Program Name : **Civil Engineering Program Group**

Program Code : **CE/CR/CS**

Semester : **Sixth**

Course Title : **Earthquake Resistant Buildings (Elective-II)**

Course Code : **22606**

1. RATIONALE

This course is the specialized subject for Civil Engineering. The students having interest in structural engineering and perceive career in this field have a better option to choose this course. Earthquake is a natural disaster phenomenon which could not be denied, but its impact on the structure can be reduced by proper analysis and design of buildings to minimize loss of properties and lives. In recent past, a major part of the peninsular India experienced earthquakes periodically; therefore study of earthquake engineering is introduced in the curriculum of sixth semester civil engineering diploma students.

2. COMPETENCY

The aim of this course is to help the student to attain the following industry identified competency through various teaching learning experiences:

- **Execute construction of earthquake resistant buildings using relevant IS code provisions.**

3. COURSE OUTCOMES (COs)

The theory, practical experiences and relevant soft skills associated with this course are to be taught and implemented, so that the student demonstrates the following ***industry oriented*** COs associated with the above mentioned competency:

a) Execute the principles of earthquake resistant buildings in the constructions.
b) Relate the failure in the structures on the basis of the intensity of damage.
c) Select the relevant shape of building for seismic sustainability of structures.
d) Execute the relevant method of removal of defect in structures causing failure.
e) Execute the relevant provisions of IS code in construction of earthquake resistant buildings.
f) Execute the post-earthquake management system.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme			Credit (L+T+P)	Examination Scheme												
				Theory							Practical					
L	T	P		Paper Hrs.	ESE		PA		Total		ESE		PA		Total	
					Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
3	-	2	5	3	70	28	30*	00	100	40	25#	10	25	10	50	20

(*): Under the theory PA; Out of 30 marks, 10 marks of theory PA are for micro-project assessment to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessment of the UOs required for the attainment of the COs.

***Legends: L**-Lecture; **T** – Tutorial/Teacher Guided Theory Practice; **P** - Practical; **C** – Credit, **ESE** - End Semester Examination; **PA** - Progressive Assessment*

5. COURSE MAP (with sample COs, PrOs, UOs, ADOs and topics)

This course map illustrates an overview of the flow and linkages of the topics at various levels of outcomes (details in subsequent sections) to be attained by the student by the end of the course, in all domains of learning in terms of the industry/employer identified competency depicted at the centre of this map.

