Interdisciplinary Observations on The January 2001 Bhuj, Gujarat Earthquake

compiled and edited by

Ravi Mistry
Weimin Dong
Haresh Shah

sponsored by

World Seismic Safety Initiative
Earthquakes and Megacities Initiative

Translation of wall writing:
400 rallying (to attend India Republic Day flag hoisting ceremony in Anjar) children gone (died). God Bless.

April 2001

About WSSI & EMI

World Seismic Safety Initiative

WSSI - An IAEE Undertaking

WSSI, an undertaking of the International Association of Earthquake Engineering, was founded to advance and spread earthquake engineering knowledge worldwide. Its goals are to: a) enhance the distribution of earthquake engineering information and knowledge so that engineers can design and construct earthquake-resilient structures; b) improve earthquake engineering practices for all types of construction by incorporating experience and research findings into recommended practices and codes in earthquake-prone countries; and c) advance engineering knowledge through problem-focused research.

WSSI sponsors projects that will: a) transfer technology; b) develop professional engineering practice; and c) address crucial research questions that constitute gaps in our knowledge of structures respond to earthquakes and how they can be built to withstand them.

EMI

Earthquakes and Megacities Initiative

EMI is an international scientific non-government organization dedicated to the acceleration of earthquake preparedness, mitigation, and recovery of large urban areas (i.e., Megacities). EMI is a catalyst for scientific and technical knowledge to the end-users. EMI focuses its efforts on developing capacity in Megacities of the developing world where the effects of earthquakes could be devastating to the people, their economy, their culture, and their environment

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WSSI/EMI contributions by

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ACKNOWLEDGEMENTS

Dr. Haresh Shah, Professor-Emeritus, Stanford University, founder and Chairman of the Board of Risk Management Solutions, Inc. (RMS), California, USA, and Chairman of the Board, World Seismic Safety Initiative (WSSI), organized an international team of engineers, geologists, seismologists, sociologists, and disaster management experts for an interdisciplinary reconnaissance of the January 26, 2001, Bhuj, Gujarat earthquake. The reconnaissance was sponsored in part by World Seismic Safety Initiative (WSSI), and Earthquakes and Megacities Initiative (EMI). Partial funding was also provided by the Oyo Corporation of Japan, RMS, and RMSI. The WSSI/EMI team members, who participated in the reconnaissance and contributed to the writing of this report, are:

- Mehedi Ahmed Ansary, Bangladesh University, Bangladesh
- Michael Baur, University of Karlsruhe, Germany
- Teddy Boen, Indonesia
- Louise Comfort, University of Pittsburgh, USA
- Amod Dixit, National Society for Earthquake Technology, Nepal
- Weimin Dong, RMS, California, USA
- Laura Dwelley Sampat, Geohazards International, Palo Alto, USA
- Maureen Fordham, Anglia Polytechnic University, United Kingdom
- Rohit Jigyasu, India (Doctoral student at Norwegian Uni. of Science and Technology, Norway)
- Badru Kiggundu, Makerere University, Uganda
- Tetsu Masuda, Oyo Corporation, Japan
- Charles Menun, Stanford University, USA
- Ravi Mistry, USA
- Timothy Sabiiti Mutebile, Ministry of Defence, The Republic of Uganda
- Ahmad Naderzadeh, Center for Earthquake & Environmental Studies of Tehran, Iran
- Naresh Raheja, RMSI, India
- Swaroop Reddy, India
- Mohd Rosaidi bin Che Abas, Malaysian Meteorological Service, Malaysia
- Violeta Seva, The Philippines
- Svetlana Uranova, Kyrgyz-Russian Slavic University, Kyrgyz Republic
- Vikas Wadhera, RMSI, India

In addition, RMSI, under the direction of Col. J. S. Kahlon and with the help of Naresh Raheja, Vikas Wadhera, and other RMSI staff members, managed complete logistics of the trip including lodging, boarding, and air/ground transportation to visit the affected areas throughout the State of Gujarat.

Contact with local officials, including the collectors of various districts, was made possible by Mr. Mukesh Shah of NRG. Mr. Shah, along with Mr. Bhupendra Amin, also made arrangements to have Mr. Ashish Desai, a local civil engineer from Ahmedabad, to accompany the reconnaissance team and to serve as the local coordinator in Gujarat.

Collectors Mr. A. K. Srinivas of Ahmedabad District, Mr. Anil Mukhim of Bhuj District, Mr. P. N. Patel of Rajkot District, and Mr. H. B. Varia of Surendranagar District took time out of their busy schedule to provide us with up-to-date briefing about the events that happened, and ongoing relief and rehabilitation efforts.

Prof. Gautam Gandhi, Chair of Civil Engineering Department, DD Institute of Technology, Nadiad, Gujarat, shared his observations of post-earthquake inspection of buildings in Ahmedabad. Mr. Mihir Bhatt of Disaster Mitigation Institute (DMI) in Ahmedabad met us for about two hours to educate us on the disaster mitigation work performed by DMI. Representatives of Rashtriya Seva Sangh (RSS), Mr. Somnath Khetkar and Mr. Gautam Patel, gave a brief summary of their activities of relief and rebuilding effort, and presented a master plan of rebuilding the villages.

The contributions and support of the entire WSSI/EMI international team, the aforesaid organizations and individuals, and sponsoring organizations listed in Appendix A-2, are sincerely acknowledged and appreciated.

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PREFACE

The Bhuj, Gujarat earthquake (Bhuj earthquake) of January 26, 2001 was a major event both in terms of its seismological characteristics and in terms of its economic, life loss and social consequences. Like many earthquakes in recent times, numerous academic, professional, and humanitarian organizations sent teams of experts to study and learn from this unfortunate event. As a result, many reports will be published which will focus individually on scientific, technical, economic and social issues. The World Seismic Safety Initiative (WSSI) and the Earthquakes and Megacities Initiative (EMI) wanted to make sure that they provide to the international community an additional opportunity to learn from this earthquake in the form of on-site training to team members assembled from developed and developing countries. The two organizations wanted to send an interdisciplinary team of experts from around the world to study and report on this earthquake in a holistic manner.

This idea of assembling the unique team was first conceived by the board members of WSSI and EMI. Prof. Wilfred Iwan, Mr. Satoru Ohya, Prof. T. C. Pan and Dr. Tsuneo Katayama discussed this idea at length in Japan soon after the occurrence of the Bhuj earthquake. After considerable deliberation amongst the board members of WSSI, they developed the plan of sending a team made up of individuals from developing and developed countries around the world with different interests and different professional backgrounds. They conveyed this plan to the Chairman of WSSI, Haresh Shah, who in turn recruited the participation and support of EMI through its Chairman, Dr. Fouad Bendimerad. This was, to our knowledge, the first such experiment to look at the earthquake consequences as a learning tool for many individuals from developing countries. Without such an experiment, many of the team members might not get an opportunity to be on site, and see the technical, economic, scientific, social, and political forces that contributed to the death and destruction.

This report is a result of that experiment. It is a result of looking at the earthquake and its consequences by a unified team of people from developing and developed countries and with backgrounds as varied as structural engineering, geography, social sciences, urban planning, public policy, seismology, and disaster planning. Not only did the experiment result in this report, it also provided a dynamic and live learning experience for many. Only through such an effort that organizations such as WSSI and EMI can increase the awareness of nations about what are the main drivers of death and destruction due to earthquake events. We hope that this awareness-raising experience will provide some countries represented in this team to address the problem of earthquake risk reduction, and will give them the perspective and value of pre-disaster planning for mitigating the effects of future earthquakes.

TEAM MISSION

Prof. Haresh Shah articulated the objectives of sending a multi-disciplinary team to learn from this earthquake in a letter by him to the team members before they started their field visit. That letter is paraphrased below:

"This mission will provide a learning experience for those who have never been to a disaster site of this magnitude. Interaction between team members who have and who have not experienced such disasters at first hand will be valuable to all team members. As I had indicated in my previous e-mail, this team's mission is uniquely different than most reconnaissance teams. The mix of team members and where they are coming from will give you an idea of what WSSI/EMI is trying to achieve. The purpose of this mission is as follows:

- ***Understand the setting under which this event occurred.*** *This includes the social, political, technological, and scientific settings. Towards this end, please try to collect as much as you can in your specified field of interest about the setting. We will also provide you with background information when you reach Delhi at the 3:00 pm meeting on February 25.*
- ***The actual observation of the damage and destruction.*** *This is not only to structures and infrastructure of the region, but also to the social fabric, economy, government, and quality of life.*
- ***Talk to as many local people as possible to understand the performance of government, international organizations, local self-help groups, and of average citizens in rescue and recovery efforts.*** *The ability of a society to face the disaster and through self-help, recover and move on with the business of living should be investigated. Some members of the group may also be interested in investigating the gender issues and issues related to age, financial status, and other aspects in suffering losses and the consequent recovery.*
- ***Dismal performance of schools, hospitals, and emergency centers.*** *Investigate as to why and what lead to such consequences.*
- ***Why are the codes not implemented?*** *Why was the awareness so poor? Why were the buildings not constructed as designed? What and where were the main centers of corruption?*
- ***Most important, please articulate as to what should be done to prevent such disasters in future.*** *This is a tall order. We should be able to articulate not only technical solutions but also how the societies can be made aware of death and destruction in the absence of pre-earthquake planning.*

One of the major objectives of this trip is, what you have learnt and how that learning can be used for future benefit in especially developing societies. WSSI/EMI is hoping that the team members from developing countries will provide us with their impression of what they need to do in their respective countries and how they intend to achieve those things. Raising awareness is *our expectation. How this can be achieved through the efforts of the team members is hard if not impossible to articulate. We will look to you all for guidance."*

EXECUTIVE SUMMARY

This summary provides a brief description of the activities and observations of a field trip to observe damage caused by the January 26, 2001, Bhuj earthquake. The reconnaissance survey was conducted by a team of 21 professionals that included representatives from the fields of engineering, disaster management, public administration, political science, social geography and seismology. The individuals were sponsored by numerous organizations, including the World Seismic Safety Initiative (WSSI), Earthquakes and Megacities Initiative (EMI), and OYO Corporation. The team also represented a number of countries including Bangladesh, Germany, India, Indonesia, Iran, Japan, Kyrgyz Republic, Malaysia, Nepal, The Philippines, Uganda, United Kingdom, and United States. The trip spanned a period of eight days beginning February 25, 2001 and ending on March 4, 2001, and included affected regions of the Districts of Ahmedabad, Kachchh, Rajkot, and Surendranagar. The team visited the following cities / towns / villages: Ahmedabad, Anjar, Bhachau, Bhuj, Gandhidham, Kandla, Limbdi, Morbi, Navlakhi, Rajkot, and Surendranagar.

The mission of the trip was to investigate the Gujarat earthquake catastrophe from several angles including, but not limited to, engineering, rebuilding and reconstruction, social, economic, political, organizational, and disaster management perspectives, and identify: 1) factors leading to the catastrophe, and 2) ways to mitigate it. The investigation addressed following issues: Technical, Disaster Management, and Social.

Earthquake at a Glance

An earthquake measuring 7.9 on the Richter Scale (7.6 Moment Magnitude), hit the Kachchh region, located in the northwest region of the State of Gujarat at 8:46 am on January 26, 2001. It was felt in most parts of India. The earthquake caused substantial loss of life and property. According to the estimates available from the government sources at the time of this report, 18,253 people lost their lives, and another 166,836 suffered injuries of various degrees. 7,904 villages in 182 talukas of 21 districts in Gujarat were affected. 332,188 houses were destroyed while 725,802 houses were damaged to varying degrees. The strong motion records obtained from the Passport Office Building under construction in Ahmedabad, about 230 kms from the epicenter, indicated a peak ground acceleration of about 0.11g.

Technical Issues

The team investigated technical issues as they related to buildings, and lifelines (electrical, communications, water, and transportation). The lifelines were all affected to some extent; however, in most cases, service was partially or fully restored within four

days of the earthquake. Government-designed and operated overhead water tanks with capacities ranging from 10,000 liters to one million liters withstood the earthquake without any damage. Many non-engineered houses collapsed or were severely damaged, and several reinforced concrete buildings sustained slight to severe damage. Large tent cities currently house many of the residents of Kachchh and it is understood that they will have at least temporary homes within the next 3-6 months.

It was observed that buildings constructed inadequately for seismic safety, even at remote distances from the fault, were severely damaged. The team visited numerous engineered buildings in Ahmedabad that were damaged beyond repair and must be demolished. However, it was also observed that properly constructed buildings (both engineered and non-engineered) located at the epicentral areas of Bhachau and Bhuj survived the earthquake without severe damage.

For those buildings that were severely damaged, the team noted several commonly occurring factors that contribute to such failures: damage to reinforced-concrete frame buildings primarily due to poor design, construction and materials; presence of heavy roof (concrete slab or tiles) or a water reservoir at the roof level; the deterioration of building materials of many non-engineered houses located in the older sections of Anjar, Bhachau, Bhuj and villages in the vicinity; the lack of integrity between the walls and the roofs and foundations; inadequacy of connections between various structural elements to prevent the buildings from coming apart; the stone parapets inadequately reinforced or anchored, posing a threat to life if they fall to the street below.

We observed that a large number of engineered and traditional structures withstood the earthquake. Based on this observation we conclude that good design practice does exist. New construction should draw from such design practice in addition to the lessons learned from the aforesaid observations.

Disaster Management Issues

The State of Gujarat began developing an emergency plan after the cyclone of 1998 that focused on cyclones, drought and floods. After the recent tremors in Bhavanagar, the State Government began developing an earthquake plan, but they did not expect an earthquake of such magnitude to strike so soon. When the earthquake struck, limited preparations inhibited timely emergency response. Communications were totally disabled; electrical power was down; water supplies were severely disrupted. Many government offices were damaged; government personnel were killed and injured, and many were tending to their families. Loss of lives and property, including business interruption losses or loss of employment for residents of the damaged communities, were catastrophic. The following aspects of disaster management were examined during our reconnaissance:

For the first 48 hours, ham radios and police wireless system were used to notify various district collector offices in the Kachchh region. Cell phone communications were also established in the first 48 hours. Immediate rescue operations were initiated by the people, followed by military and other non-government organizations (NGOs).

As a result of damage to many medical facilities, medical treatment was provided temporary quarters or tents in the Kachchh region. In Ahmedabad, the local hospitals were overwhelmed by the need to treat a very large number of injured people. There was an overwhelming response of doctors and other medical volunteers who arrived from all over India.

Although most roads were cleared off debris, there still remains debris from collapsed buildings on site.

Large number of school buildings in the vicinity of Bhuj were severely affected by the earthquake. Classes were suspended for 30 days and have now resumed in tents or temporary quarters.

A lack of planning to prepare for such a disaster resulted in poor response to the emergency. This may have resulted from priority given to the more frequent hazards such as drought and cyclones, and underestimation of the magnitude and occurrence of the earthquake phenomenon.

Public awareness and establishment of proper disaster management processes are an imperative if disaster mitigation is desired.

Social Issues

The Bhuj earthquake, occurring in an area with a rich culture and wide industry base, presents a complex range of social issues; some unique to the area and others common to earthquakes generally. The WSSI/EMI team addressed four dimensions of social issues: economic, political, cultural and psychological, and also commented on relief and reconstruction aspects.

In terms of economic aspects, the earthquake affected the full range of social classes – from royalty to the homeless – albeit to varying degrees. However, there was considerable variability of human impact between and within locations. The most affected people in Ahmedabad, for example, appeared to be the middle- and upper-middle class who lost their property and seemed to lack the personal resources to deal with the loss. On the other hand, the people of Navlakhi represented extreme impact at the other end of the scale; partly due to the failure of employers and government to enable their recovery from previous disasters. Because many people rely on social networks for support, relocating entire settlements could cause economic hardships, and disruption of local cultures. Distribution of rebuilding funds fairly and effectively will be a challenging task that, if not properly handled, could lead to social tensions. People's livelihood needs must be addressed in the widest sense.

On the political front, the government seems pressured to rebuild quickly. Both official and professional guidance in proper construction techniques seemed to be lacking. A small number of NGOs were developing programs to provide construction advice, but these programs had not yet begun. Providing repair and reconstruction guidance could be one of the most cost effective means for national and international organizations to prevent a similar calamity in the future. Our recommendation will be to construct sustainable communities using proper design and construction methods with proper accountability on the part of the engineers, contractors, and government agencies responsible for enforcing the codes.

Culturally, the Gujarati community has demonstrated their closeness and enterprise by helping one another out in time of need. The determination of people to restart their lives and to not be brought down by this immense disaster is inspirational. We noted variations between different social groups in terms of access to resources or coping ability but further research is necessary before any detailed conclusions can be drawn.

The psychological injuries of affected people should be taken as seriously as physical injuries. The rebuilding of temples, schools and hospitals should be prioritized to promote community cohesiveness and psychological support.

Local coping mechanisms have developed out of strong community and religious structures. The idea that the earthquake was meant to happen, part of a divine plan, seemed to help many people pragmatically restart their lives. On the other hand, a fatalistic view – attributing the events of life to divine will rather than personal actions – may encourage people to continue the unsafe practices that led to such massive destruction in this earthquake.

In Conclusion

Our observations indicate that if properly designed for earthquake loads and constructed, most buildings would have been able to withstand the earthquake forces with minimum loss of life and property. Although knowledge about earthquake-resistant design does exist in top academic institutions, it has not been practiced professionally. In addition, Indian codes provide recommendations rather than requirements for earthquake-resistant design. This, coupled with lack of proper inspection during construction, adds to the vulnerability of structures to resist earthquakes.

In as much as technical aspects of building design and construction are responsible for many deaths and the severe destruction of hundreds of villages, it is as important to address these issues in the context of the social disruption they have brought and suggest ways to reduce vulnerability and promote social development. Multiple levels of government must ensure that hazards of a similar nature are mitigated. For example, while proper design and construction techniques to make a structure earthquake-tolerant may cost 5% - 20% more, it would substantially reduce loss of life and property damage. Such action would avoid the level of social crisis that has been experienced by the people of Gujarat.

Disaster management programs must be designed, practiced frequently, and implemented, to aid the reduction of societal risk and promote resiliency. Public awareness about the nature of earthquake hazards and ways to mitigate them, including preparations for disaster management, should be created through education of and participation by the community at large.

Effective recovery should go beyond returning to the pre-disaster state. Sustainable development that enhances the economic opportunity and community well being while respecting, protecting and restoring the natural environment upon which people and economies depend must take place as part of the rebuilding process. The government must focus on creating such sustainable communities through a collaborative effort of public agencies, the private sector, people of the community, and key community leaders.

1. RECONNAISSANCE AT A GLANCE

Based on Meeting Notes Provided by

Ravi Mistry, USA
Naresh Raheja, India
Vikas Wadhera, India

Compiled by

Ravi Mistry

It is the dawn of the 51st Republic Day of India, January 26, 2001. Some 400 students with their teachers are marching toward the town hall of Anjar to participate in the flag hoisting ceremony in observance of the India Republic Day. There is slight chill in the air on a clear and sunny morning, quite usual during the winter days. The students, future leaders of republic India, are marching through very narrow streets - perhaps less than 10-ft wide - of downtown Anjar, singing popular patriotic songs. The narrow streets are surrounded by 2-story stone/masonry buildings. Suddenly, the earth beneath them snaps, first making a loud noise as if a bomb went off, followed by violent ground shaking that lasts for over a minute. A cloud of dust arises making it difficult to see what has happened. When dust clears, the surrounding buildings are no more standing. The violent shaking of the earth has leveled them burying under its rubble the marching students and teachers, and some inhabitants of the buildings that have collapsed. Joyful singing turns into painful screams for help. Very few students and teachers escape injury or death; most of them perish, leaving their parents and loved ones behind. It is a sight that Anjar would not forget for a very, very long time to come.

