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POST EARTHQUAKE MANAGEMENT: INDIAN EXPERIENCE

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Introduction

Earthquake is one of the most devastating of disasters, causing a large number of deaths and injuries and severe damage to built environment in just a few minutes. The socio-economic impact of an earthquake can be very severe in developing countries, not only due to direct losses but also due to the shifting of various resources towards rehabilitation and reconstruction of affected areas. Thus, it becomes very important to manage the post earthquake situation very effectively and efficiently. The post earthquake reconstruction determines the level of community preparedness for the next earthquake. To reduce vulnerabilities to future earthquakes, it is very important to have a clear understanding of how and why the buildings failed in the previous one. This knowledge is necessary to eliminate the causes of failures in the repair, restoration and reconstruction of buildings in the post earthquake phase. The post-earthquake management experiences of two earthquakes are discussed in the present paper.

Earthquakes in India

India is an earthquake-prone country with a long history of earthquake occurrence. A large portion of the land area of the country is liable to a wide range of seismic activities. Many shallow earthquakes of magnitude 5.0 or more on Richter Scale have been recorded in the last one hundred years or so in different parts of the country. Based on the degree of seismicity, the country can be divided into the following regions:

(i) Kashmir and Western Himalayas
(ii) Central Himalayas (Including Nepal Himalayas)
(iii) North-east India
(iv) Indo-gangetic basin and Rajasthan
(v) Cambay and Rann of Kutchh
(vi) Peninsular India, including the Islands of Lakshdweep
(vii) Andaman and Nicobar Islands.

The earthquake distribution in the above regions and other features are represented in Table 1. The major earthquakes recorded in India over the past century are given in Annexure - I

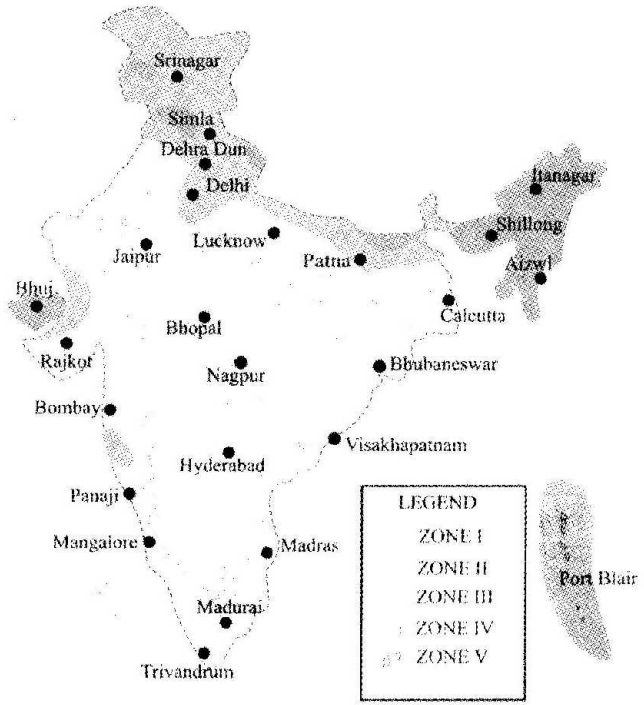
Table 1: Earthquake (M>5.O) Occurrence: Regional Distribution in India, (1897-1993)

S.No	Seismic Region	Mag 5.0-5.9	Mag 6.0-6.9	Mag 7.0-7.9	8.0 or more	Return Period, yrs
1	Kashmir & Western Himalayas (J&K, HP, Parts of Punjab).	25	7	2	1	2.5-3
2	Central Himalayas (U.P, Nepal Himalayas, North Bihar)	68	28	4	1	1
3	North East India	200	128	15	4	<0.3
4	Indo-Gangetic basin, Rajasthan, Punjab, Haryana, Delhi, UP plains, Bihar, Bengal	14	6	-	-	5
5	Rann of Kutchch	4	4	1	1	20
6	Peninsular India	31	10	-	-	2.5-3
7	Andaman and Nicobar	80	68	1	1	<0.6

Source Prof. A.S. Arya (University of Roorkee)

Based on the available data and expected maximum intensity of earthquake in different parts of the country, a seismic zone map of India (Fig. 1) was standardised by Bureau of India Standards (BIS) in 1970. This map is still in its original form as IS 1983-1984. According to this map, entire country can be divided into five seismic zones based on past experience as well as expected

probable intensities on the 12 point Modified Mercali Intensity scale. Zone V with a probable intensity of XI or more covers 12% of India, Zone IV (probable intensity : VIII) covers 18% and Zone III (probable intensity : VII) covers 26% of the country. Destruction and substantial damage to structures can be expected within these three zones covering over half of India. Within Zone II, based on a probable intensity of VI, damage to rural buildings could occur while in Zone I non-damaging intensities may be expected. Since the Marathwada earthquake (1993), the present seismic map of India is under revision.



