



# Performance Of Various Parameters of Buildings Under The Composite Action Of Blast Load And Earthquake

Natish M. Sayyed<sup>1</sup>, Amey Khedikar<sup>2</sup>

<sup>1</sup> M-Tech Research Scholar (Structure), Civil Engineering Department, Tulsiramji Gaikwad-Patil College of Engineering and Technology, Mohgaon, Nagpur, MH.

snatish@gmail.com

<sup>2</sup> Asst. Professor Civil Engineering Department, Tulsiramji Gaikwad-Patil College of Engineering and Technology, Mohgaon, Nagpur, MH.

amey.khedikar@gmail.com

## Abstract:

An earthquake (or quakes, tremors) is shaking caused by sudden movements of rocks in the Earth's crust. They can be extremely violent. Earthquakes are usually quite brief, but may repeat. They are the result of a sudden release of energy in the Earth's crust.

Some of the largest earthquakes of the world have occurred in India and the earthquake engineering developments in the country started rather early. This paper briefly reviews the development of earthquake resistant design of Indian structural buildings. Measurement of ground acceleration of ground started from 1930's and data calculations were made possible in 1940's. Design and development were formulated in late 1950's to 1960's. Non-linear response was introduced in seismic design in 1960's and capacity design concept was generally introduced in 1970's for collapse safety. The damage of statistics of reinforcement concrete building in 1897 Assam earthquake consideration the movement of building performance with the development of design methodology. Buildings designed and constructed using outdated methodology should be upgraded. Performance based engineering should be emphasized, especially for the protection of building functions following frequent earthquake. It has clearly underlined the inadequate preparedness of the country to face damaging earthquakes. The paper discusses the developments of earthquake engineering in India during the last one hundred years, the current status of earthquake risk reduction in India, strengths and weaknesses of Indian model of earthquake engineering developments, and the future challenges.

## Keywords

tremors, ground acceleration, non-linear response.

## 1. Introduction

An earthquake, caused by a fault movement on the earth surface, result in serve ground. Shaking leading to the damage and collapse of building and civil infrastructure, landslides soil. If an earth quake secure under the sea, the associated water moment causes high tidal waves called tsunamis.

Indian earthquake problem cannot be overemphasized. More than about 60% of the land area is considered prone to shaking of intensity VII and above (MMI scale). In fact, the entire Himalayan belt is considered prone to great earthquakes of magnitude exceeding 8.0, and in a short span of about 50 years, four such earthquakes have occurred: 1897 Assam (M8.7), 1905 Kangra (M8.6), 1934 Bihar-Nepal (M8.4), and 1950 Assam-Tibet (M8.7). Earthquake engineering developments started rather early in India. For instance, development of the first seismic zone map and of the earthquake resistant features for masonry buildings took place in 1930's, and formal teaching and research in earthquake engineering started in late 1950's. Despite an early start, the seismic risk in the country has been increasing rapidly in the recent years. Five moderate earthquakes in the last eleven years

Reinforced concrete has been used for building construction since the middle of the 19th century, first for some parts of building, and then for the entire building structure. Reinforced concrete is a major construction material for civil infrastructure in the current society. Construction has always preceded the development of structural design methodology. Each damage case has provided important information regarding the improvement of design and construction practices and attention has



directed to prevention of structural collapse of protect the occupant of building in the last century.

Thanks to the effort of many pioneering researchers and engineers, the state of the art in earthquake resistant design and construction can reduce the life threat in reinforced concrete building. Attention should be directed to the protection of existing structures constructed using old technology. The vulnerability of this existing structure should be examined and seismically deficient structures should be retrofitted. One of the important research target in present earthquake engineering is the development of design methodology to maintain building functions after infrequent earthquakes. For example, through the application of structural control technology. This paper reviews the development of earthquake engineering in relation to

Earthquake resistance of building and discuss the current problem in earthquake engineering related to reinforced concrete construction in India.

## 2. Action Of Earthquake In India

1988 Bihar-Nepal: M6.6, about 1,004 dead;  
1991 Uttarkashi: M6.6, about 768 dead;  
1993 Latur: M6.4, about 8,000 dead;  
1997 Jabalpur: M6.0, about 38 dead;  
1999 Chamoli: M6.5, about 100 dead  
2001 Gujarat M7.7 about 13,806 dead  
2005 Kashmir M7.6, about 8000 dead  
2016 India M6.7 about 200 dead  
2015 India M7.7 about 2536 dead  
2013 Kashmir M5.7 about 90 dead

It has clearly underlined the inadequate preparedness of the country to face damaging earthquakes. The paper discusses the developments of earthquake engineering in India during the last one hundred years, the current status of earthquake risk reduction in India, strengths and weaknesses of Indian model of earthquake engineering developments, and the future challenges.

