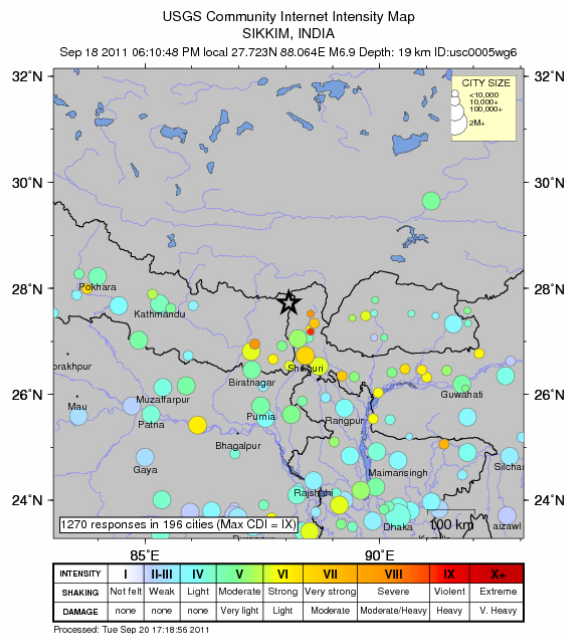
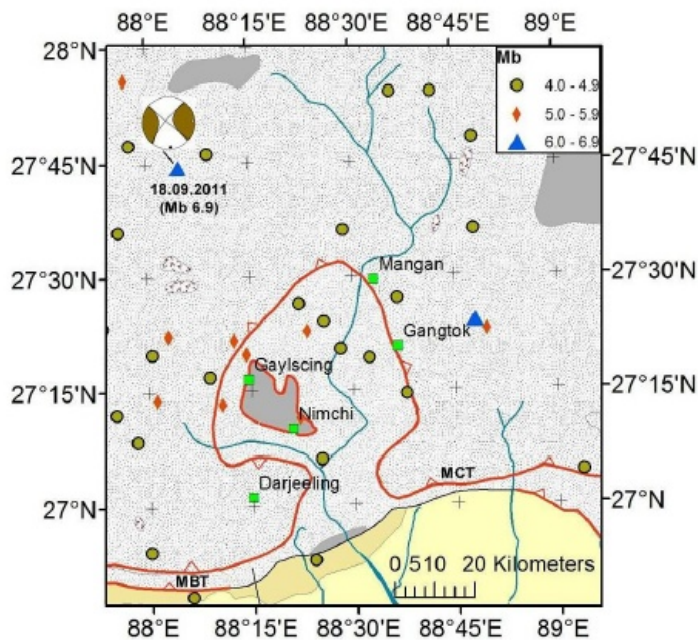


Sikkim Earthquake 2011 – A Roadmap for Resurrection



REPORT
Submitted to
The Ministry of Home Affairs, Govt. of India



Towards a disaster free India

NATIONAL INSTITUTE OF DISASTER MANAGEMENT
Ministry of Home affairs, Govt. of India, New Delhi

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FOREWORD

National Institute of Disaster Management (NIDM) deputed Dr. Chandan Ghosh, Professor and Head and Dr Surya Parkash, Associate Professor, Geohazards Division, to document the M_w 6.8 Sikkim Earthquake that struck on Sunday, 18 September 2011, at 18:10:48 hrs (IST). The team carried reconnaissance survey of the affected areas from 21 to 25 September 2011 and held interactions with officials from the State and Central Government Agencies, armed forces, communities, NGOs and civil societies involved in the relief and rescue operations. The team mainly noted the extent of damages incurred to buildings, roads and infrastructures; response mechanism and relief measures being adopted, emergency control room operation at the district head quarters, in addition to media and press briefing to tackle the situation on emergent basis.

The team also inspected damage patterns of **buildings** – such as cracks, foundation settlement, collapse, distressed load bearing members; **roads** – pavement cracks, landslides patterns, rock falls, subsidence, clogged surface drainage, earth retaining walls, roadside culverts, etc., **infrastructures** – sewer system, water supply pipelines, Jhora training works, electric transmission lines, communication towers atop buildings, etc., along the Bagdogra-Siliguri-Rongpo-Singtam-Ranipool-Gangtok and Gangtok-Mangan via Singtam and Dikchu routes.

The earthquake damaged thousands of houses and public buildings, destroyed infrastructure including roads and bridges and temporarily cut off electricity and telephone landline connections. It also caused multiple landslides cutting road access to many of the affected populations. In brief the disaster caused significant damage not only to properties but also resulted of livelihood resources. The rehabilitation of deserted community needs systematic planning, both for short term as well as long term rehabilitation. The first and the most important of this planning is scientific Post disaster Damage and Needs Assessment and Recovery Framework (**PDNA/RF**). The PDNA/RF for the Sikkim Earthquake is to be carried out by a specialized team. It will ensure pulling together information into a single, consolidated report detailing information on the physical impacts of the earthquake event, the economic value of the infrastructure and social damages, physical and economical losses, the human impacts as experienced by affected populations, and related early and long-term recovery needs and priorities. Following recommendation of the report, NIDM proposes to constitute a **central PDNA team** under the directives from Ministry of Home Affairs, Govt. of India, consisting of experts from different sectors.

Finally the amount of hard work put up by Prof. Ghosh with incisive illustration of overall scenario is highly appreciable. I wish this report shall be of immense help in providing necessary route map for post disaster resurrection of the earthquake affected region of the country.

Satendra
Executive Director, NIDM

ACKNOWLEDGEMENT

NIDM team would like to sincerely express its gratitude and thanks to Dr. Satendra, Executive Director, National Institute of Disaster Management, Ministry of Home Affairs for his kind permission to undertake the present study and encouragement to us in preparing this report. Without his initiatives, support and cooperation, the work would not have been possible. We are grateful to Shri R.K. Srivastava, JS-DM, MHA and his entire staffs for constant encouragement and support. We would also like to thank the faculty members and project staffs, particularly Dr Ravinder Singh, at NIDM who provided their inputs for the field work and compilation of report.

We are obliged to the State Government and Administration in Sikkim for extending necessary logistic support and cooperation in the field visit. We are particularly thankful to Shri B.K. Kharel, Secretary, Land Revenue and Disaster Management (LR&DM), Government of Sikkim; Shri Anandan, District Collector, East Sikkim; Mr. Prabhakar Rai, Deputy Secretary, LR & DM; Mr. G.C. Khanal, Joint Director, Mr. Lepcha, Senior Geologist and Mr Kesang Luitel from DMMG; Mr Raju Tamang, Mr Nehru Pradhan from UD &HD; Mr. A.B. Karki, SDM; Basant Kumar Lama, SDM, Mangan; Ms. Kassang Nema Bhutia, Training Officer, UNDP, Mangan; Shri Bhupendra Sharma, State Project Officer (UNDP-DRR); Mr. C.T. Wangdi, Secretary, Labour Department; and Mr. Tashi Wangdi Lama from LR& DM, Shri Anil Ganeriwala, Principal Secy (Rural), Mr Arvind Kumar, Resident Commissioner, Sikkim House, Delhi.

We are also thankful to Dr. K.K. Singh, Scientist and Shri Ashok Sharma, DM Faculty from GB Pant Institute of Himalayan Environment & Development, Gangtok Unit, Sikkim, for extending timely support and cooperation in field studies.

The team would like to express its sincere thanks to the officials of Border Roads Organization, particularly Brigadier Rajiv Sahni, Chief Engineer and Er Chowbey, BRO, Er. Rohan Sonkar and Sudhir Mishra from 87 RCC, for sharing with us the information and experiences related to landslides along the highways. Thanks are due to the management of Rumtek Monastery, Gangtok and Ringhim Monastery, Mangan for facilitating our visit to their compound. We are grateful to the volunteers of civil society and NGOs who involved us in their meetings and shared their experiences regarding relief activities. We would particularly like to thank Mr. Vikrant Mahajan and Ms Neha from SPHERE Network for inviting us to participate in the meetings of NGOs network. Thanks are also due to Ms Debadrita Sengupta and Mr Pallab De from Caritas India for sharing their field photographs of the affected areas with us.

Last but not the least, we are indebted to the people in Sikkim who have provided us all kinds of hospitality and support despite the worst suffering they were facing due to the earthquake. We would like to extend our heartiest wishes to the victims of the earthquake for an early recovery and normalcy in the State.

Surya Parkash
Associate Professor

Chandan Ghosh
Professor & Head
GeoHazards

EXECUTIVE SUMMARY

An earthquake measuring M6.8 on Richter scale occurred on September 18, 2011 at 18.10hrs in the Sikkim-Nepal border (27.723°N, 88.064°E) region. It was widely felt in all the North Eastern states of India, West Bengal, Bihar, Uttar Pradesh, Haryana, Rajasthan, including capital city Delhi. The earthquake claimed 60 human lives in Sikkim, including 16 at the Teesta Stage III Hydroelectric power project site, 719 persons injured and also caused substantial loss to livestock. It shook for more than 30 seconds at intensity MSK-VII, triggered landslides, and caused extensive damages to houses and infrastructures, mainly roads, water supply, transmission towers etc. in the state of Sikkim and North Bengal districts such as Siliguri, Darjeeling, Kalimpong, New Jalpaiguri. Wide scale damages were also reported from neighbouring countries like Nepal, Bhutan, Tibet and Bangladesh. The Secretariat building, Sikkim Press building, Education, Health and Police Headquarters in Gangtok suffered severe damage. More than 34,000 buildings in Sikkim, such as multi-storey RCC buildings, monasteries, hospitals, schools, Gumpas, Panchayat Ghars, public health centres have suffered various degrees of damages. Urban water supply and drainage schemes in Gangtok, irrigation channels, PMGSY - village roads and rural water supplies in various districts have also been adversely affected. National Highways, State Highways including the rural connectivity in the Chungthang, Lachung and Lachen area have been snapped. Several aftershocks accompanied with incessant rainfall were causing further distress in the relief and rescue operations. As per information received, while BRO (GREF) cleared debris at more than 20 spots along NH31A upto Gangtok within 20 hrs, followed by road to Mangan, the North District HQ., via Dikchu in 3 days, road to Nathu-la, the Chinese border by 2nd October, and from Mangan to Chungthang by 18th October, it will take more time to allow traffic upto Lachung and further north. It is reported that roads so cleared for traffic have not been yet found fit for carrying heavy machineries to many Hydroelectric Power (HEP) project sites, thus resulting in inordinate delay in their target achievements. It is urgently required to conduct detail damage as well as vulnerability assessment survey of all these establishments in the affected areas with particular motivation towards the development of national policies/strategies for repair, strengthening and retrofitting measures.

After the earthquake the response actions were becoming very difficult due to access problems and bad weather conditions. Failed telecommunication, inadequacy of Helipad, severed road alignments due to landslides aggravated with inclement weather advisories from IMD put up challenges to the timely rescue and relief operation for more than a fortnight. Many of the areas in North Sikkim including Chungthang, Lachen, Lachung and Dzongu were inaccessible without the services of choppers and helicopters. Army, Air force, Teesta Urja and State Department of Tourism were using helicopters to rescue people trapped in these inaccessible areas and provide relief to them from Ringhim helipad at Mangan in North Sikkim district. There are few buildings in Gangtok, which have

collapsed after the earthquake. Demolition of collapsed buildings in such hill slope is a challenging task, which is in progress now. However, it is earnestly required to prepare a building demolition policy based on detail structural and non-structural safety assessment by expert team.

Though the life loss was not much, the impact of this earthquake in terms of a) direct and indirect economic loss to nation, b) expenses to be incurred for mass scale reconstruction and rehabilitation measures, c) affecting tourism industry, d) setback to developmental perspectives of the affected area; needs thorough assessment and the outcome should find a space in the 12th plan document of Planning Commission, which is under formulation stage now.

This report carries first hand observation by two member NIDM team on issues of rescue and relief operations, functioning of emergency control room, damages encountered from the view point of vulnerable establishments impacting on the regional economy and suggesting roadmap for restoration with activity plan.

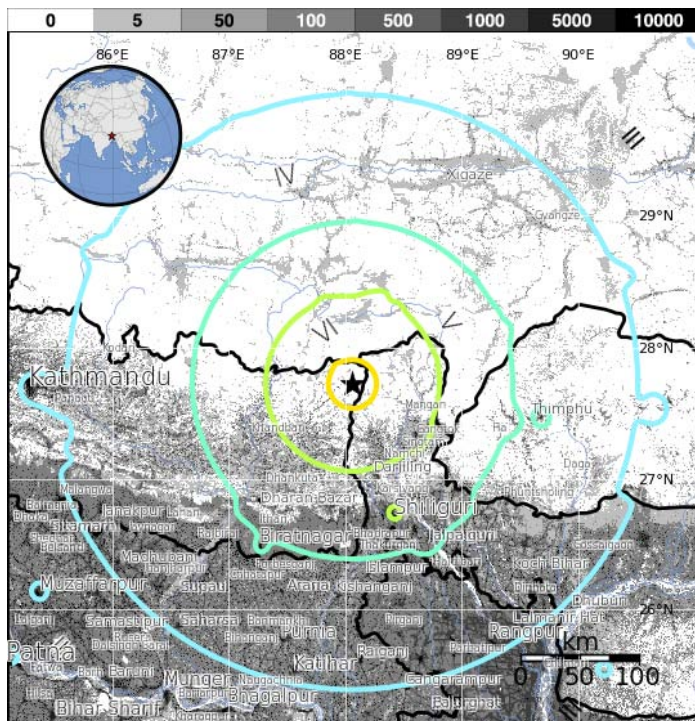
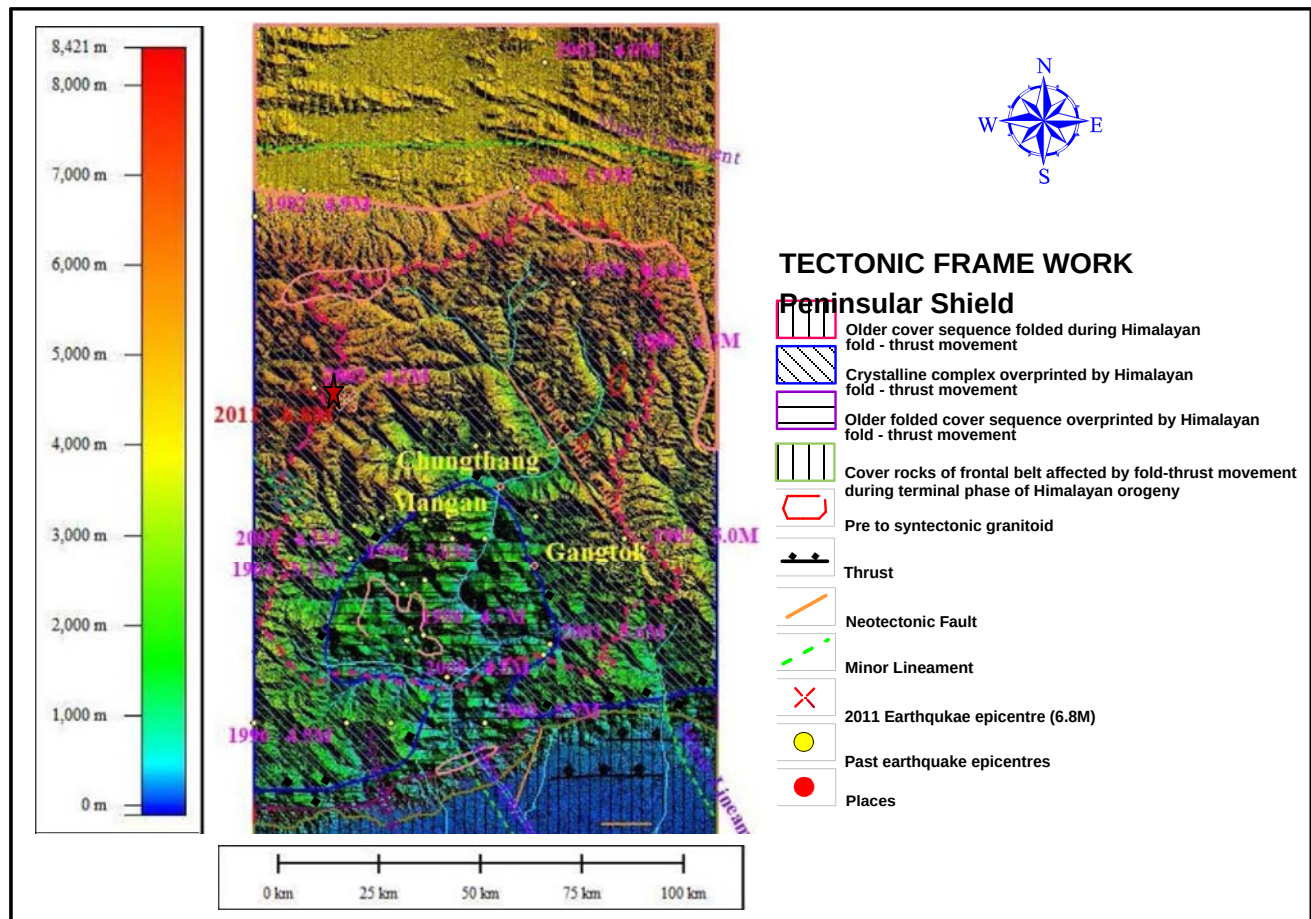
Based on the preliminary survey of affected area and analysing the situation the team recommends:

- 1) Measures for systematic damage as well as vulnerability assessment survey along with suggestive timelines for carrying out specific task of repair, retrofitting and rehabilitation framework. Experts team to be formed by involving various national agencies/companies/ organisations in coherence with the aims and objective of Govt. organs such as NDMA, NIDM, MHA and state govt. agencies.
- 2) To develop a plan of action for the rehabilitation and reconstruction for the affected area based on above study and implement it through various agencies.
- 3) Establishment of National Earthquake and Landslides Mitigation Engineering Institute [NELMEI] in the NE and accelerate formalisation of nationwide capacity building program under **National Earthquake Risk Mitigation Project** by NDMA
- 4) Development/upgradation of Indian standards and guidelines dealing with earthquake resistant design of buildings on slopes, landslides and rock fall protection measures by modern techniques such as geosynthetics reinforced earth, soil nailing, anchored earth, geonetting, bioengineering, etc.
- 5) Vulnerability assessment exercise for all Hydroelectric power generation project in the NE.
- 6) To formulate **suitable legislative mechanisms** for regulating the professional conduct (with penal provisions) and related responsibilities of architects, engineers (responsible for structural design and supervision) builders, developers and promoters.

- 7) Strategies for pre and post event data collection and further instrumentation of the affected area for understanding unique tectonic features by reputed Indian organisations such as NGRI, GSI, IMD, NEIST, WIHG, IIG, IITs.
- 8) Validation of Hazard map by **Seismic microzonation** of Sikkim state, which was carried out under DST funding in 2006. It requires status monitoring and road map with particular motivation towards their practical application in the new construction and land use planning for the entire state and similar exercise to be extended to all seismically high risk areas in the North East
- 9) Post-disaster Damage and Needs Assessment (PDNA), including strategies for Psychosocial assistance, trauma care training for NDRF medical team.
- 10) To create a protocol for **Disaster Watch TV channel** by involving MHA, Ministry of Information and Broadcasting and scientific organizations like IMD, GSI, NGRI, WIHG, NEIST, IIG, NEC, IITs etc.
- 11) Establishment of more no. of **earthquake and landslides resilient Helipads** in the Seismic Zone-V area (covering 12% of Indian land mass) and provision of satellite and WLL telephones with defined emergency communication protocol
- 12) To provide a forum **for inter-changing of ideas and views** pertaining to earthquake risk mitigation, capacity building of mason, architect, engineers, town planners, contractors and other stake holders
- 13) The **performance check of the existing conventional earth retaining** structures such as gravity retaining wall, cantilever wall against earthquake induced vibration. **A brain storming workshop** for all those organizations involved in the hill road construction and maintenance highlighting efficacy of modern techniques based on the on-site assessment of damage patterns and mitigating them through a pilot-project along NH31A.
- 14) Upgradation of present seismic zonation of Sikkim and adjoining areas to **Zone – V**, i.e., same as rest of the NE India
- 15) Earthquake induced damages and principles of earthquake resistant design – demonstration of buildings in manual/mechanized **Shake and Shock table** to be taken as public campaign throughout the country.

The report also explains type of vulnerabilities of roads on hill slopes as well as portending scenarios of road widening works, multi-storey buildings juxtaposed on steep slopes with little or no breathing space and dwindling lifeline infrastructures in hilly terrain. It gives simple guidelines for crack repair and treatment along with name of products and companies, restoration and strengthening; format for detail damage assessment; and introduction of some sustainable technology in landslides mitigation, including bioengineering methods for slope stabilisation, anchored earth and geosynthetics application, to name a few. Finally the report explains about classified information to be maintained as essential component of documentation of this earthquake.

SNAPSHOTS OF SIKKIM EARTHQUAKES - 2011



M6.8 earthquake on September 18, 2011 shook the NE states including neighboring countries Nepal, Tibet, Bhutan and Bangladesh, killing 77 in India, damaging infrastructures and development prospects. Sikkim is in seismic zone – IV and has the potential to face MSK VIII intensity earthquake. Despite having details of seismic microzonation in 2006, well developed seismic code and National Building Code-2005, the end result is still unchecked construction as seen above, are rampant in the entire country

EARTHQUAKE IMPACTS IN SIKKIM

S. No.	Type of Element	Number of Elements	Degree of Damage/Loss
1	Human Lives	60	Killed
		710	Injured
2	Houses	34159	Collapsed / damaged
3	Primary Schools	416 out of total 779	Damaged
	Junior High Schools	192 out of total 348	Damaged
	Secondary and Sr. Secondary Schools	151 out of total 195	Damaged
4	Hospitals and Health Centres	377	Damaged
	Primary Health Centres	350	Require reconstruction
	Community Health Centres	25	
	Other important health buildings	2	
5	Water Supply Schemes	1529 (1484 in rural areas and 44 in urban areas)	
6	Roads	3230km	
	State Roads	178.71 km	
	District Roads	744.77 km	
	Other district roads	1289 km	
	Urban Roads	132.44 km	
	PMGSY Road	884.89 km	
	Bridges	314	
	Culverts	7081	
	Rural bridges & culverts	360	
	Foot bridges	380	
7	Agri. Crops	7500 Hectares	
8	Minor Irrigation Channels	204	
	Flood Control Works	365	
	Urban Drainage	168km	
9	Community Assets		
	Panchayat Ghar	60	
	Rural marketing Centres	8	
	Community Toilets	155	
	Intra-village roads	156	
	Anganwadi centres	875	
	Village Cooperatives	49	
10	Religious buildings	259	
1	RCC/Pucca House	432 houses	100% damaged
		2965 houses	Major damages
		481 houses	Minor damages
2	Kutcha House	643 houses	100% damaged
		5398 houses	Major damages
		456 houses	Minor damages
3	Livestocks killed	307 Cows	
		210 Goat	
		232 Bull	
		250 Pig	
		410 yak	
		800 Sheep	
4	Vehicles	231 (including bus, trucks, taxis, and government vehicles)	

Source: Resident Comm. Office, Sikkim state, New Delhi

**Fig. a. VULNERABLE COMPONENTS OF A
TYPICAL BUILDING IN SEISMIC ZONE IV**



Large opening and windows

Floating wall at corner

Over hangs and cantilever

Corner with floating wall

Poor quality construction and wrong construction process/shuttering

Windows are too large and not uniformly placed in same floor

Basement with irregular placement of beams on columns

Extension of upper floor with improper shuttering

Basement with opening and short column

Mixed use- large opening –door shutter

Adjacent building and re-entrant corner

Long verandah with parapet – nonstructural damage

Column spacing not uniform and beams sizes are compromised at each floor

Irregular opening and long floating verandah with 1/3rd brick wall

Extremely poor quality concreting and poor brick work all along

Openings at each floor are different orientation, size and shape

Fire proof system not in place

Non-engineered, constructed local mason with *no application* of earthquake resistance measures

Triangular shape in plan, no integrity in loading frame

Floating wall with very weak brick works

Adjacent to electric poles – health hazard

Different dead load at each floor, 3rd floor heavier and with complete floating wall

Cantilever projection with slant extension of beam

Mixed use – shops-residential, congested, no space for emergency operation –fire, ambulance



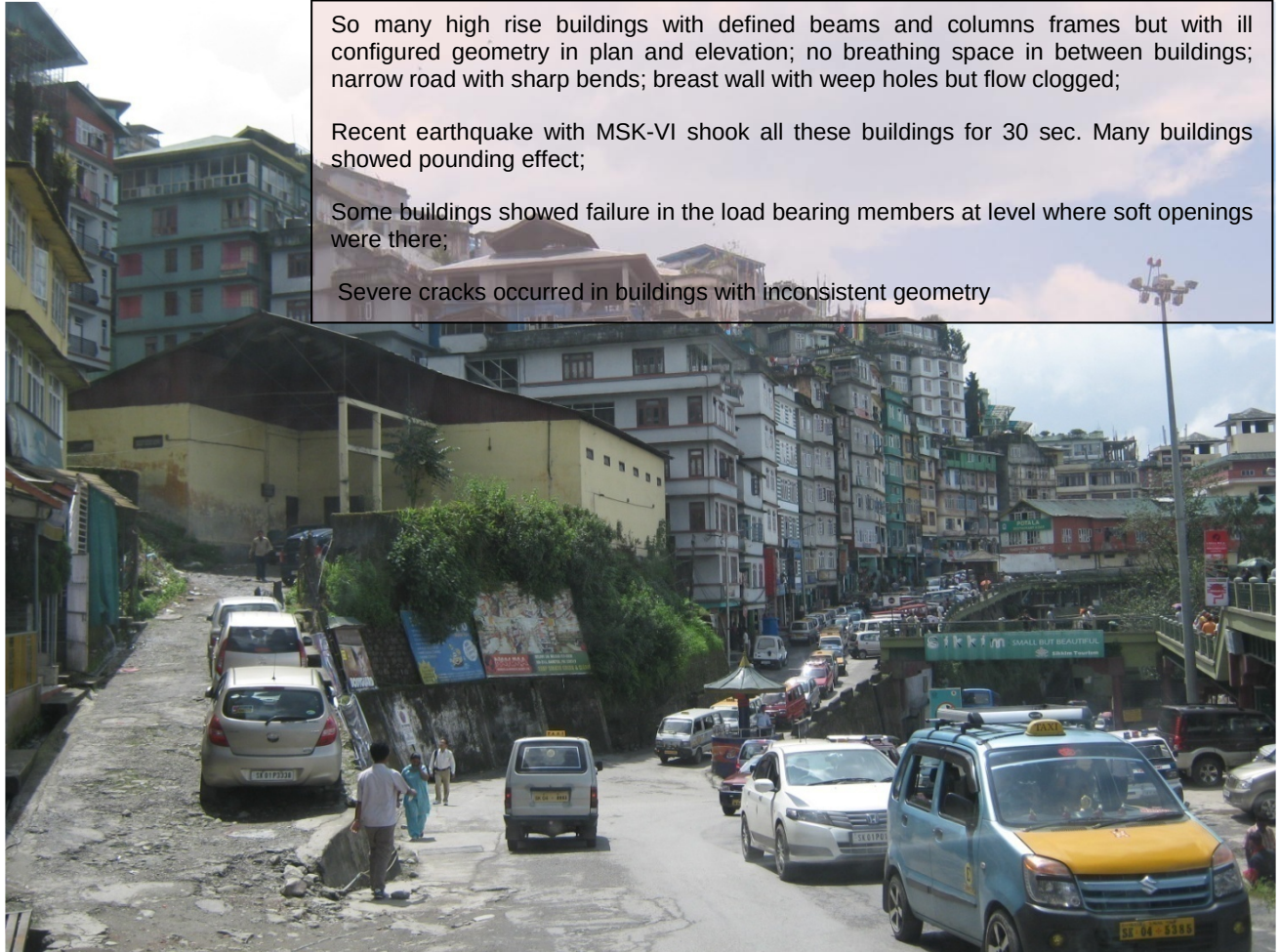
Such buildings are highly vulnerable and no plausible remedial /strengthening measures would be sufficient enough to cater earthquake of M6 or MSK- VII

CONSTRUCTION INDUCED VULNERABILITY

Fig. b. Ongoing Barrage construction site at Sirwani, near Singtam, Sikkim state, along with 26km tunnel for hydropower generation by Lanco Infratech Limited



Buildings in the heart of the city, Gangtok – way forward to disaster resilience and preparedness



So many high rise buildings with defined beams and columns frames but with ill configured geometry in plan and elevation; no breathing space in between buildings; narrow road with sharp bends; breast wall with weep holes but flow clogged;

Recent earthquake with MSK-VI shook all these buildings for 30 sec. Many buildings showed pounding effect;

Some buildings showed failure in the load bearing members at level where soft openings were there;

Severe cracks occurred in buildings with inconsistent geometry



Fig. c-1 Road conditions became worse due to landslides and drains got choked

Fig. c-2. Buildings in capital city Gangtok are standing on steep slope with little or no measures for foundation protection. Almost same is the situation in all hilly states of India, mostly in seismic zone –V. They are laid one adjacent to others with no spaces in between for free vibration during earthquake shaking.

