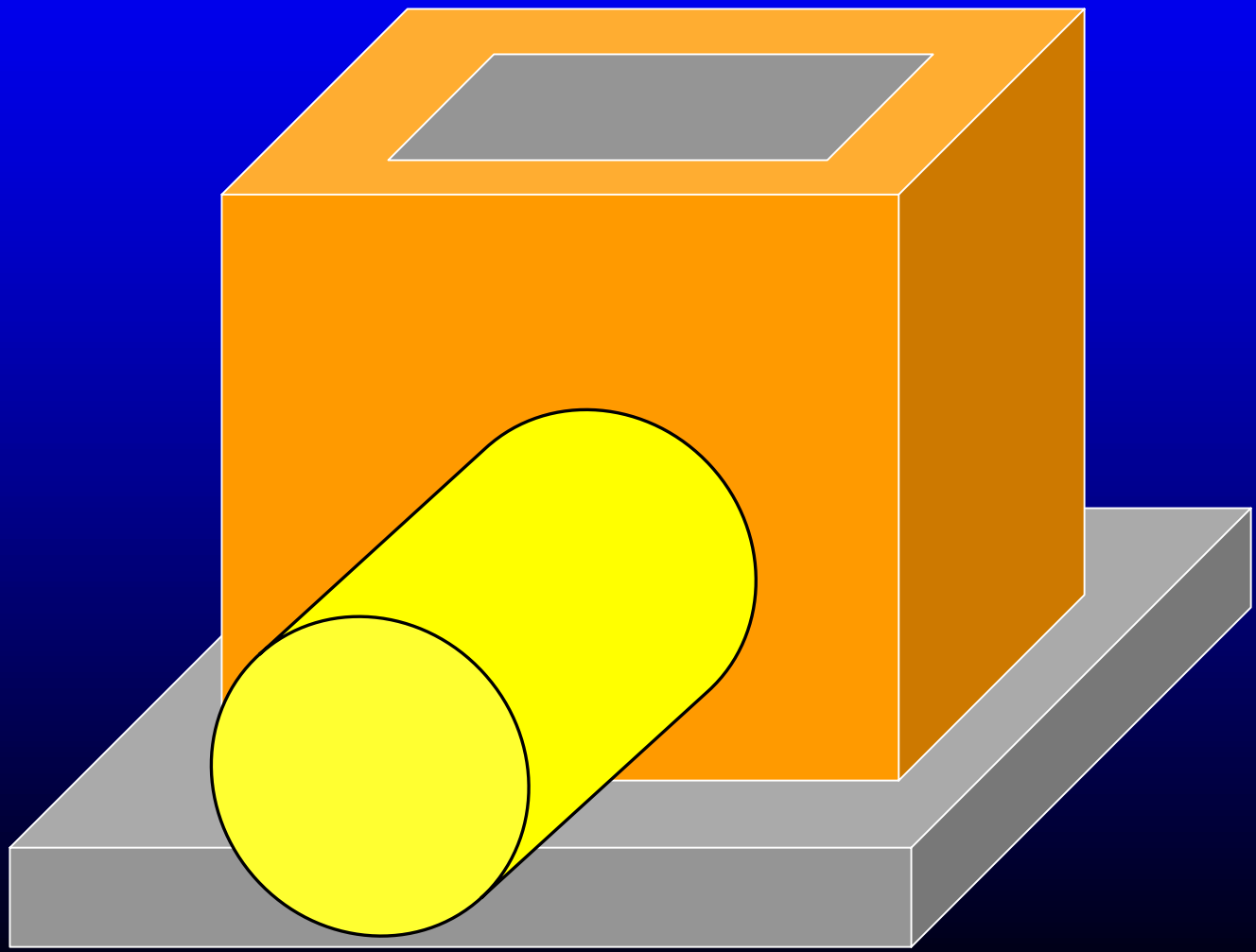
Structural Design Considerations

By Gene Gopenko, P.E.



GOALS:

- Serviceability
- Durability
- Low Permeability
- Limiting Deflections and Cracks

References

- ACI 318-89. Building Code Requirements for Reinforced Concrete
- ACI 350R-89. Environmental Engineering Concrete Structures
- “Strength Design for Reinforced Concrete Hydraulic Structures” by ASCE, (adapted from COE Manual)

References (cont.)

- Structural Design of Standard Covered Risers. Technical Release No30 (1965) by SCS.
- “Rectangular Concrete Tanks” by Portland Cement Association
- “Moments and Reactions for Rectangular Plates” by US Bureau of Reclamation

ACI 350R-89:

“ This report presents recommendations for structural design, materials, and construction of concrete tanks, reservoirs, and other structures commonly used in ***water containment****, industrial and domestic water, and wastewater treatment works, where dense, impermeable concrete with high resistance to chemical attack is required.”*

Among Types of Structures: intakes and conduits.

START WITH RIGHT INGREDIENTS!

Concrete Requirements

- Min. Concrete Strength=4000 psi at 28 days
- Air Entrainment=5%±1%
- Maximum Water-cement Ratio=.45
- Maximum Slump=4 inches
- Aggregates per ASTM C33, max. aggregate size=1 inch
- No admixtures containing calcium chloride

Steel Reinforcing

- New Billet Steel to Confirm to ASTM A615 Grade 60
- Epoxy Coated Rebars

Minimum Concrete Cover:

- Concrete Base=3 inches (4” COE)
- Concrete Walls=2 inches (3” COE)
- Stilling Basin=6” (COE)

Temperature and Shrinkage Reinforcing

ACI 318 for Grade 60 Steel:

