ARCHITECTURAL STRUCTURES:
FORM, BEHAVIOR, AND DESIGN
ARCH 331
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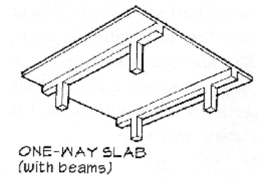
FALL 2013

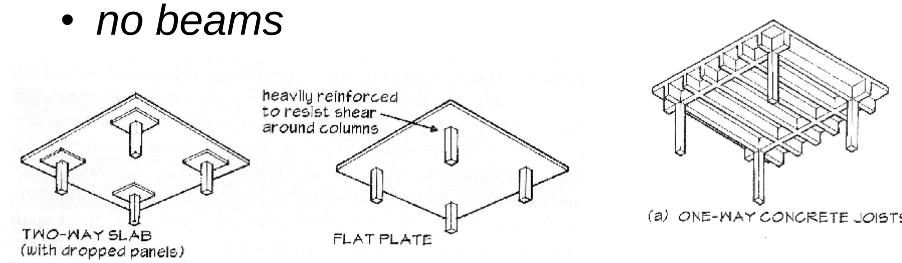
lecture
twenty three

concrete construction: T-beams & slabs

Systems

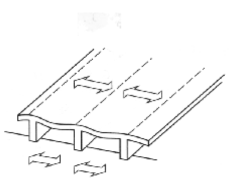
- beams separate from slab
- beams integral with slab
  - close spaced
- continuous beams
- no beams

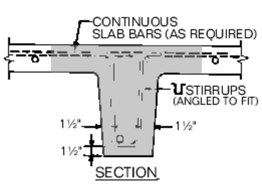


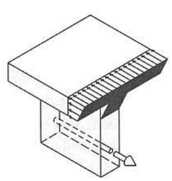


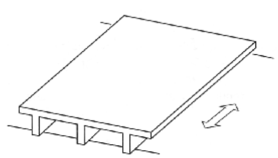
T sections

- two areas of compression in moment possible
- one-way joists
- effective flange width









T sections

- negative bending: min A_s, larger of:

$$A_s = \frac{6\sqrt{f'_c}}{f_y}(b_w d) \qquad A_s = \frac{3\sqrt{f'_c}}{f_y}(b_f d)$$

- effective width (interior)
  - L/4
  - b_w + 16t
  - center-to-center of beams

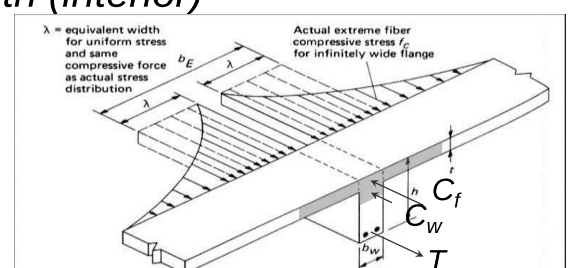
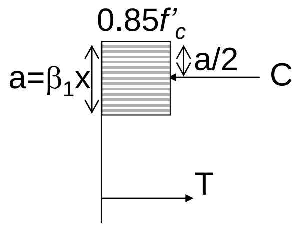


Figure 9.3.1 Actual and equivalent stress distribution over flange width.

T sections

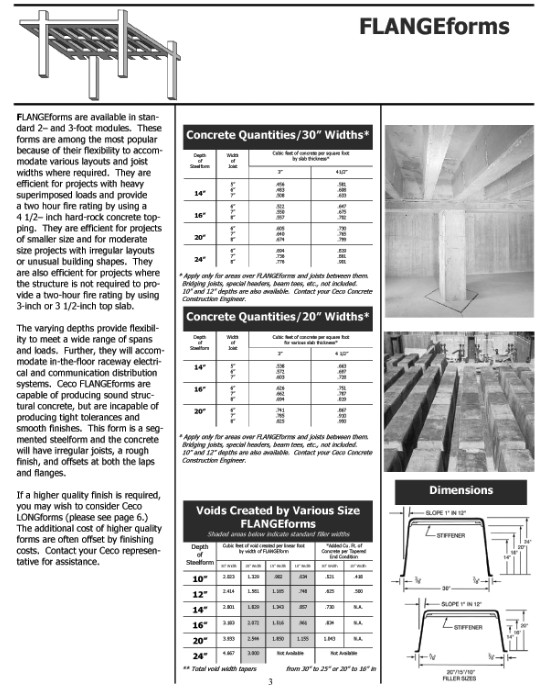
- usual analysis steps

1. assume no compression in web
2. design like a rectangular beam
3. needs reinforcement in slab too
4. also analyze for negative moment, if any



