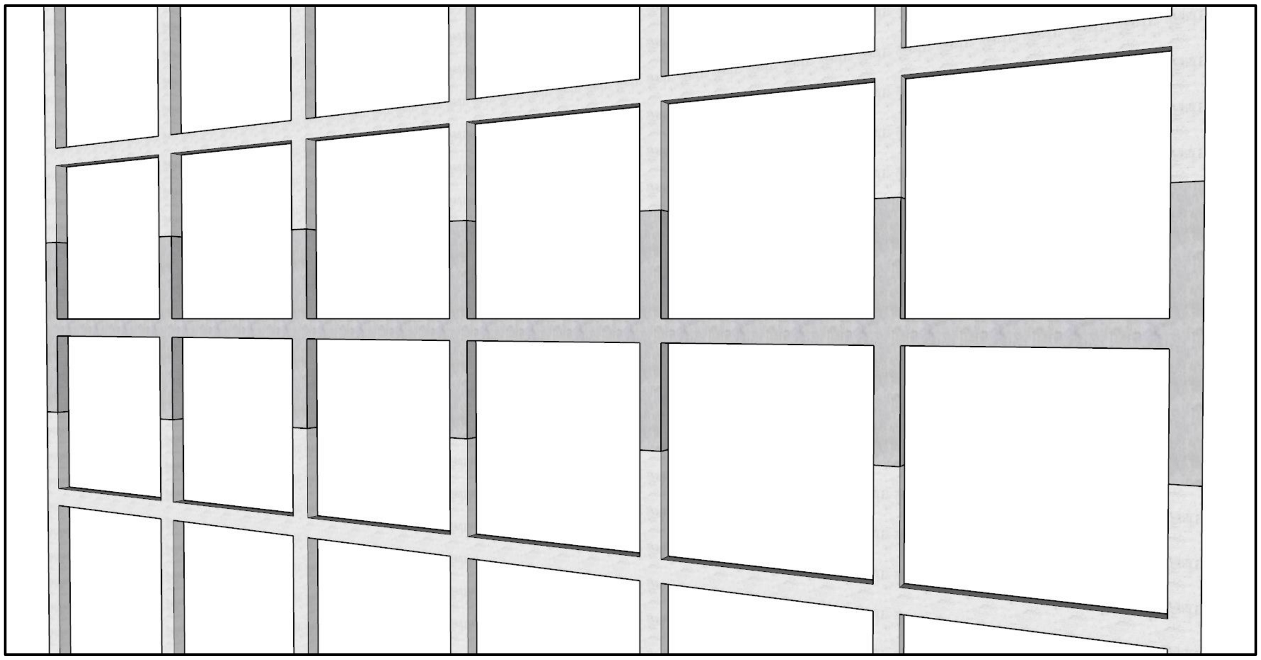
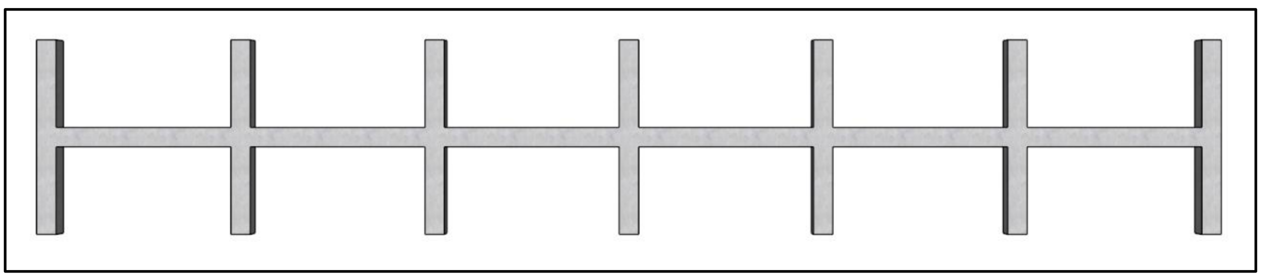
Arrangement of Live Load Patterns for Moment Envelope (ACI 318-14)





Arrangement of Live Load Patterns for Moment Envelope (ACI 318-14)

Determining the moment envelopes at the middle and the ends of each span in a beam-column frame due to uniformly distributed loads. The frame is composed of six equal spans supported by equal height columns as shown in Figure 1. The uniform live load w_L is twice the uniform dead load w_D and that the flexural stiffness (*EI/L*) of the columns is twice the stiffness of the beams. Moment envelopes values obtained in the reference and the hand calculations are compared with the values obtained by spBeam engineering software program from StructurePoint.

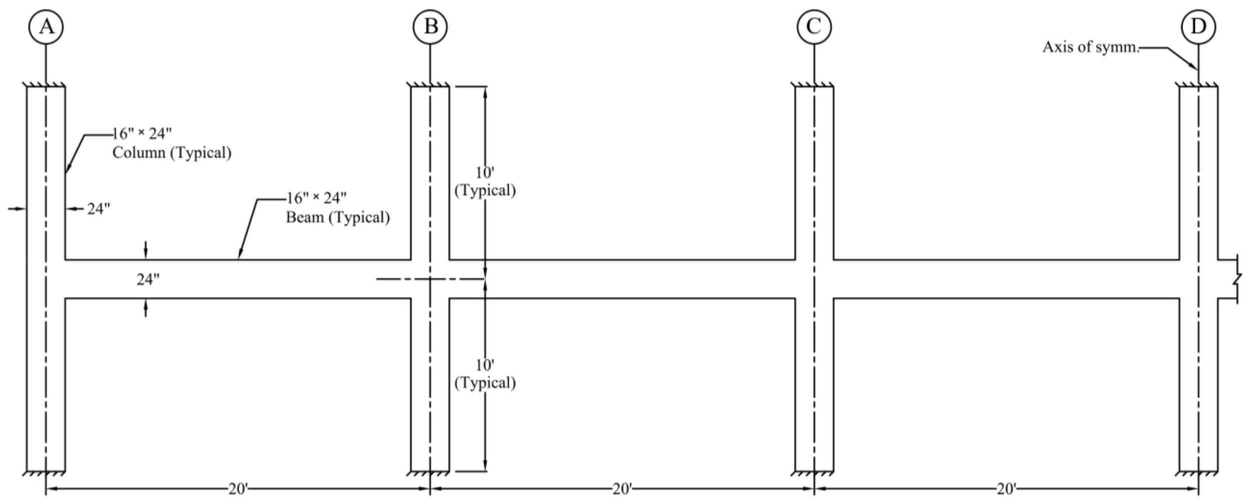


Figure 1 – Continuous Frame Elevation

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2. Continuous Beam Analysis – Moment Distribution Method 3
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4. Comparison of Design Results 19

Reference

[1] Reinforced Concrete Design, 8th Edition, 2017, Chu-Kia Wang, Charles G. Salmon, Jose A. Pincheira, Gustavo J. Parra-Montesinos, Oxford University Press, Example 7.3.1.

