# SPECTRAL AMPLIFICATION FACTORS OF INDIAN EARTHQUAKE GROUND MOTION

MAAZ ALLAH KHAN1 SYED SAMEER HUSAIN2 SHIVANGI YADAV3 SHARAD YADAV4
AZAD INSTITUTE OF ENGINEERING & TECHNOLOGY

**Abstract:**

On the study of Uttarkashi earthquake of 19 October 1991 (MS = 7.0) had occurred in the greater Himalayas region north of the main central thrust, at an estimated depth of 12 km. The fault plane solution indicates a low-angle thrust mechanism, striking northwest, consistent with the tectonic pattern of thrusting in the region. The amplitudes and frequency content of the strong ground motions are more or less consistent with expectations for an earthquake of this magnitude in California. Synthetics generated using the composite source model and synthetic Green's functions are successful in producing acceleration, velocity, and displacement with a realistic appearance and the correct statistical properties of the two accelerograms recorded nearest the fault (Bhatwari and Uttarkashi). Two velocity models were used in the prediction strong ground motions at Bhatwari and Tehri, with a potential magnitude 8.5 earthquake filling part of the seismic gap along the Himalayas frontal faults. The synthetics show peak accelerations that are only somewhat larger than those in the Uttarkashi event, but much longer durations and increased amplitudes of response spectra at long periods.

**Keywords:**

Site response analysis, bedrock motion, amplification factors, hazard index, seismic microzonation, response spectra, synthetic ground motion, time history.

## Introduction

Earthquake which can also be known as EQ is generated from ground motion and are altered at a site due to the presence of the local soil which is available under the ground. So as a result, a complete change in ground motion characteristics between the bedrock and the surface is clearly observed. Thus by this a changed ground motion in building response as well as induced effect are controlled. Effects of local soil in controlling the Earthquake damage were evidenced during 1918 Srimangal EQ in Assam,1985 Michoacan EQ in Mexico ,1989 Loma Peieta EQ in San Francisco,1999 Chamoli EQ in Delhi, 2001 Bhuj EQ in Ahemdabad in India,2005 Kashmir EQ in India,2011 Sendai EQ in Japan, 2015 Nepal and many more. A very detailed discussion of this suggests a failure of geotechnical structures during the year 2001 in BhujEQ. Due to this event ground shaking was also felt upto many locations which is Nepal in the east, Pune in the south-west, Himachal Pradesh and Haryana which is in the north and Uttar Pradesh and Bihar which is in the east. There are many examples of local site effects which is in the year 2011 Sydney EQ which is located about 130km off from the Eastern coast of Sydney in the Pacific Ocean. Ground shaking developed during this event triggered liquefaction and differential settlement in the area of Maihama. Induced ground motion were assigned intensity of VIIin thepicentral region and the intensity which was felt in the south east of the epicentre was 170km.The shaking of the ground was so intense that it was felt in Delhi which is located 850km from the epicentre. The severe intensity which was felt was of IV. These were some examples of induced ground shaking which has not only caused damage to concentrated area which is near the epicentral area but also the larger area distance which is covered by the presence of the local soil. The correct estimation of the induced effect will also help in the correct estimation and the accuracy of the site responsive analysis. Much emphasis is given while the determination of the properties of subsoil while addressing the local site effects. The selection of input motion at bedrock is very important. However the importance is not highlighted in many of the available site response studies. Highlighting these limitations in ongoing practices, an attempt was been made to study the dependency of the bedrock PHA on site amplification factor .A soil column was analyzed for large set of the globally record input ground motion.

