Role of Information Technology in Earthquake Disaster Mitigation

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ROLE OF INFORMATION TECHNOLOGY IN EARTHQUAKE DISASTER MITIGATION

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ABSTRACT

India has witnessed 6 earthquakes during past 15 years causing around 40,000 casualties and immense property loss. More than 90% of these casualties are due to collapse of buildings and they occurred within very short period of time after the earthquake. Hence, for reducing casualty losses and subsequent consequences due to earthquake, it is very important to study the response of structures due to seismic excitations. For studying the response of the structures and consequent issues after the earthquake disaster, information technology can play a major role. This paper contributes to understand the importance of information technology in earthquake disaster mitigation.

INTRODUCTION

According to latest seismic code, IS: 1893:2002, more than 60% of India is prone to earthquakes. Metropolitan cities like Delhi, Calcutta, Mumbai, Chennai, Ahmedabad etc., lie in Zone III or above. In these cities and other parts of the country, seismic response of existing structures should be studied and proper retrofitting activity should be carried out in order to reduce the casualty and property losses due to forthcoming earthquakes. Attempts were being made in order to predict the earthquake. Results from such studies say that we can now fairly well locate the place and the size of the event. However, it is has not yet been possible to provide an advance warning for an impending earthquake like one is able to do for floods or cyclones. Hence, there is a need to plan for a disaster mitigation system.

EFFECTS DUE TO PAST EARTHQUAKES

We have clearly witnessed during the recent Sumatra, Indonesia earthquake (M 9.0) the amount of damage an earthquake can cause to the society. Had this earthquake occurred on land, it would have easily damaged few hundreds of kilometers and the damage estimates would have been unimaginable. Earthquakes are not new to our country. We have experienced many great earthquakes in the past (see Table 1). Entire Himalayan belt is considered prone to great earthquakes of magnitude exceeding 8.0 and in a short span of about 50 years, four such earthquakes have occurred [Jain et al., 2002], 1897 Assam (M8.7), 1905 Kangra (M8.6), 1934 Bihar-Nepal (M8.4) and 1950 Assam-Tibet (M8.7). And now within a short span of 15 years we have witnessed 6 moderate earthquakes causing around 40,000 casualties and innumerable property loss (see Fig. 1). These earthquakes occurred in different parts of the country. Bihar-Nepal earthquake of magnitude M6.4 occurred in 1988 caused 1004 casualties, Uttarkashi earthquake of magnitude M6.6 occurred Uttar Pradesh in 1991 caused 768 casualties, Killari earthquake of magnitude M6.4 occurred in the district of Latur in Maharastra in 1993 caused 8000, Jabalpur earthquake of magnitude M6.0 occurred in Madhya Pradesh caused 38 casualties and Chamoli earthquake of magnitude M6.8 occurred in Uttar Pradesh caused 63 casualties.

These earthquakes were tragic but they also provided us some important lessons. Unfortunately, with these lessons there was no major social impact. Bhuj earthquake of magnitude M6.9 occurred in

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Table 1 List of significant earthquakes in India and neighborhood

DATE	EPICENTRE		LOCATION	MAGNITUDE
	Lat(Deg N)	Long(Deg E)		
1819 JUN 16	23.60	68.60	KUTCH,GUJARAT	8.0
1869 JAN 10	25.00	93.00	NEAR CACHAR, ASSAM	7.5
1885 MAY 30	34.10	74.60	SOPOR, J&K	7.0
1897 JUN 12	26.00	91.00	SHILLONGPLATEAU	8.7
1905 APR 04	32.30	76.30	KANGRA, H.P	8.0
1918 JUL 08	24.50	91.00	SRIMANGAL, ASSAM	7.6
1930 JUL 02	25.80	90.20	DHUBRI, ASSAM	7.1
1934JAN 15	26.60	86.80	BIHAR-NEPALBORDER	8.3
1941 JUN 26	12.40	92.50	ANDAMAN ISLANDS	8.1
1943 OCT 23	26.80	94.00	ASSAM	7.2
1950 AUG 15	28.50	96.70	ARUNACHAL PRADESH-CHINA BORDER	8.5
1956 JUL 21	23.30	70.00	ANJAR, GUJARAT	7.0
1967 DEC 10	17.37	73.75	KOYNA, MAHARASHTRA	6.5
1975 JAN 19	32.38	78.49	KINNAUR, HP	6.2
1988 AUG 06	25.13	95.15	MANIPUR-MYANMAR BORDER	6.6
1988 AUG 21	26.72	86.63	BIHAR-NEPAL BORDER	6.4
1991 OCT 20	30.75	78.86	UTTARKASHI, UP HILLS	6.6
1993 SEP 30	18.07	76.62	LATUR-OSMANABAD, MAHARASHTRA	6.3
1997 MAY 22	23.08	80.06	JABALPUR,MP	6.0
1999 MAR 29	30.41	79.42	CHAMOLI DIST, UP	6.8
2001 JAN 26	23.40	70.32	BHUJ, GUJARAT	6.9

