

Hand Calculation

Problem Statement:

Determine if 14 x 24 in. rectangular concrete beam with 4 - #8 tension bars and #3 stirrups @10 in. OC is adequate for the applied dead and live loads. Verify flexural capacity, shear capacity, and tension-controlled classification

Beam width	$b := 14 \text{ in}$
Beam height	$h := 24 \text{ in}$
Span	$L := 20 \text{ ft}$ (simply supported)
Dead load (uniform, including self-weight)	$D_L := 2 \text{ klf}$
Live load (uniform)	$L_L := 1.5 \text{ klf}$
Concrete compressive strength	$f'_c := 4000 \text{ psi}$
Steel yield strength (grade 60)	$f_y := 60000 \text{ psi}$
Clear cover to stirrups	$c_{stirrup} := 1.5 \text{ in}$
Tension reinforcement	(4) - #8 bars
Shear reinforcement	#3 bar at 10" oc (2 legs)
Modulus of elasticity of steel	$E_s := 29000 \text{ ksi}$
Design Method: Strength Design (LRFD) - ACI 318 - 25	

Solution:

Step 1: Beam Geometry and Effective Depth

#8 bar diameter	$d_{bar} := 1 \text{ in}$
#3 stirrup diameter	$d_{stirrup} := 0.375 \text{ in}$

Effective depth (compression face to centroid of tension steel) is

$$d := h - c_{stirrup} - d_{stirrup} - \frac{d_{bar}}{2} = 21.625 \text{ in}$$

Step 2: Factored Loads and Applied Forces (ACI 318 - 25 Table 5.3.1)

Load combination is

$$U := 1.2 \cdot D_L + 1.6 \cdot L_L = 4.8 \text{ klf}$$

Applied moment for simply supported beam is

$$M := U \cdot \frac{L^2}{8} = 240 \text{ ft} \cdot \text{kip}$$

Maximum shear at support is

$$V := U \cdot \frac{L}{2} = 48 \text{ kip}$$

Step 3: Section Properties (ACI 318 - 25 Section 22.2.2.4)

Stress block factor $\beta_1 := 0.85$ for $f'_c = 4,000 \text{ psi}$ (ACI 318 - 25 Section 22.2.2.4.3)

Area per bar $A_b := 0.79 \cdot \text{in}^2$ Number of bar $n := 4$

Steel area is

$$A_s := n \cdot A_b = 3.16 \text{ in}^2$$

Depth of equivalent rectangular stress block is

$$a := \frac{A_s \cdot f_y}{0.85 \cdot f'_c \cdot b} = 3.983 \text{ in} \quad (\text{ACI 318 - 25 Section 22.2.2.4.1})$$

Depth to neutral axis is

$$c := \frac{a}{\beta_1} = 4.686 \text{ in}$$

Step 4: Tension - Controlled Classification (ACI 318 - 25 Section 21.2.2)Concrete crushing strain $\varepsilon_{cu} := 0.003$ (ACI 318 - 25 Section 22.2.2.1)

Net tensile strain in extreme tension steel at nominal strength is

$$\varepsilon_t := \varepsilon_{cu} \cdot \frac{d - c}{c} = 0.0108$$

Tension - Controlled , ACI 318-25 Section 9.3.3

 $\varepsilon_t = 0.0108 \geq 0.005$, therefore , $\phi := 0.90$ (Tension Controlled)**DESIGN CHECKS (Step 5 to Step 7)**Step 5: Flexural Capacity Check (ACI 318 - 25 Section 22.2.2.4.1)

Nominal flexural strength is

$$M_n := A_s \cdot f_y \cdot \left(d - \frac{a}{2} \right) = 310.21 \text{ (ft} \cdot \text{kip)}$$

Design moment capacity is

$$M_c := \phi \cdot M_n = 279.187 \text{ ft} \cdot \text{kip}$$

Calculated from step 2 , $M = 240 \text{ ft} \cdot \text{kip}$

Demand to capacity ratio

$$DCR_{moment} := \frac{M}{M_c} = 0.86 < 1.0 \text{ PASS } \checkmark$$

Step 6: Shear Capacity Check (ACI 318 - 25 Section 22.5 , 9.5 , 9.7.6) and (Section 9.4.3.1 and 9.4.3.2)

Critical section for shear is permitted to be taken at distance d from face of support for non-prestressed members. However, to take this reduction, additional conditions must be met. ENERCALC does not examine these conditions, hence, ENERCALC does not take this reduction (AKA $V = 48$ Kips). This calculation will show the logic that ENERCALC uses which is more conservative. However, the same process shall apply if the user decides to reduce the applied shear and use the shear at d distance from the support.

Normal weight concrete $\lambda := 1.0$ (ACI 318 - 25 Section 19.2.4.1)

Concrete shear contribution is

$$V_c := 2 \cdot \lambda \cdot \frac{bf}{in^2} \sqrt{\frac{f'_c}{psi}} \cdot b \cdot d = 38.295 \text{ kip} \quad (\text{ACI 318 - 25 Section 22.5.5.1})$$

$$\phi := 0.75 \quad (\text{ACI 318 - 25 Table 21.2.1})$$

$$V_{cn} := \phi \cdot V_c = 28.721 \text{ kip}$$

Steel shear contribution:

(ACI 318 - 25 Table 21.2.1)

number of legs $n_l := 2$

Area per leg $A_l := 0.11 \text{ in}^2$

Total area of steel is $A_v := n_l \cdot A_l = 0.22 \text{ in}^2$

Stirrup spacing $s := 10.81 \text{ in}$ This assumption for min stirrup spacing will be calculated and validated later

$$V_s := A_v \cdot f_y \cdot \frac{d}{s} = 26.406 \text{ kip} \quad (\text{ACI 318 - 25 Section 22.5.10.5.3})$$

$$\phi = 0.75$$

$$V_{sn} := \phi \cdot V_s = 19.805 \text{ kip}$$

Total design shear capacity is

$$V_n := V_{cn} + V_{sn} = 48.526 \text{ kip}$$

Demand to capacity ratio

$$DCR_{shear} := \frac{V}{V_n} = 0.989 < 1.0 \text{ PASS } \checkmark$$

Step 7: Minimum shear reinforcement check (ACI 318 - 25 Section 9.6.3.3)

$$A_{v_min} := \max \left(0.75 \cdot \frac{bf}{in^2} \sqrt{\frac{f'_c}{psi}}, \frac{50}{f_y} \cdot \frac{bf}{in^2} \right) \cdot b = 0.0117 \frac{in^2}{in}$$

$$A_{v_prov} := \frac{A_v}{10.81 \cdot in} = 0.02 \frac{in^2}{in}$$

Minimum shear reinforcement is

$$\frac{A_{v_prov}}{A_{v_min}} = 1.744 > 1.0 \text{ PASS } \checkmark$$

Maximum stirrup spacing is

$$s_{max} := \min \left(\frac{d}{2}, 24 \text{ in} \right) = 10.81 \text{ in}$$

The ACI 318 maximum allowed stirrup spacing controls the design, hence, stirrups must be spaced at 10.81" OC max.

