Roll No.												

PRESIDENCY UNIVERSITY
BENGALURU

SCHOOL OF ENGINEERING

TEST – 1

Sem & AY: Odd Sem. 2019-20
Course Code: CIV 310
Course Name: ELEMENTS OF EARTHQUAKE ENGINEERING
Program & Sem: B.Tech (Civil) & VII DE

Date: 27.09.2019
Time: 9:30AM to 10:30AM
Max Marks: 40
Weightage: 20%

Instructions:

(i) *Read the question properly and answer accordingly.*
(ii) *Write legibly and draw clear diagrams wherever required.*
(iii) *Diagrams to be drawing using a pencil and scale only. Pen diagrams will be penalized.*
(iv) *Scientific and non-programmable calculators are permitted.*

Part A (Memory Recall Questions)

Answer all the Questions. Each question carries four marks. (3Qx4M=12M)

1. What are the inputs required to evaluate seismic risk? (C.O.NO.1) [Knowledge]

2. What are the different types of tectonic plate boundary? (C.O.NO.1) [Knowledge]

3. What is the classification of earthquake based on magnitude?

(C.O.NO.1) [Knowledge]

Part B (Thought Provoking Questions)

Answer all the Questions. Each question carries eight marks. (2Qx8M=16M)

4. Write a short note on seismic waves. (C.O.NO.1) [Knowledge]

5. For the plan shown in Figure 1, locate the center of mass.

(C.O.No.2) [Comprehension]

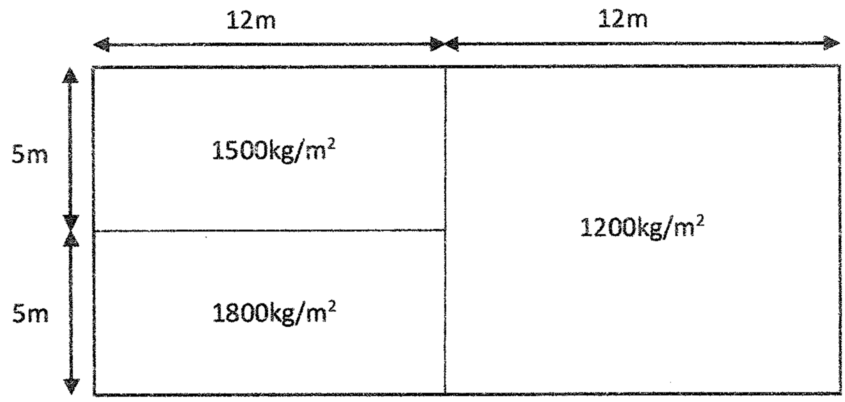


Figure 1

Part C (Problem Solving Questions)

Answer the Question. The Question carries twelve marks. **(1Qx12M=12M)**

6. Explain the Elastic Rebound Theory with neat sketches.

(C.O.NO.2) [Comprehension]

SCHOOL OF ENGINEERING

Semester: VII

Course Code: CIV 310

Course Name: Elements of Earthquake Engineering

Date: 27 September, 2019

Time: 9:30am to 10:30am

Max Marks: 40

Weightage: 20%

Extract of question distribution [outcome wise & level wise]

Q.NO.	C.O.NO	Unit/Module Number/Unit /Module Title	Memory recall type [Marks allotted] Bloom's Levels	Thought provoking type [Marks allotted] Bloom's Levels		Problem Solving type [Marks allotted]	Total Marks
			K	K	C	C	
1	1	1	4	-	-	-	4
2	1	1	4	-	-	-	4
3	1	1	4	-	-	-	4
4	1	1	-	8	-	-	8
5	2	2	-	-	8	-	8
6	2	2	-	-	-	12	12
	Total Marks		12	8	8	12	40

Note: While setting all types of questions the general guideline is that about 60%

Of the questions must be such that even a below average students must be able to attempt, About 20% of the questions must be such that only above average students must be able to attempt and finally 20% of the questions must be such that only the bright students must be able to attempt.

