, everything in the building is crushed and lost. But some of the deaths, many or most of the injuries, a large proportion of economic damage, destruction and disruption associated with earthquakes are caused by "non-structural" building elements and building contents that break, fall or slide. In a large-scale disaster, medical response resources are found insufficient to meet the immediate needs. Minor injuries occurring due to non-structural elements can take scarce medical resources away from people with life-threatening injuries. Thus, moderate injuries that are normally easily handled can become life-threatening. For this reason, it is very important for us to do the small things that can prevent even the small injuries. Many "non-structural" hazards are easily and inexpensively avoided. People in many different countries have found new and simple ways to mitigation these risks.

## 9.2 What happens during an earthquake?

The theory of plate tectonics tells us that earthquakes are caused by the release of energy when the large 'plates' that float on the earth's surface suddenly slip past each other. The energy released creates seismic waves that shake the ground as they pass through. The ground motion comes in different types of waves. The waves vary in their vibration characteristics and affect the objects and structures differently. As earthquake waves are generated, *unsecured objects* are set into motion and *slide, topple or collide*. This is very similar to a passenger riding in a car without a seatbelt. If the brakes are applied suddenly, the people inside can go flying. Heavy and large objects that can seriously injure people or block exits must be secured to prevent this kind of damage in an earthquake. The solution is to secure the objects to the floors or walls or the columns of the building so that they move back and forth together without damage.

## 9.3 Seismic intensities

Roughly, earthquake of magnitudes 5.0-5.9 cause maximum MSK intensity VI to VII, **M** 6.0 to 6.7 may create maximum MSK intensity VII to VIII and larger magnitude may create higher intensity IX and more.

MSK-VI: -Frightening

- a) Felt by most indoors and outdoors. Many people in buildings are frightened and run outdoors. A few persons lose their balance. Domestic animals run out of their stalls. In few instances, dishes and glassware may break, books fall down. Heavy furniture may possibly move and small steeple bells may ring.
- b) Slight damage (Grade 1) is sustained in 5% of ordinary brick buildings.

MSK VII: -Damage of buildings

- a) Most people are frightened and run outdoors. Many find it difficult to stand. The vibration is noticed by persons driving motor cars. Large bells ring.
- b) In 50% buildings of reinforced concrete, slight damage (Grade 1) is caused; in 50% of ordinary brick buildings moderate damage (Grade 2). Infill walls of half brick thick in cement mortar 1:6 may fail in out of plane.

MSK VIII: -Destruction of buildings

- a) Fright and panic; also persons driving motor cars are disturbed. Here and there branches of tree break off. Even heavy furniture moves and partly overturns. Hanging lamps are damaged in part.
- b) 75% buildings of reinforced concrete suffer moderate damage (Grade 2) and 5% of heavy damage (Grade 3); 75% ordinary brick buildings suffer heavy damage (Grade 3). Occasional bursting of pipes. Memorials and monuments move and twist. Tombstones overturn. Stone wall collapse. Infill walls of half brick thick in cement mortar 1:6 will fall out of plane unless laterally supported. Higher intensity earthquakes IX or more will cause much more damage in hospital building externally and internally.

Higher earthquakes, intensity IX or more, will cause much more damage in hospital buildings externally and internally. It is, therefore, seen that whereas strong shaking can cause moderate to heavy damage to life and property in seismic zones VII, VIII and IX in India, even moderate shaking of intensity VI can cause substantial non-structural damage. For these reasons, it is important to take measures for reducing the impact of future earthquakes on the hospital facilities.

To reduce the risk to the life and limb of the communities, we must ensure that:

- i) The hospital building remains safe against collapse or heavy damage.
- ii) The functioning of the hospital facilities continues with only minimum interruption.
- iii) While the building safety from probable maximum earthquakes will require special studies by competent structural engineer (see chapter 5), the functionality of the medical services could be ensured by the hospital management, its staff and maintenance engineers, by safeguarding non-structural damages to the contents and equipment in the hospital.

#### **9.4. Importance Of Non-Structural Elements Safety**

Experience in damaging intensity of earthquakes has shown that buildings are destroyed or damaged to various extents. Also their contents are badly shaken and they fall down by toppling over, or by rolling if resting on rollers or wheels, or by sliding on their supports and crashing down onto the floor. Many times such objects injure or

even kill the inmates by cutting, piercing or hammering effects. In most cases, the functioning of the building as a hospital gets adversely impacted.

A building may remain standing after an earthquake, but it might become non-functional due to the damage to the equipment, lifeline conduits and other non-structural elements like partition walls, veneers, ceilings, windowpanes, etc. Assessment of non-structural vulnerability is to be made in order to estimate the expected damage that these elements may suffer when subjected to earthquake shaking at different levels of intensity and the consequence to the functionality of the hospital. The cost of the non-structural elements in a building may even be much higher than that of the structure. Particularly in hospitals, it may reach up to 80-90% of the total facility value. Moreover, the susceptibility to non-structural damage could be high even in a moderate earthquake (MM VI-VII). This can affect or destroy vital aspects of a hospital, including those directly related to its function, without significantly affecting the structural components. Thus, in an earthquake, the external appearance of a hospital might be unaffected, but it may not be able to care for patients if the internal facilities have been damaged. The desired level of performance of hospital facilities is much higher than that of other utility services because it is imperative that hospitals remain fully functional after an earthquake. In case a large number of injuries occur, demand for medical services will be very high within the first 24 hours. In summary, a non-structural vulnerability assessment and consequent implementation of mitigation measures in hospitals will be justified on the following grounds:

- i) Hospital facilities must remain as intact as possible after an earthquake due to their role in providing routine medical services as well as attending to the possible increase in demand for medical treatment following an earthquake.
- ii) In contrast to other types of buildings, hospitals accommodate a large number of patients who, due to their disabilities, are unable to evacuate a building in the event of an earthquake.
- iii) Hospitals have a complex network of electrical, mechanical and sanitary facilities as well as a significant amount of costly equipment, all of which are essential both for the routine operation of the hospital and for emergency care.

Failure of these installations due to a seismic event cannot be tolerated in hospitals as this could result in its functional collapse.

- iv) The ratio of the cost of non-structural elements to the total cost of the building is much higher in hospitals than in other buildings. In fact, while non-structural elements represent approximately 60% of the value in housing and office buildings, in hospitals these values range from 80% to 90%, mainly due to the cost of medical equipment and specialised facilities.

### **9.5 Reducing "Non-Structural" Hazards In Hospitals**

Past experience shows that during an earthquake, building contents, and parts of the building that are not fixed are severely shaken. Serious dangers are caused by falling, sliding and crashing objects that can crush, pierce and cut or spill dangerous chemicals. The purpose of this chapter is to introduce the importance of securing the contents of hospital buildings, so that in an earthquake the furnishings and other objects do not *overturn* or *slide*. These "*nonstructural* risk reduction" measures will do four important things:

- 1). Prevent deaths and injuries to doctors, nurses, patients, visitors and staff.
- 2). Protect hospital equipment and other materials.
- 3). Increase the community's ability to keep the hospital open for use in the emergency.
- 4). Enable the hospital management to continue its services with minimum disruption.

### **9.6. Non-Structural Mitigation**

Disaster risk reduction can be achieved through a series of small steps. *Everyone* needs to play his role in reducing the dangers of natural and man-made hazards. We already have the knowledge. We only need to create a culture of safety. Decisions and steps taken by individuals and families at home, by workers and students in schools and offices, by doctors and workers in the hospitals, by citizens in their neighborhood's, and by politicians, government agency workers and professionals are all important. Here it is intended to show to the hospital management the actions to be taken by the doctors and staff and some of the things they can do that will make a real improvement towards safety in the hospital during earthquakes. Non-structural mitigation in hospitals can be accomplished as follows:

- 1). Sensitisation (understanding earthquakes and safety requirements)
- 2). Earthquake hazard identification in the hospital
- 3). Hazard survey and prioritisation.
- 4). Reducing non-structural hazards.

**9.6.1 Understanding Earthquakes And Safety Requirements**

The first step is awareness and sensitisation about earthquakes. This includes learning what earthquakes are and what happens during an earthquake, knowing the earthquake and other kinds of risks in the area, and recognising the "structural" and "non-structural" damage in hospitals. Keeping risks in mind, one may need to think creatively about how to balance different needs with safety.

a) What is "Structural Element"?

The "structural elements" of a building carry the weight of the building itself, the people and things inside, and the forces of nature. These "load-bearing" elements include the frame (columns, slabs, beams) and the walls in masonry and adobe construction.

b) What is "Non-Structural" Element?

The "non-structural elements" of a building do not carry the weight of the building, and include windows, doors, chimney, stairs, infill partition walls, pipes and ducts. They include "building contents" that users bring with them: furniture, coolers, water tanks, etc., and importantly the various types of hospital equipment.

The non-structural components to be considered in the vulnerability assessment are listed in Table 9.1

**Table 9.1 Non-Structural Elements In Hospital**

Architectural	Equipment & furnishings	Basic installations and services
<ul style="list-style-type: none"> <li>• Divisions and partitions</li> </ul>	<ul style="list-style-type: none"> <li>• Medical equipment</li> </ul>	<ul style="list-style-type: none"> <li>• Medical gases</li> </ul>
<ul style="list-style-type: none"> <li>• Interiors</li> </ul>	<ul style="list-style-type: none"> <li>• Industrial equipment</li> </ul>	<ul style="list-style-type: none"> <li>• Industrial fuel</li> </ul>
<ul style="list-style-type: none"> <li>• Facades</li> </ul>	<ul style="list-style-type: none"> <li>• Office equipment</li> </ul>	<ul style="list-style-type: none"> <li>• Electricity</li> </ul>
<ul style="list-style-type: none"> <li>• False ceilings</li> </ul>	<ul style="list-style-type: none"> <li>• Furnishings</li> </ul>	<ul style="list-style-type: none"> <li>• Telecommunications</li> </ul>
<ul style="list-style-type: none"> <li>• Covering elements</li> </ul>	<ul style="list-style-type: none"> <li>• Supplies</li> </ul>	<ul style="list-style-type: none"> <li>• Vacuum network</li> </ul>
<ul style="list-style-type: none"> <li>• Cornices</li> </ul>	<ul style="list-style-type: none"> <li>• Clinical files</li> </ul>	<ul style="list-style-type: none"> <li>• Drinking water</li> </ul>



• Terraces	• Pharmacy shelving	• Industrial water
• Chimneys		• Air-conditioning
• Surfacing		• Steam
• Glass		• Piping
• Attachments (signs, etc.)		• Waste disposal
• Ceilings		
• Antennas		

It is important to remember that in reinforced concrete frame buildings, the cladding as well as partition walls will be in the nature of infill panels and may not be stable. These will need stabilisation with the help of a qualified structural engineer. Heavy furnishings may then be fastened to such infill panel walls; otherwise they should better be fastened to the frames.

### **9.6.2 Earthquake hazard identification in hospital**

#### **a) Tall or narrow furniture can fall!**

Objects that are taller than their width or depth like freely standing cupboards can easily topple forwards, backwards or sideways. Objects that are much heavier on the top than on the bottom can easily topple in all directions.

#### **b) Items on wheels or smooth surfaces can roll or slide!**

Objects on wheels can roll, or on slippery surfaces can slide. Objects that are much heavier on the bottom than on the top can also slide, but not overturn.

#### **c) Large or small things can knock into one another!**

Objects can bang and collide with one another. Small objects can fall and cause dangerous breakages and spills.

#### **d) Hanging objects can fall!**

Heavy objects that are hung on walls or from the ceiling can fall.

e) Items inside the building can fall harming people and blocking exits.

### **9.6.3 Reducing Non-Structural Hazard**

There are three important ways for reducing the risk from non-structural hazards:

- a) To relocate furnishings and contents,
- b) To secure non-structural building elements,

c) To secure the furnishings and equipment to walls, columns or floors.

For b) & c) consultation with engineers and technicians may be sought.

a). Relocate furnishing & contents

Heavy furniture should be kept away from the places where people sit (or sleep). If items cannot be secured to a sound structural member, they may need to be moved to a place where they will not cause a hazard. Corridors and exist routes should be kept free of obstructions. Large occupancy rooms should have two exist doors.

- **Move Furnishings:-** the simplest way to reduce risk is to move some furniture items so they will not hit anyone or block exits.
- **Clear Corridors, doorways and exit paths:-**  
Relocate or re-position items that cannot be secured, so that they do not block exit corridors.
- Place heavy item lower down conversely lighter objects on upper shelves.

b) Secure the non-structural building elements

The most important but hazardous element is the brick infill partition wall which can topple over laterally or badly crack longitudinally. One way to stabilise such walls will be to provide vertical steel angles 50x50x6 mm on its both faces vertically and attached to the wall through bolts. The ends of the angles should be fixed in the floors below and above. The angles may be spaced not farther than 1.5m apart. The angles will not only provide the requisite stability to the wall but may also be used for fixing the equipment and the furnishings.

c) Secure the furnishings and equipment

Most of this can be done with easily available supplies and simple methods. Secure objects to the structure of the building, so that they shake *with* the building. Some objects can be secured to a table or top of counter.

d) Fasten tall and heavy furnishings

Use "L-brackets" or finely woven nylon strapping to secure furniture to wall.

e) Hanging objects

To avoid injury from broken glass and objects is to use a hook that is closed, or tie picture frames and similar items to a hook in the wall.

Secure wall-mounted items, shelf contents and hazardous materials

Each item should be considered separately for the simplest solution.

Objects that can slide

Short squat items with wheels or placed on slippery surfaces can be chained to a hook on the wall. If their height/width ratio is 3/2 or more, the items may need to be secured with straps.

Secure Water tanks

Water tanks should be secured from all sides so that they cannot topple. There must be enough vertical support and strapping so that that the tank will not jump up out of its seat, during the vertical and lateral motion of an earthquake. Stabilising wires must be secured to concrete rooftop, or beams, not to parapet.

Secure signage, satellite dishes, architectural, cladding and glass

### **9.7 Hazard Survey And Prioritisation**

Now there is a need to identify all of the non-structural hazardous items in a systematic way, and to prioritise for taking action immediately or later on in due course. This has to be done room by room to identify those things that could be dangerous in case of an earthquake by fall from above, by sliding or breaking when the earth shakes. An example of list of evaluated equipment in hospital is given in Table 9.2 for ready reference. It is to be considered whether an item poses a threat to life, could cause injury, would disrupt business continuity, cause economic hardship if lost or would cause loss of cultural or historical heritage and to decide how you would tackle each item. Based on what is perceived, it has to be decided in each case whether the item is of "high", "medium" or "low" priority.

It is important to survey in each and every room and corridor of the building. One should not forget the kitchen, the library, and the labs where some of the most hazardous items can be found. This is a good activity to be undertaken by the hospital administrative committee or a safety committee or a disaster preparedness committee as the hospital administration may decide. The survey committee should include

administrators, doctors, staff, and community members. As the risks are identified, it will be useful to consult with all the users of the room or area in order to understand the simplest solutions to make the environment safer - and the solutions that everyone can live with. This is the best way to be sure that the mitigation efforts will be maintained.

**Table 9.2: Example of a list of evaluated equipment**

<b>Type of equipment</b>	<b>Location</b>	<b>Size</b>	<b>Vulnerability (V)</b>	<b>Consequences (C)</b>	<b>Priority</b>	
<i>Component</i>	<i>System or service</i>	<i>Characteristics</i>	<i>(H.M.L)</i>	<i>(H.M.L.)</i>	<i>t(V.C.)</i>	<i>Type of support</i>
Oxygen tank	Oxygen network	5.5 x 2.3	H	H	1	Legs w/ bolts
Transformer	Power network	3 x 2.5 x 2	H	H	1	Bolt
Circuit boards	Power network	6 x 2 x 1	H	H	1	Simple brace
Anaesthesia machine with monitor	Operating theatres	1x 2 x 2.2	H	H	1	
Water tanks	Drinking water supply		M	H	2	
Gas connection	Gas supply		M	H	2	Without anchors
Emergency generator	Power network		M	H	2	Bolts
Miscellaneous equipment	Clinical laboratory	Various	L	H	3	Tabletop equipment
Telephone switchboard	Communications	5x1.4	H	H	4	Simple brace
Shelves	Sterilisation centre	Various	H	H	4	Without anchors
Freezer	Blood bank	2.5 x 2x 0.5	H	H	4	Simple brace
Oxygen cylinders	Operating theatres	Various	H	H	4	
Elevator engine	Elevators		M	H	5	Bolts
Elevator controls	Elevators	2.5 x 1	M	H	5	Bolts
Elevator pulleys	Elevators		M	H	5	Bolts
Dialysis unit	Haemodialysis	0.8 x 1.2	M	H	5	Simple brace w/ rollers
Lamp	Plastic surgery	Various	M	H	5	Built in
Incubator	Neonatology	Various	M	H	5	Simple brace w / rollers

The earthquake hazard survey can also be carried out as an activity involving the medical students which will serve to sensitise them about the non-structural hazards.

### **9.8 Implementation of Priorities**

Structural risk reduction is something that is unique to each and every hospital. There are some very important partners in achieving nonstructural risk reduction. All should understand sense of ownership for non-structural risk reduction, Doctors and staff should be involved. The more people who understand this work, the better will be the maintenance and ongoing continuation of this effort. This will include:

- Hospital Director/Dy. Director
- Public Works Department personnel assigned to the hospital
- Local Fire Department personnel
- Hospital welfare committee
- Staff
- Medical students

Implementation of non-structural mitigation plan requires a modest investment of time and money. Considering that death, injuries and significant economic losses are caused by non-structural elements, the investment is well worth making. When resources are scarce, one can use the priorities set, High, Medium and Low, to stagger the project into two or three steps. Often it is easy to do many small lower priority items at the same time.

In hospitals, the safety of patients, doctors and nursing staff are of highest importance. Anything that can harm them or block safe evacuation should be given top priority. For example, exits and corridors should be kept clear of all obstacles, so that large numbers of persons can move out of the building safely in the shortest possible time. There may be some items that are more difficult or costly to secure that are also important to safety and survival -- for example water tanks, which will be needed for their contents. For these items, one will need the help of a qualified engineer.

In a potential mass casualty situation, there is a greater need to reduce moderate or minor injuries. Hazard-prone areas, like chemistry labs or electrical warehouses, should be secured as these areas can have a multiplier effect, leading to fire and hazardous material release and thereby greatly increasing the number of casualties.

Any other designated area, which would serve as a control room during emergencies should also be secured. These areas ensure operational continuity in times of emergency.

Ultimately, the final decision on what would be the best way to implement the non-structural mitigation plan lies with the hospital management. The design and layout of the building, availability of open spaces, and strength of the hospital, etc., are important factors that determine the priorities for implementation.

### **9.9 National Rural Health Mission (2005-2012)**

Recognising the importance of health in the process of economic and social development and improving the quality of life of citizens, the Government of India resolved to launch the National Rural Health Mission to carry out necessary architectural correction in the basic healthcare delivery system. The mission adopted a synergistic approach by relating health to determinants of good health, viz. segments of nutrition, sanitation, hygiene and safe drinking water. The plan of action includes increasing public expenditure on health, reducing regional imbalance in health infrastructure, etc., meeting Indian Public Health Standards in each block of the country.

There are some hospital building components in the strategies adopted in the mission as stated below:

(a) Core strategies:

- Strengthening sub-centre through an untied fund to enable local planning and action and more multi-purpose workers (MPWs).
- Strengthening existing PHCs and CHCs, and provision of 30-50 bedded CHC per lakh population for improved curative care to a normative standard (Indian Public Health Standards defining personnel, equipment and management standards).

b) Strengthening sub-centres

- In case of additional outlays, sanction of new sub-centres as per 2001 population norm, and upgrading existing sub-centres, including buildings for sub-centres functioning in rented premises, will be considered.

c) Strengthening Primary Health Centres

Mission aims at strengthening PHC for quality preventive, promotive, curative, supervisory and outreach services.

- In case of additional outlays, new programmes for control of non communicable diseases, upgradation of 100% PHCs for 24 hours referral service and provision of 2nd doctor at PHC level (1 male, 1 female) would be undertaken on the basis of the need felt.

d) Strengthening CHC for First Referral Care

- In case of additional outlays, creation of new Community Health Centres (30-50 beds) to meet the population norm as per Census 2001, and bearing their recurring costs for the Mission period could be considered.

**9.10 Suggestions for mainstreaming DRR**

In regard to the above, with the aim of mainstreaming DRR into the hospital system in the country, the following suggestions are offered:

- i) Hazard safety to be emphasised in siting, planning and designing all new hospital facilities in rural and urban areas, in which use of BIS codes should be made mandatory.
- ii) Safety of non-structural building elements, particularly under seismic conditions, must be taken care of as per the BIS codes, IS 1893-2002 and IS 4326-1993.
- iii) Safety of hospital contents, including equipment and services, has to be ensured as explained in this chapter above.

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## 10 Safety Guidelines For Multistoried & Special Buildings

### 10.1 Introduction

A large number of reinforced concrete multi-storied frame buildings were heavily damaged and many of them collapsed completely in Bhuj earthquake of 2001 in the towns of Kachchh District (viz., Bhuj, Bhachao, Anjar, Gandhidham and Rapar) and towns of other districts, including Surat and Ahmedabad. In Ahmedabad alone, situated more than 250 kilometres away from the epicentre of the earthquake, 69 buildings collapsed killing about 700 persons. Earlier, in the earthquake at Kobe (Japan 1995) large number of multi-storied RC frame buildings of 'pre-1981 code-based design' were severely damaged due to various deficiencies. Such behaviour is normally unexpected of RC frame buildings in MSK Intensity VIII and VII areas. The main contributing factors which lead to poor performance during the earthquake are highlighted and recommendations made for planning and designing the multi-storied reinforced concrete buildings so as to achieve adequate safe behaviour under future earthquakes.

### 10.2 Causes of The Collapse of RC Frame Buildings And Recommendations

- 1) Ignorance of architects and structural engineers about the contents of the relevant earthquake-resistant Building Codes and poor quality of construction. The earthquake shakes the building in all three directions; longitudinal, transverse and vertical (not accounted for in design), and the foundation along with the soil plays critical role in amplifying the ground motion (not properly explored, nor considered in design).

