Recent developments toward earthquake risk reduction in India

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A developing country like India, with a variety of building practices and social and economic structure, needs to evolve its own strategies for seismic hazard evaluation. Occurrence of few damaging earthquakes during the last decade has pointed to our shortcoming in risk reduction programmes. A meaningful programme must incorporate appropriate building codes and also create public awareness. Several initiatives are now being taken at research and management levels. An update of these initiatives and steps to strengthen disaster mitigation programmes are discussed in this paper.

Introduction

INDIA is a large country that has more than its share of major natural hazards like drought, floods, earthquake and cyclones throughout its history of civilization. Naturally, the country has developed its own practices and strategies for coping with the expected calamities. Since independence in 1947, the country has developed a nationwide relief administration programme, which envisages a lead role for the state governments. The ten-year period of the International Decade for Natural Disaster Reduction (IDNDR), came as a good opportunity for the country to look back at what had been done in the past, new initiatives taken during the decade, and plan ahead for reducing the impact of natural hazards on its people, settlements and economic development. In this short paper, some of the recent developments in earthquake risk reduction programmes are discussed and a few suggestions for reducing the impact of natural hazards are made.

Earthquake hazards and disasters

Earthquakes occur due to movements along faults that have evolved through geologic and tectonic processes. Often they occur without any prior warning and are therefore unpredictable. Among all the natural calamities, earthquakes are the most disastrous since their impacts can cover large areas causing deaths, injuries and destruction on a massive scale. The extent of the impact of an earthquake depends on its magnitude, location and time of occurrence.

A large part of India is liable to a wide range of probable maximum seismic intensities, where shallow earthquakes of magnitudes of 5.0 or more on the Richter scale, are known to have occurred in the historical past or have been recorded in the last 100 years or so (Figure 1). A catalogue prepared by the India Meteorological Department (IMD) lists about 1200 known earthquakes. According to this catalogue, there are 8 earthquakes of $M \geq 8.00$, 43 of M 7.0–7.9, 312 of M 6.0–6.9, the rest of M 5.00–5.9. Table 1 gives a list of different magnitude earthquakes in India, with more than thousand deaths.

The largest earthquake in India occurred in 1897 in the Shillong Plateau and it had a magnitude of 8.7. This and

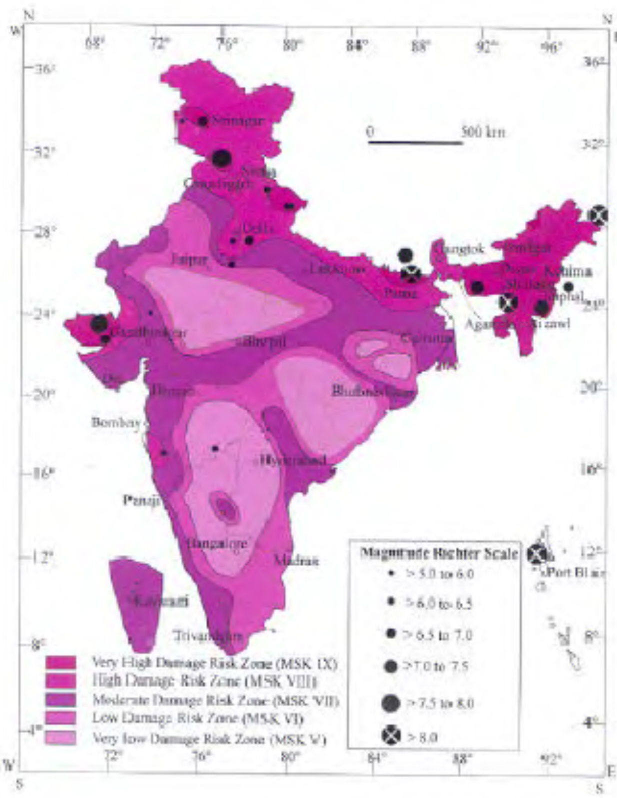

Figure 1. Earthquake hazard zoning map of India showing some damaging earthquakes.

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the 1950 earthquake of M 8.6 in Sadiya region have been so intense that the rivers changed their courses, ground elevations got changed permanently and stones were thrown upward with an acceleration exceeding 1 g (ref. 1).