## 3. History Of Earthquake In India

The Indian subcontinent has a history of devastating earthquake. 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 & 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. The latest seismic zoning map can be accessed from The India Meteorological Department website. The MSK (Medvedev-Sponheuer-Karnik) intensity broadly associated with the various seismic zones is VI (or less), VII, VIII and IX (and above) for Zones 2, 3, 4 and 5, respectively, corresponding to Maximum Considered Earthquake (MCE). The IS code follows a dual design philosophy: (a) under low probability or extreme earthquake events (MCE) the structure damage should not result in total collapse, and (b) under more frequently occurring earthquake events, the structure should suffer only minor or moderate structural damage. The specifications given in the design code (IS 1893: 2002) are not based on detailed assessment of maximum ground acceleration in each zone using a deterministic or probabilistic approach. Instead, each zone factor represents the effective period peak ground accelerations that may be generated during the maximum considered earthquake ground motion in that zone. Each zone indicates the effects of an earthquake at a particular place based on the observations of the affected areas and can also be described using a descriptive scale like Modified Mercalli intensity scale or the Medvedev-Sponheuer-Karnik scale.

## 4. Developments In The Study Of Earthquakes In Last Decades

Dr. Thomas Oldham, the first Director of the Geological Survey of India (GSI), is credited with laying the foundation of the scientific studies of earthquakes in India (West, 1937). He compiled the well-known catalogue of Indian earthquakes and carried out investigations of the Cachar earthquake of 1869. His son, R.D. Oldham, also went on to become Director of the GSI and contributed very substantially to the earthquake studies. His memoir (Oldham, 1899) of the 1897 Assam earthquake was considered by Richter (1958) as one of the most valuable source books in seismology. Since the days of Oldham, the GSI officers have carried out extensive field studies of important Indian earthquakes and published their findings, e.g., the 1905 Kangra (Middlemiss, 1910) and the 1934 Bihar-Nepal (GSI, 1939) earthquakes. Some of the early Indian earthquakes also led to interesting insights into the subject. For instance, the 1819 Runn of Cutch earthquake (Oldham 1898) of M8.3 created



a fault scarp about 100 km long and 3 m high (named Allah Bund: embankment created by the God); it provided the earliest clear and circumstantially described occurrence of faulting during earthquakes (Richter 1958). The descriptions of 1897 Assam earthquake provided the principal model for the highest grade, XII, of the MMI Scale (Richter 1958). Referring to Oldham's 1899 volume on Assam earthquake, Tandon (1959) states: It was in this study that Oldham, for the first time recognized the existence of longitudinal (P), transverse (S) and surface (L) waves on records of seismographs, and thereby laid the foundations of modern seismology. The devastation of the 1897 earthquake led to the development of the Assam-type house, which later became popular in the entire northeastern India. The first seismograph in India was installed in 1898 at the olaba Observatory in Bombay. The first major initiatives for earthquake resistant constructions emerged after the Baluchistan (now in Pakistan) earthquakes of the 1930's. After the Mach earthquake of 1931 (M7.4; intensity VIII on RF scale), about 60 km from Quetta, formal earthquake resistant construction was carried out in the region for the railways using a seismic coefficient of 0.10g. S.L. Kumar, the young railway engineer who designed these constructions, documented this work (Kumar 1933), provided the first seismic zone map of the country and suggested seismic design coefficients (Table 1). In the 1935 Quetta earthquake (M7.6; intensity up to X on RF scale; about 20,000 dead), the earthquake-resistant railway quarters located in the area of maximum damage were the only houses that remained undamaged.