[I hereby certify that All the questions are set as per the above guide lines. Ms. Anju Mathew]

Reviewers' Comments

Annexure- II: Format of Answer Scheme

SCHOOL OF ENGINEERING

Semester: VII

Course Code: CIV 310

Course Name: Elements of Earthquake Engineering

Date: 27 September, 2019

Time: 9:30am to 10:30am

Max Marks: 40

Weightage: 20%

Part A

(3Q x 4M = 12Marks)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
1	Seismological Inputs: Seismic zones and acceleration response spectrum. Geological Inputs: Rock type, active faults, type of fault displacement, landslide flood and tsunami histories. Soil Engineering Inputs: Liquefaction potential of soil, soil strata and ground water table, stability of slope, settlement	4 M	**5 min**
2	Divergent Boundaries Convergent Boundaries - Oceanic-Continental boundary - Oceanic-Oceanic Boundary - Continental-Continental Boundary Transform Boundaries	4 M	**5 min**
3	Micro earthquake < 3.0 b. Intermediate earthquake 3 – 4.9 c. Moderate earthquake 5 – 5.9 d. Strong earthquake 6 – 6.9 e. Major earthquake 7 – 7.9 f. Great earthquake > 8	**2 + 2 = 4M**	**10 min**

Part B

(2Q x 8M = 16 Marks)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
4	**1. Body Waves** Body Waves travel through the interior of the Earth. There are two types of body waves: a. P-Waves (primary, longitudinal or compressional waves)	4 + 4 = 8M	15 min

In P-waves, the material particles oscillate back and forth in the direction of propagation of wave and cause alternate compression and tension of the medium. This results in momentary volume change in the material through which they pass. It is the fastest type of seismic wave. It can travel through any medium.

<u>b. S-Waves (secondary, transverse or shear waves)</u>

In S-waves, the material particles oscillate at right angles to the direction of propagation of the wave, and cause shear deformation in the material. It can further be classified as SV (vertical plane movement) and SH (horizontal plane movement) depending on the direction of propagation. Velocity of S-wave is proportional to the shear strength of the material through which it passes. It does travel through liquids as liquids have no shear strength. It causes maximum damage.

<u>2. Surface Waves</u>

Surface Waves travel through the surface layers of the Earth. There are two types of surface waves:

<u>a. Rayleigh Waves</u>

Rayleigh waves make material particles oscillate in an elliptical path in the vertical plane with horizontal motion along the direction of energy transmission. It is produced by an interaction between P and SV waves on the earth's surface.

<u>b. Love Waves</u>

Love waves are similar to S-waves without the vertical component. The particle motion occurs in a horizontal plane perpendicular to the direction of motion. Love waves are trapped inside a soil layer with multiple reflections. The combination of Love waves and SH waves causes the maximum damage during an earthquake.

5	$X = \frac{(5\times12\times1500\times6)+(5\times12\times1800\times6)+(10\times12\times1200\times18)}{(5\times12\times1500)+(5\times12\times1800)+(10\times12\times1200)} = 11.05m$ $X = \frac{(5\times12\times1500\times7.5)+(5\times12\times1800\times2.5)+(10\times12\times1200\times5)}{(5\times12\times1500)+(5\times12\times1800)+(10\times12\times1200)} = 4.86m$	4 + 4 = 8M	10 min

Part C

(Q x M = Marks)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
6	**1. <u>Elastic Rebound Theory</u>** The high pressure and temperature gradients between the crust and the core cause convection currents to develop in the mantle. The	10 M Fig = 2 M	25 min

convective flow of the mantle causes the crust and some portion of the mantle to slide on the hot molten outer core. Therefore, the earth's crust is always in motion. It consists of several gigantic rock plates called tectonic plates. These plates move laterally and push against their margins creating earthquake faults.

The origin or causes of tectonic earthquakes are explained by Elastic Rebound Theory. It was first proposed by M.F. Reid in 1906. According to this theory, when the tectonic plates strike against each other along the fault, further movement is prevented due to friction. But this leads to development of stresses along the fault. When the elastic limit is reached over time, a slip occurs at the fault, releasing stored energy in the form of seismic waves which leads to earthquakes. The maximum shaking effect is felt along the fault or plate boundaries. The earthquakes occurring along the plate boundaries are called interplate earthquakes and ones occurring within the plates away from the boundaries are known as intraplate earthquakes. Slips generated at the fault in both horizontal and vertical directions are known as dip slip and the lateral direction is known as strike slip.

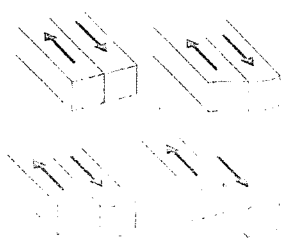


Fig 1: Elastic Rebound Theory (Strike Slip)

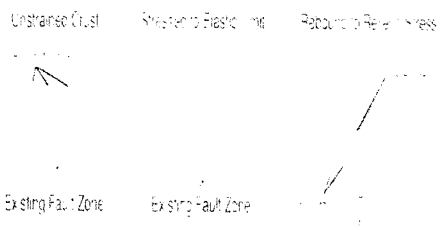


Fig 2: Elastic Rebound Theory (Dip Slip)

The probability of an earthquake is more likely along the fault with no seismic activity in recent times because it takes time for the rocks to develop stresses and reach elastic limit. By plotting fault movements and historical earthquake activities, most probable location of an earthquake can be located.