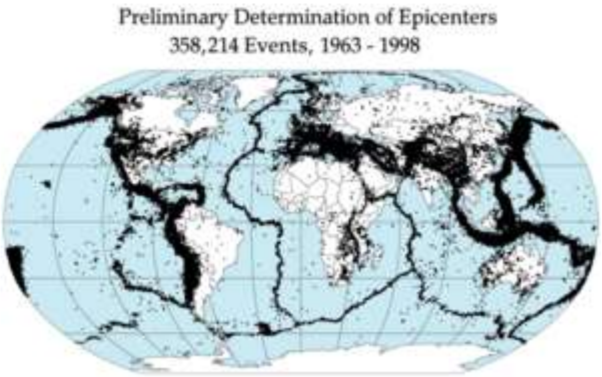
## STUDY AREAS

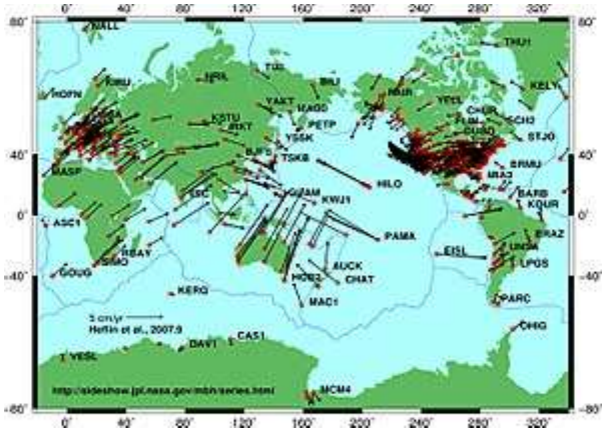
According to the present analysis, four months after the earthquake the Gujarat government announced the Gujarat Earthquake Reconstruction and Rehabilitation Policy. The main objectives of the policy included repairing, building, and strengthening houses and public buildings. Earthquake in Bengal, Bihar, and Assam are more dangerous areas because the located more than 500 kilometers from the Indian border, an earthquake measuring 6.8 on the Richter scale has hit Myanmar, Bihar, Patna, and Kolkata. While it has been reported that the tremors lasted for 10 sec in Kolkata, Patna experienced the strong earthquake for about three seconds. People within these constructions experienced their worst nightmare within a few seconds time. The earthquake shook building situated in Myanmar's biggest city of Yangon and a range of other cities and towns.11:00 AM IST, 14 April 2016 – The earthquake jolts were also Uttar Pradesh, Chhattisgarh, Odisha and Madhya Pradesh. As the National Central for Seismology, the earthquake occurred around 7:25 P.M and was 74 km South East of Mawlaik. The earthquake was the sec. one in the day as the northeast had already a medium intensity earthquake measuring 4.6 hitting areas .it is the scientific study of earthquake and the propagation of elastic waves through the earth or through other planet-like bodies. A related atmospheric and artificial field that uses geology of inter information regarding part earthquakes is paleo seismology.

### What is earthquake?

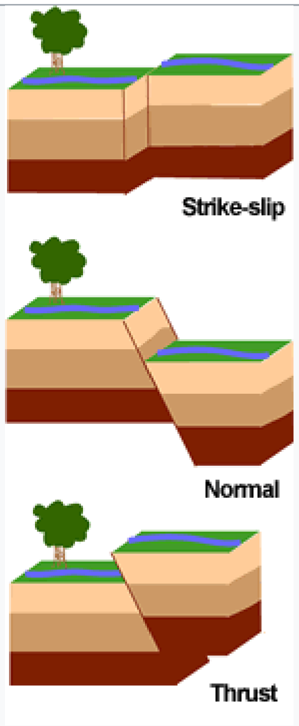
An earthquake (also known as a quake, tremor or temblor) is the shaking of the surface of the Earth, resulting from the sudden release of energy in the Earth's lithosphere that creates seismic waves. Earthquakes can range in size from those that are so weak that they cannot be felt to those violent enough to toss people around and destroy whole cities. The seismicity or seismic activity of an area refers to the frequency, type and size of earthquakes experienced over a period of time.

At the Earth's surface, earthquakes manifest themselves by shaking and sometimes displacement of the ground. When the epicenter of a large earthquake is located offshore, the seabed may be displaced sufficiently to cause a tsunami. Earthquakes can also trigger landslides, and occasionally volcanic activity. In its most general sense, the word earthquake is used to describe any seismic event whether natural or caused by humans — that generates seismic waves. Earthquakes are caused mostly by rupture of geological faults, but also by other events such as volcanic activity, landslides, mine blasts, and nuclear tests. An earthquake's point of initial rupture is called its focus or hypocenter. The epicenter is the point at ground level directly above the hypocenter.





