e-conference(2)

Q. In your view, how safe are the high-rise constructions going-on these days in Kathmandu Valley considering Earthquake Scenario?

Comments

Why is Our Country Nepal Vulnerable in Earthquakes?

Nepal and its capital, the Kathmandu Valley, is vulnerable in earthquakes mainly due to following factors:

- **Geographical Location**
- **Geological Conditions**
- **Current Design Practices**
- **Current Design Deficiencies**
- **Poor Construction Practices**
- **Social & Legal Aspects**

Of which first two factors are beyond our control and the rest could be in our control.

Geographical Location

Nepal, situated at the Convergent plate boundaries; in between the convergence of Indian and Tibetan (Eurasian) tectonic Plates, where Indian Plate is subsiding into the Tibetan plate (Figs-1,2). Such boundaries are considered highly sensitive in terms of occurrence of earthquakes as per the theory of **Plate-tectonics**.

In terms of occurrence of earthquakes, Nepal lies at the **Alpide belt,** the second most seismically active region. Records have shown that earthquakes occur on mainly three zones on the earth :

Circum-Pacific belt *(Ring of Fire)*

Alpide belt

Mid Atlantic Range

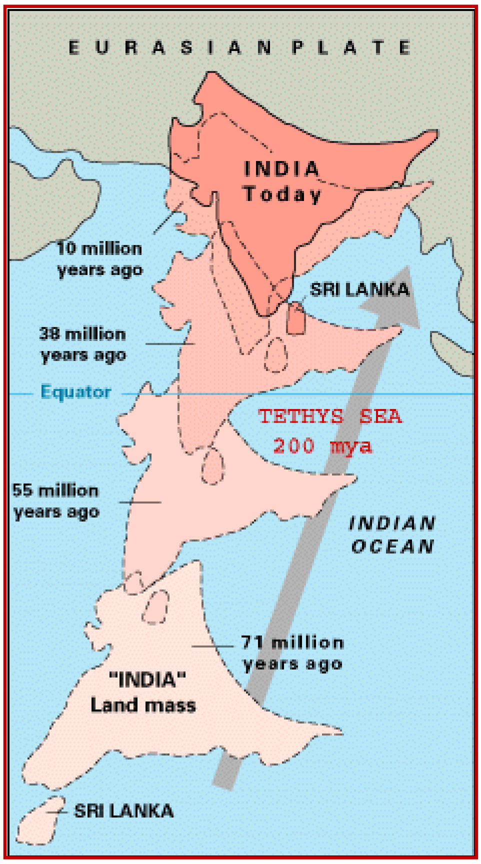
Circum-Pacific belt, also called the *Ring of Fire,* is the zone surrounding the Pacific Ocean which is the most seismically active zone in the earth. About 81% of the world's earthquakes occur there. The belt extends from Chile, northward along the South American coast through Central America, Mexico, the West Coast of the United States, and the southern part of Alaska, through the Aleutian Islands to Japan, the Philippine Islands, New Guinea, the island groups of the Southwest Pacific, and to New Zealand.

Alpide belt, the next most seismically active region responsible for 17% of earthquakes, extends from Mediterranean region, eastward through Turkey, Iran, and northern India.

Mid Atlantic Range, the third prominent belt follows the submerged **Mid Atlantic Range**. The remaining shocks are scattered in various areas of the world.

Theory of Plate-tectonics

The theory of plate tectonics states that the Earth's outermost layer is fragmented into a dozen or more large and small plates (Fig-3) that are moving relative to one another as they ride atop hotter, more mobile material at the earth's interior. The type of plate movements could be away from each other (Divergent Boundaries), towards each other (Convergent Boundaries) and Past each other (Transform Boundaries).

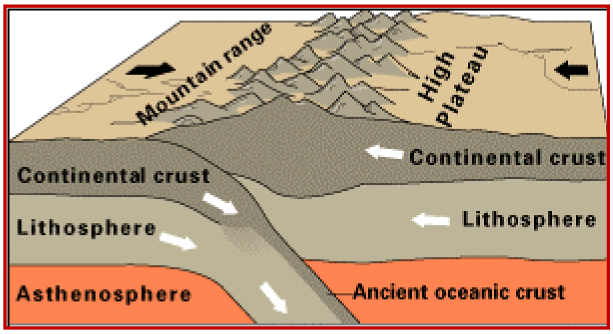


(Fig-1 : Gradual Northward movement of Indian Plate towards the Eurasian Plate showing its current position and its positions 71, 55, 38 & 10 million yrs. Back)

Eighty percent of earthquakes occur within these boundaries and rest 20 % within the plates. Major earthquakes greater than M 6.0 in Richter scale are likely in such zones; now & then.