Major elements of earthquake risk reduction structure

Earthquakes fall in the class of hazards, which have low probability of occurrence but high consequences. Hence, post-disaster response usually occurs on ad-hoc basis without prior preparedness. Considering that most human losses are due to failure or collapse of man-made structures (buildings in particular), the problem of safety could best be taken care of through a pre-disaster 'prevention' approach. So far, disaster prevention and mitigation were not addressed as such in government bodies. The recent earthquake of M 6.3 (1993) at Killari in Maharashtra highlighted the need for upgrading the seismological instrumentation in peninsular India to state-of-the-art level and also expanding the network in the region so as to enhance the capability of recording as well as locating earthquakes of $M \geq 4.0$. Besides, strong motion instrumentation of a number of tall buildings has been carried out in this region and extension of similar activity in north India cities is planned. Thus, a number of actions are being taken in the country, which contribute to disaster prevention and mitigation. Some of these are described here.

Hazard evaluation and risk assessment

For a country like India, with a variety of building practices and social and economic structure, seismic hazard evaluation strategies followed in many developed countries may not be appropriate, especially in view of the types of building materials and traditional construction practices generally used. Some of the critical issues are discussed here.

Mapping and quantification of earthquake hazard: Earthquake hazard of the country is being monitored mainly by Geological Survey of India (GSI) and the India Meteorological Department (IMD). A macro-level map has already been prepared, which divides the country into five hazard zones, V to I, of various probable maximum intensities on a decreasing scale (see Figure 1). For all engineering design purposes, the earthquake hazard has been quantified in terms of MM (or MSK) intensities as follows:

Seismic zone designation	V	IV	III	II	I
Prob. max. intensities (MM scale)	IX or more	VII	VII	VI	V or less

Earthquake risk is the product of the hazard intensity and the vulnerability of buildings and the output of a seismic risk analysis could give the probability of damage and loss from a nearby earthquake. Quantification of risk would therefore require socio-economic and housing statistics.

Census of housing: India has been carrying out population census every ten years and housing data are readily available for the years 1971, 1981 and 1991. For the 1991 census, (see Table 2) the whole information is available on computer disks. Therefore, retrieval of this data and their analysis have become very easy. It was indeed this housing data which have been utilized in the district-wise vulnerability and risk tables included in the Vulnerability Atlas of India prepared in 1997. Table 2 shows the numbers and percentages of the building types in the rural and urban areas in the total 195 million housing units.

The damage vulnerability of each building type is also shown. The trend in building construction since 1991 is that, relatively larger numbers of brick and concrete block walls are being used compared with earthen and stone walls. But overall, the number of highly vulnerable buildings is increasing.

Vulnerability of buildings and structures: A comprehensive study of vulnerability of buildings and structures to various earthquake intensities has not been conducted in a systematic way in the country so far. A proper way of presentation of vulnerability versus earthquake intensity is to develop vulnerability functions such as those grossly developed for various building types under the earthquake intensities as shown in Figure 2.

Table 1. Damaging earthquakes in India with more than 1000 deaths

Year	Area	Date	(I.S.T) time h:min:s	Magnitude M	Max. MM Intensity	Deaths
1819	Gujarat (Kutch)	16 June	18:50	8.0	XI	Many thousands
1897	Assam (Shillong)	12 June	16:36	8.7	XII	1600
1905	Himachal Pradesh (Kangra)	4 Apr	06:20	8.0	XI	20,000
1934	Bihar–Nepal	15 Jan	14:13:26	8.3	XI	14,000
1950	Assam (NE)	15 Aug	19:39:28	8.6	XII	1500
1988	Bihar–Nepal	21 Aug	04:39:10	6.6	VIII	1003
1993	Maharashtra	30 Sep	03:55:47	6.3	VIII	7928

Disaster preparedness and prevention

Building damage scenario of a major earthquake: In order to develop realistic prepared plans, as a first step, development of damage scenarios under the likely major earthquakes needs to be done. A hypothetical recurrence of earthquake of M 8.0 in Kangra area of Himachal Pradesh (like that of 1905) has been considered (Table 3). The scenario highlights the disastrous situation that could have developed if the repeat earthquake had occurred in the census year 1991. The results are obtained for two cases of all buildings being of traditional construction (i) *without* earthquake safety features, (ii) *with* earthquake-resistant features as per the Indian Standard Building Codes. It is seen that:

- If all the 18,15,858 houses are without earthquake safety provisions, the direct losses will amount to Rs 51.04 billion. Since about 65,000 lives may be lost and 399,695 houses ruined completely, the trauma will be too great and cost of emergency relief will be exorbitant.
- If all the houses were made earthquake-resistant as per IS: 4326 and IS: 13928 when built initially, the direct losses will amount only to Rs 19.6 billion. The extra cost of earthquake safe provision for all houses would only be Rs 6.35 billion. Hence, there will be a net saving of Rs 25.09 billion or about 50%. Besides, the lives lost will only be one-fifth and totally ruined houses reduced to about one-fourth, the trauma and relief costs will also be reduced to about one-fourth.

