# CHAPTER 2

# Load Combinations

## Problem 2.1

### SOLUTION

**Table P2.1 Summary of Load Combinations Using Strength Design for Beam in Problem 2.1**

| IBC Equation No. | Equation | Load Combination | | |
|---|---|---|---|---|
| | | Exterior Negative | Positive | Interior Negative |
| 16-1 | 1.4$D$ | –18.6 | 61.5 | –74.5 |
| 16-2 | 1.2$D$ + 1.6$L$ | –36.6 | 120.7 | –146.4 |
| 16-3, 16-4, 16-5 | 1.2$D$ + 0.5$L$ | –22.4 | 73.9 | –89.6 |
| 16-6, 16-7 | 0.9$D$ | –12.0 | 39.5 | –47.9 |

## Problem 2.2

### SOLUTION

**Table P2.2 Summary of Load Combinations Using Strength Design for Beam in Problem 2.2**

| IBC Equation No. | Equation | Load Combination | | |
|---|---|---|---|---|
| | | Bending Moment | | Shear Force |
| | | Support | Midspan | Support |
| 16-1 | 1.4$D$ | –80.6 | 57.5 | 16.5 |
| 16-2 | 1.2$D$ + 1.6$L$ | –105.1 | 75.2 | 21.5 |
| 16-3 | 1.2$D$ + 0.5$L$ | –80.4 | 57.4 | 16.5 |
| | 1.2$D$ + 0.5$W$ | –42.1 | 49.3 | 11.8 |
| | 1.2$D$ – 0.5$W$ | –96.1 | 49.3 | 16.6 |
| 16-4 | 1.2$D$ + 1.0$W$ + 0.5$L$ | –26.4 | 57.4 | 11.7 |
| | 1.2$D$ – 1.0$W$ + 0.5$L$ | –134.4 | 57.4 | 21.3 |
| 16-5 | 1.2$D$ + 0.5$L$ | –80.4 | 57.4 | 16.5 |
| 16-6 | 0.9$D$ + 1.0$W$ | 2.2 | 37.0 | 5.8 |
| | 0.9$D$ – 1.0$W$ | –105.8 | 37.0 | 15.4 |
| 16-7 | 0.9$D$ | –51.8 | 37.0 | 10.6 |

# Problem 2.3

## SOLUTION

**Table P2.3 Summary of Load Combinations Using Basic Allowable Stress Design for Beam in Problem 2.3**

| IBC Equation No. | Equation | Load Combination | | |
|---|---|---|---|---|
| | | Bending Moment | | Shear Force |
| | | Support | Midspan | Support |
| 16-8, 16-10 | $D$ | –57.6 | 41.1 | 11.8 |
| 16-9 | $D + L$ | –80.1 | 57.3 | 16.4 |
| 16-11, 16-14 | $D + 0.75L$ | –74.5 | 53.3 | 15.3 |
| 16-12 | $D + 0.6W$ | –25.2 | 41.1 | 8.9 |
| | $D - 0.6W$ | –90.0 | 41.1 | 14.7 |
| 16-13 | $D + 0.75(0.6W) + 0.75L$ | –50.2 | 53.3 | 13.1 |
| | $D - 0.75(0.6W) + 0.75L$ | –98.8 | 53.3 | 17.4 |
| 16-15 | $0.6D + 0.6W$ | –2.2 | 24.7 | 4.2 |
| | $0.6D - 0.6W$ | –67.0 | 24.7 | 10.0 |
| 16-16 | $0.6D$ | –34.6 | 24.7 | 7.1 |

# Problem 2.4

## SOLUTION

**Table P2.4 Summary of Load Combinations Using Alternative Basic Allowable Stress Design for Beam in Problem 2.4**

| IBC Equation No. | Equation | Load Combination | | |
|---|---|---|---|---|
| | | Bending Moment | | Shear Force |
| | | Support | Midspan | Support |
| 16-17, 16-21 | $D + L$ | –80.1 | 57.3 | 16.4 |
| 16-18, 16-19 | $D + L + 0.6\omega W$ | –38.0 | 57.3 | 12.7 |
| | $D + L - 0.6\omega W$ | –122.2 | 57.3 | 20.1 |
| 16-20 | $D + L + 0.6\omega W/2$ | –59.0 | 57.3 | 14.5 |
| | $D + L - 0.6\omega W/2$ | –101.2 | 57.3 | 18.3 |
| 16-22 | $0.9D$ | –51.8 | 37.0 | 10.6 |

# Problem 2.5

## SOLUTION

Because the live loads on the floors are equal to 100 psf, $f_1 = 0.5$.