Utilities are mostly lying in tattered mode. Jhora training works are massive yet overly inconsistent with the reality of landslips triggered during monsoon

Buildings are having openings at random, soft storeys and stiffness variation knows no bounds, drainage measures on the natural slopes are way behind with the needs, roads are facing subsidence and they are being filled up without looking into proper cross drainage works, rock shooting are happening with warning sign,

Post earthquake trauma with building failure at Baluakhani, Gangtok and the difficulty of demolition as no such policy/strategy being framed so far despite the country learned a lot from Bhuj-2011, Kashmir-2005 earthquake



Fig. d-1. Two buildings at Baluakhani developed excessive tilt on 23rd Sept 2011. Special team from Hyderabad were engaged for demolition. Several buildings in Gangtok have been declared unfit and they are being demolished one by one. However, it important to look into the safety of these buildings by expert team. It would be wise to check if retrofitting is possible by careful planning and supervision of the entire works. Some guidelines for damage survey are given in the appendix.



Sikkim collapsed during earthquake. This has to be demolished completely



Fig.d-3. Earthquake survivors run past a school building damaged in Sunday's 6.9-magnitude earthquake in Chungthang, India, Sept. 21, 2011. AP/ Altaf Qadri



Fig. d-4.. Ringhim monastery at Mangan, North Dist., and Govt. secretariat at Gangtok suffered huge damage

Aftermath of Sikkim Earthquake 2011 – challenges of structural safety assessment and adopting cost effective demolition and retrofitting policy



Fig. e-1. Cracks in Community Centre, Singtam and many such buildings can be **repaired and retrofitted without much cost and time**. Just deciding to demolish these kinds of buildings without detail structural safety assessment would be rather unwise and costly exercise.



Fig. e-2.. This pvt. Building at Singtam town lost load bearing power to two of the front columns at ground floor, thus it could be a fit case for demolition. However, it was found that this building suffered very little structural damage to the upper floors. **The amount required for proper retrofitting of the same could be much less** than demolition and thereby fresh construction cost by the owner. The govt. need to devise proper policy for load sharing of reconstruction burden else punitive order to carryout such work by affected owner would be difficult to sustain.



Fig. e-3. Fearing from aftershock effect many residents in Deorali area, Gangtok spend nights in this narrow lane vied with tall buildings. Almost all buildings in this area developed cracks in the partition wall.



Fig. e-4. Torrent Pharmaceutical Industry complex, with more than 500 employees, near Sikkim Supreme Factory, NH31A, suffered severe damage in the walls. Upon inspection of the same it was conveyed that owner shall be taking sufficient measures to restore everything. **It is required to have a check on such commitments by pvt. Industries and hydroelectric project authorities.**

This complex is also vulnerable to landslides along NH31A for which no effective preventive measures found.

MANAGING EVENTS AFTER THE EARTHQUAKE

On issues of nature of information dissemination at the disaster control room, managing VVIPs, reaching out to the affected people, giving relief and managing with inclement weather in hilly terrain affected with landslides



Fig.f-1. Press brief at control room, Gangtok on 22nd sept 2011



Fig. f-2. NGO coordination meeting at Gangtok on 22nd Sept



Fig. f-3. Visit of Hon'ble Home Minister Shri P. Chidambaram at STNM Hospital on 22nd Sept 2011 and many others including Hon'ble PM on 29th Sept 2011 – a must in disaster days for which Incident Commander is to be properly equipped with greater outlook to the minimum needs in rescue and relief operation



Fig. f-4. NDRF medical camp at Mangan, North Dist. HQ. Many of workers at Teesta Stage III project site had to leave project site and waiting for bus to Siliguri. They walked for 2-3 days to reach here.



In retrospect after 17 yrs of Yokohama declaration Impact of SDMA as per DM act-2005, National Guidelines on DM by MHA and NDMA, operation of EOC, impact of USAID-MHA trainings on Incident command system (ICS –now IRS), round table meeting of NGOs at Gangtok – GO-NGO coordination

ROADS MADE FOR DEVELOPMENT – ISSUES OF SUSTAINABILITY AND TECHNICAL KNOWHOW

Road blocks due to earthquake induced landslides cleared in jet-speed, showing prowess of BRO but their sustainability and timeline to normalcy is point of serious concern to the proponents of various industry and power projects in the region



Fig. g-1. Road clearance made upto Mangan, North dist. HQ., in 3 days time after the earthquake but long term performance measures not ensured thus affecting work of power projects,



Fig. g-2. Road widening along NH31A near Ranipool is on but technical feasibility of taming cut slope as seen here are very much local and pristine



Fig. g-3. Controlling measures around the Bagthang water falls, in the form of buttressed retaining walls are no way effective in preventing landslides. The road has no culvert or x-drains. Boulders are constant threat to unwary travellers.



Fig. g-4. Landslides caused severe trouble to dwindling infrastructures services and utilities. Once again restoration of the same has hardly any technology in place

MENACE OF EARTHQUAKE INDUCED LANDSLIDES AND IMPACT ON POWER PROJECTS



Fig.h. An aerial view of Teesta III hydro power project site partially damaged in Sunday's earthquake in Chungthang, India, Wednesday, Sept. 21, 2011 and aerial view of massive landslides triggered by the earthquake along Gangtok-Mangan highway. (source AP / Altaf Qadri)

GOOD QUALITY CONSTRUCTION IN PROGRESS AT THE TASHILING SECRETARIAT COMPOUND, GANGTOK

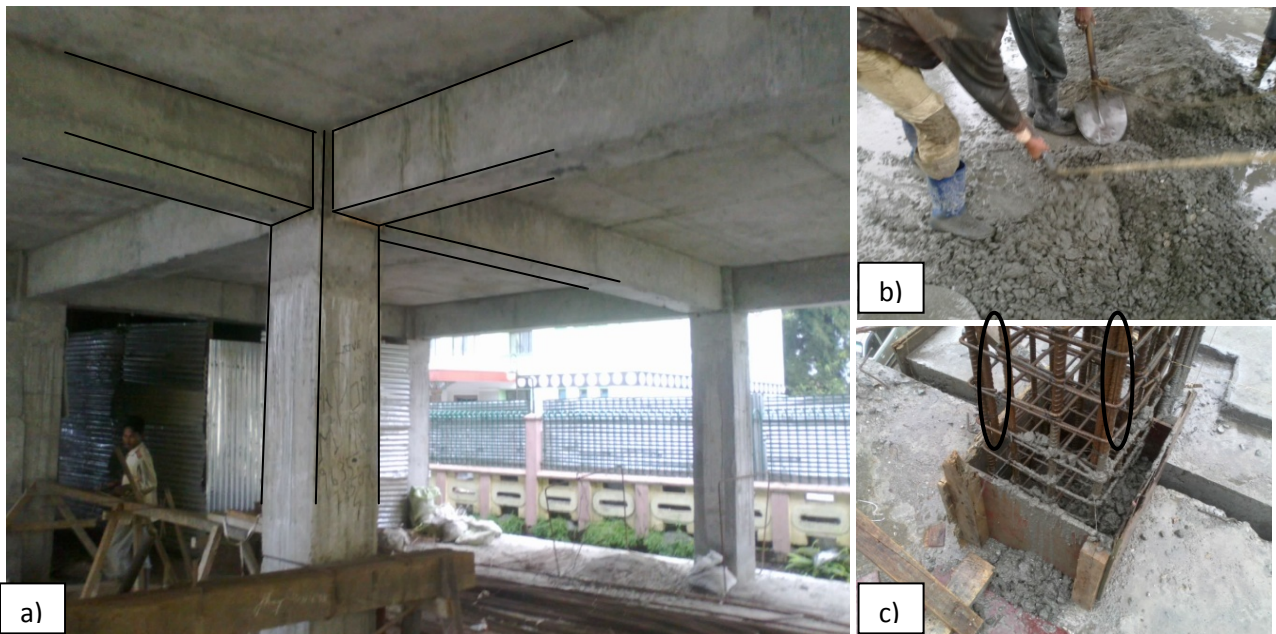


Fig. i. This above multi-storey building is under construction for more than a year with combined footing for columns, which are placed in regular spacing. Designer must have taken all measures in providing extra amount of steel reinforcement with multiple shear stirrup yet with 90° lapping. There seems to be no compromise on the quality of building materials but concrete in (b) and lapping type seen in (c) in the 4th floor might have not been revealed in the recent earthquake.

ABBREVIATIONS

BRO	Border Roads Organization
BIS	Bureau of Indian Standards
BMTPC	Building Materials Technology Promotion Council
CBRI	Central Building Research Institute
CRRI	Central Road Research Institute
DC	District Collector
DM	Disaster Management
DMMG	Department of Mines, Minerals and Geology
DST	Department of Science & Technology
EWS	Early Warning System
GREF	General Reserve Engineers Force
G1	Grade 1 damage
G5	Grade 5 damage
GSI	Geological Survey of India
IIT	Indian Institute of Technology
IIT-KGP	Indian Institute of Technology, Kharagpur, West Bengal
ISRO	Indian Space Research Organization
IPR	Information and Public Relations
ITBP	Indo Tibetan Border Police
ITPI	Institute of Town Planning in India
HM	Home Minister
IITB	Indian Institute of Technology, Bombay
IITR	Indian Institute of Technology, Roorkee
IMD	Indian Meteorology Department
INGO	International Non Governmental Organization
IIG	Indian Institute of Geomagnetism
JS-MHA	Joint Secretary, Ministry of Home Affairs
LR & DM	Land Revenue and Disaster Management
LS	Landslide
MHA	Ministry of Home Affairs
MoES	Ministry of Earth Sciences

MoRD	Ministry of Rural Development
MoUD	Ministry of Urban Development
NBC	National Building Code
NBCC	National Building Construction Corporation
NDMA	National Disaster Management Authority
NDRF	National Disaster Response Force
NEC	North Eastern Council
NEHU	North Eastern Hill University
NEC	North Eastern Council
NEIST	North Eastern Institute of Science & Technology
NGO	Non Governmental Organization
NGRI	National Geophysical Research Institute
NIDM	National Institute of Disaster Management
NRSC	National Remote Sensing Centre
PDNA	Post-disaster Damage and Needs Assessment
PMO	Prime Minister's Office
PWD	Public Works Department
R & D	Research and Development
RCC	Reinforced Cement Concrete
RRL	Regional Research Laboratory
RVS	Rapid Visual Screening
SDMA	State Disaster Management Authority
UD & HD	Urban Development and Housing Development
UN	United Nations
UNDP	United Nations Development Programme
UNDP DRR	United Nations Development Programme – Disaster Risk Reduction
UNDMT	United Nations Disaster Management Team
VIP	Very Important Person
VVIP	Very Very Important Person
WIHG	Wadia Institute of Himalayan Geology

EARTHQUAKE TERMINOLOGY

Acceleration

The rate of change of velocity of a reference point. Commonly expressed as a fraction or percentage of the acceleration due to gravity (g) where $g = 980 \text{ cm/s}^2$. – (USGS)

Active Fault

A fault that is considered likely to undergo renewed movement within a period of concern to humans. Faults are commonly considered to be active if they have moved one or more times in the last 10,000 years, but they may also be considered active when assessing the hazard for some applications even if movement has occurred in the last 500,000 years. (USGS)

Aesthenosphere

The highly viscous mechanically weak region of the upper mantle of the Earth. It lies below the lithosphere, at depths between 100 and 200 km below the surface, but perhaps extending as deep as 400 km. (Wikipedia)

Aftershock

Secondary tremors that may follow the largest shock of an earthquake sequence. Such tremors can extend over a period of weeks, months, or years. USGS)

Blind fault

A fault that does not extend upward to the Earth's surface. It usually terminates upward in the axial region of an anticline. If its dip is less than 45 degrees, it is a blind thrust. (IASPEI)

Body Waves

A seismic wave that propagates through the interior of the Earth, as opposed to surface waves that propagate near the Earth's surface. P and S waves are examples. Each type of wave has distinctive strain characteristics. (USGS)

Building Code

A building code, or building control, is a set of rules that specify the minimum acceptable level of safety for constructed objects such as buildings and non-building structures. The main purpose of building codes are to protect public health, safety and general welfare as they relate to the construction and occupancy of buildings and structures. A seismic code, refers to a building code which uses earthquake-resistant design principles. (USGS – CEDIM)

Continental Crust

Outermost solid layer of the earth that forms the continents and is composed of igneous, metamorphic, and sedimentary rocks. Overall, the continental crust is broadly granitic in composition. Contrast with oceanic crust. (PDC)

Critical Structures

1) Structures whose ongoing performance during an emergency is required or whose failure could threaten many lives. May include (1) structures such as nuclear power reactors or large dams whose failure might be catastrophic; (2) major communication, utility, and transportation systems; (3) involuntary- or high-occupancy buildings such as schools or prisons; and (4) emergency facilities such as hospitals, police and fire stations, and disaster-response centers. , 2) The primary physical structures, technical facilities and systems which are socially, economically or operationally essential to the functioning of a society or community, both in routine circumstances and in the extreme circumstances of an emergency. 2) Critical Loss Facilities are hospital and health care facilities, public buildings, telecommunications, airports, energy systems (coal, nuclear etc.), bridges and other facilities that are critical to the recovery and rehabilitation of a region post-earthquake. (IASPEI-UN/ISDR)

Crust

The outermost major layer of the Earth, ranging from about 10 to 65 km in thickness worldwide. The continental crust is about 40 km thick in the Pacific Northwest. The thickness of the oceanic crust in this region varies between about 10 and 15 km. The crust is characterized by P-wave velocities less than about 8 km/s. The uppermost 15-35 km of crust is brittle enough to produce earthquakes. The seismic crust is separated from the lower crust by the brittle-ductile boundary. (USGS)

Deep Earthquake

An earthquake whose focus is located more than 300 kilometers from the earth's surface. Earthquake-

report.com differs from the official notification calling earthquakes with a depth of more than 100 km as “Deep”. This is mainly because of the non-damaging impact of these earthquakes. (USGS)

Depth

The distance (usually measured in km) below the surface of the earth delineated by 0km (the mean spheroid). Also known as earthquake depth “ Earthquakes can occur anywhere between the Earth’s surface and about 700 kilometers below the surface. For scientific purposes, this earthquake depth range of 0 “ 700 km is divided into three zones: shallow, intermediate, and deep. (USGS-CEDIM)

Disaster

An event that causes major disruption on the economy, society and the environment. Its origin or causes may be directly derived from natural phenomena, i.e. geophysical (as volcanic or seismic events that cause collapse of infrastructure, landslides or liquefaction, etc.) or climatic (as hurricanes, typhoons, tornadoes, major variation in rainfall both in terms of excess or deficit causing drought). Although usually not covered by the methodology, disasters may also have a human or anthropic origin as chemical spills, industrial accidents, or voluntarily caused events such as war, terrorist actions, etc. Disaster consequences or damage will always be associated with human intervention before, during and after the event (the disaster cycle). (UN)

Duration

Time interval between the first and last peaks of strong ground motion above a specified amplitude. (EQCanada)

Earthquake

Ground shaking and radiated seismic energy caused most commonly by sudden slip on a fault, volcanic or magmatic activity, or other sudden stress changes in the Earth. An earthquake of magnitude 8 or larger is termed a great earthquake.

Earthquake Risk

The expected (or probable) life loss, injury, or building damage that will happen, given the probability that some earthquake hazard occurs. Earthquake risk and earthquake hazard are occasionally used interchangeably. (USGS)

Epicenter

The point on the Earth’s surface vertically above the point (focus or hypocenter) in the crust where a seismic rupture nucleates. (EQCanada)

Fault Plane

The surface on which the earthquake movement takes place. (CEDIM))

Fault Scarp

Steplike linear landform coincident with a fault trace and caused by geologically recent slip on the fault. (USGS)

Fault Trace

Intersection of a fault with the ground surface; also, the line commonly plotted on geologic maps to represent a fault. (USGS)

Faults

A fracture along which there has been significant displacement of the two sides relative to each other parallel to the fracture. (USGS)

Focal Depth

A term that refers to the depth of an earthquake focus. (USGS)

Ground Motion (Shaking)

General term referring to the qualitative or quantitative aspects of movement of the Earth’s surface from earthquakes or explosions. Ground motion is produced by waves that are generated by sudden slip on a fault or sudden pressure at the explosive source and travel through the Earth and along its surface. (USGS)

Gutenberg-Richter

Earthquakes appear to follow a pattern through time in terms of no. of earthquakes vs. magnitude. This is called the Gutenberg-Richter criterion. (CEDIM)

Hazard

Any physical phenomenon associated with an earthquake that may produce adverse effects on human activities. This includes surface faulting, ground shaking, landslides, liquefaction, tectonic deformation, tsunami, and seiche and their effects on land use, manmade structures, and socioeconomic systems. A commonly used restricted definition of earthquake hazard is the probability of occurrence of a specified level of ground shaking in a specified period of time. (USGS)

Hypocenter

The point within the Earth where an earthquake rupture initiates. Also commonly termed the focus. (USGS)

Intensity

A subjective numerical index describing the severity of an earthquake in terms of its effects on the Earth's surface and on humans and their structures. Several scales exist, but the ones most commonly used in the United States are the Modified Mercalli scale and the Rossi-Forel scale. (HAZUS Guidelines)

Intermediate Earthquake

An earthquake whose focus is located between 70 to 300 kilometers from the earth's surface. Earthquake-report.com differs from the official notification calling earthquakes with a depth of more than 40 to 60 km as "Intermediate". This is mainly because of the limited damaging impact of these earthquakes. (USGS)

JMA

The Japan Meteorological Agency seismic intensity scale is a measure used in Japan and Taiwan to indicate the strength of earthquakes. This scale is a numerical system, assigning earthquakes levels 0-7. (Wikipedia)

Landslide

An abrupt movement of geological materials downhill in response to gravity. Landslides can be triggered by an earthquake or other natural causes. (EQ Canada)

Latitude

Angular distance north or south from the earth's equator measured through 90 degrees. (NASA)

Liquefaction

The transformation of a granular material from a solid state into a liquefied state as a consequence of increased pore water pressures and reduced effective stress. In engineering seismology, it refers to the loss of soil strength as a result of an increase in pore pressure due to ground motion. This effect can be caused by earthquake shaking. (IASPEI)

Lithosphere

The outer solid part of the Earth, including the crust and uppermost mantle. The lithosphere is about 100 km thick, although its thickness is age dependent. The lithosphere below the crust is brittle enough at some locations to produce earthquakes by faulting, such as within a subducted oceanic plate. (USGS)

Local site conditions

A qualitative or quantitative description of the topography, geology, and soil profile at a site that affect ground motions during an earthquake. (IASPEI)

Locked Fault

A fault that is not slipping because frictional resistance on the fault is greater than the shear stress across the fault. Such faults may store strain for extended periods that is eventually released in an earthquake when frictional resistance is overcome. A locked fault condition contrasts with fault-creep conditions and an unlocked fault. (USGS)

Longitude

the arc or portion of the earth's equator intersected between the meridian of a given place and the prime meridian and expressed either in degrees or in time. (NASA)

Magnitude

A number that characterizes the relative size of an earthquake. Magnitude is based on measurement of the maximum motion recorded by a seismograph (sometimes for earthquake waves of a particular frequency), corrected for attenuation to a standardized distance. Several scales have been defined, but the most commonly used are (1) local magnitude (ML), commonly referred to as Richter magnitude, (2) surface-wave magnitude (Ms), (3) body-wave magnitude (Mb), and (4) moment magnitude (Mw). ML, Ms and Mb have limited range and applicability and do not satisfactorily measure the size of the largest earthquakes. The moment magnitude (Mw) scale, based on the concept of seismic moment, is uniformly applicable to all sizes of earthquakes but is more difficult to compute than the other types. In principle, all magnitude scales could be cross calibrated to yield the same value for any given earthquake, but this expectation has proven to be only approximately true, thus the need to specify the magnitude type as well as its value. An increase of one unit of magnitude (for example, from 4.6 to 5.6) represents a 10-fold increase in wave amplitude on a seismogram or approximately a 30-fold increase in the energy released. In other words, a magnitude 6.7 earthquake releases over 900 times (30 times 30) the energy of a 4.7 earthquake – or it takes about 900 magnitude 4.7 earthquakes to equal the energy released in a single 6.7 earthquake! There is no beginning nor end to this scale. However, rock mechanics seem to preclude earthquakes smaller than about -1 or larger than about 9.5. A magnitude -1.0 event releases about 900 times less energy than a magnitude 1.0 quake. Except in special circumstances, earthquakes below magnitude 2.5 are not generally not felt by humans. (USGS-IASPEI)

Mainshock

The biggest earthquake in a series is termed the main shock.

Mantle

The layer of rock that lies between the outer crust and the core of the earth. It is approximately 1,802 miles (2,900 kilometers) thick and is the largest of the earth's major layers. (PDC)

MMI

The Mercalli scale rates the intensity of shaking from an earthquake. The ratings vary from I (felt only under especially favourable circumstances) to XII (total destruction). (Wikipedia)

Ocean Spreading Ridge

A fracture zone along the ocean bottom that accommodates upwelling of mantle material to the surface, thus creating new crust. This fracture is topographically marked by a line of ridges that form as molten rock reaches the ocean bottom and solidifies. (USGS)

Oceanic Crust

The outermost solid layer of Earth that underlies the oceans. Composed of the igneous rocks basalt and gabbro, and therefore basaltic in composition. Contrast with continental crust. (PDC)

Oceanic Trench

A linear depression of the sea floor caused by and approximately coincident with a subduction thrust fault. (USGS)

Oscillator

A mass that moves with oscillating motion under the influence of external forces and one or more forces that restore the mass to its stable at-rest position. In earthquake engineering, an oscillator is an idealized damped mass-spring system used as a model of the response of a structure to earthquake ground motion. A seismograph is also an oscillator of this type (USGS)

P Wave

A seismic body wave that involves particle motion (alternating compression and extension) in the direction of propagation. (USGS)

Peak Acceleration

The highest acceleration in terms of value. (USGS)

PGA

The maximum acceleration amplitude measured or expected in a strong-motion accelerogram of an earthquake. (IASPEI)

Phase

(1) A stage in periodic motion, such as wave motion or the motion of an oscillator, measured with respect to a given initial point and expressed in angular measure. (2) A pulse of seismic energy arriving at a definite time. (USGS) Plate a large, relatively rigid segment of the Earth's lithosphere that moves in relation to other plates over the asthenosphere. (USGS)

Plate Tectonics

A theory supported by a wide range of evidence that considers the Earth's crust and upper mantle to be composed of several large, thin, relatively rigid plates that move relative to one another. Slip on faults that define the plate boundaries commonly results in earthquakes. Several styles of faults bound the plates, including thrust faults along which plate material is subducted or consumed in the mantle, oceanic spreading ridges along which new crustal material is produced, and transform faults that accommodate horizontal slip (strike slip) between adjoining plates. (USGS)

Preparedness

Definition: The knowledge and capacities developed by governments, professional response and recovery organizations, communities and individuals to effectively anticipate, respond to, and recover from, the impacts of likely, imminent or current hazard events or conditions. Comment: Preparedness action is carried out within the context of disaster risk management and aims to build the capacities needed to efficiently manage all types of emergencies and achieve orderly transitions from response through to sustained recovery.