Roll No.													

PRESIDENCY UNIVERSITY
BENGALURU

SCHOOL OF ENGINEERING

TEST – 2

Sem & AY: Odd Sem 2019-20
Date: 16.11.2019
Course Code: CIV 310
Time: 9:30 AM to 10:30 AM
Course Name: ELEMENTS OF EARTHQUAKE ENGINEERING
Max Marks: 40
Program & Sem: B.Tech (Civil), VII
Weightage: 20%

Instructions:

(i) *Read the question properly and answer accordingly.*
(ii) *Write legibly and draw clear diagrams wherever required.*
(iii) *Diagrams to be drawing using a pencil and scale only. Pen diagrams will be penalized.*
(iv) *Scientific and non-programmable calculators are permitted.*
(v) *Use of IS1893 (Part 1): 2016 is permitted.*

Part A [Memory Recall Questions]

Answer both the Questions. Each Question carries eight marks. (2Qx8M=16M)

1. Explain any 2 lateral load resisting system with neat sketch. [8 M]

(C.O.NO.2) [Comprehension]

2. Explain the different horizontal irregularities affecting the seismic performance of the structure. [8 M]

(C.O.NO.2) [Comprehension]

Part B [Thought Provoking Questions]

Answer the Question. The Question carries twelve marks. (1Qx12M=12M)

3. A four-storey RCC residential building have seismic weight $W_1 = W_2 = W_3 = 4200kN$ and W_4 (roof) = 3000kN. The storey height for ground floor is 4.2m and for all the other floors is 3.2m. The building is located in seismic zone IV. The type of soil encountered is hard and it is proposed to design the building with a special moment resisting frame without infill. Determine the design seismic loads on each floor of the structure by static analysis. (C.O.NO.3) [Application]

Part C [Problem Solving Questions]

Answer the Question. The Question carries twelve marks. **(1Qx12M=12M)**

4. Analyse the building in question 3 using dynamic analysis and find the lateral force distribution, given that

	Mode 1
Time Period	0.86
Mode Shape	
Storey 4	1
Storey 3	0.904
Storey 2	0.716
Storey 1	0.441

(C.O.NO.3) [Application]

SCHOOL OF ENGINEERING

GAIN MORE KNOWLEDGE
REACH GREATER HEIGHTS

Semester: VII

Course Code: CIV 310

Course Name: Elements of Earthquake Engineering

Date: 16 November, 2019

Time: 9:30am to 10:30am

Max Marks: 40

Weightage: 20%

Part A (2Q x 8M = 16Marks)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
1	rigidly connected. It is a necessity to ensure the predictable and well-thought-out path of the resistance [illegible] the lateral forces in a structural system. Following are the lateral load-resisting structural systems in practice: (a) Special moment-resisting frame (SMRF); (b) shear wall structure; (c) braced frame; (d) shear wall frame interactive system (dual structural system); (e) coupled shear wall system; (f) frame-tube system; (g) outrigger braced shear wall system. We will discuss them one by one. **3.5.3.1 Special Moment-Resisting Frames** These are skeletal beam–column structural frames indicated in Fig. 7(a) where the inelastic deformability [illegible] achieved by specially detailing the beams, columns and the beam–column joints. Special moment-resisting frames (SMRFs) resist the lateral seismic forces predominantly by the flexural action of its structural members. The structural detailing in such moment-resisting frames must ensure the flexural yielding [illegible] failure) of frame members prior to shear (brittle) failure. The sum of design flexural strength of columns [illegible] joint is to be greater (at least 20% greater) than the sum of design flexural strength of beams, to ensure [illegible] *column–weak beam* philosophy of SMRFs. Architects prefer this type of structure as it does not [illegible] with the functional utility of the building. Although the moment-resisting frame is an efficient [illegible] under the action of gravity forces, it requires special attention under the action of lateral forces. [illegible] lateral stiffness of this structural system is comparatively less than the other structural systems, namely [illegible] braced and shear wall systems, the lateral deflections are relatively large. **3.5.3.2 Shear Walls** The RCC structural walls are referred to as shear walls as indicated in Fig. 7(b), because being very stiff [illegible] resist most of the lateral shear forces due to earthquake and reduce the lateral displacements. The floor [illegible] are rigidly connected to the RCC shear walls so that these act as diaphragms resisting axial (compression [illegible] tension) forces at the edges. The shear stresses are distributed in the entire diaphragm. The shear walls [illegible] generally located symmetrically and in both the directions in the plan of the structure so as to avoid [illegible] least to minimize the torsional forces. It is now an established fact that stiffer structures attract larger seismic forces; hence the stronger [illegible] stiffer buildings need to dissipate or absorb more earthquake energy. Practically, such buildings can [illegible] short duration earthquakes (say 15-s duration) very efficiently. **3.5.3.3 Braced Frames** These are the structural frames with trusses as bracing elements indicated in Fig. 7(c), and they resist lateral forces predominantly with members in tension or compression. In this system, diagonal braces are provided in the selected or all bays of the building. Diagonals stretch across the bay to form triangulated vertical frame. Braced frames are subjected to predominantly axial stresses and, therefore, are able to handle stresses better than a rectangular moment-resisting frame. The structure with braced frames is supposed to perform better. Braces can be configured as diagonals (X) or even V-shaped. Braces are of two types, concentric and eccentric. Concentric braces connect at the beam–column intersection, whereas eccentric braces connect to the beam at some distance away from the beam–column intersection. These structures with braced frames increase the lateral strength and also the stiffness of the structural system and hence reduce the drift. **3.5.3.4 Shear Wall–Frame Interactive System (Dual Structural System)** This is a structural system that combines the gravity-load-carrying efficiency of the frame and the lateral load-resisting ability of the shear wall. The frames may be of reinforced concrete or steel with semi-rigid or rigid joints. The reinforced concrete walls are rigid and are capable of acting as shear wall. This system	Each type with sketch = 4 M (2*4 = 8M)	**10 min**

