THEMATIC SESSION A1: EARTHQUAKE

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ABSTRACTS

FEASIBILITY OF SEISMIC ALERT SYSTEMS IN INDIA

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Indian subcontinent has been worst hit by the natural disasters like earthquakes, floods, cyclones and landslides. As far as the casualties are concerned, earthquakes top the list. Besides this, the property loss due to these earthquakes is too high to be estimated. In the light of the present knowledge base, we are far away from any earthquake predictive tool. An early earthquake warning has potential to save all the precious human lives. In the present day scenario seismic instrumentation and telecommunication permits the implementation of seismic alert system based on the real-time measurement of ground motions near the source. Such systems are capable of providing a warning of several seconds before the arrival of destructive seismic waves caused by a large earthquake. Such systems are successfully operational in many countries of the world like Japan, America, Mexico, Taiwan, Turkey etc. In a country like India where earthquakes are taking heavy toll of human lives and property, Seismic Alert Network may prove to be very important step in natural hazard mitigation strategy.

Seismic Alert Network may help us to give an alarm before the destructive earthquake waves reach to a populated place. S-waves are in most of the cases responsible for structural damages. The time, which may be available for alarm, depends on the distance of the earthquake source. If earthquake □picenter is 300 km away from the selected site, the alarm time (S-wave arrival time) will be more than one minute. This time gap helps in evacuation of buildings in urban areas, shutting down the critical systems like nuclear reactors, stopping high speed trains and human transportation, shutting down the elevators etc. In this paper an attempt has been made to compute the available alarm time for cities like Delhi, Lucknow, Patna and Kolkata taking Himalaya as the source.

ASSESSING THE SEISMIC HAZARD OF THE STABLE SHIELD REGIONS: AN EXAMPLE OF BANGALORE

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Ever since the occurrence of the M 6.3 earthquake at Killari, there has been a growing realization that many regions in the peninsular India, hitherto considered “safe” from earthquake hazard point of view might need to be monitored. This is especially true for fast developing urban centres, where the pressure on land is high (leading to reclamation, landfills, etc.) and construction practices are not rigorous. The fast developing city of Bangalore is a classic example for this kind of growth. Although Bangalore city has been traditionally regarded as of low seismic activity, the above situation necessitates a review of the vulnerability of the region, considering a scenario where the occurrence of a moderate earthquake cannot be totally ruled out. This paper presents results of Deterministic Seismic Hazard Analysis (DSHA) carried out for Bangalore, taking into account, the past earthquake history, inferred subsurface fault rupture lengths and point source synthetic ground motion model. Data on historic and recent earthquakes, mapped faults in the region and subsurface bore hole data, SPT results, shear wave velocity studies and microtremor studies shave been used to calculate the ground accelerations and their dependency on site-specific properties, such as the nature of the substrata and bed rock depth configurations. Observations from 950 boreholes drilled to depths up to 40m, shear wave velocity profiles at 55 locations and microtremor studies at 50 locations, were used in this study to compute the PGA at ground level, for an area of 220 sq. km (which is the Bangalore metropolitan area). The maximum peak ground acceleration (PGA) at rock depth is estimated to be about 0.15g. There are significant variations of PGA, depending on the subsurface conditions. Studies show that Bangalore is moderately amplifying in nature, the amplification factor varying from 1 to 5.4. This study calls attention to the need for focused efforts to monitor the earthquake sources, recognizing the site-specific effects of earthquake ground motion and dividing the city into different zones based on their hazard potential (microzonation maps of PGA at ground, spectral accelerations at different frequency and period of soil column) and the implementation of more rigorous construction practices. The study for Bangalore city is an example damage mitigation efforts for a region not traditionally considered very active.

UNDERSTANDING EARTHQUAKE RECURRENCE: A STEP TOWARDS HAZARD MITIGATION

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Earthquake recurrence has different meanings in different tectonic environments. While active regions such as the plate boundaries are prone to moderate, large and great earthquakes (the Himalaya, Andaman-Sumatra subduction zone etc. for example), the plate interiors are associated with much slower deformation rates and therefore infrequent earthquake activity. With the morphologic, tectonic and other features of past movements well expressed, evaluating the past earthquake history of actively deforming zones pose lesser challenges, compared to the stable regions. Nevertheless, the threat from such regions cannot be underestimated, especially because they offer a false sense of security, leading to a casual attitude, when it comes to earthquake preparedness. The case of the Killari earthquake in peninsular India, is a good example of this situation. Interseismic intervals running to several tens of thousands of years and significant lack of earthquake related surface features preclude reasonable estimation of recurrence interval in such regions. However, in regions close to the plate boundaries and other sites of stress localization (as in paleorift systems such as the Kutch rift), geologic evidence, sometimes complemented by historic data helps identification of seismic sources that have been activated in the

past; they also allow some rough estimation of recurrence intervals. This abstract summarizes results of our studies in the Rann of Kutch (characterized by multiple sources, with varying recurrence intervals); Northeast India (where the past earthquakes is dated about 1000 years. B.P.); and the Andaman and Nicobar region (where the predecessor of the 2004 megathrust earthquake is dated at 1000 years B.P). Studies at each of these sites are complemented by historic and archeological data, adding confidence to our estimates on timing of the past earthquakes. We believe that extensive studies in earthquake source zones and identification of faults that have moved in the past are most effective in understanding the histories of causative structures that are likely to fail in future. These efforts certainly help in identifying potential sources, estimating the likelihood of future earthquakes, assessing the risk and thereby mitigating damage from future earthquakes.

ROLE OF SPACE TECHNOLOGY IN SHORT TERM EARTHQUAKE PREDICTION

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According to statistics, earthquakes rate first among natural disasters in the severity of damage and the loss of human life they inflict. The strategy of short-term prediction of earthquakes using space technology consists of a whole set of critical parameters, the precursors of earthquake, including the ionosphere, magnetosphere and the electromagnetic phenomena resulting in the observed variations. The search for electromagnetic phenomena possibly associated with earthquakes has been taken up for a long time. Recently it became possible to use satellite data in searching for electromagnetic phenomena that accompany seismic activity. The launch of DEMETER (Detection of Electromagnetic Emissions Transmitted from Earthquake Regions) satellite on June 29, 2004 has provided an opportunity to study the electromagnetic phenomena associated with earthquakes in the ionosphere. The main scientific objective of this mission is to study the ionospheric perturbations, which are linked to seismic activity. The orbit of DEMETER is polar, circular with an altitude of 710 km. There are several sensors onboard DEMETER to survey the ionosphere. This paper presents examples of ionospheric variations observed before strong earthquakes by DEMETER satellite in different seismically active regions. The possibility of using these variations as precursors is also discussed.

POSSIBILITIES OF EARTHQUAKE PREDICTION USING GROUND AND SATELLITE-BASED TECHNIQUES

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Earthquakes have proven to be devastating for mankind every time they have struck. This form of disaster plays havoc normally without many indications of their occurrences. Since the past few years, the whole of the geo-scientific community along with space scientists are involved in studying and exploring the methods that one may undertake successfully for studying pre-earthquake signatures and find out if they can be vital for prediction of earthquakes. In this regard, the ground as well as space based techniques are found to evolve in the scientific community. With the help of electric and magnetic signatures detectable by these experiments, the studies may be useful in prediction of earthquakes in future. This paper discusses some of the vital methodologies involved for detection of certain anomalies that can be vital for earthquake prediction if carried out with consistent efforts.

SEISMO-ELECTRO-MAGNETIC AND OTHER PRECURSORY OBSERVATIONS FROM RECENT EARTHQUAKES

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During the period January 2001 to October 2005 three major seismic events have occurred. These are Bhuj Earthquake (2001), Sumatran Earthquake and Tsunami (2004) and Kashmir Earthquake (2005). These events have taken a death toll of about 3,20,000 lives in Asian Countries. After each destructive earthquake a common question frequently crops up. It is," Is it possible to predict earthquake?" Majority of the replies are invariably, "earthquakes cannot be predicted." A few years back, I was of the opinion that earthquakes cannot be predicted. But after undertaking field surveys of the above three earthquakes, I am now convinced that it is possible to predict earthquake to a sufficient degree of accuracy. The most important precursory parameter is Seismo-Electro-Magnetic Effect. Bapat (1981) has coined this terminology of Seismo-Electro-Magnetic Effect. Prior to the occurrence of any medium to large earthquake (M> 6.0), the two parts on fault move slowly. This movement causes frictional heat. The release of heat causes the sub-surface temperature to rise. It is estimated that near the hypo central area, the rise in temperature is of the order of 20 to 50 degrees Celsius. The rise in temperature has a direct effect on the geomagnetic field. The geomagnetic field decreases. This decrease has direct influence on the propagation of electromagnetic radiation. It could be through cable of through transmitter. If a radio station is transmitting signal at 1000 kHz then it will be received in the potential epicentral area, few hours before the

quake, at 1100, 1200, 1300…1700.1800…kHz. Similarly, the reception on Television is disturbed. It gets repeated audio, visual and spectral disturbances. The degree of adverse effect on antenna television is more than the cable television. The reception on cable and mobile telephones is also disturbed. The mathematical equation for reception of electromagnetic waves by the receiver is given by the following equation.

$$F = 1 / 2\Pi\sqrt{(LC)}$$

2 and Π are constants. C is capacitor of the receiver. It could be C1, C2, C3, etc. for different receivers. L is inductance. As the value of geomagnetic field decreases, the reception of frequency in the receiver increases. As L is in denominator and also in Square Root, a small decrease in geomagnetic field makes the reception frequency to raise many folds. The most interesting part is the effect on mobile telephones. It was seen that most of the mobile telephones start mal-functioning or non-functioning about 100 to 150 minutes before the occurrence of earthquake. This was seen prior to the above three earthquakes.

In addition to the above effect, the well known abnormal animal behavior before the earthquake was extensively seen. Further, similar to animal behavior, there are also cases of abnormal Human behavior. These were seen at some hospitals. Everybody extensively sees all these precursory indicators about ten to twenty hours before the occurrence of earthquake. This time is sufficient to organize proper mitigation measures and save the population. It is proposed to discuss these points in the paper.

