CHAPTER

5c

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DEVELOPMENT, SPLICES, AND SIMPLE SPAN BAR CUTOFFS

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Part I – Concrete Design and Analysis

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ENCE 355 - Introduction to Structural Design

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Simple-Span Bar Cutoffs and Bends

- Determination of Bar Cutoffs
  - Recall that the maximum required A_s for a beam is needed only where the moment is maximum.
  - This maximum steel may be needed at points along a bending member where the bending moment is smaller.
  - This can be done by either stopping or bending the bars in a manner consistent with the theoretical requirements for the strength of the member and the ACI Code.

Simple-Span Bar Cutoffs and Bends

- Determination of Bar Cutoffs
  - In theory bars can be stopped or bent in bending members whenever they are no longer needed to resist the bending moment.
  - However, the ACI Code requires that each bar be extended beyond the point at which it is no longer needed for flexure a distance equal to the effective depth d of the cross section or $12d_b$, whichever is greater.

Simple-Span Bar Cutoffs and Bends

- Determination of Bar Cutoffs
  - The ACI code gives the following exceptions to the previous rules:
    1. At supports of simple spans, and
    2. At free ends of cantilever beams.
  - This in effect prohibits the cutting off of a bar at the theoretical cutoff point, but can be bent at the theoretical cutoff point.
  - If bars are to be bent, it is common to start the bend at a distance equal to one-half the effective depth beyond the point.

Simple-Span Bar Cutoffs and Bends

- General Procedure for Determining the Theoretical Cutoff Point
  1. Establish a bar cutoff scheme (i.e., select the bars that will be cut off first).
  2. Plot the complete M_u diagram.
  3. Superimpose on the M_u diagram the values of ϕM_n corresponding to the bars of Step 1 that will not be stopped.
  4. The theoretical points are established where the ϕM_n lines intersect the M_u curve.

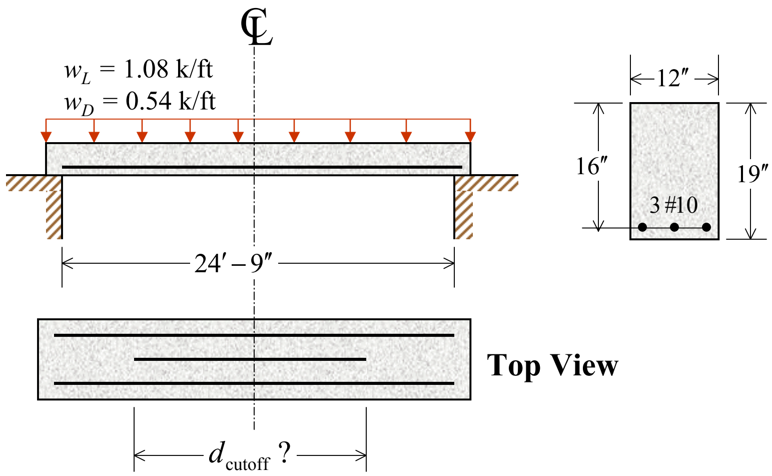
Simple-Span Bar Cutoffs and Bends

- Example: Bar Cutoff Point

  For the simply supported beam shown in the figure, determine the theoretical and actual cutoff point for the center No. 10 bar. The beam is to carry a distributed dead load of 0.54 kips/ft including its own weight, and live service load of 1.08 kips/ft. Material strengths specified are f_c' = 4,000 psi and f_y = 60,000 psi.