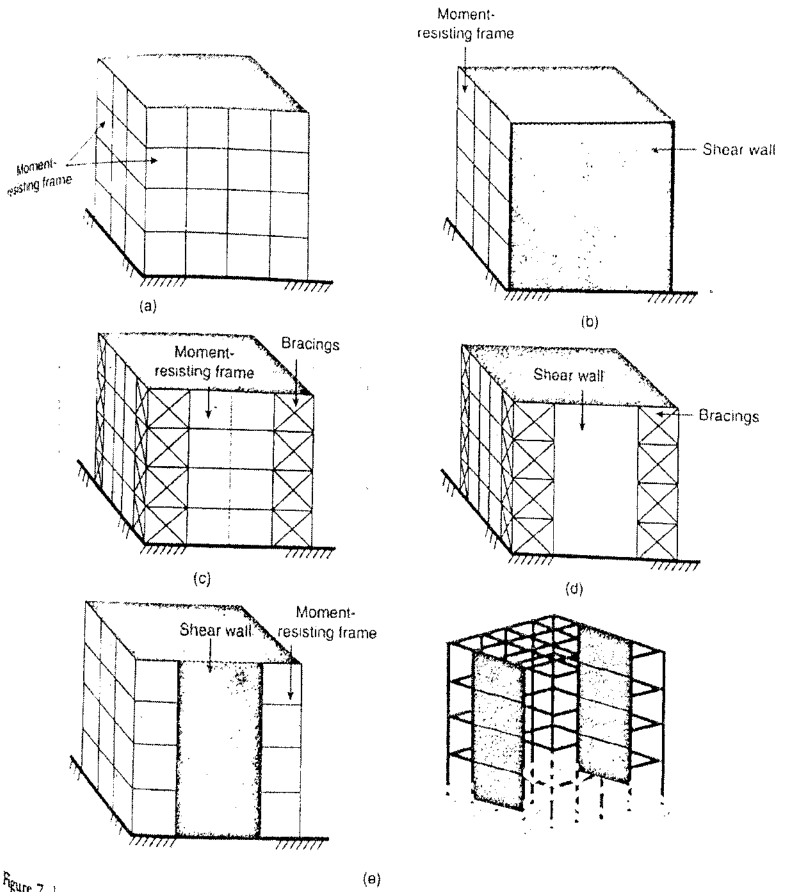
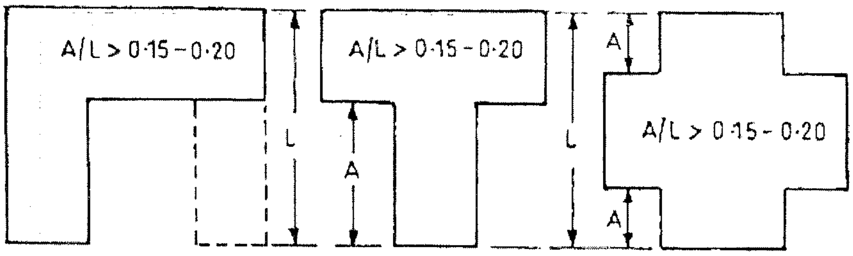
<table>
<tr><td></td><td>Shown in Fig. ... is considered as the best structural system for reinforced concrete multi-storey structures in regions of high seismicity. The main advantage of the system is the layout of shear walls which may be planned to provide flexibility of interior space and at the same time provide adequate rigidity and lateral load resistance. The greater share, to the extent of 75% of lateral force, may be assigned to the shear walls so that the structural frame elements may be designed for the remaining small share of 25% of the lateral forces due to earthquake. This sharing of lateral forces between the moment-resisting frame system and the shear wall system is in accordance with their relative stiffnesses.