EARTHQUAKE PROTECTION OF INFRASTRUCTURES IN INDIAN CITIES

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Our cities are experiencing exponential growth in size due to explosion in population as well as huge migration of people from rural areas. Also an average city today is far better than as it was few decades ago with respect to infrastructure facilities. Most of our cities now have skyscrapers, instant global communication system, fast travel facilities etc. Our infrastructures installations are increasingly becoming more and more complex consisting of civil engineering structures like flyovers, towers, underground tunnels etc. These infrastructure installations are providing basic economic foundations required for our country. As infrastructure installations are increasing, the potential for earthquake destruction is also increasing. The world witnessed many catastrophic earthquakes in the history. Where these events have occurred near cities, the destruction has been legendary. In recent times San Francisco in USA, Kobe in Japan, Tangshan in China and Messina in Italy have all been devastated by massive earthquakes. In India, 2001 Gujarat earthquake created significant damage to Bhuj city. Unless serious efforts are made to combat these disasters we can expect similar and great disasters with increasing frequencies in the years to come.

As compared to buildings, loss of human life and injury are considerably less in case of infrastructure damage. But their economic consequences are far reaching. The cost of their repair and reconstruction is very large. Apart from direct loss due to physical damage, loss of function can also be a major loss. Since these facilities are most needed following an earthquake, the emergency operations involved in managing earthquake disaster are severely affected. Additional losses occur due to reduction in revenue and opportunity costs. As a result, practice of earthquake disaster management in urban infrastructure is developing very rapidly during recent years. A body of knowledge has been built up by engineers, urban planners, administrators and financiers about earthquake disaster management of infrastructures. The primary objective of earthquake disaster management is to formulate policies which can be implemented for reducing damaging effects of earthquakes in given circumstances.

This paper makes a review on various aspects of combating destructive power of earthquakes with reference to infrastructure installations. Technical measures, traditional practices and public experiences reported in literature have developed the ability among people to combat destructive powers of earthquakes in many countries. The paper also attempts to explore these measures for protection of infrastructure installations in Indian cities.

EXPERIMENTAL INVESTIGATION ON REHABILITATION OF BEAM-COLUMN KNEE JOINT USING GFRP SHEETS

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The beam column joint is a crucial zone in a reinforced concrete moment resisting frames. It is subjected to large shear forces and its behaviour has significant influences on the response of the structure. The beam-column joints usually fail in shear. The shear failure was brittle in nature, which significantly reduce the overall ductility of the structure with little acceptable performance. The exterior beam-column joints are more susceptible to such failure as they are confined by less number of beams attached to their sides. Composite materials are used in a variety of forms both in new construction and retrofitting of a damaged structure due to any disaster.

The objective of the present experimental study is to strengthen the shear resistance of exterior knee joint by using Glass Fiber Reinforced Polymer (GFRP) sheets to eliminate the brittle shear failure and ensure that the ductile flexural hinging will take place in the beam. In the present study, the effect of different GFRP reinforcements used to retrofit the failed conventional reinforced cement concrete specimens and also a scheme is presented to apply GFRP sheets.

Slag cement conforming to IS 455-1976 was used for casting of beam-column joint. Natural fine sand from local river passing through 4.75mm IS sieve and not more than 10.0% pass through IS 600μm sieve were used in the investigation. Graded course aggregate of nominal size 12.5mm were used in this study. Concrete of M_{30} grade with mix proportion 1:1.137:2.25 mix proportion was used during casting of the beam-column. E-glass fiber sheets used were bi-directional woven roving mat and randomly oriented chopped strand mat of hybrid quality. Density of woven roving and chopped strand mats were 900 gm/mm^2 and 600 gm/mm^2 respectively. Epoxy resin is used as the binder of GFRP sheets with the concrete surface.

Results show that the joint jacketing by GFRP reinforcements is greatly effective in improving the joint strength and load carrying capacity of the rehabilitated structures. The proposed rehabilitation scheme is successful in eliminating shear mode of failure and ensures the ductile flexural hinging of the connecting beam.

MODERN TECHNIQUES FOR EARTHQUAKE RESISTANT DESIGN OF EARTH RETAINING STRUCTURES

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Design of earth retaining structure is an important area of research for geotechnical engineers and more so under earthquake condition. In India, the recent devastating effect of earthquakes which causes extensive damages to many earth retaining structures is noticeable. The conventional methods of analysis using pseudostatic approach based Mononobe-Okabe method for earthquake forces are found to be unsafe in some specific conditions during several recent incidents across the world. Hence, in this paper, the modern techniques to analyze and design the earth retaining structures subjected to the earthquake forces are mentioned. Among these techniques, the recently developed pseudo-dynamic method is found to be a better dynamic solution for retaining structures under earthquake condition, considering the effect of time period, variation of seismic accelerations with depth and time, shear and primary wave velocities, other soil parameters, period of ground shaking and soil amplification into the seismic earth pressure computation. It also reveals the non-linear behaviour of seismic earth pressure distribution compared to the conventional linear distribution obtained by using the pseudo-static approach which changes the point of application of the total thrust. The dynamic centrifuge test results are also confirming the proposed recent pseudo-dynamic solutions for the computation of seismic earth pressures. The stability analyses of earth retaining structures under earthquake conditions are carried out and the significant decrease in the factor of safety against sliding and overturning mode of failures are noticed. Variation of the proposed results from the conventional method is also reported. Role of design codes like IS: 1893 – 2002, Part 3; Eurocode 8 and design report of US Army Corps of Engineers (1992) is mentioned. The extreme need for updating the Indian design code, IS: 1893 – 2002, Part 3 for the seismic design of retaining structures considering the latest technical developments across the world are also highlighted.

STRUCTURAL MEASURES FOR IMPROVING PERFORMANCE OF BUILDINGS AND STRUCTURES AGAINST EARTHQUAKES

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Disaster mitigation through pre-disaster preparedness strategies has been the most effective message that the researchers have advanced in the recent past which is also gaining wide acceptance by the industry and the society. Structural Engineering Research Centre, a national laboratory under the Council of Scientific and Industrial Research, has undertaken many programmes for realising the goal of pre-disaster preparedness leading to reduced human/economic loss. Disaster resistant construction features can be easily incorporated in the design stage for the buildings and structures that are being planned for the future. However, the more onerous task for the engineering community is to improve the performance of a wide range of existing buildings and structures which are in varied states of vulnerability. The primary task is to evaluate the existing buildings through analytical and experimental means to assess the present status. Presently, pushover analysis is extensively used for this purpose, particularly for reinforced concrete framed structures. Once the evaluation is completed and the building/structure is found suitable for retrofitting, a suitable retrofit strategy needs to be chosen. Global/local retrofitting are feasible. A large number of tests have been conducted at SERC on various repair techniques on beams, columns, and beam-column joints. These have led to identification of certain performance indices for evaluating various repair strategies. It has been observed that an inherent detailing deficiency in the original structure shows up even after repair and hence careful assessment is needed to tackle such cases. Base isolation is a globally accepted methodology for reducing seismic damage. Base isolators using natural rubber have been designed, fabricated, and tested at very high vertical and horizontal strain levels. The tests have demonstrated that these can be used in buildings and structures for obtaining seismic base isolation. Tests have also been conducted on various types of viscous damping devices for incorporation in existing framed buildings. Any radical repair strategy needs to be evaluated using advance testing techniques. An earthquake engineering laboratory with two tri-axial shake tables, monotonic and cyclic test facilities, and pseudo-dynamic test facility is nearing completion. The paper presents a brief overview of the activities undertaken at SERC covering all the aspects mentioned above. The paper is intended to trigger interesting discussion for taking future R&D projects, particularly aimed at seismic disaster mitigation to buildings and structures.

ESTIMATION OF SEISMIC VULNERABILITY OF EXISTING BUILDINGS OF DELHI MUNICIPAL AREA

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Assessment of seismic vulnerability of existing building stock in urban areas would help in disaster mitigation and management by planning mitigation measures before an earthquake, selecting engineered retrofitting schemes for the existing buildings and carrying out rehabilitation following an earthquake. Delhi being the national capital has had the privilege of planned development but the unusual growth of this burgeoning mega city has set off all the plans. The city is dotted with all kinds of buildings and infra structural facilities comprising of very good construction to poorly designed & constructed ones. The most challenging task is to evaluate seismic safety of these constructions and take necessary steps for their retrofitting so as to protect them from future earthquakes at a place like Delhi, which is seismically very active.

The paper dwells upon the seismic vulnerability assessment of existing building stock of Delhi municipal area. The entire Delhi is suitable divided into three types of buildings for vulnerability assessment (i) Type-A: Buildings in field-stone, rural structures, unburnt brick house, clay houses; (ii) Type-B: Ordinary brick building, buildings of the large block and prefabricated type, half-timbered structures, building in natural hewn stone; (iii) Type-C: Reinforced building, well built wooden structures. The paper presents two approaches for vulnerability assessment, viz. demand-capacity

approach (quantitative assessment) and rapid screening procedure (qualitative assessment). The administrative wards as defined by Municipal Corporation of Delhi have been considered as micro-zones for vulnerability assessment. There are 134 wards, which are further divided into number of colonies in Delhi. Each micro-zone has been formed in terms of these 134 wards defined by Municipal Corporation of Delhi and subsequently reconnaissance survey of existing buildings stocks of each colony in each ward has been carried out to select representative samples of different building types. The sample building survey in different zones encompassing different types of buildings from each zone has been carried out and a comprehensive database has been created for efficient handling of collected data for further analysis.

The study concludes that Type-A buildings in Delhi lack seismic resistant measures and are likely to fail in the event of an earthquake. The majority of building stock (85%) in Delhi composed of Type-B buildings, out of which 24.% buildings are safe, while 75.9% buildings are likely to suffer damages in form of excessive cracking, falling of walls, falling hazard of non-structural component and combination thereof. It is estimated that around 61.4% buildings are safe whereas rest of 38.6% Type-C buildings are likely to suffer damages in the form of excessive cracking, diagonal cracking, falling hazard and its combination. The overall vulnerability of Delhi can be stated, as 58.4% buildings are vulnerable from seismic considerations. Assuming 40 lakh to be the estimated number of buildings in Delhi, it is about half the structures require detailed seismic evaluation leading to viable retrofitting measures to minimize losses during future seismic motions.