Simple-Span Bar Cutoffs and Bends

- Example: Bar Cutoff Point (cont'd)



Simple-Span Bar Cutoffs and Bends

- Example: Bar Cutoff Point (cont'd)

  Determine factored distributed load:

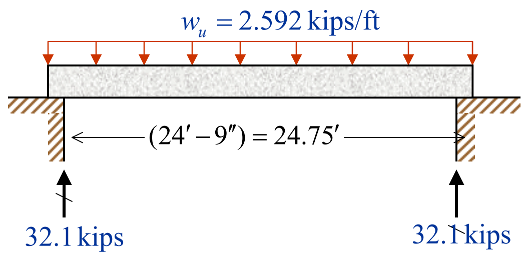
$$w_u = 1.4(0.54) + 1.7(1.08) = 2.592 \text{ kips/ft}$$

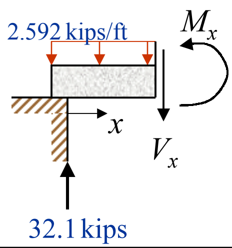
1. Bar cutoff scheme has been established for the center No. 10 bar.
2. **Plot of the complete M_u diagram:**

   In order to do that, we have to find an expression for M_u based on the loading

Simple-Span Bar Cutoffs and Bends

- Example: Bar Cutoff Point (cont'd)



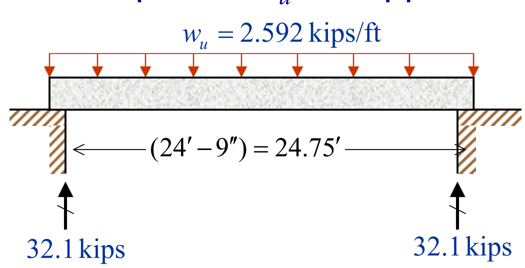


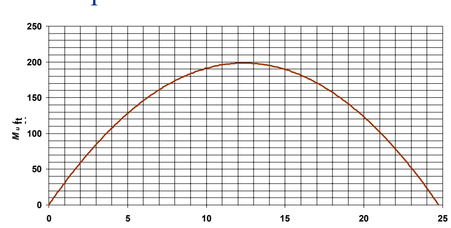
$$\boxed{M_x = 32.1x - 2.592\frac{x^2}{2} = 32.1x - 1.296x^2} \quad (1)$$

Note: $M_x = M_u(x)$

Simple-Span Bar Cutoffs and Bends

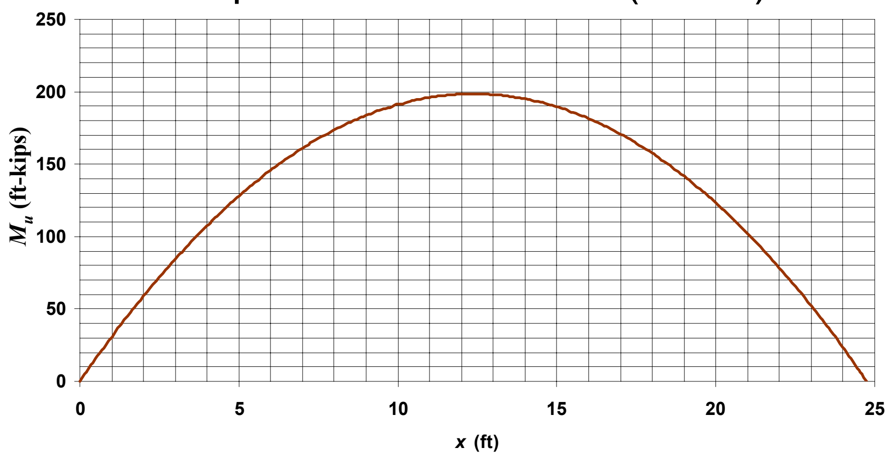
- Example: Bar Cutoff Point (cont'd)
  - Thus, the plot of M_u will appear as follows:





Simple-Span Bar Cutoffs and Bends

- Example: Bar Cutoff Point (cont'd)



Simple-Span Bar Cutoffs and Bends

- Example: Bar Cutoff Point (cont'd)
  3. **Superimpose on the M_u diagram the values of ϕM_u corresponding to 2 No. 10 bars:**

