Department of Civil Engineering

Prestressed Concrete

Materials for Prestressing (1)
Prestressing steel

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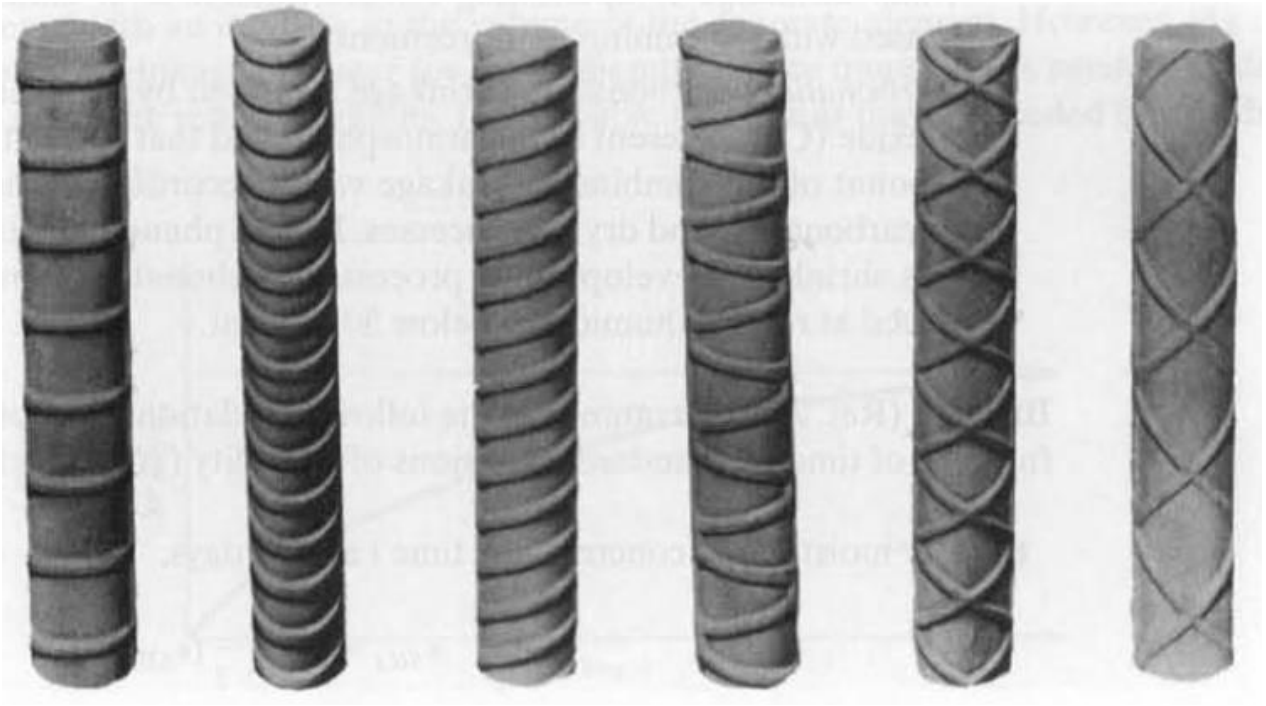
Non-Prestressing steel