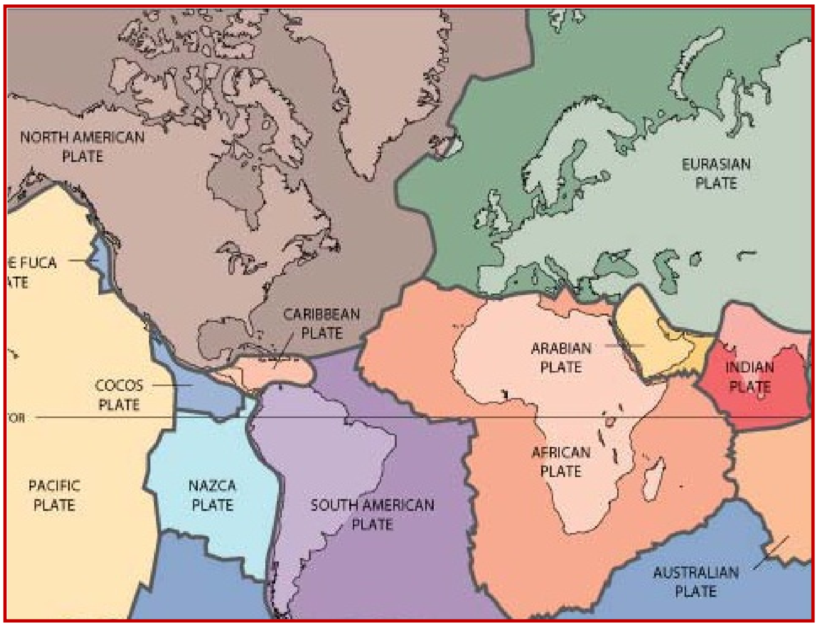
Nepal lies in the Convergent Boundary formed by the tectonic movement of Indian and Eurasian (Tibetan) plates (Figs-1 & 2). According to the precise measurements made by Universities of Alaska and Colorado since March 1991, the Indian plate moves 53-63 mm northward as Tibet moves 34-39 mm to the same direction each year which means that the Kingdom of Nepal is rowed by 19-24 mm every year.

The rise of Himalayan mountain range practically demonstrates one of the most visible and spectacular consequences of plate tectonics. When two continents meet head-on, neither is subducted because these continental rocks are relatively light and are almost of same rock density (Fig-2). In such, the colliding masses tend to deform as squeeze, buckle and thrust upward or sideways.



(Fig-2 : Convergence of Continental Plates. Nepal lies between the collision of Indian and Eurasian continental Plates with Indian Plate subsiding at the rate of 19-24 mm/yr into the Eurasian/Tibetan Plate)

The collision of Indian plate with the Eurasian Plate some 40 million years ago caused to fold up and override the Indian Plate (Fig-1 & 2). After the collision, the slow continuous convergence of these two plates over millions of years pushed up the Himalayas and the Tibetan Plateau to their present heights. Most of this growth occurred during the past 10 million years.



(Fig - 3 : Surfacial layer of the Earth divided into several Plates that moves relative to each other; showing Indian & Eurasian Plates at the right side)

The Himalayas, towering as high as 8,854 m above sea level form the highest continental mountains in the world and the Tibetan Plateau, at an average elevation of about 4,600 m. Himalayas stretch 2900 km in Nepal, along the border between Nepal and China.

Energy developed at the plate boundaries due to relative movement of the plates is relieved through the fractures in the rocky plates; also called fault planes, by means of shear dislocation. Mainly, fault planes lying around the tectonic plate boundaries release this energy. This release of energy is termed as Earthquake; when it reaches the ground surface.

Geographically, Nepal lies within the zone of this **Geo-Dynamism** (Fig-2) imposed by the Plate movements hence unstable; that may be manifested in the form of earthquakes anytime.

Geological Conditions

Earthquakes occur in various Magnitudes which actually is the measure of energy released. Not only the magnitude of earthquakes at source (hypocenter) but also the local soil condition at the particular place greatly determines the amplitude of ground shaking at that particular place. This phenomenon is also called the **Local Soil Effect**.

Earthquake waves travelling through Bed rock at earth's Crust could be magnified by factor more than 10 before reaching the earth's surface due to relatively softer soils that overlain the bed rock. Soft soil deposits over the bed rocks act as a water in a glass lying on a shaking table. Soft soil deposits over the Bed Rock amplify the earthquake motions as per their properties & frequency of earthquake waves. So the same earthquake could have entirely different effect at different sites depending upon the distance of sites from the epicenter and local soil conditions at those sites. The response of earthquake is thereby the **Site Specific**.

Kathmandu valley once supposed to be lake has mostly Lacustrine Soil deposits that will amplify the earthquake induced wave motions due to its soft, unconsolidated nature. Also, Lacustrine Soil deposits are prone to global failure of ground by **Liquefaction** that occurs during intense ground shaking. Valley has maximum of 500-550m thick unconsolidated sediment deposit at its central part. Microtremor study has shown the tremendous potential of **amplification up-to the factor of 15** within the Kathmandu Valley.

Liquefaction occurs in saturated uniformly graded fine grained soil deposits those are loosely deposited as incase of alluvial, colluvial, Aeolian and Lacustrine deposits. Sensitive Clayey soils are also vulnerable to phenomenon similar to liquefaction. Liquefaction causes the severe loss in shear strength of soil followed by subsidence of ground that supports the structure.

Soil Strata's in most of the localities of Kathmandu valley possess SPT values of 3-10 at shallow depths. Greater depths also don't have good SPT values at most places. Even if there is no possibility of liquefaction, presence of soft soils in most of the areas of valley are weak to support heavy structures. Also, amplification effect would be quite severe as happened in 1934 Nepal- Bihar Earthquake. Site Specific Geotechnical Investigations are seldom carried out that provide us the soil profile over the bed rock along with its Geo-technical properties.

Current Design Practices

Kathmandu Valley is in highly vulnerable situation not only due to its geographical location across the globe and its geological conditions but also due to weaker structures built on it in our part. Design and construction practices have not evolved as per the technological advancement and the building design codes adopted are also obsolete.

Besides the above-mentioned geological & geographical disadvantages in our part, we could still be safe by applying the modern advancements in Engineering. Structural Engineering has developed so far that it has now made possible to build high-rise with a tremendous height of 1 Km.

It should first be realized that safety of structures couldn't be maintained if it was poorly designed, structurally. Here Poor design means the basic principle, approach adopted during analysis & design phase by the Structural Engineers.