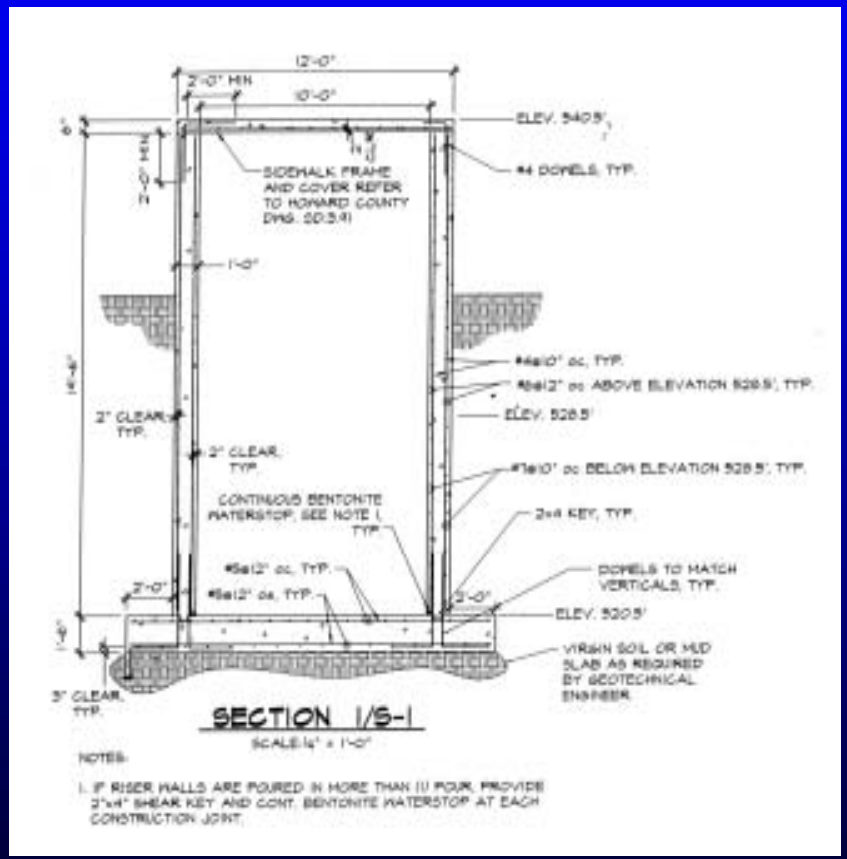
A_s=0.0018bh

ACI 350R (use chart), but

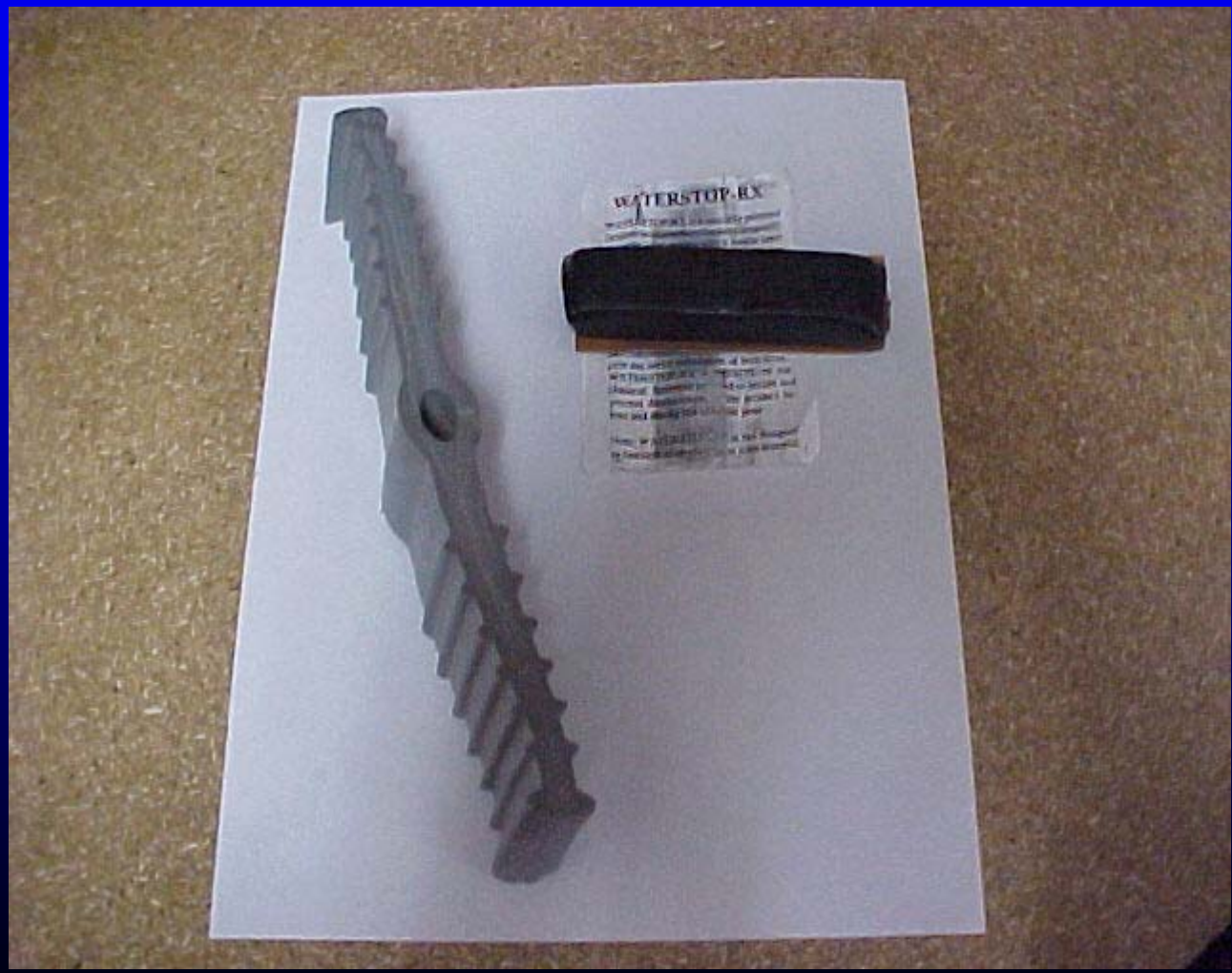
A_s(min.)=0.0024bh

Concrete Joints

- Construction Joints
- Expansion Joints
- Separation Joint



Waterstops



Crack Reduction

- Joint Spacing

  “Joint is controlled crack. Crack is uncontrolled joint”
- Reinforcing Distribution-try to reduce bar spacing!

  “Where the structure must be watertight, bar spacing should not exceed 12 inches”.

Minimum Thickness

ACI 350R:

“Walls with height greater than 10 feet shall be a minimum of 12 in thick and shall contain reinforcement on both faces.“

“A minimum of 8 in is required where 2 in concrete cover is desired”- criteria for top slabs.

Flotation Criteria

(Structural Design of Covered Risers, SCS TR 30)

FS=1.5

- Riser Located in Reservoir-
  Low stage inlets plugged
- Riser Located in Embankment
  Add buoyant weight of fill over base

Flotation Criteria

(Flotation Stability Criteria for Concrete Hydraulic Structures, US Army COE)

