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SEISMIC DESIGN OF REINFORCED CONCRETE STRUCTURE

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ABSTRACT*:*
Seismology is the study of the generation, progression and recording of elastic waves in the earth, and the source that produce them. An earthquake is a sudden tremor or movement of the earth's crust, which originates naturally at or below the surface. The world nature is important here, since it excludes shock waves caused by man-made explosions, nuclear test, etc. about 90% of all earthquake results from tectonic events, primarily movements on the faults the remaining is related to volcanism, collapse of subterranean cavities or man-made effects. Tectonic earthquake are triggered when the accumulated strain exceeds the shearing strength of rocks. Elastic rebound theory gives the physics behind earthquake genesis.

To promote the implementation of existing knowledge in the seismic design of engineering structures and to contribute to more effective disaster migration, primarily design practitioners are addressed to this end, simplicity in the application of a rational deterministic design philosophy which has are successfully. After the review of basic aims, a detailed description of the design strategy relevant to ductile multi storey frames, building with structural wall and dual structural system is presented.

KEYWORDS:-*Seismic design, Captive columns, Performance-Based Seismic Design.*

I. INTRODUCTION:

Amongst the natural disasters, earthquakes have the potential for causing the greatest damages. Since earthquake forces are random in nature & unpredictable, the engineering tools needs to be sharpened for analyzing structures under the action of these forces. The traditional prescriptive design approach based on linear elastic techniques has been developed for many years. One major drawback of this design approach is that it does not directly address structural inelastic seismic responses and thus cannot effectively deal with damage loss due to structural and nonstructural failure during earthquakes. As a result, the long-term risk and benefit implications cannot be assessed using a traditional design approach. The Structural Engineers Association of California (SEAOC) first recognized the need for the development of a new performance-based methodology for seismic design and construction of buildings after the Northridge Earthquake in 1994. Since then, the advent of the performance-based design approach has appeared to be the future direction of seismic design codes. The international earthquake engineering community has mobilized in an effort to develop methods of performance-based earthquake engineering. As defined by the Structural Engineers Association of California (SEAOC), in their Vision 2000 report (SEAOC, 1988, P.l-C), the intent of performance-based earthquake engineering is to provide methods for sitting, designing, constructing and maintaining buildings, such that they are capable of providing predictable performance when affected by earthquakes. As used here, performance is measured in terms of the amount of damage sustained by a building, when affected by earthquake ground motion, and the impacts of this damage on post-earthquake disposition of the building. The concept is not limited to buildings alone, but is generally applicable to all structures and their supported non-structural components and contents.

What is SEISMIC?

SEISMIC is a term related to earthquakes or other vibrations of the earth and its crust. **Seismic waves** are the waves of energy caused by the sudden breaking of rock within the earth or an explosion. They are the energy that travels through the earth and recorded on seismographs. There are several types of seismic waves, and they all move in different ways.

SEISMIC DESIGN:

Seismic design is a subset of structural analysis and is the calculation of the response of a building (or non-building) structure to earthquakes. It is part of the process of structural design, earthquake engineering or structural assessment and retrofit in region where earthquakes are prevalent.

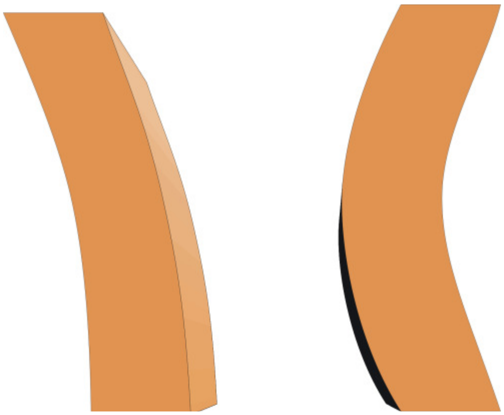


Fig 1: Seismic behaviour on Earthquake

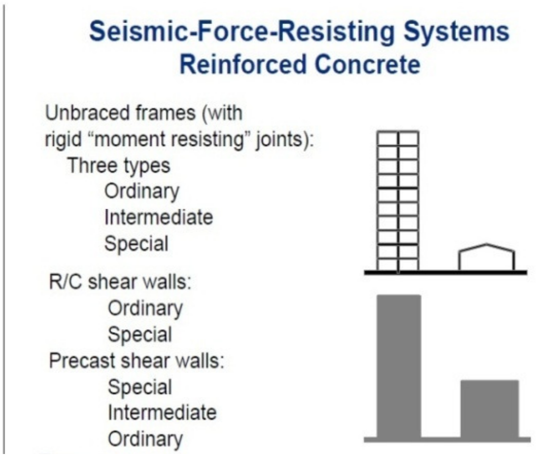
As seen in the figure, a building has the potential to 'wave' back and forth during an earthquake (or even sever in storm) this is called the 'fundamental mode', and is the lowest frequency of building response. Most buildings however, have higher modes of response, which are uniquely activated during earthquakes. The figure just shows the second mode, but there are higher 'shimmy' (abnormal vibration) modes. Nevertheless, the first and second modes tend to cause the most damage in most cases.

