Gujarat Earthquake, January 2001 – lessons to be learnt

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ABSTRACT: The news media published many articles and reports on the devastation caused by the recent earthquakes in India, El Salvador, Turkey, Japan, Philippines, Greece and Taiwan.

These earthquakes caused serious damage to buildings and consequential loss of human lives. According to the initial press reports on the Gujarat Earthquake in India on 26 January 2001, which registered 7.9 on the Richter scale, the death toll was estimated to be 125,000. The Gujarat Recovery Program Assessment Report dated March 14, 2001 prepared by the World Bank & The Asian Development Bank reported that one million homes, two district hospitals, 1,200 health clinics, over 11,600 schools and other infrastructure services were damaged or destroyed.

Death and suffering caused by major earthquakes such as in Gujarat, have a direct social and psychological impact on survivors. Economic consequences follow as a result of direct losses and there are enormous costs of organising the rescue operations and additional unbudgeted expenditure for rehabilitation. These outcomes eventuate due to political and social norms overriding knowledge and technology in earthquake mitigation. Suggestions on how these impediments could be overcome are put forward in this paper.

1 INTRODUCTION

Several assessment reports on the devastation caused by the Gujarat quake clearly point to the fact that colossal loss of life and damage to property could have been minimised if structures were designed and constructed in a manner to withstand seismic loads. Similar conclusions have been drawn in reports on devastation caused by other major earthquakes around the world, including New Zealand. In the summing up of the official Government report of the 1931 Napier Earthquake produced by the Building Regulations Committee report, the following was stated:

> *Perhaps the most striking fact impresses itself upon one's notice, in even a cursory examination of damaged structures in this area, is the evident inadequacy or total lack of competent supervision during construction. Omission of minor details in plans and departure from recognized standard practice in building-construction have resulted in serious and unnecessary damage.*
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> - Building Regulations Committee, 1931

Although research work continues to focus on understanding the precise behaviour of structures under varying conditions of seismic loading, sufficient information is currently available worldwide to be able to construct buildings to withstand earthquake forces. Professional engineers and scientists in India and other parts of the world possess the necessary expertise,

knowledge and skills to design and construct earthquake–resistant structures. Yet people do not always benefit from this sea of knowledge.

2 INDIAN EXPERTISE

It is worth noting that the number of agencies and institutions in India associated with education and research work in this area are many. Even associations responsible for continuing education programmes for the benefit of practicing structural engineers and architects are many. These include:

University of Roorkee, Institution of Engineers, Bureau of Indian Standards, Indian Institute of Technology, Indian Meteorological Department, National Remote Sensing Agency, Earthquake Risk Evaluation Centre of the Department of Science and Technology, School of Planning and Architecture, Indian Society of Structural Engineers, National Geological Research Institute, National Geophysical Research Institute, Indian Society of Earthquake Technology and International Institute for Sustainable Future.

The Bureau of Indian Standards has published codes of practice and guidelines related to the earthquake resistant design and construction of buildings. IS 4326 (1993), IS 1893 (1984), IS 13827 (1993), IS 13828 (1993) and IS 13935 (1993) cover design criteria, loading standards, plain and reinforced concrete, unreinforced masonry, guidelines for repair and seismic strengthening, and so forth. The Indian Road Congress Codes of Practice on design and construction of bridges also deal with the issue of earthquake-resistance. The Vulnerability Atlas of India, 1977, includes an earthquake zoning map for India. Current building codes endeavour to ensure that structures are able to withstand seismic loads of moderate intensity without structural damage and are able to withstand heavy intensity loads without total collapse.

A manual of Earthquake Resistant Non-Engineered Construction was published in 1981 by the Indian Society of Earthquake Technology with the permission of the International Association for Earthquake Engineering. This manual provides details of inexpensive earthquake resistance measures in non-engineered structures with simple illustrations aimed at fulfilling an urgent need of providing the relevant information for ready use. It is not only directed to architects and engineers, but also the public and private builders who may not have the necessary technical background in building earthquake-resistant structures.

Indian experts in the field have also attended many international workshops on this topic; one of them being the 2nd Japan-United States Workshop on Urban Earthquake Hazards Reduction held at Tokai University, Shimizu, Japan in July 1988.