[2] spBeam Engineering Software Program Manual v5.50, StructurePoint LLC., 2018.

Analysis Data

The reference book solved Example 7.3.1 symbolically in term of the span length *L* and the total loads *w* (w_{D+} w_L). Numerical values are practically assumed in order to compare the analysis output from spBeam with the reference output when using the same analysis parameter.

f_c'= 4,000 psi normal weight concrete for beams and columns.

Span length, *l* = 20 ft, center-to-center of columns.

Column height = 10 ft, from center of beams to column support.

Beam and column cross-sections are rectangular with dimensions of 16 in. × 24 in.

Live load, w_L = 1.35 kip/ft.

Dead load, w_D = 0.675 kip/ft.

Solution

1. Span Loading Scenarios

As per the ACI 318-14 code requirements for arrangement of live load on continuous beams, the following arrangements are permitted to obtain maximum positive moment and maximum negative moment, respectively:

- Maximum positive moment near midspan occurs with w_L applied on the span under consideration and on alternate spans. ***ACI 318-14 (6.4.2.a)***
- Maximum negative moment at a support occurs with w_L applied on adjacent spans only.

ACI 318-14 (6.4.2.b)

Seven loading scenarios as shown in Figure 2 are investigated. The frame is analyzed by classical method of structural analysis, namely, the moment distribution method. Moment distribution procedures for each loading scenario are carried out in the next section.

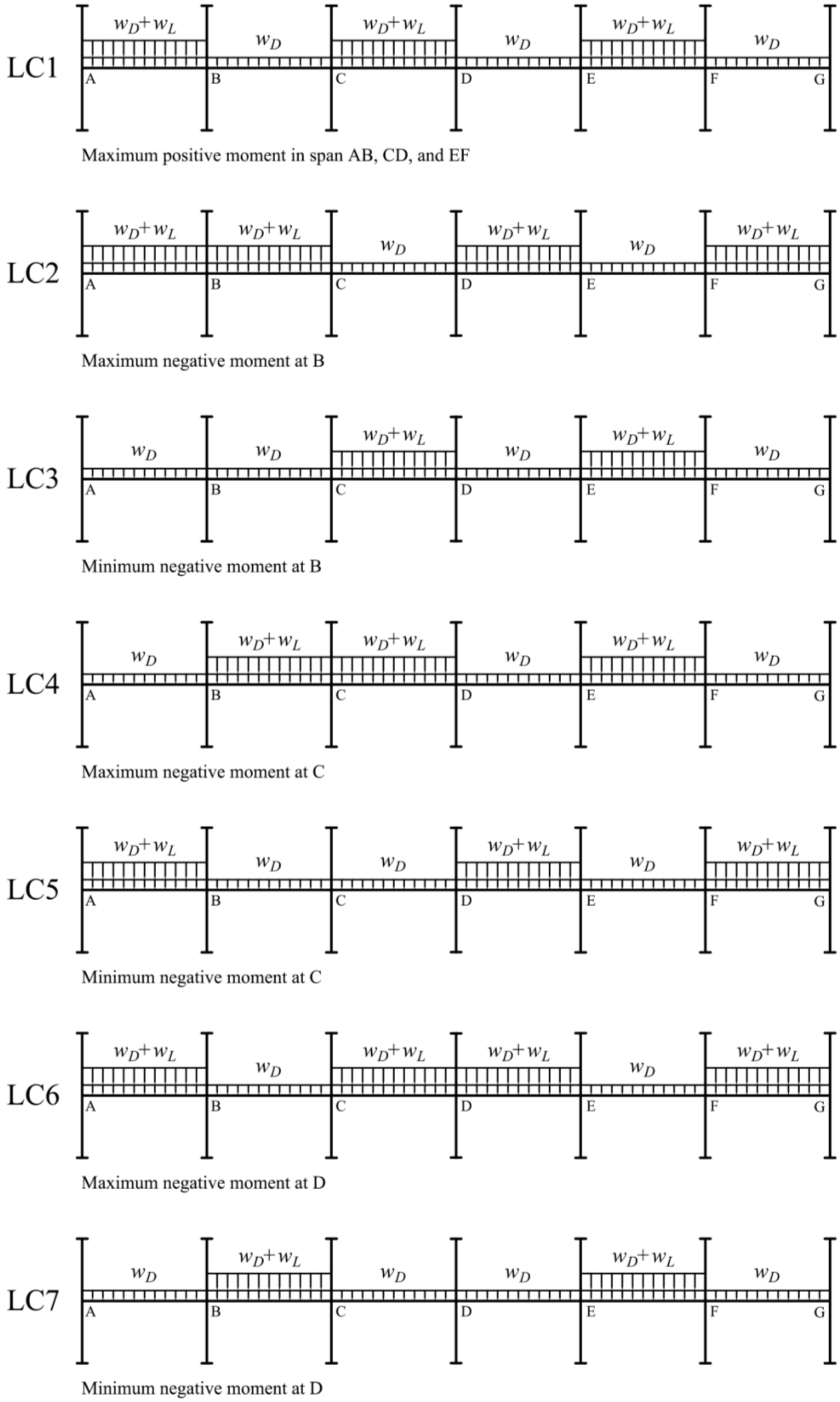


Figure 2 – Loading Scenarios for Six-Span Continuous Frame

2. Continuous Beam Analysis – Moment Distribution Method

The moment distribution procedures are used to analyze the frame. Stiffness factors, carry over factors, and fixed-end moment factors for the beams and columns for the seven load scenarios:

Flexural stiffness of beams and columns ends, K

$$K = \frac{4 \times E_c \times I}{l}$$

Where K is referred to as stiffness factor at beam or column end and can be defined as the amount of moment required to rotate the end of the beam or column 1 rad.

For a rectangular section with dimensions of 16 in. × 24 in, moment of inertia, I:

$$I = \frac{b \times h^3}{12} = \frac{16\text{ in.} \times (24\text{ in.})^3}{12} = 18,432\text{ in.}^4$$

Concrete modulus of elasticity for normal weight concrete, E_c:

$$E_c = 57000\sqrt{f_c'} = 57000\sqrt{4000\text{ psi}} = 3605\text{ ksi}$$ ***ACI 318-14 (19.2.2.1.b)***

For the beams:

$$l = 20\text{ ft}$$

$$K_{Beam} = \frac{4 \times 3605\text{ ksi} \times 18,432\text{ in.}^4}{20\text{ ft} \times 12\text{ in./ft}} = 1107.456\text{ kip-in.}$$

For the columns:

$$K_{Column} = 2 \times K_{Beam} = 2 \times 1107.456\text{ kip-in.} = 2214.9\text{ kip-in.}$$

Distribution factor, DF

$$DF = \frac{K}{\sum K}$$

The distribution factor for a member that is connected to a fixed joint is defined as the fraction of the total resisting moment supplied by this member.

