Homework No. 5.1

Calculate the demand value of the curvature ductility factor, μ_φ, at the base of the walls and columns and at the ends of all beams if T_C=0.6 sec, in the following cases of concrete buildings:

a) Fundamental period T_1=0.5 sec, design for a basic value of the q-factor equal to q_o=4;

b) As in case (a), but for design with q_o=6;

c) As in case (a), but for T_1=0.7 sec;

d) As in case (b), but for T_1=0.7 sec.

Homework No. 5.2

Calculate the maximum top reinforcement ratio of a beam in all four cases (a) to (d) of Homework No. 5.1, assuming that half of that ratio is provided at the opposite flange (bottom) of the beam. The concrete has a nominal (characteristic) strength f_{ck}=25MPa and the steel is of S500 grade. Provide answers for the following cases:

i) Material strengths equal to their design values, $f_{cd}=f_{ck}/\gamma_c$, $f_{yd}=f_{yk}/\gamma_s$, where γ_c =1.5, γ_s=1.15;

ii) Material strengths equal to their mean (expected) values $f_c=f_{ck}$+8MPa, $f_y=1.15f_{yk}$.

Comment on the magnitude of the maximum reinforcement ratio resulting in the cases considered (if it is too low, how would you increase it in a real design?) and on the differences between the results of cases (i) and (ii) above.

Homework No. 5.3

A column has a 400mm square section, 10mm diameter stirrups with 30mm cover, eight 16mm vertical bars (one intermediate bar at each side), concrete with nominal strength f_{ck}=25MPa and grade S500 steel. Calculate the required confining reinforcement for the four values of the curvature ductility factor calculated in Homework No. 5.1, if the column is subjected to a normalized axial load (design value) $\nu_d=N_d/A_cf_{cd}$=0.3. Use design values of material strengths, $f_{cd}=f_{ck}/\gamma_c$, $f_{yd}=f_{yk}/\gamma_s$, with γ_c =1.5, γ_s=1.15.

Homework No. 5.4

The building in the Figure has many similar 4-bay, 2-storey frames in direction X. Column tops are connected in direction Y, through beams of type B3, into five parallel Y-direction frames, each one with practically infinite, similar bays. There is a diaphragm only at roof level.

Simplifying assumptions:

a) The self weight of beams and columns is neglected for all purposes.

b) The roof comprises one-way slabs, supported only on the Y-direction beams B3; beams of type B1 may be taken as not loaded by the roof slabs.

c) Under gravity loads, beams of type B3 are considered as fixed at the end section against rotation.

d) Bending of columns due to gravity loads is ignored.

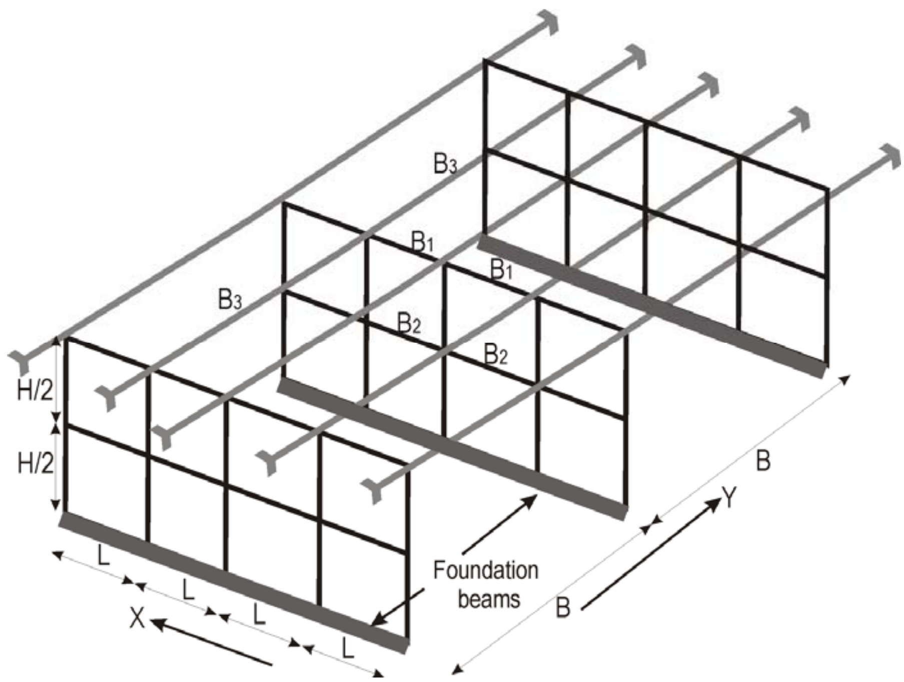
e) The seismic action is considered to produce horizontal forces only at the roof level.

