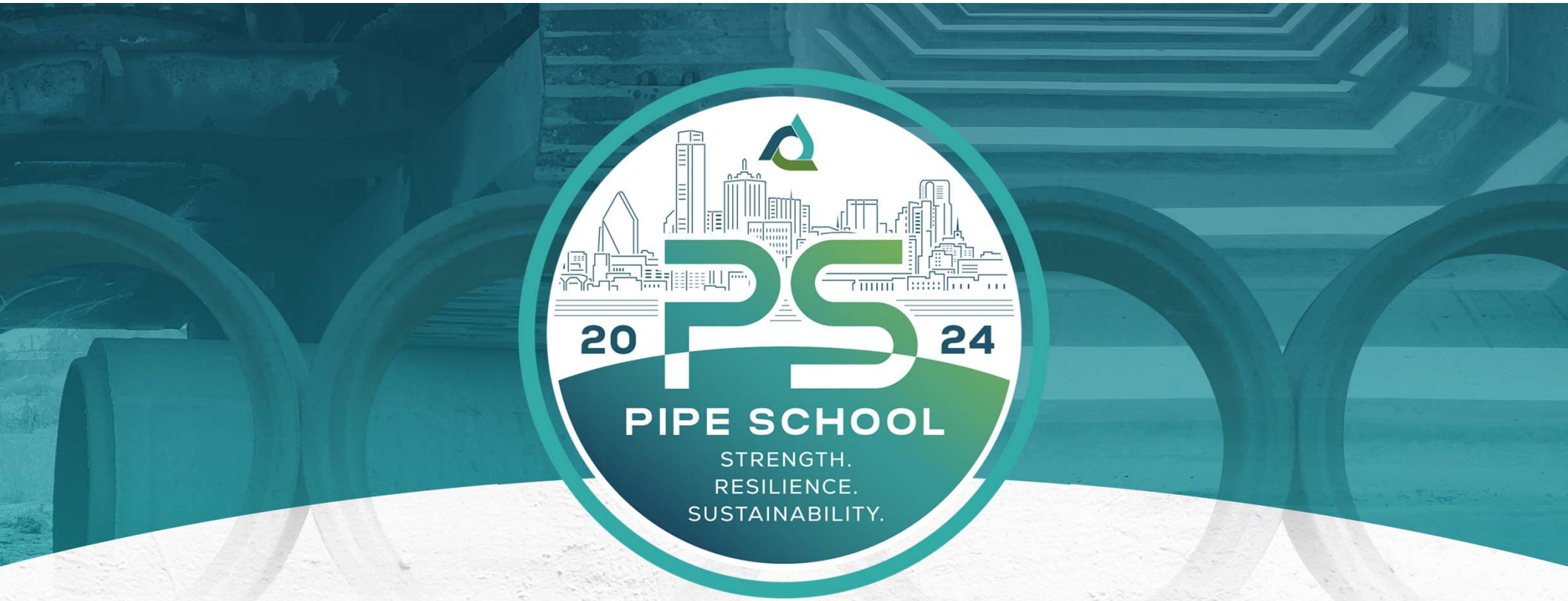


Reinforcement 1

Jake Jyrkama, P.E.

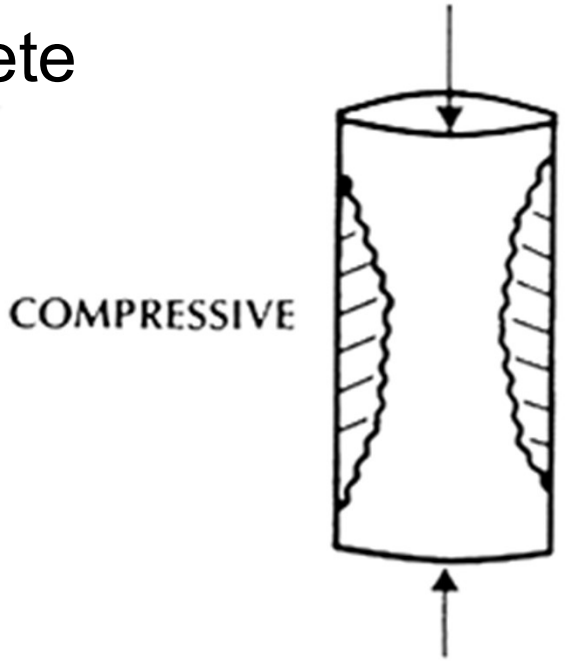
Rinker Materials


REINFORCEMENT
HOW IT'S MADE

Purpose of Reinforcement

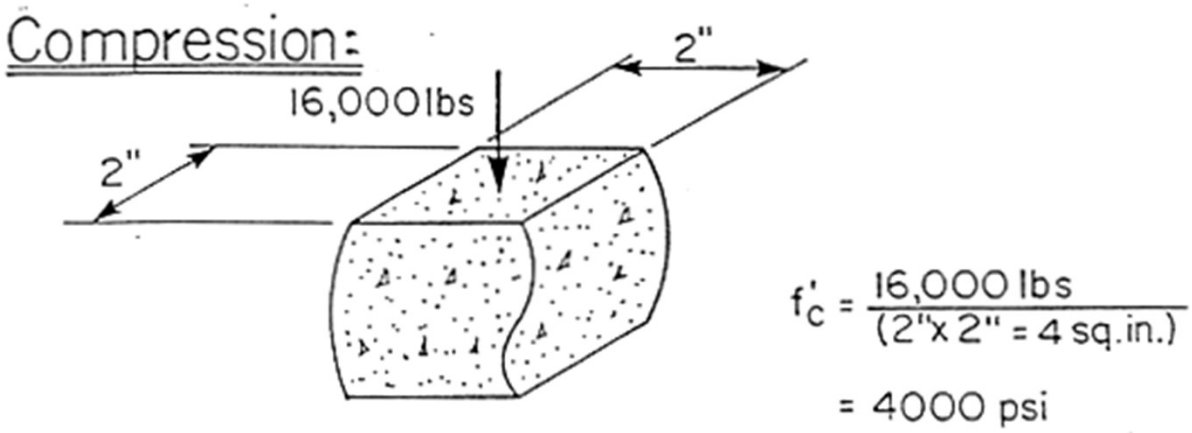
- Concrete properties
  - Strong in compression
  - Weak in tension
- Reinforcement supplies strength to withstand tensile and shear forces experienced by concrete

