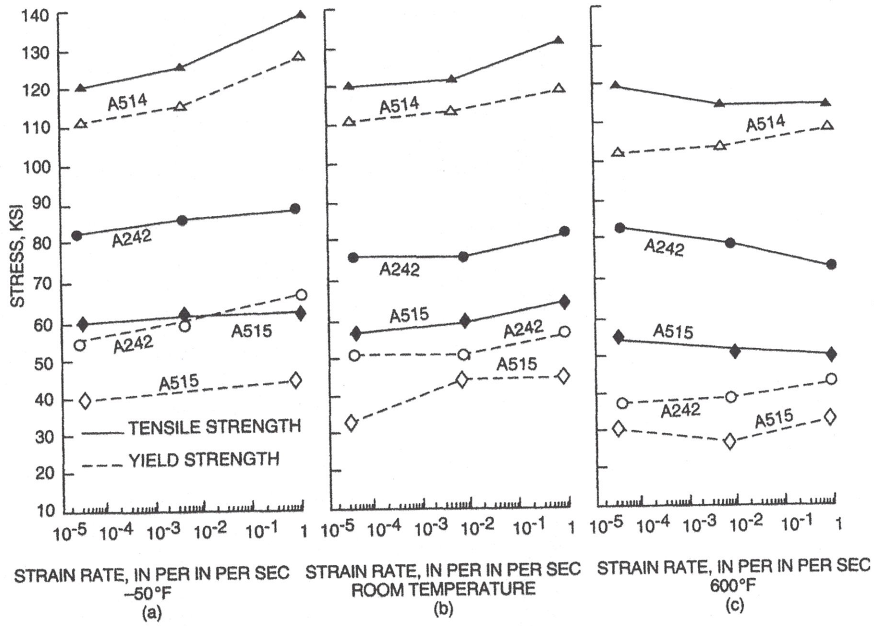


FIGURE 1.7 Effects of strain rate on yield and tensile strengths of structural steels at low, normal, and elevated temperatures. (*From R. L. Brockenbrough and B. G. Johnston,* USS Steel Design Manual, *R. L. Brockenbrough & Associates, Inc., Pittsburgh, Pa., with permission.*)

has a relatively small influence on the yield strength. But a faster strain rate causes a slight decrease in the tensile strength of most of the steels.

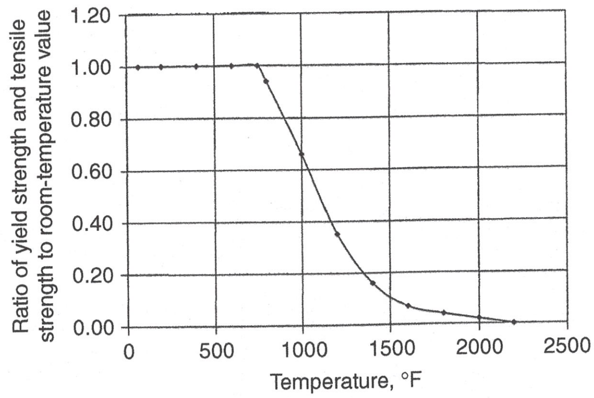
Ductility of structural steels, as measured by elongation or reduction of area, tends to decrease with strain rate. Other tests have shown that modulus of elasticity and Poisson's ratio do not vary significantly with strain rate.

1.11 EFFECT OF ELEVATED TEMPERATURES ON TENSILE PROPERTIES

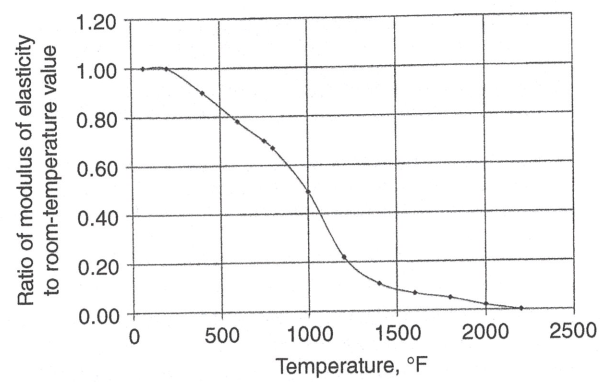
The behavior of structural steels subjected to short-time loadings at elevated temperatures is usually determined from short-time tension tests. In general, the stress-strain curve becomes more rounded and the yield strength and tensile strength are reduced as temperatures are increased. The ratios of the elevated-temperature value to room-temperature value of yield and tensile strengths typical for structural steels are shown in Fig. 1.8*a*.

