BIRLA INSTITUE OF TECNOLOGY & SCIENCE, PILANI
SECOND SEMESTER, 2021-2022
COMPREHENSIVE EXAMINATION
CE G615 EARTHQUAKE ENGINEERING

Time: 180 min. Date: 19-05-2022 Maximum Marks:35 Weightage:35%

Note: Part A is closed book and Part B is closed book, IS Codes and formula sheets allowed. Part A and Part B must be written on separate answer sheets. You can start Part B after submission of Part A only.

PART A (CLOSED BOOK)

Q1. IS:1893 Part 1: 2016 specifies 5% damping ratio for concrete, steel, or masonry buildings. But Steel as a material exhibits lower (2%) damping than concrete/ masonry and therefore, different damping should be specified for three types of building materials as specified in IS 1893-part 2, 4. However, as per IS 16700-2017, article 6.2.2.4 (page 6) "the damping ratio considered shall not be greater than 2 percent of critical for concrete buildings". Other IS 1893 codes are recommending 2% for steel structure. Which one is correct? Are these codes contradicting each other? Explain. Can we have less than 1% damping ratio for all type of structure during earthquake analysis, if yes provide details/ explain? Can we have damping of concrete structures more than 5%, explain? **[3 marks]**

Q2. Do you think screening criterion for liquefaction given in IS1893-part1-2016 are appropriate? If not, what would be suggested modification according to recent developments, explain? **[2 Marks]**

Q3. Define response spectrum. Draw neat sketches of spectra given in IS1893-part1. On what basis you can use response spectra of SDOF system to find response of MDOF system, explain. **[2 Marks]**

Q4. Why allowable soil pressure (determined as per IS code of practices for static loads) is increased upto 50% as per IS1893-part1-2016, when considering dynamic forces such as due to earthquake in addition to dead load and imposed load? Dynamic bearing capacity (due to earthquake loading) of soil is less or more compare to static bearing capacity? and why? As per IS: 2974 (Part I) – 1982, soil stress below the machine foundations shall not exceed 80 percent of the allowable stress. Are these two codes (IS1893-Part1 and IS:2974) contradicting each other? Explain by numerical example to justify specific percentage increase or decrease in allowable soil pressure. **[3 marks]**

Q5. Soil/ site classification A, B, C and Type I, II, III are respectively same or different given in IS 1893-1:2016 and why? What is the need/ application of these soil/ site classification, explain and justify your answer? **[2 Marks]**

Q6. Identify the following statements are true or false, and justify your answer (No marks without correct justification).

(a) The Seismic force acting on the vehicular live load plying over the bridge is not considered when the seismic force acts in the direction of traffic.
(b) For the EQ-resistant design of bridges, the piers are designed and the reinforcement is detailed with the intention that a plastic hinge may develop at the mid-height of a pier.
(c) The sloshing wave effect in the water tank is associated with the impulsive mode of vibrations.
(d) The two-mass spring model is used for tanks resting ground as well as for the elevated water tanks.

[4x1 = 4]

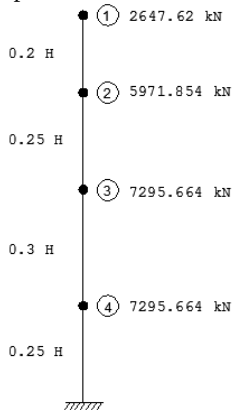
PART B (CLOSED BOOK) IS Codes and formula sheets are allowed
You can start Part B after submission of Part A only in separate answer sheet.

Q1. For a three-storey masonry building in Zone V (A_h=0.12), find the design force for tie beam for two isolated footing for two columns (Column 1 load 1000 kN, Column 2 load = 700 kN). What are the shortcomings in design of tie beams in Indian seismic codes? Discuss. **[2 marks]**

Q2. A hill road gravity retaining wall 8 m high is inclined 12° (towards the backfill) to vertical and retains a horizontal dry cohesionless backfill subjected a surcharge of 20 kPa. Backfill properties are, γ = 20 kN/m3, Φ' = 38°, c'=0. Find all components of static and seismic earth pressure with point of application for wall in seismic zone IV. Draw neat sketches. Use IS-1893-(Part3) 2014 and IRC6-2017. **[3 Marks]**

Q3. A 200 kN equipment with low deformability elements is to be installed on the 6th floor of a ten storey building at Coimbatore, India. It is attached by four anchored bolts, one at each corner of the equipment, embedded in a concrete slab. Floor to floor height of the building is 3.3. The height of the center of gravity of the equipment from the supporting floor is 0.5 m and width of the equipment is 1.5 m. Determine the shear and tension demands on the anchored bolts during earthquake shaking. Use IS 16700-2017. **[2.5 Marks]**