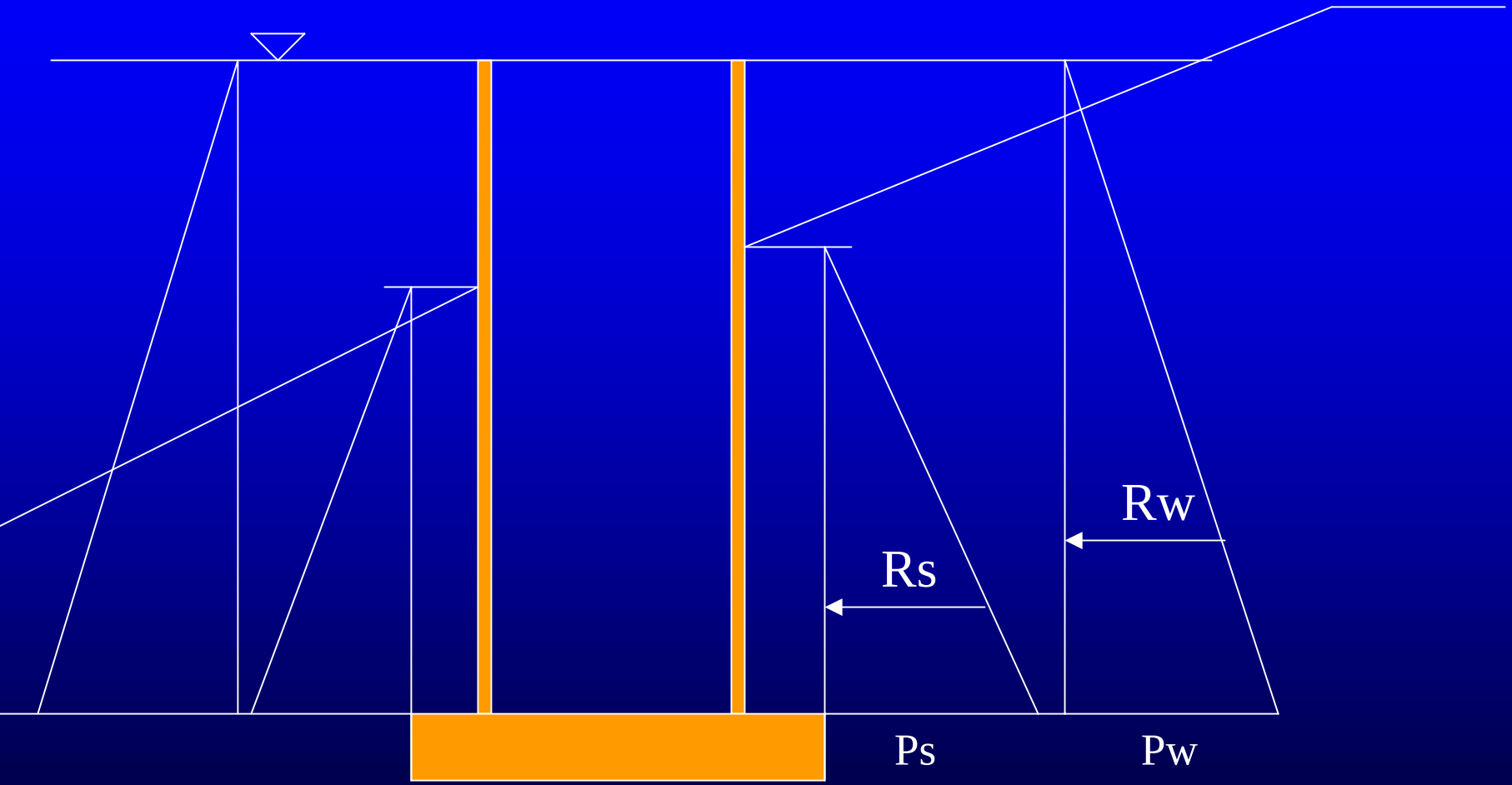
Loading Conditions	FS
• Construction	1.3
• Normal Operation	1.5
• Extreme (max. pool)	1.1

Design Loads

- **Dead Loads:**
  - Weight of Concrete
  - Weight of Equipment

- **Live Loads:**
  - Earth and Silt Pressure
  - Water (Hydrostatic Load)
  - Surcharge
  - Cover slab LL=100 psf
  - Wind Load=50 psf, for risers in reservoir only
  - Ice Load (max. 2’ thick, 5 kips/sq. ft)

LOAD DIAGRAM FOR CONCRETE RISER WALLS



Hydrostatic Load:

$Pw=\gamma_w Hw$, in lb/ft^2 , $\gamma_w = 62.4\ lb/ft^3$,

Soil Load:

$Ps=(Kr)(\gamma_s-\gamma_w)Hs$, where

$Kr=.5$ (soil assumed at rest condition)

$\gamma_s=126\ lb/ft^3$ (soil weight available from Soil Report)