The 1935 Quetta earthquake led to massive reconstruction programs by the railways, military, and the civil administration (Thomson, 1940; GOI, 1940; Robertson 1948). A seismic coefficient of 0.125g was adopted and comprehensive guidelines developed for earthquake resistant features. A code was also proposed along with an excellent commentary (GOI, 1940). These new constructions were put to test in 1941 when an earthquake caused shaking of intensity VIII to IX on R.F. scale, and they performed extremely well (Mair, 1942). Clearly, the 1935 Quetta earthquake was interesting from several viewpoints. For the

First time, serious and systematic efforts were made in the country at earthquake resistant constructions and for developing earthquake codes. For the first time first time in India, efficacy of earthquake resistant constructions was tested during a severe earthquake. The evolution of the provision of reinforced concrete bands at plinth, lintel, and roof levels in masonry buildings took place after this earthquake. In the Quetta area an excellent building

code has recently been drawn up, and reconstruction has been rigidly enforced in terms of that code. Such enforcement is, perhaps, easier in such a military area, but at least Quetta provides an example of the practicability of a building code and of its usefulness. It is, perhaps, not too much to hope that the rest of Northern India will someday follow Quetta's lead (GSI, 1939). The concrete industry developed an early interest in earthquake engineering. The Indian Concrete Journal brought out a special issue (ICJ, 1934) on the 1934 Bihar-Nepal earthquake with excellent well-captioned photographs. After the Anjar (Cutch) earthquake of 1956, two articles (ICJ, 1956a; ICJ, 1956b) were published in the same journal outlining the design principles of earthquake-resistant buildings. A monograph on earthquake resistant buildings was published in 1954 which was revised in 1958 and 1965 (CAI, 1965). Institutional base for earthquake engineering was established around 1958, when after a visit to the California Institute of Technology (Caltech), Professor Jai Krishna started teaching and research in earthquake engineering at the University of Roorkee. First of the four-yearly symposium on earthquake engineering was organized at Roorkee in 1959. Professors D.E. Hudson and G.W.Housner of Caltech stayed at Roorkee for a few months to help in setting up the academic programme and in organizing the first symposium. School of Research and Training in Earthquake Engineering (now Department of Earthquake Engineering, DEQ) was set up at Roorkee in 1960. The Indian Society of Earthquake Technology (ISET) was established in 1962 which now has about 1,000 members. The first Indian seismic code was published in 1962 (IS: 1893-1962) and a comprehensive earthquake catalogue was published in 1983 (ISET, 1983). Several academics from India have also played major roles in the international activities. For instance, Professor Jai Krishna and a few others helped Yugoslavia establish earthquake engineering activities at Skopje. India hosted the 6th World Conference and Professor Jai Krishna served as President of the International Association of Earthquake Engineering (IAEE). Professor A. S. Arya chaired the IAEE group to develop the seismic guidelines for non-engineered constructions (IAEE 1986), and recently received the prestigious Sasakawa Award. The important research projects undertaken at Roorkee in the early years include: lateral resistance of masonry walls and enclosures, development of indigenous strong motion instruments, and studies on liquefaction. Research on base isolation of masonry buildings was conducted at DEQ as early as 1970's. Several innovative experimental set ups were developed at Roorkee to conduct research, including a two-dimensional shake



table. DEQ provided earthquake engineering consultancy for major dams and nuclear power plants; for instance, the Narora atomic power plant located on a site with deep alluvium (zone IV) and the rock-fill dam at Tehri in the Himalaya (zone V).

The first damaging earthquake to occur in India after the setting up of the earthquake school at Roorkee, helped create awareness about the earthquake problem and justified the investments in the institutional development.

## 5. Various Zone Factors And Its Existence

There are five seismic zones named as I to V as details given below:

Zone I: Here the maximum intensity is estimated as MM V or less. This zone is termed here as Very Low Damage Risk Zone.

Zone II: The probable intensity is MM VI. This zone is referred to as Low Damage Risk Zone.

Zone III: The associated intensity is MM VII. This is termed here as Moderate Damage Risk Zone.

Zone IV: Gives the area liable to MM VIII. This, zone is second in severity to zone V. This is referred here as High Damage Risk Zone.

Zone V: Covers the areas liable to seismic intensity IX and above on Modified Mercalli Intensity Scale. This is the most severe seismic zone and is referred here as Very High Damage Risk Zone.

