NCSEA Structural Engineering Exam Review Course

Vertical Forces Review

Bridges – Spring 2017

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Topics

- Design Lanes
- Load Combinations
- Dead Loads
- Live Loads
- Slabs
- Slab on Girder Bridges
- Lever Rule

Design Lanes

Problem 1: Discuss the concept of design lanes as applied to bridge design.

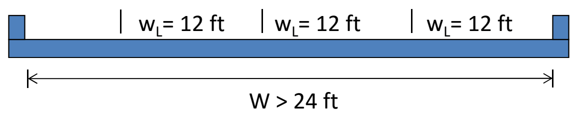
For $20 \le w < 24$ ft:

$N_L = 2$ and $w_L = w/2$

For $w \ge 24$ ft:

$N_L = INT(w/12)$ and $w_L = 12$ ft

Per AASHTO 3.6.1.1.1, the number of design lanes N_L is related to the clear deck width w between barriers. Design lanes are typically 12 ft wide.



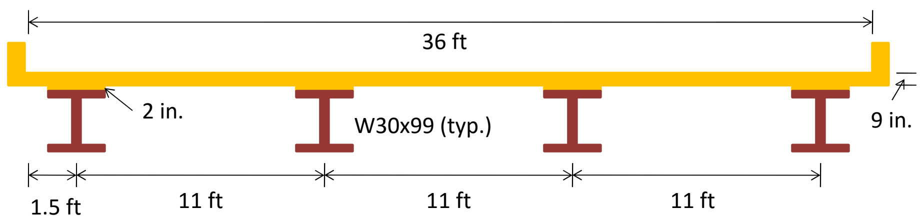
Design Lanes

Problem 2: Determine the number of design lanes for the bridge deck shown.

For $w \ge 24$ ft:

$N_L = INT(w/12)$ and $w_L = 12$ ft

$N_L = INT(36/12) = 3$ design lanes



Load Combinations

Problem 3: Discuss the basic design expression (AASHTO 1.3.2) that must be satisfied for all bridge elements in accordance with AASHTO LRFD.

$$Q_u = \Sigma \eta_i \gamma_i Q_i \leq \phi R_n$$

Q_i is the force effect
R_n is the nominal resistance
γ_i is the load factor
η_i is the load modification factor
ϕ is the strength resistance factor (1.0 for nonstrength limit states)

Load Combinations

Problem 4: Discuss the load modification factor in more detail.

To maximize loads, the combined load modification factor is:

$$\eta_i = \eta_D \eta_R \eta_I \geq 0.95$$

To minimize loads, the combined load modification factor is:

$$\eta_i = \frac{1}{\eta_D \eta_R \eta_I} \leq 1.0$$

Load Combinations

Problem 5: Discuss the load modification factor for ductility (AASHTO 1.3.3).

For the strength limit state, the load modification factor for ductility is:

$$\eta_D = \begin{cases} \geq 1.05 & \text{(nonductile components / connections)} \\ 1.00 & \text{(conventional designs and details)} \\ \geq 0.95 & \text{(enhanced ductility components)} \end{cases}$$

For all other limit states, the load modification factor for ductility is 1.0.

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Load Combinations

Problem 6: Discuss the load modification factor for redundancy (AASHTO 1.3.4).

For the strength limit state, the load modification factor for redundancy is:

$$\eta_R = \begin{cases} \geq 1.05 & \text{(nonredundant components)} \\ 1.00 & \text{(conventional levels of redundancy)} \\ \geq 0.95 & \text{(enhanced levels of redundancy)} \end{cases}$$

For all other limit states, the load modification factor for redundancy is 1.0.

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Load Combinations

Problem 7: Discuss the load modification factor for importance (AASHTO 1.3.5).

For the strength limit state, the load modification factor for importance is:

$$\eta_I \begin{cases} \geq 1.05 \text{ (critical or essential bridges)} \\ = 1.00 \text{ (typical bridges)} \\ \geq 0.95 \text{ (less important bridges)} \end{cases}$$

For all other limit states, the load modification factor for importance is 1.0.

Load Combinations

Problem 8: Discuss the four limit states (i.e., groups of load combinations) considered by AASHTO 1.3.2 (also see 3.4.1).

- Strength: typical loads including wind but not extreme loads; used for bending, shear, torsion, and axial design; $\Phi \leq 1.0$
- Extreme event: extreme loads that include seismic, ice, and collisions; $\Phi = 1.0$
- Service: regular service loads for checking stresses, deflections, and crack widths; $\Phi = 1.0$
- Fatigue/fracture: live load only since limiting crack growth and preventing fracture; $\Phi = 1.0$

Load Combinations

Problem 9: Discuss the applicability of the five strength limit states.

- Strength I: basic load combination for use without wind
- Strength II: used for owner specified design vehicles, evaluation permit vehicles, or both without wind
- Strength III: high winds in excess of 55 mph (no live load due to high winds)
- Strength IV: very high dead to live load applicable to long span bridges
- Strength V: normal use of bridge with winds of 55 mph (considers live load on bridge, wind on live load, and reduced wind on the structure)

Load Combinations

Problem 10: Discuss the applicability of the two extreme event limit states.

- Extreme Event I: basic load combination for seismic (live load factor is 0 to 1.0 based on engineering judgment)
- Extreme Event II: ice, collision, and hydraulic events with reduced live load

Load Combinations

Problem 11: Discuss the applicability of the four service limit states.

- Service I: general load combination for normal operation with 55 mph wind and all loads taken at nominal values (also used for deflection of buried structures, crack control in reinforced concrete structures, concrete compressive stress in prestressed members, etc.)
- Service II: only applies to steel structures to control yielding and slip of slip critical connections due to live load
- Service III: only used for tension in prestressed concrete longitudinal members (superstructures) for crack control
- Service IV: only used for tension in prestressed substructures

Load Combinations

Problem 12: Discuss the applicability of the two fatigue and fracture limit states.

- Fatigue I: only live load considered and load factor of 1.5 accounts for infinite load-induced fatigue life. The design truck for the fatigue and fracture limit state is slightly different (fixed wheel spacing of 30 ft; one lane loaded; m = NA) than the design truck for live load (AASHTO 3.6.1.4.1 and 3.6.1.1.2).
- Fatigue II: load factor is 0.75 (finite load-induced fatigue life) and accounts for the fact that lighter weight trucks result in the significant number of cycles as compared to the design truck.

Load Combinations

Problem 13: Simplify the design load combinations from AASHTO Table 3.4.1-1 to those likely to apply for SE Exam type problems that involve gravity design of members.

Table 3.4.1-1 presents a comprehensive list of load factors and load combinations that must be considered in design. When considering only the typical effect of dead and live loads, the table simplifies to the following:

Load Combination	DC and DW	LL and IM
Strength I	γ_p	1.75
Service I	1.00	1.00
Fatigue I / Fatigue II	-----	1.50 / 0.75

Dead Loads

Problem 14: Discuss permanent loads applicable to typical superstructure designs (AASHTO Table 3.4.1-2).

- Permanent loads remain on the bridge, possibly for the entire service life.
- DC – dead load of structural components and nonstructural attachments (e.g., curbs, parapets, barrier rails, signs)
- DW – dead load of wearing surfaces and utilities

Load Type	$\gamma_{p,max}$	$\gamma_{p,min}$
DC	1.25	0.9
DW	1.5	0.65

Live Loads

Problem 15: Discuss HL-93 loading as required per AASHTO 3.6.1.2.

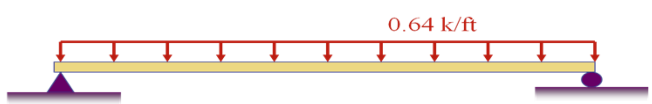
The design live load (HL-93) is the most critical of the following:

1. Design lane load combined with a design truck
2. Design lane load combined with a design tandem

Live Loads

Problem 16: Discuss the design lane load per AASHTO 3.6.1.2.4.

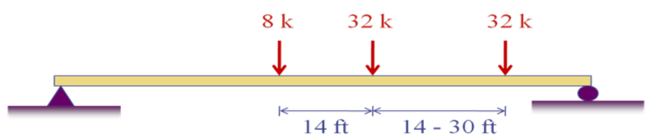
The design lane load is defined as 0.64 k/ft. When continuous beams are used, this load shall be placed in multiple spans to create the maximum effect. The design lane load shall be placed uniformly over a 10 ft width in a design lane to create the maximum effect.



Live Loads

Problem 17: Discuss the design truck load per AASHTO 3.6.1.2.2.

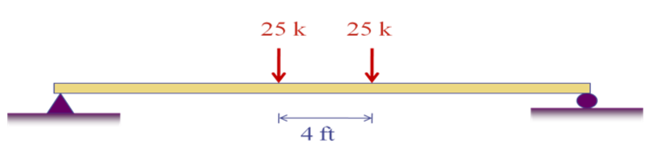
The design truck load (axle loads) is defined in the figure below and shall be located to create the maximum effect. The longitudinal spacing between the two 32 k axles varies and shall be established to create the maximum effect. The transverse spacing of the wheels is 6 ft. Truck loads shall not be placed within 2 ft of the design lane edge nor within 1 ft from the face of the curb (design deck overhang). See AASHTO 3.6.1.3.1.



Live Loads

Problem 18: Discuss the design tandem load per AASHTO 3.6.1.2.3.

The design tandem load (axle loads) is defined in the figure below and shall be located to create the maximum effect. The transverse spacing of the wheels is 6 ft. Tandem loads shall not be placed within 2 ft of the design lane edge nor within 1 ft from the face of the curb (design deck overhang). See AASHTO 3.6.1.3.1.



Live Loads

Problem 19: Discuss rules for placing truck or tandem loads in a lane (AASHTO 3.6.1.3.1).

