University of Asia Pacific
Department of Civil Engineering
Final Examination Spring 2013
Program: B.Sc. Engineering (Civil)

Course Title: Structural Engineering IX (Earthquake Resistant Design and Retrofitting) — Course Code: CE 423

Time: 2 Hour — Full Marks: 50

*There are 7 **(Seven)** questions. Answer any **5 (Five)**.*

N.B. Students are allowed to bring Chapter 21 of ACI code. Handwritten documents/handwriting on the code are not permitted.

1. a) State d'Alembert's Principle. **(3)**
b) Explain Dynamic Equilibrium. **(3)**
c) Write short notes on: **(4)**
(i) TMD
(ii) TLD

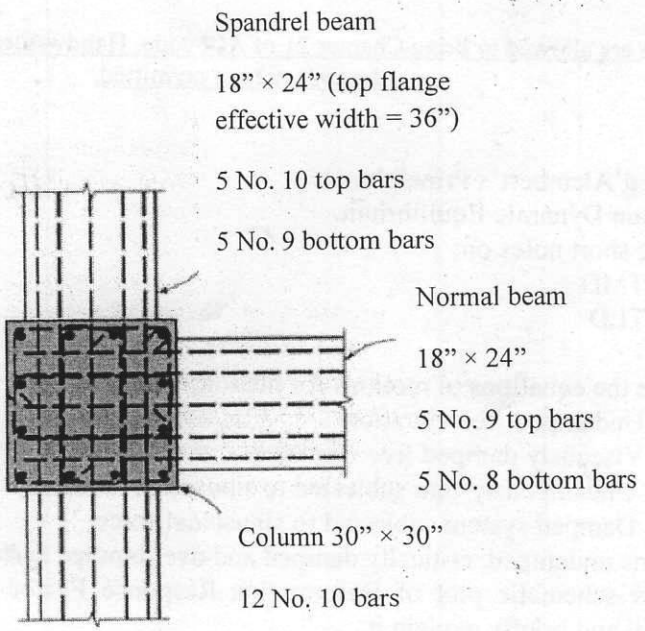
2. a) Write the equations of motions for the following cases: **(4)**
(i) Undamped free vibration
(ii) Viscously damped free vibration
(iii) Undamped system subjected to sinusoidal force
(iv) Damped system subjected to sinusoidal force
b) Define undamped, critically damped and overdamped systems. **(3)**
c) Draw schematic plot of Deformation Response Factor (R_d) vs Frequancy Ratio (β) and briefly explain it. **(3)**

3. A one storey building is idealized as a rigid girder supported by weightless columns. In order to evaluate the dynamic properties of this structure, a free vibration test is made, in which the roof system (rigid girder) is displaced laterally by a hydraulic jack and then suddenly released. During the jacking operation, it is observed that a force of 16.4 kips is required to displace the girder 2 in. At the end of four complete cycles, the time is 2.0 sec and the amplitude is 1 in. From these data compute the following: **(10)**
(i) Damping ratio
(ii) Natural period of undamped vibration
(iii)Stiffness
(iv)Weight
(v) Damping coefficient

4. An 18 in. wide by 24 in. deep (including 6 in slab) reinforced concrete beam spans between two interior columns in a building frame designed for a region of high seismic risk. The clear span is 24 ft and the c/c spacing of the beams is 20 ft. The reinforcement at the face of the support consists of four No. 9 top bars and four No. 8 bottom bars in one layer. Design the shear reinforcement for the regions adjacent to the column faces for DL = 1.0 kip and LL = 1.2 kip. Also **(10)**