India Meteorological Department

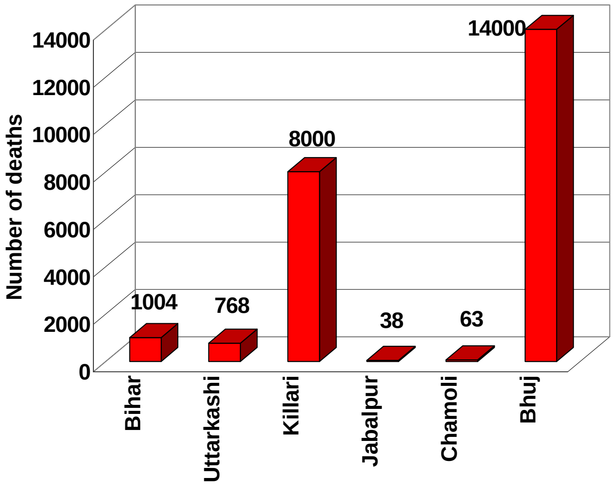


Fig. 1 Casualties during past events

Gujarat on 26th January 2001 created major impact on society because this is the first earthquake that hit Indian metropolitan city and it affected middle and upper middle class people. It caused around 14,000 casualties and innumerable property loss. Over 150 multistoried RC buildings collapsed in Ahmedabad city itself. Author visited Gujarat as a member of reconnaissance team from Japan and studied the earthquake-affected areas. Following are some important observations and recommendations during his visit to Gujarat.

OVERVIEW ON 26th JANUARY BHUJ EARTHQUAKE

Extensive damage was observed in non-engineered structures (see Figure 2). In these structures, large blocks were usually piled up with weak mortar joints. This results in very poor lateral strength. Even under slightest shaking the structures were brought down to rubble. In some areas, almost 100% of the structures collapsed. These adobe and masonry structures have two main inconveniences. First, in the case of collapse they leave very small free space underneath debris and thus the probability of survival is low if somebody is trapped under the debris and second, due to the dust generated by the collapse, even if the person can survive collapse, it might be inconvenient for him/her to breath.

-RC Structures

Many multi-story reinforced concrete structures collapsed in Ahmedabad and Gandhidham. The common feature observed in most of these structures is their ground storey is open (see Fig. 3) for parking with few or no filler walls, which resulted in a top-heavy and soft-ground floor. Sometimes it may have smaller stiffness resulting larger deformation and sometimes its lateral strength is weak. Around 130 building collapsed in Ahmedabad, most were of open ground story configuration [Jain et al., 2002 and Sono and Tanaka, 2001] Among those that did not collapse, the damage was confined mostly to open ground story columns with only nominal frame infill separation in the upper stories.

Fig. 2 Extensive damage occurred in non-engineered structures

Fig. 3 Soft bottom storey

- Cracking of masonry wall panels

The most commonly observed damage to RC structures was in the form of cracking and falling of infill walls. The infill walls were very vulnerable and damage to those walls resulted in significant economic loss and human casualties. However, the most striking failures were the structural failures of modern multi-storey buildings. The damage spread not only to cities close to the epicenter but also to major cities far from epicenter. Some of those cities are Morbi (125 km), Rajkot (150 km), Ahmedabad (300 km). Although local geotechnical conditions and site amplification seemed to have influenced the damage patterns in Ahmedabad which is located on thick alluvial deposits along the Sabarmati River, the maximum recorded peak ground acceleration was as less as 0.11g at the basement of passport office building [Kono and Tanaka, 2001].