- One truck or tandem shall be used (per lane) when obtaining the maximum positive bending moment for continuous spans. Two trucks or tandems (tandems not required) in adjacent spans and within the same lane are used to determine the maximum negative bending moment over the support or the interior support reaction for a continuous span system. Loaded spans are determined using influence lines.
- When using two trucks: minimum distance of 50 ft between adjacent truck axles; 14 ft between 32 k axles of each truck; axles not contributing to maximum effect are neglected; use 0.9 reduction factor on total moment (lane plus 1.33 times truck)
- When using two tandems: 26–40 ft between adjacent tandem axles; no 0.9 reduction factor applied (two tandems not required)

Live Loads

Problem 20: Discuss multiple lane loading considerations.

AASHTO 3.6.1.1.2 states that the number of loaded lanes shall be selected to create the maximum effect. When multiple lanes are loaded, the force effect shall be multiplied by a multiple presence factor m (Table 3.6.1.1.2-1) as follows:

Number of Loaded Lanes	m
One	1.2
Two	1.0
Three	0.85
More than three	0.65

Live Loads

Problem 21: Discuss dynamic load allowance applied to live load.

Design lane loads are NOT increased using the dynamic load allowance IM. Design truck loads and design tandem loads are increased by IM. AASHTO 3.6.2 presents dynamic load allowances for various cases as follows:

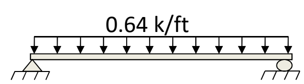
Structural Element	IM
Deck joints	75%
All other components (fatigue)	15%
All other components (all other limit states)	33%

Live Loads

Problem 22: Determine the maximum reaction at the support and the maximum moment along the bridge caused by the design lane load using only hand calculations.

$$R_{right,lane} = 0.64(35/2) = 11.2 \quad k$$

$$M_{max,lane} = 0.64(35)^2 / 8 = 98 \quad k-ft$$

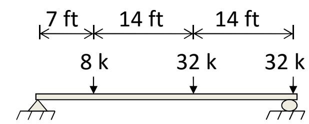


Live Loads

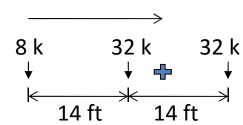
Problem 23: Determine the maximum reaction at the support and the maximum moment along the bridge caused by the design truck using only hand calculations.

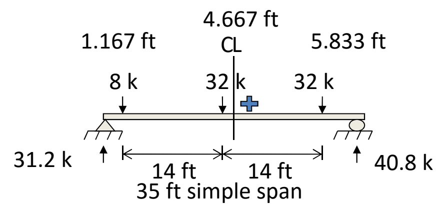
$$R_{right,truck} = [8(7) + 32(21) + 32(35)] / 35 = 52.8 \text{ k}$$

$$M_{max,truck} = 31.2(15.167) - 8(14) = 361 \text{ k} - \text{ft}$$



$$\bar{x} = \frac{8(0) + 32(14) + 32(28)}{(8 + 32 + 32)} = 18.67 \text{ ft}$$





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Live Loads

Additional comments

For simply supported span:

1. Maximum reaction due to moving loads occurs at one support when one of the loads is at the support
2. Maximum moment due to moving loads occurs under one of the loads when that load is the same distance from one support as the center of gravity of all loads is from the other support

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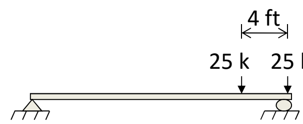
Live Loads

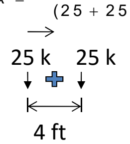
Problem 24: Determine the maximum reaction at the support and the maximum moment along the bridge caused by the design tandem using only hand calculations.

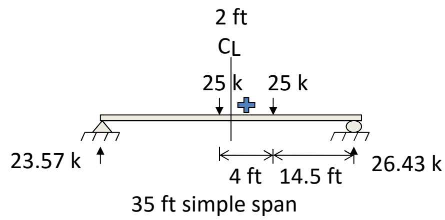
$R_{right,tandem} = [25(31) + 25(35)] / 35 = 47.14 \ \ k$

$M_{max,tandem} = 23.57(35 - 18.5) = 389 \ \ k - ft$



$\bar{x} = \frac{25(0) + 25(4)}{(25 + 25)} = 2 \ \ ft$





Live Loads

Problem 25: Considering HL-93 loading with dynamic load allowance, determine the maximum reaction at the support and the maximum moment along the bridge using only hand calculations.

$R_{right,lane} = 11.2 \ \ k$

$R_{right,truck} = 52.8 \ \ k$

$R_{right,tandem} = 47.14 \ \ k$

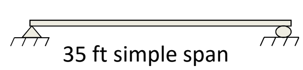
$R_{right,HL-93,impact} = 11.2 + 1.33(52.8) = 81.4 \ \ k$

$M_{max,lane} = 98 \ \ k - ft$

$M_{max,truck} = 361 \ \ k - ft$

$M_{max,tandem} = 389 \ \ k - ft$

$M_{max,HL-93,impact} = 98 + 1.33(389) = 615 \ \ k - ft$



Live Loads

Problem 26: Considering HL-93 loading, determine the maximum moment along the bridge and maximum reaction at the support using CALTRANS design aids found at the following link: www.dot.ca.gov/hq/esc/techpubs/manual/bridgemanuals/bridge-design-aids/bda.html.

LRFD

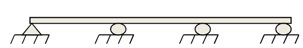
BRIDGE DESIGN AIDS • FEBRUARY 2008

Table of Maximum Moments, Shears, and Reactions Simple Spans, One Lane **With** Dynamic Load Allowance (cont.)

Span(ft)	Moment (k-ft)		End Shear and End Reaction (k)		Span(ft)	Moment (k-ft)		End Shear and End Reaction (k)	
11	126.7	b	57.9	b	31	525.8	b	76.8	a
12	144.5	b	59.3	b	32	547.4	b	78.1	a
13	163.1	b	60.4	b	33	569.2	b	79.2	a
14	181.9	b	61.5	b	34	591.2	b	80.4	a
15	200.9	b	62.4	b	35	613.4	b	81.4	a

Live Loads

Problem 27: Considering HL-93 loading, determine the maximum positive moment in the middle of the interior span using AISC design aids found at the following link: http://www.steeltools.org/STEELTOOLS/STEELTOOLS/Resources/ViewDocument/Default.aspx?DocumentKey=b5845557-a4ac-4702-8269-61da2648e519.



$$M_{max,lane} = 0.075(0.64)(35)^2 = 58.8 \quad k-ft$$

$$M_{max,truck} = 35[32(0.1750) + 32(0.0230) + 8(0.0230)] = 228 \quad k-ft$$

$$M_{max,tandem} = 35[25(0.1750) + 25(0.122)] = 260 \quad k-ft$$

$$M_{max,HL-93,impact} = 58.8 + 1.33(260) = 405 \quad k-ft$$

Live Loads

Unit load at		MOMENTS/PL																				
		SPAN 1											SPAN 2									
		A	.1	.2	.3	.4	.5	.6	.7	.8	.9	B	.1	.2	.3	.4	.5	.6	.7	.8	.9	C
SPAN 1	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	.1	0	.0874	.0747	.0621	.0494	.0368	.0242	.0115	-.0011	-.0138	-.0264	-.0231	-.0198	-.0165	-.0132	-.0099	-.0066	-.0033	.0000	.0033	.0066
	.2	0	.0749	.1498	.1246	.0995	.0744	.0493	.0242	-.0010	-.0261	-.0512	-.0448	-.0384	-.0320	-.0256	-.0192	-.0128	-.0064	.0000	.0064	.0128
	.3	0	.0627	.1254	.1882	.1509	.1136	.0763	.0390	.0018	-.0355	-.0728	-.0637	-.0546	-.0455	-.0364	-.0273	-.0182	-.0091	.0000	.0091	.0182
	.4	0	.0510	.1021	.1531	.2042	.1552	.1062	.0573	.0083	-.0406	-.0896	-.0784	-.0672	-.0560	-.0448	-.0336	-.0224	-.0112	.0000	.0112	.0224
	.5	0	.0400	.0800	.1200	.1600	.2000	.1400	.0800	.0200	-.0400	-.1000	-.0875	-.0750	-.0625	-.0500	-.0375	-.0250	-.0125	.0000	.0125	.0250
	.6	0	.0298	.0595	.0893	.1190	.1488	.1786	.1084	.0381	-.0322	-.1024	-.0896	-.0768	-.0640	-.0512	-.0384	-.0256	-.0128	.0000	.0128	.0256
	.7	0	.0205	.0410	.0614	.0819	.1024	.1229	.1434	.0638	-.0157	-.0952	-.0833	-.0714	-.0595	-.0476	-.0357	-.0238	-.0119	.0000	.0119	.0238
	.8	0	.0123	.0246	.0370	.0493	.0616	.0739	.0862	.0986	.0109	-.0768	-.0672	-.0576	-.0480	-.0384	-.0288	-.0192	-.0096	.0000	.0096	.0192
	.9	0	.0029	.0058	.0088	.0218	.0272	.0326	.0381	.0435	.0490	-.0456	-.0399	-.0342	-.0285	-.0228	-.0171	-.0114	-.0057	.0000	.0057	.0114
	B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SPAN 2	.1	0	-.0039	-.0078	-.0117	-.0156	-.0195	-.0234	-.0273	-.0312	-.0351	-.0390	.0534	.0458	.0382	.0306	.0230	.0154	.0073	.0002	-.0074	-.0150
	.2	0	-.0064	-.0128	-.0192	-.0256	-.0320	-.0384	-.0448	-.0512	-.0576	-.0640	.0192	.1024	.0856	.0688	.0520	.0352	.0184	.0016	-.0152	-.0320
	.3	0	-.0077	-.0154	-.0231	-.0308	-.0385	-.0462	-.0539	-.0616	-.0639	-.0770	.0042	.0686	.1414	.1142	.0870	.0598	.0326	.0054	-.0218	-.0490
	.4	0	-.0080	-.0160	-.0240	-.0320	-.0400	-.0480	-.0560	-.0640	-.0720	-.0800	-.0184	.0432	.1048	.1664	.1280	.0896	.0512	.0128	-.0256	-.0640
	.5	0	-.0075	-.0150	-.0225	-.0300	-.0375	-.0450	-.0525	-.0600	-.0675	-.0750	-.0250	.0250	.0750	.1250	.1750	.1250	.0750	.0250	-.0250	-.0750
	.6	0	-.0064	-.0128	-.0192	-.0256	-.0320	-.0384	-.0448	-.0512	-.0576	-.0640	-.0256	.0128	.0512	.0896	.1280	.1664	.1048	.0432	-.0184	-.0800
	.7	0	-.0049	-.0098	-.0147	-.0196	-.0245	-.0294	-.0343	-.0392	-.0441	-.0490	-.0218	.0054	.0326	.0598	.0870	.1142	.1414	.0686	-.0042	-.0770
	.8	0	-.0032	-.0064	-.0096	-.0128	-.0160	-.0192	-.0224	-.0256	-.0288	-.0320	-.0152	.0016	.0184	.0352	.0520	.0688	.0856	.1024	.0192	-.0640
	.9	0	-.0015	-.0030	-.0045	-.0060	-.0075	-.0090	-.0105	-.0120	-.0135	-.0150	-.0074	.0002	.0078	.0154	.0230	.0306	.0382	.0458	.0534	-.0390
	C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Live Loads