Codal based Static analytical approaches also known as **Seismic Coefficient Method** are still widely used to evaluate Structures response under the earthquake loading. Following presents the step by step drawbacks on Codal Based Seismic Design Approaches:

Codal Based Seismic Design Approaches

Conventional Codal based Static approach: **Seismic Coefficient Method,** is still widely used. Earthquake forces and its distribution on the structure are calculated using simplified approach that neglects the distribution of mass and stiffness distribution in a structure.

Seismic codes were developed assuming a certain coefficient, **Seismic Coefficient**, assigned against the mass of structure. These methods were based on several simplified assumptions all the way back from 1920's when there was little or no understanding on earthquake engineering, building dynamics, local soil effects & soil structure interaction. Since then, it had been upgraded time to time but its underlying principle remained unchanged.

Following factors, which constitutes the important part of these Seismic Codes, are discussed here.

- **Strength Reduction Factor (R)**
- **Structural Configuration**
- **Local Soil Effect & Soil Structure Interaction**
- **Drift Limitations**

Strength Reduction Factor (R)

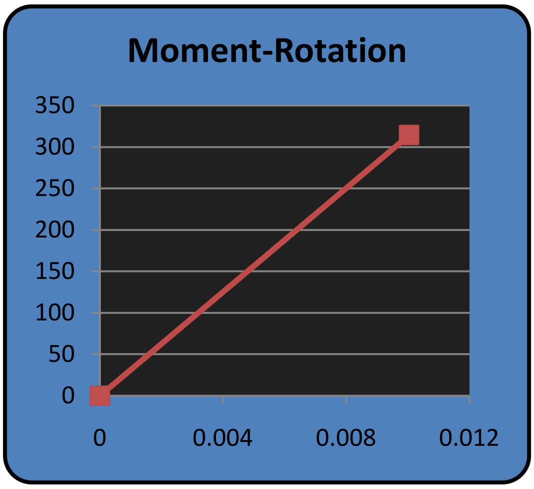
Major assumption of seismic codes is that in major earthquakes, building structures will invariably undergo large inelastic rotations at several locations leading to the formation of failure mechanism. *Collapse Prevention* is its safety level. Ductility, required for such inelastic action is assumed to be inherently present merely by following of Special Ductile Detailing Codes. In such, current seismic codes rely mostly on structural ductility.

Prevention of collapse of building structures is its performance level. Provision of large value of **Load Reduction Factor (R**) applied on the **Maximum Credible Earthquake (MCE)** and Ductile detailing practice have been made to ensure the inelastic behavior thereby the formation of failure mechanism. **IS 1893 : 2002** applies this factor **R** as high as 5, provided that the building structure is detailed and designed as Special Moment Resisting Frame (SMRF).

The assumed inelastic performance of structures could be achieved only if they are **Ductile** (Fig-4, B) enough; so that in can deform within inelastic zone without losing its capacity. Inelastic behavior can be relied upon only if they possess sufficient **Ductility** as per the Strength Reduction Factor **R** envisioned in the seismic codes. Local and global Ductility factors required corresponding to the Strength Reduction Factor **R** shall be evaluated to ensure this and the formation of mechanism too.

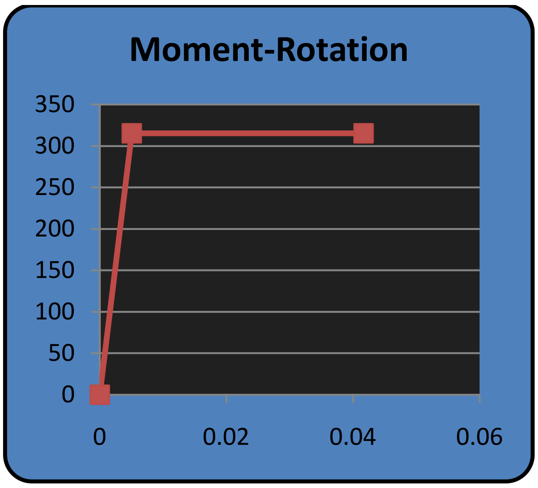
Reinforced Concrete **(RC)** Sections have inherently very limited amount of Ductility. Special Ductile detailing provisions as given in codes doesn't ensure the **initiation of Inelastic Behavior**. What it does for RC sections is enhancement in ductile performance after entering into the inelastic range. Several other factors are responsible for the initiation of ductile behavior. If a section doesn't enter into the inelastic range then ductile detailing becomes worthless in attainment of inelastic behavior.

Overall Structural Ductility and Ductility at its corresponding sections are necessary to confirm the Inelastic Behavior; which could be achieved by advanced analytical methods and Ductile Design approach. Current codes apply the Load Reduction Factor (R) but say nothing on the amount of Ductility required as per this factor. It can be considered as its major drawback.



(A) Ductility Factor, μ_{rot} = 1

(Elastic Design, Conventional Approach)



(B) Ductility Factor, μ_{rot} = 8.25

(Inelastic Design, Modern Approach)

(Fig-4 : Moment-Rotation Curves for RC beams of size 600 x 300 mm each. Both have equal Moment Capacity of 315 Kn-m. Beam (A) was designed for its elastic range only; whereas Beam (B) was designed to perform in inelastic range using Ductile design approach. Beam (B) has Ductility factor of 8.25 corresponding to the Load Reduction Factor, R. But Beam (A) has no ductility at all. Despite of being same capacity, Beam (A) will fail instantly after failure Moment of 315 Kn-m is reached. But Beam (B) would survive and continue to function even after failure load of 315 Kn-m is reached due to its inelastic action provided by ductility. Inelastic region has been depicted by the horizontal portion of curve in Beam (B))

Also, formation of reliable failure mechanism of plastic hinges as envisioned in seismic codes is quite dubious not only due to lack of ductile design approach but also due to modeling defects. Usually effects of infill masonry walls are allowed to be neglected and only bare frame analysis could be carried out while using codal based modeling approach. Brick Masonry Infill walls are highly stiff under in-plane loading that will certainly have significant role in load sharing. Due to the presence of infilled brick masonry walls, development of plastic hinges and failure mechanism may not take place.