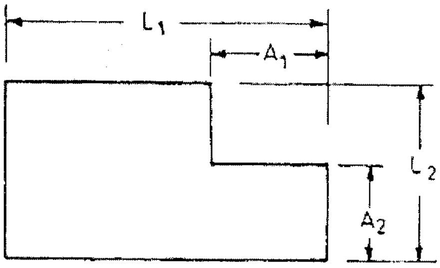
Figure 7 Lateral load-resisting structural systems. (a) Special moment-resisting frame. (b) Shear wall structure. (c) Braced: moment-resisting frame. (d) Shear wall: braced frame. (e) Shear wall: moment-resisting frames.</td><td></td><td></td></tr>
<tr><td>2</td><td><u>1. Torsional Irregularities</u>

Torsion or twisting of building occurs due to eccentricity in its center of mass and center of stiffness. This can be explained using a swing analog. Generally occurs in case of unequal distribution of mass throughout one floor, unequal length of column and unsymmetrical plan. Best way to prevent torsion is to provide a symmetrical plan.

<u>2. Re-entrant Corners</u>

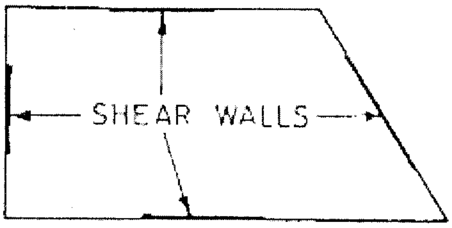
A re-entrant or inside corner which is common in the case of an L, T, H, + etc. is not preferred in case of earthquakes. If both the projections beyond the re-entrant corner is greater than 15% of its plan dimension in a given direction is subjected to two types of problems: stress concentration at the notch due to difference in rigidity hence differential motion; and torsion.</td><td>4*2 = 8M</td><td>10 min</td></tr>
</table>





3. Non-parallel System

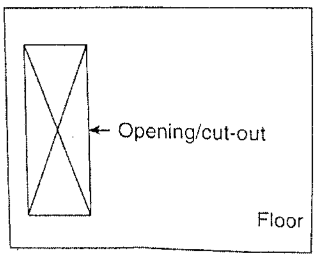
When the vertical load resisting elements are not parallel or symmetrical about a major orthogonal axis. This may lead to torsion in buildings because the center of mass and rigidity will not coincide. The narrower the corner, more the torsion.



BUILDING PLAN

4. Diaphragm Discontinuity

When the floor slab has an opening of more than 50% of its total area. This will decrease its stiffness and reduce its load carrying capacity.



Part B

(1Q x 12M = 12 Marks)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
3	Z = 0.24 I = 1 R = 5 W = 3x4200 + 3000 = 15600kN $T_a = 0.075 \text{ x } 13.8^{0.75} = 0.537s$ $S_a/g = 1/0.537 = 1.862$ $A_h = \frac{\frac{Z}{2} x \frac{Sa}{g}}{\frac{R}{I}} = 0.045$ $V_B = 0.045x15600 = 702kN$ $Q_i = \left(\frac{W_i h_i^2}{\sum W_j h_j^2}\right) V_B$ Q4 = 297.68kN Q3 = 245.88kN Q2 = 119.83kN Q1 = 38.6kN	Z = 1 M I = 1 M R = 1 M W = 1 M A_h = 3 M V_B = 1 M Q = 4 M	20 min

Part C

(1Q x 12M = 12 bMarks)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
4	$M_k = \frac{\left[\sum_{i=1}^{n} W_i \phi_{ik}\right]^2}{g\sum_{i=1}^{n} W_i (\phi_{ik})^2}$ M = 14450.36/g kN $P_k = \frac{\sum_{i=1}^{n} W_i \phi_{ik}}{\sum_{i=1}^{n} W_i (\phi_{ik})^2}$ P = 1.24 $Q_{ik} = A_k \phi_{ik} P_k W_i$ T = 0.86 $S_a/g = 1/0.86 = 1.16$ A = 0.0278 Q4 = 103.5kN Q3 = 131kN Q2 = 103.8kN Q1 = 63.9kN V4 = 103.5kN V3 = 234.6kN V2 = 338.4kN V1 = 402.3kN	M = 2 M P = 1 M A = 1 M Q = 4 M V = 4 M	20 min