The damage scenario brings out clearly the economic and other social benefits of pre-earthquake preventive measures. Also, disaster managers will have an estimate of what situation they may have to face and make management plans before the disaster actually occurs (also see refs 2–5).

Preventive measures: Disaster prevention, by definition, involves engineering intervention in buildings and structures to make them strong enough to withstand the impact of probable earthquakes or to impose restrictions on land use, so that the exposure of the society to disastrous situations is avoided or minimized. So far, land use restrictions are not provided in the town and country planning laws or master plan rules. Also, the municipal by-laws are silent about earthquake safety requirements of buildings. The result is that the cities are expanding in all directions, occupying even hazard-prone areas, and more and more unsafe buildings are being constructed, adding to the already existing huge stock of unsafe buildings.

Indian standard codes and guidelines for earthquake-resistant design and construction of buildings and structures were first developed in 1962 and 1967, then revised, updated and expanded every few years until 1993. However, the recent earthquakes in Uttarkashi (1991), Latur–Osmanabad (1993), Jabalpur (1997) and Chamoli (1999) have clearly shown that the implementation of these codes and guidelines has not been satisfactory, except in the case of some central government departments, mainly because the standards are not mandatory and do not yet form part of the by-laws of the local bodies.

Research and development, education and training

Research, education and training in earthquake engineering were started by the University of Roorkee (UOR) through School of Research and Training in Earthquake Engineering (SRTEE) in 1960. Through this initiative, a national capacity has been built for design and construction of earthquake-resistant structures from small to tall buildings, all types of bridges and dams, conventional to

Table 2. Various building types by wall materials in India*

Wall type	Number (million)	Per cent of total	Damage vulnerability MSK intensity		
			VII	VIII	IX
Earthen walls (mud, unburnt brick/blocks)	R – 67.20 U – 7.50	R – 34.46 U – 3.83	M	H	VH
Stone walls	R – 17.30 U – 4.40	R – 8.87 U – 2.23	M	H	VH
Burned brick walls	R – 36.35 U – 32.25	R – 18.64 U – 16.54	L	M	H
Concrete walls	R – 1.16 U – 2.80	R – 0.59 U – 1.44	VL	L	M
Wood and ekra walls	R – 2.00 U – 1.12	R – 1.02 U – 0.58	VL	L	L
GI and other metal sheets	R – 0.25 U – 0.76	R – 0.13 U – 0.39	VL	VL	L
Bamboo thatch, leaves, etc.	R – 18.43 U – 3.20	R – 9.45 U – 1.64	VL	VL	L

*Census of housing 1991, total housing units = 195 million.
VH = Very high, H = High, M = Moderate, L = Low, VL = Very low.
R = Rural, U = Urban.

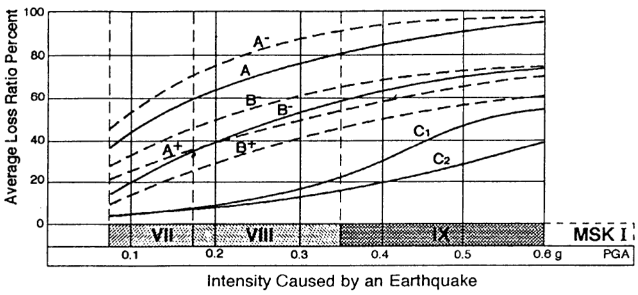

Figure 2. Vulnerability functions for various building types vs the earthquake intensities. A: Buildings in field stone, rural buildings, unburnt brick houses, clay house (1 to 1 ½storey); B: Ordinary brick buildings, buildings in large blocks, half timbered buildings in natural dressed stone (1 to 1 ½storeys); C_1: Buildings in strengthened masonry in cement (1 to 2 storeys); C_2: Reinforced concrete and steel buildings, well built wooden buildings; A^-: A type, but taller (2 or more storeys); A^+: A type, earthquake-resistance features; B^-: B type, but taller (2 or more storeys); B^+: B type with earthquake-resistance features.

