Design Guide 11- Floors (Slabs-on-Ground) for Concrete Structures

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This guide assists designers in the selection of the appropriate floor (Slabs-on-Ground) to be used in conjunction with Waste Storage Facilities (313), Heavy Use Area Protection (561), Waste Transfer (634), Agrichemical Handling Facility (309), etc. Tables are presented for each floor type from which the designer can select the appropriate steel schedule based on joint distance and slab thickness. The tables show common bar sizes and spacing that establishes a basic design using a common range or distance for the steel schedule and spacing. Formulas are included that allow the designer an option to develop a site specific design for the steel schedule and spacing based on the known distance or for a different slab thicknesses.

Floors require a minimum subbase thickness as prescribed in each table. It is the responsibility of the designer to increase the subbase thickness or add appropriate geotextile for foundations with bearing capacity not meeting the associated practice standard.

The required concrete specifications can be found with the associated practice.

The alternative to using this guide is to go to Title 210- National Engineering Manual, section 536.22 and follow the appropriate ACI design guide.

Table Selection

Floors can be categorized based on consideration of a combination of waste consistency (liquids, solids or semi-solids), environmental situation at that site such as Sensitive Environmental Site (SES) or non-SES as defined by NRCS Practice Standard (313) and/or the anticipated loaded single axle weight of the equipment used to process the materials. A separate table is included for floors that support stationary tanks used to store chemical in Agrichemical Handling Facilities.

- **Floors under liquids**.
  - Non-SES sites or SES sites with a secondary liner* under the floor use **Table 1.**
  - SES sites and all Agrichemical Handling Facilities** use **Table 2.**
- **Floors under solids or semi-solids.**
  - Manure that stacks at least 4’ high and equipment with a single axle load less than 15K pounds use **Table 3.**
- **Floors under solids or semi-solids**.
  - Manure that stacks up at least 4’ high and equipment with a single axle load of 15K pounds or more use **Table 4.**
- **Floors supporting stationary storage tanks**.
  - Floors under storage tanks associated with Agrichemical Handling Facility use **Table 5.**

*Compacted earth or materials meeting the PA Practice Standard Pond Sealing or Lining Geomembrane or Geosynthetic Clay Liner (521)

use **Table 5 for areas with fertilizer or chemical storage tanks.

Floors Under Liquids

The minimum floor thickness, t shall be 5 inches. Use either Table 1 or Table 2 for appropriate steel schedule based on environmental site condition. Steel shall be located within 2" of surface. Minimum sub-base (stone) under slab shall be 4 inches for both Table 1 and Table 2.

Table 1 -Minimum Shrinkage and Temperature Reinforcement steel for non-SES floors or SES floors with a secondary liner.

Joint distance (D) or tank diameter in feet based on Steel Schedule	Minimum end area (As) of steel (in^2) for slab thickness, t= 5 inch *	Steel schedule for t = 5 inch Slab* (Grade 60 KSI steel)
0-50'	0.058	WWF 6"x6"-6 gauge Sheets
>50-75'	0.09	#3@15" both ways
>75-110'	0.13	#4@18" both ways
>110'-170'	0.20	#4@12" or #5@18" both ways
>170'-220'	0.26	#4@9" or #5@15" both ways"
>220' – 275' **	0.31	#5@12" both ways

* For other combinations of slab thickness (t) and diameter or distance (D) determine As (end area of steel, in^2) as shown below and use the USDA NRCS Standard Drawing ES-46 to select bar size and spacing that meets or exceeds the computed end area of steel or refer to ACI 330R as per Title 210 NEM Part 536, Section 536.22 A.

$$A_s = 0.0002265\ (D)(t)$$

** Joint spacing above this range requires approval by the State Conservation Engineer for NRCS projects receiving funding or technical assistance.

Table 2- Minimum Shrinkage and Temperature Reinforcement for SES floors. The minimum floor thickness t shall be 5 inches.