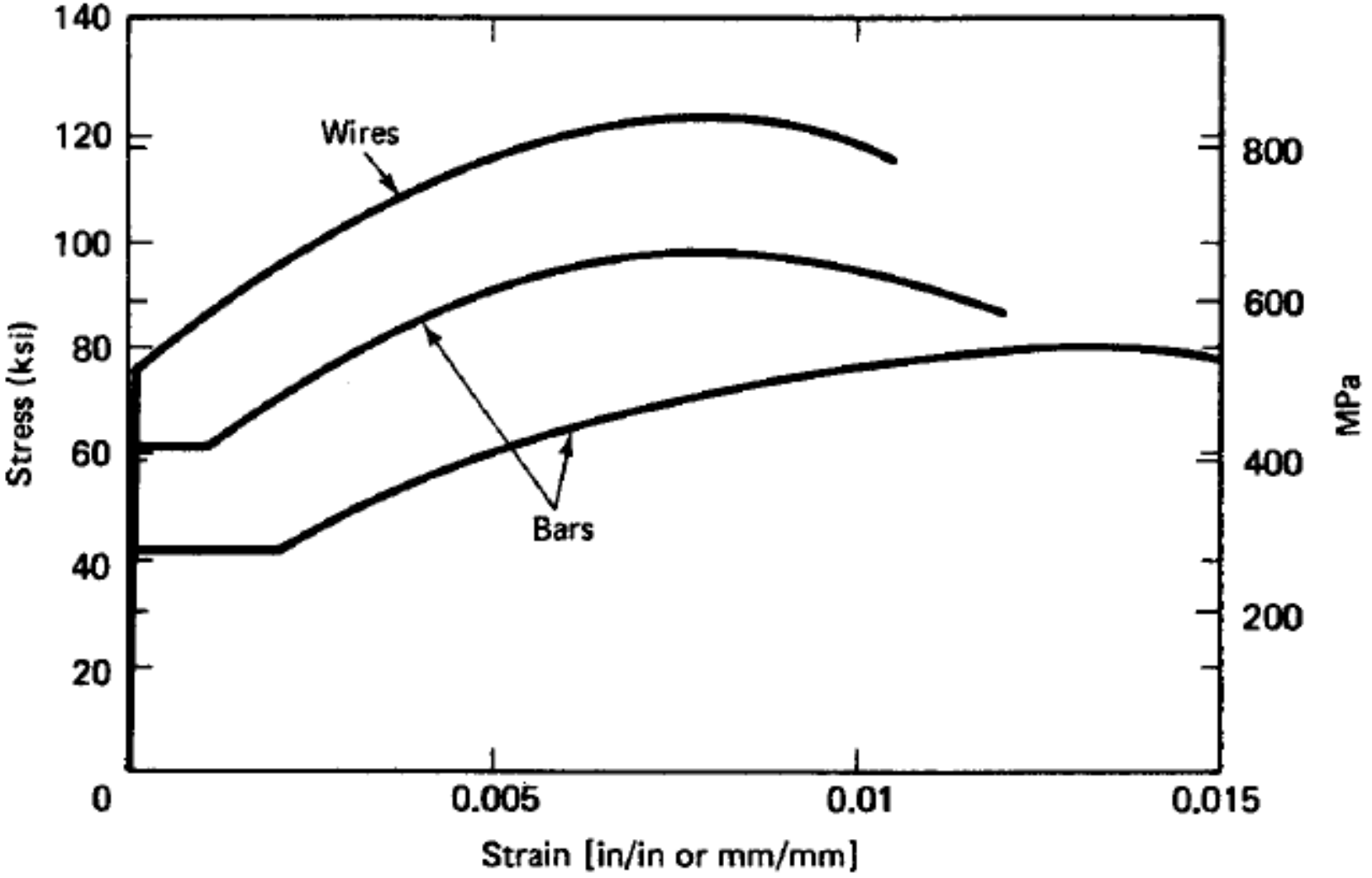
- Plain and deformed wires and bars used for RC.
- The most important properties are: Young's modulus E_c, Yield strength f_y, Ultimate strength f_u, grade and diameter.



Properties of standard reinforcing bars (Non-Prestressing steel)

Bar designation number	Weight per foot (lb)	Standard nominal dimensions		
		Diameter, d_b [in. (mm)]	Cross-sectional area, A_b (in.^{2})	Perimeter (in.)
3	0.376	0.375 (10)	0.11	1.178
4	0.668	0.500 (13)	0.20	1.571
5	1.043	0.625 (16)	0.31	1.963
6	1.502	0.750 (19)	0.44	2.356
7	2.044	0.875 (22)	0.60	2.749
8	2.670	1.000 (25)	0.79	3.142
9	3.400	1.128 (29)	1.00	3.544
10	4.303	1.270 (32)	1.27	3.990
11	5.313	1.410 (36)	1.56	4.430
14	7.65	1.693 (43)	2.25	5.32
18	13.60	2.257 (57)	4.00	7.09