Compressive Forces on Concrete



Concrete can withstand compression

Concrete Under Compression

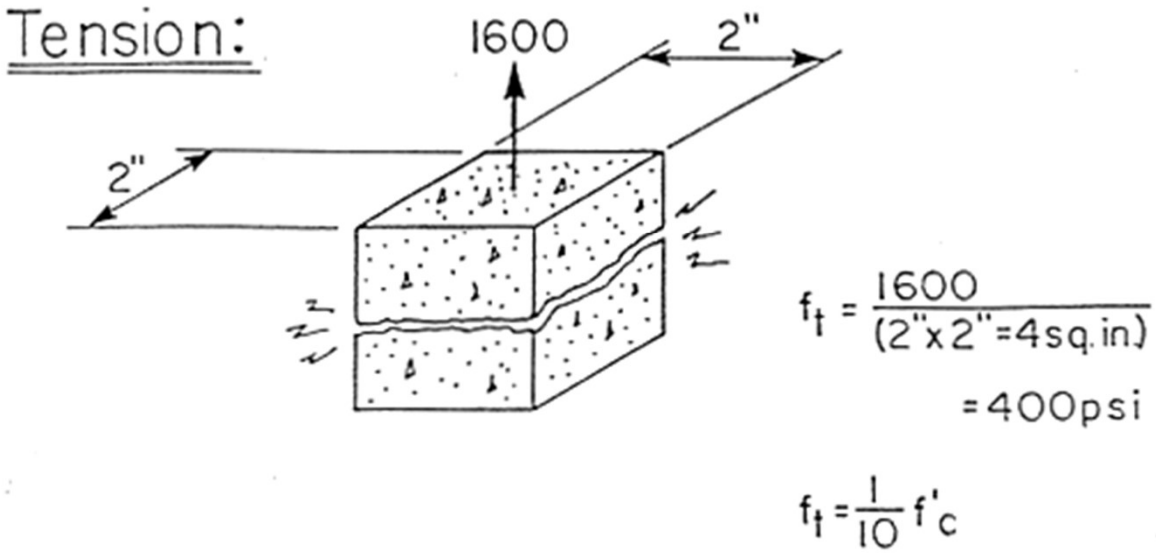


This 2” X 2” cube of concrete withstands a 4000 psi compressive force

Tensile Forces on Concrete

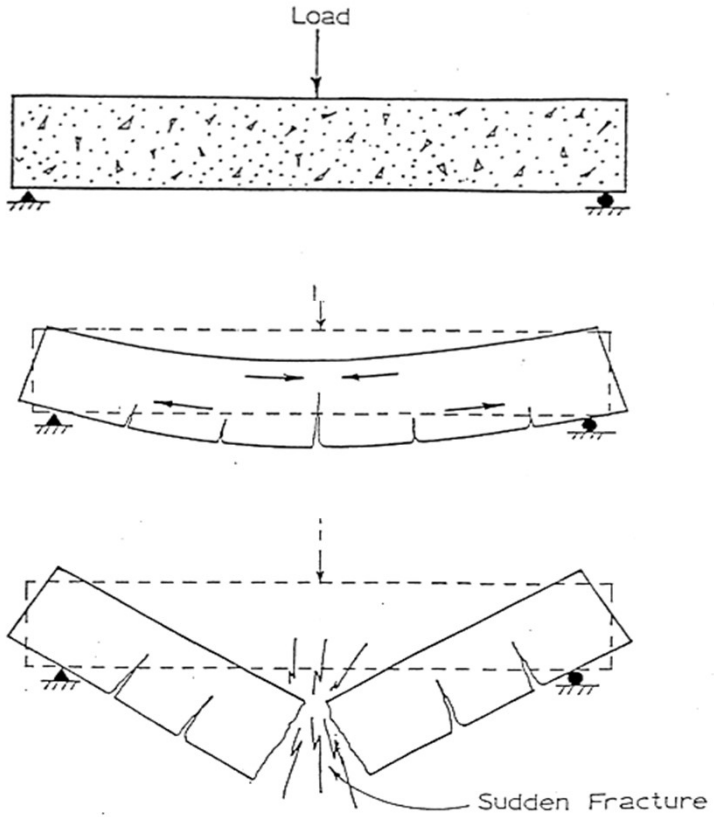
Without reinforcement, concrete will fail in tension