Modulus of elasticity decreases with increasing temperature, as shown in Fig. 1.8*b*. The relationship shown is typical for structural steels. The variation in shear modulus with temperature is similar to that shown for the modulus of elasticity. But Poisson's ratio does not vary over this temperature range.

Ductility of structural steels, as indicated by elongation and reduction-of-area values, decreases with increasing temperature until a minimum value is reached. Thereafter, ductility increases to a value much greater than that at room temperature. The exact effect depends on the type and thickness of steel. The initial decrease in ductility is caused by strain aging and is most pronounced in the temperature range of 300 to 700°F. Strain aging also causes an increase in tensile strength in this temperature range shown for some steels.



(a)



(b)

FIGURE 1.8 Effect of temperature on (*a*) yield strength and tensile strength and (*b*) modulus of elasticity of structural steels. (*Adapted from data in AISC "Specification for Structural Steel Buildings," 2010.*)

Under long-time loadings at elevated temperatures, the effects of creep must be considered. When a load is applied to a specimen at an elevated temperature, the specimen deforms rapidly at first but then continues to deform, or creep, at a much slower rate. A schematic creep curve for a steel subjected to a constant tensile load and at a constant elevated temperature is shown in Fig. 1.9. The initial elongation occurs almost instantaneously and is followed by three stages. In stage 1, elongation increases at a decreasing rate. In stage 2, elongation increases at a nearly constant rate. And in stage 3, elongation increases at an increasing rate. The failure, or creep-rupture, load is less than the load that would cause failure at that temperature in a short-time loading test.

Table 1.6 indicates typical creep and rupture data for a carbon steel, an HSLA steel, and a constructional alloy steel. The table gives the stress that will cause a given amount of creep in a given time at a particular temperature.

For special elevated-temperature applications in which structural steels do not provide adequate properties, special alloy and stainless steels with excellent high-temperature properties are available.

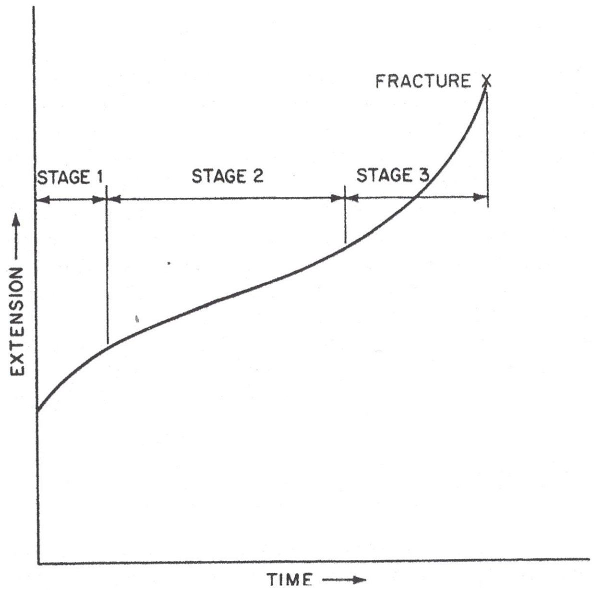


FIGURE 1.9 Creep curve for structural steel in tension (schematic). (*From R. L. Brockenbrough and B. G. Johnston,* USS Steel Design Manual, *R. L. Brockenbrough & Associates, Inc., Pittsburgh, Pa., with permission.*)

TABLE 1.6 Typical Creep Rates and Rupture Stresses for Structural Steels at Various Temperatures

Test temperature, °F	Stress, ksi, for creep rate of: 0.0001% per h*	Stress, ksi, for creep rate of: 0.00001% per h†	Stress, ksi, for rupture in: 1000 h	Stress, ksi, for rupture in: 10,000 h	Stress, ksi, for rupture in: 100,000 h
		A36 steel			
800	21.4	13.8	38.0	24.8	16.0
900	9.9	6.0	18.5	12.4	8.2
1000	4.6	2.6	9.5	6.3	4.2
		A588 Grade A steel‡			
800	34.6	29.2	44.1	35.7	28.9
900	20.3	16.3	28.6	22.2	17.3
1000	11.4	8.6	17.1	12.0	8.3
1200	1.7	1.0	3.8	2.0	1.0
		A514 Grade F steel‡			
700	—	—	101.0	99.0	97.0
800	81.0	74.0	86.0	81.0	77.0

*Equivalent to 1% in 10,000 h.
†Equivalent to 1% in 100,000 h.
‡Not recommended for use where temperatures exceed 800°F.