Typical stress-strain curve of nonprestressing (reinforcing) steel



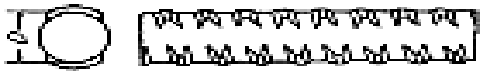
Prestressing steel

For prestressed concrete, high strength steel is used to provide high elongation to maintain the steel stress after the prestress loss. Ideally, it should also:

- Remain elastic up to relatively high stress.
- Show sufficient ductility before failure.
- Have good bonding properties, low relaxation, good resistance to corrosion.
- Be economical and easy to handle.

Prestressing reinforcement can be in the form of single wires, strand composed of several wires twisted to form single element, and high strength bars.

Types of prestressing steel

Type	Size (Diameter)		Shape
	mm	in.	
Plain round wire	2.0 ~ 9.0	0.06 ~ 0.360	
Indented wire	5.0 ~ 7.0	0.200 ~ 0.276	
Sumi - Twist	7.3 ~ 13.0	0.276 ~ 0.512	
Two-wire strand	2.9 x 2	0.114 x 2	
Seven-wire strand	8.2 ~ 15.2	0.250 ~ 0.600	
Nineteen-wire strand	17.8 ~ 21.8	0.700 ~ 0.860	
Round bar	9.2 ~ 32.0	0.362 ~ 1.260	
Threaded bar	23.0 ~ 32.0	0.906 ~ 1.260	

Seven-wire standard strand properties

Nominal diameter of strand (in.)	Breaking strength of strand (min. lb)	Nominal steel area of strand (sq in.)	Nominal weight of strands (lb per 1000 ft)*	Minimum load at 1% extension (lb)
		GRADE 250		
1/4 (0.250)	9,000	0.036	122	7,650
5/16 (0.313)	14,500	0.058	197	12,300
3/8 (0.375)	20,000	0.080	272	17,000
7/16 (0.438	27,000	0.108	367	23,000
1/2 (0.500)	36,000	0.144	490	30,600
3/5 (0.600)	54,000	0.216	737	45,900
		GRADE 270		
3/8 (0.375)	23,000	0.085	290	19,550
7/16 (0.438)	31,000	0.115	390	26,350
1/2 (0.500)	41,300	0.153	520	35,100
3/5 (0.600)	58,600	0.217	740	49,800

*100,000 psi = 689.5 MPa

0.1 in. = 2.54 mm; 1 in.^{2} = 645 mm^2

weight: mult. by 1.49 to obtain weight in kg per 1,000 m.

1,000 lb = 4,448 Newton

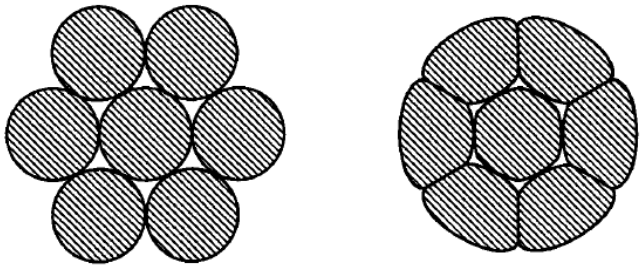
Source: Post-Tensioning Institute

The most commonly used is the 0.5 in diameter strand with minimum tensile strength of 270 ksi (1860 Mpa)