One-Way

- Joists
  - standard stems
  - 2.5" to 4.5" slab
  - ~30" widths
  - reusable forms



FLANGEforms

FLANGEforms are available in standard 2– and 3-foot modules. These forms are among the most popular because of their flexibility to accommodate various layouts and joist widths where required. They are efficient for projects with heavy superimposed loads and provide a two hour fire rating by using a 4 1/2– inch hard-rock concrete topping. They are efficient for projects of smaller size and for moderate size projects with irregular layouts or unusual building shapes. They are also efficient for projects where the structure is not required to provide a two-hour fire rating by using 3-inch or 3 1/2-inch top slab.

The varying depths provide flexibility to meet a wide range of spans and loads. Further, they will accommodate in-the-floor raceway electrical and communication distribution systems. Ceco FLANGEforms are capable of producing sound structural concrete, but are incapable of producing tight tolerances and smooth finishes. This form is a segmented steelform and the concrete will have irregular joists, a rough finish, and offsets at both the laps and flanges.

If a higher quality finish is required, you may wish to consider Ceco LONGforms (please see page 6.) The additional cost of higher quality forms are often offset by finishing costs. Contact your Ceco representative for assistance.

Concrete Quantities/30" Widths*

Depth of Steelform	Width of Joist	Cubic feet of concrete per square foot by slab thickness*	
		3"	4 1/2"
14"	5" 6" 7"	.456 .483 .508	.581 .608 .633
16"	6" 7" 8"	.522 .550 .557	.647 .675 .702
20"	6" 7" 8"	.605 .640 .674	.730 .765 .799
24"	6" 7" 8"	.694 .738 .776	.839 .881 .901

* Apply only for areas over FLANGEforms and joists between them. Bridging joists, special headers, beam tees, etc., not included. 10" and 12" depths are also available. Contact your Ceco Concrete Construction Engineer.

Concrete Quantities/20" Widths*

Depth of Steelform	Width of Joist	Cubic feet of concrete per square foot for various slab thickness*	
		3"	4 1/2"
14"	5" 6" 7"	.538 .572 .603	.663 .697 .728
16"	6" 7" 8"	.626 .662 .694	.751 .787 .819
20"	6" 7" 8"	.741 .785 .825	.867 .910 .950

* Apply only for areas over FLANGEforms and joists between them. Bridging joists, special headers, beam tees, etc., not included. 10" and 12" depths are also available. Contact your Ceco Concrete Construction Engineer.

Voids Created by Various Size FLANGEforms

Shaded areas below indicate standard filler widths

Depth of Steelform	Cubic feet of void created per linear foot by width of FLANGEform				*Added Cu. Ft. of Concrete per Tapered End Condition	
	30" Width	20" Width	15" Width	10" Width	30" Width	20" Width
10"	2.023	1.329	.982	.634	.521	.418
12"	2.414	1.581	1.165	.748	.625	.500
14"	2.801	1.829	1.343	.857	.730	N.A.
16"	3.183	2.072	1.516	.961	.834	N.A.
20"	3.933	2.544	1.850	1.155	1.043	N.A.
24"	4.667	3.000	Not Available		Not Available	

