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EARTHQUAKE CAPACITY BUILDING AND RISK REDUCTION MEASURES IN GUJARAT POST BHUJ 2001 EARTHQUAKE.

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SUMMARY

The Bhuj earthquake of January 26, 2001 and the ensuing damage brought to the fore deficits in the knowledge, practice and implementation of seismic engineering in the state of Gujarat, India. Almost the entire state lies in zones of moderate to high seismic hazard. Consequent to the earthquake, a program for seismic capacity building was launched across the state. The paper describes some of the initiatives taken up in this program and the methodology used to implement them. It also discusses the level of success achieved, the pitfalls encountered while implementing these measures in a developing country, and the on-line corrections required.

INTRODUCTION

The Bhuj Earthquake of January 26, 2001 of magnitude 7.7, left 13805 persons dead and caused direct losses of about Rs. 150 billion (approx. US $ 3.2 billion) and indirect losses of about Rs. 30 billion (approx. US $ 650 million). Seismic hazard distributions have been defined in Gujarat since more than five decades (IS 1893 [1]). The worst affected area during the earthquake was the Kutch district. This is classified predominantly as Zone V in the seismic zoning map of India, which is the highest hazard zone. Zones III, IV and V correspond to VII, VIII and IX (and above) on the Modified Mercalli (MM) Intensity scale. Clearly, the earthquake came as no surprise.

The earthquake affected about 1.2 million homes. Over 5000 health units and over 50,000 schoolrooms were also damaged or destroyed. Thus, when a comprehensive reconstruction and rehabilitation program was launched immediately after the earthquake, the initial focus was, expectedly, on reconstruction of housing and other infrastructure. Two models were adopted for housing reconstruction. One was owner-driven housing in which the reconstruction was carried out by the home-owners with financial,

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technical and material assistance provided by the government. The other model was a public private partnership program, wherein 50% of the cost of reconstruction was borne by non-government agencies (NGOs) and 50% by the government. The owner-driven program found more favor with the community and about 82% of the housing reconstruction in the affected regions was owner-driven.

Besides the housing reconstruction, other livelihood rehabilitation and community participation projects were launched. A capacity building program was also initiated. As the Bhuj earthquake was within expected levels of seismicity in that region, building protection could well have been provided, and yet it was not. The reasons for the catastrophe were twofold: firstly general disregard for existing standards allied with the absence of a robust regulation enforcement system, and secondly, the almost non-existence of seismic engineering skills in the local construction community and the implementation agencies. The task of capacity building therefore was not so much one of developing technology but one of education in that technology and in developing an effective and competent enforcement procedure for its application. A complete change in culture in both the public and the private sector was required and that meant tackling the problem on many fronts. It was not just the engineering community that had to embrace change; decision-makers at State level were also deeply involved.

Capacity building measures were thus aimed on one end at raising the levels of consciousness to earthquake risk in the various stakeholders and furthering seismic technical knowledge and capability. This was sought to be achieved through public awareness programs and through suitable interventions at the education level, in the practice of structural engineering and in the construction of the built environment. On the other end, the capacity building program looked at numerous steps required to encourage code compliance by improvement of the existing regulatory and monitoring mechanisms, and introduction of competency barriers for the practice of engineering in the state.

This paper focuses on long-term earthquake capacity building measures in Gujarat after the earthquake.

CAPACITY BUILDING AND RISK REDUCTION MEASURES

Development of Seismic Engineering Design Skills

To improve the engineering skills in the state, a three pronged strategy was evolved:
i) Introduction of earthquake engineering in the civil engineering and architecture curricula across the State so that all future graduating civil engineers and architects will be equipped with adequate background in earthquake engineering, and a teacher training program to effect these changes
ii) Continuing education programs for the practicing engineer in earthquake engineering and
iii) Upgradation of skills in government engineers.

Syllabus Changes in Civil Engineering and Architecture Programs

A typical undergraduate civil engineering curriculum in India does not include any coverage of earthquake engineering. Even at the post-graduate level, only a small fraction of structural engineering students gets a chance to study earthquake engineering and design. This results in most civil engineers not receiving any formal training in earthquake engineering during the undergraduate or post-graduate studies. As almost all of Gujarat falls within seismic zones with moderate to severe seismic hazard, it was felt that this situation needed correction through introduction of topics of seismic engineering into the curricula of diploma, degree and post-graduate programs in civil engineering and architecture.