Concrete Under Tension

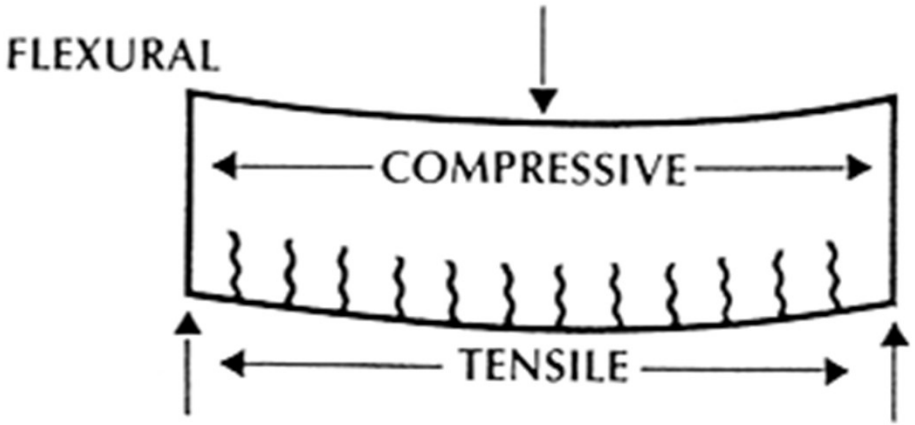


The same 2” X 2” cube of concrete fails under a 400 psi *tensile* force

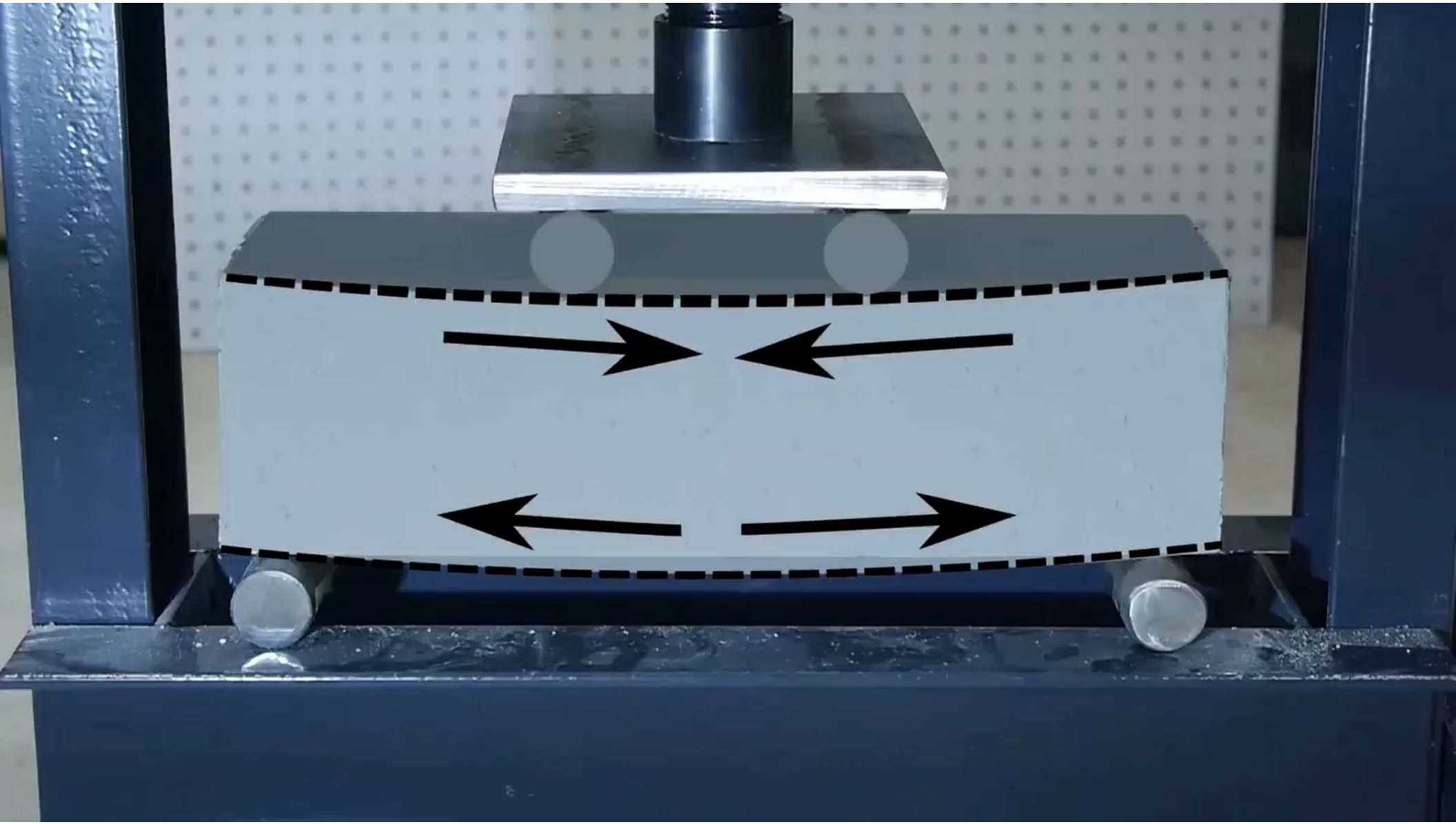
Non-reinforced Concrete Behavior



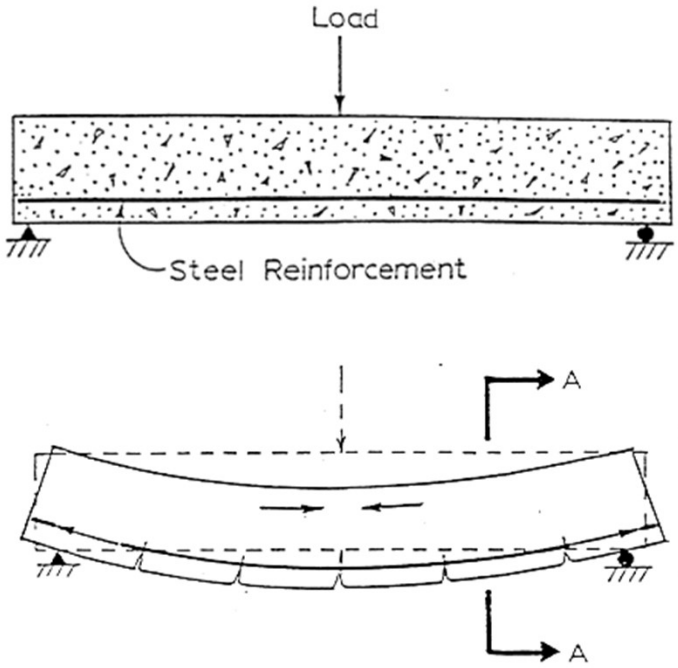
Flexural Forces on Concrete



Without reinforcement, the bottom side will fail in tension

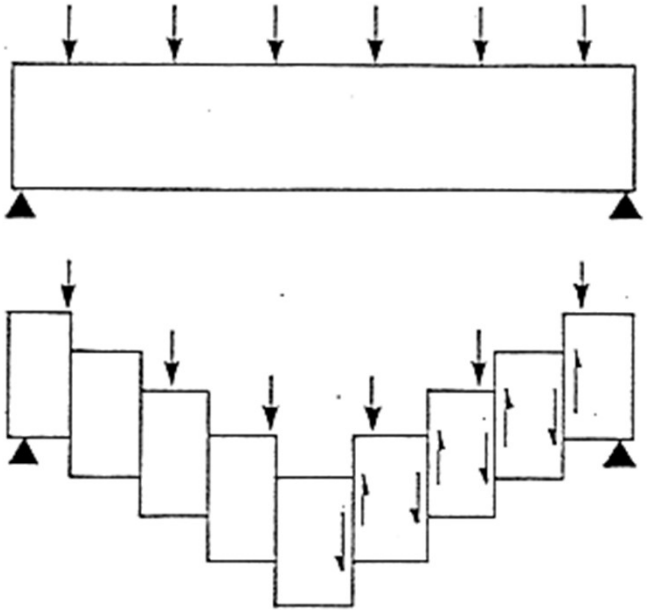


Reinforced Concrete Behavior