ENERCALC reports the stirrup spacing at 10 in OC which is a round down of the code required spacing of 10.81 in OC

Step 7: Deflection Analysis

- Concrete Stiffness Properties (ACI 318 - 25 Sec.19.2.2.1)

$$E_c := 57000 \cdot \text{psi} \cdot \sqrt{\frac{f'_c}{\text{psi}}} = (3.605 \cdot 10^6) \text{ psi}$$

- Modular Ratio

$$\eta := \frac{E_s}{E_c} = 8.044$$

- Modulus of Rapture (ACI 318 - 25 Sec.19.2.3.1)

$$f_r := 7.5 \cdot 1.0 \cdot \text{psi} \cdot \sqrt{\frac{f'_c}{\text{psi}}} = 474.342 \text{ psi}$$

- Gross moment of inertia

$$I_g := b \cdot \frac{h^3}{12} = 16128 \text{ in}^4$$

- Cracking moment M_{cr} (ACI 318 - 25 Eq.24.2.3.5b)

$$y_t := \frac{h}{2} = 12 \text{ in}$$

$$M_{cr} := f_r \cdot \frac{I_g}{y_t} = 53.126 \text{ kip} \cdot \text{ft}$$

- Cracked moment of Inertia I_{cr}

Locate cracked N.A from: $\left(\frac{b}{2}\right) k_d^2 + (\eta \cdot A_s \cdot k_d) - (\eta \cdot A_s \cdot d) = 0$

$$k_d := \frac{-\left(\eta \cdot A_s\right) + \sqrt{\left(\eta \cdot A_s\right)^2 + 4 \cdot \left(\frac{b}{2}\right) \cdot \left(\eta \cdot A_s \cdot d\right)}}{2 \cdot \left(\frac{b}{2}\right)}$$

$$I_{cr} := b \cdot \frac{k_d^3}{3} + \eta \cdot A_s \cdot (d - k_d)^2 = 7031.176 \text{ in}^4$$

$$\frac{I_{cr}}{I_g} = 0.436$$

- Effective moment of Inertia (ACI 318 - 25 Sec.24.2.3)

ACI 318 - 25 Table 24.2.3.5 - Bischoff formula (used by ENERCALC for ACI 318 - 25)

Maximum service moment $M_a := 175 \text{ ft} \cdot \text{kip}$

$$I_e := \frac{I_{cr}}{1 - \left(\frac{2}{3} \cdot \frac{M_{cr}}{M_a}\right)^2 \cdot \left(1 - \frac{I_{cr}}{I_g}\right)} = 7197.459 \text{ in}^4 < I_g = 16128 \text{ in}^4 \quad \text{PASS} \checkmark$$

- Immediate Deflection (ACI 318 25 Sec.24.2.3)

Simple supported beam, uniform load

Dead load deflection is

$$\Delta_D := \frac{5 D_L \cdot L^4}{384 \cdot E_c \cdot I_e} = 0.277 \text{ in}$$

Live load deflection is

$$\Delta_L := \frac{5 L_L \cdot L^4}{384 \cdot E_c \cdot I_e} = 0.208 \text{ in}$$

Total immediate deflection is

$$\Delta_T := \Delta_D + \Delta_L = 0.486 \text{ in}$$

See the following ENERCALC printed calc report for comparison

Concrete Beam

Project File: Reinforced Concrete Beam.ec6

LIC# : KW-06000215, Build:20.26.06.15

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DESCRIPTION: Reinforced Concrete Beam

Code References

Governing Code : IBC 2024

Referenced Design Standard(s) : ACI 318-25*

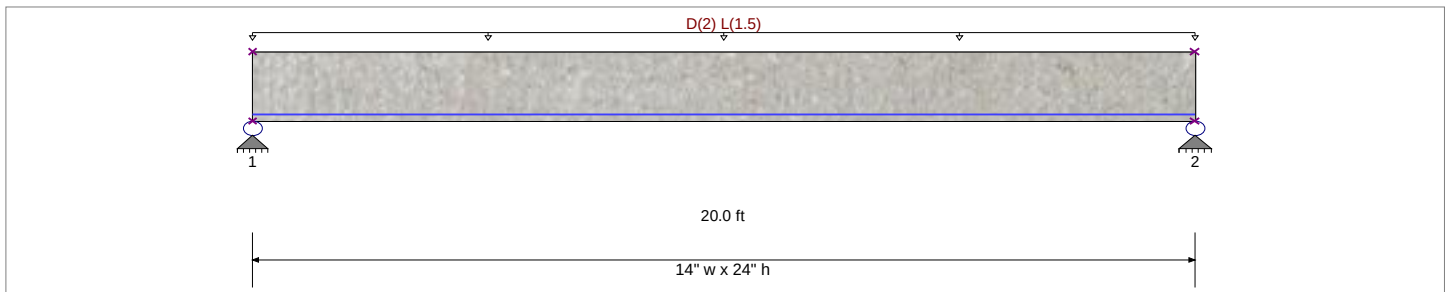
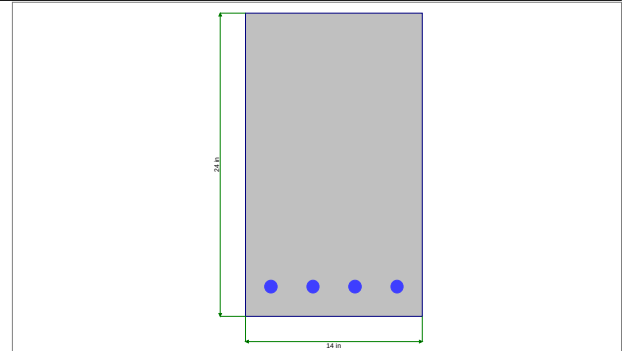
Load Combination Set : ASCE 7-22 / IBC 2024

*User-selected, not referenced by : IBC 2024

Rho (or Omega) = 1.00

General Information

f'_c	=	4.0 ksi	ϕ : Phi Values	Flexure :	0.90
$f_r = 7.5 * \lambda * f'_c^{1/2}$	=	474.342 psi		Shear :	0.750
Ψ Density	=	145.0 pcf	β_1	=	0.850
λ LtWt Factor	=	1.0			
Elastic Modulus	=	3,605.0 ksi	Fy - Stirrups	=	60.0 ksi
fy - Main Rebar	=	60.0	E - Stirrups	=	29,000.0 ksi
E - Main Rebar	=	29,000.0 ksi	Stirrup Bar Size #	=	3
			Number of Resisting Legs Per Stirrup	=	2
Seismic Design Category	=	A			



Cross Section & Reinforcing Details

Rectangular Section, Width = 14.0 in, Height = 24.0 in

Span #1 Reinforcing....

