Verification Test Number

107

Scope

- Verify the interstory drift calculations and checks.
- Verify the calculation of the P-Delta effect checks.

Files Used

Example 1 files

Procedure

The following calculations are for design combination DCOMB2 = 1.0 DL + 0.3 LL + 1.0 EX

Interstory Drifts

Primary Loadcases Displacements

Table 1 shows the primary loadcases diaphragm displacements. Denoted as UXE and UYE are the elastic translations in the X and Y directions respectively, and as RZ is the rotation about the Z axis. The inelastic translations UXI and UYI in the X and Y directions respectively, are found using the following equation, given in Eurocode 8, clause 4.3.4.

$$d_s = q \cdot d_e$$

where d_s is the inelastic translation, d_e is the elastic translation and q is the behaviour factor taken as 3.5 in this example.

Diaprhagm	Loadcase	UXE	UXI	UYE	UYI	RZ
STORY2	EX	0.002199	0.007699	5.8147E-15	2.0351E-14	5.2991E-16
STORY1	EX	0.001012	0.003543	3.1022E-15	1.0857E-14	2.8035E-16
BASE	EX	0	0	0	0	0

Table 1. Primary loadcases diaphragm displacements.

Interstory Drifts

The interstory drifts for the translational degrees of freedom are shown in Table 2.

Diaprhagm	Loadcase	DUX	DUX x *v*	DUY	DUY x *v*
STORY2	EX	0.004156	0.002078	9.4937E-15	4.7468E-15
STORY1	EX	0.003543	0.001771	1.0857E-14	5.4289E-15

Table 2. Primary loadcases interstory drifts.

Interstory Drift Limits

Eurocode 8, clause 4.4.3.2, gives the following equation for the allowable interstory drift for buildings with non-structural elements that do not interfere with structural deformations.

$$d_r \nu \leq 0.010 h$$

where d_r is the interstory dirft, and h is the story height taken as 3.0 m in this example.

The earthquake load reduction factor ν accounts for the reduced intensity of the earthquake load at serviceability limit state. The value considered here is 0.5.

The results in Table 2 show that the interstory drifts do not exceed the limit which is equal to 0.010 x 3.0 m = 0.030 m.

P-Delta Effects

Total Gravity Load

The total gravity load of the seismic design combination is calculated manually below.

Dead Load

Story 2

Slab

$$M_{slab} = 18\,\text{m} \cdot 8\,\text{m} \cdot 0.275\,\text{m} \cdot 24\,\text{KN/m}^3 = 950\,\text{KN}$$

Beams

$$M_{beams} = (4 \cdot 8\,\text{m} + 3 \cdot 18\,\text{m}) \cdot 0.25\,\text{m} \cdot 0.5\,\text{m} \cdot 24\,\text{KN/m}^3 = 258\,\text{KN}$$

Columns

$$M_{columns} = (10 \cdot 0.6\,\text{m} \cdot 0.3\,\text{m} + 2 \cdot 0.6\,\text{m} \cdot 0.4\,\text{m}) \cdot 1.5\text{m} \cdot 24\,\text{KN/m}^3 = 82\,\text{KN}$$

Sub-total

$$M_{story2} = 930\,\text{KN} + 258\,\text{KN} + 82\,\text{KN} = 1{,}290\,\text{KN}$$

Story 1

Slab

$$M_{slab} = 18\,\text{m} \cdot 8\,\text{m} \cdot 0.275\,\text{m} \cdot 24\,\text{KN/m}^3 = 950\,\text{KN}$$

Beams

$$M_{beams} = (4 \cdot 8\,\text{m} + 3 \cdot 18\,\text{m}) \cdot 0.25\,\text{m} \cdot 0.5\,\text{m} \cdot 24\,\text{KN/m}^3 = 258\,\text{KN}$$

Columns

$$M_{columns} = (10 \cdot 0.6\,\text{m} \cdot 0.3\,\text{m} + 2 \cdot 0.6\,\text{m} \cdot 0.4\,\text{m}) \cdot 3\,\text{m} \cdot 24\,\text{KN/m}^3 = 164\,\text{KN}$$

Masonry

$$M_{masonry} = (4 \cdot 8\,\text{m} + 3 \cdot 18\,\text{m}) \cdot 5\,\text{KN/m} = 430\,\text{KN}$$

Sub-total

$$M_{story1} = 930\,\text{KN} + 258\,\text{KN} + 164\,\text{KN} + 430\,\text{KN} = 1{,}802\,\text{KN}$$

Base

Columns

$$M_{columns} = (10 \cdot 0.6\,\text{m} \cdot 0.3\,\text{m} + 2 \cdot 0.6\,\text{m} \cdot 0.4\,\text{m}) \cdot 1.5\text{m} \cdot 24\,\text{KN/m}^3 = 82\,\text{KN}$$

Total

$$M_{total} = 1{,}290\,\text{KN} + 1{,}802\,\text{KN} + 82\,\text{KN} = 3{,}174\,\text{KN}$$

Live Load

Story 2

$$M_{live} = 18\,\text{m} \cdot 8\,\text{m} \cdot 1.5\,\text{KN/m}^2 = 216\,\text{KN}$$

Story 1

$$M_{live} = 18\,\text{m} \cdot 8\,\text{m} \cdot 2.0\,\text{KN/m}^2 = 288\,\text{KN}$$

Combination Load

Story 2

$$M_{story2} = 1.0 \cdot 1{,}290 \text{ KN} + 0.3 \cdot 216 \text{ KN} = 1{,}355 \text{ KN}$$

Story 1

$$M_{story1} = 1.0 \cdot 1{,}802 \text{ KN} + 0.3 \cdot 288 \text{ KN} = 1{,}888 \text{ KN}$$

$$M_{cumulative1} = 1{,}355 \text{ KN} + 1{,}888 \text{ KN} = 3{,}243 \text{ KN}$$

P-Delta Checks

Eurocode 8, clause 4.4.2.2 gives the following equation for checking the P-Delta effects

$$\theta = \frac{P_{tot} \cdot d_r}{V_{tot} \cdot h}$$

where P_{tot} is the total gravity load above the level considered in the seismic design situation, d_r is the interstory drift, V_{tot} is the total seismic story shear and h is the story height. The calculations for θ are shown in Table 3.

	P_{tot}	V_{tot}	d_r	h	θ
Story 2	1355	243	0.004156	3.0	0.008
Story 1	3243	398	0.003543	3.0	0.010

Table 3. Parameter θ calculations.

Eurocode 8 allows P-Delta effects to be ignored when θ is less than 0.10. When θ is between 0.10 and 0.20 special analysis that considers P-Delta has to be conducted. Parameter θ cannot be higher than 0.30.