Similar tragedy has taken place in many parts of Kachchh, the northwest region of the State of Gujarat where the epicenter lies, and in other parts of the State of Gujarat as far away as 400 kms, e.g., the cities of Ahmedabad and Surat. The destruction resulted from an earthquake measuring 7.9 on the Richter Scale (7.6 Moment Magnitude), which hit the Kachchh region at 8:46 am on January 26, 2001. It was felt in most parts of India. The earthquake caused substantial loss of life and property. According to the estimates available from the government sources[1] at the time of this report, 18,253 people lost their lives, and another 166,836 suffered injuries of various degrees. 7,904 villages in 182 talukas of 21 districts in Gujarat were affected. 332,188 houses were destroyed while 725,802 houses were damaged to varying degrees. The strong motion records obtained from the Passport Office Building under construction in Ahmedabad, about 230 kms from the epicenter, indicated a peak ground acceleration of about 0.11g.

What really happened here? Did we know that Anjar, and Kachchh and Gujarat of which Anjar is an integral part, are earthquake-prone? Did the area ever go through an earthquake of this magnitude in the past? If yes, did we not learn lessons from that to build earthquake-tolerant buildings and prepare ourselves in the event of such disaster? Did we not take steps to mitigate such disaster? Why were the rescue operations inadequate resulting in substantial loss of life? Are any steps being taken to bring back the social and economic life of the communities?

To get answers to many, if not all of these questions, the World Seismic Safety Initiative (WSSI) and Earthquakes and Megacities Initiative (EMI), which are under the umbrella of the International Association of Earthquake Engineering (IAEE), assembled an interdisciplinary team of experts from around the world. The WSSI/EMI team consisted of 21 professionals that included representatives from the fields of engineering, disaster management, public administration, political science, social geography, and seismology. The team represented a number of countries including Bangladesh, Germany, India, Indonesia, Iran, Japan, Kyrgyz Republic, Malaysia, Nepal, The Philippines, Uganda, United Kingdom, and United States. To the best of our knowledge, this is the only team of its kind, among all teams or individuals visiting the earthquake-affected areas of Gujarat, that represents so many countries – developed as well as underdeveloped and developing countries – and diversified backgrounds and was focused on interdisciplinary aspects of the disaster.

The mission of the trip was to investigate the Bhuj earthquake catastrophe from several angles including, but not limited to, engineering, rebuilding and reconstruction, social, economic, political, organizational, and disaster management perspectives, and identify: 1) factors leading to the catastrophe, and 2) ways to mitigate it. A further purpose of the trip was to learn from the lessons of such disaster and apply them to other areas of world which are earthquake-prone and which could suffer similar or even more damage if ways to mitigate the earthquake hazard are not employed. The investigation addressed technical, disaster management, and social issues.

The Reconnaissance

The reconnaissance trip spanned a period of eight days beginning February 25, 2001 and ending on March 4, 2001, and included affected regions of the Districts of Ahmedabad, Kachchh, Rajkot, and Surendranagar. The WSSI/EMI team visited the following cities/towns/villages: Ahmedabad, Anjar, Bhachau, Bhuj, Gandhidham, Kandla, Limbdi, Morbi, Navlakhi, Rajkot, and Surendranagar. Below is a daily recap of places visited and meetings with government officials.

During the travel, we saw tens of overhead tanks of different sizes and capacity. These tanks, designed and maintained by government agencies, went unscathed after experiencing the earthquake. This validated the need for a proper design of structures that could have minimized collapse and saved numerous lives.

Sunday, February 25, 2001

Our trip started with a kick-off meeting of the WSSI/EMI team members at the RMSI offices in Noida, India. The RMSI team of engineers and Dr. Ravi Sinha, Professor, IIT Bombay, who had visited Gujarat in the week prior to the kick-off meeting, presented their observations. After an initial discussion, the team was informally divided into three disciplines – technical (related to structural/earthquake engineering and seismology), disaster management, and social (which included economic, cultural, political, and psychological aspects).

Monday, February 26, 2001

The team flew to Ahmedabad and stayed overnight at the NRG Bhavan, a government guesthouse. We had a meeting with Mr. Mukesh Shah, member of Gujarat Planning Commission, who also made arrangements for us to meet with collectors of various districts during our trip. Mr. Shah was accompanied by Mr. Bhupendra Amin, and Mr. Ashish Desai who also accompanied the WSSI/EMI team during the entire reconnaissance trip. Mr. Shah briefed us on the rebuilding efforts, the role played by numerous Non-Government Organizations (NGOs) during the relief efforts and subsequent participation in adopting villages for rebuilding. He shared information about the financial packages offered by the government in rebuilding villages. Prof. Gautam Gandhi, Head of Civil Engineering Department, Dharamsinhji Desai Institute of Technology, Nadiad, Gujarat shared his experience and observations as a member of the team performing post-earthquake investigations of buildings to determine the level of damage suffered by them. The post-earthquake investigations were sponsored by Ahmedabad Urban Development Authority (AUDA) and followed guidelines issued by the Center for Environmental Planning and Technology (CEPT). Prof. Gandhi inspected about 90 buildings of which about 30% suffered severe damage. According to him, CEPT estimated about 18,000 buildings requiring some level of repairs.

That afternoon, the team visited some of the famous building collapses in Ahmedabad. In particular, the team visited Mansi, Shikhar, Ayodhya, and Akashdeep apartment complexes which were 4- to 10-story reinforced concrete structures that completely collapsed. These buildings had a soft-story design and completely collapsed when coupled with failure of heavy water tanks at roof level. Our next stop was a meeting with Mr. Mihir Bhatt, Executive Director of the Disaster Mitigation Institute (DMI) in Ahmedabad. DMI is an advocacy organization that provides a link between government and community and participates in policy changes needed for disaster mitigation. DMI participated in some relief work after the earthquake.

Tuesday, February 27, 2001

The WSSI/EMI team left Ahmedabad in the early morning by bus to go to Rajkot where we spent the night. On our way, we visited Limbdi and Surendranagar. We saw extensive damage in downtown area of Limbdi, over 100 years old with stone/brick masonry construction using mud mortar as binding material. We also visited a mosque, about 40-year old construction with a recent (less than 1-year old) extension of the 2-story building that was substantially damaged. Here, we saw how communities of different faiths and religions came together to help one another during the crisis. One of the elected members of Limbdi Municipal Corporation (called a corporator) accompanied us during a walking tour of the part of the city. We visited a collapsed school (in all, 6 out 10 schools in the city were destroyed). We also visited the palace of the former King and Prince of Limbdi. The palace was substantially damaged and the royal family was living in tents in their walled compound. The non-discriminatory nature of the natural disaster was evident here – whether you belonged to a royal family or were a common man, you could lose your habitat to the forces of nature and end up living in tents just like every one else. The general complaint from the people we talked to on the streets of Limbdi was that government assistance and attention were lacking. Here is where we heard a very pointed comment by a woman, **"Are you just going to take photographs or are you going to do something about it?"**

In the afternoon, we had a meeting with the Collector of Surendranagar, Mr. H. B. Varia who had been assigned to this post only a few days after the earthquake struck. In spite of that, Mr. Varia was on top of the situation and shared the information which can be found in Appendix A-3.3.

That late evening, we met with the Collector of Rajkot District, Mr. P. N. Patel, and District Development Officer of Rajkot, Mr. Mahesh Joshi. They shared with us the information that can be found in Appendix A-3.4.

Wednesday, February 28, 2001

On this day, we first visited Morbi. The downtown Morbi, comprised generally of older, non-engineered stone masonry structures, was extensively damaged along with Darbargadh, an old palace of the former king of Morbi. We observed that, in some instances where old buildings were demolished and new ones constructed of reinforced concrete, such buildings although adjoined by masonry buildings which collapsed, survived the earthquake with generally insignificant damage.

Our next stop was Port of Navlakhi on our way to Mandvi, where we stayed for two nights. The approach road to the port was damaged due to liquefaction caused by the earthquake. Numerous houses and warehouses suffered extensive damage. The port had still been recovering from the effects of cyclone in 1998 when the earthquake hit. We met a teacher (he did not want to identify himself) who voiced his frustrations, shared by his community, over lack of help and attention from the government. Although his complaints sounded genuine, why was this gentleman, an educated man, trying to hide himself instead of being their leader and fighting for his people?

Perhaps, there is a need to develop fearless social leadership that would help create awareness among its people and fight for their rights.

Thursday, March 1, 2001

Today, we visited Bhuj, the famous large city closest to the epicenter. Downtown Bhuj, comprised of old buildings constructed of stone masonry, suffered extensive damage. We also saw modern construction, buildings 3-7 stories high suffering complete or irreparable damage. That afternoon, we met with the Collector of Bhuj, Mr. Anil Mukhim (see Appendix A-3.5 for details of the meeting). Mr. Mukhim was also transferred to Bhuj just 3 days after the earthquake. He served as Collector of Vadodara district, located southeast of Ahmedabad in Gujarat, prior to taking over his responsibilities at Bhuj.

Friday, March 2, 2001

We visited two of the most devastated towns/villages: Anjar and Bhachau. In both these places, the downtowns, with buildings 50+ years old and of old construction (stone masonry with mud/cow dung mortar, were completely destroyed. Anjar is the place of the infamous incident where over 250 students died in the narrow streets while marching to celebrate the India Republic Day. We stayed overnight at Rajkot.

Saturday, March 3, 2001

We returned to Ahmedabad in early afternoon. Some members of the team visited more earthquake-stricken areas of Ahmedabad, mainly damage in Maninagar area where numerous buildings of soft-story modern construction suffered severe to total damage. It also included a school that collapsed and killed a number of students gathered for the India Republic Day celebrations. In the evening, we had a meeting with the Collector of Ahmedabad District, Mr. K. Srinivas (see Appendix A-3.6 for details of the meeting). We also heard a presentation from a local architect, Mr. Gautam Patel, who presented a master plan for rebuilding a village.

Sunday, March 4, 2001

The team flew to back to Noida and assembled at RMSI offices for a post-trip presentation that was attended, among others, by Prof. Haresh Shah, Mr. Satoru Ohya of Oyo Corporation, Prof. Kimiro Meguro of INCEDE University of Tokyo, Prof. Iyengar of Indian Institute of Science, Banglore, Professor Sudhir Jain of IIT Kanpur, and Prof. Ravi Sinha of IIT Bombay.

2. TECHNICAL ISSUES

Based on Observations Provided by

Mehedi Ahmed Ansary, Bangladesh
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2.1 Seismological Background

At 8:46 AM (local time) on January 26, 2001, a major earthquake shook the state of Gujarat in western India. The earthquake (termed the Bhuj earthquake) was felt throughout northwest India and much of Pakistan. It was also felt in western Nepal and Bangladesh. The earthquake caused damage over a large area. For example, in the city of Ahmedabad, which is located approximately 230 km from the epicenter, approximately 100 reinforced concrete structures (less than 1% of the total building stock in the city) either collapsed or were damaged beyond repair. Another few hundred buildings in Ahmedabad were severely damaged and require retrofitting before they are inhabitable.

The area of Kachchh is known to be seismically active as evidenced by major earthquakes that have occurred in the past. The Great Rann of Kachchh Earthquake, which occurred on June 16, 1819, had an estimated moment magnitude of M_w 7.8. The most recent damaging earthquake prior to the January 2001 event occurred on July 21, 1956 and had a moment magnitude of M_w 6.3.

Compared to most recent earthquakes, the details of the Bhuj earthquake are not well known, primarily due to the lack of strong motion instruments in the region. Consequently, the locations of the epicenter and hypocenter, fault geometry, magnitude and duration have been estimated from teleseismic data, aftershock data, field observations and one strong motion accelerogram that was recorded in the city of Ahmedabad. Unfortunately, this lack of ground motion data hinders our ability to assess the performance of structures and engineered facilities in the region. While the extent of the damage to the structures is easy to identify, the intensity of ground shaking that caused the damage can only be estimated.

The reported magnitude of the Bhuj earthquake varies from M_w 7.6 (Earthquake Research Institute, University of Tokyo) to M_w 7.7 (United States Geological Survey). The body-wave magnitude was reported to be mb 6.9. The United States Geological Survey (USGS) has located the epicenter at 23.36°N, 70.34°E, placing it at approximately 100km NNE of Jamnagar India and 290km SE of Hyderabad Pakistan; see Figure 2.1. The rupture propagated approximately 40 km from east to west. The source duration was approximately 20s. Estimates of the depth of the hypocenter range from 18km (Earthquake Research Institute, University of Tokyo) to 22km (USGS). The mechanism of the earthquake was pure dip slip due to north-south compressive stress. Aftershock data collected by the Mid-America Earthquake Center reconnaissance team suggests that the fault rupture plane is ENE-trending with a south-dipping thrust of 45° to 50° to a depth of 20 km to 30 km. The shallowest edge of the fault plane has been estimated to be 10 km deep. Based on the above information, the surface projection of the fault plane lies almost entirely in the Rann of Kachchh to the north of Bhuj and Bhachau.

Only one strong motion record of the earthquake is currently available. This accelerogram, Figure 2.2 was recorded at the basement of the passport building in Ahmedabad, which is located approximately 230 km ESE of the epicenter. The record shows a peak ground acceleration of 0.11g; however, note that there is a constant level of unnatural noise in the accelerogram of approximately 0.01g. Consequently, the accuracy of this accelerogram and the recorded peak ground acceleration obtained from it are dubious. It was reported that an instrument was also located in a building in Bhuj. Unfortunately, the building was severely damaged and the data recorded by the instrument is not available. However, based on observed overturned objects and the damage distribution on structures, the peak ground acceleration in Bhuj is estimated to be about 0.35g.

Due to the lack of recorded ground motion data, the WSSI/EMI team attempted to estimate the intensity of the ground shaking using the Medvedev, Sponheuer and Karnik (MSK) intensity scale and the European Macroseismic Scale (EMS). The estimated intensities for the cities, towns and villages that were visited during the reconnaissance trip along with their approximate epicentral distances are listed in Table 2.1. A preliminary map of the MSK intensity distribution is shown in Figure 2.3. Note that the highest intensity is estimated to be IX in the epicentral area, which is less than the estimate of X+ that prior reconnaissance teams had reported. There was no clear evidence of X+ intensity at any of the sites that the WSSI/EMI team visited. The relatively undamaged new areas of Bhuj and Anjar are good indicators that the ground motion was not severe in these cities. While Bhachau suffered heavy damage, it was primarily to old, non-engineered masonry structures that would be expected to collapse when subjected to ground motions associated with intensities less that X. Finally, note that Figure 3 indicates an east-west elongation of the isoseismal contours, which is consistent with the fault mechanism described above.

2.2 Observed Performance of Buildings and Other Engineered Facilities

The WSSI/EMI reconnaissance team visited many residential and commercial buildings, two ports (Navlakhi and Kandla) and a bridge that was under construction approximately 35 km east of the USGS epicenter. Additionally, elevated water tanks and transmission line towers were continually examined from a distance but never studied in detail.

As indicated in Table 2.1, the epicentral distances of the cities, towns and villages visited by the reconnaissance team ranged from 230 km to 10 km. Naturally, sites closer to the epicenter suffered more damage than sites located further away. However, the variability in the damage at a given site was surprising. For example, in the city of Anjar, one only had to walk two or three blocks away from the old town, which was destroyed, before arriving in neighborhoods that showed no evidence of an earthquake; e.g., compare Figures 2.4 and 2.5. The same was true for the city of Bhuj, although to a lesser extent. In the town of Morbi, a row of adjacent buildings would typically have a few collapsed buildings distributed along its length, as shown in Figure 2.6. In Ahmedabad, a small percentage (<1%) of the reinforced concrete buildings collapsed or were damaged beyond repair while approximately 80% of the buildings experienced minor damage or were not damaged at all. It is possible that the long period effect coupled with variations in the soil conditions are responsible for the uneven levels of performance observed; however, with the possible exception of Ahmedabad, it is more likely that the performance of the buildings was determined primarily by the quality of their design and construction.

The observed damage to the various types of structures and engineered facilities visited by the reconnaissance team is summarized in the following sections. We note that none of the observed damage can be classified as unexpected or surprising. Similar damage has been seen in recent earthquakes such as Mexico City (1985), Kobe (1995), Turkey (1999) and Taiwan (1999).

2.2.1 Residential and commercial buildings

The majority of structures examined by the reconnaissance team were residential and commercial buildings. In general, these buildings can be classified as "non-engineered" (e.g., traditional masonry construction) or "engineered" (e.g., recently constructed reinforced concrete structures).

2.2.1.1 Non-engineered buildings

Introduction of modern construction materials like reinforced concrete has not prevented construction of unreinforced masonry buildings in rural and urban areas in India. Most of the non–engineered buildings in the region affected by the earthquake are constructed using one of several types of masonry. Generally, urban masonry consists of burned brick, cutstone and cement mortar, while rural practice is random rubble masonry (RRM), unburned bricks and mud mortar. These buildings have various roof types including reinforced concrete slab, wood, and tiles. We estimate that approximately 90% of houses in rural areas were of RRM type.

The non-engineered masonry buildings, which are used mainly as housing units, suffered heavy damage and were responsible for a large proportion of the casualties during the Bhuj earthquake. Clearly, this type of construction is extremely vulnerable to earthquakes, as evidenced by the destruction of entire neighborhoods observed in Anjar, Bhachau and Bhuj; see Figures 2.4 and 2.7 through 2.13.

The following factors were identified as weaknesses of the masonry construction used in Gujarat that led to the damage and collapse of non-engineered buildings and the loss of life:

1. There is a relationship between the age of the buildings and their quality, as most of the very old buildings, especially in the non-formal sector, are constructed of poor quality materials. The deterioration of these materials, particularly mud mortar, due to lack of maintenance contributed to many of the collapses of non-engineered structures in the older sections of Anjar, Bhachau and Bhuj. Communities must be educated on how to maintain their buildings so that they do not deteriorate to a dangerous state.

2. Insufficient repair and maintenance of buildings damaged by floods and cyclones in the past also contributed to the losses incurred by the earthquake. According to the Collector of Surendranagar, Mr. H. B. Vharia, the collapse of some buildings in the District of Surendranagar could be attributed to foundation damage caused by flooding in previous years. Again, continual maintenance of structures is essential if their safety is to be maintained.

3. A major weakness observed in many non-engineered buildings was the lack of integrity between the walls and the roofs and foundations. The connections between these elements were inadequate to prevent the buildings from coming apart. Proper connections and detailing that respect the traditional style of construction must be developed to improve the structural integrity of the non-engineered masonry buildings found in Gujarat.

4. In some instances, the heavy weight of the roof exacerbated the damage that was incurred in non-engineered masonry buildings. Because these heavy roofs are necessary for protection against the cyclones that frequently occur in the region, it is impractical to eliminate them. Instead, builders must be made aware of the danger they pose and given proper instructions as to how to best construct the walls to provide adequate seismic restraint to these roofs.

5. The stone parapets and architectural facades on many buildings were inadequately reinforced or anchored and, consequently, sustained damage; e.g., see Figure 2.14. While damage to these elements does not cause buildings to collapse or become uninhabitable, the rubble does pose a threat to life if it falls to the street or sidewalk below.

6. The narrow lanes that characterize many of the older neighborhoods (see Figure 2.15) pose a significant threat to life-safety, particularly when debris can be expected to fall off of the buildings. In the old section of Anjar, over 250 school children were killed in a narrow lane when the non-engineered buildings on either side collapsed. We understand that the narrow lanes also hindered relief and rescue efforts after the earthquake. Bylaws that prohibit narrow lanes should be drafted and enforced.