For the beams continuous from one end:

$$DF_{Beam} = \frac{K_{Beam}}{K_{Column} + K_{Beam} + K_{Column}} = \frac{1107.456\text{ kip-in.}}{2214.9\text{ kip-in.} + 1107.456\text{ kip-in.} + 2214.9\text{ kip-in.}} = 0.2$$

For the beams continuous from both ends:

$$DF_{Beam} = \frac{K_{Beam}}{K_{Column} + K_{Beam} + K_{Beam} + K_{Column}}$$

$$DF_{Beam} = \frac{1107.456 \text{ kip-in.}}{2214.9 \text{ kip-in.} + 1107.456 \text{ kip-in.} + 1107.456 \text{ kip-in.} + 2214.9 \text{ kip-in.}} = 0.166$$

Flexural stiffness of beams and columns ends, COF

$$COF = 0.5$$

Where COF is the Carry-Over Factor that represents the fraction of the moment that is "carried over" from the joint to the beam end when the beam far end is fixed.

Fixed-end moments, FEMs

For a beam with uniformly distributed load and fixed ends, FEM can be found using the following equation:

$$FEM = \frac{w \times l^2}{12}$$

For member AB for load scenario LC1:

$$FEM_w = \frac{(w_D + w_L) \times l^2}{12} = \frac{(2.025 \text{ klf}) \times (20 \text{ ft})^2}{12} = 67.5 \text{ kip-ft}$$

$$FEM_{w_D} = \frac{w_D \times l^2}{12} = \frac{(0.675 \text{ klf}) \times (20 \text{ ft})^2}{12} = 22.5 \text{ kip-ft}$$

Beam analysis using moment distribution method

Moment distribution procedures for the seven loading scenarios are shown in Table 1. Counter-clockwise rotational moments acting on member ends are taken as positive. Positive span moments are determined from the following equation:

$$M_{Midspan} = M_o - \frac{(M_L + M_R)}{2}$$

Where M_o is the moment at the midspan for a simple beam, M_L and M_R are the negative moment at the span left and right end, respectively. The typical value of M_o for all spans due to the dead load w_D is:

$$M_{o\_D} = \frac{w_D \times l^2}{8} = \frac{0.675 \text{ klf} \times (20 \text{ ft})^2}{8} = 33.75 \text{ kip-ft}$$

$$M_{o\_D+L} = \frac{(w_D + w_L) \times l^2}{8} = \frac{2.025 \text{ klf} \times (20 \text{ ft})^2}{8} = 101.25 \text{ kip-ft}$$

The moment at the midspan M_s may be determined by superposition of the effect of end moments with that of the simply supported beam moment due to transverse loading.

$$M_s = M_o - \frac{1}{2} \times \left(M_L + M_R \right)$$

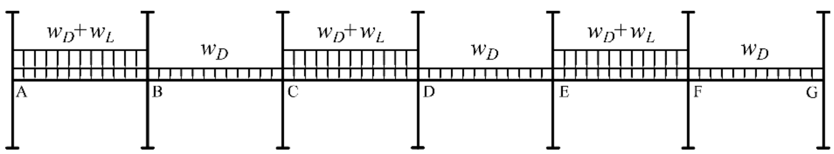
Where M_o is the moment at the midspan for a simply supported beam in the above equation, M_o, M_L and M_R are taken as positive values. When the beam end moments are not equal, the maximum moment in the span does not occur at midspan, but its value is close to that at midspan.

Table 1 – Moment Distribution Parameters

Joint	A	B		C		D		E		F		G
Member	**AB**	**BA**	**BC**	**CB**	**CD**	**DC**	**DE**	**ED**	**EF**	**FE**	**FG**	**GF**
DF	0.2	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.166	0.2
COF	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

LC1: Span AB, CD, and EF are loaded with live load

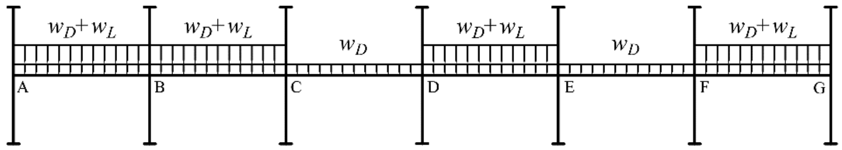
LC1



Joint	A	B		C		D		E		F		G
Member	**AB**	**BA**	**BC**	**CB**	**CD**	**DC**	**DE**	**ED**	**EF**	**FE**	**FG**	**GF**
FEM	67.5	-67.5	22.5	-22.5	67.5	-67.5	22.5	-22.5	67.5	-67.5	22.5	-22.5
Dist.	-13.50	7.47	7.47	-7.47	-7.47	7.47	7.47	-7.47	-7.47	7.47	7.47	4.50
CO	3.74	-6.75	-3.74	3.74	3.74	-3.74	-3.74	3.74	3.74	-3.74	2.25	3.74
Dist.	-0.75	1.74	1.74	-1.24	-1.24	1.24	1.24	-1.24	-1.24	0.25	0.25	-0.75
CO	0.87	-0.37	-0.62	0.87	0.62	-0.62	-0.62	0.62	0.12	-0.62	-0.37	0.12
Dist.	-0.17	0.16	0.16	-0.25	-0.25	0.21	0.21	-0.12	-0.12	0.16	0.16	-0.02
CO	0.08	-0.09	-0.12	0.08	0.10	-0.12	-0.06	0.10	0.08	-0.06	-0.01	0.08
Dist.	-0.02	0.03	0.03	-0.03	-0.03	0.03	0.03	-0.03	-0.03	0.01	0.01	-0.02
CO	0.02	-0.01	-0.02	0.02	0.02	-0.02	-0.02	0.02	0.01	-0.02	-0.01	0.01
Dist.	0.00	0.00	0.00	-0.01	-0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
M^- (kip-ft)	57.76	-65.30	27.42	-26.79	62.98	-63.04	27.02	-26.89	62.58	-64.03	32.25	-14.84
M^+ (kip-ft)	39.72		6.65		38.24		6.79		37.94		10.20	