Preparedness is based on a sound analysis of disaster risks and good linkages with early warning systems, and includes such activities as contingency planning, stockpiling of equipment and supplies, the development of arrangements for coordination, evacuation and public information, and associated training and field exercises. These must be supported by formal institutional, legal and budgetary capacities. The related term readiness describes the ability to quickly and appropriately respond when required. (UN/ISDR)

Prevention

Actions or investments needed in the face of imminent hazards. Distinct from mitigation, which is a permanent

strategy, prevention is seen as a pre-disaster set of activities. (UN/ISDR)

Residential

A building should be regarded as residential building when more than half of the floor area is used for dwelling purposes. Other buildings should be regarded as non-residential. Two types of residential buildings can be distinguished: * houses (ground-oriented residential buildings): comprising all types of houses (detached, semi-detached, terraced houses, houses built in a row, etc.) each dwelling of which has its own entrance directly from the ground surface; * other residential buildings: comprising all residential buildings other than ground-oriented residential buildings as defined above. (OECD)

Resilience

Definition: The ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions. Comment: Resilience means the ability to resile from or spring back from a shock. The resilience of a community in respect to potential hazard events is determined by the degree to which the community has the necessary resources and is capable of organizing itself both prior to and during times of need. (UN/ISDR)

Reverse Fault

Dip-slip faults are inclined fractures along which rock masses have mostly shifted vertically. If the rock above the fault is elevated by slip, the fault is termed reverse (or thrust fault). (USGS)

Risk

The probabilistic determination of the damages a certain hazard can cause given the existing vulnerability, location and time. (UN)

Risk Assessment

Definition: A methodology to determine the nature and extent of risk by analyzing potential hazards and evaluating existing conditions of vulnerability that together could potentially harm exposed people, property, services, livelihoods and the environment on which they depend. Comment: Risk assessments (and associated risk mapping) include: a review of the technical characteristics of hazards such as their location, intensity, frequency and probability; the analysis of exposure and vulnerability including the physical social, health, economic and environmental dimensions; and the evaluation of the effectiveness of prevailing and alternative coping capacities in respect to likely risk scenarios. This series of activities is sometimes known as a risk analysis process. (UN/ISDR)

Rupture

The instantaneous boundary between the slipping and locked parts of a fault during an earthquake. Rupture in one direction on the fault is referred to as unilateral. Rupture may radiate outward in a circular manner or it may radiate toward the two ends of the fault from an interior point, referred to as bilateral. (USGS)

S Wave Velocity

The velocity of a secondary or S wave. Generally measured in m/s. (CEDIM)

Secondary Wave

A seismic body wave that involves a shearing motion in a direction perpendicular to the direction of propagation. When it is resolved into two orthogonal components in the plane perpendicular to the direction of propagation, SH denotes the horizontal component and SV denotes the orthogonal component. Also known as S waves and shear waves. (PDC)

Seismic hazard

Risk of a certain ground motion occurring at a location (this can be defined by scenario modeling via stochastic catalogues, DSHA, PSHA or other such methods, and can include different types of earthquake effects) (CEDIM)

Seismic Risk

See earthquake risk, also the probabilistic risk is the odds of an earthquake occurring and causing damage within a given time interval and region. (EQ Canada)

Seismic Station

A ground position at which a geophysical instrument is located for an observation. (U-Milwaukee)

Seismic Waves

An elastic wave generated by an impulse such as an earthquake or an explosion. Seismic waves may propagate either along or near the Earth's surface (for example, Rayleigh and Love waves) or through the Earth's interior (P and S waves). (USGS)

Seismicity

1) The geographic and historical distribution of earthquakes. 2) A term introduced by Gutenberg and Richter to

describe quantitatively the space, time, and magnitude distribution of earthquake occurrences. Seismicity within a specific source zone or region is usually quantified in terms of a Gutenberg-Richter relationship. (ICW Group/IASPEI)

Seismogram

A record written by a seismograph in response to ground motions produced by an earthquake, explosion, or other ground-motion sources. (ICW Group)

Seismometer

A seismometer is a damped oscillating mass, such as a damped mass-spring system, used to detect seismic-wave energy. The motion of the mass is commonly transformed into an electrical voltage. The electrical voltage is recorded on paper, magnetic tape, or another recording medium. This record is proportional to the motion of the seismometer mass relative to the Earth, but it can be mathematically converted to a record of the absolute motion of the ground. Seismograph is a term that refers to the seismometer and its recording device as a single unit. (NASA)

Sequence

Pertains to the possible foreshock, main shock and aftershock occurrence and time period. (CEDIM)

Severity

Both intensity and magnitude “ i.e. the size/strength of an earthquake. (CEDIM)

Shake maps

Shake Maps, a product of the United States Geological Survey (USGS) Earthquake Hazards Program, are near-real-time maps of ground motion and shaking intensity that are produced following significant earthquakes. They appear as a set of links keyed to areas which have recently experienced an earthquake. The maps display instrumental intensity (modified Mercalli scale), peak ground acceleration, and peak ground velocity. They are downloadable as image (JPEG) or zipped postscript (PS) files, and datasets are downloadable as text, zipped shape files, KML, XML, or HTML files. Older shake maps are stored in an archive. The most recent maps are also available as RSS feeds. (DLESE)

Shallow Earthquake

An earthquake whose focus is located within 70 kilometers of the earth's surface. Earthquake-report.com differs from the official notification calling earthquakes with a depth up to 40 km as “Shallow”. This is mainly because of the possible damaging impact of these earthquakes. (Sci-Tech)

Strike-Slip

Strike-slip faults are vertical (or nearly vertical) fractures along which rock masses have mostly shifted horizontally. If the block opposite an observer looking across the fault moves to the right, the slip style is termed right lateral; if the block moves to the left, the motion is termed left lateral. (USGS)

Subduction

A plate tectonics term for the process whereby the oceanic lithosphere collides with and descends beneath the continental lithosphere. (USGS)

Surface Faulting

Displacement that reaches the Earth's surface during slip along a fault. Commonly accompanies moderate and large earthquakes having focal depths less than 20 km. Surface faulting also may accompany aseismic tectonic creep or natural or man-induced subsidence. (USGS)

Surface Wave

Seismic waves that propagate along the Earth's surface. Love and Rayleigh waves are the most common. (CEDIM)

Thrust fault

A reverse fault in which the upper rocks above the fault plane move up and over the lower rocks at an angle of 30° or less so that older strata are placed over younger. (EQ Canada)

Tsunami

An impulsively generated sea wave of local or distant origin that results from large-scale seafloor displacements associated with large earthquakes, major submarine slides, or exploding volcanic islands. (USGS)

Velocity

In reference to earthquake shaking, velocity is the time rate of change of ground displacement of a reference point during the passage of earthquake seismic waves commonly expressed in centimeters per second. (USGS)

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1. INTRODUCTION

An earthquake of M6.8 on Richter Scale hit the North Sikkim-Nepal border on September 18, 6.10PM (IST). The event, which comes under the category of “Moderate earthquake”, was widely felt in Sikkim, Assam, Meghalaya, Northern parts of West Bengal, Bihar, parts of other eastern and northern regions of India, including capital city Delhi. Wide scale also reported from neighboring countries like Nepal, Tibet, Bhutan and Bangladesh. The epicentre lies in a seismically known and active belt called, Alpide-Himalayan seismic belt. The main shock was followed by a few significant aftershocks located by the national seismological network, maintained by India Meteorological Department (IMD) and 16 more scientific organizations of the country. IMD recorded 2 aftershocks of M5.0, M4.5 within 2hrs and another of M4.2 at 3:21AM on September 19.

The seismic intensity of VIII on MMI scale corresponds to a horizontal ground acceleration range of 51-350 cm / sec² or an average acceleration of 172 cm / sec² in any direction. In MSK and EMS scales, the extent of damage is not provided in terms of discrete probabilities rather probable ranges have been provided. The ground acceleration and hence the intensity of an earthquake at a place depends on magnitude of earthquake, distance from the focus, duration of earthquake, type of underlying soil and its damping characteristics and liquefaction potential. The damage to the buildings founded on soft soil or filled up earth is higher than that in the similar type of buildings having their foundation on hard bedrock. Also, the damage will be higher for higher magnitude and long duration earthquakes, less epicentral distance, soft soil conditions and areas with high liquefaction potential.

2. Visit by NIDM team

A two member NIDM team visited the affected areas from 21 to 25 September 2011. The team met the Secretary, Land Revenue and Disaster Management, Government of Sikkim and the officials deputed at State Control Room as well as District Control Rooms in East District and North Districts of Sikkim.

On 21st Sept 2011, the team met with the Mayor of Siliguri, West Bengal and later inspected some of the distressed buildings along with officials of Siliguri Municipality. After visual inspection of several buildings the team advised to conduct detail damage survey of buildings in the North Bengal in a specified format being formulated by NIDM.

While travelling along NH-31A from Sevoke to Gangtok, the team noted atleast 21 stretches of landslides that now being used as single lane. These affected landslides sites become easy target for further deterioration during rains, thus resulting in traffic jams and

firefighting exercise with not so efficiently arranged earth removers by BRO (GREF). It was noted from 87 RCC (GREF) office that no. of equipments for maintaining and removing debris were not adequate. Yet GREF engineers did commendable task in clearing this important road (NH31A) by 19th September 2011 afternoon. The team used a handheld Global Positioning System (GPS) to know the geographic coordinates of these landslides and also noted location of landslides with reference to milestones on the road. The team also noted that ongoing road widening operations exposed several portions vulnerable to rainfall induced slides, which was got aggravated by earthquake vibrations. Drainage facilities, which is termed as arterial components of hill road safety, are found either inadequate or went beyond effective scope of regular maintenance. The conventional breast walls and gravity type stone masonry walls with mostly ineffective weep holes need revaluing of their efficacy and expenses incurred against modern technology in the slope stabilization.



Figure 1 Google map showing site visit by the NIDM team to the earthquake affected areas

3. Aim and objective

The purpose of this visit was to document the pros and cons of managing with quick response; coordination activities in search and rescue team comprising of Army, ITBP, Armed Police Force, Air Force, BRO (GREF), NDRF and other volunteer organizations; procurement, storage and distribution of relief materials as per needs and urgency;

evacuation and relief camp management; emergency operation centre (EOC) and control room facilities; coordination with NGOs and civil societies; press briefing; VIP movements, etc.

The team looks into the scope for sensitization of engineers, architects, town planners in the training and capacity building in the modern art of reinforced earth retaining walls vis-à-vis with the establishment of a research and development wing for early warning, landslides mitigation and wider application of bioengineering methods for slope stabilisation.

4. Buildings in Sikkim

Most old buildings in Sikkim are made of stone masonry with mud/cement mortar. Stone-masonry buildings suffered substantial damage during the present earthquake, and resident from more than 40 buildings were evacuated. Presently, RC-frame buildings with masonry infills are mostly used in private as well as government constructions. There is however, formal design practice for RC-frame buildings but quality of construction is not effectively checked. Except for a few RC buildings involving major projects, analysis and design are generally not carried out; structural drawings are prepared simply based on previous experiences of contractors/mason/engineers/architects on the basis of a few thumb-rules. Most of the new RC buildings in Gangtok suffered varying degree of damage during this earthquake. One new 3 storey building near Lumsey Govt. school collapsed completely during earthquake. The approach road is too small to carry out systematic demolition till date. The state Govt. is yet to device appropriate policy to cater such issues.

In rural areas of Sikkim, low-cost school buildings are generally constructed by the state government using stone masonry with mud mortar. Several such buildings suffered severe damage during the present earthquake. Earthquake resistant features such as horizontal bands at various levels and stones at the corners are generally not provided in such constructions. This resulted in the formation of severe cracks near the corners and at the location of openings in such buildings, when subjected to shaking. In addition, out-of-plane tilting of several masonry walls was observed at some places.

Majority of the buildings in Gangtok have very well defined loading frame and that is the reason for observing few cases of total collapse. However, in steep slopes foundation integrity of RC framed buildings need assessment. In RC buildings, burnt clay bricks or solid/hollow concrete blocks are commonly used as infills. Noticeable features of this type of construction are (i) absence of RC lintels above doors and windows in private buildings (brickwork is generally supported directly by the wooden frame used for doors/windows), (ii) floating columns in upper storeys, (iii) intermediate soft storey in multistoreyed buildings, and (iv) poor reinforcement detailing.



Figure 2 Buildings in Gangtok are standing as high as 8 floors on steep slopes with little or no spaces in between and having all vulnerable components such as floating walls, soft storey, irregular geometry in plan and elevation, etc. Though most of all, as shown above, are having defined load bearing members such as beams and columns, their integrity are subject to performance criteria defined by each visiting earthquake in the region.

5. The Seismo-tectonics of Sikkim Himalaya

The Indian plate boundary region is characterised by a continental collision segment along the Himalaya in the north, a complex to an oblique subduction along the Burma-Andaman arc in the East and transverse fault systems such as the Chaman fault in the northwest. In the Eastern Himalayan Region, the Indian plate converges into Tibetan plate at a rate of approximately 46 mm/yr towards the north-northeast. The preliminary focal mechanism of the earthquake suggests strike slip faulting, and thus an intraplate source within the upper Eurasian plate or the underlying Indian plate, rather than occurring on the thrust interface plate boundary between the two (Fig. 3). This region has experienced relatively moderate seismicity in the past, with 18 earthquakes of M5 or greater over the past 35 years within 100 km of the epicenter of the September 18 event, including the most recent one (M5.7) on February 14, 2006 with epicenter near Gangtok. The largest of these was a M6.1 earthquake in November of 1980, 75 km to the southeast.

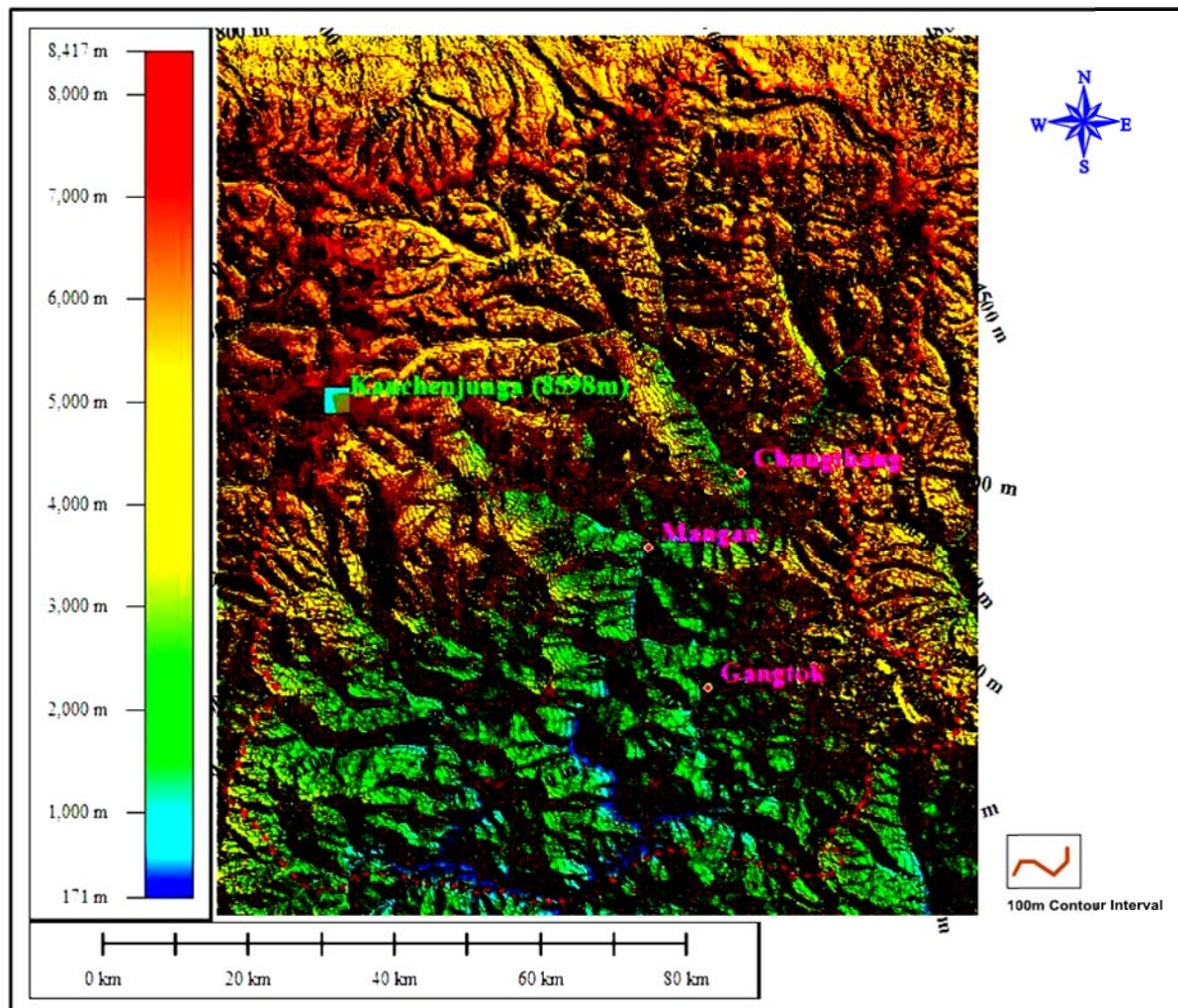


Figure 3 Digital elevation modeling showing contour of Sikkim Himalaya

6. Sikkim and its environs

Sikkim is like a stairway leading from the western border of the Tibetan plateau down to the plains of West Bengal, with a fall of about 5,215 metres in 240 kms. Sikkim, in the west is bound by the north-south spur of the Great Himalayan Range which includes the world's third highest peak, Khangchendzonga and down to its south is Singalila ridge. In the north it is bound by Dongkia range and also partly includes the Tibetan Plateau. In the east it is bound by the Chola range. Sikkim is the main catchment area for the river Teesta, which has its main source from Chho Lhamo lake in the north and is further strengthened by many streams and rivers of which Tholung, Lachung, Great Rangeet and Rangpo are important s. It also has about 180 perennial lakes, among which Khachodpalri, Gurudongmar, Chho Lhamo and Men Moi Tso are some of the most scenic (Fig. 4).

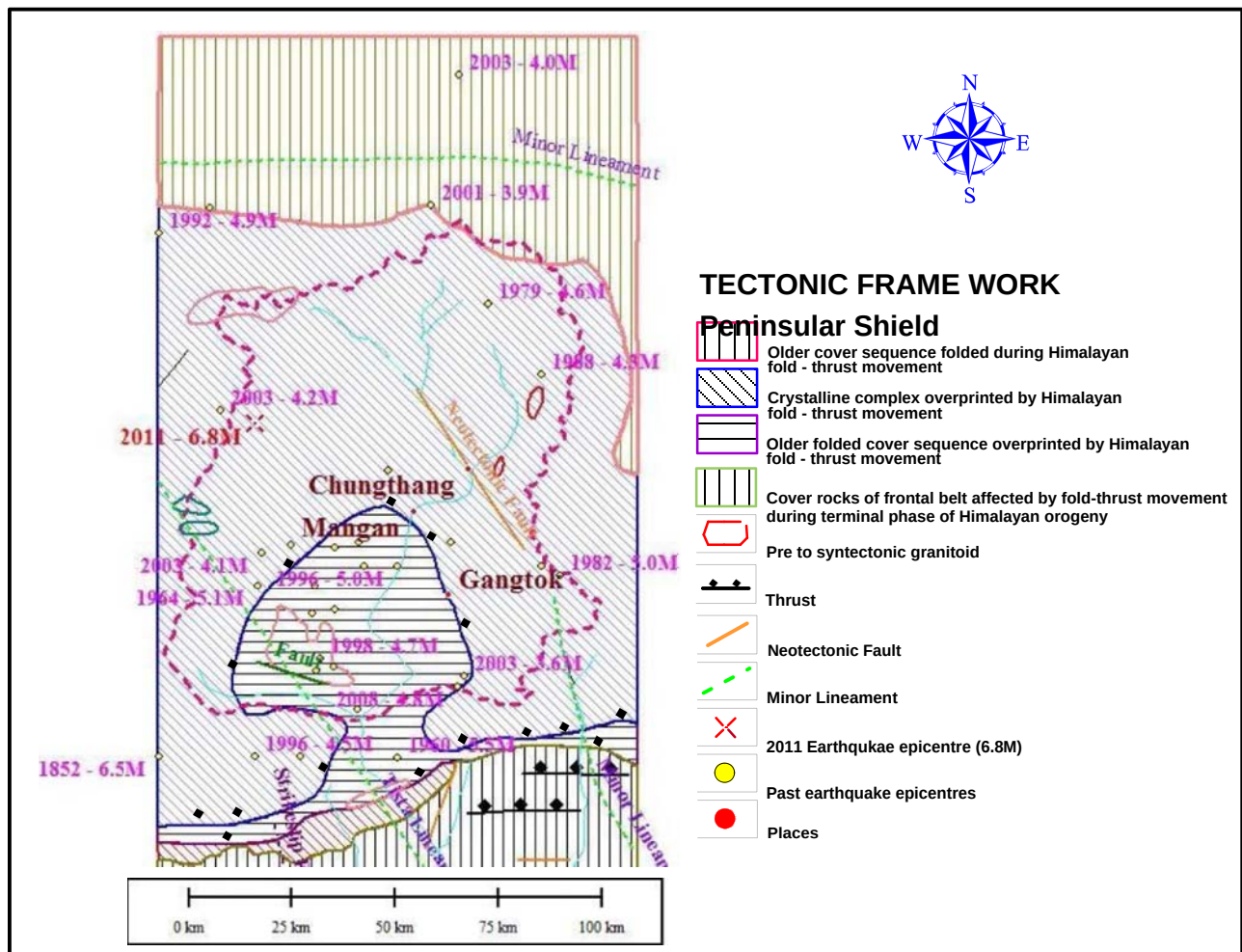


Figure 4 Seismo tectonic features of Sikkim

7. The Fateful event and emergency actions

The 2011 Sikkim earthquake was a **M_w6.9** earthquake centered within the Kanchenjunga Conservation Area between Nepal and Indian state of Sikkim. The earthquake was felt across northeastern India, Nepal, Bhutan, Bangladesh and southern Tibet. Indian army helicopters ferried rescuers and dropped food and supplies to still-inaccessible villages in Sikkim, a sparsely populated and almost entirely mountainous region. At least 91 people were killed in the earthquake. Most of the deaths occurred in Sikkim, with reports of fatalities in and near Singtam in the East Sikkim district. Several buildings collapsed in Gangtok. Eleven are reported dead in Nepal, including three killed when a wall collapsed in the British Embassy in Kathmandu. Elsewhere, structural damage occurred in Bangladesh, Bhutan, and across Tibet; another seven fatalities were confirmed in the latter region.



Figure 5 Hon'ble Prime Minister and Home Minister along with Hon'ble Vice Chairman, NDMA visited Sikkim respectively on 22nd and 29th September 2011

Hon'ble Home Minister Shri P. Chidambaram held a meeting with Shri Pawan Chamling, Hon'ble Chief Minister of Sikkim, at Gangtok. After reaching Gangtok, Shri Chidambaram met with the injured at SNTM and Sikkim Manipal Hospital. Home Minister announced Rs. 50 crore assistance to Sikkim Govt. and assured every kind of help they needed to restore normalcy. He also did an aerial survey to see the most damaged areas in the north district. Hon'ble Prime Minister of India visited Sikkim on 29th September 2011 and announced Rs 1000 cr package for immediate restoration of damaged infrastructure like road, buildings, schools, water supply and power lines. He also directed BRO to restore North Sikkim highway to be operational by October 15, 2011. An eight member central team led by Shri Shambhu Singh, JS-MHA, toured the affected region.

Sources in control room in North District said at least 13 villages on the Mangan-Djongu side remained inaccessible as well as along Mangan-Lachen route in the worst-hit district with intermittent rains and landslips blocking arterial roads at many areas.

Government of India through its Ministry of Home Affairs has been coordinating the earthquake response along with the Armed Forces – ITBP, Army, Police, NDRF, Airforce. At the district level, respective District collector is the incident commander and Secretaries of the State Government have been designated in each district to coordinate the relief efforts. National Crisis Management Committee chaired by the Cabinet Secretary and National Crisis Management Group headed by the Home Secretary. Meetings of both groups were being held on a daily basis to review the situation and response. The UN Resident Coordinator's office also issues situation reports. A UNDP focal point is in Sikkim assisting local coordination. The UNDMT is reviewing existing and emerging needs. Coordination support is being extended to the government at the local level through the on-site UNDP DRR Programme.

8. Sikkim Earthquake an Unusual Seismic Event?

The earthquake activity in this region is due to the Indian plate diving (thrusting) beneath the Eurasian plate. Sikkim is spread out on the Himalayan mountain range with two main thrust faults, the Main Boundary Thrust (MBT) and Main Central Thrust (MCT) crossing the state. Continuous thrusting of the Indo-Australian plate against the Eurasian plate has made most parts of the Himalayan collision zone seismically active. Sikkim is a part of this zone; therefore it had been a moderately active seismic region in historical times. Significant earthquakes in the region in the last 50 years include the 19 November 1980 Sikkim earthquake of *Mb* 6.0, and 21 August 1988 Bihar–Nepal earthquake of *Mb* 6.5. Thus, Sikkim is located in seismic zone IV of the Indian seismic zoning map, with the expected maximum intensity of shaking as VIII on the MSK scale. This region has experienced relatively moderate seismicity in the past, with 18 earthquakes of *M* 5 or greater over the past 35 years within 100 km of the epicenter of the September 18 event. The largest of these was a *M*6.1 earthquake in November of 1980, 75 km to the southeast.

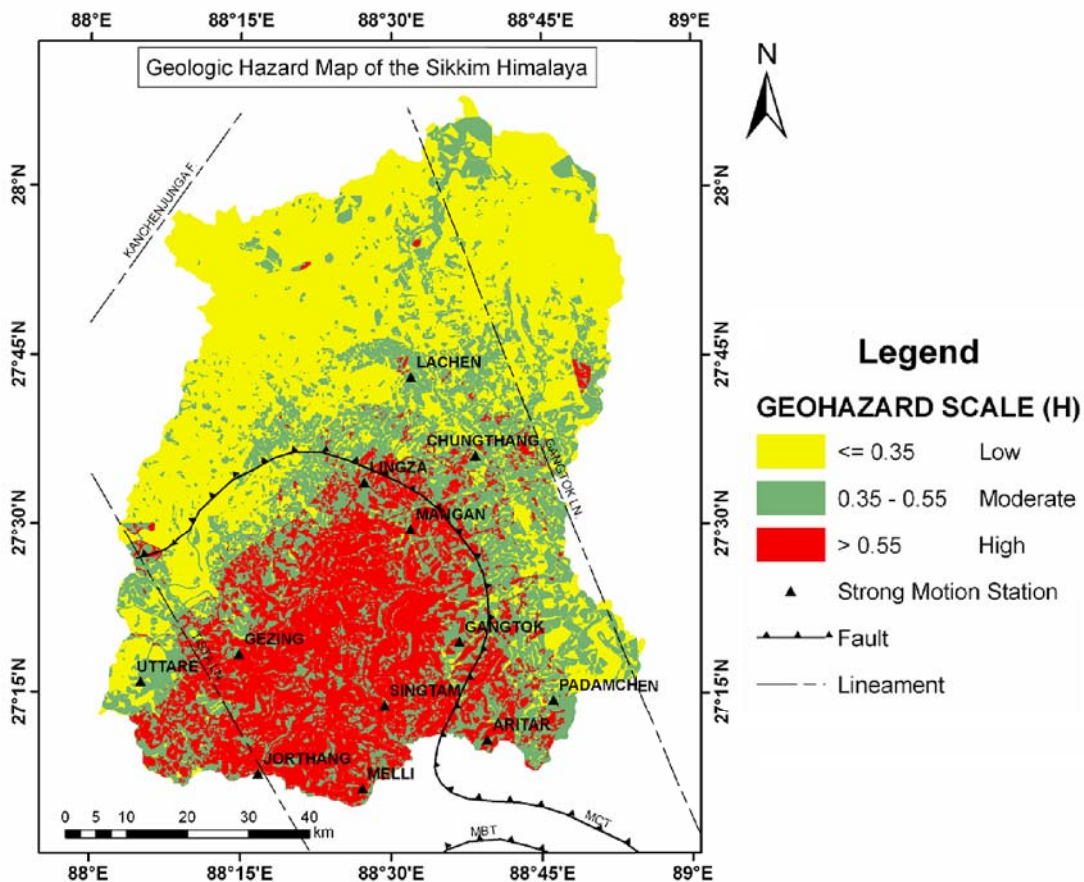


Figure 6 Seismic Hazard map of Sikkim (Nath et al, 2008)

The earthquake that rocked Sikkim Sunday is unusual in terms of its magnitude and nature of origin, says leading geologists "There is nothing surprising in this earthquake as the region north of Sikkim, which forms the outliers of Tibetan tectonics, is known for moderate earthquakes in the past," C.P. Rajendran at the Indian Institute of Science. These earthquakes are different in the sense they are along the somewhat north-south structures trending transverse to the east-west Himalayan axis, Rajendran said. They are different from the usual Himalayan thrust earthquakes that are caused by the collision of the Indian plate with the Eurasian plate. "Having said that, the fact remains that some historically earthquake-deficient parts of the Himalayas has the potential to generate large earthquakes any time, irrespective of the present earthquake," Rajendran cautioned.

Sikkim earthquake occurred between two transverse faults represented by Teesta and Gangtok lineaments where two segments of Himalayas have moved in a horizontal direction. Vineet Gahaulat at the National Geophysical Research Institute (NGRI) in Hyderabad said: "The (Sikkim) earthquake highlights the presence of the role of transverse features in the Himalayas." "This Mw6.9 earthquake possibly occurred on a northwest-southeast trending almost vertical fault through strike slip motion." Although the

transverse faults were also the result of under-thrusting of the Indian plate, this was the first time that a major earthquake had occurred along them in Sikkim region, according to R.K. Chadha, Chief Scientist, CSIR-National Geophysical Research Institute (NGRI) which deputed a team of five scientists to the affected region following the earthquake to carry out field investigations. The team has set up a network of four broadband seismic stations.