4-#8 at 2.375 in from Bottom, from 0.0 to 20.0 ft in this span

Load for Span Number 1

Uniform Load : D = 2.0, L = 1.50 k/ft, Tributary Width = 1.0 ft

DESIGN SUMMARY

Design OK

Maximum Bending Stress Ratio	=	0.860	: 1
Section used for this span		Typical Section	
Mu : Applied		239.999	k-ft
ϕ Mn : Allowable		279.187	k-ft
Location of maximum on span		9.982	ft
Span # where maximum occurs		Span # 1	

Design Limits

Tensile Strain >= Min Strain Limit	(Section 9.3.3.1)
0.01084 in / in >= 0.00507 in / in	OK
As Provided >= As,min	(Section 9.6.1.2)
3.160 in^2 >= 2.934 in^2	OK

Maximum Deflection

Max Downward Transient Deflection	0.174 in	Ratio =	1377	>=360.0	Span: 1 : L Only
Max Upward Transient Deflection	0.000 in	Ratio =	0	<360.0	
Max Downward Total Deflection	0.479 in	Ratio =	501	>=240.0	Span: 1 : +D+L
Max Upward Total Deflection	0.000 in	Ratio =	0	<240.0	

Cross Section Strength & Inertia

Top & Bottom references are for tension side of sect

Cross Section Bar Layout Description	ϕ Mn (k-ft)		Moment of Inertia (in^4)		
	Bottom	Top	I gross	Icr - Bottom	Icr - Top
Section 1 4- #8 @ d=21.625",	279.19	8.95	16,128.00	7,031.18	34.32

Maximum Vertical Reactions

Support notation : Far left is #1

Load Combination	Support 1	Support 2
Max Upward from all Load Cases & Combinations	35.000	35.000



Project Title: Reinforced Concrete Beam Module
Engineer: ENERCALC Engr. Div.
Project ID: ENERCALC
Project Descr: Verification Example

Concrete Beam

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DESCRIPTION: Reinforced Concrete Beam

Maximum Vertical Reactions

Support notation : Far left is #1

Load Combination	Support 1	Support 2
Max Upward from Load Combinations	35.000	35.000
Max Upward from Load Cases	20.000	20.000
D Only	20.000	20.000
+D+L	35.000	35.000
+D+0.750L	31.250	31.250
+0.60D	12.000	12.000
L Only	15.000	15.000

Vertical Reactions for Load Cases

Support notation : Far left is #1

Load Combination	Support 1	Support 2
Max Upward from Load Cases	20.000	20.000
D Only	20.000	20.000
L Only	15.000	15.000

Vertical Reactions for Load Combinations

Support notation : Far left is #1

Load Combination	Support 1	Support 2
Max Upward from Load Combinations	35.000	35.000
+D+L	35.000	35.000
+D+0.750L	31.250	31.250
+0.60D	12.000	12.000

Extreme Reactions

Values in KIPS

Support	D	Lr	L	S	W	E	H
Support #1	20.000		15.000				
Support #2	20.000		15.000				

Shear Stirrup Requirements

Between 0.00 to 6.99 ft, use #3 x 2-leg stirrups spaced at 10 in (Max spacing per 9.7.6.2.2)

Between 7.03 to 12.97 ft, Stirrups are not required.

Between 13.01 to 19.96 ft, use #3 x 2-leg stirrups spaced at 10 in (Max spacing per 9.7.6.2.2)

Detailed Shear Information

Load Combination	Span Number	Distance (ft)	'd' (in)	Vu (k)	Av, min Req'd?	Spacing Req'd (in)	ϕV_c (k)	ϕV_s (k)	ϕV_n (k)	Vu / ϕV_n	Vc Eqn (T22.5.5.1)	Spacing Provision
+1.20D+1.60L	1	0.00	21.63	48.00	Yes	10.81	28.72	19.80	48.52	0.989	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	0.22	21.63	46.95	Yes	10.81	28.72	19.80	48.52	0.968	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	0.44	21.63	45.90	Yes	10.81	28.72	19.80	48.52	0.946	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	0.66	21.63	44.85	Yes	10.81	28.72	19.80	48.52	0.924	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	0.87	21.63	43.80	Yes	10.81	28.72	19.80	48.52	0.903	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	1.09	21.63	42.75	Yes	10.81	28.72	19.80	48.52	0.881	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	1.31	21.63	41.70	Yes	10.81	28.72	19.80	48.52	0.860	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	1.53	21.63	40.66	Yes	10.81	28.72	19.80	48.52	0.838	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	1.75	21.63	39.61	Yes	10.81	28.72	19.80	48.52	0.816	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	1.97	21.63	38.56	Yes	10.81	28.72	19.80	48.52	0.795	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	2.19	21.63	37.51	Yes	10.81	28.72	19.80	48.52	0.773	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	2.40	21.63	36.46	Yes	10.81	28.72	19.80	48.52	0.751	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	2.62	21.63	35.41	Yes	10.81	28.72	19.80	48.52	0.730	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	2.84	21.63	34.36	Yes	10.81	28.72	19.80	48.52	0.708	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	3.06	21.63	33.31	Yes	10.81	28.72	19.80	48.52	0.687	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	3.28	21.63	32.26	Yes	10.81	28.72	19.80	48.52	0.665	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	3.50	21.63	31.21	Yes	10.81	28.72	19.80	48.52	0.643	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	3.72	21.63	30.16	Yes	10.81	28.72	19.80	48.52	0.622	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	3.93	21.63	29.11	Yes	10.81	28.72	19.80	48.52	0.600	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	4.15	21.63	28.07	Yes	10.81	28.72	19.80	48.52	0.578	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	4.37	21.63	27.02	Yes	10.81	28.72	19.80	48.52	0.557	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	4.59	21.63	25.97	Yes	10.81	28.72	19.80	48.52	0.535	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	4.81	21.63	24.92	Yes	10.81	28.72	19.80	48.52	0.514	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	5.03	21.63	23.87	Yes	10.81	28.72	19.80	48.52	0.492	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	5.25	21.63	22.82	Yes	10.81	28.72	19.80	48.52	0.470	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	5.46	21.63	21.77	Yes	10.81	28.72	19.80	48.52	0.449	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	5.68	21.63	20.72	Yes	10.81	28.72	19.80	48.52	0.427	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	5.90	21.63	19.67	Yes	10.81	28.72	19.80	48.52	0.405	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	6.12	21.63	18.62	Yes	10.81	28.72	19.80	48.52	0.384	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	6.34	21.63	17.57	Yes	10.81	28.72	19.80	48.52	0.362	Eqn (a)	Max spacing per 9.7.6.2



