IMPLICATIONS OF THE 2004 GREAT SUMATRA EARTHQUAKE AND TSUNAMI FOR RISK REDUCTION IN INDIA

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ABSTRACT

The Great Sumatra earthquake and tsunami of December 26, 2004 caused major devastations on Indian coasts. In the process, it underlined many important lessons for chalking out risk reduction programme. Important experience was gained by the country in handling a major natural disaster affecting the largest ever geographical region spread over several states. While the country was quite sensitized towards earthquakes, the tsunami took the public and the scientific community by surprise. To the already incomplete agenda of seismic safety programmes, was added the issue of tsunamis. The paper reviews these lessons and explores what needs to be done to minimize future disasters.

Introduction

The earthquake problem in India had long been recognized in view of numerous damaging earthquakes in the country. However, despite a few episodes of tsunamis affecting the Indian coasts in the past (e.g., tsunamis of 1762, 1881, 1883, 1941 and 1945), as such the tsunami hazard was not a concern in the minds of public and the scientists until the December 26, 2004 Great Sumatra earthquake and tsunami. For instance, the Indian seismic code IS1893 mentioned of the secondary effects of earthquakes as landslides, floods and fires but not tsunamis. In view of devastations caused along the Indian coasts, the event of December 2004 has lead to serious concerns about tsunami hazard in the country.

The scenario caused by the 2004 event must be seen in the context of the January 26, 2001 Bhuj earthquake. Since 1950 Assam – Tibet earthquake (M~ 8.6), India had not had a major earthquake of M>7.0 until 2001. The 1993 Latur earthquake (M 6.2) had caused 7,928 deaths but had not created proportionate impact on the psyche of the public; it was viewed as a rural earthquake since almost all deaths were caused by collapse of random rubble masonry houses. After the 2001 earthquake (M 7.6; 13,805 deaths), people for the first time saw on their television screens modern reinforced concrete buildings fall like a pack of cards. As a result, level of awareness in the country for seismic risk had been particularly high since 2001, and a

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number seismic safety programmes had been underway at the time of tsunami. Also, some institutional changes had taken place in the country after the 2001 earthquake.

An extensive reconnaissance study of the affected areas of the 2004 event revealed some interesting lessons for the future: both from the view point of safety against earthquake shaking and tsunamis. The paper briefly reviews these lessons and explores what needs to be done to minimize future disasters.

Lessons from the 2004 Event

Disaster Management

Prior to the 2001 earthquake, the Ministry of Agriculture of the Government of India was responsible for issues connected with natural disasters. A major institutional change took place in 2002 wherein the portfolio of natural disaster mitigation was shifted to the Ministry of Home Affairs. Thus, for the Ministry of Home Affairs tsunami was the first opportunity of handling a major disaster. The nature of disaster was unique in two ways: (a) the largest ever geographical area was affected and more than one state was involved, and (b) as against army playing a major role in rescue and relief after earlier earthquakes, this time the role of Navy and Coast Guards was critical. Different states handled the crisis and its aftermath somewhat differently. There were also instances of unaffected states offering assistance to the affected states, and of India extending substantial assistance to Sri Lanka while handling disaster within the country. Concerns were voiced in the initial days about inadequate coordination between different ministries. Thus, very valuable experiences were gained in disaster management which must be carefully documented and the learning institutionalized so as to improve response in future.

Public Awareness

The tsunami hit the Andaman and Nicobar Islands about two hours before reaching the mainland coasts of India. Yet, the officials in the A&N Islands failed to alert the mainland about the possibility of tsunami. This was due to total lack of awareness about tsunamis and their travel path not only amongst public but also amongst officials and scientists. In the days following the earthquake, senior government officials, scientists and ministers were seen on television stating that this was the first time ever a tsunami had hit India and hence nothing could have been done about tsunami warning systems. The fact that several damaging tsunamis had hit Indian coasts in the historical times came to be accepted much later. Four days after the event, on the morning of 30 December 2004, the Union Home Ministry issued a warning to the affected states of an impending earthquake and tsunami in the afternoon of the same day based on “a number of experts outside country”. This created a major panic and affected the relief efforts. Before that, on the evening of December 28, a senior scientist in Kerala warned of tsunami on a local TV channel causing panic. All these instances clearly illustrate (a) a rather low level of awareness even amongst the responsible persons, and (b) poor quality of expert advice available to the government ministries in some instances.

As a consequence of the 2001 Bhuj and 2005 Kashmir earthquakes and the 2004 tsunami, there is a considerable amount of awareness about these hazards amongst the public.

However, substantial public awareness effort is needed to educate the public on how to safeguard against these hazards.

Scientific and Engineering Manpower

In recent years, considerable effort has been made in India to upgrade the seismic instrumentation, and a digital strong motion instrument was installed at the observatory of the India Meteorological Department at Port Blair. Unfortunately, the instrument did not record the main event, even though it seems to have recorded some aftershocks indicating that the instrument was not adequately maintained. This clearly underlines the fact that adequate investments in human resource development are critical. This is particularly important considering that India has decided to install a sophisticated tsunami warning system for the Indian Ocean.