OVERCOMING SCHOOL SEISMIC VULNERABILITY IN DELHI

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Schools are the pivotal points in a society, places where the future of country takes shape and in the protection of the premises of schools thousands of young minds spend half of their day. But are these campuses able to provide adequate safety to its residents? Especially with relevance to a hazard like earthquake, which is making the humanity feel its towering presence with every single passing day. This question makes us ponder. And to look for some answers we went around the schools in Delhi.

Operating in all kinds of environments surrounded with buzzing market places or located in the calm a residential colony the contrasts offered were great. But when it came to seismic safety of structures the equation somehow was not very different. Where in old parts of Delhi, the buildings housing schools were as old as 100 years; the newer structures are constructed without any consideration to seismic safety standards. The complexity of the situation is further exaggerated by Delhi itself being in zone IV, i.e. at risk to earthquakes of MSK Intensity VIII and above.

The paper explores the efforts of the state government in dealing with the obstacles to improving the safety in school premises, aware of the constrained financial resources available. It also draws attention to all those non-structural mitigation measures which come with little effort, but contribute volumes to safety. An effort has been made to document the

lessons learnt through real cases of both success and failures. The paper further examines the possible interventions aimed at reducing non-structural risk vis-à-vis their economic feasibility.

HUMAN DEVELOPMENT AS IMPORTANT CATALYST IN UNDERSTANDING BYE-LAWS AND CODES FOR EARTHQUAKE RISK MANAGEMENT

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The rate of earthquake events has increased lately resulting in continuous loss to life and property. Latur earthquake of September 1993 took a toll of more than 6000 lives making scores homeless. The recent land-earthquake of Bhuj in January 2001 took a toll of over 13000 lives and injured over 1, 65,000. It impacted the economics of the nation by US$5billion. South Central Asia, of which India is a part, has experienced 138 earthquake and Tsunami related disasters in 30 years during 1974-2003, out of 356 such disasters in Asia. Earthquakes in Asia account for more than 50 percent of the world events.

Participants of building industry, i.e. architects, builders, contractors, designers and engineers need to be more concerned about seismic effects on building, as they can contribute to creation of safe shelters and settlements. Due to high pressure on land and population explosion, the development is becoming haphazard and uncontrolled. Regulations are followed in a relaxed way or the building construction takes place taking recourse to loopholes into the techno-legal regime. In the historic past construction methods were vernacular, traditional and region specific. Settlements evolved organically. However, these followed basic laws of Nature leading to less risk and consequently less vulnerability to people. The modern constructions are adventurous. The design and construction of these falls within the realm of a system well supported by rules, regulations and byelaws, specific to region. Scarcity of land and expensive building materials lead to unhealthy practices of maximizing use of land beyond the laid down norms and exceeding bye-law provisions, at times resorting to non-serious structural considerations to save on fees of consultants and compromising on construction materials and practices. It is time for technologists to understand and respect byelaws and codes to make our housing stock safer than before.

The paper takes an overview of some bye-laws and town planning rules in select cities and investigates into how these are interpreted to suit convenience and economics of builder at the cost of vulnerability of occupants of building after construction. Also, it looks into creative fancies of designer and how consultants compromise relegating structural integrity to the backstage. The paper concludes with suggestions and recommendations that would be a step toward understanding the important segment of earthquake risk management from people’s point of view and from those who are its stakeholders.

EARTHQUAKE RISK MITIGATION: ROLE OF INDIA METEOROLOGICAL DEPARTMENT

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India Meteorological Department, as a nodal agency in earthquake monitoring, is deeply concerned with the "Earthquake Hazard Evaluation & Risk Mitigation Planning" and it is fully aware of the following challenges:

i. Intrinsic characteristics of earthquake hazard viz. Sudden release of energy, potential for instantaneous damage in wide spread area, unpredictability/limited predictability in terms of space, time & magnitude and non–uniform distribution across the globe/Indian territory

ii. A typical earthquake-cycle which has six elements covering basically two phases of Disaster Management viz. Post-Disaster which includes Rescue, Relief & Rehabilitation (3R) and Pre-Disaster, which includes Prevention, Mitigation and Preparedness (PMP).

As the prediction of earthquake is still illusory and intrinsic characteristic of earthquake and sudden release of energy causes intensive damage to the property, many deaths due to collapse of buildings in the area close to the epicenter. Such events cause failure of electricity, communication and lifeline structures, making the area practically cutoff from the rest of the world. Relief and rescue operations in affected area within shortest period of time say within two to three hours are crucial and can save lives of the people trapped under the debris. Therefore, to manage post earthquake disaster, real time information of occurrence of earthquake and dissemination of information to the agencies involved in relief and rescue operations, is very important. To meet these requirements, IMD is maintaining a countrywide network of 51 seismological observatories including 47 observatories in the National Network, the rest being special purpose project observatories. IMD is also operating a 16-element V-SAT based digital seismic telemetry system around National Capital Territory (NCT) of Delhi for close monitoring of seismic activity in the region. Twenty four seismological observatories under the National Network are equipped with state-of-the-art technology broadband seismograph systems. Ten of these observatories are of the standards of Global Seismograph Network (GSN), having been linked through VSAT/ dialup modem to the Central Receiving Station (CRS) at IMD headquarters, New Delhi to enable near real-time data transmission. It maintains round-the-clock watch of seismic activity in the country. The operational task of the department is to quickly determine the earthquake parameters immediately after the occurrence of an earthquake anywhere in the country and disseminate the information to all concerned agencies.

IMD is in the process of upgrading its seismological network in a phased manner. The ongoing upgradation plans include setting up of 17 station Real Time Seismic Monitoring Network as part of the Tsunami Early Warning System, 20-station telemetry system for Northeast India and a 40-station regional seismological network as part of optimum network plan for the country as a whole.

For the management of earthquake disaster in the whole world, there is a paradigm shift from the response-centric regime, where most efforts and funds are used to strengthen the emergency response to a mitigation and preparedness-centric regime where efforts and funds will be used to address the underlying causes of vulnerability and for preparedness i.e. pre-disaster management. To recognize the importance of pre-disaster planning and management, India Meteorological Department has set up recently Earthquake Risk Evaluation Center (EREC). The center provides earthquake risk based knowledge products, develop information system, and user inter phase to continuously interact with various agencies, articulate well considered regulatory and legislative measures to catalyze development of evermore-effective risk assessment and mitigation approaches. All these aspects and capabilities of IMD are discussed in the paper.

RISK.iitb - A GIS-BASED SEISMIC RISK ASSESSMENT SYSTEM

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The earthquake risk or damage potential is due to a combination of seismic hazard, vulnerability of the built environment and the exposure. The damage during recent earthquakes in India has demonstrated the need for seismic risk assessment that is capable of predicting the consequences of earthquakes. It is also found that the complex risk assessment carried out in the scientific domain does not easily provide information and data useful for policy making. The risk assessment (in terms of consequences of earthquakes) needs to be understood by the various agencies and organizations that are likely o be affected by an earthquake disaster. Representation of results is therefore also important so that decision-making and non-technical people can understand it very easily. The use of graphical representation tools such as Geographical Information Systems (GIS) has been found to be useful for representation of results. In this paper, a newly developed GIS-based tool for seismic-risk assessment, namely RISK.iitb, has been presented. It tool quantifies seismic hazard, seismic vulnerability, and exposure and loss estimation and is particularly suitable for India and other developing countries with limited inventory data. The tool allows the user to carry out seismic hazard analysis, estimate the associated damage to buildings and also performs loss estimation for scenario earthquakes. The results are displayed in the form of color coded risk maps and also in the form of tables. A query interface is also provided which allows the user to identify buildings satisfying the desired conditions of damage and losses. A sample analysis has been performed for an example area to illustrate the system.

APPLICATION OF TAIWAN EARTHQUAKE LOSS ESTIMATION SYSTEM (TELES) ON DISASTER MANAGEMENT

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Taiwan Earthquake Loss Estimation System (TELES), developed by the National Center for Research on Earthquake Engineering (NCREE), is designed to integrate research accomplishments on seismic hazard analysis, structural damage assessments and socio-economic impacts in Taiwan. In order to mitigate seismic disasters and to reduce catastrophic risks, it is necessary to have adequate damage assessment and risk management strategies in both normal times as well as in emergency response stage. After putting lots of efforts, TELES has been successfully used in preparing disaster mitigation plans and emergency response systems by governments and cooperative institutions. Among these researches, scenario simulation technologies (including seismic scenario database) have been developed and used in the decision-making support system. The application of TELES has proved to be very helpful for hazards mitigation, and the TELES is also a handy tool for India to build a safer society.

COMPREHENSIVE REVISION OF BUILDING BYELAWS FOR MANGALORE CITY - A CASE STUDY

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National development in India has been equated with economic growth and surplus. This rush for growth has triggered haphazard urban development. Coupled with the vulnerability of the country to multiple hazards, the disaster risks have increased manifold as seen from the human and economic costs of the Latur Earthquake (1994), Orissa Super Cyclone (1999), the Gujarat Earthquake (2001) and the recent Tsunami in December 2004.

This rush has also led to increasing concentration of population in towns and cities many of which are located in hazard zones. Considering this, Government of India, in conjunction with the State Governments is working for “safe development” through improving ‘governance’. The major concern has been the existing development control regulations, building byelaws and land use zoning regulations. These do not adequately provide for ‘multi-hazard safety’. Wherever these provisions exist, they are not strictly enforced. The National Expert Committee, constituted by the Ministry of Home Affairs and chaired by Prof A S Arya, carried out a detailed study and submitted a comprehensive report recommending

incorporation of hazard safety measures into the development control regulations and building byelaws.

Mangalore is one of the 38 cities where the Urban Earthquake Vulnerability Reduction Project is under implementation. It is a sub-component of the GoI-UNDP Disaster Risk Management Programme aimed at strengthening capacities of communities, urban local bodies and administration in mitigation, preparedness and response.

The existing zoning regulations and building byelaws of Mangalore City were formulated in 1991. Since then the city has developed enormously both in terms of population and area. This biodiversity hotspot of the Western Ghats has several heavy industries too. Mangalore City is a blend of old and new and the terrain is hilly. A comprehensive revision of the zoning regulations and building byelaws has been overdue keeping in view the recurrent floods and landslides during monsoons and its location in the moderate earthquake risk zone (Zone III).