2.2.1.2 Engineered buildings

The engineered buildings that were studied were primarily multistory reinforced concrete structures. Many of these structures had been constructed in the last five years. There appeared to be little, if any, steel construction in the area and the team did not visit any steel frame residential or commercial buildings.

With the exception of non-engineered masonry buildings, reinforced concrete buildings suffered the heaviest damage during the earthquake. Many of these buildings collapsed completely and caused hundreds of deaths. Surprisingly, buildings of this type collapsed in Ahmedabad, which is approximately 230 km away from the epicenter. Apart from major factors such as proximity to the epicenter, and for the case of Ahmedabad, long period effects, the collapse of reinforced concrete buildings was mainly due to poor design and construction practices. In particular, we noted the following shortcomings in the reinforced concrete buildings that sustained damage or collapsed:

1. The predominant collapse mode of the reinforced concrete buildings in Ahmedabad and Bhuj was due to the presence of a soft story at the ground floor level. Typically, this lateral weakness was caused by large openings provided for parking stalls and shops. Some specific examples of soft story collapses include:
   a. The 11-story Shikhar apartment complex in Ahmedabad; see Figure 2.16. In this case, the depth at which the ground floor columns were founded

amplified the soft story effect. In particular, the column footings in were located approximately 2 m below grade, as seen in Figure 2.17. Consequently, the ground floor columns had an effective height of approximately 5 m (assuming no lateral support from the surrounding soil below grade), which is roughly twice the floor-to-floor height of the suspended levels.

b. One 11-story building in the Mansi apartment complex in Ahmedabad (see Figure 2.18) collapsed due to a soft story at the ground floor. Like the Shikhar building, the soft story effect was amplified in the Mansi building by the deep column footings. However, the collapse of the Mansi apartment block is interesting in that its adjacent twin tower, which is shown in Figure 2.18, did not collapse. It was learnt that at the roof of the building that collapsed, a 30,000-liter swimming pool and a 30,000-liter reservoir had been added without any structural design after the building was constructed. The fact that the twin tower, which did not have a pool added to its roof level, was able to withstand the earthquake without collapse suggests that the additional weight of the water at the roof of the collapsed building contributed to its destruction.

c. In Ahmedabad, soft story effects also caused the collapse of 5-story building in the Ayodhya apartment complex, which is shown in Figure 2.19. It is notable that a nearby apartment building, which is located approximately 300 meters from the Ayodha complex, did not suffer any apparent damage during the earthquake. This observation is evidence that properly designed and constructed structures performed satisfactorily under the level of ground shaking experienced in Ahmedabad.

d. Soft story collapses were also observed in Bhuj; see Figures 2.20 through 2.23. Figure 2.23 exemplifies the damaging effects of soft stories, since the major difference between the building that collapsed and the building that remains standing was the presence of large openings at the ground floor level of the collapsed building for shops and parking stalls. Note that in this case, the first and second floors of the collapsed building were crushed.

2. The lack of proper seismic detailing was evident in the debris of most collapsed buildings. In particular, the following was observed:

   a. In most columns examined, the spacing of the transverse reinforcement (column ties) was large, i.e., comparable to the narrow dimension of the column; e.g., see Figure 2.24. Furthermore, the hooks at the ends of the column ties were often only 90° rather than 135°, as can be seen in Figure 2.24. Consequently, the column ties are unable to provide sufficient confinement to the concrete core of the column. At one new construction site, it was evident that column ties with 90° hooks are still being used; see Figure 2.25.

b. Inadequate lap splices and embedment lengths for the longitudinal bars were observed in many damaged columns. Figure 2.26 shows a damaged column found in the rubble of a soft story collapse. Note the congestion caused by lapping all of the longitudinal bars at one location. Also note the inadequate number of lateral ties over the splice length.

c. At an apartment building being retrofitted in Ahmedabad, the longitudinal reinforcement added to the ground floor columns had no embedment into either the footing below or the beam above, as can be seen in Figure 2.27. The effectiveness of this retrofit, which is being carried out without any engineering input, is dubious.

3. Short column effects contributed to the damage of some buildings; e.g., see Figure 2.28, which shows damage to a reinforced concrete warehouse at the port of Kandla. In several instances, it was noted that the water reservoir located at the top of the building was perched on short columns extending from the roof; e.g., see Figure 2.29. In some cases, it appeared that failure of these short columns might have initiated the observed damage to the rest of the building.

4. The location of the water reservoir at the roof level is often located away from the center of the floor plan (e.g., see Figures 2.22 and 2.29), effectively amplifying the torsional modes of vibration of the building. Torsional effects due to the unsymmetrical distribution of partition walls at the ground floor of the building shown in Figure 2.30 are believed to have contributed to its collapse. Due to the three-dimensional nature of the torsional response of buildings, it is unlikely that the structural engineers properly accounted for the torsional forces in these buildings.

5. Pounding of adjacent structures was evident at some locations. For example, the Ayodhya apartments in Ahmedabad (see Figure 2.19) appear to have sustained significant damage due to pounding.

6. Many of the damaged buildings appeared to be poorly constructed with low quality materials. In particular,

   a. Poor quality concrete was evident in many damaged columns. Figure 2.31 shows a ground floor column in the Akshar Deep apartment building. The lower part of the column (below the construction joint located approximately 200 mm below the soffit of the beam) does not contain any aggregate, only sand and cement. Note the large spacing of the column ties at this beam-column joint and the use of 90° hooks. Also note the drainage pipe cast into the column near the joint. Poor quality concrete can also be seen in Figure 2.32. Additionally, there was ample evidence of insufficient consolidation of cast-in-place concrete (i.e., “honeycombing”) both in the damaged buildings visited by the reconnaissance team and in undamaged buildings currently under construction throughout the region.

b. Occasionally, the quality of the reinforcement steel was questionable. At several locations, smooth bars had been used for the longitudinal reinforcement in the beams and columns. At the site of a collapsed school in Limbdi, the remains of a reinforced concrete column had four longitudinal bars, but no two were the same. Clearly, a designer would never specify such an arrangement. If the builder had construction drawings, he did not follow them.

2.2.2 Other engineered facilities

In addition to the residential and commercial buildings described above, the reconnaissance team visited two ports, and a bridge that was under construction. Assessments of elevated water tanks and transmission line towers were also made. Summaries of the performance of these engineered facilities follows.

2.2.2.1 Ports

The reconnaissance team visited the ports of Navlakhi and Kandla.

Port of Navlakhi

Several warehouses partially collapsed at the port of Navlakhi during the earthquake; see Figures 2.33 and 2.34. These structures were reinforced concrete frames with stone masonry infill. Steel trusses, which sat directly on top of the reinforced concrete columns, supported a light corrugated steel roof. The damaged concrete frame did not appear to be designed for seismic loads. Presumably, the designer assumed that the stone masonry infill would resist any lateral forces acting on the building. For the warehouse located away from the shore, the collapse appeared to be initiated by a local failure of the stone masonry infill. However, the collapse of the warehouse near the shore appears to have been caused by movement of its foundations due to liquefaction. Lateral spreading of the embankment along the shore was evident, as can be seen in Figure 2.35. The width of the resulting fissures seen in Figure 2.35 ranges from 100 mm to 350 mm. A fissure, which was approximately 100mm wide, was found inside the foundation of the adjacent warehouse that collapsed; see Figure 2.36.

Port of Kandla

At the port of Kandla, the effects of liquefaction were evident from the damage sustained by the Port Authority Building, which is constructed on piles. The area surrounding the building, which was not on piles, subsided 200mm to 300mm relative to the building, as can be seen in Figures 2.37 and 2.38. Inside the building, areas that were not directly supported by piles sank relative to those areas that were supported. As seen in Figure 2.39, the control tower tilted approximately 15° relative to the remainder of the building due to movement of the piles when the area liquefied. Sand boils due to liquefaction were also observed in the area near the port, see Figure 2.40.

Other types of damage observed at the port of Kandla include: (1) the soft story collapse of a two-story reinforced concrete structure near the Port Authority Building shown in Figure 2.41; (2) damage to warehouses due to short column effects (see Figures 2.28 and 2.42); and (3) the partial collapse of the roof of an A-frame storage facility shown in Figure 2.43. Mr. K. J. Todarmal, a sub-divisional officer of the Kandla Port Trust, indicated that the earthquake damaged approximately 2,000 piles below the wharf.

2.2.2.2 Elevated water tanks and transmission line towers

It was noted that all government-designed and operated overhead water tanks with capacities ranging from 10,000 liters to 1,000,000 liters appeared to have withstood the earthquake without any apparent damage, regardless of their proximity to the epicenter. An example of one of these structures, which is located near Gandhidham, is shown in Figure 2.44. However, we understand that five elevated tanks failed in the area surrounding Morbi and Malia (approximately 60 km SE of the epicenter). Unfortunately, the reconnaissance team was unable to visit these tanks to ascertain the cause or severity of the damage.

There was no evidence that any transmission line towers were damaged during the earthquake. The extensive liquefaction reported by other reconnaissance teams apparently did not affect the performance of these towers.

2.2.2.3 Reinforced concrete bridge

The reconnaissance team did not have many opportunities to examine the performance of highway bridges in the earthquake-affected region. However, a four-span reinforced concrete bridge located approximately 35 km east of the USGS epicenter was studied. The bridge, which was under construction at the time of the earthquake, sustained significant damage, as seen in Figures 2.45, 2.46 and 2.47. The southern approach abutment failed and one bent rotated slightly on top of its supporting pier. Considerable liquefaction was observed at the site, which may have contributed to the poor performance of the bridge.

2.3 State of the Engineering Profession and Construction Industry in India

As noted above, the level of damage observed in Ahmedabad, Anjar and Bhuj was highly variable over short distances. Furthermore, the WSSI/EMI reconnaissance team saw no evidence of damage to overhead water tanks or transmission towers anywhere in Gujarat. Under severe ground shaking, one would expect signs of damage in all areas and to all structures. Consequently, our field observations suggest that the ground motion experienced in Gujarat was not as severe as preliminary reconnaissance reports indicated. We conclude that a major contribution to the damage in this earthquake was, in fact, poor quality engineering and construction. This contention is supported by what we learned from Prof. G. N. Gandhi (DD Institute of Technology) and the Collector of Ahmedabad, Mr. K. Srinivas, during our meetings with them in Ahmedabad on February 26 and March 3, 2001, respectively. In particular, we were told the following:

1. The Indian Standard Code IS 1893-1984 is quite advanced and similar to seismic design codes found in developed countries. However, the seismic design provisions are not mandatory, they are only recommended. Without any incentive for adopting the seismic provisions of the building code, it is unlikely that they are ever put into practice.
2. The Indian Standards Institute administers codes for all construction materials; however, compliance to these standards is not mandatory. Naturally, the absence of quality control leads to the use of substandard materials and construction procedures.
3. Currently, contractors inspect their own work. The owner and/or city building officials make only superficial checks, if any at all. Clearly, there is a potential conflict of interest in such an arrangement. This aspect of the construction process may account for some of the poor quality construction that was observed.
4. India does not have an established professional engineering association. A system of peer-review that leads to an accepted professional qualification, which is commonly employed in most countries, does not exist. Thus, there is no means by which either the government or the public can judge the competence of design professionals. We understand that upon graduating from a recognized university in India, an engineering student need only apply for a permit to practice. Consequently, many practicing engineers are probably not properly trained to design buildings for seismic loads.
5. According to the Collector of Ahmedabad District, Mr. Srinivas, there has never been a geotechnical investigation for any building in the city of Ahmedabad. Variations in site soil conditions might provide an explanation for the uneven levels of damage that were observed in some areas, including Ahmedabad; however, there is no way of knowing for sure without proper geotechnical information. Certainly, it is impossible for an engineer to properly account for the soil conditions in his/her design without a geotechnical report. Moreover, if it is true that geotechnical investigations are not performed, it is unclear how the engineers currently practicing in Ahmedabad determine quantities as fundamental as the required dimensions of spread footings. This observation

alone calls into question the entire structural design process currently employed in Ahmedabad.

6. The current state of the engineering profession and construction industry in India is appalling. Major reforms must be implemented if another catastrophe is to be avoided.

2.4 Recommendations

Most of the casualties and destruction suffered as a result of the Bhuj earthquake were caused by the collapse of seismically unsafe non-engineered masonry buildings. Consequently, it is tempting to describe this earthquake as a man-made disaster rather than as a natural disaster. However, this is unfair to the Gujarati people; it is difficult to blame them for their losses since their homes were constructed using techniques that have been used for generations without adverse consequences.

On the other hand, none of the observed damage can be classified as unexpected or surprising. In fact, similar damage has been documented before in Mexico City (1985), Kobe (1995), Turkey (1999) and Taiwan (1999). Had the Indian government and engineering profession been proactive in mitigating seismic losses by learning from the lessons taught by these previous earthquakes, the level of destruction that occurred in Gujarat could have been reduced. This contention is supported by the fact that at many of the sites visited, buildings that were apparently properly designed and well constructed performed satisfactorily during the earthquake while nearby buildings collapsed or were severely damaged. Consequently, the Bhuj earthquake is best described as a negligence-made or an ignorance-made disaster with the blame falling squarely on the shoulders of the Indian government and engineering profession.

Now that the consequences of their inaction have been felt, it is hoped that the Indian government will act to reduce the risk that future earthquakes pose. However, based on the current state of the engineering profession in India, which the government must look to for guidance, the success of the recovery and rebuilding process is uncertain. It is important that the general population of India be made aware of the seismic hazard that exists in their country; however, the engineering profession must also take note and, more importantly, act appropriately.

Based on our field observations and discussions with city and district officials, we make the following recommendations:

1. The engineering profession in India must establish a system of peer-review that leads to professional qualification. Only then can the government and public be assured that practicing engineers are competent in seismic design.
2. The current practice in which the contractor inspects his own work must be abolished and replaced with a protocol designed to avoid potential conflicts of

interest. City building officials must become more actively involved in the inspection and approval process of constructed facilities.

3. The Indian seismic design code and material standards must be continually revised, updated and, more importantly, implemented and enforced.
4. Geotechnical investigations are essential for the design and construction of engineered buildings. Consequently, geotechnical reports should be required for all new construction and major renovations.
5. In light of the poor quality seismic design observed in the field and the questionable retrofitting currently being carried out in Ahmedabad, all new construction and renovations should be reviewed and approved by qualified engineers before being allowed to proceed.
6. Engineers must work closely with communities to develop construction details that improve the seismic safety of the non-engineered masonry buildings found in Gujarat while respecting the traditional style of their construction.
7. To better understand the seismic environment and the hazards associated with it, ground motion monitoring for both seismological and strong ground motions should be implemented. Scenario studies should also be undertaken to better understand the potential seismic risk, especially in urban areas.
8. India should utilize its tremendous software development capabilities to develop an earthquake loss estimation system, similar to HAZUS[7], that can be used by government officials, city planners, engineers and disaster management professionals to: 1) raise the awareness of the seismic hazard present in India; 2) identify and prioritize vulnerable facilities for retrofitting; and 3) improve emergency response plans and earthquake preparedness.
9. Gujarat should not rush to reconstruct without first establishing a feasible plan. To act without a strategy in place will only waste the limited resources available for reconstruction and make the situation worse.
10. The successful implementation of the above recommendations will be possible only if the public awareness of the seismic hazard is increased. Therefore, education programs in earthquake safety and preparedness that are directed at the general population must be made a priority. Without education, there can be no awareness. Without awareness, there will be no improvement in the level of seismic safety.

3. DISASTER MANAGEMENT ISSUES

Based on Observations Provided by

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This statement is a brief summary of our observations and findings regarding disaster management drawn from the field trip to the disaster-stricken districts of Gujarat State following the Bhuj earthquake.

3.1 Disaster Management

The concept of disaster management is relatively new to India. The Indian Government has historically focused on the distribution of relief *after* a disaster, rather than investing in programs of vulnerability assessment and mitigation to reduce losses *before* a disaster occurs. In developing countries, scarce resources are allocated first to immediate needs. Investment in mitigation for a disaster that may not occur has not been a priority, given limited resources. In recent years, beginning steps toward disaster planning have been taken in India. After the cyclone of 1998, the State of Gujarat began to develop an emergency plan that focused on cyclones, drought and floods. After the seismic tremors in Bhavnagar in August, 2000, the State Government initiated planning for earthquakes, but the plan was not fully developed. The heavy losses in lives and property resulting from the Bhuj Earthquake provide compelling evidence of the need to reconsider the prevailing strategy of distributing relief after disaster and move decisively toward adopting a strategy of prevention to minimize losses before disaster occurs.

In our field study, we examined basic functions of disaster management in current practice after the earthquake and offer the following observations in reference to the four districts of Gujarat that we visited during our reconnaissance trip: Ahmedabad, Kachch, Rajkot, and Surendranagar.

3.1.1 Notification

Procedures for notification of disaster and requests for assistance depended upon the availability of communications. The earthquake severely damaged telephone communications in the Kachchh and Rajkot Districts, and telephone service was not available during the first 48 hours. See Figure 3.1. In these districts, local personnel used the police wireless radio to report damage to the District Collector's Office and to request assistance. In Ahmedabad and Surendranagar Districts, telephone service was available and official communications were largely made by telephone. Satellite telephones were available in the District Collectors' Offices, but in some instances (Rajkot) were not used.

3.1.2 Establishment of State Control Room (EOC)

The state government setup a Control Room (EOC) in Gandhinagar one hour after the event. However, they were not able to establish communications with Bhuj. The Control Room was able to establish connectivity with Kachchh collector in Bhuj nearly 16 hours after the disaster. The state was truly able to take charge of the situation only three days after the disaster as the magnitude of the event was overwhelming to the administration.

3.1.3 Search and Rescue Operations (SAR)

Search and rescue operations varied with the degree of destruction and the state of emergency preparedness in each district. In Kachchh District, which experienced the most severe and widespread destruction, initial search and rescue actions were taken by family, friends and neighbors not trained or without special equipment. Voluntary organizations arrived within hours of the earthquake to assist in the search for live victims. Sangh Parivar, a consortium of voluntary organizations, a highly self-motivated, organized group of NGOs, played a crucial role during the critical hours after the disaster. With the official machinery totally paralyzed, it was the Sangh Parivar that undertook the SAR operations during the first 48 hours and eventually worked with the Indian Army. By January 30, nearly 8,000 Sangh Parivar workers were deployed in the Kachchh district alone. The Indian Army arrived within two days (1/28/01) in Bhuj and Bhachau, and within three days (1/29/01) in Gandhidham and other villages. Even though the Army and the State Rapid Action Force promptly provided the manpower, they didn't have the expertise and the heavy equipment to undertake SAR. It took nearly three days before they could acquire heavy equipment and cranes.

The Indian Army and the Sangh Parivar played a key role in recovering bodies and cremation of the dead. In Rajkot and Surendranagar Districts, rescue activity was carried out by the local people and a network of voluntary organizations. In

Ahmedabad, the Fire Department was fully engaged in rescue activities, assisted by local residents and NGOs. From the figures reported by each of the District Collectors, there were 19,595 deaths due to the earthquake, the largest number in Kachchh (18,300)[5];next, Ahmedabad (751)[6]; followed by Rajkot (431)[4] and Surendranagar (113)[3]. See Figure 3.2. Seven international teams worked in the District for one week.

3.1.4 Communications

Telephone communications in the severely stricken districts of Kachchh and Rajkot were seriously disrupted. In Kachchh, all communications cables were damaged. See Figure 3.3. The district collector established contact with the State Control Room in Gandhinagar using a satellite phone about 16 hours after the disaster. Ironically, the state Principal Secretary has ordered all the district collectors in December of 2,000 to test their Inmarsat satellite phones and see if they are operational and report back. During the first round only four collectors responded. A second warning led to a positive response from all collectors. Despite their claims, the satellite phones did not seem to work when the quake wreaked havoc on January 26th. During our interviews, only two collectors confirmed that they used the satellite phones. In essence, proper design of communications architecture and testing and evaluation of communications were not done.

