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AGRICULTURAL ENGINEERS' DIGEST

Tilt-Up Concrete Horizontal Silo Construction MWPS-15

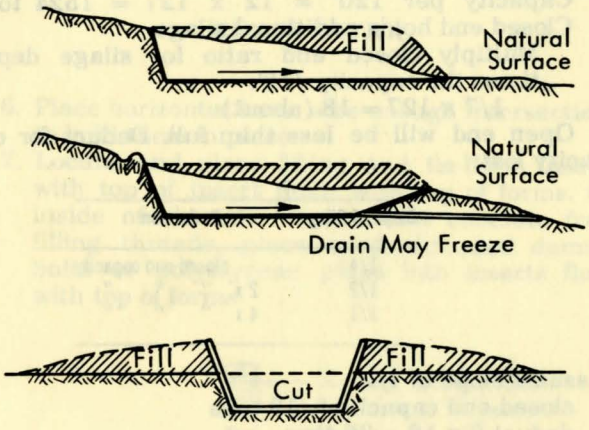
Introduction

Walls of tilt-up concrete can be built with a minimum of forming because all vertical slabs are cast flat, then erected.

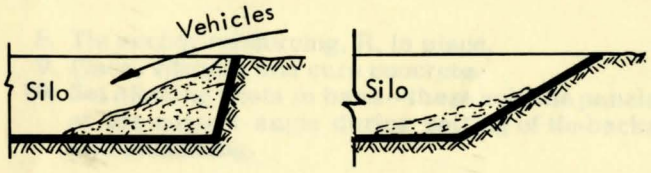
Concrete mix need not be elevated, but equipment is required for raising the cast and cured panels.

Below ground silos have several advantages over above ground silos:

- Excavation soil can be used to:
  Build or repair feedlots or earth resting mounds.
  Reduce depth of cut.



- Soil provides support for walls.
- Silage need not be elevated during filling.
- After partial filling, closed end can provide access ramp in smaller silos.
- Relatively constant cool soil temperatures aid in maintaining silage quality.



Better **Not Recommended**

NOTE: A long paved ramp at the closed end is not recommended because long "floor" and sidewalls are relatively expensive and greatly reduce capacity. Spoilage may be high in smaller areas.

Above ground silos also have advantages:

- Less site preparation.
- Adaptable to flat or poorly-drained areas.
- The buttresses shown can support 2 walls to form the center partitions between 2 silos.

Site

- Locate the silo for convenient access during filling, packing, and unloading. High ground is preferred.
- Odors may be a nuisance if a large silo is too close to a residence.
- Divert ground water away from the site.
- Provide drainage away from the lower end of the floor that will not pollute a well or spring.
- Provide protection from blowing snow.
- Do site grading and excavating before starting construction. Provide access for panel lifting equipment (tractor or truck) along both walls outside the silo.
- Do not select a site where part of the silo is above ground and part below ground: panel design is inadequate for part-soil, part-buttress support.

Specifications

Concrete: strong, dense, and resistant to silage acids.

Cement: at least 7 sacks per cubic yard of concrete.

Water: no more than 5 gallons of water per sack of cement, including water in the aggregates.

Air Entraining:

Maximum Aggregate Size	Amount of Air
3/4"	7%
1/2"	8%
3/8" or less	9%

Forms: rigid and well braced. Oil forms before placing concrete.

Placing: 5 to 15 seconds vibration, or spading, next to the forms to prevent honeycombs.

Curing: concrete does not dry; the paste sets by a chemical reaction between cement and water.

Cure panels and buttresses before tilting: 5 to 7 days with air temperatures between 50° and 100°F; 10 days if temperature is 40°-50°F.

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*Major credit for this publication goes to O.E. Cross and E.A. Olson, AE's at the University of Nebraska, and to Gayle Lewis of the Portland Cement Assn.

Wet surface of concrete, and keep covered with polyethylene sheet. In cold weather cover the plastic with 24" of straw to prevent freezing.

Silo Floor: a concrete floor is required in both above and below ground silos for structural stability.

A uniform slope of 1" per 8' of length is desirable.

Cast floor in lengthwise strips 10'-12' wide. (note bars along edge of slab in above-ground silos—no other reinforcing is required in floor).

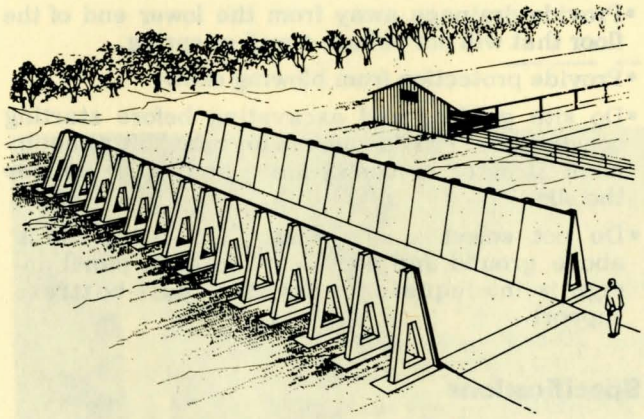
Cast a uniform thickness of 5". Thicken edge at an open end to 8".

Wall Slope

Do not change the design wall slope.

The below ground silos are designed for 1/3 wall slope; steeper slopes will be subjected to greater soil pressures and will require more steel.

The above ground silos are designed for about 1/4 slope; flatter slopes will be subjected to greater silage pressure, and steeper slopes may result in buttresses too narrow to prevent overturn.



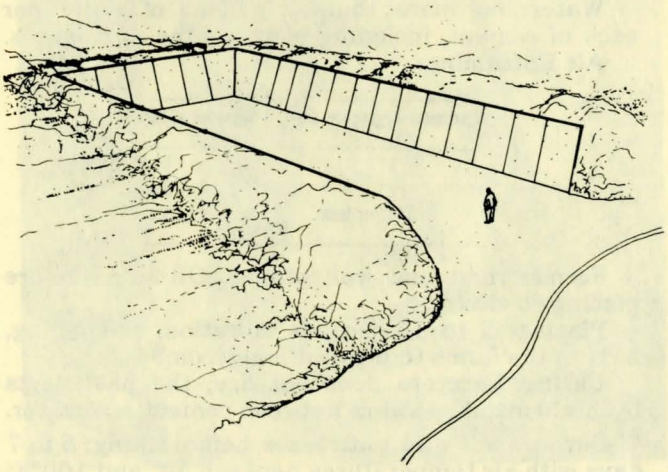


Table 1. Capacities of silos per 10 feet of length (Level full at 50 cu ft = 1 ton)

Depth	Silo Floor Width 20	30	40	50	60	70	80	90	100	Closed End Ratio
10 bu	1800	2600	3400	4200	5000	5800	6600	7400	8200	1/8
tons	45	65	85	105	125	145	165	185	205	
12 bu	2208	3168	4128	5088	6048	7008	7968	8928	9888	1/7
tons	55	79	103	127	151	175	199	223	247	
14 bu	2632	3752	4872	5992	7112	8232	9352	10472	11592	1/6
tons	66	94	122	150	178	206	234	262	290	
16 bu	3064	4344	5624	6904	8184	9464	10744	12024	13304	1/5
tons	77	109	141	173	205	237	269	301	333	
18 bu	3528	4968	6408	7848	9288	10728	12168	13608	14048	1/5
tons	88	124	160	196	232	268	304	340	376	
20 bu	4000	5600	7200	8800	10400	12000	13600	15200	16800	1/4
tons	100	140	180	220	260	300	340	380	420	

Example: 50' wide, 12' deep, 120' long, 1 end closed.