Concrete Behavior Under Shear

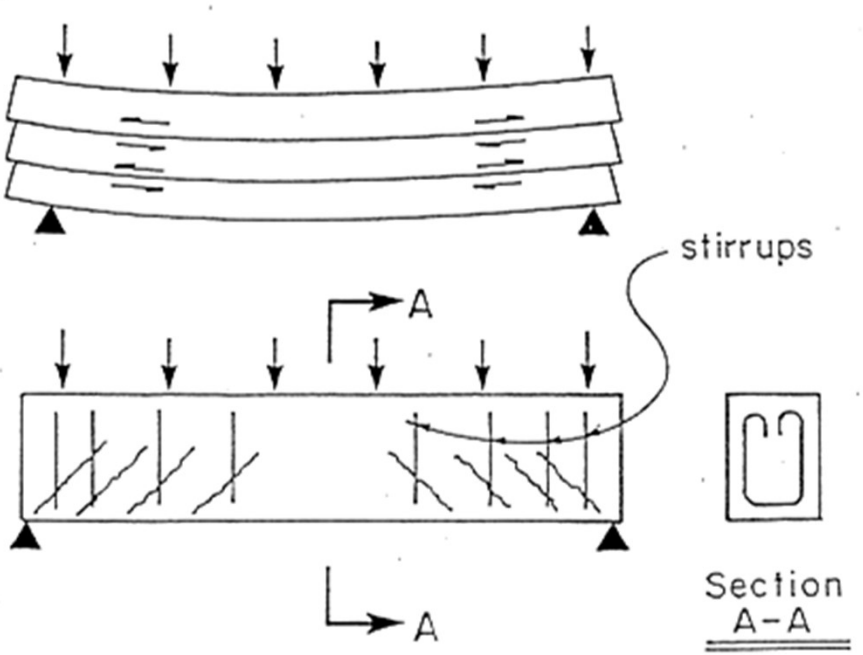
Vertical Shear



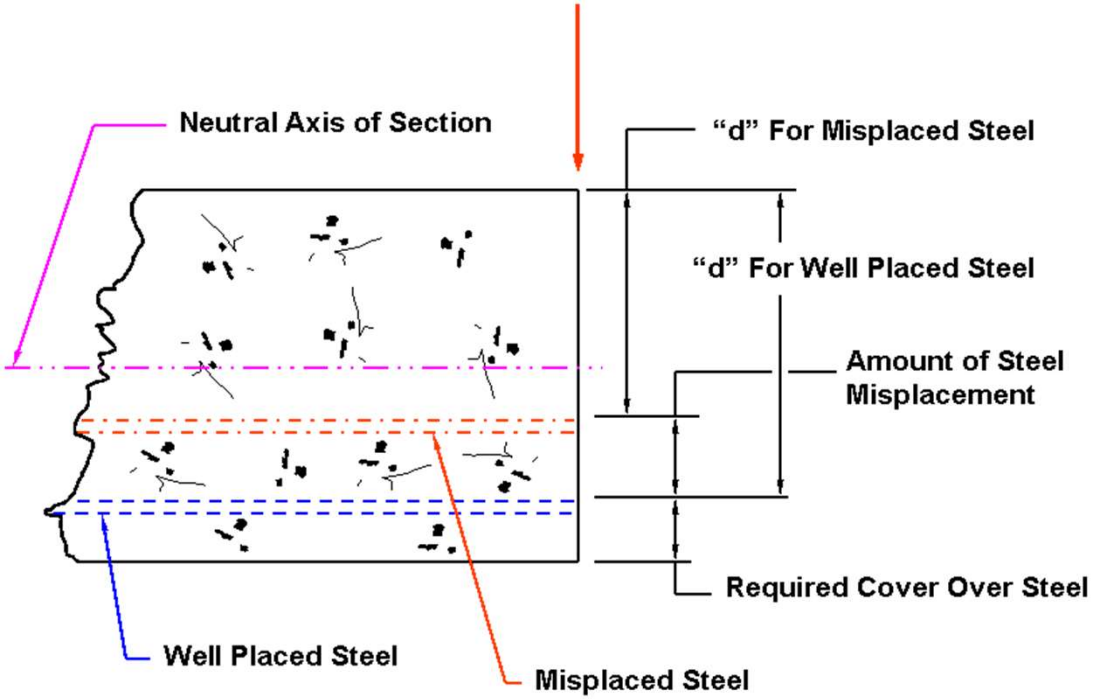
Concrete Behavior Under Shear

Horizontal shear

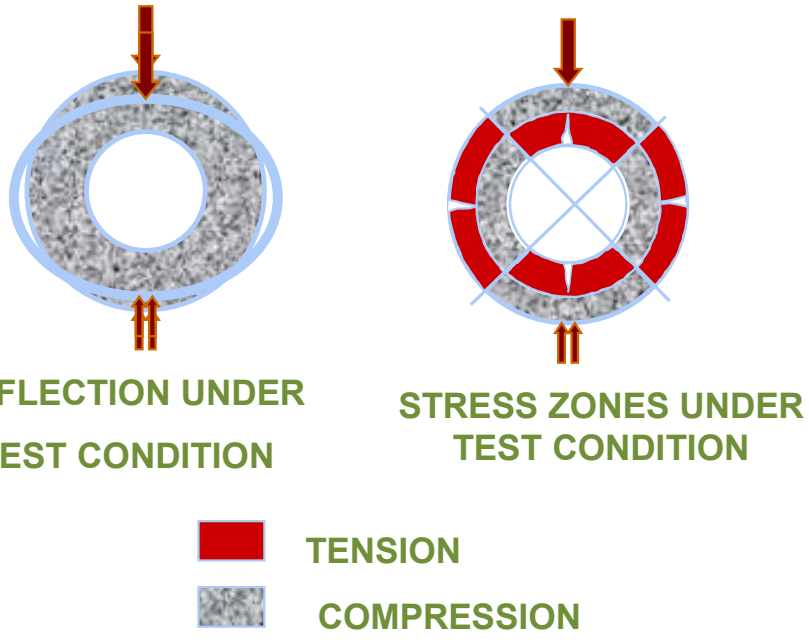
shear reinforcement



Effectiveness of Placement



0.01” Crack in Pipe



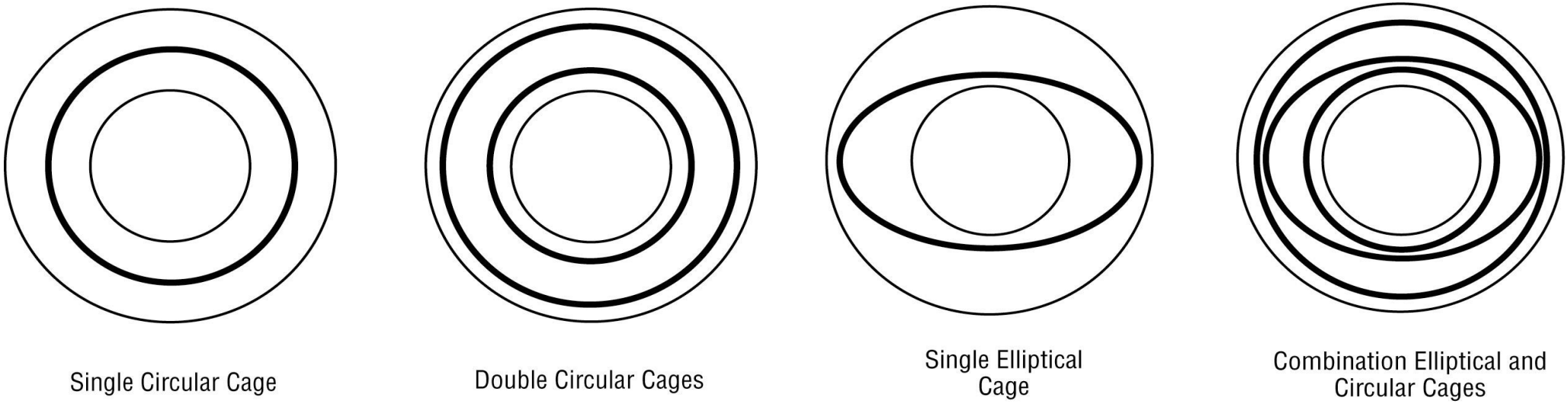
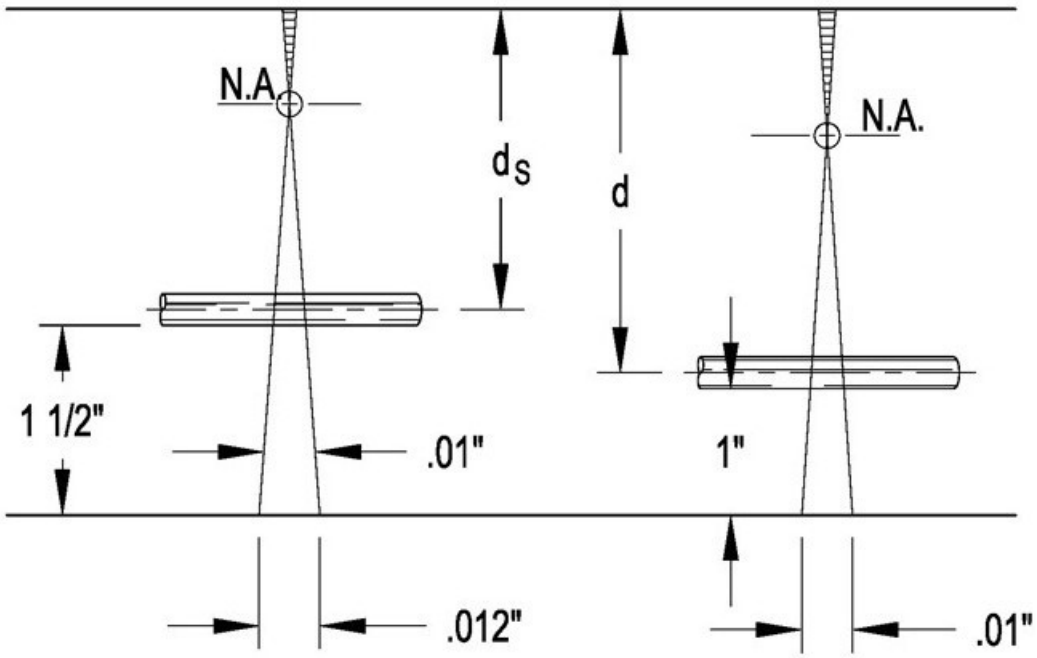


Figure 2.1. Four Cage Configurations Commonly Employed in the Manufacture of Reinforced Concrete Pipe.

