Introduction to Prestressing
CE 572

Purdue University
School of Civil Engineering

Julio Ramirez

Definition of Prestressing

- It consists of preloading the structure before application of design loads in such a way so as to improve its general performance.

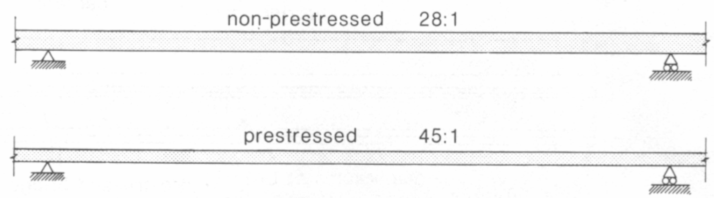
Objectives of Prestressing

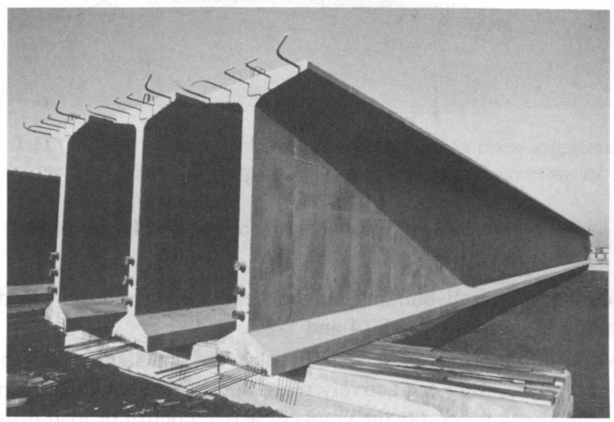
- ❖Control or eliminate tensile stresses in the concrete (cracking) at least up to service load levels.
- ❖Control or eliminate deflection at some specific load level.
- ❖Allow the use of high strength steel and concrete.

Net Result of Prestressing

- ❖Improved performance of concrete in “ordinary” design situations (compared to R/C).
- ❖Extended range of application of structural concrete (longer spans).
- ❖Innovative forms of structures.

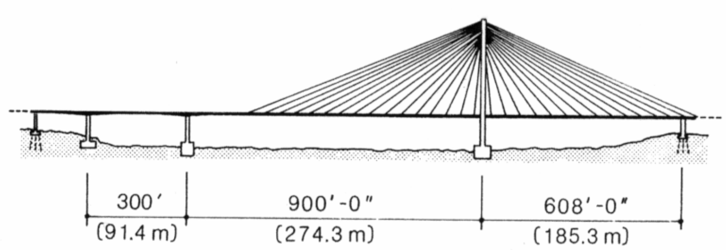
Extended Range of Application



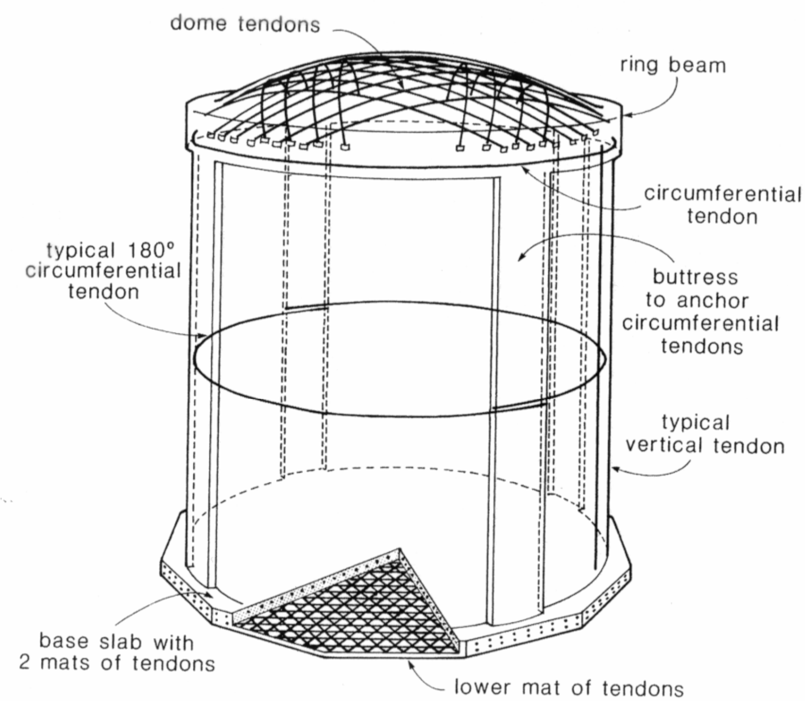


These 90 in. (2300 mm) deep pretensioned precast I-girders will be post-tensioned after erection. Photograph courtesy of Con-Force Structures Ltd.