The process of syllabus change needed to be undertaken with sensitivity to what was appropriate and practicable considering the constraints and concerns. A consultative approach was adopted, which enabled the participation of all the universities and colleges of Gujarat State in development of a revised

curriculum. This inclusive approach encouraged the colleges and the teaching faculty to take ownership of the program. Four workshops were conducted to discuss the methodology of incorporating earthquake engineering topics in the curricula at Diploma, Degree and Post-Graduate levels in the engineering colleges and polytechnics of Gujarat. While the workshops succeeded in generating a consensus regarding the basic philosophy of introducing earthquake engineering in the syllabus as also the recommendations for course content, it emerged that changes in curriculum were not something that could be indiscriminately and uniformly adopted across all colleges. Different universities would need to adapt the recommendations to suit their own faculty expertise, existing curriculum and local conditions. The review of syllabus to incorporate earthquake engineering had an added advantage of a comprehensive study of the present engineering curriculum and became an occasion to jettison or condense antiquated topics to make way for the new. The curriculum changes are dealt with in detail elsewhere (Jain [2]).

The syllabus changes were effected within 3 months of the recommended changes by almost all-engineering colleges of the State. There were initial problems in the implementation due to lack of adequate resource faculty and resource material. A few colleges did not have the necessary expertise and deferred the implementation by one semester. After the syllabus changes were, to a fair extent, successfully completed for engineering colleges, the task of introducing changes in architectural curriculum was taken up. This turned out to be a far more challenging exercise. Unless earthquake behaviour concepts were innovatively linked to the process of architectural design, it was hard to engage architectural students in the study of basic earthquake behaviour of structures. This process is currently ongoing.

Teacher Training Program

Curriculum changes required that the teaching faculty be trained in the earthquake engineering. Hence, an extensive teacher-training program was initiated. A comprehensive one-semester program in earthquake engineering was considered to be the most appropriate method of training the teachers. Six teachers from the State underwent such a program conducted under the National Program on Earthquake Engineering Education (NPEEE) held at Indian Institute of Technology Kanpur. However, due to an acute shortage of teaching faculty in the State, it was not possible to depute many teachers for such an intensive training program during the school semester. The training program was therefore divided into 13 separate one-week modules each pertaining to a different aspect of earthquake engineering. The teacher training program has been discussed at length elsewhere (Sheth [3])

During the conduct of these courses, several lessons were learnt. While a few of the courses were conducted during the semester, the number of administrative and logistics hurdles faced in the conduct of the courses during the school semester pushed the program back by almost one year and the balance courses are now scheduled during summer and term holidays. The selection of teachers for undergoing such training programs needs to be carried out carefully. Teachers who are not motivated or who are close to retirement should not be coerced into attending the training. Primarily, faculty members teaching structural design courses should be inducted into the training program. Due to a lack of understanding of the program, some colleges sent teachers of surveying and transportation courses who were understandably demoralized. The resource faculty was culled from amongst the best in the country but due to a lack of co-ordination between the different resource faculty and the coordinating authority, there were instances of some amount of repetition and overlap in courses which was a source of exasperation for the teachers. Many on-line modifications were thus required. The experience proved that for such a program to be successful, the resource faculty, stakeholders and teachers undergoing training need to work closely together to understand the needs and the constraints of each other.

Continuing Education Programs for Practicing Engineers in Private and Government Sector

Most of the recently constructed urban building stock comprises of multistory reinforced concrete frame structures. It is notable that about 120 multistory buildings (a significant number of them being less than 10 years old) collapsed in the city of Ahmedabad located 200 km away from the epicenter. One instrument in Ahmedabad recorded a peak ground acceleration of 0.11g. Such damage in a rather moderate shaking exposed the marginal designs being practised coupled with poor construction and supervision.