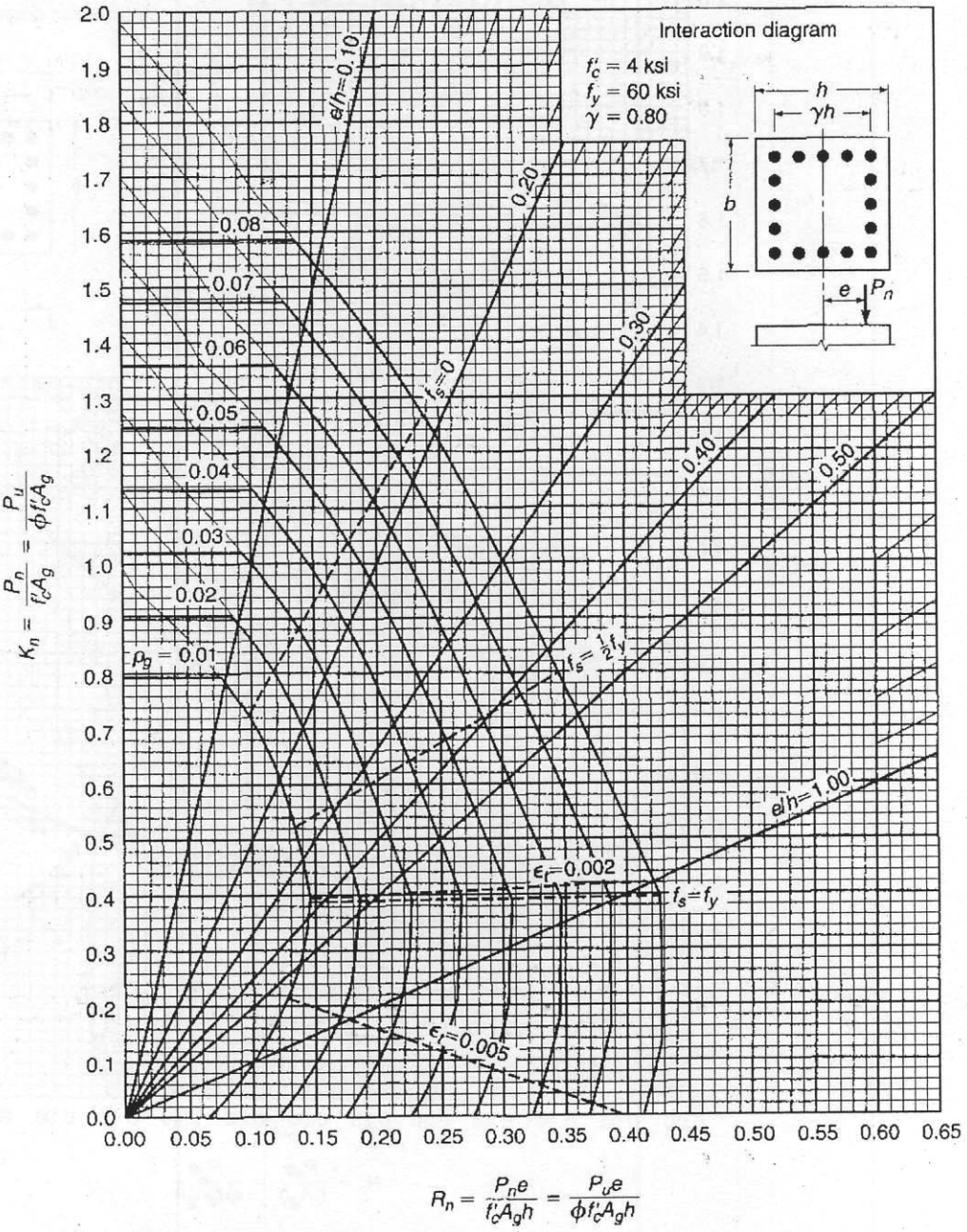
draw a cross-section of the beam. Given: $f_c' = 4000$ psi and $f_y = 60{,}000$ psi.

5. The exterior joint shown in the Figure below is part of a reinforced concrete frame designed to resist earthquake loads. A 6 in. slab, not shown, is reinforced with No. 4 bars spaced 6 in. center to center at the same level as the flexural steel in the beams. The member section dimensions and reinforcement are as shown. The frame story height is 10 ft. Material strengths are $f_c' = 4000$ psi and $f_y = 60{,}000$ psi. The maximum factored axial load on the upper column framing into the joint is 1800 kips, and the maximum factored axial load on the tower column is 2000 kips. Check if the joint satisfy weak beam-strong column design (ACI 21.6.2.2). **(10)**