## Naturally Occurring Earthquakes



## Fault types

Tectonic earthquakes occur anywhere in the earth where there is sufficient stored elastic strain energy to drive fracture propagation along a fault plane. The sides of a fault move past each other smoothly and a seismically only if there are no irregularities or asperities along the fault surface that increase the frictional resistance. Most fault surfaces do have such asperities and this leads to a form of stick-slip behavior. Once the fault has locked, continued relative motion between the plates leads to increasing stress and therefore, stored strain energy in the volume around the fault surface. This continues until the stress has risen sufficiently to break through the asperity, suddenly allowing sliding over the locked portion of the fault, releasing the stored energy. This energy is released as a combination of radiated elastic strain seismic waves, frictional heating of the fault surface, and cracking of the rock, thus causing an earthquake. This process of gradual build-up of strain and stress punctuated by occasional sudden earthquake failure is referred to as the elastic-rebound theory. It is estimated that only 10 percent or less of an earthquake's total energy is radiated as seismic energy. Most of the earthquake's energy is used to power the earthquake fracture growth or is converted into heat generated by friction. Therefore, earthquakes lower the Earth's available elastic potential energy and raise its temperature, though these changes are negligible compared to the conductive and convective flow of heat out from the Earth's deep interior.

### List Of Earthquake In India ?

The Indian subcontinent has a history of earthquakes. The reason for the intensity and high frequency of earthquakes is the Indian plate driving into Asia at a rate of approximately 47 mm/year. The following is a list of major earthquakes which have occurred in India.

| Date | Location | Mag. | I | Deaths | Injuries | Total damage / notes | |
|---|---|---|---|---|---|---|---|
| 2017-01-03 | India, Bangladesh | 5.7 $M_w$ | V | 3 | 8 | | |
| 2016-01-04 | India, Myanmar, Bangladesh | 6.7 $M_w$ | VII | 11 | 200 | | |
| 2015-10-26 | Afghanistan, India, Pakistan | 7.7 $M_w$ | VII | 399 | 2,536 | | |
| 2015-05-12 | Nepal, India | 7.3 $M_w$ | VIII | 218 | 3,500+ | | |
| 2015-04-25 | Nepal, India | 7.8 $M_w$ | IX | 8,964 | 21,952 | $10 billion | |
| 2013-05-01 | Kashmir | 5.7 $M_w$ | | 3 | 90 | $19.5 million | NGDC |
| 2011-09-18 | Gangtok, Sikkim | 6.9 $M_w$ | VII | >111 | | | |

| Date | Location | Mag. | I | Deaths | Injuries | Total damage / notes | |
|---|---|---|---|---|---|---|---|
| 2009-08-10 | Andaman Islands | 7.5 $M_w$ | VIII | | | Tsunami warning issued | |
| 2008-02-06 | West Bengal | 4.3 $M_b$ | | 1 | 50 | Buildings damaged | NGDC |
| 2007-11-06 | Gujarat | 5.1 $M_w$ | V | 1 | 5 | Buildings damaged | [2] |
| 2006-03-07 | Gujarat | 5.5 $M_w$ | VI | | 7 | Buildings damaged | [3] |
| 2006-02-14 | Sikkim | 5.3 $M_w$ | V | 2 | 2 | Landslide | [4] |
| 2005-12-14 | Uttarakhand | 5.1 $M_w$ | VI | 1 | 3 | Building destroyed | [5] |
| 2005-10-08 | Kashmir | 7.6 $M_w$ | VIII | 86,000–87,351 | 69,000–75,266 | 2.8 million displaced | |
| 2005-03-15 | Maharashtra | 4.9 $M_w$ | VII | | 45 | Buildings damaged | [6] |
| 2004-12-26 | off northern Sumatra | 9.1–9.3 $M_w$ | IX | 230,000–280,000 | | Destructive tsunami | |
| 2002-09-13 | Andaman Islands | 6.5 $M_w$ | | 2 | | Destructive tsunami | NGDC |

| Date | Location | Mag. | I | Deaths | Injuries | Total damage / notes | |
|---|---|---|---|---|---|---|---|
| 2001-01-26 | Gujarat | 7.7 $M_w$ | X | 13,805–20,023 | ~166,800 | Republic Day (India) | |
| 1999-03-29 | Chamoli district-Uttarakhand | 6.8 $M_w$ | VIII | ~103 | | | |
| 1997-11-21 | Bangladesh, India | 6.1 $M_w$ | | 23 | 200 | | |
| 1997-05-22 | Jabalpur, Madhya Pradesh | 5.8 $M_w$ | VIII | 38–56 | 1,000–1,500 | $37–143 million | |
| 1993-09-30 | Latur, Maharashtra | 6.2 $M_w$ | VIII | 9,748 | 30,000 | | |
| 1991-10-20 | Uttarkashi, Uttarakhand | 6.8 $M_w$ | IX | 768–2,000 | 1,383–1,800 | | |
| 1988-08-21 | Udayapur, Nepal | 6.9 $M_w$ | VIII | 709–1,450 | | | |
| 1988-08-06 | Myannmar, India | 7.3 $M_w$ | VII | 3 | 12 | | [7] |
| 1988-02-06 | Bangladesh, India | 5.9 $M_w$ | | 2 | 100 | | [8] |
| 1986-04-26 | India, Pakistan | 5.3 $M_s$ | | 6 | 30 | Severe damage | NGDC |