Joint Distance (D) or Tank Diameter	Minimum Shrinkage and Temperature Reinforcement Ratio ($_{Rm}$), %	Steel Schedule for a slab thickness of t=5 inch ** (Grade 60 KSI steel)
0<30’	0.003	#4@12”
30’ < 40’	0.004	#4@8” or #5@12”
40’ *** or >	0.005	#4@7.5” or #5@12”

** For alternate steel schedules and/or slab thickness determine As (end area of steel, in^2) as shown below and use USDA NRCS Standard Drawing ES-46 to select bar size and spacing that meets or exceeds the computed end area of steel.

$$A_s = R_m(t)$$

Then use USDA NRCS Standard Drawing ES-46 to select bar size and spacing that meets or exceed the required end area of steel.

*** Joint spacing above 275’ requires approval by the State Conservation Engineer for NRCS projects receiving funding or technical assistance.

Floor Under Solids or Semi-solids and Single Axle load <15,000 lbs.

The minimum floor thickness shall be 5 inches. The minimum shrinkage and temperature reinforcement shall be as per Table 3. The minimum subbase thickness shall be 4 inches.

Table 3- Minimum Shrinkage and Temperature Reinforcement for stacking facility floor slabs.

Joint spacing	Minimum Shrinkage and Temperature Reinforcement Ratio (R_m)	Steel Schedule for a slab thickness of t=5 inch * (Grade 60 ksi steel)	Steel Schedule for a slab thickness of t=6 inch * (Grade 60 ksi steel)
<50'	0.001	WWF 6"x6"-6x6 Sheets or #3@18"	#3@18"
>= 50'**	0.002	#3@12" or #4@18"	#4@16" or #3 @ 9"

* For alternate steel schedules and/or slab thickness determine As (end area of steel, in^2) as shown below and use USDA NRCS Standard Drawing ES-46 to select bar size and spacing that meets or exceeds the computed end area of steel.

$$A_s = R_m\,(t) \quad (12)$$

** Joint spacing above 150' requires approval by the State Conservation Engineer for NRCS projects receiving funding or technical assistance.

Floor Under Solids or Semi-solids and Single Axle load (15,000 lbs. or >)

The minimum floor thickness shall be 6 inches. The minimum shrinkage and temperature reinforcement shall be as per Table 4. Steel shall be located within 2" of the top or the upper 1/3 of the slab. The minimum Sub-Base thickness shall be as shown in the table.

Table 4- Minimum Shrinkage and Temperature Reinforcement for stacking facility floor slabs based on equipment axle load.

Maximum single axle load in lbs.	Slab Thickness (t) Inch	Control joints < 40' Rebar, Single layer, both ways*	Control joints, 40' <150' ** Rebar, Single layer, both ways*	Minimum Sub-Base, inches
15,000 -20,000	6	#4 @ 8"	#4 @ 6.5"	4
20,000 -30,000	8	#4 @ 6" or #5 @ 9"	#4 @ 5" or #5 @ 7"	6
30,0000 – 40,000	10	#4 @ 5" 0r #5 @ 8"	#4 @ 4" or #5 @ 6"	8

*For alternate steel schedules determine As (end area of steel, in^2) from shown schedule above table using USDA NRCS Standard Drawing ES-46. Then select alternate bar size and spacing combination that meets or exceeds that end area of steel.

** Joint spacing above 150' requires approval by the State Conservation Engineer for NRCS projects receiving funding or technical assistance.

Floors supporting stationary liquid storage tanks

Table 5- Minimum Shrinkage and Temperature Reinforcement for floor slabs with liquid storage tanks placed on top of slab. The minimum subbase thickness shall be 6 inches. This table typically associated with Agrichemical Handling Facilities. Refer to practice standard for concrete specifications.

Maximum Tank Height (ft)	Concrete thickness (t) (In.)	Reinforcing Bars and Spacing* (both ways)	Area of Steel (in^2)
10	8	#4, two layers, 12" o.c.	0.18
15	10	#5, two layers, 12" o.c.	0.34
20	12	#6, two layers, 12" o.c.	0.47
25	14	#7, two layers, 12" o.c.	0.62
30**	14	#8, two layers, 12" o.c.	0.75

*For alternate steel schedules determine As (end area of steel, in^2) from shown schedule in table above using USDA NRCS Standard Drawing ES-46. Then select alternate bar size and spacing combination that meets or exceeds that end area of steel.

** Tank height above 35' requires a specific design and approval by the State Conservation Engineer for NRCS projects receiving funding or technical assistance.