Most common prestressing steel types

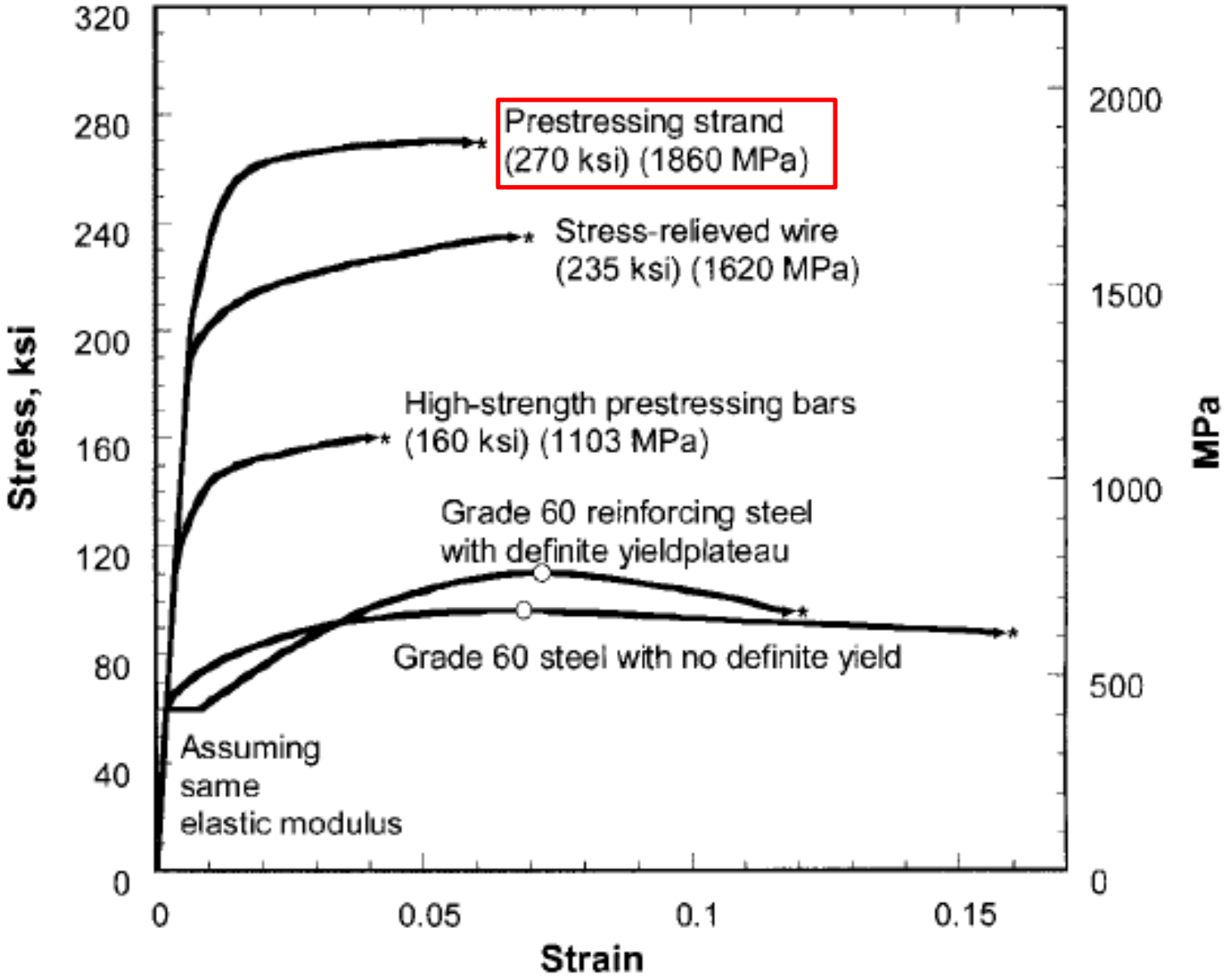
Prestressing reinforcements can be classified as:

- Stress-relieved and low relaxation wires.
- Stress-relieved and low relaxation strands, standard or compacted.



- High tensile steel bars, they must be cold drawn to raise their yield strength and stress relived to increase the ductility.

