Programme Name/s : Civil Engineering/ Civil & Rural Engineering/ Construction Technology/ Civil & Environmental Engineering/

Programme Code : CE/ CR/ CS/ LE

Semester : Sixth

Course Title : EARTHQUAKE RESISTANT BUILDING

Course Code : 316311

I. RATIONALE

The construction of a building or structure is prone to sudden collapse if enough care has not been taken against the sudden ground shaking i.e earthquakes and therefore it is an immediate priority of a civil engineer to address this issue to reduce or prevent structural damage and human deaths and injuries. Seismic design is a critical aspect of building construction, especially in areas prone to earthquakes. A civil Engineer must have basic knowledge regarding the specific guidelines and code provisions to ensure the safety and stability of structures. This course is specifically designed to develop the basic competency among the students to deal with this challenge by incorporating various key techniques, including base isolation, energy dissipation systems, and reinforcement methods etc, enabling students to design structures that can withstand earthquakes effectively.

II. INDUSTRY / EMPLOYER EXPECTED OUTCOME

The aim of this course is to help the student to attain the following industry identified competency through various teaching learning experiences: Design an earthquake resistant buildings using relevant IS code provisions.

III. COURSE LEVEL LEARNING OUTCOMES (COS)

Students will be able to achieve & demonstrate the following COs on completion of course based learning

- CO1 - Describe the various seismic zones with reference to periods and magnitude of earthquake intensity.
- CO2 - Explain the effects of earthquakes on building structures with its causes.
- CO3 - Design an earthquake-resistant building using relevant planning and design principles
- CO4 - Analyze the performance of given structure during earthquakes.
- CO5 - Apply the relevant IS code provisions for safety and serviceability of the given structure in given situation.

IV. TEACHING-LEARNING & ASSESSMENT SCHEME

Course Code	Course Title	Abbr	Course Category/ s	Learning Scheme					Credits	Assessment Scheme											
				Actual Contact Hrs./Week			SLH	NLH		Paper Duration	Theory				Based on LL & TL				Based on SL		Total Marks
															Practical						
				CL	TL	LL					FA-TH	SA-TH	Total		FA-PR		SA-PR		SLA		
											Max	Max	Max	Min	Max	Min	Max	Min	Max	Min	
316311	EARTHQUAKE RESISTANT BUILDING	ERB	DSE	3	-	2	1	6	3	3	30	70	100	40	25	10	25#	10	25	10	175

Total IKS Hrs for Sem. : 0 Hrs

Abbreviations: CL- ClassRoom Learning , TL- Tutorial Learning, LL-Laboratory Learning, SLH-Self Learning Hours, NLH-Notional Learning Hours, FA - Formative Assessment, SA -Summative assessment, IKS - Indian Knowledge System, SLA - Self Learning Assessment

Legends: @ Internal Assessment, # External Assessment, *# On Line Examination , @$ Internal Online Examination

Note :

1. FA-TH represents average of two class tests of 30 marks each conducted during the semester.
2. If candidate is not securing minimum passing marks in FA-PR of any course then the candidate shall be declared as "Detained" in that semester.
3. If candidate is not securing minimum passing marks in SLA of any course then the candidate shall be declared as fail and will have to repeat and resubmit SLA work.
4. Notional Learning hours for the semester are (CL+LL+TL+SL)hrs.* 15 Weeks
5. 1 credit is equivalent to 30 Notional hrs.
6. * Self learning hours shall not be reflected in the Time Table.
7. * Self learning includes micro project / assignment / other activities.