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Unit load at	MOMENTS/PL																				
	SPAN 1											SPAN 2									
	A	.1	.2	.3	.4	.5	.6	.7	.8	.9	B	.1	.2	.3	.4	.5	.6	.7	.8	.9	C
+ Area	0	.0400	.0700	.0900	.1000	.1000	.0900	.0700	.0402	.0204	.0167	.0152	.0300	.0550	.0700	.0750	.0700	.0550	.0300	.0152	.0167
– Area	0	-.0050	-.0100	-.0150	-.0200	-.0250	-.0300	-.0350	-.0402	-.0654	-.1167	-.0702	-.0500	-.0500	-.0500	-.0500	.0500	-.0500	-.0500	-.0702	-.1167
Total Area	0	.0350	.0600	.0750	.0800	.0750	.0600	.0350	.0000	-.0450	-.1000	-.0550	-.0200	.0050	.0200	.0250	.0200	.0050	-.0200	-.0550	-.1000

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Live Loads

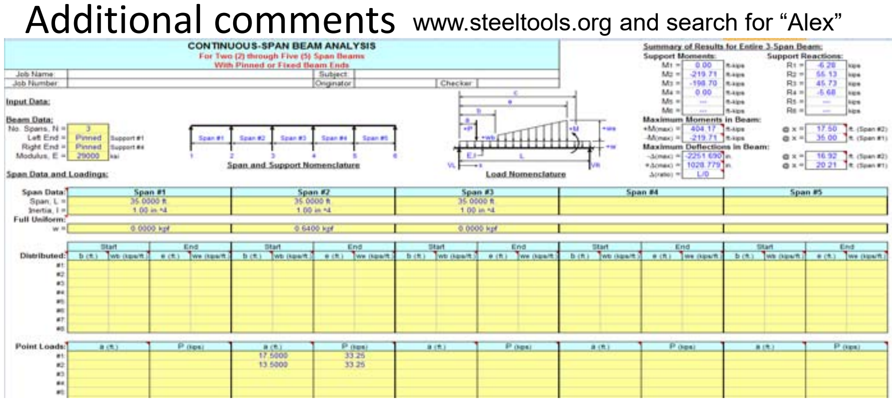
Additional comments

For the maximum positive moment:

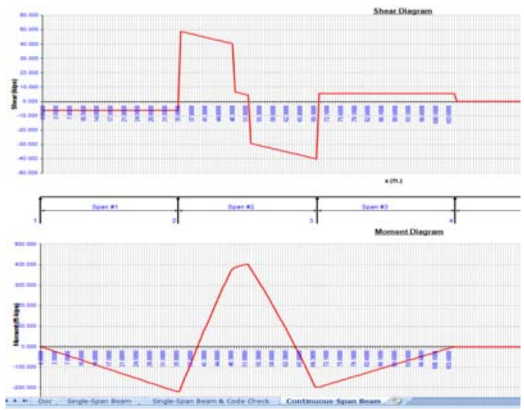
- Axle spacing was set at 14 ft by observation of influence values from AISC.
- Accuracy is limited by influence values only at the tenth points of each span.

Live Loads

Additional comments www.steeltools.org and search for "Alex"

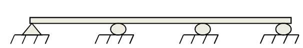


Live Loads



Live Loads

Problem 28: Considering HL-93 loading, determine the maximum negative moment at the interior support using AISC design aids found at the following link:
http://www.steeltools.org/STEELTOOLS/STEELTOOLS/Resources/ViewDocument/Default.aspx?DocumentKey=b5845557-a4ac-4702-8269-61da2648e519.



3 - 35 ft continuous spans

$$M_{max,lane} = -0.1167(0.64)(35)^2 = -91.5 \quad k-ft$$

$$M_{max,truck} = 35[32(-0.0800) + 32(-0.1024) + 8(-0.0512)] = -219 \quad k-ft$$

$$M_{max,tandem} = 35[25(-0.1024) + 25(-0.0985)] = -176 \quad k-ft$$

$$M_{max,2\ tandems} = 35[25(-0.1024) + 25(-0.0985) + 25(-0.0800) + 25(-0.0734)] = -310 \quad k-ft$$

$$M_{max,HL-93,impact} = -91.5 + 1.33(-310) = -503.8 \quad k-ft$$

Live Loads

Unit load at		MOMENTS/PL																				
		SPAN 1											SPAN 2									
		A	.1	.2	.3	.4	.5	.6	.7	.8	.9	•	.1	.2	.3	.4	.5	.6	.7	.8	.9	C
	A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SPAN 1	.1	0	.0874	.0747	.0621	.0494	.0368	.0242	.0115	-.0011	-.0138	-.0264	-.0231	-.0198	-.0165	-.0132	-.0099	-.0066	-.0033	.0000	.0033	.0066
	.2	0	.0749	.1498	.1246	.0995	.0744	.0493	.0242	-.0010	-.026	-.0512	-.0448	-.0384	-.0320	-.0256	-.0192	-.0128	-.0064	.0000	.0064	.0128
	.3	0	.0627	.1254	.1882	.1509	.1136	.0763	.0390	.0018	-.035	-.0728	-.0637	-.0546	-.0455	-.0364	-.0273	-.0182	-.0091	.0000	.0091	.0182
	.4	0	.0510	.1021	.1531	.2042	.1552	.1062	.0573	.0083	-.040	-.0896	-.0784	-.0672	-.0560	-.0448	-.0336	-.0224	-.0112	.0000	.0112	.0224
	.5	0	.0400	.0800	.1200	.1600	.2000	.1400	.0800	.0200	-.040	-.1000	-.0875	-.0750	-.0625	-.0500	-.0375	-.0250	-.0125	.0000	.0125	.0250
	.6	0	.0298	.0595	.0893	.1190	.1488	.1786	.1084	.0381	-.032	-.1024	-.0896	-.0768	-.0640	-.0512	-.0384	-.0256	-.0128	.0000	.0128	.0256
	.7	0	.0205	.0410	.0614	.0819	.1024	.1229	.1434	.0638	-.015	-.0952	-.0833	-.0714	-.0595	-.0476	-.0357	-.0238	-.0119	.0000	.0119	.0238
	.8	0	.0123	.0246	.0370	.0493	.0616	.0739	.0862	.0986	.010	-.0768	-.0672	-.0576	-.0480	-.0384	-.0288	-.0192	-.0096	.0000	.0096	.0192
	.9	0	.0029	.0058	.0088	.0218	.0272	.0326	.0381	.0435	.049	-.0456	-.0399	-.0342	-.0285	-.0228	-.0171	-.0114	-.0057	.0000	.0057	.0114
	•	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SPAN 2	.1	0	-.0039	-.0078	-.0117	-.0156	-.0195	-.0234	-.0273	-.0312	-.035	-.0390	.0534	.0458	.0382	.0306	.0230	.0154	.0073	.0002	-.0074	-.0150
	.2	0	-.0064	-.0128	-.0192	-.0256	-.0320	-.0384	-.0448	-.0512	-.057	-.0640	.0192	.1024	.0856	.0688	.0520	.0352	.0184	.0016	-.0152	-.0320
	.3	0	-.0077	-.0154	-.0231	-.0308	-.0385	-.0462	-.0539	-.0616	-.063	-.0770	.0042	.0686	.1414	.1142	.0870	.0598	.0326	.0054	-.0218	-.0490
	.4	0	-.0080	-.0160	-.0240	-.0320	-.0400	-.0480	-.0560	-.0640	-.072	-.0800	.0184	.0432	.1048	.1664	.1280	.0896	.0512	.0128	-.0256	-.0640
	.5	0	-.0075	-.0150	-.0225	-.0300	-.0375	-.0450	-.0525	-.0600	-.067	-.0750	.0250	.0250	.0750	.1250	.1750	.1250	.0750	.0250	-.0250	-.0750
	.6	0	-.0064	-.0128	-.0192	-.0256	-.0320	-.0384	-.0448	-.0512	-.057	-.0640	.0256	.0128	.0512	.0896	.1280	.1664	.1048	.0432	-.0184	-.0800
	.7	0	-.0049	-.0098	-.0147	-.0196	-.0245	-.0294	-.0343	-.0392	-.044	-.0490	.0218	.0054	.0326	.0598	.0870	.1142	.1414	.0686	-.0042	-.0770
	.8	0	-.0032	-.0064	-.0096	-.0128	-.0160	-.0192	-.0224	-.0256	-.0288	-.0320	.0152	.0016	.0184	.0352	.0520	.0688	.0856	.1024	.0192	-.0640
	.9	0	-.0015	-.0030	-.0045	-.0060	-.0075	-.0090	-.0105	-.0120	-.0135	-.0150	.0074	.0002	.0078	.0154	.0230	.0306	.0382	.0458	.0534	-.0390
	C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Live Loads