Examples of Structures



East Huntington Bridge over the Ohio River.



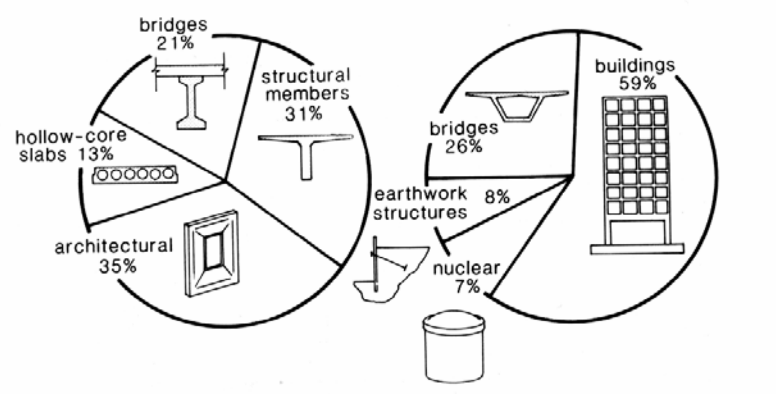
Prestressed concrete containment structure for nuclear power plant.

Partial Prestressing

❖ Intermediate state, in which tension and usually flexure cracking is allowed at full service load level. Some advantages are:
- Prevents excessive camber at more typical loads less than full service loads.
- Reduced prestressing force (less $$$) compared to full prestressing (zero tensile stresses at full service load).

Applications of Prestressed Concrete in the US and Canada – Figure 1

❖ About 200,000 tons of prestressing steel used in US/Canada each year (~ ¼ of the total world consumption)

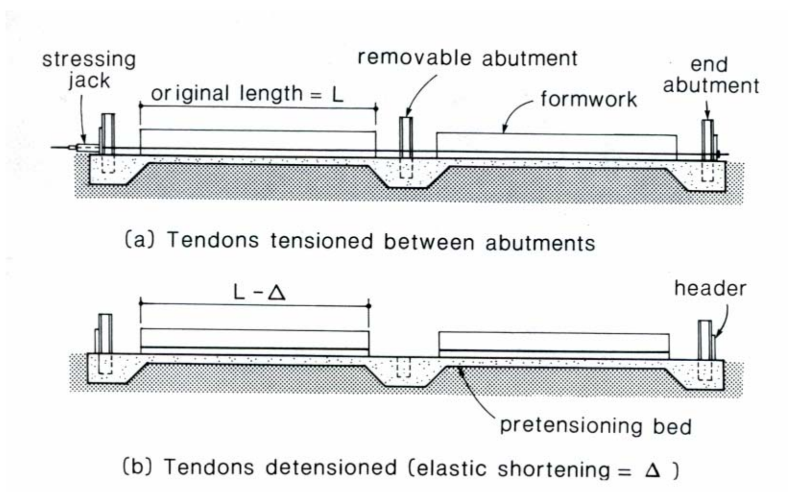


(a) Applications of precast products

(b) Applications of post-tensioning steel

Prestressing Methods

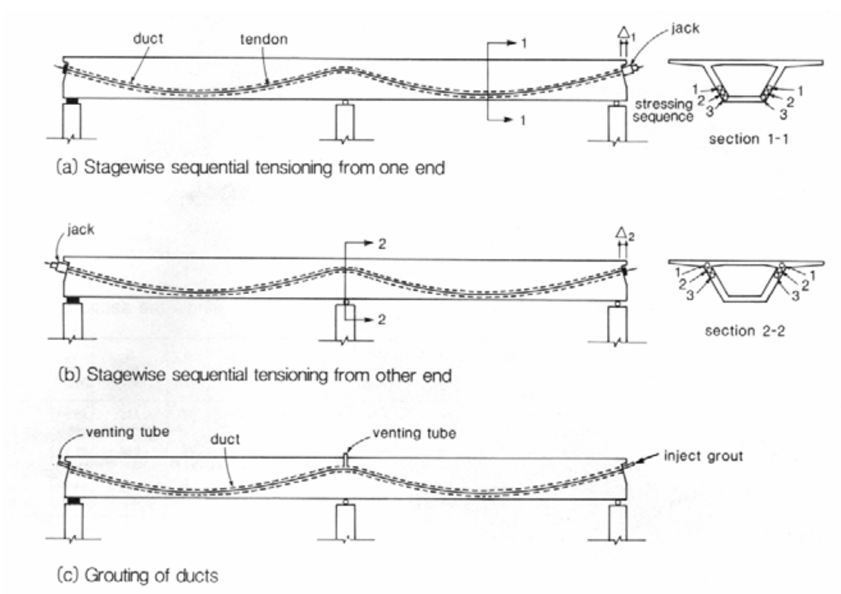
❖ Pretensioning: suited for mass production.