Capacity per 10', from table = 127 tons

Capacity per 120' = 12 x 127 = 1524 tons

Closed end holds additional silage.

Multiply closed end ratio for silage depth times the capacity /10':

1/7 x 127 = 18 (about)

Open end will be less than full. Deduct for capacity lost:

Slope of Silage	Deduction
1/4	closed end capacity
1/2	2 x " " "
1/1	4 x " " "

Assume slope of 1/2

closed end capacity = 18 tons

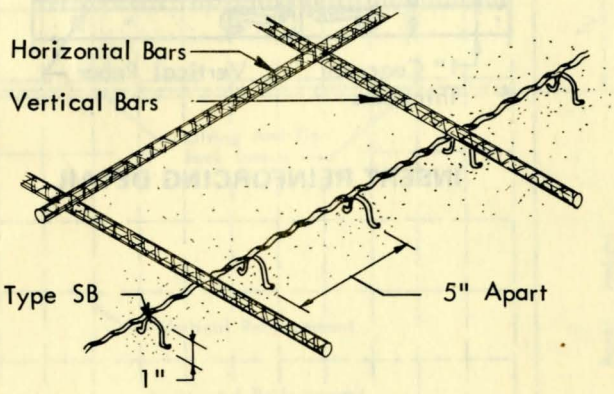
deduct 2 x 18 = 36 tons

Total capacity = 1544 + 18 - 36 = 1526 tons.

BELOW GROUND SILOS

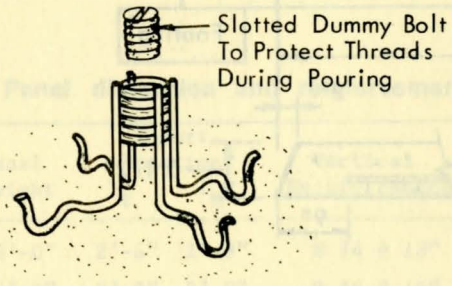
Construction Steps

1. Excavate, grade, and uniformly compact dampened sub-grade. Excavate for 5½"x12" footings.
2. Cast footings.
3. Form and cast floor (no reinforcing is required).
4. Build wall panel forms of 2x6 lumber over polyethylene film along edges of floor.
5. Place vertical reinforcing on 1" chairs.



CHAIR DETAIL

6. Place horizontal bars; wire enough intersections to hold them in place.
7. Locate and place lifting and tie-back inserts with top of insert flush with top of forms. Oil inside of threads. To prevent concrete from filling threads, place oiled threaded dummy bolts or polystyrene plugs into inserts flush with top of forms.



INSERT AND PLUG

8. Tie anchor reinforcing, R, in place.
9. Place, vibrate, and cure concrete.
10. Set aligning posts in bank—these hold the panels at the correct angle during setting of tie-backs and backfilling.
11. Place concrete in post holes for tie-back anchor reinforcement, A, or set screw anchors.
12. Lay drain tile along outside of footings.
13. Lift slabs into place. Anchor to tie-back bar, A, or screw anchor.
14. Cast concrete in trench over bar A.
15. Seal joints at floor and between panels with mortar.
16. Backfill.

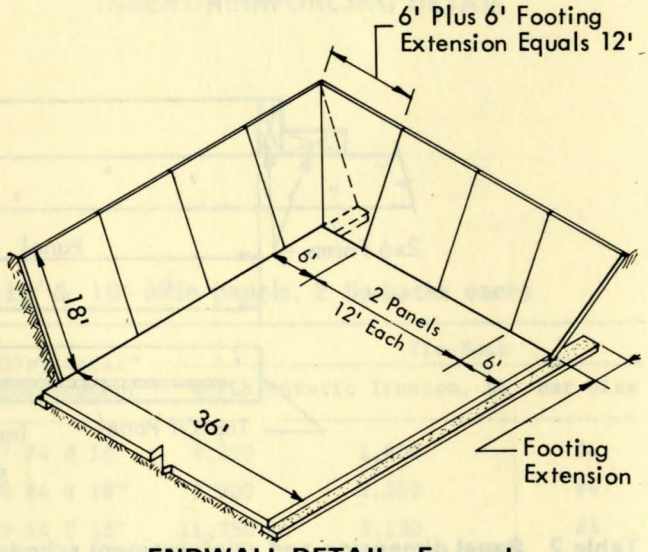
Endwalls

There are several ways of constructing an endwall. One is shown below.

1. Extend footings for sidewalls beyond end of floor the distance shown below:

Silo Depth:	10′	12′	14′	16′	18′	20′
Footing Extension:	3′-4″	4′-0″	4′-8″	5′-4″	6′-0″	6′-8″

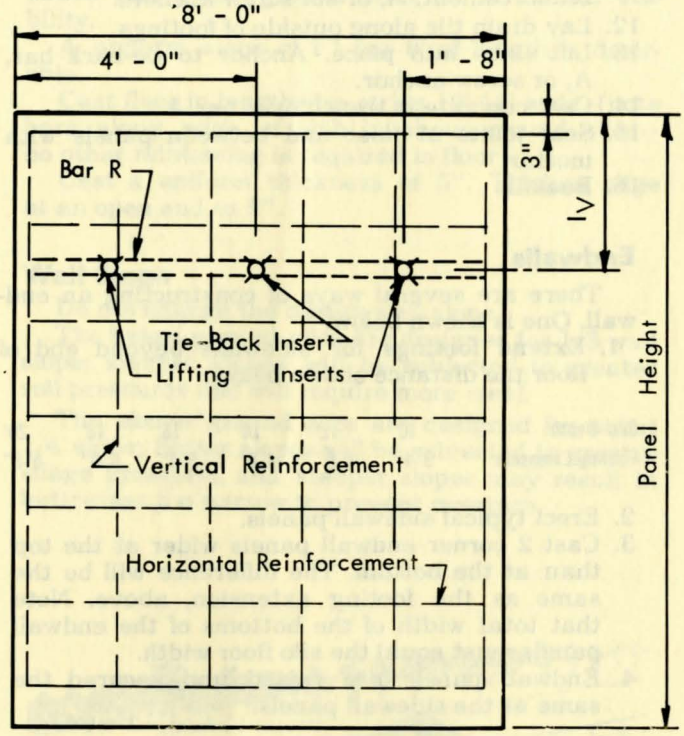
2. Erect typical sidewall panels.
3. Cast 2 corner endwall panels wider at the top than at the bottom. The difference will be the same as the footing extension, above. Note that total width of the bottoms of the endwall panels must equal the silo floor width.
4. Endwall panels are raised and secured the same as the sidewall panels.