- Highlights of observed damage:

Damage to RC structures can be attributed for the following reasons:

1. Open ground storey that resulted in soft storey.
2. Inadequate detailing and confinement at structural joints.
3. Inadequate spacing of lateral reinforcement and improper hooks.
4. Lateral force is not considered in design.
5. Improper anchoring of beam and column reinforcement.

- How IT can be useful?

Usually, at loads in the initial stages individual masonry infills and their surrounding frame members behave monolithically. This phase ends with the occurrence of interface separation, and when the load acts in the out-of-plane direction the entire wall falls outside causing huge reduction in lateral strength of structural framework. This sometimes causes the continues collapse of building in the form of

Table 2 Casualties during Kobe Earthquake

Time of death		No. of Casualties by Medical Examiners		No. of Casualties by Ordinary Doctors		Total Number
1/ 17	6:00	2,221	2,221 (91.9 %)	719	719 (58.2 %)	2,940 (80.5 %)
	9:00	16	2,237 (92.6 %)	58	777 (62.9 %)	3,014 (82.6 %)
	12:00	47	2,284 (94.5 %)	61	838 (67.9 %)	3,122 (85.5 %)
	23:59	12	2,296 (95.0 %)	212	1,050 (85.0 %)	3,346 (91.6 %)
	unidentify	110	2,406 (99.6 %)	84	1,134 (91.8 %)	3,540 (97.0 %)
1/ 18		5	2,411 (99.8 %)	62	1,196 (96.8 %)	3,607 (98.8 %)
1/ 19			2,411 (99.8 %)	13	1,209 (97.9 %)	3,620 (99.2 %)
1/ 20		2	2,413 (99.9 %)	8	1,217 (98.5 %)	3,630 (99.4 %)
1/ 21		1	2,414 (99.9 %)	6	1,223 (99.0 %)	3,637 (99.6 %)
1/ 22		1	2,415 (100.0 %)	1	1,224 (99.1 %)	3,639 (99.7 %)
1/ 24			2,415 (100.0 %)	1	1,225 (99.2 %)	3,640 (99.7 %)
1/ 25		1	2,416 (100.0 %)	1	1,226 (99.3 %)	3,642 (99.8 %)
1/ 26			2,416 (100.0 %)	2	1,228 (99.4 %)	3,644 (99.8 %)
1/ 27			2,416 (100.0 %)	1	1,229 (99.5 %)	3,645 (99.8 %)
1/ 28			2,416 (100.0 %)	1	1,230 (99.6 %)	3,646 (99.9 %)
2/ 4			2,416 (100.0 %)	1	1,231 (99.7 %)	3,647 (99.9 %)
	No record		2,416 (100.0 %)	4	1,235 (100.0 %)	3,651 (100.0 %)
Total Number		2,416		1,235		3,651

from: Kobe Earthquake report (1995)

pancake. If there is a method in which the designer is able to visualize the collapse process of structure, then he can incorporate necessary changes in the structure right at the planning stage. This technique can serve as a useful tool for finding the vulnerability of already built structures for future earthquake events. By visualizing the structure's performance carefully, suitable retrofitting measures can be taken. Applied Element Method (AEM) developed by Meguro and Hatem (2000) has the advantages to analyze the total response of the structure.

EARTHQUAKE DISASTER REDUCTION SYSTEM

Earthquake disaster reduction broadly consists of three components. They are 1. Mitigation 2. Preparedness and 3. Recovery and reconstruction. If we carefully observe Table 2, we can easily see that many casualties occur within very short period of time i.e., within few minutes after the earthquake has occurred. This means, most of the problems after the event are generated mainly because of failure of structures and hence, the response of structures under seismic excitation is very important area where the researchers should concentrate and bring out effective tools for disaster mitigation.

a. Mitigation

Damaging effects of earthquakes can be mitigated by i) controlling the vibration of tall structures and very important structures and facilities, ii) strengthening of existing structure stock and iii) building safe structures in highly seismic zones.