Stress-strain curve comparison

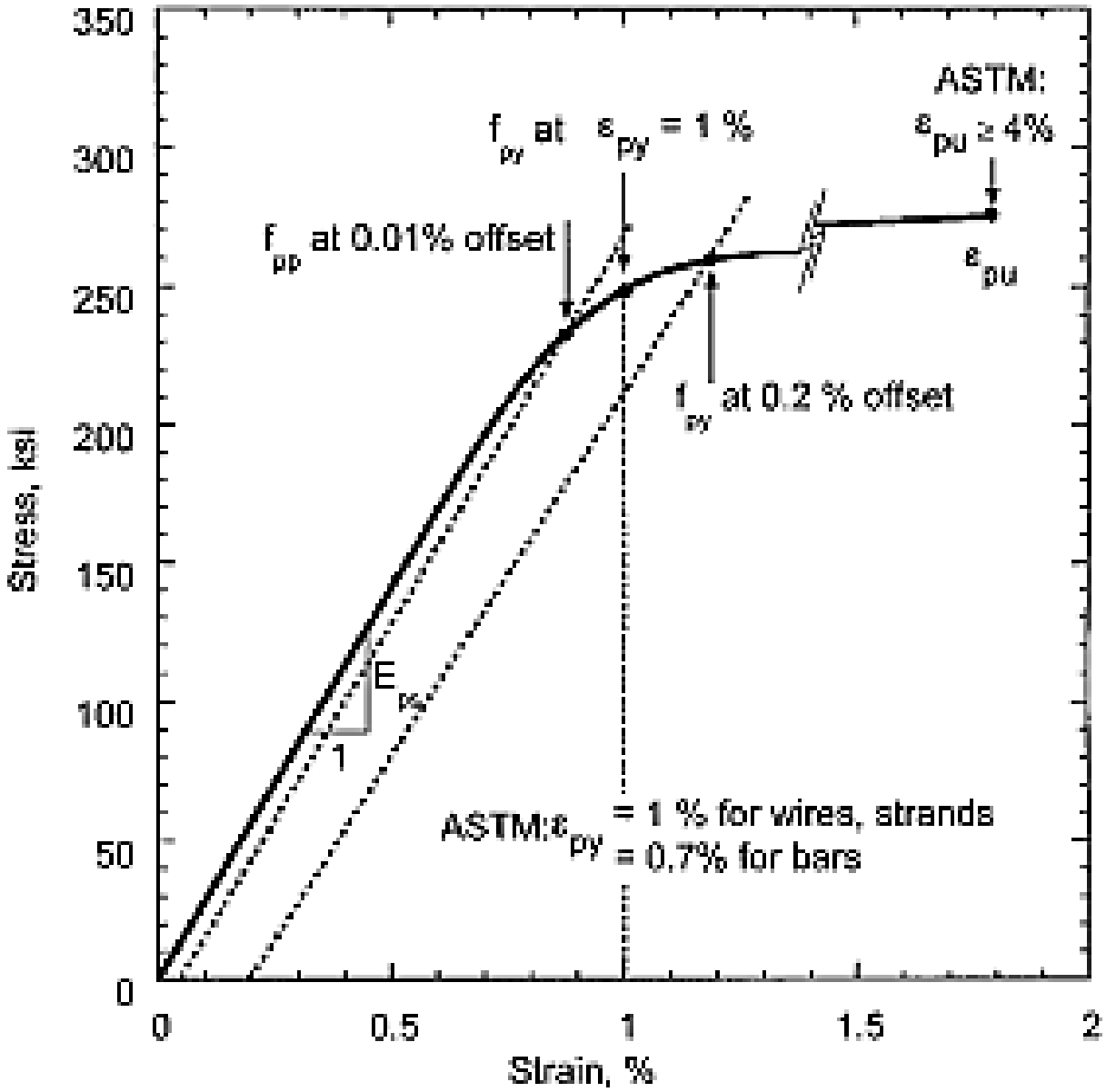


Mechanical properties of Prestressing steel

The main characteristics of prestressing steel are:

- *Yield strength (f_{py})*, it's not well defined and determine according to a strain criteria.
- *Modulus of elasticity (E_{ps})*, It's independent of the strength and calculated as the slope of the linear elastic portion of the curve.
- Minimum required *tensile strength or breaking stress (f_{pu})*, the most commonly used strands are those with an f_{pu} value of 1860 MPa.