As governments bear the primary responsibility with regard to the right to safety and security, the Deputy Commissioner of Dakshina Kannada District constituted a Committee with Dr Katta Venkataramana as the chairperson, for suggesting measures to revise the existing Building Byelaws of Mangalore City Corporation. The Committee studied all relevant documents and prepared the draft report containing the following chapters: (i) Introduction; (ii) Definitions; (iii) Zoning Regulations; (iv) Administration;

(v) General Building Requirements; (vi) Structural Design & other Requirements; (vii) Environmental Safety/Conservation Requirements; (viii) Registration, Qualification and Duties of Professionals Appendix A-Forms; Appendix B-Indian Standard Specifications.

The preparation of the draft was a Herculean task considering the need to have a futuristic outlook keeping in view the sustainable and systematic development paradigm – a decentralized disaster risk planning strategy that can empower the local community by opening the window for local participation. The suggestions try to simplify the procedures and at the same time guarantee that the necessary information would be furnished. The draft report generated lot of public interest and was given wide coverage in the local press. Several workshops and interactive seminars were conducted by the Technical Committee Members to highlight the contents to the general public as well as to the local engineering and architectural community.

This paper discusses the various stages involved, the technical & social aspects of the work, the possible areas of difficulties in implementation and how to address them. It is hoped that the present paper will provide useful inputs for other similar cities in India and in neighbouring countries.

POST TSUNAMI RECOVERY AND RECONSTRUCTION PHASE IN ANDAMAN AND NICOBAR ISLANDS

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The earthquake followed by devastating Tsunami of 26th December 2004 was not only responsible for thousands of deaths, extensive damages to the infrastructure and loss of human lives, but also dislocated the communities from their neighborhood, affected their means of livelihood and socio-cultural linkages . The tsunami damaged about 8000 hectare of crops and plantation and destroyed 10000 houses. The damages have been assessed to the tune of Rs. 3300 crores.

The disaster of tsunami is being perceived as opportunity for reshaping the lives of people by creating an environment with ample employment opportunities thorough the implementation of various relief packages announced by the government of India and also through the recovery efforts by other NGOs and the local self governments. However the communities have differential capacities to respond, accept and adapt to the changes intended or perceived to be beneficial to them and are influenced by cultural and ideological forces and sometimes driven by purely rational economic choices.

The paper discusses the approaches of the administration, community and NGOs in rebuilding not only the physical infrastructure but also the efforts made in restoration of the social and fabric of the community and promoting the culture of disaster prevention and preparedness which involves close

interactions and intensive debates/discussions among the stakeholders for assessing and projecting both the short term and long term needs and strategies with ecological sensitivity and good environmental management practices. One of the major accomplishments under the short term recovery process has been the construction of about 10,000 intermediate shelters for housing the tsunami affected families in a time period of 4 months before the onset of heavy monsoon in 2005. The paper documents this challenging task and other complex issues associated with the permanent housing for the tsunami victims, livelihood restoration, nature and extent of compensations, introduction of new technologies and initiatives in livelihood sectors particularly the farm sector and the issues of transparency and inclusion in the rehabilitation process.

SOCIO-ECONOMIC CLUSTERING IN SEISMIC RISK ESTIMATION OF DEHRADUN CITY

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In the Indian National Census, Municipal ward is the basic geographical unit used for aggregation of demographic data, while in the Housing Census; district is the unit for aggregation of sample data. A district is too large and too heterogeneous a unit for providing insight into the spatial variation of building stock. Contrary to the census tract in the US, the municipal ward is also too heterogeneous a unit to make generalizations about the seismic risk parameters, as it may consist of a number of socio-economic clusters with widely different building stock, demographic and economic conditions. Therefore, it is necessary to have a reliable database with aggregation at the level of socio-economic clusters. A database of building stock based on socio-economic parameters has been developed by identified socio-economic clusters for seismic risk assessment of Dehradun, the north Indian capital city of Uttaranchal State lying at foothills of Himalaya. The whole city has been divided into 254 clusters within and across the 60 municipal wards. A stratified random sample survey has been conducted and information has been extracted from high resolution satellite data. The reliability of the developed database has been established by comparing the

demographic data with the 2001 census, at ward level.

A comprehensive earthquake risk assessment for the city has been performed for the Seismic Intensity obtained from the Seismic Zonation of the country and Micro-zonation of the city. Different vulnerability classes of buildings have been identified using a building typology survey. A combination of MSK and EMS-98 Intensity scales with the experience of damage during past earthquake in India has been used to define the lower bound and upper bound Damage State Probabilities for the identified classes of buildings. The Severity Levels and Casualty Rates from HAZUS have been used to estimate the expected life loss and direct and indirect economic losses. The spatial distribution of the vulnerability and the expected losses has been estimated using GIS. It has been observed that old congested areas and low income group areas of the city are more vulnerable in terms of the expected life loss. The expected economic losses are higher in some other areas having high intensity of economic activity.

DAMAGE TO PORTS AND LIFELINES IN TAMIL NADU DUE TO INDIAN OCEAN TSUNAMIS OF DECEMBER 2004

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Safety of ports, harbors and lifelines are of utmost importance during natural disasters such as earthquake and tsunami. Indirect economic losses caused by the failure of these structures during natural calamity far exceed the direct losses. Widespread damage was caused on east coast of India due to tsunami generated by December 26, 2004 Sumatra earthquake. Soon after the earthquake authors visited Tamil Nadu and Pondicherry for a damage survey. Area covered was along the coast from Chennai on east coast to Thiruvananthapuram on west coast.

This paper describes the damages to ports and lifelines in the visited area. Three ports namely; Nagappattinam, Tuticorin and Kanyakumari were visited. Damage to facilities at these ports is analyzed with level of run-up there. Also damage to lifelines (roads, a bridge and a jetty) are presented. It was observed that there was significant damage to ports, roads and lifeline structures due to erosion and settlement of soil. A detailed analysis of the level of damage with type of construction and intensity of tsunami is presented. It was observed that the level of damage at a particular locality correlating well with level of run-up (measure in the field). General measures to avoid these damages in future tsunami are suggested.

DEVELOPMENT OF EARTHQUAKE ENGINEERING AND EARTHQUAKE DISASTER MITIGATION IN INDIA

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India is one of the few countries, which had initiated Earthquake Engineering and Earthquake Disaster Mitigation about five decades earlier but could not keep the pace of the fast development with the rest of the world. Ever since the first World Conference on Earthquake Engineering was held in Berkeley in 1956, India also organized the first National Symposium on Earthquake Engineering in 1959 at Roorkee. Last five decades were very event full where it has seen the establishment of School of Research and Training in Earthquake Engineering at University of Roorkee in 1960, which was later, renamed as Department of Earthquake Engineering, IIT Roorkee. Other important institutes like Geological Survey of India (GSI), Seismological Division, Indian Meteorological Department (IMD), National Geophysical Research Institute (NGRI), Wadia Institute of Himalayan Geology (WIHG) together with Department of Earthquake Engineering richly contributed in the development of Earthquake Engineering and Earthquake Disaster Mitigation in India.

The Department has richly contributed in the human resource development and capacity building in Earthquake Engineering ever since it started. It introduced Post Graduate teaching in Earthquake Engineering for the first time in 1963 and it is still the only institution awarding degrees in

Earthquake Engineering. Some of the other significant contributions made by the Department in Earthquake Disaster Mitigation are (i) collection of strong motion data using strong motion instrumentation and monitoring for use in better design; (ii) collection of micro earthquake site specific data using array of seismic instrumentation (analog/digital seismographs); (iii) basic and applied research on earthquake engineering studies (iv) dissemination of knowledge about Earthquake Engineering and related subjects; (v) taking up sponsored consultancy of major projects in the country, (vi) capacity building of field engineers and (vii) participating in national programme in Disaster Mitigation.

The country has kept pace with the technological development in Earthquake Engineering whereas its implementation was lacking for many reasons. This paper summaries the development of Earthquake Engineering and gives reasons for effective non-implementation of the technical know how for achieving Earthquake Disaster Mitigation.

EVALUATION OF LIQUEFACTION POTENTIAL OF JABALPUR URBAN AREA

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Liquefaction susceptibility is considered to be the most important input for seismic zonation and risk study. In this context, geotechnical parameters of cover sediment of Jabalpur have been investigated resorting to standard penetration test (97 SPT Sites) and the N value data obtained have been modified and analysed for liquefaction susceptibility following the methodology enunciated by Seed and Idriss, (1982) and modified by Idriss (1990). A deterministic approach has been followed for estimating A max based on a scenario earthquake with magnitude 6.5, focal depth 30 Kms, located (23^o.08'N; 80^o 06'E). in a mature zone of Son-Narmada South Fault**.** The susceptibility of sediment material to liquefaction is a function of (i) granulometric characteristic, (ii) relative density, (iii) effective confining pressure (iv) initial K_o ratio of effective horizontal to effective vertical stress under condition of zero lateral yield, (v) dynamic stress level, (vi) Number of functions of Dynamic stress level, (vii) boundaries of drainage (viii) pressure stress strain history, (ix) over consolidation effect, aging, lithification, and cementation of inter-particle boundary, (x) soil structure, fabric and micro geological detail, (xi) micro geomorphological detail and

(xii) ground water condition (Youd & Hoose,1977). Hence to comprehend liquefaction condition in depth studies on a) geotechnical attributes of sedimentary fill, (b) geological and geomorphic setting, (c) ground water condition and (d) attributes of likely seismic loading is called for.

The liquefaction susceptibility of soft sediment cover is evaluated based on (i) modified N values, (ii) two alternative values of PGA (A_{max}) calculated for each site following empirical relation given by Seed & Idriss (1982) and the one based on Attenuation relation taking into consideration the nature of soft sediments as suggested by Idriss (1990) and (iii) for pre-monsoon and post-monsoon ground water conditions.

Four liquefaction susceptibility maps have been prepared for Jabalpur Urban area for Post and Pre-monsoon conditions. In critical conditions, with shallow ground water in post monsoon FS values have been, estimated and accordingly Jabalpur domain has been classified into 19 units. Possibilities of manifestation of liquefaction on surface have been analysed after Ishihara (1995). In this paper, a brief review of methodology is given followed by lithological and geotechnical attributes of cover sediments. Liquefaction susceptibility have been analysed in geological perspective.