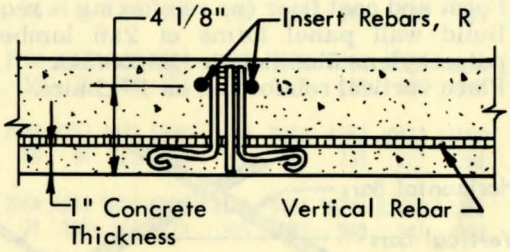
ENDWALL DETAIL—Example

Example: silo 18' deep, 36' wide, 12' panel width.
Footing extension is 6'
Two Full Panels, 12'x18', are needed.
Two Tapered Corner Panels, 6' at the bottom, and 6'+6', or 12', wide at the top.

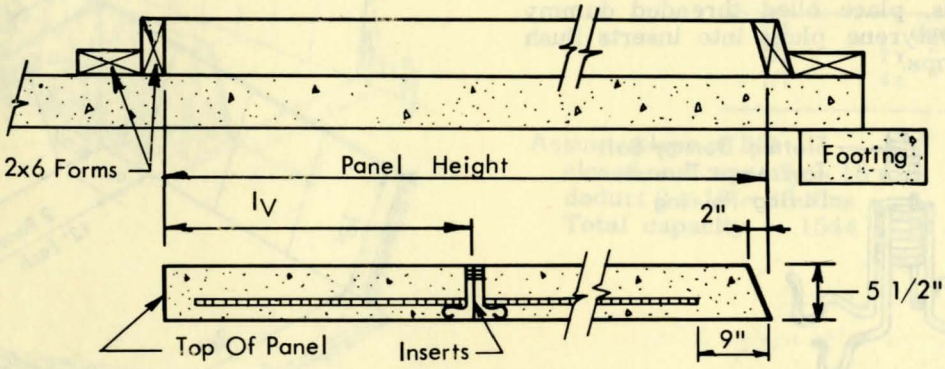
BELOW GROUND SILOS
Panels 8' Wide, 10' to 20' High
One Tie-Back Per Panel



PANEL REINFORCING



INSERT REINFORCING DETAIL

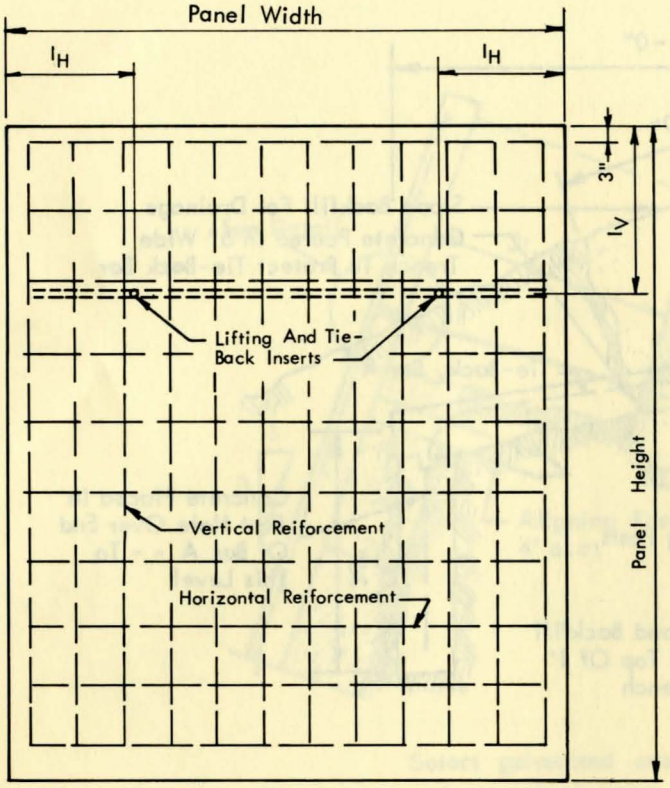


SECTION

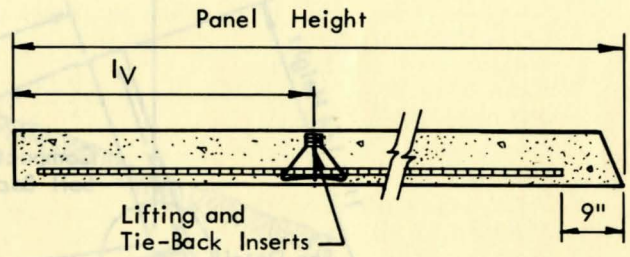
Table 2. Panel dimension and reinforcement schedule (8′ wide panels—one tie-back each)

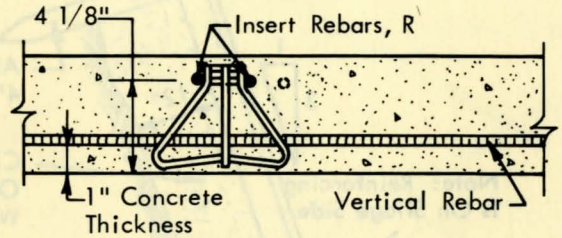
Panel Height	Insert Location I_V	Vertical Reinforcement	Anchor Insert Reinf R	Horizontal Reinforcement	Tie-Back Wt/Lb	Tie-Back Static Tension, Lb	Tie-Back Bar Size
10'-0"	2'-6"	6 #4 @ 18"	2 #4	7 #4 @ 18"	5,500	2,140	#4
12'-0"	3'-0"	6 #4 @ 16"	2 #5	8 #4 @ 18"	6,600	3,070	#4
14'-0"	3'-6"	8 #4 @ 12"	2 #5	9 #4 @ 18"	7,700	4,180	#4
16'-0"	4'-0"	13 #4 @ 7½"	3 #5	11 #4 @ 18"	8,800	5,460	#6
18'-0"	4'-6"	19 #4 @ 5"	3 #5	12 #4 @ 18"	9,900	6,920	#6
20'-0"	5'-0"	16 #5 @ 6"	4 #5	13 #4 @ 18"	10,400	8,500	#6