### 5.1 Various Codes and Schemes came into act:-

The main seismic code (IS: 1893-1962) has been revised in 1967, 1970, 1975, and 1984; its next revision is now in progress. It provides seismic design criteria for buildings, bridges, liquid retaining tanks, stacks, gravity dams, earth dams, and retaining walls. Another code (IS: 4326) was published in 1967 (revised in 1976 and 1993): it outlines the aseismic design and construction requirements for buildings. In 1993, with publication of four new seismic codes (IS: 13827, IS: 13828, IS: 13920, and IS: 13935), India became perhaps the first country to have developed codes on low-strength non-engineered masonry constructions. The early seismic zone maps of the country (e.g., Kumar, 1933; West, 1937; Auden, 1942; Krishna, 1959) divided the country into three or four seismic zones which were described in qualitative terms (e.g., areas liable to severe damage, moderate damage, etc.). The first formal zone map (IS: 1893-1962) divided the country into seven seismic zones (0 to VI)

corresponding to areas liable to MM intensity of: less than V, V, VI, VII, VIII, IX, X and above, respectively. The zone map was revised somewhat in the 1966 version. After the 1967 Koyna earthquake, the zone map went through a major revision (IS: 1893-1970). It reduced the number of zones from seven to five (I to V). Next revision of the zone map has been taken up after the Later (1993) earthquake and the number of zones will now be further reduced to four (II to V). A major concern today remains the development of Indian seismic codes. Over the years, the dynamism to update our seismic codes seems to have been lost as seen by the frequency of the revision of the main code (IS: 1893). The code committee decided to revise the seismic zone map in 1976 (Krishnaswamy, 1977); however, this could not be done. Map revision initiated after the 1993 Killari earthquake is yet to be formalized. Sluggish development of codes has led to some aspects of Indian codes being very obsolete. For example, the seismic design force prescribed by the Indian code for bridges is too low by the international benchmarks, and these provisions are so obsolete that the design force on the bridge does not depend on its flexibility (e.g., Jain and Murty, 1998). This has resulted in the bridges of recently started Delhi Metro project being designed for a constant coefficient without consideration of the structure's natural period. Another concern is the lack of integration of seismic codes with other construction codes. For instance, the main concrete design code (IS:456-1978) does not give cross reference to the seismic detailing code (IS:13920-1993) now, and IS:4326-1976 earlier) and often the professional engineers are unaware of the additional detailing requirements for high seismic regions. Indian seismic codes are yet to incorporate some of the modern concepts such as the probabilistic features. There is no effort to develop code commentaries and the seismic codes are yet to be translated into the regional languages.

## 6. Increment In Institutional Level: Training & Education

The establishment of a separate Department at Roorkee proved instrumental in rapid early growth of earthquake engineering in India. The DEQ provides under one roof all disciplines associated with earthquake engineering and currently has about 25 faculty members. It was developed unlike other typical academic departments in the sense that providing consultancy and testing services was one of its major aims and this enabled the incorporation of earthquake engineering inputs into major projects. However, the presence of such a department also had



a somewhat negative fall-out as it was felt that the DEQ can provide whatever earthquake solutions the country needs, and no efforts were made towards further institutional development. For instance, the five prestigious Indian Institutes of Technology (IIT's) and concerned laboratories of the Council of Scientific and Industrial Research (CSIR) did not take up earthquake engineering in a significant manner until very recently. This meant that the number of highly-trained manpower got highly restricted. More importantly, the DEQ was in a peculiar situation of having to meet two often conflicting objectives: on one hand to promote earthquake engineering education and carry out research and development, and on the other hand, carry out enough industrial consultancy to meet bulk of its expenditures. This also blurred the difference between the Department Encouraging and supporting the professional engineers versus it competing with the professional firms. And finally, it did not challenge the Department to have a healthy competition from groups in other institutions. The institutional development with regard to the earth science groups working on earthquake problem has been somewhat better. A number of universities have fairly strong earth science groups, many of them carry out earthquake related research. Two major organizations, Geological Survey of India and Seismology Division of the India Meteorological Department, have had a long history of working on earthquakes. Besides, a number of research institutions in earth sciences were set up after independence which have considerable interest in earthquakes.

Undergraduate civil engineering education in India, as in other countries, does not expose the students to the issues of seismic risk. In the post-graduate programmes in structural engineering, some students may get exposed to dynamic analysis and a still fewer numbers to aseismic design (Murty et al., 1998). The total number of Master's graduate from DEQ, IIT's and other premier institutions with specialization in earthquake engineering will perhaps be less than 40 per year and many of them choose a non-civil engineering career. Thus, a huge engineering work force, having no formal exposure to seismic design in college, requires training through continuing education programmes. Short courses for professionals have been conducted at Roorkee for a long time now. Since 1992, IIT Kanpur has conducted numerous short courses on seismic design of reinforced concrete buildings, the most common type of multi-storey buildings in urban areas. For a large country like India, the number of agencies, organizations and competent individuals involved in earthquake engineering is totally

inadequate to fulfil its needs. The shortage of highly-trained personnel is particularly severe in certain specializations, e.g., engineering seismology, and geotechnical earthquake engineering. The situation needs to be overcome by training of young faculty members and researchers in appropriate international environment.