After the earthquake, numerous "experts" arrived on the scene and conducted training programs in earthquake engineering. These courses ranged in duration from an hour to two days and did not have the necessary depth nor were they exhaustive or comprehensive in their scope. As most of the practicing engineers were not exposed to earthquake engineering in their academic curriculum, there was a need to acquaint them with basic concepts of earthquake engineering and the current earthquake codes. The first such serious training of five days duration was held in December 2001, almost one year after the earthquake by a leading engineering institute on their own initiative. About two hundred engineers in the public and private sector attended this course, proving that there was a keen desire on part of the engineers to learn earthquake engineering. Stress was laid in familiarizing them with seismic code requirements and the underpinning rationale. It was observed that the engineers were more liable to adopt the codes in design if they were exposed to the background of their development. Around the time of this training, the state launched a series of intensive, in-depth training programs by the country's premier institutes of technology for government engineers; these were also open to private engineers at a nominal fee.

It was not possible for the government engineers to utilize the training programs to the full extent. This was partly due to a shortage of engineers in most municipal corporations and government departments of the State prior to the earthquake. The aggressive, time-bound reconstruction phase launched immediately after the earthquake compounded this problem further. Due to a tremendous increase in the workload, the government engineers were hard-pressed and often not able to attend the training programs.

Upgradation of Skills in the Unorganized Construction Sector and Raising Awareness Levels at Community Level

Masonry buildings accounted for more than 95% of the building stock in the region of Kutch (Jain [4]). Indian codes have specified seismic detailing for masonry structures since 1967 (IS 4326 [5]). Despite both the above, seismic provisions were followed more in their breach. There was no regulatory framework in the State to monitor the quality and detailing of urban and non-urban construction and it was acknowledged that putting such a mechanism in place across the state in the short term was not going to be a viable task. Hence a demand for code compliance for masonry buildings was sought to be created from amongst the homeowners and users themselves. An aggressive campaign to familiarize the public with seismic measures was initiated through community participation and use of different media such as street plays, posters, handbills, advertisements on public transport and so on. This resulted in a fairly high level of awareness of seismic lintel bands, corner reinforcement and other seismic features amongst the public. Shake Table demonstrations were held in seismic prone areas, which explicitly brought home the message of improved behaviour of a seismically detailed building.

Illustrated guidelines for cyclone and earthquake resistance were also prepared. A Homeowner's guide is being published to direct a person proposing to buy or build a new home or desirous to check the safety of his home for the event of an earthquake.

Mason Certification Program

In most non-urban areas, the mason is the master builder, architect and structural engineer of a typical masonry home. In view of the important position held by the mason, the need to educate him about

seismic features of masonry construction became paramount. After the Bhuj earthquake, there had been numerous mason-training programs conducted by both the government and the non-government organizations. The trainings ranged from a couple of hours to a few weeks and the level of expertise generated varied greatly. These trainings did not test the skills developed in the masons.

The earthquake was used as an opportunity to improve the overall quality of construction. One of the first steps in this direction was to create a class of masons of international standard. These masons were expected to be skilled in masonry and have a working knowledge of allied trades such as plumbing and carpentry. To achieve this end, a mason certification program is being launched. This certification program will test and certify the competence and skill levels of a mason. The State has limited its role in this program to that of the certifying authority while the training required for obtaining the necessary skills has been left to non-government agencies and the private sector. While mason certification is not mandatory, a demand has been sought to be created by a long-term plan that envisages a requirement of a minimum percentage of certified masons to be employed by contractors on government projects.

A significant number of present-day masons are illiterate and may not be able to pass some of the modules requiring ability to read basic drawings or do simple arithmetic and some on-line corrections may be required to this program for the short term.

Regulatory Framework, Implementation Procedures and Monitoring Mechanisms

There is a clear need to put in place a system wherein the municipal authorities are in a position to enforce seismic code provisions in all new constructions. Two issues are involved here: to gain confidence of the concerned municipal engineers so that they feel secure in handling this new responsibility (and if needed, to offer them some incentives for performing this responsibility), and capacity building of the municipal engineers for review of structural drawings. With some training, it should be possible for the municipal engineers to make a quick review of the structural drawings to generally see that some of the main features of ductile detailing are included; they are of course not to be responsible for proof checking of the structural design. The towns of Kutch district (viz., Bhuj, Bhachao, Anjar and Gandhidham) have hired structural engineers on a temporary basis to review the building plans from seismic point of view before the town planner of the concerned town issues building permit. However, no such system still exists in major cities such as Ahmedabad or Surat wherein it is left to the structural designer to ensure code compliance.