It is possibly a little known fact that the Sixth World Conference on Earthquake Engineering (WCEE) was hosted by India, and Indian delegations and speakers have actively participated in these conferences held every four years. In the Twelfth WCEE held in 2000 in Auckland, New Zealand, Prof. Anand S Arya contributed a paper titled "Non-engineered Construction in Developing Countries" (Arya, 2000). Extracts from his paper are reproduced below to reflect the ground realities:

> *"The safety of the non-engineered buildings from the fury of earthquakes is a subject of highest priority in view of the fact that in the moderate to severe seismic zones of the developing world more than 90 percent of the population is still living and working in such buildings, and that most losses of lives during earthquakes have occurred due to their collapse. ...*
> *The present disaster management policies of the governments in the developing countries do not address the issue of preventive actions for the safety of such buildings toward seismic risk reduction… ... and the building by-laws of municipalities and corporations are silent about earthquake resistance in buildings. The Codes and Guidelines developed through the standard making bodies remain recommendatory documents of good*

engineering practices, and their implementation depends upon the decision of the Heads of Agencies, Departs (sic)*, Organisations, Institutions owning the buildings and structures in the public and private sectors. Private individuals have by and large remained uninformed".*

- Arya, 2000

Arya (2000) also dealt with the issue of preventive strategies for new constructions and strengthening of existing buildings. His paper is partly extracted from his contribution in the Report of the Expert Group appointed by the Ministry of Urban Development, Government of India, which was chaired by him.

3 INDIAN BUILDING APPROVAL AND CONSTRUCTION PROCEDURES

Unfortunately, reports and recommendations of experts seem to have collected dust and got buried in the archives. Hence, the wealth of knowledge and experience available in India remains far from effective realisation for the benefit of the society.

Application of codes and standards is generally confined to the design of major industrial structures, bridges, power stations, water supply and wastewater disposal facilities, and other similar structures. These are mostly designed and supervised by private consultants or other specialist structural engineers having the required expertise and skills. However, the process of obtaining building permits and enforcement of codes and standards for design and construction of the majority of buildings is lax.

In smaller towns (characterised by Bhuj in Gujarat which was the worst affected area), seismic requirements are almost non-existent in building regulations for obtaining building permits. Municipality by-laws prescribe an application and review process for the granting of permits on the basis of architectural plans only. Registered practicing architects with little structural engineering skills are appointed by owners to prepare the required architectural drawings. Submission of structural engineering designs and drawings, soil investigation or other related technical reports are not stipulated. Moreover, the capacity of municipality staff is very limited to review technical aspects. Builders appointed for construction works are not required to be registered with the municipality. No site inspections are required to be carried out by the Municipality staff during the construction phase and builders cut costs by adopting shoddy construction practices. On completion, only compliance with architectural plans is checked for the issue of Building Completion Certificates.

In urban areas, registered structural designers are required to submit detailed structural designs, inspect and sign off on all major buildings and high rise structures during construction and issue a Certificate of Structural Safety on completion of construction. However, the process of screening and registration of structural engineers is not rigorous and consistent throughout the country. In some instances, owners pay bribes to obtain building permits.

Flaws in the current Indian practices were clearly evident in Gujarat, both in terms of screening of engineers, architects and builders as well as in enforcement of the codes and standards. Several modern single family units up to three storey (non-engineered) structures, nearly 230 modern low-rise apartment buildings up to five storey reinforced concrete framed structures and three high-rise apartment buildings up to ten storey reinforced concrete framed structures, experienced either total collapse or damage beyond repair (The World Bank and the Asian Development Bank, 2001).

4 NATIONAL AND INTERNATIONAL OPINIONS

On the Gujarat Earthquake, the New Zealand Herald reported that virtually no building in India is designed for seismic conditions. In an interview with Archana Masih, Features Editor (News),

David J Wald, Seismologist at United States Geological Survey, commented that the shaking was undoubtedly very great but in many areas no building remained standing, and the fact that all buildings did so poorly points to either violation of the building code or an inadequate code, or more likely, a combination thereof. Similar reports appeared in the Indian press and must have appeared in many other newspapers around the world, and thus projecting Indian regulatory authorities, engineers, architects, builders and others associated with the building construction industry, in a poor light (Sharma A, 2001: Sharma N, 2001; India Abroad News Service, 2001).

It is thought that as time passes, people tend to forget the devastating effects of individual earthquakes. The value of good engineering practices also fades with time. Non-compliance of the building codes due to inadequate legislation continues to become a major factor in the construction of unsafe buildings.