- Structural Control

The protection of structures from severe dynamic loading such as earthquakes, high winds etc., can be accomplished by means of structural control. By and large, structural control can be classified into two categories: passive control and active control. While the passive control techniques have got widespread application, the active control application in civil engineering structures is slowly growing. Although the concept of structural active control has been proposed for more than two decades, a number of serious challenges remain to be resolved before active control can gain general acceptance by the engineering and construction professions (Zhu et al., 1999).

- Active control:

Active control of vibration in structures has been investigated by an increasing number of researchers in recent years. Underlying concept of this method is that waves take some time to travel inside the structure. In the meantime, seismometers monitor the response of the structure by performing non-linear analysis and they estimate the lateral forces likely to be generated in the building. Then, immediately signals are sent to the actuators located at different floors to apply suitable damping. For studying this, there has been a great deal of theoretical work and some experimental has done, examining the use of point forces for vibration control, and more recently (Young, 1995), the use of thin piezoelectric crystals laminated to the surfaces of structures.

- Passive control:

There are two approaches for passive control i.e., a) Base Isolation and b) Energy dissipaters.

a) **Base Isolation**: Usually ground motions are predominant in certain range of frequency. Buildings that fall in that range are more vulnerable to damage. In the base isolation, we shift the fundamental frequency of the structure by putting some flexible material under the structure. This material has strength as high as that it can take the gravity load of the structure in vertical direction and it is flexible in lateral direction. Elastomeric bearing commonly used for base isolation.

b) **Energy dissipaters:** Instead of isolating the structure, the vibration energy is allowed to reach higher levels in it. This energy gets converted into kinetic energy thus producing motion in structure. To reduce the damaging effects due to motion, dissipators are located places where lateral shear forces are very large. These days there are many dissipating devices available in the market. Viscous dampers, steel yielding friction plates etc., to name a few.

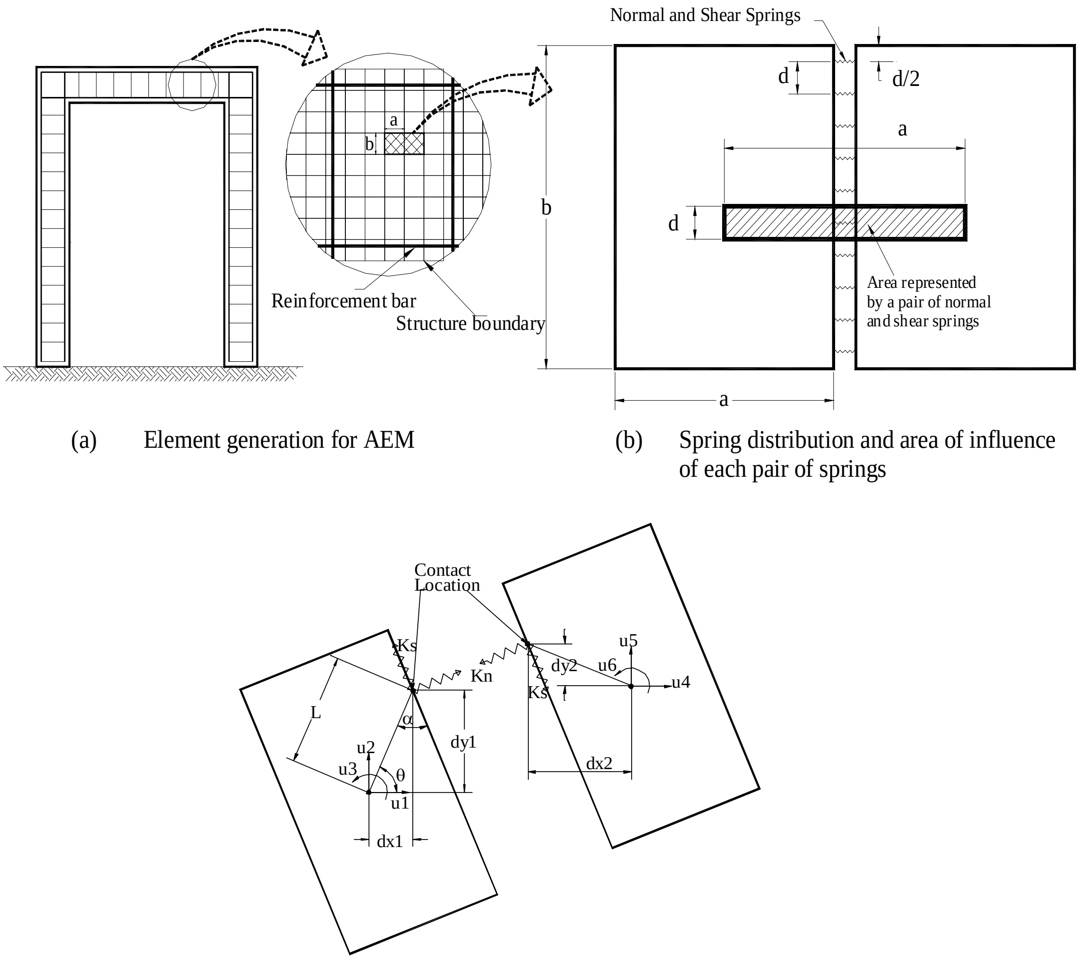
Though structural control techniques are available to make the structure earthquake resistant, their implementation is very expensive and for residential type of structures it is uneconomical.