BELOW GROUND
Panels 12' Or 16' Wide, 10' To 20' High
Two Tie-Backs Per Panel



PANEL REINFORCING



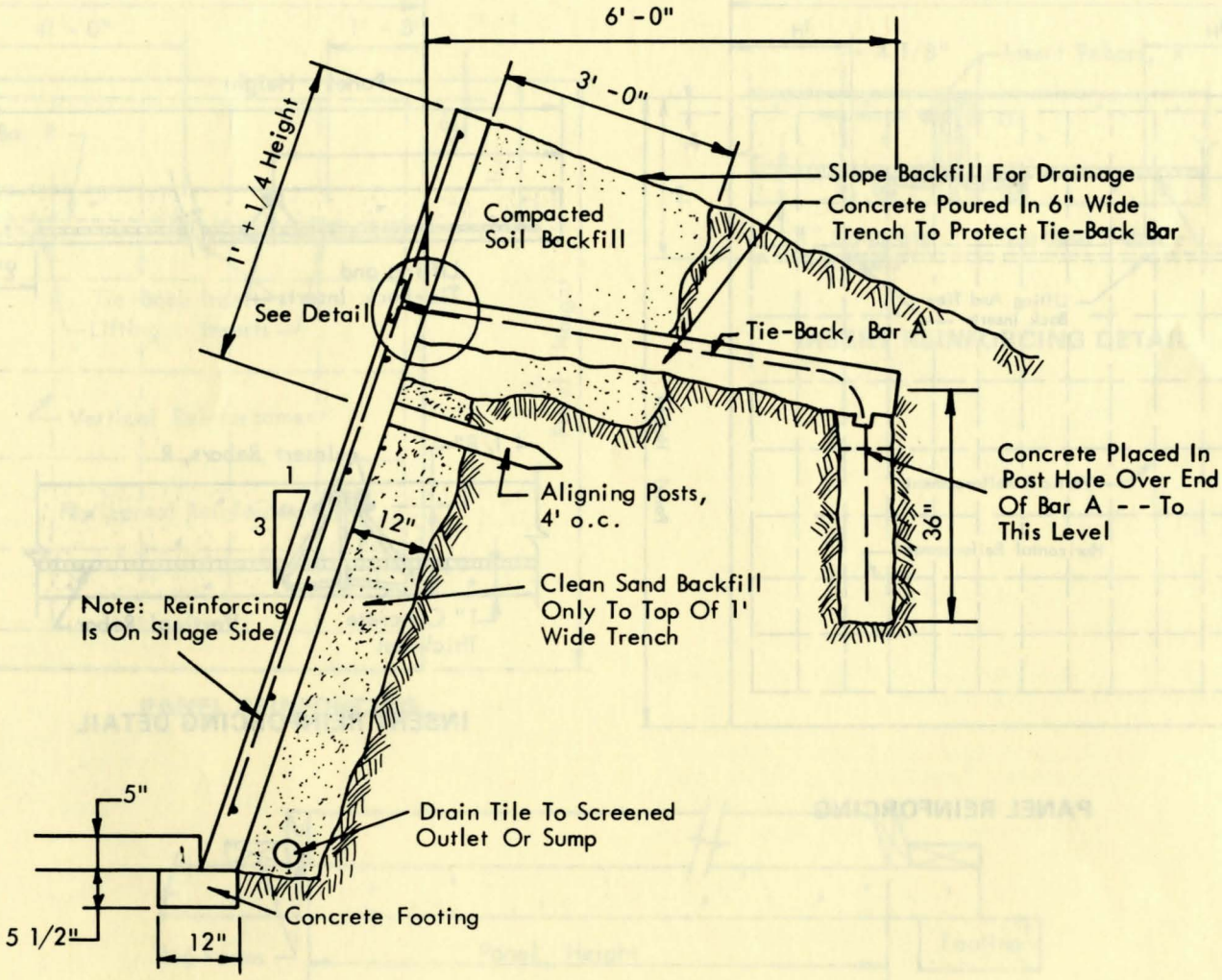


INSERT REINFORCING DETAIL

Table 3. Panel dimension and reinforcement schedule (12′ & 16′ wide panels, 2 tie-backs each)

Panel Width	Panel Height	Insert Location I_V	Insert Location I_H	Vertical Reinforcement	Insert Reinf R	Horizontal Reinforcement	Tie-Back Wt/Lb	Tie-Back Static Tension, Lb	Tie-Back Bar Size
12'-0"	10'-0"	2'-6"	2'-8"	8 #4 @ 18"	2 #4	7 #4 @ 18"	8,250	1,600	#4
12'-0"	12'-0"	3'-0"	2'-8"	9 #4 @ 16"	2 #4	8 #4 @ 18"	9,900	2,300	#4
12'-0"	14'-0"	3'-6"	2'-8"	12 #4 @ 12"	2 #4	9 #4 @ 18"	11,550	3,130	#4
12'-0"	16'-0"	4'-0"	2'-8"	19 #4 @ 7½"	2 #4	11 #4 @ 18"	13,200	4,100	#4
12'-0"	18'-0"	4'-6"	2'-8"	28 #4 @ 5"	2 #5	12 #4 @ 18"	14,850	5,190	#6
12'-0"	20'-0"	5'-0"	2'-8"	24 #5 @ 6"	2 #5	13 #4 @ 18"	15,600	6,380	#6
16'-0"	10'-0"	2'-6"	3'-4"	10 #4 @ 18"	2 #4	7 #4 @ 18"	11,000	2,140	#4
16'-0"	12'-0"	3'-0"	3'-4"	12 #4 @ 16"	2 #4	8 #4 @ 18"	13,200	3,070	#4
16'-0"	14'-0"	3'-6"	3'-4"	16 #4 @ 12"	2 #5	9 #4 @ 18"	15,400	4,180	#4
16'-0"	16'-0"	4'-0"	3'-4"	25 #4 @ 7½"	2 #5	11 #4 @ 18"	17,600	5,460	#6
16'-0"	18'-0"	4'-6"	3'-4"	38 #4 @ 5"	3 #5	12 #4 @ 18"	19,800	6,920	#6
16'-0"	20'-0"	5'-0"	3'-4"	32 #5 @ 6"	3 #5	13 #4 @ 18"	20,800	8,500	#6