In Kachchh District, the power supply to the microwave system failed. The area manager wired the microwave system to batteries, and restored the microwave system within 90 minutes. Police wireless and ham radio communications were used to transmit messages between the damaged municipalities and the District Collectors' Offices, and between the District Offices and the Gujarat State Offices in Gandhinagar. The Indian Army brought mobile communications units with them when they arrived. Within two days, India Telecommunications Ltd. had established a cell phone network to support communications within and between the Districts. India Telecommunications Ltd. distributed satellite telephones to all operators of critical facilities, such as the electrical transmission stations and the water stations, as well as to local government officials, the mamlatdars in the taluka offices. In many instances, however, they were not used. Restoring telephone service within the Kachchh District was a gradual process, but was largely accomplished within eight days. See Figures 3.4 through 3.6. By March 1, 2001, 70,000 out of 85,000 telephone lines were in service. In Ahmedabad and Surendranagar Districts, telephone service remained operational and was used as the primary means of communication among governments and also between local governments and their citizens.

3.1.5 Damage assessment

Detailed statistics on loss and damage have been provided by the District Collectors' Offices, and will not be repeated here. More relevant to this report are the process of damage assessment and the use of these data as the basis for Governmental decisions for relief, rehabilitation and reconstruction.

Damage to critical facilities was reported by the managers of those facilities directly to the District Collectors' Offices, who reported the damage to the State Government of Gujarat. These reports were sent immediately to the Prime Minister's Office in Delhi, and the respective national ministries responded to assist in the rapid restoration of operations for telecommunications, electrical transmission and water distribution. The District Collectors systematically collected damage and loss statistics from the mamlatdars, or local managers of the talukas and secretaries of the villages for losses to hospitals, health centers, schools, businesses and households. Individual residents reported damage to their local government officials. In Ahmedabad, the District Collector established a Web page and an Internet address for reporting damage, but most damage to individual households or businesses was reported by telephone. The Collectors reported the District figures to the State Government of Gujarat, and State officials, in turn, reported the State assessment to the Prime Minister's Office in Delhi. These figures were used as the basis for requests for financial assistance for disaster relief and reconstruction to the Indian Parliament.

Damage occurred to water supply stations and electrical transmission stations in Kachchh and Rajkot Districts. See Figure 3.7. Transportation was affected by damage to the railway lines near Bhachau, and some bridges and highways. The ceramic industry in Rajkot was seriously affected.

The State Government of Gujarat initiated an official survey of the disaster-stricken area to assess damage to critical facilities, buildings and households. The State Government employed 400 engineers to visit each district, town and village to do a systematic technical survey of damage resulting from the earthquake. The results of this assessment will be used as the basis for allocating government assistance for the process of rebuilding and reconstruction.

3.1.6 Direction, control and coordination

The critical task of directing, controlling and coordinating disaster operations following the Bhuj earthquake appeared to be a dynamic mix of direction and control across multiple levels of government and increasingly important voluntary action by NGOs at the community level. In policy, governmental organizations have legal responsibility to respond to the needs of their citizens after disaster. In practice, the task is too large for the limited resources of government in India to accomplish alone. Governmental authorities readily invite and encourage participation by non-governmental organizations in the distribution of relief supplies, the provision of needed health care services, reconstruction and rehabilitation of damaged homes, and counseling to families that have suffered from the earthquake. There was a lack of direction and control during the critical first twelve hours after the disaster from the district administration. The victims and voluntary organizations operated through self-initiative and improvisation.

At the local governmental level, the District Collectors serve as the focal point for mobilizing, directing and managing disaster operations. Official requests for governmental assistance are made through the Collectors' Offices, which receive financial disbursements from State and National Ministries and, in turn, make allocations to the municipalities and villages within their districts. The Collectors are also responsible for implementing national laws at the local level, so challenges to building codes or suits against contractors for failed construction also fall within their area of responsibility. The Collectors, as members of the Indian Administrative Service (IAS), have some professional training in disaster management.

In practice, the IAS moves quickly to place experienced Collectors in the Districts that have suffered severe damage in disaster. In three of the four districts that we visited - Kachchh, Rajkot, and Surendranagar - the previous District Collectors were replaced with more experienced officials. In Kachchh District, Assistant Collectors, holding IAS rank, were assigned to the five talukas that suffered the most damage. The Assistant Collectors are given the powers of a District Collector to make decisions and allocate funds for the talukas. This practice speeds the decision process for managing response and reconstruction operations. The administrative structure for managing disaster operations for public organizations is a centralized hierarchy of control, with the District Collector's Office exercising primary authority at the local level.

This pattern of direction and control shifts in relation to voluntary organizations. These organizations operate with voluntary workers and contributed funds. Their missions vary; some espouse humanitarian, some religious, and some political goals. The District Collectors face the task of coordinating the welcome assistance of voluntary organizations with the official goals and programs of the government. There is no clear plan for integrating the efforts of voluntary organizations with the work of governmental programs, and this task is managed differently among the districts. For example, the Kachchh Collector met every morning with representatives from the NGOs in an effort to build a coordinated approach between their efforts and the government's activities. But this approach depends upon the voluntary acceptance of the Collector's direction by the NGO leaders. Reports of conflicts among the NGOs over the distribution of aid along religious lines, or favorable treatment given for partisan support illustrate the challenge of managing the undefined, but important role of voluntary organizations in disaster operations.

The absence of an integrated all-hazards emergency plan, especially at the levels of local government – district, taluka and village – accentuated the central role of the District Collector in emergencies. Without adequate planning or training, other public agencies with relevant skills and personnel, depend upon direction from the Collector for mobilizing action. Only in the City of Ahmedabad did the Fire Department report a departmental emergency plan. But the Fire Chief, in practice, took his direction from the District Collector.

3.1.7 Recovery and reconstruction

The shift from response operations to recovery and reconstruction is a critical phase in disaster management. Decisions made in the response phase serve as the basis for decisions in the reconstruction phase, and the most important set of decisions for those who suffered damage from the earthquake are the decisions regarding financial allocations for rebuilding their homes, businesses and villages. Based upon the damage assessment survey that was carried out as part of the response operations, the Government has proposed four packages of assistance to the damaged towns and villages, based upon the degree of destruction suffered. These packages are, briefly:

- Severe to total destruction: Villages and towns that suffered 70% or more destruction would be rebuilt, and in some cases, relocated to safer ground, through a combination of government and voluntary assistance. The Government has proposed a program of adoption of villages, and has encouraged businesses and other Indian voluntary and governmental organizations to "adopt" a village and assist with its reconstruction. The Government would pay 50%; the volunteering agency or organization would pay 50%.
- Major damage: Villages and homes that suffered serious damage, but the people want to rebuild themselves. The Government will pay Rs. 15,000 – Rs. 90,000 (US$320 - $1915) per household to repair homes.
- Moderate damage: Villages and homes that suffered some damage and require repair. The Government will provide Rs. 13,500 – Rs. 50,000 (US$285 - $1075) per household to repair homes.
- Village infrastructure: Villages that suffered damage to their infrastructure and community facilities – water and electrical distribution systems, health care centers, schools, community halls. Government will provide Rs. 140,000 – Rs. 175,000 (US$3,000 - $3,700) depending upon the design of the facilities.

Implementation of these packages will be a major task, again falling largely to the Offices of the District Collectors. Creating a process that provides adequate information to families and villages regarding the options that are available and respecting their needs and wishes will be a major task as the rebuilding process proceeds. See Figures 3.8 through 3.11.

Some of the villages and towns have been “adopted” by the NGOS, companies and /or industrialists. One of the concerns regarding this adoption process, as raised by Disaster Management Institute is that some of the companies (like software companies) can help in many other ways, than just adopting the villages and towns. See Figure 3.12.

3.1.8 Insurance

Getting the property insured against the earthquake losses could have helped the people to have a faster recovery, but in most of the cases, the residential and small commercial establishments did not have any insurance against earthquake losses. Only the properties, for which a loan was taken from banks or any other governmental financial institutions, were automatically insured. Oriental insurance received about 1,100 claims in Bhuj, and around 1,500 in Gandhidham. New India received around 100 claims in Bhuj, and 200 in Gandhidham, with a total claim value of around only Rs. 2 crores (about US$400,000). The properties were not insured, in spite of the low value of insurance premium.

In life insurance too, there have not been many claims. Mostly, the life insurance covers only accidental death. Also several people are not aware that they have this coverage. In the past, many credit cards, bonds and loans were issues to many people with add-on personal insurance coverage, but most of the people are unaware of this, or have failed to have proper nominations.

3.2 Strengths, Weaknesses, Opportunities, Threats

In review, the disaster management process as we observed it during the brief field trip through the disaster-affected districts of Gujarat reveals strengths and weaknesses, opportunities as well as threats. They are:

3.2.1 Strengths

- A growing recognition of the importance of disaster management and the need to change existing policies and practice.
- A professional administrative structure that can serve as the focal point for engaging communities in the process of assessing and managing seismic as well as other hazards.
- A responsive Gujarati Diaspora who returned to give emotional and financial support to families and villages in need.

- The resilience of the Gujarati people, who smiled, even under the stress of disaster, and shared scarce resources with others.

3.2.2 Weaknesses

- Lack of a basic scientific and engineering infrastructure to provide the detailed knowledge needed for building disaster resistant communities.
- Lack of systematic disaster planning, based upon objective, scientific knowledge about seismic risk in the region.
- Lack of integration of disaster mitigation into development planning, so that development programs incorporate basic principles of hazard reduction.
- A high degree of illiteracy in village communities that inhibits the development of community capacity to assess and manage risk.

3.2.3 Opportunities

- A rapidly developing technical information infrastructure in India that could be used to build an interdisciplinary knowledge base for assessing, monitoring, and managing risk. See Figure 3.13.
- This same IT infrastructure, linked to organizational training, learning and decision processes, could increase the capacity of communities to manage their own risk.
- Extraordinary human resources in people who can learn, innovate, create and adapt new policies and practices for disaster reduction.
- Demonstrated interest and support of the international scientific and humanitarian communities to provide material and intellectual assistance to this process.
- An extraordinary variety of voluntary organizations based in Ahmedabad that can be used to promote community based development and risk reduction programs.

3.2.4 Threats

- Indifference to the need for change in order to reduce hazards in key government, business, educational and financial organizations of the society.
- Return to previous explanations of disaster as “fate” and acceptance of recurring, enormous losses in lives and property as events outside human control.
- Inadequate information exchange between local governments and their citizens.

- Rush to reconstruction without adequate design for building sustainable communities.
- Resistance by village citizens to accept relocation of their destroyed villages to better locations.

3.3 Recommendations

It may be presumptuous for an international team to offer recommendations for action, but recognizing the commitment of our Indian colleagues to address the problem of seismic risk in Gujarat, we suggest the following strategies for action:

1. Build an interdisciplinary knowledge base for the affected region that would include geological, meteorological, engineering, social, economic, health care and policy data.
2. Develop a technical network of information access and exchange with this knowledge base that would support community participation in disaster reduction and development programs.
3. Use an integrated, all-hazard approach to disaster planning within and between jurisdictional levels of government, focusing on local government as first responders.
4. Maintain links to the international community as a source of material support and information exchange in the global problem of reducing seismic risk.
5. Invest in: a) education and awareness of the general public, particularly for emergency relief and rescue – especially since victims and neighbors do most of the immediate search and rescue operations; and b) strengthening of local NGOs – because they know the "ground realities" best.
6. Make the insurance industry an important partner in hazard mitigation efforts.
7. Make hazard mitigation and risk reduction an integral part of all ongoing development activities.
8. Build community/industry/voluntary group partnerships in addressing hazards and risks.
9. Address the risk of industries/businesses as they are the primary source of livelihood for the local people.
10. Develop an education and training program for emergency managers, and create a dedicated emergency manager post reporting directly to the district collector.

4. SOCIAL ISSUES

Based on Observations Provided by

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The Bhuj earthquake, occurring in an area with a rich culture and wide industry base, presents a complex range of social issues; some unique to the area and others common to earthquakes generally. Furthermore, we came across communities, which had yet to recover from the 1998 cyclone, and were thus locked into a downward spiral of vulnerability – Navlakhi is a case in point.

We addressed four dimensions of social issues: economic, political, cultural and psychological. These are of course closely interlinked but for convenience of reporting they have been separated below. We end with some comments on relief and reconstruction.

4.1 Economic

The earthquake affected the full range of social classes – from royalty to the homeless – albeit to varying degrees. However, there was considerable variability of human impact between and within locations. Thus, the disaster presents a complex of social and spatial factors. Examples from various locations visited will illustrate this diversity.

4.1.1 Ahmedabad

Many reports suggest that, in the city of Ahmedabad, this earthquake hit the middle-class rather than the poorer parts of society; apartment blocks suffered damage as did various businesses. The District Collector who compared this earthquake with a cloudburst last July, which released 26 inches of rain in less than 6 hours, supported this. The rich, in their comfortable homes, were spared that time but the poor were hit badly. The emergency responders then had to reach four and a half lakh individuals (450,000). This earthquake mostly hit the rich, he said, not the poor. Our fieldwork did not provide sufficient evidence on which to confirm or deny this conclusion. However, it should be noted that often the stories and experiences of the poor are not told and thus contrary evidence may not yet have come to light. Even accepting the suggested proposition, the rich are likely to recover better and more quickly with the resources at their disposal than are the poor and this must be borne in mind when making decisions about the location of resources.

The formal economic sector is very disrupted in many areas and many households have lost their primary income source or earner. However, the disaster itself provides income generation opportunities. For example, many men are currently employed demolishing structures and many women are removing rubble. See Figure 4.1. We have learned subsequently from other field researches (Enarson *pers. comm.*) that the women are often employed in the construction trade, working for day wages for residents or landlords of the damaged buildings, whoever is responsible for clearing debris. Women generally work in the lower status jobs, clearing rubble with hand tools and carrying small amounts of rubble in containers on their heads. Men work with machinery. When asked by one of the reconnaissance team, why they don't use machinery to shift the rubble more quickly, the answer was "then there would be no work for the women." We do not yet have information on how this arrangement comes about. How is it negotiated? Formally? Informally? Is it a way of exploiting cheap (female) labor or is it more (socially) organized than this, fulfilling a vital welfare function?

4.1.2 Limbdi

In Limbdi we were told of the Prince who lives in a tent and that we must visit him. The local people were proud of the fact that the earthquake seemed to have treated all the same (and we saw evidence of this belief elsewhere). However, when we visited the Prince we found him – notwithstanding the trauma of having lived through the earthquake - camped, in some comfort, in gated and guarded grounds outside his palatial home (damaged but still available to be visited and with his belongings in place). He occupied not one but several tents, and had an electricity supply and a fan to relieve the strong heat of the afternoon. Thus, as has been said before, all may be equal but some are more equal than others!

4.1.3 Navlakhi

In Navlakhi, we came across a community, which had already been made so vulnerable due to various factors that the earthquake has just added to their misery. See Figure 4.2. This village was developed specifically for salt extraction and port-related activities, and all the people once worked in these areas. However, the port authorities have been planning to expand their area of activity and as such needed more land. To this end, they needed these people to move out and have offered them incentives in cash (e.g., Rs. 20,000 – about US$ 425) and kind. However, these people have been living here for generations and don't want to move out. To discourage them from staying, the port authorities disconnected their electricity and water supplies three years ago. So they now have to buy water, which is delivered from outside. They have no school and the nearest health center is 17 kilometers away. Besides this they have been discharged from their traditional occupations in port operations and salt-extraction. As such, they are relying solely on fishing for their livelihood. This community has been affected repeatedly by cyclones and now this earthquake has just added to their vulnerability. Most of the housing is very poor, comprising tin sheets and thatch. See Figure 4.3. Since this area is geographically and politically isolated, there is no help forthcoming for relief and rehabilitation.

SEWA (Self-Employed Women's Association) reports that the saltpans in the deserts have been damaged. The salt crystallization has also been damaged and this has resulted in heavy losses to the salt farmers. They report that the saltpans will have to be rebuilt as a matter of urgency as any delay will lead to failure of salt crystallization and failure of salt production.

4.1.4 Bhuj

"I don't want money. I want livelihood.": While we were moving around the city of Bhuj, we met a woman who was sitting at the roadside. She had been working in a shop, which had collapsed and thus she lost her source of livelihood. Unfortunately her house also suffered heavy damage. When asked about her immediate needs, she responded 'I don't want money. I want livelihood'. She was unhappy that outsiders were coming merely with help in cash and kind. What she wants is a source of income. She is very confident that once she gets a job, she will manage things on her own with the support of relatives and friends.

4.1.5 Bhachau

In Bhachau, we met a group of men outside the electricity sub-station, which was damaged in the earthquake. The men are still employed by the electricity supply company and are thus economically tied to the area but they have sent their wives and children away to stay in safety with relatives elsewhere. They live together in a male enclave of tents next to the sub-station. They seem to have come to an adjustment to their situation and say they are happy together, "sharing their sorrows." Asked if the people here want to stay and rebuild or relocate, they believe it is about a 50:50 split.

Thus we found that both the formal and informal economic sectors had been disrupted to varying degrees although it is difficult to make a judgment based on appearances alone. The formal sector whose infrastructure was destroyed was affected severely in some places while the informal sector seemed to be quite active, e.g., street markets selling mainly perishable commodities such as fruits, vegetables, etc. However, the destruction of the formal sector is more clearly visible than that in the informal sector and more detailed research needs to be carried out to investigate this.

4.2 Political

This section is divided into two parts: the first deals with communication processes between various levels of government and the people; and the second deals with administrative and legislative structures related to building control.

4.2.1 Communication processes

"Are you just going to take photographs or are you going to do something about it?": This cry from a woman in Limbdi expresses people's frustration with the apparent lack of action on the part of the government. We were struck by the lack of communication between the Government (at national and district levels) and the people. It would appear that the blockage comes at District level after which structures and resources appear to decline in quantity and quality. Numerous people we met and talked to report that they had not seen a single government officer since the tragedy. People expressed uncertainty, ignorance or a lack of faith about future plans. In Ahmedabad, we saw a banner expressing people's general satisfaction with the early responders (police, army, etc.) and extreme dissatisfaction with the government whom they regard as taking too long to act, and corrupt. See Figure 3.8.

The District Collector in Bhuj, brought in 3 days after the earthquake presumably because of his considerable organizational and personal skills, has made an emphasis on participatory mechanisms, working closely with many (50-60) NGOs and alongside the UN. "All of us here have given up our egos and are working as a team," he says. Although most officials and other speakers wished to assure us that they were working closely with, and listening to, local people and groups, we sometimes suspected this was more rhetoric than reality (e.g., one official claimed that "suggestions from local people were not very helpful"). However, we gained external support for the Collector's assessment of the positive nature of this participatory process from at least one NGO active in grassroots involvement, the Disaster Mitigation Institute in Ahmedabad.

4.2.2 Building controls

In Ahmedabad, we noted that there are relatively few buildings that have collapsed, and at certain locations, while most of the others have survived well. This led us to question why this was so.