Roll No											

GAIN MORE KNOWLEDGE
REACH GREATER HEIGHTS

PRESIDENCY UNIVERSITY
BENGALURU

SCHOOL OF ENGINEERING

END TERM FINAL EXAMINATION

Semester: Odd Sem. 2019 - 20 | **Date**: 20 December 2019

Course Code: CIV 310 | **Time**: 9:30 AM to 12:30 PM

Course Name: ELEMENTS OF EARTHQUAKE ENGINEERING | **Max Marks**: 80

Program & Sem: B.Tech (CIV), VII (DE-III) | **Weightage**: 40%

Instructions:

(i) Read the all questions carefully and answer accordingly.
(ii) Write legibly and draw clear diagrams wherever required.
(iii) Scientific and non-programmable calculators are permitted.
(iv) Use of IS1893 (Part 1): 2016 and IS 13920: 1993 is permitted.

Part A [Memory Recall Questions]

Answer all the Questions. Each Question carries 05 marks. **(4Qx5M=20M)**

1. What are the various damage potential of an earthquake? (C.O.No.1) [Knowledge]

2. What will be the design horizontal seismic coefficient for a structure for Agra Railway Station, Uttar Pradesh constructed of steel ordinary moment resisting frame, if the time period in static analysis was found to be 0.7 seconds for soft soil? (C.O.No.3) [Application]

3. List the various lateral load resisting systems. (C.O.No.2) [Knowledge]

4. What is the performance criteria considered for an earthquake resistant design?

(C.O.No.3) [Application]

Part B [Thought Provoking Questions]

Answer all the Questions. Each Question carries 10 marks. **(3Qx10M=30M)**

5. Design the confining reinforcement for a column of diameter 500mm. Assume M25 concrete and Fe415 steel. (C.O.No.3) [Application]

6. What are the requirements of an efficient earthquake resistant structural system?

(C.O.No.2) [Comprehension]

7. Locate the center of mass for the plan shown in figure 1. The mass on the whole floor is 1100kg/m^2. (C.O.No.1) [Knowledge]

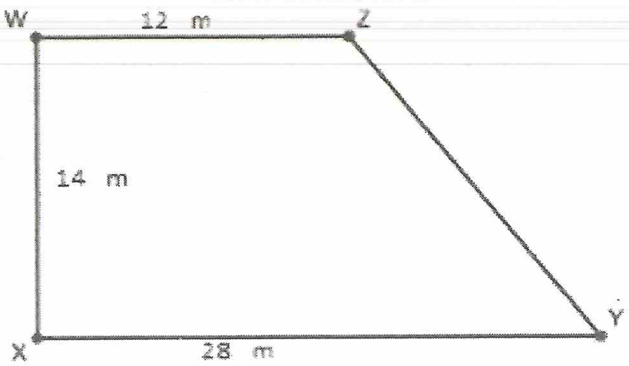


Figure 1

Part C [Problem Solving Questions]

Answer both the Questions. Each Question carries 15 marks. (2Qx15M=30M)

8. A three-storey RCC school building has a plan area of 8m x 8m and the typical storey height is 3.5m. The building is located in seismic zone V. The type of soil encountered is medium stiff and it is proposed to design the building with a special moment resisting frame with infill. The intensity of DL is 10 kN/m^2 and LL is 3 kN/m^2 on all floors. Determine the design seismic loads on each floor of the structure by dynamic analysis. (C.O.No.3) [Application]

	Mode 1
Time Period	0.533
Mode Shape	
Storey 3	1
Storey 2	0.81
Storey 1	0.45

9. Explain the general and ductile detailing for longitudinal and transverse reinforcement as per IS13920: 1993 for flexural members with neat sketches. (C.O.No.3) [Application]

SCHOOL OF ENGINEERING

GAIN MORE KNOWLEDGE
REACH GREATER HEIGHTS

END TERM FINAL EXAMINATION

Extract of question distribution [outcome wise & level wise]

Q.NO.	C.O.NO (% age of CO)	Unit/Module Number/Unit /Module Title	Memory recall type [Marks allotted] Bloom's Levels	Thought provoking type [Marks allotted] Bloom's Levels	Problem Solving type [Marks allotted]	Total Marks
			K	C	A	
1	1	1	5			5
2	3	3			5	5
3	2	2		5		5
4	1	1			5	5
5	3	3			10	10
6	1	1	10			10
7	2	2		10		10
8	3	3			15	15
9	3	3			15	15
	Total Marks		20	15	45	80

K =Knowledge Level C = Comprehension Level, A = Application Level

Note: While setting all types of questions the general guideline is that about 60%

Of the questions must be such that even a below average students must be able to attempt, About 20% of the questions must be such that only above average students must be able to attempt and finally 20% of the questions must be such that only the bright students must be able to attempt.