BELOW GROUND SILOS
Panel Placement
For Both One & Two Tie-Backs



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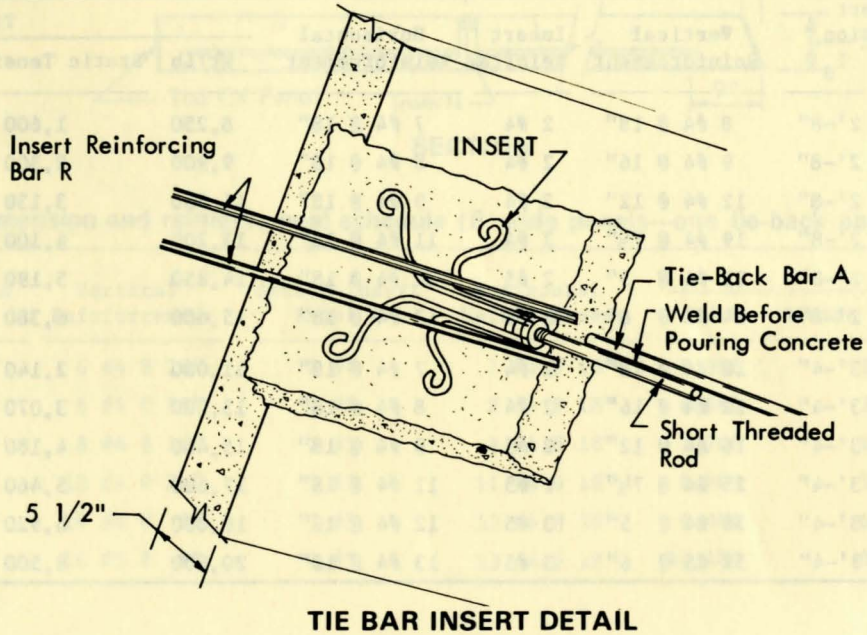
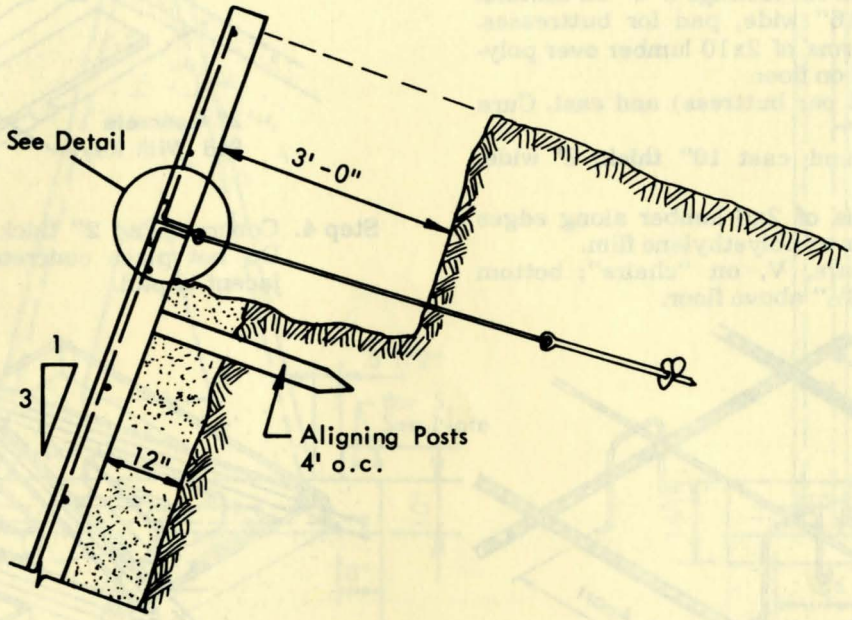
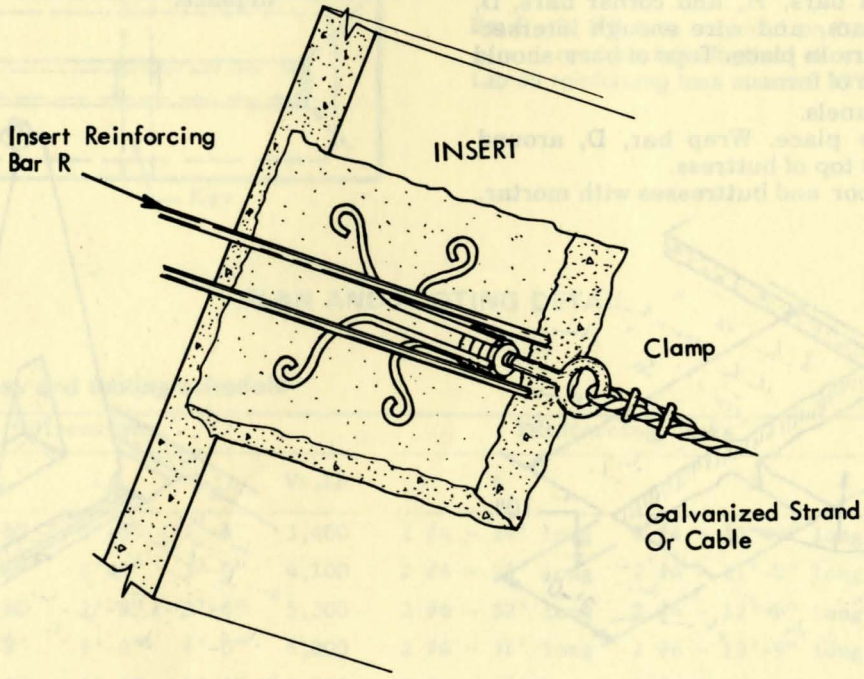


TIE BAR INSERT DETAIL

BELOW GROUND SILOS
Panel Placement—Alternate
For Both One & Two Tie-Backs



Select galvanized strand or cable tie-back and galvanized screw anchor to support the "static tension per tie-back" in Tables 2 and 3.

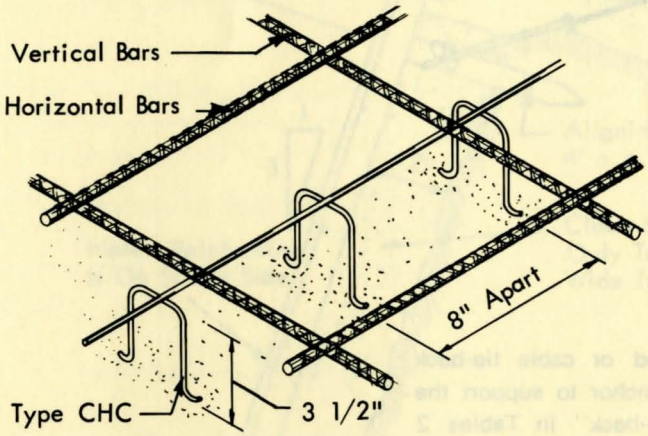


INSERT FOR SCREW ANCHOR

ABOVE GROUND SILOS
Construction

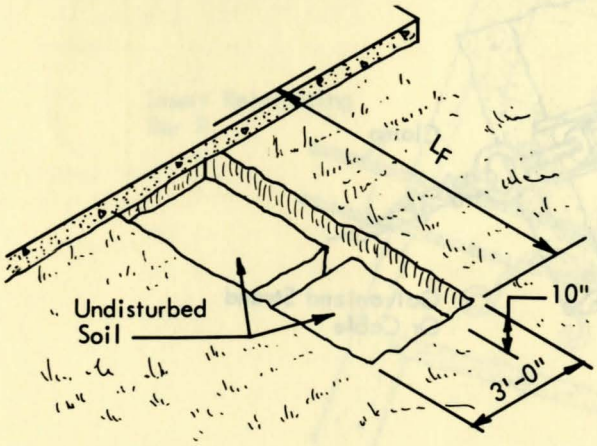
Construction Steps

1. Grade and uniformly compact dampened subgrade.
2. Form and cast floor with bars, S, along edges.
3. Excavate for buttress footings 8'-0" on centers.
4. Cast 2" thick, 16" wide, pad for buttresses.
5. Build buttress forms of 2x10 lumber over polyethylene film laid on floor.
6. Place bars, B, (2 per buttress) and cast. Cure before erecting.
7. Place bars, C, and cast 10" thick, 3' wide, footing.
8. Build panel forms of 2x6 lumber along edges of floor slab and over polyethylene film.
9. Place vertical bars, V, on "chairs"; bottom of bar should be 3½" above floor.

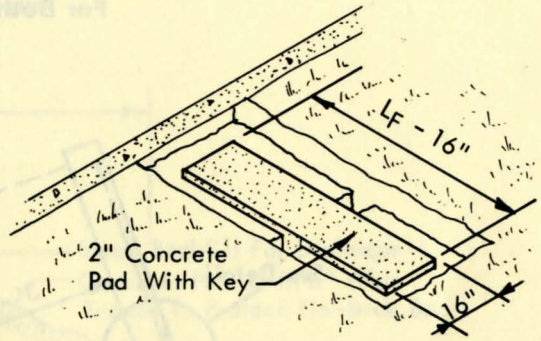


Use 3 rows of chairs: 10" from sides of forms and in center

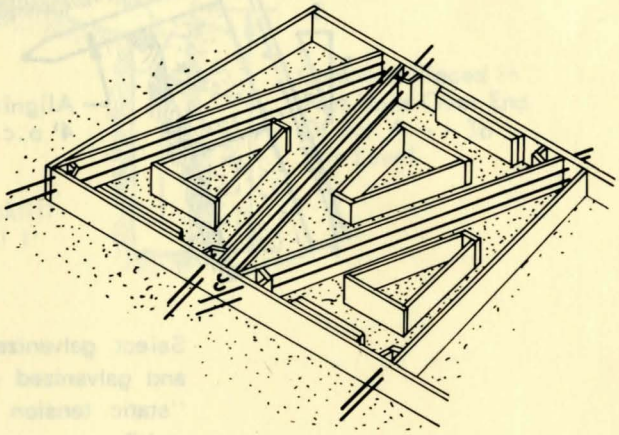
10. Place horizontal bars, H, and corner bars, D, over vertical bars, and wire enough intersections to hold bars in place. Tops of bars should be 1" below tops of forms.
11. Cast and cure panels.
12. Lift panels into place. Wrap bar, D, around loop of bar, B, at top of buttress.
13. Seal joints at floor and buttresses with mortar.



