Case Study: Gujarat Earthquake

2001 Bhuj Earthquake: Preliminary Report from IITKanpur

A Powerful Earthquake of magnitude 6.9 on Richter-Scale rocked the Western Indian State of Gujarat on the 26th of January, 2001. It caused extensive damage to life & property. This earthquake was so devastating in its scale and suffering that the likes of it had not been experienced in past 50 years. Leaving thousands seriously injured, bruised and handicapped; both physically, psychologically and economically.

The epicenter of the quake was located at 23.6 north Latitude and 69.8 east Longitude, about *20 km Northeast of Bhuj Town* of the Kutch district in Western Gujarat. At a depth of only 23 kms below surface this quake generated intense shaking which was felt in 70% region of India and far beyond in neighbouring Pakistan and Nepal too. This was followed by intense after shocks that became a continued source of anxiety for the populace.

The Seismicity of the affected Area of Kutch is a known fact with a high incidence of earthquakes in recent times and in historical past. It falls in Seismic Zone V. The only such zone outside the Himalayan Seismic Belt. In last 200 years important damaging earthquakes occurred in 1819, 1844, 1845, 1856, 1869,1956 in the same vicinity as 2001 earthquake.

Twenty-one of the total 25 districts of the state was affected in this quake. Around 18 towns, 182 talukas and 7904 villages in the affected districts have seen large-scale devastation. The affected areas even spread up to 300 km from the epicentre. In the Kutch District, four major urban areas – Bhuj, Anjar, Bachau and Rapar suffered near total destruction. The rural areas in the region are also very badly affected with over 450 villages almost totally destroyed.

In addition, wide spread damages also occurred in Rajkot, Jamnagar, Surendranagar, Patan and Ahmedabad districts. Other Urban areas such as Ganhidham, Morvi, Rajkot and Jamnagar have also suffered damage to major structures, infrastructure and industrial facilities. Ahmedabad the capital was also severely affected.

Gujarat Earthquake is very significant from the point of view of earthquake disaster mitigation in India. The problems observed in this disaster are no different from other major recent earthquakes in the world. The issues in the recovery and reconstruction phase are: the proper understanding risk among different stakeholders, training and confidence building among the professionals and masons with appropriate development planning strategies.

This quake has provided numerous examples of geo-technical and structural failures. The traditional wisdom of design and construction practises of engineered buildings prevalent in this country came under criticism for the first time. It has triggered comprehensive understanding on what needs to be done in this regard. [2]

[2] High Powered Committee Report on National Disaster Management , Ministry of Agriculture, New Delhi, 2001

A common site of destruction of the villages in the meizoseismal area.

Rubble of collapsed buildings being cleared at Anjaar. Narrow lanes caused significant casualties and made rescue and relief very difficult. Kudos to the rescue/relief workers for their daring efforts!!

Virtually nothing could be recovered from most RC frame buildings that collapsed. Clearing of debris from collapse of numerous multistorey RC frame buildings was an even bigger challenge.

Relief distribution after the earthquake.

Temporary shelters in the town of Morbi.

Chamoli (Himalaya, India) Earthquake of 29 March 1999

The Chamoli earthquake of 29 March 1999 in northern India is yet another important event from the viewpoint of Himalayan seismotectonics and seismic resistance of non-engineered constructions. The earthquake occurred in a part of the Central Himalaya, which is highly prone to earthquakes and has been placed in the

highest seismic zone (zone V) of India. There has been a bitter controversy during the recent years regarding the seismic safety of a 260-m-high rock-fill dam under construction at Tehri, about 80 km west of the epicenter. Fortunately, there are no major cities in the meizoseismal region and the population density is the second lowest in the state. The earthquake caused death of about 100 persons and injured hundreds more. Maximum MSK intensity was up to VIII at a few locations.

The quake was felt at far-off places such as Kanpur (440 km south-east from the epicenter), Shimla (220 km north-west) and Delhi (280 km south-west). Maximum death and damage occurred in the district of Chamoli where about 63 persons died and over 200 injured; about 2,595 houses collapsed and about 10,861 houses were partially damaged. In all, about 1,256 villages were affected. A few buildings at the far away mega-city of Delhi sustained non-structural damages. No instances of liquefaction were reported. Longitudinal cracks in the ground were seen in some locations in the affected area.