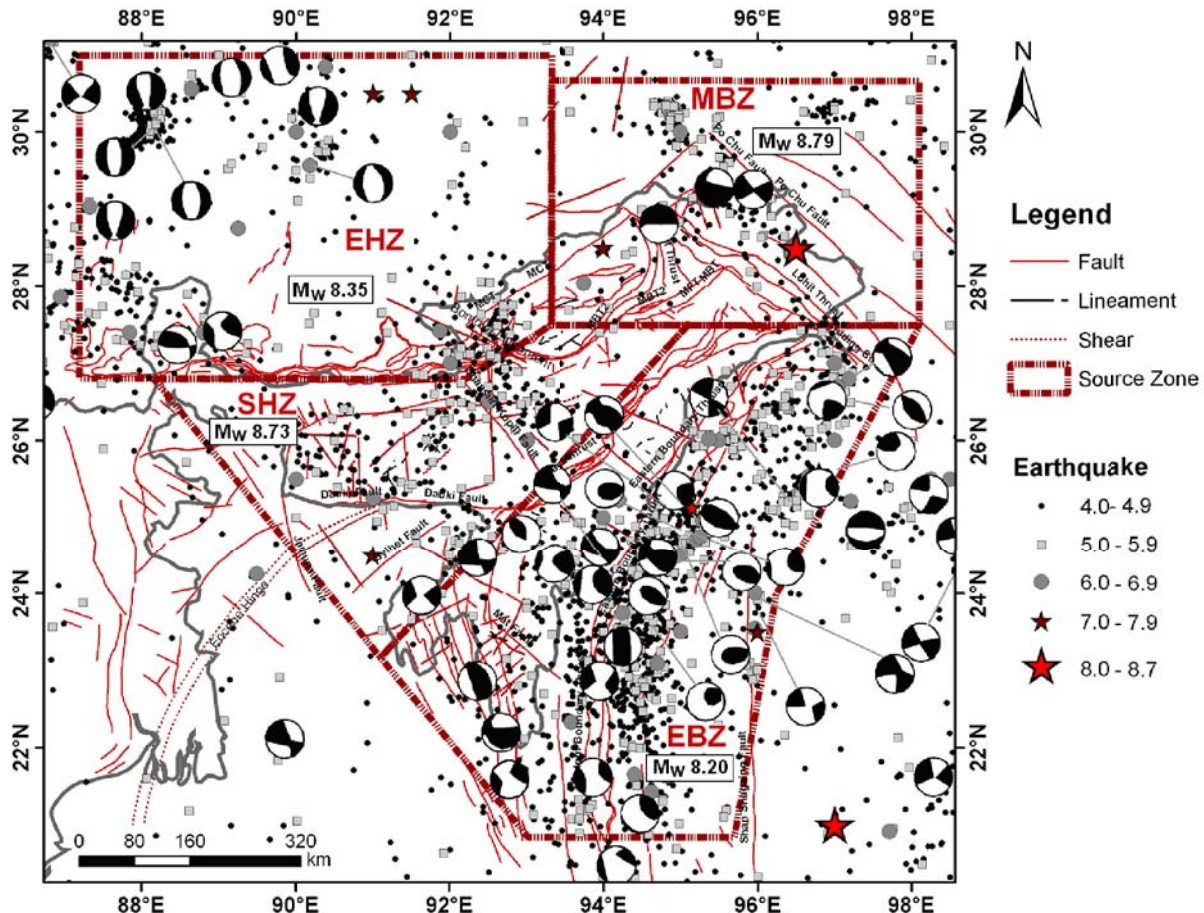


Figure 7 Seismo tectonic activities of Sikkim and adjoining region (Nath et al, 2008)

The entire Himalayan belt is one of the most seismically active regions in the world. In the last 110 years, four great earthquakes (magnitude equal to or greater than 8.0) have occurred along this subduction zone causing largescale damage in the surrounding areas^{5,6}. These are the 1897 Shillong (M 8.0), 1905 Kangra (M 7.8 to M 8.0), 1934 Bihar–Nepal (M 8.1), and 1950 Assam (M 8.5) earthquakes. The area between the 1934 and 1950 events (Sikkim falls in this region) stands out as a seismic gap that has not produced any major earthquake in the historical times. Another known seismic gap is in the area between the 1905 and 1934 events. There is a high probability of a major event in these seismic gaps in near future. It has been reported that there were large-scale damages (intensity VII and above) in Sikkim after the 1897 and 1934 events. It may be mentioned here that even smaller earthquakes of 1980 (Sikkim, M 6.0) and 1988 (Bihar–Nepal, M

6.5), have caused damage in Sikkim. Therefore, there is possibility of widespread damage in the state during another major event in the seismic gap regions near Sikkim.

9. Seismic Zonation of Sikkim

Based on the history of occurrences of earthquakes the country has been classified into different zones indicating the intensity of damage or frequency of earthquake occurrences. These zoning maps indicate broadly the seismic coefficient that could generally be adopted for design of buildings in different parts of the country. These maps are based on subjective estimates of intensity from available information on earthquake occurrence, geology and tectonics of the country. The Indian seismic zoning is a continuous process which keeps undergoing changes as more and more data on occurrence of earthquakes becomes available.

Considering the recorded history of earthquakes in the country, seismologists have classified 59% of the land mass of India as prone to earthquakes of different magnitudes – 11% in very high risk zone V, 18% in high risk zone IV and 30% moderate risk zone III. The capital cities of Guwahati and Srinagar are located in seismic zone V, while national capital of Delhi is in zone IV and the mega cities of Mumbai, Kolkata and Chennai are in zone III. 38 cities with population of half a million and above each and a combined population of million are located in these three regions (Fig. 8)

Seismic Zone Map of India: -2002

About **59 percent** of the land area of India is liable to seismic hazard damage

Zone	Intensity
Zone V	Very High Risk Zone Area liable to shaking Intensity IX (and above)
Zone IV	High Risk Zone Intensity VIII
Zone III	Moderate Risk Zone Intensity VII
Zone II	Low Risk Zone VI (and lower)

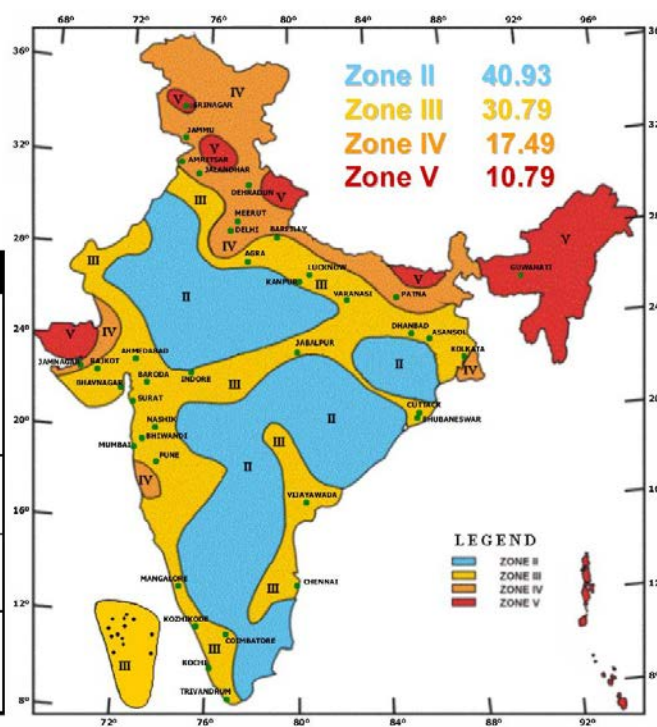


Figure 8: Macro-Seismic zonation map of India with Sikkim falling in Zone –IV (high risk with potential for MSK intensity as high as VIII)

Table 1 : Distribution of Indian earthquakes in the last 110 years, indicating one M5+ earthquake occurring in less than every 4 months in the North East region

Seismic Regions in India	No. of Earthquakes of Magnitude				Return Period
	5.0-5.9	6.0-6.9	7.0-7.9	8.0+	
Kashmir & Western Himalayas	25	7	2	1	2.5-3 yrs.
Central Himalayas	68	28	4	1	1 yrs.
North East India	200	128	15	4	<4 months
Indo-Gangetic Basin and Rajasthan	14	6	-	-	5 yrs
Cambay and Rann of Kutch	4	4	1	1	20 yrs.
Peninsular India	31	10	-	-	2.5-3 yrs.
Andaman & Nicobar	80	68	1	1	<8 months

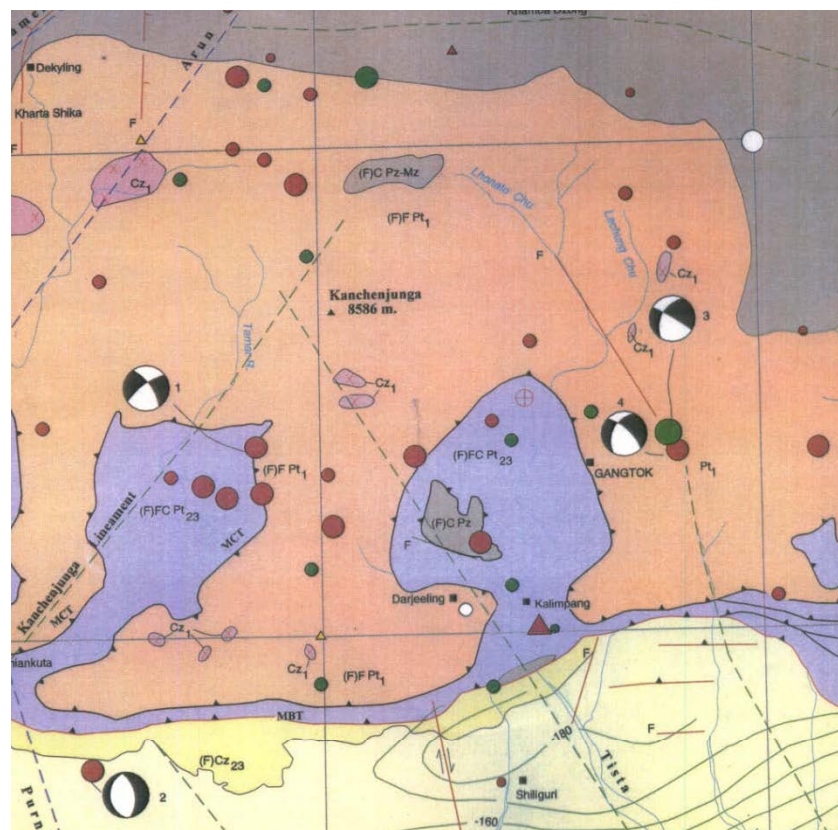


Figure 9 Seismo-tectonic map of India – Sikkim region (GSI Atlas, 2000)

The high seismicity of the northeast Indian region has been attributed to a complex tectonic province displaying juxtaposition of the E-W trending Himalaya and the N-S trending Arakan Yoma belt (Nath et al, 2008). The major tectonic background includes the Eastern Himalayan structures, the Mishmi massif, the Indo Myanmar arc, the Brahmaputra valley, and the Shillong plateau. The Himalayan structures mainly consist of the thrust planes namely the Main Central Thrust (MCT), Main Boundary thrust (MBT), Main Frontal Thrust (MFT), and their subsidiaries (Nandy 2001). The movement along the Po Chu fault, in the North Eastern part of the region, is believed to have caused the 1950 Great Assam Earthquake of **MW** 8.7 (Ben-Menahem 1974; Thingbaijam *et al* 2008). The Shillong plateau has been implicated with a pop-up tectonics associating the 1897 Great Earthquake of **MW** 8.1 (Bilham and England 2001). The southern end of the Kopili fault is believed to have generated the 1869 Cachar earthquake of **MW** 7.4. The Indo-Myanmar arc, sidelined by Patkoi-Naga-Manipur-Chin hills, has been associated with 1988 Manipur Earthquake of **MW** 7.2.

Nath et al (2008) carried out a comprehensive analytical as well as numerical treatment of seismological, geological, geomorphological and geotechnical concepts of the Sikkim Himalaya, representing cases of contrasting geological backgrounds - hilly terrains and predominantly alluvial basin respectively. The estimated maximum earthquakes in the underlying seismic source zones, demarcated in the broad northeast Indian region, implicates scenario earthquakes of M_w 8.3 and 8.7 to the respective study regions for deterministic seismic hazard assessments. The geomorphological themes for the Sikkim Himalaya include surface geology, soil cover, slope, rock outcrop and landslide integrated to achieve geological hazard distribution. Seismological themes, namely surface consistent peak ground acceleration and predominant frequency were, thereafter, integrated with the geological hazard distribution to obtain the seismic hazard microzonation map of the Sikkim Himalaya. The five broad qualitative hazard classifications - 'Low', 'Moderate', 'High', 'Moderate High' and 'Very High' could be applied in both the cases, albeit different implications to peak ground acceleration variations (Fig. 10) (Nath et al, 2008).

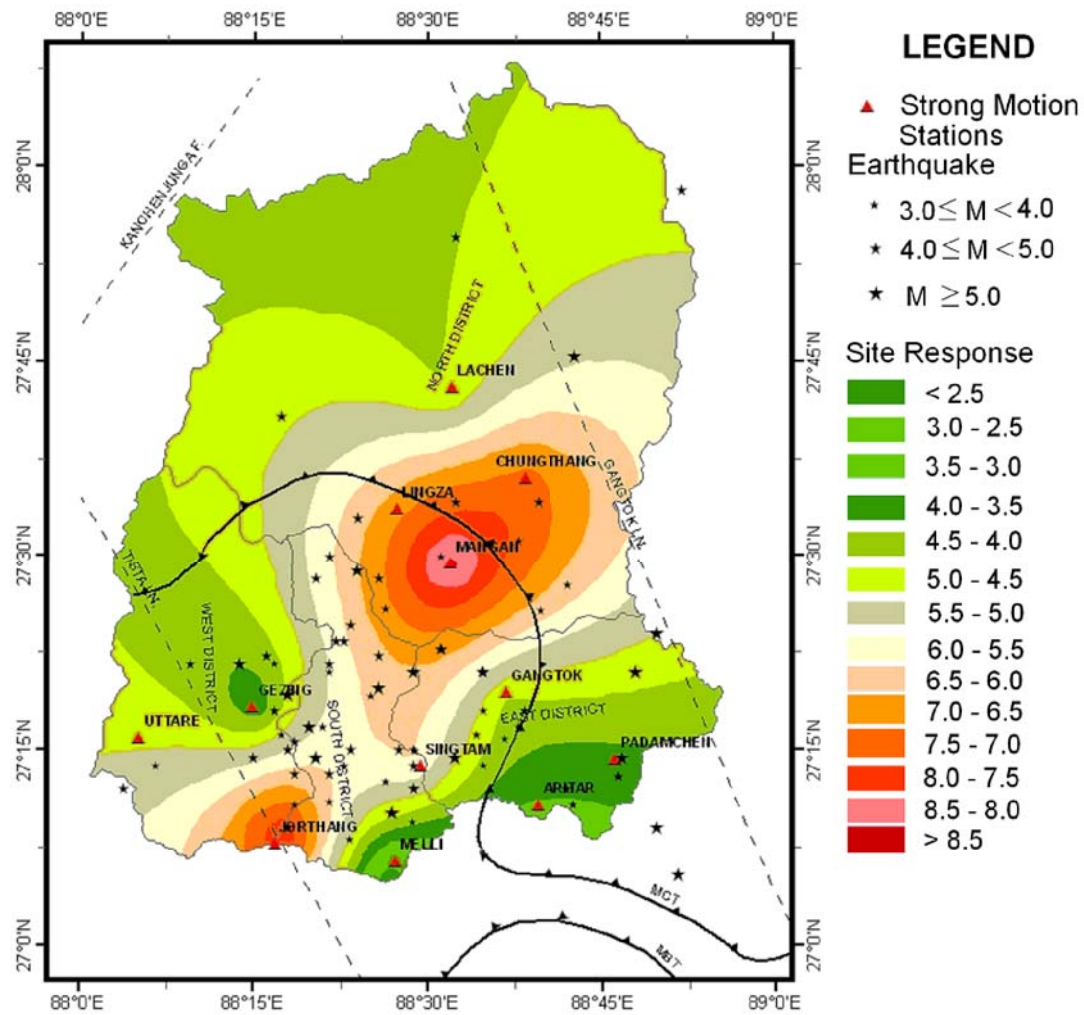


Figure 10 Site response showing predominant frequencies (Nath et al, 2008)

Box -1: M6.9 Bhuj (2001) Earthquake

Five districts in the State of Gujarat were severely impacted, but the worst affected was Kutch, where more than 90 percent of the deaths and 85 percent of the asset losses occurred. This district is a sparsely populated region, poor in natural resources (in a relatively rich state), and vulnerable to cyclones and drought, as well as earthquakes. The 6.9 magnitude earthquake struck in a second consecutive drought year. Four towns, including the district's largest – Bhuj and more than 400 villages were severely hit, destroying lives, infrastructure, buildings, the economy, and livelihoods. The death toll was nearly 14,000, and 167,000 were injured. More than 1.2 million homes were damaged or destroyed. So were small enterprises, schools, health clinics, rural and urban water systems, and electricity and telecommunications systems. While the greatest asset losses were in the housing sector, the livelihoods of many families were also disrupted. A joint assessment by the World Bank and Asian Development Bank a month later found that 19,000 handicraft artisans and several thousand salt farmers in Kutch were the most severely affected. Some 20,000 cattle deaths were also reported, the loss of another important source of livelihood.

Bhuj was one of the worst affected towns in the district; almost 50 percent of its walled city alone was considerably damaged. Over 7,000 people perished in Bhuj, most of them in the walled city area, as buildings constructed of stone and mud collapsed on extremely narrow streets. The lack of an effective street pattern was a major obstacle to disaster management in the earthquake's aftermath. Over the years, poorly framed building regulations had been weakly enforced, and this had exacerbated congestion in the city. Many historic buildings had to be demolished during the rubble removal, making retracing the original street form and architectural character difficult

Local Governance paralysed

Many Bhuj municipal buildings were destroyed, and records were lost. The municipality lost several staff, and other staff members lost their families and suffered injuries. The municipality lacked the internal capacity to take the lead in relief, rehabilitation and reconstruction activities. Bhuj's societal structure is fractured along the lines of community groups and economic interests. The petty interests of such rival groups often compromised the principle of the common good. No strong political leadership emerged in the process. However, these caste-based and special interest groups contributed significantly to recovery by leading localized relief and rehabilitation activities for their constituent communities.

(adapted from “Reconstruction of Bhuj”, B.R. Balachandran)

Box 1 (contd.)**Social and Economic Infrastructure**

Social assets (both public and private sector) such as schools, hospitals, community halls, town halls, markets, libraries, colleges, recreational buildings (a local gymkhana, an open-air theatre) and religious buildings were badly affected. However, the community facilities that *did* survive were quickly made available to the city by community groups. Since such places are the first refuge for people needing shelter, this demonstrates the enormous value in strategizing the future provision of social assets designed to withstand disasters and managed either by local government or local institutions themselves.

Physical Infrastructure

Water and sewer networks in the old city were badly damaged, ironically more during the movement of heavy machinery to demolish damaged buildings and to remove debris than during the earthquake itself. Outside the old city, too, important facilities such as reservoirs, pipelines, telephone exchanges and power infrastructure were damaged. However, the trunk lines in these networks survived with minor damage, enabling the quick restoration of services. Buildings and infrastructure networks had not been designed specifically to withstand an earthquake's impact and neither had the possibility to isolate – and separately repair – badly affected components of the infrastructure system.

Urban Planning and Development Regulation

The state government found itself searching for an appropriate regulatory framework in the absence of specific regulatory measures that would respond quickly to the earthquake and the complex challenges of reconstruction. The previous development plan for Bhuj had been prepared twenty-five years earlier. Its strategy was outdated, and its maps did not reflect the city's present-day vastly expanded limits; the old plan would need to be completely revamped to respond to new needs. To compound matters, citizens showed little respect for a municipality that had a record of poor enforcement of whatever regulations had earlier existed, and as a result unregulated development in the months following the earthquake have proven difficult to control. Citizens showed no culture of conforming to rules that should apply to society as a whole, in a disaster situation or otherwise. All said and done, the earthquake gave the state government an opportunity to completely rethink the applicability of existing planning, regulatory and development mechanisms in an unlikely context.

“Build Back Better” – Defining Basic Principles and Policy for Reconstruction

- To build the city back better, applying a policy of encouraging partial relocation and partial *in situ* reconstruction.
- To continue with the city's existing infrastructure, repairing and revamping it after the earthquake so that it is better managed responds better to natural disasters. This approach would save the government the considerable expenditure of building new infrastructure in the aftermath of a future disaster.
- To improve building construction quality so that it incorporates earthquake-resistant technologies and adheres to regulatory norms.
- Assist people in the reconstruction process; help them to understand statutory requirements in planning, build consensus, and frame projects that respond to people's concerns and needs.
- Make the planning process as participatory as possible, by encouraging public - private partnerships, building fora at which citizens can participate in decision making and voice their concerns; and build a modicum of public trust in the process to ensure implementation.



Figure 11 One 3 storey newly constructed building near Lumsey primary school, Gangtok collapsed during earthquake. Reason for failure not known yet. Approach road for demolition equipments are not available. Debris are precariously retained till date by few trees, main trunk of which were cut by electric power department

10. Seismo-tectonics of NE Himalaya

At its location, the continental Indian and Eurasian Plates converge with one another along a tectonic boundary beneath the mountainous region of northeast India near the Nepalese border. Although earthquakes in this region are usually interplate in nature, preliminary data suggests the Sikkim earthquake was triggered by shallow strike-slip faulting from an intraplate source within the over-riding Eurasian Plate. Initial analyses also indicate a complex origin, with the perceived tremor likely being a result of two separate events occurring close together in time at similar focal depths.

Located at a shallow depth beneath the surface, the earthquake caused strong shaking in many areas adjacent to its epicenter reportedly lasting 30–40 seconds. The strongest shaking occurred to the west in Gangtok and further south in Siliguri, although similar ground motions registering at MM VI (strong) on the Mercalli scale were recorded in many smaller towns such as Mangan across elevated regions. Lighter tremors (MM IV–III) spread southward through populous regions, with these motions reported in the Patna capital of Bihar and as far southwest as Bihar Sharif. In all, the earthquake was felt in Nepal, India, Bhutan, Bangladesh and China. Tremors were felt in Assam, Meghalaya, Tripura, parts of West Bengal, Bihar, Jharkhand, Uttar Pradesh, Rajasthan, Chandigarh and Delhi. In Tibet, the earthquake was felt in Shigatse and Lhasa.

While the river Teesta flows in a north-south direction, the Himalayan fault lines lie in the east-west direction. A major fault line is located at Kalijhora (considered the best location to study Himalayan fault lines) and Teesta Low Dam Stage 4 is located at Kalijhora. “The sheer weight of water can trigger a seismic movement,” Paul said. This has happened in the past. In the sixties, a major earthquake in Maharashtra was triggered by the Koyna dam located on the Sahyadri Hills. Though the role of the dams on the River Teesta in the recent quake has yet to be studied, the earthquake could have been induced or accelerated by what scientists describe as ‘dam induced seismicity.’ Globally, there are over 90 identified sites of earthquakes triggered by the filling of water reservoirs.

10.1 Significant earthquakes in Sikkim and adjoining region

The earthquake measuring 6.8 on the Richter Scale, which hit the east and north east (NE) region, was the biggest in 20 years. Records of Central Seismological Observatory here showed increasing seismic activity in the region. A total 34 quakes of light and moderate intensity were felt in the region in 2009. The area witnessed 26 earthquakes each in 2008 and 2007, while it was 23 in 2006, the data showed.

On February 4 this year, a quake of 6.4 magnitude with its epicentre in the Indo-Myanmar border in Manipur shook the region. An earthquake of similar intensity (6.8) had rocked the northeast on August 6, 1988.

On October 11, 2000 a quake of 6.0 intensity was felt in the region, while on September 21, 2009, another measuring 6.2 had claimed six lives in neighbouring Bhutan, where it was epicentred. The north eastern region had experienced some of world's worst quakes like the Shillong quake and the Assam quake of 1950 both measuring around 8.5. An earthquake in 1897 in Shillong plateau had left 1,542 people dead.

15 January 1934 - Indo-Nepal Border region, Mw 8.0

14:21:25 IST / 08:43:25 UTC, 26.50N, 86.50E

Nearly 10,500 people were killed in Bihar and Nepal. Damage was also reported from many towns in Sikkim.

12 January 1965 - West of Gangtok (Indo-Nepal Border region), 6.1 (TS)

13:32:24 UTC, 27.60N, 88.00E

19 November 1980 - Near Gangtok (Sikkim-West Bengal Border region), 6.1 Ms (PAS)

19:00:46.9 UTC, 27.39N, 88.75E, 17 kms depth

Eight people were injured in Gangtok and there was also minor damage reported from the city. The quake was felt in eastern and north-eastern India, Bangladesh, Bhutan and Nepal.

21 August 1988 - Udaipur Gahri, Nepal (Indo-Nepal Border region), Mw 6.8 (NEIC)

23:09:09 UTC / 04:39:09 IST, 26.755N 86.616

Nearly 900 people were killed in the border districts of Nepal and Bihar, India. Damage was also reported from Kathmandu and Sikkim. Felt over much of northern and eastern India and much of Nepal. Felt as far as New Delhi.

14 February 2006 - Mana, North Sikkim, Mw 5.3

27.377 N, 88.362 E, D=020.1 kms, OT=00:55:23 UTC

A moderate earthquake struck the Sikkim Himalayas on 14 February 2006 at 06:25 AM local time resulting in two deaths and minor damage to property in the state of Sikkim, India. It had a magnitude of Mw=5.3. This is the strongest earthquake in this immediate region since a Mw=6.3 earthquake on 19 November 1980.

18 May 2007 - Nambu, North Sikkim, Mb 4.6

27.302 N, 88.159 E, D=021.1 kms, OT=12:40:02 UTC

A light earthquake struck the Sikkim Himalayas on 18 May 2007 at 18:10 PM local time resulting in some panic in the state of Sikkim, India. It had a magnitude of Mb=4.6.

20 May 2007 - Singyang, North Sikkim, Mb 5.0
27.303 N, 88.191 E, D=021.1 kms, OT=14:18:18 UTC

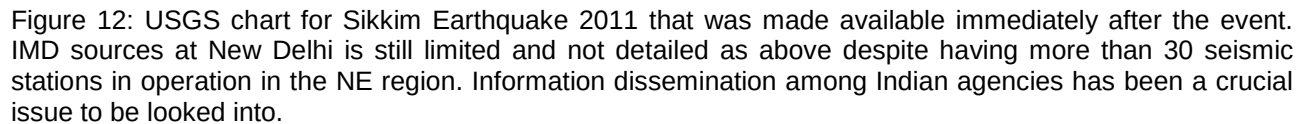
A moderate earthquake struck the Sikkim Himalayas on 20 May 2007 at 19:48 PM local time resulting in some panic and minor damage in the state of Sikkim, India. It had a magnitude of Mb=5.0. Fig. 7 shows the position of all the earthquakes in NE region.

11. Aftershocks and shaking intensity

Sikkim experienced three aftershocks since the earthquake, occurring at magnitudes of 5.7, 5.1, and 4.6 (M_w) within 30 minutes of the initial earthquake. Kathmandu experienced two aftershocks that both had a magnitude of 4.8 M_w . The aftershocks had no serious impact in the region. At least 20 aftershocks back-to-back throughout the night created panic in the Gangtok. Many prefers to stay on the street even when they are flanked by multistory buildings on both sides.