USDA-NRCS ES-46

Use Spacing and Bar Size to find End Area of steel. (upper number)

STRUCTURAL DESIGN: REINFORCED CONCRETE DESIGN. AREAS AND PERIMETERS OF BARS AT VARIOUS SPACINGS FOR 12 INCH WIDTH

Areas given in top figures in square inches
Perimeters given in bottom figures in inches

Spacing	Bar Size									Spacing
	#3	#4	#5	#6	#7	#8	#9	#10	#11	
2	0.66 7.07	1.18 9.42	1.84 11.78	2.65 14.14						2
2 1/4	0.59 6.28	1.05 8.38	1.64 10.47	2.36 12.57	3.21 14.66					2 1/4
2 1/2	0.53 5.65	0.94 7.54	1.47 9.42	2.12 11.31	2.89 13.20	3.77 15.08				2 1/2
2 3/4	0.48 5.14	0.86 6.85	1.34 8.57	1.93 10.28	2.62 12.00	3.43 13.71				2 3/4
3	0.44 4.71	0.79 6.28	1.23 7.85	1.77 9.42	2.40 11.00	3.14 12.57	4.00 14.18			3
3 1/4	0.41 4.35	0.73 5.80	1.13 7.25	1.63 8.70	2.22 10.15	2.90 11.60	3.69 13.09			3 1/4
3 1/2	0.38 4.04	0.67 5.39	1.05 6.73	1.51 8.08	2.06 9.42	2.69 10.77	3.43 12.15	4.34 13.68		3 1/2
3 3/4	0.35 3.77	0.63 5.03	0.98 6.28	1.41 7.54	1.92 8.80	2.51 10.05	3.20 11.34	4.05 12.77	5.00 14.18	3 3/4
4	0.33 3.53	0.59 4.71	0.92 5.89	1.33 7.07	1.80 8.25	2.36 9.42	3.00 10.63	3.80 11.97	4.69 13.29	4
4 1/4	0.31 3.33	0.55 4.44	0.87 5.54	1.25 6.65	1.70 7.76	2.22 8.87	2.82 10.01	3.57 11.27	4.41 12.51	4 1/4
4 1/2	0.29 3.14	0.52 4.19	0.82 5.24	1.18 6.28	1.60 7.33	2.09 8.38	2.67 9.45	3.37 10.64	4.17 11.81	4 1/2
4 3/4	0.28 2.98	0.50 3.97	0.78 4.96	1.12 5.95	1.50 6.94	1.98 7.94	2.53 8.95	3.20 10.08	3.95 11.19	4 3/4
5	0.26 2.83	0.47 3.77	0.74 4.71	1.06 5.65	1.44 6.60	1.88 7.54	2.40 8.51	3.04 9.58	3.75 10.63	5
5 1/4	0.25 2.69	0.45 3.59	0.70 4.49	1.01 5.39	1.37 6.28	1.80 7.18	2.29 8.10	2.89 9.12	3.57 10.13	5 1/4
5 1/2	0.24 2.57	0.43 3.43	0.67 4.28	0.96 5.14	1.31 6.00	1.71 6.85	2.18 7.73	2.76 8.71	3.41 9.66	5 1/2
5 3/4	0.23 2.46	0.41 3.28	0.64 4.10	0.92 4.92	1.25 5.74	1.64 6.56	2.09 7.40	2.64 8.33	3.26 9.25	5 3/4
6	0.22 2.36	0.39 3.14	0.61 3.93	0.88 4.71	1.20 5.50	1.57 6.28	2.00 7.09	2.53 7.98	3.12 8.86	6
6 1/2	0.20 2.18	0.36 2.90	0.57 3.62	0.82 4.35	1.11 5.07	1.45 5.80	1.85 6.54	2.34 7.37	2.88 8.18	6 1/2
7	0.19 2.02	0.34 2.69	0.53 3.37	0.76 4.04	1.03 4.71	1.35 5.39	1.71 6.08	2.17 6.84	2.68 7.59	7
7 1/2	0.18 1.89	0.31 2.51	0.49 3.14	0.71 3.77	0.96 4.40	1.26 5.03	1.60 5.67	2.03 6.38	2.50 7.09	7 1/2
8	0.17 1.77	0.29 2.36	0.46 2.95	0.66 3.53	0.90 4.12	1.18 4.71	1.50 5.32	1.90 5.99	2.34 6.65	8
8 1/2	0.16 1.66	0.28 2.22	0.43 2.77	0.62 3.33	0.85 3.88	1.11 4.44	1.41 5.00	1.79 5.63	2.21 6.25	8 1/2
9	0.15 1.57	0.26 2.09	0.41 2.62	0.59 3.14	0.80 3.67	1.05 4.19	1.33 4.73	1.69 5.32	2.08 5.91	9
9 1/2	0.14 1.49	0.25 1.98	0.39 2.48	0.56 2.98	0.76 3.47	0.99 3.97	1.26 4.48	1.60 5.04	1.97 5.60	9 1/2
10	0.13 1.41	0.24 1.88	0.37 2.36	0.53 2.83	0.72 3.30	0.94 3.77	1.20 4.25	1.52 4.79	1.88 5.32	10
10 1/2	0.13 1.35	0.22 1.80	0.35 2.24	0.50 2.69	0.69 3.14	0.90 3.59	1.14 4.05	1.45 4.56	1.79 5.06	10 1/2
11	0.12 1.29	0.21 1.71	0.33 2.14	0.48 2.57	0.66 3.00	0.86 3.43	1.09 3.87	1.38 4.35	1.70 4.83	11
11 1/2	0.12 1.23	0.20 1.64	0.32 2.05	0.46 2.46	0.63 2.87	0.82 3.28	1.04 3.70	1.32 4.16	1.63 4.62	11 1/2
12	0.11 1.18	0.20 1.57	0.31 1.96	0.44 2.36	0.60 2.75	0.79 3.14	1.00 3.54	1.27 3.99	1.56 4.43	12
13	0.10 1.09	0.18 1.45	0.28 1.81	0.41 2.18	0.56 2.54	0.72 2.90	0.92 3.27	1.17 3.68	1.44 4.09	13
14	0.09 1.01	0.17 1.35	0.26 1.68	0.38 2.02	0.52 2.36	0.67 2.69	0.86 3.04	1.08 3.42	1.34 3.80	14
15	0.09 0.94	0.16 1.26	0.25 1.57	0.35 1.89	0.48 2.20	0.63 2.51	0.80 2.84	1.01 3.19	1.25 3.54	15
16	0.08 0.88	0.15 1.18	0.23 1.47	0.33 1.77	0.46 2.06	0.59 2.36	0.75 2.66	0.95 2.99	1.17 3.32	16
17	0.08 0.83	0.14 1.11	0.22 1.39	0.31 1.66	0.42 1.94	0.55 2.22	0.71 2.50	0.89 2.82	1.10 3.13	17
18	0.07 0.79	0.13 1.05	0.20 1.31	0.29 1.57	0.40 1.83	0.52 2.09	0.67 2.36	0.84 2.66	1.04 2.95	18
	#3	#4	#5	#6	#7	#8	#9	#10	#11	