Structural design based on Seismic Codes are supposed to build the building structures, in which damage & drift caused could be excessive; may be beyond repairment in case of major earthquakes; but with avoidance of total collapse so that loss of lives is prevented. This too could only be achieved, if Structural Ductility could be maintained (Fig-4,B); which is very difficult to maintain in RC structures (Fig-5) with the current ductile detailing guidelines given in such codes. The reasons for this fact have been mentioned above.

Critical structures as Hospitals, Telecommunication buildings, Government offices & other Community building structures should be designed so that it basically remains elastic; which could be reoccupied immediately. Immediate Occupancy should be its performance level. Only minor damages are allowed. Such structures couldn't offer damages as they need to remain operational even after major earthquake.

(Fig-5 : A Shear Wall-Framed Structured Building analyzed using modern techniques and designed to maintain Ductility)

A special modern analysis & design technique as Performance Based Design is necessary to ensure all these. Codal provisions & current design practice is way back in this regard.

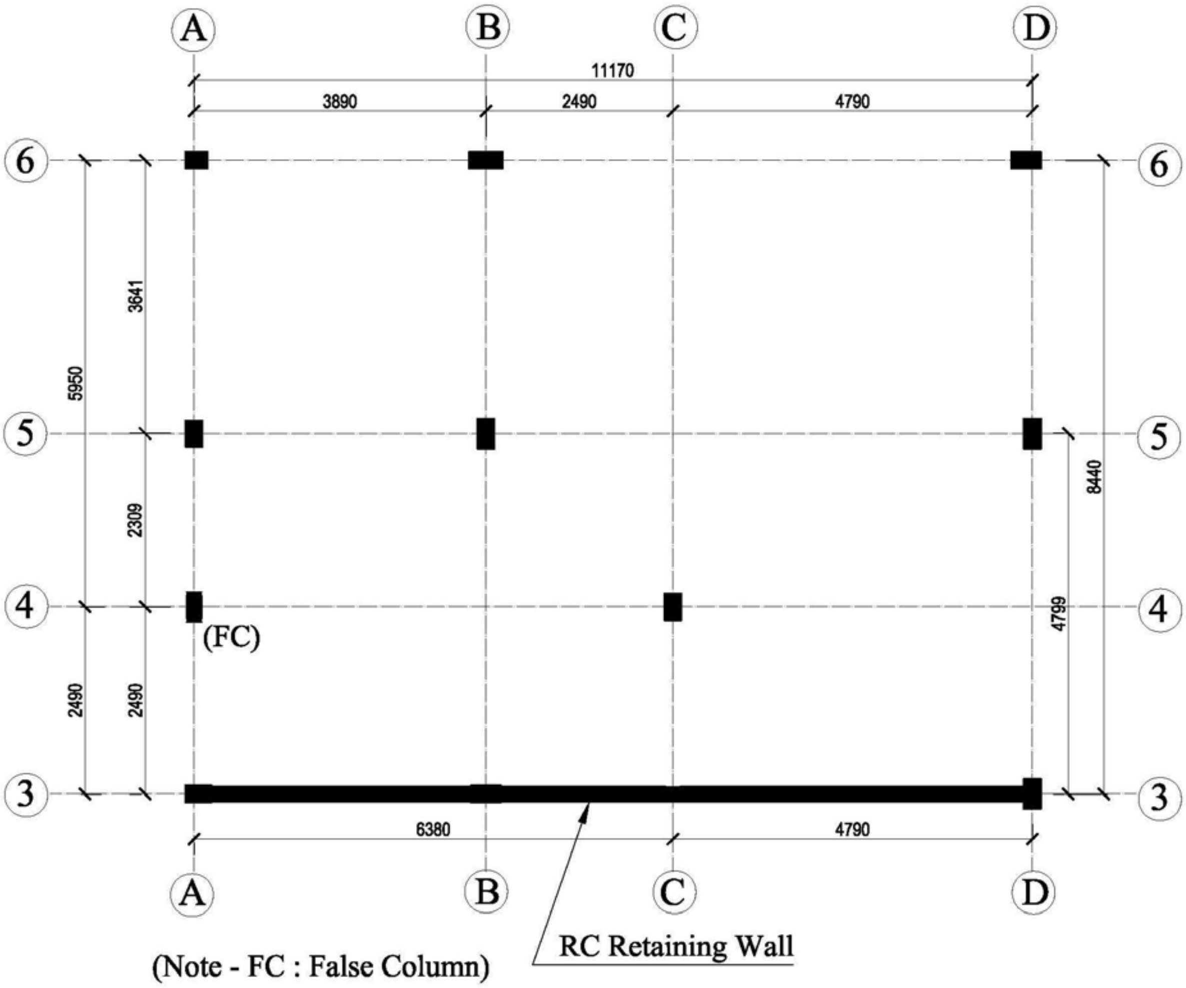
Structural Configuration

Seismic codes have proposed that in case of Regular Buildings situated in highly seismically active zone as ours, Dynamic Analysis shall be carried if height exceeds 40 m (10-13 storeyed). In case of Irregular Buildings, Dynamic Analysis shall be performed that exceeds the height of 12 m (3-4 storeyed). In order words, regular buildings of height less than 40 m and irregular buildings of height less than 12 m could be analyzed using simplified Seismic Coefficient Method.