(Source: IMD)

Figure 1 : Seismic Zonation map of India (IS : 1983-1984)

In India, the Indian Meteorological Department (IMD) is the nodal government agency for earthquake monitoring and related matters. IMD operates a national network of 36 seismic stations. A Few other organisations like the National Geophysical Research Institute, University of Roorkee and Several River Valley Projects also operate local networks for earthquake activities. These stations have been collecting seismic data over a long period of time, however, large gaps still exist in the network. To overcome the inadequacies in the existing network and to cover the potential seismic sources effectively, 31 stations are being provided with sophisticated instruments.

Recent Earthquakes in India

India is facing regularly earthquakes of moderate magnitude. In the present decade (since 1990), the country has already faced three earthquakes :
Uttarkashi, magnitude 6.6 (1991),
Latur, magnitude 6.3 (1993), and
Jabalpur, magnitude 6.0 (1997).
In the present paper we are discussing the post-earthquake management experiences relating to the last two of these earthquakes.

(I) Latur Earthquake (1993)

The Latur earthquake of September 30, 1993, caused widespread damages to life and property (about 10,000 people died and 16,000 were injured) in the southern parts of Maharashtra State. The damage due to this earthquake was confined to rural areas. In the sixty seven severely affected villages, the majority of residential constructions were either destroyed or severely damaged. A major contributor to the extent of the damage was the poor construction quality of the houses built using locally available stones set in mud mortar. Another reason may be the unexpected severity of this earthquake as this region is under Zone I according to the seismic map of the country.

The Government of Maharashtra launched a comprehensive rehabilitation and reconstruction programme in the post-earthquake phase. This programme comprised physical development of villages and socio-economic support to the affected community. The Maharashtra Earthquake Emergency Rehabilitation Programme (MEERP), taken up by the Government of Maharashtra, had the following components:

i) Housing Construction and Repair:

- Reconstruction and rehabilitation of 49 fully serviced relocated villages that were totally destroyed, about 23,000 houses and associated infrastructure with civic amenities being provided;
- Reconstruction on existing sites of 29,600 houses that were destroyed or substantially damaged and the repair of about 180,000 partially damaged houses; and,
- The construction of 500 model houses and a pilot strengthening programme for about 5,000 vulnerable houses.

ii) Infrastructure:

- Repair, reconstruction and strengthening of public buildings and infrastructure (including schools, health centres, social service facilities, roads, bridges, irrigation facilities, public buildings and historical monuments), and the improvement of transit shelters, including flooring, drainage and sanitation;

iii) Economic Rehabilitation:

- Provision for replacement and reconstruction, on grant basis, of business losses

iv) Social Rehabilitation:

- Provision for special facilities and activities to address the needs of women and children affected by the earthquake and marginal improvement of facilities throughout the 13 districts.

v) Community Rehabilitation:

- the cost of works and materials to reestablish essential services; and,

vi) Technical Assistance, Training and Equipment:

- Design, supervision and monitoring of project components, other Consultancy services and equipment, including the development of a disaster management programme for the state of Maharashtra and a seismic and research programme for the Government of India.

Programme Cost and Financing

Table 2 shows the component-wise cost summary for the Latur post-earthquake recovery programmes.

Table 2 : Latur Earthquake : Component cost-wise Summary (Rs. Million)

Project Component	Local Gov't contribution	Foreign Aid	Total cost
1. Housing	4773.5	522.5	5296.0
2. Infrastructure	2135.5	235.7	2371.2
3. Social Rehabilitation	339.4	35.7	375.1
4. Economic Rehabilitation	150.9	16.8	167.7
5. Community Rehabilitation	250.5	27.8	278.3
6. Technical Assistance Training & Equipment :			
* Project preparation and implication	85.1	14.9	100.0
* Incremental cost of PMU	85.0	15.0	100.0
* Training & study tours	50.0	0.0	50.0
* Material equipment : State share	75.6	8.4	84.0
* Material equipment : Central share	100.0	150.0	250.0
7. Physical contingencies	178.5	19.0	197.5
8. Design, supervision & management	443.8	52.0	495.8
9. Price contingencies	1030.5	73.7	1104.2
TOTALS	**9698.3 (89.2%)**	**(1171.5%) (10.8%)**	**10869.8**