Review of Development Control Regulations

Presently there are different development control rules for different cities and development authorities. A study was commissioned to review the existing development control rules of various cities and development areas of the State. The study identified numerous problems. On one end there existed a multiplicity of enabling legislations in urban areas while at the other end there were no legislations, standards, enforcement agencies or enforcement protocol for village revenue areas. The central and state government establishments were outside the purview of most controlling regulations. Oftentimes, the rules were poorly framed; at times incomprehensible, badly structured or outdated. There was also poor housekeeping and records maintenance systems.

During a detailed review of the Development Control Rules of Ahmedabad Municipal Corporation, the study brought out that development regulation system therein was severely stressed. Permissions and approvals required lengthy and tedious protocols. The engineers in the municipal corporations were understaffed and overloaded. Another disturbing fact brought out was the unhealthy role of politicians in the various town planning committees and area development authorities. The development control rules do not clearly establish a hierarchy of responsibilities, duties and responsibilities and make no mention of

maintenance of structures. There was no system or protocol for pinning responsibility in cases of building failures and there were no systems for penalizing defaulting professionals.

In view of the magnitude and scale of deficiencies in the development control rules, the study recommended a complete overhaul of the development control rules in the long term. For this, the development control rules were sought to be divided into two parts- One part would be applicable statewide while the other part would pertain to issues dependent on local conditions. The State level code was proposed for issues such as procedure regulations and application formats, Statewide building regulations and standards (such as structural design regulations; fire safety regulations; hazardous waste disposal / pollution regulations). Issues such as planning regulations, local building regulations and standards, maintenance and upgradation regulations were recommended to be framed locally with local considerations. For the short term, the study suggested changes in existing development rules which could be implemented immediately. The State is currently in discussion with the urban development department to look at means of implementing the suggestions.

Certification of Engineers

In most cities of Gujarat, structural engineers need to be registered with the Municipal Corporation or development authority in order to practice. This registration is based on experience and an engineering degree and does not check competency. With an ever-increasing number of engineering colleges mushrooming in the country, a degree in civil engineering together a certificate of experience is no longer an adequate qualification for competent practice as a design engineer. Additional tests need to be conducted to ensure proficiency in the field. Accordingly, a Bill for professional Engineers has been mooted which would allow only engineers registered with the Gujarat Council of Professional Engineers (to be created through the legislation) to practice in the state. Registration with the Council would be based on a written competency examination and experience.

It is quite clear that along with design engineers, there is an urgent need to bring construction engineers and other players of the construction industry into the gambit of registration. Based on the success of the registration of structural engineers program, the registration of construction engineers will be taken up in the next phase.

Other Long-term Seismic Capacity Building Measures

Review of Building Codes pertaining to Earthquake Design

There are a number of Indian Standards Codes governing seismic design and detailing in the country. Historically, there has been a notorious delay in revisions to Indian Standards Codes. As a result of this, the codes tend to be behind the international state of art and practice. One part of the main seismic code IS 1893 was revised in 2002 after eighteen years (IS 1893 [6]). The other parts of the code covering liquid retaining structures, industrial structures, bridges, dams, equipments and their supports, retaining walls are yet to be published. The other codes have not been updated since more than ten years. There are also no commentaries to these codes nor are there any handbooks. In view of this dismal situation, the Gujarat State commissioned an independent review of the existing earthquake, wind and fire codes and preparation of commentaries and handbooks for the same. This study may turn out to be a watershed development for the future course of code preparation and revisions in India. New draft codes covering hitherto un-addressed topics and significant revisions to the existing codes have emerged from this study.

It is still not clear how these new codes and the proposed revisions to the existing codes will be applied, and whether or when they will be accepted and adopted by the Bureau of Indian standards for the entire country. Typically, development control rules make reference to these national codes while defining design and construction parameters. While the State of Gujarat may be desirous to implement the

recommendation locally, the legislative ramifications of introducing a separate code for the state in variance to the national codes have to be studied.

Seismic Microzonation

In view of the high seismicity in Gujarat, it was felt that a more sophisticated zonation of areas of high seismic risk should be carried out. Thus the plan for seismic microzonation was mooted. Before a serious microzonation exercise could be conducted, it was necessary to understand the methodology of microzonation to be adopted and the area most suitable for conducting microzonation, given the varying levels of seismic hazard and vulnerability in different regions of the state and the present amount and quality of data available. Thus a feasibility study was taken up which assessed the amount and quality of information available and the added data to be generated as well as the cost for the same. Based on the results of this study the state may or may not decide to go for a microzonation.