In Sikkim, major damage occurred in the district of North Sikkim including in the Mangan-Chumthang-Singtam area along with several significant landslides and rock falls. Modern buildings were heavily damaged at Chumthang and Jorhang. Media reports claimed a number of villages north of Mangan such as Sakyong, Naga have been entirely destroyed and roads are completely obliterated. Search and rescue operation are still going on by Army helicopter. In Gangtok, the earthquake caused widespread panic with many running outdoors. A number of structures in the city were badly damaged and some precariously perched buildings completely collapsed down hillsides. On 23rd September one building collapsed and affected another one. Highways and other roads were blocked by landslides and rock falls. At many stretches NH31A is functioning as one lane and the severity of traffic mounts up as it rains.

In North Bengal, the earthquake caused some damage, a few fatalities and many injuries in the Darjeeling, Jalpaiguri, Kalimpong and Siliguri areas. Many people ran outdoors and a number were struck by falling masonry. Damage also occurred in a number of tea estates in the region with at least one fatality was attributed to the complete collapse of a building in the Nideen Tea Estate. A levee was also damaged near Jalpaiguri. Severe tremors were felt in most parts of the region including at Alipurduars, Dim Dam, Mal Bazaar, Matabhanga and other places. This is the most damaging earthquake to have affected north Bengal since the 1930 Dhubri earthquake. Southward, damage was reported in West Bengal from Maldah, Murshidabad and Uttar Dinajpur. As far south as Kolkata, a few buildings developed cracks and people ran out of high-rise buildings (ASC-India).



Shaking from this earthquake has been felt over a large part of the Subcontinent including as far west as Ahmedabad, Ajmer, Jaipur and Indore in western India and as far south as Nagpur in central India. In lower Assam, the shock was severely felt with damage reported at Dhubri. Many modern apartment buildings were damaged in the city of Guwahati. Seismic seiches were observed in the Brahmaputra River in central Assam during the earthquake. In north-eastern India, the earthquake was felt at Itanagar in Arunachal Pradesh, at Dimapur, Mokochung and Kohima in Nagaland, at Imphal in Manipur and at Jowai, Shillong and Tura in Meghalaya. Buildings developed cracks or isolated wall collapses occurred in the districts of north Bihar such as Araria, Madhubani, Katihar, Samastipur, Sitamarhi and Purnea. Damage and widespread panic also occurred in the districts of Bhagalpur, Munger and Patna. Similarly in Jharkhand, damage was reported from Dhanbad, Godda, Hazaribagh, Ranchi and north-eastern parts of the state. Shaking was relatively strong in many parts of eastern Uttar Pradesh including at Deoria, Ghazipur,

Gorakhpur, Siddharthnagar and Varanasi. Westward it was felt lightly or by people in tall buildings in places such as Agra, Aligarh, Amethi, Farukhabad, Lucknow, Kanpur and Rai Bareilly. In Madhya Pradesh, it was felt in districts adjoining Uttar Pradesh such as Bhind, Datia and Gwalior as well as in tall buildings in Bhopal, Jabalpur, Hoshangabad and Indore. In Chhattisgarh, the earthquake was strongly felt in the northern part of the state and caused minor damage in the Bilaspur area. In other parts of India, the earthquake was felt in tall buildings in the Bhubaneswar-Cuttack area in Orissa and in Delhi, Ghaziabad, Faridabad and Gurgaon in the NCR (ASC-India).

In Bangladesh, the earthquake caused panic in the northern districts in Rajshahi division. Many people were hurt in stampedes at places such as Gaibandha and Rangpur. Elsewhere, buildings sustained minor damage and isolated wall collapses were reported from Brahmanbaria, Bogra, Lalmonirhat, Natore, Nilphamari, Kishorganj and Panchagarh. In the capital Dhaka, people in tall buildings ran outdoors in panic. Minor damage is believed to have been sustained by a few high-rise buildings in the city. Southward, the shock was perceptible at places such as Barguna and Chittagong. Seismic seiches were observed in rivers in the Sunderbans (ASC-India).

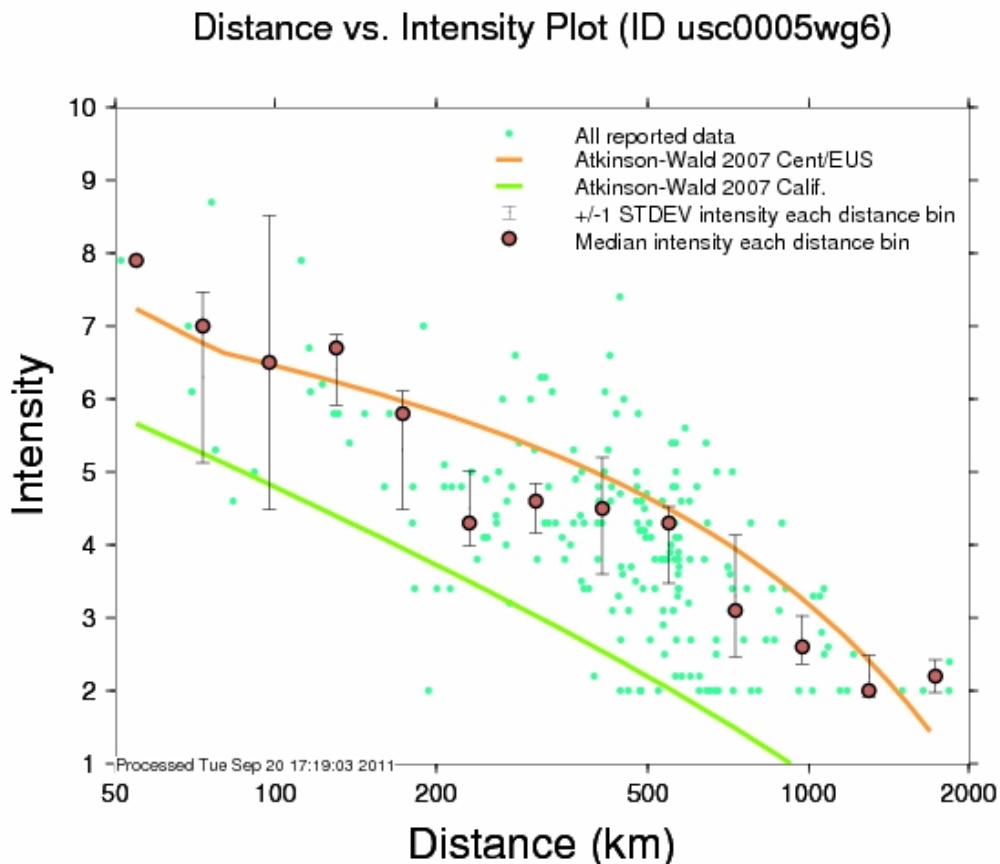


Figure 13 Distance vs intensity plot for Sikkim earthquake (USGS)

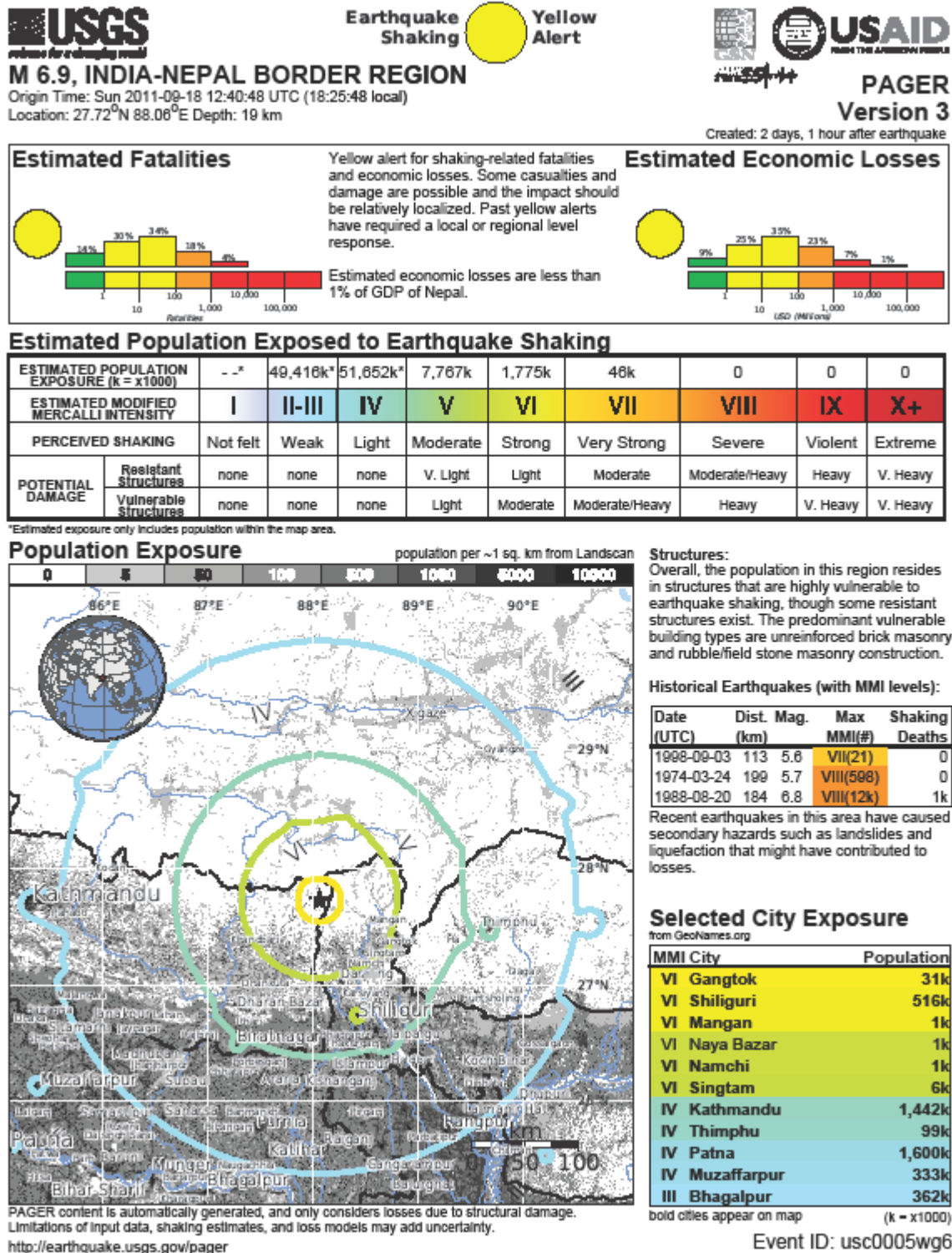


Figure 14 PAGER plot for Sikkim Earthquake (USGS)

12. Rescue and relief operations

Nine helicopters were mobilised and 10 doctors airlifted to Chungthang in North Sikkim. The Army has also deployed 10 medical units. The enormity of the damage is finally emerging, besides the loss to human lives. Aerial pictures showed that the earthquake ripped apart the landscape in the stretch between Gangtok and Chung Thang, causing cracks, landslides and much destruction. The pictures also showed the destruction at the Teesta Dam site where several people lost their lives. At Chung Thang in North Sikkim, one of the worst affected sites, a school building one of the worst affected structures. 120 columns of Army including 10 engineering columns have also been deployed in restoration/relief work

The Armed Forces have mobilized rescue and relief operation on a war footing. Two MI-17 helicopters of the IAF carried relief material and National Disaster Relief Force (NDRF) to Lachen and Mangan, the interior regions of North Sikkim. Over 5,000 army personnel, including ten columns of army engineers each comprising 15-20 personnel, were pressed into rescue operations immediately after the first tremors were felt. Troops stationed in the area have provided shelter to over 1,500 people including 1,000 civilians at Gangtok and 200 civilians at Darjeeling.

Within hours after the earthquake, two C-130J Hercules Aircraft took to the skies last night with 203 NDRF personnel, sniffer dogs, search and rescue teams, medical personnel and carrying 9 tonnes of relief materials including tents, medicines and food stocks, from Air Force Station Hindon to Bagdogra. A team of 20 doctors from the Army Medical Corps (AMC) carrying 200 kg of essential medical supplies flew to Bagdogra from New Delhi this afternoon on board an IAF Avro aircraft. An MI-17 helicopter with medical team and relief equipment also took off from Bagdogra for Gangtok. Another two Cheetah helicopters from Bagdogra carried out aerial recce missions to assess the damage caused by the 6.8 magnitude earthquake with its epicentre on Indo-Nepal border in Sikkim.

More men and material are being pressed into rescue and relief operations. One IL-76 with 100 volunteers of No.2 NDRF battalion and 8 tonnes of material flew from Chandigarh to Bagdogra this morning. It will come back and make another sortie tonight. To augment the relief operations, two AN-32 aircraft flew from Delhi to Bagdogra early today. Relief efforts are expected to pick momentum after the personnel of the Border Roads Organisation (BRO) toiled throughout the night to restore traffic on the National Highway No.31 this afternoon.

Four ALH and Five Cheetah Helicopters are on standby at Sukna Military Station. Two Cheetah and one MI-17 Helicopters also on standby at Bagdogra Airbase. Besides this two Mi-17 Helicopters are kept on standby at Guwahati. They will be operational once the weather improves.

Five teams of NDRF are deployed for search and rescue operations at Shipgyar, Biha and Bringbang Ramam, Lingzya and Dzongu villages in Mangan.

Two teams of NDRF comprising 14 personnel and 16 personnel each are deployed at Chungthan and Lachung respectively. The doctors of the NDRF team deployed at Mangan with medical detachment are providing medical relief at the camp set up at Manul Mangan. A total of 827 ITBP personnel are engaged in rescue operations and have also been running relief camps where rescued villagers have been given shelter.

The State Govt. has opened 11 relief camps. 2700 and 550 people have been provided shelter into Army camps and ITBP camp (Pengong) respectively.

A total of 5500 Army personnel located in Sikkim have been pressed into relief and rescue operations. Out of this 94 Army columns (strength of columns varies from 15-40 personnel each) are deployed for rescue operations. Rescue columns comprising 281 personnel deployed at Mangan have set up Integrated Command Centre.

A medical team comprising 19 doctors (Surgeon – 4, Orthopedician – 6, Anaesthesian – 5, Neuro Surgeon – 2, and medicine – 2) have been deployed by the Ministry of Health, Government of India from Delhi on 19th September, 2011. A team of 10 doctors reached Chungthan on Sept. 20 2011 and remaining 9 doctors have been deployed at STNM Hospital, Gangtok. So far 940 civilians have been treated at Military hospitals. 28 civilians evacuated by Army helicopters are currently under treatment at Military Hospitals. Approximately 10,000 food packets have been air-dropped so far in the northern part of North District. Another 5000 food packets are ready for dropping at Chungthan, Lachung and Lachen after weather clears on Friday, sept 23, 2011. Fifteen helicopters of Army and Air Force have been pressed into relief work. For airdropping and reconnaissance, 150 sorties have been carried out so far.

13. Govt. actions

Hon'ble Prime Minister Dr. Manmohan Singh, on 19 September, announced ₹2 lakh as ex-gratia to a family member of those killed in the earthquake and ₹1 lakh for seriously injured. Ex-gratia compensation of ₹5 lakh for the kin of the deceased, ₹50,000 for those grievously injured and ₹25,000 for those with minor injuries was announced by Sikkim Chief Minister Shri Pawan Chamling. The Government is leading initial rapid assessments into the affected areas supported by relief organisations based in India. Initial data indicates extensive earthquake damage to buildings in Sikkim with a continued threat of landslides in the mountain areas due to the destabilised mountain slopes and heavy rainfall.

In India, relief workers including personnel from the National Disaster Response Force (NDRF), Armed Forces and Police immediately deployed to the areas hit by the earthquake. The response is reportedly spearheaded in Sikkim, the most affected area in India. As heavy rains eased on 22 September, relief teams reached the worst affected areas in northern Sikkim State by Indian Air Force's (AIF) helicopters. Relief work is on-going to provide urgent assistance to the earthquake survivors. Rice and other food items were airdropped for about 1,000 people in at least nine villages that remain inaccessible. Ten NDRF teams consisting of 403 personnel continue to carry out relief work across Sikkim in Gangtok, Mangan, Ramam, Lingzya, Dzongu, Chungthan and Lachung. Relief camps were set up in every affected district, as well as a medical relief centre in Manul Mangan. Over 5,000 people have been provided shelter. Fifteen Indian Air Force helicopters have airdropped relief.

Box – 2 'We are doing our level best,' says NDRF head DGP JKS Rawat

Posted on [September 29, 2011](#) by [iSikkim](#)

The 400 rescuers of National Disaster Response Force (NDRF) were airlifted from Greater Nodia and Kolkata on 18th September when a violent earthquake rocked the state of Sikkim. The entire teams of NRDF had reached Bagdogra airport by early morning of 19th September whereas five teams of NDRF reached Gangtok by the same evening and were further deployed to North District of Sikkim, Mangan. Two teams of NRDF were also deployed at Chungthang and Lachung respectively. One team of NDRF was based at Gangtok focusing the city and, a standby team at Siliguri.

While speaking to media, NDRF head DIG JKS Rawat, told that their first tasked was to search out the dead's and reach in the remote areas of Mangan and Chungthang. Similarly, to assess damage of houses, requirement of food, medicines, tents, to locate medical camps, extend assistance in loading and distribution of relief materials at Mangan Helipad.

Rawat mentioned that considering the execution of task, NDRF has divided rescuers in small teams consisting of 15 to 20 personnel and with the help of local guides climbed mountains terrain of north district of Mangan and reached Bring Bong, Saffu, Biha, Shipgyar, Bey, Lingzye, Manul, Thang, Ramam, Panan, Thung and Barakh. To ensure proper search NDRF teams remained in these areas for three days self contained in all respect and provided valuable information about the damages of houses, the requirement of tents, food and medicines which helped the district administration of Mangan to plan the distribution of relief material in an organised manner. He also said that during the rescue operation, one of the NRDF team was able to extricate a dead body of a lady and of a boy named, Subrata Ranjan Nath (68 yrs) residence of west Bengal from Shipgyer village. The dead bodies of Akhil Roy (45 yrs) of New Bugaigaon, Assam and Tapan Biswas (35 yrs) of west Bengal, from Moonlight School Chungthang was found. Furthermore the NRDF team at Gangtok retrieved one dead body of Ramakanta Singh (27 yrs) residence of Dzongue from a building that collapsed at Baluakhani near Vajra Cinema Hall.

NRDF organized Medical camps on 21st September at Manul and Mangan treated 721 patients with free medicines and provided 200 tents to DM Mangan on 22nd September for the earthquake victims. Further the NRDF also recovered five dead bodies from Chungthang, Bringbong, Shipgyer and Gangtok (from collapsed building). Likewise, on 27th September, NRDF rescuers along with local guides helped villagers of Tung area to reach Mangan safely. NRDF is also helping loading and unloading of relief materials at helipads.



Figure 15a, b NDRF medical camp and Helipad services at Mangan, North District HQ,

14. Civil Society and NGO coordination services

Box – 3: 49 NGOs including Red Cross join hand for Sikkim quake relief

Posted on [September 24, 2011](#) by [iSikkim](#) |

Forty nine NGO's from different parts of the country, abroad and within state has joint together here in state to provide every relief measures along with supporting the rescue operation in different affected parts of the state caused by the massive, devastating earth quake that rocked Sikkim on Sunday, 18th of September 2011.

The NGO's clubbed and has formed and named 'Inter Agency Response Group, Sikkim (IARGS)' and the group formed will be headed by Paljor Lachungpa as President, Vice President Karma Laden, General Secretary Kailash Agarwal, Treasurer Chamber of Commerce, Sikkim, coordinator Public Relation Prashant Subedi, Coordinator (Volunteer) Naveen Suklani and Coordinator (Distribution) Mahesh Agarwal, respectively. While speaking to media President Lachungpa said that the main concept behind forming this group is to provide necessary relief measures to the needy in an organised manner. There are numerous NGO's who are willing to help, support the people of the affected areas in state but due to lack of proper coordination the relief required in the areas affected was not met so far properly. The group formed consists of international, national and local NGO's operation here in state to lend a helping hand in ways possible in the affected areas. Furthermore Lachungpa stated that numerous expert NGO's from different parts of the country and abroad has also come forward to help, support the needy in the state currently and the organization that worked in rescue and relief in Ladak crisis has also come here in state to carry on the relief measures. The scientist, specialist in rescue, building and medical works has also joined the group to move ahead the rescue, relief operation in state.

The main priority of the constituted group is to work in close coordination with the state government, other agencies operating in state since day one and on the basis of the assessment met by the agencies functioning to provide the necessary services required in the affected areas respectively. Lachungpa added that the group has also constituted core committee, district level committees and village level committees in establishing proper networking system to avail the services, relief to the needy in the grass root as much as possible. The group is also working hand in hand with the state government agencies, Army, Civil defense in dispatching the relief; rescue in the affected areas in state as without the help of all this agencies no output can be availed mentioned Lachungpa. The group currently in the first phase is preparing the list of essential items, commodities badly needed by the people in the affected areas like shelters, medicines, doctors, commodities, torch lights, gumboots and many more. Lachungpa said that the group constituted in days ahead will also support the affected areas people in construction of houses as much as possible.

The NGO's presently working jointly in relief and rescue measures under IARGS are IAG Assam, IAG West Bengal, VHAS, Action Aid, IGSSS, World Vision India, EFICOR, EHA, Discipleship Center, SEEDS, CRS, CASA, Caritas India, OXFAME India, ADRA India, Rotaract Club, **NIDM**, Sphere India, NIDCORD, SAATO, Sikkim Chamber of Commerce, Sikkim Chemist Association, Blue Sky Tour and Travels, TAAS, Live to Love, Tulip Social Organization, Lions Club, Rotary Club, Pear Drops Association, SHRA, Sheep Society, Civil Defense, WFA, Delisso Aborde, Allumania Association, Inner Wheel Club, YAT, Sikkim Archery Association, Yargay Association, Gangtok Task Force and Red Cross respectively.

Box – 4: Sikkim Earthquake Updates as on Monday, Sept 27, 2011

Posted by PIB@Gangtok on September - 27 - 2011

Gangtok, September 27: 1. The Number of deaths in the recent earthquake, as reported by the State Government of Sikkim is 77. The Break up of death toll is as follows – East District-13, North District -59, West District -04 and South District -01. 64 persons are hospitalized. The search and rescue operations teams of NDRF, Army and officials of the State Government are still on.

2. The details of damage reported by the State Government (tentatively) in respect of houses, schools and hospitals are as follows :

Sl.No.	District	No. of House damaged	No. of Schools damaged	No. of hospitals damaged
1	North	6000 FD	NR	07 FD
2	South	820 FD 446 PD 1582 MD	21 FD 41 PD 68 MD	NR (Relief camp opened-14)
3	East	6000 FD 9000 PD	201 FD	23 FD
4	West	1679 FD 5327 SD 8342 PD	64 FD	NR
	Total	14494 FD 17788 PD 1582 MD 5327 SD	285 FD 41 PD 68 MD	30 FD

(NR-Not reported, FD-Fully damaged, PD-Partially damaged, SD-Severely damaged, MD- Mildly damaged.)

3. 10 teams of NDRF consisting of 419 personnel along with necessary search and rescue equipment are deployed in Sikkim. Teams stationed at Lachung and Chungthang area of Sikkim are carrying out rescue and relief operations. Team at Gangtok and Chungthang recovered one dead body each yesterday.

4. A medical team comprising 19 doctors (Surgeon – 4, Orthopedician – 6, Anaesthesian – 5, Neurosurgeon – 2, and medicine – 2) deployed by the Ministry of Health, Government of India continues to provide medical help.(03 doctors continue work in Chungthang, 06 doctors at Distt. Hospital,Mangan and 10 doctors at STNM hospital, Gangtok).

5. The doctors of the NDRF team organised a medical camp at Mangam.

6. The State Government has opened total 85 relief camps. 2700 and 550 people have been provided shelter in two Army camps and ITBP (Pegong) respectively.

8. A 5 member team of experts from NIMHANS, Bangalore to provide psycho-social care is en route to Sikkim. The team is likely to reach Siliguri today.

9. Approximately 11,000 food packets have been air dropped so far in the northern part of North District. A total of 1500 food packets were airdropped on 25-9-2011. The airdropping of food packets today was held up due to inclement weather.

10. A total of 22 sorties were carried out by helicopters on 25-9-2011.

The following roads have also been opened for traffic:

- i. Sevok-Gantok
- ii. Singtam-Rangrang
- iii. Rangpo-Rhenock
- iv. Rhenock-Kupup-Nathula
- v. Indra Bypass
- vi. Chungthang-Lachung-Yumthang-Yumesamdong (Road opened upto 5 Km from Chungthang)
- vii. Namasa- Dombang
- viii. Lachung-Katao-Patala (Road opened upto 18 Km from Lachung)

11. Road from Toong to Police check post i.e 12 Km ahead of Chugthang has been cleared on 26/09/11. Some roads are still blocked but open to some extent. Border Roads Organization (BRO) and Army Engineers are working for restoration of different roads.

12. Due to heavy continuous rains, landslides occurred in Dzongu. No casualty has been reported. Relief work is being carried out by NDRF/State Police and NGOs

13. Due to heavy rains, airlift and other relief activities is not being carried out in Chugthang, Lachen and Lachung

14. Landlines and Microwave links are operational. The present status of mobile tower/BTS which are functional viz-a-viz the total no. is given as follows :

Vodafone	- All fault restored
Reliance	- 52 (54)
Idea	- All fault restored
Aircel	- 54(55)
Airtel	- 67 (69)
BSNL	- 106(122)

15. A total of Rs. 14.21 crore has been disbursed as relief by the State Government till date.

15. Damages of buildings and infrastructures

The details of damage reported by the State Government (tentatively) in respect of houses, schools and hospitals are as follows : (as on Sept 28, 2011)

	Deaths	Estimated	Houses/Buildings			
	Number	Homeless	Destroyed	Severely Damaged	Partially Damaged	Slightly Damaged
North Sikkim	59	20160	6000	Unknown	Unknown	Unknown
South Sikkim	1	2755	820	Unknown	446	1582
East Sikkim	13	20160	6000	Unknown	9000	Unknown
West Sikkim	4	18170	1679	5327	8342	Unknown
TOTAL	77	61245	14499	5327	17788	1582

	Schools			Hospitals	
	Destroyed	Partially Damaged	Slightly Damaged	Destroyed	Damaged
North Sikkim	Unknown	Unknown	Unknown	7	Unknown
South Sikkim	21	41	68	Unknown	Unknown
East Sikkim	201	Unknown	Unknown	23	Unknown
West Sikkim	64	Unknown	Unknown	Unknown	Unknown
TOTAL	286	41	68	30	0

Around 80 per cent of the houses at Chungthang have suffered damages with major and minor cracks. Several people have lost their lives and many families have been displaced. The damage to houses is substantial. Many thousands of houses have collapsed while others have suffered structural damage.

15.1 Buildings and infrastructure damage

The entire area is highly affected due to building damages, disruption in water and power supply, road blockades due to numerous landslides along the highways, lack of alternate communication facilities like satellite phones in inaccessible areas. Several government, public and private buildings have suffered damages in the form of cracks in the walls, floors, foundation, columns, beams and the ground. A majority of buildings in Gangtok, Singtam, Mangan, Jorethang, Siliguri have suffered some form of minor or significant non-structural damage which is repairable; few have suffered structural damages, which can be retrofitted. In Gangtok only three buildings collapsed, 57 have been put on notice for evacuation and 15 have been ordered full or partial demolition. The legislative assembly building, which had undergone retrofitting following the Feb 2006 quake, suffered widespread non-structural damage. The same is the state of the police headquarters and a hospital in Gangtok. The earthquake has also affected the heritage and culturally important structures like monasteries, churches and temples. The affected people were

found in panic state due to aftershocks and came out in the streets and took shelters in open areas during the aftershocks. Some of the damaged buildings are shown in Fig. 16



Figure 16 Damages in buildings in and around Gangtok. These cracks are entirely repairable but cannot be assured for enduring moderate shock again

15.2 Landslides due to earthquake

The National Highway-31A has suffered landslides at over 21 places, over a cumulative length of 700 meters. It was reported by Director General, Border Road Organization and Chief Secretary, Sikkim that the road could be opened for traffic by 19th Sept. 2011. The NDRF personnel who are stranded at Bagdogra will be able to reach Sikkim once the road is opened for traffic. (At 1.30 p.m. information has been received that NH-31A is functional till Singtam, 29 km short of Gangtok).