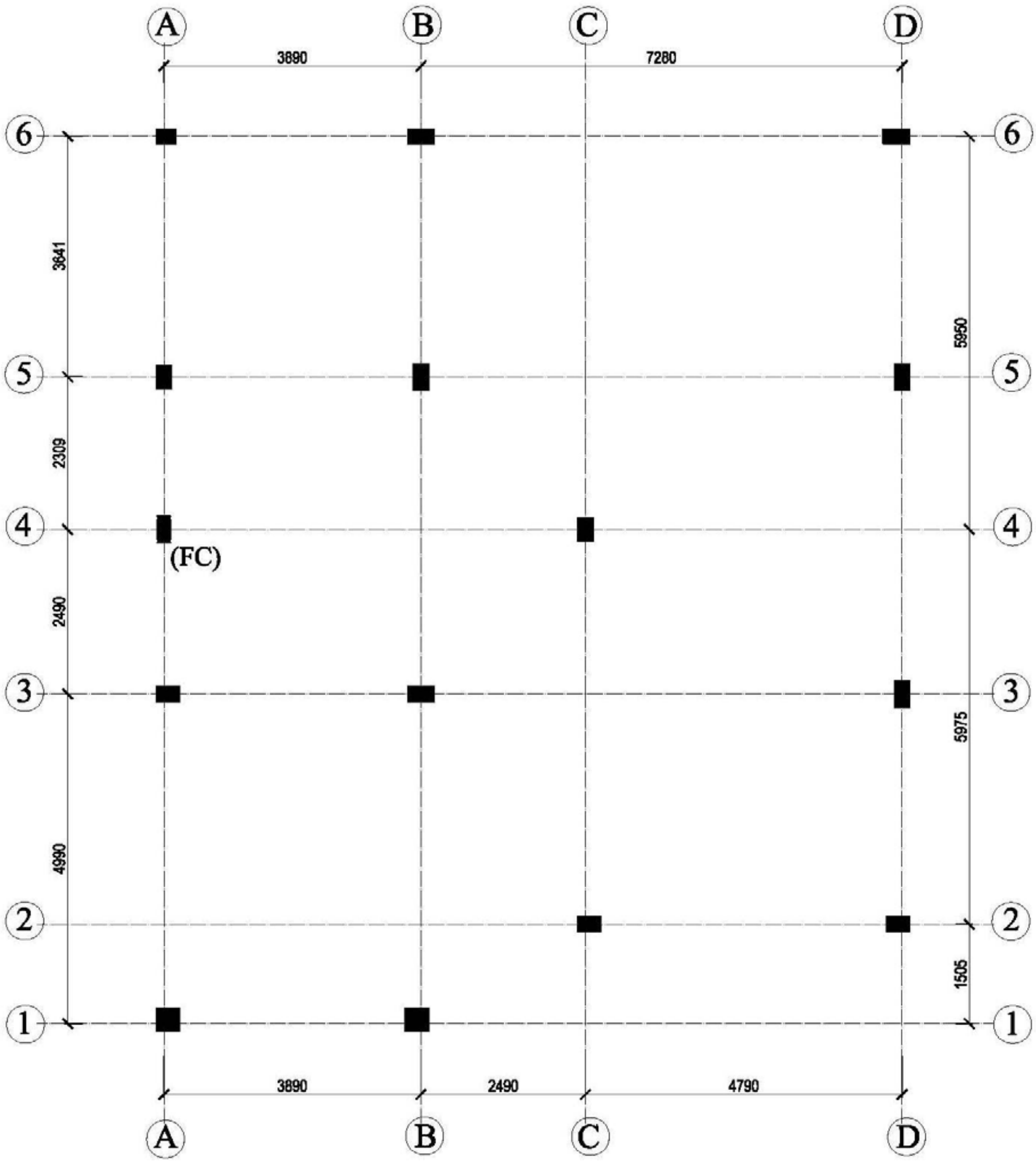
Seismic Coefficient Method has been developed considering building's first mode of vibration only. Higher modes are neglected. For buildings with low-height, symmetric configuration in every aspect, this approach holds good. Building structures may activate several modes of vibration depending upon irregularity in configuration; that affect the distribution of earthquake generated stresses within the structural elements.

The categorization of regular or irregular buildings is quite vague. Buildings are seldom regular. Irregularity exists in one or another way; only the degree of irregularity would be different. With modern architectural designs by architects even residential buildings of height less than 12 m could have highly irregular configuration demanding Dynamic Analysis. Following presents the example of such building (Fig-6). Use of Seismic Coefficient Method will be ineffective to catch the proper stress distribution imposed by earthquake loadings on various structural elements in such case.

It is really difficult to categorize : Up to what extent of irregularities such codes could be used ??? First need of evaluation of irregularities in plans and elevations and only then selection of proper method of analysis & design is to be carried if Seismic Codes are to be followed!!!



(BASEMENT FLOOR PLAN)



(GROUND FLOOR PLAN)

(Fig-6 : Basement & Ground Floor Plans of the $3\frac{1}{2}$ Storeyed Residential Building with total height less than 12 m. Highly irregular configuration can be seen in floor plans; in terms of distribution of mass and stiffness. Dynamic Analysis becomes inevitable in such cases to catch the proper stress distribution amongst the structural elements as against the Seismic Coefficient Method prescribed by Seismic Codes)

Rather it would be safer, easier and less time consuming to go for Dynamic analysis by skipping the above step!! Because every Structure is irregular to some extent in one or another way.

Local Soil Effect & Soil Structure Interaction

Local Soil Effect

Local soil conditions have pronounced effect on modifying the amplitude of earthquake waves. Type of soil deposits, its thickness above the bed rock along with the frequency content of seismic waves combinely determines the extent of damage on the structures founded at earth's surface.