## **7. Important Factors To Be Look For:-**

A number of groups in the country have carried out post-earthquake reconnaissance studies of the recent damaging earthquakes. However, we are yet to develop a formal learning from earthquakes programme which will ensure that reconnaissance of all damaging earthquakes are carried out in a systematic manner and the findings disseminated expeditiously. The country is yet to formally take up activities in seismic micro zonation. There is not much activity in the area of earthquake prediction. Data sharing remains a major handicap; we have yet to develop mechanisms for open data sharing. There are not much inter-institutional or inter-disciplinary collaboration activities in the country. Except the DEQ, none of the institutions in the country have strong groups of engineers and earth scientists working together on earthquakes. The result is that both groups, engineers and scientists, often tend to have a rather narrow view of the earthquake problem. Similarly, architects, town planners, and social scientists have no involvement in earthquake issues. The Himalayan Seismicity programme of the Department of Science and Technology has enabled nurturing of a reasonable level of activity in the area of seismology. A similar programme on earthquake disaster mitigation needs to be operated by a major nodal agency in the country to nurture the research, development and extensional activities. A vibrant earthquake industry wherein earthquake-related services and products can be conveniently made available within the country on a commercial basis is yet to develop (Murty et al., 1999).

Even though some academics maintain good international linkages, the country has not yet developed any significant official collaborative programmes with other earthquake countries. In recent years, there have been no worthwhile collaborative workshops with researchers from outside the country. Even the four-yearly symposium at Roorkee, which used to attract a sizable number of participation from abroad, has ceased to do so. On the other hand, participation of Indians in the international conferences outside has been coming down due to weak Indian currency. The country which hosted the 6WCEE in 1977 at New Delhi was represented by just six persons in the 10WCEE and



by thirteen persons in the 11WCEE. Past two years we installed and operated a broadband seismic network in Nepal, and continuous GPS tracking sites in Bhutan and Pakistan, with GPS remeasurements in The Altyn Tagh, eastern Tibet and the Ladakh Himalaya.

## 8. Future Of Earthquake

Two important elements emerge which need urgent attention to improve the earthquake safety scenario in the country: the institutional development whereby the discipline of earthquake engineering is nurtured and developed at a much larger number of locations, and involvement of professional engineers and architects into the seismic agenda. Quality manpower in earthquake engineering is clearly in short supply and a major effort needs to be made to strengthen the same. With the above background, it may be pertinent to discuss some recent positive developments:

1. In recent years, earthquake engineering activities have spread to other institutions in the country and active earthquake engineering groups now exist at IIT Kanpur and Mumbai. Also, some of the CSIR laboratories are now engaged in earthquake engineering research and consultancy. In addition, Nuclear Power Corporation and other organizations dealing with nuclear power plants now have considerable capabilities in earthquake engineering as is the case with some of the top consulting firms. A few individual enthusiasts are now spearheading the efforts towards earthquake safety in their own region. For instance, a few engineers and architects in Darjeeling (zone IV) have been instrumental in incorporation of nominal aseismic provisions in the building bye-laws for that region. Another local group has been pushing the agenda of earthquake safety in Imphal (zone V) in north-east India.

2. The highly successful continuing education programmes conducted by IIT Kanpur at different locations in the country, at times with class size of about 100 persons, have created considerable interest amongst professional engineers, and clearly demonstrated that the professional engineers are willing to join the seismic safety agenda if given the right tools.

3. The Indian Concrete Journal, a very old and respected journal with wide-spread readership amongst the professional engineers, has brought out two exclusive issues related to earthquake engineering (ICJ 1994, 1998). The recently published Vulnerability Atlas of India (BMTPC, 1997) is expected to help contribute significantly in sensitizing the administrators and engineers to the earthquake problem.