Mechanical properties of prestressing steel



Minimum properties of Prestressing Tendons

Prestressing steel	ASTM standard	ASTM minimum specified		Other expected properties		
				Elastic modulus		Prop. limit: f_{pp} at 0.01% offset strain
		Yield strength	Elongation at failure	ksi	MPa	
Wires	A421	$f_{py} = 0.85 f_{pu}$ at $\varepsilon_{py} = 0.010$	ε_{pu}=0.040 Gauge length: 10 in (254 mm)	29,000	200,000	75 to 85% of minimum specified strength
Strands: Stress-relieved	A416	$f_{py} = 0.85 f_{pu}$ at $\varepsilon_{py} = 0.010$	ε_{pu}=0.040 Gauge length: 24 in (610 mm)	27,000	186,000	70 to 75% of minimum specified strength
Low-lax	A416	$f_{py} = 0.90 f_{pu}$ at $\varepsilon_{py} = 0.010$				
Bars	A722	Smooth bars: $f_{py} = 0.85 f_{pu}$ at $\varepsilon_{py} = 0.0070$ Deformed bars: $f_{py} = 0.80 f_{pu}$ at $\varepsilon_{py} = 0.0070$	ε_{pu}=0.40 Gauge length: 20 bar diameter	28,000	193,000	60 to 65% of minimum specified strength