atomic power plants and petro-chemical industrial structures, etc. A degree programme for masters in earthquake engineering exists since 1965 and hundreds of short training programmes have been organized by the UOR for engineering teachers and professionals. Research, education and specialized training activity have now expanded to several institutions such as the IITs (particularly IIT-Kanpur and IIT-Bombay), universities and research institutions. Sophisticated testing, measuring and computing facilities, including shake-tables have also become available at the UOR, and Structural Engineering Research Centre (SERC), Chennai.

Initiatives taken during the international decade of natural disaster reduction 1990–1999

The Yokohama message emanating from the IDNDR mid-term review conference held at Yokohama in May 1994, underlined the need for an emphatic shift in the strategy for disaster mitigation. The message reads as follows: 'Disaster prevention, mitigation and preparedness are better than disaster response in achieving the goals and objectives of the Decade. Disaster response alone is not sufficient, as it yields only temporary results at a very high cost. Prevention contributes to lasting improvement in safety and is essential to integrated disaster management'.

In the light of this message and to meet the objectives stated in the IDNDR, a number of important initiatives were taken by government as well as non-government organizations (NGOs). The initiatives and the results achieved thereby are summarized in the following sections.

Hazard mapping and vulnerability assessment of buildings: Under the initiatives of the Ministry of Urban Development, a Vulnerability Atlas of India[6] has been prepared during the period 1994–1997, in which the earthquake, cyclone and flood hazard maps for every state and union territory of India have been prepared to a scale of 1 : 2.5 million. In these maps, the boundaries of the districts are clearly shown so that the areas of the districts prone to the various intensities of hazards are clearly visible. An earthquake hazard map for Andhra Pradesh, with district boundaries is shown in Figure 3. Also the vulnerability of the buildings, as per the census of housing 1991, has been brought out in tabular from in one sheet for each district. These details for the east Godavari district are given in Table 4. This information clearly highlights the risk to buildings of various types in every district when subjected to the different intensities of the three hazards. As an extension, state-wise vulnerability atlases also have been prepared, including an action plan that the state may adopt, for achieving disaster reduction.

Techno-legal regime for the country

The Town and Country Planning Acts governing the planning of settlements and preparation of Master Plans were studied and found deficient in regard to planning from the viewpoint of natural disasters[5]. Also the present building by-laws do not address the problem of safety from natural hazards. A complete techno-legal regime has been proposed for amending the acts and by-laws to include the safety aspects from the point of view of natural hazards. In addition, several states have taken up review of relief manuals and preparation of calamity preparedness guidelines to suit local needs and geo-climatic conditions. The

Table 3. Losses in magnitude 8.0 hypothetical earthquake if occurred again in Kangra, Himachal Pradesh in 1991 (Total housing units in the affected area = 1,815,858)

		Scenario if all the buildings are *without* earthquake resistance		Scenario if all buildings are *with* earthquake resistance	
Sl no.	Item	Physical damage	Loss in INR* (million)	Physical damage	Loss in INR* (million)
1	Loss of lives	65,000	6500	12,000	1200
2	Total collapse of buildings (G5)	136,339	9540	8298	580
3	Destroyed buildings (G4)	263,356	18,430	94,997	6650
2 + 3	Buildings to rebuild	399,695	27,970	103,295	7230
4	Heavily damaged buildings (G3; to repair and retrofit)	915,602	12,820	312,382	4370
5	Moderately damaged buildings (G2; to repair and retrofit)	357,510	3750	648,040	6800
6	Total loss		51,040		19,600

*INR = Indian rupees, 1 US$ ~ INR 40.0 in 1997; G5, G4, G3, G2 are grades of damage defined in MSK intensity scale.
Losses estimated in 1997 at 1997 costs (Source: Arya[3]).

legislation issues are now before the Central and State governments.

Guidelines for disaster-resistant construction and technology transfer

Realizing that majority of constructions in India are non-engineered types, consisting of walls of clay, stone, brick and the like, built in traditional ways without hazard safety provisions, appropriate guidelines have been developed to cover the aspects of (a) land-use zoning, (b) earthquake-resistant building construction, (c) cyclone-resistant building construction, and (d) flood-resistant building construction. Transfer of better construction technologies is being effected through Building Centres established by Housing and Urban Development Corporation (HUDCO) and Building Materials and Technology Promotion Council (BMTPC) in a few hundred districts in the country.