Architect's and structural engineer's design office should have the current copies of the standards available in their offices and all their staff should fully familiarise with contents of these codes:

1. IS: 456 -2000 Code of practice for plain and reinforced concrete.
2. IS: 875 Part 1 Unit weights of materials.
3. IS: 875-1987 Design loads (other than earthquake) for buildings and structures, Part 2 Imposed loads.
4. IS: 875-1987 Design loads (other than earthquake) for buildings and structures, Part 3 Wind loads.
5. IS: 1904-1987 Code of practice for structural safety of foundation.
6. IS: 1905-1987 Code of practice for structural safety of buildings: masonry.

7. IS: 1893 (Part-I)-2002 Criteria for earthquake resistant design of structures (fifth revision).
8. IS:13920-1993 Ductile detailing of reinforced concrete structures subjected to seismic forces - Code of practice.
9. IS: 4326-1993 Earthquake resistant design and construction of buildings - code of practice (second revision).
10. IS-NBC-2005 National Building Code of India.
11. IS-800-2007 Design of steel structures.

## **2) Softness of Base Soil**

The soft soil on which most buildings in Ahmedabad were founded would have affected the response of the buildings in the following ways:

- (i) Amplification of the ground motion at the base of the building;
- (ii) Absence of foundation raft or piles;
- (iii) Relative displacement between the individual column foundations vertically and laterally, in the absence of either the foundation struts as per IS: 4326 or the plinth beams;
- (iv) Resonance or, semi-resonance, of the whole building with the long period ground waves;
- (v) In the absence of the beam at plinth or, ground level, the length of ground storey columns gets increased, which increases the flexibility of the ground storey and if the columns become 'long' the buckling moments due to P-  $\Delta$  effect will increase loading to cause collapse of the columns.
- (vi) Tilting, cracking and failure of superstructure may result from soil liquefaction and differential settlement of footings.

Soil exploration at the buildings site must be carried out at sufficient points and to sufficient depth so as to give the following data:

- (i) Soil classification in various layers and the properties like grain-wise distribution, field density, angle of internal friction and cohesion, plastic and liquid limits and coefficient of consolidation of cohesive soils.
- (ii) Position of water table just before and just after monsoon.

- (iii) SPT values and CPT values.
- (iv) The output results should include liquefaction potential, safe bearing capacity and the type of foundation to be adopted.

### **3) Soft-First Storey**

Open ground storey (stilt floor) used in most severely damaged or, collapsed RC buildings, introduced 'severe irregularity of sudden change of stiffness' between the ground and upper stories since they had infilled brick walls which increase the lateral stiffness of the frame by a factor of three to four times.

Such a building is called a building with '*soft*' ground storey, in which the dynamic ductility demand during the probable earthquake gets concentrated in the soft storey and the upper stories tend to remain elastic.

In view of the functional requirements of parking space under the buildings, more and more tall buildings are being constructed with stilts. To safeguard the soft first storey from damage and collapse, clause **7.10** of IS: 1893-2002 (Part 1) provides two alternative design approaches:

- (i) The dynamic analysis of the building is to be carried out which should include the strength and stiffness effects of infills as well as the *inelastic deformations* under the design earthquake force disregarding the Reduction Factor R.
- (ii) The building is analysed as a bare frame neglecting the effect of infills and the dynamic forces so determined in columns and beams of the soft (stilt) storey are to be designed for 2.5 times the storey shears and moments: OR the shear walls are introduced in the stilt storey in both directions of the building which should be designed for 1.5 times the calculated storey shear forces.

### **4) Intermediate Soft Storey**

Sometimes a soft storey is created somewhere at mid-height of the multi-storey building, for using the space as restaurant or gathering purposes. For such a case also, the storey columns should be designed for the higher forces, OR a few shear walls introduced to make up for the reduced stiffness of the storey.

### **5) Bad structural system:**

The structural system adopted using floating columns, for reasons of higher FSI is very undesirable in earthquake zones of moderate to high intensity as in Zone III, IV & V since it will induce large vertical earthquake forces even under horizontal earthquake ground motions due to overturning effects.

The structural engineer should provide for the *load path* in the building from roof to the foundation. For example, a building with floating columns requires transfer of the floating column loads to horizontal cantilever beams through shear forces. The *load path*, therefore, is not vertical but changes from vertical to horizontal members before reaching the foundation.

**6) Heavy water tanks on the roof:**

Heavy water tanks add large lateral inertia forces on the building frames due to the so-called 'whipping' effect under seismic vibrations, but remain unaccounted for in the design.

All projected systems above the rooftop behave like secondary elements subjected to *roof-level horizontal earthquake motions* which act as base motions to such projecting systems. To account for such heavy earthquake forces, IS:1893-2002 (Part 1) provides in clause **7.12** that their support system should be designed for *five times* the design horizontal seismic co-efficient  $A_h$  specified in clause **6.4.2**.

Similarly any horizontal projections as the balconies or the cantilevers supporting floating columns, the cantilevers need to be designed for *five times* the *design vertical co-efficient* as specified in clause **6.4.5** of IS: 1893-2002 (Part 1)

**7) Lack of Earthquake-Resistant Design:**

The buildings were not designed for the earthquake forces specified in IS:1893, which was in existence from 1962, revised in 1970, 1976 and 1984. The applicable seismic zoning in Gujarat had remained the same as adopted in 1970 version. It is the same even in 2002 version of IS:1893 (Part I). In spite of that, the structural designers ignored the seismic forces in design.

All buildings must be designed for earthquake forces as per IS:1893, 4326 and 13920.

The design lateral forces specified in the standard {IS:1893 (Part 1)} shall be considered in each of the two orthogonal horizontal directions of the structure.

**8) Improper Dimensioning of Beams & Columns:**

The structural dimensioning of beams and columns was inadequate in terms of provisions in IS: 13920-1993 and also for proper installation of reinforcements in beam-column joints as per IS: 456 and IS: 13920.

The relative dimensions of beams and columns become very important in tall buildings from the point of view of provision of longitudinal and transverse reinforcement in the members as well as the reinforcement passing through and anchored in the beam-column joints, permitting enough space for proper concreting and without involving any local kinking of the reinforcing bars. The practice of using small dimension columns like 200 or 230 mm thick and beams of **equal width** is totally unacceptable from the reinforcement detailing viewpoint.

**9) Improper Detailing of Reinforcement:**

In detailing the stirrups in the columns, no conformity appeared to satisfy lateral shear requirements in the concrete of the joint as required under IS:4326-1976 and IS:13920-1993. The shape and spacing of stirrups seen in collapsed and severely damaged columns with buckled reinforcement was indicative of non-conformity even with the basic RC Code IS:456-1978.

In respect of proper detailing of reinforcement in beams, columns, beam-column joints as well as shear walls, all the provisions in IS:13920 have to be carefully understood and adopted in design. The philosophy is overdesign of beams in shear to force flexural hinge formation before shear failure specifically confining of highly-compressed concrete in columns and the use of properly-shaped shear stirrups with 135 degree hooks is most important for achieving ductility.

Those are some low-cost but extremely important provisions for overall safety of the frame, design based on the concept of strong-column, weak-beam system should be adopted as far as practical.

It may be mentioned that the full ductility details as specified in IS:13920 permit the use of the high reduction factor  $R=5$  which would make the design economical. But if such ductility details are not adopted, the reduction factor permitted is only 3.0, which means that the design force will become 1.67 times the case when full ductile detailing is adopted which may indeed turnout to be more expensive and at the same time brittle and relatively unsafe.

#### **10) Short Column Detailing**

In some situations, the column is surrounded by walls on both sides such as up to the window sills and then in the spandrel portion above the windows but it remains exposed in the height of the windows. Such a column behaves as a short column under lateral earthquake loading where the shear stresses become much higher than normal length columns and fail in shear.

To safeguard against this brittle shear failure in such columns, the special confining stirrups should be provided throughout the height of the column at short spacing as required near the ends of the columns.

#### **11) Torsional Failures**

Torsional failures are seen to occur where the symmetry is not planned in the location of the lateral structural elements as for example providing the lift cores at one end or at one corner of the building or un-symmetrically planned buildings in L-shape at the street corners.

#### **12) Pounding Damage of Adjacent Buildings**

Severe damage even leading to collapse are seen due to severe impact between two adjacent buildings under earthquake shaking if the adjacent blocks of a building or two adjacent buildings are of different heights with floors at different levels and with inadequate separation. Such buildings can vibrate out of phase with each other due to very different natural frequencies thus hitting each other quite severely.

#### **As Per Cl. 7.11.3 The Separation Gap**

=  $R_1d_1 + R_2d_2$  as per the code for dissimilar blocks, but

=  $(R_1d_1 + R_2d_2)/2$  for equal similar blocks.

### As Per Research In Greece, Gap Needs Be

$$= \sqrt{(R1d1)^2 + (R2d2)^2}$$

For similar block, it may only be half of the above.

Here R1, R2 are reduction factors as per the code and d1, d2 are the calculated dynamic displacement of the blocks.

### 13) Lack of Stability Of Infill Walls

The infill walls were not properly attached either to the column or the top beams for stability against out-of-plane bending under horizontal earthquake forces. Their cracking and falling was widespread.

Stability of infill walls is important in two ways: first, they introduce their brittle failure due to the diagonal compression in the panel and or diagonal tension cracking; secondly, and more important is their lateral stability under out of plane earthquake force acting on their own mass.

While conducting the retrofitting studies of three lifeline buildings in Delhi, the 114 mm thick brick infill walls have turned out to be one of the main issues to handle while retrofitting the building so as to save the inmates and the property inside from damage due to the failure of the infill walls.

It has been found that such walls will have to be contained within pairs of vertical angles spaced at 1.2 to 1.5 m apart. Therefore, while designing a new multi-storey building, the stabilisation of the infill wall panels should be properly considered either by providing confining angles near the top or by providing slits on the vertical sides of the walls and stabilising by the means of vertical angles or channels.

### 14) Poor Construction Quality

The construction quality of the damaged RC buildings was found to be much below that desired, as seen by the cover to reinforcement in the damaged members and the bad quality of concrete in the columns in 150 to 300 mm length just below the floor beams and within the beam-column joints.

Needless to say that if the quality of construction is not commensurate with the quality of design, even a well-planned and a well-designed building can show extremely bad behaviour under earthquake shaking. It should be remembered that during earthquake shaking all bad quality constructions will be revealed and nothing can be kept hidden.

Good quality of construction will include: proper mixing water, good quality sand and aggregates, designed quantity of cement in the mix, proper mixing of all the ingredients with control on water cement ratio, adequate compaction in the placement of concrete preferably by using vibrators, proper placement of steel with control on the cover to steel and adequate curing before striking of the form work.

The engineer in-charge of the construction should personally be present at site to supervise all operations. He should have appropriate sampling and testing of materials carried out in a recognised laboratory, the results of test being kept in a well-maintained register for inspection by quality audit team. He should organise the taking of sample of steel reinforcement and concrete cubes in adequate numbers which should be tested at the specified age of testing.

### **10.3 Some Important Codal Provisions**

#### **10.3.1 The Earthquake Load**

For working out the earthquake loading on a building frame, the dead load and imposed load and weights are to be lumped at each column top on the basis of contributory areas. The imposed load is to be reduced as specified in IS:1893 (Part1)-2002 for seismic load determination.

- a. Estimate fundamental time period ( $T_a$ ) using empirical expressions given in the Code IS: 1893-2002.

$$T_a = 0.075 h^{3/4}, \text{ (IS: 1893 Cl.7.6.1 for bare frame along each axis)}$$

$$T_{ax} = 0.09h/\sqrt{d} \text{ along x-axis (S: 1893 Cl.7.6.2 for frame with substantial infills)}$$

$$T_{az} = 0.09h/\sqrt{b}, \text{ along z-axis, (IS: 1893 Cl.7.6.2 for frame with substantial infills)}$$

where h is the height of the building and d and b are the base dimensions of the building along x and z axis respectively.

Where the infill walls are thin and with openings, some designers take the mean of these values in each principal axis x and z.



b. Calculate the design horizontal seismic coefficient  $A_h$

Now compute the fundamental time periods  $T'_x$  and  $T'_z$  for the bare frame along the two axes by dynamic analysis. These are generally found to be higher than  $T_{ax}$  and  $T_{az}$  respectively. The design horizontal coefficient  $A_h$  is given by

$$A_h = (Z/2) \cdot (I/R) \cdot (S_a/g)$$

Take Z for the applicable seismic zone (IS: 1893 Cl.6.4.2), Take I for the use importance of the building (IS: 1893 Table 2), Take R for the lateral load resisting system adopted (IS:1893 Table 7).

c. Calculate the design horizontal seismic coefficient  $A_h$

And take  $S_a/g$  for the computed time period values  $T'_x$ ,  $T_{ax}$  and  $T'_z$ ,  $T_{az}$  with 5% damping coefficient using the response spectra curves (IS:1893 Fig 2) for the soil type observed. Thus, four values of  $A_h$  will be determined as follows:

In x-direction  $A'_{hx}$  for  $T'_x$  &  $A_{hax}$  for  $T_{ax}$

In z-direction  $A'_{hz}$  for  $T'_z$  &  $A_{haz}$  for  $T_{az}$

Calculate the total horizontal shear (the base shear)

The design value of base shear  $V_B$

$$V_B = A_h W$$

As per 1893 Cl.7.5.3, for design of the building and portions thereof, the base shear corresponding to higher of  $A_{hx}$  and  $A_{hax}$ , similarly between  $A_{hz}$  and  $A_{haz}$  will be taken as minimum design lateral force.

**Note: Minimum Value Of Design Base Shear**

Currently code IS:1893 (part 1)-2002 does not specify a minimum value of *design base shear*, but specifies a capping on the design time period in the form of empirical formulae as given above. This may result in very low Design Base Shear Coefficients in case of high-rise buildings. There is a need to provide a minimum value. Cl. 12.8.1.1 of ASCE-07 provides a flooring of 1% on Design Base Shear. Until the code takes a decision, we may adopt the following value for minimum Base Shear Coefficient: Zone V 2.4%; Zone IV 1.6%; Zone III 1.1% & Zone II 0.7%.

d. Seismic moments and forces in frame elements

Calculate the seismic moments and axial forces in the columns, shears and moments in the beams by using the seismic weights on the floors/(column-beam joints) through an appropriate computer software (having facility for using floors as rigid diaphragm and torsional effects as per IS: 1893:2002).

It may be performed by Response Spectrum or Time History analysis. The important point is that according to IS:1893 Cl.7.8.2., the base shear computed in either of the dynamic method, say  $V_B$  shall not be less than  $V_B$  calculated under Cl.7.5.3 using  $A_{max}$  and  $A_{min}$ . If so, all shears, moments, axial forces etc worked out under dynamic analysis will be increased proportionately, that is, in the ratio of  $V_B/V_B$ .

#### **10.4 Strong Column-Weak Beam Design**

Presently, this design approach is not provided in our Code, IS:1893 (Part1)-2002. For reliable earthquake safety of the tall buildings, it will be necessary to adopt a provision as given below:

At all beam-columns joints of frame buildings, the following conditions should be satisfied:

$$\sum M R_c \geq 1.2 \sum M R_b$$

where:

$\sum M R_c$  = Sum of design values of the moments of resistance of the columns framing into a joint. The minimum value of the column moments of resistance within the range of column axial forces produced by the seismic design situation should be used in this expression.

$\sum M R_b$  = Sum of design values of the moments of resistance of the beams framing into that joint.

#### **10.5 Seismic Design of Flat Slab Special Structures**

In such structural systems, the load is transferred to the column by thickening the slab near the column, using drop panels and/or by flaring the top of the column to form a column capital. The drop panel commonly extends about one sixth of the span each way from each column, giving extra strength in the column region while minimising the amount of concrete at mid-span. The flat-slab type of construction provides architectural flexibility, more clear space, less building height, easier formwork, and, consequently, shorter construction time.

In such cases, slab-column connections must undergo the lateral deformations of the primary lateral load-resisting structural elements without punching failure in order to sustain the gravity loads acting at the instance of earthquake occurrence in addition to unbalanced moments resulting from earthquake lateral forces. It has been suggested that the primary lateral load resisting structural elements, such as shear walls, should be combined with flat plates in seismic zones to keep the lateral drift ratio lower than 1.5%.

### **Use of Standards And Codes In The Construction of High-Rise Buildings In The Private Sector**

It is learnt that the present construction of reinforced concrete high-rise buildings in the National Capital Region is being largely carried out using the National Building Code and the associated Indian Standards covering earthquake and wind safety requirements. Certain cities in the region require that such building designs should be reviewed by Civil Engineering Professors of one of the IITs. However, deficiencies have been noted in the designs since the requirement does not limit to the review by structural engineering experts of IITs. It is also noted that whereas the general clauses of the Code IS:1893 and IS:875 Part III are being followed but the special requirements of safety of buildings on stills (soft ground story building design) and the special requirements of detailed reinforcement of beams and columns of the frames as specified in IS:13920 are not being followed. This deficiency will impact the performance of these buildings when subjected to design intensities stipulated in the Code for Seismic Zone 4.

In view of the above, it will be desirable that the buyers of flats in multi-storied buildings from the private developers may demand the certificate for safety against earthquake and wind forces from the builders before buying the flats.

### **10.6 Concluding Remarks**

In a nutshell, the seismic safety of a multi-storied or special reinforced concrete building will depend upon the initial architectural and structural configuration of the total building, the quality of the structural analysis, design and reinforcement detailing of the building frame to achieve stability of elements and their ductile performance under severe seismic loading. Proper quality of construction and stability of the infill walls and partitions are additional safety requirements of the structure as a whole. Any weakness

left in the structure, whether in design or in construction, will be fully revealed during the postulated maximum considered earthquake for the seismic zone in the earthquake code IS: 1893.

**References:**

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## 11 Implementation of Techno-Legal Regime To Promote DRR In Housing & Building Sector

### 11.1 The Context

It is widely recognised and stands proven that a considerable share of human and physical losses occur due to natural hazards as a direct result of damage to the built environment (buildings and infrastructure) in the affected region. This reflects on poor quality and safety of construction works and many a time inappropriate land-use – i.e. location of built assets. Recent national hazard events during the period 1990-2001 [like Latur (1993), Jabalpur (1997), Chamoli (1999) and Bhuj (2001) and after cyclone of Orissa] have highlighted the vulnerability of built environment to these hazards.

High vulnerability of built elements in urban and rural settlements in India is mainly the result of a huge non-engineered stock of housing and the buildings built without compliance to standards, codes and regulatory requirements for safety, even ignoring the mandatory ones. Yet another factor which compounds the problem further is continuing migration of large number of families migrating from rural to urban settlements thereby resulting in the growth of slums, squatter settlements which in many cases are located on unsafe land and built with very inadequate construction techniques using fragile materials.

In this situation that prevails in most of urban settlements and huge non-engineered housing stock both in large, medium, small urban centres and in rural settlements, there is a need to address the issues of quality and safety in construction, design standards and codes, site selection, control of land-use, permissible densities and role of all these in mitigation of risk due to natural hazards.

Recognising the importance and need for introducing regulatory measures to ensure safety in planning, design and construction of buildings, regulating the land-use zoning and controlling development patterns in both urban and rural settlements as essential steps for risk reduction in built assets from natural hazards, the Governments at Central and State levels have been concerned and making required efforts to establish techno-legal mechanisms to ensure that all stakeholders adopt and adhere to acceptable safety benchmarks in design and construction of new buildings, maintenance and strengthening of existing ones and post-disaster reconstruction and rehabilitation schemes.

## 11.2 Existing Technical Legal Framework

A large body of standards and codes developed by BIS, regulating instruments, documents and systems exist which define the acceptable safety norms/levels expected to be incorporated in the planning, design, construction and maintenance, and retrofitting by all stakeholders, builders, architects, engineers, government departments, public sector undertakings and all those concerned for adoption, enforcement and regulation of disaster-safe construction practices.

A large number of Standards, Codes and Guidelines have been developed by Bureau of Indian Standards, aimed at ensuring general structural safety and design and construction of buildings and other structures for achieving safety and protection of built assets from natural hazards. A few are listed in **Annex.....** for ready reference and use. Besides these codes, BIS has also revised the National Building Code (NBC-2005) which provides guidance for design of buildings to conform to accepted safety levels with respect to forces created during natural hazards like earthquakes, cyclones, (high velocity winds), landslides.

BMTPC has developed guidelines for improving resistance of housing against forces during cyclones, earthquakes and floods.

The Ministry of Home Affairs, GOI, appointed multi-disciplinary Expert Group to study the existing Municipal Byelaws and other documents meant to control and regulate growth and development in urban areas, etc., and propose essential amendments in buildings byelaws. Land-use zoning regulations, development control rules, and in Town and Country Planning Legislations to ensure that all these regulatory instruments can enforce safety measures in planning design, construction, siting of different types of buildings and adequately regulate developments in urban centres.

## 11.3 Lack of Compliance And Laxity In Enforcement of Techno-Legal Measures

Despite the fact that appropriate building codes and standards for structural safety are in place, compliance and correct application in design and construction is one of the major causalities in the country. Not that every time the codes are ignored deliberately but many times skilled and trained engineers, architects and builders are not available besides effective enforcement and inspection procedures are not strictly complied with. It is commonly seen that poor governance and often corruption at local bodies level

leading to abuse of land-use controls, illegal expansion of buildings, aggravate the damage caused by disasters. In many cities, there is no certification and licensing system for qualified professional (who could be depended upon). Even the financial institutions do not ensure that experienced specialty should coordinate or implement housing construction projects. The devastation suffered by a large number of residential multi-storied buildings in Ahmedabad after Bhuj earthquake is perhaps a glaring example of poor governance, lack of proper enforcement procedures and corruption at ULBs level. Thus, the present techno-legal regimes fail in their objectives because of absence of will in local bodies to enforce the regulatory measures enshrined in buildings byelaws, development control rules and land-use zoning regulations.

Realising the need for large-scale survey maps of vulnerable and flood-prone areas, to enable proper floodplain zoning, the CWC had initiated, in 1978 a programme for surveying areas prone to floods through Survey of India (Sol) to assist state governments. Maps to Scale 1:15,000 were prepared and sent to respective State Governments (of Bihar, Assam, Jammu & Kashmir). However, no progress was made by any of the States, till 2008, to finalise and publicise such maps.

#### **11.4 Zoning Regulations For Flood Hazard**

India is the most flood-affected country in the world after Bangladesh. Floods affect both rural and urban area – especially the fast growing cities. Rapidly rising population and high rate of development activities are forcing most of urban centres to extend habitation into the floodplains thereby making the built environment highly vulnerable to flood losses.