Unit load at	MOMENTS/PL																				
	SPAN 1											SPAN 2									
	A	.1	.2	.3	.4	.5	.6	.7	.8	.9	•	.1	.2	.3	.4	.5	.6	.7	.8	.9	C
+ Area	0	.0400	.0700	.0900	.1000	.1000	.0900	.0700	.0402	.020	.0167	.0152	.0300	.0550	.0700	.0750	.0700	.0550	.0300	.0152	.0167
– Area	0	-.0050	-.0100	-.0150	-.0200	-.0250	-.0300	-.0350	-.0402	-.065	-.1167	-.0702	-.0500	-.0500	-.0500	-.0500	-.0500	-.0500	-.0500	-.0702	-.1167
Total Area	0	.0350	.0600	.0750	.0800	.0750	.0600	.0350	.0000	-.045	-.1000	-.0550	-.0200	.0050	.0200	.0250	.0200	.0050	-.0200	-.0550	-.1000

Live Loads

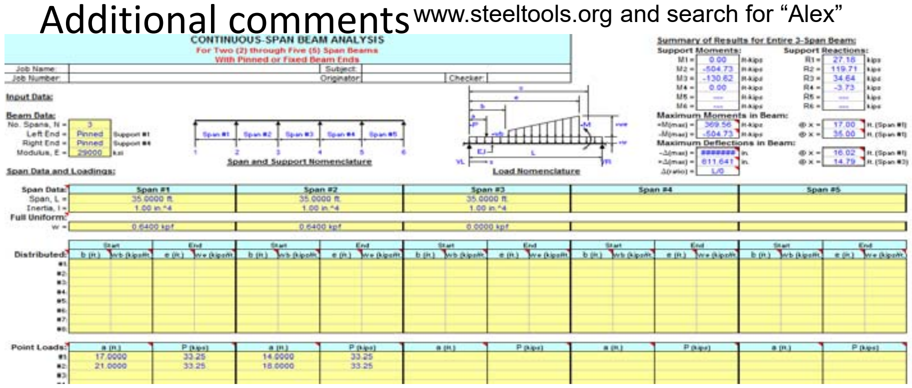
Additional comments

For the maximum negative moment:

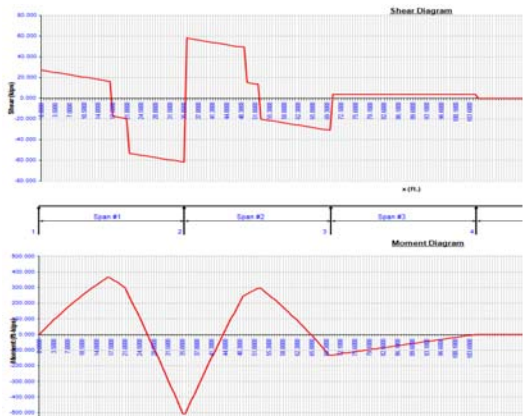
- Axle spacing of truck was set at 28 ft (<30 ft) by observation of influence values from AISC.
- Clear axle spacing of two tandems was set at 28 ft (>26 ft) by observation of influence values from AISC.
- Accuracy is limited by influence values only at the tenth points of each span.

Live Loads

Additional comments www.steeltools.org and search for “Alex”



Live Loads



Slabs

Problem 29: For slabs that are part of slab-girder bridges, discuss the analytical strip method (AASHTO 4.6.2.1) and the empirical method as permitted by AASHTO.

- Analytical method is linear elastic (or AASHTO Table A4-1).
- Empirical method requires following a set of rules so that standard details are assumed to satisfy strength and serviceability limit states.
- One way slabs when aspect ratio is 1.5 or larger (typical aspect ratios are 3–10).
- Width of the strip is the primary issue for the analytical method.

Slabs

Problem 30: For slabs that are part of CIP slab-girder bridges, discuss strip widths (SW) in regards to the analytical strip method (AASHTO Table 4.6.2.1.3-1).

$$M^{+} \rightarrow SW = 26 + 6.6S$$

$$M^{-} \rightarrow SW = 48 + 3.0S$$

$$\text{Overhang} \rightarrow SW = 45 + 10.0X$$

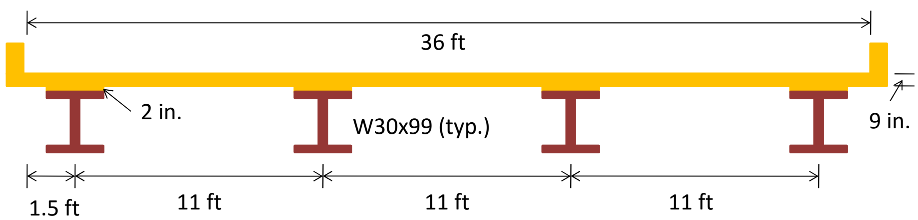
where:

S = girder spacing (ft)

X = distance from the load point to the centerline of the support (ft)

Slabs

Problem 31: Determine the strip widths for the CIP concrete slab shown.



$$X = 1.5 - 1 = 0.5 \text{ ft}$$

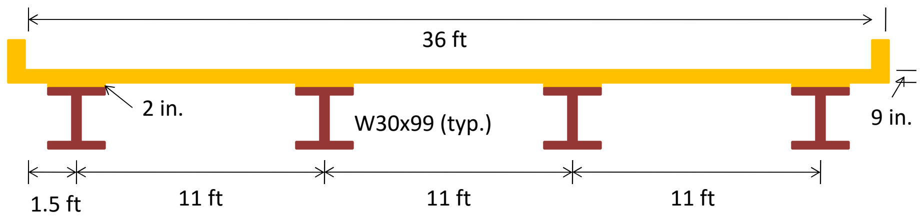
$$M^{+} \rightarrow SW = 26 + 6.6S = 26 + 6.6(11) = 98.6 \text{ in.} = 8.22 \text{ ft}$$

$$M^{-} \rightarrow SW = 48 + 3.0S = 48 + 3.0(11) = 81 \text{ in.} = 6.75 \text{ ft}$$

$$\text{Overhang} \rightarrow SW = 45 + 10.0X = 45 + 10.0(0.5) = 50 \text{ in.} = 4.17 \text{ ft}$$

Slabs

Problem 32: Determine the maximum unfactored live load moments using AASHTO Table A4-1.



$M^{+} = 7.46 \ \ k-ft/ft$

$M^{-} = -9.14 \ \ k-ft/ft$

Note: Maximum negative moment assumed at beam centerline (could use 2.6 in. from centerline of steel beam; AASHTO 4.6.2.1.6)

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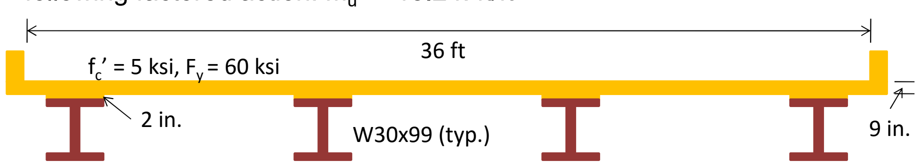
Slabs

Problem 33: Check the adequacy of #5 at 6 in. o.c. bottom bars for the following factored action: M_u^{+} = 15.2 k-ft/ft



Note: concrete cover (AASHTO Table 5.12.3-1) is 1.0 in. clear to bottom steel (d^{+} = 9 – 1 – 5 / 16 = 7.69 in.)

$a = \frac{A_s F_y}{0.85 f_c' b} = \frac{(2)(0.31)(60)}{0.85(5)(12)} = 0.729 \ \ in.; \ \ c = a/\beta_1 = 0.729/0.80 = 0.911 \ \ in.$

$\varepsilon_t = 0.003(d-c)/c = 0.003(7.69-0.911)/0.911 = 0.0223 > 0.005 \ \ (\varphi = 0.9)$

$\varphi M_n = 0.9 A_s F_y (d - a/2) = 0.9(2)(0.31)(60)(7.69 - 0.729/2)/12 = 20.4 > 15.2 \ \ k-ft/ft \ \ (ok)$

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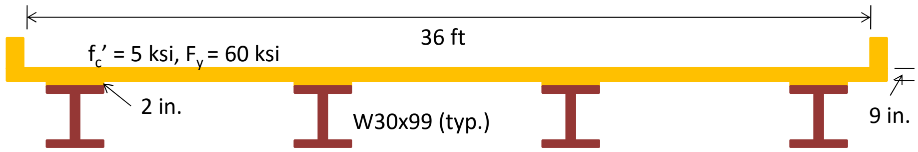
Slabs

Problem 34: Check the adequacy of #5 at 6 in. o.c. top bars for the following factored action: $M_u^- = -13.2$ k-ft/ft



Note: Concrete cover (AASHTO Table 5.12.3-1) is 2.5 in clear to top steel ($d^- = 9 - 2.5 - 5/16 = 6.19$ in.).

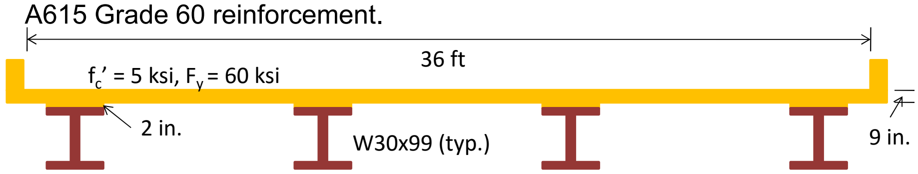
$$a = \frac{A_s F_y}{0.85 f_c' b} = \frac{(2)(0.31)(60)}{0.85(5)(12)} = 0.729 \text{ in.}; \quad c = a/\beta_1 = 0.729/0.80 = 0.911 \text{ in.}$$

$$\varepsilon_t = 0.003(d\text{-}c)/c = 0.003(6.19 - 0.911)/0.911 = 0.0174 > 0.005 \quad (\phi = 0.9)$$

$$\phi M_n = 0.9 A_s F_y (d - a/2) = 0.9(2)(0.31)(60)(6.19 - 0.729/2)/12 = 16.3 > 13.2 \text{ k-ft/ft} \quad \text{(ok)}$$

Slabs

Problem 35: Check spacing and minimum steel requirements for the adequacy of #5 at 6 in. o.c. top and bottom reinforcement. Assume A615 Grade 60 reinforcement.