Strengthening of information technologies

The Ministry of Agriculture, which is the nodal Ministry for Disaster Management in India, has laid great emphasis on using the various state-of-the-art technologies, namely Remote Sensing, Geographical Information System (GIS), Global Positioning System (GPS), Computer Modelling and Expert Systems, and Electronic Information Management System (collection, storage, retrieval and dissemination of information) in managing the situation caused by natural disasters. Active and ongoing efforts are being made for modernizing the control rooms so as to make them more effective and community friendly in several states. In addition, databases are being compiled to keep track of past events and benefit from the experience (also see ref. 5).

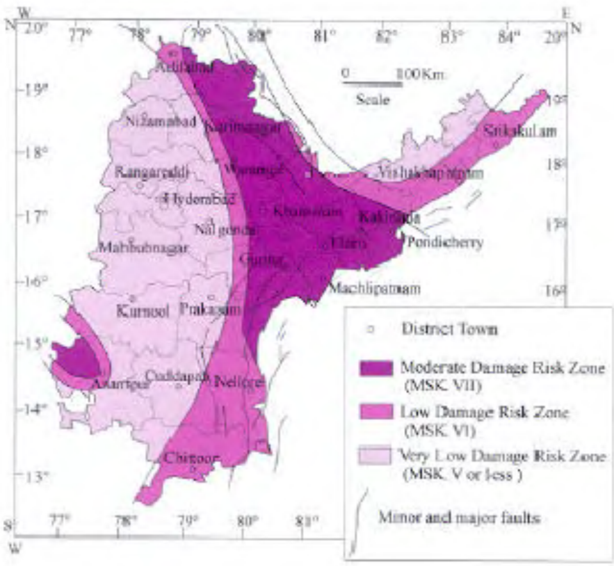

Figure 3. Earthquake hazard map of Andhra Pradesh.

Human resource development

The Department of Agriculture and Cooperation under the Ministry of Agriculture (MOA), initiated a Central Sector Scheme in 1993, including human resource development, research, consultant services and documentation of various natural disasters. Under the scheme, a National Centre for Disaster Management (NCDM) was established at the Indian Institute of Public Administration (IIPA) at New Delhi and 15 states of India set up faculties in disaster management in different institutions of the states. In addition, investments are being made on building capacity of NGOs, and Community-Based Organizations (CBOs) for working with the community as well as with the government.

The research and development work, education and training in the institute of higher learning like Department of Earthquake Engineering, University of Roorkee, (DEQ-UOR); the Central Building Research Institute, Jadavpur University, IIT-Kanpur and IIT-Bombay and SERC, Chennai, have been further expanded and a good number of ME and Ph D theses have been written during the decade.

A large number of national and international conferences, symposia and workshops were organized and proceedings published by number of institutions and learned societies and organizations on various subjects related with disaster mitigation, prevention and management (see ref. 7 for details.)

Upgrading and strengthening of seismological instrumentation network

DST coordinated a World Bank-assisted project through which the seismological observatories in the peninsular shield region have been strengthened. Under this programme, 20 existing observatories of IMD in full operation (10 GSN stations, 10 stand-alone broadbrand digital stations) have been strengthened and 10 new observatories have been established. These will provide a state-of-the-art station network. Besides, telemeter clusters at Koyna, Khandawa and Latur have been installed which will provide information from three important locations in the shield region. The ongoing strong motion accelerograph arrays and network programme through DEQ-UOR have been expanded and strengthened.

DST has also launched a nationally coordinated project on the study of seismicity and seismotectonics in the Himalayan region involving several research organizations.