** Total void width tapers from 30" to 25" or 20" to 16" in

3

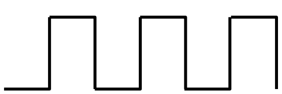
Dimensions

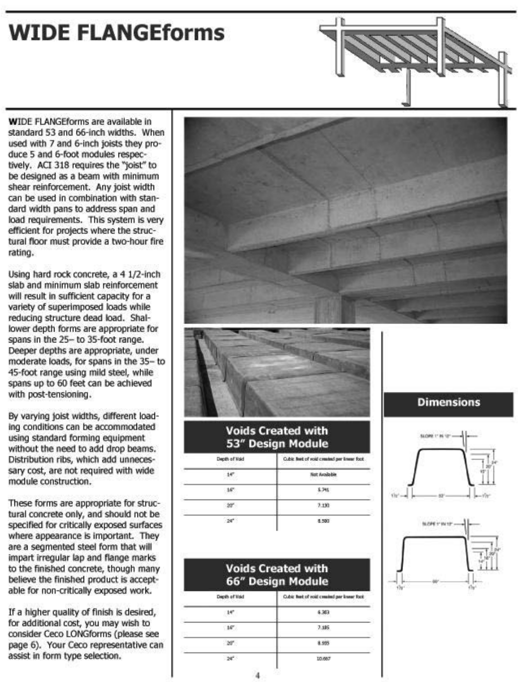
SLOPE 1" IN 12"

STIFFENER

One-Way

- Joists
  - wide pans
  - 5', 6' up
  - light loads & long spans
  - one-leg stirrups





WIDE FLANGEforms

WIDE FLANGEforms are available in standard 53 and 66-inch widths. When used with 7 and 6-inch joists they produce 5 and 6-foot modules respectively. ACI 318 requires the "joist" to be designed as a beam with minimum shear reinforcement. Any joist width can be used in combination with standard width pans to address span and load requirements. This system is very efficient for projects where the structural floor must provide a two-hour fire rating.

Using hard rock concrete, a 4 1/2-inch slab and minimum slab reinforcement will result in sufficient capacity for a variety of superimposed loads while reducing structure dead load. Shallower depth forms are appropriate for spans in the 25– to 35-foot range. Deeper depths are appropriate, under moderate loads, for spans in the 35– to 45-foot range using mild steel, while spans up to 60 feet can be achieved with post-tensioning.

By varying joist widths, different loading conditions can be accommodated using standard forming equipment without the need to add drop beams. Distribution ribs, which add unnecessary cost, are not required with wide module construction.

These forms are appropriate for structural concrete only, and should not be specified for critically exposed surfaces where appearance is important. They are a segmented steel form that will impart irregular lap and flange marks to the finished concrete, though many believe the finished product is acceptable for non-critically exposed work.

If a higher quality of finish is desired, for additional cost, you may wish to consider Ceco LONGforms (please see page 6). Your Ceco representative can assist in form type selection.

Voids Created with 53" Design Module

Depth of Void	Cubic feet of void created per linear foot
14"	Not Available
16"	5.741
20"	7.130
24"	8.500

Voids Created with 66" Design Module

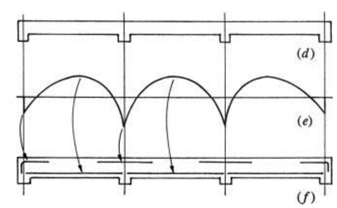
Depth of Void	Cubic feet of void created per linear foot
14"	6.303
16"	7.185
20"	8.935
24"	10.667

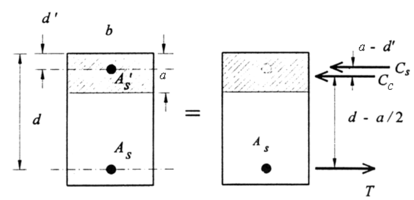
Dimensions

4

Compression Reinforcement

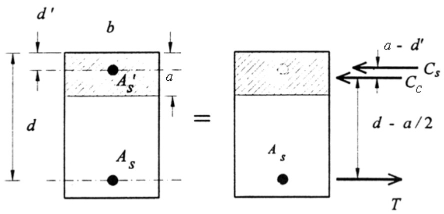
- doubly reinforced
- negative bending
- two compression forces
- bigger M_n
- control deflection
- increase ductility
- needs ties because of buckling