LC2: Span AB, BC, DE, and FG are loaded with live load

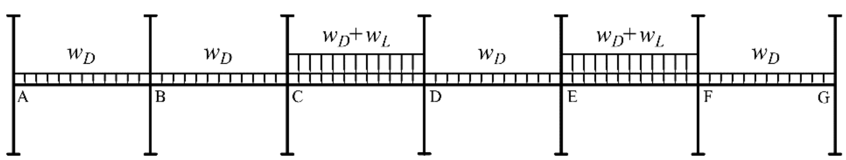
LC2



Joint	A	B		C		D		E		F		G
Member	**AB**	**BA**	**BC**	**CB**	**CD**	**DC**	**DE**	**ED**	**EF**	**FE**	**FG**	**GF**
FEM	67.5	-67.5	67.5	-67.5	22.5	-22.5	67.5	-67.5	22.5	-22.5	67.5	-67.5
Dist.	-13.50	0.00	0.00	7.47	7.47	-7.47	-7.47	7.47	7.47	-7.47	-7.47	13.50
CO	0.00	-6.75	3.74	0.00	-3.74	3.74	3.74	-3.74	-3.74	3.74	6.75	-3.74
Dist.	0.00	0.50	0.50	0.62	0.62	-1.24	-1.24	1.24	1.24	-1.74	-1.74	0.75
CO	0.25	0.00	0.31	0.25	-0.62	0.31	0.62	-0.62	-0.87	0.62	0.37	-0.87
Dist.	-0.05	-0.05	-0.05	0.06	0.06	-0.15	-0.15	0.25	0.25	-0.16	-0.16	0.17
CO	-0.03	-0.03	0.03	-0.03	-0.08	0.03	0.12	-0.08	-0.08	0.12	0.09	-0.08
Dist.	0.01	0.00	0.00	0.02	0.02	-0.03	-0.03	0.03	0.03	-0.03	-0.03	0.02
CO	0.00	0.00	0.01	0.00	-0.01	0.01	0.01	-0.01	-0.02	0.01	0.01	-0.02
Dist.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00
M $^-$ (kip-ft)	54.18	-73.83	72.03	-59.11	26.23	-27.31	63.10	-62.96	26.78	-27.42	65.30	-57.76
M $^+$ (kip-ft)	37.25		35.68		6.98		38.22		6.65		39.72	

LC3: Span CD and EF are loaded with live load

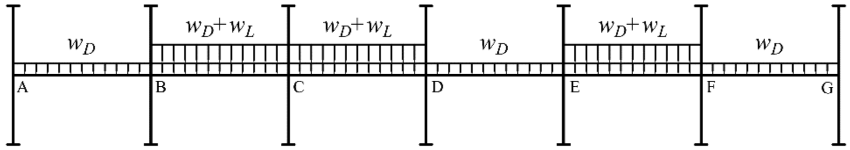
LC3



Joint	A	B		C		D		E		F		G
Member	**AB**	**BA**	**BC**	**CB**	**CD**	**DC**	**DE**	**ED**	**EF**	**FE**	**FG**	**GF**
FEM	22.5	-22.5	22.5	-22.5	67.5	-67.5	22.5	-22.5	67.5	-67.5	22.5	-22.5
Dist.	-4.50	0.00	0.00	-7.47	-7.47	7.47	7.47	-7.47	-7.47	7.47	7.47	4.50
CO	0.00	-2.25	-3.74	0.00	3.74	-3.74	-3.74	3.74	3.74	-3.74	2.25	3.74
Dist.	0.00	0.99	0.99	-0.62	-0.62	1.24	1.24	-1.24	-1.24	0.25	0.25	-0.75
CO	0.50	0.00	-0.31	0.50	0.62	-0.31	-0.62	0.62	0.12	-0.62	-0.37	0.12
Dist.	-0.10	0.05	0.05	-0.19	-0.19	0.15	0.15	-0.12	-0.12	0.16	0.16	-0.02
CO	0.03	-0.05	-0.09	0.03	0.08	-0.09	-0.06	0.08	0.08	-0.06	-0.01	0.08
Dist.	-0.01	0.02	0.02	-0.02	-0.02	0.03	0.03	-0.03	-0.03	0.01	0.01	-0.02
CO	0.01	0.00	-0.01	0.01	0.01	-0.01	-0.01	0.01	0.01	-0.01	-0.01	0.01
Dist.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M $^-$ (kip-ft)	18.43	-23.73	19.42	-30.26	63.65	-62.75	26.96	-26.92	62.58	-64.03	32.25	-14.84
M $^+$ (kip-ft)	12.67		8.91		38.05		6.81		37.94		10.20	

LC4: Span BC, CD and EF are loaded with live load

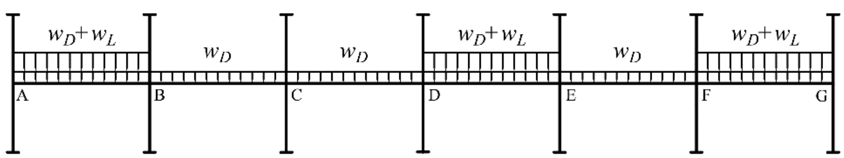
LC4



Joint	**A**	**B**		**C**		**D**		**E**		**F**		**G**
Member	**AB**	**BA**	**BC**	**CB**	**CD**	**DC**	**DE**	**ED**	**EF**	**FE**	**FG**	**GF**
FEM	22.5	-22.5	67.5	-67.5	67.5	-67.5	22.5	-22.5	67.5	-67.5	22.5	-22.5
Dist.	-4.50	-7.47	-7.47	0.00	0.00	7.47	7.47	-7.47	-7.47	7.47	7.47	4.50
CO	-3.74	-2.25	0.00	-3.74	3.74	0.00	-3.74	3.74	3.74	-3.74	2.25	3.74
Dist.	0.75	0.37	0.37	0.00	0.00	0.62	0.62	-1.24	-1.24	0.25	0.25	-0.75
CO	0.19	0.37	0.00	0.19	0.31	0.00	-0.62	0.31	0.12	-0.62	-0.37	0.12
Dist.	-0.04	-0.06	-0.06	-0.08	-0.08	0.10	0.10	-0.07	-0.07	0.16	0.16	-0.02
CO	-0.03	-0.02	-0.04	-0.03	0.05	-0.04	-0.04	0.05	0.08	-0.04	-0.01	0.08
Dist.	0.01	0.01	0.01	0.00	0.00	0.01	0.01	-0.02	-0.02	0.01	0.01	-0.02
CO	0.00	0.00	0.00	0.00	0.01	0.00	-0.01	0.01	0.00	-0.01	-0.01	0.00
Dist.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M $^-$ (kip-ft)	15.14	-31.54	60.31	-71.16	71.52	-59.34	26.31	-27.20	62.64	-64.01	32.25	-14.84
M $^+$ (kip-ft)	10.41		35.51		35.82		7.00		37.93		10.20	