Table 4. Distribution of houses in East Godavari district, Andhra Pradesh, by predominant materials of roof and wall* and level of damage risk

	Census houses			Level of risk under						
				EQ intensity MSK		Wind velocity m/s		Flood		
				VII	≤ VI	≥ 50	44 and 39	Prone	Protected**	Out-side
				Area in %		Area in %		Area in %		
Wall and roof combination	No. of houses		%	60.2	39.8	65.1	34.9	18.3	15.3	66.4
Category-A	U	57,930	5.07							
A1. Mud wall	R	190,900	16.71							
(all roofs slopping)	*Total*	248,830	21.79	M	L	VH	M	VH	M	L
A2. Unburned brick wall	U	4,930	0.43							
a) Slopping roof	R	60,390	5.29							
	Total	65,320	5.72	M	L	VH	M	VH	M	L
b) Flat roof	U	285	0.02							
	R	275	0.02							
	Total	560	0.04	M	L	VH	M	VH	M	L
A3. Stone wall	U	960	0.08							
a) Slopping roof	R	5,825	0.51							
	Total	6,785	0.59	M	L	VH	M	VH	M	L
	U	380	0.03							
b) Flat roof	R	925	008							
	Total	1,305	0.11	M	L	VH	M	VH	M	L
Category A total		**322,800**	**28.86**							
Category-B	U	380	0.03							
B. Burned brick wall a) Slopping roof	R	925	008							
	Total	1,305	0.11	M	L	VH	M	VH	M	L
	U	61,065	5.35							
b) Flat roof	R	30,165	2.64							
	Total	91,230	7.99	M	L	VH	M	VH	M	L
Category B total		**520,870**	**45.60**							
Category-C	U	3,510	0.31							
C1. Concrete wall	R	13,500	1.18							
(all roofs slopping)	*Total*	17,010	1.49	VL	NIL	H	M	L	VL	VL
	U	9,545	0.84							
b) Flat roof	R	7,620	0.67							
	Total	17,165	1.50	VL	NIL	L	VL	L	VL	VL
	U	3,495	0.31							
C2. Wood wall	R	17,890	1.57							
(all roofs)	*Total*	21,385	1.87	VL	NIL	VH	M	H	M	VL
C3. Ekra wall	U	60	0.01							
(all roofs)	R	115	0.01							
	Total	175	0.02	VL	NIL	VH	M	H	M	VL
Category C total		**55,735**	**4.88**							
Category-X	U	245	0.02							
XI. GI and other metal sheets (all roofs)	R	500	0.04							
	Total	754	0.06	NIL	NIL	VH	M	H	L	VL
X2 Bamboo, thatch, grass,	U	33,335	2.92							
leaves, etc. (all roofs)	R	208,695	18.27							
	Total	242,030	21.19	NIL	NIL	VH	H	VH	M	L
Category X total		**242,775**	**21.26**							

Building category: (A), Buildings in field stone, rural structures, unburnt bricks and clay; (B), Ordinary brick buildings: large block and prefabricated types, half-timbered structures; buildings in natural hewn stone; (C), Reinforced buildings, wall built wooden structures; (X), Other types not covered in A, B, C, generally light (Expert Group MOUA&E, Building Materials and Technology Promotion Council, GOI).
U: Urban; R: Rural.
*Source: Census of Housing, Govt. of India, 1991.
**With probability of more severe damages under failure of protection works. Probable maximum precipitation in 24 h is 520 mm. The local damages may be more severe under heavy rains.

The strong motion data collection programme is being expanded and a number of tall buildings are being instrumented to study their behaviour during future earthquakes, including soil structure interaction effects. GPS-aided geodetic studies are being initiated with DST support and a national GPS programme has been evolved and planned for monitoring the seismotectonic provinces in the country. A number of projects have been initiated in various parts of the country involving palaeoseismology as a tool to date pre-historic earthquakes (also see ref. 5).

Disaster-related standardization

For preventive action regarding safety of buildings and structures, the first pre-requisite is to develop appropriate building codes. In this regard India has made good progress.

A number of building codes and guidelines for earthquake-resistant construction were revised and further developed through the Bureau of Indian Standards as stated below.

(i) IS 4326: 1993 Earthquake-Resistant Design and Construction of Buildings – Code of Practice (Revision of 1976 Standard);
(ii) IS 13827: 1993 Improving Earthquake Resistance of Earthen Building – Guidelines;
(iii) IS 13828: 1993 Improving Earthquake Resistance of Low Strength Masonry Buildings – Guidelines;
(iv) IS 13920: 1993 Ductile Detailing of Reinforced Concrete Structures subjected to Seismic Forces – Code of Practice.

Revision of IS 1893: 1894 Criteria for Earthquake-Resistant Design of Structures is taken in hand. The effective implementation of these codes could only be ensured through their mandatory provision in the building By-laws. This is where action is lacking and the issue has been raised with the concerned authorities.