Other Studies

Several other major studies have been or are in the process of being commissioned for Damage and Loss Assessment, Early Warning and Communication Systems, Establishment of Emergency Response Centres, Hazard Risk and Vulnerability Assessment, and Information Technology for Disaster Management. The State is also setting up the Gujarat Institute of Disaster Management. The aim of these studies is to bring the state-of-the-art in the respective fields to the State of Gujarat. Separate review committees have been established to review and monitor these studies.

THE UNFINISHED AGENDA- CAPACITY BUILDING MEASURES TO BE YET TAKEN UP

In addition to the numerous efforts initiated and completed, some issues remain which have not been addressed at all or have been addressed only cursorily. These measures need to be taken up seriously and urgently.

Code Compliance

Not all structures being built after the earthquake, especially in urban areas such as Ahmedabad are being designed or built in compliance with seismic codes. This is primarily because a robust mechanism to ensure compliance to building codes is not yet in place and the misconceived perception of risk that an earthquake does not strike at the same place twice in one lifetime. Unless a code compliance monitoring mechanism is put in place, many of the other capacity building measures will be futile.

Accountability

There is presently no clear protocol defining the responsibility and accountability of various stakeholders such as the structural designer, contractor, construction engineer/supervisor, builder/developer, municipal engineer or government in the event of failure of a structure. As a result, there is no motivation for any of the players to strictly and scrupulously perform their roles and responsibilities. Even in the unlikely event of the identification of the errant party, there are no punitive measures laid down and the offender tends to go scot-free. This situation needs to be addressed on priority.

Seismic Safety Commission

Special Capacity Building Technical Assistance projects initiated after the earthquake have already been concluded or are in the process of being completed. However, the business of seismic vulnerability and risk reduction is an ongoing one and the State needs to define a clear seismic safety policy towards that end. A Commission, in line with the California Seismic Safety Commission, may be established which besides drafting a seismic safety policy for the State, would be responsible for commissioning and

monitoring research and development in earthquake related fields. Further, it would make recommendations to the State regarding projects, programs, legislation and policies required for seismic vulnerability and risk reduction.

Essential Services

Essential facilities such as schools and hospitals which cater to the needs of a special section of society and which are desired to be functional after a seismic event require special specifications for design and performance. The state may consider putting in place performance criteria for all hospital and health care facilities which are to be conformed to by a realistic deadline. A seismic survey of all such facilities may be mandated to understand the extent of the problem.

The damage/destruction to over 50,000 schoolrooms during the 2001 earthquake is a matter of grave concern especially in view of the fact that it is statutory for children to attend primary schools. Hence the responsibility of the state to ensure safe schools cannot be overemphasized. The State may set a target date to ensure required seismic resistance of all school buildings. It may also need to establish a policy of retrofit versus reconstruction especially for the old stock of school buildings. The State has recently initiated a program for seismic retrofit of public buildings including hospitals and schools in the State.

Insurance

In the current Indian scenario there is no requirement of seismic code compliance to procure a housing insurance. The premium for insuring a house against an earthquake remains the same irrespective of whether the structure has been designed for earthquakes or not. In such a scenario, a possible incentive for ensuring seismic safety is lost. The State may work along with the insurance companies to remedy this situation.

CONCLUDING REMARKS

The Bhuj earthquake created an opportunity for the State to review the present condition of earthquake preparedness and reduce the vulnerability and risk for future seismic events. The problems of the urban areas are in many ways more complex and there are no easy answers. In the past about three years some significant steps in the right direction have been taken; such as incorporation of earthquake engineering in the engineering syllabus, licensing of structural engineers, continuing education programs for the practicing engineers, review of development control rules and earthquake codes, amongst others. Despite a few teething troubles most of these initiatives have met with a good rate of success. But this is only the beginning. There is a long journey ahead. The Gujarat State Disaster Management Authority was formed immediately after the earthquake. An institutional mechanism has thus been created to take the agenda of seismic safety forward. The Gujarat Disaster Management Act was passed recently and can provide a powerful platform for carrying out many of the unfinished tasks.

The challenge lies in sustaining and augmenting the activities even as the Bhuj earthquake recedes in the memory of people and administrators.

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