LC5: Span AB, DE and FG are loaded with live load

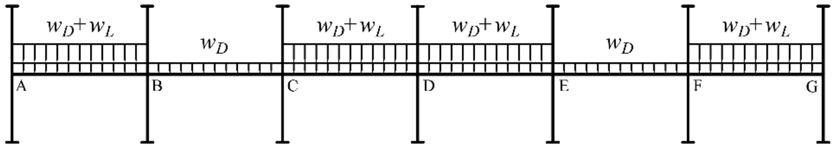
LC5



Joint	**A**	**B**		**C**		**D**		**E**		**F**		**G**
Member	**AB**	**BA**	**BC**	**CB**	**CD**	**DC**	**DE**	**ED**	**EF**	**FE**	**FG**	**GF**
FEM	67.5	-67.5	22.5	-22.5	22.5	-22.5	67.5	-67.5	22.5	-22.5	67.5	-67.5
Dist.	-13.50	7.47	7.47	0.00	0.00	-7.47	-7.47	7.47	7.47	-7.47	-7.47	13.50
CO	3.74	-6.75	0.00	3.74	-3.74	0.00	3.74	-3.74	-3.74	3.74	6.75	-3.74
Dist.	-0.75	1.12	1.12	0.00	0.00	-0.62	-0.62	1.24	1.24	-1.74	-1.74	0.75
CO	0.56	-0.37	0.00	0.56	-0.31	0.00	0.62	-0.31	-0.87	0.62	0.37	-0.87
Dist.	-0.11	0.06	0.06	-0.04	-0.04	-0.10	-0.10	0.20	0.20	-0.16	-0.16	0.17
CO	0.03	-0.06	-0.02	0.03	-0.05	-0.02	0.10	-0.05	-0.08	0.10	0.09	-0.08
Dist.	-0.01	0.01	0.01	0.00	0.00	-0.01	-0.01	0.02	0.02	-0.03	-0.03	0.02
CO	0.01	0.00	0.00	0.01	-0.01	0.00	0.01	-0.01	-0.02	0.01	0.01	-0.02
Dist.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M $^-$ (kip-ft)	57.47	-66.02	31.15	-18.21	18.36	-30.73	63.76	-62.67	26.73	-27.45	65.31	-57.76
M $^+$ (kip-ft)	39.51		9.07		9.21		38.04		6.66		39.71	

LC6: Span AB, CD, DE and FG are loaded with live load

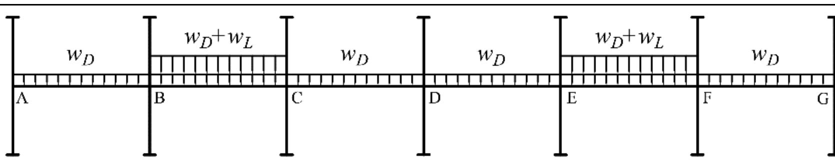
LC6



Joint	A	B		C		D		E		F		G
Member	**AB**	**BA**	**BC**	**CB**	**CD**	**DC**	**DE**	**ED**	**EF**	**FE**	**FG**	**GF**
FEM	67.5	-67.5	22.5	-22.5	67.5	-67.5	67.5	-67.5	22.5	-22.5	67.5	-67.5
Dist.	-13.50	7.47	7.47	-7.47	-7.47	0.00	0.00	7.47	7.47	-7.47	-7.47	13.50
CO	3.74	-6.75	-3.74	3.74	0.00	-3.74	3.74	0.00	-3.74	3.74	6.75	-3.74
Dist.	-0.75	1.74	1.74	-0.62	-0.62	0.00	0.00	0.62	0.62	-1.74	-1.74	0.75
CO	0.87	-0.37	-0.31	0.87	0.00	-0.31	0.31	0.00	-0.87	0.31	0.37	-0.87
Dist.	-0.17	0.11	0.11	-0.14	-0.14	0.00	0.00	0.14	0.14	-0.11	-0.11	0.17
CO	0.06	-0.09	-0.07	0.06	0.00	-0.07	0.07	0.00	-0.06	0.07	0.09	-0.06
Dist.	-0.01	0.03	0.03	-0.01	-0.01	0.00	0.00	0.01	0.01	-0.03	-0.03	0.01
CO	0.01	-0.01	0.00	0.01	0.00	0.00	0.00	0.00	-0.01	0.00	0.01	-0.01
Dist.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M^- (kip-ft)	57.74	-65.36	27.73	-26.07	59.25	-71.62	71.62	-59.25	26.07	-27.73	65.36	-57.74
M^+ (kip-ft)	39.70		6.85		35.81		35.81		6.85		39.70	

LC7: Span BC and EF are loaded with live load

LC7



Joint	A	B		C		D		E		F		G
Member	**AB**	**BA**	**BC**	**CB**	**CD**	**DC**	**DE**	**ED**	**EF**	**FE**	**FG**	**GF**
FEM	22.5	-22.5	67.5	-67.5	22.5	-22.5	22.5	-22.5	67.5	-67.5	22.5	-22.5
Dist.	-4.50	-7.47	-7.47	7.47	7.47	0.00	0.00	-7.47	-7.47	7.47	7.47	4.50
CO	-3.74	-2.25	3.74	-3.74	0.00	3.74	-3.74	0.00	3.74	-3.74	2.25	3.74
Dist.	0.75	-0.25	-0.25	0.62	0.62	0.00	0.00	-0.62	-0.62	0.25	0.25	-0.75
CO	-0.12	0.37	0.31	-0.12	0.00	0.31	-0.31	0.00	0.12	-0.31	-0.37	0.12
Dist.	0.02	-0.11	-0.11	0.02	0.02	0.00	0.00	-0.02	-0.02	0.11	0.11	-0.02
CO	-0.06	0.01	0.01	-0.06	0.00	0.01	-0.01	0.00	0.06	-0.01	-0.01	0.06
Dist.	0.01	0.00	0.00	0.01	0.01	0.00	0.00	-0.01	-0.01	0.00	0.00	-0.01
CO	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00
Dist.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
M^- (kip-ft)	14.87	-32.19	63.72	-63.30	30.62	-18.44	18.44	-30.62	63.30	-63.72	32.19	-14.87
M^+ (kip-ft)	10.22		37.74		9.22		9.22		37.74		10.22	

Moment envelopes at each span ends and positive moment near midspan are summarized in Table 2. Positive moment values are underlined.

