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Exercise #6: Inelastic SDF systems and their seismic design for ductility

Problem 1

Consider a long reinforced-concrete bridge. The total weight of the superstructure, $2{,}000\ kg/m$, is supported on identical bents $10\ m$ high, uniformly spaced at $40\ m$. Each bent consists of a single circular column $1.5\ m$ in diameter (see Fig. 1.1). The anticipated period of a bridge bent is, $T_n = 1\ s$. Design the longitudinal reinforcement ratio, ρ_t, of the column under the El Centro ground motion (see Fig. 1.2 the response spectra) for 2% damping ratio for the following two cases:

1. to remain elastic; and
2. for an allowable ductility factor of μ =5 (assume, $R_y = \mu = 5$)
3. For the reinforcement ratio, ρ_t you estimated check if the bridge bent will exceed a maximum inelastic displacement of $u_m = 500mm$.

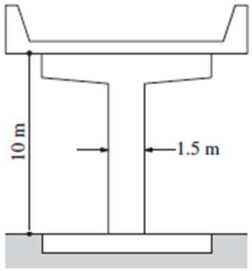

Figure 1.1

Notes:

a) A simplified formula for calculating the flexural resistance of a circular column pier is as follows:

$$M_{Rd} = \frac{2}{3} r^3 \sin^3\theta\, f'_{cd} + \frac{2}{\pi}(r-c) A_s sin\theta f_{yd}$$

r: radius of column bent cross section.
$f'_{cd} = 30MPa$; $f_{yd} = 420MPa$
c: concrete cover (assume 50mm in this case)
θ: is the angle defining the extension of compression zone (assume $26^o \cong \pi/7$ in this case)
A_s: is the steel reinforcement area.

The longitudinal steel reinforcement ratio can be calculated as follows, $\rho_t = \frac{A_s f_{yd}}{\pi r^2 f'_{cd}}$

b) According to ACI-318-05, the effective stiffness EI for circular columns under lateral load is given by,

$$EI = E_c I_g \left(0.2 + 2\rho_t \gamma^2 \frac{E_s}{E_c}\right)$$

Where:

I_g is the second moment of area of the gross cross section;
E_c and E_s are the elastic moduli of concrete and reinforcing steel, respectively; assume $E_c = 30GPa$ and $E_s = 200GPa$;
ρ_t is the longitudinal reinforcement ratio;
γ is the ratio of the distances from the center of the column to the center of the outermost reinforcing bars and to the column edge; assume $\gamma = 0.9$ for this problem.

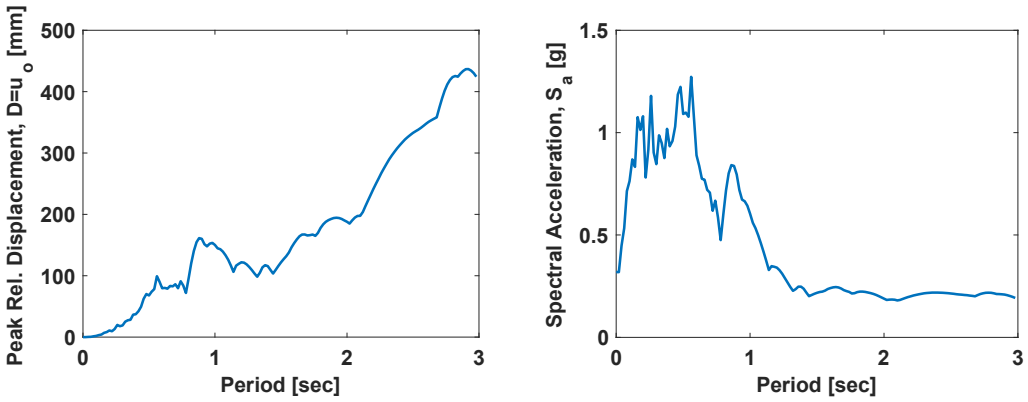

Figure 1.2 response spectra for ElCentro ground motion (2% damping ratio)