Engineering for Natural Disaster Management

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ENGINEERING FOR NATURAL DISASTER MANAGEMENT

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ENGINEERING FOR NATURAL DISASTER MANAGEMENT

PREFACE

The risks related to natural disasters specially in the case of earthquakes in an area can be considered to be a function of four components as follows:

Seismic Risk = f (Hazard, Exposure, Vulnerability, Location)

Hazard means the occurrence of an earthquake of sufficient Magnitude (hence peak Intensity at the epicenter) capable of causing damage to the man-made structures.

Exposure indicates the objects and structures built by man which are exposed to the effects of the 'hazard' and will include buildings, bridges, dams, power plant, life-line structures, equipments, building contents etc.

Vulnerability indicates the damageability of the 'exposure' under the ac ion of the hazard, weaker constructions being more vulnerable and 'risky' than the stronger ones.

Location means, firstly how far the 'exposure' is situated from the location of the 'hazard' the nearer ones being in greater danger than those far away, and secondly, the local site conditions which can modify the hazard and/or affect the stability of the exposure, such as topography, soil deposit, water table etc.

The determination of seismic risk level involves considerable uncertainty and requires special study and understanding of the phenomena involved. The policy planning regarding mitigation of earthquake risk is not only concerned with the existing risk level but also with what would be the acceptable risk taking into account the trade offs involving cost to the individual, cost to the society, amount of safety increased per unit of additional cost, etc. Seismic microzonation studies in hazard prone urban areas and damage scenario estimates in severe seismic zones could establish the seismic risk levels to be taken care of by concerted mitigation measures.

Out of the four factors making up the risk, the earthquake hazard can neither be prevented from occurrences nor predicted precisely. Earthquake prediction studies will help in defining the hazard and its location and in stimulating preparedness actions including preventive measures before the occurrence of the hazard and emergency relief measures after the event. Prediction as a means of saving human lives in earthquakes is extremely unreliable at present and for saving economic losses it will be utterly useless since seismologically weak buildings and structures will remain liable to catastrophic behaviour during strong earthquakes. The 'exposure' consisting of man-made structures and systems, already exists, and is getting expanded day by day with the growth of population and modern economic development, the pressure on land is increasing with the result that even unsuitable and unstable sites are being occupied for settlements. Land use planning, monitoring or control is absolutely necessary for preventing expansion of Risk.

The 'locations' of population centres within the severe seismic zones are already fixed by history and tradition. There is some choice in locating the future settlements and major projects away from the known seismogenic features, but for various other reasons such as economical and socio-political considerations, they may have to be located within tide available areas whether highly seismic or otherwise. The local site conditions rarefy govern the choice of site, either with the people who usually opt for the cheapest, or for the projects who do treat it as an engineering problem. Improvement of the site and adoption of earthquake resistant construction technology will only reduce the disaster risk.

This Book will be of immense help to all those contemplating to acquire an expert knowledge of engineering techniques for natural disaster management.

Suggestions are welcome for improving the next edition of this important publication.

New Delhi
Earth Day, 22 April 2010

Dr. Kadambari Sharma
Dr. Avinash Chiranjeev

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ENGINEERS ROLE IN EARTHQUAKE DISASTER REDUCTION IN INDIA

*Dr. Anand S. Arya**

ABSTRACT

During the last 100 years India has lost about 100,000 lives due to earthquakes in which some areas have been damaged repeated. The paper attempts to answer the question what could be done to reduce the disastrous impact of earthquakes and the critical role that the engineers have to play in this task, through prevention, mitigation and preparedness measures in the predisaster phase in a pro active manner. Considering a huge stock of existing unsafe buildings in the earthquake prone areas, momentous effort has to be made to assess their damageability and carry out retrofitting measures as per the Indian Standard Codes and Guidelines. It is shown that preventive measures before qa damaging earthquake occurrence are not only safer but also cost-effective.