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DESCRIPTION: Reinforced Concrete Beam

Detailed Shear Information

Load Combination	Span Number	Distance (ft)	'd' (in)	Vu (k)	Av, min Req'd?	Spacing Req'd (in)	ϕV_c (k)	ϕV_s (k)	ϕV_n (k)	Vu / ϕV_n	Vc Eqn (T22.5.5.1)	Spacing Provision
+1.20D+1.60L	1	6.56	21.63	16.52	Yes	10.81	28.72	19.80	48.52	0.341	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	6.78	21.63	15.48	Yes	10.81	28.72	19.80	48.52	0.319	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	6.99	21.63	14.43	Yes	10.81	28.72	19.80	48.52	0.297	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	7.21	21.63	13.38	No	N/A	19.97	0.00	19.97	0.670	Eqn (c)	Stirrups Not Req'd
+1.20D+1.60L	1	7.43	21.63	12.33	No	N/A	19.97	0.00	19.97	0.617	Eqn (c)	Stirrups Not Req'd
+1.20D+1.60L	1	7.65	21.63	11.28	No	N/A	19.97	0.00	19.97	0.565	Eqn (c)	Stirrups Not Req'd
+1.20D+1.60L	1	7.87	21.63	10.23	No	N/A	19.97	0.00	19.97	0.512	Eqn (c)	Stirrups Not Req'd
+1.20D+1.60L	1	8.09	21.63	9.18	No	N/A	19.97	0.00	19.97	0.460	Eqn (c)	Stirrups Not Req'd
+1.20D+1.60L	1	8.31	21.63	8.13	No	N/A	19.97	0.00	19.97	0.407	Eqn (c)	Stirrups Not Req'd
+1.20D+1.60L	1	8.52	21.63	7.08	No	N/A	19.97	0.00	19.97	0.355	Eqn (c)	Stirrups Not Req'd
+1.20D+1.60L	1	8.74	21.63	6.03	No	N/A	19.97	0.00	19.97	0.302	Eqn (c)	Stirrups Not Req'd
+1.20D+1.60L	1	8.96	21.63	4.98	No	N/A	19.97	0.00	19.97	0.250	Eqn (c)	Stirrups Not Req'd
+1.20D+1.60L	1	9.18	21.63	3.93	No	N/A	19.97	0.00	19.97	0.197	Eqn (c)	Stirrups Not Req'd
+1.20D+1.60L	1	9.40	21.63	2.89	No	N/A	19.97	0.00	19.97	0.145	Eqn (c)	Stirrups Not Req'd
+1.20D+1.60L	1	9.62	21.63	1.84	No	N/A	19.97	0.00	19.97	0.092	Eqn (c)	Stirrups Not Req'd
+1.20D+1.60L	1	9.84	21.63	0.79	No	N/A	19.97	0.00	19.97	0.039	Eqn (c)	Stirrups Not Req'd
+1.20D+1.60L	1	10.05	21.63	-0.26	No	N/A	19.97	0.00	19.97	0.013	Eqn (c)	Stirrups Not Req'd
+1.20D+1.60L	1	10.27	21.63	-1.31	No	N/A	19.97	0.00	19.97	0.066	Eqn (c)	Stirrups Not Req'd
+1.20D+1.60L	1	10.49	21.63	-2.36	No	N/A	19.97	0.00	19.97	0.118	Eqn (c)	Stirrups Not Req'd
+1.20D+1.60L	1	10.71	21.63	-3.41	No	N/A	19.97	0.00	19.97	0.171	Eqn (c)	Stirrups Not Req'd
+1.20D+1.60L	1	10.93	21.63	-4.46	No	N/A	19.97	0.00	19.97	0.223	Eqn (c)	Stirrups Not Req'd
+1.20D+1.60L	1	11.15	21.63	-5.51	No	N/A	19.97	0.00	19.97	0.276	Eqn (c)	Stirrups Not Req'd
+1.20D+1.60L	1	11.37	21.63	-6.56	No	N/A	19.97	0.00	19.97	0.328	Eqn (c)	Stirrups Not Req'd
+1.20D+1.60L	1	11.58	21.63	-7.61	No	N/A	19.97	0.00	19.97	0.381	Eqn (c)	Stirrups Not Req'd
+1.20D+1.60L	1	11.80	21.63	-8.66	No	N/A	19.97	0.00	19.97	0.434	Eqn (c)	Stirrups Not Req'd
+1.20D+1.60L	1	12.02	21.63	-9.70	No	N/A	19.97	0.00	19.97	0.486	Eqn (c)	Stirrups Not Req'd
+1.20D+1.60L	1	12.24	21.63	-10.75	No	N/A	19.97	0.00	19.97	0.539	Eqn (c)	Stirrups Not Req'd
+1.20D+1.60L	1	12.46	21.63	-11.80	No	N/A	19.97	0.00	19.97	0.591	Eqn (c)	Stirrups Not Req'd
+1.20D+1.60L	1	12.68	21.63	-12.85	No	N/A	19.97	0.00	19.97	0.644	Eqn (c)	Stirrups Not Req'd
+1.20D+1.60L	1	12.90	21.63	-13.90	No	N/A	19.97	0.00	19.97	0.696	Eqn (c)	Stirrups Not Req'd
+1.20D+1.60L	1	13.11	21.63	-14.95	Yes	10.81	28.72	19.80	48.52	0.308	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	13.33	21.63	-16.00	Yes	10.81	28.72	19.80	48.52	0.330	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	13.55	21.63	-17.05	Yes	10.81	28.72	19.80	48.52	0.351	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	13.77	21.63	-18.10	Yes	10.81	28.72	19.80	48.52	0.373	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	13.99	21.63	-19.15	Yes	10.81	28.72	19.80	48.52	0.395	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	14.21	21.63	-20.20	Yes	10.81	28.72	19.80	48.52	0.416	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	14.43	21.63	-21.25	Yes	10.81	28.72	19.80	48.52	0.438	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	14.64	21.63	-22.30	Yes	10.81	28.72	19.80	48.52	0.459	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	14.86	21.63	-23.34	Yes	10.81	28.72	19.80	48.52	0.481	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	15.08	21.63	-24.39	Yes	10.81	28.72	19.80	48.52	0.503	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	15.30	21.63	-25.44	Yes	10.81	28.72	19.80	48.52	0.524	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	15.52	21.63	-26.49	Yes	10.81	28.72	19.80	48.52	0.546	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	15.74	21.63	-27.54	Yes	10.81	28.72	19.80	48.52	0.568	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	15.96	21.63	-28.59	Yes	10.81	28.72	19.80	48.52	0.589	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	16.17	21.63	-29.64	Yes	10.81	28.72	19.80	48.52	0.611	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	16.39	21.63	-30.69	Yes	10.81	28.72	19.80	48.52	0.632	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	16.61	21.63	-31.74	Yes	10.81	28.72	19.80	48.52	0.654	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	16.83	21.63	-32.79	Yes	10.81	28.72	19.80	48.52	0.676	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	17.05	21.63	-33.84	Yes	10.81	28.72	19.80	48.52	0.697	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	17.27	21.63	-34.89	Yes	10.81	28.72	19.80	48.52	0.719	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	17.49	21.63	-35.93	Yes	10.81	28.72	19.80	48.52	0.741	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	17.70	21.63	-36.98	Yes	10.81	28.72	19.80	48.52	0.762	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	17.92	21.63	-38.03	Yes	10.81	28.72	19.80	48.52	0.784	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	18.14	21.63	-39.08	Yes	10.81	28.72	19.80	48.52	0.805	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	18.36	21.63	-40.13	Yes	10.81	28.72	19.80	48.52	0.827	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	18.58	21.63	-41.18	Yes	10.81	28.72	19.80	48.52	0.849	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	18.80	21.63	-42.23	Yes	10.81	28.72	19.80	48.52	0.870	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	19.02	21.63	-43.28	Yes	10.81	28.72	19.80	48.52	0.892	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	19.23	21.63	-44.33	Yes	10.81	28.72	19.80	48.52	0.914	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	19.45	21.63	-45.38	Yes	10.81	28.72	19.80	48.52	0.935	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	19.67	21.63	-46.43	Yes	10.81	28.72	19.80	48.52	0.957	Eqn (a)	Max spacing per 9.7.6.2
+1.20D+1.60L	1	19.89	21.63	-47.48	Yes	10.81	28.72	19.80	48.52	0.978	Eqn (a)	Max spacing per 9.7.6.2