- Strengthening of existing structures

As a countermeasure for reducing the loss due to upcoming earthquake events, upgrade of the seismic performance of existing structures is most urgent issue in highly seismic regions. This involves economic and social aspects. In our country, majority of buildings are constructed without following seismic code provisions. These structures cause great strain on the economy of the states and centre and people themselves, besides misery and suffering that have to bear. Adoption of preventive strategies will go long way in reducing not only the suffering of the people but also the economic losses and calamity relief costs in the long run. Post-construction strengthening of structures for upgrading seismic resistance is more involved and costlier than ensuring adequate resistance at the time of initial construction. Hence, there is a need to develop some technique to assess the strength of the existing weak structures and suggest a suitable retrofitting method.

- Design earthquake resistant structures

To assure the safety of general public in the event of earthquakes, it is important to analyse the collapse process of structures. Where and how the structures undergo collapse? Is the time of collapse short or long? Will the structure collapse partially or fully? To answer all these, it is important to study the non-linear dynamic response of the structure under the event of earthquake. However, it is difficult to perform these investigations experimentally because it is difficult to prepare a model similar to real structure. On the other hand, numerical models which can predict the behaviour accurately in small and large deformation range and in non-linear range have the advantage of modelling any kind of structure with a flexibility to change the parameters such as strength of concrete, reinforcement ratio, section sizes. The Finite Element Method (FEM) [Zienkiewicz, 1993 and Reddy, 1993] is one of the most important developments in applied mechanics. The method is applicable to wide range of problems. It assumes that the media is descritized in the form of a mesh. The accuracy of the method depends on the mesh size. Results of high accuracy can be obtained in the elastic analysis. Non-linear analyses can also be carried out till the large deformation cases except the simulation of separation of