| Date | Location | Mag. | I | Deaths | Injuries | Total damage / notes | |
|---|---|---|---|---|---|---|---|
| 1984-12-30 | Cachar district | 5.6 $M_b$ | | 20 | 100 | Severe damage | NGDC |
| 1982-01-20 | Little Nicobar | 6.3 $M_s$ | | | Some | Moderate damage | NGDC |
| 1980-08-23 | Kashmir | 4.8 $M_s$ | | Few | | Limited damage / doublet | NGDC |
| 1980-08-23 | Kashmir | 4.9 $M_s$ | | 15 | 40 | Moderate damage / doublet | NGDC |
| 1980-07-29 | Nepal, Pithoragarh district | 6.5 $M_s$ | | 200 | Many | $245 million | NGDC |
| 1975-01-19 | Himachal Pradesh | 6.8 $M_s$ | IX | 47 | | | |
| 1970-03-23 | Bharuch district | 5.4 $M_b$ | | 26 | 200 | Moderate damage | NGDC |
| 1967-12-11 | Maharashtra | 6.6 $M_w$ | VIII | 177–180 | 2,272 | $400,000 | |
| 1966-08-15 | North India | 5.6 | | 15 | | Limited damage | NGDC |
| 1966-06-27 | Nepal, India | 5.3 $M_s$ | VIII | 80 | 100 | $1 million | NGDC |

| Date | Location | Mag. | I | Deaths | Injuries | Total damage / notes | |
|---|---|---|---|---|---|---|---|
| 1963-09-02 | Kashmir | 5.3 | | 80 | | Moderate damage | NGDC |
| 1960-08-27 | North India | | | | | Moderate damage | NGDC |
| 1956-07-21 | Gujarat | 6.1 $M_s$ | IX | 115 | 254 | | |
| 1954-03-21 | India, Myanmar | 7.4 $M_s$ | | | | Moderate damage | NGDC |
| 1950-08-15 | Assam, Tibet | 8.6 $M_w$ | XI | 1,500–3,300 | | | |
| 1947-07-29 | India, China | 7.3 $M_w$ | | | | | |
| 1941-06-26 | Andaman Islands | 7.7–8.1 $M_w$ | | 8,000 | | Destructive tsunami | |
| 1935-05-31 | Quetta, Baluchistan | 7.7 $M_w$ | X | 30,000–60,000 | | | |
| 1934-01-15 | Nepal | 8.0 $M_w$ | XI | 6,000–10,700 | | | |
| 1932-08-14 | Assam, Myanmar | 7.0 $M_s$ | | | | Moderate damage | NGDC |

| Date | Location | Mag. | I | Deaths | Injuries | Total damage / notes | |
|---|---|---|---|---|---|---|---|
| 1905-04-04 | Kangra | 7.8 $M_s$ | IX | >20,000 | | | |
| 1897-06-12 | Shillong, India | 8.0 $M_w$ | X | 1,542 | | | |
| 1885-06-06 | Kashmir | | | | | Severe damage | NGDC |
| 1885-05-30 | Srinagar | | | 3,000 | | Extreme damage | NGDC |
| 1881-12-31 | Andaman Islands | 7.9 $M_w$ | VII | | | Significant in seismology | |
| 1869-01-10 | Assam, Cachar | 7.4 $M_w$ | VII | 2 | | Severe damage | |
| 1845-06-19 | Rann of Kutch | 6.3 $M_s$ | VIII | Few | | Limited damage / tsunami | NGDC |
| 1843-04-01 | Deccan Plateau | | | | | Moderate damage | NGDC |
| 1833-08-26 | Bihar, Kathmandu | 8.0 $M_s$ | | | | Severe damage | NGDC |
| 1828-06-06 | Kashmir | | | 1,000 | | Severe damage | NGDC |

| Date | Location | Mag. | I | Deaths | Injuries | Total damage / notes | |
|---|---|---|---|---|---|---|---|
| 1819-06-16 | Gujarat | 7.7–8.2 $M_w$ | XI | >1,543 | | Formed the Allah Bund | |
| 1618-05-26 | Bombay | | IX | 2,000 | | Severe damage | NGDC |
| 1505-06-06 | Saldang, Karnali zone | 8.2–8.8 | | 6,000 | | | |