(ii) Jabalpur Earthquake (1997)

An earthquake of magnitude 6.0 caused widespread damage in Jabalpur city and in the adjacent areas of Madhya Pradesh State. 39 people lost their lives in this event. The government of Madhya Pradesh acted very quickly in

providing relief and rehabilitation work for the affected persons. The following steps were taken by the government and noted NGOs plus local groups :

(a) Relief and rehabilitation

A number of relief camps were set up to provide for the immediate relief of the victims. Various including food, clothes, utensils, medicines etc. were provided free of charge to the affected community. A number of NGOs came forward to help the local administration in carrying out the relief work and in providing the temporary' shelters to the victims of the earthquake.

The Government of Madhya Pradesh launched a comprehensive rehabilitation programme with the active support of NGOs. The aim of rehabilitation programme was to restore the physical environment of the region to pre-earthquake state through various measures and to bring back the community activities to normal. Special measures were taken up to take care of the special categories of the society like women, children, farmers, artisans etc. The small and marginal farmers were provided seeds and fertilisers to restart the farming activities. A number of activities were started for women and children by integrating various government programmes with the earthquake rehabilitation programmes.

(b) Repair and Retrofitting work:

The damage pattern to the buildings during the earthquake included the urban/rural and engineered/non-engineered buildings. The prevalent rural house construction practices in the region include the earthen single storey type, where earthen walls support the tiled roofs on wooden rafters. There is no tradition of joinery work between various elements such as walls and roofs. In the urban areas majority of buildings are one or two story brick masonry type in cement or mud mortar. Reinforced Cement Concrete framed structures with infilled brick walls are also very common.

The repair and retrofitting work carried out in the post earthquake phase can be divided broadly in the two phases:

- **Immediate Phase:** Repair and retrofitting work started immediately after the earthquake with the help of local contractors by the owners of the buildings. The main objective of this phase was to bring back the buildings to their original shapes. The repair works carried out in this phase with limited knowledge of repair, retrofitting and restoration of damaged buildings. The type of repair and restoration in this phase was restricted to repair of cracked brick walls by filling up the cement, sand slurry into the cracks At some places R.C.C. bricks were inserted into the cracked walls.

- **Planned Phase:** The planned phase started after a few months time in the form of extensive repair, restoration and retrofitting works. This phase was planned by Govt. agencies, NGOs and local residents. The objective of this phase was to improve the seismic resistance of the buildings. To achieve this objective, extensive training programmes for local engineers, architects and artisans etc. were conducted to improve their knowledge of earthquake resistant construction. The technological back-up support to the local people were provided through distribution of brochures containing do's and don'ts for repair, restoration, retrofitting and reconstruction of damaged houses. The measures adopted for strengthening the seismic resistance of the buildings with load bearing brick masonry walls are as:

a. Repairing the Cracks: The following methods were adopted for the crack repair

- Plaster was removed near the cracks from both sides i.e. inside as well as outside of the brick wall,
- Cracks were cleaned up and were filled up with cement mortar in 1:3 cement : Sand mortar, starting from downside through port holes.
- In case of severe cracking in the walls , new walls were constructed to replace the damaged wall

b. Provision of Seismic Belts : The seismic belts were provided to provide the additional strength against the future earthquake in various colonies developed by Housing Board and local households The following procedure was adopted for the same:

- Existing plaster was removed at lintel levels in a width of 60 cm., surface was cleaned up with water.
- Plastering was done with the mortar of neat cement slurry in 12 mm thickness. Then the surface was roughened.
- The welded wire mesh of 11 gauge in one square inch openings was fixed over the first coat of the plaster with the help of nails.
- Plastering was done once again over the mesh in a coat of 16 mrn thickness.
- An overlap at the corners or otherwise of I 50 mrm was made

The seismic belt was provided only on the outside of the walls in the Housing Board colonies. At a few other places, private households provide the belt on both the sides i.e. inside as well as outside

c. Reconstruction of Damaged Houses:

NGOs are providing good assistance to the local administration in the reconstruction of damaged houses. The NGOs usually adopted damaged villages for reconstruction and reconstructed houses on their original sites. There is no provision of any other infrastructural facility in these villages. The majority of NOOs are use earthquake resistant construction practices by providing R.C.C. bands at various levels and through corner strengthening by providing one steel bar, cement concrete column. There are few NGOs who had just provided material help to the earthquake victims to reconstruct their houses In these cases the reconstruction of houses is taking place in the old (pre-earthquake) fashion without any earthquake resistant feature being adopted. This type of construction is highly vulnerable to future earthquakes.