Strength Design

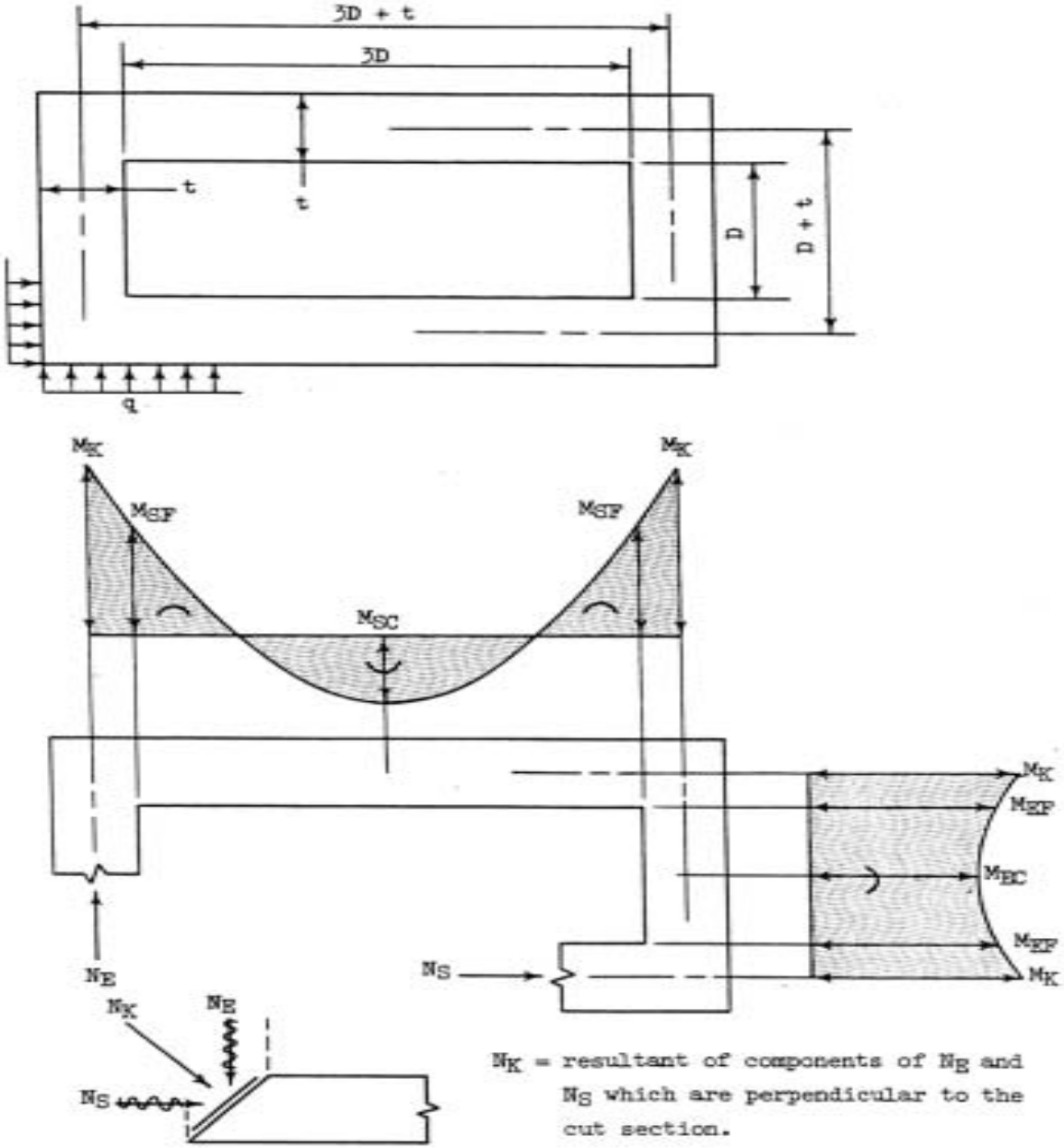
U=R*Load Factors

U=1.4(DL)+1.7(LL), from ACI 318

ACI 350: In Hydraulic Structures, when reinforcing in flexure, the required strength 1.3U.

Strength Reduction Factor φ-Second Safety Provision in ACI.

Mr= φMn, φ=.9 for bending, φ=.85 for shear



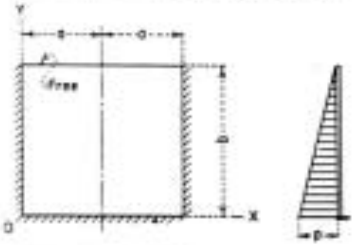
Moment Diagram

Analysis for Plates (vs Simple Beam)

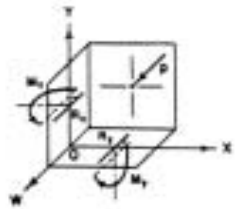
- Finite Elements Computer Model
- Tables of Moments and Reactions Coefficients
- Moment Balance using Distribution Factors