***Video (PCI)**

Prestressing Methods

❖ Post-Tensioning: jacking against the member and the eccentricity is easily varied along the length of the member.



(a) Stagewise sequential tensioning from one end

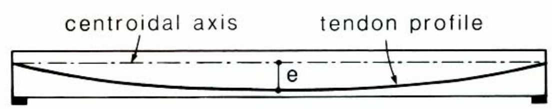
(b) Stagewise sequential tensioning from other end

(c) Grouting of ducts

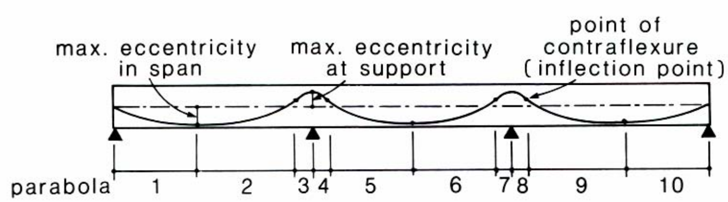
Post-Tensioning Sequence

- Place reinforcing cage and post-tensioning ducts inside the formwork.
- After casting and curing of the concrete, the tendons are tensioned and anchored with special jacks that react against the member.
- Unless unbonded tendons are being used, the duct is then grouted to complete the post-tensioning operation.
- Slides (PTI)-------

Profiles of Post-Tensioned Tendons

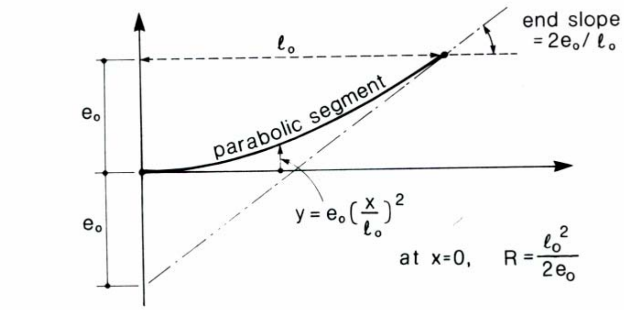


(a) Parabolic tendon profile for simply supported beam

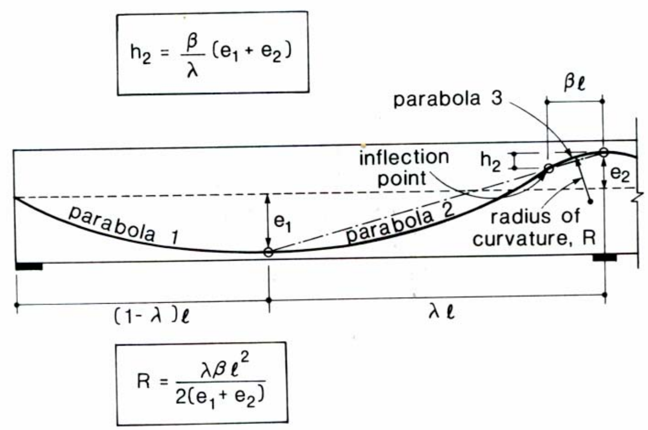


(b) Parabolic segments used to describe tendon profile of three-span continuous beam