Figure 5: Ground fissure at Telecom Hill near Gopeshwar

Ground cracks at several places also developed as part of slope failure and these pose threat to the down-slope settlements. Cracks were seen in asphalt roads at some locations, indicating the possibility of failure due to ground slippage. At several sites, large-scale earthquake-induced landslide/rock falls were observed (*Figure 6*). Those near Gopeshwar, Chamoli and Gadi continued even after a fortnight of the event. Interestingly, these rockslides are also confined to locations along MCT-I.

Figure 6: A major landslide about 1km north of Gopeshwar. It blocked the road traffic to Okhimath for a considerable period.

Figure 7: Collapse of one of the wythes in a traditional house in slate wafer masonry.

Figure 8: Partial collapse in a random rubble stone masonry. Note that the front portion has RC beam supported on concrete block columns and roof consists of RC slab

Figure 9: Two-storey house at Pipalkoti with no damage. Ground storey in slate wafer masonry, upper storey added later in concrete block masonry. Both storeys have RC lintel band

Figure 10: Partial collapse in a stone masonry house at Gadi village. Lintel band, present in the front portion, does not continue in the side wall

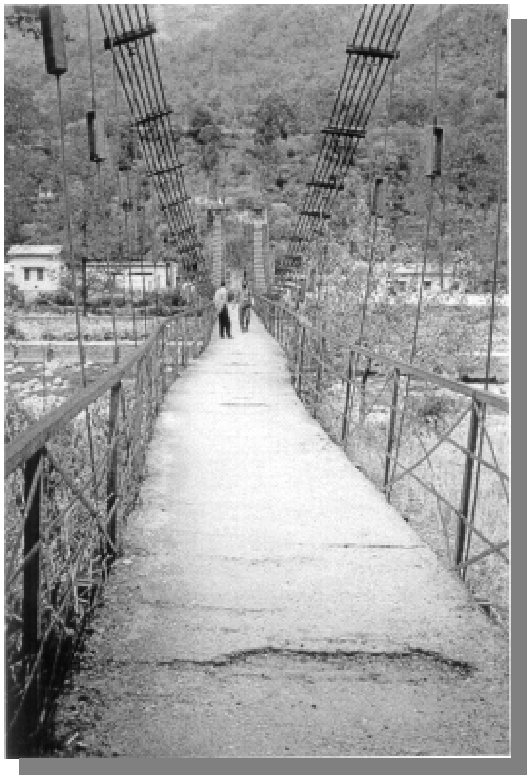


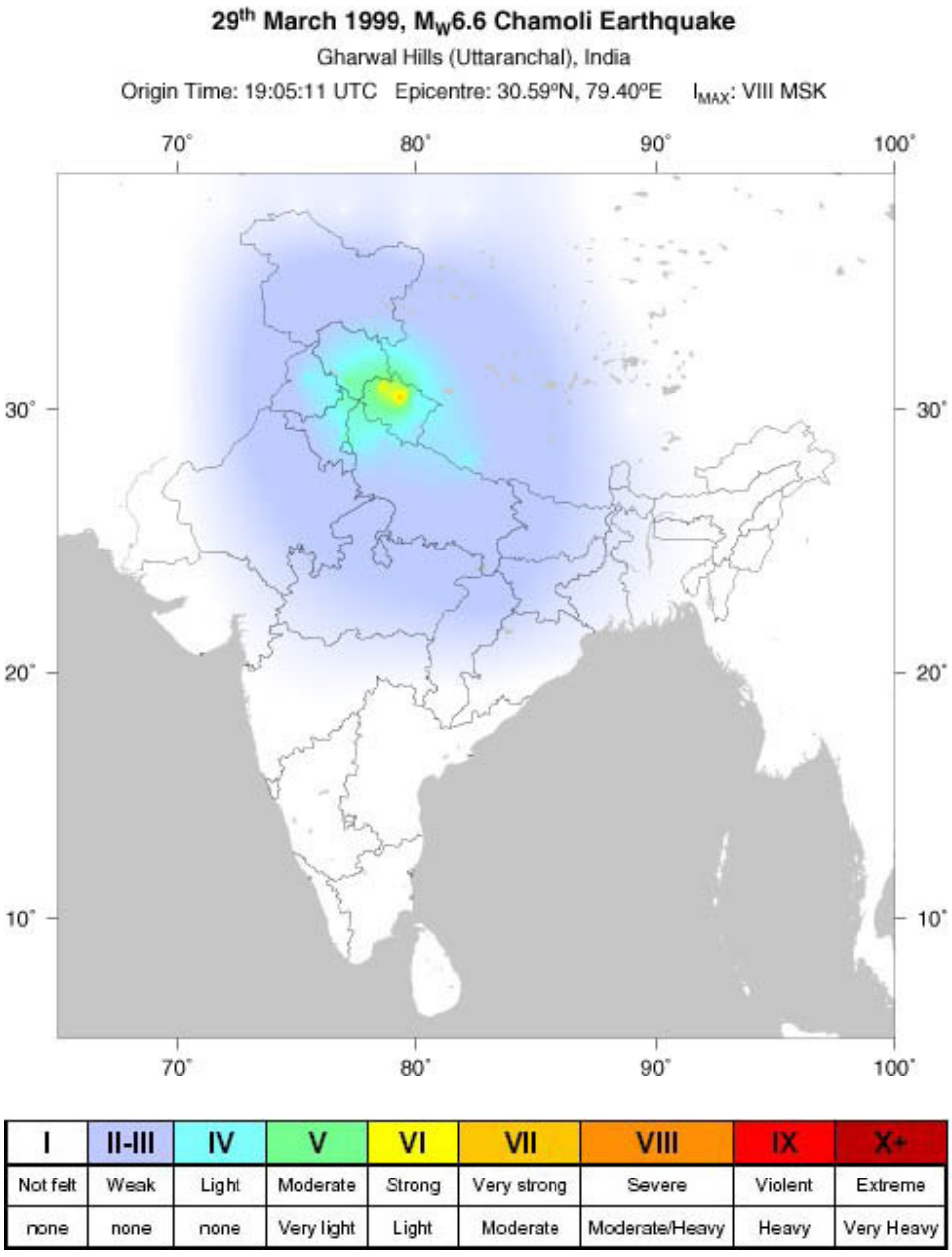
Figure 12: Lateral buckling of the deck of a suspension bridge at Bairagna

Emergency Response

Fortunately, the number of fatalities in the earthquake was relatively less at about 100 as compared to about 800 in the 1991 Uttarkashi earthquake. Interestingly, at the time of earthquake a popular movie was being screened by a TV channel and many people who were awake could easily escape. The area has major Hindu shrines and draws huge tourist traffic during May to October; the timing of this earthquake was fortunately during the lean tourist season. Hence, the task of search and rescue operations was easier and was carried out by the local people. Army and paramilitary personnel were also called-in to help in relief operations the very next day. Some cash compensation, food rations, and cloth tents were provided by the state government. By March