Maximum Forces & Stresses for Load Combinations

Concrete Beam

Project File: Reinforced Concrete Beam.ec6

LIC# : KW-06000215, Build:20.26.06.15

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DESCRIPTION: Reinforced Concrete Beam

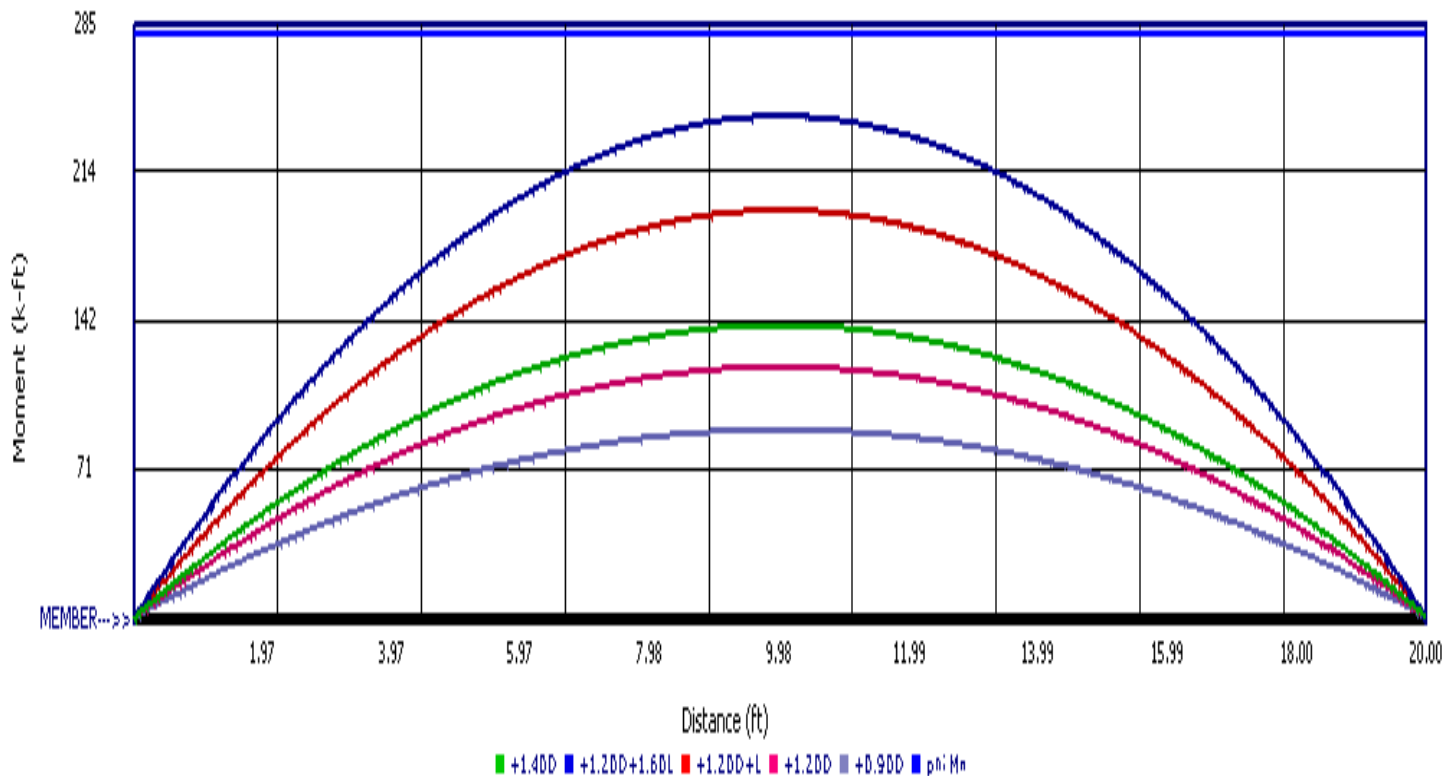
Load Combination Segment	Span #	Location (ft) along Beam	Bending Stress Results (k-ft)		
			Mu : Max	ϕ Mn	Stress Ratio
MAXimum BENDING Envelope					
Span # 1	1	20.000	240.00	279.19	0.86
+1.40D	1	20.000	140.00	279.19	0.50
+1.20D+1.60L	1	20.000	240.00	279.19	0.86
+1.20D+L	1	20.000	195.00	279.19	0.70
+1.20D	1	20.000	120.00	279.19	0.43
+0.90D	1	20.000	90.00	279.19	0.32

