# 1001 – Moment Frame Design According to AISC

## Description

Determine the required strengths and effective length factors for the ASTM A992 material columns in the moment frame shown in Figure **1** for the maximum gravity load combination, using LRFD and ASD, see [1]. The uniform load $w_D$ includes beam self-weight and an allowance for column self-weight. Use the direct analysis method.

| | | | | | |
|---|---|---|---|---|---|
| Material | | Modulus of Elasticity | $E$ | 29000.000 | ksi |
| Geometry | Structure | Length | $L$ | 30.000 | ft |
| | Cross-section W 12×65 | Gross Area | $A_g$ | 19.100 | in$^2$ |
| Load | | Dead | $w_D$ | 0.400 | kip·ft |
| | | Live | $w_L$ | 1.200 | kip·ft |

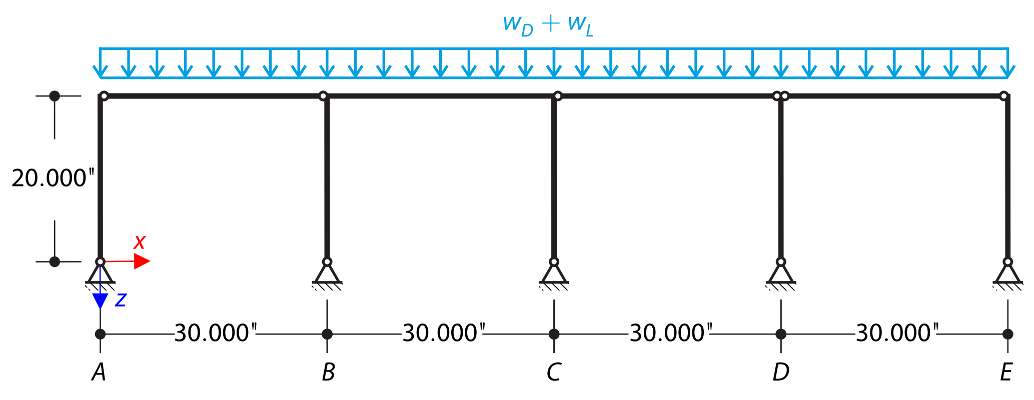


**Figure 1:** Moment Frame Elevation

## AISC Solution

The beams from grid lines A to B and C to E and the columns at A, D, and E are pinned at both ends and do not contribute to the lateral stability of the frame. There are no P-$\Delta$effects to consider in these members and they may be designed using $L_c = L$.

From Chapter 2 of ASCE/SEI 7, the maximum gravity load combinations are

| LRFD | ASD |
|---|---|
| $\omega_u = 1.2w_D + 1.6w_L = 1.600$ kip·ft | $\omega_u = w_D + w_L = 1.600$ kip·ft |

Per AISC Specification Section C2.1(d), for LRFD, perform a second-order analysis and member strength checks using the LRFD load combinations. For ASD, perform a second-order analysis using 1.6 times the ASD load combinations and divide the analysis results by 1.6 for the ASD member strength checks.

The uniform gravity loads to be considered in a second-order analysis on the beam from B to C are

| LRFD | ASD |
|---|---|
| $\omega'_u = 2.400$ kip·ft | $\omega'_u = 2.560$ kip·ft |

Concentrated gravity loads to be considered in a second-order analysis on the columns at B and C contributed by adjacent beams are

| LRFD | ASD |
|---|---|
| $P'_u = (\omega'_u \cdot l)/2 = 36.000$ kips | $P'_a = (\omega'_a \cdot l)/2 = 38.400$ kips |

Per AISC Specification Section C2.2, frame out-of-plumbness must be accounted for either by explicit modeling of the assumed out-of-plumbness or by the application of notional loads. Use notional loads.

Per AISC Specification Equation C2-1, the notional loads are

| LRFD | ASD |
|---|---|
| $\alpha = 1$<br>$Y_i = 288.000$ kips<br>$N_i = 0.002 \cdot \alpha Y_i = 0.572$ kips | $\alpha = 1.6$<br>$Y_i = 192.000$ kips<br>$N_i = 0.002 \cdot \alpha Y_i = 0.614$ kips |

Assume, subject to verification, that $(\alpha P_r)/P_{ns}$ is not greater than 0.500; therefore, no additional stiffness reduction is required

$$\tau_b = 1$$

Half of the gravity load is carried by the columns of the moment-resisting frame. Because the gravity load supported by the moment-resisting frame columns exceeds one-third of the total gravity load tributary to the frame, per AISC Specification Section C2.1, the effects of $P$-$\delta$ and $P$-$\Delta$ must be considered in the frame analysis.

## RFEM 6 Settings

- Modeled in RFEM 6.01.0007
- Isotropic linear elastic model is used
- Shear stiffness of members is activated

## Results

Results from both a first-order and a second-order analysis are shown. (The first-order analysis is shown for reference only.) In each case, the drift is the average of drifts at grid lines B and C.