**Note:** The inclusion criteria for adding events are based on Wiki Project Earthquakes' notability guideline that was developed for stand alone articles. The principles described also apply to lists. In summary, only damaging, injurious, or deadly events should be recorded.

## Earthquake zones of India

## Earthquake hazard zoning map of India

The Indian sub continent has a history of devastating earthquakes. The major reason for the high frequency and intensity of the earthquakes is that the Indian plate is driving into Asia at a rate of approximately 47 mm/year. Geographical statistics of India show that almost 54% of the land is vulnerable to earthquakes. A World Bank and United Nations report shows estimates that around 200 million city dwellers in India will be exposed to storms and earthquakes by 2050. The latest version of seismic zoning map of India given in the earthquake resistant design code of India [IS 1893 (Part 1) 2002] assigns four levels of seismicity for India in terms of zone factors. In other words, the earthquake zoning map of India divides India into 4 seismic zones (Zone 2, 3, 4 and 5) unlike its previous version, which consisted of five or six zones for the country. According to the present zoning map, Zone 5 expects the highest level of seismicity whereas Zone 2 is associated with the lowest level of seismicity.

### Zone 1

Since the current division of India into earthquake hazard zones does not use Zone 1, no area of India is classed as Zone 1.

Future changes in the classification system may or may not return this zone to use.

### Zone 2

This region is liable to MSK VI or less and is classified as the Low Damage Risk Zone. The IS code assigns zone factor of 0.10 (maximum horizontal acceleration that can be experienced by a structure in this zone is 10% of gravitational acceleration) for Zone 2.

### Zone 3

This zone is classified as Moderate Damage Risk Zone which is liable to MSK VII. And also 7.8 the IS code assigns zone factor of 0.16 for Zone 3. Mumbai comes in Zone 3

### Zone 4

This zone is called the High Damage Risk Zone and covers areas liable to MSK VIII. The IS code assigns zone factor of 0.24 for Zone4 Jammu and Kashmir, Himachal Pradesh,Uttarakhand, Sikkim, the parts of Indo-Gangetic plains (North Punjab, Chandigarh, Western Uttar Pradesh, Terai, North Bengal, Sundarbans) and the capital of the country Delhifall in Zone 4. In Maharashtra, the Patan area (Koynanagar) is also in zone no-4. In Bihar the northern part of the state like Raxaul, Near the border of India and Nepal, is also in zone no-4.

### Zone 5

Zone 5 covers the areas with the highest risks zone that suffers earthquakes of intensity MSK IX or greater. The IS code assigns zone factor of 0.36 for Zone 5. Structural designers use this factor for earthquake resistant design of structures in Zone 5. The zone factor of 0.36 is indicative of effective (zero Period) level earthquake in this zone. It is referred to as the Very High Damage Risk Zone. The region of Kashmir, the Western and Central Himalayas, North and Middle Bihar, the North-East Indian region, the Rann of Kutch and the Andaman and Nicobar group of islands fall in this zone.

Generally, the areas having trap rock or basaltic rock are prone to earthquakes.

### Earthquake-Resistant Structures

Earthquake-resistant structures are structures designed to withstand earthquakes. While no structure can be entirely immune to damage from earthquakes, the goal of earthquake resistant construction is to erect structures that fare better during seismic activity than their conventional counterparts.

According to building codes, earthquake-resistant structures are intended to withstand the largest earthquake of a certain probability that is likely to occur at their location. This means the loss of life should be minimized by preventing collapse of the buildings for rare earthquakes while the loss of the functionality should be limited for more frequent ones.[1]

To combat earthquake destruction, the only method available to ancient architects was to build their landmark structures to last, often by making them excessively stiff and strong.