ϕM_n for 2 #10 bars:

$$\rho = \frac{A_s}{bd} = \frac{2.54}{12(16)} = 0.0132$$

From Table 2, $\overline{k}$ corresponding to 0.0132 is

$$\overline{k} = 0.6998 \text{ ksi}$$

$$A_{s,\min} = 0.0033(b)(d) = 0.0033(12)(16) = 0.63 \text{ in}^2 < 2.54 \text{ in}^2 \text{ OK}$$

Simple-Span Bar Cutoffs and Bends

- Example: Bar Cutoff Point (cont'd)

Table 1. Areas of Multiple of Reinforcing Bars (in^2)

Number of bars	Bar number #3	#4	$5	#6	#7	#8	#9	#10	#11
1	0.11	0.20	0.31	0.44	0.60	0.79	1.00	1.27	1.56
2	0.22	0.40	0.62	0.88	1.20	1.58	2.00	2.54	3.12
3	0.33	0.60	0.93	1.32	1.80	2.37	3.00	3.81	4.68
4	0.44	0.80	1.24	1.76	2.40	3.16	4.00	5.08	6.24
5	0.55	1.00	1.55	2.20	3.00	3.95	5.00	6.35	7.80
6	0.66	1.20	1.86	2.64	3.60	4.74	6.00	7.62	9.36
7	0.77	1.40	2.17	3.08	4.20	5.53	7.00	8.89	10.92
8	0.88	1.60	2.48	3.52	4.80	6.32	8.00	10.16	12.48
9	0.99	1.80	2.79	3.96	5.40	7.11	9.00	11.43	14.04
10	1.10	2.00	3.10	4.40	6.00	7.90	10.00	12.70	15.60

Table A-2 Textbook

Simple-Span Bar Cutoffs and Bends

- Example: Bar Cutoff Point (cont'd)

Table 2 (Table A-10, Text)

ρ	$\bar{k}$	ρ	$\bar{k}$	ρ	$\bar{k}$
0.0092	0.5072	0.0128	0.6813	0.0164	0.8417
0.0093	0.5122	0.0129	0.6859	0.0165	0.8459
0.0094	0.5172	0.0130	0.6906	0.0166	0.8502
0.0095	0.5222	0.0131	0.6952	0.0167	0.8544
0.0096	0.5272	0.0132	0.6998	0.0168	0.8586
0.0097	0.5322	0.0133	0.7044	0.0169	0.8629
0.0098	0.5372	0.0134	0.7090	0.0170	0.8671
0.0099	0.5421	0.0135	0.7136	0.0171	0.8713
0.0100	0.5471	0.0136	0.7181	0.0172	0.8754

Simple-Span Bar Cutoffs and Bends

- Example: Bar Cutoff Point (cont'd)

$$\phi M_n = \phi b d^2 \bar{k} = \frac{0.9(12)(16)^2(0.6998)}{12} = 161.2 \text{ ft-kips}$$

– The line ϕM_n = 161.2 intersects the curve of M_u at 7 in. and 17.7 in. Therefore, the theoretical cutoff point is located 7 ft. from the face of either support.

– The actual cutoff point:

$$d = 16'' = 1.33' \text{ and } 12 d_b = 12(1.27) = 15.24'' = 1.27'$$

controls Dia. No. 10 bar

Hence,

$$\text{actual cutoff point} = 7 - 1.33 = 5.7 \text{ ft from F.O.S}$$

Simple-Span Bar Cutoffs and Bends

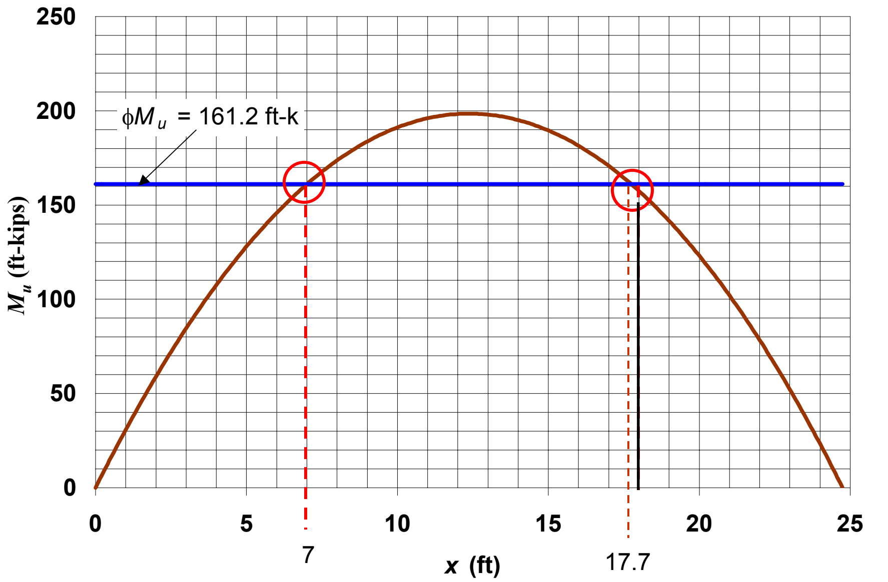
- Example: Bar Cutoff Point (cont'd)

Table 3. ASTM Standard - English Reinforcing Bars

Bar Designation	Diameter in	Area in^2	Weight lb/ft
#3 [#10]	0.375	0.11	0.376
#4 [#13]	0.500	0.20	0.668
#5 [#16]	0.625	0.31	1.043
#6 [#19]	0.750	0.44	1.502
#7 [#22]	0.875	0.60	2.044
#8 [#25]	1.000	0.79	2.670
#9 [#29]	1.128	1.00	3.400
#10 [#32]	1.270	1.27	4.303
#11 [#36]	1.410	1.56	5.313
#14 [#43]	1.693	2.25	7.650
#18 [#57]	2.257	4.00	13.60

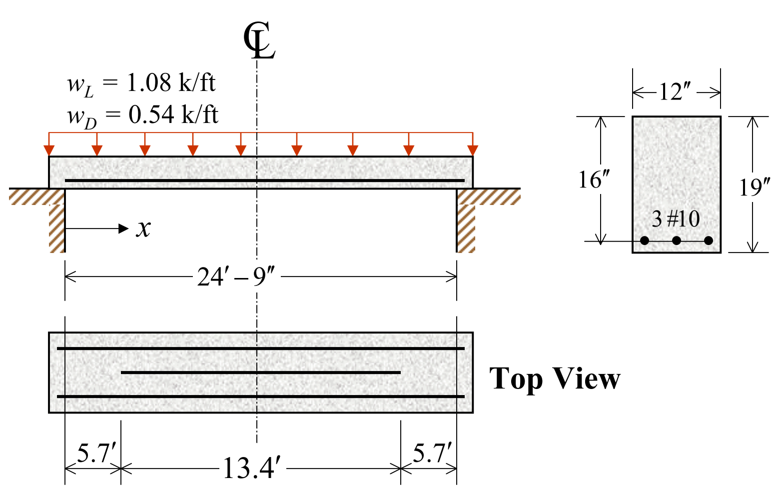
Note: Metric designations are in brackets

Simple-Span Bar Cutoffs and Bends



Simple-Span Bar Cutoffs and Bends

- Example: Bar Cutoff Point (cont'd)



Simple-Span Bar Cutoffs and Bends

- Example: Bar Cutoff Point (cont'd)
  - Alternative Method to Find the Theoretical Cutoff Point:
    - In method, the ϕM_n value for the continuous reinforcement can be substituted into Eq. 1, and consequently the distances from the face of the right support can be located analytically as follows:

$$\phi M_n = 161.2 = 32.1x - 1.296x^2$$

or $\quad 1.296x^2 - 32.1x + 161.2 = 0$

from which (quadratic formula):

$$x = \frac{32.1 \pm \sqrt{(32.1)^2 - 4(1.296)161.2}}{2(1.296)} = 7.0 \text{ in}, 17.7 \text{ in}$$