Guidelines for Management of Floods, issued by National Disaster Management Authority, say the concept of Floodplain Zoning is to regulate land-use in the floodplains to restrict the damage caused to human life and buildings by floods. Floodplain zoning should help in determining the locations and the extent of areas where development activities can be undertaken with minimum damage. Floodplain zoning lays down limitations on development of both the unprotected as well as the protected areas. In the unprotected areas, boundaries of area in which developmental activities will be prohibited are to be established to prevent indiscriminate growth. In the protected areas, only such developmental activities can be allowed, which will not

involve heavy damage in case the protective measures fail. Thus, zoning will greatly help in minimising flood damage in new developments. Floodplain zoning is not only necessary in the case of floods to be caused by rivers but is useful in reducing the damage likely to be caused by drainage congestion particularly in urban areas, where urban drainage, in many cases, may not be designed for the worst conditions.

#### **11.4.1 Prioritisation of Structures In Floodplain Zoning**

The NDMA Guidelines for regulation of land-use in floodplains recommend the grouping of buildings and utility services under three priorities from the point of view of the damage likely to occur and the floodplain zone in which they are to be located. In the master plans, such land use priorities need to be adhered by planners in order to reduce risk from floods.

Priority 1: Defense installations, industries, public utilities like hospitals, electricity installation, water supply, telephone exchanges, aerodromes, railway stations, commercial centres, etc. – Buildings should be located in such a fashion that they are above the levels corresponding to a 100-year frequency or the maximum observed flood levels. Similarly, they should also be above the levels corresponding to a 50-year rainfall and the likely submersion due to drainage congestion.

Priority 2: Public institutions, government offices, universities, public libraries and residential area. –Buildings should be above a level corresponding to a 25-year flood or a 10-year rainfall with stipulation that all buildings in vulnerable zones should be constructed on columns or stilts as indicated above.

Priority 3: Parks and playgrounds. –Infrastructure such as playgrounds and parks can be located in areas vulnerable to frequent floods. Since every city needs some open areas and gardens, by restricting building activity in a vulnerable area, it will be possible to develop parks and play grounds, which would provide a proper environment for the growth of the city.

In order to enforce Floodplain Zoning Regulations, the Central Water Commission (CWC) had brought out a model draft bill for floodplain zoning legislation which was circulated by Union Government in 1975 to all States. There has been resistance on the part of the States to follow-up the various aspects of floodplain management, including possible legislation. The lukewarm response of the States towards the



enactment and enforcement of the floodplain regulations has given rise to significant increase in the encroachments into the floodplains, sometimes authorised and duly approved by the town planning authorities.

The NDMA had asked the State Governments/State Disaster Management Authorities to enact and enforce appropriate laws for implementing floodplain zoning regulations by March 2009. The State-wise status needs to be ascertained. Yet another important recommendation made by NDMA to State Governments/SDMAs was to restrict unplanned growth so that construction of structures obstructing natural drainage resulting in increased flood hazard is not allowed.

#### **11.4.2 Recommended Amendments In Byelaws For Buildings In Flood-Prone Areas**

Following provisions have been recommended and these have been circulated by Ministry of Home Affairs, Govt. of India, to State to be incorporated by the State Governments/SDMAs/Local Bodies in the building byelaws for buildings in flood-prone areas.

(a) Plinth levels of all buildings should be 0.6 m above the drainage/flood submersion times.

(b) In the area liable to floods, all buildings should preferably be double and multiple stories.

Wherever there are single storey buildings, a stairway will invariably be provided to the roofs so that temporary shelter can be taken there during floods.

#### **11.5 Amendment In Development Control Regulations**

This part deals with the development control rules and general building requirements to ensure health and safety of the public. The regulations for Land Use Zoning in Hazard-Prone Areas are to be taken into consideration while formulating the Development Plans and special Area Plans under the Town Planning and Urban Development Act.

Every person who gives notice under relevant section of the Act shall furnish all information in forms and format prescribed herein and as may be amended from time to time by the Competent Authority. The following particulars and documents shall also be submitted along with the application.

1) The forms, plans, sections and descriptions to be furnished under these Development Control Regulations shall all be signed by each of the following persons:

- A person making application for development permission under relevant section of the Act.
- A person who has prepared the plans and sections with descriptions who may be Architect or Engineer on Record.
- A person who is responsible for the structural design of the construction, i.e., a Structural Engineer on Record.
- A Construction Engineer on Record who is to look after the day-to-day supervision of the construction.
- A Developer, Promoter

2) A person who is engaged either to prepare plan or to prepare a structural design and structural report or to supervise the building shall give an undertaking:

Certificate in the prescribed Form no. 1 by the “Owner, Developer, Structural Engineer on Record and Architect on Record”; Form No. 2 by the “Architect on Record” / “Engineer on Record”; and Form No. 3 by the “Structural Engineer on Record”; Form No. 4 by the “Construction Engineer on Record” as prescribed in Form No. 6 of Proposed Amendment in Town & Country Planning Legislations, Regulations for Land Use zoning, Additional Provisions in Development Control Regulations for Safety & Additional Provisions in Building Regulations / Bylaws for Structural Safety – in Natural Hazard Zones of India.

#### **11.5.1 No Land Shall Be Used As A Site For The Construction Of Building**

- i) If the site is found to be liable to liquefaction by the Competent Authority under the earthquake intensity of the area, except where appropriate protection measures are taken.
- ii) If the Competent Authority finds that the proposed development falls in the area liable to storm surge during cyclone, except where protection measures are adopted to prevent storm surge damage.
- iii) In hilly terrain, the site plan should include location of landslide-prone areas, if any, on or near the site, detected during reconnaissance. The Authority in such

case shall cause to ensure that the site is away from such landslide-prone areas.

- iv) The site plan on a sloping site may also include proposals for diversion of the natural flow of water coming from uphill side of the building away from the foundation.

#### **11.5.2 Grant Or Refusal Of The Permission For Development**

On receipt of the application for development permission, the Competent Authority after making such enquiry and clearance from such an expert whenever considered necessary for the safety of building, as it thinks fit may communicate its decisions granting with or without conditions, including condition of submission of detailed working drawing/structural drawing along with soil investigation report before the commencement of the work or refusing permission to the applicant as per the provisions of the Act.

The Competent Authority, however, may consider to grant exemption for submission of working drawing, structural drawing and soil investigation report in case the Competent Authority is satisfied that in the area where the proposed construction is to be taken, similar types of structure and soil investigation reports are already available on record and such request is from an individual owner/developer, having plot of not more than 500 sq. mt. in size and for a maximum three-storeyed residential building.

If the local site conditions do not require any soil testing or if a soil testing indicates that no special structural design is required, a small building having up to ground +2 floors, having load bearing structure, may be constructed. If the proposed small house is to be constructed with load bearing type masonry construction technique, where no structural design is involved, no certificate from a Structural Engineer on Record will be required (to be attached with Form No. 2). However, a Structural Design Basis Report (Form No. 6) has to be submitted, dully filled in. Notwithstanding anything stated in the above regulations it shall be incumbent on every person whose plans have been approved to submit revised (amended) plans for any structural deviations he proposes to make during the course of construction of his building work and the procedure laid down for plans or other documents here to before shall apply to all such revised (amended) plans.

## **11.6 Open Spaces**

Out of the open spaces earmarked as district parks, neighborhood parks and local parks in the development plan, zonal plans and local plans, suitable and approachable parks/open spaces should be identified for the use during the emergency to provide shelter and relief caused by a natural hazard. Such pockets should be clearly marked on the city maps.

## **11.7 Model Development Control And Building Regulations Including Safety Provisions In Rural Areas**

### **11.7.1 Context**

According to 2001 Census, India had a population of 1,027 million (27.8% in urban and 72.2% in rural areas) with 249.1 million housing units (177.5 million in rural and 71.6 million in urban areas). There are about 5,86,706 villages and about 3,969 towns and cities in the country.

Considering that nearly 750 million people live in rural settlements in about 177 million housing units constructed with large variety of materials and construction techniques most of which are highly vulnerable to destruction under the impact of one or the other natural hazards (viz., earthquakes, cyclones, floods and landslides), the Ministry of Home Affairs, under their GOI-UNDP Disaster Risk Management Programme, prepared the Model Development Control and Building regulations for health and safety of the people, including safety in construction against natural hazards, in the form of simplified guidelines for construction with mud walls, stone and brick masonry. These suggested guidelines are to be followed by Panchayats but necessary directions need to be issued by the governments of respective States and UTs.

The above-mentioned regulations were recommended for compliance in sub-division development or re-development of land or construction, reconstruction or alterations of buildings in Panchayat areas.

The model document submitted to the MHA, Govt. of India, includes the guidelines on the following aspects;

**Part A**        Some legislative provisions in the Constitution of India and in some States regarding the Panchayat Raj along with recommendations to devolve powers for self-governance in rural area.

**Part B** Model Development and Building Regulations, including safety provisions needed in buildings to be constructed in rural areas.

**Part C** Guidelines for construction with burnt brick work, stone masonry and earthen walls.

The Model Development Control & Building Regulations are envisaged to be amended by States/UTs as per the local needs and be used as the basis to control the development and safety in construction activities in rural areas.

### **11.7.2 Capacity Building Of Officials And Professionals Of Local Authorities**

Urban Local Bodies, numbering nearly 5,100 in the country, are the largest owners of lifeline buildings, structures and infrastructure networks.

As regulators of all development works, the ULBs and Development Authorities undertake the following functions:

- (i) Own, retain, maintain and construct large stock of public and lifeline buildings and structures.
- (ii) Implement master and land-use plans with the support of development control rules, building byelaws and regulations.
- (iii) Scrutinise and approve plan, designs and construction systems of all buildings and structures to be built in their areas.
- (iv) Enlist/license practising engineers, architects, town planners, project consultants, contractors.
- (v) Exercise a periodic check on the ongoing planned developments and construction projects.

In a hurry for achieving targets and widespread declining tendency to pay attention to details, the regulatory responsibilities at ULBs are increasingly being ignored. The result is that 'safety' and 'quality' become the first casualties both during approval and construction of the projects which belong to them or to other entities but need approval

by them. Efforts so far made through development of guidelines, advocacy for adherence to standards and codes and creating awareness about consequences, the ULBs have miserably failed in changing the mindset of officials concerned, particularly with reference to compliance and enforcement of techno-legal requirements in design, construction and supervision of buildings.

While the country today, is witnessing a new spatial order in the growth of cities, the role and responsibilities of ULBs is increasingly becoming significant in improving preparedness and reducing vulnerability of city's built assets. With more than 300 districts in Seismic Zone III, IV and V and 180 facing multi-hazards threat, improved practices for management of seismic risk in the fast growing urban centres is essentially required and should not be ignored at any cost by the authorities and staff of ULBs.

Emphasising the need for capacity development, a four-pronged action plan is recommended. It includes, (i) Periodic awareness meets at regional level for Mayors/Corporators focusing on reporting of quantifiable progress achieved by each ULB, lying in seismic regions, (ii) Regular training programmes for town planners, architects, engineers and plan approving officials for regulating seismic safety in the new projects and in methods of carrying structural safety audit of existing built stock, (iii) ULBs must collaborate with academic institutions of excellence and eminent professionals having practical experience from large construction entities to provide training to their staff and practising local engineers and architects in structural safety auditing methods and practice of forensic engineering.

### **11.7.3 Scrutiny of Designs And Building Permissions**

Structural design and construction provisions related to safety are the concerns of engineers, and urban planning provisions and architectural design aspects related to functional planning and building science are the concerns of architects. For most commonly built new buildings, self-audit will be practised by the architects and engineers involved in the project. Notwithstanding this, the architects and engineers in municipal offices will be trained to scrutinise structural design calculations and drawings submitted by the clients' architects and engineers. A checklist of items to be examined will be developed, and the municipal architects and engineers trained to be able to do this scrutiny. Annually, detailed design and construction audit should be

undertaken for a limited number (say 1-2%) of randomly chosen structures to ensure that the complete process of structural design and detailing is being followed. The shortcomings identified in this process will be published for the consumption of the architects and engineers in their future projects. For special and important new structures, peer review of structural designs will be undertaken by other noted architects and engineers. The cost incurred in this process will be borne by the client owner of the structure.

Modifications to existing buildings, including seismic strengthening projects, will also require approval from the municipal offices. Again, the structural design calculations and drawings will be scrutinised for common buildings and peer reviewed for special and important structures.

**References:**

- 11.1 Expert Committee Chaired by A.S. Arya, Techno Legal Regime Vol., I, Vol. IA, Vol. I.B. for Rural Panchayats, printed by BMTPC, 2006-2009.

## 12 Techno-Financial Regime

### 12.1 Impact of Past Disasters In India

Over the past two decades, India has suffered a number of natural disasters. Some of these disasters, e.g., 1999 Super Cyclone in Orissa and 2001 Bhuj earthquake, have caused large loss of life, significant destruction of built environment, and major direct and indirect economic setback. The adverse impact of these disasters is primarily attributable to the damage to the built environment; which resulted in loss of life, property and economy. The built environment includes buildings, lifeline and infrastructure facilities whose damage or failure can be attributed to most human suffering and impact on the economy. To mitigate the negative effect of natural hazards, it is imperative that the built environment is made *multi-hazard-resistant*, so that the impact of natural disasters is reduced.

With financial supports from banks and other lending institutions, there is a steady growth trend in housing construction by real estate companies and individuals. Eleventh Five-Year Plan estimates that housing finance disbursement by banks, finance corporations, and cooperative sector institutions would grow at a rate of about 15% per annum during the Plan period. Taking this into account, it is estimated that for the new housing, the flow of credit disbursement from these institutions would be about Rs 3.90 lakh crore during 2007-2012. Besides, Reserve Bank of India (RBI) has asked the commercial banks to lend 3% of deposits of commercial banks in priority sector lending including financing housing by individuals and others (cooperative & private sectors). In this backdrop, the safety of the financed constructions to different natural hazards is important to secure the finance against the assets that are developed. Damage or destruction to these assets not only result in adverse economic consequences but may also compromise the lending institutions financial security due to the drastic reduction in asset values following their damage or destruction.

### 12.2 Current Practice Of Banks To Fund Construction-Related Projects

#### 12.2.1 Sanction of Loans

Currently, construction projects in India are expected to comply with several technical provisions that are specified in various Techno-legal Acts and Regulations being implemented by Urban Local Bodies (ULBs) or local Urban Development Authorities. While some provisions of these Acts and Regulations stipulate for town planning norms



(viz., land use zoning, road width, siting of other urban amenities, setback of buildings), a few other provisions speak about building bylaws/regulations defining standardised norms for various components of the building. Many of the provisions of building bylaws (building regulations) are intended to ensure that all constructions meet certain safety norms and do not adversely affect the safety of their occupants or the people at large. However, experiences from recent natural disasters clearly illustrate that these provisions are not fully complied with, resulting in avoidable damage to the built environment and the consequent adverse impacts. Secondly, the building bylaws, which are generally of urban concern and are implemented in jurisdiction of ULBs or local Urban Development Authorities, do not have any regulatory control over building constructions in rural areas. Therefore, the onus of checking safety provisions incorporated in the building and its durability lies on the banks and the lending institutions extending the loans in *rural areas*. There are three critical aspects in the current practice of the banks offering financial assistance to construction projects that do not guarantee disaster-resistance in the structure proposed to be built or being built. These are:

- i) At the time an application is made to a bank seeking financial loan to construct any building or structure, *it is not necessary that it is designed in full*. The architect and/or structural engineer provide a certificate that they will undertake the design appropriately at later stage.
- ii) Even before the construction of the building or structure is started, the design of the whole structure is not always furnished either to the municipal corporation due to the lack of such definitive provisions in prevailing local building bylaws or to the banks funding the construction.
- iii) The technical professionals (structural engineer and/or architect) assisting the banks recommend that loan may be given to a project, without necessarily seeing the design of the complete structure, and sometimes simply based on their perception of the credentials of the architect and structural engineer of the project. All of these are loopholes of the practice that augur against ensuring safety of the constructions.

### 12.2.2 Disbursement of Loan

In the current practice, the banks give installments of financial assistance linked to issue of a series of certificates, namely

- i) **Initial loan amount based on the Stability Certificate** by structural design consultants *before* the structural design of the asset is performed stating that they *shall comply* with the requirements of structural safety during the process of design (to be undertaken at a later stage).
- ii) **Partial loan amount based on the Stage-wise Completion Certificates** by architects *after* the construction is underway, stating that a said list of works have been completed as per the approved construction drawings.
- iii) **Final loan amount based on the Final Completion Certificate** by architects *after* the construction is complete, stating that all the works have been completed as per the approved construction drawings.

In general, in the said sequence of release of installments, independent assessment of the safety of the project is often missed by the banks themselves.

The structural damage and economic setback thereof, as have been noticed in the past on bank financed buildings after a disaster, is a testimony to the above fact. While the banks are passing on the financial liability due to natural disasters to their *re-insurance companies* (who are underwriting the losses of the banks), they are unable to account for losses of lives occurring in construction projects funded by the banks.

## 12.3 RBI Guidelines

### 12.3.1 Construction Activities Eligible For Bank Credit As Housing Finance

Under the master circular dated July 1, 2010, RBI has specified the following types of bank credit which will be eligible for being treated as housing finance.

- (i) Loans to individuals for purchase/construction of dwelling unit per family and loans given for repairs to the damaged dwelling units of families;

- (ii) Finance provided for construction of residential houses to be constructed by public housing agencies like HUDCO, housing boards, local bodies, individuals, cooperative societies, employers, priority being accorded for financing construction of houses meant for economically weaker sections, low income group and middle income group;
- (iii) Finance for construction of educational, health, social, cultural or other institutions/centres, which are part of a housing project and which are necessary for the development of settlements or townships;
- (iv) Finance for shopping complexes, markets and such other centres catering to the day-to-day needs of the residents of the housing colonies and forming part of a housing project and;
- (v) Finance for construction meant for improving the conditions in slum areas for which credit may be extended directly to the slum-dwellers on the guarantee of the Government, or indirectly to them through the State Governments.
- (vi) Bank credit given for slum improvement schemes to be implemented by Slum Clearance Boards and other public agencies;
- (vii) Finance provided to –
  - (a) The bodies constituted for undertaking repairs to houses, and
  - (b) The owners of building/house/flat, whether occupied by themselves or by tenants, to meet the need-based requirements for their repairs/additions, after satisfying themselves regarding the estimated cost (for which requisite certificate should be obtained from an engineer/architect, wherever necessary) and obtaining such security as deemed appropriate;

### **12.3.2 Advisories Issued By RBI**

Reserve Bank of India (RBI) has issued several proactive advisories to banks for verifying disaster safety and planning issues while granting loans for any building construction. In this regard, RBI's circular of 1st March 2006 asking banks to ensure prior permission from Government/Local Governments/other statutory authorities for the project, wherever required, while giving loans to real estate sector is to be noted.

Similarly, again emphasising importance to safety of buildings, especially against natural disasters, RBI has issued advisory to all banks on 12 June 2006 for adherence of National Building Code, 2005, while approving loans for any building construction. Further, RBI taking cognizance of orders of the Delhi High Court (writ petition by Kalyan Sanstha Welfare Organisation against Union of India and others) has circulated the following:

A. Housing loan for building construction

- i) In cases where the applicant owns a plot/land and approaches the banks/FIs for a credit facility to construct a house, a copy of the sanctioned plan by *Competent Authority* in the name of a person applying for such credit facility must be obtained by the banks/FIs before sanctioning the home loan.
- ii) An affidavit-cum-undertaking must be obtained from the person applying for such credit facility that he shall not violate the sanctioned plan, the construction shall be strictly as per the sanctioned plan and it shall be the sole responsibility of the executants to obtain completion certificate within three months of completion of construction, failing which the bank shall have the power and the authority to recall the entire loan with interest, costs and other usual bank charges.
- iii) An architect appointed by the bank must also certify at various stages of construction of building that the construction of the building is strictly as per sanctioned plan and shall also certify at a particular point of time that the completion certificate of the building issued by the competent authority has been obtained.

B. Housing loans for purchase of constructed property/built-up property

- i) In cases where the applicant approaches the banks/FIs for a credit facility to purchase the built up house/flat, it should be mandatory for him to declare by way of an affidavit-cum-undertaking that the built-up property has been constructed as per the sanctioned plan and/or building byelaws and as far as possible has a completion certificate also.

- ii) An architect appointed by the bank must also certify before disbursement of the loan that the built up property is strictly as per sanctioned plan and/or building byelaws.

#### C. Unauthorised colonies

No loan should be given in respect of those properties which fall in the category of unauthorised colonies unless and until they have been regularised and development and other charges paid.

#### D. Commercial property

No loan should also be given in respect of properties meant for residential use but which the applicant intends to use for commercial purposes and declares so while applying for loan.

### **12.4 Important Suggestions For Guidelines**

#### **12.4.1 Techno-Financial Regime For Urban And Rural Areas**

A techno-financial regime of banks and other lending institutions extending loans for building construction in both urban and rural areas should take care in regulating all construction as disaster-resilient construction in the country. In this context, the loan delivery mechanism needs to be considered as an opportunity for financial institutions to introduce appropriate disaster resistance in constructions in building sector. The financial institutions would also be equally keen to ensure that the physical assets created through their lending schemes remain safe during at least repayment period of 15-30 years.

Depending on the housing project and the proneness of its location to any or many of the hazards, the financial institutions could insist on the condition to ensure incorporation of disaster-resistant features in the construction before the loan is sanctioned/disbursed. Therefore, role of the FIs and banks is critical in creating such a regime. The regime should be applicable to both new constructions as well as additions or alterations to full or part of existing constructions. The regime should be applicable to all constructions, including

- i) The entire range of housing constructions, from those built for self-occupation to those provided by builders and developers to individuals, and
- ii) Other bank-financed constructions, such as lifelines, infrastructure, and commercial complexes and buildings.

#### **12.4.2 Role Of Insurance Sector In DRR**

To integrate Disaster Risk Reduction with the policies, programmes and projects in Housing Sector and cut down on the mounting economic costs of natural disasters, insurance has been used as a strong policy tool for disaster management in several developed countries. It is treated as a public-private partnership strategy for disaster risk sharing and reduction. Insurance companies are expected to address the twin problems of reducing losses at community level resulting from disasters and providing financial protection to individual families.