Table 2 - Moment Envelopes Results

Span	AB		BC		CD		DE		EF		FG	
	M_L	M_R	M_L	M_R	M_L	M_R	M_L	M_R	M_L	M_R	M_L	M_R
Negative Moment (kip-ft)	57.67	-73.79	71.93	-71.12	71.44	-71.52	71.52	-71.44	71.12	-71.93	73.79	-57.67
Positive Moment (kip-ft)	39.85		37.99		38.31		38.31		37.99		39.85	

3. Arrangement of Live Load for Moment Envelope –spBeam Software

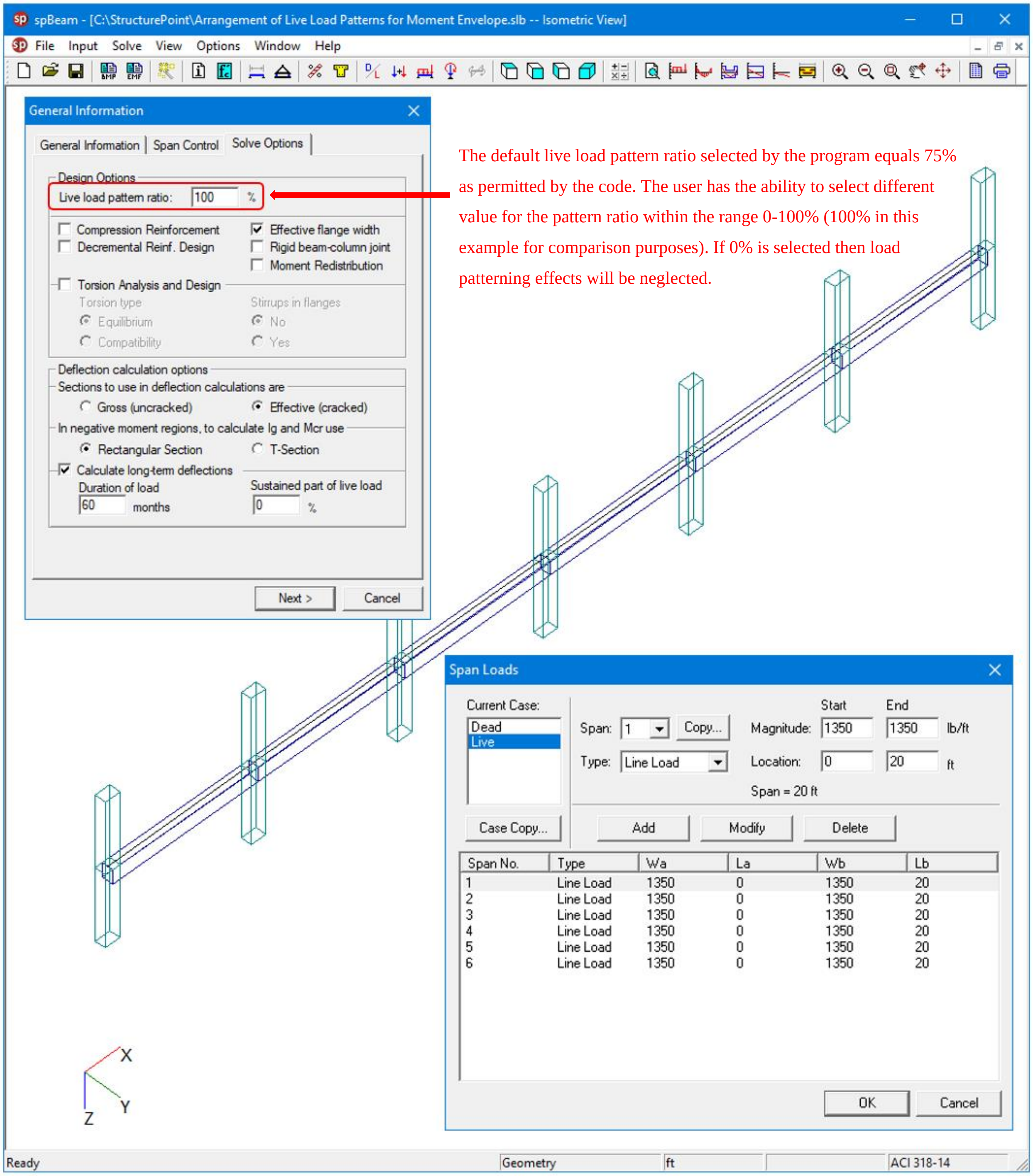
spBeam is widely used for analysis, design and investigation of beams, and one-way slab systems (including standard and wide module joist systems) per latest American (ACI 318) and Canadian (CSA A23.3) codes. spBeam can be used for new designs or investigation of existing structural members subjected to flexure, shear, and torsion loads. With capacity to integrate up to 20 spans and two cantilevers of wide variety of floor system types, spBeam is equipped to provide cost-effective, accurate, and fast solutions to engineering challenges.

spBeam provides top and bottom bar details including development lengths and material quantities, as well as live load patterning and immediate and long-term deflection results. Using the moment redistribution feature engineers can deliver safe designs with savings in materials and labor. Engaging this feature allows up to 20% reduction of negative moments over supports reducing reinforcement congestions in these areas.

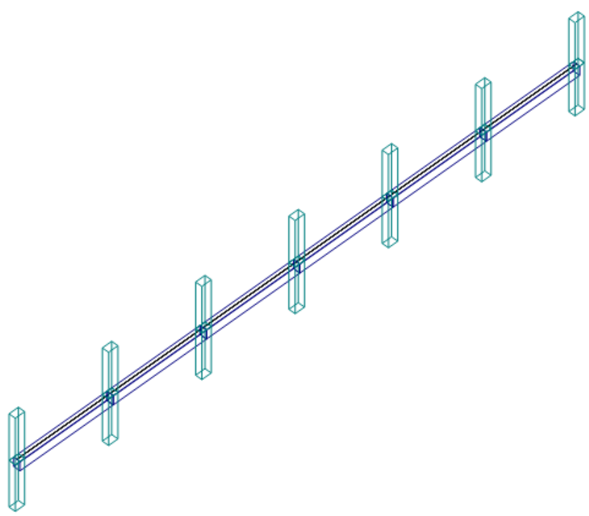
Beam analysis and design requires engineering judgment in most situations to properly simulate the behavior of the targeted beam and take into account important design considerations such as: designing the beam as rectangular or T-shaped sections; using the effective flange width or the center-to-center distance between the beam and the adjacent beams. Regardless which of these options is selected, spBeam provide users with options and flexibility to:

1. Design the beam as a rectangular cross-section or a T-shaped section.
2. Use the effective or full beam flange width.
3. Include the flanges effects in the deflection calculations.
4. Invoke moment redistribution to lower negative moments
5. Using gross (uncracked) or effective (cracked) moment of inertia
6. Design the beam as singly or doubly reinforced section.