## 1 First-Order Analysis Results

| Design | Joint [Units] | AISC Solution | RFEM Solution | Ratio [-] |
|---|---|---|---|---|
| LRFD | $B_{Fy}$ [kips] | 71.600 | 71.612 | 1.000 |
| | $C_{Fy}$ [kips] | 72.400 | 72.380 | 1.000 |
| | $B_{Fx}$ [kips] | 5.640 | 5.640 | 1.000 |
| | $C_{Fx}$ [kips] | -6.210 | -6.216 | 1.001 |
| | $B_{My}$ [kips·ft] | 113.000 | 112.790 | 0.998 |
| | $C_{My}$ [kips·ft] | 124.000 | 124.310 | 1.002 |
| ASD | $B_{Fy}$ [kips] | 47.588 | 47.742 | 0.997 |
| | $C_{Fy}$ [kips] | 48.300 | 48.407 | 0.998 |
| | $B_{Fx}$ [kips] | 3.760 | 3.645 | 0.969 |
| | $C_{Fx}$ [kips] | -4.140 | -4.259 | 1.029 |
| | $B_{My}$ [kips·ft] | 75.200 | 72.890 | 0.969 |
| | $C_{My}$ [kips·ft] | 82.800 | 85.170 | 1.029 |

## 2 Second-Order Analysis Results

| Design | Joint [Units] | AISC Solution | RFEM Solution | Ratio [-] |
|---|---|---|---|---|
| LRFD | $B_{Fy}$ [kips] | 71.400 | 71.376 | 0.999 |
| | $C_{Fy}$ [kips] | 72.600 | 72.617 | 1.000 |
| | $B_{Fx}$ [kips] | 5.520 | 5.523 | 1.000 |
| | $C_{Fx}$ [kips] | -6.260 | -6.274 | 1.002 |
| | $B_{My}$ [kips·ft] | 109.000 | 108.650 | 0.997 |
| | $C_{My}$ [kips·ft] | 127.000 | 127.270 | 1.002 |
| ASD | $B_{Fy}$ [kips] | 47.742 | 47.450 | 1.001 |
| | $C_{Fy}$ [kips] | 48.400 | 48.546 | 1.003 |
| | $B_{Fx}$ [kips] | 3.680 | 3.580 | 0.973 |
| | $C_{Fx}$ [kips] | -4.180 | -4.297 | 1.028 |
| | $B_{My}$ [kips·ft] | 72.200 | 72.560 | 1.005 |
| | $C_{My}$ [kips·ft] | 84.800 | 87.000 | 1.026 |

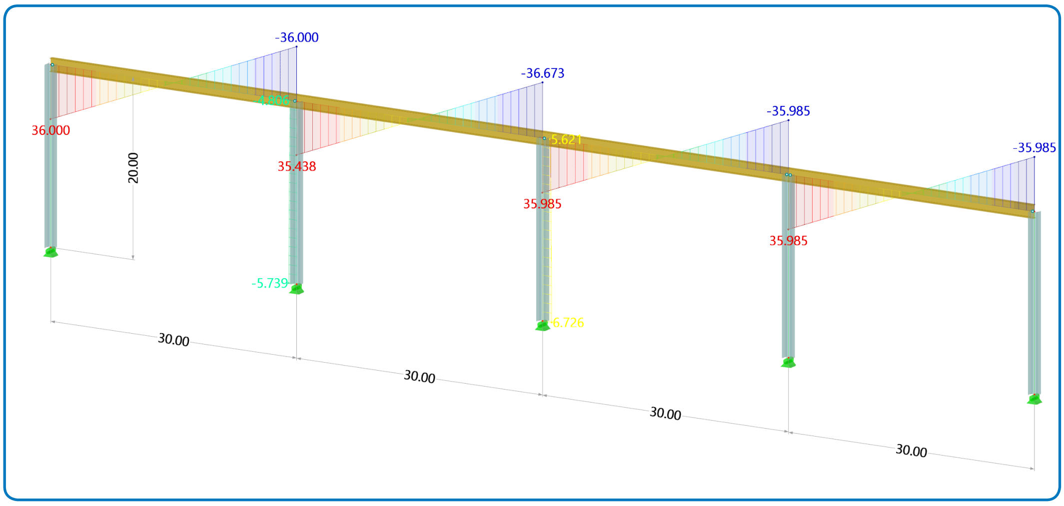


**Figure 2:** RFEM 6 results - Shear $V_z$ in z-axis (2nd Order LRFD)

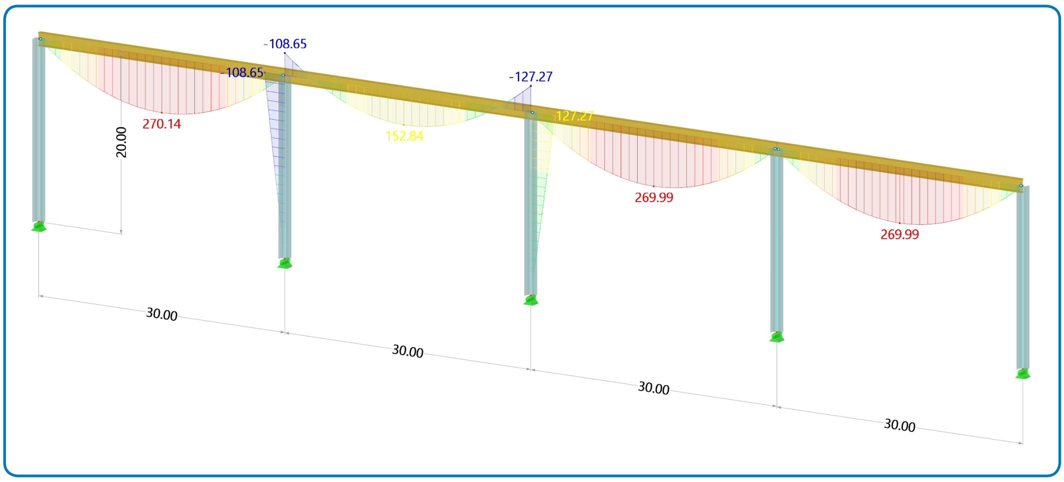


**Figure 3:** RFEM 6 results - Moment $M_y$ about y-axis (2nd Order LRFD)

## References

[1] AMERICAN INSTITUTE OF STEEL CONSTRUCTION, *Specification for Structural Steel Buildings*. 2016.