EXAMPLE:

Ø36″ X 4″ WALL



MOVING STEEL INTO WALL TO 1 ½” VS 1” COVER INCREASED STEEL BY 47% DUE TO SHORTER d AND DUE TO CRACKING GEOMETRY

Ø36″ X 4″ WALL

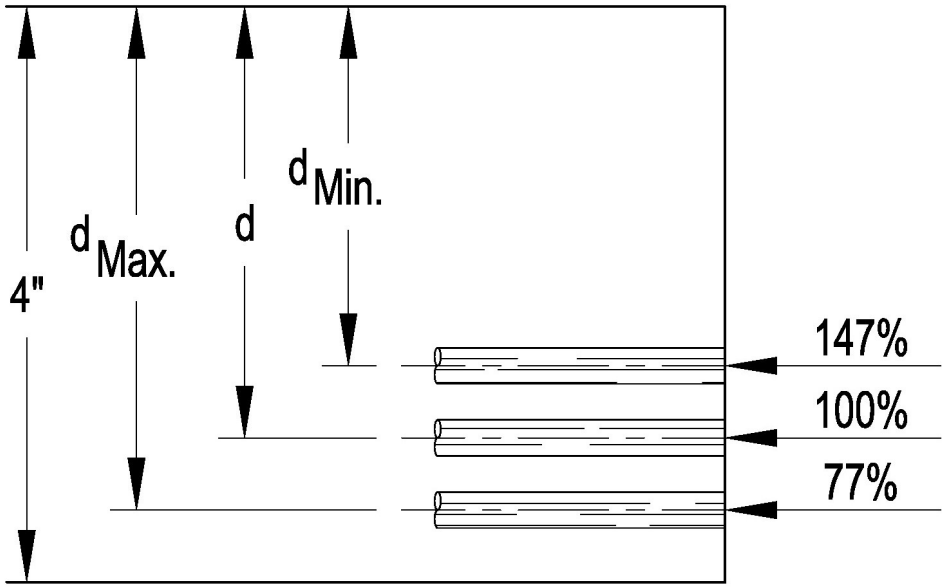
AS d = RESISTANCE TO CRACK WIDTH

d. MIN. = 147 %

d. NOM. = 100%

d. MAX. = 77%

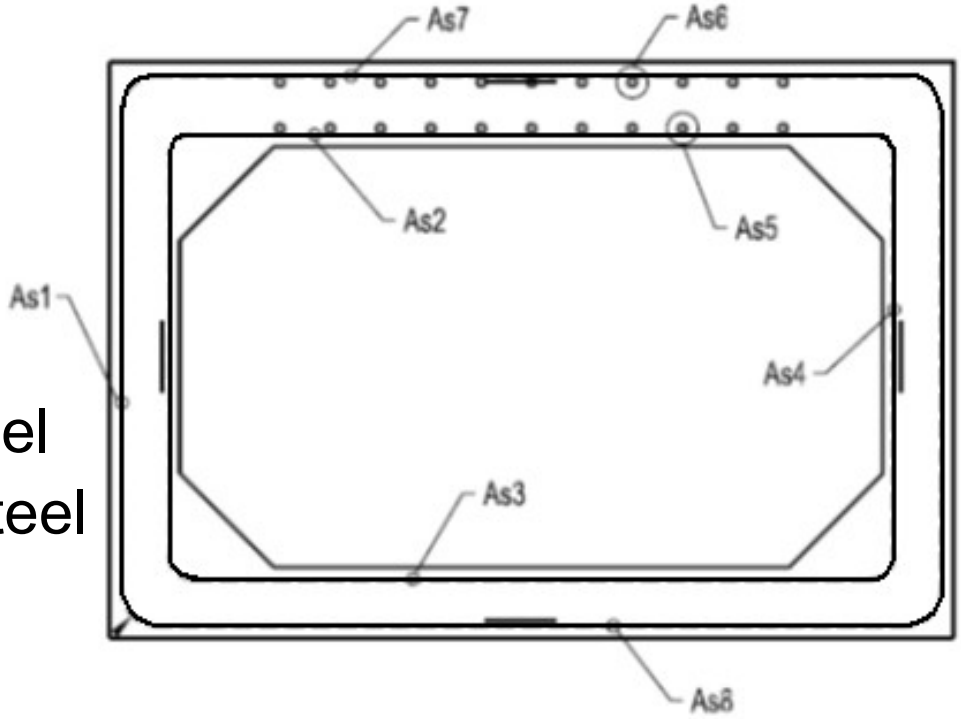
D- LOAD WOULD VARY BY 34% IF WE USED THE ALLOWED CAGE POSITION TOLERANCE FROM C76



