GUJARAT TECHNOLOGICAL UNIVERSITY

Master of Engineering
Subject Code: 3732007
Semester – III
Subject Name: Earthquake Resistant Design of structures

Type of course: Elective

Prerequisite: Design of concrete structures**,** Structural Dynamics and Engineering Mathematics

Rationale: Earthquake force is time-dependent force acting on the structure and thereby it induces vibration in the structures. Structures are designed as earthquake resistant structures which allow damage in the structures. Therefore, it is very challenging to design structures which remain safe during earthquake disaster. ERD of Structures becomes very important for the structural engineers to make them safe.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
L	T	P	C	Theory Marks		Practical Marks		
				ESE(E)	PA (M)	ESE (V)	PA(I)	
3	0	0	3	70	30	0	0	100

Content:

Sr. No.	Content	Total Hrs	% Weightage
1	**Earthquake Ground Motion:** Engineering seismology - Causes of earthquakes; seismic waves; magnitude, intensity and energy release, Seismic zoning map of India - Strong motion studies in India - Strong motion characteristics - Evaluation of seismic design parameters.	03	05
2	**Concepts of earthquake resistant design & Effects of Irregularities in RC Structures:** Earthquake Resistant Design Philosophy, Earthquake Proof v/s Earthquake Resistant Design, four virtues of good earthquake resistant structures (strength, stiffness, ductility and configuration), Earthquake resistant building architecture. Effect of various structural irregularities like improper Load Transfer Path, Floating Columns, Short Column, Soft Storey, Improper gap between adjacent structures (Pounding), Eccentric loading, Unsymmetrical plan/elevation, Setbacks and Improper Detailing of reinforcement on performance of RCC buildings during earthquakes, Effect of Masonry Infill Walls, Performance of buildings in past earthquakes, Identification of seismic damages & Lessons learnt from past earthquakes.	06	15
3	**Lateral Load Distribution, Seismic analysis and modeling of RCC structures:** Rigid diaphragm effect, centers of mass and stiffness, lateral load distribution in torsionally coupled and uncoupled system. Lateral load resisting systems-moment resisting frame, Building with shear wall system, building with dual system; Code based procedure for determination of design lateral loads - Seismic analysis procedure as per IS 1893 code - Equivalent static force method - Response spectrum method - Time history analysis - Advantages and	10	20

	disadvantages of these methods, Estimation of earthquake forces using equivalent static force method & response spectrum method as per IS:1893-2016, Calculation of design horizontal seismic base shear and story drift, Mathematical modeling of multi-storey RCC buildings with Infill walls		
4	**Ductility considerations in earthquake resistant design of RCC buildings :** Impact of ductility; Requirements for ductility; Assessment of ductility– Member/element ductility, Structural ductility; Factor affecting ductility; Ductility considerations as per IS 13920-2016, Design and detailing of typical flexural member, typical column, footing and beam-column joint as per IS13920-2016, Importance of Beam Column Joints.	06	15
5	**Earthquake resistant design of RCC structures:** Development of structural framing plan from architectural plan. Ductility considerations - Earthquake resistant design & detailing of multi-storey RCC buildings and shear walls based on Capacity Design Concept - IS 13920-2016, 3D modeling and analysis of RC Framed Building Structures under design load combinations including earthquake loads using standard commercial software such as STAAD Pro, SAP/ETABS etc. Post-processing of analysis results for design of structural Elements. Comparison with design output of the software.	10	25
6	**Structural controls:** Active & Passive Controls systems & their suitability. **Passive Control Systems:** Base isolation of structures; Considerations for seismic isolation; Basic elements of seismic isolation; seismic isolation design principle; Feasibility of seismic isolation; Seismic-isolation configurations Characteristics of Viscous Dampers, Visco-Elastic Dampers, Yielding Dampers, Tuned Mass Dampers, Tuned Liquid Dampers, Friction Pendulum Dampers, MR Dampers etc. & their suitability Concepts of Active, Semi-active & Hybrid Control Systems Application of controls in design of structures	08	20

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
20%	30%	20%	20%	5%	5%

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Note: This specification table shall be treated as a general guideline for students and teachers. The actual distribution of marks in the question paper may vary slightly from above table.

Reference Books:

1. B.C. Punmia, Ashok K. Jain and Arun K. Jain, "Reinforced Concrete Structures, Vol, 1", Laxmi Publications
2. M.L. Gambhir, "Fundamentals of Reinforced Concrete Design", Prentice Hall of India Private Limited.
3. P.C. Varghese, "Design of Reinforced Concrete Foundations", Prentice Hall of India Private Limited,

4. T. Paulay and M.J.N. Priestley, "Seismic Design of Reinforced Concrete and Masonry Buildings", John Wiley and Sons Inc.
5. P. Agarwal and M. Shrikhande, "Earthquake Resistant Design of Structures", Prentice-Hall of India Private Limited
6. S.K. Duggal, "Earthquake Resistant Design of Structures", Oxford University Press
7. IS 456:2000, Indian Standard Plain and Reinforced Concrete - Code of Practice, Bureau of Indian Standards, New Delhi.
8. IS 875 (Part 1 to 5): Indian Standard Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures & load combination
9. IS:1893-2016, Indian Standards Criteria for Earthquake Resistant Design of Structures, Bureau of Indian Standards, New Delhi.
10. IS:13920-2016, Indian Standard Code of Practice for Design & Ductile Detailing of Reinforced Concrete Structures subjected to Seismic Forces, Bureau of Indian Standards, New Delhi.

Course Outcome:

Sr. No.	CO statement	Marks % weightage
CO-1	Apply the concept of Earthquake Resistant Design & appraise the effect of structural & architectural irregularities of buildings.	10
CO-2	Determine the lateral loads on SDOF & MDOF structural system subjected to earthquake.	15
CO-3	Analyze RCC framed structures through Equivalent static force method - Response spectrum method for determining the lateral forces generated due to earthquake. Design & detailing of Multi-storey RC building using the available software.	40
CO-4	Appraise the concepts of ductile detailing for various structural elements in RC structures.	15
CO-5	Classify & Describe various control systems & apply to framed structures	20

Major Equipment:

1. Structural engineering software

List of Open Source Software/learning website:

1. http://www.cdeep.iitk.ac.in/nptel
2. http://www.nptel.iitm.ac.in
3. opensees.berkeley.edu/
4. www.nicee.org
5. http://www.earthquakeinfo.org/
6. www.eeri.org/
7. www.earthquakeengineering.com/
8. www.curee.org
9. Non-lin software