If insurance has to play an important role in helping to reduce disaster losses, it should work together with financial institutions and funding agencies and the capital market. In India, a coherent policy and strategy by insurance sector has not been developed for coping with the impact of natural hazards on built environment and communities. Governmental intervention should, therefore, facilitate development of innovative insurance products and linking the role of insurance sector with other stakeholders to deal with natural hazard syndrome.

#### **12.4.3 Self-Contained User-Friendly Guidelines**

A self-speaking simplified user-friendly technical guidelines has been proposed in Table 14.1 in Chapter 14 (covering masonry reinforced concrete and steel buildings) will aid the FIs and banks towards putting in place a robust techno-financial regime, that will help them to ensure safety *by themselves* (without relying on the techno-legal processes controlled by municipalities and other such bodies). Using such guidelines, the verification wings of banks and their empanelled technical experts will be in an easy position to check that the safety-related codes and regulations, as specified in NBC-2005, covered BIS standards, are complied with and the designs of the proposed buildings and structures are disaster-resistant.

In the event that the natural hazard becomes a reality, the assets created through financial assistance by banks and other FIs will perform as per the codes and

standards, and not adversely affect either their safety, or value. After this is ensured, the banks/FIs may study the other aspects of the application for loan and take a considered decision on it - either to fund the project or not. This way the FIs would offer a disaster-resistant built environment to their clients and the occupants/users.

With above intention, a set of checklists are appended (Chapter 14, Table 14.2 to 14.5) to aid *the structural engineers and architects assisting the FIs* for assessing buildings-related constructions on their own. These checklists are meant for ensuring that all necessary aspects of safety are addressed in the construction of the building.

## **12.5 Pro Forma For Assessment of Natural Hazard Impact**

### **12.5.1 General Information of The Project**

Name of the project:

State:

District:

Siting of the project

- Location of project site
- Latitude
- Longitude
- Height above mean sea level

### **12.5.2 Nature/Type of Project**

- All the projects of the nature/type mentioned below are liable to damage by natural disasters and inadequacies of design or any of their components is likely to accentuate the vulnerability of the area to the disaster and/or lead to rise in damage/loss to lives, property, livelihood systems environment,
- Communications: towers, lines building
- Transportation: roads, railways, bridges, tunnels
- Power: powerhouses, substations, power lines
- Habitations: township planning from the point of view of safety against hazards
- Water supply and sanitation projects, including sewer lines
- Building projects
- Any other

### **12.5.3 Hazard Proneness of The Project**

- 1) Earthquake zone (any known geological fault nearby may be listed).
- 2) Flood proneness & vulnerability:
  - a. Past history of floods in the area
  - b. Observed highest flood level
  - c. Frequency of flooding
  - d. Depth of flooding
  - e. Duration of flooding
  - f. Damage /loss (maximum, average, potential)
- 3) Cyclone proneness (If close to sea coast) & vulnerability:
  - a. Frequency and Intensity
  - b. Wind speed zone – information on highest wind speed
  - c. Distance of site from sea coast
  - d. Record of past storm surge
- 4) Landslide proneness & vulnerability:
  - a. Location of hill slope vis-à-vis the project's location
  - b. Past history of landslides,
  - c. Possibility of mudflows/rock falls/snow avalanches, etc.
- 5) Tsunami proneness (If close to sea coast) & vulnerability:
  - a. Past history

### **12.5.4 Hazards Risk To The Project**

- Have the following been evaluated:
- Probable maximum seismicity at site and site dependant seismic design parameters
- Probable maximum storm surge
- Probable maximum wind speed
- Probable maximum precipitation
- Probable maximum flood discharge and level
- Probable of occurrence of floods, earthquakes, land slides, mudflows, avalanches, cyclones, tsunamis
- Soil liquefaction proneness under probable earthquake intensities

### **12.5.5 Mitigation/Reduction of Risk:**

- 1) There are specific codes, manuals, guidelines etc. developed by Bureau of Indian Standards, NDMA, and organisations concerned for siting,



design, construction maintenance of various types of infrastructures.

Indicative and not exhaustive list of some of them is given in Annexure 4.

- 2) Have the relevant BIS codes and guidelines been complied with?
- 3) Have adequate safeguards to meet the risks of natural hazards as evaluated at para 12.5.3 above, been adopted?

#### **12.5.6 Relevant References To Standard Codes/Guidelines**

*A. For general structural safety*

- BIS National Buildings Code 2005
- IS:456:2000 Code of practice for plain and reinforced concrete.
- IS:800-2006 Code of practice general construction in steel
- IS: 875 (Part-2):1987 Design loads (other than earthquake) for buildings and structures, Part 2 Imposed loads
- IS 875 (Part 4):1987 Design loads (other than earthquake) for buildings and structures, Part 4 Snow loads
- IS 875 (Part 5):1987 Design loads (other than earthquake) for buildings and structures, Part 5 Special loads and load combination
- IS:883:1966 Code of practice for structural timber in buildings
- IS:1904:1987 Code of practice for structural safety of buildings: foundations
- IS:1905:1987 Code of practice for structural safety of buildings: masonry walls
- IS:2911 (Part I):1979
- Section 1 Code of practice for design and construction of pile foundation
- Section 2 Based Cast-in-situ piles
- Section 3 Driven precast concrete piles
- Section 4 Based precast concrete piles
- Part 2 Timber piles
- Part 3 Under reamed piles
- Part 4 Load test on piles

*B. For earthquake protection*

- IS:1893 (Part1)-2002 Criteria for earthquake resistant design of structures (fifth revision)
- IS:13920-1993 Ductile detailing of reinforced concrete structures subjected to seismic forces-code of practice.

- IS:4326-1993 Earthquake resistant design and construction of buildings- code of practice (second revision)
  - IS:13828-1993 Improving earthquake resistance of low strength masonry buildings- guidelines
  - IS:13827-1993 Improving earthquake resistance of earthen building – guidelines
  - IS:13935-1993 Repair and seismic strengthening of buildings-guidelines
- C Protection from cyclones/wind storms
- IS 875 (3)-1987 Code of practice for design loads (other than earthquake) for buildings and structures, part 3, wind loads
  - IS:15498-2004 Guidelines for improving the cyclonic resistance of low rise houses & other building/structures
- D. Flood protection
- IS:11532-1995 Construction and maintenance of river embankments (levees)-guidelines
  - IS: 12094-2000 Guidelines for planning and design of river embankments (levees)
  - IS:14262-1995 Planning and design of revetments-guidelines
- E. Landslide hazard
- IS:14458 (Part I):1998 Guidelines for retaining wall for hill area
  - Part 1- Selection of type of wall; Part 2 Design of retaining/breast walls; Part 3 Construction of dry stone walls
  - IS: 14496: 1998 Guidelines for preparation of landslide–Hazard Zonation maps in mountainous terrains: Part 1 Macro-Zonation; (Part 2):1999 Guidelines for landslide control
  - IS:14948 :Code of practice for reinforcement of rock slopes with plain edge of failure
  - IS:14804: Guidelines for siting, design and selection of materials for residential building in hilly areas

**References:**

- 12.1 RBI Guidelines, Master Circular in Housing Finance, July 1, 2010.

## **13. Multi-Hazard-Resistant Construction of Houses – A Case Study**

### **13.1 Statement of the Problem**

The reconstruction of houses destroyed in the floods of 2008 in Kosi river in four districts of Bihar is based on safety of the reconstructed houses against future floods, earthquakes as well as high wind speeds. In view of the fact that the districts of North Bihar fall in Seismic Zone V and IV, subjected to floods in the various branches of Kosi river as well as cyclonic high wind travelling from the Bay of Bengal over West Bengal and districts of Bihar.

### **13.2 Approach To Multi-Hazard Safety Of New Houses**

Safety against floods will in most cases depend on the safety of foundations up to plinth level of the house and can be achieved by constructing these elements using burnt brick or stone masonry laid in good cement mortar or reinforced concrete. The depth of foundation has to be kept deep enough to avoid sinking by flood waters and to remain stable if the soil gets liquefied under a high-intensity earthquake. For safety of the superstructure under the lateral loading by earthquakes or high winds, the masonry walls should be reinforced by seismic bands and vertical steel bars. Also, if constructed using bamboo, the superstructure needs to be properly braced with diagonal members. Light roofs consisting of burnt clay tiles or CGI/AC sheet roofing laid on bamboo or wooden understructure have to be properly tied together using special bolts. The new houses proposed for reconstruction have incorporated the above safety measure. The details adopted are given in the following paragraphs.

### **13.3 House Types Included In Reconstruction Programme**

The documentation of the earthquake of 1934 indicates damage was more pronounced in earthen or earthen-brick composite houses and less in well-built fired-brick houses. Also bamboo structures with mud plaster suffered much less damage. With particular context of the Seismic Zones V and IV (MSK Intensity IX or higher, and Intensity VIII respectively), flood hazard and high wind velocities of up to 47m/s, these damages aim to provide safety of foundations and plinths in floods, integrity of structure during earthquakes and anchoring of the roof and other components for safety in high wind conditions.

Considering the availability of building materials, local construction practices as well as financial constraints, the following type of houses are designed.

A. Brick wall house with two variations

A1. Brick walls of one brick or half brick thick with piers, solid RC/RBC slab roof. See Fig. 13.1, 13.2 (lofts are included at the door lintel level to provide relief to the occupant under high flood situation).

A2. Brick walls of one brick or half-brick thick with piers, using sloping roof with bamboo understructure and CGI sheet roofing (bamboo attic floor has been provided to help the occupants saving themselves and the contents of the house under high flood condition).

B. Bamboo superstructure with sloping roof and attic floor as in A2 above. See Fig. 13.5

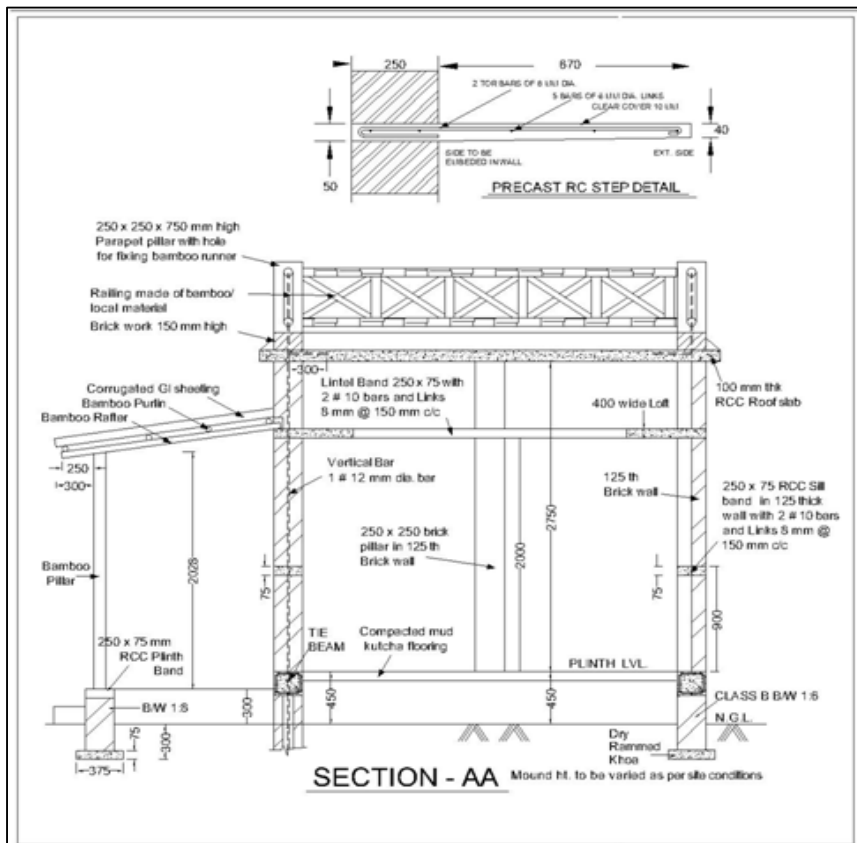


Fig. 13.1 Brick Wall House-Plan

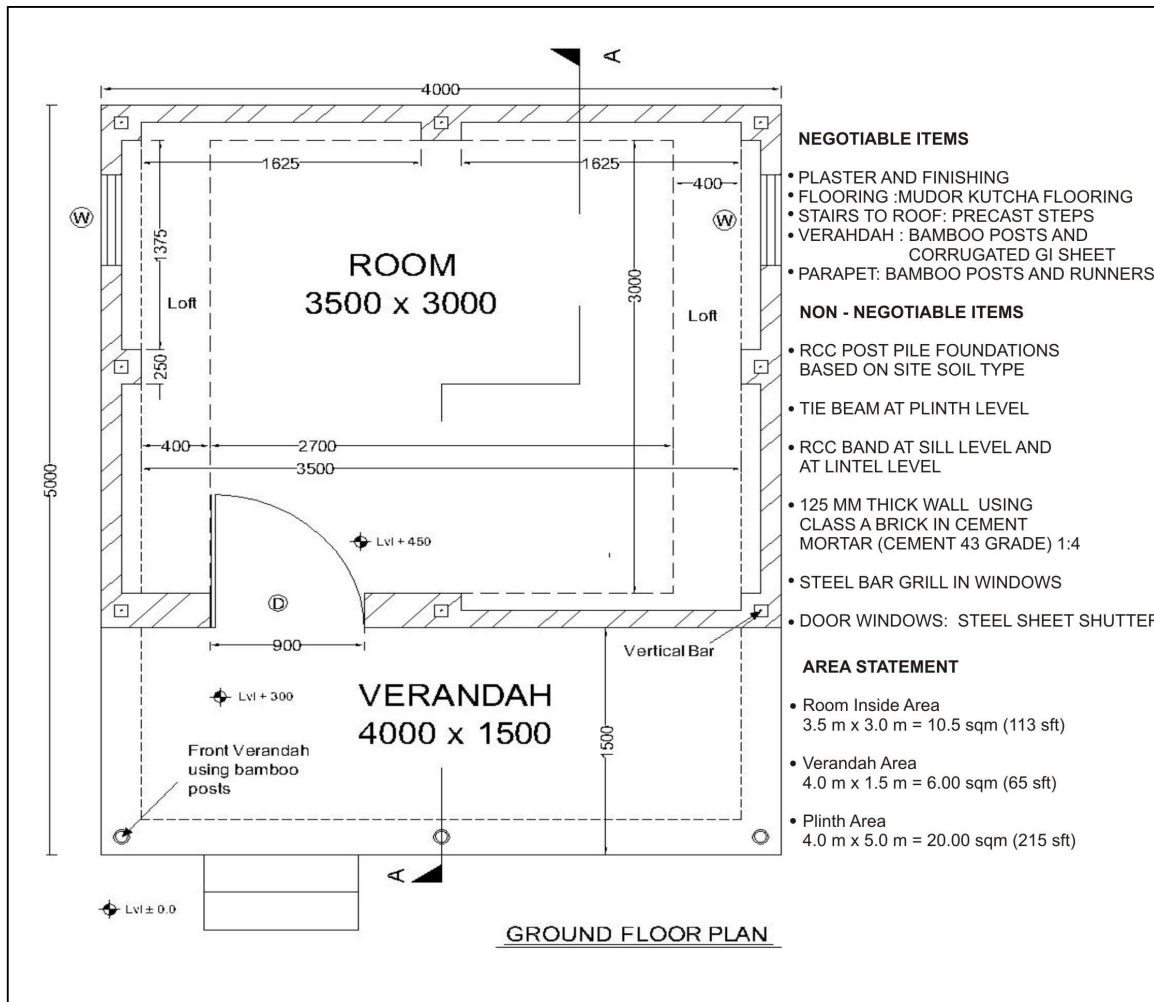


Fig. 13.2 Brick Wall House- Section

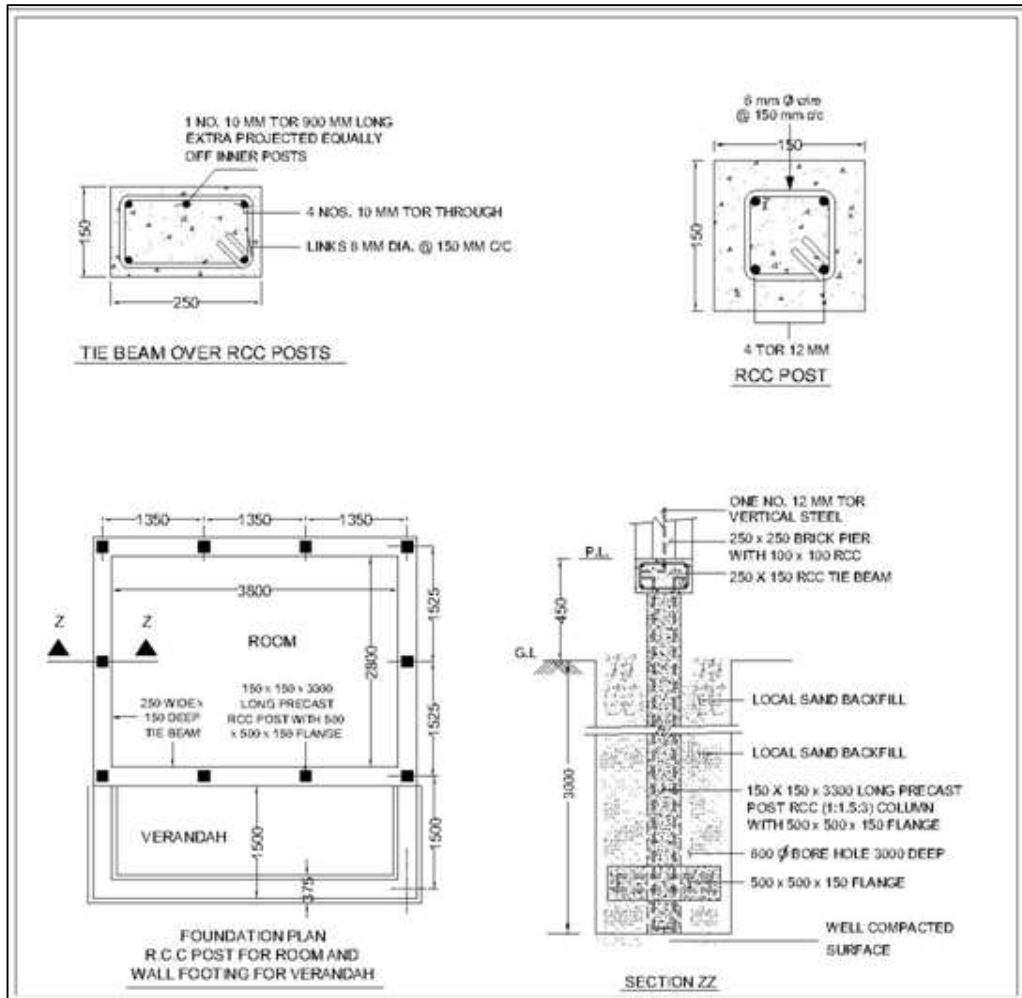
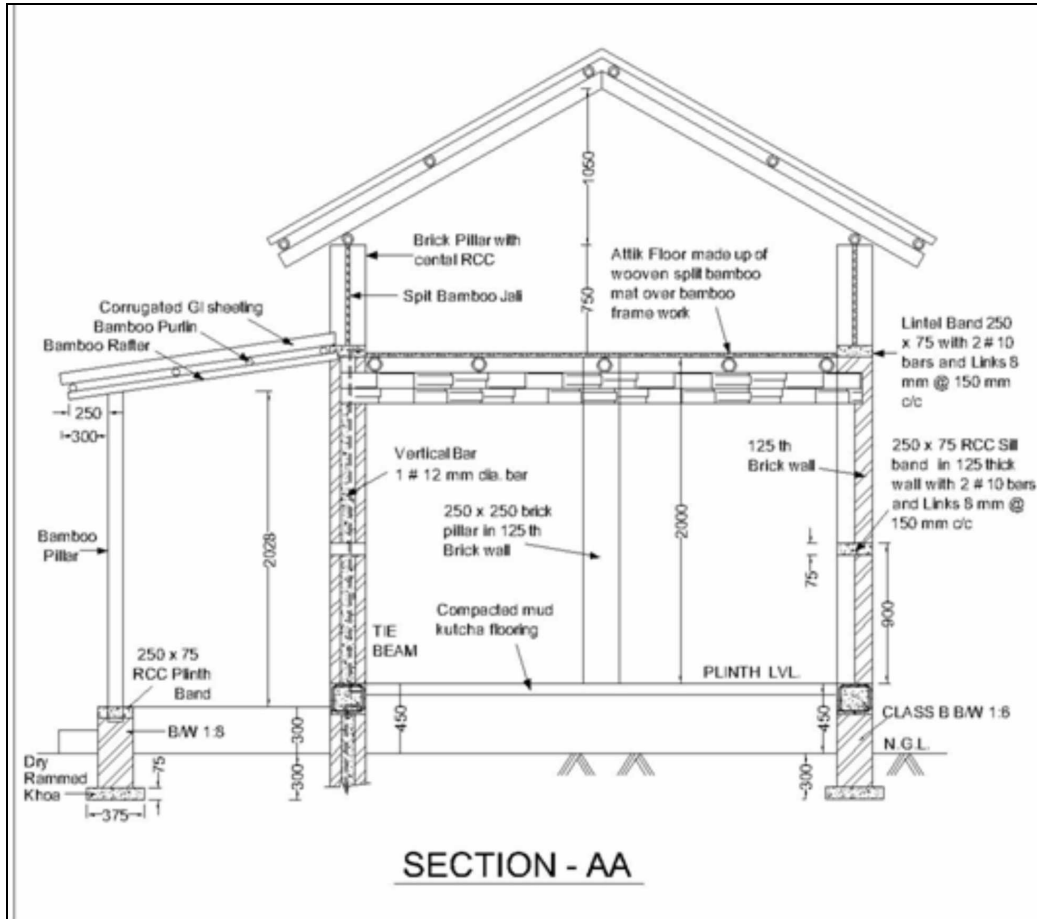
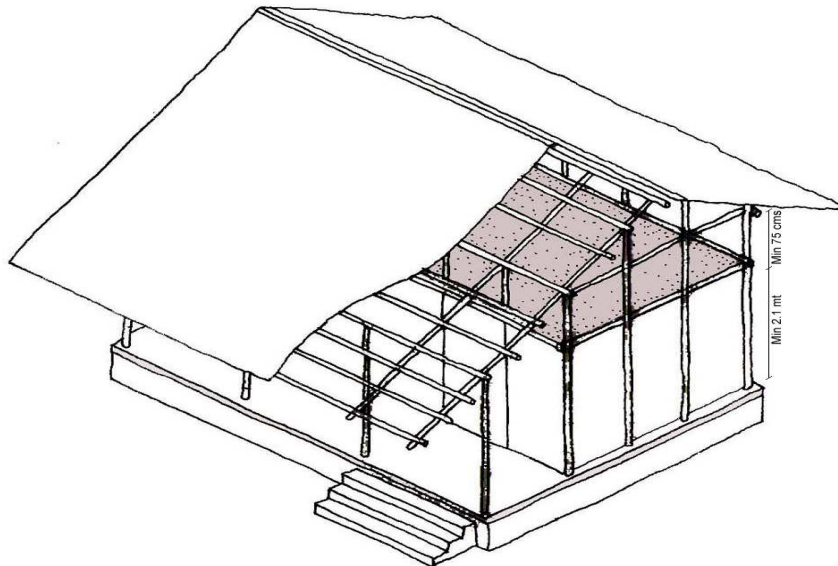


Fig. 13.3 Brick Wall House-Details of Deep Foundation



**Fig. 13.4 Brick Wall House with Sloping Roof-Section**  
(Mound height (NGL) to be varied as per site conditions)



**Fig. 13.5 Bamboo house with attic floor**

### **13.4 Site Soil Conditions**

The soil data obtained from two building sites in the districts gave the following information:

- i) Silty clay with cohesion  $C = 0.2 - 0.4$  range &  $\Phi = 6^\circ - 10^\circ$  range. Safe bearing capacity at 1.5 to 2 m depth as 6 to 7 t/m<sup>2</sup> for strip and 7 to 9 t/m<sup>2</sup> for square footing.
- ii) Silty sand with  $C = 0$ , &  $\Phi = 27^\circ - 28^\circ$  range with Safe bearing capacity as 7 – 8 t/m<sup>2</sup> for strip and 8 – 9 t/m<sup>2</sup> for square footing.