the winter is over, and hence, cloth tents were sufficient for temporary shelters. Food and other supplies had to be air-dropped to numerous villages which were normally inaccessible by motorable roads or cut-off due to landslides. Due to poor accessibility, relief operations were quite challenging and caused dissatisfaction in remote villages which could not be attended to on time.

The headquarters for Chamoli district is at Gopeshwar, 10 km by road from Chamoli. Since Gopeshwar did not experience major damages, the entire administrative machinery could function effectively. However, frequent visits by senior politicians and administrators from the state and central governments may have significantly diverted attention of the district officials. Damage assessment for individual houses was initiated by the revenue officials immediately after the earthquake. This was also a difficult task due to the inaccessibility of many villages leading to some complaints about the fairness in damage assessment.

Significant aftershock activity, which included a few events of M >5, created a lot of fear amongst the people and they hesitated to sleep indoors even when their dwellings had little or no damage. Speculations about an impending large earthquake added to the fear and panic. Massive forest fires, which are common during this time of the year, drove some wild animals towards the villages adding to the insecurity. Impending monsoons in the next two months remained a major concern; slope failures and additional damage to partially damaged houses were feared.



I	II-III	IV	V	VI	VII	VIII	IX	X+
Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy

Figure 26 Shake Map for 29th March 1999, Chamoli Earthquake

The earthquake occurred on March 29th at 12:35 am (local time) near the town of Chamoli in the state of Uttar Pradesh in northern India (Figure 1). The earthquake magnitude was calculated as mb=6.3, MS=6.6 by USGS, and as mb=6.8, MS=6.5 by the India Meteorological Department (IMD). The preliminary locations of the epicenter by the different agencies are 30□49.2□N, 79□28.8□E by USGS; and 30□17.82□N, 79□33.84□E by IMD. Distances in this report refer to the USGS location.