Currently, there are several design philosophies in earthquake engineering, making use of experimental results, computer simulations and observations from past earthquakes to offer the required performance for the seismic threat at the site of interest. These range from appropriately sizing the structure to be strong and ductile enough to survive the shaking with an acceptable damage, to equipping it with base isolation or using structural vibration control technologies to minimize any forces and deformations. While the former is the method typically applied in most earthquake-resistant structures, important facilities, landmarks and cultural heritage buildings use the more advanced (and expensive) techniques of isolation or control to survive strong shaking with minimal damage. Examples of such applications are the Cathedral of Our Lady of the Angels and the Acropolis Museum.

**Earthquake shelter**

One Japanese construction company has developed a six-foot cubical shelter, presented as an alternative to earthquake-proofing an entire building.

Concurrent shake-table testing

Concurrent shake-table testing of two or more building models is a vivid, persuasive and effective way to validate earthquake engineering solutions experimentally.

Thus, two wooden houses built before adoption of the 1981 Japanese Building Code were moved to E-Defense for testing (see both pictures aside). The left house was reinforced to enhance its seismic resistance, while the other one was not. These two models were set on E-Defense platform and tested simultaneously.

**Combined Vibration Control Solution**

Close-up of abutment of seismically retrofitted Municipal Services Building in Glendale, California

Designed by architect Merrill W. Baird of Glendale, working in collaboration with A. C. Martin Architects of Los Angeles, the Municipal Services Building at 633 East Broadway, Glendale was completed in 1966. Prominently sited at the corner of East Broadway and Glendale Avenue, this civic building serves as a heraldic element of Glendale's civic center.

In October 2004 Architectural Resources Group (ARG) was contracted by Nabih Youssef & Associates, Structural Engineers, to provide services regarding a historic resource assessment of the building due to a proposed seismic retrofit.

In 2008, the Municipal Services Building of the City of Glendale, California was seismically retrofitted using an innovative combined vibration control solution: the existing elevated building foundation of the building was put on high damping rubber bearings.

**Steel Plate Walls System**

before operation could be resumed.

On May 9, 2009, one unit (Unit 7) was restarted, after the seismic upgrades. The test run had to continue for 50 days. The plant had been completely shut down for almost 22 months following the earthquake.

**Seismic Test of Seven-Story Building**

A destructive earthquake struck a lone, wooden condominium in Japan. The experiment was webcast live on July 14, 2009 to yield insight on how to make wooden structures stronger and better able to withstand major earthquakes.

The Miki shake at the Hyogo Earthquake Engineering Research Center is the capstone experiment of the four-year NEES Wood project, which receives its primary support from the U.S. National Science Foundation Network for Earthquake Engineering Simulation (NEES) Program.
"NEES Wood aims to develop a new seismic design philosophy that will provide the necessary mechanisms to safely increase the height of wood-frame structures in active seismic zones of the United States, as well as mitigate earthquake damage to low-rise wood-frame structures," said Rosowsky, Department of Civil Engineering at Texas A&M University. This philosophy is based on the application of seismic damping systems for wooden buildings. The systems, which can be installed inside the walls of most wooden buildings, include strong metal frame, bracing and dampers filled with viscous fluid.

## Super Frame Earthquake Proof Structure

The proposed system is composed of core walls, hat beams incorporated into the top level, outer columns and viscous dampers vertically installed between the tips of the hat beams and the outer columns. During an earthquake, the hat beams and outer columns act as outriggers and reduce the overturning moment in the core, and the installed dampers also reduce the moment and the lateral deflection of the structure. This innovative system can eliminate inner beams and inner columns on each floor, and thereby provide buildings with column-free floor space even in highly seismic regions.

## SUB SOIL PROPERTY

The work of civil engineering especially in a seismic region is to provide maximum safety in the structures designed and constructed by him against earthquake shocks at the acceptable economic costs. Briefly expressed task of engineers is:

(a) To know the seismic history of the area.
(b) To introduce suitable factors of safety in the new construction.

The high incidence of liquefaction during earthquakes, with its potential to damage, has made the liquefaction a prime subject of concern in geotechnical earthquake engineering.
The term ‘’ Amplification factor’’ is hence used here to refer to the ratio of the peak horizontal acceleration at the bedrock. This factor is evaluated for all the boreholes using the PHA at bedrock obtained from the synthetic acceleration time history for each Borehole and the peck ground surface acceleration obtained as a result of ground response analysis using SHAKE 2000.