MOMENTS AND REACTIONS FOR RECTANGULAR PLATES

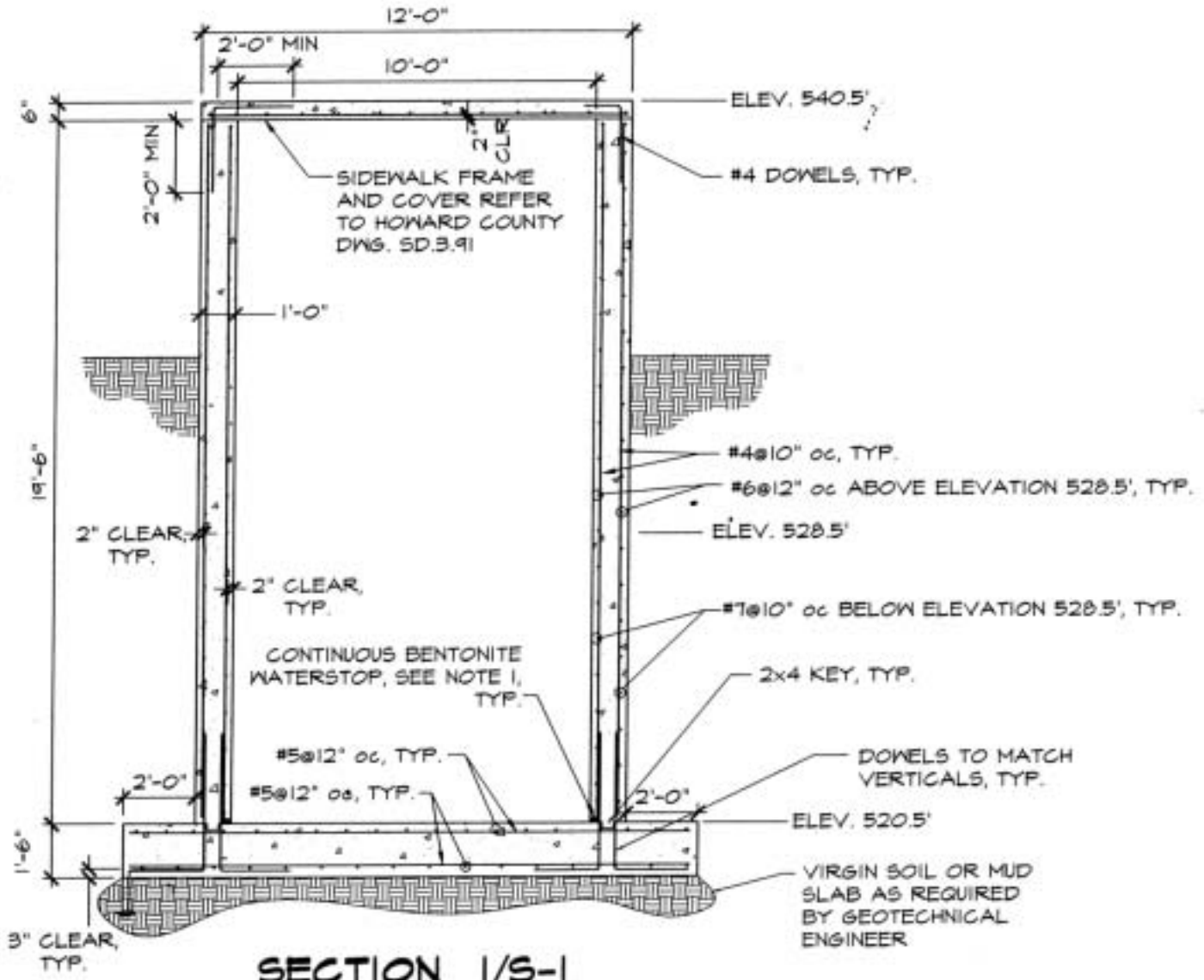
			M_x						M_y					
	y/b	α_x x/a	0	0.2	0.4	0.6	0.8	1.0	0	0.2	0.4	0.6	0.8	1.0
a/b = 1/2	1.0	+.0082	+.0004	+.0002	+.0000	−.0001	−.0002	−.0002	0	0	0	0	0	0
	0.8	+.0251	+.0011	+.0005	+.0000	−.0003	−.0005	−.0005	+.0002	+.0001	+.0000	−.0000	−.0001	−.0001
	0.6	+.0496	+.0021	+.0009	+.0001	−.0006	−.0009	−.0011	+.0004	+.0002	+.0000	−.0001	−.0002	−.0002
	0.4	+.0751	+.0031	+.0014	+.0001	−.0008	−.0014	−.0016	+.0006	+.0003	+.0000	−.0002	−.0003	−.0003
	0.2	+.0942	+.0038	+.0016	+.0000	−.0010	−.0017	−.0019	+.0008	+.0005	−.0000	−.0003	−.0005	−.0005
	0	+.0460	0	+.0001	+.0003	+.0005	+.0006	+.0006	0	+.0005	+.0014	+.0023	+.0028	+.0030
		α_1 α_2	+.0460	+.0136	+.0543	+.0839	+.1004	+.1056						
a/b = 1/4	1.0	+.0147	−.0022	+.0012	+.0002	−.0006	−.0012	−.0014	0	0	0	0	0	0
	0.8	+.0523	+.0046	+.0022	+.0002	−.0012	−.0021	−.0024	+.0009	+.0005	+.0002	−.0000	−.0002	−.0002
	0.6	+.1015	+.0083	+.0037	+.0002	−.0023	−.0038	−.0042	+.0017	+.0007	−.0000	−.0005	−.0009	−.0010
	0.4	+.1514	+.0114	+.0049	+.0001	−.0032	−.0051	−.0057	+.0023	+.0008	−.0004	−.0013	−.0019	−.0021
	0.2	+.1894	+.0132	+.0057	−.0004	−.0030	−.0043	−.0047	+.0020	+.0004	−.0011	−.0022	−.0029	−.0031
	0	+.0304	0	+.0004	+.0010	+.0016	+.0020	+.0021	0	+.0020	+.0052	+.0081	+.0100	+.0107
		α_1 α_2	+.0304	+.0309	+.1052	+.1563	+.1856	+.1950						
a/b = 3/8	1.0	+.0189	+.0066	+.0040	+.0008	−.0020	−.0039	−.0045	0	0	0	0	0	0
	0.8	+.0685	+.0117	+.0056	+.0006	−.0031	−.0054	−.0062	+.0023	+.0012	+.0004	−.0002	−.0005	−.0007
	0.6	+.1541	+.0178	+.0075	+.0001	−.0049	−.0079	−.0088	+.0035	+.0013	−.0006	−.0020	−.0029	−.0032
	0.4	+.2107	+.0208	+.0079	−.0007	−.0061	−.0090	−.0099	+.0042	+.0009	−.0019	−.0042	−.0056	−.0061
	0.2	+.1691	+.0145	+.0045	−.0012	−.0042	−.0057	−.0061	+.0029	+.0001	−.0022	−.0039	−.0048	−.0051
	0	+.0102	0	+.0008	+.0020	+.0030	+.0038	+.0040	0	+.0039	+.0099	+.0152	+.0188	+.0200
		α_1 α_2	+.0102	+.0474	+.1488	+.2154	+.2526	+.2645						
a/b = 1/2	1.0	+.0326	+.0151	+.0088	+.0015	−.0046	−.0084	−.0097	0	0	0	0	0	0
	0.8	+.1315	+.0216	+.0099	+.0007	−.0059	−.0099	−.0112	+.0043	+.0020	+.0002	−.0011	−.0019	−.0022
	0.6	+.1978	+.0273	+.0108	−.0005	−.0079	−.0119	−.0132	+.0055	+.0015	−.0020	−.0047	−.0064	−.0070
	0.4	+.2421	+.0277	+.0092	−.0019	−.0082	−.0115	−.0125	+.0055	+.0004	−.0042	−.0076	−.0097	−.0104
	0.2	+.1607	+.0160	+.0041	−.0017	−.0044	−.0055	−.0058	+.0032	−.0002	−.0026	−.0039	−.0044	−.0046
	0	−.0045	0	+.0014	+.0033	+.0050	+.0061	+.0065	0	+.0068	+.0167	+.0250	+.0307	+.0325
		α_1 α_2	−.0045	+.0744	+.1942	+.2699	+.3108	+.3236						
a/b = 3/4	1.0	+.1061	+.0408	+.0196	+.0013	−.0115	−.0190	−.0214	0	0	0	0	0	0
	0.8	+.2077	+.0433	+.0177	−.0003	−.0119	−.0184	−.0205	+.0087	+.0031	−.0012	−.0042	−.0061	−.0067
	0.6	+.2408	+.0426	+.0145	−.0026	−.0124	−.0174	−.0189	+.0085	+.0010	−.0055	−.0102	−.0130	−.0139
	0.4	+.2542	+.0349	+.0091	−.0039	−.0102	−.0130	−.0138	+.0070	−.0011	−.0075	−.0115	−.0127	−.0143
	0.2	+.1557	+.0165	+.0031	−.0017	−.0031	−.0033	−.0033	+.0033	+.0001	−.0030	+.0014	+.0029	+.0035
	0	−.0196	0	+.0028	+.0064	+.0093	+.0111	+.0117	0	+.0139	+.0320	+.0485	+.0554	+.0584
		α_1 α_2	−.0196	+.1256	+.2666	+.3496	+.3923	+.4065						
a/b = 1	1.0	+.1985	+.0644	+.0255	−.0013	−.0172	−.0252	−.0278	0	0	0	0	0	0
	0.8	+.2564	+.0601	+.0210	−.0028	−.0161	−.0226	−.0245	+.0120	+.0034	−.0026	−.0065	−.0088	−.0095
	0.6	+.2485	+.0515	+.0149	−.0047	−.0145	−.0189	−.0201	+.0103	+.0003	−.0075	−.0125	−.0151	−.0159
	0.4	+.2411	+.0372	+.0078	−.0049	−.0100	−.0118	−.0122	+.0074	−.0021	−.0076	−.0099	−.0106	−.0107
	0.2	+.1108	+.0154	+.0025	−.0006	−.0006	−.0000	+.0003	+.0031	+.0018	+.0060	+.0116	+.0160	+.0175
	0	−.0241	0	+.0044	+.0096	+.0137	+.0161	+.0169	0	+.0220	+.0482	+.0683	+.0804	+.0845
		α_1 α_2	−.0241	+.1691	+.3199	+.4038	+.4457	+.4584						
a/b = 3/2	1.0	+.3127	+.0857	+.0207	−.0087	−.0199	−.0252	−.0258	0	0	0	0	0	0
	0.8	+.2929	+.0730	+.0158	−.0086	−.0172	−.0194	−.0198	+.0146	+.0025	−.0042	−.0072	−.0082	−.0085
	0.6	+.2352	+.0560	+.0094	−.0083	−.0134	−.0142	−.0141	+.0112	−.0013	−.0077	−.0096	−.0096	−.0094
	0.4	+.2148	+.0359	+.0038	−.0053	−.0085	−.0057	−.0053	+.0072	−.0021	−.0023	+.0012	+.0046	+.0059
	0.2	+.0897	+.0132	+.0021	+.0025	+.0050	+.0069	+.0076	+.0026	+.0077	+.0220	+.0356	+.0444	+.0474
	0	−.0204	0	+.0079	+.0158	+.0212	+.0243	+.0252	0	+.0396	+.0791	+.1062	+.1214	+.1262
		α_1 α_2	−.0204	+.2452	+.3964	+.4668	+.4988	+.5047						