I hereby certify that all the questions are set as per the above guidelines.

Faculty Signature:

Reviewer Commend:

Format of Answer Scheme

SCHOOL OF ENGINEERING

GAIN MORE KNOWLEDGE
REACH GREATER HEIGHTS

SOLUTION

Semester: Odd Sem. 2019-20
Course Code: CIV 310
Course Name: Elements of Earthquake Engineering
Program & Sem: B.Tech (Civil), VII Semester

Date: 20.12.2019
Time: 3 HRS
Max Marks: 80
Weightage: 40%

Part A (4Q x 5M = 20Marks)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
1	1. By inertial forces generated in the structures due to severe ground shaking. 2. By changes in the physical properties of the foundation soil (e.g. consolidation, settlements and liquefaction) causing damages to buildings 3. By direct fault displacement at the site of a structure, causing damages to roadways, railways, bridges and dams. 4. By landslides, slope instability or other movements of soil mass on the surface of the earth. 5. By seismically induced water waves such as tsunamis and fluid motions in reservoirs and lakes.	**1 x 5 = 5**	**10 min**
2	$A_h = \frac{\frac{Z}{2} x \frac{Sa}{g}}{\frac{R}{I}}$ Z = 0.16 R = 3 I = 1.5 $S_a/g = 1.67/0.7 = 2.38$ $A_h = 0.0952$	**Z = 1** **R = 1** **I = 1** **S_a/g = 1** **A_h = 1**	**20 min**
3	1. Special Moment-Resisting Frames 2. Shear Wall 3. Braced Frame 4. Shear Wall-Frame System (Dual Structural System) 5. Coupled Shear Wall System 6. Framed-Tube Structure	**1 x 5 = 5**	**10 min**

	7. Outrigger Braced Shear Wall System		
4	The structure should resist 1. minor earthquakes without damage 2. moderate earthquakes with minor structural or some non-structural damage 3. major earthquake without collapse	**5**	**10 min**

Part B (3Q x 10M = 30 Marks)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
5	Spacing = (1/4) x 500 = 125mm Take spacing S = 100 mm Assume 10mm dia circular hoop and cover of 40mm Dia of core = 500 – (2x40) +(2x10) = 440mm Ag = 196349.54mm^2 Ak = 152053.08mm^2 $A_{sh} = 0.09\, S D_k \frac{f_{ck}}{f_y}\left[\frac{A_g}{A_k} - 1.0\right]$ Ash = 69.49mm^2 Provide 10mm at 100 mm c/c.	S = 2 D_k = 3 A_g = 1 A_k = 1 A_{sh} = 3	25 min
6	$\overline{X} = \frac{(1100\times12\times14\times6)+(1100\times0.5\times14\times16\times17.33)}{(1100\times12\times14)+(1100\times0.5\times14\times16)}$ $= 10.53m$ $\overline{Y} = \frac{(1100\times12\times14\times7)+(1100\times0.5\times14\times16\times4.66)}{(1100\times12\times14)+(1100\times0.5\times14\times16)}$ $= 6.06m$	X = 5 Y = 5	15 min
7	1. The building and its superstructure should be simple, symmetrical and regular in plan and elevation to prevent torsion forces. The simplicity of the structural form improves the predictability of the seismic performance. Torsional forces result if the center of rigidity of the structure does not coincide with the center of mass. Larger the eccentricity, larger will be the torsional force. 2. The building and its superstructure should have uniform and continuous distribution of mass, stiffness, strength and ductility to avoid stress concentrations at discontinuities. The building should have a good lateral load resisting system and direct load path without discontinuity. 3. The different elements of the superstructure and substructure should be rigidly connected so that they can work as a single unit. 4. The superstructure should have compatible strength and stiffness between the members, connections supporting foundation and soil.	All 8 points = 1 x 8 = 8 Explanation = 2 8+2 = 10	20 min

	5. The superstructure should be detailed for adequate ductility so that the deformations can be constrained (controlled) to desired regions. The seismic energy is dissipated by yielding if these members. 6. The building should be light and should avoid unnecessary masses. Larger the mass, larger the seismic (inertia) forces. 7. It is preferable not to have high height to width ratio to avoid large drift. 8. The superstructure should not have large cantilevers to avoid large deflections.		