DESIGN OF RCC STRUCTURE:-

i. STRUCTURAL MODELLING:-

Earthquake response analysis is an art to simulate the behaviour of a structure subjected to an earthquake ground motion based on dynamics and a mathematical model of the structure. The correct analysis will depend upon the proper modelling of behaviour of connections, materials, elements and structure. Models may be classified mainly by essential difference in the degree-of-freedom. The model or the or the degree of freedom should be selected carefully considering the objective of the analysis, sometimes sophistication or complicated models are not only useless but also create misunderstandings to intercept the results in practical problems, therefore it is important to select an appropriate and simple model to match the purpose of the analysis. Analytical methods should be based on physical observation and its behaviour under dynamic load different type of structural model are described as below to simulate the behaviour of a frame modelling.

ii. SEISMIC-FORCE-RESISTING SYSTEMS REINFORCED CONCRETE:



Seismic-Force-Resisting Systems
Reinforced Concrete

Unbraced frames (with rigid "moment resisting" joints):
- Three types
  - Ordinary
  - Intermediate
  - Special

R/C shear walls:
- Ordinary
- Special

Precast shear walls:
- Special
- Intermediate
- Ordinary

Fig 2: Seismic-Force-Resisting Systems Reinforced Concrete

Two possible seismic resisting systems using reinforced concrete are moment frames and shear walls. ***Provisions*** present design coefficients and system limitations for various Seismic Design Categories. Precast walls can be used; however they will not be addressed in detail in this lecture. To understand some of the detailing requirements and how they relate to the ductility of these structural systems, we will first review basic reinforced concrete behavior.

iii. REINFORCED CONCRETE BEHAVIOR:

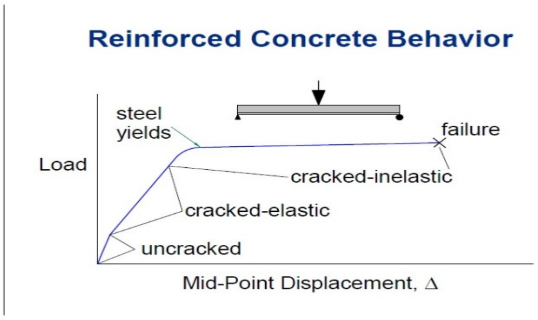


Fig 3: Reinforced Concrete Behavior

This graph shows stages of behavior of a reinforced concrete beam. At low loads the section is untracked and an analysis using untracked-transformed section properties can be used to predict behavior. After the concrete cracks, the concrete on the tension side of the beam is neglected, and a cracked-transformed section analysis can be used to predict behavior. However, this method is only valid as long as both the steel and the concrete stress-strain behaviors are linear. Concrete can be assumed to have a linear stress-strain behavior up to approximately 50% of maximum concrete stress (*f'c*).

After the concrete stress exceeds about 50%*f'c*, a strain compatibility approach can be used, using a realistic concrete stress-strain model such as the Congested model presented in Slide 7. After the steel yields, there is typically an extended plateau in which the displacement increases significantly with very little increase in applied load. A commonly used indicator of member ductility is the ratio of the displacement at ultimate to the displacement at first yield. This is known at the displacement ductility, and for seismic design in particular, bigger is better.

iv. REINFORCING STEEL STRESS-STRAIN BEHAVIOR:

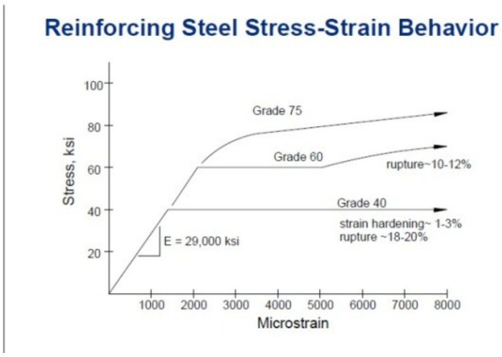


Fig 4: Reinforcing Steel Stress-Strain Behavior

This graph (Fig. 5) shows typical stress-strain behavior of common grades of reinforcing steel. The most commonly used is Grade 60 which shows a distinct yield plateau and strain hardening at between 0.5% and 1% elongation. For common analysis of reinforced concrete behavior, strain hardening is ignored. For seismic design, it is important that the actual yield strain of the steel is not significantly higher than the value used in design.