SEISMIC RISK ANALYSIS OF REINFORCED CONCRETE FRAMED STRUCTURES

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Risk analysis of reinforced concrete framed structures located in seismically active regions would provide the information regarding the expected damage that the structure would suffer taking into account the expected seismic hazard levels in the given region. The results of risk analysis would be useful for design engineers involved in performance based design, for decision-making authorities in public- and private-sector organizations for allocation of resources and, for insurance agencies in fixing the premiums.

It is not uncommon to find reinforced concrete structures (particularly in coastal regions) affected by corrosion of steel reinforcement. Estimation of expected damage of such structures should take into account the degradation in strength and stiffness of the structure. A methodology for estimation of statistical properties (viz. mean and standard deviation) of the expected damage to a corrosion-affected reinforced concrete framed structure, subjected to stochastic seismic excitation, over a specified reference time (typically the service life of the structure) is proposed in this paper. The methodology is formulated within the framework of Monte Carlo simulation. The service life of the structure is divided into reference times,

and the statistical properties of the expected damage to the structure during these times are determined. The time to corrosion initiation and rate of corrosion propagation are considered as random variables to take into account the uncertainties in the material properties and variations in the exposure conditions. The earthquake occurrences during the reference time period are modelled as Poisson process, and the stochastic seismic excitation is represented by an ensemble of acceleration time histories. The damage to the structure under the earthquake loading is determined from the results of an inelastic dynamic analysis. The inelastic damage analysis program IDARC 2D is used for this purpose. The damage to the structure under the earthquake loading is characterised by the damage index, determined using the modified Park & Ang damage model. The paper also considers the effect of soil type (as classified in IS 1893-2002) on the statistical properties of expected damage to the structure. By relating the expected damage and the variance of the damage to the linguistic definition of possible damage scenario as defined by Park and Ang, generalised cost functions have been formulated to estimate the expected loss. This would give the risk to the structure in a given region. The proposed methodology is illustrated through an example problem.

EARTHQUAKE RISK MITIGATION DEMONSTRATION PROJECT-CASE STUDY IN DELHI

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The Earthquake Risk at any location is basically related to the vulnerability of the built environment and the capacity of the community to cope with the threat of an earthquake and to minimise the impacts. Reducing earthquake risk will require a systematic approach and elements of risk mitigation should be seamlessly integrated into the all development projects. Earthquake Risk Mitigation measures will have to aim at the reduction of the vulnerabilities and to build Capacities at all levels including the administration to deal with the hazard.

Reducing vulnerability will include a) training of all members of the construction fraternity including Architects, Builders, Contractors, Designers, Engineers, Masons etc b) Including earthquake resistant provisions in the local building byelaws with proper enforcement measures. But all these measures when taken will only improve the earthquake resistance of future constructions. The existing vulnerable housing stock has to be addressed through retrofitting and this has to be taken up by the administration as a long term mitigation measure. Lifeline buildings which are critical in a post disaster scenario such as Hospitals, Fire Stations, Command and control centres etc should be taken up for retrofitting in a systematic and planned manner as pilot retrofitting projects. The Ministry of

Home Affairs is addressing this in an upcoming project 'The National Earthquake Risk mitigation Project' which will be covering all districts in the country in seismic Zones IV and V. As a pilot to this important initiative, a project-"Delhi Earthquake Safety Initiative for Lifeline Buildings" is being carried out in Delhi with five key public buildings such as the Delhi Secretariat, the Delhi Police Headquarters, the Guru Tegh Bahadur hospital, the office complex of the Divisional Commissioner and the Govt. Ludlow Castle School in a partnership project between the Ministry of Home Affairs-Govt. of India, the Govt. of Delhi and GeoHazards International.

Another important component of the project is the focus on demonstrative Non-structural hazard mitigation in the School and the Hospital. Non-structural damages account for almost 50% of the injuries and losses in an earthquake. In general, Non-structural components and building contents become hazards when they slide, break, fall, or tip over during an earthquake. Securing the Non-structural components and building contents improves safety and security of the buildings during an earthquake by Reducing the potential for fatalities and injuries, helping to maintain safe and clear exit ways for evacuation and to access the building and reducing the potential for fires and gas leaks. This component of the projects includes basic disaster awareness for the staff and students and also demonstration rooms to help in wider dissemination of the methodologies adopted for securing building contents. This paper will elaborate on the importance of decision making in a retrofitting project and the processes followed under the project to ensure capacity building at all levels.

EARTHQUAKE RISK MITIGATION – A HOLISTIC VIEW

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Earthquakes fall in the category of hazards which have low probability of occurrence but highly disastrous consequences. The occurrence of an earthquake cannot be prevented nor predicted with any precision at present. Hence an earthquake occurs all of a sudden without any warning and people are caught anywhere. Therefore post disaster response usually occurs on Adhoc basis. Earthquake risk reduction involves a number of steps so as to achieve reasonable preparedness for better post earthquake response.

The following steps are needed to be taken towards Earthquake Risk Mitigation. First, monitoring of earthquake occurrences, delineating active seismo-tectonic faults and preparation of earthquake hazard maps (including Micro-Zoning wherever feasible; Second, mapping the physical assets e.g. Buildings of various types, Bridges, Power Plants, Airport and Railway structures, etc, and determining their vulnerability of damage under various Intensities of earthquakes to which they may be subjected at some future time; and Third, estimation of the risk to life and property in the given area based on the probable hazard Intensity and the vulnerability of the physical assets. The Seismic Zoning Map of India classifies the country in four seismic zones, having 10.8 percent of land area in most serve seismic zone

V, 17.5 percent land area in next severe seismic zone IV, and 30.8 percent land area in moderate seismic zone III. Thus the country has about 59% area liable to the risk of earthquake damage.

The Censes of Housing 2001 lists 245 million housing units covering residences, schools, Dharmshalas, places of worship and shops etc out of which 73.8 million have earthen walls, 25.5 million have stone walls, that is, about 40% can suffer total collapse in seismic zone V, destruction in seismic zone IV and severe cracking in seismic zone III. Burnt brick wall buildings constitute 11.9 million (45% of the total) which are liable to suffer destruction in zone V, severe cracking in zone IV and lighter cracking in zone III. Now for reducing the risk to the people and to the functioning of the society, the most effective remedy will be to *reduce the vulnerability* of the physical assets by structural measures of *safer new construction* and *retrofitting the existing unsafe assets* for which effective building Codes have been already developed through the Bureau of Indian Standards. The preparedness measures will involve the capacity building of Architects, Engineers and Masons through training, certification, and licensing, besides other preparedness measures for improving the capabilities of rescue, evacuation and providing timely relief as a measure of effective response. To achieve effective earthquake risk reduction, we have a long way to go and all sectors of the society have to be made aware as well as sensitized to play their role in this national task.

SEISMOTECTONICS AND SEISMIC EVENT PREDICTION IN THE NORTH-EASTERN INDIA BY RADON MONITORING NEAR THE HOT SPRING

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The North Eastern part of India has an extremely complex geotectonic framework coupled with high seismic status. The NE Himalayas are evolved due to the intra-continental collision. Various EW trending linear structures were developed to accommodate the shortening due to the progressive translation like, Himalayan Frontal Thrust, Main Boundary Thrust, Main Crystalline Thrust, Dawki Thrust and Oldham fault. The region has undergone many predominant shallow focus earthquakes. The proximity to the linear tectonic structures and recurrence of many minor earthquakes increases the possibility of a severe earthquake. Normally, the severe earthquake is preceded by foreshocks/ active tectonic activity. The area has few hot water springs like Jakrem, Garampani, etc. The Hot water spring in the basement rocks of the region i.e., Granite Gneiss are of importance and can be a sensitive location to understand the seismo-tectonics.

The earthquakes are caused when the stress is accumulated in the rocks, which may partially close the pore spaces. When the stress exceeds the strength of the rocks, the cracks develop and fluid present increases the pore fluid pressure and finally the rock ruptures causing the devastating earthquake. These ruptures occur as a group of related fault traces and create relatively permeable and porous zones that may serve as conduits to the surface for radon produced at depth. The radon moves through the newly created planes of weakness, after radon recoil, and by diffusion and advection. Various methods have been used to predict earthquakes like water level changes, turbidity of ground waters, unusual gas exhalations, chemical changes in well and spring waters, Vp / Vs ratio, etc. Amongst all these techniques for earthquake prediction, the anomalous radon concentration is the promising precursor, as Radon is a noble, heavy gas. Radon-222 is produced by the decay of radium, has a half-life of 3.8 days, and emits an alpha particle as it decays to polonium-218, and eventually to stable lead. Radon easily dissolves in water. Although, dissolved gas easily escapes from water when exposed to the atmosphere, especially if it is stirred or agitated. The radon constantly emanates from earth into the atmosphere/hydrosphere by the omnipresent radium in the crustal materials and local ground water may contain high concentrations of radon; radon has larger fluctuations over time. The release of high soil gas radon emanation associated with seismotectonic activities might help us to predict the occurrence of an earthquake and minimize the disaster.

As a preliminary survey, the radon concentration near the Jakrem Hot Spring in Meghalaya was monitored using the SSNTD technique. In this technique, the LR 115 dosimeter is placed in a bore hole of approximately 1m depth for about 40 days and then is chemically etched by 2.5 N NaOH at 55^0C for 90 minutes and finally the number of alpha tracks counted and studied under high power microscope. Then the average Radon concentration is determined in units of picoCuries per Liter (pCi/L) or Becquerels per cubic meter (Bq/m3). The anomalous radon concentration near the weathered granite gneiss zones indicates the active tectonics and sensitivity along the hot spring. The detailed study along these zones will be made, which includes the petrology, porosity, permeability, soil cover and structures and other meteorological parameters. And long-term continuous radon monitoring by using BARASOL MC 2 be made, which can be utilized for seismic event prediction.