Moment = (Coefficient)(pb²)
Reaction = (Coefficient)(pb)



POSITIVE SIGN CONVENTION

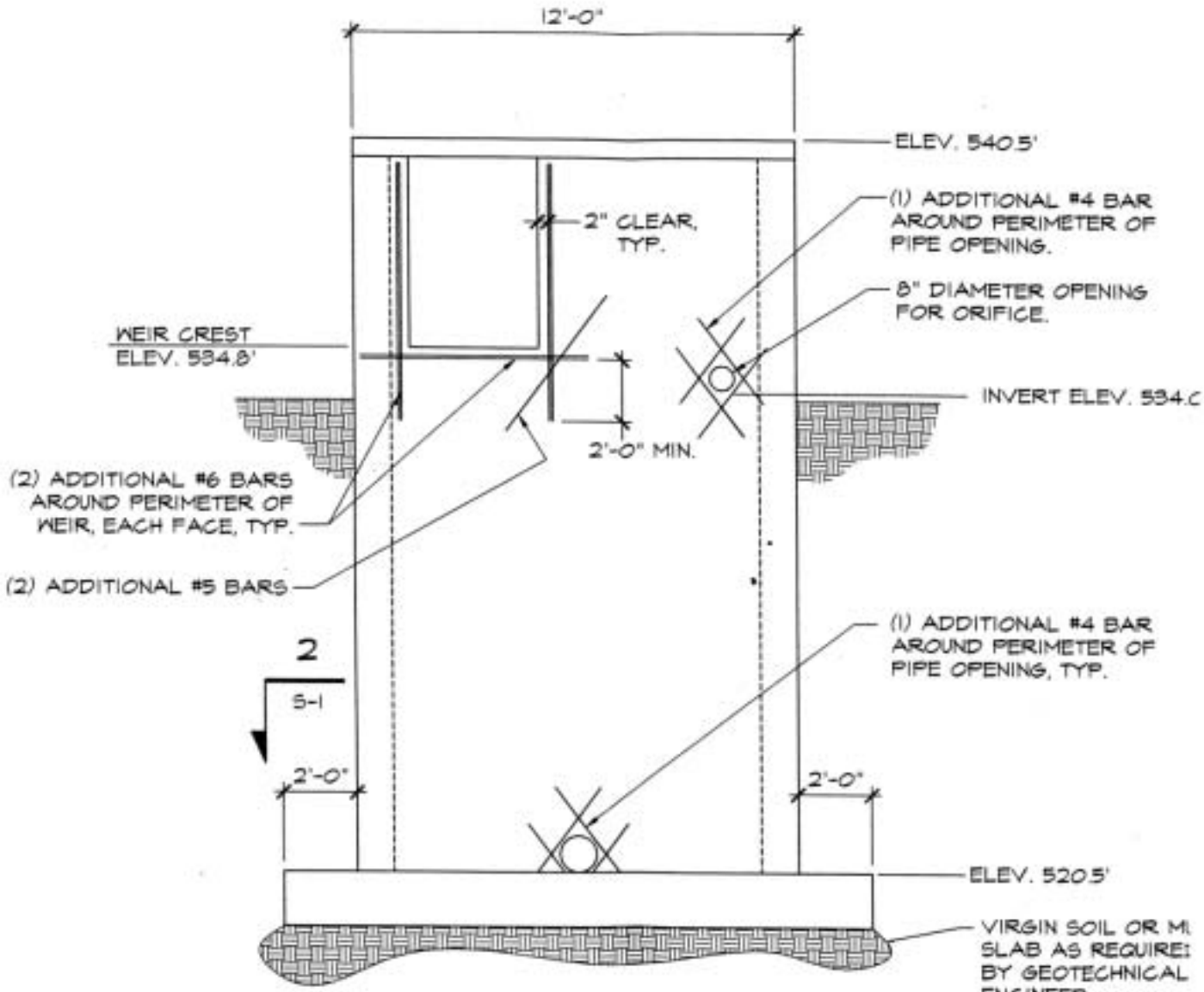


SECTION 1/S-1

SCALE: 1/4" = 1'-0"

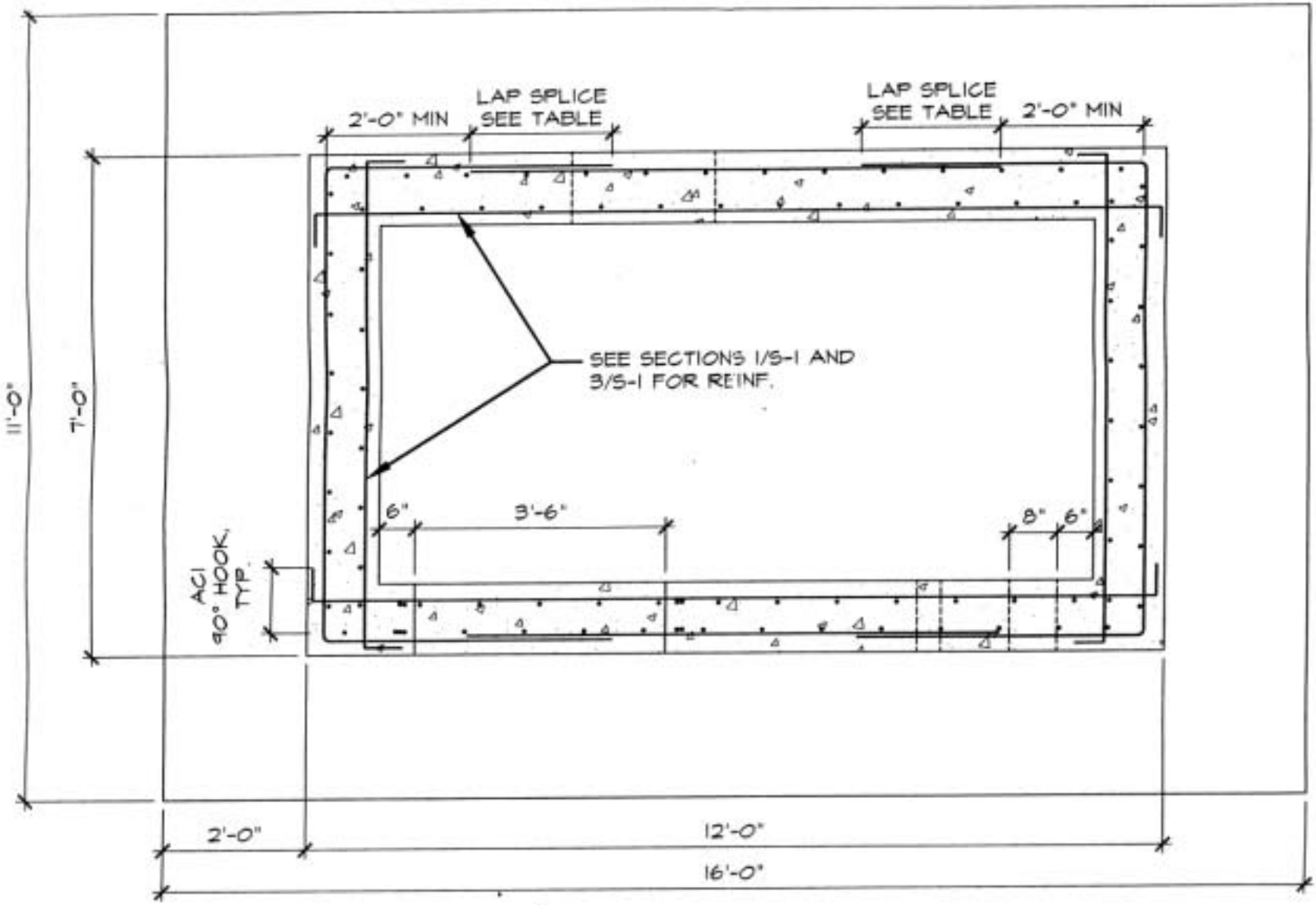
NOTES:

1. IF RISER WALLS ARE POURED IN MORE THAN (1) POUR, PROVIDE 2"x4" SHEAR KEY AND CONT. BENTONITE WATERSTOP AT EACH CONSTRUCTION JOINT.

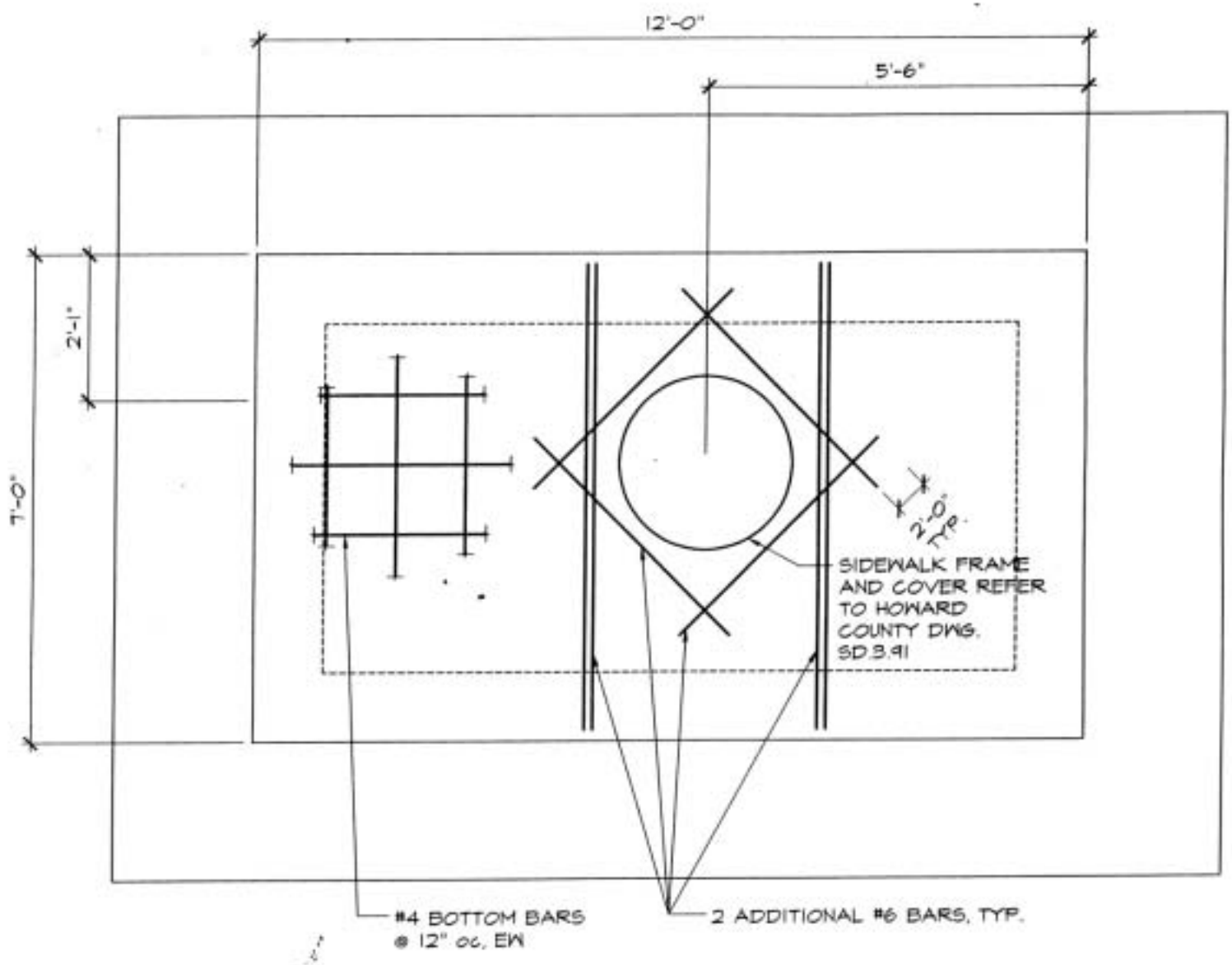


RISER ELEVATION

SCALE: ¼" = 1'-0"


2'-0" MIN
LAP SPLICE
SEE TABLE
LAP SPLICE
SEE TABLE
2'-0" MIN
SEE SECTIONS 1/S-1 AND
3/S-1 FOR REINF.
6"
3'-6"
8"
6"
ACI
90° HOOK,
TYP.
11'-0"
7'-0"
2'-0"
12'-0"
16'-0"

SECTION 2/S-1



PLAN - TOP SLAB

SCALE: 1/2" = 1'-0"