For illustration and comparison purposes, the following figures provide a sample of the input modules and results obtained from an spBeam model created for the beam covered in this design example.


spBeam - [C:\StructurePoint\Arrangement of Live Load Patterns for Moment Envelope.slb -- Isometric View]
General Information
Live load pattern ratio: 100 %
The default live load pattern ratio selected by the program equals 75% as permitted by the code. The user has the ability to select different value for the pattern ratio within the range 0-100% (100% in this example for comparison purposes). If 0% is selected then load patterning effects will be neglected.
Span Loads
Current Case: Dead Live
Span: 1
Magnitude: Start 1350 End 1350 lb/ft
Type: Line Load
Location: 0 20 ft
Span = 20 ft
Span No. Type Wa La Wb Lb
1 Line Load 1350 0 1350 20
2 Line Load 1350 0 1350 20
3 Line Load 1350 0 1350 20
4 Line Load 1350 0 1350 20
5 Line Load 1350 0 1350 20
6 Line Load 1350 0 1350 20
ACI 318-14

spBeam v5.50
A Computer Program for Analysis, Design, and Investigation of
Reinforced Concrete Beams and One-way Slab Systems



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1. Input Echo

1.1. General Information

File Name	...\Arrangment of Live Load for Moment Envelop...
Project	Arrangement of Live Load for Moment Envelope
Frame	
Engineer	SP
Code	ACI 318-14
Reinforcement Database	ASTM A615
Mode	Investigation
Number of supports =	7
Floor System	One-Way/Beam

1.2. Solve Options

Live load pattern ratio = 100%
Deflections are based on cracked section properties.
In negative moment regions, Ig and Mcr DO NOT include flange/slab contribution (if available)
Long-term deflections are calculated for load duration of 60 months.
0% of live load is sustained.
Compression reinforcement calculations NOT selected.
Default incremental rebar design selected.
Moment redistribution NOT selected.
Effective flange width calculations selected.
Rigid beam-column joint NOT selected.
Torsion analysis and design NOT selected.

1.3. Material Properties

1.3.1. Concrete: Slabs / Beams

w_c	150	lb/ft^3
f'_c	4	ksi
E_c	3605	ksi
f_r	0.47434	ksi

1.3.2. Concrete: Columns

w_c	150	lb/ft^3
f'_c	4	ksi
E_c	3605	ksi
f_r	0.47434	ksi

1.3.3. Reinforcing Steel

f_y	60	ksi
f_{yt}	60	ksi
E_s	29000	ksi
Epoxy coated bars	No	

1.4. Span Data

1.4.1. Slabs

Span	Loc	L1	t	wL	wR	bE_{ff}	H_{min}
		ft	in	ft	ft	in	in
1	Int	20.000	0.00	0.667	0.667	16.00	0.00
2	Int	20.000	0.00	0.667	0.667	16.00	0.00
3	Int	20.000	0.00	0.667	0.667	16.00	0.00
4	Int	20.000	0.00	0.667	0.667	16.00	0.00
5	Int	20.000	0.00	0.667	0.667	16.00	0.00
6	Int	20.000	0.00	0.667	0.667	16.00	0.00

1.4.2. Ribs and Longitudinal Beams

Span	Ribs			Beams		Span
	b	h	Sp	b	h	H_{min}
	in	in	in	in	in	in
1	0.00	0.00	0.00	16.00	24.00	12.97
2	0.00	0.00	0.00	16.00	24.00	11.43
3	0.00	0.00	0.00	16.00	24.00	11.43
4	0.00	0.00	0.00	16.00	24.00	11.43
5	0.00	0.00	0.00	16.00	24.00	11.43
6	0.00	0.00	0.00	16.00	24.00	12.97

1.5. Support Data

1.5.1. Columns

Support	c1a	c2a	Ha	c1b	c2b	Hb	Red %
	in	in	ft	in	in	ft	
1	24.00	16.00	10.000	24.00	16.00	10.000	100
2	24.00	16.00	10.000	24.00	16.00	10.000	100
3	24.00	16.00	10.000	24.00	16.00	10.000	100
4	24.00	16.00	10.000	24.00	16.00	10.000	100
5	24.00	16.00	10.000	24.00	16.00	10.000	100
6	24.00	16.00	10.000	24.00	16.00	10.000	100
7	24.00	16.00	10.000	24.00	16.00	10.000	100

1.5.2. Boundary Conditions

Support	Spring		Far End	
	K_z	K_{ry}	Above	Below
	kip/in	kip-in/rad		
1	0	0	Fixed	Fixed
2	0	0	Fixed	Fixed
3	0	0	Fixed	Fixed
4	0	0	Fixed	Fixed
5	0	0	Fixed	Fixed
6	0	0	Fixed	Fixed
7	0	0	Fixed	Fixed

1.6. Load Data

1.6.1. Load Cases and Combinations

Case	Dead	Live
Type	DEAD	LIVE
U1	1.000	1.000

1.6.2. Line Loads

Case/Patt	Span	Wa lb/ft	La ft	Wb lb/ft	Lb ft
Dead	1	675.00	0.000	675.00	20.000
	2	675.00	0.000	675.00	20.000
	3	675.00	0.000	675.00	20.000
	4	675.00	0.000	675.00	20.000
	5	675.00	0.000	675.00	20.000
	6	675.00	0.000	675.00	20.000
Live	1	1350.00	0.000	1350.00	20.000
	2	1350.00	0.000	1350.00	20.000
	3	1350.00	0.000	1350.00	20.000
	4	1350.00	0.000	1350.00	20.000
	5	1350.00	0.000	1350.00	20.000
	6	1350.00	0.000	1350.00	20.000
Live/Odd	1	1350.00	0.000	1350.00	20.000
	3	1350.00	0.000	1350.00	20.000
	5	1350.00	0.000	1350.00	20.000
Live/Even	2	1350.00	0.000	1350.00	20.000
	4	1350.00	0.000	1350.00	20.000
	6	1350.00	0.000	1350.00	20.000
Live/S1	1	1350.00	0.000	1350.00	20.000
Live/S2	1	1350.00	0.000	1350.00	20.000
	2	1350.00	0.000	1350.00	20.000
Live/S3	2	1350.00	0.000	1350.00	20.000
	3	1350.00	0.000	1350.00	20.000
Live/S4	3	1350.00	0.000	1350.00	20.000
	4	1350.00	0.000	1350.00	20.000
Live/S5	4	1350.00	0.000	1350.00	20.000
	5	1350.00	0.000	1350.00	20.000
Live/S6	5	1350.00	0.000	1350.00	20.000
	6	1350.00	0.000	1350.00	20.000
Live/S7	6	1350.00	0.000	1350.00	20.000