Some answers were forthcoming from various NGOs, politicians and professionals in Ahmedabad. The most striking was the absence of accountability at the municipal level concerning the technical specifications for buildings. While adequate drawings were made for legal sanction from the municipality, the actual construction was left to the contractor who may or may not follow these drawings. After execution, the municipality was only responsible for checking certain building byelaws regarding ground coverage, floor area ratio and height regulations. They were not responsible for ensuring the technical details have been followed as per the drawings. This has led to poor structural design and in some cases the use of poor building material due to corruption, black marketeering and simple economic considerations on the part of the client/builder. In addition, there appeared to be considerable ignorance of earthquake risk in the area. Because of this the buildings did not take lateral forces into account as they did for vertical forces. Since most of the stand-alone water tanks were designed to resist lateral forces, most of them survived this earthquake very well. Additionally, the residents/owners made inappropriate changes such as removing partition walls, and constructing swimming pools and water tanks on the roof, which made the buildings weaker, heavier, and very vulnerable to earthquakes. Another reason for building collapse has been the absence of soil testing at the building site prior to construction. Thus we saw and heard of many such failures in the legislative and administrative processes governing safe building design and construction.

The District Collector in Ahmedabad gave the following personal conclusions and lessons learned:

- Not a single building in Ahmedabad was ever constructed with prior soil testing.
- There is no method of verifying or certifying structural drawings of any building.
- There is no peer review or vetting.
- Engineering is not a profession in India. It must be made one. Professional bodies regulate other areas, e.g., medicine but nothing regulates engineering activity.
- There is good technical and IT education but no discipline in the engineering profession.
- Structural engineers have “gone to ground”.

4.3 Cultural

Many times we heard of the distinctive cultural context of this disaster. The Gujaratis are held to be a particularly entrepreneurial and organized people. Gujaratis have migrated around the world and have organized support and relief supplies from outside and within India. Local people in Ahmedabad went out and found the heavy machinery needed to shift the rubble from the 88 collapsed buildings, the Collector having promised to underwrite the costs (“go ahead and do what you have to do”).

This disaster has demonstrated the closeness of communities in Gujarat. Many people reported that communities of all economic, religious and cultural backgrounds worked, and are still working together helping each other in time of need. The determination of people to restart their lives and to not be brought down by this immense disaster is inspirational. This is best reflected in the statement from schoolgirls in Anjar: “We don’t want the earthquake to shake our spirit.” The girls at the Secondary school are determined to work hard for their examinations - which were postponed until March 12, 2001. Despite the fact that teaching is now carried out in tents, they said they wanted to pass with higher marks than they would have achieved normally. The role of the school as a focus of community cohesiveness and future orientation was noticeable in many locations.

The economic / social / political constraints in the region are such that resilience comes through social / cultural structures rather than physical structures. It is the socio-cultural networks that are the main source of strength for so many living in this harsh region - the extended family, neighbours, workmates. Destroy this through relocation and total - daily - vulnerability is likely to be increased, not decreased. When we were in Gujarat, we spoke to only a small minority of people and had no way of measuring the representation of that sample. However, what we saw consistently was the interdependence within communities; the acknowledged strength people gained from helping and being helped by their neighbours. To disrupt such social strengths is to risk replacing one disaster with another - as has been evidenced elsewhere. This presents a cautionary lesson for the government considering relocation (see below).

As in many parts of the world, some traditional buildings were observed to use earthquake resistant elements. See Figure 4.4. This type of construction seems to be no longer used due to a lack of locally available wood, and the introduction of reinforced concrete. However, the presence of these earthquake resistant elements in traditional homes can be used as a way to encourage earthquake resistant construction in the future while strengthening local pride and identity. Individual human memory is short and many lessons learnt in previous earthquakes get lost over time. It is important that institutional mechanisms are instigated to ensure local cultural attributes are preserved.

Many cultural aspects remain to be researched. We were told, or read, of variations in the experiences of people due to gender, age, class and caste differences. For example, we read[8] that many Gujarati women had soon restarted their (often informal) businesses and lives while their husbands had been totally brought down by the disaster. We were told by some of our local guides that those in the age group of 60 and above seemed hardest hit by the disaster because they had lost everything and felt they did not have enough time left to rebuild their lives. We read[9] about inequality of access to resources because of caste differences, with those from the lowest castes being excluded from relief supplies. Future research must foreground socio-cultural differences, by disaggregating disaster victims and survivors, and examine these aspects further.

Finally, as mentioned above, we observed a lack of communication between government and the people. We concluded that communication was hindered partly by a top-down bureaucratic culture, which may not be conducive to a truly participatory process of rehabilitation. We felt that this was one aspect of culture that required some review and revision.

4.4 Psychological

We observed that in many instances the psychological injuries of affected people were felt as strongly as the physical injuries. See Figure 4.5. The rebuilding of temples in particular was identified as an urgent need in order to provide solace and support within families and communities. Many people identified schools as important for community cohesiveness and for giving a promise for a more positive future - something that could be salvaged from the wreckage.

We heard how, in the immediate aftermath of the earthquake, friends and neighbors came to help each other in immediate relief and rescue, even though each of them had lost their family members and friends. Still, after one month, they are the best supporters and helpers. Many of the neighbors also helped in cremating the dead, often directly outside the homes that had killed them. One man in Bhuj, searching through the rubble for retrievable objects from his home, found photographs of his family including his wife who had died in the earthquake. While members of the team stood with tears in their eyes, he said that no one here has time to cry over their loved ones who are lost. They are supported by their faith in God, through which they have gained internal strength to fight against these tragic circumstances and reassemble their disrupted lives.

This incident brought us face to face with the harsh reality in the aftermath of such a disaster and also helped us see the local coping mechanisms that have developed out of strong community and religious structures that characterize Indian society in general and the Gujarati community in particular. The idea that the earthquake was meant to happen, part of a divine plan, seemed to help many people pragmatically restart their lives. On the other hand, a fatalistic view – attributing the events of life to divine will rather than personal actions – may encourage people to continue the unsafe practices that led to such massive destruction in this earthquake. An owner of a construction company in Bhuj, who had lost his house and his wife, told us that he believed no one could be blamed for the house collapses. Higher powers were responsible for which buildings collapsed and which did not. This attitude does not encourage learning from the previous mistakes that were used in construction and is perhaps a convenient excuse for some negligent builders.

4.4.1 Fear trauma

The Collector in Ahmedabad identified fear trauma as the major problem to deal with. The city didn't sleep indoors for 3 weeks for fear of falling buildings. This was made worse by the many aftershocks. Temporary shelters (123) were set up so that people could sleep there at night. Most night activities were affected but most daytime economic practices continued. How do you assure people that their buildings are safe? NGOs, social psychologists and doctors were organized to talk to people in the evenings. Meetings of 3,000-4,000 people were common. Trauma treatment is taking place in schools.

Although people throughout the earthquake-hit area are sleeping outside of their homes due to concerns about safety, many people are working in buildings that are heavily damaged or even partially collapsed despite frequent aftershocks. A number of stores in the heavily damaged areas of old Bhuj seem to have opened as soon as the roads were cleared. A barber in Morbi whose shop had completely lost its roof and had heavy cracks in the walls was still open for business. In the barber's words, he felt that he had no choice but to continue his business: he needed to survive. One shopkeeper in Ahmedabad, whose shop was on the ground floor of a two-story building, which had lost its top story, stated that he had reopened his store as soon as the government had cleared the rubble in the street. Since he only spent his days in this building and because the building was not tall, he thought it worth the risk to open his shop. It is difficult to imagine people placing their long-term safety as a high priority – i.e., through taking the effort to construct an earthquake resistant home or strengthen their current home – when their safety in the present appears to be such a low priority compared to everyday economic imperatives.

4.4.2 Response, relief and reconstruction

We met an elderly man in the town square of Bhachau who described the panic that engulfed the people when the earthquake happened. They did not eat or sleep for some days. Everyone helped each other. The role of the Indian army and some private organizations was highly appreciated while the government was outrightly condemned for its apathy towards the victims. This man's argument was supported by scores of local people who had surrounded us by that time.

We also heard many times of the inappropriate handling of the dead. We heard stories of makeshift cremation grounds, summary burning of bodies outside destroyed homes, and that some bodies remain buried under rubble (one month after the earthquake).

Batuk Vora of the Times of India Online reports on the complex interweaving of sudden and chronic disasters. The pre-existing drought has been relegated to a lower priority in policy and action terms even though it is a prominent issue for the earthquake survivors. The example given is of the village of Keradi (district of Jamnagar), which needs to be entirely rebuilt. As with a number of other villages, it has been adopted, this time by the Digjam company. But the water scarcity is exacerbating their post-earthquake misery. Five days after the quake, they received water through tankers but they had nowhere to conserve it. There was no overhead tank or other facilities. Water is being collected in a common water pool (havado), from which both humans and cattle drink. No relief commission people are to be seen, as they regard the village as "adopted", although the adopting company has yet to begin any work of rehabilitation.

4.4.3 Relief

Bhuj has the dubious honor of naming the earthquake. It does bring benefits, however. Relief supplies have been concentrated here and many local people elsewhere claim that other areas have been neglected in its favor. Many people complained that resources had been unfairly distributed during the relief phase. Many of the victims are still without temporary shelter. One must ask, where are all the 'international' tents that we have heard of? Have they reached the really needy? The Times of India (March 2, 2001) reported that relief supplies are getting piled up at airports. Are these being equitably distributed? One low-level government worker in Bhuj said that he had been requesting tents from the district collector for his family, but was denied in favor of higher-level government workers. Although it is unclear how true or widespread stories like the above are, it is clear that people *perceive* unfairness and this perception is likely to intensify in the reconstruction period when larger resources are at stake.

In the relief camp in Anjar, we spoke to some of the earthquake victims, who are living in tents provided by the Indian Army. See Figure 4.6. They reported that there is no shortage of food although some needed clothes. Some of the family members were injured and are undergoing treatment at the makeshift hospital. They complained about the long distances they have to travel to get daily treatment. Besides physical effort, it is also financially pressing for them. All of them wanted immediate permanent shelter, as they are very worried about the coming monsoon. Many of them complained about complicated bureaucratic structures, which make things very difficult for them. As an example, they mentioned that in order to get compensation for the injured, they have to get a form signed by the doctors but the doctors are refusing to sign this paper as they feel that this will place responsibility on them.

Even one month after the earthquake, we note that some of the narrow lanes are still partly blocked and people are unable to retrieve belongings from beneath the rubble. See Figure 47. We also noted that most of the rubble is being disposed of in open green areas and in river beds which is an invitation to an environmental disaster. Furthermore, we observed (particularly in Ahmedabad) total ignorance of safe methods to demolish damaged structures.

4.4.4 Reconstruction and relocation

The government of Gujarat has devised a very comprehensive package for rehabilitation and reconstruction of the earthquake victims. Relocation is encouraged for all villages where 70% or more destruction has taken place, irrespective of whether the people actually want it or if it is socially, economically or culturally feasible. The situation, which occurred in Latur, Maharashtra, India is being sadly replayed in Gujarat. There is a huge gap between what people need and what the government thinks should be provided to them. People want outside help in clearing rubble while government wants new ready-made houses at new locations without consideration of social and cultural factors. City-like planning is here, wrongly, considered 'appropriate development' for villages. According to a recent newspaper report, 90% of Kachchh villagers have already rejected relocation (Times of India, February 28, 2001).

Financial compensation is proposed for all those villages and towns with less than 70% damage. However, one does not know how this money will be used in the absence of sound management policy and mechanisms for disseminating earthquake resistant technology to the people.

People were actively repairing homes and businesses during our visit, and many had already been completed. See Figure 4.8. A few structures that had entirely collapsed were being rebuilt as well. Although people were actively moving ahead with this work, it was clear that some people had anxiety about whether the construction methods they were using were safe. There seemed to be no access to information about safe construction techniques and materials. In Ahmedabad, when residents of one neighborhood discovered that there were structural engineers among our team members, they took us from house to house and asked our opinion on the safety of the structures and whether the repair techniques they were using were appropriate. The District Collector of Ahmedabad informed us that the city decided to let people proceed with repair work because they did not want to discourage personal initiative and also they saw it as a lesser evil than having large numbers sleeping on the streets. There was no way the government could approve or supervise every case of repair required. Both official and professional guidance in proper construction techniques seemed to be lacking. A small number of NGOs were developing programs to provide construction advice, but these programs had not yet begun. Providing repair and reconstruction guidance could be one of the most cost effective means for national and international organizations to prevent a similar calamity in the future.

"Just clear the rubble and we can take care of reconstruction, on our own": In Bhachau, we were introduced to a man who owned a nearby 5-storey housing block, which had suffered extensive damage. According to him, the people of Bhachau have adequate skills and capacity to rebuild on their own. They just want government and outside agencies to help in clearing the rubble and this is proving to be the big hindrance in starting the process. He said, "Just clear the rubble and we can take care of reconstruction, on our own". Most people we spoke to did not want to be relocated due to strong cultural links to the land and neighborhood, but some were unable to decide on this issue due to continuing fear.

"Look ! My grandparents' house is one of the only two standing amidst rubble": While moving around the main bazaar of old Anjar and looking at the collapsed buildings, we met a middle aged man, who wanted to show us his house, which he proudly proclaimed to be one of the two standing houses in the old bazaar area of Anjar. This was a 2-storey wooden house. His grandmother had told him not to tear down this house at a time when everyone was changing over to 'modern' concrete structures. See Figure 4.9. And it is only his house along with a nearby house of his friend, which are standing amidst the rubble. According to him, there were many wooden houses before 1956, and these behaved much better in the earthquake that hit Anjar that time. However, gradually all those houses were replaced by 'concrete' ones and those have behaved very badly in this earthquake.

On the way to the Prince's home in Limbdi, we are shown some illegal settlements, which our local guide says, will not be eligible for compensation. However, later in Ahmedabad, the Collector says that illegal settlements in Ahmedabad will receive some compensation but it is not clear exactly what. One is left wondering about the place of disaster reconstruction within broad development aims. Is the status quo to be reconstructed? Will the rebuilding, the resources, the training, the opportunities include those sleeping on the streets? Will the newly reconstructed communities, rebuild the pre-disaster social structures?

4.5 Recommendations

On the basis of the aforesaid observations, we recommend the following:

1. People's livelihood needs must be addressed in the widest sense. This will include stimulation for the informal as well as the formal employment sectors. This is as important as the reconstruction of the physical environment.
2. In order to construct sustainable, disaster-resilient communities, long-term needs must be balanced with short-term needs when designing rehabilitation programs.
3. There are wide gaps between government regulations and guidelines for building safe structures and the economic, political and social realities associated with their implementation. Dealing with this is a major challenge but is of high priority for sustainable development.
4. Reconstruction plans must be based on a truly participatory process of grassroots involvement. Without this, seemingly well-designed plans will fail to meet the actual needs of the recipients.

5. Efforts must be made to reach communities in outlying areas who may be out of the media or political spotlight and thus may not benefit from reconstruction efforts.
6. The Government has been criticized for not acting quickly or sufficiently in the aftermath of the disaster. Irrespective of the truth of this claim, it has not succeeded in communicating its plans or its activities to large numbers of people. It needs to be more active at the local level to convince the people that it is performing adequately.
7. Individual human memory is short and many lessons learnt in previous earthquakes get lost over time. It is important that institutional mechanisms are instigated to ensure local cultural attributes (particularly the design of earthquake-tolerant traditional structures) are preserved.
8. Providing repair and reconstruction guidance could be one of the most cost effective means to prevent a similar calamity in the future.

5. CHALLENGES AND OPPORTUNITIES AHEAD

Compiled by

Ravi Mistry, USA
Weimin Dong, USA
Haresh Shah, USA

Catastrophes of this nature bring along challenges as well as opportunities. Challenges arise because of the large-scale destruction of property and lives that has not been experienced in a generation. It catches people off-guard; in the particular case of Kachchh, the government is pressed to pay attention to more frequent disasters such as cyclones and draught. This lack of preparedness for earthquake hazard creates chaos that prevents a community to bounce back to normalcy expeditiously. The challenges identify opportunities that must be seized in order to develop sustainable communities and prepare for mitigation of future hazards.

5.1 Challenges

On the technical side, the challenges relate to: Code implementation; Earthquake-tolerant design of structures and lifelines; Construction practices in terms of proper detailing and inspection; Special design requirements for critical facilities such as schools; Introduction of courses in earthquake engineering and disaster management at undergraduate/graduate levels in colleges; Active involvement in the entire process by practicing engineers; Implementation of geotechnical requirements; Workshops/Seminars to create public awareness about the earthquake hazard and continuing education courses.

Disaster management requires introduction of disaster management programs/workshops and development of decision support systems.

Social challenges comprise of: Creation of public awareness programs; mobilization and solicitation of public opinion; relocation issues; coordination with talukas and districts; social equity issues; and creation of sustainable communities.

5.2 Opportunities

Tragic disaster of Gujarat earthquake has huge impact to the society as well as to the government. Political window is wide open for earthquake mitigation now. However, this period will not last too long. We should take this opportunity to take action which will lead to mitigate future disasters. This is one of the missions of the WSSI/EMI team.

Following opportunities are identified based on the recommendations from the previous sections:

1. Take Legal action to enforce the Indian seismic design code and material standards. There are wide gaps between government regulations and guidelines for building safe structures and the economic, political and social realities associated with their implementation. Dealing with this is a major challenge but is of high priority for sustainable development.
2. India should utilize its tremendous software development capabilities to develop an earthquake loss estimation system, similar to HAZUS, that can be used by government officials, city planners, engineers and disaster management professionals to: 1) raise the awareness of the seismic hazard present in India; 2) identify and prioritize vulnerable facilities for retrofitting; and 3) improve emergency response plans and earthquake preparedness.
3. Develop an education and training program for emergency managers, and create a dedicated emergency manager post reporting directly to the district collector. In order to raise public and government awareness of earthquake risk in developing countries, WSSI has organized High Level Meeting (HLM) in many countries. Such meeting should be attended by government officials, business leaders, representatives of social and cultural institutions, mass media and technical and scientific leaders. It is time for WSSI to sponsor a nation-wide High Level Meeting (HLM) in year 2001 in Gujarat.
4. Develop repair and reconstruction guidance that could be one of the most cost-effective means to prevent a similar calamity in the future. Reconstruction plans must be based on a truly participatory process of grassroots involvement.

Individual human memory is short and many lessons learnt in this earthquake might get lost over time. After a while, government has many other pressing issues to be taken care, and earthquake mitigation might be put to the end of to-do list. It is of paramount importance that all above mentioned opportunities be pursued rigorously so that the tragic lessons learned from this earthquake will not be wasted.

6. CONCLUDING REMARKS

Compiled by

Ravi Mistry, USA
Weimin Dong, USA
Haresh Shah, USA

A catastrophe of large-scale magnitude, such as the Bhuj earthquake, brings along more questions than answers as a result of the complexity and multitude of issues, including technical aspects, social aspects, and disaster management aspects. People of Gujarat have been affected in two ways: 1) loss of loved ones and, in some instances, loss of head of household; 2) loss of personal property; and 3) loss of livelihood. Only time will help heal the wounds but the physical problems created as a result of the earthquake will linger on for a long time to come.

Mental anguish and hurt run deep; however, time is the best healer and in a short time, many people bounce back from such a tragedy (loss of loved ones) with the help of relatives and spiritual attitude.

When it comes to loss of livelihood and property, however, the problems are compounded because of several reasons: 1) financial investment loss; 2) involvement of many agencies in resolving the issues of settlement; 3) time taken to rebuild; 4) bureaucracy; 5) socio-economic issues of who gets how much settlement; 6) socio-political issues.

A holistic approach needs to be designed to address the totality of the situation which would cover the diversity of the local culture and local needs. The intent is to incorporate diversity and similarity into reconstruction and mitigation strategies. Granted that all problems may not be resolved at the same time; however, it is vital to take a step at a time to solve them and get people involved in the decision making process. Although the NGOs are participating heavily in the rebuilding process, government still needs to play an active role as a neutral party and ensure that all people will benefit.

