* 13–5 Thermal Stresses

In many situations, such as in buildings and roads, the ends of a beam or slab of material are rigidly fixed, which greatly limits expansion or contraction. If the temperature should change, large compressive or tensile stresses, called *thermal stresses*, will occur. The magnitude of such stresses can be calculated using the concept of elastic modulus developed in Chapter 9. To calculate the internal stress, we can think of this process as occurring in two steps. The beam tries to expand (or contract) by an amount ΔL given by Eq. 13–1; secondly, the solid in contact with the beam exerts a force to compress (or expand) it, keeping it at its original length. The force F required is given by Eq. 9–4:

$$\Delta L = \frac{1}{E}\frac{F}{A}L_0,$$

where E is Young's modulus for the material. To calculate the internal stress, F/A, we then set ΔL in Eq. 13–1a equal to ΔL in the equation above and find

$$\alpha L_0\,\Delta T = \frac{1}{E}\frac{F}{A}L_0.$$

Hence, the stress

$$\frac{F}{A} = \alpha E\,\Delta T.$$

EXAMPLE 13–8 **Stress in concrete on a hot day.** A highway is to be made of blocks of concrete 10 m long placed end to end with no space between them to allow for expansion. If the blocks were placed at a temperature of 10°C, what compressive stress would occur if the temperature reached 40°C? The contact area between each block is 0.20 m^2. Will fracture occur?

PHYSICS APPLIED
Highway buckling

APPROACH We use the expression for the stress F/A we just derived, and find the value of E from Table 9–1. To see if fracture occurs, we compare this stress to the ultimate strength of concrete in Table 9–2.

SOLUTION

$$\frac{F}{A} = \alpha\,E\,\Delta T = (12\times10^{-6}/\mathrm{C}^\circ)(20\times10^{9}\,\mathrm{N/m^2})(30\,\mathrm{C}^\circ) = 7.2\times10^{6}\,\mathrm{N/m^2}.$$

This stress is not far from the ultimate strength of concrete under compression (Table 9–2) and exceeds it for tension and shear. If the concrete is not perfectly aligned, part of the force will act in shear, and fracture is likely. This is why soft spacers or expansion joints (Fig. 13–3) are used in concrete sidewalks, highways, and bridges.

13–6 The Gas Laws and Absolute Temperature

Equation 13–2 is not very useful for describing the expansion of a gas, partly because the expansion can be so great, and partly because gases generally expand to fill whatever container they are in. Indeed, Eq. 13–2 is meaningful only if the pressure is kept constant. The volume of a gas depends very much on the pressure as well as on the temperature. It is therefore valuable to determine a relation between the volume, the pressure, the temperature, and the mass of a gas. Such a relation is called an **equation of state**. (By the word *state*, we mean the physical condition of the system.)

If the state of a system is changed, we will always wait until the pressure and temperature have reached the same values throughout. We thus consider only **equilibrium states** of a system—when the variables that describe it (such as temperature and pressure) are the same throughout the system and are not changing in time. We also note that the results of this Section are accurate only for gases that are not too dense (the pressure is not too high, on the order of an atmosphere or so) and not close to the liquefaction (boiling) point.