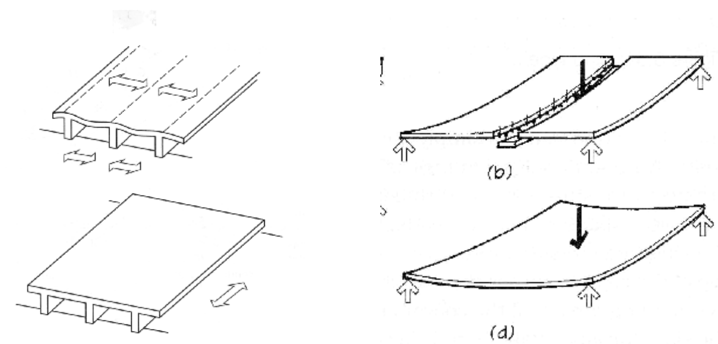
Compression Reinforcement

- *analysis*
  - – A_s & A_s'
  - – $T = C_c + C_s$
  - – $T = A_s f_y$
  - – $C_s = A_s'(f'_s - 0.85f'_c)$
  - – $C_c = 0.85f'_c ba$ with $a = \beta_1 x$
  - – f_s' not known, so solve for x (n.a.)
  - – $f_s' < f_y$?
  - – $M_n = T(d\text{-}a/2)+C_s(d\text{-}d')$



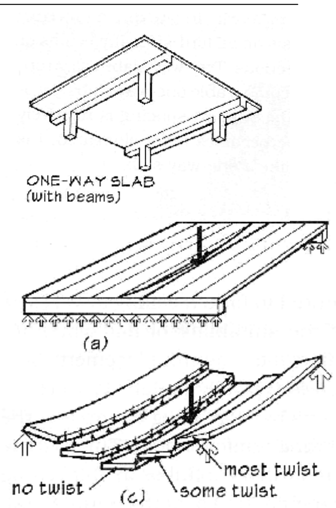
Slabs

- *one way behavior – like beams*
- *two way behavior – more complex*



Slab Design

- *one unit wide "strip"*
- *with uniform loads*
  - – like "wide" beams
  - – moment / unit width
  - – uniform curvature
- *with point loads*
  - – resisted by stiffness of adjacent strips
  - – more curvature in middle



Slab Design

- *min thickness by code*
- *reinforcement*
  - – bars, welded wire mesh
  - – cover
  - – minimum by steel grade
    - 40-50: $$\rho = \frac{A_s}{bt} = 0.002$$
    - 60: $$\rho = \frac{A_s}{bt} = 0.0018$$

TABLE 9.5(a)—MINIMUM THICKNESS OF NONPRESTRESSED BEAMS OR ONE-WAY SLABS UNLESS DEFLECTIONS ARE COMPUTED

	Minimum thickness, *h*			
	Simply supported	One end continuous	Both ends continuous	Cantilever
Member	Members not supporting or attached to partitions or other construction likely to be damaged by large deflections.			
Solid one-way slabs	ℓ/20	ℓ/24	ℓ/28	ℓ/10
Beams or ribbed one-way slabs	ℓ/16	ℓ/18.5	ℓ/21	ℓ/8

Notes:
Values given shall be used directly for members with normalweight concrete and Grade 60 reinforcement. For other conditions, the values shall be modified as follows:
a) For lightweight concrete having equilibrium density, w_c, in the range of 90 to 115 lb/ft³, the values shall be multiplied by $(1.65 - 0.005w_c)$ but not less than 1.09.
b) For f_y other than 60,000 psi, the values shall be multiplied by $(0.4 + f_y/100{,}000)$.

One-Way Slabs

- A_s tables
- max spacing
  - $\leq$ 3(t) and 18”
  - $\leq$ 5(t) and 18” – temp & shrinkage steel
- no room for stirrups

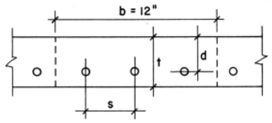


Table 3-7 Areas of Bars per Foot Width of Slab—A_s (in.^{2}/ft)

Bar size	Bar spacing (in.) 6	7	8	9	10	11	12	13	14	15	16	17	18
#3	0.22	0.19	0.17	0.15	0.13	0.12	0.11	0.10	0.09	0.09	0.08	0.08	0.07
#4	0.40	0.34	0.30	0.27	0.24	0.22	0.20	0.18	0.17	0.16	0.15	0.14	0.13
#5	0.62	0.53	0.46	0.41	0.37	0.34	0.31	0.29	0.27	0.25	0.23	0.22	0.21
#6	0.88	0.75	0.66	0.59	0.53	0.48	0.44	0.41	0.38	0.35	0.33	0.31	0.29
#7	1.20	1.03	0.90	0.80	0.72	0.65	0.60	0.55	0.51	0.48	0.45	0.42	0.40
#8	1.58	1.35	1.18	1.05	0.95	0.86	0.79	0.73	0.68	0.63	0.59	0.56	0.53
#9	2.00	1.71	1.50	1.33	1.20	1.09	1.00	0.92	0.86	0.80	0.75	0.71	0.67
#10	2.54	2.18	1.91	1.69	1.52	1.39	1.27	1.17	1.09	1.02	0.95	0.90	0.85
#11	3.12	2.67	2.34	2.08	1.87	1.70	1.56	1.44	1.34	1.25	1.17	1.10	1.04