Until recently there was no systematic effort to teach the concepts of earthquake resistant constructions in the curriculum of civil engineers and architects. The National Programme on Earthquake Engineering Education (www.nicee.org/npeee) launched by the government of India in 2003, has made some attempt to tackle this situation. However, a lot remains to be done and most of the new engineers and architects coming out of the colleges still do not have basic understanding of earthquake related issues.

Constructions on Coast

The issue of earthquake safety is closely linked with the quality of governance. By the very nature of construction industry, there will always be pressures and temptations to violate the codes and bye laws. Violations of Coastal Regulation Zone (CRZ) norms lead to heavy damages to buildings and structures due to tsunami of 2004. While it is easy to state that the CRZ norms need to be strictly followed, a careful study of the public policy system is a must to develop a robust regulatory system to successfully prevent such violations.

Buffer zones provided by raised land mass and forests helped in reducing the sea intrusion into the mainland, while felling of trees and removal of mangrove forests increased the devastation caused by the tsunami. Attention therefore needs to be given to prevention of deforestation and protection of mangrove forests.

Tsunami Warning System

Immediately after the tsunami, government of India announced that it will put in place a modern tsunami warning system, and efforts are currently underway in this direction. One key element of this decision was that rather than join up a consortium of countries around the Indian Ocean, India will develop its own warning system. The country already has a cyclone warning system along the coasts and one could integrate the tsunami warning systems with it. However, as compared to the Pacific Ocean, Indian Ocean poses additional complexities in modeling the tsunami hazard in view of criticality of wave reflections in the area. Therefore, for the warning system to be effective, India must invest substantial effort in developing scientific manpower and expertise.

It is however important to realize that a warning system has limitations, particularly so in view of rather infrequent occurrence of tsunamis in the Indian Ocean. Therefore, such a system must be in addition to, and not in lieu of, other structural measures such as enforcement of CRZ norms and management of coastal regions vis-à-vis deforestation.

Code Compliance and Training of Professional Engineers

In general, it is believed in India that the constructions by the government agencies by and large comply with the seismic codes. However, in the case of A&N Islands, at least some construction projects in recent years in the government sector did not follow the codes. For instance, the reinforced concrete Passenger Terminal Building in Port Blair was built about five years back. A part of the building was supported on piles while the other part was situated on spread footings on relatively soft soil. The building did not comply with the requirements of IS13920, mandatory for seismic zone V, on ductile detailing, and underwent partial collapse (Fig.1).

Figure 1. Partially collapsed Passenger Terminal Building at Haddo Wharf, Port Blair.

As a consequence of recent earthquakes and a number of capacity building activities in the country (Jain and Murty, 2003), many more structural engineers now know about the concepts of earthquake engineering than was the case a decade back. However, the above example clearly illustrates that a lot more work remains to be done to train and sensitize the government engineers and structural consultants on earthquake resistant design.

Development of Seismic Codes

A newly-constructed 268m long bridge connecting the North and Middle Andaman Islands on the Andaman Trunk Road became non-functional due to shaking (Jain et al, 2005a):

three middle spans of the superstructure were displaced laterally by about 70 cm and vertically by about 22 cm from the original position and fell off from the bearing. The bridge was provided with bearings consisting of simple neoprene pads that were not anchored to the superstructure and the substructure. Such bearings are not desirable in high seismic zones (hence, the damage was expected, e.g., Rai and Murty, 2003), but are currently allowed by the Indian Roads Congress codes of practice. Indian seismic design provisions on bridges had remained the same for several decades, until some interim provisions were adopted in the year 2002; more comprehensive provisions are under discussion for some years now. Similarly, the seismic design provisions for water tanks, and for dams and embankments need major upgradation. In view of the rapid developments in the field of earthquake engineering, seismic codes require constant upgradation which unfortunately has not been happening in India. The country needs to invest much more on development of codes and other supporting documents and on propagation of the same amongst the professionals.

This event has also created a need world wide to develop design guidelines for protection of structures against tsunamis. Unlike in the case of earthquakes, human lives may not be saved just because a building could withstand the tsunami. However, in many situations, it is important that the structures are provided with some protection against the forces induced by a tsunami. For instance, all four spans of the RC bridge at Melmannakudi (Kanyakumari District in the state of Tamil Nadu) were washed away by the tsunami (Jain et al. 2005b); lateral restrainers, commonly provided in earthquake regions, if present would have been helpful in this situation.

Construction Practices

The A&N Islands were colonized by the British only after 1857 and originally the preferred mode of construction was brick masonry (Fig. 2). As a consequence of the M7.7 earthquake on June 26, 1941, the wood became the preferred construction material. Such traditional wood houses in the A&N Islands performed well during the seismic shaking (Fig. 3). However, in recent years, new constructions are either in reinforced concrete or masonry. Many recently built masonry and RC constructions suffered damages due to ground shaking, some even collapsed (Fig. 4). This is due to lack of expertise by the public to use such materials in earthquake regions. Thus, vulnerability of the islands to earthquakes has been increasing dramatically in recent years.

Figure 2. Cellular Jain in Port Blair; historical construction practice in brick masonry.

Figure 3. Undamaged traditional wood house at Port Blair.