Box Culvert

Steel Nomenclature

As_1 = Sidewall outside face
As_2 = Top slab inside face
As_3 = Bottom slab inside face
As_4 = Sidewall inside face
As_5 = Top slab inside distribution steel
As_6 = Top slab outside distribution steel
As_7 = Top slab outside face
As_8 = Bottom slab outside face



Effectiveness of Placement

1” cover vs. 1-1/4” cover for various fill heights

PRECAST BOX CULVERT DESIGNS

Spec.	Box Size S x R	Fill Ht.	Live Load	Slab / Wall Thickness Tt	Tb	Ts	H	Bx Wt. (lb/ft)	Circumf. Reinf. Areas, in.^{2}/ft. A_{s1}	A_{s2}	A_{s3}	A_{s4}	A_{s7}	A_{s8}	Long. A_{s5}	A_{s6}	M	Clear Concrete Cover, in. c_1	c_2	c_3	c_4	c_7	c_8	f'c ksi	f_v ksi
C1577	8' x 6'	5'	HL93	8"	8"	8"	8"	3,200	0.19	0.27	0.29	0.19	-	-	-	-	45"	1.00	1.00	1.00	1.00	-	-	5.0	65
C1577	8' x 6'	5'	HL93	8"	8"	8"	8"	3,200	0.19	0.28	0.30	0.19	-	-	-	-	45"	1.25	1.25	1.25	1.25	-	-	5.0	65
									0%	4%	3%														
C1577	8' x 6'	10'	HL93	8"	8"	8"	8"	3,200	0.22	0.33	0.35	0.19	-	-	-	-	42"	1.00	1.00	1.00	1.00	-	-	5.0	65
C1577	8' x 6'	10'	HL93	8"	8"	8"	8"	3,200	0.23	0.35	0.37	0.19	-	-	-	-	42"	1.25	1.25	1.25	1.25	-	-	5.0	65
									5%	6%	6%														
C1577	8' x 6'	15'	HL93	8"	8"	8"	8"	3,200	0.30	0.45	0.47	0.19	-	-	-	-	42"	1.00	1.00	1.00	1.00	-	-	5.0	65
C1577	8' x 6'	15'	HL93	8"	8"	8"	8"	3,200	0.31	0.47	0.49	0.19	-	-	-	-	42"	1.25	1.25	1.25	1.25	-	-	5.0	65
									3%	4%	4%														
C1577	8' x 6'	20'	HL93	8"	8"	8"	8"	3,200	0.38	0.58	0.60	0.19	-	-	-	-	42"	1.00	1.00	1.00	1.00	-	-	5.0	65
C1577	8' x 6'	20'	HL93	8"	8"	8"	8"	3,200	0.39	0.61	0.63	0.19	-	-	-	-	42"	1.25	1.25	1.25	1.25	-	-	5.0	65
									3%	5%	5%														
C1577	8' x 6'	25'	HL93	8"	8"	8"	8"	3,200	0.46	0.72	0.74	0.19	-	-	-	-	42"	1.00	1.00	1.00	1.00	-	-	5.0	65
C1577	8' x 6'	25'	HL93	8"	8"	8"	8"	3,200	0.49	0.75	0.77	0.19	-	-	-	-	42"	1.25	1.25	1.25	1.25	-	-	5.0	65
									7%	4%	4%														

Effects of Increased Steel Cover

- Reduced 0.01” strength
- Reduced shear strength
- Reduced radial tension strength
- Increased cost
- Waste of steel

Effectiveness of Placement

- It is critical to have correct steel placement for both pipe and box culverts

Reinforcement Type and Identification

Reinforcement Types

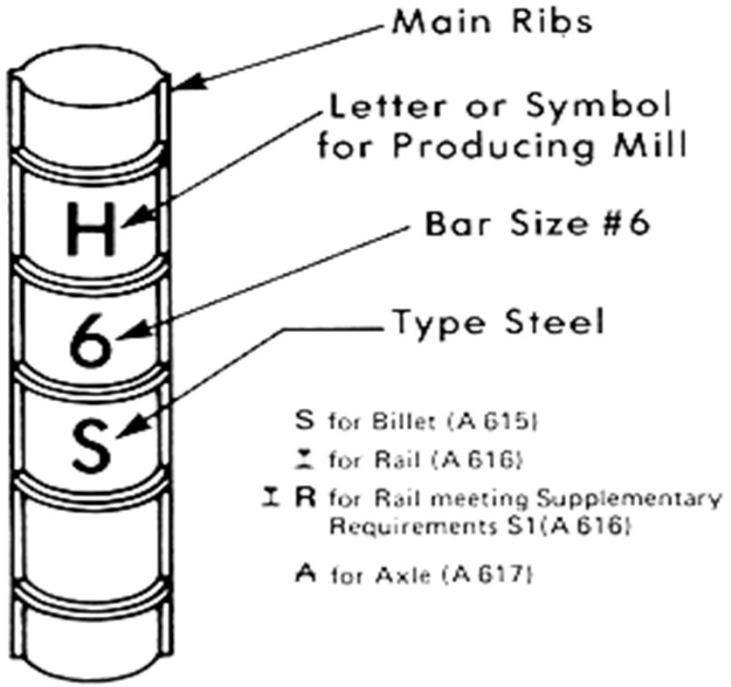
- Reinforcing bars
- Reinforcing wire
- Bar mats and welded wire fabric
- Zinc or epoxy coated reinforcement
- Prestressing and post tensioning