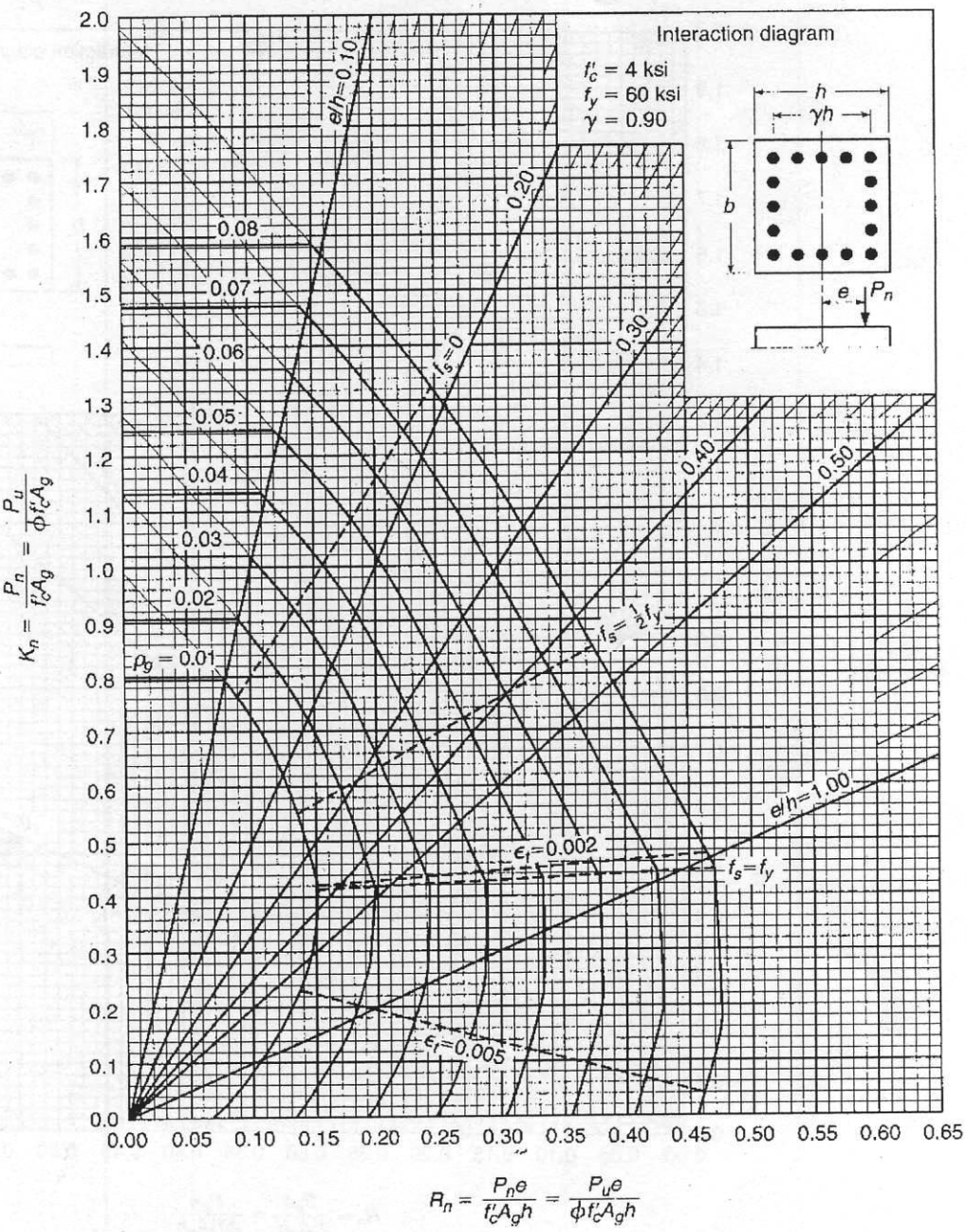


6. For the same column in **Question 5**, determine the minimum transverse reinforcement required over the length l_0 . **(10)**

7. Briefly describe different methods for seismic retrofitting of existing RC structures. **(10)**



GRAPH A.7
Column strength interaction diagram for rectangular section with bars on four faces and $\gamma = 0.80$.



GRAPH A.8
Column strength interaction diagram for rectangular section with bars on four faces and $\gamma = 0.90$.