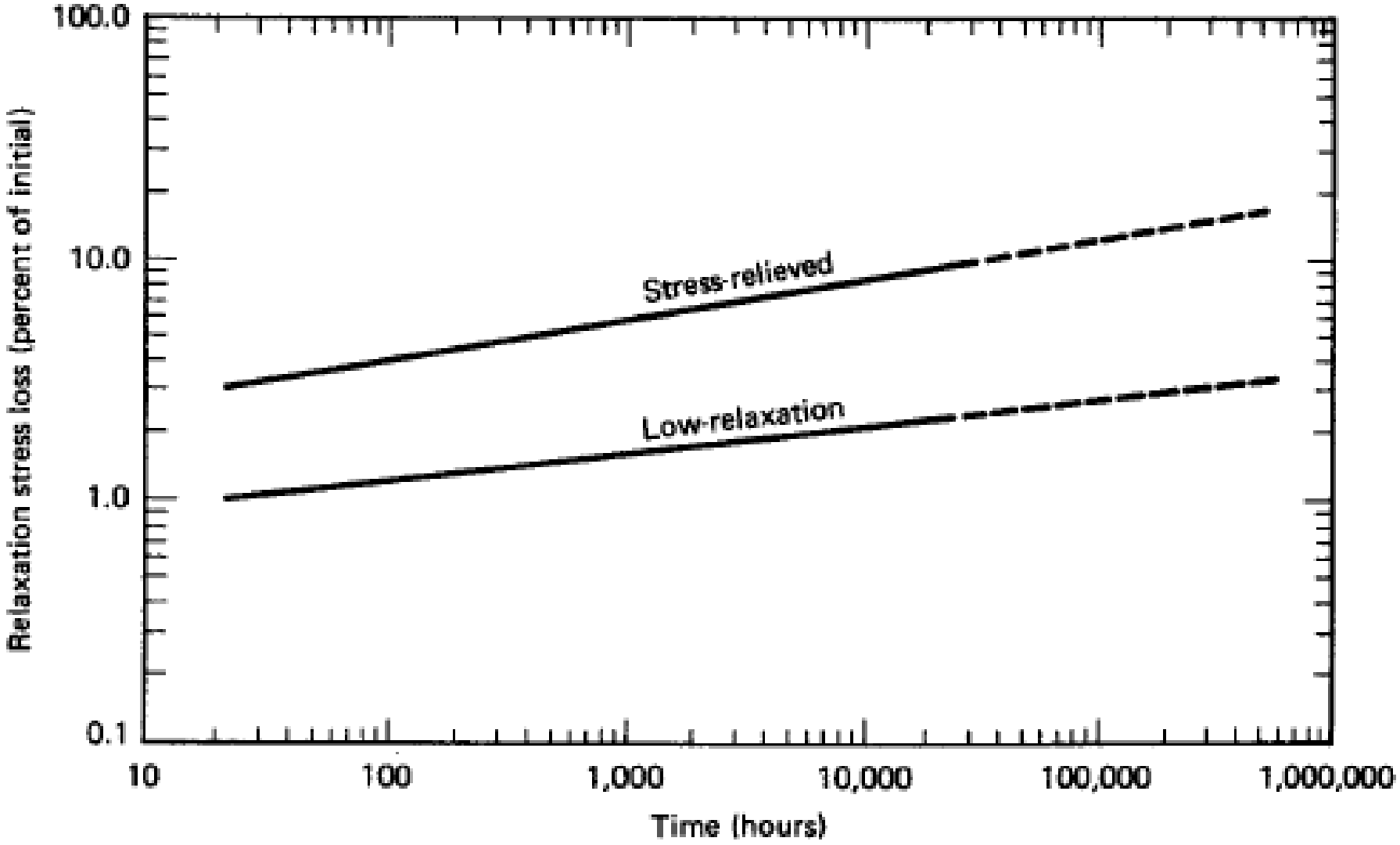
Relaxation of prestressing steel

- It is a loss of prestress when the wires and strands are subjected to essentially constant strain.
- It is identical to creep in concrete, except that creep is a change in strain while steel relaxation is a loss in steel stress.
- Relaxation is expressed as:

$$\Delta f_R = f_{pi} \frac{\log t}{10} \left(\frac{f_{pi}}{f_{py}} - 0.55 \right)$$ for stress-relieved wires and strands

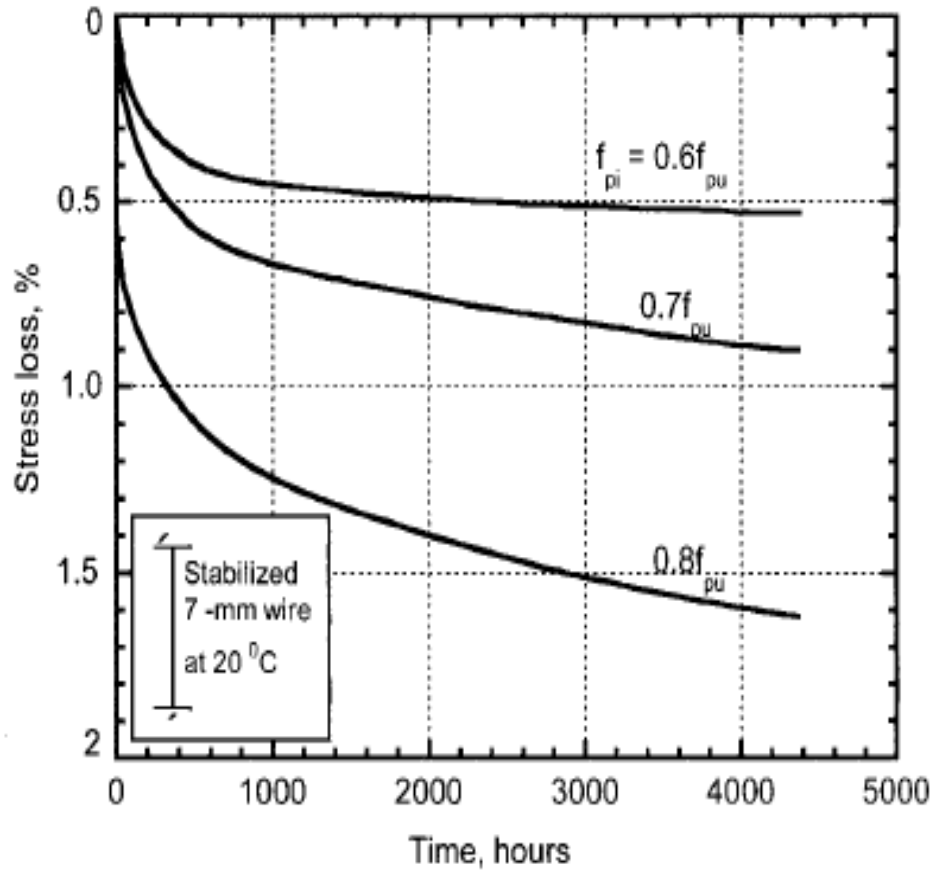
$$\Delta f_R = f_{pi} \frac{\log t}{45} \left(\frac{f_{pi}}{f_{py}} - 0.55 \right)$$ for low-relaxation wires and strands