(a) Element generation for AEM

(b) Spring distribution and area of influence of each pair of springs

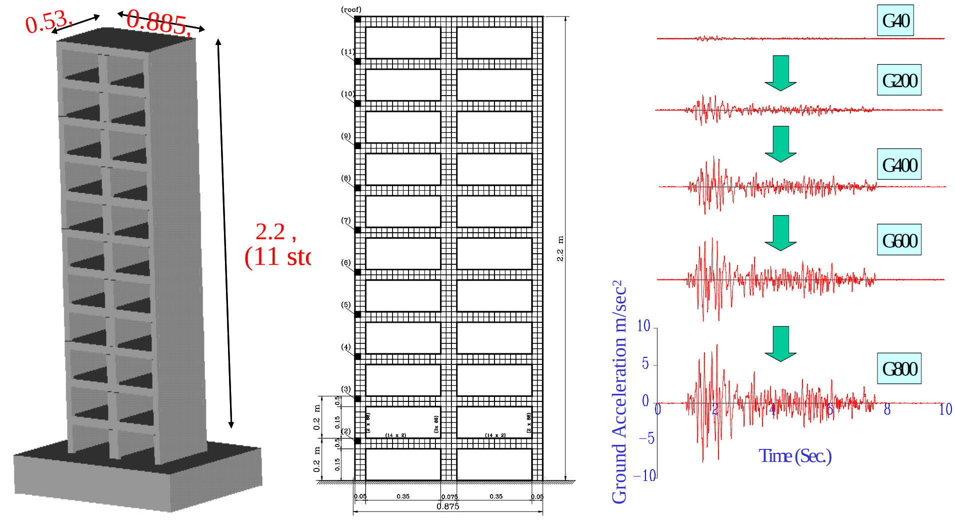
c) Spring connectivity

Fig. 4 Modeling of structure in AEM

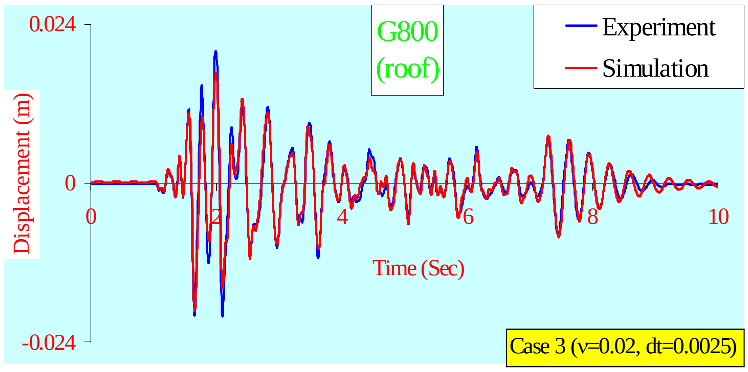
the media into many parts. FEM faces lot of complications when we want to apply it to the materials that have discontinuities like rocks. These complications are mainly due to the basic assumption i.e. material is continuum. Special techniques must be used to deal with the discontinuities or discrete cracks.

Extended Distinct Element Method (EDEM) [Meguro and Hakuno 1989, 1993] showed good accuracy in following the large geometrical changes in the studied media. However, the accuracy in the linear range is not comparable to the accuracy of FEM and moreover since there is no generation of the global stiffness matrix, it is difficult to perform the eigen value analysis. The advantages of the above-mentioned numerical techniques are available in the recently developed numerical technique, called Applied Element Method (AEM). Using AEM, the structural behaviour can be carried out from zero loading, crack initiation and propagation, separation of structural members and till total collapse in reasonable time, reliable accuracy and with relatively simple material models.

Applied Element Method (AEM) that was developed by Meguro and Tegel-Din [Meguro and Tagel-Din, 2000 and Tagel-Din 1998], showed accuracy in predicting the behavior of structure in small and large deformation ranges in static and dynamic cases. In this method the structure is modeled as an assembly of small elements that are made by dividing the structure virtually, as shown in Fig. 4 (a). The two elements shown in Fig. 4 (b) are assumed to be connected by pairs of normal and shear springs located at contact locations that are distributed around the element edges. Each pair of springs totally represents stresses and deformations of a certain area (hatched area in Fig. 4 (b)) of the studied