❖ SEISMIC DESIGN STEPS:

A. PLANNING STAGE
B. DESIGN STAGE (Structural analysis)
C.CONSTRUCTION STAGE:

➢ PLANNING STAGE:

Plan the building and structures in a symmetrical way both in plan (horizontal axis) and elevation (Vertical axis).

1. Avoid open ground (Soft storey) which is used for car parking.
2. Avoid weak storey and provide strong diaphragm. That is thinner slabs and flat slabs are to be avoided.
3. Provide openings for doors and windows at a distance of min 0.6 m from the column edges. Follow the IS code 4326 –page 11-for more details for masonry structures.
4. Do not add appendages like water tanks and swimming pools etc which will create a vast difference of Cm and Cr. (Center of Mass & Center of rigidity)
5. Conduct soil test and investigate the soil nature to avoid soil liquefactions.
6. Follow the IS code and NBC provisions while in Planning stage which will aid safer structures.
7. Select good materials-concrete ingredients, brick, steel etc. Especially steel having an elongation of above 14% and yield strength of 415N/mm^2.
8. The yield stress shall not be greater than 415N/mm^2. Steel having an yield strength 500 N/mm^2 may be used provided the % of elongation is above 14%. Make sure before approving it by means of lab test results.
9. Provide plinth beam at ground level, lintel and roof band (masonry structures).
10. Do not lower the beams in RCC frames at lintel level to have financial savings since the load path will not be there.

GEOMETRY**:**

(Ref: page 624 to 628 of earthquake Design concept-by Dr. C.V.R.Murthy)

- Building need to be proportioned reasonably to avoid unduly long, tall or wide dimensions which are known to result in poor seismic performance during an earthquake. Thus urban by-laws tend to control the overall geometry of the buildings with respect to the plot size. These are helpful in controlling problems like blockade of roads or collapsing on adjacent buildings in an unfortunate situation of a building collapse during an earthquake.
- Height/plot width <1.3 as per clause 6.6 NBC (1983) (part III) for plot size and clause 9.4.1 for height.
  Ex: plot area 10.0x18.0m-Max.permissible height=1.3x10=13.0m
- Length to width ratio<1.66 Clause 6.6 NBC & 8.2.1 for side open space.
- Ex: helps in ensuring rigid diaphragm action.
- Plot area 12mx20m
  -deduct standard setbacks.
  -Remaining maximum coverage area: 6.0mx15.5m.
  -Maximum possible plan size: 6mx9.6m.

LENGTH OF BUILDING:

- Shall not be more than 150m.
- Clear height of 6m at every 30m intervals at ground level for a passage of 7.5m width.
- Thermal consideration requires expansion joints after every 45m. These joints become seismic joints in buildings locate in seismic zones. In such situations, the 150m specified is not relevant.

OTHER CONSIDERATIONS: (IS 1893 Provisions)

-Improve shape and subsequently behavior of building during earthquake shaking. Design provisions may not exist to explicitly limit the height of buildings. But, it is desirable to ensure that

- Buildings are not made too long.
- Building height gives a regular (desired) slenderness ratio.

➢ **DESIGN STAGE (Structural analysis):**

The structural designer should address the influence of masonry infill walls in the lateral force behavior of the structure, either by taking them into account in the design process or by a separation gap from the column. If a separation gap is provided, then appropriate measures should be taken to warrant the out-of-plane stability of the masonry when subjected to lateral forces from wind or earthquake. The gap min 20 mm to 50mm or but comply with calculation.