❖All types must meet “Buy America” Requirements for federally funded projects

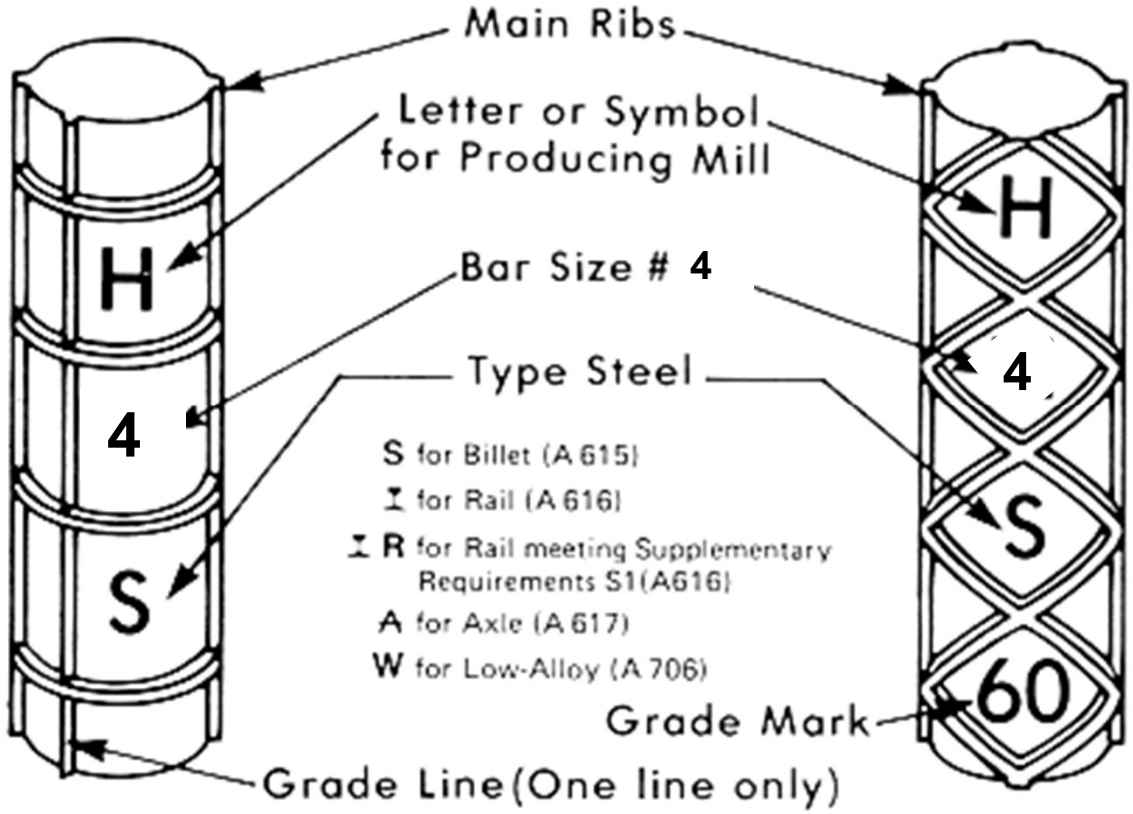
Reinforcing Bars

- Conform to specifications
  - ASTM A615 (New Billet)
  - ASTM A616 (Rail)
  - ASTM A617 (Axle)
  - ASTM A706 (Weldable)
- Other bars may be used if permitted by design
- Mill certificates required for each shipment

Grade 40 & 50 Rebar



Grade 60 & A706 Rebar



Steel Area Using Different Combinations of Bar Sizes and Spacing

Spacing	#4	#5	#6	#7	#8	#9	#10	#11
2 in.	1.20	1.86	2.64					
3 in.	0.80	1.24	1.76	2.40	3.16	4.00		
4 in.	0.60	0.93	1.32	1.80	2.37	3.00	3.81	4.68
5 in.	0.48	0.74	1.06	1.44	1.90	2.40	3.05	3.74
6 in.	0.40	0.62	0.88	1.20	1.58	2.00	2.54	3.12
7 in.	0.34	0.53	0.75	1.03	1.35	1.71	2.18	2.67
8 in.	0.30	0.47	0.66	0.90	1.19	1.50	1.91	2.34
9 in.	0.27	0.41	0.59	0.80	1.05	1.33	1.69	2.08
10 in.	0.24	0.37	0.53	0.72	0.95	1.20	1.52	1.87
11 in.	0.22	0.34	0.48	0.65	0.86	1.09	1.39	1.70
12 in.	0.20	0.31	0.44	0.60	0.79	1.00	1.27	1.56
13 in.	0.18	0.29	0.41	0.55	0.73	0.92	1.17	1.44
14 in.	0.17	0.27	0.38	0.51	0.68	0.86	1.09	1.34
15 in.	0.16	0.25	0.35	0.48	0.63	0.80	1.02	1.25
16 in.	0.15	0.23	0.33	0.45	0.59	0.75	0.95	1.17
17 in.	0.14	0.22	0.31	0.42	0.56	0.71	0.90	1.10
18 in.	0.13	0.21	0.29	0.40	0.53	0.67	0.85	1.04

Reinforcing Wire (Plain and Deformed)

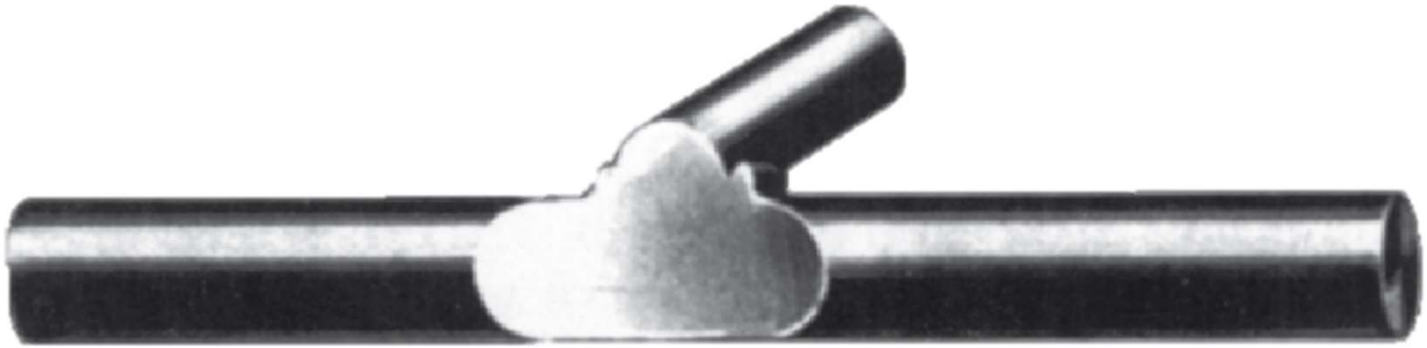
- Conform to (except prestressing wire)
  - ASTM A1064
- Other wire may be used if permitted by design
- Mill certificates for each shipment

Bar Mats and WWR (Plain and deformed)