Recorded aftershocks and the damage pattern suggest that the zone of activity was close to Chamoli; this region also showed a maximum intensity of VIII on the MSK scale. USGS estimated the focal depth at 12 km. The quake was felt at far-off places such as Kanpur (440 km southeast of the epicenter), Shimla (220 km

northwest) and Delhi (280 km southwest). Maximum death and damage occurred in the district of Chamoli, where about 63 persons died and over 200 were injured. About 2,595 houses collapsed and more than 10,850 were partially damaged. In all, about 1,256 villages were affected. A few buildings at the distant city of Delhi sustained nonstructural damage. No instances of liquefaction were reported. Linear cracks in the ground were seen in some locations in the affected area.

Nonstructural damage to some buildings in far-off Delhi clearly underlines the potential for a major disaster there. Considering the political and social significance of such an eventuality, efforts should be directed towards effective earthquake disaster mitigation and management in the Indian capital.

P1. Partial collapse in a random rubble stone masonry building. Note that the front portion has RC beam supported on concrete block columns, and that the roof consists of an RC slab.

P2. Collapse of one of the wythes in a traditional house in slate wafer masonry

P3.Tarang Apartment in Delhi that sustained damage to infill walls.

The September 29, 1993, M6.4 Killari, Maharashtra Earthquake in Central India.

Most of the world seismicity is concentrated along the plate boundaries. However, a significant number of earthquakes, including some large and damaging ones, do occur within the plates. Our understanding of intracratonic seismogenesis and the hazard it entails is poor, in part because data are scarce.

The 1993 Killari earthquake in central peninsular India is the latest intracratonic event to be responsible for a large disaster. The positive side of this tragedy is that it will provide new insights into geologic, engineering and cultural factors that control the distribution and degree of damage, which will aid in turn the development of a more effective hazard reduction program for peninsular India and similar intrapolate environments.

This report summarizes our observations during a ten-day investigation of the mesoseismal area of the 1993 Killari earthquake. Several aspects of the earthquake were investigated, ranging from the surface rupture and related deformation to the pattern of damage to engineered and traditional structures. Finally, the rescue and reconstruction efforts following the earthquake brought out important issues that are generally relevant to earthquake hazard reduction in traditional rural settings; these are also briefly discussed.

Figure 4: In some buildings, the traditional heavy clay roof was supported on a frame of wood posts and beams. In most cases, the timber columns continued to hold the roof together while the walls collapsed, generally outwards from the timber frame, saving the lives of many occupants

Figure 5: A brick masonry school building in Rajegaon collapsed. The roof of precast panels lacked adequate connections

Figure 6: While most elevated water tanks performed well, this tank of Kautha collapsed straight down into its crumpled supports. Circumferential displacement of about 0.5m suggests that rotational vibration led to its collapse.

Emergency Response

The affected area does not suffer from floods and was considered Aseismic. The only natural disaster known in the area is drought. Hence, the earthquake took the people and administration by surprise. It took

the administration 2 to 4 days to effectively organize rescue and relief operations. What then followed appeared to be well-organized and effective. Civilian as well as military authorities cooperated in the effort. Since the reconnaissance team did not visit the affected areas of Karnataka, the discussion here is based on the response in the districts of Latur and Osmanabad only.

Of all the villages devastated by the quake, only the village of Killari had a wireless connection with the district police headquarters at Latur. Within minutes, the information about the devastation in Killari was conveyed to Latur and from there to the state headquarters at Bombay. Immediately, about 20 policemen stationed at Ausa (28 km) were rushed to Killari, followed by district level administrators (District Collector, Superintendent of Police, etc). About 50 policemen were also dispatched from Latur (42 km). Immediate search and rescue was conducted by the survivors and the limited police rescue teams. As the day progressed, information about equally severe devastation from nearby villages started reaching Killari. By early next morning (Oct. 1), the Indian army took over the task of search and rescue.

By the afternoon of the day of the earthquake, many curious onlookers had arrived in the area. This led to traffic jams and hampered the task of search and rescue. Beginning Oct. 2, entry to the affected area was controlled to allow entrance only to government personnel and members of volunteer organizations.