f) The seismic action components in direction X and Y are taken to act separately, not concurrently.

g) Columns take the horizontal seismic forces, as well as the gravity loads acting on the roof, in proportion to their tributary area in plan. Exterior columns have one-half the moment of inertia of interior ones; so, their share of the forces may be assumed to be half of that of interior columns.

h) Under the seismic action, the inflection point (zero moment) of the columns may be taken at storey mid-height and of the beams at mid-span.

i) The effective flange width of roof beams B1 and B3 may be taken per Eurocode 2: on each side of the web where there is a slab: 10% of the distance of the beam from the nearest parallel one (but not greater than 7% of the beam span) plus another 7% of the beam span.



1) What is the value of the behaviour factor, q, of the building in directions X and Y according to Eurocode 8 for Ductility Class High (H)?

2) Calculate the fundamental periods of the building in directions X and Y, after computing the stiffness of the corresponding single-degree-of-freedom (SDOF) system by Virtual Work, using for members 50% of the uncracked section stiffness.

3) From the outcomes of 1) and 2), compute the floor seismic forces for the design of the building in directions X and Y and use them to calculate the seismic moments at the ends of interior elements.

4) Calculate the interstorey drifts under the design seismic action in directions X and Y and use them to estimate the sensitivity coefficients to second-order effects and the interstorey drifts under a damage limitation earthquake equal to 50% of the design seismic action.

5) What is the use of X-direction beams of type B2 at building mid-height, since there are no slabs or seismic forces at that level?

6) Dimension the longitudinal reinforcement of interior beams B1, B2 and B3 at the supports.

7) Dimension the vertical reinforcement of an interior column, separately in directions X and Y, on the basis of the analysis results for the seismic forces in 3) above.

8) Calculate the capacity design shears at the ends of interior beams B1, B2, B3 and at both storeys of an interior column, in directions X and Y.

9) Dimension and detail the shear reinforcement of Beams B1, B2 and B3.

10) Dimension and detail the transverse reinforcement of an interior column.

- Type 1 spectrum of Eurocode 8 for ground type C and design ground acceleration 0.42g.
  - S_a=2.5α/q if T < T_C=0.5sec,
  - S_a=(2.5α/q)T_C/T if T_D=2.5sec > T > T_C=0.5sec,
  - S_a=(2.5α/q)($T_C T_D/T^2$) if T > T_D =2.0sec,
- Ductility Class H (High).
- Bay lengths: L = 3.0 m, B = 10 m.
- Height to mid-depth of roof slab, where the seismic forces are applied: H = 7 m.
- Concrete C35/45, S500 steel. Cover of reinforcement 25 mm.
- The roof slab is 160 mm thick and has only permanent loads: g = 6.5 kN/m^2
- Beams B1, B2: width 0.3 m; depth 0.45 m; beams B3: width 0.3 m; depth 0.55 m.
- Interior column: 0.35 m in direction X, 0.60 m in Y; Exterior column: 0.30 m in X, 0.50 m in Y.

Homework No. 5.5

Asses the seismic performance of the building you designed in Homework no. 5.4 under its design earthquake. To this end, follow the procedure below:

1) Using the longitudinal reinforcement placed in interior elements per 6) and 7) of Homework no. 5.4 and the mean values of material strengths (f_{ck}+8=43 MPa for concrete, 1.15f_{yk} = 575 MPa for steel), calculate the secant-to-yield-point (effective stiffness) of these elements, $EI_{eff}=M_y L_s/3\theta_y$ (see assumption h of Homework no. 5.4 concerning the values of the shear span L_s).

2) Using the effective stiffness values from 1) and assuming again that exterior elements have half the

effective stiffness of exterior ones, repeat point 2) of Homework no. 5.4 and estimate an elastic base shear force per direction X and Y.

3) From the elastic base shears in X and Y from 2) calculate the chord rotation demands at the ends of beams B1, B2, B3 and of the interior columns in both X and Y, as $\theta=(M/EI_{eff})L_s/3$, using the elastic seismic moments *M* due to the design earthquake ("equal displacement rule").

4) Calculate the ultimate chord rotations under cyclic loading, θ_u, at the ends of beams B1, B2, B3 and of the interior columns in both X and Y and compare them to the chord rotation demands from 13) above. Use in this calculation the transverse reinforcement from 9) and 10) of Homework no. 5.4.