1. Avoid weak column and strong beam design.
2. Provide thick slab which will help as a rigid diaphragm. Avoid thin slab and flat
3. Slab construction.
4. Provide cross walls which will stiffen the structures in a symmetric manner.
5. Provide shear walls in a symmetrical fashion. It should be in outer boundary to have large lever arm to resist the EQ forces.
6. For cantilevers it is designed for gravity and other loads as usual for the top bars and thickness but designed in addition to that as per the is code 1893-2002 clause 7.12.2.2 which states: All horizontal projections like corniced and balconies shall be designed and checked for stability for five times the design coefficient specified in 6.4.5(that is =10/3 Ah). .{Vb=AhW}

➢ **CONSTRUCTION STAGE:**

1. Good planning and design will not alone aid in resisting seismic forces but good workmanship and construction practice will add more strength for resisting the seismic forces.
2. Select good materials. Follow the mix design as obtained by the lab.
3. Provide the covers as per codal provisions. Do not use the aggregates, marble pieces and other means except the mortar cover blocks.
4. Follow the design details as furnished by the structural engineer and do not make any deviations.
5. Compact the concrete by means of needle vibrator.
6. Cure the concrete for at least a minimum period.
7. Experienced supervisor should be employed to have good quality control at site.

II. HOW TO INCREASE THE DUCTILITY:

Ductility is defined as the ability of a structure to undergo inelastic deformations beyond the initial yield deformation with no decrease in the load resistance. Can be increased in a section by:

1. Decrease the percentage of tension steel (pt).
2. Increase the percentage compression steel (pc).
3. Decrease in the tensile strength of steel. (Fy=415N/mm^2).
4. Increase in the compressive strength of concrete.-Min M20 to M30 and above.
5. Increase in the compression flange area in flanged beams (T and L beams) and
6. Increase in the transverse (Shear) reinforcement.

III. CAPTIVE COLUMNS:

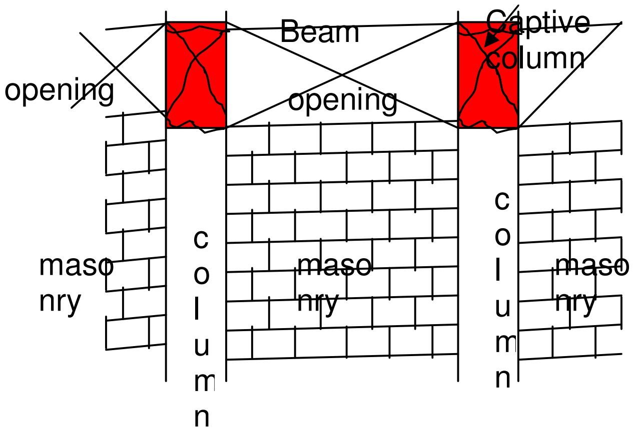


Fig 5: Captive column

Solution**:**

1. Add ties at closer spacing. Preferably spiral ties. Provide masonry walls on either side equal to twice the opening sizes by reducing the openings.
2. The best solution is to avoid the opening so that no captive column is created.

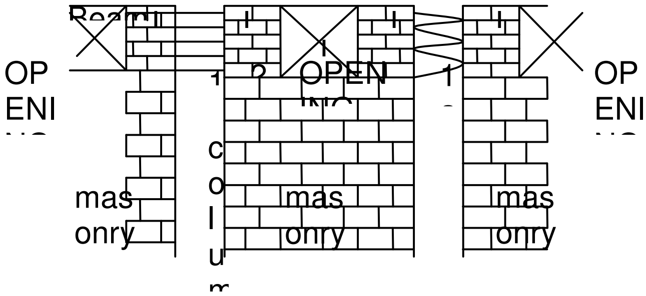


Fig 6: Captive columns Solution

IV. PERFORMANCE BASED SEISMIC DESIGN PROCESS:

The performance-based seismic design process explicitly evaluates how a building is likely to perform, given the potential hazard it is likely to experience, considering uncertainties inherent in the quantification of potential hazard and uncertainties in assessment of the actual building response. In performance-based design, identifying and assessing the performance capability of a building is an integral part of the design process, and guides the many design decisions that must be made. Performance-based design begins with the selection of design criteria stated in the form of one or more performance objectives. Each performance objective is a statement of the acceptable risk of incurring specific levels of damage, and the consequential losses that occur as a result of this damage, at a specified level of seismic hazard. Losses can be associated with structural damage, nonstructural damage, or both. They can be expressed in the form of casualties, direct economic costs, and downtime (time out of service), resulting from damage

In performance-based design, identifying and assessing the performance capability of a building is an integral part of the design process, and guides the many design decisions that must be made. Figure 1-1 shows a flowchart that presents the key steps in the performance-based design process. It is an iterative process that begins with the selection of performance objectives, followed by the development of a preliminary design, an assessment as to whether or not the design meets the performance objectives, and finally redesign and reassessment, if required, until the desired performance level is achieved.