Geometry of Parabolic Profiles

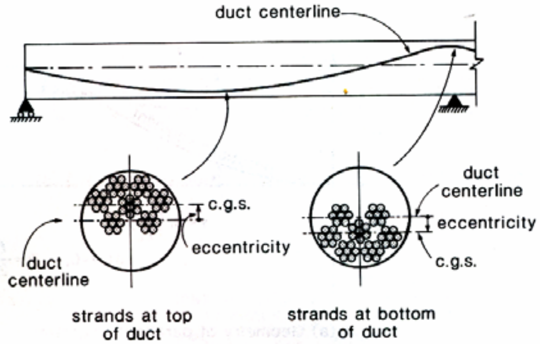


(a) Geometry of parabolic segment



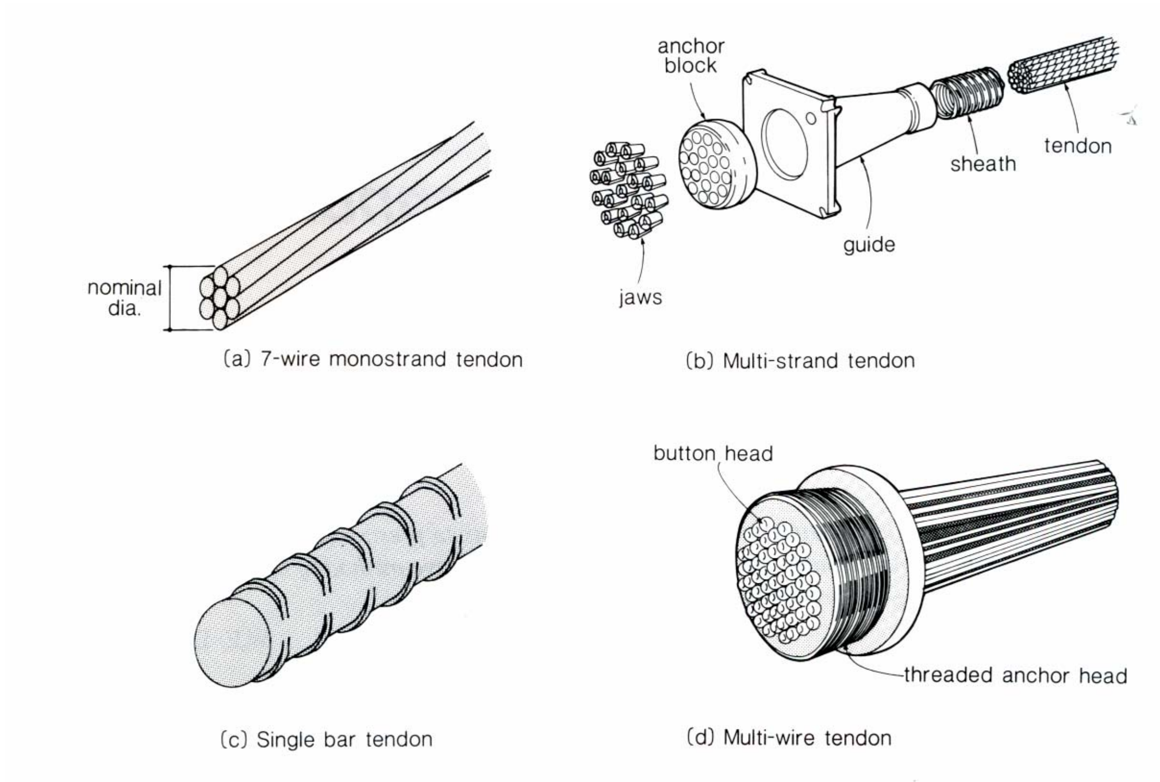
(b) Parabolic segments with compatible slopes