Q4. A RCC Chimney 130m high has a uniform cross section Ac = 8.16m^2 and Moment of Inertia, I = 87.9m^4. The structure is located in Delhi. The soil has a design SPT N value of 26. The structure is supported on raft foundation of diameter 16m. Consider 5% damping for the analysis. The concrete used is having E_{conc} = 3.4 x 10^7 kN/m^2. Evaluate top mass displacement and base shear using response spectrum modal analysis (use CQC modal combination) under earthquake considering the problem as fixed base as per IS 1893-part4. Chimney is divided in four lumped seismic weight as 7295.664 kN, 7295.6643 kN, 5971.854 kN, and 2647.62 kN respectively as show below. Natural frequencies and first two mode shapes are as below:

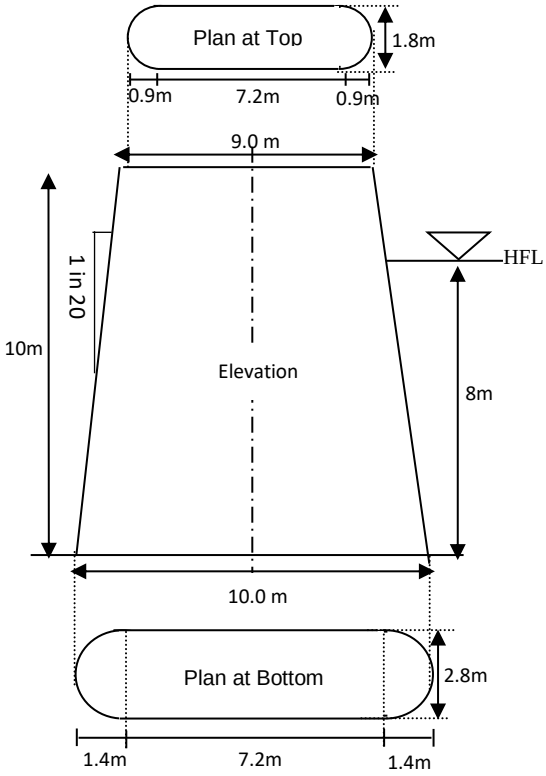


$$[\phi] = \begin{bmatrix} 1.00 & 1.00 \\ 0.723 & -0.0293 \\ 0.396 & -0.7805 \\ 0.096 & -0.4458 \end{bmatrix}$$

Natural frequency (rad/sec) = $\begin{matrix} 2.42 & 14.9 \end{matrix}$

[6 marks]

Q5. In a multi-span simply supported bridge, the height of the pier is 10.0 m and its cross-section is round-ended rectangular. At the top level, the overall width of pier is 9.0 m and its thickness is 1.8 m (measured along the span of the bridge). The cross-sectional dimensions are linearly increasing from the top to bottom level. At the base of the pier, the width and thickness of the pier are 10.0 m and 2.8 m respectively as shown in Figure. At the HFL, the 8.0 m height of the pier is submerged. Determine the magnitude of the seismic force and bending moment produced at the foundation level due to seismic force acting on the pier along the span of bridges. The foundation level is as 12.0 m below the base of pier. Take the magnitude of the seismic coefficient in the horizontal direction α_h as 0.10. **[4 marks]**



Q6. The geometrical details of a square concrete tank are:

Internal side length = 8 m,
Height of water in tank = 4.25 m,
Freeboard = 0.25 m,
Thickness of each wall = 0.2 m,
Thickness of base slab =0.3 m.

The walls of the tank are free at the top and they are rigidly connected to the base slab. The tank is resting on hard soil (Damping 0.5%) and it is located in Zone V.

a) Using the simplified approach (treating the wall as a cantilever subjected to an equivalent concentrated force), calculate the time period of the impulsive mode of vibration of tank,

b) Determine the time period of the convective mode of vibration of tank and Check the adequacy of the provided freeboard for the Sloshing Wave effect. **[5 marks]**

Q7. The capacity of an intze water tank is 250, 000 liters. The internal diameter of the cylindrical part of the tank is 7.5 m and the reduced level (RL) of top water level is 220.0 m. For the determination of spring-mass model parameters, calculate the magnitude of (h/d) ratio for the tank and calculate the RL of the center of mass of water. **[1.5 marks]**

PAPER ENDS