PROBABILISTIC SEISMIC HAZARD ASSESSMENT IN LOW SEISMICITY REGION

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Seismic hazard assessment of low seismicity regions of the world is now-a-days becoming more common. The seismic hazard assessment involves the quantitative estimation of ground motion characteristics at a particular site. The assessment of probabilistic seismic hazard is required for the establishment of zoning maps over large regions or in the context of seismic risk studies for sites that deserve special attention such as nuclear power plant sites. Probabilistic seismic hazard analysis (PSHA) allows uncertainties in the size, location, rate of recurrence, and effects of earthquakes to be explicitly considered in the evaluation of seismic hazards. The conventional PSHA implies an integration of all the potential magnitudes and source distances to estimate the mean frequencies of earthquake ground motions occurring at the site in any given time period i.e., the estimation of $P(A \geq A^{*}$ in t), the probability with which ground motion values of interest (A^{*}) are expected to be exceeded at least once during a certain time interval of duration t.

Specification of ground motion model relating the ground motion parameters at a site to earthquake magnitude, source-to-site distance, and other variables such as style of faulting, site geology, etc. constitutes major ingredients of the seismic hazard analysis. These attenuation equations can be derived from

analysis of empirical data or from theory justified by comparison with strong-motion observations. In this paper, firstly the typical calculations for numerical example of probabilistic seismic hazard assessment are presented. Later, the study is extended for carrying out seismic hazard analysis for Tamil Nadu region of southern India. As the seismicity data of the study area are scarce, appropriate assumptions are made in the completeness analysis of the records. Two locations namely Chennai and Kalpakkam are selected and seismic hazard results are presented in the form of hazard curves, which indicate the annual probability of exceeding the peak horizontal ground acceleration in a specified period of time.

MICROZONATION STUDIES OF SOME INDIAN CITIES - AN INITIATIVE OF DST

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The occurrence of great (M>=8) earthquake in Himalaya, North East India and Rann of Kuchch during 1819, 1897, 1905,1950 & 2001 has attracted the attention of geoscientists more towards Himalayas in view of the rather long quiescence phase in the region after 1950. This is because the destructive earthquake in Himalaya not only causes local impact but affects its neighbouring areas, especially, which lie in alluvium along the river beds, mainly due to rapid increase in urban population. Therefore, cities located in these regions are more vulnerable to earthquakes for which long term measures are needed.

Efforts for prediction of earthquakes have so far not enabled the researchers to effectively predict the location, time & size of an earthquake. Therefore, there is a strong need to reduce the adverse impact of an earthquake by implementing earthquake disaster management plans. Seismic microzonation is one of the tool, which is considered to be very important to help in mitigating future earthquake disaster.

The seismic microzonation basically involves mapping of geology related hazards, which is depended on seismic and geological data structure in general and earthquake source, deep underground and site specific conditions in particular. One of the major components of seismic microzonation study is the estimation of Peak Ground Acceleration (PGA) on the surface due to a possible future scenario earthquake, which will help the builders/designers/architects to design earthquake resistant structures.

Keeping in view the importance of the study, Department of Science & Technology initiated a multidisciplinary & multi-institutional experiment on Seismic Microzonation study of Jabalpur Urban agglomerate. The above pilot study was aimed at i) establishing a model for seismic microzonation with Indian perspective and ii) evolving strategies for hazard & risk prognosis for pre-disaster mitigation planning. In pursuance of the above focused objectives, a model for seismic microzonation has been evolved.

Based on the model developed for Jabalpur, Seismic Microzonation studies were initiated for Delhi, Guwahati & Bangalore city. A first order Microzonation map at 1:50, 000 scale has now been prepared for NCT of Delhi by Earthquake Risk Evaluation Centre (EREC). Necessary efforts are being made to further refine the microzonation maps of Delhi at large scale (1: 10,000) incorporating PGA values at the surface. Similarly, 1st order microzonation maps for Guwahati city have been prepared taking into account the seismological, geological, geomophological and site response studies data. The microzonation study for Bangalore city is under progress and 1st order maps of the city are likely to be ready within a year.

In another study, microzonation of the Sikkim has been completed utilizing the strong motion data recorded for the earthquakes occurred in that region during the last few years. Though the microzonation studies initiated by DST has established standard methodologies for such studies, it needs further improvement, especially in developing response spectra to be used by engineering community for designing specific structures and estimation of PGA at bedrock and surface as well.

EVALUATION OF AMPLIFICATION HAZARD FOR CHENNAI CITY

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This paper presents the evaluation of seismic hazard based on amplification rating at the selected sites of Chennai city. In order to implement effectively the procedures of earthquake-resistant design, it is necessary to know the maximum dynamic load coming on the structure during strong earthquakes. The main cause for site amplification is the local geologic and soil conditions which amplify the bed rock motion. Amplification of seismic waves is usually taking place in the case of soft soils deposits, as waves travel from bedrock to the ground surface by transferring more seismic energy in the form higher accelerations to the structures. The amplification of ground motion causes damage to structures, particularly when the resulting seismic wave frequency matches with one of the resonant frequencies of the structures more specifically the fundamental frequency. A proper design of seismic resistant structures requires a good estimation of the site amplification during the expected earthquake.

After Bhuj Earthquake in 2001, Indian seismicity programme has upgraded the seismic zonation of the country. In the revised zonation, Chennai city has been upgraded from Zone II to Zone III in order not to have severe damages to the forthcoming built-in-environment in future earthquakes. Moreover the city is highly populated with structures of all kinds which need special attention in view of the revised zonation for their strengthening and seismic retrofit. In this regard, the outcome from site specific amplification studies will be of immense use. In the present study, seismic hazard and ground response analyses have been carried out to evaluate the site amplification. The amplification hazard is expressed in terms amplification rating with respect to bedrock motion which is a candidate ground motion typical of regional seismicity of the Chennai city. Seismic hazard analysis has been carried out based on the seismological and geological details of the study area to evaluate the ground motion parameters. For these ground motion parameters, an equivalent time history of bed rock motion is chosen from the strong motion data base. Ground response analysis is then carried out using these acceleration time histories with geotechnical data, which comprises of the subsurface profile and dynamic properties of the layers of the selected sites in the Chennai city. Results of the ground response analysis are provided in the form amplification rating based on the NEHRP recommendations for the study areas of the Chennai city.

SITE RESPONSE – A VITAL PARAMETER IN EARTHQUAKE HAZARD EVALUATION

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Large earthquakes cause damage to buildings and other structures in near and far fields, claiming human lives and causing heavy economic losses. This has been very well exemplified by the recent Mw 7.7 Bhuj earthquake in 2001 where several multi-storied buildings in the Ahmedabad city, about 300 km from the epicenter of the earthquake, suffered either partial or total collapse. This phenomenon of far field damages to buildings has been reported, worldwide, notable being the 1985 Mexico earthquake, where the epicenter was 400 km offshore from the Mexico city, which suffered very heavy damage. This observation brings out the importance of local site conditions in either reducing or enhancing the earthquake hazard in a region. Damage to structures are caused due to several reasons, most important being, i) magnitude and depth of the earthquake, ii) nearness to the epicenter, iii) shaking, iv) design of the structure, v) local site conditions like thickness of the soil layer and vi) quality of construction. While the first three are beyond the human control, the damage due to the other three factors can be countered by a conscious human effort. The local site conditions can be studied by various methods, either using the background noise, in case of infrequent earthquakes in a region or using earthquake data recorded on an Accelerograph. The site response forms a very vital parameter in the preparation of a Seismic Hazard Microzonation map for a

region which incorporates other geological and geotechnical information. Thus, site response studies, especially for high density urban cities located in the vicinity of seismically active faults become very important. Studies done by us in and around the 2001 Bhuj earthquake epicentral zone has brought out a very good correlation between the maximum damage area and higher amplification values obtained for the Bhuj region. A study was also undertaken by us to study site response of various localities for the Bangalore Metropolis, as it has attained the status of the fastest growing city in India. with a number of high profile institutes and Laboratories, a major hub for space and aeronautics, together with the largest concentration of IT industry. The site response studies undertaken in the Bangalore city during 2006, was based on recording the ambient noise for a selected period of duration. The duration of recording was for a minimum of 3 hours and a maximum of 26 hrs. The noise was recorded at 64 different locations. The site response parameters mainly the peak frequency and amplification were estimated using the spectral ratio technique proposed by Nakamura. The results suggest the predominant frequencies range between 1.2 Hz -11 Hz with the eastern part of Bangalore being characterized by lower frequencies.

In addition to the site response studies, several other region-specific conditions will be discussed which are essential while making an Earthquake Hazard Evaluation of a region, taking examples from Indian earthquakes which have occurred in the past in the country.

STATIC COSEISMIC GROUND MOVEMENTS IN ANDAMAN AREA DUE TO SUMATRA-2004 EARTHQUAKES

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Field survey in the Andaman Islands has brought out an interesting pattern of distribution of coseismic vertical ground movements related to the 26 December 2004 earthquakes. A NNE-SSW trending neutral line, obtained by joining the points of no discernible vertical ground movement, is a significant feature of the pattern. The neutral line, broadly parallel to the trench-axis of the subduction zone, separates the domain of uplift on the trench-ward side, from the domain of ground subsidence on the other side of the line The vertical movement increases away from the neutral line, reaching 1.2 meter uplift at the western coast of North Andaman and 1.25 meter subsidence at the eastern coast of South Andaman.

In addition to the vertical movements, decameter to hectometer scale lateral ground movement because of liquefaction and lateral spread induced by ground vibration of the earthquake, was observed in North Andaman. The hazard associated with such vertical and lateral ground movements can be assessed from the movement magnitudes and their spatial distribution. The static vertical ground movements in Andaman area indicate a sinusoidal

pattern of permanent deformation of the hanging-wall block. The small amplitude-wavelength ratio of the pattern points to limited hazard potential of such deformation. The ground movements however, may modify the seismic ground acceleration. The hazard potential of coseismic static ground movements of blind faults, in which the tip line of slip remains below the ground surface, is also comparable.

The hazard potential of surface-rupturing active faults, however, is very high because of displacement discontinuity across the fault traces. The active fault trace zones should be avoided in developmental activities and excluded from all developmental planning. An appropriate techno-legal measure, in line with a 1972 Act of Califormia (USA) Legislature, might be an effective step in seismic hazard management initiatives in India.