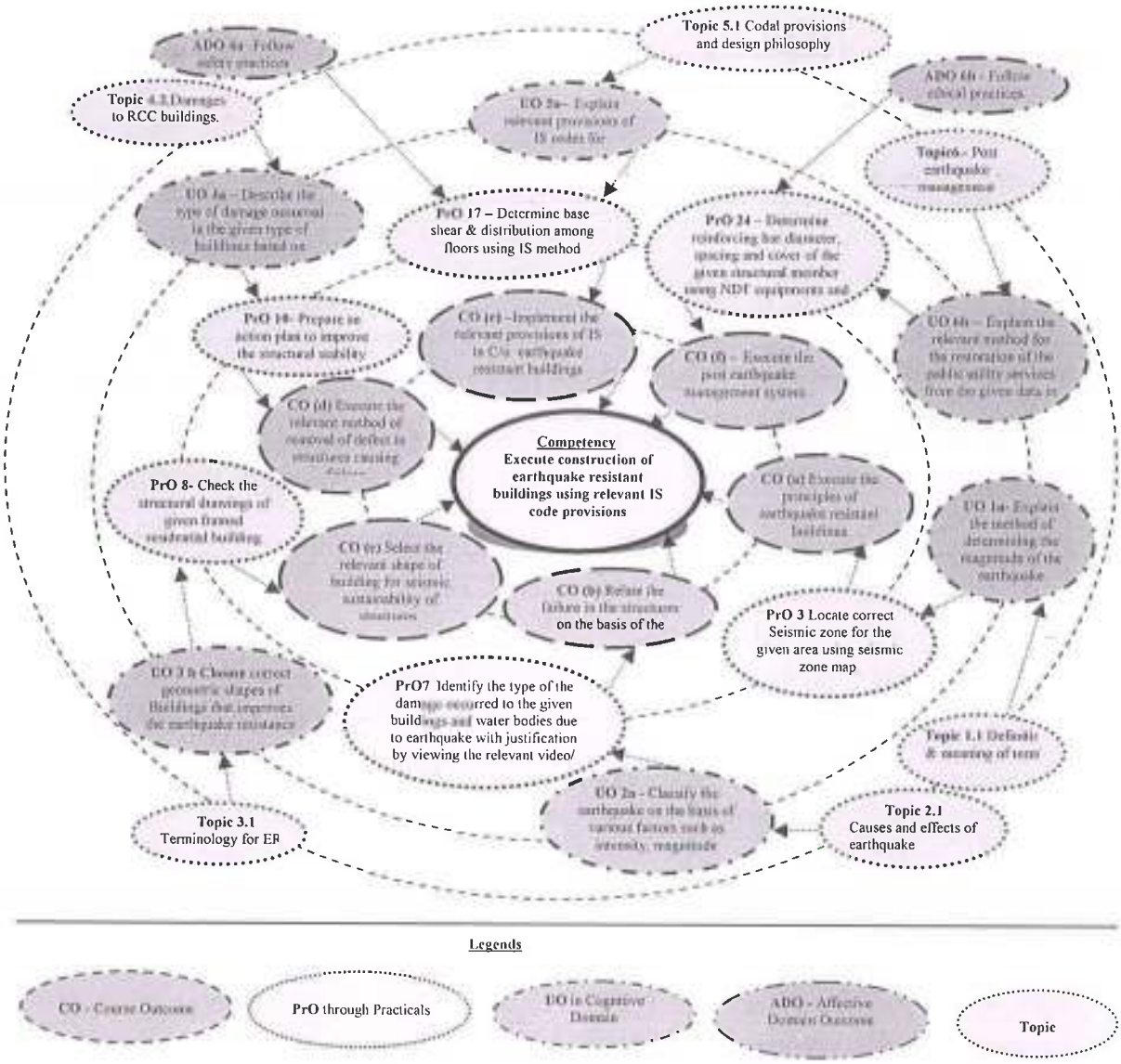

Figure 1 - Course Map

6. SUGGESTED PRACTICALS/ EXERCISES

The practicals in this section are PrOs (i.e. sub-components of the COs) to be developed and assessed in the student for the attainment of the competency.

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
1	Interpret the past earthquake having magnitude less than 6 (richter scale) through internet survey and submit your report including sketches/photos wherever necessary.	I	02*
2	Relate magnitude of the earthquake occurred in the given area to the severity of the damages by viewing the relevant video/ simulation/ photographs and Submit your observations along with your comments.	I	

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
3	Locate correct Seismic zone for the given area using seismic zone map.	I	
4	Interpret the past earthquake having magnitude more than 6 (richter scale) through internet survey and submit your report including sketches/photos wherever necessary.	I	02
5	Mark various seismic zones on a printed map of India with earthquake magnitude as per the guidelines provided in IS: 1893-2002 to list four cities in India in each earthquake zone.	I	02*
6	Interpret the damages to the masonry and concrete structures from the relevant information of any two past earthquakes from India w.r.t.type of structures, zones, site conditions, type of failures etc.	II	02*
7	Identify the type of the damage occurred to the given buildings and water bodies due to earthquake with justification by viewing the relevant video/ simulation/ photographs and Submit your observations along with your comments..	II	02
8	Check the structural drawings of the given framed residential building for seismic vulnerability for the given seismic zone	III	02*
9	Check the structural drawings of the given framed public building for seismic vulnerability for the given seismic zone	III	02
10	Prepare an action plan to improve the structural stability of the given structure against earthquake.	IV	02
11	Draw the sketches of the given method of retrofitting for improving seismic resistance of existing framed building with a report on its procedure including other methods of retrofitting.	IV	02
12	Determine strength of any two given structural members of framed building using rebound hammer and comment on its seismic stability	IV	02*
13	Classify damages occurred in the given buildings based on earthquake intensity in the given seismic zone by viewing the relevant video/ simulation/ photographs and Submit your observations along with your comments.. .	IV	02
14	Identify the failure pattern observed in the building failure occurred due to earthquake in the given seismic zone by viewing the relevant video/ simulation/ photographs and Submit your observations along with your comments.	IV	02
15	Check the stability of the given two members of framed building using ultrasonic pulse velocity and comment on its seismic stability.	IV	02
16	Determine compressive strength of the given member of framed structure by taking core from cubes or from existing concrete structures and comment on its seismic stability.	IV	02
17	Determine base shear and distribution among floors using IS method for two bay single storey RCC building.	V	02*
18	Calculate base shear and distribution among floors using any ETAB software for two bay single storey RCC building.	V	02
19	Calculate base shear and distribution among floors using Indian Standard method for three storied RCC building.	V	02
20	Calculate base shear and distribution among floors using software for single bay three storey RCC building.	V	02
21	Draw typical sketches of beam, column and beam-column joint	V	02*