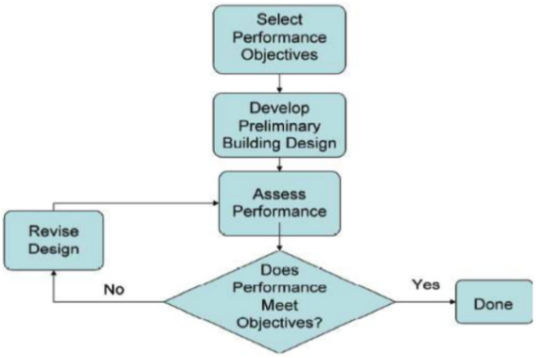


Fig 7: Performance-based design flow diagram

DETAILING:

1) Good detailing is as important as design and planning.
2) Follow the ductile detailing as per is code 13920-1993. Anchorage and overlapping are to be as per the code.
3) Is code 4326-1993-earthquake resistant design and construction of buildings-is to be followed.

V. FUTURE DEVELOPMENT OF PERFORMANCE BASED SEISMIC DESIGN:

As the state of knowledge and experience base advances, limitations in present generation procedures are being identified by researchers and practitioners. These include questions regarding the accuracy of analytical procedures in predicting actual building response, questions regarding the level of conservatism present in acceptance criteria, the inability to reliably and economically apply performance-based procedures to the design of new buildings, and the need for alternative ways of communicating performance to stakeholders that is more meaningful and useful for decision-making purposes. The future performance-based design procedures are needed to:

1. Revise the discrete performance levels defined in previous procedures to create new performance measures (e.g. repair costs, casualties, and time of occupancy interruption) that better relate to the decision-making needs of stakeholders, and that communicate these losses in a way that is more meaningful to stakeholders.
2. Create procedures for estimating probable repair costs, casualties, and time of occupancy interruption, for both new and existing buildings.
3. Develop a framework for performance assessment that properly accounts for, and adequately communicates to stakeholders, limitations in our ability to accurately predict response, and uncertainty in the level of earthquake hazard.
4. Refine current analytical techniques to improve our ability to more accurately simulate building response.
5. Modify current structural procedures to assess performance based more on global response parameters, so that the response of individual components does not unnecessarily control the prediction of overall structural performance.

VI. CONCLUSION:

The main objective of seismic design of buildings is to avoid total catastrophic damage so that structural damages caused, if any, could be repaired after the earthquake event. However, considering economic losses, the requirement for better performance has led to the envelopment of the performance-based seismic design methodology.

Performance-based seismic engineering implies design, evaluation, and construction of engineered facilities whose performance under common and extreme loads responds to the diverse needs and objectives of owners-users and society. It is based on the premise that performance can be predicted and evaluated with quantifiable confidence in order to make, together with the client, intelligent and informed trade-offs based on life-cycle considerations rather than construction costs alone

VII. REFERENCES:-

1. Er.T.Rangarajan,B.E,M.Sc(Struct.Engg) Consulting structural engineer.
2. page 624 to 628 of earthquake Design concept-by Dr.C.V.R.Murthy
3. SAA It.R.X;LU, M., et al, 1999 Turkey Earthquake: Performance of RC Structures, Concrete International, March, 2001, Vol. 23, No. 3, pp. 47 - 56.
4. MARTIN, 1. Full scale load test of a prestressed folded plate unit, Journal of the American Concrete Institute, December 1971, Vol. 68, No. 12, pp. 937-944; Discussions, Vol. 69, No. 6, June 1972, pp. 349-356.
5. Atiout,-WAI mu, H.M.S., and AI.I, W.M. Strength and behavior of reinforced concrete obtuse corners under opening bending moments, ACI Structural Journal, November - December 1989, Vol. 86, No.6, pp. 679-685.
6. S. Chandrasekaran and Varun Gupta," Performance Based Design for RC Framed Buildings" Dept of Civil Engineering, Institute of Technology, BHU, Varanasi, INDIA.
7. Ronald O. Hamburger (1997), "A framework for Performance-Based Earthquake Resistive Design", National Information Service for Earthquake Engineering (nisee), University of California, Berkerley
8. Andreas J. Kappos and GeorgiosPanagopoulo, "Performance-Based Seismic Design Of 3d R/C Buildings Using Inelastic Static And Dynamic Analysis Procedures", ISET Journal of Earthquake Technology, Paper No. 444, Vol. 41, No. 1, March 2004, pp. 141 158.
9. For design example wide page 335 of ADVANCED R.C. DESIGN BY P.C. VARGHESE.