INTRODUCTION

During the last 100 years, India has lost about 100,000 lives due to earthquakes, or at average of about 1000 lives per year. The corresponding average for the whole world is about 18000 lives

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per year. It may be argued that these figures are not so impressive since traffic accidents now may be accounting for many more lives than the above. But when one looks at such figures as 20,000 lives perishing in a matter of seconds in the 1905 Kangra Earthquake of M = 8.0 in Himachal Pradesh or 13800 lives lost in Gujarat in the recent Kachchh earthquake of 2001, together with hundreds of thousands of houses collapsed or severely damaged, in each event, one can imagine its impact on the misery of the survivors and the economy of the region affected by the earthquake. Even more important is the question *"if the 1905 Kangra earthquake is to repeat itself, which would not be unlikely after a hundred years or more, what would be the shape of things then?"* The startling answer would be that there are more numerous houses as well as people to suffer the consequences since the wood-framed brick-nogged construction adopted after 1905 earthquake in urban areas has long been forgotten and the highly vulnerable brick and stone constructions using mud mortar, have taken its place. No wonder that in the April 1986 Dharmasala earthquake of only 5.7 Richter Magnitude, several thousand buildings got severely damaged requiring extensive repair and reconstruction costing Rs. 65 crores (1986 prices)!

The tragedy of A1 Asnam in Algeria should indeed be an eye opener to all planners, engineers and builders. In October 1980, an earthquake of 7.5 Magnitude on Richter Scale rocked the town and reduced most of its sandstone modern buildings to heaps of rubble. Estimate of lives lost was 2500 and injured 200,000. The worst part of the story is, however, the fact that barely 26 years earlier, the same town had been destroyed by an earthquake killing 1600 people at that time, and the present town was mostly built anew after that earthquake!

In India itself, after the tragic occurrence of Bihar-Nepal Earthquake of 1934 (M = 8.4) in which more than 13000 people had died in India and Nepal, no improvements were made in construction practices due to which even during moderate earthquake of Aug. 21, 1988 with magnitude 6.6 only, the results were catastrophic with a loss of lives of about 900 on both sides of the border and property of hundreds of crores was destroyed!

The great earthquake in Kachchh on January 26, 2001, which resulted in huge calamity in five districts of Gujarat again destroyed the old part of the city of Anjar, also showed that lessons were not learnt in Anjar even after the trajedy of 1956 earthquake. The constructions in the market were so bad that the collapse of buildings buried 400 School children who were marching with Republic Day flags in their hands when the buildings fell on them from both sides of the street.

Another apt question may now be asked, *'Could the repeat catastrophe at A1 Asnam, Dharmsala or Anjar have been avoided'?* The answer *should be, 'Yes"*, since although earthquakes can not be prevented, the collapse and severe damage to buildings can certainly be minimised and most lives can be saved by *appropriate engineering measures of earthquake resistant design and construction of the buildings and the infrastructure elements.* This point would be evident from an interesting comparison made by Ambraseys (1) regarding the financial losses for each life lost in four countries, namely U.S.A., Turkey, Iran, and land area now forming part of Pakistan, during the period 1900-1968. *The ratio of financial loss per life lost in these countries is 1500, 5.1, 3.4 and 1.0* respectively which shows that by better design and construction quality, the collapse of structures can be avoided almost altogether as in USA so that even though economic loss due to damage or cracking may still be appreciable, the life is saved. The aim of this paper is to highlight the status of the earthquake hazard in India, the existing seismic disaster risk and the role of engineers in the reduction of the vulnerability of buildings and the infrastructures for achieving the safety of the habitat.

EARTHQUAKE RISK

The earthquake risk in an area can be considered to be a function of four components as follows:

Seismic Risk = f (*Hazard, Exposure, Vulnerability, Location*)

Hazard means the occurrence of an earthquake of sufficient Magnitude (hence peak Intensity at the epicenter) capable of causing damage to the man-made structures.

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The determination of seismic risk level involves considerable uncertainty and requires special study and understanding of the phenomena involved. The policy planning regarding *mitigation of earthquake risk* is not only concerned with the *existing risk level* but also with what would be the *acceptable risk* taking into account the trade offs involving cost to the individual, cost to the society, amount of safety increased per unit of additional cost, etc. *Seismic microzonation studies in hazard prone urban areas and damage scenario estimates in severe seismic zones could establish the seismic risk levels to be taken care of by concerted mitigation measures.*

Out of the four factors making up the risk, the earthquake hazard can neither be prevented from occurrences nor predicted precisely. Earthquake prediction studies will help in defining the hazard and its location and in stimulating preparedness actions including preventive measures before the occurrence of the hazard and emergency relief measures after the event. *Prediction as a means of saving human lives in earthquakes is extremely unreliable at present and for saving economic losses it will be utterly useless since* *seismologically weak buildings and structures will remain liable to catastrophic behaviour during strong earthquakes.*