The task of search and rescue became extremely difficult due to the heavy rains, which immediately followed the earthquake and the enormous quantities of the rubble. In places 2-3 m of rubble has to be removed to extricate the bodies. The narrow village streets were choked by fallen rubble, which further hampered rescue operations.

Mass cremations that were held on the first two days after the earthquake were done without adequate record keeping. This led to confusion about the actual number of deaths. At one time, the newspapers were reporting up to 30000 dead. Later it was discovered that about 9000 fatalities actually occurred.

Recovery

Medical Aid: The number of injured in Maharashtra was about 15500. About 50 mobile teams of doctors were pressed into service; at least – doctor was made available at each of the affected villages. The 125 beds civil hospital at Latur had to convert the nearby Rajasthan School into a hospital ward to care for about 300 indoor patients. On the other hand, the rural medical college and hospital at Ambe Jogai, which is only 60km from Latur, had a 510-bed capacity but only had 86 patients maximum at any given time. On the whole, in a few days, there were more government and private doctors available than could be used.

Food, water, Provisions: Cooked food was provided in the affected villages during the first fortnight by large number of voluntary agencies and the army. After 15 days the community kitchens were closed. Enough rations and other provisions to last a month were provided to the people, requiring them to cook their own food.

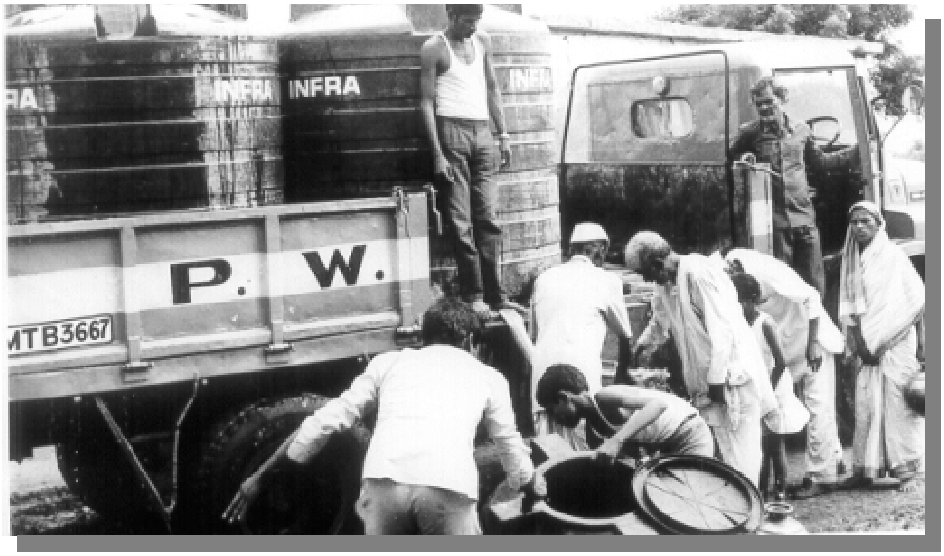


Figure 7: After the earthquake, water was trucked into the region. Generally, each village was assigned a truck requisitioned from unaffected neighbouring districts

Drinking water was supplied regularly by mobile water carrying units, generally one for each village, requisitioned from the neighbouring districts. Water storage tanks (5000 l), donated by UNICEF/CARE, were being used for storing water in villages. In some villages, these tanks were lying upside down while quite a few were still resting in storage yards, indicating excess availability of the tanks. A total of 227 water hand pumps in the earthquake-affected areas of the Latur district were found operative.

Simultaneously, a program for installation of tube wells in the temporary settlements was initiated. In the Latur district, 83 deep-bore wells at the temporary shelter sites needed to be dug. 47 of these had been completed by Oct 19. For this task, eleven deep-bore rigs were mobilized from the other districts of Maharashtra.

Figure 8: Distribution of relief supplies was systematized through the issuance of 'family cards' and 'individual cards' to residents of the affected areas

The government and several voluntary agencies distributed clothes and household goods like utensils, stoves, storage cans, and provisions for daily needs, either through the administration or directly. A team consisting of an officer from the administration, an officer from the police, and a local head of the village issued every affected family a “family card” and every affected person an “individual card” to record and regulate the goods distributed as a relief aid. This, to a large extent, systematized the relief distribution. Spontaneous offers of aid were received from within the country and outside. Bombay International Airport made special arrangements to receive and clear planeloads of clothes, medicine, tents and food. Within about 3 weeks, the relief material available was somewhat in excess of the needs.