The seismic load effect, $E$, is determined as follows:

For use in IBC Equation 16-5: $E = E_h + E_v = \rho Q_E + 0.2S_{DS}D$

$= (1.0 \times Q_E) + (0.2 \times 0.41 \times D) = Q_E + 0.08D$

For use in IBC Equation 16-7: $E = E_h - E_v = \rho Q_E - 0.2S_{DS}D$

$= (1.0 \times Q_E) - (0.2 \times 0.41 \times D) = Q_E - 0.08D$

Substituting for $E$, IBC Equation 16-5 becomes: $1.2D + Q_E + 0.08D + 0.5L = 1.28D + Q_E + 0.5L$

Similarly, IBC Equation 16-7 becomes: $0.9D + Q_E - 0.08D = 0.82D + Q_E$

**Table P2.5 Summary of Load Combinations Using Strength Design for Column in Problem 2.5**

| IBC Equation No. | Equation | Load Combination | | |
|---|---|---|---|---|
| | | Axial Force | Bending Moment | Shear Force |
| 16-1 | $1.4D$ | 235.1 | 29.8 | 3.2 |
| 16-2 | $1.2D + 1.6L + 0.5L_r$ | 275.3 | 59.2 | 6.3 |
| 16-3 | $1.2D + 1.6L_r + 0.5L$ | 246.1 | 36.1 | 3.9 |
| | $1.2D + 1.6L_r + 0.5W$ | 232.1 | 86.1 | 8.3 |
| | $1.2D + 1.6L_r - 0.5W$ | 218.5 | –34.9 | –2.8 |
| 16-4 | $1.2D + 1.0W + 0.5L + 0.5L_r$ | 243.3 | 157.1 | 15.0 |
| | $1.2D - 1.0W + 0.5L + 0.5L_r$ | 216.1 | –84.9 | –7.2 |
| 16-5 | $1.28D + Q_E + 0.5L$ | 272.1 | 469.9 | 46.2 |
| | $1.28D - Q_E + 0.5L$ | 199.3 | –394.3 | –38.2 |
| 16-6 | $0.9D + 1.0W$ | 164.7 | 140.2 | 13.2 |
| | $0.9D - 1.0W$ | 137.5 | –101.8 | –9.0 |
| 16-7 | $0.82D + Q_E$ | 174.1 | 449.6 | 44.1 |
| | $0.82D - Q_E$ | 101.3 | –414.6 | –40.3 |

## Problem 2.6

### SOLUTION

Because the shear wall is in a parking garage, $f_1 = 1.0$.

The seismic load effect, $E$, is determined as follows:

For use in IBC Equation 16-5: $E = E_h + E_v = \rho Q_E + 0.2S_{DS}D$

$$= (1.0 \times Q_E) + (0.2 \times 1.0 \times D) = Q_E + 0.2D$$

For use in IBC Equation 16-7: $E = E_h - E_v = \rho Q_E - 0.2S_{DS}D$

$$= (1.0 \times Q_E) - (0.2 \times 1.0 \times D) = Q_E - 0.2D$$

Substituting for $E$, IBC Equation 16-5 becomes: $1.2D + Q_E + 0.2D + 1.0L = 1.4D + Q_E + 1.0L$. Similarly, IBC Equation 16-7 becomes: $0.9D + Q_E - 0.2D = 0.7D + Q_E$

**Table P2.6 Summary of Load Combinations Using Strength Design for Shear Wall in Problem 2.6**

| IBC Equation No. | Equation | Load Combination | | |
|---|---|---|---|---|
| | | Axial Force | Bending Moment | Shear Force |
| 16-1 | $1.4D$ | 903.0 | 0 | 0 |
| 16-2 | $1.2D + 1.6L$ | 1,012.4 | 0 | 0 |
| 16-3, 16-4 | $1.2D + 1.0L$ | 923.0 | 0 | 0 |
| 16-5 | $1.4D + Q_E + 1.0L$ | 1,052.0 | 4,280.0 | 143.0 |
| | $1.4D - Q_E + 1.0L$ | 1,052.0 | –4,280.0 | –143.0 |
| 16-6 | $0.9D$ | 580.5 | 0 | 0 |
| 16-7 | $0.7D + Q_E$ | 451.5 | 4,280.0 | 143.0 |
| | $0.7D - Q_E$ | 451.5 | –4,280.0 | –143.0 |