Awareness and information dissemination

A number of brochures and fliers with regard to earthquakes and cyclones have been printed and distributed to the lower level technical personnel as well as the people of the disaster-affected regions, on a large scale. Brochures and specific guidelines prepared for use in the aftermath of Latur, Jabalpur and Chamoli earthquakes are listed below:

Brochures and guidelines

- Brochure for mitigating damage to dwellings (in English, Hindi, Tamil, Telugu, Oriya and Bengali by HUDCO)
- Brochures on house construction in Jabalpur and Chamoli earthquake-affected areas (in Hindi, by HUDCO).
- Retrofitting of stone houses in Marathwada area of Maharashtra, (BMPTC), 1994.
- Guidelines for repair, strengthening and reconstruction of houses damaged in the 30 Sep. 1993 earthquake in Maharashtra (Government of Maharashtra), 1994.
- *Earthquake and Building*, A guidebook to understand the relationship between the two, (TARU), 1994.
- Build Your Home with Earthquake Protection, (BMPTC), 1995.
- Guidelines 1 – Earthquake-resistant construction of houses in Jabalpur earthquake-affected areas (in Hindi, English by BMTPC), 1997
- Guidelines 2 – Repair and retrofitting of damaged houses in Jabalpur earthquake-affected areas (in Hindi, English, BMTPC), 1997.
- Guidelines 1 – Visual Damage Identification for Chamoli earthquake-affected areas of Uttar Pradesh (in Hindi, English, BMTPC), 1999.
- Guidelines 2 – Repair and retrofitting of damaged buildings in the Chamoli earthquake-affected areas of Uttar Pradesh (in Hindi, English, BMTPC), 1999.
- Guidelines 3 – Reconstruction and New Construction of Buildings in Chamoli earthquake-affected areas of Uttar Pradesh (in Hindi, English, BMTPC), 1999.

Video films: Training films were prepared in VHS format in English and Hindi on retrofitting of stone houses (BMPTC) as follows:

- A Stitch in Time – An Introduction to Seismic Retrofitting of Stone Houses (English, 15 minutes).
- Seismic Retrofitting in 4 parts (Hindi, 45 minutes): Installation of headers; Reduction of weight on the roof; Installation of knee braces, and Installation seismic bands.
- Build a Safer Technology.

The films were made available to NGOs for dissemination of the technology in the field and shown in a number of professional training courses in India and abroad.

Looking ahead in the next decade

Based on the experience of the last decade in dealing with natural disasters in India, a national mission named 'Natural Disaster Management Information Services Through Space Technologies' is in the process of being launched in India on an operational scale during 1999–2003 for the entire country.

Population pressure, environmental degradation and unplanned urbanization are some of the major factors contributing to increased vulnerability in the country. As such, need has been felt to accelerate the pace of disaster mitigation efforts in the country[7]. It is planned to lay more emphasis on the following areas:

- linkage of disaster mitigation with development plans;
- effective communication system;
- use of latest information technology;
- insurance in all relevant sectors;
- extensive public awareness and education campaigns, particularly in the rural areas;
- legal and legislative support;
- greater involvement of NGOs/private sector.

Preparation of seismotectonic atlas of India

The GSI has included the preparation of seismotectonic atlas of India in its programme, which will consist of 43 sheets of maps covering 3° longitude × 4° latitude in each sheet to scale of 1 : 1 m. The maps will be of derived nature, and intended to include earthquake data, gravity data, magnetic data, stress field data, geological faults, major and minor lineaments and geodetic data. Seismotectonic maps so generated could be used for the seismic hazard risk assessment and preparation of reliable seismic zoning map of India.

Suggestions for the next decade

For rapid progress towards appreciable reduction in the disastrous impact of natural hazards, the policy of the government may include the following:

- To invest on global observations, and to give a boost to the science of observation and measurement on which the real progress depends.
- To enhance the scientific content of prediction methodologies and reliability of forecast, if and when it becomes feasible.
- To map the earthquake hazards on a large scale and link the maps intimately with the process of development planning; to conduct micro-zonation of urban areas at earthquake risk.
- To foster closer partnerships with financial and legal institutions, insurance companies, community-based organizations and industry.
- To create an All India Institutional Network, to involve in disaster preparedness, mitigation management and prevention.
- To invest more on public awareness, education, training and human resource development in the area of disaster mitigation.

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