CONSTRUCTION TECHNIQUE: A CASE STUDY OF EARTHQUAKE RESISTANT CONSTRUCTION IN STATE OF UTTARANCHAL

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Evaluation of new construction techniques together with increasing understanding of the seismic forces and the building response has certainly contributed positively to decrease seismic vulnerability. The up-gradation of the seismic standards has resulted in accurate and appropriate calculation of seismic forces that would act upon any structure. It is always easy to set standards but to comply with these is a Herculean task. Even after immense progress in earthquake engineering overwhelming large proportion of the building stock still has lower standards of earthquake safety and these would give way in case of earthquake loading. The common people, at present, do not adhere to correct design and construction methodology while using modem seismic design methods or even the use of our indigenous practices. Case study of Uttaranchal State clearly brings forth deterioration of time tested indigenous construction practices and proliferation of nonscientific and improper use of concrete. This adds to the vulnerability of the region that is at present much higher than what it was a decade before when the region last experienced a major quake. The case study highlights three inter-related aspects. First, these bring forth key features of local traditional knowledge and capacity of rural communities for mitigation, preparedness and recovery from earthquakes. The traditional knowledge is embodied in

physical planning and building, skillfully using local resources, mutual support systems and informal livelihood mechanisms. Second, these provide an in-depth understanding qf the transformation processes (pertaining to changes in built form, land use and ownership, occupational structure and social and economic structure) and their impact on traditional knowledge and capacity and resulting enhanced earthquake vulnerability. Third, these show the implications of post earthquake rehabilitation on disaster vulnerability in the long run. These show how certain decisions during rehabilitation not only reinforce pre-disaster vulnerabilities but also create new ones.

EARTHQUAKE PRECURSORY STUDIES IN INDIA

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Earthquake precursory studies have been initiated in India for the 3 to 4 decades. These were based on seismicity patterns, seismic gap changes in b value in Gutenberg Richter frequency magnitude frequency relation and focal mechanism. Most of the damaging earthquakes from 1960 to 2005 showed a well marked seismic quiescence before the main earthquake. Detailed analysis suggested that the seismicity pattern showed a marked variation from event to event. Even in the same region, the pattern showed remarkable difference between two earthquakes in spite of same magnitude and focal depth. A closure examination of some of the seismicity patterns like earthquakes of Uttarkashi (1991), Chamoli (1991) and Muzfrabad (2005) showed the development of quiescences preceding the main earthquake which could be attributed to the complexity of the region.

Precursory studies were extended in India to include other geophysical parameters like electrical resistivity, geomagnetic anomalies, VLF and ULF electromagnetic anomalies, satellite thermal anomalies under different programmes of the Department of Science and Technology. In view of the encouraging results, a Task Force was set up to find ways of accelerating the efforts at national level in earthquake precursory research. The Department

is also setting up of multiparametric observatories, through Wadia Institute of Himalayan Geology and Indian Institute of Geomagnetism, which will gain more confidence from operational angle instead of a single parameter in general. The paper also discusses latest developments in Chaos Physics and principal components analysis towards earthquake predictability and modeling.

INFLUENCE OF Q_S FACTOR OVER THE COMPLEX GEOLOGICAL FORMATION - A CASE STUDY OF OHCHIGATA FAULT IN JAPAN

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An attempt has been made to estimate the frequency dependent Q_s value and its lateral variation over Ohchigata graven and surrounding area in Noto peninsula, Ishikawa prefecture, Japan by using the double spectral ratio method that is applied to the strong motion records of the KiK-Net. The Q_s value in the central part is low as compared to the northern and the southern areas. The earthquakes of magnitude above 3 and below 4 are used for the analysis, as per the available strong motion records obtained by KiK-Net in the study area. These local shallow earthquakes, of which focal depth varies from 10 to 20 km, are well efficient to find out the lateral variation of Q_s over the study area. The frequency dependent Q_s are estimated in the frequency (f) range from 0.5 to 10Hz for better consideration of signal to noise ratio and elimination of high frequency site effects.

The result showed that Q_s value at the central part is $Q_s = 8 f^{0.89}$. In the wide spread northern part, three successive Q_s have been studied from extreme north towards the south that is closer to the western part of the graven: $Q_s = 31 f^{0.96}, Q_s = 21 f^{0.90}, Q_s = 16 f^{1.42}$, respectively. In the southern part

$Q_s = 40f^{0.53}$ is obtained. The Q_s value in the central part lower than the others may be due to the fractured material of upper crust under the graven.

SEISMIC HAZARD ASSESSMENT BASED ON ATTENUATION RELATIONSHIP FOR TAMIL NADU STATE, INDIA

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Seismic Hazard Assessment is the basic approach to understand the seismic risk of population, buildings and infrastructures for an earthquake prone state or major city. Tamil Nadu is located in the southern most part of the Peninsular India. The part of northern and western Tamil Nadu state and its capital city Chennai (formerly known as Madras) have been categorized under Zone III [maximum magnitude 6.0 and PGA 0.2g as per seismic zonation of India published by Bureau of Indian Standard (BIS) 2001]. The seismic hazard assessment carried out for the State of Tamil Nadu and the results are discussed in this paper.

The objectives of the study for Tamil Nadu were to identify the seismicity, to delineate potential seismic sources and calculate the Peak Ground Acceleration (PGA) at bedrock level. The potential seismic source zones for Tamil Nadu were identified as 12 in number and they were considered for the estimation of seismic hazard assessment of Tamil Nadu State in terms of Maximum magnitude M_{max} and Peak ground Acceleration of the respective sources. Seven sources generated M_{max} in the range of 5 to 6 (zones 1 to 7) and other five sources M_{max} 4.1 to 4.5. The estimated PGA for the 12 sources are in the range of 0.257 g to 0.146g.

The PGA values correlatable to the concept that source have higher magnitude and higher PGA. The PGA values are estimated from the closest potential source zones for major cities of Tamil Nadu viz., Chennai, Coimbatore, Salem, Madurai and Trichirappalli cities, which have PGA of 0.192 to 0.21 g, 0.194 g, 0.16 g, 0.072 and 0.098g respectively.

ROLE OF SITE CONDITIONS ON BUILT-ENVIRONMENT OF DELHI

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Delhi region has a long seismic history, being affected by local earthquakes, as well as by the Himalayan earthquakes. 5^{th} -6^{th} Century AD Sanskrit texts and 18^{th} – 19^{th} century Persian texts mentioned northern India, including Delhi region as the felt region of severe earthquakes. 1720 Delhi and 1803 Mathura earthquakes created large scale destruction in the built city space. Frequent seismic activities in Himalaya have direct bearings on this mega city as 1991 Uttarkashi and 1999 Chamoli earthquakes generated visible cracks in multistoried apartments in few isolated pockets. Seismologists believe that central Himalaya is due for a great earthquake & Delhi may fall pray to its devastating fury.

It has been observed that an earthquake might generate different ground motions in different localities and the pattern of damage in Delhi during previous earthquakes may be taken as a warning. The influence of local geological and soil conditions on the intensity of ground shaking and structural damage has been well documented. Local site conditions can profoundly influence the major characteristics – amplitude, frequency content and duration – of strong ground motion. Thickness of soil cover, surface topography and basin geometry may play important role in structural damages. Buildings standing on filled up ground (on river bed or dried up lakes) may experience largely amplified ground motions in future earthquakes. Historical records show that river Yamuna used to flow touching Lal Quila and Humayun’s Tomb and a complete system of all season canal was flowing through Chandni Chowk during Moughal period. Residential, Utility and commercial buildings have taken over all these vulnerable localities. NCR is growing day by day and new habitations are planned without giving serious thought to the above said considerations. This paper tries to focus on the factors of seismic vulnerability of built environment of Delhi on the basis of available knowledge base.

REMOTE SENSING BASED PRECURSORY STUDIES FOR EARTHQUAKES

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Earthquakes, perhaps the most devastating natural calamity on earth, have generated interest in scientists from time immemorial. Yet, understanding of this natural phenomenon has not completely been established. It is true that earthquakes cannot be predicted, however, devastating earthquakes keep coming and foster challenges to researchers world over. If earthquakes forewarn us before they strike, it is of utmost importance that we understand and pick up the clues. Satellite based radiometers, which can sense the thermal emission originating from the earth's surface and the intervening atmosphere, can be used to study any thermal anomaly developing near surface of the earth. Thermal anomalies have been observed prior to several past important earthquakes in India, Algeria, China, Iran, Sumatra, Afghanistan, Turkey and Pakistan. It has been observed that there were detectable short-term thermal anomalies which went away along with the earthquake events. The anomalies varied from 5-13^{0} C than the usual temperature of the region and appeared a few days to a few hours preceding the earthquakes. Air temperature collected by meteorological stations situated near and around the epicentral area was obtained for the earthquake in (Bhuj) India and (Bam and Zarand) Iran. Temperature variation curves showed spikes of temperature increase before the earthquakes. It has also been observed that the generation of thermal anomalies, their spatial extent, intensity and the days of their appearance prior to an earthquake depend on the magnitude, focal depth of the earthquake, terrain and meteorological conditions etc. Such satellite-aided detection of land surface temperature (LST) anomaly related to an earthquake is an important breakthrough for earthquake researchers and have to be brought on a near-realtime basis for effective results and disaster management.

EVALUATION OF LIQUEFACTION POTENTIAL OF DELHI SUB-SOIL

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Liquefaction of saturated soil deposits during moderate to great earthquake is one of the most pervasive threats to the safety of structures. Liquefaction resulted in large sand boils, excessive settlement, loss of bearing capacity, lateral spreading, landslides, mud flows and slope movements. The type of failure and amount of ground displacement are a function of several parameters including the looseness of the liquefied soil layer, the thickness and extent of the liquefied layer, the thickness and permeability of unliquefied material overlying the liquefied layer, the ground slope, and the nearness of a free face. Liquefaction of both natural and artificial deposits has been observed in almost all major earthquakes, e.g. 1995 Kobe (Japan), 1999 Kocaeli (Turkey), 1999 Chi-Chi (Taiwan), 2001 Bhuj (India). Currently, several in situ techniques, such as SPT, CPT, shear wave velocity, BPT are used for assessing the liquefaction potential of soil deposits. These methods are based on the cyclic stress approach, first proposed by Seed and Idriss (1971) and subsequently developed by Seed and Idriss (1982), NRC (1985), Idriss (1990), Youd and Idriss (1997) and Idriss and Boulanger (2004). In this approach, the liquefaction potential of a site is evaluated

based on the estimation of: (1) the Cyclic Stress Ratio (CSR) induced by the earthquake; and (2) the Cyclic Resistance Ratio (CRR) of the soil, which represents the cyclic stress ratio required to initiate liquefaction in a given number of loading cycles. If the CSR is greater than the CRR, the soil is expected to liquefy during the earthquake. Additionally, several correction factors have been incorporated in the design procedure that account for earthquake magnitude scaling factor, high overburden pressures, and initial static shear stresses.