The damage of road from Gangtok to Nathula (61 kms) is yet to be assessed fully. The first 24 kms of road has been surveyed so far showing 12 landslides and severe damage to the road-formation over a cumulative stretch of 90 meters. Restoration of this road is unlikely to take place immediately, as indicated by DG, BRO (on 1st October 2011, this stretch of the road is reported to be OK).

The third important road in Sikkim which is affected badly is North Sikkim Highway from Gangtok to Chungthang (95 kms). About 400 meters of road-formation has been damaged due to 16 landslides. Restoration of this road too is likely to take some time (Road to Mangan via Dikchu is restored to traffic).

The quake triggered landslides in Kalimpong and Kurseong hill sub-divisions while several patients in a nursing home in Siliguri sub-division of Darjeeling district were injured



Figure 17 Landslides along NH31A. earthquake has triggered several landslides along national highways. The fragility of roads in the hilly area has been exposed by this earthquake, which otherwise too vulnerable to season rain fall. Road widening works in many roads has made them more vulnerable than before. BRO has been active in removing debris but not yet so effective on the promulgation of new technologies. Clearing roads just for allowing one way traffic for the time being is not enough to continue with the ongoing power house construction project. Teesta stage III project is now on halt due to labour shortage. They fled after the earthquake.

16. OBSERVATIONS

During the last 23 years, the country has experienced seven major (M6+) earthquakes that have resulted in over 25,000 deaths. As per the current seismic zone map of the country (IS 1893: 2002), about 60% of India's land area is under threat of moderate to severe seismic hazard, *i.e.*, prone to shaking of MSK Intensity VII and above (BMTPC, 2006). The frequent occurrence of damaging earthquakes clearly demonstrates the high seismic hazard of the State/country and highlights the need for a comprehensive earthquake risk mitigation programme.

Sikkim and its adjoining areas is likely witness more major earthquakes in the future. Despite severe damages to buildings noted in the Feb 2006 earthquake (M5.3) and subsequent selective repairing and retrofitting of buildings in Gangtok, this earthquake has once again exposed the lacuna in adopting earthquake resistance measures. Even though retrofitting of some non RC framed buildings have been done in many places of the country, their performance, including some in Gangtok, raised doubt in the wake of Sikkim-2011 earthquake. Buildings in Gangtok have somewhat well defined load bearing beams and columns but their plan and elevation asymmetry make them summarily vulnerable to even seismic intensity MSK-VI. This combined with the poor construction practices prevalent in the area and making them founded on steep slopes spells tremendous risk for the population of this region. Therefore, it is required to opt for safer constructions through choice of appropriate construction systems, incorporation of rational earthquake resistant technology, use of good construction materials and their quality control, and involvement of competent manpower for design, construction and supervision. Severe damages to the Teesta Stage-III, HEP at Chungthang and possible fallout to other several such projects running across the region need to be assessed by a team of experts.

Many buildings in Siliguri, which is about 120 km from the epicenter, developed cracks and some buildings got tilted due to excessive vibration induced settlements. Strong tremors were also felt in parts of North and East India and parts of Bangladesh and Nepal, triggering widespread panic in different parts of Eastern and North east part of India. Mobile communication and power supply were disrupted in Sikkim, Bihar Jharkhand, and parts of West Bengal. The earthquake tremors coupled with heavy rain fall caused rock fall and consequent blockade of important road corridors in Sikkim and Darjeeling Hills. Roads also reportedly cracked in several places and residents ran out on the streets in Nepal and Bhutan. India Meteorological Department (IMD) reported three aftershocks, of magnitude 5.7, 5.1 and 4.6 which were also felt in Sikkim and North Bengal.

16.1 Life loss and building collapse

The epicenter of moderate earthquake was eventually 68 km away from state capital Gangtok. The degree of damage was quite significant in the last earthquake of Feb 2006. While granting permission to build Multi-storey buildings the relevant government department such as UD&HD, in Gangtok, even doesn't require the involvement of a qualified structural engineer. Structural drawings even if given in the sanctioned plan, there are hardly any field check by structural engineer towards proper ductile reinforcement. So the homeowner, who is suppose to have no idea about earthquake engineering or ductility requirements as per seismic zone IV, constructs his house only with a grid of columns and beams. Such houses with uniform stiffness and frames on regular grid behaved well in the moderate-intensity Sikkim earthquake, but they may not do so if the quake is a high-intensity one with duration more than 40 seconds or so. Those buildings that had an open or soft storey have high potential for collapse or had severe structural damage.

16.2 Damage to Infrastructures

The earthquake caused substantial damage to heritage structures as well as modern RCC buildings. The damage seen in Gangtok, Singtam, Mangan, Jorethang were substantial even when shaking intensity was of MSK-VI. This very clearly establishes the high level of seismic vulnerability of the region. Such damage is a direct consequence of poor design and construction practices prevalent that is challenged by the lack of trained human resources in the region. Due to paucity of flat land, buildings even upto 6-8 storeys are constructed in plenty with little or no breathing space for emergency operations. The situation gets worse during monsoon when inappropriate foundation of buildings lying on steep slopes give in to landslips/subsidence.

Buildings in earthquake affected areas have definite load bearing frames but they are spatially located in steep slopes with little or no measures for earthquake safety. Mere following of earthquake resistant design as per BIS codes (seismic Zone IV), are not enough for buildings in steep slopes. The team observed serious lacuna in the ongoing construction site, where there is hardly any trace of ductility design measures as per BIS code. Moreover, buildings as high as 8 storeys, in Gangtok are constructed without much consideration of appropriate approach roads. This has now resulted into serious setback in the demolition operations. The team carried out rapid visual inspections of many buildings in Gangtok along with engineers from urban development and housing. Majority of the buildings developed horizontal cracks in the brick partition/infill walls, for which simple repair measures are suggested in Appendix.

Though National Building Code-2005 and BIS codes on earthquake resistant design are recommendatory, lawful inclusion into the local building byelaws along with rigorous construction quality check would be going to reduce vulnerability to a great extent.

16.3 Psychosocial care service provision

Psychosocial care is essential for all the population experiencing a disaster. People differ only in terms of the degree of support needed. A reflection of this recognition of the need and improvement with care is seen in the disaster care policy of many countries. International organisations like the WHO (see box), Red Cross, etc., have also identified this component of care as essential in their activities. It is a holistic approach to rehabilitation. Psychosocial care provide a vivid and moving account of the experiences of survival and bereavement under different types of conditions faced in hilly terrain, which remained inaccessible more than a fortnight. NIDM and NIMHANS propose to summarize the most up-to-date thinking about the psychological effects of disaster, and describe the therapeutic strategies available for treating victims with persistent problems, emphasizing the welfare needs of staff involved in rescue and support. It will discuss in detail the practical aspects of coordinating earthquake disaster relief, such as the organization and planning of specific services like outreach facilities and crisis help lines after the event.

The three aspects of psychosocial assistance in disaster care are:

- Helping the affected persons to recognise and understand the disaster experience and the changes that they experience in their body and mind.
- Decreasing the physical and psychological effects by listening, encouraging relaxation and externalisation of interests and activities.
- Giving practical support to rebuild their shattered lives in areas of housing, work, health and community life.

It is proposed that for the next **one year**, **NIDM and NIMHANS** shall form a team to organize the following events in each affected district:

1. Grass root level training => community level training on disaster psychosocial care
2. Health need assessment as per WHO guidelines
3. Community level service
4. Special therapeutic service

16.4 . Recovery framework

Post Disaster Damage and Needs Assessment and Recovery Framework (**PDNA/RF**) for the Sikkim Earthquake is to be carried out by a specialized team. It will ensure pulling together information into a single, consolidated report detailing information on the physical

impacts of the earthquake event, the economic value of the infrastructure and social damages, physical and economical losses, the human impacts as experienced by affected populations, and related early and long-term recovery needs and priorities. Post-Disaster Damage Needs Assessment (PDNA) works in two motives: (i) the valuation of physical damages and economic losses; and, (ii) the identification of human recovery needs based on information obtained from the affected population.

The Recovery Framework provides decision makers, especially governments, with an operating envelope to allow sectoral proposals to be incorporated in a national plan and, as often as possible, integrate response options across sectors. The ultimate goal of recovery managers is that the sectors' outcomes, when achieved, contribute to and ensure the overall intended recovery outcome, i.e., that the affected area recovers effectively and that people, families, businesses, and public officials find it a safe and attractive place to live, invest, and prosper. A Recovery Framework is specific to a particular disaster and geographic context and may vary across and within countries even with regards to the same disaster event.

NIDM proposes to constitute a **central PDNA team** under the directives from Ministry of Home Affairs, Govt. of India, consisting of experts from all areas working in disaster management. It shall work out strategies in **one year** time.

17. ROAD MAP – LONG TERM IMPLICATIONS AND STRATEGIES

1. **Seismic microzonation** of Sikkim state, which was carried out under DST funding in 2006, requires status monitoring and road map with particular motivation towards their practical application in the new construction and land use planning for the entire state and similar exercise to be extended to all seismically high risk areas in North east.
2. **National** network of seismic instrumentation, strong motion recording and data processing in the NE region – need for upgradation, R& D for effective early warning system (EWS) in the NE region. Despite having more than 34 seismic stations in place in the NE region, country is yet to bring out rational earthquake information dissemination through information media for common public.
3. **Seismological data** so far being collected at IMD, New Delhi needs up gradation to their quality and acceptability across the world, which is possible only when these limitations shall be highlighted in the Indian scientific Diaspora. [On 14th October 2011, Hon'ble Central Minister of Earth Sciences released a manual for microzonation study for the entire country. Application of the same for seismic design has been highlighted in the panel discussion. It is emphasized that damage statistics following Sikkim earthquake - 2011, must be compared with existing microzonation map of Sikkim].
4. To frame strategies to **construct and maintain major hospitals, school buildings** and public amenity building for storage of essential life saving materials (food, medicine), community halls, equipments and machinery for removal of damaged material, using disaster resistant technologies of a higher order, so that these buildings not only serve as good examples of disaster resistant technology but also could be **utilised as relief shelters** providing the necessary emergency support facilities.
5. **Portending future** of existing built-establishments in the highly populated areas to be investigated and new land usage policy to be initiated keeping in mind of the earthquake and landslides hazards
6. **National building code - 2005**, relevant BIS codes, NDMA guidelines on earthquake management to be made compulsory. A documentary of the process of earthquake resistant construction may be made and the same be distributed to all districts, town, Panchayat, etc. Each district/Taluka/block must have a typical building showing **all earthquake resistant** features.
7. Rigorous training **of masons and certification** ensuring higher wage for them to be carried out with utmost priority.

8. **Techno-legal and techno-financing regime** should be brought in to ensure that all public funded housing and buildings and construction, be it for health, education, industry, community amenities, etc. be only built with disaster resistant construction features. Further, public financing institutions for housing and infrastructure development be advised to extend financial assistance to projects from States only when disaster resistant construction features are introduced in the proposed housing and building construction programmes. Earthquake induced damage potential on the **Hydropower projects** in the Sikkim state required to be evaluated by a special team.

17.1 Road map – short term

Based on the analysis of the situation, the main recommendations of the team are:

17.1.1 DAMAGE ASSESSMENT SURVEY

- i) A detail survey of all affected buildings (>34000 no.) and infrastructure must be undertaken by **an expert team** consisting of the following members:
 - a. Secretary, LR &DM as Chair or anyone to be recommended by Hon'ble CM of Sikkim
 - b. Project leader, preferably a Civil Engineer having sound knowledge in Earthquake resistant design, seismo-tectonics, Microzonation, Landslides mitigation, site geology and disaster management - to be selected by State Govt. for a period not more than 6 months
 - c. Urban Development and Housing Department – 2
 - d. Town and planning, Gangtok - 2
 - e. Geology and Mines, Sikkim – 2
 - f. BRO (GREF) – 3
 - g. Land revenue and disaster management, Sikkim – 2
 - h. PWD – roads – 2
 - i. 3-5 more subject experts to be selected by project leader
 - j. 3-5 project staffs to selected by project leader

Aim

To assess the damages/ losses and recommend appropriate actions for restoration, repairing, retrofitting, re-strengthening, demolition and reconstruction prospects. A format for carrying out detail damage survey is being developed by NIDM

Scope of the works

NIDM proposes to conduct 4 days training of engineers and architects at Gangtok, in which damage assessment shall be conducted on the spot and all survey data collected so far by state govt. shall be analysed and explained to the participants. Participants so trained shall be effectively involved in the damage assessment survey as proposed under:

- All major roads and landslides prone areas shall be surveyed in association with BRO, PWD, forest dept. and sustainable landslides mitigation measures such as reinforced earth retaining wall, soil nailing by rock bolts/wooden piles, slope stabilization by anchored (semi Z and composite type – patented by Prof. R.B. Singh), geosynthetic retaining wall, gabion walls, rock fall protection by Geonetting, Jhora training works by slope stitching
 - utilizing the potential of seismic microzonation works done by Prof. S.K. Nath, IIT-KGP, and other team members) all damage data shall be placed on the GIS map and extent of damage pattern shall be reassessed for guidance to city planners and administration
- ii) **Workmanship, supervision, and construction** methods must be revised in the form of strict regulation and implementation drives. Thus, strict adherence to prescribed standards, of construction materials and processes is essential in assuring an earthquake resistant building. Regular testing of materials to laboratories, periodic training of workmen at professional training houses, and on-site evaluation of the technical work are elements of good quality control.
- iii) Many buildings have developed cracks **and proper policy framework** for mass scale repair and restoration is earnestly required. Though people are much aware of the Seismic threat and zonation of Sikkim state, it is required to provide necessary expertise in the repairing and strengthening of damaged structures. Some guidelines on the method of identifying cracks and dressing the same by commercially available grouting/filling materials are given in the Appendix - I,II,III. Further details will follow after formation of the team as proposed above.

- iv) Water supply, electrical, sewerage lines, mobile/landline communication tower and Jhora-training works needs performance assessment for which **damage survey format** to be devised based on site conditions encountered in the affected areas. A flowchart is included in Appendix III for guidance.

New methodology of designing such infrastructures suiting specific site conditions in Hilly terrain and earthquake resiliency measures for ensuring their safety as well as keeping safe alternate arrangements in the form of **contingency measures** shall be devised.

- v) Damage potential of slope protection measures being used in service so far needs evaluation and **efficacy of the existing conventional earth retaining** structures such as gravity retaining wall, cantilever wall against earthquake induced vibration needs performance check. BRO (GREF), PWD officials must be encouraged to open a research and development wing on the application new technologies in the landslides mitigation.

NIDM propose to conduct a brain **storming workshop** for all those organizations involved in the hill road construction and maintenance highlighting efficacy of modern techniques based on the on-site assessment of damage patterns and mitigating them through a pilot-project along NH31A.

17.1.2. PSYCHOSOCIAL CARE

What it is?

- Psychosocial care is widely accepted and practiced as a community-based intervention model
- Innovative micro models of operation at grassroots incorporating contextual realities and cultural practices noticed.
- Standardized capacity-building models presented
- Availability of the huge resource material on PSC in regional languages was mapped.
- Working with specific risk groups like children, women, disabled and elderly people emerged.
- Evidence-based research findings with practice models discussed.

- Psychosocial care is not a “time-bound” activity rather a “time-line” activity.
- The status of people living in difficult situations as a result of conflict and forced migration is currently excluded from disaster response initiatives.

How it benefits?

- **Create opportunities** for people to talk and share experiences in supportive groups. This is often done best in familiar surroundings such as religious places, schools or community centers.
- **Provide accurate and practical information** especially concerning the larger recovery efforts. Special attention to the needs of relief applicants is necessary as relating to the rules and regulations of the relief organizations during the crisis can be overwhelming.
- **Give particular consideration** to the needs of special groups such as children, those who have been most intensely exposed or had a history of previous events (exposure to trauma), rescue workers, and people with pre existing mental health conditions.
- Children and adolescents **will need the support** of their caregivers. This support should reflect accurate concerns, and diminish any words or actions that would increase the child or adolescent's anxiety. Caregivers should offer reassurance as to their presence and availability during this time. Exposure to television, movies or print matter that offers too graphic depictions of the destruction or victims should be limited.
- A percentage of people, as high as 30%, who experience the most direct exposure to the events may go on **to develop more serious mental health** concerns and should be referred for services if they develop persistent issues.

(WHO, Geneva, October 2001)

Important steps

- Inter-ministerial support both in the form of policy and Government orders should be speeded up as disaster management involves effective efforts of different ministries – Home/Health/ Education/ Welfare/ Human Resource Development etc.
- Such support must be reflected on ground at the District / Taluka level
- Acknowledge that disaster rehabilitation has two sides: material as well as psychosocial.
- Adequate operational funds should be made available both for short and long-term psychosocial rehabilitation activities.
- Community Level Workers should be identified, trained and empowered for community disaster preparedness measures at the rate of one for every 100 families.
- Convergence of relief, rehabilitation and psychosocial care has to be micromanaged.

- Disaster psychosocial care needs to be for a minimal period of 5 years.
- Preparedness as a mitigation strategy needs to be taken up through various human resource training, research and documentation activities.
- Psychosocial rehabilitation needs to culminate into disaster mental health and be integrated with the district mental health programme in the ensuing Plan.
- There should be policy and field level interventions to address the special needs of people affected by conflicts and/or forced to migrate.

17.1.3 Post earthquake damage and need assessment survey (PDNA)

A PDNA should commence as soon as possible after the disaster onset, ideally within the first weeks. A first objective for the PDNA is to support the elaboration of the Recovery Framework in time for the revision of a humanitarian flash appeal - normally within five to six weeks following the onset of a disaster. This provides the foundation for more in-depth assessments, ongoing recovery and transition to development as the Recovery Framework continues to be more fully elaborated. Needs identified by the PDNA beyond national capacity may be used as an evidence base for the mobilization of further international resources in support of recovery, e.g. in connection with an international donor conference in response to the disaster.

Assessments of the impact of a Sikkim earthquake on individual, household, community and national assets, coping mechanisms, and early and longer-term recovery needs build the evidence base for and underpin the development of the Recovery Framework, including an Early Recovery Strategic Framework. Such assessments necessarily need to integrate a number of different but interconnected perspectives. These perspectives may be broadly categorized as the identification of human recovery needs and the valuation of damages and losses to support both recovery programming and the mobilization of the necessary capital to finance the recovery process.

Detailed survey of the affected areas should be made to assess impacts on **physical, socio-cultural, psychological, economic and environmental aspects**. This survey may be done by NIDM/NIMHANS under PDNA (Post Disaster Need Assessment) team.

18. DOCUMENTATION OF SIKKIM EARTHQUAKE

Two formats for documenting Sikkim earthquake are given in Appendix –IV and V. It is required to take note of rescue, relief and shelter operations under some of the following categories:

- a) About the earthquake source, location and nature of shaking – any authentic warning/precursor received by state govt.? If so what are they and how present day knowhow be accumulated for devising more comprehensive disaster information for public and media?
- b) When state govt./district Collectorate received first information (from IMD, Delhi?) about Earthquake in North Sikkim and in what format? Is it enough or more improvement in the disaster incident protocol required for near future?
- c) Any base map, geology map, resource and establishment information maps of the affected area available with the District collector and LR&DM office? If not how to facilitate all these information made available before similar incident take place.
- d) Is the Seismic microzonation map developed by IIT-KGP in 2006 available for Administrative use as well as for UD&HD engineers of Sikkim for adopting the findings city planning and resource establishment mapping? If not what strategies to be devised to make it practicable as site specific studies?
- e) **State level response** in terms of receiving damage and injury information from the affected people and responding to the needs – what were the communication problems faced, how they have been looked into, were there enough preparedness in place?
- f) **Where and how many Disaster control rooms were** established? Are they having facility with electronic display/dash board, email, fax, video conferencing, satellite teleFax, Internet, blogs, SMS server, VHF network, V-SAT network? If not what were made available and what difficulties were faced by the Incident Commander.
- g) Was there any **master control room** established? If so what are the classified information about rescue operations, name of armed forces, no. and location of helipads, no. of helicopter used and their schedule of sorties, chronology of operational difficulties due to bad weather and other allied problems, name of NGOs and other volunteering organizations, position and deployment of rescue team,

- h) Details of relief materials received from various local, district, state and inter-state agencies, location and place of receiving such materials, delivery of relief materials, including stock as on date
- i) Details of relief camp established so far, their location, no. of days in operation, materials supplied and used so far, local help obtained (if any), no. of people deployed in relief camp, facilities rendered in man and materials, expenses incurred, etc.
- j) No. of rescue calls received immediately after the earthquake, condition of mobile communications and alternate arrangement made to cope up with the emergencies
- k) No., place, personnel along with details of press briefings given by District control officer and state IPR and interpretation given by the media representative to the public – newspaper dailies, web portals and TV. Any lapse/lacuna from either side noticed by state govt.? If so what improvements to be made for future?
- l) Protocols maintained for VIP and VVIP visits to the affected area, details of various occasions, meetings and press briefing held, expenditures incurred and human resources deployed for facilitating such visits
- m) Is there any existence of SDMA (with state CM as Chairman) as per Disaster Management Act -2005 in place? How well the role of various functionaries such as Police, Fire, municipal authorities, medical services, BRO, Land and Revenue department, UNDP-DRR, DM cells, etc. have defined before earthquake and what befalling situations were encountered during actual emergency following North Sikkim earthquake?
- n) Brief account of the Teesta Hydropower projects sanctioned so far and actual operation activities running in the entire region. Was there any damage during earthquake? If so what are the extent of damage and what actions have been taken up by the State Govt.?
- o) Details of financial assistance rendered/assured by the Central Govt., other state governments, domestic and international community, NGOs & INGOs, UN organizations etc., amount received by state govt. so committed as above.
- p) Damage assessment details in terms of housing, health, education, urban and rural water supply, Jhora trainings works, power transmission lines, telecommunication, sewerage, public buildings and historic monuments/Gumpas/monasteries, agriculture and live stock, pharmaceutical and other industries, roads and transport infrastructure such as bridges, retaining walls, dams and hydropower projects, army camps, etc.

- q) Details of **pre-existing** vulnerable landslides along all National and state highways, village roads and changes in the landform found after the earthquake, no. and extent of landslides occurred due to earthquake, road block due to earthquake induced rockfall/landslides, effectiveness of slope stabilization measures against earthquakes, failure/bulging of retaining walls, ...details of road block clearance exercised by BRO and other agencies, no. of vehicle damaged, no. of rescue vehicle deployed, chronology of such operations leading to road clearance, in addition to weather report during rescue and relief operation, status of drainage conditions seen at the road side and possible impact on the road transport if such patches are not recuperated in due course of time
- r) **First hand damage assessment** (cost) estimate done so far by state govt. with time frame required and priority set for repair and restoration of facilities both at state govt. and BRO level
- s) Details of the amount of **debris removal** specially for road clearance, type of equipments used, haul distance, cost incurred, etc.
- t) Details of **medical camp** established by NDRF, Ministry of Health and other organizations – place, date, duration, no. of medical team and their structure, no. of injured people treated – compensation package served as per govt. declaration, details of medicines supplied, name of people died and injured along with communication address, name of the hospitals/nursing homes/health centres where injured people treated, details of social and livelihood rehabilitation, grievance redressal mechanism adopted, cases of trauma and psychosocial care and status as on date.
- u) Total no. and location of **emergency help centres** established and details of help provided by various agencies/voluntary organizations
- v) Name of the NGOs, INGOs, community based organizations that took part in the relief and rescue operation, type and extent of help provided, details of areas of Govt.-non Govt. cooperation and its impact

19. Conclusions and Recommendations

This earthquake has appreciably opened up an opportunity for overall developmental perspectives in the entire NE region. It is also worthwhile to look into the impact of such mega event on the ongoing hydro power projects that propelling the mushrooming of

human settlements. Traditional Assam Type (Collq. Ekra) construction has performed well against the earthquake but they are not often meeting the aspiration and taste of the burgeoning population. The widespread damages have caused mental health issues to house owners (especially who had made large investments) and counseling is an immediate need. Therefore, it is required to collect all post earthquake information and carry out need assessment for total recovery.

19.1 Disaster Data Collection

1. Develop a location specific damage assessment survey format for buildings and infrastructures [few samples are given in Appendix] for all the affected cities such as – Gangtok, Singtam, Mangan, Lachen, Chungthang, Lachung, Siliguri, Darjeeling, Jalpaiguri, Kalimpong, New Jalpaiguri.... [4 weeks] ...The filled up format shall be used for quantitative assessment of degree of structural and nonstructural damage patterns and create a database in GIS platform for ready reference by administration.
2. Based on the Sikkim Microzonation map submitted to DST by Prof. S.K. Nath, IIT-KGP and his team, categorise all types damages and correlate them with hazard map in terms of predominant frequencies, site response factor and fault movement, etc.... [2 months]...this will help Bureau of Indian standards to incorporate damage perception into design codes, which will be used by town planners and urban development department before sanctioning fresh building construction plans.
3. Collect satellite images of pre and post earthquake scenario from NRSA (Cartosat)/IKONOS/Geo-Eye/World view, of all affected city establishments in the NE region... [6 weeks]... These will help assessing damage scenario in Arc-GIS and shall be of immense help to the Urban development department
4. Deploy magneto-telluric, microtremor and seismological tools for studies of seismotectonic activity in association with IMD, NGRI, IIG, GSI, IIT-G, NERIST and NEHU... [6 months] ..Seismotectonics of world's most active mountain range must be understood by Indian scientific community.
5. Collect status report of all 30+ power projects on the aftermath of Sikkim-2011 earthquake [6 months] ..Though one plant (Teesta Stage III) has suffered damage it is important to check the others.

6. Collect relief and rescue data carried out by Army, Air Force, NDRF, Police and NGOs and conduct PDNA **...[6 months]**..it could be important step to synthesize all these data and prepare 12th plan documents accordingly.
7. Collect data from all control room at Gangtok, Mangan, Chungthang... giving all information about rescue and relief operation, VVIP and media management, relief material received, medical teams and psychosocial care rendered, details of death and injuries, damage of buildings and infrastructures, etc. **..[3 months]**..details of data type has been explained at the end. Once such disaster data are classified, Govt. action based on these information would more rational and fact oriented.