These ranges of properties were adopted for design of footings.

Floods occurring in the alluvial plains of the rivers give rise to the following types of problems:

- i) The bearing capacity of the soil gets reduced because of saturated condition. Hence, buildings of heavy materials may sink and get damaged by differential settlements.
- ii) The soil can be eroded under the action of flowing water and scouring can take place around and under the foundations resulting in the uprooting of the lighter posts or sinking and tilting of the heavier buildings.
- iii) Siltation can take place around the buildings when the floodwater recedes away from the site.
- iv) In case of an intense earthquake the phenomenon of soil liquefaction can take place in Zone IV or Zone V if the soils, particularly non-cohesive soils, are saturated due to floods or high groundwater table (it actually happened in large areas of North Bihar during August 1988 earthquake when the area was already under floods).

All the above site effects can lead to severe damage to the housing units unless constructed using appropriate types of foundations, materials and technologies.



### 13.5 Building Materials

#### Bricks

The fired clay bricks should be well burnt with red colour, neither under-burnt nor over-burnt, having a minimum compressive strength of 5.0 N/mm<sup>2</sup> (50 kg/cm<sup>2</sup>) when tested flat. The bricks should give a ringing sound when struck with each other. Alternatively, fly ash bricks or blocks of appropriate size and 28 day compressive strength of 5.0N/mm<sup>2</sup> may be used for the construction walls and piers.

The standard nominal burnt brick size in India is 9x4.5x3.0 inch units (or 228x114x76mm units). However, 10 inch units (25cm) long bricks are generally made in Bihar. In using one brick thick walls, use of 25cm bricks will be very wasteful (about 11% extra) in the consumption of clay soil, cement sand mortar and energy use for burning. Change of brick length to 9 inches (228 mm) is recommended particularly in view of the requirement of crores of bricks for the reconstruction programme only. Use of fly ash bricks or blocks is also recommended to the feasible extent.

#### Cement

Cement of 43 grade is preferred and cement of 53 grade shall not to be used for masonry construction due to high requirements of curing to attain strength. 43 grade cement takes longer time to set and attain strength and therefore even with less frequent curing can attain better strength. Pozzolona cement can also be used as this has less permeability.

#### Brick Concrete Blocks

Brick concrete blocks may be used in foundation and plinth construction. In Kosi region, where stones are not available, brick aggregate or broken bricks may be used to make concrete blocks. Blocks can be made manually by using steel or wooden mould in the size 290x190x140mm.

Blocks should be casted on hardened flat surface using concrete mix of 1:5:8 and achieving minimum crushing strength of 5.0 MPa. Brickbats of class one brick or over-burnt brick can be used in these blocks. Sand used for block should be of good quality of river sand-free from dust, silt and organic material within limit as per IS code 2116-1980. Pozzolona Portland cement or 43 grade

cement can be used. These blocks shall be cured for at least 7 days in stacks and then 7 days in constructed wall. The water absorption of the block shall not exceed 15%.

### **Bamboo In Kosi Region**

The Gangetic basin of North Bihar has several bamboo species that are used by the people in the region. Harot (*bambusa balcoa*), Chab (*bambusa tulda*) and Makhaur (*bambusa nutans*) are used for building houses. Harot's thick wall makes it strong and is, therefore, used for the main structural elements of the house, including poles, trusses, rafters, ridges and purlins; the straightness of Chab is used for the roof rafters and Makhaur along with other bamboos is used for the lattice work in wattle and daub.

## **13.6 Provisions For Multi-Hazard Safe Construction**

### **13.6.1 Considerations For Site Selection**

- i) The site should be chosen on high enough ground, wherever possible, above the normal annual average flood level in the area. Where it is not feasible, action is needed to raise the ground so that the plinth level is at least 150 mm above the normal annual average flood level. See Fig. 13.9.

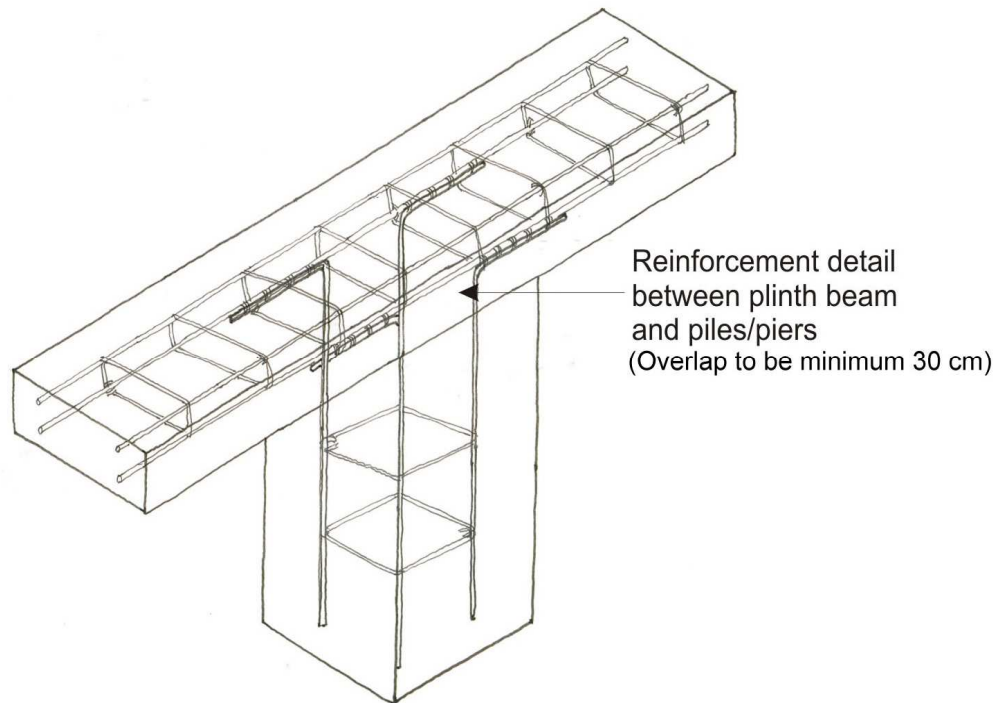
### **13.6.2 Safety Provisions Required For Foundation And Plinth**

It may be emphasised that the type of foundation will be most critical to provide safety to the house under flood, earthquake and high velocity wind conditions.

- i) Detailed site exploration to know the soil profile up to 8 m depth, soil bearing capacity at suitable depths and groundwater table should be made to arrive at correct foundation system and detail of design.
- ii) In case of cohesive soils (clayey, silty clayey or clayey silty soils) *square pedestal piers* may be used with foundation depth of 1.5 m below ground level using a safe bearing capacity of 7-9 t/m<sup>2</sup>. However, if scouring depth at any particular location is more, the foundation depth may need to be revised accordingly.
- iii) In case of available stiff soil at a depth of about 60 cm below ground level which may not be eroded neither under flowing flood water nor subject to

liquefaction, the strip foundation which is normally used by the people in the rural areas be adopted.

- iv) In conditions of non-cohesive, soft alluvial soils saturated during floods or high water table, with possibility of scour, a minimum depth of 1.5 m below ground level is recommended for the pedestal footings. Where possibility of deeper scour or liquefaction during earthquake exists, pile foundations are recommended. A deep RC pile foundation with appropriate concrete bulb at the bottom may be used with the desired load capacity of the foundation. In such a situation, a depth of 3 to 8m may be required based on liquefaction potential of the soil strata. A minimum depth of 3m for the single storey houses may be adopted.
- v) The foundation and the plinth masonry should be constructed using *pucca* building materials. Pedestal or pile foundations will have to carry a reinforced concrete beam at the plinth level to support the superstructure. Reinforcement from the piles and piers shall be anchored in the plinth beam as per the diagram below.
- vi) The distance between two pedestal footings/piles shall not be more than 1.5 m.
- vii) Plinth beam to tie the piles/ pedestals shall be designed based on superstructure loads and distance between piles or piers. The reinforcement of the beam shall be at top as well as bottom of the beam. See Fig. 13.6



**Fig. 13.6 Reinforcement from RC piles in plinth beam.**

- viii) A toe wall between the pedestal footings/ piles may be constructed to hold the earth filling of the plinth. This toe wall may be constructed with lean cement mortar of 1:8 and be constructed from 23 cm below ground.
- ix) Extended plinth by using earth filling with pitching and toe wall around the house protects it from scouring damage to the foundation. Where found necessary, brick pitching may be done on the edges of the soil mound slopes to minimise erosion of soil. Deformed or over-burnt bricks shall be permissible for this purpose.

## **13.7 Brick walls**

### **13.7.1 Brick Bonding**

In normal construction, English bond is used in brickwork in India for one brick thick walls, as normally used in one to two storied constructions using cement mortar. In the reconstruction of one storey houses, use of *half brick wall with pillars* or *rat-trap bond* is suggested in order to save on bricks, labour as well a

weight on foundation. The rat-trap construction will automatically provide pockets for installation of vertical bars at corners of walls and the jambs of doors. In rat-trap bond walls, 1:5 cement mortar may be used.

Bricks being porous absorb water. It is, therefore, essential that the bricks are soaked in water fully before laying on the cement mortar layer. Unsoaked bricks will suck water from the mortar and create hindrance in the setting of cement mortar.

For achieving full strength of brickwork, it is necessary that all vertical joints between the bricks must be fully filled with mortar, that is, the longitudinal joint between two bricks should be filled with mortar.

Also the frog should be upward, so that development of proper shear key between the brick courses is achieved.

Proper curing of the brickwork is to be carried out for a minimum period of 7 days.

*With the above precaution full strength of the brick work under vertical as well as lateral loading due to wind or earthquake will be achieved as specified.*

### **13.7.2 Seismic bands in brick walls**

A seismic band consists of reinforced concrete flat runner through **all external and internal masonry walls** at the following levels in the building.

- a) at the plinth level of the building over strip footing but not required where RC plinth beam is provided.
- b) at window sill level, when half brick walls are made. This is not required in full brick walls or rat-trap bond walls.
- c) at the levels of lintels of doors and windows.
- d) at the ceiling level of roofs consisting of clay tiles or, pre-fabricated reinforced concrete beams or, planks. (Such band will not be necessary if the roof consists of reinforced concrete or, reinforced brick slabs cast on the walls covering a minimum of 2/3 of the thickness of the wall.)

- e) at the eave gable level and top of gable walls in sloping roofs consisting of clay tiles or CGI sheets.

### **13.7.3 Openings in brick walls**

- i) Door and window openings shall be at least 45 cm from the wall corners.
- ii) The distance between two openings shall be not less than 60 cm.

### **13.7.4 Placement of Reinforcement Bars**

- i) The bars should be straight, not crooked, cut to required sizes and bent to proper shapes as per drawings.
- ii) The bars for the seismic bands should have a minimum cover of 25 mm below and above them. The concrete mix should be M20 to prevent corrosion.
- iii) To keep the vertical reinforcing bars at the corners and maintained properly vertical, an L-bend should be provided at its bottom end and each bar should be held by a tripod of bamboos or other spare reinforcing bars till such time that the concrete filled in the pocket around the bar is fully set and capable of holding the bar in vertical position.
- iv) A minimum overlap of 50x diameter of bar should be provided. The overlap should be bound by wrapping the binding wire around it.
- v) The cover to any bar (main or distribution) should be kept 15mm minimum and 20 mm maximum in concrete slabs used as floor or roof. The cover in beams to the main bars should not be less than 25 mm and to the stirrups not less than 15 mm.

For achieving proper cover, either cover blocks of 1:3 cement sand mortar of required thickness or PVC cover parts should be used.

### **13.7.5 Reinforced Concrete Lintels And Slabs**

#### **a) Concrete mix**

The concrete mix shall be M 20 (1:1.5:3 nominal) using cement, coarse sand and crushed grit of less than 20 mm size. The slump should not exceed 10 cm

and the concrete should be compacted by rods using 16mm bars of about 600 mm length. Use of vibrator will, of course, be better keeping the slump of about 5 cm. When the mix is to be designed to give the characteristic strength of 20 Mpa, the target strength in the mix design should be 26.5 Mpa on 150mm cubes at the age of 28 days. For quality control on the concrete mix during construction, regular sampling and testing of concrete using 150mm cubes should be carried out and the concrete should give an average strength at 28 days of 24 Mpa, the individual cube strength lying between  $\pm 15\%$  of the mean strength obtained.

**b) Slope in the flat RCC roofs**

To prevent ponding of water on the roof and consequent leakage, the concrete roofs must be laid so as to have a minimum camber of 1/200 of span at the centre and a minimum slope of about 1 in 60. That is, for a roof width of 3 to 4m, the camber may be kept as 15 to 20 mm and the height difference between the opposite edges should be about 50 to 60 mm. It is further suggested that the roof slab be kept projecting beyond the wall with a minimum of 75 mm at the lower edge and provided with a drip course.

**c) Curing of Concrete/Plaster**

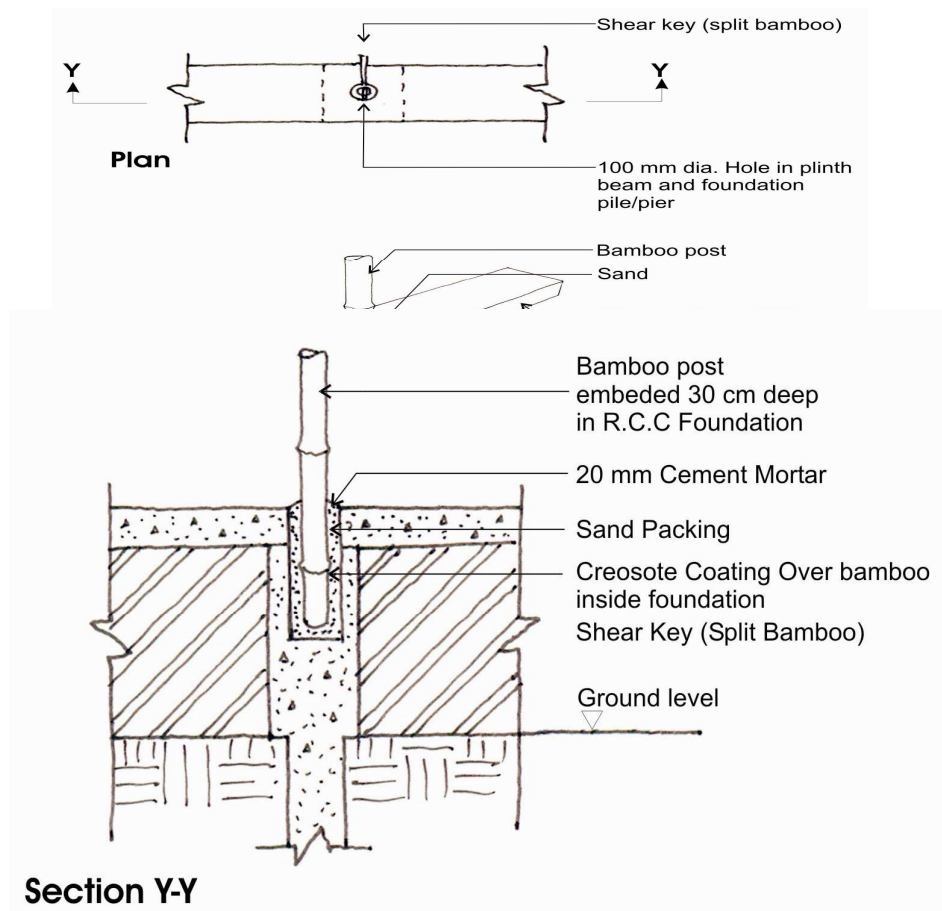
Exposed surface of concrete or plaster should be kept continuously in a damp or wet condition by ponding or by covering with a layer of sacks, canvas, Hessian or similar materials and kept constantly wet for at least seven days from the date of placing concrete in case of ordinary Portland Cement of 43 Grade. The period of curing shall not be less than 10 days for concrete exposed to dry and hot weather conditions.

**13.8 Safety Provisions Required For Bamboo Superstructure**

**13.8.1 Posts**

- i) Use only mature Harot (Bambusa Balcooa) variety of bamboo for structural posts and main beams.
- ii) All structural bamboo should be treated chemically to conform to IS 9096: 2006.

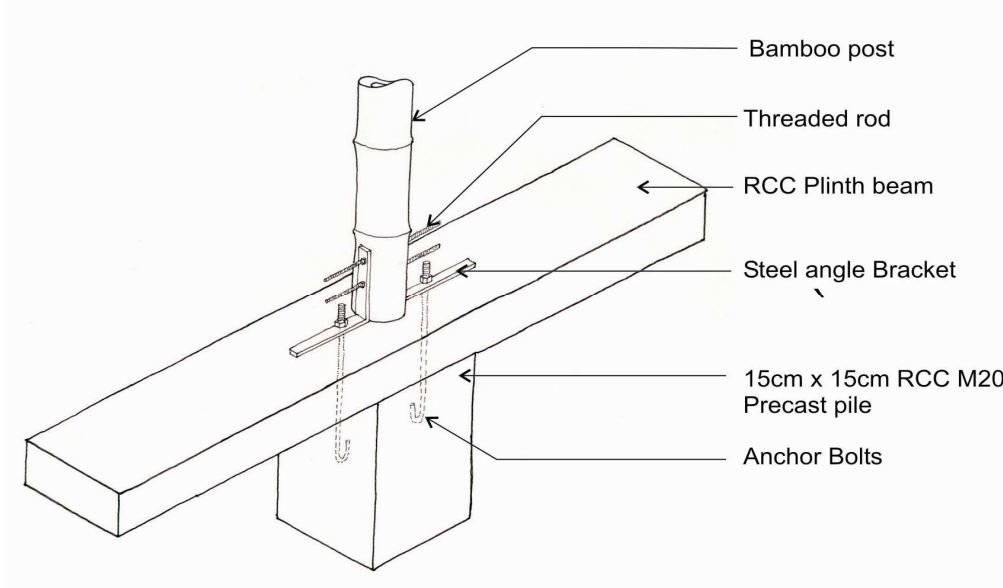
- iii) The distance between two posts shall be not more than 1.2 m centre to centre.
- iv) Minimum diameter of bamboo posts at thinner and shall be not less than 70 mm in any case and preferably 90 mm.
- v) Unsupported height of the post shall be not more than 3.0 m. If the height of the post is longer, a horizontal tie of the bamboo shall be provided.
- vi) Tar or Creosote treatment at the bottom of the post is required that needs to be embedded in the plinth.
- vii) A 30 cm deep and 100 mm dia. hole shall be made in the plinth beam and the foundation pile/pier below to embed and fix the bamboo post. The post shall be erected in this hole and clean sand shall be filled and compacted around the post in the hole. A shear key of split bamboo shall be fixed through the plinth beam and the bamboo post as per **Fig. 13.7**.





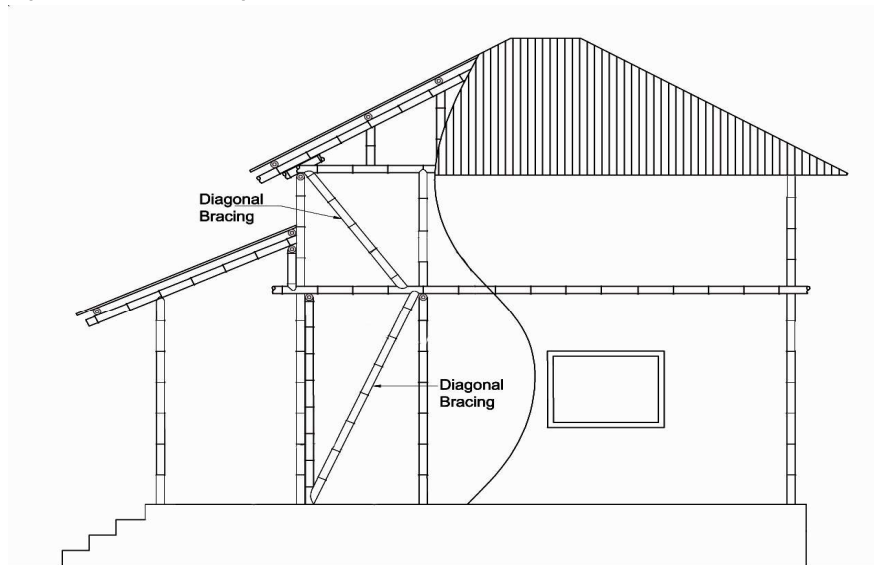
**Fig. 13.7 Fixing Detail of Bamboo Post Into Plinth Masonry**

- viii) Alternatively, the bamboo post can be fixed with bolts to the plinth. In this case, bolts shall be embedded at appropriate places at the time of casting plinth beam (Fig. 13.8).