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
	showing reinforcement details as per I.S. 13920-1993.		
22	Draw the sketches to represents the methods to strengthen steel structure with roof truss against earthquake damages with a brief note on it.	VI	02
23	Draw the sketches to represents the methods to strengthen steel structure with gable frame against earthquake damages with a brief note on it.	VI	02
24	Determine reinforcing bar diameter, spacing and cover of the given structural member using NDT equipments and comment on ductile detailing requirement.	VI	02
25	Submit your observations along with your comments on case study of an earthquakes occurred in India by viewing the relevant video/simulation/photographs.	VI	02*
26	Carryout the earthquake simulation for the given type of building structure using software STADDPRO/E-TABS/ABAQUS/ SAP	VI	02
	Total		**48**

Note

*i. A suggestive list of **PrOs** is given in the above table. More such PrOs can be added to attain the COs and competency. A judicial mix of minimum 12 or more practical UOs/tutorials need to be performed, out of which, the practicals marked as '*' are compulsory, so that the student reaches the 'Precision Level' of Dave's 'Psychomotor Domain Taxonomy' as generally required by the industry.*

ii. The 'Process' and 'Product' related skills associated with each PrO is to be assessed according to a suggested sample given below:

S. No.	Performance Indicators	Weightage in %
1	Interpretation of data and its presentation.	10
2	Selection of case studies/ collection of data and its relevance/process followed in analysis, estimate, drawing and interpretation	30
3	Precision in drawing sketches /data collection/ presentation, neatness, cleanliness, relevance with COs	30
4	Individual work and working in groups	20
5	Submission of assigned work in time	10
	Total	**100**

The above PrOs also comprise of the following social skills/attitudes which are Affective Domain Outcomes (ADOs) that are best developed through the laboratory/field based experiences:

a. Follow safety practices.
b. Practice good housekeeping.
c. Work as a leader/a team member.
d. Follow ethical Practices.

The ADOs are not specific to any one PrO, but are embedded in many PrOs. Hence, the acquisition of the ADOs takes place gradually in the student when s/he undertakes a series of practical experiences over a period of time. Moreover, the level of achievement of the ADOs

according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

- 'Valuing Level' in 1st year.
- 'Organization Level' in 2nd year.
- 'Characterization Level' in 3rd year.

7. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

The major equipment with broad specification mentioned here will usher in uniformity in conduct of experiments, as well as aid to procure equipment by administrators.

S. No.	Equipment Name with Broad Specifications	PrOs. S. No.
1	Concrete core cutter	10
2	Rebound Hammer	8
3	Ultrasonic Pulse Velocity Equipment	9
4	Compression Testing Machine, capacity minimum 2000 kN.	10
5	Any design related software such as STAAD Pro/ STRUDS etc.	14

8. UNDERPINNING THEORY COMPONENTS

The following topics/subtopics should be taught and assessed in order to develop UOs in cognitive domain for achieving the COs to attain the identified competency. More UOs could be added.