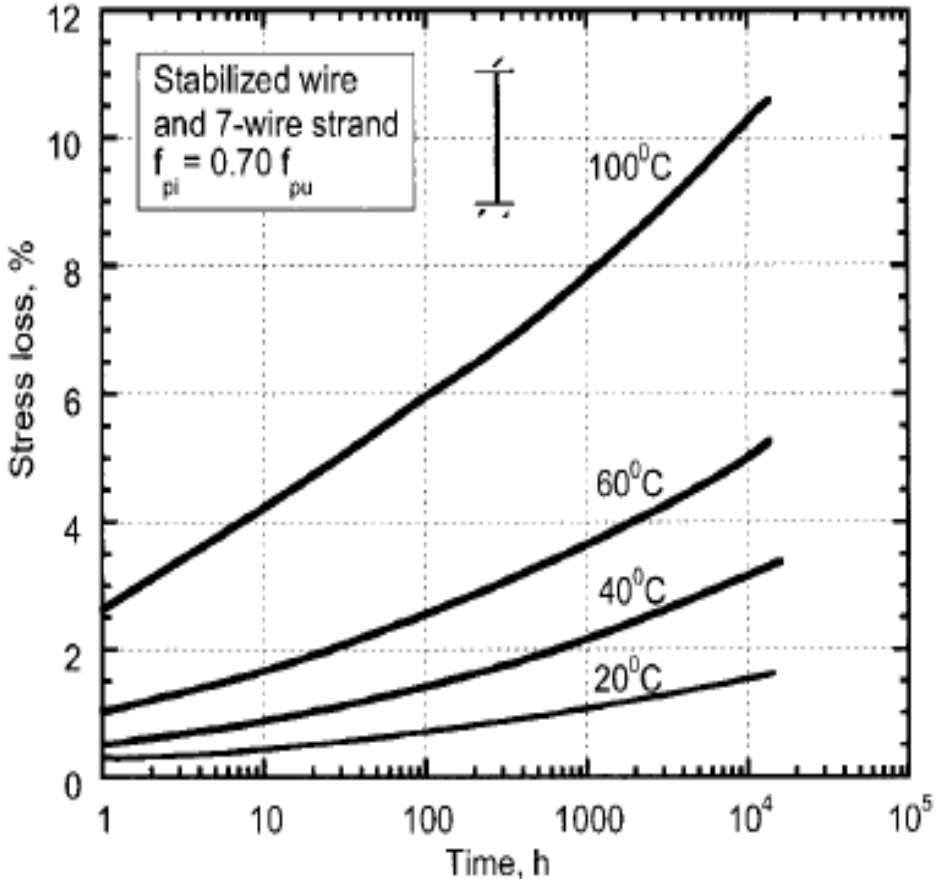
Relaxation loss vs. time



Relaxation affecting factors

Steel relaxation is dependent on the type and grade of steel and affected by the initial stress and the temperature.





Effect of temperature

- The mechanical properties of prestressing steel; ultimate strength, yield stress and elastic modulus; are not affected when ambient temperature varies over a reasonable range.
- Extreme temperature conditions can seriously affect these properties; a sharp decrease in temperature might lead to improvements in strength and modulus, but deterioration in ductility and impact resistance.

Effect of corrosion

- The magnitude and consequences of corrosion in prestressing steel are much more sever than in reinforcing steel due to that high-grade is more susceptible to corrosion and the diameter of prestressing tendons are relatively small.
- Even a small uniform corrosive layer or corroded spot can reduce the cross sectional area, induce stress concentrations, and eventually lead to premature failure.