Overall Maximum Deflections

Span	Load Combination	Max. "-" Defl (in) in Span	Location (ft) in Span	Load Combination	Max. "+" Defl (in) in Span	Location (ft) in Span
1	+D+L	0.4788	10.000		0.0000	0.000

Maximum Deflections for Load Combinations

Span	Load Combination	Max. Downward Defl	Location in Span	Max. Upward Defl	Location in Span
1	D Only	0.2537	10.000	0.0000	0.000
1	+D+L	0.4788	10.000	0.0000	0.000
1	+D+0.750L	0.4235	10.000	0.0000	0.000
1	+0.60D	0.1244	10.000	0.0000	0.000
1	L Only	0.1743	10.000	0.0000	0.000



Concrete Beam

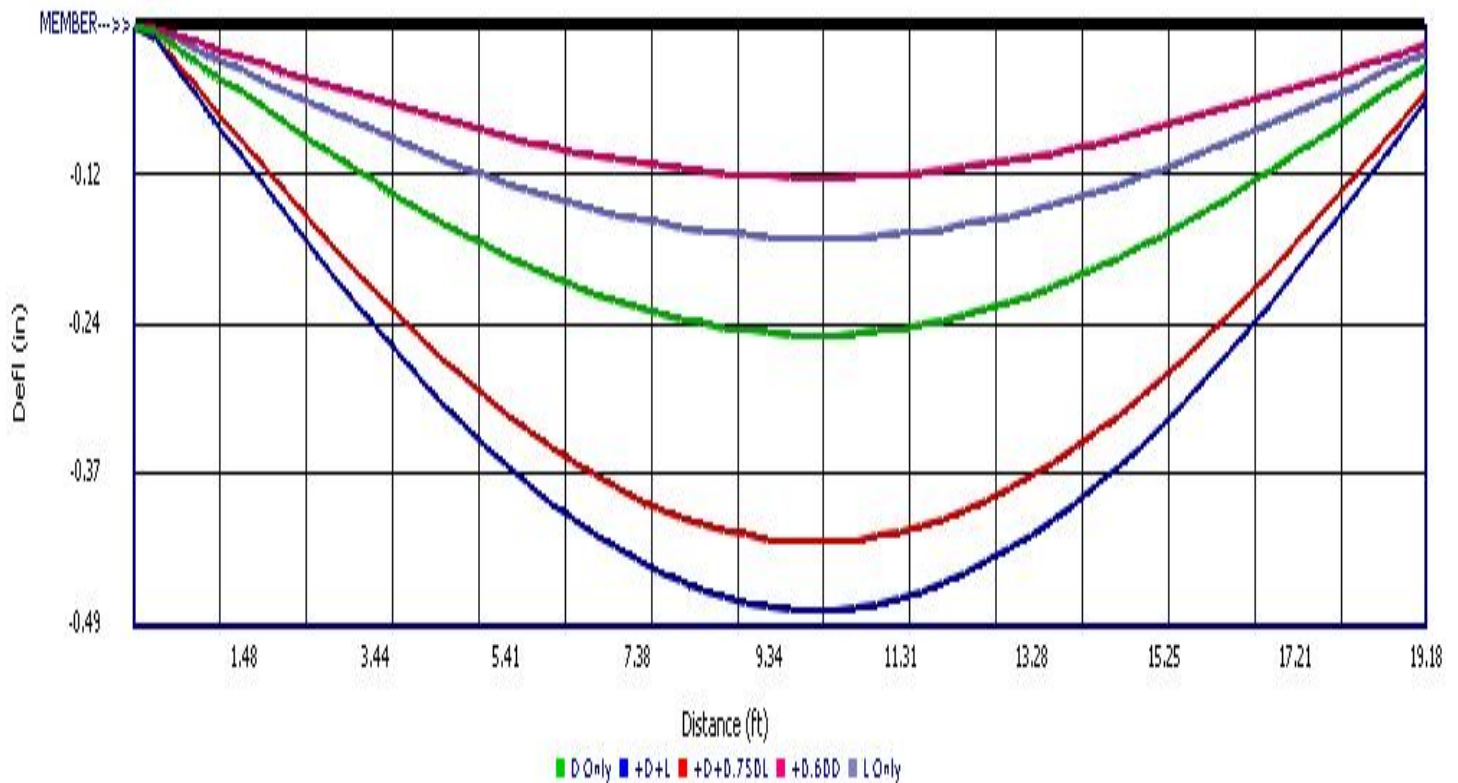
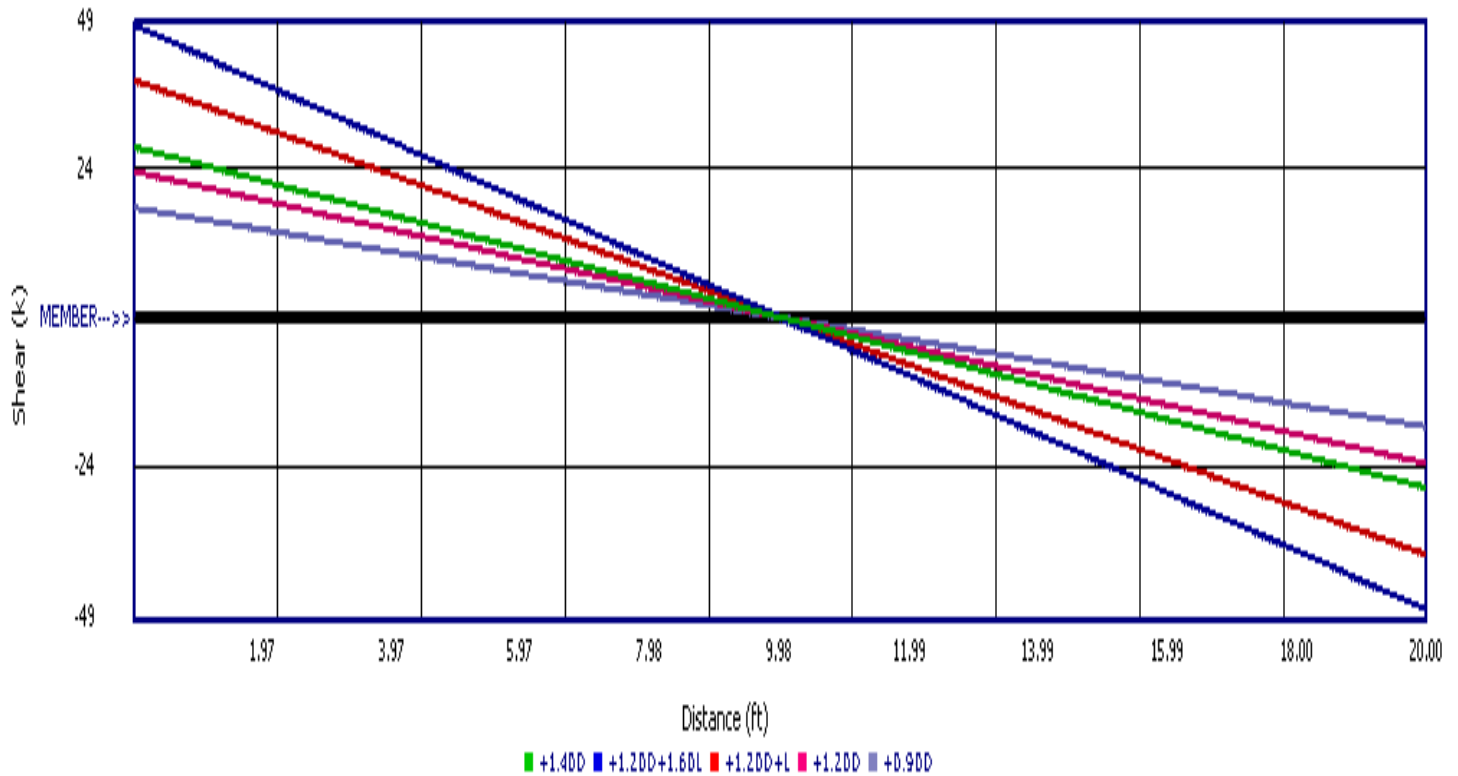
Project File: Reinforced Concrete Beam.ec6