Precast

- prestressed
  - PCI Design Handbook
  - double T’s
  - hollow core
  - L’s
- topping
- load tables

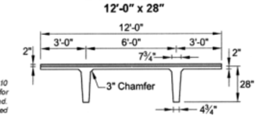
Strand Pattern Designation

No. of strand (16)
S = straight D = depressed
168-D1
No. of depression points
Diameter of strand in 16ths

Safe loads shown include dead load of 10 psf for untopped members and 15 psf for topped members. Remainder is live load. Long-time cambers include superimposed dead load but do not include live load.

Key
142 – Safe superimposed service load, psf
1.4 – Estimated camber at erection, in.
1.8 – Estimated long-time camber, in.

DOUBLE TEE
12′-0″ x 28″



$f'_c = 5{,}000$ psi
$f_{pu} = 270{,}000$ psi

Section Properties

	Untopped	Topped
A =	640 in.^{2}	–
I =	44,563 in.^{4}	61,410 in.^{4}
y_b =	20.21 in.	23.19 in.
y_t =	7.79 in.	6.81 in.
S_b =	2,227 in.^{3}	2,648 in.^{3}
S_t =	5,577 in.^{3}	9,018 in.^{3}
wt =	511 plf	822 plf
DL =	43 psf	68 psf
V/S =	1.62 in.	

Normal Weight Concrete **12DT28 + 2**

Table of safe superimposed service load (psf) and cambers (in.) **2 in. Normal Weight Topping**

Strand Pattern	y_s(end) in. y_s(center) in.	Span, ft 40	42	44	46	48	50	52	54	56	58	60	62	64	66	68	70	72
108-S	6.00 6.00	127 0.8 0.8	110 0.9 0.8	95 0.9 0.8	82 0.9 0.8	70 0.9 0.7	60 0.9 0.6	51 0.9 0.5	42 0.8 0.3	35 0.8 0.1	29 0.7 –0.1							
128-S	7.00 7.00	154 1.0 1.0	134 1.0 1.0	117 1.1 1.0	102 1.1 1.0	88 1.1 1.0	77 1.1 0.9	66 1.1 0.8	57 1.1 0.7	49 1.1 0.5	41 1.0 0.3	32 0.9 0.0						
148-S	8.00 8.00	177 1.1 1.1	155 1.1 1.2	136 1.2 1.2	119 1.2 1.2	105 1.3 1.1	92 1.3 1.1	80 1.3 1.0	70 1.3 0.9	60 1.3 0.8	50 1.2 0.6	41 1.2 0.3	32 1.1 0.1					
168-S	9.00 9.00	197 1.1 1.2	173 1.2 1.3	152 1.3 1.3	134 1.3 1.3	118 1.4 1.3	104 1.4 1.2	90 1.4 1.2	78 1.4 1.1	66 1.4 0.9	56 1.4 0.8	47 1.3 0.5	39 1.3 0.3	31 1.2 0.0				
168-D1	13.00 3.75			199 1.5 1.7	177 1.6 1.7	157 1.7 1.7	140 1.8 1.8	125 1.9 1.7	111 1.9 1.7	97 2.0 1.6	84 2.0 1.5	72 2.0 1.3	62 2.0 1.1	52 1.9 0.8	43 1.8 0.5	36 1.8 0.2	30 1.6 –0.2	
188-D1	14.39 4.00							143 2.0 1.9	126 2.1 1.9	111 2.1 1.9	97 2.2 1.8	85 2.2 1.7	73 2.3 1.5	63 2.3 1.3	54 2.2 1.0	45 2.1 0.7	37 2.0 0.3	31 1.9 –0.2