Note: AASHTO 5.10.3.2 and 5.7.3.3.2 present spacing (s_{max}) requirements for primary reinforcement and minimum steel, respectively.

$$s_{max} = \min \left| \begin{array}{l} 1.5h = 1.5(9) = 13.5 \text{ in.} \\ 18 \text{ in.} \end{array} \right. = 13.5 \text{ in.} > 6 \text{ in.} \quad \text{(ok)}$$

$$M_{cr} = \gamma_3 \gamma_1 f_r S_c = 0.67(1.6)0.24\sqrt{5}[(1/6)(12)(9)^2]/12 = 7.77 \text{ k-ft/ft} < \phi M_n \quad \text{(ok)}$$

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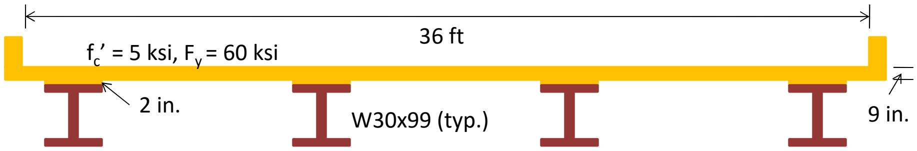
Slabs

Problem 36: Determine distribution steel (bottom only) per AASHTO 9.7.3.2 and T&S steel per 5.10.8.



Note: T&S is required on both faces (distributed equally) for slabs. Providing half on top, provide #4 at 18 in. o.c. on top.

$S = 11\ \text{ft}\ \ (\text{not monolithic})$

$$\text{Percent} = \min\left|\begin{matrix} 220/\sqrt{S} = 220/\sqrt{11} = 66.3\% \\ 67\% \end{matrix}\right. = 66.3\%$$

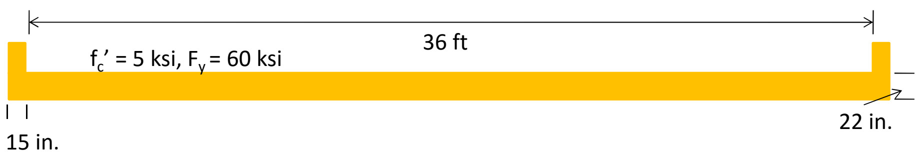
$$A_{distribution} = 0.663(2)(0.31) = 0.411\ \text{in}^2/\text{ft}\ \ (\#5@9\ \text{in. o.c.})$$

$$A_{T\&S} = 0.0018bh/2 = 0.0018(12)(9)/2 = 0.097 > 0.11\ \text{in}^2/\text{ft}\ \ (\text{each face})$$

Note: AASHTO Eq. 5.10.8-1 will not control for slabs.

Slabs

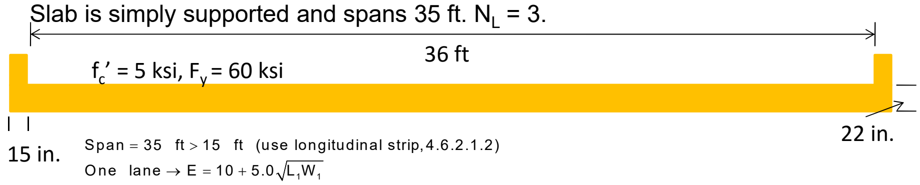
Problem 37: Check adequacy of solid slab thickness per AASHTO Table 2.5.2.6.3-1. Slab is simply supported and spans 35 ft.



$$h_{min} = \frac{1.2(S+10)}{30} = \frac{1.2(35+10)}{30} = 1.8\ \text{ft} = 21.6\ \text{in.} < 22\ \text{in.}\ (\text{ok})$$

Slabs

Problem 38: Determine the live load interior strip width per AASHTO 4.6.2.3. Slab is simply supported and spans 35 ft. N_L = 3.



$\text{Span} = 35 \text{ ft} > 15 \text{ ft}$ (use longitudinal strip, 4.6.2.1.2)

$\text{One lane} \rightarrow E = 10 + 5.0\sqrt{L_1 W_1}$

$L_1 = \min\left|\begin{matrix}\text{SPAN} = 35 \text{ ft} \\ 60 \text{ ft}\end{matrix}\right. = 35 \text{ ft}; W_1 = \min\left|\begin{matrix}\text{WIDTH} = 38.5 \text{ ft} \\ 30 \text{ ft}\end{matrix}\right. = 30 \text{ ft}$

$E = 10 + 5.0\sqrt{(35)(30)} = 172 \text{ in.} = 14.33 \text{ ft}$

$\text{Multiple lanes} \rightarrow E = 84 + 1.44\sqrt{L_1 W_1} \le 12.0W / N_L$

$L_1 = \min\left|\begin{matrix}\text{SPAN} = 35 \text{ ft} \\ 60 \text{ ft}\end{matrix}\right. = 35 \text{ ft}; W_1 = \min\left|\begin{matrix}\text{WIDTH} = 38.5 \text{ ft} \\ 60 \text{ ft}\end{matrix}\right. = 38.5 \text{ ft}$

$E = 84 + 1.44\sqrt{(35)(38.5)} = 137 \text{ in.} = 11.4 \text{ ft} \le 12.0W / N_L = 12(38.5)/3 = 154 \text{ in. (ok)}$

Note: E includes multiple presence factor m.

Use E = 11.4 ft

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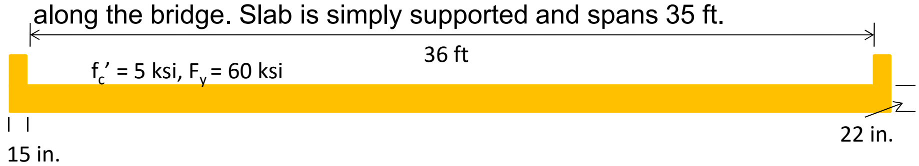
Slabs

Problem 39: Determine the maximum live load moment (for one lane) along the bridge. Slab is simply supported and spans 35 ft.



Span(ft)		Moment (k-ft)	End Shear and End Reaction (k)	Span(ft)		Moment (k-ft)	End Shear and End Reaction (k)
11		126.7 b	57.9 b	31		525.8 b	76.8 a
12		144.5 b	59.3 b	32		547.4 b	78.1 a
13		163.1 b	60.4 b	33		569.2 b	79.2 a
14		181.9 b	61.5 b	34		591.2 b	80.4 a
15		200.9 b	62.4 b	35		613.4 b	81.4 a

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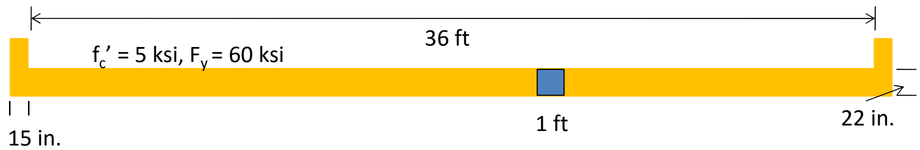
Slabs

Problem 40: Determine live load moment for a 1 ft interior strip of the simply supported 35 ft span flat slab bridge. E = 11.4 ft.

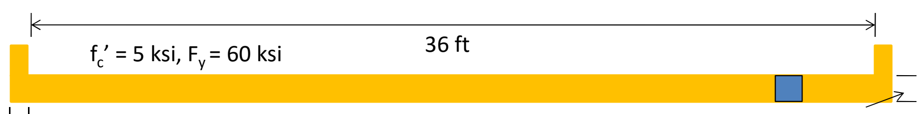


$$V_{HL-93,impact} = 81.4/11.4 = 7.14 \quad k/ft$$

$$M_{HL-93,impact} = 613.4/11.4 = 53.8 \quad k-ft/ft$$

Slabs

Problem 41: Determine the live load strip width for the slab edges per AASHTO 4.6.2.1.4 and the resulting shear and moment for a 1 ft strip near the slab edge.



$$E_{EDGE} = \text{barrier width} + 12 \text{ in.} + E_{controlling}/4 \le \min \begin{vmatrix} E_{controlling}/2 \\ 72 \text{ in.} \end{vmatrix}$$

$$E_{EDGE} = 15 \text{ in.} + 12 \text{ in.} + (11.4)(12)/4 = 61.2 \text{ in.} \le \min \begin{vmatrix} 11.4(12)/2 = 68.4 \\ 72 \text{ in.} \end{vmatrix}$$

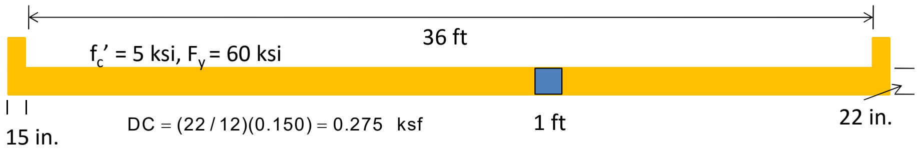
$$E_{EDGE} = 61.2 \text{ in.} = 5.1 \text{ ft}$$

$$V_{HL-93,impact} \approx (0.5)81.4/5.1 = 7.98 \quad k/ft$$

$$M_{HL-93,impact} \approx (0.5)613.4/5.1 = 60.2 \quad k-ft/ft$$

Slabs

Problem 42: Determine the dead loads DC and DW and the maximum moment and shear for an interior strip of the simply supported 35 ft span flat slab bridge. Include a 25 psf future wearing surface.