Figure 9: Temporary shelters of galvanised iron sheet were rapidly erected. Each provides shelter for five families

Temporary Shelter: Immediate shelter was provided by erecting temporary galvanized iron sheet houses. Each shelter consisted of 5 units of about 15 m^2 areas each; each affected family was offered one such unit. Common toilets and hand operated bore wells were provided. Some families chose to take tents and tin sheets instead and made their own shelters.

Resettlement and Housing: A large number of villages which were totally destroyed are being relocated to places not far away. Most of the sites for relocation have been identified.

Every affected family will be provided a housing unit with a covered area of 20, 40 or 60 m^2 (depending on the needs of the family) and an open area of 15 to 45 m^2 for animal shelters and future extensions. The government will bear the cost of only 20 m^2 of the housing per family. For houses with a larger constructed area, the remaining cost will be treated as a long-term low-interest loan payable on terms similar to those for World Bank loans.

Transportation

The primary mode of transport in the area is bus. The affected area has no rail network. The nearest railway stations are at Latur and Sholapur. The nearest airports are at Hyderabad and Aurangabad. Since there was no damage to roads or bridges, the bus services were not adversely affected, even though the lanes inside the villages were blocked with the rubble of collapsed houses. Most of the villages have been temporarily shifted to new locations to the main roads.

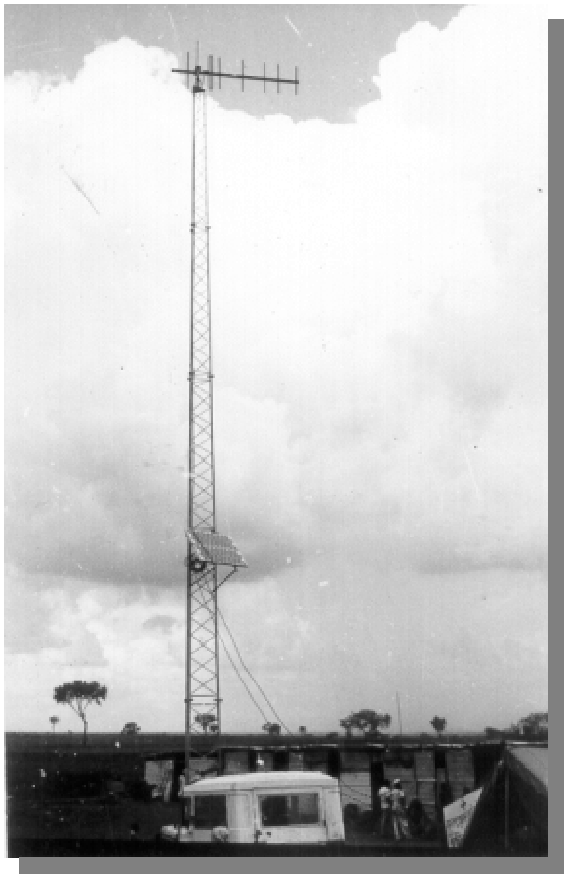


Figure 10: Solar Powered Satellite Communication Towers were brought in to connect the larger villages to the outside world

Communications

An excellent communication network was set up after the earthquake. Initially, a number of HAM sets were called in. Later, solar powered satellite communication towers were installed in most of the bigger villages. The district collectors were provided with a hotline to the chief secretary at Bombay. This enabled the state to take immediate action on the requests from the local administrations for men and materials.

Economic activity

The economy of the area is primarily farm based with very few industries. The only major industry in the region was a sugar factory at Killari Pati, which had closed quite some time prior to the earthquake. It suffered no apparent damage and was being used as a relief distribution center.

A large chicken farm about 15km north of the epicentral area reported that egg production fell substantially after the quake. Production was still down about 7% three weeks later. (No fluctuations in egg laying preceded the quake.)

Though it is harvesting season for the Kharif crop and the sowing season the Rabi crop, the farmers have been unable to resume regular farming activity. This is due to incessant rains, unexpected at this time of year, and the non-availability of farm laborers, who do not seem concerned about daily wages due to the availability

of free relief provisions. There are reports that the government may have to help in harvesting by bringing in labor from outside the area.