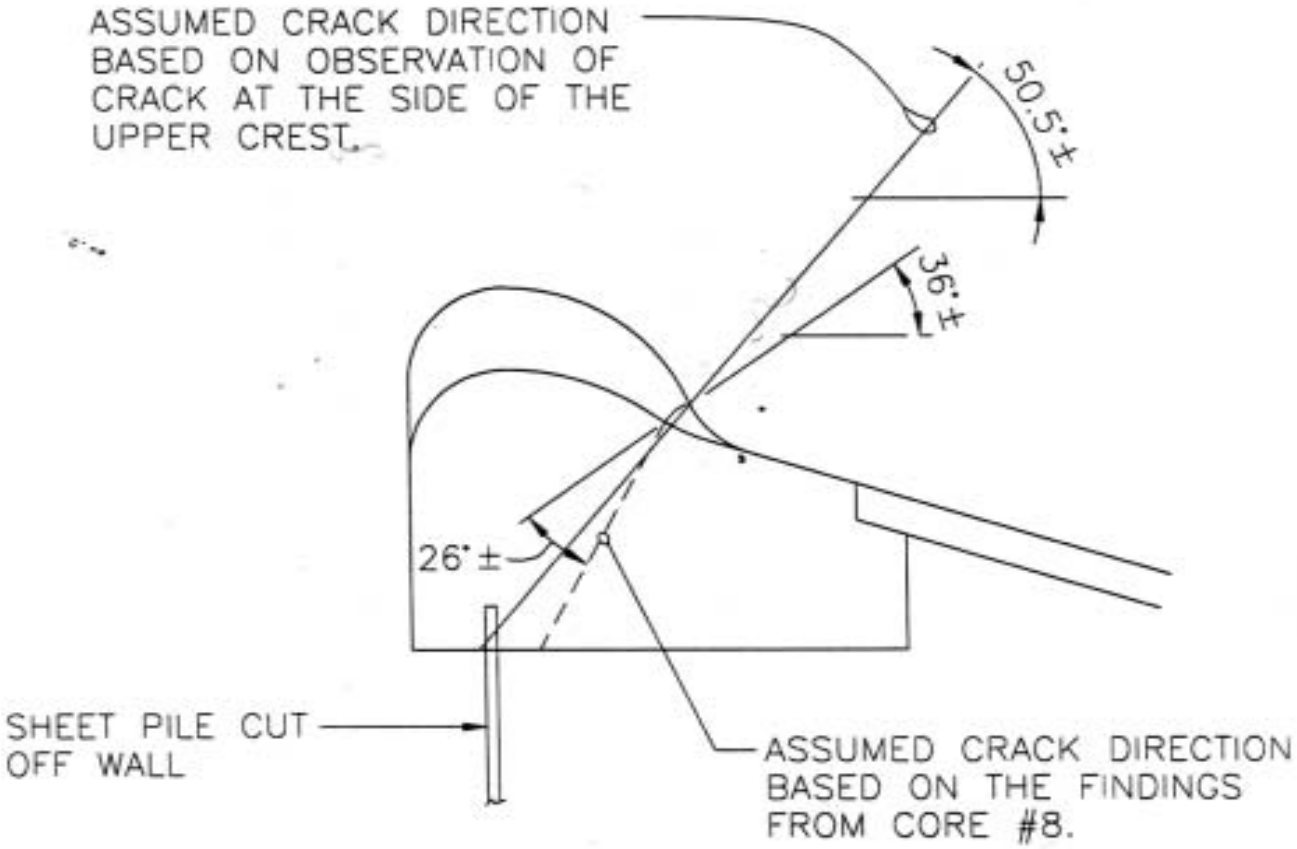
Precast vs Cast-in-Place
Pros and Cons


99 12 9

Lake Elkhorn Spillway Repair, Howard County, MD

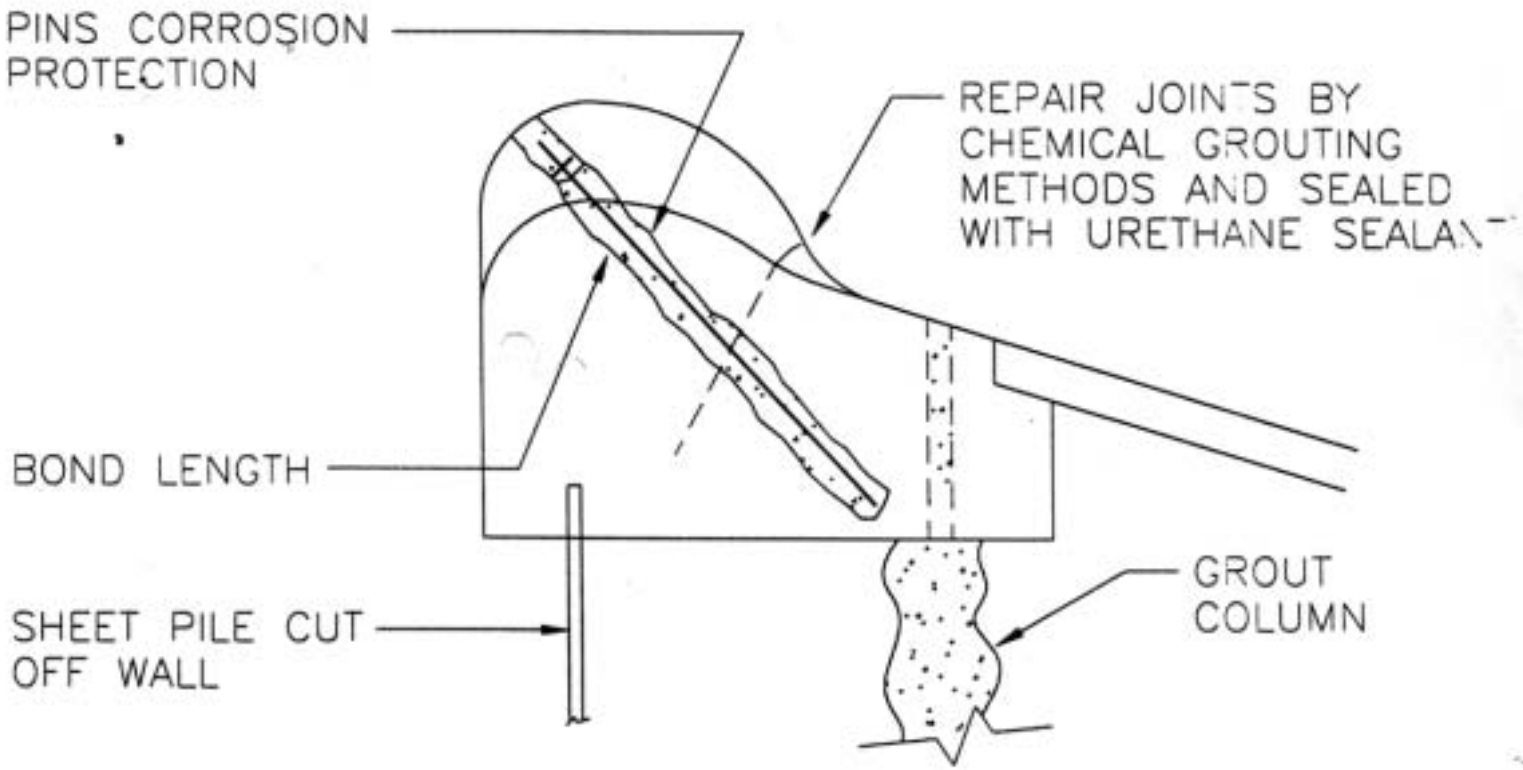
Dam Statistics

- Significant Hazard Dam
- Built in 1974 on tributary to Little Patuxent
- 18 high earthfill dam with 145 ft long ogee spillway
- Drainage Area 3.6 sq. miles



ASSUMED DIRECTION OF CRACK THROUGH THE WEIR CROSS SECTION

SCALE: 1/4" = 1'-0"



PROPOSED CONCEPT REPAIR AT WEIR

SCALE: NTS