The international community can provide assistance in terms of financial aid (be it funds raised from non-resident Indians or other donors living abroad, or loans from international banks and agencies). The international teams of experts, such as the WSSI/EMI team responsible for this report, can help in terms of providing technical help in context of the social and economic fabric of the people of Gujarat. However, a bigger burden is on the government and its agencies to ensure that the people return to normalcy as quickly as possible but also be better off than before as a result of creation of sustainable communities.

Mental anguish and hurt from this earthquake run deep; however, time is the best healer and in a short time, many people bounce back from such a tragedy with the help of relatives and spiritual attitude. While people are still fresh in memory of this tragic disaster, **it is time to take action**. Don’t let disaster repeat.

7. REFERENCES

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4. Meeting with Mr. P. N. Patel, Magistrate & District Collector of Rajkot, and Mr. Mahesh Joshi, District Development Officer, February 27, 2001, Office of District Collector, Rajkot, Gujarat, India
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6. Meeting with Mr. K. Srinivas, Collector of Ahmedabad, March 3, 2001, NRG Bhavan, Ahmedabad, Gujarat, India
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8. See "Pride survives amid the ruins" BBC News online: http://news.bbc.co.uk/hi/english/world/south_asia/newsid_1163000/1163204.stm
9. See "Indian quake widens rifts between the castes" Guardian Unlimited: http://www.guardianunlimited.co.uk/naturaldisasters/story/0,7369,439143,00.html

TABLES

Table 2.1

Epicentral Distances and Estimated Ground Motion Intensities of the Cities, Towns and Villages Visited by the WSSI/EMI Team

Location	Epicentral distance[1] (km)	Ground motion intensity	
		Medvedev, Sponheuer and Karnik (MSK)[2]	European Macroseismic Scale (EMS)[3]
Ahmedabad	230	IV	VI
Anjar	40	VII	VIII
Bhachau	10	VIII	IX
Bhuj	65	VIII	IX
Gandhidham	40	VI	VII - VIII
Kandla	45	VI	VII
Limbdi	175	V	VI - VII
Morbi	80	VI	VI - VII
Navlakhi	50	VI	VII
Rajkot	130	IV	V
Surendranagar	150	V	VI

[1] Based on USGS location of the epicenter.

[2] Estimated by Ahmad Naderzadeh based on field observations during reconnaissance trip from February 25 to March 4, 2001.

[3] Estimated by Mehedi Ahmed Ansary based on field observations during reconnaissance trip from February 25 to March 4, 2001.

FIGURES

Figures for Section 2: Technical Issues

Photographs in this section were provided by: Ahmad Naderzadeh, Amod Dixit, Charles Menun, Svetlana Uranova, Tetsu Masuda, and Weimin Dong

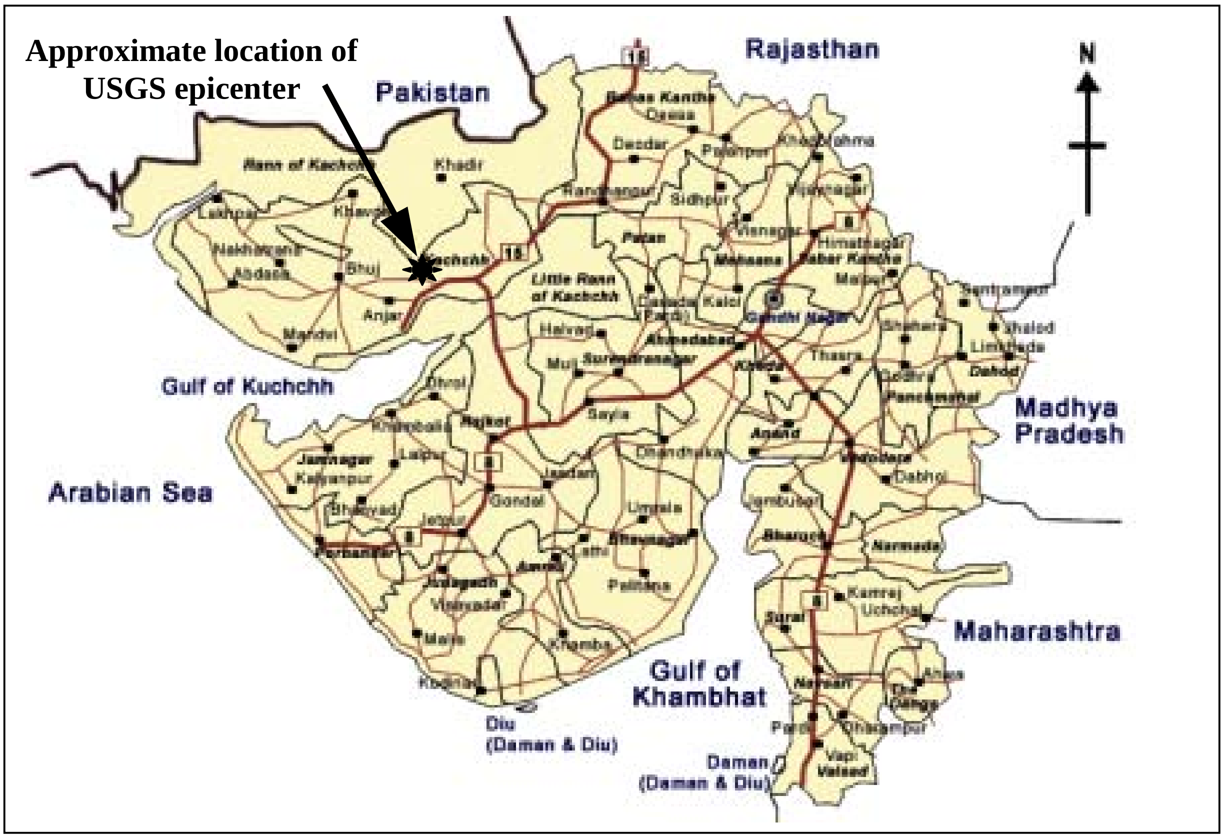

Figure 2.1. Epicenter location determined by the United States Geological Survey for the January 26, 2001 Gujarat earthquake.

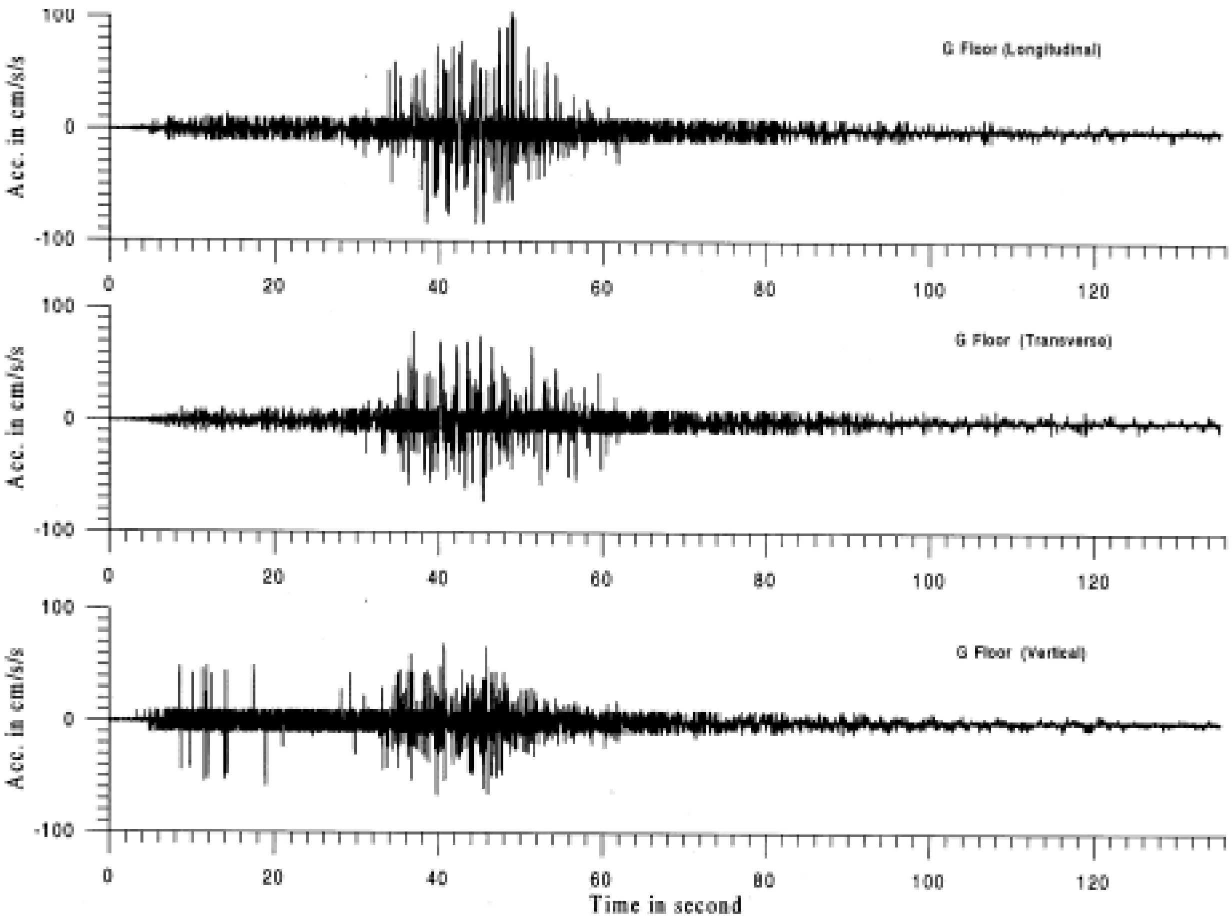

Figure 2.2. Accelerograms recorded in basement of passport building in Ahmedabad during January 26, 2001 earthquake.

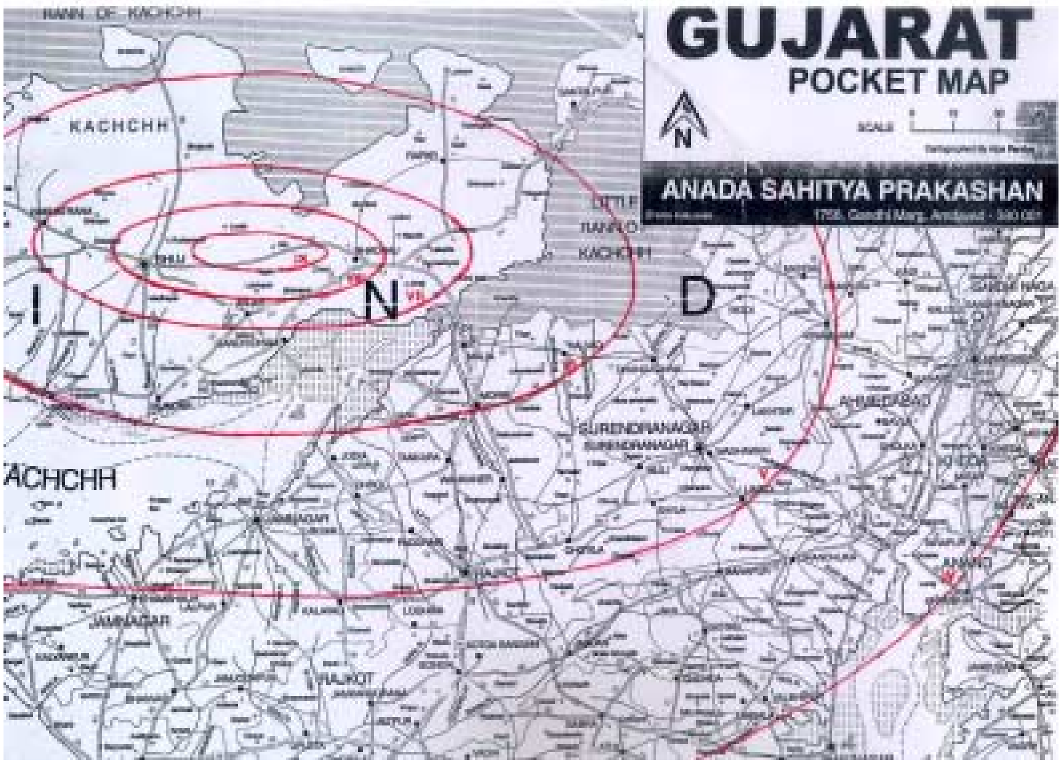

Figure 2.3. Preliminary map of the MSK intensity distribution in Gujarat due to the January 26, 2001 earthquake. Map courtesy of Ahmad Naderzadeh.

Figure 2.4. Destruction of masonry structures in the old section of Anjar. Photos courtesy of Charles Menun.

Figure 2.5. Buildings that performed well in Anjar were located only 2-3 blocks from location where the photos in Figure 2.4 were taken. Photos courtesy of Charles Menun.

(a)

(b)

(c)

Figure 2.6. Damage in Morbi showing the variable performance of adjacent buildings. Photos (a) and (b) courtesy of Svetlana Uranova. Photo (c) courtesy of Charles Menun.

Figure 2.7. Damage to a stone masonry house in Anjar. Photo courtesy of Ahmad Naderzadeh.

Figure 2.8. Collapse of a stone masonry house in Anjar. Photo courtesy of Ahmad Naderzadeh.

Figure 2.9. Destruction in Bhachau. Photo courtesy of Ahmad Naderzadeh.

Figure 2.10. Most stone houses in the old town of Bhuj collapsed. Photo courtesy of Tetsu Masuda.

Figure 2.11. Destruction in Bhuj. Photo courtesy of Ahmad Naderzadeh.

Figure 2.12. Damage to a rubble stone and mud mortar house in old Bhuj. Photo courtesv of Ahmad Naderzadeh.

Figure 2.13. Damage to cutstone and lime mortar masonry building in old Bhuj. Photo courtesy of Ahmad Naderzadeh.

Figure 2.14. Damage to the tower and parapets of a palace in Limbdi. Photo courtesy of Svetlana Uranova.

Figure 2.15. Narrow lane in Limbdi. Such lanes are common in older neighborhoods. Photo courtesy of Tetsu Masuda.

Figure 2.16. Shikhar Apartments, Ahmedabad. Building D (originally in foreground) collapsed due to soft story effects. Photo courtesy of Ahmad Naderzadeh.

Figure 2.17. Column footings located approximately 2 m below grade at Shikhar Apartments in Ahmedabad. Photo courtesy of Tetsu Masuda.

Figure 2.18. Manasi Apartments, Ahmedabad. 11-story building, in front of the building shown, collapsed due to soft story effects. Weight of swimming pool and reservoir at top of the collapsed building contributed to the severity of the damage. Photo courtesy of Weimin Dong.

Figure 2.19. Ayodhya Apartments, Ahmedabad. Building identical to that shown collapsed as a result of soft story effects. Building in photo was significantly damaged by pounding during the collapse of the adjacent building. Photo courtesy of Svetlana Uranova.

Figure 2.20. Taksila Apartments, Bhuj. Both 5-story buildings collapsed due to soft story effects. Photo courtesy of Svetlana Uranova.

Figure 2.21. Soft story collapse of a five-story apartment building in Bhuj. Photo courtesy of Amod Dixit.

Figure 2.22. Different view of soft story collapse shown in Figure 21. Note the location of the water reservoir at the roof level relative to the floor plan. Photo courtesy of Ahmad Naderzadeh.

Figure 2.23. Komal Vihar Apartments, Bhuj. Collapsed building resulted from soft story effects. Photo courtesy of Svetlana Uranova.

Figure 2.24. Damaged column from the Ayodhya apartment complex shown in Figure 2.19. Note the large column tie spacing and the use of 90° hooks. Photo courtesy of Weimin Dong.

Figure 2.25. Evidence at a new construction site in Ahmedabad that 90° hooks instead of 135° hooks are still used for column ties. Photo courtesy of Weimin Dong.

Figure 2.26. Reinforcement details of a column damaged in a soft story collapse. Note the congestion caused by lapping all of the longitudinal bars at one location. Also note the inadequate number of lateral ties over the splice length. Photo courtesy of Amod Dixit.

Figure 2.27. First floor of an apartment building in Ahmedabad being retrofitted without proper seismic design or details. Photo courtesy of Weimin Dong.

Figure 2.28. Damage due to short column effect in warehouse at the port of Kandla. Photo courtesy of Ahmad Naderzadeh.

Figure 2.29. Roof level water reservoir perched on top of short columns. Location of the reservoir at a corner of the building amplified torsional motions and resulting loads. The photo shows the roof of a collapsed two-story RC building in Bhachau. Photo courtesy of Charles Menun.

Figure 2.30. Damage caused by torsion due to unsymmetrical distribution of partition walls on the ground floor. Photo courtesy of Ahmad Naderzadeh.

Figure 2.31. Ground floor column in Akshar Deep apartment complex, Ahmedabad. Photo courtesy of Amod Dixit.

Figure 2.32. Poor quality concrete and lack of seismic detailing evident in beam column connection. Photo courtesy of Ahmad Naderzadeh.

Figure 2.33. Collapse of a warehouse at the port of Navlakhi. Photo courtesy of Ahmad Naderzadeh.

Figure 2.34. Collapse of a warehouse at the port of Navlakhi. Photo courtesy of Svetlana Uranova.

Figure 2.35. Lateral spreading due to liquefaction at the Port of Navlakhi. Photo courtesy of Svetlana Uranova.

Figure 2.36. Lateral spreading due to liquefaction initiated collapse. Note the wide fissure inside the building footprint. Photo courtesy of Charles Menun.

Figure 2.37. Subsidence of ground relative to pile-supported structure. Photo courtesy of Tetsu Masuda.

Figure 2.38. Subsidence of ground relative to pile-supported structure. Photo courtesy of Tetsu Masuda.

Figure 2.39. Port Authority Building, Kandla. Tilting of the control tower is due to settlement caused by liquefaction. Control tower is founded on piles. Photo courtesy of Ahmad Naderzadeh.

Figure 2.40. Sand boils due to liquefaction near the port of Kandla. Photo courtesy of Svetlana Uranova.

Figure 2.41. Soft story collapse of a two-story reinforced concrete building at the port of Kandla. Photo courtesy of Charles Menun.

Figure 2.42. Damage to a warehouse at the port of Kandla due to short column effects. Photo courtesy of Svetlana Uranova.

Figure 2.43. Partial collapse of roof of A-frame storage facility. Photo courtesy of Svetlana Uranova.

Figure 2.44. Government-designed elevated water tank near Gandhidham. No apparent damage. Photo courtesy of Charles Menun.

Figure 2.45. Damage to RC highway bridge under construction approximately 35 km east of the USGS epicenter. Photo courtesy of Charles Menun.

Figure 2.46. Damage to RC highway bridge under construction approximately 35 km east of the USGS epicenter. Photo courtesy of Charles Menun.

Figure 2.47. Damage to reinforced concrete highway bridge under construction approximately 35 km east of the USGS epicenter. Photo courtesy of Charles Menun.

Figures for Section 3: Disaster Management Issues

Photographs in this section were provided by Louise Comfort

Figure 3.1. Telephone exchange, Bhachau, February 28, 2001.

Figure 3.2. K. Srinivas (3rd from left), District Collector, Ahmedabad, with local officials in a meeting with the Team, Ahmedabad, March 3, 2001, 7:30 p.m.

Figure 3.3. Destruction outside the Communications Center for Kachchh District, Gandhidham, March 2, 2001. Tower remained standing.

Figure 3.4. Amod Dixit explains seismic mitigation strategies in Kathmandu to G.M. Patel and S.V. Tari at the Anjar Telephone Exchange, March 1, 2001.

Figure 3.5. Telephone Exchange, Anjar, March 1, 2001.

Figure 3.6. Telecommunications tower, Gandhidham, March 2, 2001.