4. Five damaging earthquakes in the last eleven years have made it easier to initiate discussions in the country on earthquake issues. The enormous tragedy of the Latur earthquake and the massive earthquake rehabilitation

## 9. Parameters To Be Considered During Load Action.

Dynamic Actions On Buildings – Wind Versus Earthquake

Dynamic actions are caused on buildings by both wind and earthquakes. But, design for wind forces and for earthquake effects are distinctly different. The intuitive philosophy of structural design uses force as the basis, which is consistent in wind design, wherein the building is subjected to a pressure on its exposed surface area; this is force-type loading. However, in earthquake design, the building is subjected to random motion of the ground at its base (Figure 1.1), which induces inertia forces in the building that in turn cause stresses; this is displacement-type loading. Another way of expressing this difference is through the load-deformation curve of the building – the demand on the building is force (i.e., vertical axis) in force-type loading imposed by wind pressure, and displacement (i.e., horizontal axis) in displacement-type loading imposed by earthquake shaking.

Wind force on the building has a non-zero mean component superposed with a relatively small oscillating component (Figure 1.2). Thus, under wind forces, the building may experience small fluctuations in the stress field, but reversal of stresses occurs only when the direction of wind reverses, which happens only over a large duration of time. On the other hand, the motion of the ground during the earthquake is cyclic about the neutral position of the structure. Thus, the stresses in the building due to seismic actions undergo many complete reversals and that too over the small duration of earthquake.

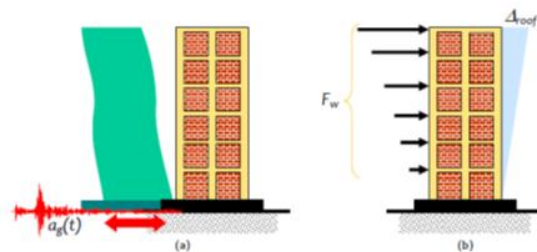
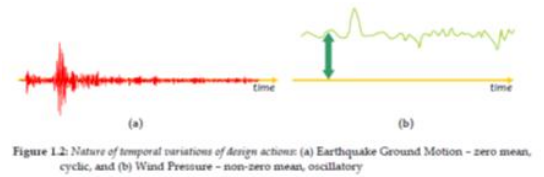


Figure 1.1: Difference in the design effects on a building during natural actions of (a) Earthquake Ground Movement at base, and (b) Wind Pressure on exposed area



13. IS: 13935-1993 (1993), Indian Standard Guidelines for Repair and Seismic Strengthening of Buildings, Bureau of Indian Standards, New Delhi.

14. IS: 1893-1962 (1962), Indian Standard Recommendations for Earthquake Resistant Design of Structures, Bureau of Indian Standards, New Delhi.

## 10. References

1. IS: 1893-1984 (1984), Indian Standard Criteria for Earthquake Resistant Design of Structures, Bureau of Indian Standards, New Delhi.
2. IS: 4326-1993 (1993), Indian Standard Code of Practice for Earthquake Resistant Design and Construction of Buildings, Bureau of Indian Standards, New Delhi.
3. IS:13920-1993 (1993), Indian Standard Code of Practice for Ductile Detailing of Reinforced Concrete Structures Subjected to Seismic Forces, Bureau of Indian Standards, New Delhi.
4. IS: 13935-1993 (1993), Indian Standard Guidelines for Repair and Seismic Strengthening of Buildings, Bureau of Indian Standards, New Delhi.
5. Murty, C.V.R., Rai, D.C., Sinha, R., and Jain, S.K. (1999), "Special Report on the Workshop on Developing Earthquake Engineering Industry in India: Opportunities and Challenges," The Indian Concrete J., 73, 8, pp481-487.
6. CAI (1965), Earthquake Resisting Buildings: Requirements and Design Procedure for Concrete Construction, the Concrete Association of India, Bombay.
7. EERI (1999) Innovative Earthquake Rehabilitation in India, Lessons Learned Over Time, Vol. 2, Earthquake Engineering Research Institute, and Oakland, CA.
8. IS: 456-1978 (1979), Indian Standard Code of Practice for Plain and Reinforced Concrete (Third Revision), Bureau of Indian Standards, New Delhi.
9. IS: 1893-1962 (1962), Indian Standard Recommendations for Earthquake Resistant Design of Structures, Bureau of Indian Standards, New Delhi.
10. IS: 1893-1984 (1984), Indian Standard Criteria for Earthquake Resistant Design of Structures, Bureau of Indian Standards, New Delhi.
11. IS: 4326-1993 (1993), Indian Standard Code of Practice for Earthquake Resistant Design and Construction of Buildings, Bureau of Indian Standards, New Delhi.
12. IS:13920-1993 (1993), Indian Standard Code of Practice for Ductile Detailing of Reinforced Concrete Structures Subjected to Seismic Forces, Bureau of Indian Standards, New Delhi.