In order to use the expression for K in this example an effective depth d will have to be assumed. If it is assumed that a single layer of 25 mm diameter main bars will be adopted with 10 mm diameter links and 25 mm cover, the resulting effective depth would be as follows:

$$\text{Assumed effective depth } d = 500 - \frac{25}{2} - 10 - 25 = 452.5\,\text{mm}$$

Then

$$K = \frac{M}{bd^2 f_{cu}} = \frac{208.25 \times 10^6}{250 \times 452.5^2 \times 30} = 0.136 < 0.156$$

This is satisfactory. Then the lever arm is given by

$$z = d[0.5 + \sqrt{(0.25 - K/0.9)}] = d[0.5 + \sqrt{(0.25 - 0.136/0.9)}] = 0.814d$$

Hence

$$A_s = \frac{M}{0.87 f_y z} = \frac{208.25 \times 25 \times 10^6}{0.87 \times 460 \times 0.814 \times 452.5} = 1413\,\text{mm}^2$$

Provide three 25 mm diameter HY bars ($A_s = 1474\,\text{mm}^2$). Since 25 mm diameter main bars have been adopted, the effective depth assumed was correct and therefore the overall depth of 500 mm is satisfactory. Check percentage steel content:

$$\text{Steel content} = \frac{1474}{500 \times 250} \times 100 = 1.18 > 0.13 < 4 \text{ per cent}$$

The beam is adequate in bending.

The deflection SLS can be checked by reference to the recommended span to depth ratios given in BS 8110. The basic span to effective depth ratio (from Table 3.9) is 20. This must be modified by the factor for the amount of tension reinforcement in the beam, obtained from Table 3.10. So

$$\frac{M}{bd^2} = \frac{208.25 \times 10^6}{250 \times 452.5^2} = 4.07$$

From the expression given in the second footnote to the table:

$$f_s = \frac{5}{8} f_y \frac{A_{s,req}}{A_{s,prov}} = \frac{5}{8} \times 460 \times \frac{1413}{1474} = 276$$

The modification factor may be obtained by interpolation from Table 3.10 or by using the formula given at the foot of the table:

$$\text{Modification factor} = 0.55 + \frac{477 - f_s}{120(0.9 + M/bd^2)}$$

$$= 0.55 + \frac{477 - 276}{120(0.9 + 4.07)} = 0.887 \leqslant 2$$

Therefore the allowable span to effective depth ratio modified for tension reinforcement is $20 \times 0.887 = 17.74$. Finally,

$$\text{Actual span to effective depth ratio} = \frac{7000}{452.5} = 15.47 < 17.74$$

Hence the beam is adequate in deflection.

3.9.10 Shear ULS

The effect of shear at the ULS must be examined for all concrete beams. Except in members of minor structural importance, such as lintels, some form of shear reinforcement should be introduced. Such reinforcement may consist of either vertical links alone or vertical links combined with bent-up bars.

Shear failure in concrete beams is of a complex nature and can occur in several ways. A typical failure mode, for a simply supported beam, is illustrated in Figure 3.13. The manner in which links and bent-up bars assist in resisting shear is also shown.

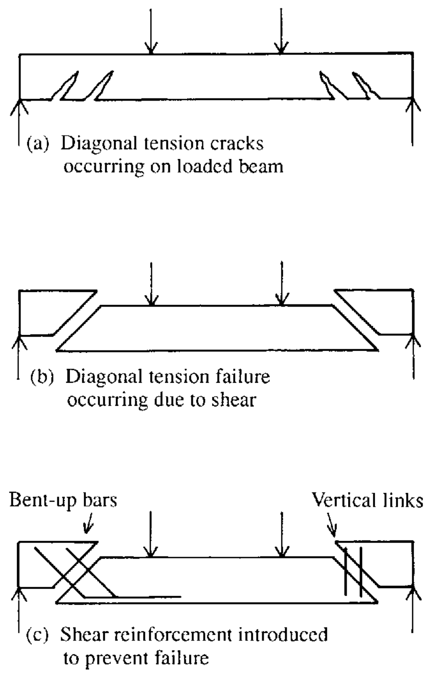

Figure 3.13 *Typical failure mode due to shear for a simply supported beam*

The procedure for checking the shear resistance of concrete beams is carried out in the following manner. First, calculate the design shear stress occurring from

$$v = \frac{V}{b_v d}$$

where

- v design shear stress occurring at cross-section being considered
- V design shear force due to ultimate loads
- b_v breadth of section
- d effective depth