Location and Eccentricity of Tendon in Duct After Stressing



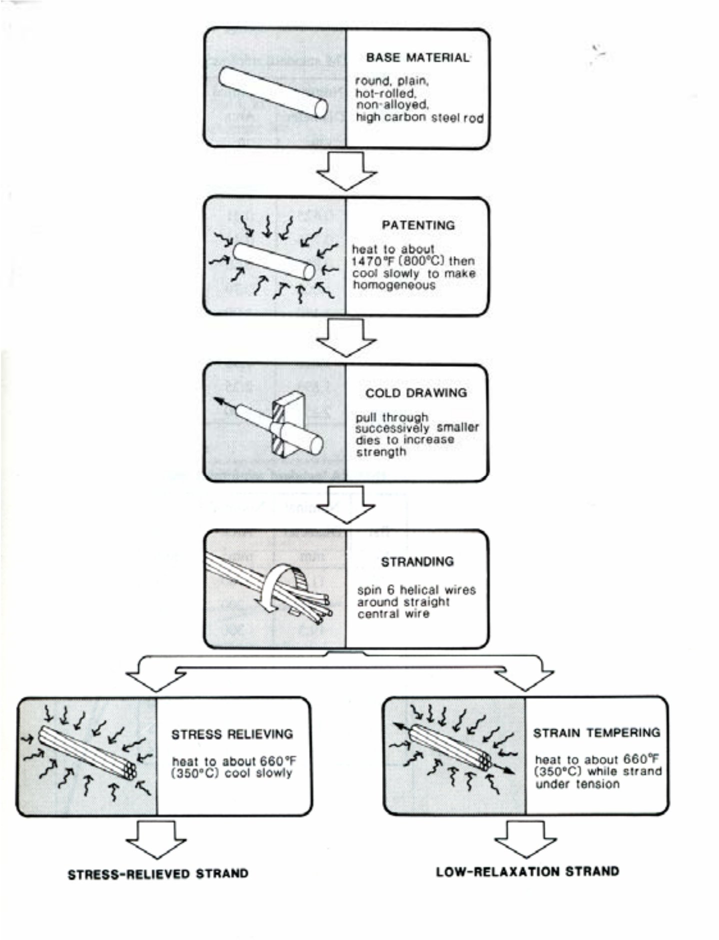
tendon size	sheath diameter in. (mm)	eccentricity in. (mm)
no. of 1/2 in. dia. (13mm) strands		
3	1.25 (32)	0.28 (7)
4	1.63 (41)	0.28 (7)
7	2.00 (51)	0.32 (8)
12	2.50 (64)	0.43 (11)
19	3.13 (80)	0.51 (13)
22	3.38 (86)	0.47 (12)
31	4.00 (102)	0.55 (14)
55	5.50 (140)	0.90 (23)
no. of 0.6 in. dia. (15mm) strands		
3	1.50 (38)	0.20 (5)
4	2.00 (38)	0.20 (5)
7	2.25 (57)	0.40 (10)
12	3.00 (76)	0.50 (13)
19	3.75 (95)	0.70 (18)
31	5.00 (127)	0.90 (23)
55	6.50 (165)	1.20 (30)

Materials: Types of Prestressing Steel



Production of Seven Wire Strand

❖ **Low relaxation versus stress-relieved**



MATERIAL PROPERTIES
PRESTRESSING STEEL

Design Aid 11.2.4 Properties and design strengths of prestressing bars

Plain Prestressing Bars, f_{pu} = 145 ksi[a]						
Nominal Diameter, in.	¾	⅞	1	1⅛	1¼	1⅜
Area, sq. in.	0.442	0.601	0.785	0.994	1.227	1.485
Weight, plf	1.50	2.04	2.67	3.38	4.17	5.05
0.7 f_{pu} A_{ps}, kips	44.9	61.0	79.7	100.9	124.5	150.7
0.8 f_{pu} A_{ps}, kips	51.3	69.7	91.0	115.3	142.3	172.2
f_{pu} A_{ps}, kips	64.1	87.1	113.8	144.1	177.9	215.3

Plain Prestressing Bars, f_{pu} = 160 ksi[a]						
Nominal Diameter, in.	¾	⅞	1	1⅛	1¼	1⅜
Area, sq. in.	0.442	0.601	0.785	0.994	1.227	1.485
Weight, plf	1.50	2.04	2.67	3.38	4.17	5.05
0.7 f_{pu} A_{ps}, kips	49.5	67.3	87.9	111.3	137.4	166.3
0.8 f_{pu} A_{ps}, kips	56.6	77.0	100.5	127.2	157.0	190.1
f_{pu} A_{ps}, kips	70.7	96.2	125.6	159.0	196.3	237.6

Deformed Prestressing Bars						
Nominal Diameter, in.	⅝	1	1	1¼	1¼	1⅜
Area, sq. in.	0.28	0.85	0.85	1.25	1.25	1.58
Weight, plf	0.98	3.01	3.01	4.39	4.39	5.56
Ult. strength, f_{pu}, ksi	157	150	160[a]	150	160[a]	150
0.7 f_{pu} A_{ps}, kips	30.5	89.3	95.2	131.3	140.0	165.9
0.8 f_{pu} A_{ps}, kips	34.8	102.0	108.8	150.0	160.0	189.6
f_{pu} A_{ps}, kips	43.5	127.5	136.0	187.5	200.0	237.0