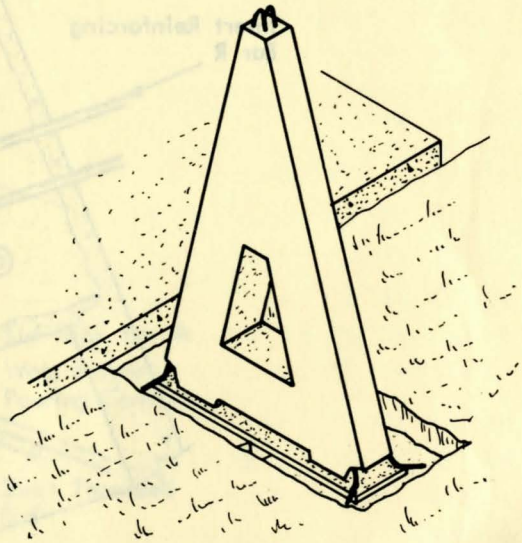
Step 3. Excavation for buttress base with key. Buttress footing is 10" thick, plus 6" Key Trench and extends about 8" under floor.



Step 4. Concrete Pad 2" thick, 16" wide with key. Do not place concrete in key trench adjacent to pad.

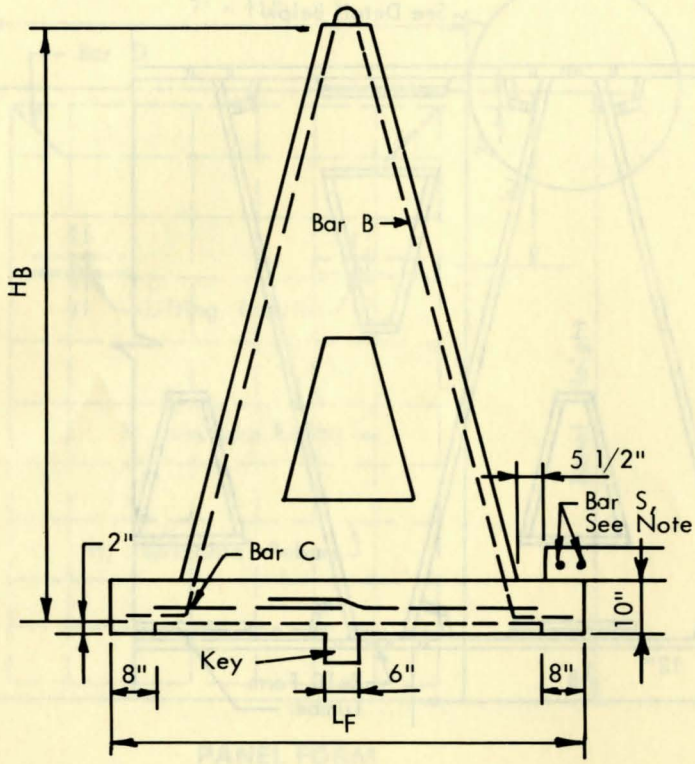


Step 5. Buttress forms with reinforcing bars, B, in place.

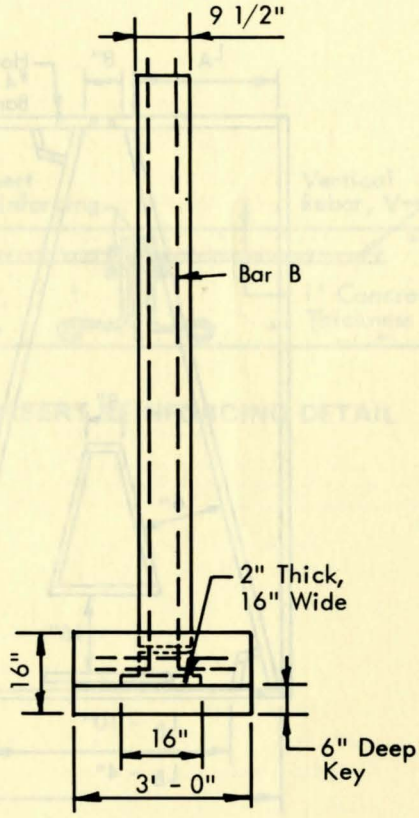


Place buttress on 2" Concrete Pad plumb and align using wood templates to position buttress. Pad is 16" wide in a 3' wide hole in sod. Cast footing.