5 CONCERN FOR THE FUTURE

It is common knowledge that India is located in a high seismically-active zone. According to recent press reports, scientists have voiced fears that the Indian subcontinent may become increasingly vulnerable to earthquakes. Major earthquakes are expected to rock Assam before 2010 (Press Trust of India, 2001), and major cities like Delhi and Kolkata (formerly known as Calcutta) are among the cities at potential risk. There is a high probability of damage to buildings on the area of reclaimed land adjacent to the harbour foreshore of cities like Mumbai (formerly known as Bombay) (Mayur, 2001). The death toll and damage to buildings and infrastructure due to a major earthquake will be far more alarming in these densely populated cities. Although no definite study has been carried out on the incidence of earthquakes in India, scientists at the Seismology Division of the Indian Meteorological Department accept that the incidences of earthquakes in India have been increasing, with a major earthquake jolting India once every two years (Vishnu, 2001).

It is well known that New Zealand, like many other countries, falls in a high seismically active zone. Since the probability of damage to buildings on areas of reclaimed land adjacent to buildings and infrastructure due to a major earthquake is far more alarming in densely populated cities, Wellington is clearly a city that is situated in an extremely hazardous location and is at potential risk.

6 PREPAREDNESS PLANNING IN SOME COUNTRIES

There is now increased understanding of the potential problems that must be considered and resolved before a disaster strikes a community or region. Also, the challenge of rebuilding cities after a disaster needs to be considered and planned for in the pre-impact period, together with planning for the immediate response and mitigation. Only by using this understanding in recovery planning will it be possible to act effectively to reduce human suffering, minimise economic loss and disruption in services and restore some normality to the affairs of the nation.

Studies on disaster research and procedures for recovery are being formulated by several countries, New Zealand being one of them. Wellington has already started to plan its response to the likelihood of a future earthquake, defined its emergency management procedures in legislation and defined the relative roles and responsibilities of the different levels of government (EQC & the CAE, 1995).

"*In the US, political action such as the imposition of construction standards and regulation takes place only based on expressions of need by the society itself*" (Arnold, 1988). Laws have been passed requiring all local government in the US Seismic Zone 4 to identify unreinforced masonry buildings and to adopt time-bound programmes to mitigate the hazards posed by these structures (Tobin, 1988). US policy dealing with recovery requires all levels of government that

receive federal disaster assistance to prepare a plan for averting recurrence of the loss. Building codes to which ordinary buildings are designed have also developed impressively so that they are now much better suited to result in realistic designs against earthquake (Bertero, 1988).

Japan has also taken earthquake countermeasures which are primarily based on the principles of making cities more disaster-resistant, strengthening the prevention of disasters and promoting earthquake prediction. Japanese preparedness planning places priority in helping people understand the importance of self and mutual-help activities to avoid over-dependence on government initiative (Mukunoki, 1988).

7 WHAT ELSE IS HAPPENING IN NEW ZEALAND

Apart from the disaster and recovery plans developed by the New Zealand Earthquake Commission, several initiatives have been taken here based on the lessons learnt from 1931 Napier Earthquake and other major earthquakes around the globe. The New Zealand Society for Earthquake Engineering (NZSEE) has recently formulated recommendations on earthquake risk buildings. "An Initial Evaluation Process For Identifying Buildings Not Safe In Earthquake" prepared by the NZSEE for the Building Industry Authority, will help practicing structural engineers with specific training to identify, with an acceptable confidence level, all those buildings which may prove not safe in earthquake.

Changes are proposed to the New Zealand Building Act in relation to buildings that are not safe in earthquake. In view of the local construction practices, these changes are intended to apply to all buildings (except houses and small apartment blocks), not just to unreinforced masonry buildings. The proposed amendments target buildings of all ages, but especially those designed and/or constructed prior to 1976. In summary, buildings that are likely to give rise to loss of life in an earthquake, and have a seismic strength of less than one-third of current building code requirements, would be deemed to be "not safe in earthquake". The primary emphasis is on larger, taller buildings in highly populated locations. However, low risk buildings and industrial buildings with comparatively low occupancy are not excluded but could have lower priority for action.

It is envisaged that this Initial Evaluation Procedure would be applied by engineers on behalf of:

- Local Territorial Authorities to review their building stock preparatory to issuing building owners notices to carry out necessary remedial works to reduce or remove any danger to the occupants in it or to persons on other adjacent property or damage to any other adjacent property.
- Building owners and managers as part of an overall risk management, and in response to the new legislation.
- Building owners and managers when buildings are being assessed for alterations or changes of use.

It is a difficult task to enact legislation to deal with seismic evaluation of all existing buildings and strengthening of buildings found to be unsafe. However, the events in India, El Salvador, Turkey, Japan, Philippines, Greece and Taiwan remind us that NZSEE's approach is in the right direction and in the best interest of the community. However, communities need to be informed of the importance of prudent structural and architectural design practices.