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
Unit – I Basics of earthquake phenomena	1a. Explain the method of determining the magnitude of the earthquake occurred in the given type of structure in the specified seismic zone. 1b. Classify seismic waves on the basis of given criteria in the given situation. 1c. Select the relevant Seismic zone for the given area using seismic zone map. 1d. Describe the different safety measures required to minimize the damage in the given zone. 1e. Explain the procedure to increase resistance against earthquake of the given building in the given seismic zone.	1.1 Definition and meaning of terms: Focus, Epicenter, Focal depth, foreshocks, aftershocks, magnitude and intensity of Earthquake. Seismic waves, Body waves. 1.2 Natural period, fundamental natural period, nodal natural period, response spectrum, seismic mass, seismic weight, structural response factor, time history analysis, earthquake zones, zone map, zero period acceleration. 1.3 Measurement of earthquake shaking and it's working principle, Richter scale. 1.4 Guidelines for Earthquake preparedness: Individual, Home and community planning.
Unit– II Causes and effects of earthquake	2a Classify the earthquake on the basis of given criteria. 2b Explain the procedure of formation of the earth and movement of tectonic plates for the given earthquake zone. 2c Explain the elastic rebound theory method of determining the	2.1 Causes and effects of earthquake 2.2 Formation of earth and its cores. Formation, types and movement of tectonic plates, Elastic rebound theory, Types of earthquake and Faults. 2.3 Ground shaking, Ground failure,

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
	intensity of earthquake occurred in the specified zone. 2d Compare the given type of failure of building with another type of failure occurred due to earthquakes in the specified zone based on the given criteria.	Tsunami and fire.
Unit III- Planning and design aspects	3a. Establish relationship between mass centers, stiffness from the given data. 3b. Choose correct geometric shapes of the given Buildings to improve its resistance against earthquake with justification. 3c. Select the most relevant site for constructing earthquake resistant building on the basis of the given data of soil strata with justification. 3d. Justify significance of seismic base shear in the design of the given earthquake resistant building in the given zone. 3e. Explain the effect of given geometric shape on the damages due to earthquake for the given zone.	3.1 Terminology for Earthquake resistant Building - Base, base dimensions, centre of mass, centre of stiffness, design eccentricity, design seismic base shear (Vb), diaphragm, storey drift, storey shear, weak storey 3.2 Plan of Building- symmetry, regularity, separation of blocks, simplicity, enclosed area, separate building for different functions, soft storey effect 3.3 Choice of site- Stability of slopes, loose sand
Unit –IV Concrete and masonry buildings	4a. Describe the type of damage occurred in the given type of buildings based on earthquake intensity in the given seismic zone. 4b. Explain the causes of the failure observed in the given type of the building from the given seismic zone. 4c. Correlate damage of building for the given type of masonry building for the given data. 4d. Compare the types of damages before and after earthquake with reference to the given data.	4.1 Typical damage and failure patterns of brick masonry, causes of damages in brick masonry. 4.2 Damage to RCC buildings: Sliding of roof support, falling of infill walls, crushing of column ends, diagonal cracking of column beam joints, pulling out of reinforcement bars, foundation sinking and tilting. 4.3 Typical damage and failure of stone masonry, causes of damages in stone masonry
Unit –V Codal provisions and design philosophy	5a. Explain the relevant provisions of IS codes for construction of earthquake resistant building for the given seismic zone. 5b. Check reinforcement requirements for the given structural element from the given data as per IS:13920-1993. 5c. Explain the relevant method of calculating the base shear for the	5.1 Codal Provision and Design Philosophy : 5.2 IS: 1893 (part I)-2002: General provisions and principles for design of earthquake resistant buildings: Definition of seismic zone factor, Importance factor, damping, critical damping, floor spectra, seismic mass, seismic weight, meaning of soft storey,