REFERENCE	U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE ENGINEERING DIVISION - DESIGN SECTION	STANDARD DWG. NO. ES – 46 SHEET 1 OF 1 DATE 12-14-50

REVISED 7-64

(See Example usage of this table on the next page)

Example usage of Table USDA-NRCS ES-46: Planned/proposed layout is No. 4 bars @ 8 inches from a reference table. What is the alternate layout if using No. 5 bars instead of No. 4 bars?

From table: Find spacing in far left column and move across to column under No.4 bar. The top number, 0.29 is the required end area of steel (in^2). Now find the No. 5 bar column and drop down till you find an end area of 0.29 or greater. In this case, the value lands between the 12 and 13 inch spacing. From an installation/ inspection point of view, do not use one half inch spacings. Go up and use the 12 inch spacing which yields a 0.31 in^2 end area that exceeds the 0.29. Therefore, this can be used as an alternate layout.

References:

Table 1- ACI-330R as per Title 210 NEM, 4th Ed, June 2017, 536.22 A.

Table 2- ACI-350, Appendix H and Ch. 7- Table 7.12.2.1 as per Title 210 NEM, 4th Ed, June 2017, 536.22 C.

Table 3-ACI-318

Table 4- MWPS-37,1st Edition 1991, Table 24

Table 5- MWPS-37,1st Edition 1991, Table 21

USDA-NRCS ES-46

Support documentation on file at the PA NRCS State Office