The government agency Housing and Urban Development Corporation (HUDCO) is reconstructing/ developing two villages as model villages with all the necessary physical and social infrastruaure. The state Housing Board is also developing a large number (22,600) of housing units for low income groups affected due to the earthquake. The houses constructed by the government agencies have proper earthquake resistant features.

A series of five building centres have been started in the earthquake affected area to take care of the standard building material required for the reconstruction, retrofitting and repair of damaged houses. The repair and reconstruction of damaged religious places is being done at Government expense.

Experiences from Past Events

In a the country like India, where the frequency of damaging earthquake occurrence is 2-3 years, it become very important to learn the lessons from the past earthquakes. There are certain deficiencies in the preparedness and management of earthquakes, pointed out repeatedly through the severe damages experienced. To reduce the impact of future earthquakes, we have to concentrate on the following:

1. The non-engineered buildings are the major causes of heavy losses of life and property in case of earthquakes. Lack of awareness in the community for earthquake resistant construction is the prime cause of such damages. To improve the condition, we must work for more aware community.
2. The traditional construction practices of the earthquake-prone areas have all the necessary features to withstand the earthquake forces. These practices have been degraded over a period to times due to various reasons. The traditional methods of earthquake resistanr construction have to be revived and upgraded with the state-of-art techniques and skills for the same.

3. Large quantities of relief materials pours in after every disaster. This material need proper management. The presence of various voluntary and local groups must be utilised in proper collection and distribution of this type of material under proper supervision of administrative machinery.
4. A number of NGOs come forward to assist the administration for providing the houses. There should be some mechanism to check the donor houses. The supply of materials to the affected victims is not the proper solution. Even the vanous groups adopt different methods and techniques for earthquake resistance of houses, there should be some organisaiton / institute to certify the provision of necessary features in the houses for earthquake resistance.

Annexure 1 : SOME DAMAGING EARTHQUAKES IN INDIA: APPROXIMATE NUMBERS OF LIVES LOST

Year of occurrence	Location	Magnitude (Richter)	Max Inten -sity (MM)	Other features
1618	Bombay	-	-	2000 lives lost
1720	Delhi	6.5	-	Some lives lost
1737	Bengal	-	-	300,000 Lives lost
1803	Mathura	6.5	-	Shocks felt in Calcutta
1803	Kumaon	6.5	-	200-300 lives lost
1819	Kutchch	8.0	XI	Towns of Tera, Kathara & Mothala destroyed
1828	Srinagar	6.0		1000 lives lost
1833	Bihar	7.7	X	Hundreds killed
1848	Mt. Abu, Rajasthan	6.0	-	Few lives lost
1869	Assam	7.5	-	Affected area of 250,000 square miles
1885	Srinagar	7.0	-	Kamiarary area destroyed
1897	Shillong	8.7	XII	Widespread destruction
1905	Himachal Pradesh	8.0	XI	Thousands killed
1906	Himachal Pradesh	7.0	-	Heavy damage
1916	Nepal	7.5	-	All houses in Dhur chulla collapsed
1918	Assam	7.6	-	Heavy damage
1930	Dhubri, Meghalaya	7.1	IX	Much damage in Dhubri
1934	Bihar, Nepal	8.3	XI	Many killed in border area
1935	Quetta (Pakistan)	7.5	IX	25,000 lives lost
1941	Andaman	8.1	X	Very heavy damage

Year of occurrence	Location	Magnitude (Richter)	Max Inten -sity (MM)	Other features
1947	Dibrugarh	7.8	X	Heavy damage
1950	Assam	8.6	XII	Heavy damage to life & property
1952	Pondgo & Tango, NE India	7.5		Heavy damage
1956	Bulandshahar, UP	6.7	VIII	Many killed
1956	Anjar, Gujarat	7.0	VIII	Hundreds killed
1958	Kapkote, UP	6.3	VIII	Many killed
1967	Koyna,Maharashtra	6.1	VIII	Koyna Nagar destroyed
1969	Bhadrachalam	6.5		Heavy damage
1986	Dharamshala, HP	5.7	VIII	Much damage
1988	Assam	7.2	IX	Few killed
1988	Bihar-Nepal	6.5	VIII	Many killed
1991	Uttarkashi	6.6	VIII	Lots of damage, many killed
1993	Latur	6.4	VIII	10,000 lives lost, much damage
1997	Jabalpur	6.0	VIII	39 lives lost, much damage

Source : Ministry of Agriculture and other sources