Figure 3.7. Electrical transmission station in Limdi, February 27, 2001.

Figure 3.8. Democracy in action, Ahmedabad, February 26, 2001.

Figure 3.9 Directions to Shikhar Complex in Ahmedabad, now in rubble, February 26, 2001.

Figure 3.10. Two women discussing housing problems in Ahmedabad, February 26, 2001.

Figure 3.11. Receiving satellite, apartment house, Ahmedabad, February 26, 2001.

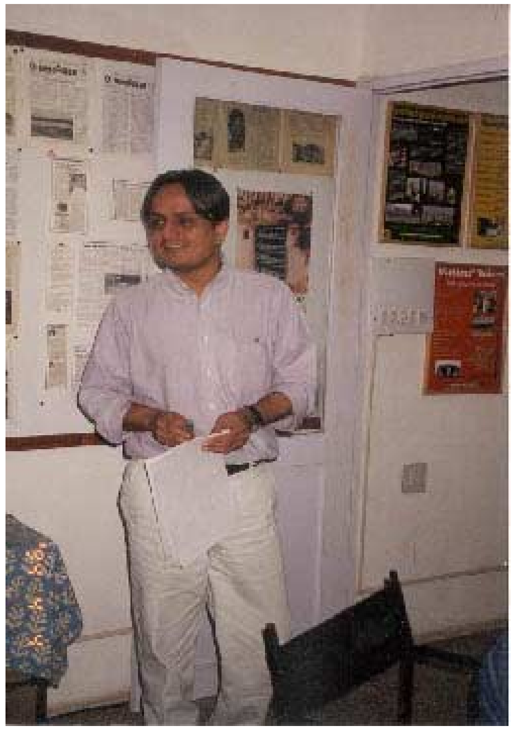

Figure 3.12. Mihir Bhatt, Director, Disaster Mitigation Institute, Ahmedabad, February 26, 2001.

Figure 3.13. Signals of technical change in Anjar, March 1, 2001.

Figures for Section 4: Social Issues

Photographs in this section were provided by Rohit Jigyasu.

Figure 4.1. Women employed in demolition work, Ahmedabad.

Figure 4.2. Families posing at Navlakhi.

Figure 4.3. Typical housing constructed of tin plates, Navlakhi.

Figure 4.4. A low-rise residential structure of wooden construction, Limbdi.

Figure 4.5. Spiritual / motivational writings on a wall in Bhuj.

Figure 4.6. Temporary tent shelters provided by the Indian Army, Anjar.

Figure 4.7. Rubble still exists one month after the earthquake, Morbi.

Figure 4.8. Temporary non-engineered shoring of a damaged residence, Morbi.

Figure 4.9. A damaged but still standing house of wooden construction, Anjar.

APPENDIX A-1

Individual Profiles of Team Members

Individual Profiles of Team Members

From Left to Right (Standing): Timothy Mutebile, Weimin Dong, Swaroop Reddy, Vikas Wadhera, Ahmad Naderzadeh, Amod Dixit, Mr. Seva, Charles Menun, Violeta Seva, Ravi Mistry, Teddy Boen, Svetlana Uranova, Michael Baur, Maureen Fordham, Tetsu Masuda, Louise Comfort, Laura Dwelley Samant, Rohit Jigyasu, Mohd Rosaidi, Mehedi Ansary, Naresh Raheja. **Sitting:** Badru Kiggundu.

Ahmad Naderzadeh has been active in the field of earthquake engineering and engineering seismology since 1984. He served as the Head of the Earthquake Engineering Department of the Building and Housing Research Center (BHRC) and was responsible for the Iranian strong motion accelerogragh network for about ten years. In that position, besides carrying out research projects, he was also responsible for the data processing of the recorded accelerograms. He also served as the Deputy for the Building Research at BHRC in 1993. He was one of the founders of the Center for Earthquake and Environmental Studies of Tehran (CEST) in 1994 where he has served as the Head of the Center since its establishment. His most recent activity at CEST was to carry out the Study on Seismic Microzoning of the Greater Tehran Area with the cooperation of Japan International Cooperation Agency (JICA). Ahmad has observed almost all damaging earthquakes occurred in Iran and several world earthquakes since 1985 and has published several reconnaissance/technical reports on the most damaging events. He has carried out/supervised many research projects. Some of them include: Experimental and analytical determination of dynamic properties of existing structures and sites by conducting ambient vibration and microtremor measurements; vulnerability assessment, damage estimation, and strengthening of existing buildings and bridges; and the attenuation law of Iranian plateau using strong motion records. Some other activities include: Taking part in preparation of the new Iranian Code for Seismic Resistant Design of Buildings (Standard 2800), and the Iranian seismic hazard map; seismic hazard assessment; design and supervision of several building structures, some relevant consulting works including site selection of important structures and causes of collapse of structures during earthquakes.

Ahmad has been an active member of several local and international technical committees and associations since 1985. He has also served as the Iranian delegate to International Association for Earthquake Engineering (IAEE) and European Association for Earthquake Engineering (EAEE). He was a member of EERI, ASCE, and SEAONC.

He received his BS degree (1981) and MS degree (1983) both in Civil Engineering (Structures) from San Jose State University (SJSU), California, USA. Later in 1988 he continued his postgraduate studies at the International Institute of Seismology and Earthquake Engineering (IISEE) in Tsukuba, Japan. He is the author or co-author of over fifty technical papers and reports.

Badru M. Kiggundu has over 31 years of engineering experience in areas of academic and research in geotechnical and pavements materials. Badru has management experience of research programs at Auburn University (USA), New Mexico Engineering Research Institute, academic departments and whole faculty of Technology at Makerere University. Badru has been a manager of construction operations in National Housing and Construction Corporation (Uganda).

While studying in the USA, Badru earned membership to Chi Epsilon fraternity (Civil Engineers honorary), Sigma Tau fraternity (an all-engineers honorary) and Kappa Mu Epsilon fraternity (an all-Mathematics Honorary). Badru also earned certificates of championships in soccer both at the University of New Mexico and in the Western Athletic Conference. Lastly, Badru earned Fullbright scholarships throughout undergraduate and postgraduate studies.

Badru has authored and presented more than 30 publications, at numerous International and National conferences. Badru has served as President of Uganda

Institution of Professional Engineers (1997-98), and Vice Chairman of Engineers Registration Board of Uganda (1998-2000). Currently he is the First Chairman of the Uganda Seismic Safety Association (USSA), a brainchild of a resolution taken at the end of the 8th Kampala WSSI HLM in December 1997.

As Dean of Faculty of Technology in Makerere University, Badru has been a very active promoter of awareness for earthquake-induced disasters in Uganda (the most seismically active nation on the continent of Africa) in general, and in Kampala in particular.

Chuck Menun is a professor of structural engineering at Stanford University. He joined the Stanford faculty in September, 1999. His research focuses on the development of probabilistic methods for safety and reliability assessment in structural engineering. Of particular interest are applications of the theory of random vibrations and structural reliability to the design and analysis of structures subjected to seismic loads.

Currently, Chuck and his students are pursuing several lines of earthquake engineering research. One project is focused on the development of procedures for predicting critical seismic response combinations in linear and nonlinear structural systems. The results of this effort will provide guidelines for the design of structural elements resisting multiple simultaneous seismic responses. A second research effort concerns the development and calibration of probabilistic models of near-fault ground motions. The objective of this research is to develop simple and robust models that adequately capture those characteristics of near-fault ground motions that most influence the nonlinear response of conventional structures. A third research project focuses on the preparation of fragility curve guidelines for structural engineers to use in the seismic reliability assessment of existing buildings.

Before joining the Stanford faculty, Chuck spent six years with Jones Kwong Kishi Consulting Engineers in Vancouver, British Columbia, Canada. There he worked as a structural engineer specializing in the design of residential and commercial high-rise buildings.

Haresh Shah is the Obayashi Professor of Engineering, Emeritus and former Chairman of the Civil Engineering Department at Stanford University. He is currently the Chairman of the Board of the World Seismic Safety Initiative (WSSI), which is an undertaking of the International Association of Earthquake Engineering (IAEE).

Haresh's current research interest is in the field of catastrophe risk assessment and management. His most recent work with his students in this field has resulted in the development of the Earthquake Disaster Risk Index (EDRI) for various megacities of the world. They have also developed tools for evaluating the efficacy of strategies to mitigate and manage earthquake losses.

Haresh is the founding member of the Board of Directors of Risk Management Solutions, Inc. (RMS, Inc.) This corporation is a leader in developing software and providing consulting services for managing risk due to natural hazards. He is also Chairman of the Board of Stanford Management Group, Inc. (SMG).

Haresh strategized and initiated this trip, and participated at the post-reconnaissance meeting in Noida, India.

Louise K. Comfort is a Professor of Public and International Affairs at the University of Pittsburgh. Her research focuses on the design and development of sociotechnical systems, which use information technology to provide decision support to practicing agencies. She has done field research on organizational response and information processes in disaster operations following earthquakes in Mexico City, 1985; San Salvador, 1986; Ecuador, 1987; Whittier Narrows, California, 1987; Armenia, 1988; Loma Prieta, California,1989; Costa Rica, 1991; Erzincan, Turkey, 1992; Killari, Maharashtra State, India, 1993; Northridge, California, 1994; Hanshin, Japan, 1995, Izmit, Turkey, 1999 and ChiChi, Taiwan, 1999. Her degrees are in political science from Macalester College (B.A.); University of California, Berkeley (M.A.), and Yale University (Ph.D.). Her most recent book is *Shared Risk: Complex Systems in Seismic Response.* 1999. Oxford and New York: Pergamon Press.

Maureen Fordham, Ph.D., is a Senior Lecturer at Anglia Polytechnic University, Cambridge, UK. She has been researching in the broad field of hazards and disasters since 1988. Her work has made a major focus on floods, and on vulnerability in particular. It has examined definitions of vulnerability, gender analyses and socially-inclusive disaster management. She has also researched environmentally-sensitive engineering for flood management. She has many years of project management experience including the supervision of administrative and research staff, liaison with government and other agencies, consultants and clients. She is a consultant to government agencies in the UK and holds several honorary professional posts in the academic disciplines of Sociology and Geography. She was a co-founder and is co-editor of a new website – Radix: Radical Interpretations of Disaster – and manages several others which also have the international dissemination of disaster research as their objective.

Maureen joined the WSSI/EMI team to learn more about the earthquake hazard and, in particular, to examine the gender dimensions and opportunities for participatory decision making in major disasters.

Mehedi Ahmed Ansary has over 10 years of teaching and consulting experience in civil engineering. His main research interest is in engineering seismology, strong ground motion and ground liquefaction. Presently, he is involved in the estimation of seismic risk of Bangladesh. Mehedi has authored 70+ technical reports and publications. He received his B.Sc. and M.Sc. in Civil Engineering from Bangladesh University of Engineering and Technology (BUET), Bangladesh, and Ph.D. from University of Tokyo.

Mehedi joined the WSSI/EMI team to learn from reconnaissance of the earthquake-stricken areas.

Michael Baur is a structural engineer working at the University of Karlsruhe, Germany. He possesses a master's degree in structural engineering from University of Metz, France. For the past five years, he is working at the Institute for Reinforced Concrete Structures and Building Materials, University of Karlsruhe, where he has actually submitted his doctoral thesis titled: "Seismic Isolation of Buildings, Taking into Account Non-Linear Site Effects". He also has a working experience for 3 years in a consulting engineers office, before starting his academic career. His research and work profile includes structural dynamics and earthquake engineering, with the main focus on: Seismic Isolation and Non-Linear Site Effects; Retrofitting of Vulnerable and Pre-Damaged Buildings; and Disaster Management – Models and Simulation.

His research activities are integrated in the Collaborative Research Center (CRC) 461 'Strong Earthquakes: A Challenge for Geosciences and Civil Engineering' at Karlsruhe University. He has published seven technical papers on International Conferences.

Beside his academic work, Michael is represented in the German EC8-Committee for Standardization and the German Task Force Committee for Earthquakes. He also was a member of the German Task Force Reconnaissance Team for the Kocaeli Earthquake, Turkey, 1999.

Michael joined the WSSI/EMI team with the objective of studying damage patterns and retrofitting work and to learn from the vast experience of the senior experts in the team.

Naresh Raheja has over 10 years of multidisciplinary civil engineering and catastrophic risk management project execution and management experience. His responsibilities have included supervision of engineering, software and marketing staff, project management, and relationship building with the offices in USA, UK, and Japan, to learn modeling, technology and business issues from them. Starting in 1988, he worked for two public sector companies in India. There, he has worked on building and special foundation design and construction of a major power plant for the Delhi region, and on water resources projects in many states of India, using state-of-the-art software tools. In 1995, Naresh reengineered his career from the traditional civil engineering field to the catastrophic risk management for insurance industry and the governmental sector, when he joined RMSI, the Indian subsidiary of the RMS, California. Naresh has been responsible for the inception, growth and development of the risk management area at RMSI, and has executed and managed a wide variety of IT-based analytical services, implementation, modeling, and software tool development projects. He has worked on many projects related with natural perils like earthquakes, wind hazards (including tornado and hail), floods, and other areas (fire following earthquake and network business interruption, etc.). The work involves communicating and working together with the teams in India, USA, London, and Japan. He and his team have also worked with Indian governmental agencies on some GIS-based disaster management projects. He has made technical presentations in many conferences and seminars, in India and abroad. He holds a B. Tech degree in Civil Engineering from Indian Institute of Technology, New Delhi (IIT Delhi), and a Masters degree in Civil Engineering from Delhi University. He has also completed MBA program with emphasis in Technology Management, Strategic Management, and Information Technology from IIT Delhi.

Naresh joined the WSSI/EMI team to learn from reconnaissance of the earthquake-stricken areas, with focus on technical and disaster management aspects.

Ravi Mistry has over 25 years of engineering project management, marketing, and operations experience. His management responsibilities have included supervision of technical and administrative staff, liaison with interdisciplinary departments, consultants and clients, budgeting, and scheduling. He has made technical presentations to clients and licensing authorities. He has performed finite element analysis of nuclear and traditional power, industrial, commercial, and research facilities using state-of-the-art software and hardware. He has authored 30+ technical reports and publications. He worked for Engineering Decision Analysis Company, John A. Blume & Engineers, and NASA. In late 1990s, Ravi reengineered his career from the traditional engineering world to the hi-tech industry of Silicon Valley, California. He has written business plan summaries for hi-tech startups. Ravi was an advisor to Axial Systems, an Internet startup in construction industry, and Catheter Effects, a medical products start-up in Sacramento. Recently, Ravi joined Karna Global Technologies, a Silicon Valley-headquartered IT consulting company with offices in India, to manage its international financial operations. He is Gold Medallist from Gujarat University, India, with a BE in Engineering and holds a Masters degree in Structural Engineering from Stanford University. He has attended MBA program with emphasis in Marketing & Finance at California State University, Hayward, USA.

Ravi joined the WSSI/EMI team to learn from reconnaissance of the earthquake-stricken areas and develop a blue print to rebuild a model village.

Rohit Jigyasu is an architect, planner and a conservation consultant from India. At present, he is undertaking his doctoral studies at Norwegian University of Science and Technology in Trondheim. His research area is 'Holistic eco-developmental framework for building local Skills and Capacity and reducing vulnerability of traditional rural settlements in South Asia'. Before starting his doctoral studies in 1999, he initially worked as a Research Associate in School of Planning and Architecture, New Delhi, and then on several architectural conservation projects, teaching and research assignments.

Rohit graduated from Chandigarh College of Architecture, India in 1994 followed by his post graduation with specialization in Architectural Conservation in 1996 from School of Planning and Architecture, New Delhi for which he was awarded gold medal. He has also been a NORAD fellow in Intensive Continuing Education Course in 'Urban Ecological Planning' and has participated in International Course in Wood Conservation Technology in 2000 under the auspices of UNESCO. He has presented several papers in national and international conferences and seminars. Some of his papers are published.

Tetsu Masuda is a seismologist working with Oyo Corporation, Japan, a geotechnical consulting company. His seismological career began with theoretical work concerning the crack propagation under given stress conditions when he was a graduate student at Tohoku University in Sendai city, Japan from 1973 to 1977. With his dynamic model of seismic source, he made his own observation of earthquakes near the hypocenters and analyzed source processes of small earthquakes, to find that there is a different scaling relationship between source parameters for small earthquakes from those for large earthquakes. His work of seismic sources continued after he became an assistant professor of Tohoku University in 1977. He was mainly interested in developing methods to resolve the seismic source and inelastic attenuation effect from observed spectrum of seismic waves. For this contribution he was given the degree of Ph.D. by Tohoku University in 1982. In 1982 to 1984, he worked with the Department of Terrestrial Magnetism, Carnegie Institution of Washington, Washington DC, to study the rupture characteristics of large earthquakes by applying the second central moment theory, which uniquely detects the rupture mode of the earthquake faulting. In late 1980s, he started to establish a scaling relationship of source parameters of earthquakes for a wide range of magnitudes from micro-earthquakes to large earthquakes. He also was a member of Research Group for Explosion Seismology to study the velocity structure of earth's crust, and he was also interested in statistical studies of earthquake occurrences.

In 1991, he joined Oyo Corporation, where he was involved in geophysical exploration works, ground water problems, slope stability problems. For his work of slope stability prediction, he was awarded a prize from the Japanese Geotechnical Society in 1994. After the Kobe earthquake in 1995, he was involved in projects of strong motion observation networks of Ministry of Construction, Japan, and helped to establish four networks by installing more than 400 strong motion accelerometers in Tohoku, Kanto, Hokuriku, and Kinki Bureaus. In 2000, he was involved in the WSSI project of Myanmar Strong Motion Observation Network.

Tetsu joined the WSSI/EMI team to learn what can be done for the mitigation.

Timothy Sabiiti-Mutebile is an Architect working with Uganda Peoples Defence Forces and the Ministry of Defence at their Headquarters. Timothy has been working as Chief Technical Adviser to the National Army and Ministry of Defence in areas of building construction and housing for the last 15 years. His work profile includes budgeting, project planning, project design and documentation, supervision of Military Engineering and Building Contractors' operations in the building construction field, supervision and coordination of Building Engineering Consultants hired by the Ministry of Defence, advising the Ministry of Defence and the Commander-in-Chief (C.I.C) of the National Defence Forces on Building Construction and Housing Policy issues.

Prior to working with Ministry of Defence, Timothy worked as a Consultant with private firms of Architects and Engineering Consultants. Between 1978 and 1982 Timothy worked on Construction Sites in Kazakstan Republic and in the Russian Arctic Region of Siberia at the Natural Gas Field in Urengoi, where they were constructing pile foundations and buildings to support operations of Siberia - Western Europe Gas-Pipeline.

Timothy holds a Master of Science Degree in Architecture from Kiev Institute of Civil Engineering. He has just been promoted to a rank of Major in the National Army, elected to serve on the statutory National Council of Sciences and Technology for the 3rd four year term on the Physical Sciences Committee. He was elected Vice President of the Architects Institute of Uganda and has recently submitted a National Defence Housing Policy Proposal which includes Earthquake Management and Disaster Mitigation Consideration for Ministry of Defence buildings in earthquake-prone areas of Uganda. For the first time, the Ministry of Defence Budget has provided a separate vote for expenditure on Disaster Management issues.

Timothy joined the WSSI/EMI team with the objective of studying the types of buildings that were damaged, their designs, building materials used and conditions under which they were built, types and causes of damages, to look for solutions to prevent or minimize such damages on future buildings, and also to learn from the past experience of members of WSSI.