V. THEORY LEARNING OUTCOMES AND ALIGNED COURSE CONTENT

Sr.No	Theory Learning Outcomes (TLO's)aligned to CO's.	Learning content mapped with Theory Learning Outcomes (TLO's) and CO's.	Suggested Learning Pedagogies.
1	TLO 1.1 Explain the given terms related to Earthquakes TLO 1.2 Classify seismic waves on the basis of given criteria in the given situation. TLO 1.3 Identify the seismic zone of given area on seismic zone map. TLO 1.4 Explain the Identify the seismic zone of given area on seismic zone map, significance of term, â€œperiodâ€ with other allied concepts used in Earthquakes TLO 1.5 Evaluate the impact of the earthquake based on its magnitude and intensity w.r.t given scale.	**Unit - I Overview of Earthquake phenomenon** 1.1 Definition and meaning of terms: Focus, Epicenter, Focal depth, foreshocks, aftershocks, 1.2 Seismic waves â€“ Types and propagation , Body waves ,P waves and S waves ,Surface waves L and R waves, Propagation of Seismic Waves, pathways , reflection and refraction and shadow zones 1.3 Enlist the various seismic zones of India, classifying them into moderate to severe zones 1.4 Natural period, fundamental natural period, nodal natural period, response spectrum, seismic mass, seismic weight, structural response factor, time 1.5 Earthquake magnitude, intensity, and measurement (Richter scale, Mercalli scale) and risk assessment	Video Demonstrations Presentations Hands-on
2	TLO 2.1 Explain the effects of earthquakes on buildings with its causes. TLO 2.2 Describe the process of formation of earth and its core in the given situation. TLO 2.3 Determine the intensity of earthquake using elastic rebound theory method. TLO 2.4 Compare the different types of failures occurred due to earthquakes in the specified zone based on the given criteria.	**Unit - II Causes and effects of earthquake** 2.1 Causes and effects of earthquake 2.2 Formation of earth and its cores, Formation, types and movement of tectonic plates, procedure of formation of the tectonic plates for the given earthquake zone. 2.3 Elastic rebound theory, Types of earthquakes and Faults. 2.4 Primary and secondary effects: Ground shaking, liquefaction, landslides, tsunamis and fire	Video Demonstrations Presentations Case Study

Sr.No	Theory Learning Outcomes (TLO's)aligned to CO's.	Learning content mapped with Theory Learning Outcomes (TLO's) and CO's.	Suggested Learning Pedagogies.
3	TLO 3.1 Explain the Principles of planning for earthquake resistant structures TLO 3.2 Select the safe location for the proposed building based on soil investigations. TLO 3.3 Select the correct geometric shapes of the given buildings to improve its resistance against earthquake with justification TLO 3.4 Explain the role of damping on resistance to earthquake using the relevant method of base isolation techniques	**Unit - III Planning and design aspects** 3.1 Principles of earthquake-resistant planning: Site Selection and Soil Assessment, Building Design and Structural Configuration 3.2 Site selection and soil considerations for buildings 3.3 Building configuration: Importance of shape, symmetry, and stiffness Load path and lateral load resistance in building 3.4 Role of damping systems, Types of dampers , tuned mass dampers , viscous dampers and friction dampers base isolation techniques using Elastomeric bearings, sliding plates, ball bearings and springs	Video Demonstrations Case Study Presentations
4	TLO 4.1 Correlate the damages occurred in the given type of building with its intensity in the given seismic zone. TLO 4.2 Interpret the earthquake to identify the causes of the failure w.r.t the given seismic zone. TLO 4.3 Compare damages of buildings at two different seismic zones for the given type of masonry building TLO 4.4 Compare the earthquakes of similar intensity with reference to the given data including its impact on concrete structure	**Unit - IV Earthquakes affected masonry and concrete buildings** 4.1 Behavior of masonry and reinforced concrete structures during earthquakes 4.2 Earthquake-resistant construction techniques for masonry buildings: Material Selection, Structural Configuration, Reinforcement Techniques, Construction Practices 4.3 Common failures in concrete and masonry buildings due to earthquakes: Sliding of roof support, falling of infill walls, crushing of column ends, and diagonal cracking of column beam joints, pulling out of reinforcement bars, foundation sinking and tilting 4.4 Retrofitting Methods for concrete and masonry Buildings: Grouting, Reinforced Concrete (RC) Jacketing, Steel Bracing, Fiber-Reinforced Polymer (FRP) wrapping, wall Strengthening with Wire mesh, Methods for strengthening and retrofitting existing structures like shear walls, infill walls and steel braces, Reinforced concrete (RC) Jacketing	Video Demonstrations Case Study Presentations Hands-on Flipped Classroom
5	TLO 5.1 Explain the relevant provisions of IS codes for construction of Earthquake resistant building for the given seismic zone. TLO 5.2 Explain the relevant method of retrofitting for the given damaged building affected by earthquake TLO 5.3 Undertake the relevant damage assessment techniques to evaluate the structural safety of the affected building TLO 5.4 Undertake the relevant Disaster management policies Community awareness Programs and Community awareness programs	**Unit - V Codal provisions and management Strategies** 5.1 Codal Provisions and Design Philosophy (IS 13920 2016, IS: 1893 (part I)-2002, IS:4326:2003) 5.2 Retrofitting Methods for Masonry Buildings, Grouting , Reinforced Concrete (RC) Jacketing, Steel Bracing, Fiber-Reinforced Polymer (FRP) Wrapping ,Wall Strengthening with Wire Mesh ,Base Isolation 5.3 Damage assessment and Structural safety evaluation- Immediate response and rescue Operations. Repair, rehabilitation, and retrofitting techniques 5.4 Disaster management policies, Objectives of Disaster Management Policies, Key Components of Disaster Management Policies, United States: Stafford Act (1988) India: Disaster Management Act (2005) Japan: Basic act on disaster management (1961), European Union Civil protection Mechanism (UCPM) ,Education and Training ,Capacity Building, First Aid and Basic Life Support Training , Search and Rescue Training , Fire Safety Training, Mock Drills and Simulation Exercises â€¢Early Warning Systems, Community-Based Disaster Risk Reduction (CBDRR)	Video Demonstrations Case Study Presentations Hands-on Site/Industry Visit Flipped Classroom