19.2 Special study and reporting

1. Preparation of specific remedial/repair/retrofitting measures for some of the selected severely damaged buildings so far reported by Sikkim Govt. along with cost implication and time allocation, availability expertise in the country, manpower support from state govt. and necessary training/capacity building plans **[4 months]**
2. Forensic report on the nature of failure encountered and prepare achievable retrofitting strategy of the buildings at Singtam, Ringhim monastery at Mangan, Rumtek Monastery, Govt. Tashiling secretariat building, Police, Education HQ. at Gangtok, State guest house at Rongpo and other strategically important buildings. **[6 months]**
3. Device people oriented rehabilitation and retrofit policy for the country based on the lessons learned from Kashmir (2005), Tsunami (2004), Bhuj (2001), Latur (1993) and overseas (Japan – 1995, 2011), Mexico-1985, Taiwan-1999, Turkey-1999. **[6 months]**
4. Training and capacity building of PWD, UD&HD (Gangtok), BRO (GREF) engineers on the modern technology of Landslides mitigation measures by soil nailing, geosynthetics and geonetting, anchored earth, etc. and also scope for bioengineering by Vetiver Grass. [CBRI, GSI, Mines & Geology, UD&HD, IIT-Roorkee may form a team] **[1 year]**
5. A study on earthquake triggered landslides should be initiated to know the impacts of earthquakes on slopes and distinguish between earthquake triggered new slides and reactivated landslides. [Despite having more than 34 seismic stations in place at the NE region, till date hardly any pre and post processed satellite images of earthquake affected region and seismic signatures are seen in Indian context in the public domain. It is learned that some Indian organizations like Manipur University,

IIT-KGP; have their own sensors based in the NE region, which are supported by Govt. funding agencies, such as DST, MoES. Yet IMD, the nodal agency for earthquake information for the country, has seems no system in place to collect those information and disseminate those for public and media on emergent basis]. NRSA, NGRI, IMD, BRO, NEIST, NEC, GSI, IRS and other allied Indian scientific organizations/agencies must be pulled into a consortium under MHA/MoES/MoUD/MoRD and develop a protocol for the development of such information based on earthquake induced landslides, pre and post precursor scenarios, etc. **[1 year]**

6. Microzonation studies for Sikkim state (done by IIT-KGP under a DST project funding) requires re-appropriation based on the damage survey of 34000+ buildings in the entire state. Similar exercises have to be carried for mapping of damage scenarios for North Bengal and represent them in GIS platform so that requisite repair and reconstruction measures be planned based on the nature and extent of damage pattern. [NIDM,IIT-KGP, GSI, IIRS,DST.. may form a team] **[2 years]**
7. 3D contour survey with 3D laser scanning of all habitat (buildings, roads, infrastructures, slopes, etc.) in the NE states must be carried out. These technologies are easily available in the country. NIDM has developed an ONLINE Vulnerability survey software (RVS-SOFT) for buildings in East Delhi, which can be extended to all over India. This can be applied to earthquake affected area in association with IIT-Kanpur, IIT-Bombay, IIT-Guwahati, IIT-Roorkee and IIRS-Dehradun. **[2 years]**

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Appendix - I

REPAIR, RESTORATION AND STRENGTHENING

The method of repair and strengthening would naturally depend very largely on the structural scheme and materials used for the construction of the building in the first instance, the technology that is feasible to adopt quickly and on the amount of funds that can be assigned to the task, usually very limited. Some methods like "splints and bandages", "wire mesh with gunite", "epoxy injection," etc., have already been tried and applied in a few countries for repairing as well as strengthening earthquake damaged buildings.

Repairs

The main purpose of repairs is to bring back the architectural shape of the building so that all services start working and the functioning of building is resumed quickly. Repair does not pretend to improve the structural strength of the building and can be very deceptive for meeting the strength requirements of the next earthquake. The actions will include the following:

- a. Patching up of defects such as cracks and fall of plaster.
- b. Repairing doors, windows, replacement of glass panes.
- c. Checking and repairing electric wiring.
- d. Checking and repairing gas pipes, water pipes and plumbing services.
- e. Re-building non-structural walls, smoke chimneys, boundary walls, etc.
- f. Re-plastering of walls as required.
- g. Rearranging disturbed roofing tiles.
- h. Relaying cracked flooring at ground level.
- i. Redecoration — whitewashing, painting, etc.

The architectural repairs as stated above do not restore the original structural strength of cracked walls or columns and may sometimes be very illusive, since the redecorates building will hide all the weaknesses and the building will suffer even more severe damage if shaken again by an equal shock since the original energy absorbing capacity will not be available.

Restoration

It is the restitution of the strength the building had before the damage occurred. This type of action must be undertaken when there is evidence that the structural damage can be attributed to exceptional phenomena that are not likely to happen again and that the original strength provides an adequate level of safety.

The main purpose of restoration is to carry out structural repairs to load bearing elements. It may involve cutting portions of the elements and rebuilding them or simply adding more structural material so that the original strength is more or less restored. The process may involve inserting temporary supports, underpinning, etc. Some of the approaches are stated below:

- (i) Removal of portions of cracked masonry walls and piers and rebuilding them in richer mortar. Use of non-shrinking mortar will be preferable.
- (ii) Addition of reinforcing mesh on both -faces of the cracked wall, holding it to the wall through spikes or bolts and then covering it suitably. Several alternatives have been used.
- (iii) Injecting epoxy like material, which is strong in tension, into the cracks in walls, columns, beams, etc.

Where structural repairs are considered necessary, these should be carried out prior to or simultaneously with the architectural repairs so that total planning of work could be done in a coordinated manner and wastage is avoided.

Strengthening of existing buildings

The seismic behaviour of old existing buildings is affected by their original structural inadequacies, material degradation due to time, and alterations carried out during use over the years such as making new openings, addition of new parts inducing dissymmetry in plan and elevation, etc.

The possibility of substituting them with new earthquake resistant buildings is generally neglected due to historical, artistic, social and economical reasons. The complete replacement of the buildings in a given area will also lead to destroying a number of social and human links. Therefore seismic strengthening of existing damaged or undamaged buildings can be a definite requirement in same areas.

Strengthening is an improvement over the original strength when the evaluation of the building indicates that the strength available before the damage was insufficient and restoration alone will not be adequate in future quakes.

The extent of the modifications must be determined by the general principles and design methods stated in earlier chapters, and should not be limited to increasing the strength of members that have been damaged, but should consider the overall behaviour of the structure. Commonly, strengthening procedures should aim at one or more of the following objectives:

- (i) Increasing the lateral strength in one or both directions, by reinforcement or by increasing wall areas or the number of walls and columns.
- (ii) Giving unity to the structure by providing a proper connection between its resisting elements, in such a way that inertia forces generated by the vibration of the building can be transmitted to the members that have the ability to resist them. Typical important aspects are the connections between roofs or floors and walls, between intersecting walls and between walls and foundations.
- (iii) Eliminating features that are sources of weakness or that produce concentrations of stresses in some members. Asymmetrical plan distribution of resisting members, abrupt changes of stiffness from one floor to the other, concentration of large masses, large openings in walls without a proper peripheral reinforcement are examples of defect of this kind.

- (iv) Avoiding the possibility of brittle modes of failure by proper reinforcement and connection of resisting members. Since its cost may go to as high as 50 to 60% of the cost of rebuilding, the justification of such strengthening must be fully considered.

REPAIR MATERIALS

The most common materials for damage repair works of various types are cement and steel. In many situations non-shrinking cement or an admixture like aluminium powder in the ordinary portland cement will be admissible. Steel may be required in many forms, like bolts, rods, angles, channels, expanded metal and welded wire fabric. Wood and bamboo are the most common material for providing temporary supports and scaffolding etc., and will be required in the form of rounds, sleepers, planks, etc.

Besides the above, special materials and techniques are available for best results in the repair and strengthening operations. They are described below:

Shotcrete

Shotcrete is a method of applying a combination of sand and portland cement which mixed pneumatically and conveyed in dry state to the nozzle of a pressure gun, where water is mixed and hydration takes place just prior to expulsion. The material bonds perfectly to properly prepared surface of masonry and steel. In versatility of application to curved or irregular surfaces, its high strength after application and good physical characteristics, make for an ideal means to achieve added structural capability in walls and other elements. There are some minor restrictions of clearance, thickness, direction of application, etc.

Epoxy resins

Epoxy resins are excellent binding agents with high tensile strength. There are chemical preparations the compositions of which can be changed as per requirements. The epoxy components are mixed just prior to application. The product is of low viscosity and can be injected in small cracks too.

The higher viscosity epoxy resin can be used for surface coating or filling larger cracks or holes. The epoxy mixture strength is dependent upon the temperature of curing (lower strength for higher temperature) and method of application.

Epoxy mortar

For larger void spaces, it is possible to combine epoxy resins of either low viscosity or higher viscosity, with sand aggregate to form epoxy mortar. Epoxy mortar mixture has higher compressive strength, higher tensile strength and a lower modulus of elasticity than Portland cement concrete. Thus the mortar is not a stiff material for replacing reinforced concrete. It is also reported that epoxy is a combustible material. Therefore it is not used alone. The sand aggregate mixed to form the epoxy mortar provides a heat sink for heat generated and it provides increased modulus of elasticity too.

Gypsum cement mortar

It has got rather limited use for structural application. It has lowest strength at failure among these three materials.

Quick-setting cement mortar

This material is patented and was originally developed for the use as a repair material for reinforced concrete floors adjacent to steel blast furnaces. It is a non-hydrous magnesium phosphate cement with two components, a liquid and a dry, which can be mixed in a manner similar to portland cement concrete.

Mechanical anchors

Mechanical type of anchors employ wedging action to provide anchorage. Some of the anchors provide both shear and tension resistance. Such anchors are manufactured to give sufficient strength. Alternatively chemical anchors bonded in drilled holes polymer adhesives can be used.

TECHNIQUES TO RESTORE ORIGINAL STRENGTH

While considering restoration work, it is important to realise that even fine cracks in load bearing members which are unreinforced, like masonry and plain concrete reduce their resistance very largely. Therefore all cracks must be located and marked carefully and the critical ones fully repaired either by injecting strong cement or chemical grout or by providing external bandage. The techniques are described below along with other restoration measures.

Small cracks

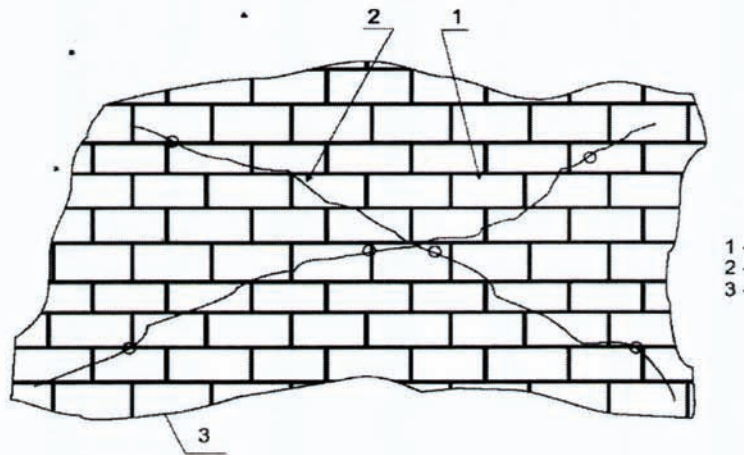
If the cracks are reasonably small (opening width = 0.075 cm), the technique to restore the original tensile strength of the cracked element is by pressure injection of epoxy. The procedure is as follows, *Fig 1.1 (a) and (b)*.

The external surfaces are cleaned of non-structural materials and plastic injection ports are placed along the surface of the cracks on both sides of the member and are secured in place with an epoxy sealant. The centre to centre spacing of these ports may be approximately equal to the thickness of the element. After the sealant has cured, a low viscosity epoxy resin is injected into one port at a time, beginning at the lowest part of the crack in case it is vertical or at one end of the crack in case it is horizontal.

The resin is injected till it is seen flowing from the opposite sides of the member at the corresponding port or from the next higher port on the same side of member. The injection port should be closed at this stage and injection equipment moved to the next port and so on.

The smaller the crack, higher is the pressure or more closely spaced should be the ports so as to obtain complete penetration of the epoxy material throughout the depth and width of member. Larger cracks will permit larger port spacing, depending upon width of the member. This technique is appropriate for all types of structural elements — beams, columns, walls and floor units in masonry as well as concrete structures. Two items should however be taken care of in such type of repair:

In the case of loss of bond between reinforcing bar and concrete, if the concrete adjacent to the bar has been pulverised to a very fine powder, this powder will dam the epoxy from saturating the region. So it should be cleaned properly by air or water pressure to pressure inject. So cracks smaller than this should not be repaired by this method.



(a) Grout or epoxy injection in cracks

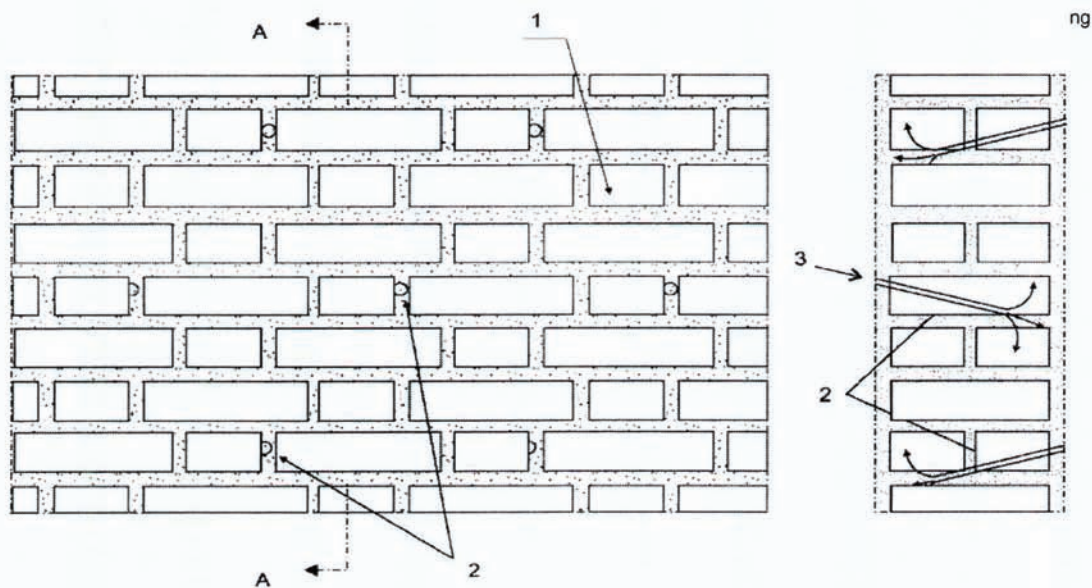


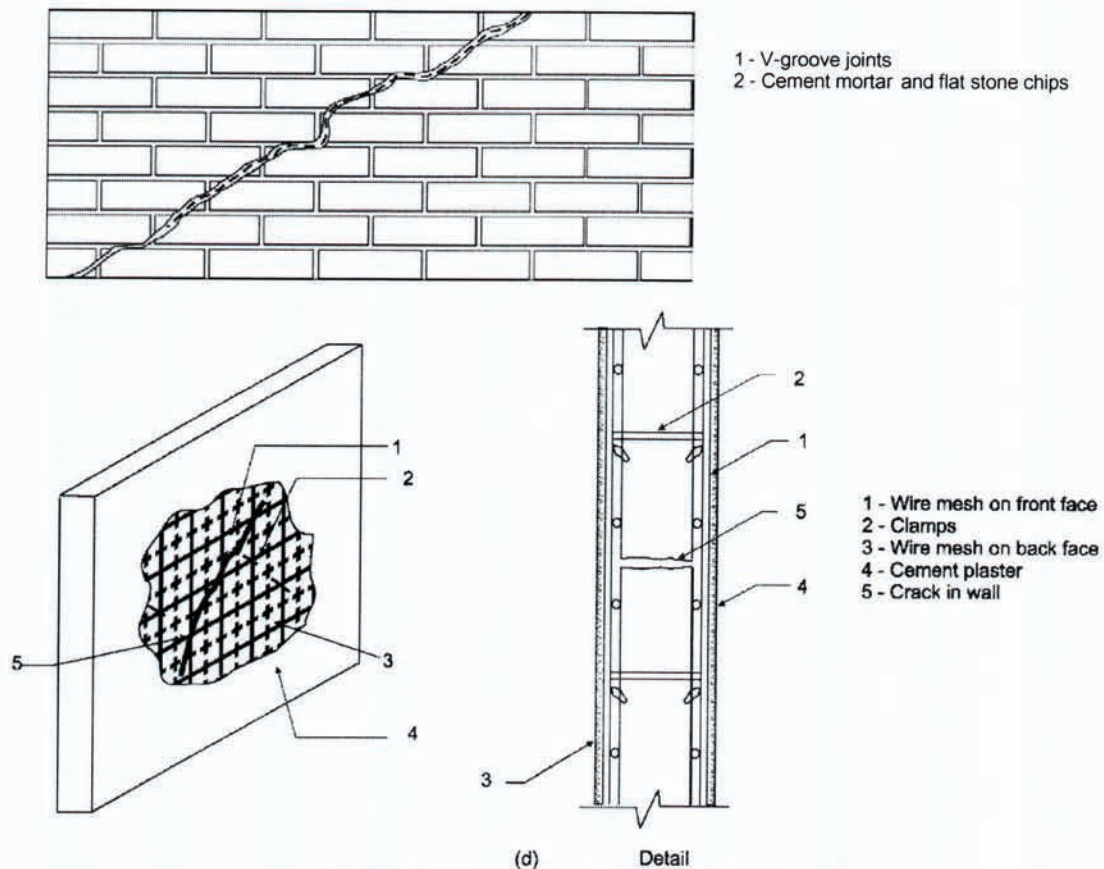
Figure 1.1 Strengthening of existing masonry

Large cracks and crushed concrete

For cracks wider than about 6 mm or for regions in which the concrete or masonry has crushed, a treatment other than injection is indicated. The following procedure may be adopted.

- (i) The loose material is removed and replaced with any of the materials mentioned earlier, i.e., expansive cement mortar, quick setting cement or gypsum cement mortar, Fig 1.1 (c).

Where found necessary, additional shear or flexural reinforcement is provided in the region of repairs. This reinforcement could be covered by mortar to give further strength as well as protection to the reinforcement, *Fig 1.1 (d)*.



(d)
Detail
Fig 1.1 Strengthening of existing masonry

- (ii) In areas of very severe damage, replacement of the member or portion of member can be carried out.
- (iii) In the case of damage to walls and floor diaphragms, steel mesh could be provided on the outside of the surface and nailed or bolted to the wall. Then it may be covered with plaster or micro-concrete, *Fig 1.1 (d)*

(adapted from IAEE manual - 2002, Chapter 9)

Appendix II

Building Crack Repair & Treatment

Pidilite Industries Limited

KOLKATA

Everest House, 10th Floor
46/ C, Chowringhee Road
KOLKATA - 700 071.

Phone : (033) 22888844 / 7610

Fax : (033) 22881701

DELHI

6th Floor, Vikas Deep
Laxmi Nagar, District Centre
Vikas Marg, DELHI - 110 092

Phone : (011) 45529000

Fax : (011) 22422916, 22500720

Repair Methodology For Restoration of Distressed Reinforced Concrete (RC) Members By Micro-concrete Encasement

[http://www.doctorfixit.com/repair Methodology For Restoration Of Distressed%20 Rc Members.asp](http://www.doctorfixit.com/repair%20Methodology%20For%20Restoration%20Of%20Distressed%20Rc%20Members.asp)

Method Statement

Supports

The R C members shall be properly supported before chipping the spalled / loose concrete. The props provided shall be adequate to provide sufficient structural support to the load carrying members.

Surface Preparation of concrete

All the spalled cracked concrete or any other pre-applied mortar shall be removed by chipping to expose the reinforcing bars. The concrete shall be chipped to a minimum depth of 10mm behind the reinforcing bars. The areas to be repaired shall be profiled to get rectangular or square shape with an inward tapering edges

Surface preparation of reinforcement

The exposed reinforcing bars shall be cleaned thoroughly to remove all traces of rust, scales, etc., by using wire brush, emery paper etc. The lateral ties/stirrups shall also be cleaned in the same way. After removal of corroded portion, the diameter of the reinforcement shall be checked and compared with the drawings.

Provision of additional reinforcement

As the diameter of reinforcing bars is reduced substantially (say >20%) additional bars shall be provided as per the design. This additional reinforcement shall be properly anchored to the existing concrete by providing adequate shear connectors. Weld mesh

may also be provided if found necessary depending on the recommendation of Structural / Design Engineer.

Provision of shear connectors

Shear connectors of 8mm dia shall be provided in holes of 14mm dia and 75 mm deep. These shall be provided at every 500 mm c/c on all the faces of the beams in staggered form. The holes shall be cleaned with compressed air or water jet to remove all the dust etc. and then the shear connectors shall be fixed in the holes using polyester resin anchor grout **Dr. Fixit Anchorfix P**

Priming of reinforcement bars

The exposed and cleaned reinforcing bar shall be provided with a coat of **DR.Fixit Epoxy Zinc Primer** such that the coated film will have a dft of 40 microns. The film shall be continuous especially in the regions where pitting, imperfections etc., are present on the surface of the bars. It is important that the rear portion of the bars should not be left without coating. A second coat if needed may be provided to achieve a uniform and continuous film. The additional reinforcement provided and also the shear connectors shall be coated with **DR.Fixit Epoxy Zinc Primer**. The weld mesh if provided shall also be coated with **DR.Fixit Epoxy Zinc Primer**.

Provision of Epoxy based bonding agent (Dr. Fixit Epoxy Bonding Agent)

The base and hardener component of epoxy resin based bonding agent must be mixed well to get a uniform grey coloured mix. Apply the material to properly cleaned and dry concrete substrate using stiff nylon brush by scrubbing it well into the substrate. The coat should be uniform and well spread on the entire surface area of the repair patch. The mixed material must be applied before the elapse of its pot life and the new repair mortar must be applied before the elapse of overlay time. As a fully dried epoxy resin coat acts as debonding layer, the repair material should be applied whilst the bonding coat is tacky. In case the applied epoxy bond coat gets dry, an extra coat should be applied before application of repair mortar.

Formwork and shuttering

Slurry tight and strong form work shall be provided. The shuttering for encasement shall be kept ready such that the formwork shall be placed in position and fixed such that the Microconcrete can be poured into the formwork within the overlay time of the bonding agent (5 hours). Adequate supports shall be provided for the formwork. Care should be taken to ensure leak proof shuttering. Under no circumstance the slurry shall flow out of the shuttering during pouring of microconcrete.

Mixing of microconcrete

Dr. Fixit Microconcrete, a cementitious, non-shrink microconcrete shall be mixed using the appropriate water powder ratio as mentioned in the product data sheet. The mixing shall be done mechanically and under no circumstance hand mixing shall be done. Mixing shall be carried out for 3 to 5 minutes to ensure that homogeneous mix is

obtained without any bleeding or segregation. In hot climate ice cooled water shall be used to maintain the temperature of mixed material. If the encasing thickness is more than 75 mm, add stone aggregates up to 50 % by weight of microconcrete to the mixed microconcrete directly into the mixer hopper. The stone aggregates must be 12 mm and down and shall be clean, washed and dried. Mix first microconcrete with recommended dose of water for about 3 minutes in mixer and then pre weighed stone aggregates into the mixer. Mix further for about 2 minutes till lump free mix is obtained. Do not add extra water than mentioned in the product data sheet.

Pouring of microconcrete

The mixed **Dr. Fixit Microconcrete** shall be poured into the formwork using a suitable funnel or through a hose pipe. It must be poured from one end only. A suitable hopper / funnel arrangement shall be made at site to facilitate the pouring operations. The pouring operation shall be continuous and it shall not be stopped unless the job is completed. To achieve this sufficient mixers / drilling machines and work force shall be arranged at site.

De-shuttering

The shuttering from the sides of the R C members shall be removed after a period of 24 hours. However, the formwork of the soffit shall be retained and removed after 3 days.

Curing

All the repaired and encased area shall be fully cured as per standard concrete practices. Curing compound shall be used for effective curing of sides and soffits of beams. Note : If a curing compound is applied, care shall be taken to ensure that proper surface preparation is carried out so as to remove any traces of curing compound on the surface. If this is not done, it may lead to debonding of any protective coating applied on top.

Products

<u>Dr. Fixit Anchorfix P</u>		Is a two-component polyester resin anchor grout for anchoring of bolts from 8 to 50 mm dia into concrete, rock, masonry or brickwork.
<u>Dr. Fixit Epoxy Zinc Primer (Zinc primer)</u>		Used as a coating to re-bars and steel surfaces.
<u>Dr. Fixit Micro-concrete</u>		Used for repairs to damaged reinforced concrete elements like beams, columns, etc.

Repair Methodology For Restoration of Spalled RCC Members By Site Made Polymer Modified Mortars

Method statement

Surface Preparation

All the loose cracked & de-laminated concrete shall be removed by chipping or other mechanical means. The extremities of repair locations shall be cut behind the reinforcement or saw cut to a depth of at least 10 mm to avoid feather edging. The areas to be repaired shall be profiled to get rectangular or square shape with an inward tapering edges. Clean the surface to remove all traces of dust, oil, paint, grease, algae etc. Oil & grease deposits can be removed by steam cleaning, detergent scrubbing or by using de-greaser. The area cleaned shall be washed with water to remove all traces of dust, loose particles etc.

Surface preparation of steel

Steel reinforcement encountered during repair shall also be cleaned to remove all traces of rust, corrosion scales etc. using wire brush / emery paper. If sand blasting is allowed it can be resorted to. Extra steel if necessary shall be provided. If chlorides are anticipated then high pressure washing with water shall be carried out.

Reinforcement Priming

The exposed and cleaned reinforcing bar shall be provided with anti corrosive coat of **Dr.Fixit Zinc Epoxy Primer** such that the coated film will have a dft of 40 microns. The film shall be continuous especially in the regions where pitting, imperfections etc. are presents on the surface of the bars. It is important that the rear portion of the bars should not be left over without coating. A second coat if needed may be provided to achieve a uniform and continuous film

Priming Concrete Surface / Bonding agent

The exposed concrete surfaces shall be cleaned to remove any traces of dust, loose concrete etc. with the help of compressed air. The substrate shall be thoroughly washed with water jet to remove any traces of contamination. The surface shall be primed with Dr.Fixit Pidicrete MPB an Acrylic based bonding agent **Acrylic Emulsion Based bonding agent (Dr. Fixit Pidicrete MPB)** The material must be stirred well inside the container before using. Apply neat coat on a well prepared and cleaned concrete substrate whist the surface is damp. The material should be applied using stiff nylon brushes by scrubbing it well into the substrate. The applied material should not be allowed to dry. The repair mortar should be applied when the bond coat is still tacky. In

case the applied bond coat dries, an extra coat should be applied before application of repair mortar

Preparation of polymer modified mortar

Polymer modified mortar shall be prepared at site in the following proportion

Cement – 50 kg

Sand - 150 kg (Screened river sand or quartz sand of Zone II & I)

SBR / Acrylic polymer – 10 ltrs Water - 10 ltrs

Mixing

Forced action mixer like pan mixer or heavy duty drilling machine (slow speed) with paddle attachment shall be used for the mixing. Add first water and polymer and then add dry mix of cement and sand into the mixer. Mix the material for 3 to 5 minutes till homogeneous mix is obtained. Add extra water if required at site to achieve the required constancy. The river sand shall not contain any silt or similar contamination. It shall be washed, screened and dried before using. Alternatively for better results quartz sand of zone I & II also can be used in 1:1 proportion.

Application

Mixed material then shall be applied on the tacky bond coat by hand in 15 to 20 mm thickness. The compaction shall be ensured while applying. Allow 1st layer to dry and then subsequently apply one more layer, if required, after applying a bond coat. No application shall be done without accompanying the bond coat. The final layer can be finished smooth with trowel.

Curing

All the repaired areas shall be cured with a coat of acrylic polymer Pidicrete MPB immediately. Alternatively moist curing for 3 days also can be done by sprinkling water or by covering the area by wet Hessian cloth.