**Fig. 13.8 Fixing Detail of Bamboo To Plinth Using Bolted Connection**

- ix) Diagonal bracing between the posts in each wall at the corners from plinth level end to attic level end shall be provided. It shall be mirrored in the opposite corners of the wall as shown in Fig 13.9. Alternatively, knee bracings may be provided at each post to connect post and the attic level beam.



**Fig. 13.9 Diagonal bracing for earthquake and wind resistance**

- x) Additional bamboo should be bundled with the posts for supporting main beams of the attic. This bamboo shall be tied to the post at least at 3 places and be rested on the plinth beam.

### **13.8.2 Walling Lattice (Wattle And Daub)**

- i) The wall shall be made out of wattle and daub.
- ii) For latticework between the posts, any mature split bamboo – Harot, Chab or Makhaur shall be used. Traditionally, Chab is used more often.
- iii) The bamboo strips shall be coarsely woven (vertical weft and horizontal warp).
- iv) This bamboo shall be treated as per the IS 1902: 2006 recommendations for non-structural bamboo.
- v) For lattice, *jafri* (the woven mat of split bamboo) may be used. This provides skeleton for daub work.
- vi) Lattice shall be tied properly to the posts and the eave level beam.
- vii) The inside of the wall panel shall be mud/cement plastered and outside will be cement plaster.

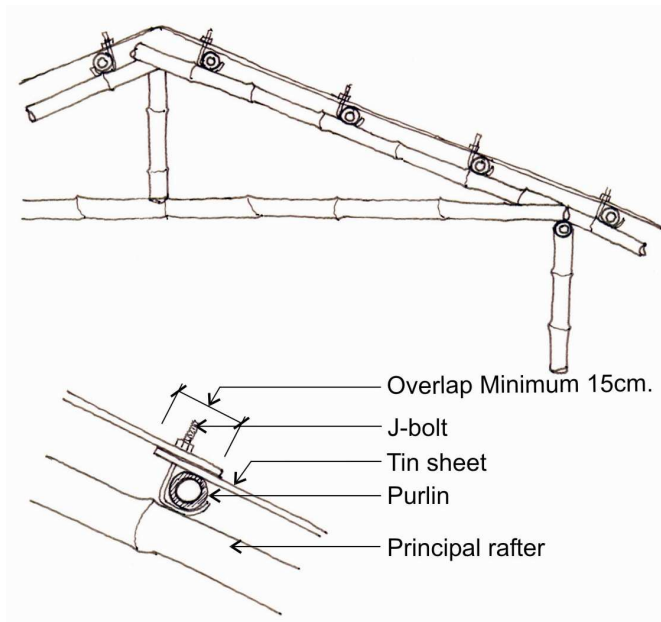
### **13.8.3 Attic-Level Floor (Fig. 13.5)**

- i) In all bamboo houses, attic is non- negotiable for flood safety. It shall be strong enough to take live load along with dead load in flood conditions.
- ii) The attic height at the eave level shall be minimum 75 cm and the clear storey height below attic shall be minimum 2.1 m.
- iii) Total area of the attic shall be minimum 10 m<sup>2</sup>.
- iv) Diagonal bracing or knee bracing in the posts above attic level shall be done.
- v) Only mature Harot bamboo shall be used for beams.
- vi) For the span more than 3 m, the main beams shall be made by bundling at least 2 bamboos (minimum 75 mm) placed one on top the other and tied together with shear pins or three bamboos tied tighter in star pattern. For smaller spans, single bamboo beams will be enough. These bamboo beams shall be placed on bundled posts as explained earlier.
- vii) Bamboos (minimum 60 mm in diameter) as secondary beams on main beams shall be placed at distance of not more than 60 cm. Secondary beams shall be tied to main beams at each junction.

### 13.8.4 Pitched Roofs

Houses with bamboo walls can have following type of roofs.

- a) CGI sheet roofs – hipped or gable
- b) Burnt clay tile roof – hipped or gable
- i) The understructure for roofs can be made with bamboo or wood.
- ii) For roof understructure, mature Harot or Chab varieties of bamboo shall be used.
- iii) The spacing between principal rafters shall not be more than 60 cm in case of CGI sheet roofs; in case of burnt clay tiles, it shall be not more than 30 cm.
- iv) The slope of the roof shall be as per relevant IS codes. In case of burnt clay tile roofs, the slope shall be minimum  $29^{\circ}$ , in sheet roofs  $22.5^{\circ}$  to avoid suction.
- v) The roof shall have an overhang of minimum 45 cm on all four sides.
- vi) In case of CGI sheets, it needs to be fixed with the understructure by using J-bolts with galvanised and bitumen washers to make it waterproof. Nails shall not be used for anchoring. See Fig. 13.10.



**Fig. 13.10 Fixing Details of Tin Sheets Using J-Bolts**

- vii) The J-bolts shall be galvanised and have minimum 6 mm diameter. J-bolts shall hold up to at least half the diameter of bamboo purlin as shown in **Fig. 13.10**.

- viii) The spacing between two consecutive J-bolts shall not be more than 45 cm.
- ix) In case of burnt clay tile roofs, cross bracing shall be provided with wire.
- x) The last row of burnt clay tiles shall be held by sandwiching them between split bamboo strips so as to ensure the tiles are not blown away due to high winds or slide off.

### **13.9 A Few Examples Of Earthquake And Wind-Resistant Bamboo Constructions**

– based on

structural design basis as per relevant codes.

#### **13.9.1 School at Mizoram**

The design is shown in figures 13.11



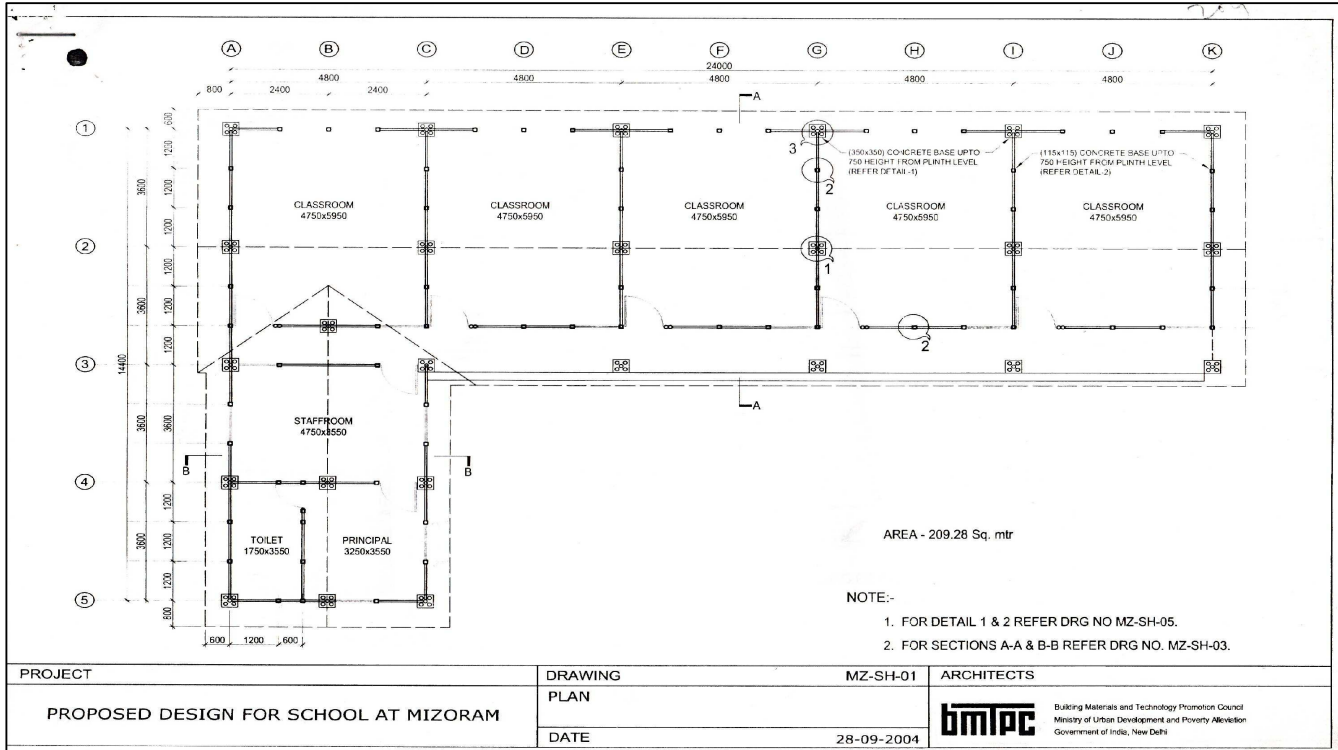
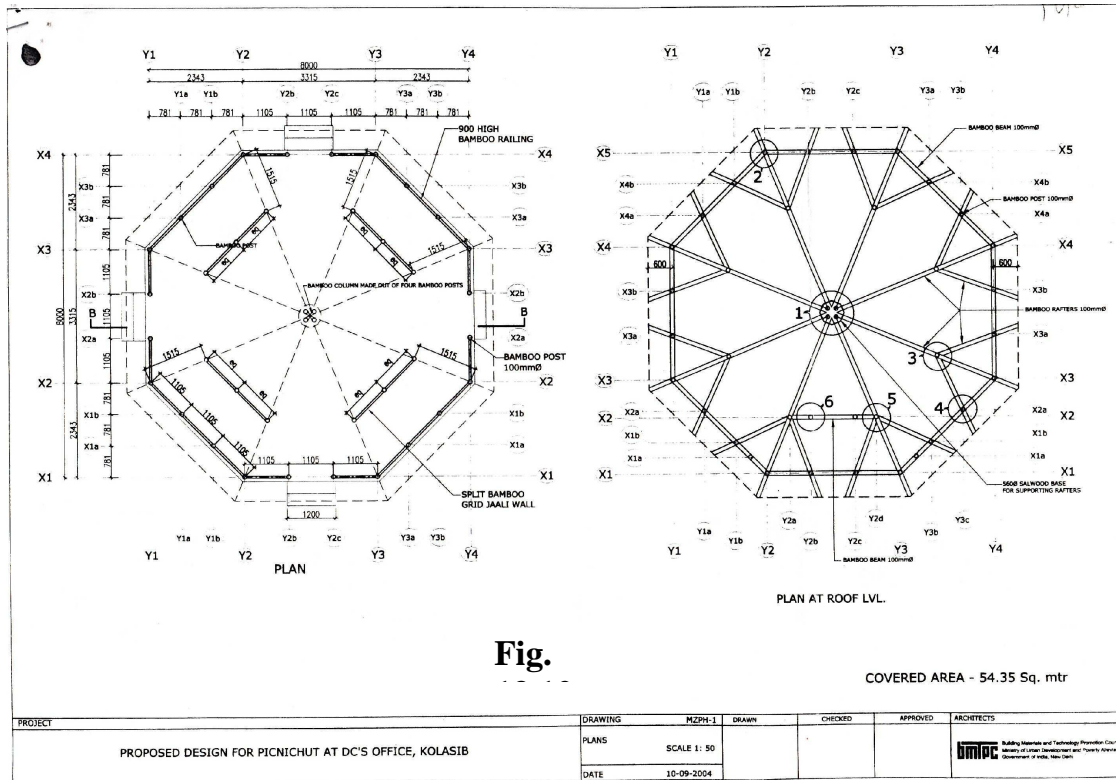


Fig. 13.11

### 13.9.2 Picnic Hut At DC's Office Kolasid Mizoram

The design of the building shown in figure 13.12 along with photograph thereof. The some design details are shown in figure 13.13 below:





### 13.10 References

1. BIS. (2006). Preservation of Bamboo for Structural Purpose- Code of Practice, IS: 6874-2006. New Delhi: BIS.
2. BIS. (2006). Preservation of Bamboo and Cane for Non- Structural Purposes- Code of Practice, IS: 1902- 2006. New Delhi: BIS.
3. Oberoi, V. S. (2004). The book of Bamboo. New Delhi: NMBA, TIFAC, DST (GoI).
4. Oberoi, V. S. (2004). Building with Bamboo. New Delhi: NMBA, TIFAC, DST (GoI).
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6. Bamboo in Housing & Building Construction – Institute of BMTPC and BMTPC Annual Reports 2003/4/2005/7.



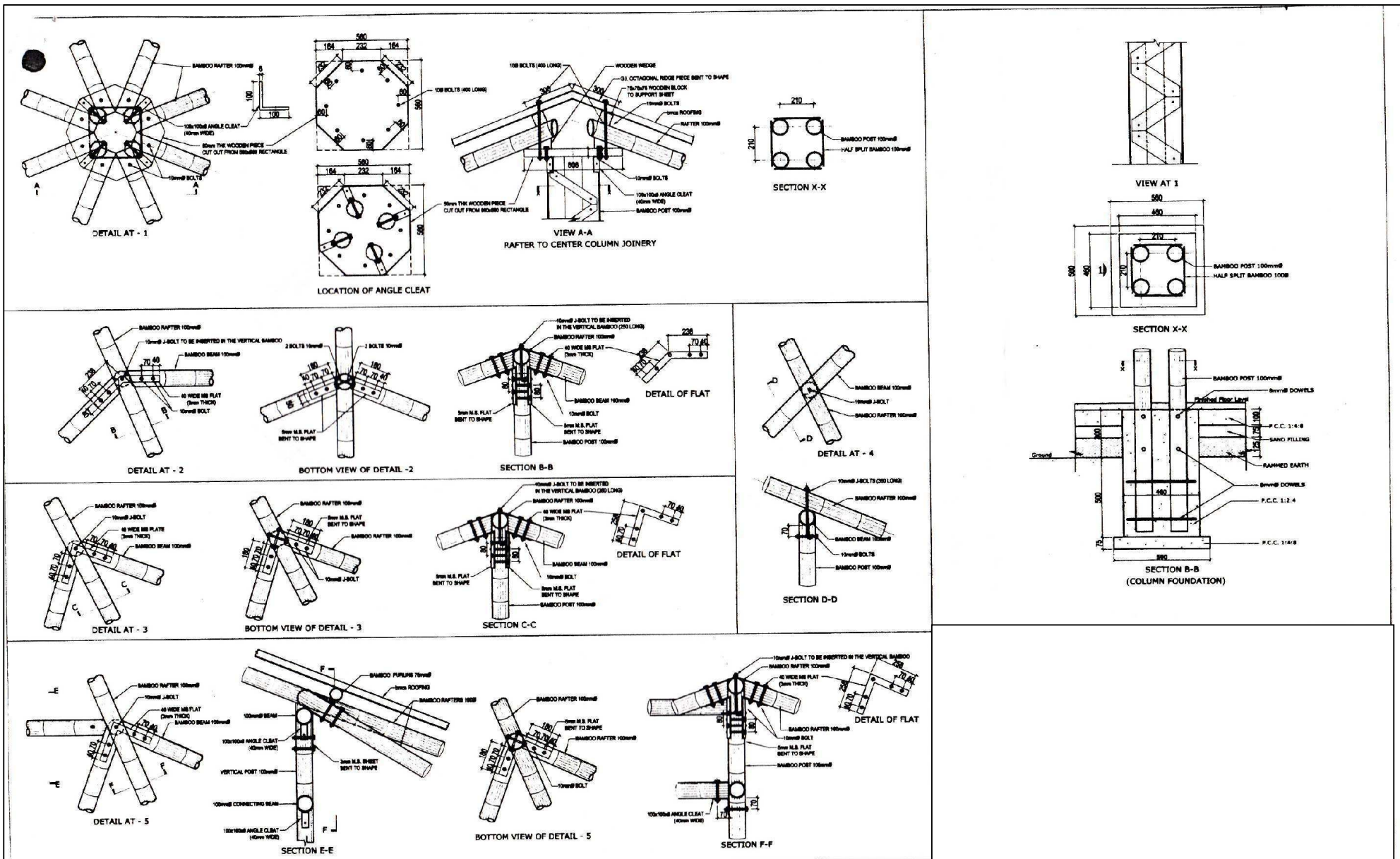


Fig. 13.13 Bamboo Construction Details

## **14. Checklists For Ensuring Disaster Safety of Building Projects**

### **14.1 Housing proposals**

While preparing housing proposals, implementation of disaster risk reduction must be taken into consideration. The essential information which needs to be collected and submitted as part of detailed project report for soliciting approval of the competent authorities is collected in Table 4.1 for ready reference.

### **14.2 Data To Be Submitted With A Building Project**

Tables 14.2 to 14.5 present the data required so as to prepare appropriate design basis report. These tables are extracted from Form No. 6 of Proposed Amendment in Town & Country Planning Legislations, Regulations for Land Use zoning, Additional Provisions in Development Control Regulations for Safety & Additional Provisions in Building Regulations/Bylaws for Structural Safety – in Natural Hazard Zones of India, by Expert Group appointed by Ministry of Home Affairs, Govt. of India. Table 14.2 presents the required general information about building project. Table 14.3 covers the design information required on load bearing masonry buildings. Table 14.4 gives the details to be furnished in regard to reinforced concrete frame buildings and table 14.5 covers the building frames to be constructed in structural steel. Depending upon the material of the building project chosen, the relevant table for that material has to be referred to along with Table 14.2 covering general aspects of the buildings.

### **14.3 Review Of Building Design**

Special buildings, like convention halls, entertainment hall, commercial hall as in malls, halls for educational and hospital buildings as well as tall buildings constructed more than six storeys are supposed to be reviewed by designated structural experts before taking up their construction.

### **14.4 Inspection And Technical Audit**

In order to ensure appropriate quality control in the selection of material, preparation of concrete, bending and placing of reinforcement in beams, columns and shear walls etc. and to ensure the construction to be in conformity with design drawings, inspection by competent engineers/supervisor will be necessary at various stages of the building



construction. A pro forma is given in Table 14.6 for recording the item of technical audit after each inspection.

**TABLE 14.1**  
**Implementation of DRR in housing schemes**  
**[Essential Information to be submitted as part of Detailed Project Report (DPR)]**

Sr. No.	Topics
<b>1.</b>	<b><i>General Information of the Project</i></b>
1.1	Address - Name of the project: - State: - District:
1.2	Siting of the building project - Location of project site - Latitude - Longitude - Height above mean sea level
<b>2.</b>	<b><i>Nature/type of project:</i></b> All the projects of the nature/type mentioned below are liable to damage by natural disasters and inadequacies of design or any of their components
2.1	Communications: Towers, building
2.2	Transportation: Bus/railway stations
2.3	Power: Powerhouses, substations
2.4	Habitations: Township planning
2.5	Water supply and sanitation projects, pump houses
2.6	Building projects
<b>3.</b>	<b><i>Hazard proneness of the project site</i></b>
3.1	Earthquake Zone (Any known geological fault near by may be listed)
3.2	Flood proneness & vulnerability: g. Past history of floods in the area h. Observed highest flood level i. Frequency of flooding j. Depth of flooding k. Duration of flooding l. Damage/loss (maximum, average, potential)
3.3	Cyclone proneness (If close to sea coast) & vulnerability: a. Frequency and intensity b. Wind speed zone – information on highest wind speed c. Distance of site from sea coast d. Record of past storm surge/tsunami
3.4	Landslide proneness & vulnerability: a. Location of hill slope vis-à-vis the project's location b. Past history of landslides, c. Possibility of mudflows/rock falls/snow avalanches, etc.
<b>4</b>	<b><i>Hazards risk to the project -- have the following been evaluated:</i></b>
4.1	Probable maximum seismicity at site
4.2	Probable maximum storm surge
4.3	Probable maximum wind speed
4.4	Probable maximum precipitation
4.5	Probable maximum flood discharge and level
4.6	Probable occurrence of floods, earthquakes, landslides, mudflows, avalanches, cyclones, tsunamis
4.7	Soil liquefaction proneness under probable earthquake intensities

**Table 14.2 General Data**

S.No.	Description	Information	Notes
1	<b>Address of the building</b> <ul style="list-style-type: none"> <li>• Name of the building</li> <li>• Plot number</li> <li>• Subplot number</li> <li>• TPS scheme                             <ul style="list-style-type: none"> <li>a. Name</li> <li>b. Number</li> </ul> </li> <li>• Locality/Township</li> <li>• District</li> </ul>		
2	Name of owner		
3	Name of Builder on record		
4	Name of Architect/Engineer on record		
5	Name of Structural engineer on record		
6	Use of the building		
7	Number of storeys above ground level (including storeys to be added later, if any)		
8	Number of basements below ground level		
9	<b>Type of structure</b> <ul style="list-style-type: none"> <li>• Load bearing walls</li> <li>• R.C.C frame</li> <li>• R.C.C frame and Shear walls</li> <li>• Steel frame</li> </ul>		
10	<b>Soil data</b> <ul style="list-style-type: none"> <li>• Type of soil</li> <li>• Design safe bearing capacity</li> </ul>		IS: 1893 Cl. 6.3.5.2 IS: 1904
11	<b>Dead loads (unit weight adopted)</b> <ul style="list-style-type: none"> <li>• Earth</li> <li>• Water</li> <li>• Brick masonry</li> <li>• Plain cement concrete</li> <li>• Reinforced cement concrete</li> <li>• Floor finish</li> <li>• Other fill materials</li> <li>• Piazza floor fill and landscape</li> </ul>		IS: 875 Part 1