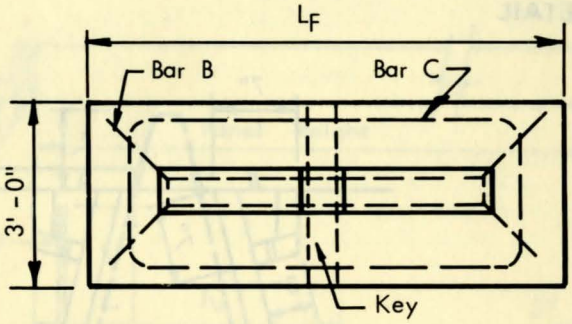
ABOVE GROUND SILOS
Buttress



SIDE VIEW



END VIEW



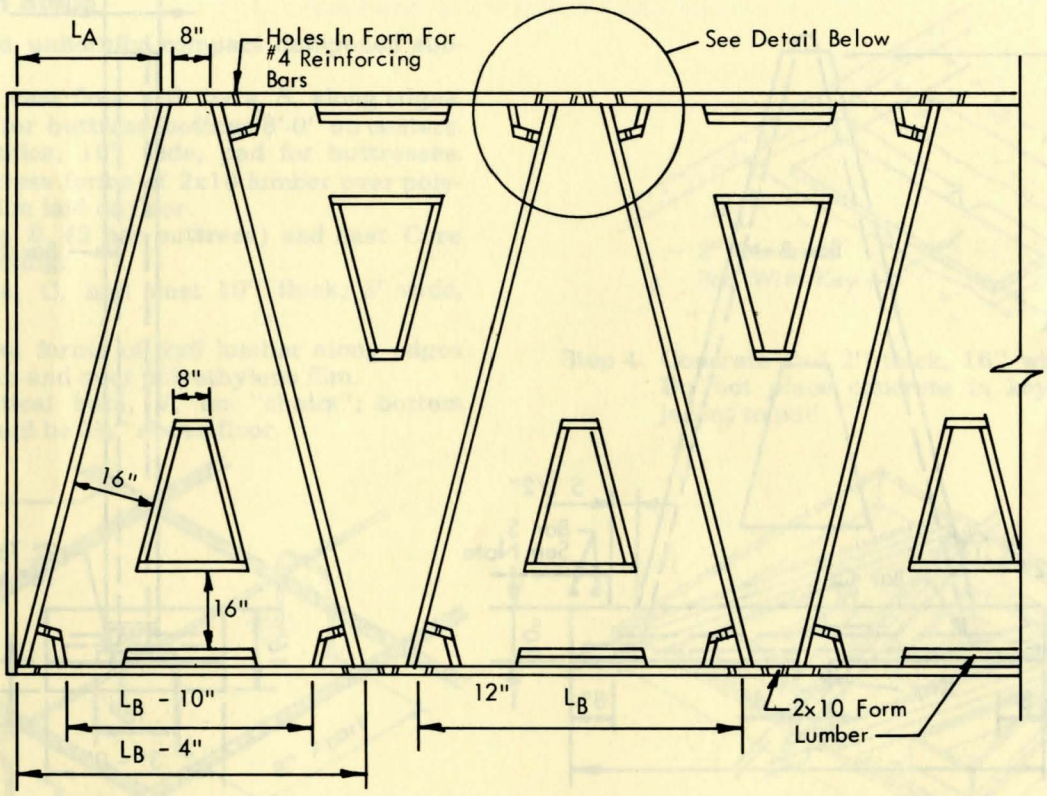
Bar S—2 #3 bars required on both sides of silo floor; run bars full length of silo.
Lap all reinforcing bars at least 10"

PLAN AND FOOTING DETAIL

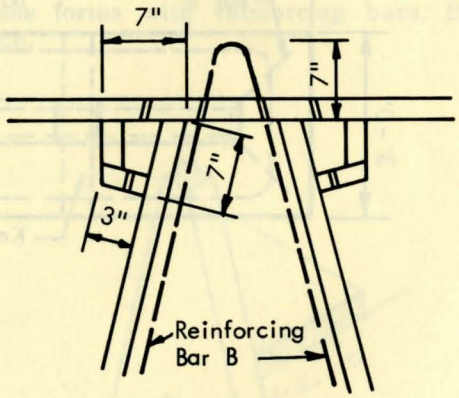
Table 4. Buttress and footing schedule

Dimensions					Reinforcing Bars	
H_B	L_F	L_B	L_A	Wt,Lb	B	C
9'-8"	7'-8"	5'-8"	2'-6"	3,400	2 #4 - 24' long	2 #4 - 10'-9" long
11'-8"	8'-8"	6'-8"	3'-0"	4,100	2 #4 - 28' long	2 #4 - 11'-9" long
13'-8"	9'-8"	7'-8"	3'-6"	5,300	2 #6 - 32' long	2 #4 - 12'-9" long
15'-8"	10'-8"	8'-8"	4'-0"	6,000	2 #6 - 36' long	2 #6 - 13'-9" long
17'-8"	11'-8"	9'-8"	4'-6"	6,900	2 #6 - 40' long	2 #6 - 14'-9" long
19'-8"	12'-8"	10'-8"	5'-0"	7,800	2 #8 - 44' long	2 #8 - 15'-9" long