Repair Methodology For Non shrink cement slurry for injection grouting of Honeycombs/ Voids / Cracks etc.,

[http://www.doctor-fixit.com/repair Methodology For Non shrink cement slurry.asp](http://www.doctor-fixit.com/repair%20Methodology%20For%20Non%20shrink%20cement%20slurry.asp)

Method Statement

Material Properties

The non shrink cement slurry shall be used for filling cracks of width greater than 8 mm in concrete and masonry, sealing honeycombing / voids in concrete, using injection grouting method. The slurry shall be made at site by the addition of plasticising and expanding grout additive to a cement slurry mix.

Surface Preparation

Clean the concrete surface along the crack. Surface cracks should be sealed to keep the grout from leaking out before it has set. A high strength, rapid setting and water insensitive polyester resin based mortar shall be used for this. The material shall be applied by cutting a V groove along the crack line.

Installation of grouting nozzles

This method shall be used in conjunction with V grooving of the cracks. The method entails drilling a hole into the crack, approximately 3/4" in diameter and 1/2 to 1" below the apex of the V-grooved section. In this holes fix PVC or Aluminium Nozzle and seal with a high strength, fast setting plugging compound. If polyester resin mortar is used for filling grooves, the same materials shall be used for plugging the entry port. When the crack is sealed, flush with water to clean it and test the seal for any leakage

Preparing grout mix

Injection grout mix shall have the following mix proportions.

Cement : 50 Kg

Pidicrete AM : 225 gm

Water : 20-22 litres

The grout mixture should be mechanically mixed using a forced action mixture to a uniform consistency

Application

For small volumes, a manual injection gun may be used; for larger volumes, a pump should be used. The pressure used for injection must be carefully selected based on grout properties, crack characteristics, and structural integrity of the medium to be grouted

A pressure of 2-3 kg shall be maintained during grouting.

If the crack is vertical, the injection process should begin with pumping grout into the entry port at the lowest elevation until the grout level reaches the entry port above. The lower injection port is then capped, and the process is repeated at successively higher ports until all the nozzles are grouted and capped.

For horizontal cracks, injection should proceed from one end of the crack to the other in the same manner.

If the pressure cannot be maintained, the grout will flow into the unfilled portions or will leak out of the crack.

After the grout has set completely, the extra length of the nozzle shall be cut or removed from the surface.

Filling Honeycombing / Voids in concrete

The same grout mixture shall be used for this purpose. The injection ports should be fixed on the entire area to be grouted in a staggered manner at distance of 500 mm c/c. Fixing or as directed by the concerned engineer, sealing and grouting of injection ports shall be carried out as per the application methodology given above.

Products

<u>Dr. Fixit Pidicrete AM</u>		Used for producing cementitious grouts which are suitable for bed grouting, duct grouting, filling, etc.
<u>Dr. Fixit Epoxy Zinc Primer (Zinc primer)</u>		Used as a coating to re-bars and steel surfaces.

Repair Methodology For Low viscous, clear epoxy for injection grouting of structural cracks, beam-column joints

([http://www.doctor-fixit.com/repair Methodology For Low viscous clear epoxy.asp](http://www.doctor-fixit.com/repair%20Methodology%20For%20Low%20viscous%20clear%20epoxy.asp))

Method Statement

Material Properties

All structural cracks of size ranging from 0.25 mm to 8 mm in concrete and beam-column joints should be injected with Low viscous, non solvented clear epoxy resin by drilling holes and fixing injection ports as under.

Application Methodology

Mixing

Two components of Epoxy Injection Grout shall be mixed in a suitable container with heavy duty slow speed drilling machine with paddle attachment. Empty the entire content of base first and then add hardener. Start the mixer and mix it for 2 to 3 minutes till uniform colour is obtained. Under no circumstances part mixing shall be done.

Application

Cut open the cracks and clean it to remove loose materials, dust etc., and shall be washed with water.

Drill holes to fix 8 mm dia injection packers at a spacing of 200 - 300 mm c/c. Fix the nozzle and fill the crack length between the packers with Epoxy Putty

Grout the injection packers with low viscous, solvent free epoxy resin. A suitable manual / electrical operated injection pump with pressure not exceeding 2-3 kg per sq.cm shall be used. Continue applying pressure until resin appears at the next packer location or till refusal of the material. Remove pressure from the injection gun, close valve and crimp injection packer. Move on to the next packer.

After the grouting operation is over, extra length of nozzle shall be cut or fully removed from the surface.

Products

Dr. Fixit Epoxy Injection Grout



Used for repairs, rehabilitation of underwater structural members and to fill up cracks in roof slabs and other structural members

Appendix - III

Damage assessment framework – strategy

Damaged buildings shall be inspected between the third day and the seventh day after the earthquake, or for a longer period depending on the disaster level, to evaluate building safety against aftershocks by the visual inspection of their appearance and in the buildings' interiors by building structure engineers. The judgment result of this inspection shall be classified as "inspected", "limited entry", or "unsafe" and posted near the building entrance.

The purpose of the quick inspection of damaged buildings is to judge the risk of collapse or tip-over of the buildings damaged by an earthquake or falling of building components due to aftershocks as soon as possible, and to provide information on the risk of using the buildings before they are restored for long-term use. This should help prevent secondary disasters that would endanger people in earthquake-stricken areas.

The primary responsibility to ensure the safety of a building rests with its owner, building manager, or occupant. The owner and relevant people have the responsibility to ensure the safety of the building damaged by an earthquake. In case the damage by the earthquake is too large or there are a number of owners for a building, however, it is not always possible for the owners of the damaged building or relevant people to confirm the safety of the building by themselves. A large-scale earthquake normally has a number of aftershocks. Buildings damaged by an earthquake will be destroyed further by the intense vibration of aftershocks and might collapse, thereby subjecting a number of people to the threat of secondary disasters. Damaged buildings that would affect roads or adjacent houses in particular can hurt third parties. Therefore, from the viewpoint of the safety of citizens after an earthquake, it is not desirable to entrust the entire responsibility for the safety of damaged buildings to the owners or relevant people without taking administrative action.

Damage: Destruction, deformation, inclination and settlement of a building foundation caused by an earthquake.

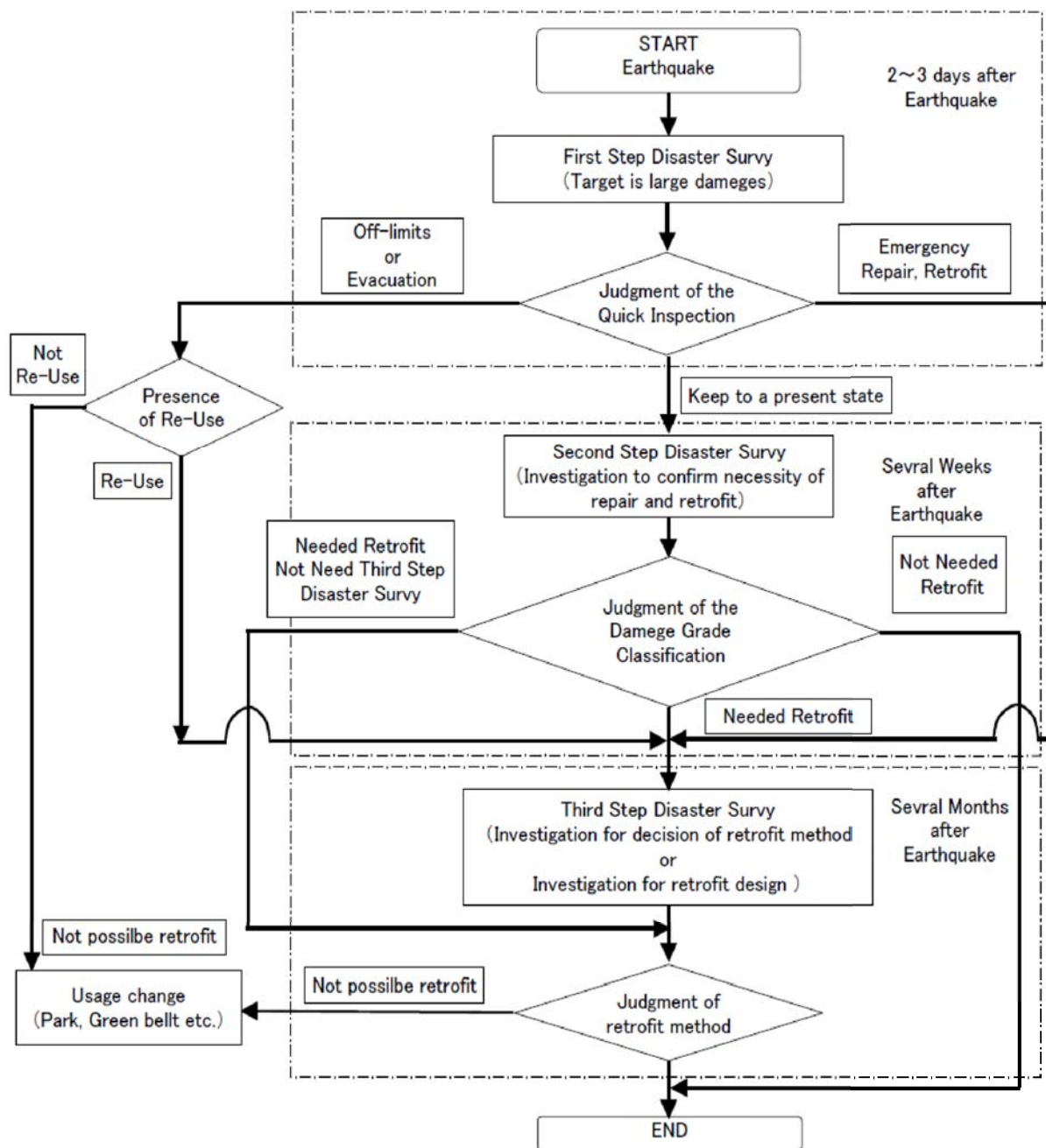
Damage grade: Degree of danger of destruction, deformation, inclination and settlement of a building foundation caused due to earthquake.

Retrofit: Secure a necessary aseismic capability reinforcing the aseismic capability of existing building foundations which decreases due to an earthquake, and assume an existing building to be reusable.

Safety: Building foundation conditions which ensure the safety of human life even at a possible severe earthquake.

"Quick Inspection" of the ground is made within two or three days after an earthquake, with emphasis placed on the more seriously damaged ground. The purposes are to:

1. judge whether it is necessary to take measures such as preventing people from entering or evacuating the residents,
2. determine if emergency repair and reinforcement is needed, determine whether the current ground should be maintained, and when the current ground is maintained, the necessity of repair or reinforcement is judged according to "Damage Grade Classification" that is conducted within several weeks.



In cases where repair or reinforcement is needed to restore the ground, either the restoration method is selected or the restoration design is investigated. The method is decided several weeks to several months after the earthquake. But when the ground is judged impossible to restore, the use of the area in question has to be reconsidered.

(adapted from Guideline for Damage Survey Methods of Earthquake Disaster Related with Buildings and Houses, <http://iisee.kenken.go.jp/eqtap/guide.htm>)

APPENDIX – IV

COMMON RAPID ASSESSMENT FORM (TO BE FILLED WITHIN 36 TO 48 HRS)

1. TYPE OF DISASTER:				ASSESSMENT DATE AND TIME:				
				ASSESSMENT BY:				
2. AFFECTED AREA								
	Village	Gram Panchayat	Block/Taluka	District				
Worst Affected								
Affected								
Moderately Affected								
3.a) DEMOGRAPHIC DAMAGE								
Total population/HH/families	Affected Families/HH	Other sections /classes (SC/ST/Minorities)	Reported human deaths	Main causes of mortality	Reported humans missing	Reported injured		
3.b) REPORTED HUMAN LOSS BY GROUPS								
Women	Men	Infants (0-1yrs)	Children (2-5yrs)	Children (6-14yrs)	Unaccompanied children	handicapped	Elder persons	TOTAL
4 a). INFRASTRUCTURE								
Services		Status (Before)-			Status(After) fully/partially damaged			
School								
Panchayat Office								
PHC								
Road to the affected area								
Electricity/Power Supply								
Tele Communication								
Source of Drinking Water								
PDS Shop								
Community emergency shelter								
4 b) LOGISTICS								
Availability of warehousing facilities (partners/outside)	Availability of transport facility (Vehicles)	Availability of space for control room/site office/ Response office	Existence of local partners network/ existing Agency programmes		Mechanism for distribution and management of relief stock			
5. SHELTER, HOUSING AND CAMP SITE								
No. of houses partially damaged	No. of houses fully damaged	Local construction materials			Site for relief Camps			

6. LIVELIHOOD							
Agricultural crop damage (partial /full)	Agriculture Field damage	Livestock mortality	Disposal of Animal corps	Availability of fodder	Effect on Petty businesses	Shops/market place damages	
7. HEALTH							
Removal of dead bodies and debris	Medical services/immunization carried by Govt (Humans and livestock)		Possible disease out break (measles, cholera, diarrhea)		Availability of first aid/ medicine and services by Private, NGO and civil society		
8. EDUCATION							
Damage to school infrastructure (class rooms, toilets, common facilities)		Damage to educational material (books , uniforms)					
9. WATSAN							
Condition of drinking water sources	Availability of water sources/supply	Quality of water and access	Defecation sites		Availability and condition of toilets	Damage and status of drainage facilities	
10. FOOD AND CLOTHING							
Availability of Dry ration (for 2 weeks)	Availability of cooking fuel / and utensils		Need for community kitchen	Availability and clothing requirements		Nutritional requirements	
11.SOCIAL SECURITY AND POLITICAL SITUATION							
Access and distribution to relief materials	Religion/caste/class based biases		Reports of hording/looting and price rise		Statements by the local govt officials /disaster authorities		General trend of news in local newspapers and radio
12. RESPONSES							
From Local govt/departments/panchayats	From local CBOs- SHG/Youth groups			From INGO's and NGO working in the region			
13. UNMEET NEEDS /SUMMARY							

14. SOURCES OF INFORMATION
15. CONTACT NUMBERS OF KEY INDIVIDUALS

This format is a complied from the following Sphere member agencies assessment checklist/format : CRS, LWSI, OXFAM, CARE, UNICEF, SEEDS, CARITAS, CASA, World Vision, Concern Worldwide, German Red Cross, SCF, ADRA, EFICOR, Christian Aid, DCA, ActionAid, Goal India, UNDMT, Vietnam IAG, Orissa and Gujarat IAG, RVC

APPENDIX-V
COMMON DAMAGE ASSESSMENT FORM (TO BE FILLED WITHIN 72 to 96 hrs)

TYPE OF DISASTER:		ASSESSMENT DATE AND TIME:													
		ASSESSMENT BY:													
Area Assessed															
Urban				Rural											
Affected Area/site				Camp											
Sector/s assessed:				<table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 50%; text-align: center;">WATSAN</td> <td style="width: 50%; text-align: center;">FOOD/NUTRITION</td> </tr> <tr> <td style="text-align: center;">HEALTH</td> <td style="text-align: center;">SHELTER</td> </tr> <tr> <td style="text-align: center;">EDUCATION</td> <td style="text-align: center;">PROTECTION</td> </tr> <tr> <td style="text-align: center;">LIVELIHOOD</td> <td style="text-align: center;">NON-FOOD ITEMS</td> </tr> </table>				WATSAN	FOOD/NUTRITION	HEALTH	SHELTER	EDUCATION	PROTECTION	LIVELIHOOD	NON-FOOD ITEMS
WATSAN	FOOD/NUTRITION														
HEALTH	SHELTER														
EDUCATION	PROTECTION														
LIVELIHOOD	NON-FOOD ITEMS														
1)AFFECTED AREAS															
	Village	Gram Panchayat	Block/Taluka	District											
Worst Affected															
Affected															
Moderately Affected															
Any available Maps															
1.b) AFFECTED POPULATION															
	VILLAGE/WARD	PANCHAYAT	TOWN/BLOCK	DISTRICT	STATE										
Est. no. of villages affected:															
Est. No. of families affected:															
Est. no. of persons affected:															
Est. no. of women affected:															
Est. no. of children affected:															
Est. no of infants affected															
Est. no of elderly affected															
Est. no. of female headed HH															
Est. displaced population															
1.c) PHYSICAL INFRASTRUCTURE IN THE AREA VISITED FOR ASSESSMENT															
	Roads	Rail Link	Power	Water Supply	Communication	Fuel pumps	Others								
Functional:															
Damaged:															
Destroyed:															
Est. time to repair:															

Remarks/Notes

1.d) SOCIAL INFRASTRUCTURE IN THE AREA VISITED FOR ASSESSMENT

	Primary School	Sec/High School	College/Other Institutions	Health Centres /dispensaries	Hospital	PDS Shops &Panchyat office	Relief Shelters
No. Existing:							
No. Functional:							
No. Damaged:							
No. Destroyed:							
No. Used as relief centres/camps:							
Distance from the area visited:							
Capacity in terms of beds/persons:							

Remarks/Notes

1.e) Evacuation Status		
1.f) Status on Search and Rescue		

SECTION 2: FOOD, FOOD SECURITY & NUTRITION

2.a) Food Basket – FOOD BASKET PER PERSON CURRENTLY AVAILABLE

ITEM	QUANTITY	FROM WHERE	WHO PROVIDES

2.b) Household

Normal Food consumption patterns of the affected populations					
Expected food availability trend among HH	Next three weeks		Next month		
Food availability by categories of populations	0-6 yrs	6-11 yrs	11-18 yrs	18-55 yrs	55 yrs and above
Is there equal distribution of food at the house hold level ?					

2.c) Malnutrition Status

Malnutrition rate among children under five yrs and micronutrient deficiencies?						
Symptoms of malnutrition and micronutrient deficiencies since the disaster						
	Infants	Children 1-4	Pregnant	For	For	For 55 yrs

Any special food items prepared or purchased by the household for the following groups		yrs	and lactating mothers	malnourished	micronutrient deficient	plus people

2.d) Cooking Facilities

From where do the families get water?	Secure Source			Open and insecure source		
Is there storage facility for water	YES	NO	If yes, is it sufficient	YES	NO	
Where do they cook	Kitchen		Room	Outside	Others:	
If camp, Is there separate place to cook	YES	NO	If no, where do they cook	Within	Open	
Is there separate place to wash	YES	NO	If yes, where is it located	NEARBY	FAROFF	
Is there any kitchen drain	YES	NO	If yes, is it secure?	YES	NO	
Where do they dump the kitchen waste						
What type of fuel do they use	LPG		Kerosine	Coal	Wood	Leaves
From where do they get the fuel	Buy		Own	Collect	Relief	

2.e) Market

Availability of food in the market					
Market price of essential commodities	Cereals /Rice		Pulses	Oil	Sugar/spices/salt
% of the affected populations which could afford the current prices					
Black marketeering and Govt action					

SECTION 3: WATER, HYGIENE AND SANITATION

3.a) Safe Drinking Water

	Total No. of units	Functional Units	Defunct Units	Repairable units	% of HH using	Average distance	Capacity	Flow / access
River								
Ponds								
Canal/stream								
Open Wells								
Handpumps								
Piped Systems								
Tanker/Truck								
Other:.....								
Other								

Remarks/Notes on perceived quantity of water available/distance/access

Remarks on perceived quality of water available (contamination, taste, risks)

3.b) Household Level Water Consumption (ESTIMATED AVERAGE)

	Quantity (ltrs)	Source	Distance	Responsibility	Storage Facility
Average HH size					

Direct Consumption					
Cooking					
Washing/cleaning					
Bathing					
Sanitation					
Others:.....					

3.c) Sanitation

Defecation practices			
Open Air	Toilets	If open air, how far is the place	
		If toilets, are they being used now?	
% families using open space	% of families having toilets	If camp, How many toilets are there in the camp?	
		How many people are living in the camp?	
Do you find evidence of human waste in the open?		Type of toilet?	
		Are the toilets clean?	
Is the defecation practise a threat to water supplies?		How far is the water source?	
		Are the toilets secured?	

Notes/Remarks:

3.d) Solid Waste Disposal			Notes/Remarks:
Do You find evidence of sewage in open, both at household level and in general?	YES	NO	
Is there any solid waste disposal bins in the household level?	YES	NO	
What will be the estimated quantity of solid waste produced?			
Is there any existing waste collection mechanism?	YES	NO	
Is there any existing waste disposal mechanism?	YES	NO	
Is there any proper drainage facility at the household level or at the site?	YES	NO	

3.e) Vector Borne Diseases

Is there any evidence/reporting of vector borne disease in the area	YES	NO
If yes, what type of disease is reported?		
How many people are affected?		
Who are the primarily affected groups?		
Who are the vulnerable groups?		
Are there any existing vector control measures?	YES	NO
If yes, what are they?		
Are people aware of vector control measures?		

SECTION 4: HEALTH AND MEDICAL

What is the status of mortality and morbidity?	
What is the crude and under five mortality rates?	
What are the principal causes of death (e.g.	

malnutrition, measles, injury, Acute Respiratory infection (ARIs),)?			
What are the principle causes of morbidity including measles, diarrheal disease, ARIs, malaria, injuries) and who is primarily affected?			
Health facilities operational	Number	Capacity	Location
Mobile Health Units Available with	Govt	NGO's	UN Agencies
Are more mobile health units required? If yes, for how long.			
Availability of medical professionals			
Availability of laboratories			
Availability of facilities for deliveries			
Status of Animal medical facilities			
Mortality and morbidity status of livestock? And reasons.			
Unmet needs for livestock health care			
Availability of essential medicines and medical consumables in the affected area			
Drugs			
IV fluids			
Syringes and needles			
Blood bank			
ORS			
Vaccines			
Serums			
Contraceptives			
Dressing and bandages			
Surgical Supplies			
Antiseptics			
Disinfectants			
Blood transfusion and infusion sets			
Availability of capacity for correction of disabilities			

SECTION 5: NON-FOOD ITEMS

Total number of households needing assistance.

Types and average numbers needed per household:

Items	Numbers (Approximate)
Plastic Sheetting	
Clothing and type	
Washing/cleaning	
Transport	
Cooking: Fuel/Stoves	
Heating	
Blankets/Quilts/Mattresses	
Family toilet kits/Hygiene kits	
Water containers for storage	
Cooking/kitchen utensils	
Disinfectants (Phenyl, Dettol, Chlorine, Bleaching powder, etc.)	

SECTION 6: SITE AND SHELTER

No of families remaining on the site of their damaged/destroyed shelter	
Number of families displaced and accommodated by host families	
Number of families displaced and accommodated collectively within existing publicly or privately owned houses such as schools, temples, community houses, etc.	
Displaced and collectively settled in newly built relief camps/temp shelters.	

Availability and number of temporary shelters	For people		For livestock		
Public buildings which are being used as temporary shelters and their capacity					
Types of temporary shelters	Tents	Polythene Sheets	Tarpaulin Sheets	Tin Sheets	Straw and pullas
Accessibility of vulnerable and marginalized groups to temporary shelters					
Need for additional temporary shelters and their expected duration					
Structural Damage	Degree of damage				
Types of Structures	Totally collapsed	Major damage and unsafe for use	Significant damage, unsafe for use, repairable in short term	Some damage, safe for use	Minor or no damage, safe for use
Houses					
Pvt buildings					
Public buildings					
Govt buildings					
Predominant type of structure and construction materials used					
Type of roof and covering					
Percentage of building can be retrofitted in short time					
Any damage reported to the local building and construction industry					

SECTION 7: LIVELIHOOD

Major livelihood pattern and options for the community	Pre-disaster		Post-disaster	
Extent of damage to livelihood				
Extent of loss of employment opportunity and likely migration				
Number and types of workers affected	Cultivators	Agriculture Labourers	Unskilled labourers	Skilled
Extent of damage to fisheries	Equipment /boats		Loss of catch	Processing facilities
Existence of any risk cover schemes /insurance				
Steps taken and Resources available by Govt. and NGOs for restoration of livelihood for different types of workers				

7.1) Agriculture

	Agriculture	
1	Amount crop totally lost in the area.	
2	How much of the available land is cultivable?	
3	Where in the cropping cycles are farmers, e.g. harvest, preparation, planting	
4	Number of households still have the following:	
	o Current season's crops(s)	
	Multiple seasons' crop(s)	
	Seed stocks	
	Labor sources	
	Tools	
	Livestock	

	Market access	
	Resources available for land reclaiming	
	Damage to agricultural infrastructure (finance, seeds banks, marketing-corporatives)	
	Status on irrigation facilities	
	Current status of fodder availability	
6	Improvements required (e.g. irrigation systems, storage facilities, fencing, terraces)	
7	What is the current response plan by the government to address the livelihood issues in the community?	
8	Are other agencies planning to respond? How?	
9	Are partners planning to respond? How?	

SECTION 8: EDUCATION AND COUNSELING

Extent of damage to school infrastructure	
Percentage of schools being used as relief centers	
Affect on educational and schooling activities	
Damage to educational material (books, uniform etc)	
Are children being engaged with other activities (labour, domestic help)	
Psychosocial counseling need among the affected community	
Resources available for psychological support to teachers and students and capacity of teachers to provide psychological support to students	
Need for training/ capacity building of volunteers for handling post -traumatic stress disorders and psychological support to affected groups	

SECTION 9: PROTECTION

Indicate if any of the following groups are at significant risk/threat from protection issues.

Risks	Overall population	Children		Adolescents		Adult women	Others
		M	F	M	F		
Sexual abuse/rape							
Abduction/Trafficking							
Forced migration							
Forced militia recruitment							
HIV							
Political manipulation							
Other concerned diseases							
Any Other							

Are the places where people are staying/camping safe enough from the above potential threats? If no, why?

SECTION 10: UNMEET NEEDS/SUMMARY

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SECTION 11: KEY CONTACT DETAILS

Administration/Local Leadership (please give name, designation and contact details, if any)

State Relief Authority:			
District Relief Authority:			
Block Relief Authority /dealing officer:			
Panchayat/Municipal President:			
Village level representative:			
Local leadership 1:			
Local leadership 2:			

SECTION 12: INFORMATION ON ASSESSMENT PROCESS AND METHODOLOGY

	No. of people interviewed	Male	Female	Children	Category of leadership
Interview with local affected persons					
Interview with local leaders					
Interview with elected representatives					

	No.	Male	Female	Category of representative
Interview with government officers				
	Place and time	No. of participants (male/female/child)	Remarks	

Focus Group Discussions			
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This format is a complied from the following Sphere member agencies assessment checklist/format : CRS, LWSI, OXFAM, CARE, UNICEF, SEEDS, CARITAS, CASA, World Vision, Concern Worldwide, German Red Cross, SCF, ADRA, EFICOR, Christian Aid, DCA, ActionAid, Goal India, UNDMT, Vietnam IAG, Orissa and Gujarat IAG, RVC



Sikkim Earthquake – A road map for resurrection

This report has been prepared by Dr. Chandan Ghosh, Professor and Head [Geohazards and Hydro-Met Divisions], NIDM based on the onsite inspection of relief, rescue and emergency operations, infrastructure damages in the earthquake and landslides affected areas due to M6.9 Sikkim Earthquake of September 18, 2011 in association with Dr. Surya Parkash, Associate Professor, NIDM.



Towards a disaster free India

NATIONAL INSTITUTE OF DISASTER MANAGEMENT
Ministry of Home affairs, Govt. of India, New Delhi



Church bells which will not toll

6.9 Richter quake of 18Sep2011: Kalimpong's most enduring and iconic landmark damaged

Amongst the many houses, structures and monuments which were damaged is the Macfarlane Memorial Church which was built in 1891 by Scottish missionaries. The steeple housing the massive bell was damaged and two of the spires were knocked down. The church bell is now silent and services in the church will be discontinued for the time being and held elsewhere.