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
	given building frames as per relevant IS provision. 5d. Explain the provisions of IS: 4326:1993 to improve seismic behavior of masonry buildings in the given seismic zone. 5e. Integrate the relevant provisions of IS: 13920 in design of earthquake resistant building to be constructed in the given seismic zone.	storey drift, assumptions in earthquake resistant design of structure.(No numerical) 5.3 IS:13920-1993 Ductile detailing, meaning of ductility, need of ductility in concrete structure, critical sections in the building where ductile detailing is required, typical sketches with reinforcement details of columns, beams and beam column connections showing longitudinal steel , splicing of steel, transverse steel, stirrups as per IS:13920. (No numerical) 5.4 Determination of design base shear using equivalent static lateral force method, distribution of design base shear. 5.5 IS:4326:1993 Recommended provisions to improve seismic resistance of buildings earthquake resistance of masonry buildings: mortar, wall enclosure, openings in walls, masonry bond, horizontal bands, section of bands, dowels at corners and junctions, vertical reinforcement in walls
Unit –VI Post-earthquake management	6a. Suggest action plan required to handle the earthquake of building in the given area with justification. 6b. Explain the relevant method for the restoration of the public utility services from the given data in the given area after earthquake. 6c. Explain the process of executing the plan for restoration of the given public utility services in the given area/zone. 6d. Suggest with justification the precautions to be taken in design and construction of earthquake affected zone.	6.1 Post-earthquake handling of building, Lifelines, Roads, Bridges, communication systems, electricity, water distribution systems 6.2 Learning from Prominent past earthquakes in India such as Koyna, Killari(Latur), Jabalpur, Bhuj.

***Note**: To attain the COs and competency, above listed UOs need to be undertaken to achieve the 'Application Level' of Bloom's 'Cognitive Domain Taxonomy'.*

9. SUGGESTED SPECIFICATION TABLE FOR QUESTION PAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Basics of Earthquake Phenomenon	06	02	04	04	10
II	Causes and Effects of Earthquake	08	02	04	06	12
III	Planning and Design Aspects	08	02	04	06	12
IV	Concrete and Masonry Buildings	08	02	04	06	12
V	Codal Provisions and Design Philosophy	10	04	04	08	16
VI	Post-Earthquake Management	08	02	00	06	08
Total		**48**	**14**	**20**	**36**	**70**

Legends: *R=Remember, U=Understand, A=Apply and above (Bloom's Revised taxonomy)*
Note*: This specification table provides general guidelines to assist student for their learning and to teachers to teach and assess students with respect to attainment of UOs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may vary from above table.*

10. SUGGESTED STUDENT ACTIVITIES

Other than the classroom and laboratory learning, following are the suggested student-related ***co-curricular*** activities which can be undertaken to accelerate the attainment of the various outcomes in this course: Students should conduct following activities in group and prepare reports of about 5 pages for each activity, also collect/record physical evidences for their (student's) portfolio which will be useful for their placement interviews:

a) Prepare journals based on practical performed in laboratory/data collection/case studies.
b) Give seminar on relevant topic.
c) Undertake micro-projects.
d) Study any two case studies of past earthquake in Maharashtra.
e) Study any two case studies of past earthquakes in India
f) Study any two case studies of past earthquakes in World
g) Study of minimum earthquake related to magnitude, intensity, epicenter and damages caused.
h) Study of tsunami after earthquake.
i) Indian standard provisions for earthquake resistant structures for your regions.
j) Behavior of old masonry structures during earthquake.
k) Effect of earthquakes on reservoirs/dams.
l) Behavior of steel structures during earthquake.
m) Effect of earthquakes on liquefaction of soils during earthquake.
n) Behavior of buildings with open parking during earthquake.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

These are sample strategies, which the teacher can use to accelerate the attainment of the various learning outcomes in this course:

a) Massive open online courses (***MOOCs***) may be used to teach various topics/sub topics.
b) ***'L' in item No. 4*** does not mean only the traditional lecture method, but different types of teaching methods and media that are to be employed to develop the outcomes.
c) About ***15-20% of the topics/sub-topics*** which is relatively simpler or descriptive in nature is to be given to the students for ***self-directed learning*** and assess the

development of the COs through classroom presentations (see implementation guideline for details).

d) With respect to item No.10, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
e) Guide student(s) in undertaking micro-projects.
f) Demonstrate students thoroughly before they start doing the practice.
g) Encourage students to refer different websites to have deeper understanding of the subject.
h) Observe continuously and monitor the performance of students in Lab.
i) Demonstrate students thoroughly before they start doing the practice.
j) Encourage students to refer different websites to have deeper understanding of the subject.

12. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her in the beginning of the semester. In the first four semesters, the micro-project are group-based. However, in the fifth and sixth semesters, it should be preferably be ***individually*** undertaken to build up the skill and confidence in every student to become problem solver so that s/he contributes to the projects of the industry. In special situations where groups have to be formed for micro-projects, the number of students in the group should ***not exceed three.***

The micro-project could be industry application based, internet-based, workshop-based, laboratory-based or field-based. Each micro-project should encompass two or more COs which are in fact, an integration of PrOs, UOs and ADOs. Each student will have to maintain dated work diary consisting of individual contribution in the project work and give a seminar presentation of it before submission. The total duration of the micro-project should not be less than ***16 (sixteen) student engagement hours*** during the course. The student ought to submit micro-project by the end of the semester to develop the industry oriented COs.

A suggestive list of micro-projects are given here. Similar micro-projects could be added by the concerned faculty:

a) Write 5 to 6 page report with sketches and photographs on case study of any one earthquake occurred in India in past covering following: focal length, focus, intensity, magnitude, natural period, damages occurred in terms of property and lives with reasons, pre earthquake preparation of local administration and post-earthquake handling of situation, lesson learned and corrective measures taken for future.
b) Visit a site of earthquake resistant building construction and prepare a report based on building foundation and RCC work with detailed sketches (only sample members be taken).
c) Visit structural designer's office and collect data about ductile detailing of any one structure in progress.
d) Carry out market survey and collect data of new building materials more suitable for earthquake resistant construction.
e) Visit web site of prominent institutes (IIT Kanpur) having research and development cell on earthquake engineering and prepare a report.
f) Visit seismic data analysis and measurement centre of Government of Maharashtra for your district and prepare a report.
g) 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.
h) Study effect of pure parking space at ground floor without bracing of walls.

13. SUGGESTED LEARNING RESOURCES :

S. No.	Title of Book	Author	Publication
1	Earthquake Resistant Design of Structures	Agarwal, Pankaj Shrikhande, Manish	PHI Learning, Delhi,2011 ASIN: B00K7YFYVE ISBN-13 9788120328921
2	Elements of Earthquake Engineering	Jai Krishna , A. R. Chandrashekharan Chandra, B.	South Asian Publishers Pvt Ltd, Delhi, 2014, ISBN13 9788180142192
3	Earthquake Resistant Design of Structures	Duggal, S. K.	Oxford University Press, Delhi, 2013 ISBN-13 9780198083528

I.S. Codes:

4 IS 1893(Part I):2002 ,Indian Standard Criteria for Earthquake Resistant Design of Structures- General Provisions and Buildings , BIS, New Delhi.
5 IS 13920:1993 Ductile Detailing of Reinforced Concrete Structures subjected to Seismic forces-Code of Practice, BIS, New Delhi.
6 IS 456:2000 - Plain and Reinforced concrete code of Practice
7 I.S. 875 (Part 1-5) - 1987 code of practice of design loads for Buildings and structures
8 IS 13935- Repair and seismic strengthening of building: Guidelines
9 IS 4326-1993 Earthquake resistant design and construction of buildings
10 IITK-BMTPC Earthquake Tips- IIT Kanpur
11 A CD on Earthquake Engineering- An ICJ Compilation

14. SOFTWARE/LEARNING WEBSITES

a) www.nptel.ac.in
b) https://youtu.be/uBMqJMXhs4M
c) https://youtu.be/n0_LNyfQTJg
d) https://youtu.be/DR_PQyYMaA0
e) www.tn.gov.in/tsunami/digitallibrary/ebooks
f) https://www.nicee.org/EQTips.php