## Mainstreaming Disaster Risk Reduction In Housing Sector

Table 14.3 Load Bearing Masonry Buildings																				
S.No.	Description	Information			Notes															
1	Building category				IS:4326 Cl. 7 read with IS: 1893  <table border="1" style="margin-left: auto; margin-right: auto;"> <tr> <td style="text-align: center;">Bldg \ Zone</td> <td style="text-align: center;">II</td> <td style="text-align: center;">III</td> <td style="text-align: center;">IV</td> <td style="text-align: center;">V</td> </tr> <tr> <td style="text-align: center;">Ordinary</td> <td style="text-align: center;">B</td> <td style="text-align: center;">C</td> <td style="text-align: center;">D</td> <td style="text-align: center;">E</td> </tr> <tr> <td style="text-align: center;">Important</td> <td style="text-align: center;">C</td> <td style="text-align: center;">D</td> <td style="text-align: center;">E</td> <td style="text-align: center;">E</td> </tr> </table>	Bldg \ Zone	II	III	IV	V	Ordinary	B	C	D	E	Important	C	D	E	E
Bldg \ Zone	II	III	IV	V																
Ordinary	B	C	D	E																
Important	C	D	E	E																
2	Basement Provided																			
3	Number of floors including Ground Floor (all floors including stepped floors in hill slopes)																			
4	Type of wall masonry																			
5	Type and mix of Mortar				IS:4326 Cl. 8.1.2															
6	<b>Re: size and position of openings (See note No.1)</b> <ul style="list-style-type: none"> <li>• Minimum distance (b<sub>5</sub>)</li> <li>• Ratio (b<sub>1</sub>+b<sub>2</sub>+b<sub>3</sub>)/l<sub>1</sub> or (b<sub>6</sub>+b<sub>7</sub>)/l<sub>2</sub></li> <li>• Minimum pier width between consequent opening (b<sub>4</sub>)</li> <li>• Vertical distance (h<sub>3</sub>)</li> <li>• Ratio of wall height to thickness<sup>4</sup></li> <li>• Ratio of wall length between cross wall to thickness</li> </ul>				IS:4326 Table 4, Fig.7															
7	<b>Horizontal seismic band</b> <ul style="list-style-type: none"> <li>• at plinth level</li> <li>• at window sill level</li> <li>• at lintel level</li> <li>• at ceiling level</li> <li>• at eave level of sloping roof</li> <li>• at top of gable walls</li> <li>• at top of ridge walls</li> </ul>	<b>P</b> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	<b>IP</b> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	<b>NA</b> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	(see note no.2)  IS:4326 Cl. 8.4.6 IS:4326 Cl. 8.3 IS:4326 Cl. 8.4.2 IS:4326 Cl. 8.4.3 IS:4326 Cl. 8.4.3  IS:4326 Cl. 8.4.4															
8	<b>Vertical reinforcing bar</b> <ul style="list-style-type: none"> <li>• at corners and T junction of walls</li> <li>• at jambs of doors and window openings</li> </ul>	<input type="checkbox"/>  <input type="checkbox"/>	<input type="checkbox"/>  <input type="checkbox"/>	<input type="checkbox"/>  <input type="checkbox"/>	IS:4326 Cl. 8.4.8  IS:4326 Cl. 8.4.9															

**Mainstreaming Disaster Risk Reduction In Housing Sector**

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9	Integration of prefab roofing/flooring elements through reinforced concrete screed	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	IS:4326 Cl. 9.1.4
10	<b>Horizontal bracings in pitched truss</b> <ul style="list-style-type: none"> <li>• in horizontal plane at the level of ties</li> <li>• in the slopes of pitched roofs</li> </ul>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	
		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	

**Notes**

1. Information in item 6 should be given on separate A4 sized sheets for all walls with large number of openings.
2. P indicated "Information Provided"  
 TP indicates "Information to be Provided"  
 NA indicates "Not Applicable"  
 Tick mark one box

**Mainstreaming Disaster Risk Reduction In Housing Sector**

**Table 14.4 Reinforce Concrete Framed Buildings**

Sl no	Description	Information	Notes
1	<b>Type of Building</b> <ul style="list-style-type: none"> <li>• Regular frames</li> <li>• Regular frames with Shear walls</li> <li>• Irregular frames</li> <li>• Irregular frames with shear walls</li> <li>• Soft storey</li> </ul>		IS: 1893 Cl. 7.1
2	Number of basements		
3	Number of floors including ground floor		
4	<b>Horizontal floor system</b> <ul style="list-style-type: none"> <li>• Beams and slabs</li> <li>• Waffles</li> <li>• Ribbed Floor</li> <li>• Flat slab with drops</li> <li>• Flat plate without drops</li> </ul>		
5	<b>Soil data</b> <ul style="list-style-type: none"> <li>• Type of soil</li> <li>• Recommended type of foundation                             <ul style="list-style-type: none"> <li>- Independent footings</li> <li>- Raft</li> <li>- Piles</li> </ul> </li> <li>• Recommended bearing capacity of soil</li> <li>• Recommended, type, length, diameter and load capacity of piles</li> <li>• Depth of water table</li> <li>• Chemical analysis of ground water</li> <li>• Chemical analysis of soil</li> </ul>		IS: 1498
6	<b>Foundations</b> <ul style="list-style-type: none"> <li>• Depth below ground level</li> <li>• Type                             <ul style="list-style-type: none"> <li>▪ Independent</li> <li>▪ Interconnected</li> <li>▪ Raft</li> <li>▪ Piles</li> </ul> </li> </ul>		
7	<b>System of interconnecting foundations</b> <ul style="list-style-type: none"> <li>• Plinth beams</li> <li>• Foundation beams</li> </ul>		IS: 1893 Cl. 7.12.1
8	Grades of concrete used in different parts of building		
9	Method of analysis used		
10	Computer software used		
11	Torsion included		IS: 1893 Cl. 7.9



## Mainstreaming Disaster Risk Reduction In Housing Sector

12	<b>Base shear</b> <ol style="list-style-type: none"> <li>a. Based on approximate fundamental period</li> <li>b. Based on dynamic analysis</li> <li>c. Ratio of a/b</li> </ol>		IS: 1893 Cl. 7.5.3
13	Distribution of seismic forces along the height of the building		IS:1893 Cl. 7.7 (provide sketch)
14	The column of soft ground storey specially designed		IS:1893 Cl. 7.10
15	<b>Clear minimum cover provided in</b> <ul style="list-style-type: none"> <li>• Footing</li> <li>• Column</li> <li>• Beams</li> <li>• Slabs</li> <li>• Walls</li> </ul>		IS: 456 Cl. 26.4
16	<b>Ductile detailing of RC frame</b> <ul style="list-style-type: none"> <li>• Type of reinforcement used</li> <li>• Minimum dimension of beams</li> <li>• Minimum dimension of columns</li> <li>• Minimum percentage of reinforcement of beams at any cross section</li> <li>• Maximum percentage of reinforcement at any section of beam</li> <li>• Spacing of transverse reinforcement in 2-d length of beams near the ends</li> <li>• Ratio of capacity of beams in shear to capacity of beams in flexure</li> <li>• Maximum percentage of reinforcement in column</li> <li>• Confining stirrups near ends of columns and in beam-column joints                             <ol style="list-style-type: none"> <li>a. Diameter</li> <li>b. Spacing</li> </ol> </li> <li>• Ratio of shear capacity of columns to maximum seismic shear in the storey</li> </ul>		IS: 456 Cl. 5.6 IS:13920 Cl. 6.1 IS:13920Cl. 7.1.2 IS: 456 Cl. 26.5.1.1(a) IS:13920 Cl. 6.2.1 IS: 456 Cl. 26.5.1.1(b) IS:13920 Cl. 6.2.2 IS: 13920 Cl. 6.3.5  IS: 456 Cl. 26.5.3.1  IS: 13920 Cl. 7.4

### General Notes

1. A certificate to the effect that this report will be completed and submitted at least one month before commencement of Construction shall be submitted with the application for Building Development Permission.
2. In addition to the completed report following additional information shall be submitted, at the latest, one month before commencement of Construction.
  - 2.1 Foundations
    - 2.1.1 In case raft foundation has been adopted indicate K value used for analysis of the raft
    - 2.1.2 In case pile foundations have been used give full particulars of the piles, type, dia, length, capacity
    - 2.1.3 In case of high water table indicate system of countering water pressure, and indicate the existing water table, and that assumed to design foundations.
  - 2.2 Idealization for Earthquake analysis
    - 2.2.1 In case of a composite system of shear walls and rigid frames, give distribution of base shear in the two systems on the basis of analysis, and that used for design of each system.
    - 2.2.2 Indicate the idealization of frames and shear walls adopted in the analysis with the help of sketches.
  - 2.3 Submit framing plans of each floor
  - 2.4 In case of basements, indicate the system used to contain earth pressures

**Table 14.5 Buildings in Structural Steel**

<b>S. No.</b>	<b>Description</b>	<b>Information</b>	<b>Notes</b>
4.7	<b>Adopted method of design</b>		
(a)	Simple		IS: 800; Cl. 3.4.4
	Semi-rigid		IS: 800; Cl. 3.4.5
	Rigid		IS: 800; Cl. 3.4.6
4.7	<b>Design based on</b>		
(b)	Elastic analysis		IS: 800; Section-9
	Plastic analysis		SP: 6 (6)
4.3	<b>Floor construction</b>		
	Composite		
	Non-composite		
	Boarded		
4.4	<b>Roof construction</b>		
	Composite		
	Non-composite		
	Metal		
	Any other		
4.5	<b>Horizontal force resisting system</b>		
	Monsanto-resistant frames		<b>Note: Seismic force As per IS: 1893 would depend on system</b>
	Braced frames		
	Frames & shear walls		
4.8	<b>Slenderness ratios maintained</b>		
	Members defined in Table 3.1		IS: 800; Cl. 3.7
4.9	<b>Member deflection limited to</b>		
	Beams, Rafters, Crane, Girders, Purlins		
	Top of Columns		IS: 800; Cl. 3.13

4.1	<b>Structural members</b>		
	Encased in concrete		IS: 800; Section-10
	Not encased		
4.2	<b>Proposed material</b>		
	General weld-able		IS: 2062
	High strength		IS: 8500
	Cold formed		IS: 801, 811
	Tubular		IS: 806
4.11	<b>Minimum metal thickness for corrosion protection</b>		
	Hot rolled sections		IS: 800, Cl. 3.8
	Cold formed sections		Cl. 3.8.1 to Cl. 3.8.4
	Tubes		Cl. 3.8.5
4.6	<b>Structural connections</b>		
	Rivets		IS: 800; Section-8
	C T bolts		IS: 1929,2155,1149
	S H F G bolts		IS: 6639, 1367
	Black bolts		IS: 3757, 4000
	Welding field		IS: 1363, 1367
	Welding shop		IS: 816, 814, 1395,
			7280, 3613, 6419, 6560, 813, 9595
	Composite		
4.12	<b>Minimum fire rating</b>		
	Rating ----- hours		IS: 1641, 1642, 1643
	Method proposed-		
	In tumescent painting		
	Spraying		
	Quilting		
	Fire retardant boarding		



**TABLE 14.6 Pro forma for technical audit**

	<b>Item</b>	<b>Comments</b>
<b>1.</b>	<b>Design</b>	
1.1	Design/drawings available?	Y/N
1.2	Design category <ul style="list-style-type: none"> <li>• Type design?</li> <li>• Specific design? If yes, design to be shown to technical auditor</li> </ul>	Y/N Y/N
1.3	Drawings prepared/checked by competent authority?	Y/N
1.4	Design drawings/details <ul style="list-style-type: none"> <li>• Structural detail included?</li> <li>• Earthquake/wind resistant features included?</li> </ul>	Y/N Y/N
1.5	Design verified/vetted by Dept./Govt. approved agency/competent authority?	Y/N
1.6	Design changes approved by Dept./Govt. approved agency/competent authority?	Y/N
<b>2.</b>	<b>Foundation</b>	
2.1	Foundation used	Existing/New
2.1.1	Depth of foundation below ground	<50cm/50-70/>70cm
2.1.2	Type of masonry	Stone/Bricks/PCC Blocks
2.1.3	Thickness of masonry (above ground)	23cm/35/>35 cm
2.1.4	Mortar used	Cement-Sand/Lime/Mud
2.1.5	Mix of cement mortar	1:4/1:6/Leaner
2.1.6	Height up to plinth	<60/>60 cm
2.1.7	If stone masonry <ul style="list-style-type: none"> <li>• Through stones</li> <li>• Corner stones</li> </ul>	Yes/No, if Yes Adequate/Inadequate Yes/No, if Yes Adequate/Inadequate
2.2	Reinforcement in foundation	Yes/No / NA
<b>3.</b>	<b>Walling</b>	
3.1	Type of masonry	Stone/Brick/PCC Blocks
3.2	Mortar used	Cement – Sand/Lime/Mud
3.3	Mix of cement mortar	1:4/1:6/Leaner
3.4	Thickness of wall	>23cm/23cm/<23cm
3.5	Joint properly filled	OK/NOT OK
3.6	If stone masonry <ul style="list-style-type: none"> <li>• Through stones</li> <li>• Corner stones</li> </ul>	Yes/No Yes/No
3.7	Overall workmanship	Good / Medium / Poor
<b>4.</b>	<b>Roofing</b>	
4.1	Type of roof	Flat/Sloping
4.2	If sloped	Morbi tiles/ A.C. sheet/ G.I.

**Mainstreaming Disaster Risk Reduction In Housing Sector**

		sheet
4.3	Purlins	Angle-Iron / Timber / other
4.4	Truss type	Steel / Timber / Other
4.5	Anchorage with wall	Adequate/ Inadequate
<b>5.</b>	<b>Materials</b>	
<b>5.1</b>	<b>Cement</b>	
5.1.1	Type of cement	OPC/PPC/PSC
5.1.2	If OPC	Grade (33/ 43/ 53)
<b>5.2</b>	<b>Sand</b>	
5.2.1	Source	Quarry / Dealer
5.2.2	Type of sand	River sand / Stone dust
5.2.3	Presence of deleterious materials	Mild / Moderate/ High
<b>5.3</b>	<b>Coarse aggregates</b>	
5.3.1	Source	Quarry / Dealer
5.3.2	Type of coarse aggregates	Gravel/ Crushed Stone
5.3.3	Presence of deleterious material	Mild/ Moderate / High
<b>5.4</b>	<b>P.C.C. blocks</b>	
5.4.1	Source	Onsite Maker/ Dealer
5.4.2	Type of P.C.C. blocks	Solid blocks/Hollow blocks
5.4.3	Ratio of concrete in blocks	Mix
5.4.4	Interlocking feature	Yes/No
<b>5.5</b>	<b>Bricks blocks, hewn stone, etc.</b>	
5.5.1	Source	Quarry / Dealer
5.5.2	Strength (field assessment)	Low/Medium/High
5.5.3	Dimensional accuracy	Yes/No
<b>5.6</b>	<b>Concrete</b>	
5.6.1	Mix of concrete	(1:1 ½:3)/ (1:2:4)/Design Mix
5.6.2	Batching	Weigh batching/Volume batching
5.6.3	Compaction	Vibrators/Thappies and rods
5.6.4	Workability	Low / Medium / High
5.6.5	Availability of water	Sufficient / Insufficient
5.6.6	Curing	Satisfactory/Unsatisfactory.
<b>5.7</b>	<b>Reinforcing steel</b>	
5.7.1	Type of steel	Plain mild steel/HYSD bars
5.7.2	Source	Authorised Dealer/Market
5.7.3	Whether IS marked	Yes/No
5.7.4	Conditions of bars	Clean/Corroded / Cleaned
5.7.5	Fixing of reinforcement as per drawing	Yes/No
5.7.6	Suitable cover	Yes/No
5.7.7	Spacing of bars	Regular/Irregular
5.7.8	Overlaps as per specifications	Yes/ No
<b>5.8</b>	<b>Form work</b>	
5.8.1	Type of form work	Timber/Plyboard/ Steel
5.8.2	Use of mould oil	Yes/No
5.8.3	Leakage of cement slurry	Observed/Not observed
<b>6.</b>	<b>Seismic resistance features-</b>	

	<b>masonry buildings</b>		
<b>6.1</b>	<b>Provision of adequate bands at</b>		
6.1.1	Plinth level	Yes/No	
6.1.2	Sill level	Yes/No	
6.1.3	Lintel level	Yes/No	
6.1.4	Flat roof level (if applicable)	Yes/No	
6.1.5	If sloped roof		
	• Gable wall top	Yes/No	
	• Eaves level	Yes/No	
<b>6.2</b>	<b>Provision of adequate vertical steel at</b>		
6.2.1	Each corner	Yes/No	
6.2.2	Each T-junction	Yes/No	
6.2.3	Each door jamb	Yes/No	
6.2.4	Around each window > 900 mm wide	Yes/No	
<b>6.3</b>	<b>Openings</b>		
6.3.1	Total width of openings ratio to wall length (percent)	33/33-42/42-50/>50	
6.3.2	Clearance from corner	OK/Not OK	
6.3.3	Pier width between two openings	OK/Not OK	
<b>7.</b>	<b>Seismic resistance features -RC frames</b>		
7.1	Ductile detailing	Done / Note Done	
7.2	Spacing of stirrup	OK/Not OK	
7.3	Sizes of members	OK/Not OK	
7.4	End anchorage	OK/Not OK	
7.5	Lapping (length, location etc.)	OK/Not OK	
7.6	Angle of stirrup hook	90 / 135 degrees	
<b>8.</b>	<b>Testing carried out by owner/engg. supervisor</b>	<b>Testing done</b>	<b>Testing results</b>
8.1	Water	Yes/No	OK/Not OK
8.2	Cement	Yes/No	OK/Not OK
8.3	Bricks/PCC blocks/stones	Yes/No	OK/Not OK
8.4	Aggregate	Yes/No	OK/Not OK
8.5	Mortar	Yes/No	OK/Not OK
8.6	Concrete	Yes/No	OK/Not OK
8.7	Reinforcement	Yes/No	OK/Not OK

**Reference:**

- Proposed Amendment in Town & Country Planning Legislations, Regulations for Land Use zoning, Additional Provisions in Development Control Regulations for Safety & Additional Provisions in Building Regulations / Bylaws for Structural Safety – in Natural Hazard Zones of India, Volume I published by BMTPC on behalf of Ministry of Home Affairs Govt. of India, 2004.

## 15 The Checklist For Stakeholders

The successful implementation of the framework given in the Report, for Mainstreaming of DRR in housing sector is possible to be achieved through a strong national commitment supported by a participatory process involving all the stakeholders. Firstly, the stakeholders should be aware of their own lines of responsibility and should be empowered for efficient discharge of such responsibilities which may require inter-sectoral cooperation and operational linkages into development planning. An adaptation plan specific to housing sector will include following activities, which would be adequately supported through policy based on decentralised planning at national, state and local government levels, private sector players along with participation from civil society and communities and with allocated budgets to address the various related disaster risk reduction issues and activities.

With a view to effectively implement the Guidelines given in the foregoing chapters, following checklist is recommended,

### 15.1 Does The Goals Of The Disaster Management Act 2005 Support The Concept Of DRR – And Indicates A National Commitment?

Actions —	If the Act is silent, decide what needs to done and at what level?
Supporting intention	} Paradigm shift from relief centric approach – to proactive approach of prevention, mitigation & prepared
National policy of DM	
recognises – Disaster Risk Reduction	

### 15.2 Project, Programme & Planning – Project

To assess whether DRR concerns / issues have been considered in the proposed project, the pro forma given in **Chapter 14, Table 14.1** should be filled and evaluated.

Has information on significant natural hazards effecting the project acquired, collated and analysed?

If not, the Head of the team should be given freedom to acquire the needed information from designated institutions, agencies, sources.

Information providers could include:

- Local stakeholders, vulnerable communities.
- SDMAs/ DDMA's, planning organisations other Ministries and Departments.
- National/international meteorological offices

### **Programme**

It pertains to identification of project beneficiaries in terms of the vulnerability to hazards and other stakeholders from public, private and community sectors.

- Study disaster-related issues to determine stakeholder interest and concerns of community project team to decide if consultation with stakeholders needed.
- Study development objectives of the programme under which project is proposed to be implemented and their impact on hazard vulnerability and environment.

### **Planning**

Right at the conceptual stage, assessment of following issues is essential to ensure that DRR can be integrated in planning, design and construction of the project.

- Relevant land-use regulation
- Design, construction and disaster safety codes and standards to be applied
- Capacity of professionals constituting the project team – in terms of expertise and knowledge to understand and apply codal and regulatory provisions
- Capacity of the team to identify disaster risk reduction measures to be incorporated in the preparation of the project.
- Capacity of the team for development of an environment plan and monitoring.

## **15.3 Project Preparation For Submitting The Proposal For Development Permission**

Construction projects in housing sector may be of three types,

- i) Newly proposed housing project**
- ii) Repairs up gradation of existing housing complex**
- iii) Post-disaster reconstruction as a part of relief and rehabilitation**

Strategies and measures required to ensure that disaster risk, vulnerability management are adequately and systematically addressed in the preparation of projects will be different for all three types of projects mentioned above. The expertise and capabilities of the members of the design team may also vary.

**(i) For New Constructions**

While preparing the project for new construction there is a need to ascertain if the techno-legal regime (refer to Chapter 11) is in position at the authority which will appoint the project and give permission to build. Planning, design and construction scheme will be according to hazard-resistant standards and codes (depending upon the hazard risk of the proposed site) and it will be so certified by the government-nominated agency. Besides, the design team will be responsible to ensure that acquired hazard-information has been fully utilised in the decision-making and how the project after being implemented will respond to hazard threats. To ensure that hazard threat and DRR have been incorporated in the preparation of project, the design team should fill the SDBR and checklist as per chapter 14; tables 14.2, 14.3, 14.4 and 14.5 before submitting the project for approval. If needed by the team, relevant technical support and expertise must be sought.

**(ii) Project For Repair And Upgradation**

In such a case of an existing housing scheme, the “objectives and purpose of repair and upgradation” must be thoroughly analysed and discussed with all stakeholders (building owners, occupiers, financial institution if involved, the local development regulatory authority, etc). A performance evaluation and monitory mechanism should be set up jointly with stakeholders before taking up preparation of the project. Assessment of hazard safety and basic vulnerability of the building/s must be undertaken before starting the exercise for design of repairs and up gradation. For undertaking Hazard Safety Assessment, please refer to Chapter 6 of Guidelines. Then hazard safety objectives of the proposed project be determined so that design team ensures selected design objectives. (For design of rehabilitation and retrofitting the design team may refer and take help from Chapter 7 of the Guidelines).

**(iii) Project For Post-Disaster Reconstruction And Rehabilitation**

One important aspect for such post-disaster reconstruction projects is that results of post-disaster diagnostic surveys are fully integrated into the disaster reconstruction programme. In order to determine socially acceptable risk applicable relevant national building codes and standards, and some good practices obtaining globally for such reconstruction programmes should be examined before preparation of these projects. It is important to note for such post-disaster reconstruction projects that the level of socially acceptable risk will vary according to the use and importance of the building and/or facility. In such projects, the hazard vulnerability of site is a must before starting the planning and design of reconstruction project because the level of current hazard risk may be higher than socially acceptable risk. Then the need for re-sting may have to be examined by experts.