a) RC scaled building b) AEM modeling c) Input ground motion



d) Comparison of response at roof

Fig. 5Comparison with shake table test results

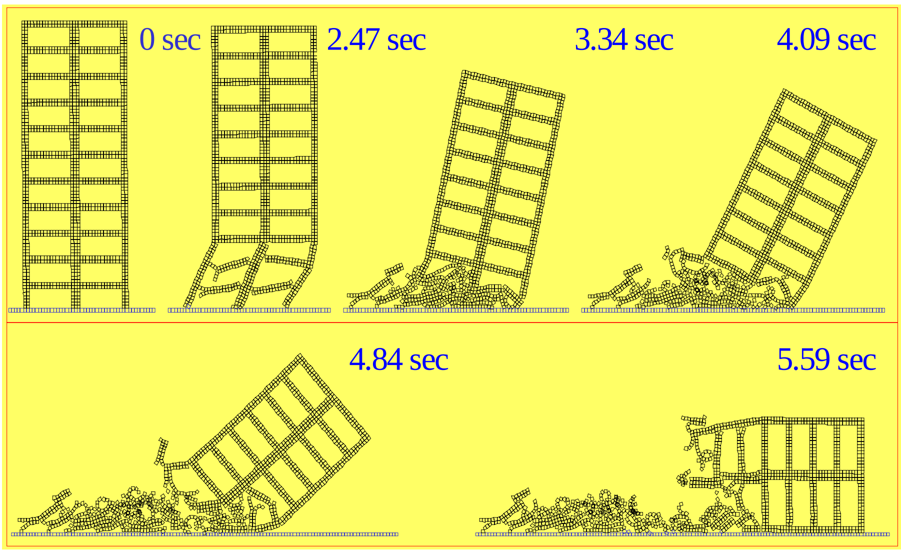


Fig. 6 Simulation of collapse behavior

elements. Three degrees of freedom are assumed for each element. These degrees of freedom represent the rigid body motion of the element. Although the element motion is a rigid body motion, its internal stress and deformations can be calculated by the spring deformation around each element. This means that although the element shape doesn't change during analysis, the behavior of assembly of elements is deformable.

This method has been applied to see the comparison of numerical results with that of experimental results obtained during shake table tests. Details of the shake table test results and collapse analysis results are shown in Figs. 5 and 6 respectively. For more details about this method please refer Meguro and Tagel-Din (2000).

B. Preparedness

There is a general lack of understanding about the occurrence of earthquake hazards, the underlying scientific phenomena, the extent and type of possible effects, the methods and effectiveness of protective methods and the cost of protection etc. Not only lack of understanding, but even misunderstanding and wrong beliefs also exist in the society. A concerted effort needs to be made in a well-planned structured way to address the target audiences.

C. Recovery and reconstruction activity

Immediately after the earthquake the primary concern is to know the extent of damage and how much area is affected. Figure 7 shows the flow chart of recovery and reconstruction activity. To carry out the activities in flowchart aerial photography and GIS can provide us with tools to carry out the plan explained in flowchart. The assessment and demarcation of earthquake-affected area can be done through quick aerial photography after an earthquake. Classification of damaged areas into worst; moderate and least affected areas can be done through the use of different color tones on the satellite imageries and aerial photographs. With the help of hand held GPS we can locate the alternate shortest possible routes.

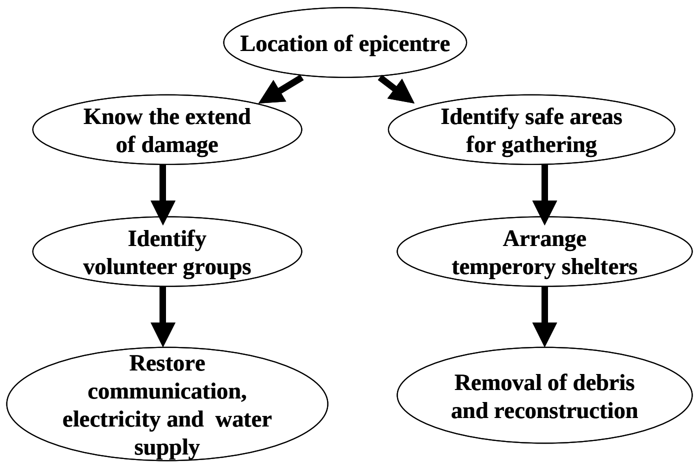


Fig 7. Flow chart of recovery and reconstruction

IMPORTANCE OF EARTHQUAKE RESISTANT CONSTRUCTIONS

Over past two decades, India had a major boom in RC constructions. Basically constructions were of infilled masonry walls with RC structural framework. Due to technology advancement these days, more daring structures are being attempted. These structures are highly susceptible to seismic vibrations that demand the need for lighter construction materials so as to reduce the total weight of structure. However, our cities are growing at rapid pace without giving any consideration for earthquake safety. There is an urgent need to educate people on the safety issues because all the time, owner of the structure is looking for cutting the cost by employing unskilled designer or when the money is not the factor, there the owner is looking for cosmetic effects rather than safety aspects. Hence, it is the responsibility of every house owner/user to know whether their structure is safe or not.

CONCLUSIONS

As a conclusion author likes to emphasis that earthquake itself never kills people, it is badly constructed buildings that kill. Hence, it is necessary to understand the performance of the structure in the event of earthquake and consequences arising after structures damage. For achieving this purpose, how the information technology can be used as a tool for minimizing the losses due to earthquake is explained.

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