LIC# : KW-06000215, Build:20.26.06.15

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DESCRIPTION: Reinforced Concrete Beam



Summary of Values per Beam Span



Project Title: Reinforced Concrete Beam Module
 Engineer: ENERCALC Engr. Div.
 Project ID: ENERCALC
 Project Descr: Verification Example

Concrete Beam

Project File: Reinforced Concrete Beam.ec6

LIC# : KW-06000215, Build:20.26.06.15

Licensed ENERCALC User

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DESCRIPTION: Reinforced Concrete Beam

Beam Span Moments & Shears at Incremental Locations

Load Type/ Combination	Span Location (ft)	Span ID	Shear (k)	Moment (ft-k)
MAXimum BENDING Envelope	0.00	Span 1	28.000	0.000
MAXimum BENDING Envelope	2.04	Span 1	22.288	87.935
MAXimum BENDING Envelope	4.08	Span 1	16.576	155.893
MAXimum BENDING Envelope	6.12	Span 1	10.863	203.874
MAXimum BENDING Envelope	8.16	Span 1	5.151	231.877
MAXimum BENDING Envelope	10.20	Span 1	-0.561	239.904
MAXimum BENDING Envelope	12.24	Span 1	-6.273	227.953
MAXimum BENDING Envelope	14.28	Span 1	-11.985	196.025
MAXimum BENDING Envelope	16.32	Span 1	-17.698	144.121
MAXimum BENDING Envelope	18.36	Span 1	-23.410	72.239
MAXimum SHEAR Envelope	0.00	Span 1	48.000	0.000
MAXimum SHEAR Envelope	2.04	Span 1	38.208	87.935
MAXimum SHEAR Envelope	4.08	Span 1	28.415	155.893
MAXimum SHEAR Envelope	6.12	Span 1	18.623	203.874
MAXimum SHEAR Envelope	8.16	Span 1	8.831	231.877
MAXimum SHEAR Envelope	10.20	Span 1	-0.962	239.904
MAXimum SHEAR Envelope	12.24	Span 1	-10.754	227.953
MAXimum SHEAR Envelope	14.28	Span 1	-20.546	196.025
MAXimum SHEAR Envelope	16.32	Span 1	-30.339	144.121
MAXimum SHEAR Envelope	18.36	Span 1	-40.131	72.239
+1.40D	0.00	Span 1	28.000	0.000
+1.40D	2.04	Span 1	22.288	51.295
+1.40D	4.08	Span 1	16.576	90.937
+1.40D	6.12	Span 1	10.863	118.926
+1.40D	8.16	Span 1	5.151	135.262
+1.40D	10.20	Span 1	-0.561	139.944
+1.40D	12.24	Span 1	-6.273	132.973
+1.40D	14.28	Span 1	-11.985	114.348
+1.40D	16.32	Span 1	-17.698	84.070
+1.40D	18.36	Span 1	-23.410	42.139
+1.20D+1.60L	0.00	Span 1	48.000	0.000
+1.20D+1.60L	2.04	Span 1	38.208	87.935
+1.20D+1.60L	4.08	Span 1	28.415	155.893
+1.20D+1.60L	6.12	Span 1	18.623	203.874
+1.20D+1.60L	8.16	Span 1	8.831	231.877
+1.20D+1.60L	10.20	Span 1	-0.962	239.904
+1.20D+1.60L	12.24	Span 1	-10.754	227.953
+1.20D+1.60L	14.28	Span 1	-20.546	196.025
+1.20D+1.60L	16.32	Span 1	-30.339	144.121
+1.20D+1.60L	18.36	Span 1	-40.131	72.239
+1.20D+L	0.00	Span 1	39.000	0.000
+1.20D+L	2.04	Span 1	31.044	71.447