Svetlana K. Uranova is head of Laboratory "Seismic Risk", Kyrgyz-Russia Slavic University(KRSU), Doctor in earthquake engineering since 1987 (Moscow, Central Research Institute of Construction). Uranova S. has over 25 years of experience in design and scientific work in the field of earthquake engineering. From 1976 to 1981, she worked as design engineer. Since 1981 worked in Kyrgyz Construction Research and Design Institute and was Head of Department. Area of activity is estimate of earthquake resistant of existing buildings, engineering observation of existent buildings, analysis of earthquake consequences, seismic risk estimation and reduction actions, development of building norms, standards and codes, theoretical investigations, experimental testing and elaboration of the seismo-resistant structures and systems. Uranova S. has 44 publications on the theory and experimental testing. Uranova S is Member of Engineer Academy of Kyrghyz Republic, and Member of Earthquake Engineering Research Institute, Participant of EERI/IAEE Housing Encyclopedia Project and other international projects. Uranova S. has constant collaboration with scientists from different countries.

Vikas Wadhera is a structural engineer working with RMSI, Noida, India, a subsidiary of Risk Management Solutions Inc., California. At RMSI, Vikas has been working in the area of catastrophic risk management for the past 3 years. His work profile includes model development, model calibration & validation, and model implementation for catastrophes such as earthquakes, hurricanes, and tornado/hail. Some of his key projects include earthquake modeling for US, Taiwan and Turkey. He possesses a civil engineering degree from Punjab Engineering College, Chandigarh, India and a master's degree in structural engineering from Delhi College of Engineering, Delhi. His master's degree thesis work involved experimental testing to study the behavior of different types of concrete walls against blast loads. Based on this research, performed at the Defense Research & Development Organization (DRDO), Chandigarh, he has published two technical papers at the International Conference on Experimental Mechanics held by the Society for Experimental Mechanics, Connecticut, US.

Vikas joined the WSSI/EMI team with the objective of studying intensity & damage patterns and to learn from the vast experience of the senior experts in the team.

Weimin Dong is the Chief Risk Officer for Risk Management Solutions, Inc. (RMS), California, USA, a firm dedicated to the transfer of earthquake-related technology from research to the consumer, and to further technology development.

Weimin has over 30 years of industrial, teaching, and research experience and has specialized in seismic hazard evaluation and risk assessment. His research interests include seismic design of buildings, structural responsibility, and the application of neural networks, pattern recognition, artificial intelligence techniques to earthquake hazard mitigation and risk assessment. He has worked extensively with the insurance and investment industries, structural engineering firms, the State of California, and local and city government bodies in the transfer of earthquake technology. He has also participated in many joint venture projects (US-China, US-Japan) to share knowledge in hazard mitigation with other countries with similar concerns. He also served as one of the principal investigators for Earthquake Loss Estimation Methodology (HAZUS 97), funded by the Federal Emergency Management Agency (FEMA). During his career, Dr.

Dong has published over 100 papers and technical reports. Weimin received his Ph.D. from Stanford University.

APPENDIX A-2

Sponsoring Organizations

Sponsoring Organizations

Anglia Polytechnic University, United Kingdom

Bangladesh University, Bangladesh

Earthquakes and Megacities Initiative (EMI)

Deutsche Forschungsgemeinschaft, University of Karlsruhe, &

State of Baden- Württemberg, Germany

Geohazards International, USA

Graduate School of Public and International Affairs, University of Pittsburgh

John A. Blume Earthquake Engineering Center, Stanford University, USA

Kyrgyz-Russian Slavic University, Kyrgyz Republic

Makerere University, Uganda

Malaysian Meteorological Service, Malaysia

Ministry of Defence, The Republic of Uganda

Natural Hazards Center, University of Colorado, Boulder, CO

National Science Foundation, USA

National Society for Earthquake Technology, Nepal

Norwegian University of Science and Technology, &

Trondheim & Norwegian Council for Universities, Norway

Oyo Corporation, Japan

Ravi Mistry, USA

RMS, USA

RMSI, India

Swaroop Reddy, India

World Seismic Safety Initiative (WSSI)

APPENDIX A-3

Notes on Meetings with District Collectors and Other Individuals

Appendix A-3.1

Meeting with Mr. Mukesh Shah, NRG Foundation

Date: February 26, 2001
Venue: NRG Bhavan, Ahmedabad

From Left to Right (against the facing wall): Mohd Rosaidi, Mukesh Shah (NRG), Bhupendra Shah (APCO), Ashish Desai (Civil Engineer, Ahmedabad), Badru Kiggungu

The meeting was held to brief the WSSI/EMI team of the latest developments on the Bhuj earthquake. Mr. Mukesh Shah, who is a member of Gujarat Planning Commission, was instrumental in providing full support during the entire trip, including making arrangements to meet with collectors of various districts. Following are the salient points of the meeting:

- 450 villages (population 500 –5,000) suffered more than 70% damage.
- Numerous NGOs and MNOs, including CII and FICCI have come forward to adopt villages for rebuilding.
- Estimated cost of rebuilding is about Rs. 4 crores (US$800,000).
- Rebuilding of villages to be undertaken by NGOs.
- Financing for these villages – 50% by government; 50% to be borne by NGOs (money coming from NRIs)
- Design Options:
  - RCC, brick, block masonry using local material
  - Four types of housing with about 150 sq. m. land
    - Below poverty group – 30 sq. m. construction
    - Landless laborers group – 40 sq. m. construction
    - Trade professionals / middle income group – 50 sq. m. construction
    - Land owners group – 60 sq. m. construction
- Anjar, Bhachau, Bhuj, Gandhidham, and Rapar will be rebuilt by government at a cost of Rs. 6,000 crores (US$1.2 billion)
- Separate budgets will be available for communications, infrastructure, irrigation, etc.
- $1,500 million World Bank loan may be available at a low interest.
- Rs. 1,000 crores (US$200 million) to be spent in 3 months for temporary rehabilitation (one pakka room) of 7,000 villages.
- In Ahmedabad:
  - about 800 people dead and 100 buildings collapsed.
  - Damage resulted from improper design / construction and poor material management.
  - Liquefaction in Maninagar and Vastrapur areas.
  - Ham radios were used for the first 2-3 days.
  - Rescue operations were conducted by people with bare hands as machinery could not be mobilized for the first 2-3 days.
- Central (federal government) has established Disaster Management Authority reported directly to the Prime Minister.
- Gujarat State Government has established Relief Operations Management to help NGOs and people.

Prof. Gautam Gandhi, Chair of Civil Engineering Department, DD Institute of Technology, Nadiad, Gujarat, participated in the post-earthquake investigations of damaged structures. Following is the summary of his presentation:

- Inspections required by AUDA – Ahmedabad Urban Development Authority and performed under the supervision of CEPT – Center for Environmental Planning and Technology.
- Damage divided in three categories –
  - G1 – minor damage, people could move in right away.
  - G2 – damage to partition walls, could move in with repairs conducted.
  - G3 – Severe damage, need retrofits before move in can be permitted.
  - G4 – Collapse.
- He visited about 90 buildings – 50% fell under G1, 20% fell under G2 and 30% fell under G3.
- Overall, per CEPT, 18,000 buildings fall under G3 category.

Appendix A-3.2

Meeting with Mr. Mihir Bhatt, Disaster Mitigation Institute, Ahmedabad

Date: February 26, 2001

Venue: Disaster Mitigation Institute, Ahmedabad

From Left to Right: Mehedi Ansary, Mihir Bhatt (Director, Disaster Mitigation Institute), Badru Kiggundu, Swaroop Reddy

- DMI is an advocacy organization that aims to change policy and make tangible change in communities " Crossroads of research, policy and practice"
- Positioned as link between government & community. Good links with government at many levels, NGOs, Indian and International Companies
- Funding from government (State and National), local and international NGOs

- Programs focus on food security, water security, work security and shelter security. Work on many different types of disasters. But earthquake of this magnitude is first time
- Modes of work are training programs and policy advocacy, link mitigation and development. Communication through monthly newsletters and web.
- In Gujarat earthquake, DMI had some involvement in relief process, although it is not their defined area.
- Now DMI is working to influence government rehabilitation packages to incorporate lessons of past disasters
- DMI is developing programs for rehabilitation of livelihoods since this seems to be filling the gaps in the government programs
- Tries to direct international aid in most productive ways
- Works with international volunteers
- Receives interns from Indian and foreign students
- Uses current technologies to communicate with national, international agencies
- Used satellite phone in the recent operation

Appendix A-3.3

Meeting with Mr. H. B. Varia, Collector, Surendranagar District

Date: February 27, 2001
Venue: District Collectorate Office, Surendranagar

- Population: 1.4 million, 50% are affected
- Housing units: over 0.4 million
  - 30,000 fully collapsed
  - 300,000- 400,000 partially collapsed
  - Some houses partially damaged
- Death: 113, Injured: 2,000
- Rural area most affected
- Major damage in 3 of the 10 talukas of Surendranagar district
- Schools: 4,000 school rooms; 2,000 rooms completely damaged, 1,300 rooms partially damaged
- Hospitals: 28 Primary Health Complexes; 7 totally damaged, 13 partially damaged
- Tents used temporarily for hospitals and schools
- Water supply system not at all affected
- No casualties reported in hospitals
- 35 voluntary organizations are working in the district
- 4-6 months to rebuild the damaged houses
- Reasons for structural damage:
  - Most non-engineered buildings are made of uneven heavy stones; mortars are made of mud and cow dung
  - The foundation of adobe houses may have been weakened due to previous year's floods
- Communication between district and state officials by telephone, cell phones, police VHF radios, and satellite phones
- Government announced four packages for disaster-affected people

- For relocation / reconstruction of houses:
    - 50% cost will be borne by government of Gujarat
    - 50% will be borne by NGO
    - Rs 15,000-Rs 19,000 per family (@$300 - $400)
    - Rebuilding cost due to minor damages Rs 35,000- Rs 50,000 (@ $700 to $1,000)
    - Reconstruction cost – Rs. 150,000 (@$3,000)

Appendix A-3.4

Meeting with Mr. P. N. Patel, Collector, Rajkot District

Date: February 27, 2001
Venue: District Collectorate Office, Rajkot

Facing: P. N. Patel (Collector, Rajkot District)

Damage Statistics:

Four northern talukas, namely Maliya, Morbi, Tukank, and Vankaver, are seriously affected. They lie close to the earthquake source zone. Other talukas lying in the west and south of Rajkot, namely Pardhavi, Upleta and Lodhika are relatively less affected, although there were instances of heavy damage to buildings in some villages. In the rest of the talukas, earthquake damage was conspicuous only in private properties.

Water Supply System:

No appreciable effect except, due to lack of electricity for a few days, the pumps were non-operational. The exception is Maliya taluka where the water supply system was totally destroyed.

Electricity System:

System affected, but restored in a few days.

Communication:

There was a problem of failure for the first four days. Satellite phone was not used.

Only the Police wireless system worked.

- Could report to Central Control Room (Gandhinagar)
- Getting back communication from outside (including Central Control Room) was difficult

Disaster Management Plan:

- Cyclone and drought are frequent, so have District Level Disaster Management Plan
- Cyclone and drought emphasized
- After the tremors in Bhavnagar, State Secretary instructed all District Collectors to consider Earthquake Issues in the Disaster Management plan
- Provided Satellite phones to each district
- But the phone didn't work during the Earthquake
- Plan was prepared with the participation of the district level authorities of all line agencies including Army, Police and some NGOs
- Villagers / people were not involved in the planning process
- Suggestion of people / villagers are not always useful as they may be not practical
- They do not know the available response capabilities, and hence will not be relevant to the plan

- Not much consideration given to earthquake in the plan.
- Nobody anticipated such large magnitude earthquake
- Nobody thought that assistance from outside the District or State would be necessary
- The plan was discussed at Panchayat level after preparation
- NGOs were consulted and given responsibilities in the plan (based on interest, areas of expertise)
- It is an open document, can be provided to anybody

Rehabilitation and Reconstruction:

- Talked about financial aid packages offered by the government
- First priority is on totally destroyed villages
- 3 crores rupees (US$ 625,000) per village of 200 families plus social infrastructure and utilities such as school, medical center, cultural center etc.
- Talked about opening of the possibility of Social orgs/NGO adopting the village reconstruction
- 400 engineers are mobilized to guide/assist villagers to repair and reconstruct their houses before the next monsoon rains
- Government will provide plans of earthquake-resistant buildings that would be used by all including NGOs.
- NGOs adopting the villages can bring in their engineers to prepare appropriate lay out and design of earthquake-resistant buildings
- Apparent reliance on the scientific and technical assessment survey by 400 engineers
- Will lead to classification of areas for "packages"
- Retrofitting: will be done step by step. (I wonder if the question was fully understood)
- DDO referred to the Bhunga–style buildings along the coast line: circular, without heavy roof, using indigenous materials and technologies; they are cyclone–resistant and earthquake–resistant. No life lost in such buildings. In 1956 also no Bhunga was destroyed.

Policy Changes following the Disaster:

- State level Disaster Management Committee formed. That will bring in the required technology for stronger building construction
- Building EQ-resistant buildings will become mandatory. There would not have been such disaster if only the building were constructed with earthquake-resistant technology. It was only the non-engineered buildings that were damaged.
- IAS Officers deputed as Additional Collectors with full power in the worst affected talukas
- The Collectors have engineers working for him who shall be used to inspect construction works
- Line agencies are also working at his direction (under the new Collectors at the worst affected talukas)
- State level Disaster Management Committee formed. That will bring in the required technology for stronger building construction

Conclusions:

- Both the Collector and District Development Officer were up-to-date with data although they are only recently transferred to the district. Their knowledge on the details on damage, geography, and their desire to affect normalcy is appreciable.
- The damage estimation methods seem to be simplified! What is the quality of damage assessment data? Who did it?
- Is there any standard format for damage assessment for rescue / relief purpose?
- There was no reference to community, and their role in rehab / reconstruction planning
- Top–down approach only, bottom–up approach not considered.
- The approach is still reactive (fire-fighting). “Mitigation” was not a common word during the conversation.
- The need to impart training to the officials is conspicuous! It should be done to better prepare them for an effective rehab / reconstruction with integration of mitigation in the process.
- Disaster Management plan did not work at least in the communication are: satellite phone did not work! The Plan was supposed to make sure that it works during disaster!

Appendix A-3.5

Meeting with Mr. Anil Mukhim, Collector, Bhuj District

Date: March 1, 2001
Venue: Temporary Tent Office, District Collectorate, Bhuj

From Left to Right: Anil Mukhim (Collector, Bhuj District), Violeta Seva, Swaroop Reddy (standing), Naresh Raheja, Amod Dixit, Badru Kiggundu

General:

- The earthquake of magnitude 7.4 struck Kachchh district on January 26, 2001 at 8:46 AM. The total numbers of persons affected is 277,000 with 5,000 dead and 85,000 injured.

- Out of 10 talukas in the district of Kachchh, there was more than 70% damage in 5 Talukas and rest had less than 70% damage.
- Out of 890 villages, 179 were completely damaged while 140 villages suffered more than 70% damage.
- 25,000 new buildings were completely destroyed while 15,427 were partly damaged. 17,000 old structures were totally damaged whereas 8,342 were partly damaged.
- A survey by a team of 500 engineers duly trained by Dr. A.S. Arya is currently being undertaken for a 10-day period to ascertain which buildings shall be given a final certificate of livability.

Rescue and Relief Operations:

- The collector acting as focal person of the emergency response operations coordinated the efforts of the army, police, NGOs involved in rescue efforts undertaken for 2 weeks.
- They were able to retrieve 18,300 bodies.
- Thereafter, efforts were shifted to clearing the roads, demolition of structures deemed dangerous to the community.
- 18,000-strong government staff could not be used to their strength as they themselves were affected. 200 government personnel died in the earthquake.

Water Supply:

- There was disruption to the water supply after the earthquake but the same was restored in next 4 days.
- Out of 144 villages, 123 got the water supply through their regular supply lines, 18 through tankers and the remaining 3 through other sources.

Electricity:

- The electric supply was disrupted and was restored only after 7 days.

Communication:

- Satellite phones were in place within 48 hours. The communication was restored on 3rd day.
- Out of 85000 individual phone connections, 70000 were non-functioning.

- The police wireless i.e. communication system of police and ham radios were very useful during rescue operations.

Transportation:

- Most of the roads are intact and there is no major damage to the roads and bridges.

Hospitals/Medical Facilities:

- The injured were immediately treated in 18 hospitals and most of them were discharged after necessary primary aid.
- Some hospitals were damaged but the operations were restored within one day only.
- There are no reports of epidemic.
- The Red Cross, NGOs, government medical doctors and medical staff provided the much-needed medical assistance.

Schools:

- 90% of the public schools got damaged whereas the 90% of the government schools suffered only minor damage.

Food:

- The grain is being distributed through 500 public shops.

Shelters:

- Emergency shelter was provided in 473 relief camps. Intermediate shelter will have to be constructed within a year.
- For permanent housing and relocation of people is an issue, which has not, been clearly defined. In rural areas, there will probably be no restriction but in urban areas an authorization will be have to be undertaken for construction.

Issues/Problems Identified By the Collector:

- The Disaster Management plan that addresses floods, cyclones, earthquakes and drought was not adequate to meet the magnitude of the event.

- System of inspection of approved plans by qualified engineers.
- Prior to the disaster, public awareness for preparedness in case of an earthquake was not high due to the unpredictability and long gap of earthquake incidents.
- There should be a long and medium term emergency response plan.

Conclusion:

- Total loss was of the order of Rs. 500 crores.
- Collaborating with NGOs and UNDP for relief and reconstruction work.
- Issue of relocation was yet to be discussed.
- Overall role of media was to keep the government on its toes and to generate awareness.
- Penal action against the builders, whose building failed is being taken up.

Appendix A-3.6

Meeting with Mr. K. Srinivas, Collector, Ahmedabad District

Date: March 3, 2001
Venue: NRG Bhavan, Ahmedabad

From Left to Right (facing) : Bhupendra Shah (APCO), Mukesh Shah (NRG), K. Srinivas (Collector, Ahmedabad District), Somnath Khetkar (RSS), Gautam Patel (RSS)

General and Social Issues:

- During earthquakes, rich people are mainly affected: but during floods, poor people are hit
- High rises with soft ground floor mostly hit

- 750 people died and 136 rescued. Within first 3 days, all the dead bodies were taken out
- No one was aware of the damage caused by the EQ as electricity, water-supply and other lifelines were OK and all social activities continued uninterrupted.
- After the damage assessment (88 buildings collapsed) the people of Ahmedabad couldn't sleep for the next three weeks. So 123 shelters were opened by the Collectorate for the city people to sleep at night. Still 30 such shelters are open.
- Gujarati community acted nicely
- People will always try to use substandard material

Engineering Issues:

- CEPT categorized the damages of building in 4 categories and started to certify the buildings from 30th January 2001. So far 60,000 houses were certified.
- False alarm by local astrologer kept Collector's office busy
- Partially damaged houses at 484 villages were found
- For reconstruction of village houses the maximum loan provided by the government is 20% of the total cost. The process was started on 01/03/01
- So far assistance has been provided to 205 houses out of 1,250 houses
- For reconstruction of high rises a maximum loan of Rs. 8,00,000 will be provided
- Government will provide training to structural engineers to supervise construction of EQ resistant structures
- Following guidelines were circulated among citizens who would repair their houses
    - Consult an engineer before repair
    - Take photograph before repair
- Mark the repaired part
- Debris removal at Ahmedabad was easy
- Lesson learnt from this EQ
    - None of the structures constructed at Ahmedabad conducted soil investigations
    - There is no mechanism to verify the structural design of approved building

Role of Collector during Crisis:

- Collector has to take the lead and is in charge of communications
- Within Municipal area, rescue is done by Fire Service, otherwise in other areas collector's office supervises the rescue work