Soft soil deposits tend to amplify the seismic waves depending upon its natural frequency & frequency content of input seismic waves. In fact, soft soil deposits over the bed rock acts as a glass of water over the shaking table.

Current seismic codes present spectral acceleration coefficients for three soil types to account for local soil conditions: Soft, Medium & Hard (Fig-7). Three separate curves have been presented taking into these three soil types. Such codes consider variation in amplification factor in maximum of 2.5 between the hard & soft soil types!

The soil amplification factor of about 2.5 is very narrow range considering wide variability in local soil conditions. In modern Geotechnical Technical Investigations, Soil Amplification factor is determined by means of detail soil exploration, various tests and analytical methods. Due to wide variability in soil conditions in engineering geology, it has been found that soft soils could amplify earthquake waves by several times when they reach at ground surface or at the base of structures.

In such, it is always mandatory to conduct Site Specific Response Analysis for every important project. Codal provisions seem to be highly unsafe in this regard.

Soil Structure Interaction

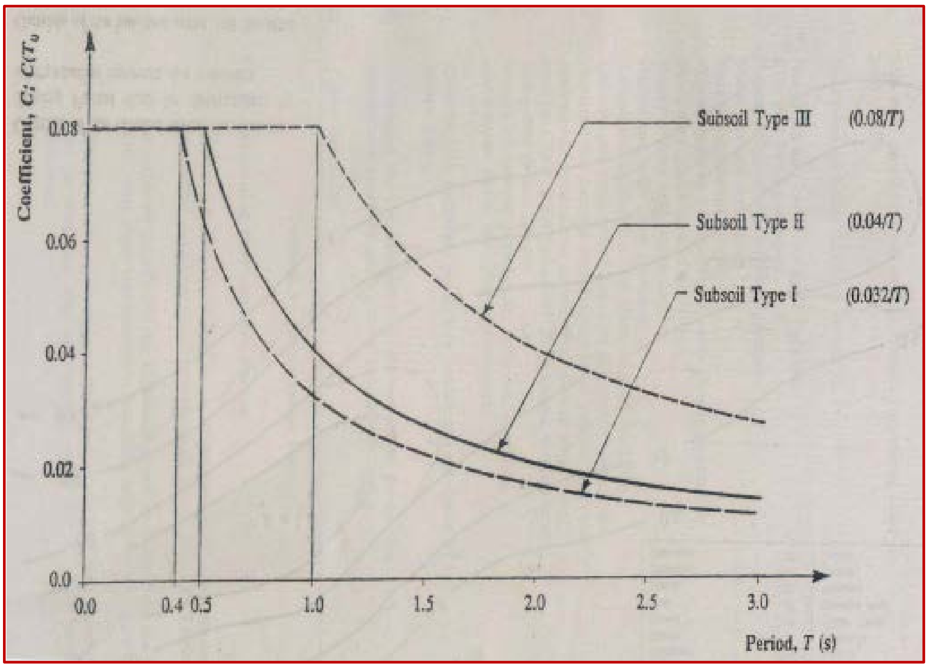
Soil Structure Interaction is in fact a boundary-condition problem between a structure and its base on which it is founded. The interplay between structure and flexible soil support at its base and its influence on the response of the superstructure and soil components are studied under **Soil Structure Interaction (SSI)**.

The current seismic codal provisions neglect this **SSI** effect and consider the base of building structures as a fixed one. Flexibility of soil is not taken into account. Response spectra curves presented in such codes (Fig-7) have been prepared considering fixed based SDOF model. It tacitly assumes that increase in fundamental Time Period of building structures due to SSI effect including the increase in Damping characteristics of soil would be beneficial always.

Response spectra presented in seismic codes have maximum value of spectral acceleration, represented by the flat portion of response spectrum curve extending up-to 1 sec. Beyond 1 sec, the response spectrum curve descends rapidly with increase in time period.

But the records of various devastating earthquakes tell us something different about the SSI effect.

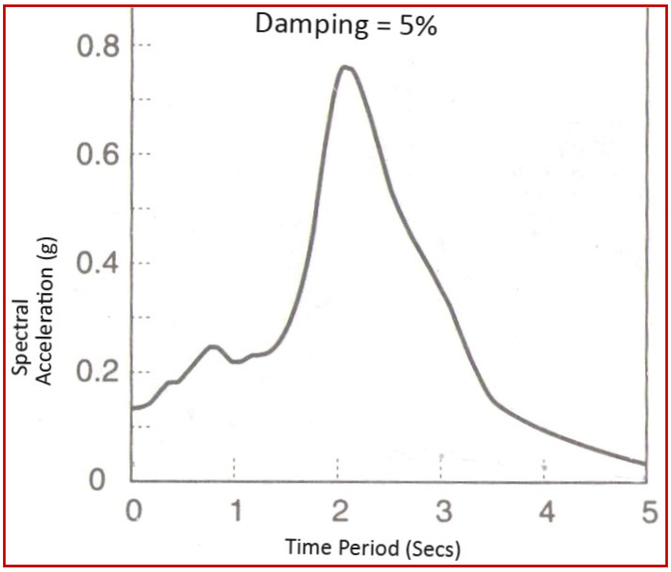
Great earthquakes as Kobe earthquake 1995, Mexico Earthquake 1985 and others showed some different behavior deviating from the above spectra.



(Fig-7 : Response Spectra Curves for three soil types as presented in NBC 105 : 1994 code for 5% Damping)

In those earthquakes, well defined peaks of spectral acceleration were attained at periods exceeding 1 sec (Fig-8). This phenomenon is strikingly different than that presented in NBC (Fig-7) and other seismic codes above in which spectral acceleration decreases after 1 sec.