## Problem 2.7

### SOLUTION

The governing load combination in IBC 1605.2 is Equation 16-2:

Negative bending moment:

$1.2D + 1.6L = (1.2 \times 80.6) + (1.6 \times 42.1) = 164.1$ ft-kips

Positive bending moment:

$1.2D + 1.6L = (1.2 \times 53.7) + (1.6 \times 30.4) = 113.1$ ft-kips

Shear force:

$1.2D + 1.6L = (1.2 \times 29.7) + (1.6 \times 19.0) = 66.0$ kips

The following basic combinations for strength design with overstrength are also applicable:

- $(1.2 + 0.2S_{DS})$ D + $\Omega_O Q_E + 1.0L$
  Axial force: $\Omega_O Q_E = 2.0 \times 241 = 482$ kips tension or compression
  Negative bending moment:
  $(1.2 + 0.2S_{DS})D + 1.0L = (1.38 \times 80.6) + (1.0 \times 42.1) = 153.3$ ft-kips
  Positive bending moment:
  $(1.2 + 0.2S_{DS})D + 1.0L = (1.38 \times 53.7) + (1.0 \times 30.4) = 104.5$ ft-kips
  Shear force:
  $(1.2 + 0.2S_{DS})D + 1.0L = (1.38 \times 29.7) + (1.0 \times 19.0) = 60.0$ kips
  Note that the load factor on $L$ must be equal to 1.0 because of the assembly occupancy.

- $(0.9 - 0.2S_{DS})D + \Omega_O Q_E$
  Axial force: $\Omega_O Q_E = 2.0 \times 241 = 482$ kips tension or compression
  Negative bending moment:
  $(0.9 - 0.2S_{DS})D = 0.72 \times 80.6 = 58.0$ ft-kips
  Positive bending moment:
  $(0.9 - 0.2S_{DS})D = 0.72 \times 53.7 = 38.7$ ft-kips
  Shear force:
  $(0.9 - 0.2S_{DS})D = 0.72 \times 29.7 = 21.4$ kips

## Problem 2.8

### SOLUTION

The governing load combination in IBC 1605.3.1 is Equation 16-9:

Negative bending moment:

$D + L = 80.6 + 42.1 = 122.7$ ft-kips

Positive bending moment:

$D + L = 53.7 + 30.4 = 84.1$ ft-kips

Shear force:

$D + L = 29.7 + 19.0 = 48.7$ kips

The following basic allowable stress design load combinations with overstrength are also applicable:

- $(1.0 + 0.14S_{DS})D + 0.7\Omega_O Q_E$

  Axial force:

  $0.7\Omega_O Q_E = 0.7 \times 2.0 \times 241 = 337.4$ kips tension or compression

  Negative bending moment:

  $(1.0 + 0.14S_{DS})D = 1.13 \times 80.6 = 91.1$ ft-kips

  Positive bending moment:

  $(1.0 + 0.14S_{DS})D = 1.13 \times 53.7 = 60.7$ ft-kips

  Shear force:

  $(1.0 + 0.14S_{DS})D = 1.13 \times 29.7 = 33.6$ kips

- $(1.0 + 0.105S_{DS})D + 0.525\Omega_O Q_E + 0.75L$

  Axial force:

  $0.525\Omega_O Q_E = 0.525 \times 2.0 \times 241 = 253.1$ kips tension or compression

  Negative bending moment:

  $1.1D + 0.75L = (1.1 \times 80.6) + (0.75 \times 42.1) = 120.2$ ft-kips

  Positive bending moment:

  $1.1D + 0.75L = (1.1 \times 53.7) + (0.75 \times 30.4) = 81.9$ ft-kips

  Shear force:

  $1.1D + 0.75L = (1.1 \times 29.7) + (0.75 \times 19.0) = 46.9$ kips

- $(0.6 - 0.14S_{DS})D + 0.7\Omega_O Q_E$

  Axial force:

  $0.7\Omega_O Q_E = 0.7 \times 2.0 \times 241 = 337.4$ kips tension or compression

  Negative bending moment:

  $(0.6 - 0.14S_{DS})D = 0.47 \times 80.6 = 37.9$ ft-kips

  Positive bending moment:

  $(0.6 - 0.14S_{DS})D = 0.47 \times 53.7 = 25.2$ ft-kips

  Shear force:

  $(0.6 - 0.14S_{DS})D = 0.47 \times 29.7 = 14.0$ kips