Figure 4. Collapsed 2-storey RC building on stilts at Bamboo Flat near Port Blair.

The Marine Jetty Dry Dock in Port Blair provided a rather interesting situation. A 50 -year old office building in timber was considered dilapidated. Hence, across the road a three-storey RC frame building was constructed about 10 years back to replace it. The new building underwent severe corrosion in a rather short time span and due to the shaking caused by the December 2004 earthquake underwent some damage. As a result, at the time of the author's visit two weeks after the earthquake, the old timber building was being used for office while the new RC building had been vacated.

The above state of affairs clearly illustrates that (a) it is hard enough to ensure quality in modern RC frame buildings by government departments having trained engineers and with systematic checks and balances, and (b) it is virtually impossible to expect the public to bring in enough engineering expertise for construction of one- or two-storey dwellings in reinforced concrete. As has been seen in numerous earthquakes around the world, if not designed and constructed correctly, RC frame buildings can be major killers. And yet, in most towns and cities in the country, numerous RC frame buildings continue to be built by the public without any engineering support and expertise. It is unrealistic to expect that this situation will change substantially in the short term. Hence, a paradigm shift is needed in our construction practices: we must develop and propagate construction types that are more resilient against earthquakes and yet do not require major engineering inputs. For instance, even in a developed country such as the US, an ordinary house is not expected to be designed following the calculations specified in codes meant for major buildings. Instead, empirical provisions of a small building code (ICC 2003) govern such constructions. In case of India, confined masonry may be a very good option for one- or two-storey buildings and should be encouraged in place of ordinary masonry. Similarly, reinforced concrete shear walls should be systematically encouraged in place of RC moment resisting frames, both in formal and informal constructions.

Some of the indigenous construction types such as the Assam type houses (prevalent in the north eastern states), timber houses in the A&N islands, and the Dhajji Dehri type constructions (in Kashmir and in Himachal Pradesh) have repeatedly shown superior performance in the past earthquakes. Unfortunately, these construction types are being abandoned in these highly seismic regions due to environmental concerns. Substantial research and development efforts are needed to develop contemporary versions of these constructions types that would either not use timber or use timber in a more sustainable manner.

Repair and Retrofitting of Buildings

Many buildings require repairs of varying level after an earthquake. That is also a time when concerns about seismic safety are at the peak. Hence, post-earthquake scenario provides a major opportunity for undertaking seismic retrofitting of buildings concurrently with the repairs. In fact, the Jama Masjid, Aberdeen in Port Blair provides a very fine example of the same. The mosque made of brick masonry with arches, domes and minarets was completed in 1913. In the 1941 earthquake in A&N Islands, the mosque underwent some damage and was repaired, and retrofitted by providing tie rods to develop an integrated box action of the walls (Fig. 5). About two years back, while undertaking major renovation of the mosque, the tie rods that had fallen due to corrosion over the years were replaced. As a result, the mosque was well prepared to face the ground shaking of the 2004 earthquake and underwent only minor damage wherein some of the small minarets fell down while the main structure remained intact and safe.

Figure 5. Retrofitting of an old Mosque using tie rods at Aberdeen, Port Blair.

In 2002, a M6.5 earthquake in Diglipur in north Andamans had caused damage to some buildings that were repaired subsequently. In the 2004 earthquake, these very buildings showed poor performance (Rai and Murty, 2005) due to inadequate repair and retrofitting. After the 2001 earthquake too, a significant amount of retrofittings in Gujarat have been of questionable value in terms of seismic safety. Thus, we continue to lose opportunity for sensible seismic retrofitting in the affected areas after damaging earthquakes due to inadequate engineering expertise and insufficient indigenous research on retrofitting methodologies suitable for Indian construction typologies. Substantial engineering and research efforts are needed in this direction.

Lifeline Structures

After the 2004 event, relief efforts in the islands of A&N were severely handicapped due to collapse of a number of jetties. Damage to harbour structures, airport and seaport control towers, and the Passenger Terminal Building in Port Blair clearly illustrate vulnerability of our lifeline structures. Careful structural evaluation of lifeline structures in moderate to severe seismic zones of the country, and strengthening where necessary, needs to be taken up. In view of the large number of failures of jetties, Indian standards must be developed for seismic design of harbour structures.

Concluding Remarks

Every major disaster is also an opportunity for implementing changes towards safer future. Most progress towards earthquake safety has been triggered by damaging earthquakes. On the other hand, there are enough examples wherein no effective change took place in construction practices after disastrous earthquakes and the opportunity was wasted. The 2004 event coming within four years of the 2001 Bhuj earthquake could be a major opportunity. Unfortunately, far too much focus on setting up of a tsunami warning system may have reduced the attention from other substantial issues. As this article is being written, the devastating earthquake in Kashmir on October 8, 2005 has again brought to focus the vulnerability of large parts of India and other developing countries to earthquakes. A decade or two later, we will be judged by what we successfully implement and not by what we intended to do. It is important to be realistic and take up what can be sustained rather than to chalk out ambitious plans that are not likely to succeed due to limitations of resources in terms of scientific and engineering manpower and otherwise.

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