The *'exposure'* consisting of man-made structures and systems, already exists, and is getting expanded day by day with the growth of population and modern economic development, the pressure on land is increasing with the result that even unsuitable and unstable sites are being occupied for settlements. Land use planning, monitoring or control is absolutely *necessary for preventing expansion of Risk.*

The '*locations*' of population centres within the severe seismic zones are already fixed by history and tradition. There is some choice in locating the future settlements and major projects away from the known seismogenic features, but for various other reasons such as economical and socio-political considerations, they may have to be located within tide available areas whether highly seismic or otherwise. The local site conditions rarefy govern the choice of site, either with the people who usually opt for the cheapest, or for the projects who do treat it as an engineering problem. Improvement of the site and adoption of earthquake resistant construction technology will only reduce the disaster risk.

The fourth factor is the *'vulnerability'* of the exposure to the hazard. This appears as the factor which is much more in the engineers hands to deal with. For reducing the seismic risk and to mitigate earthquake disasters, this is where our efforts should be directed to a much greater extent than done upto now. *Reduction of vulnerability of our buildings and other structures and systems, those existing and those being built or to be built, is the key to earthquake protection.* It is here, the engineers have their most critical role to play.

APPROACHES TO HANDLE THE PROBLEM

Apparently three situations exist advertently or otherwise for handing the earthquake disasters (2).

The *first* and the most prevalent in the country seems to be "fatalistic" that is, everything left to the mercy of super-natural powers or fate. This is where the destiny of most of rural population in developing countries seems to lie.

The second appears to be of Response, that is, to take whatever possible action could be taken after the tragedy by way of rescue, relief and rehabilitation. Where the natural disasters take place frequently, this becomes a heavy burden on the resources of the State without a long term solution. The population remains under the fear of the tragedy and development of the region remains restricted.

The *third* and most scientific approach is that of *pro-active pre-disaster planning and actions to meet the challenge by using appropriate preventive and preparedness measures so that the disastrous effects are largely reduced and the post-disaster relief works are reduced to a minimum.* Hence life will become normal and people continue their economic pursuits within the least amount of time.

The IDNDR Yokohama Message (1994) is most relevant in developing disaster management policy.

"The impact of natural disasters in terms of human and economic losses has risen in recent years, and society in general has become more vulnerable to natural disasters.

"Disaster Prevention, Mitigation and Preparedness are better than disaster Response in achieving the goals and objectives of disaster reduction. 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".

DISASTER MANAGEMENT

Disaster management should effectively deal with all the time phases of the earthquake disaster, namely, the pre-disaster peace-time phase, the occurrence phase of the earthquake motion, and the response phase after the occurrence of the earthquake involving rescue, relief and rehabilitation, etc. The whole gamut of activities could be considered under two parts namely Mitigation and Response as shown in Figure 1.

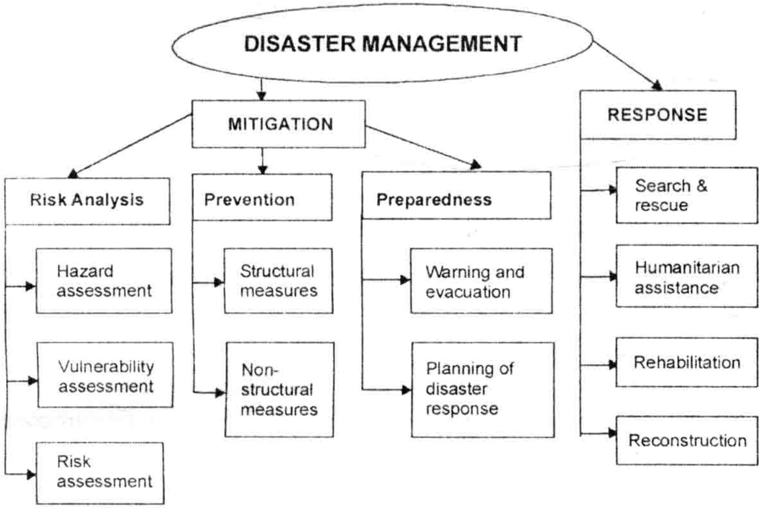

Figure 1: Main Elements of Disaster Management.

For carrying out the disaster management functions towards natural disaster reduction, a large number of activities are required as illustrated in Figure 2 which shows the total functional structure of disaster management as developed by the 'Think tank' of Ad-hoc Expert Group of IDNDR.