$DC = (22/12)(0.150) = 0.275 \text{ ksf}$

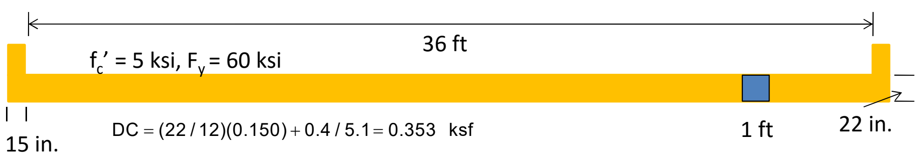
$DW = 0.025 \text{ ksf}$

$M_{DC} = 0.275(35)^2/8 = 42.1 \text{ k-ft/ft}; \quad V_{DC} = 0.275(35)/2 = 4.81 \text{ k/ft}$

$M_{DW} = 0.025(35)^2/8 = 3.83 \text{ k-ft/ft}; \quad V_{DW} = 0.025(35)/2 = 0.438 \text{ k/ft}$

Slabs

Problem 43: Determine the dead loads DC and DW and the maximum moment and shear for an exterior strip of the simply supported 35 ft span flat slab bridge. Include a 25 psf future wearing surface. Assume barrier weight (0.4 k/ft) carried by edge strip. E_{EDGE} = 5.1 ft.



$DC = (22/12)(0.150) + 0.4/5.1 = 0.353 \text{ ksf}$

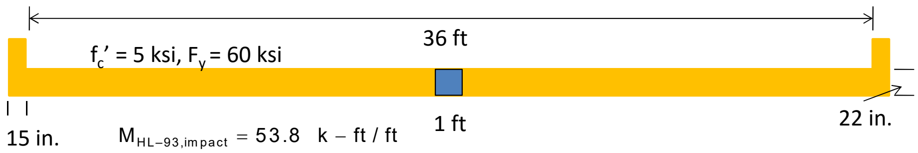
$DW = 0.025(5.1 - 15/12)/5.1 = 0.0189 \text{ ksf}$

$M_{DC} = 0.353(35)^2/8 = 54.1 \text{ k-ft/ft}; \quad V_{DC} = 0.353(35)/2 = 6.18 \text{ k/ft}$

$M_{DW} = 0.0189(35)^2/8 = 2.89 \text{ k-ft/ft}; \quad V_{DW} = 0.0189(35)/2 = 0.331 \text{ k/ft}$

Slabs

Problem 44: Determine the Service I factored moment for the interior strip of the simply supported 35 ft span flat slab bridge. $\eta_i = 1.0$. Assume #9 bars at 6 in. o.c. for structural steel in slab. d = 20.4 in.



$$M_{HL-93,impact} = 53.8 \quad k-ft/ft$$

$$M_{DC} = 42.1 \quad k-ft/ft$$

$$M_{DW} = 3.83 \quad k-ft/ft$$

$$M = \sum \eta_i \gamma_i Q_i = 1.0(1.0M_{HL-93,impact} + 1.0M_{DC} + 1.0M_{DW})$$

$$M = 1.0(53.8 + 42.1 + 3.83) = 99.7 \quad k-ft/ft$$

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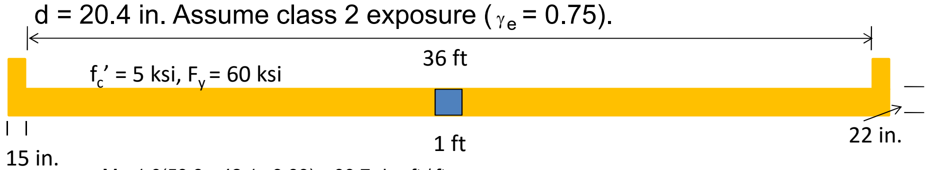
Slabs

Problem 45: Check crack control (AASHTO 5.7.3.4, 5.4.2.6, 5.7.1, and 5.4.2.4) for the interior strip of the simply supported 35 ft span flat slab bridge. $\eta_i = 1.0$. Assume #9 bars @ 6 in. o.c. for structural steel in slab. d = 20.4 in. Assume class 2 exposure ($\gamma_e = 0.75$).



$$M = 1.0(53.8 + 42.1 + 3.83) = 99.7 \quad k-ft/ft$$

$$f_c = M/S = 99.7(12)/[12(22)^2/6] = 1.24 \quad ksi > 0.8f_r = 0.8(0.24\sqrt{5}) = 0.429 \quad ksi \quad \text{(cracked)}$$

$$n = E_s/E_c = 29{,}000/[1{,}820\sqrt{5}] = 7.13 \quad (\text{use } n = 7)$$

$$nA_s = 7(2)(1) = 14 \quad in^2/ft$$

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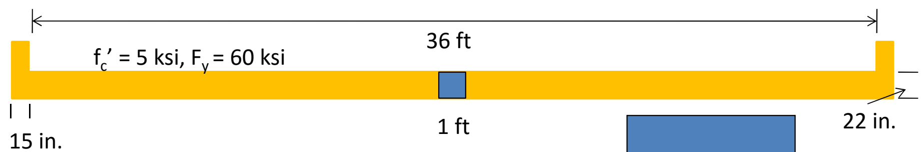
Slabs

Problem 45: d = 20.4 in.

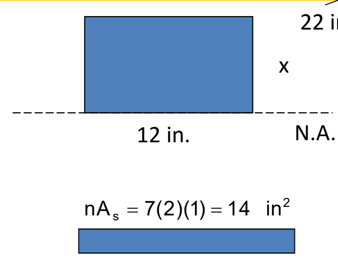


$$12x\left(\frac{x}{2}\right) = 14(20.4 - x)$$

$$x = 5.83 \text{ in}$$

$$I_{cr} = \frac{12x^3}{12} + 12x\left(\frac{x}{2}\right)^2 + 14(20.4 - x)^2$$

$$I_{cr} = 3{,}765 \text{ in}^4/\text{ft}$$



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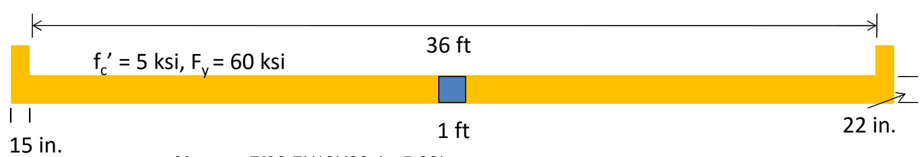
Slabs

Problem 45: Assume class 2 exposure (γ_e = 0.75). AASHTO 5.7.3.4.



$$f_{ss} = \frac{nMy_{steel}}{I_{tr}} = \frac{7(99.7)(12)(20.4 - 5.83)}{(3{,}765)} = 32.4 \text{ ksi}$$

$$d_c = 1 + 9/8/2 = 1.56 \text{ in.}$$

$$\beta_s = 1 + \frac{d_c}{0.7(h - d_c)} = 1 + \frac{1.56}{0.7(22 - 1.56)} = 1.11$$

$$s = 6 \text{ in.} < \frac{700\gamma_e}{\beta_s f_{ss}} - 2d_c = \frac{700(0.75)}{(1.11)(32.4)} - 2(1.56) = 11.5 \text{ in. (ok)}$$

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Slabs

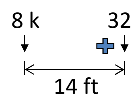
Problem 46: Determine the maximum factored moment for an interior strip of the simply supported 35 ft span flat slab bridge for Fatigue I. Note that IM = 15% for this limit state and that the design truck axle spacing is set at 30 ft. η_i = 1.0. m = NA (AASHTO 3.6.1.1.2).

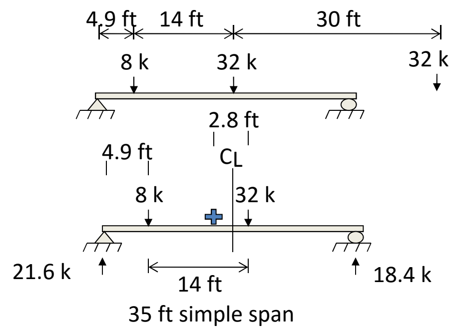
$$M_{max,truck,fatigue} = 21.6(18.9) - 8(14) = 296 \text{ k-ft}$$

$$M = \sum \eta_i \gamma_i Q_i = 1.0(1.5)(M_{max,truck,fatigue})(1+IM)$$

$$M = 1.0(1.5)(296)(1.15) = 511 \text{ k-ft/lane}$$

$$\bar{x} = \frac{8(0)+32(14)}{(8+32)} = 11.2 \text{ ft}$$





Slabs

Problem 47: Determine the maximum factored stress in the interior strip slab reinforcement due to the design truck. Assume #9 bars at 6 in. o.c. for structural steel in slab. d = 20.4 in. n = 7.0.