## LOCAL SITE EFFECTS 29 June 2015 – A 5.6

Magnitude earthquake struck Assam at around 6.40 am Sunday morning. According to district officials, three people sustained injuries when an old wall collapsed near the Kokrajhar railway station. The appearance of an earthquake of appreciable magnitude is generally accompanied by a train of effects some of which may be highly destructive in nature. The character of the various with the severity of the earthquake as well as the distance of the place under consideration from the epicenter of that particular earthquake.

**Richter classified the effects of the earthquake into two categories:**
(a) Primary Effects.
(b) Secondary Effects.

## ANALYSIS AND RESULTS

There are several methods and related computer procedures available for studying the dynamic response of embankment to seismic loading. Since response analysis began their way into geotechnical engineering practice in the early 1970s with the development of SHAKE.

These program divided into different ways, but it is useful to distinguish them on the basis of general soil model.

Equivalent linear models use an iterative usion approach to approximate the nonlinear, in the clastic behavior of soils. An average shear modulus is used over an entire cycle of loading approximate the hysteresis loop. The actual nonlinear behavior of the shear modulus and damping ratio dynamic loading conditions can be simulated approximately by an equivalent linear analysis. Combing the observations from the above two steps indicate that the built correction in SHAKE 2000for the estimation of Gmax can be used confidently for the present study.

In another attempt to perform the seismic microzonation of Lucknow, Abhishek1 assigned ranks to the values of PHA as well as factor of amplification independently. In the presently analysis, as shown in figure 4, the values of PHA and factors of amplification are found related to each other such that higher values of amplification factors are corresponding to low PHA values only and vice versa. The range of PHA and the corresponding range of amplification factor for above three categories are presented in table 2. In addition, the ranks to each range of PHA and the amplification factor are also given in table2 It can be observed from table 2 that ranks to both PHA and the amplification factor are interrelated This clearly indicates that ranks assigned to both the PHA as well as the amplification factor should be considered in a more combined manner while estimating the hazard index value. In addition, both PHA and the amplification factor cannot have a high rank simultaneously. As Seismic microzonation of urban centre utilizes various thematic layers in determining the hazard index values including the PHA and the amplification factor. In the present work the interrelation between the PHA and the amplification factor has been studied. In a similar way, the correlation between other thematic layers such as PHA, average shear wave velocity, depth to overburden etc. can be studied in future to provide a more rational approach in estimating the hazard index values.

## CONCLUSION

- Building should be light in weight, particularly roof and upper stories.
- Integrity and continuity in construction such that it forms a continuous load path between the foundation to all daiphragm levels and tying all portions of building together.
- Projection / suspended ceiling should be avoided, otherwise reinforceband firmly attached with main structure.
- Building plan and elevation should be symmetrical with respect to mass and stiffness, otherwise use separation joints.

- Avoid close proximity, use separation
- Foundation of building should be firm and uniform, otherwise seperate the building in units.
- Doors and windows should be as small as possible and placed centrally as recommended.
- Top level of the openings should be the same, covered with lintel band.

## References

1. Reinforced Concrete – Limit State Design by A. K. Jain, Nem Chand & Bros., Roorkee.
2. Reinforced Concrete Design by P. Dayaratnam.
3. Reinforced Concrete Structures by R. Park and Pauley.
4. V.N.S. Murthy – Soil Mechanics and Foundation Engineering (Fifth Edition)
5. K.R. Arora – Soil Mechanics and Foundation Engineering
6. J.E. Bowles – Foundation Analysis and Design
7. GopalRanjan and A.S.R. Rao – Basic and Applied Soil Mechanics
8. C. Venkataramaiah – Geotechnical Engineering
9. M.J. Tomilson – Foundation Design
10. PurshothamRaju – Ground Improvement
11. Earthquake Resistant Design of Structures by P. Agarwal&M.Shrikhande
12. Structural Dynamics – Theory & Computation by Mario Paz
13. Elements of Earthquake Engineering by Jai Krishna and A.R.Chandrasekharan
14. Fundamental of Earthquake Engineering by N.M. Neumarks and E. Rosenblueth
15. Engineering Vibrations byL.S. Jacobsen & R.S. Ayre
16. Structural Dynamics by R. Roy Craig Jr.
17. Dynamics of Structures by R.W. Clough & J. Penjien

**I.S. Codes**

1. IS: 456 - 2000
2. IS: 1893 (Part –1) – 2002
3. IS: 1893 (Part –4) – 2005
4. IS: 13920 – 1993.