VI. LABORATORY LEARNING OUTCOME AND ALIGNED PRACTICAL / TUTORIAL EXPERIENCES.

Practical / Tutorial / Laboratory Learning Outcome (LLO)	Sr No	Laboratory Experiment / Practical Titles / Tutorial Titles	Number of hrs.	Relevant COs
LLO 1.1 Prepare a detailed report distinguishing between P-waves, S-waves, and surface waves based on the given earthquake data from the given seismograph	1	*Identify the types of waves from the given seismograph.	2	CO1
LLO 2.1 Mark four seismic zones on a printed map of India as per IS: 1893-2002 with color code.	2	*Use IS:1893-2002 guidelines to mark seismic zones	2	CO1
LLO 3.1 Draw the Seismic load distribution diagram for a Multi-Story Buildings G+4) Using a Shake Table.	3	Use a shake table to create load distribution diagram for given structure.	2	CO2
LLO 4.1 Prepare a report on earthquake simulations by observing videos to note structureâ€™s response to dynamic forces w.r.t shape and size of any two buildingsÂ in the given earthquake zone	4	*Undertake earthquake simulations for testing the stability of the structure having specific shape and size.	2	CO2

Practical / Tutorial / Laboratory Learning Outcome (LLO)	Sr No	Laboratory Experiment / Practical Titles / Tutorial Titles	Number of hrs.	Relevant COs
LLO 5.1 Prepare a report on impact of earthquake on the bearing capacity of soil present below the damaged structure.	5	*Prepare a report on impact of earthquake on the bearing capacity of soil present below the damaged structure.	2	CO3
LLO 6.1 Analyze the given soil sample and Prepare a report using Ground shaking techniquesÂ to observe effect of soil properties on intensity and behavior of seismic waves.	6	Analyze the given soil sample using ground shaking techniques with its impact on earthquake intensity.	2	CO3
LLO 7.1 Draw typical sketches on minimum five types of beam, column and beam-column joint with reinforcement details for making the structure earthquake resistant as per I.S. 13920-2016).	7	*Draw detailing of Reinforcement for Earthquake Resistance structure (As per IS: 13920-1993)	2	CO4
LLO 8.1 Draw minimum 3 typical sketches out of steel bracing, jacketing, and both fiber wrapping techniques used in retrofitting of Existing Structures and prepare a report commenting on the same.	8	*Draw the typical sketches of steel bracing, jacketing, and both fiber wrapping techniques used in retrofitting of Existing Structures with comments.	2	CO4
LLO 9.1 Draw minimum five sketches to represent the methods to strengthen steel structure with roof truss against earthquake damages with a brief note on it.	9	*Strengthening of steel structures with roof trusses against earthquake damages.	2	CO4
LLO 10.1 Draw minimum five sketches to represents the methods to strengthen steel structure with gable frame against earthquake damages with a brief note on it.	10	*Strategy framework to safeguard structures against earthquake damage.	2	CO4
LLO 11.1 Prepare a brief report on the effect of earthquake on Structural (minimum 3)and Non-Structural Components of building. (minimum 3)	11	Impact of earthquake on Structural and Non-Structural Components of building	2	CO5
LLO 12.1 Prepare a brief report on the effect of earthquake on Structural (minimum 3)and Non-Structural Components of building. (minimum 3)	12	Interprete Seismic codes in earthquake resistant design of buildings	2	CO5
LLO 13.1 Analyse the relevant videos and data to assess the structural damage occurred after earthquake in the given seismic zone. Give suggestions to repair the damaged structure.	13	Interprete damage mechanism and repair techniques using videos etc.	2	CO5
LLO 14.1 Identify the failure pattern observed in the video /simulation/ photographs due to earthquake with your comments.	14	Identification of failure pattern due to Earthquakes	2	CO5
LLO 15.1 Identify the weak floors prone to collapse due to earthquake to analyze soft story and stiffness irregularities.	15	Use of soft story and stiffness irregularities to address structural weaknesses	2	CO5

Note : Out of above suggestive LLOs -

- '*' Marked Practicals (LLOs) Are mandatory.
- Minimum 80% of above list of lab experiment are to be performed.
- Judicial mix of LLOs are to be performed to achieve desired outcomes.