It will be seen that the total tree structure consist of the supporting activities at the root, such as public awareness, research and development education and training, and the various levels at which various activities are to be carried out such as local, state, subregional, regional and global, Scientific activities involving hazard monitoring, vulnerability assessment, disaster risk evaluation, prediction and forcasting studies form the stem of the tree. The three branches of this tree are: *first*, the prevention activities involving development of building codes, implementation of structural and non structural measures and retrofitting of building structures and systems: *second*, the preparedness for post disaster response actions involving rescue, evacuation, providing relief; maintaining law and order, communications, transportation routes; fire fighting, medical help etc., and *third*, repair, restoration, retrofitting and reconstruction of damaged buildings and structures, and providing economic rehabilitation to the affected population. These activities infact must involve most sectors of the society for effective implementation.

The engineering profession has to play a very important role in practically all activities of the disaster reduction matrix.

EARTHQUAKE OCCURRENCE IN INDIA

Seismological information about earthquakes occurring in and around India is available only for about the past 200 years. The first-ever catalogue of Indian earthquakes was prepared by T. Oldham (3); a former Director of the Geological Survey of India. This catalogue, though extremely useful, was by no means complete. The seismological Division of the India Metrological Department have compiled a catalogue of Indian earthquakes having magnitudes 5 and above. This contains fairly reliable information, at least since 1897. However, this catalogue has not been published. A catalogue of earthquakes occurrence in Indian and surrounding areas upto Dec. 1979 is however available in printed form (4). Better known damaging earthquakes are listed in Table 1.

For considering the regional distribution of earthquakes in the Indian subcontinent the whole area can be divided into the following seismic regions (6).

(*a*) Kashmir and Western Himalayas
(*b*) Central Himalayas (including Nepal Himalayas)
(*c*) Northeast India
(*d*) Indo-Gangetic Basin and Rajasthan
(*e*) Cambay and the Rann of Kutch
(*f*) Peninsular India
(*g*) Andaman & Nicobar Islands

The seismic activity of these regions is summarized in Table 2 based on earthquakes listed in Ref. (6) with the damaging earthquakes occurring thereafter included. The table shows the various magnitude earthquake numbers in each region and the average return period of M $\geq$ 5.0 earthquakes.

The Geological Survey of India (GSI) has been in the forefront for studying the earthquake damages and effects in the past. Their reports have been published in detail in the form of Memoirs of the Geological Survey of India. The major Indian earthquakes since 1897 have mostly been reported in this way.

Now GSI has published Seismotectonic Atlas of India, which consists of 43 sheets of maps covering 3° longitude × 4° latitude in each sheet to scale of 1:1 m. The maps are of derived nature, and

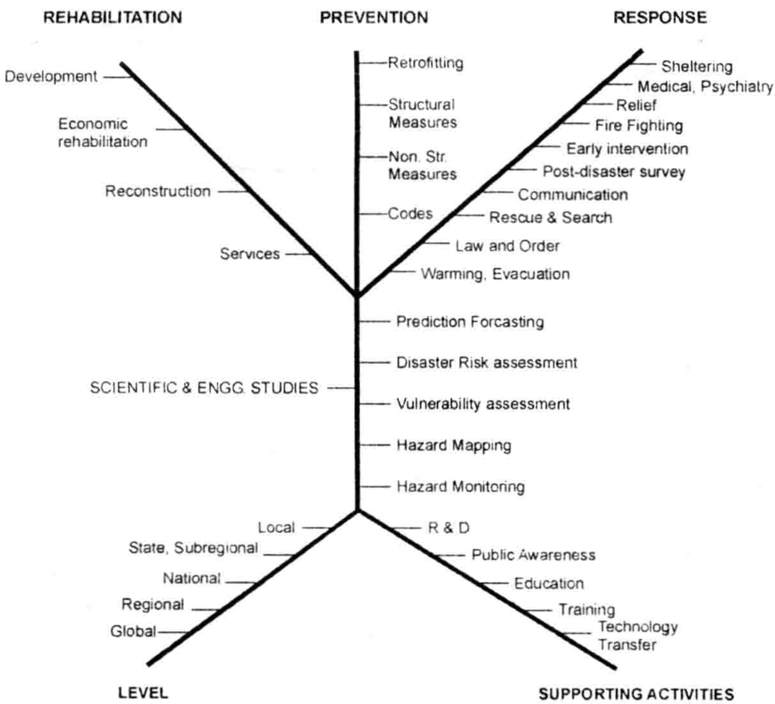

Figure 2: Functional Structure of Natural Disaster Reduction.