**15.4 Taking Cognizance of Correct Information/Data On Hazards, Vulnerabilities, Risks And Capacities To Cope**

For ensuring safety and minimising disaster risk to housing projects in various States and UTs in the country, which are subject to earthquakes, cyclones, floods, landslides acting mostly separately but sometimes in combination of two or more of them, the best approach is to plan, design, construct and monitor the projects in accordance with the relevant BIS Standards, Codes, Guidelines and Handbooks. A brief list of most applicable codes and guidelines are given in Annexure 4. These cover most of the critical parameters for safety against natural hazards either for single or multi-hazard situation.

Besides following the codes, project and programme planners should consider where relevant and reliable hazards information is located. For example, two versions (1997 and 2006) of Vulnerability Atlas of India with respect to earthquakes, cyclones, and floods have been brought out by BMTPC functioning under Govt. of India. The information that can be asked by most project planners regarding vulnerability mapping, risk to different building types is already available. This information has already been revised from 1996 version to 2006. Besides, a Landslides Hazard Zonation Atlas for India has also been published by BMTPC. Thus, the project planners should make use of 'hazard information' for various districts as presented in these Atlases, they must also make themselves familiar with

the formats in which hazard and risk related information has been given in these documents.

### **15.5 Planning, Design And Construction of Critical (Life Line) Facilities – School And Hospital Buildings**

Recent events, particularly Bhuj Earthquake of 2001, have once again highlighted the vulnerability of schools and hospitals to natural hazards. These facilities are considered critical for post-disaster relief. In case of hospitals, it is not only the loss of structural integrity that can compromise their operation (functionality) but also damage to hospital equipment and to surrounding infrastructure (e.g. loss of access, water supply and electricity).

The present report provides series of guidelines for analysis of structural content and systems network, risk, etc. Similarly, damage to schools which provide community shelter and organisational focus in the aftermath of a disaster, needs to be avoided through their design and construction.

Considering the fact that siting and design of critical facilities like schools and hospitals and associated infrastructure are essential for relief and recovery purposes the, designers and project planners in housing sector as well should refer to the provisions of disaster safety features and guidance given in Chapter 8 and 9 of this report. These guidelines cover aspects of siting, planning, design, construction and maintenance, and for hospitals, these also include safety of non-structural elements.

### **15.6 Critical Factors For Successfully Integrating DRR In Housing Projects: Responsibility Of Project Owners**

Following are critical factors that need to be addressed for ensuring the successful mainstreaming of disaster safe construction are;

#### **15.6.1 Incorporating Design Checks, Enforcement And Quality Control –**

Relevantly trained technical personal, appropriate internal management policy (in owner's establishment) and effective implementation measures are necessary.



**15.6.2 Consultation With Hazard And Construction Experts** – This is a major factor for success and mainstreaming of hazard proof measures in construction projects. Normally the funding agencies or financial institutions supporting the project would also like to ensure that such factors are addressed in project formulation and implementation. (Refer Chapters 5,6,8,9,10,11, 12 and 14).

**15.6.3 Land-Use Planning And Incorporating Building Codes** – For paying full attention to these aspects reference may be made to Chapters 5,6,8,9,11. Techno-legal regime as given in Chapter 11 should be adopted by all local bodies, development authorities and other government departments.

**15.6.4 Improving Construction And Implementation Practices** – Capacity building for officials, professionals, (in private and public sector) and plan approving officials in Urban Local Bodies should be undertaken. For details of nature and type of training programmes, sensitisation and awareness strategies refer to Chapters 3,5,11.

**15.6.5 Guidelines For Performance – Based Design of Structures With Respect To Natural Hazards** – Most of these measures and guidelines are already existing in BIS Codes, Standards, Guidelines and Handbooks. Please refer to Annexure 4 in the Report.

**15.6.6 Current Status Of Buildings Byelaws, Development Control Rules, Land-Use Zoning Regulations** should be ascertained from the Urban Local Body or any other development authority where the project/building proposals are to be submitted. The project owners should procure an authorised copy or printed copy of regulations which will apply while approving the proposal.

**15.7 The Municipal Corporations, Development Authorities** responsible for regulating construction activities and development works, should undertake widespread dissemination of the regulations adopted by them. These bodies should also ensure that all amendments as approved by Govt. of India, Ministry of Home, for regulatory documents are incorporated in their regulations and bye-laws. Printed copies of revised techno-legal regulations

should be made available at cost on the shops where govt. publications are available for general public.

**15.7.1** The State Governments/SDMAs and Public Sector Undertakings should normally notify the agencies/organisations or structural engineering experts who should certify the proposals for important, particularly high-rise buildings, that these are based on Disaster Safety Codes, and proposed designs have incorporated all critical requirements.

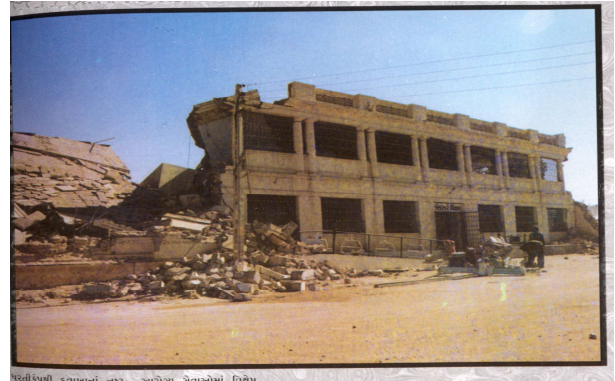
**15.7.2** In case it is found that during execution the builders/contractors are deviating from the original designs details concerning regulations and safety requirements as per codes, the project management consultants should report the matter in writing to (a) the civic authorities (b) to concerned organization who had certified the proposal before submission.

## Annexure – 1 - Some Examples of Building Damage During Recent Earthquakes In India

### 1.1 Performance Of Masonry Buildings



Collector Office at Bhuj Collapse of Second Storey



Collapse of General Hospital at Bhuj



Government Hostel Collapse (Bhuj)



High School of Dudhai Village



Destruction Due to Recent Earthquake in Jammu & Kashmir



Collapse of Stone Masonry Walls



### **Bad Performance of Masonry Buildings**

- i) Old decaying buildings predating modern construction practices
- ii) New buildings not built to Indian earthquake Codes
- iii) Lack of knowledge understanding or training in the use of these Codes by local builders



Total Destruction

- iv) Buildings erected without the owners seeking proper engineering advice
- v) Improper detailing of masonry building
- vi) Poor materials, construction and workmanship used
- vii) Absence of 'header' or 'through' stones and long corner stones in random rubble (RR) masonry
- viii) Buildings having poor quality foundations or foundations built on poor soils
- ix) Alterations and extensions being carried out without proper regard for effects on structure during an earthquake

### **1.2 Performance of Reinforced Concrete Buildings**



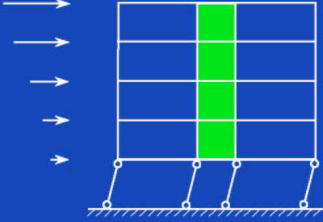
Soft Storey (Open Plinth), Vertical Split Between Two Blocks (Bhuj)



The well – braced upper part of the building collapsed onto the ground floor (Kachchh, 2001)

Basic principles for the seismic design of buildings

4



Avoid soft-storey ground floors!

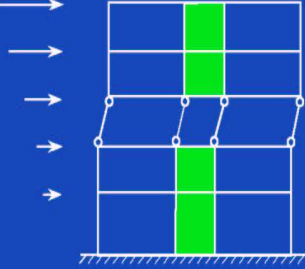
Prof. Hugo Bachmann ibk - ETH Zurich



Soft Middle storey collapse (Bhuj)

Basic principles for the seismic design of buildings

5



Avoid soft-storey upper floors!

Prof. Hugo Bachmann ibk - ETH Zurich



All the upper floors were too soft (Izmit, Turkey 1999)

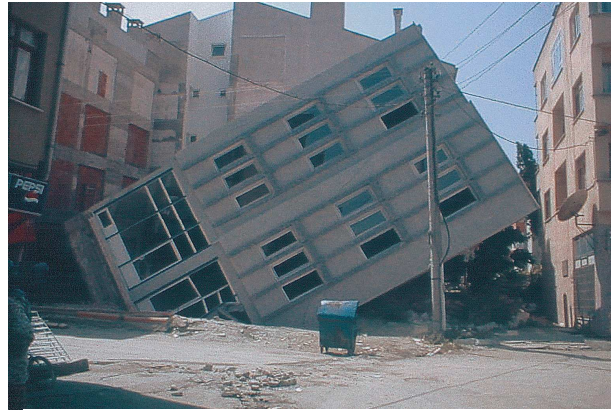


School roof with precast RC Panels collapsed (Gandhidham)





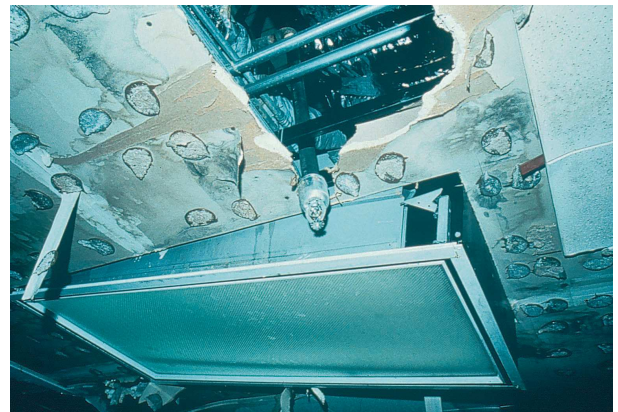
The consequences of bad planning & insufficient design & detailing of a prefabricated industrial building



The solid building tilted as a rigid body and the raft foundation rises above the ground. The building itself suffered only relatively minor damage.

### **Bad Performance of Reinforced Concrete Buildings**

- Bad design creating soft stories at ground or at intermediate level of the building
- Bad design creating the various stories soft and flexible along one the long axis of the building
- In adequate encourage of the prefabricate elements with the mainframe
- Soil investigation for liquefaction potential not carried out and depth of foundation inadequate
- Internal detailing of fixtures not properly designed against earthquake effects
- In appropriate detailing of reinforcement in the structural members of the RC frames



Poorly fastened light fittings, such as these, can fall and endanger people

## Annexure-2- Definitions of Disaster-Related Terms

1. **Disaster:** A catastrophe, mishap, calamity or grave occurrence in any area, arising from natural or man-made causes, or by accident or negligence which results in substantial loss of life or human suffering or damage to, and destruction of, property, or damage to, and degradation of, environment, and is of such a nature or magnitude as to be beyond the coping capacity of the community of the affected area.
2. **Disaster Management:** A continuous and integrated process of planning, organising, coordinating and implementing measures which are necessary or expedient for prevention of danger or threat of any disaster; mitigation or reduction of risk of any disaster or its severity or consequences; capacity building; preparedness to deal with any disaster; prompt response to any threatening disaster situation or disaster; assessing the severity or magnitude of effects of any disaster; evacuation, rescue and relief; and rehabilitation and reconstruction.
3. **Disaster Risk Reduction:** Technical, social or economic actions or measures used to reduce direct, indirect and intangible disaster losses. The expression 'disaster risk reduction' is now widely used as a term that encompasses the two aspects of a disaster reduction strategy: **Mitigation and Preparedness.**
4. **Exposure (Element at Risk):** The buildings population, properties, infrastructures, lifelines economic activities, including public services, etc., in a given area which are exposed to the threat of the hazard occurrence.
5. **Hazards:** A threatening event or the probability of occurrence of a potentially damaging phenomenon (e.g., natural hazards namely an earthquake, a cyclonic storm or a large flood or a landslide) within a given time period and area or man-made hazard such as building fire.
6. **High Risk Area:** Geographical areas which fall under seismic zones III, IV and V, which are vulnerable to potential impact of earthquakes, landslides, rock falls or mudflows.

7. **Local Authority:** It includes Panchayati Raj institutions, Municipalities, a District Board, Cantonment Board, Town Planning Authority or Zilla Parishad or any other body or authority, by whatever name called, for the time being invested by law, for rendering essential services or, with the control & management of civic services, within a specified local area.
8. **Mainstreaming:** Mainstreaming risk reduction describes a process to fully incorporate disaster risk reduction into relief and development policy, and practice. It means expanding and enhancing disaster risk reduction so that it becomes normal practice, fully institutionalised within an agency's relief and development agenda.
9. **Mitigation:** Measures aimed at reducing the risk, impact or effects of a disaster or threatening disaster situation.
10. **Non-structural Measures:** Non-engineered measures to reduce or avoid possible impacts of hazards such as education, training, capacity development, public awareness, communication, etc.
11. **Performance Target:** A specific, well-defined target to be aimed for in the course of a programme or project and its implementation.
12. **Performance Indicator:** An indicator of progress that has been reached in any given topic. Within disaster management and disaster risk reduction, there may be a wide range of social, physical and economic indicators identifying stages in development which will enable disaster managers to recognize where they now stand, defining what stage they have reached or where they need to go next.
13. **Preparedness:** The state of readiness to deal with a threatening disaster situation or disaster and the effects thereof.
14. **Rapid Visual Screening:** Rapid Visual Screening is a procedure requiring visual evaluation to assess the vulnerability of buildings, by permitting vulnerability assessment based on walk around of the building by a trained assessor. (The evaluation procedure and system is compatible with GIS-



based city database and also permits use of the collected building information for a variety of other planning and mitigation purposes.)

15. **Resilience:** The capacity of a system to tolerate perturbation or disturbances without collapsing into a qualitatively different state, to withstand shock and rebuild when necessary.
16. **Risk:** It consists of the expected number of lives lost. Persons injured damage to buildings and other property, and disruption of economic activity due to a particular natural or man-made hazard.
17. **Risk Assessment:** The determination of the nature and extent of risk by analysing potential hazards and evaluating existing conditions of vulnerability that could pose a potential threat or harm to people, property, livelihoods and the environment
18. **Risk Management:** The systematic process of using administrative decisions, organisation, operational skills, and capacities to implement policies, strategies, and coping capacity of the society and communities to lessen the impact of hazards.
19. **Seismic Hazard:** Seismic hazard in the context of engineering design is defined as the predicted level of ground acceleration which would be exceeded with 10% probability at the site under construction due to occurrence of earthquake anywhere in the region, in the next 50 years.
20. **Seismic Retrofitting:** The structural modifications to upgrade the strength, ductility and energy dissipating ability of seismically deficient or earthquake-damaged structures.
21. **State Authority:** The State Disaster Management Authority established under sub-section (I) of the section 14 of DM Act, 2005 and includes the Disaster Management Authority for the Union Territory.
22. **State Government:** The Department of the Government of the State having administrative control of the Disaster Management and includes Administrator of the Union Territory.

23. **Structural Measures:** Any physical construction to reduce or avoid possible impacts of hazards, which include engineering measures and construction of hazard-resistant and protective structures and infrastructure.

24. **Vulnerability:** The degree of loss to an exposure element at risk or set of such elements resulting from the occurrence of a natural man-made hazard (or man-made) of a given magnitude or intensity. It is expressed on a scale from 0 (no damage) to 1 (total loss).

### Annexure-3- MSK 1964 Intensity Scale (Extract)

(Source: IS:1893-2002)

The scale was discussed generally in the inter-governmental meeting convened by UNESCO in

April 1964. Though not finally approved, the scale is more comprehensive and describes the intensity of earthquake more precisely. The main definitions used are as follows:

**a) Type Of Structures (Buildings):**

Structure A Buildings in field-stone, rural structures, unburnt-brick houses clay houses.

Structure B Ordinary brick buildings, buildings of the large block and prefabricated type, half timbered structures, building in natural hewn stone.

Structure C Reinforced buildings, well-built wooden structures.

**b) Definition of Quantity:**

Single, few About 5 per cent

Many About 50 per cent

Most About 75 per cent

**C) Classification of Damage to Buildings:**

Grade 1 *Slight damage* - Fine cracks in plaster; fall of small pieces of plaster

Grade 2 *Moderate damage* - Small cracks in walls; fall of fairly large pieces of plaster, pantiles slip off; cracks in chimneys; parts of chimney fall down.

Grade 3 *Heavy damage* - Large and deep cracks in walls; fall of chimneys.

Grade 4 *Destruction* - Gaps in walls; parts of buildings may collapse; separate parts of the building lose their cohesion; and inner walls collapse.

Grade 5 *Total damage* - Total collapse of buildings.

**d) Intensity Scale:**

II *Scarcely noticeable (very slight)*

Vibration is felt only by individual people at rest in houses, especially on upper floors of buildings.

**VI Frightening**

- a) Felt by most indoors and outdoors. Many people in buildings are frightened and run outdoors. A few persons lose their balance. Domestic animals run out of their stalls. In few instances, dishes and glassware may break, books fall down. Heavy furniture may possibly move and small steeple bells may ring.
- b) Damage of Grade 1 is sustained in single buildings of Type B in many of Type A. Damage in few buildings of Type A is of Grade 2.
- c) In few cases cracks up to widths of 1 cm possible in wet ground; in mountains occasional landslips; change in flow of springs and in level of well water are observed.

**VII Damage to Buildings**

- a) Most people are frightened and run outdoors. Many find it difficult to stand.  
The vibration is noticed by persons driving motor cars. Large bells ring.
- b) In many buildings of Type C damage of Grade 1 is caused; in many buildings of Type B damage is of Grade 2. Most buildings of Type A suffer damage of Grade 3, few of Grade 4. In single instances landslips of roadway on steep slopes; cracks in roads; seams of pipelines damaged; cracks in stonewalls.

**VIII Destruction of Buildings**

- a) Fright and panic; also persons driving motor cars are disturbed. Here and there branches of trees break off. Even heavy furniture moves and partly overturns. Hanging lamps are damaged in part.
- b) Most buildings of Type C suffer damage of Grade 2, and few of Grade 3. Most buildings of Type B suffer damage of Grade 3, and most buildings of Type A suffer damage of Grade 4. Occasional breaking of

pipe seams. Memorials and monuments move and twist. Tombstones overturn. Stone walls collapse.

- c) Small landslips in hollows and on banked roads on steep slopes; cracks in ground up to widths of several centimetres. Water in lakes becomes turbid. New reservoirs come into existence. Dry wells refill and existing wells become dry. In many cases change in flow and level of water is observed.

## **IX General Damage To Buildings**

- a) General panic; considerable damage to furniture, animals run to and fro in confusion and cry.
- b) Many buildings of Type C suffer damage of Grade 3, and a few of Grade 4. Many buildings of Type B show damage of Grade 4, and a few of Grade 5. Many buildings of Type A suffer damage of Grade 5. Monuments and columns fall. Considerable damage to reservoirs; underground pipes partly broken. In individual cases, railway lines are bent and roadway damaged.
- c) On flat land overflow of water, sand and mud is often observed. Ground cracks to widths of up to 10 cm, on slopes and river banks more than 10 cm; furthermore a large number of slight cracks in ground; falls of rock, many landslides and earth flows; large waves in water. Dry wells renew their flow and existing wells dry up.

## **Annexure-4 - Relevant References To Standard Codes / Guidelines**

### **I For General Structural Safety**

1. BIS:2005 National Building Code of India
2. IS: 456:2000 Code of Practice for Plain and Reinforced Concrete
3. IS: 800-2006 Code of Practice for General Construction in Steel
4. IS: 801-1975 Code of Practice for Use of Cold Formed Light Gauge Steel Structural Members in General Building Construction
5. IS 875 (Part 1) : 1987 Design loads ( other than earthquake ) for buildings and structures Part 1 unit weights of materials
6. IS 875 (Part 2) : 1987 Design loads ( other than earthquake ) for buildings and structures Part2 Imposed Loads
7. IS 875 (Part 3):1987 Design loads ( other than earthquake ) for buildings and structures Part 3 Wind Loads
8. IS 875 (Part 4):1987 Design loads (other than earthquake) for buildings and structures Part 4 Snow Loads
9. IS 875 (Part 5):1987 Design loads (other than earthquake) for buildings and structures Part 5 special loads and load combination
10. IS: 883:1966 Code of Practice for Design of Structural Timber in Building
11. IS: 1904:1987 Code of Practice for Structural Safety of Buildings: Foundation
12. IS: 1905:1987 Code of Practice for Structural Safety of Buildings: Masonry
13. IS 2911:1979 (Part 1) Code of Practice for Design and Construction of Pile Foundation Section 1 ; Section 2 Cast-in-situ Piles; Section 3 Driven Precast Concrete Piles; Section 4 precast Concrete Piles.
14. IS 2911:1979 (Part 2) Timber Piles
15. IS 2911:1979 (Part 3) Under Reamed Piles
16. IS 2911:1979 (Part 4) Load Test on Piles

### **II**

#### **For Cyclone/Wind Storm Protection**

17. IS 875 (3)-1987 Code of Practice for Design Loads (other than Earthquake) for Buildings and Structures, Part 3, Wind Loads
18. IS 15498: 2004 Improving cyclone resistance of low rise houses and other buildings  
BMTPC : 2010 Improving Wind / Cyclone Resistance of Housing – Guidelines

### **III**

#### **For Earthquake Protection**

19. IS: 1893-2002 Criteria for Earthquake Resistant Design of Structures (Fifth Revision)
20. IS: 13920-1993 Ductile Detailing of Reinforced Concrete Structures subjected to Seismic Forces - Code of Practice
21. IS: 4326-1993 Earthquake Resistant Design and Construction of Buildings - Code of Practice (Second Revision)
22. IS: 13828-1993 Improving Earthquake Resistance of Low Strength Masonry Buildings – Guidelines
23. IS: 13827-1993 Improving Earthquake Resistance of Earthen Buildings – Guidelines
24. IS: 13935-1993 Repair and Seismic Strengthening of Buildings - Guidelines

25. BMTPC : 2010                      Improving Earthquake Resistance of Housing – Guidelines

**IV**

**For Protection of Landslide Hazard**

26. IS 14458 (Part 1): 1998      Guidelines for retaining wall for hill area:  
27. Part 1                              Selection of type of wall  
28. Part 2                              Design of retaining/breast walls  
29. Part 3                              Construction of dry stone walls  
30. IS 14496: 1998                Guidelines for preparation of landslide – Hazard zonation maps in mountainous terrains  
31. IS: 14680: 1999                Guidelines for land slide control  
32. IS: 14804                         Guidelines for Siting, Design and selection of materials for Residential Building in Hilly Areas

**V**

**For Protection of Flood Hazard**

33. BMTPC : 2010                      Improving Flood Resistance of Housing – Guidelines

\*As these codes and guidelines are being updated from time to time different Instructions organization therefore the latest updated version shall be referred at the time of conforming a project list has been attempted which may not be complete.