Project Title: Reinforced Concrete Beam Module
 Engineer: ENERCALC Engr. Div.
 Project ID: ENERCALC
 Project Descr: Verification Example

Concrete Beam

Project File: Reinforced Concrete Beam.ec6

LIC# : KW-06000215, Build:20.26.06.15

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DESCRIPTION: Reinforced Concrete Beam

Beam Span Moments & Shears at Incremental Locations

Load Type/ Combination	Span Location (ft)	Span ID	Shear (k)	Moment (ft-k)
+1.20D+L	4.08	Span 1	23.087	126.663
+1.20D+L	6.12	Span 1	15.131	165.647
+1.20D+L	8.16	Span 1	7.175	188.400
+1.20D+L	10.20	Span 1	-0.781	194.922
+1.20D+L	12.24	Span 1	-8.738	185.212
+1.20D+L	14.28	Span 1	-16.694	159.271
+1.20D+L	16.32	Span 1	-24.650	117.098
+1.20D+L	18.36	Span 1	-32.607	58.694
+1.20D	0.00	Span 1	24.000	0.000
+1.20D	2.04	Span 1	19.104	43.967
+1.20D	4.08	Span 1	14.208	77.946
+1.20D	6.12	Span 1	9.311	101.937
+1.20D	8.16	Span 1	4.415	115.939
+1.20D	10.20	Span 1	-0.481	119.952
+1.20D	12.24	Span 1	-5.377	113.977
+1.20D	14.28	Span 1	-10.273	98.013
+1.20D	16.32	Span 1	-15.169	72.060
+1.20D	18.36	Span 1	-20.066	36.119
+0.90D	0.00	Span 1	18.000	0.000
+0.90D	2.04	Span 1	14.328	32.976
+0.90D	4.08	Span 1	10.656	58.460
+0.90D	6.12	Span 1	6.984	76.453
+0.90D	8.16	Span 1	3.311	86.954
+0.90D	10.20	Span 1	-0.361	89.964
+0.90D	12.24	Span 1	-4.033	85.482
+0.90D	14.28	Span 1	-7.705	73.510
+0.90D	16.32	Span 1	-11.377	54.045
+0.90D	18.36	Span 1	-15.049	27.089

Beam Span Deflections at Incremental Locations

Load Type/ Combination	Span Location (ft)	Span ID	Deflection (in)
Overall MAXimum Envelope	0.00	Span 1	0.000
Overall MAXimum Envelope	2.13	Span 1	0.157
Overall MAXimum Envelope	4.43	Span 1	0.308
Overall MAXimum Envelope	6.72	Span 1	0.417
Overall MAXimum Envelope	9.02	Span 1	0.473
Overall MAXimum Envelope	11.31	Span 1	0.469
Overall MAXimum Envelope	13.61	Span 1	0.405
Overall MAXimum Envelope	15.90	Span 1	0.288
Overall MAXimum Envelope	18.20	Span 1	0.134
Overall MAXimum Envelope	20.00	Span 1	0.000
D Only	0.00	Span 1	0.000
D Only	2.13	Span 1	0.082
D Only	4.43	Span 1	0.161



Project Title: Reinforced Concrete Beam Module
Engineer: ENERCALC Engr. Div.
Project ID: ENERCALC
Project Descr: Verification Example

Concrete Beam

Project File: Reinforced Concrete Beam.ec6

LIC# : KW-06000215, Build:20.26.06.15

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DESCRIPTION: Reinforced Concrete Beam

Beam Span Deflections at Incremental Locations

Load Type/ Combination	Span Location (ft)	Span ID	Deflection (in)
D Only	6.72	Span 1	0.220
D Only	9.02	Span 1	0.251
D Only	11.31	Span 1	0.248
D Only	13.61	Span 1	0.214
D Only	15.90	Span 1	0.151
D Only	18.20	Span 1	0.069
D Only	20.00	Span 1	0.000
+D+L	0.00	Span 1	0.000
+D+L	2.13	Span 1	0.157
+D+L	4.43	Span 1	0.308
+D+L	6.72	Span 1	0.417
+D+L	9.02	Span 1	0.473
+D+L	11.31	Span 1	0.469
+D+L	13.61	Span 1	0.405
+D+L	15.90	Span 1	0.288
+D+L	18.20	Span 1	0.134
+D+L	20.00	Span 1	0.000
+D+0.750L	0.00	Span 1	0.000
+D+0.750L	2.13	Span 1	0.139
+D+0.750L	4.43	Span 1	0.272
+D+0.750L	6.72	Span 1	0.369
+D+0.750L	9.02	Span 1	0.419
+D+0.750L	11.31	Span 1	0.415
+D+0.750L	13.61	Span 1	0.358
+D+0.750L	15.90	Span 1	0.255
+D+0.750L	18.20	Span 1	0.118
+D+0.750L	20.00	Span 1	0.000
+0.60D	0.00	Span 1	0.000
+0.60D	2.13	Span 1	0.039
+0.60D	4.43	Span 1	0.077
+0.60D	6.72	Span 1	0.107
+0.60D	9.02	Span 1	0.123
+0.60D	11.31	Span 1	0.122
+0.60D	13.61	Span 1	0.104
+0.60D	15.90	Span 1	0.072
+0.60D	18.20	Span 1	0.033
+0.60D	20.00	Span 1	0.000
L Only	0.00	Span 1	0.000
L Only	2.13	Span 1	0.055
L Only	4.43	Span 1	0.110
L Only	6.72	Span 1	0.151
L Only	9.02	Span 1	0.172
L Only	11.31	Span 1	0.170
L Only	13.61	Span 1	0.146
L Only	15.90	Span 1	0.102



Project Title: Reinforced Concrete Beam Module
Engineer: ENERCALC Engr. Div.
Project ID: ENERCALC
Project Descr: Verification Example

Concrete Beam

Project File: Reinforced Concrete Beam.ec6

LIC# : KW-06000215, Build:20.26.06.15

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DESCRIPTION: Reinforced Concrete Beam

Beam Span Deflections at Incremental Locations

Load Type/ Combination	Span Location (ft)	Span ID	Deflection (in)
L Only	18.20	Span 1	0.047
L Only	20.00	Span 1	0.000