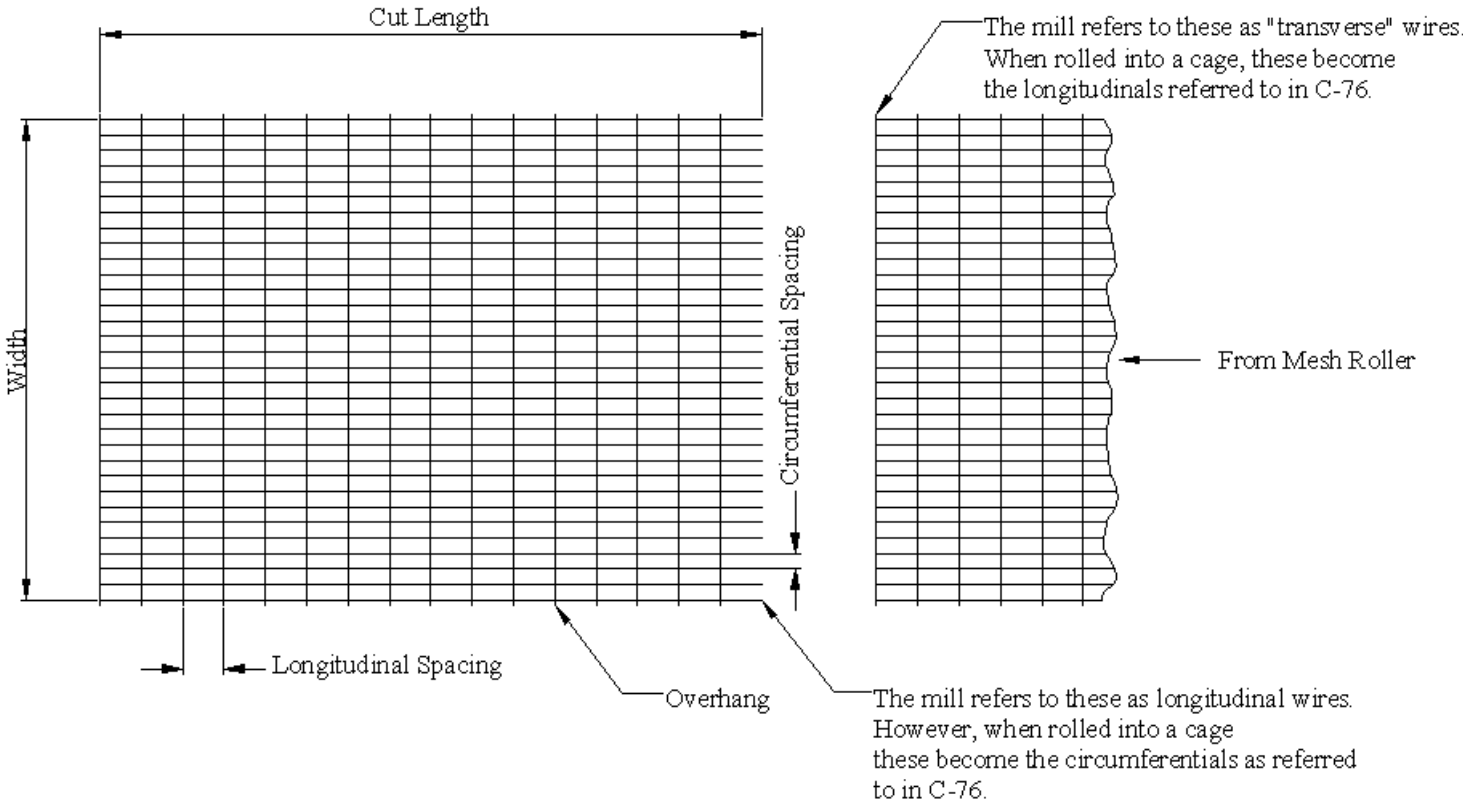
- Conform to
  - ASTM A1064
- Mill certificates for each shipment
- Applications of rolled vs. straight

How Welded Wire Reinforcement is Made

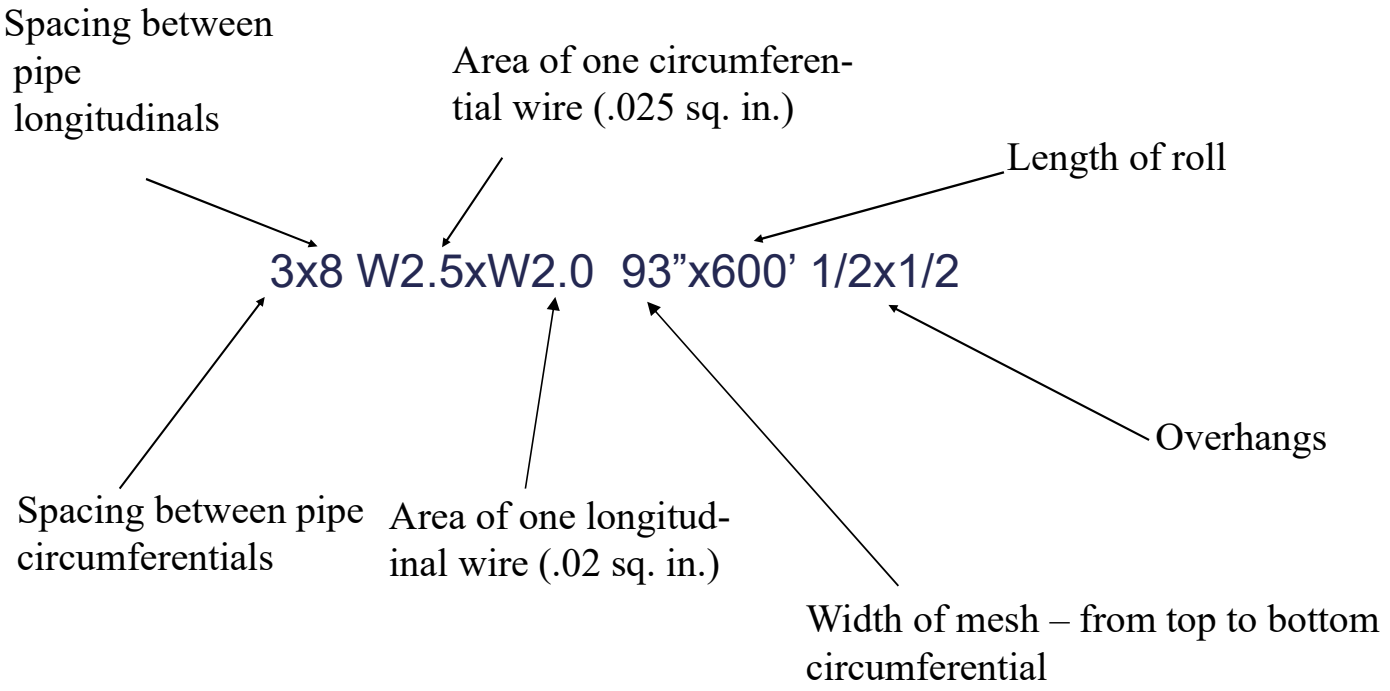
Welded Wire Reinforcement



Welded Wire Reinforcement



Cage Basics



W = Plain/Smooth, D = Deformed

Wire Size and Designation

- No. = Cross sectional Area in Hundredths of Sq. In.
- Thus
  - W5 = 0.05 Sq. In.
  - W5.5 = 0.055 Sq. In.
  - D10 = 0.10 Sq. In.

Cage Basics

- Given 3x8 W2.5xW2.0
- **What is the steel area per foot of pipe?**

$$A = 0.025 \times \frac{12}{3} = 0.10 \text{ in}^2/\text{ft}$$

Structural Integrity Depends on

- **Grade** of the reinforcing steel
- **Size** of the reinforcing steel
- **Spacing** of the reinforcing steel
- **Positioning** of the reinforcing steel

Thank You

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ACPA

American Concrete Pipe Association