Structures founded on deep soft soil deposit tend to follow different spectra than that presented in Fig-7. 1985 Mexico earthquake within the Lake zone was the spectacular example of this. It was underlain by 38-50 m soft soil deposit whose fundamental time period was 2 secs. In that earthquake mostly 10-12 storeyed Buildings were damaged; whose fundamental time period as fixed based ones would be 1 sec.



(Fig-8: Response Spectra Curve for 1985 Mexico Earthquake at the Lake Zone. Peak response was recorded at a Time period of 2 secs.)

Due to SSI effect their time periods were increased to 2 secs; that happened to be the time period of soil deposit too. In such resonance of the building structures occurred and devastation followed.

Kathmandu valley underlain by soft soil deposit of considerable thickness at most of its parts is much similar to the example cited above. Design based on above codal provisions thereby neglecting the SSI effect could be highly detrimental.

Drift Limitations

Both **IS 1893 (Part 1) : 2002** and **NBC 105 : 1994** have almost similar criterion regarding the inter-storey drift limitation in buildings. Inter-storey Drift ratio at the particular storey level shall not exceed 1%.

Nevertheless, the **Collapse Prevention** is safety level of such seismic codes with large load reduction factors and provision of ductile detailing at critical components. Severe yielding at critical components thereby the formation of failure mechanism had been envisioned in such codes. Only overall, global collapse of structures is prevented as per this Safety Level. Human casualties are also expected. Such buildings suffer irreparable damage in major earthquakes hence are to be demolished.

As per the international norms, Drift Limit of 1% is for **Immediate Occupancy** safety level in which buildings remain almost elastic. Minor or no damage is expected in structural elements of the buildings designed for this performance level. Such buildings can be immediately reoccupied safely.

In such, a Drift limitation as presented in current IS & NBC seismic codes are in sheer contradiction with international guidelines.

Current Design Deficiencies

- **Variation in Floor Plans in a Building**
- **Variation in Column's Height in Same Floor**
- **Variation in Building's Heights in a Row**
- **Improper Foundations**

Variation in Floor Plans in a Building

Open basement or ground floors mainly for the purpose of parking (Fig-9) is the common feature found in almost all high-rise constructions as Apartments, Shopping complexes & others. Departmental stores also have open hall like spaces at lower floors.

Also, not only in ground floors or basement floors, such open, hall type floors could be seen in other floors too. Office buildings & Hotels could have such large open area at upper floors with other storeys partitioned with brick masonry walls for different functional purposes. In such, two adjacent storeys could have significant variation in storey stiffness.

(FIG-9 : A Commercial Complex with Open Basement floor for the parking purpose. Almost all the Commercial Complexes have this feature in common)

Such structural configuration is dangerous in the sense that it could trigger Soft-Storey Mechanism failure. Stress concentration takes place at these floor levels. This is widely observed configuration that demands advanced analysis if the variation in adjacent storeys stiffness is more than 20 %.

Variation in Column's Height in Same Floor

Variation in columns height even in the same storey is also observed. Such variation in column's height may lead to stress concentration in short-heighted columns (Fig-10). Usually, this type of configuration is observed in buildings built on different ground levels. Kathmandu valley has such topography at many places.

Short Columns could also be encountered around the staircases, in the buildings with floors at the intermediate levels and in the columns attached to infill walls with partial height. Though columns height is equal in the latter case, effective height of columns is reduced due to restraining action of stiff infill walls.

In a building, as earthquake strikes, short columns will be the first ones to suffer damage if it wasn't analyzed and designed to capture this effect. Special analysis & design considerations in such columns are needed to prevent its brittle shear failure.

Also long, slender columns are encountered usually due to variation in storey heights. Columns would be slender if its unsupported height to shortest cross-sectional dimension, width, exceeds 12.

(FIG-10 : A newly built Commercial Complex with variation in Column heights within a Storey for double level Parking. Long, Slender Column is seen to be retrofitted with Steel Channels)

Such columns could be vulnerable even in gravity loadings; let alone the earthquake. Special analysis & design considerations in such columns as in the case of short columns are needed to prevent its stability failure.

Variation in Building's Heights in a Row

In core city areas, buildings are rowed together, attached to each other. With the development, old buildings are being demolished to build new one with higher storeys. New buildings are being built with heights far greater than the attached old ones (Fig-11). In such, different dynamic performances are expected in between these tall & short buildings.

(FIG-11 : Newly built Nine Storeyed RC Building attached to Old Five Storeyed building. These Buildings may pound against each other due to difference in their vibrational characteristics; causing damage to the weaker one)

Due to difference in modes of vibration of tall & short buildings, there is a higher probability of collision of buildings against each other in earthquakes. In such damages could be more severe than if it were unattached and free for vibration.

It is normally thought that it is always beneficial for a structure to be attached. It could be true if the buildings were of similar heights. Tall & Short buildings attached to each other (Figs - 12) may prove to be quite disastrous than unattached ones.

(FIG-12 : Collapse of adjacent building due to pounding effect in 1985 Mexico Earthquake)

Gap between these two structures shall be maintained if their modes of vibration are out of phase. Detail Dynamic analysis shall be carried out for this. Current Codal based analysis may not help in such cases.

Improper Foundations

Design of Foundation part of structures in our scenario attracts least attention may be because it is an undergrounded part!

It is widespread perception amongst the clients and most of the technicians that if Raft Foundations are provided in buildings then it would be almost safe in earthquakes. It is considered as one of the prerequisite elements of ERD here.

It's true that Raft Foundations are superior to Isolated Footings as it prevents differential settlements in soft soils. It would be difficult to control the differential settlement in Isolated Footings.