Part C (2Q x 15M = 30Marks)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
8	Z = 0.36 I = 1.5 R = 5 W1=W2 = 8x8x(10+0.25x3) = 688kN W3 = 8x8x10 = 640kN W = 2x688 + 640 = 2016kN $M_k = \frac{\left[\sum_{i=1}^{n} W_i \phi_{ik}\right]^2}{g\sum_{i=1}^{n} W_i (\phi_{ik})^2}$ M = 1845.1/g kN $P_k = \frac{\sum_{i=1}^{n} W_i \phi_{ik}}{\sum_{i=1}^{n} W_i (\phi_{ik})^2}$ P = 1.22 $Q_{ik} = A_k \phi_{ik} P_k W_i$ T = 0.533 S_a/g = 2.5 A = 0.225 Q1 = 175.68kN Q2 = 152.97kN Q3 = 84.98kN V1 = 175.68kN V2 = 328.65kN V3 = 413.63kN	Z = 1 M I = 1 M R = 1 M W = 2 M M = 2 M P = 1 M A = 2 M Q = 3 M V = 2 M	35 min
9	**6.1.1** The factored axial stress on the member under earthquake loading shall not exceed 0.1 *f*ck.	General = 5 Longitudinal = 5	35 min

	6.1.2 The member shall preferably have a width-to-depth ratio of more than 0.3. **6.1.3** The width of the member shall not be less than 200 mm. **6.1.4** The depth D of the member shall preferably be not more than 1/4 of the clear span. **6.2 Longitudinal Reinforcement** **6.2.1** a) The top as well as bottom reinforcement shall consist of at least two bars throughout the member length. b) The tension steel ratio on any face, at any section, shall not be less than ρmin = 0.24 ; where *f*ck and *f*y are in MPa. **6.2.2** The maximum steel ratio on any face at any section, shall not exceed ρmax = 0.025. **6.2.3** The positive steel at a joint face must be at least equal to half the negative steel at that face. **6.2.4** The steel provided at each of the top and bottom face of the member at any section along its length shall be at least equal to one-fourth of the maximum negative moment steel provided at the face of either joint. It may be clarified that redistribution of moments permitted in IS 456 : 1978 (clause **36.1**) will be used only for vertical load moments and not for lateral load moments. **6.2.5** In an external joint, both the top and the bottom bars of the beam shall be provided with anchorage length, beyond the inner face of the column, equal to the development length in tension plus 10 times the bar diameter minus the allowance for 90 degree bend(s) (*see* Fig. 1). In an internal joint, both face bars of the beam shall be taken continuously through the column. **6.2.6** The longitudinal bars shall be spliced, only if hoops are provided over the entire splice length, at a spacing not exceeding 150 mm (*see* Fig. 2). The lap length shall not be less than the bar development length in tension. Lap splices shall not be provided (a) within a joint, (b) within a distance of 2*d* from joint face, and (c) within a quarter lengh of the member where flexural yielding may generally occur under the effect of earthquake forces. Not more than 50 percent of the bars shall be spliced at one section. **6.2.7** Use of welded splices and mechanical connections may also be made, as per **25.2.5.2**	Transverse = 5	

	of IS 456 : 1978. However, not more than half the reinforcement shall be spliced at a section where flexural yielding may take place. The location of splices shall be governed by **6.2.6**. **6.3 Web Reinforcement** **6.3.1** Web reinforcement shall consist of vertical hoops. A vertical hoop is a closed stirrup having a 135° hook with a 10 diameter extension (but not < 75 mm) at each end that is embedded in the confined core (*see* Fig. 3a). In compelling circumstances, it may also be made up of two pieces of reinforcement; a U-stirrup with a 135° hook and a 10 diameter extension (but not < 75 mm) at each end, embedded in the confined core and a crosstie (*see* Fig. 3b). A crosstie is a bar having a 135° hook with a 10 diameter extension (but not < 75 mm) at each end. The hooks shall engage peripheral longitudinal bars. **6.3.2** The minimum diameter of the bar forming a hoop shall be 6 mm. However, in beams with clear span exceeding 5 m, the minimum bar diameter shall be 8 mm. **6.3.3** The shear force to be resisted by the vertical hoops shall be the maximum of : a) calculated factored shear force as per analysis, and b) shear force due to formation of plastic hinges at both ends of the beam plus the factored gravity load on the span. This is given by (*see* Fig. 4): inclined hoops to shear resistance of the section shall not be considered. **6.3.5** The spacing of hoops over a length of 2d at either end of a beam shall not exceed (a) d/4, and (b) 8 times the diameter of the smallest longitudinal bar; however, it need not be less than 100 mm (*see* Fig. 5). The first hoop shall be at a distance not exceeding 50 mm from the joint face. Vertical hoops at the same spacing as above, shall also be provided over a length equal to 2d on either side of a section where flexural yielding may occur under the effect of earthquake forces. Elsewhere, the beam shall have vertical hoops at a spacing not exceeding d/2.		