VII. SUGGESTED MICRO PROJECT / ASSIGNMENT/ ACTIVITIES FOR SPECIFIC LEARNING / SKILLS DEVELOPMENT (SELF LEARNING)

Micro project

- Prepare a report on the measurement of earthquake magnitude and intensity using case studies comparing the Richter and Mercalli scales with real earthquake data.
- Collect data of any three non-destructive equipments and prepare a report giving technical specifications, make, cost, nature of test, degree of accuracy of results etc.

- Visit web site of prominent institutes (IIT Kanpur) having research and development cell on earthquake engineering and prepare a report.
- Visit seismic data analysis and measurement centre of Government of Maharashtra for your district and prepare a report
- Prepare a report on the use of Dugong Technique to construct Earthquake resistant building
- Prepare a detailed report on construction and testing of masonry walls with and without Reinforcement
- Prepare a detailed report on comparing seismic performance of reinforced and unreinforced brick walls.
- Prepare a detailed report after conducting a field survey to assess structural damage and suggest repair methods for any two damaged buildings
- Prepare a detailed report on the testing of reinforced concrete beams for seismic resistance, applying cyclic loads to study ductility and energy absorption.
- Prepare a detailed report on the analysis of a simple building structure using response spectrum method using freeware software such as STAAD.Pro, ETABS etc. to perform seismic analysis.

Assignment

- Prepare a detailed report on the four virtues of Earthquake resistant buildings
- Prepare a detailed report on Introduction to IS 1893 Part I , Box action and different types of bands
- Study the effect of earthquake on minimum two reservoirs/dams and prepare a report focusing on its earthquake preparedness
- Study any two case studies of past earthquakes in India and prepare a report comparing the damages caused to concrete and masonry buildings
- Prepare a detailed report on Importance of beam column joints
- Prepare a detailed report on Importance of buildings with shear walls
- Prepare a report on the basic principle of seismic isolation and its application
- Prepare a detailed report on post-earthquake damage assessment and rehabilitation of the earthquake at killari, in Latur district
- Study any two case studies of past earthquakes in Maharashtra and prepare a report comparing the damages caused to concrete and masonry buildings
- Study any two case studies of past earthquakes in the World and prepare a report comparing the damages caused to concrete and masonry buildings

- Prepare a detailed report on minimum five ductility considerations as per IS 13920 :1993, and comment on its implementation in earthquake resistant structures
- Study the behavior of buildings with open parking during earthquake, considering any past earthquake in India and prepare a report on its pros and cons .

Note :

- Above is just a suggestive list of microprojects and assignments; faculty must prepare their own bank of microprojects, assignments, and activities in a similar way.
- The faculty must allocate judicial mix of tasks, considering the weaknesses and / strengths of the student in acquiring the desired skills.
- If a microproject is assigned, it is expected to be completed as a group activity.
- SLA marks shall be awarded as per the continuous assessment record.
- For courses with no SLA component the list of suggestive microprojects / assignments/ activities are optional, faculty may encourage students to perform these tasks for enhanced learning experiences.
- If the course does not have associated SLA component, above suggestive listings is applicable to Tutorials and maybe considered for FA-PR evaluations.

VIII. LABORATORY EQUIPMENT / INSTRUMENTS / TOOLS / SOFTWARE REQUIRED

Sr.No	Equipment Name with Broad Specifications	Relevant LLO Number
1	Seismometers- Frequency 500 Hz to 0.00118 Hz (1/500 = 0.002 seconds per cycle, to 1/0.00118 = 850 seconds per cycle).	1
2	Sample Seismograph	1
3	Ultrasonic Pulse velocity	13
4	Rebound Hammer	13
5	Shake Table - a table capable of handling a scaled model's weight and simulating earthquake ground motions, typically with a table size of at least 3.26 x 2.26 meters and a triaxial capability for multi-directional testing	4

IX. SUGGESTED WEIGHTAGE TO LEARNING EFFORTS & ASSESSMENT PURPOSE (Specification Table)

Sr.No	Unit	Unit Title	Aligned COs	Learning Hours	R-Level	U-Level	A-Level	Total Marks
1	I	Overview of Earthquake phenomenon	CO1	6	2	4	4	10