As already mentioned above, soil conditions over here are susceptible to liquefaction. In such, provision of surfacial shallow foundations may not help. Soil exploration is to be carried out for all high-rises and deep foundation as piles shall be provided. Deep foundation protects the buildings from such soil failures and also improves the dynamic response of buildings.

Provision of Raft Foundations doesn't protect building structures from overturning type of failure in slender buildings.

(FIG-13 : Four Storeyed RC Building overturned due to foundation failure in 2001 Bhuj Earthquake, India. Lifting of Raft Slab is seen in the Pic.)

A slender building as shown in Fig-14 with height around 90’-0” and minimum base width of 15’-0” which gives H/B ratio of 6.0. Even with a raft foundation it may fail by overturning in earthquakes.

Block failure or Overturning failure could be the probable case of failure as shown in Fig-13 from 2001 Bhuj Earthquake, India even for medium-rise buildings where foundation soil liquefied.

Deep foundations are rarely found in practice in Kathmandu Valley.

(FIG-14 : Slender Eight &Half Storeyed RC Building with overall height of around 90’-0” and front width of 15’-0” only; H/B ratio is 6 for this building)

Poor Construction Practices

Any structure will behave in the way they are constructed and not in the way that had been supposed to perform during structural analysis & design phase. Performance of the built structure will definitely vary from that of the modeled one.

Following presents some of the prevailing poor construction practices in Kathmandu; either engineered or non-engineered ones.

(FIG-15 : A Seven Storeyed Building Under-Construction with 9" x 9" Column size and Meager Steel Rebars. The perfect example of non-engineered building. Normally such buildings are constructed without any technical consult & supervision. Construction took place on technical knowhow of Local Contractor only)

(FIG-16 : Severe Joggling of Column longitudinal Rebars to maintain column position in place; that was out of place due to faulty construction. Such severe bending of Rebars could be equivalent to cutting them at this level. Structurally designed building but weak Technical Supervision. Such Joggling of main Rebars in Beams, Columns are common practice even amongst Civil Engineers here)

(FIG-17 : An Eight Storeyed Building including basement with 4" width brick walls along its boundary. The Brick Wall Panels were placed outside the Column Grids; directly on the Slabs, making it highly vulnerable in off-plane failure. Structurally designed & approved by the concerned Government Authority. But still lacks earthquake safety features as seen from the visual inspection)

(FIG-18 : Column above Plinth Level misplaced by the offset of almost 3" outside; Column may fail prematurely at such places. Weak Technical Supervision; Similar problem as shown in FIG-16 above)

(FIG-19 : Inferior Concreting Works with Honey Combings and Holes; Design Capacity & desired Durability couldn't be achieved rendering weaker structures. Poor Quality Control)

Social & Legal Aspects

General Public, Investors seem not to be so aware of weak designs and poor construction practices going even in their own projects. If one take a trip of Kathmandu city, such RC buildings with weaker structures could be seen here and there.

Concerned government authorities have made it mandatory to submit the Structural Design Drawings of high-rises for construction approval. But it is NOT mandatory to be designed by Structural Engineers. In such, public seem to be perplexed to hire the Structural Engineers where Civil Engineers are practicing such designs using simplistic codal approach neglecting the Local soil effect, Building Dynamics, Structural Ductility and many more factors that are essentials elements for structural safety. Design prepared using such simplistic approach will be *highly inaccurate* hence unsafe incase of earthquakes.

Structural Engineers as per their expertise demand higher design charge than Civil Engineers keeping in the view of extent of detail analysis and design that is to be carried out.

Technicians who use simplistic design methods demand lower design charge that seems to be beneficial for Clients initially. But such design methods could lead their buildings unsafe and uneconomic too. Meager savings in design cost may be overweighed by the enhanced project cost due to uneconomical design. **NOT TO FORGET : Loss of human lives surely would be irreparable loss in earthquakes caused by unsafe design practices as being practiced by so called technicians in most of the cases.**

Modern analysis techniques that capture the near-true behavior of structures are now available but use of these methods is very limited; only amongst handful of Structural Engineers.

Such sophisticated and modern techniques demand high degree of expertise and considerable time and bit higher design charge. But it could be indispensable depending on the importance and complexity of the structure. For instance, even 2-3 storeyed residential building demands modern analysis techniques if it is vulnerable to *Soft-Storey Mechanism* or any other kind of structural complexities. *Also important building structures as Hospitals, Banks, Government Offices and other Public Buildings shall remain functional immediately after an earthquake. Such structures can't afford damage.*

Advancement in Earthquake Engineering, Structural Dynamics, Seismic Control devices and Real time analysis techniques and development in Material technology made it possible now to build building structures that simply resists Earthquakes with higher level of safety than ever before. Such well designed building simply vibrates smoothly in earthquakes and sustains it without damage and retains normal life for its occupants within.

Stringent legal provision by the government is essential to prevent the loss of thousands of lives. At least it should be made mandatory that all the critical structures should be designed by the competent Structural Engineers only. Simultaneously public awareness shall be raised in this matter.

WE must not forget that recent Chilean Earthquake of magnitude Mw 8.8 claimed about 800 human lives whereas Haitian earthquake Mw 7.0 claimed more than 200, 000 human lives. Of course this huge difference in casualties was due to the non-engineered buildings in Haiti which could have been saved by the use of proper technology.

It is quite easier just to erect building structures that have to carry its self weight in vertical direction. Real challenge lies in lateral shaking of such structures during earthquakes. Higher risks are looming large in earthquakes when the ground shakes in a random fashion inducing far higher dynamic stresses. Real performance of the so-called seismically designed high-rise will be tested then by the Mother Nature; to whom no one can cheat.

BREINS Structural Care

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