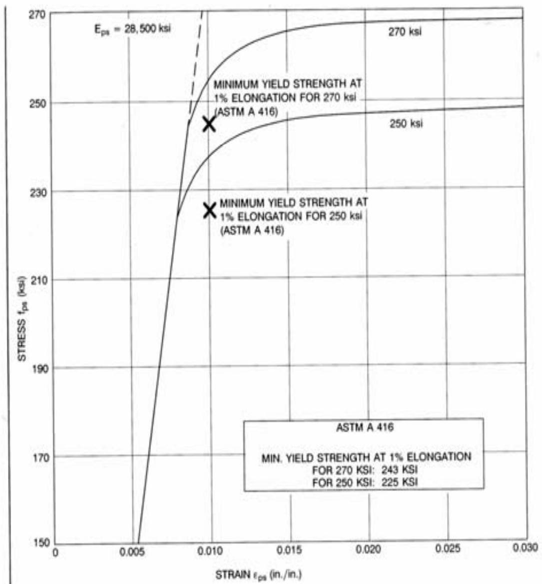
Stress-strain characteristics (all prestressing bars):
For design purposes, following assumptions are satisfactory:

E_s = 29,000 ksi

$f_y = 0.95 f_{pu}$

a. Verify availability before specifying.

Design Aid 11.2.5 Typical stress-strain curve, 7-wire low-relaxation prestressing strand



These curves can be approximated by the following equations:

250 ksi

$\varepsilon_{ps} \le 0.0076 : f_{ps} = 28,500\varepsilon_{ps}$ (ksi)

$\varepsilon_{ps} > 0.0076 : f_{ps} = 250 - \dfrac{0.04}{\varepsilon_{ps} - 0.0064}$ (ksi)

270 ksi

$\varepsilon_{ps} \le 0.0086 : f_{ps} = 28,500\varepsilon_{ps}$ (ksi)

$\varepsilon_{ps} > 0.0086 : f_{ps} = 270 - \dfrac{0.04}{\varepsilon_{ps} - 0.007}$ (ksi)

Concrete

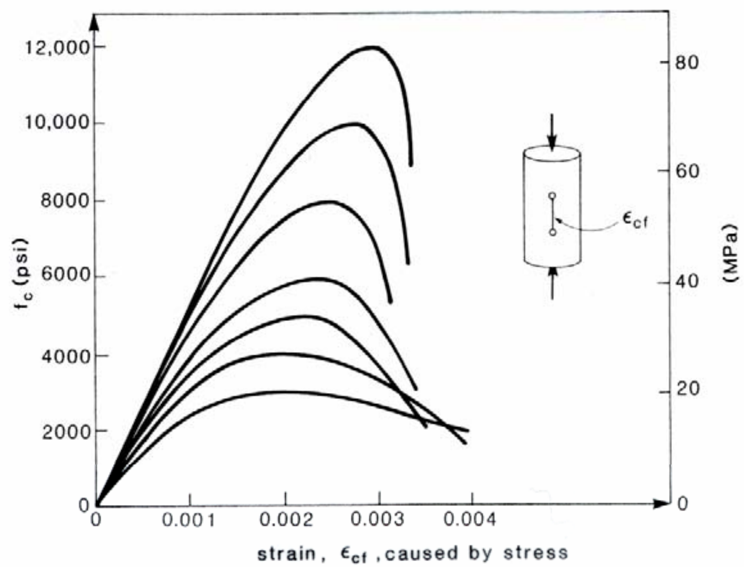


Table 3-3 Compressive stress-strain coefficients for normal-weight concrete.

f'_c	psi	3000	3500	4000	5000	6000	8000	10,000	12,000	16,000
	(MPa)	(20.7)	(24.1)	(27.6)	(34.5)	(41.4)	(55.2)	(69.0)	(82.7)	(110.3)
E_c	ksi	3191	3366	3530	3828	4098	4578	5000	5382	6060
	(MPa)	(22 000)	(23 200)	(24 300)	(26 400)	(28 300)	(31 600)	(34 500)	(37 100)	(41 800)
$\epsilon'_c \times 1000$		1.88	1.91	1.94	2.03	2.13	2.33	2.53	2.71	3.07
n		2.00	2.20	2.40	2.80	3.20	4.00	4.80	5.60	7.20
k		1.00	1.06	1.11	1.23	1.34	1.56	1.78	2.00	2.45

Hognestad Parabola

$$fc(\varepsilon) := \left[fcmax \cdot \left[\left(2 \cdot \frac{\varepsilon}{\varepsilon o} \right) - \left(\frac{\varepsilon}{\varepsilon o} \right)^2 \right] \right] \qquad Ec := 57000 \frac{\sqrt[2]{(fcmax)}}{1000}$$

Calculate ε_o (strain corresponding to peak stress, fcmax) using the secant Modulus of Elasticity at 0.5fcmax. Thus, fit The Hognestad expression through a point corresponding to 0.5fcmax and 0.5fcmax/Ec.

Prestress Force Levels