National Capital Territory (NCT) of Delhi is frequently affected with distant earthquakes occurring in the Himalayan belt. With burgeoning population surge in the megacity, uncontrolled infrastructure development and non-engineered construction practices the city built environment is becoming increasingly vulnerable to earthquakes and related risk. The problem of earthquake induced liquefaction and/or lateral spreading have become a key consideration in the mitigation process. From the geotechnical engineering view-points, design issues concerning to liquefaction damages consist of three parts: (a) evaluation of liquefaction hazard, (b) evaluation of potential ground displacement, and (c) mitigating the hazard by designing to resist excessive ground displacement or strength loss, by reducing the potential for liquefaction, or by choosing an alternative site with less possible hazard.

Followings have been considered as input parameters for SPT-based liquefaction analysis: SPT energy transfer efficiency as 60%, a scenario earthquake M8.2, peak ground acceleration at bed rock level from 0.1 to 0.36g with maximum magnification factor at surface level as 2.5, pre and post monsoon ground water table map (2005) from Central Ground Water

Board (CGWB), bed rock profile from Geological Survey of India and CGWB. Based on 2500 borehole data (6 to 30m depth, SPT-N value 2 to 50) from 491 geotechnical investigation reports procured from DDA, CPWD, DMRC and various other agencies, this paper presents liquefaction potential of NCT of Delhi following Idriss and Boulanger (2004) approach. Results show that about 80% of the soil cover in Delhi are of liquefying type (ML, CL-ML) and Yamuna river belt area is having high potential for liquefaction induced damages.

SEISMIC HAZARD AND RISK MICROZONATION OF JABALPUR URBAN AREA - LESSONS LEARNT

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Seismic Hazard and Risk Microzonation (SHRM), is a multi-criteria based discretisation of a given geographical domain into smaller units of uniform response to the impounding ground motion. This response is in terms of the hazard level, nature and damage pattern or risk. A multi disciplinary and multi-organizational experiment on SHRM of Jabalpur Urban area was carried out to generate desired collateral inputs from geology, geophysics, seismology, geotechnical engineering. The exercise was carried out with an endeavor to generate parameters for- ‘source’, ‘wave path’ and ‘ground’ characterization. Based on these, a ground character map of the area was evolved. This map in conjunction with the vulnerability of the built-in environment has developed into a preliminary risk map of Jabalpur Urban area. Studies of Jabalpur were taken up with two objectives; (1) constraining a comprehensive model for seismic microzonation and (2) generating input data for studies on SHRM of Jabalpur Urban area. Thus, a hierarchical model (comprising of four precession levels) with multidisciplinary inputs was evolved as a goal towards the fulfillment of the first objective. The second objective was accomplished following guidelines as per the aforesaid

model. The exercise was carried out considering a scenario earthquake (Mw 6.5, h. 30 km) with epicenter 20 km south of Jabalpur in a mature zone of seismicity endemic to fundamental, ENE-WSW trending and steep southerly dipping Son-Narmada- South Fault (SNSF). The geometry and orientation of the causative fault vis-à-vis the regional principal stress regime and its kinematics, gives a strong sense of directivity to the ground motion as experienced during the May 1997 Jabalpur EQ.

This paper highlights the following:

- The geotechnical characterization especially the mechanical properties of various litho units and the mechanical properties studies of soft sediments is extremely necessary. The realistic assessment of the liquefaction susceptibility and opportunity available in an area for liquefaction is possible, only if proper granulometric analysis together with geohydrological, geological and geotechnical evaluation is carried out.
- Nakamura type of site response studies is not only time and cost effective but also provides stable response curves for ground characterization and determination of predominant frequency. As regards to the determination of amplification, this has to be used with caution. Wherever possible, cross check should be carried out with other techniques viz. event and reference site based studies.
- Shear wave velocity studies (V_s^{30}) form an essential component of the Seismic Microzonation and forms an effective tool for site classification and generating many essential data sets for such studies. The MASW is the most rapid screening, non invasive technique for such studies. It can

also generate ‘N’ values which are similar to those generated by SPT as seen in Jabalpur area.

COPING MECHANISM AND TECHNOLOGIES FOR EARTHQUAKE RISK REDUCTION

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This paper explains the coping mechanism for disasters which might take place due to earthquake vulnerability of the Indian subcontinent. For coping mechanism to be a success, it will necessitate "hazard assessment" & "vulnerability analysis" based on demographic pattern and local construction practices. It will certainly lead to enhancement of managerial capacity to minimize the loss caused by natural calamities. Disasters are no longer viewed as extreme events created by natural forces but as unresolved problems of development. It is now recognised that risks (Physical, Social and Economic) unmanaged (or mismanaged) for a long time lead to occurrence of disasters. Min of Urban Development has taken a positive step in right direction to make the NBC of 2005 mandatory for structural safety of the buildings during natural calamities like quakes.

Disaster risk reduction needs to be an integral part of National and sub-national/provincial development plans, besides linking it to existing sustainability programmes such as ISO 14001 and larger integrated natural resource management programmes. Comprehensive urban development strategies and proper land use planning also go a long way in ensuring that the necessary conditions are set to reduce and mitigate the risk of damage

from disasters. Quite clearly, focus needs to be paid to developing mechanisms to bring new, and influential local stakeholders closer into the global action programmes and vice versa – for example, the business sector by creating new consultation and cooperation mechanisms. Capacities of governments (national and local), but also business groups in dealing with risk factors will need to be built, along with the strengthening of mainstream development actors to incorporate risk reduction into their decisions. Reducing the underlying risk factors is indeed a critical cross-cutting issue that runs through all stages of the disaster management cycle, from prevention, mitigation, preparedness, response, to recovery/rehabilitation.

Ministry of Urban Development has taken steps for not only implementation of the National Building Code (NBC), 2005 but also to make it mandatory to prevent damages during earthquakes and ensure structural safety of constructions in the country. The Urban Ministry has filed an affidavit in the Supreme Court with initiative of NGO "Society for Safe Structures". Accordingly, the Urban Development Ministry has discussed with the Banking and Insurance Division of the Ministry of Finance to explore the possibility of insisting on the NBC and requested to explore the feasibility of bringing about a system that makes it mandatory for lending institutions to insist on the necessity of insuring the constructions built with borrowed finances.

POST EARTHQUAKE RECONSTRUCTION PROGRAMMES IN INDIA

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On account of geo-physical location, India is highly prone to earthquakes of damaging intensities. The country keeps on experiencing earthquakes of varying magnitude on regular intervals. Over a period of last 15 years country had witnessed six earthquakes of M 6+, causing significant damage to life and property. These earthquakes had disrupted the normal life pattern of the affected regions due to severe impact on socio- economic and physical infrastructure including public and private properties.

To bring back the life to normalcy, concerted efforts had been taken under relief, recovery, rehabilitation and reconstruction programmes by the respective state governments after all such events. The rehabilitation/reconstruction phase generally starts at the end of the relief/recovery phase and may last for several years. The reconstruction programmes emphasize upon the creating better living standards in the affected areas than what existed before the disaster through construction of lifelines and infrastructures facilities. Post-earthquake rehabilitation and reconstruction programmes provide opportunity to work with communities and serve local needs. For a successful reconstruction programme there are certain prerequisite like empowerment of affected community, decentralization, concentration on mitigation efforts and minimum relocation.

A number of massive reconstruction programmes had been initiated to rebuild the earthquake-affected areas of the country with the financial assistance from the World Bank like Latur (M 6.4, 1993) and Bhuj (M 6.9, 2001) earthquakes. The Bhuj earthquake reconstruction programme is a trendsetter in terms of empowering community and emphasizing much on structural and non-structural mitigation efforts in the state of Gujarat. Similarly, there are number of events, where respective state governments had initiated reconstruction programmes, which could not generate much hype either on public participation or mitigation efforts. For example the reconstruction programme after the recent Kashmir earthquake (M 7.4, 2005) could not create much needed impetus for effective earthquake mitigation programme through community participation.

Post-earthquake reconstruction is a complex issue with several dimensions. Government, nongovernmental and international organizations have their own stakes in disaster recovery programs, and links must be established among them, as well as with the community. It had been observed that the performance of the reconstruction programmes depend upon the implementation mechanism established by the state government for this purpose. There are number of post earthquake reconstruction programmes which are more successful and resulted achieving the expected results like Bhuj earthquake reconstruction programme, which had been a leading light not only at national level but also at international level.

The present paper will review different approaches adopted during the post earthquake reconstruction programmes after recent earthquakes in India. Lessons learnt from such programmes will also be discussed in the paper.

EARTHQUAKE RISK MITIGATION AND MANAGEMENT-AN OVERVIEW

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Earthquake is one of the most devastating and frightening natural disasters causing deaths, injuries and extensive property damages. India has witnessed some of the most devastating earthquakes in the last 25 yrs. Deaths are mostly caused by failure of buildings and other human constructions during an earthquake.

About 59% area of the country occurs in Seismically active zone. The Himalayan belt, North-Eastern states, Kutch region of Gujarat are considered as most vulnerable. Ground shaking, ground rupture, fire, rapid mass wasting processes, Tsunamis, liquefaction are some of the after effects caused by earthquake.

As of today earthquakes cannot be predicted precisely. However, mitigation measures ranging from improved building codes to homeowner education to upgrading bridges and other lifelines, can reduce earthquake damages. One of the effective earthquake mitigation, is improved building codes and standards. By far the most serious earthquake damage is structural, which can be hidden or apparent, and can be cosmetic or can compromise with the structural integrity of the building. Non-structural building damage might include impacts to sprinklers, pipes, suspended ceilings, etc.

This paper attempts to highlight various mitigation measures that can be opted in India to reduce the disastrous impact of earthquakes.