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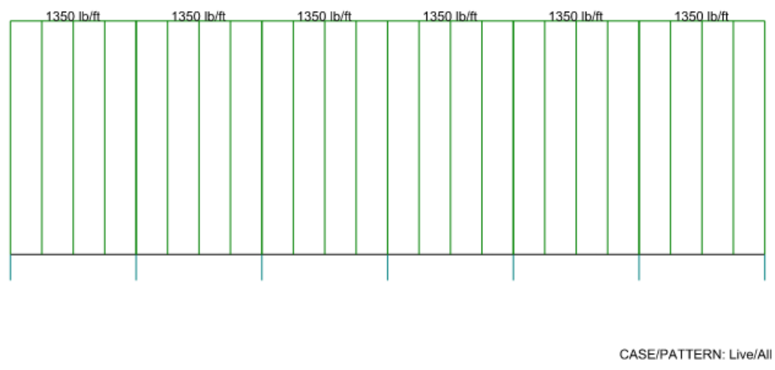
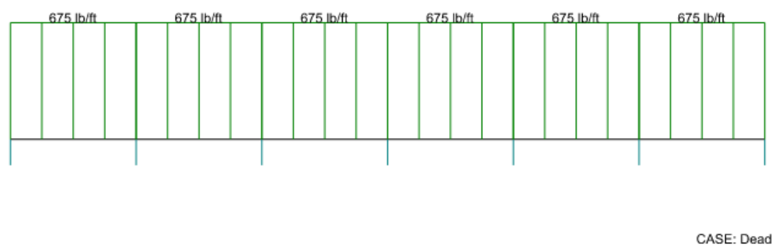
2. Diagrams

2.1. Loads





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Project: Arrangement of Live Load for Moment Envelope
Frame:
Engineer: SP
Code: ACI 318-14
Date: 11/04/21
Time: 14:07:59

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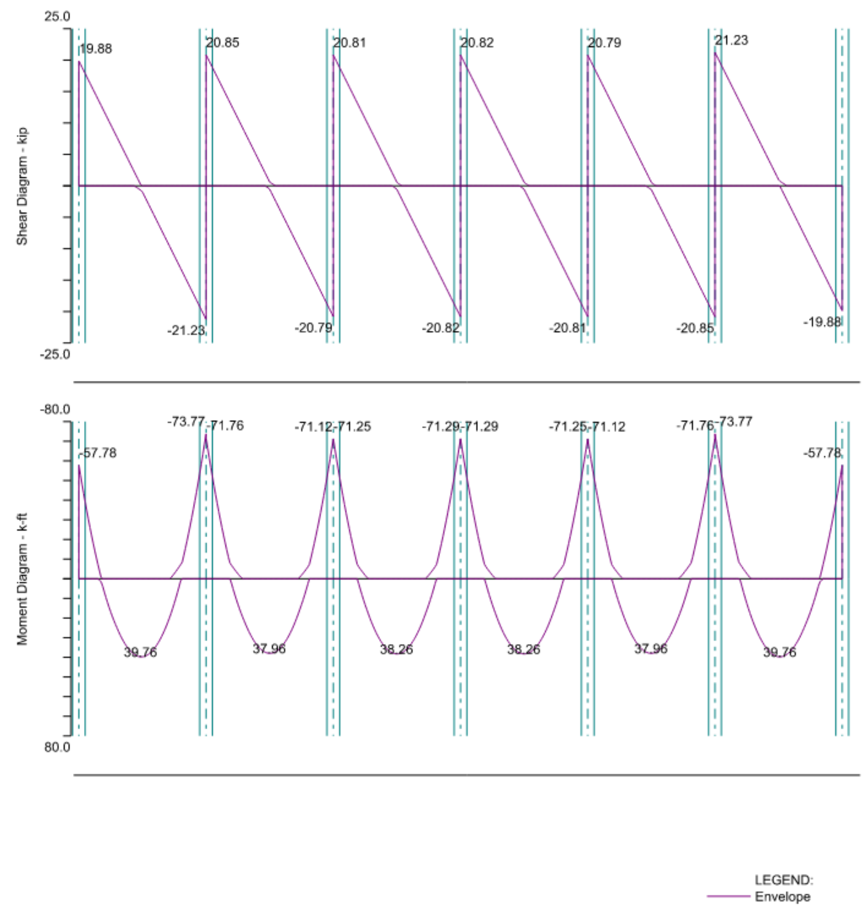
2.2. Internal Forces



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Project: Arrangement of Live Load for Moment Envelope

Frame:

Engineer: SP

Code: ACI 318-14

Date: 11/04/21

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4. Comparison of Design Results

<table>
<tr><th colspan="9">Table 3 - Comparison of Results</th></tr>
<tr><th colspan="2" rowspan="2">Span</th><th colspan="2">AB</th><th colspan="2">BC</th><th colspan="2">CD</th><th rowspan="8">Line of symmetry</th></tr>
<tr><th>M_L</th><th>M_R</th><th>M_L</th><th>M_R</th><th>M_L</th><th>M_R</th></tr>
<tr><td rowspan="3">Negative Moment (kip-ft)</td><td>Hand</td><td>57.76</td><td>-73.83</td><td>72.03</td><td>-71.16</td><td>71.52</td><td>-71.62</td></tr>
<tr><td>Reference</td><td>57.67</td><td>-73.79</td><td>71.93</td><td>-71.12</td><td>71.44</td><td>-71.52</td></tr>
<tr><td>spBeam</td><td>57.78</td><td>-73.77</td><td>71.76</td><td>-71.12</td><td>71.25</td><td>-71.29</td></tr>
<tr><td rowspan="3">Positive Moment (kip-ft)</td><td>Hand</td><td colspan="2">39.72</td><td colspan="2">37.74</td><td colspan="2">38.24</td></tr>
<tr><td>Reference</td><td colspan="2">39.85</td><td colspan="2">37.99</td><td colspan="2">38.31</td></tr>
<tr><td></td><td>spBeam</td><td colspan="2">39.76</td><td colspan="2">37.96</td><td colspan="2">38.26</td><td></td></tr>
</table>

Comparison of results has been limited to the envelope values for the first three spans AB, BC, and CD since this is the goal of this case study. The results of reference and the hand calculations illustrated above are in precise agreement with the automated exact results obtained from the spBeam program.