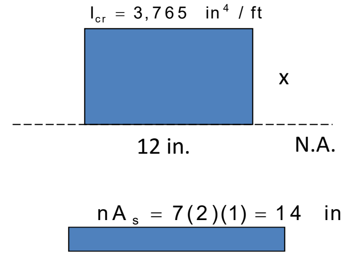
$$M = 511 \text{ k-ft/lane (see previous)}$$

$$E = 14.33 \text{ ft (see previous, one lane)}$$

$$M = 511/14.33 = 35.7 \text{ k-ft/ft}$$

$$x = 5.83 \text{ in}$$

$$I_{cr} = 3{,}765 \text{ in}^4\text{/ft}$$



$$nA_s = 7(2)(1) = 14 \text{ in}^2$$

$$f_{s,truck} = \frac{nMy_{steel}}{I_{tr}} = \frac{7(35.7)(12)(20.4-5.83)}{(3{,}765)} = 11.6 \text{ ksi}$$

Slabs

Problem 48: Check the adequacy of the interior strip slab reinforcement for fatigue per AASHTO 5.5.3.2.

$$f_{s,truck} = 11.6 \text{ ksi (see previous)}$$

$$M_{DC} = 42.1 \text{ k-ft/ft (see previous)}$$

$$M_{DW} = 3.83 \text{ k-ft/ft (see previous)}$$

$$M_{DL} = M_{DC} + M_{DW} = 42.1 + 3.83 = 45.9 \text{ k-ft/ft}$$

$$f_{s,DL} = \frac{nM_{DL}y_{steel}}{I_{tr}} = \frac{7(45.9)(12)(20.4 - 5.83)}{(3,765)} = 14.9 \text{ ksi}$$

$$f_{min} = 0 + 14.9 = 14.9 \text{ ksi}$$

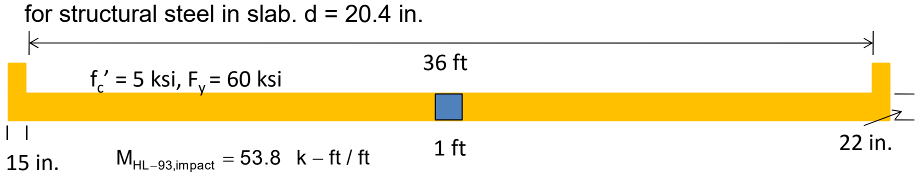
$$f_{max} = 11.6 + 14.9 = 26.5 \text{ ksi}$$

$$\gamma(\Delta f) = 26.5 - 14.9 = 11.6 \text{ ksi}$$

$$(\Delta F)_{TH} = 24 - 0.33f_{min} = 24 - 0.33(14.9) = 19.1 > 11.6 \text{ ksi (ok)}$$

Slabs

Problem 49: Determine the Strength I factored moment for the interior strip of the simply supported 35 ft span flat slab bridge. η_i = 1.0. Assume #9 bars at 6 in. o.c. for structural steel in slab. d = 20.4 in.



$$M_{HL-93,impact} = 53.8 \text{ k-ft/ft}$$

$$M_{DC} = 42.1 \text{ k-ft/ft}$$

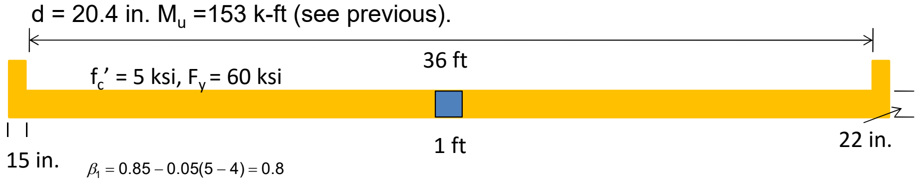
$$M_{DW} = 3.83 \text{ k-ft/ft}$$

$$M = \sum \eta_i \gamma_i Q_i = 1.0(1.75M_{HL-93,impact} + 1.25M_{DC} + 1.5M_{DW})$$

$$M_u = 1.0(1.75(53.8) + 1.25(42.1) + 1.5(3.83)) = 152.5 \text{ k-ft/ft}$$

Slabs

Problem 50: Determine ϕM_n for the interior slab strip of the 35 ft simple span bridge. Assume #9 bars at 6 in. o.c. for structural steel in slab.
d = 20.4 in. M_u =153 k-ft (see previous).



$$\beta_1 = 0.85 - 0.05(5-4) = 0.8$$

$$a = \frac{A_s F_y}{0.85 f_c' b} = \frac{(2)(1.00)(60)}{0.85(5)(12)} = 2.35 \text{ in.}$$

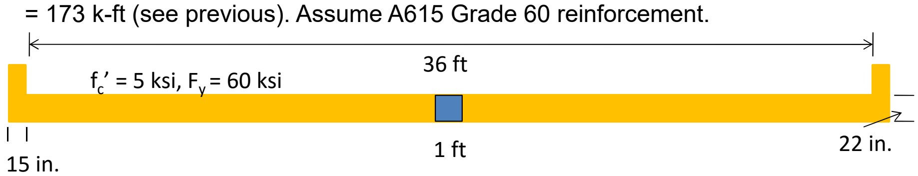
$$c = a/\beta_1 = 2.35/0.8 = 2.94 \text{ in.}$$

$$\varepsilon_t = 0.003(d_s - c)/c = 0.003(20.4-2.94)/2.94 = 0.0178 > 0.005 \quad (\phi = 0.9,\ 5.7.3.3.1)$$

$$\phi M_n = 0.9 A_s F_y (d - a/2) = 0.9(2)(1.00)(60)(20.4 - 2.35/2)/12 = 173 > 153 \text{ k-ft/ft (ok)}$$

Slabs

Problem 51: Check spacing and minimum steel requirements for the adequacy of #9 bars at 6 in. o.c. for structural steel in slab. d = 20.4 in., M_u = 153 k-ft, ϕM_n = 173 k-ft (see previous). Assume A615 Grade 60 reinforcement.



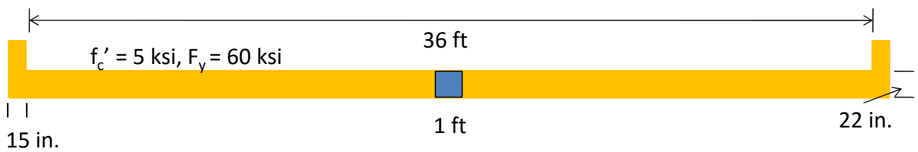
Note: AASHTO 5.10.3.2 and 5.7.3.3.2 present spacing (s_{max}) requirements for primary reinforcement and minimum steel, respectively.

$$s_{max} = \min \left| \begin{array}{l} 1.5h = 1.5(22) = 33 \text{ in.} \\ 18 \text{ in.} \end{array} \right. = 18 \text{ in.} > 6 \text{ in. (ok)}$$

$$M_{cr} = \gamma_3 \gamma_1 f_r S_c = 0.67(1.6)0.24\sqrt{5}[(1/6)(12)(22)^2]/12 = 46.4 \text{ k-ft/ft} < \phi M_n \text{ (ok)}$$

Slabs

Problem 52: Determine distribution steel (bottom only) per AASHTO 5.14.4.1 and T&S steel per 5.10.8.



Note: T&S is required on both faces (distributed equally) for slabs. Providing half on top, provide #4 at 10 in. o.c. on top, each way.

$$\text{Percent} = \min \left| \begin{matrix} 100/\sqrt{L} = 100/\sqrt{35} = 16.9\% \\ 50\% \end{matrix} \right. = 16.9\%$$

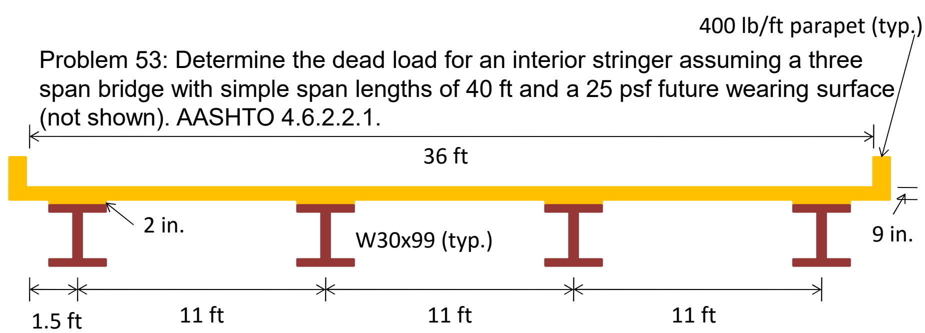
Note AASHTO Eq. 5.10.8-1 will not control for slabs.

$$A_{distribution} = 0.169(2)(1.00) = 0.34 \text{ in}^2/\text{ft} \quad (\#5@10 \text{ in. o.c.})$$

$$A_{T\&S} = 0.0018bh/2 = 0.0018(12)(22)/2 = 0.238 \text{ in}^2/\text{ft} > 0.11 \text{ in}^2/\text{ft} \quad (\text{each face})$$

Slab on Girder Bridges

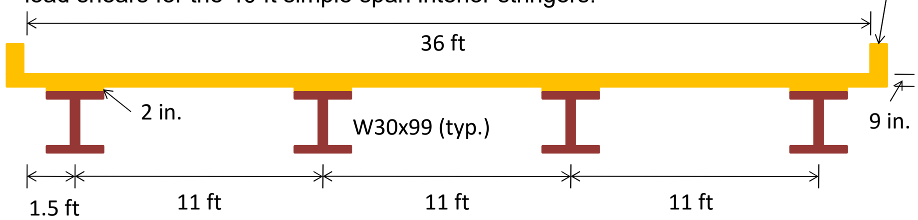
Problem 53: Determine the dead load for an interior stringer assuming a three span bridge with simple span lengths of 40 ft and a 25 psf future wearing surface (not shown). AASHTO 4.6.2.2.1.



$$DC_{slab} = 11(9/12)(0.150) = 1.24 \text{ k/ft}$$
$$DC_{haunch} = (10.5/12)(2/12)(0.150) = 0.0219 \text{ k/ft}$$
$$DC_{steel} = 0.099 \text{ k/ft}$$
$$DC_1 = 1.24 + 0.0219 + 0.099 = 1.36 \text{ k/ft} \quad (\text{non-composite})$$
$$DC_2 = 0.400(2)/4 = 0.2 \text{ k/ft} \quad (\text{composite})$$
$$DW = 36(0.025)/4 = 0.225 \text{ k/ft} \quad (\text{composite})$$

Slab on Girder Bridges

Problem 54: Determine the maximum dead load moments and maximum dead load shears for the 40 ft simple span interior stringers.