Sr.No	Unit	Unit Title	Aligned COs	Learning Hours	R-Level	U-Level	A-Level	Total Marks
2	II	Causes and effects of earthquake	CO2	8	2	4	6	12
3	III	Planning and design aspects	CO3	9	4	4	6	14
4	IV	Earthquakes affected masonry and concrete buildings	CO4	12	4	6	8	18
5	V	Codal provisions and management Strategies	CO5	10	2	6	8	16
Grand Total				**45**	**14**	**24**	**32**	**70**

X. ASSESSMENT METHODOLOGIES/TOOLS

Formative assessment (Assessment for Learning)

- Assignments
- Term work
- microprojects
- Term work
- SLH(60% weightage to process and 40% weightage to product)
- Question and Answer

Summative Assessment (Assessment of Learning)

- Written test (Pen and paper test)
- Practical exam

XI. SUGGESTED COS - POS MATRIX FORM

Course Outcomes (COs)	Programme Outcomes (POs)							Programme Specific Outcomes* (PSOs)		
	PO-1 Basic and Discipline Specific Knowledge	PO-2 Problem Analysis	PO-3 Design/ Development of Solutions	PO-4 Engineering Tools	PO-5 Engineering Practices for Society, Sustainability and Environment	PO-6 Project Management	PO-7 Life Long Learning	PSO- 1	PSO- 2	PSO- 3
CO1	2	2								
CO2		2			2	-				
CO3			2		2					
CO4		2	2	2	2	2				
CO5			2		2	2				

Legends :- High:03, Medium:02,Low:01, No Mapping: -
*PSOs are to be formulated at institute level

XII. SUGGESTED LEARNING MATERIALS / BOOKS

Sr.No	Author	Title	Publisher with ISBN Number
1	Agarwal Pankaj, Shrikhande Manish	Earthquake Resistant Design of Structures	PHI Learning, Delhi,2011 ,ASIN: B00K7YFYVEISBN-13 9788120328921
2	Duggal, S. K.	Earthquake Resistant Design of Structures	Oxford University Press, Delhi, 2013 ISBN-13 9780198083528
3	Jai Krishna , A. R. Chandrashekharan Chandra, B.	Elements of Earthquake Engineering	South Asian Publishers Pvt Ltd, Delhi, 2014ISBN13 9788180142192
4	A.K.Chopra	Dynamics of structures	Pearson , New Delhi ISBN: 813171329
5	Mario Paz	Structural dynamics theory and computation	Springer (India) P. Ltd., ISBN:8181287724
6	BUREAU OF INDIAN STANDARDS	IS 1893:PartI :2002 Indian Standard CRITERIA FOR EARTHQUAKE RESISTANT DESIGN OF STRUCTURES PART 1 GENERAL PROVISIONS AND BUILDINGS (Ffth Revision)	BUREAU OF INDIAN STANDARDS MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG NEW DELHI 110002
7	BUREAU OF INDIAN STANDARDS	IS 4326:2003 EARTHQUAKE RESISTANT DESIGN AND CONSTRUCTION OF BUILDINGS â€" CODE OF PRACTICE (Second Revision (Incorporating Amendment Nos. 1, 2 & 3) UDC 699.841 (026)	B U R E A U O F I N D I A N S T A N D A R D S MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG NEW DELHI 110002
8	BUREAU OF INDIAN STANDARDS	IS 13920 : 2016: Ductile Design and Detailing of Reinforced Concrete Structures Subjected to Seismic Forces - Code of Practice (First Revision)	BUREAU OF INDIAN STANDARDS MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG NEW DELHI 110002

XIII . LEARNING WEBSITES & PORTALS

Sr.No	Link / Portal	Description
1	https://www.nicee.org/EQTips.php	National Information Centre of Earthquake Engineering at IIT Kanpur, INDIA
2	https://archive.nptel.ac.in/courses/105/101/105101004/	Introduction to Earthquake Engineering , syllabus coordinated by IIT Mumbai- Online NPTEL -E content
3	https://pib.gov.in/PressReleasePage.aspx?PRID=1740656	National Centre for Seismology under Ministry of Earth Sciences is the nodal agency of Government of India (GoI), for monitoring earthquakes in and around the country
4	https://iricen.gov.in/LAB/res/pdf/test-31.pdf	Rebound hammer test
5	https://dailycivil.com/ultrasonic-pulse-velocity-test-upv-test/	Ultrasonic pulse velocity test

Note :

- Teachers are requested to check the creative common license status/financial implications of the suggested online educational resources before use by the students