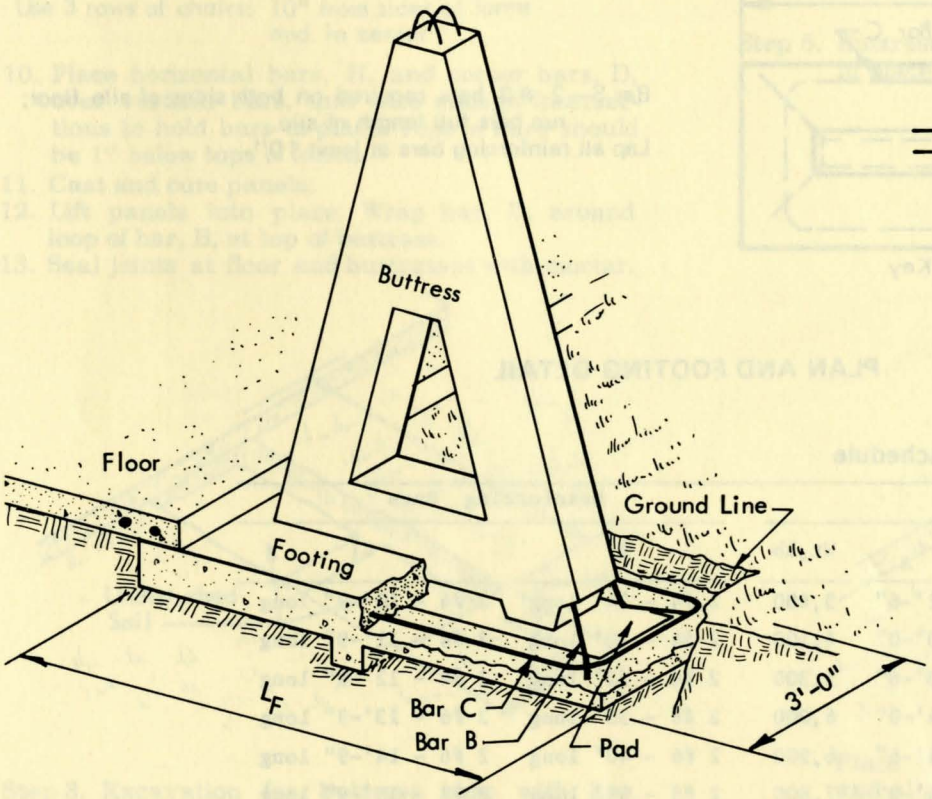
ABOVE GROUND SILOS
Buttress Forms



PLAN
FORM DETAIL

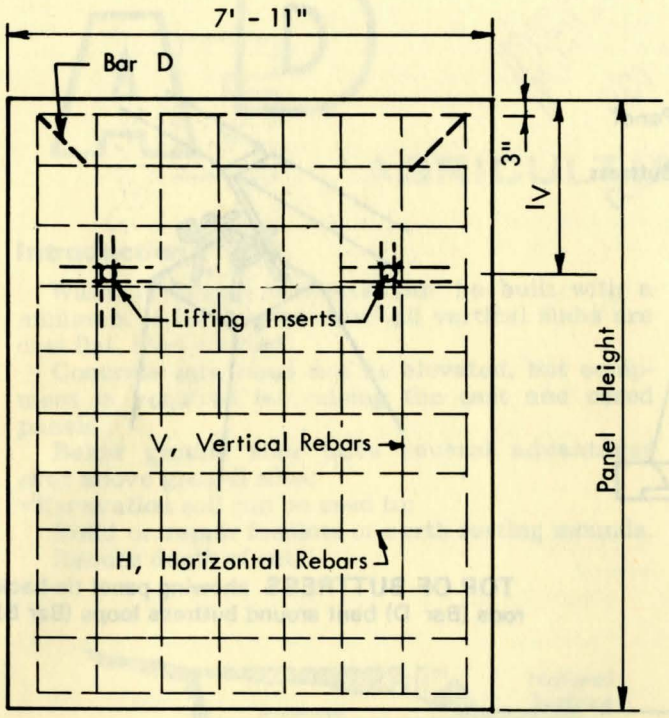


BAR B DETAIL

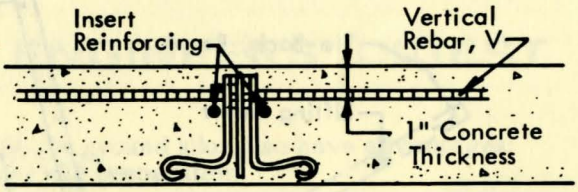


CUT-AWAY VIEW of footing and buttress, showing position of reinforcing bars

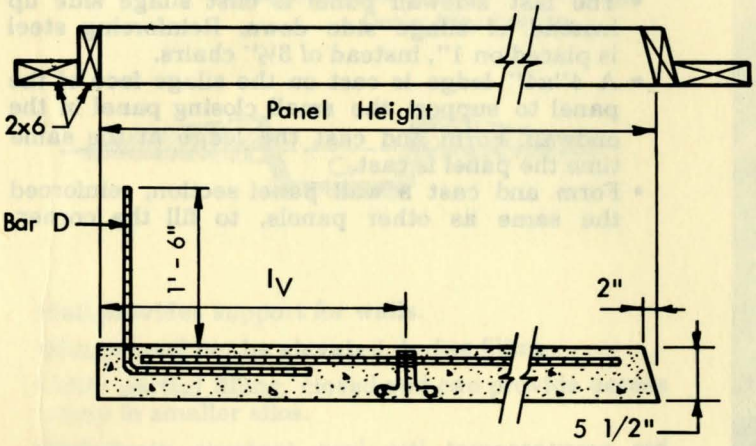
ABOVE GROUND SILOS
Panels



PANEL FORM



INSERT REINFORCING DETAIL



FORM SECTION

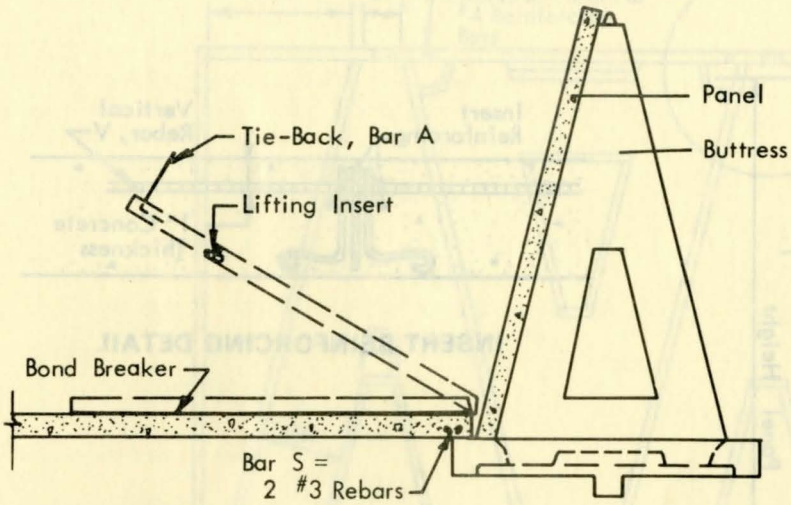
Table 5. Panel dimension schedule

Panel Height	Width	l_V	Weight
10'-0"	7'-11"	3'-0"	5,500
12'-0"	7'-11"	3'-6"	6,600
14'-0"	7'-11"	4'-0"	7,700
16'-0"	7'-11"	4'-6"	8,800
18'-0"	7'-11"	5'-0"	9,900
20'-0"	7'-11"	5'-6"	10,900

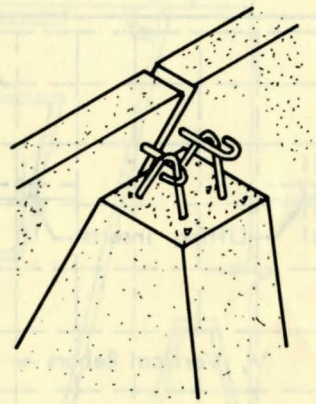
Table 6. Panel reinforcement schedule

			10'		12'		14'		16'		18'		20'	
Bar	Shape	Size	No.	Length	No.	Length	No.	Length	No.	Length	No.	Length	No.	Length
H	———	#4	11	7'-6"	13	7'-6"	15	7'-6"	17	7'-6"	19	7'-6"	21	7'-6"
V	———	#4	8	9'-6"	8	11'-6"	8	13'-6"	8	15'-6"	8	17'-6"	8	19'-6"
D	└———	#4	2	2'-6"	2	2'-6"	2	2'-6"	2	2'-6"	2	2'-6"	2	2'-6"

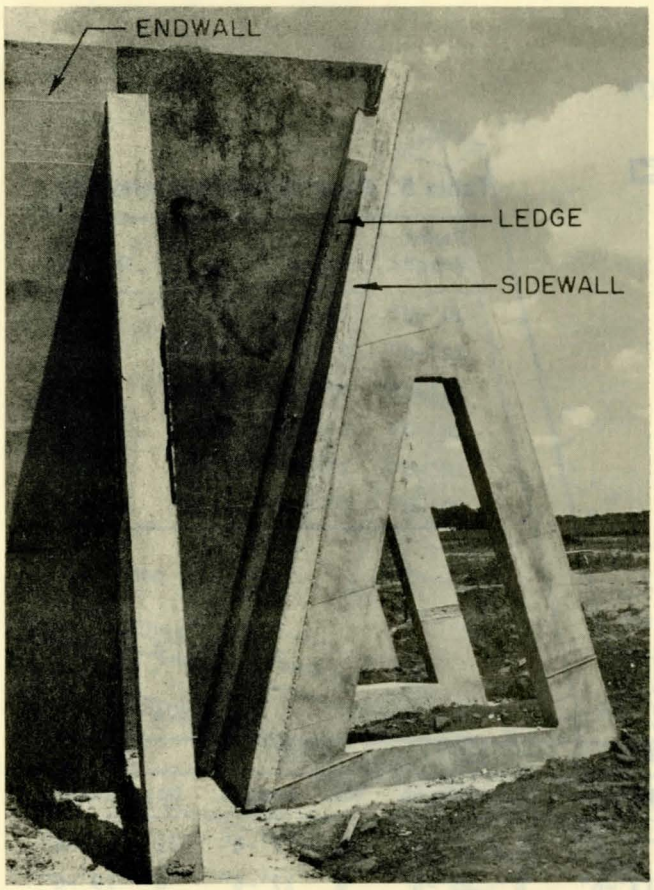
ABOVE GROUND SILOS
Panel Erection



SILO SECTION



TOP OF BUTTRESS showing panel tie-back rods (Bar D) bent around buttress loops (Bar B)



Courtesy U. of Nebraska

Build an endwall for above ground silos the same as the sidewalls. One method of closing the corner is shown in the photograph:

- The last sidewall panel is cast silage side up instead of silage side down. Reinforcing steel is placed on 1", instead of 3½" chairs.
- A 4"x4" ledge is cast on the silage face of the panel to support the small closing panel in the endwall. Form and cast the ledge at the same time the panel is cast.
- Form and cast a wall panel section, reinforced the same as other panels, to fill the corner.