$DC_1 = 1.36 \ k/ft$ (previous slide)
$DC_2 = 0.2 \ k/ft$ (previous slide)
$DW = 0.225 \ k/ft$ (previous slide)
$M_{DC1} = 1.36(40)^2/8 = 272 \ k-ft; \ V_{DC1} = 1.36(40)/2 = 27.2 \ k$
$M_{DC2} = 0.2(40)^2/8 = 40 \ k-ft; \ V_{DC2} = 0.2(40)/2 = 4 \ k$
$M_{DW} = 0.225(40)^2/8 = 45 \ k-ft; \ V_{DW} = 0.225(40)/2 = 4.5 \ k$

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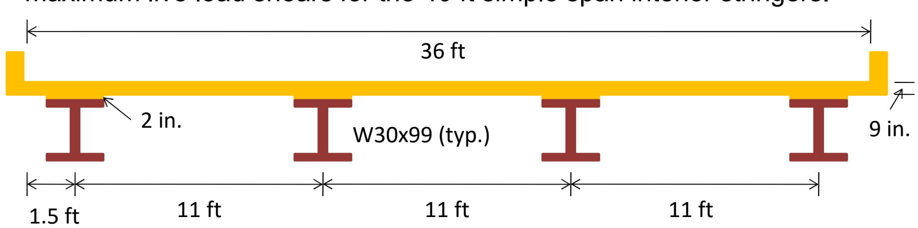
Slab on Girder Bridges

Problem 55: Determine the maximum live load moments and maximum live load shears for the 40 ft simple span interior stringers.



Note: Using Caltrans Design Aid (No IM option)
578 – 128 = 450
68 – 13 = 55

$M_{LL,truck/tandem} = 450 \ k-ft$ (Caltrans Design Aid, HL – 93)
$V_{LL,truck/tandem} = 55 \ k$ (Caltrans Design Aid, HL – 93)
$M_{LL,lane} = 0.64(40)^2/8 = 128 \ k-ft$
$V_{LL,lane} = 0.64(40)/2 = 12.8 \ k$

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Slab on Girder Bridges

Problem 56: For the previous problem, determine the controlling live load distribution factor for moment. Note that the structure shown satisfies all limitations allowing the use of the simplified procedure. Assume n = 8. AASHTO 4.6.2.2.

$I = 3{,}990 \text{ in}^4$ (W30x99, AISC Manual)

$A = 29.1 \text{ in}^2$ (W30x99, AISC Manual)

$d = 29.7 \text{ in.}$ (W30x99, AISC Manual)

$n = E_B / E_D = 8$

$e_g = (t_s + d)/2 + t_{haunch} = (9 + 29.7)/2 + 2 = 21.35 \text{ in.}$

$K_g = n(I + Ae_g^2) = 8[3{,}990 + 29.1(21.35)^2] = 138{,}035 \text{ in}^4$

$$g_1 = 0.06 + \left(\frac{S}{14}\right)^{0.4}\left(\frac{S}{L}\right)^{0.3}\left(\frac{K_g}{12Lt_s^3}\right)^{0.1}$$

$$g_1 = 0.06 + \left(\frac{11}{14}\right)^{0.4}\left(\frac{11}{40}\right)^{0.3}\left(\frac{138{,}035}{12(40)(9)^3}\right)^{0.1} = 0.62$$

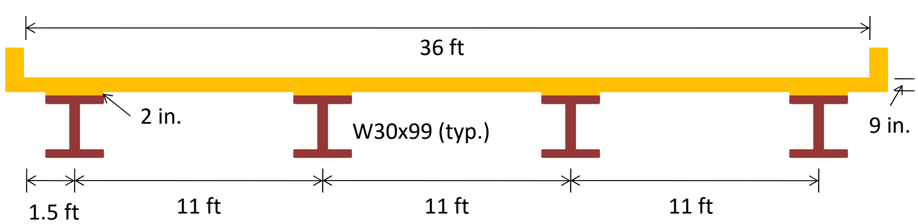
AASHTO Table 4.6.2.2.2b-1

$$g_m = 0.075 + \left(\frac{S}{9.5}\right)^{0.6}\left(\frac{S}{L}\right)^{0.2}\left(\frac{K_g}{12Lt_s^3}\right)^{0.1}$$

$$g_m = 0.075 + \left(\frac{11}{9.5}\right)^{0.6}\left(\frac{11}{40}\right)^{0.2}\left(\frac{138{,}035}{12(40)(9)^3}\right)^{0.1} = 0.84 \quad \text{(controls)}$$

Slab on Girder Bridges

Problem 57: Determine the controlling live load distribution factor for shear. Note that the structure shown satisfies all limitations allowing the use of the simplified procedure. Assume n = 8.



AASHTO Table 4.6.2.2.3a-1

$$g_1 = 0.36 + \frac{S}{25}$$

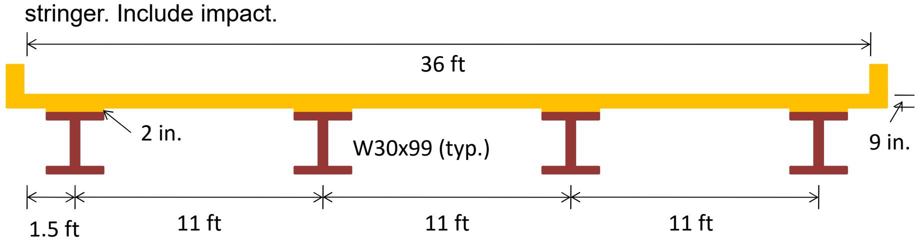
$$g_1 = 0.36 + \frac{11}{25} = 0.8$$

$$g_m = 0.2 + \frac{S}{12} - \left(\frac{S}{35}\right)^2$$

$$g_m = 0.2 + \frac{11}{12} - \left(\frac{11}{35}\right)^2 = 1.02 \quad \text{(controls)}$$

Slab on Girder Bridges

Problem 58: Determine the controlling live load moment and shear for an interior stringer. Include impact.



$M_{LL,truck/tandem} = 450 \;\; k-ft \;\; \text{(previous slide)}$

$V_{LL,truck/tandem} = 55 \;\; k \;\; \text{(previous slide)}$

$M_{LL,lane} = 128 \;\; k-ft \;\; \text{(previous slide)}$

$V_{LL,lane} = 12.8 \;\; k \;\; \text{(previous slide)}$

$g_m = 0.84 \;\; \text{(moment, previous slide)}$

$g_m = 1.02 \;\; \text{(shear, previous slide)}$

$M_{LL+IM} = 0.84[1.33(450)+128] = 610 \;\; k-ft$

$V_{LL+IM} = 1.02[1.33(55)+12.8] = 87.7 \;\; k$

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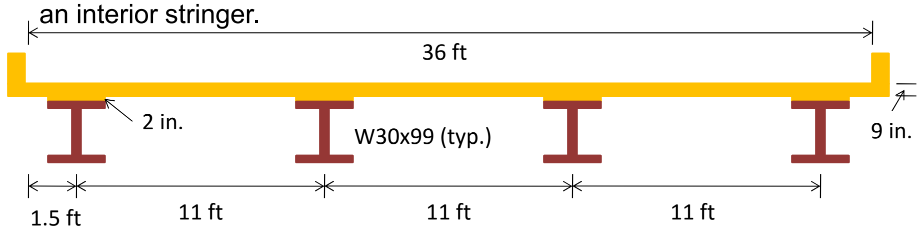
Slab on Girder Bridges

Problem 59: Determine the Strength I factored moment and shear for an interior stringer.



$M_{DC1} = 272 \;\; k-ft; \;\; V_{DC1} = 27.2 \;\; k \;\; \text{(previous slide)}$

$M_{DC2} = 40 \;\; k-ft; \;\; V_{DC2} = 4 \;\; k \;\; \text{(previous slide)}$

$M_{DW} = 45 \;\; k-ft; \;\; V_{DW} = 4.5 \;\; k \;\; \text{(previous slide)}$

$M_{LL+IM} = 610 \;\; k-ft \;\; \text{(previous slide)}$

$V_{LL+IM} = 87.7 \;\; k \;\; \text{(previous slide)}$

$M_u = 1.25(M_{DC1}+M_{DC2})+1.5M_{DW}+1.75M_{LL+IM}$

$M_u = 1.25(272+40)+1.5(45)+1.75(610) = 1{,}525 \;\; k-ft$

$V_u = 1.25(V_{DC1}+V_{DC2})+1.5V_{DW}+1.75V_{LL+IM}$

$V_u = 1.25(27.2+4)+1.5(4.5)+1.75(87.7) = 199 \;\; k$

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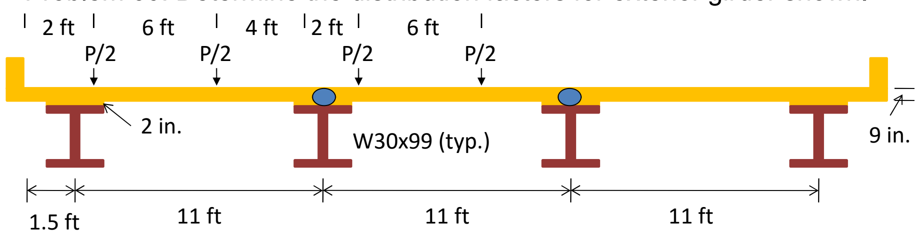
Lever Rule

Problem 60: Determine the distribution factors for exterior girder shown.



Note: Distribution factors are the same for shear and moment. One lane loaded controls.

$$R_{Exterior} = \frac{P/2(12.5-2)+P/2(12.5-8)}{11} = 0.68P$$

$$mg_1 = 1.2(0.68) = 0.816$$

AASHTO 3.6.1.3.1

$$mg_2 = 1.0(0.68) = 0.68$$

Structural Design Standards Relevant for Vertical Forces

- AASHTO LRFD Bridge Design Specifications (7th Edition, 2014)

Recommended References & Study Materials

- *Structural Engineering Sample Questions and Solutions*. NCEES, 2014.
- Williams, Alan. *Structural Engineering Reference Manual*. Professional Publications, Inc., 2012.
- Barker, Richard M., and Jay A. Puckett. *Design of Highway Bridges: An LRFD Approach*. Wiley, 2013.
- "Bridge Design Aids," 2013, Caltrans.
- *Moments, Shears and Reactions for Continuous Highway Bridges*. AISC, 1986.