8 ROLE OF ENGINEERS

Deficient construction techniques can be attributed to the fact that over recent years, new-age commercialism in construction processes has led to less supervision or construction observation by engineers. While comments made in various articles have been an indictment of some

engineers' actions or roles in writing standards, this aspect of deficient construction techniques is due to a non-participation by engineers. Although this latter problem is not one that is the direct fault of engineers, it is one that only engineers can do something about (Walls, 1998).

That is only likely to happen when engineers become a more cohesive, politically active, and a generally more proactive group. Making public statements and speaking out more on important issues, as has been called for in recent times by some eminent professional engineers in New Zealand, is one of the processes for commencing to deal with such issues.

Today's commercial pressures in such areas as peer review of structural design, producer statements, developer/engineer relationships, and the vying for future work from an established client, are all matters that need to be considered if we are concerned about the quality of our completed buildings (Walls, 1998).

9 SUGGESTIONS AND CONCLUSIONS

The Gujarat earthquake, and other major earthquakes, have been far too tragic to be ignored. Lessons need to be learnt by the public, and particularly by the policy-makers (including engineers and scientists) and law-makers of India as well as other developing countries, who should act without delay.

9.1 *Dissemination of Knowledge*

Widening the use of the available knowledge base is of paramount importance to minimise destruction caused by major earthquakes. While scientists and engineers continue their further research on prediction of earthquakes and on refining our understanding of earth motions and structural responses, the existing expertise, knowledge and skills should be used to their full potential with complete support of political institutions. Not only should the buildings of high importance factor be designed and constructed by competent engineers but seismic detailing should be provided in all types of structures including non-engineered buildings such as residential dwellings. There needs to be a sensible balance of responsibilities between those affected such as the central government, state governments, local authorities, individuals and businesses.

9.2 *Enforcement of Codes and Standards*

There is obviously the need to enact a law to make earthquake safety norms binding on all new buildings. The codes and guidelines should not remain recommendatory documents but should be made mandatory by incorporating into relevant building by-laws and regulations through an appropriate legal framework. The regulatory authorities should exercise necessary controls and ensure that the designs incorporate earthquake safety measures. Equal emphasis should be laid by the regulatory authorities on providing a reasonable level of construction supervision to ensure that the construction works proceed in accordance with the approved drawings and specifications. In order to make the regulatory authorities accountable, the legislation should empower an independent team of experts to carry out technical audits and review their functioning periodically.

9.3 *Retrofitting*

Reducing earthquake hazards from existing buildings remains the foremost problem facing India and other countries prone to disasters. The buildings where most of the losses will be concentrated are already standing. These buildings should be retrofitted where necessary or demolished. Because local state government and private business action is needed to address these hazards, a strategy should be pursued to facilitate action by these agencies.

9.4 *Earthquake Safety Programmes & Emergency Planning*

Earthquake safety programmes should become standard topics in boardrooms, council chambers and homes. Earthquake mitigation and emergency planning should not be viewed as an

autonomous, single-purpose activity carried out by specialists. Government and business managers should consider earthquake safety measures as a normal part of their responsibilities. Educational programmes should be televised to increase the level of awareness amongst the people on building safer structures.

9.5 *Funding & Recovery Policies*

Forging new efforts and redoubling existing efforts should be planned with a realistic understanding of the factors that stand between good intentions and committing the nation's resources. A new earthquake-hazard reduction strategy is needed to address jurisdictional, funding, social, organizational, management and engineering considerations in the context of government and business reality. The new strategy should provide the incentives, information, and encouragement needed for local state governments and private business to act.

9.6 *Management Leadership*

Building officials and emergency service professionals serve as key forces to improve building codes, and to move local and central government towards preparedness programmes. They should retroactively address existing potentially hazardous buildings. Although these professionals serve as the earthquake conscience of the central and state governments, they cannot provide the dynamic public policy leadership needed to extend the scope of earthquake programmes at government level. Thus to move earthquake safety into the mainstream of Indian life, the involvement of people should be expanded. In addition to leaders in geology, engineering, building departments, and emergency services, initiatives should also come from business and political leaders, advocates, attorneys, insurance and banking executives, city planners and long-term corporate planners. These are the people who can integrate seismic safety into government programmes and business activities.

Having experienced the aftermath of an earthquake and seen the terrible damage in human terms – the pain and suffering, the economics of lost likelihoods, bankrupt businesses and the fear and guilt – we must realise that the investment in enforcing seismic codes on a nation-wide basis and strengthening unsafe structures in risk areas is a smaller price to pay (Tobin, 1988).

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