beam will be in a situation of mild exposure and be provided with 10 mm diameter links:

Effective depth d	600
Diameter of lower bars	25
Diameter of links assumed	10
Cover, mild exposure assumed	25
Overall depth h	660 mm

Provide a 660 mm × 350 mm grade 30 concrete beam.

The percentage reinforcement area provided can now be compared with the requirements of BS 8110:

$$\text{Steel content} = \frac{2948}{660 \times 350} \times 100 = 1.28 \text{ per cent}$$

This is greater than the minimum area of 0.13 per cent required for high yield steel and less than the maximum area of 4 per cent required for all steels. The beam is therefore adequate for the bending ULS.

For comparison let us now look at the use of the BS 8110 Part 3 design charts for this example. Chart 2, shown in Figure 3.4, relates to singly reinforced beams containing tension reinforcement with a yield stress of 460 N/mm^2. We have

$$\frac{M}{bd^2} = \frac{550 \times 10^6}{350 \times 600^2} = 4.37$$

From the chart this gives $100A_s/bd = 1.37$ for an f_{cu} of 30 N/mm^2. By rearranging this expression the area of tensile steel required can be determined:

$$A_s \text{ required} = 1.37\frac{bd}{100} = \frac{1.37 \times 350 \times 600}{100} = 2877 \text{ mm}^2$$

This is the area previously obtained using the design formulae, and we would therefore provide the same bars.

The remaining calculations needed to complete the design are exactly as those made previously.

Example 3.5

A reinforced concrete beam is required to transmit an ultimate bending moment of 140 kN m, inclusive of its own weight. Using the simplified stress block formulae given in BS 8110 Part 1, determine the depth of beam required and the amount of steel needed in a 250 mm wide beam for the following combinations:

Grade 30 concrete with mild steel reinforcement

Grade 35 concrete with high yield reinforcement.

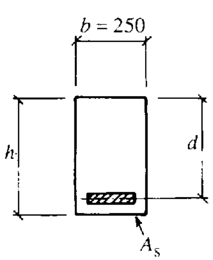

Figure 3.8 *Beam cross-section*

As can be seen from the beam cross-section shown in Figure 3.8, the breadth b is known but the effective depth d, the overall depth h and the area of tensile reinforcement A_s are not. The formulae must therefore be used in conjunction with the ultimate bending moment to determine these values.

Grade 30 concrete, MS reinforcement

Grade 30 concrete $f_{cu} = 30\,\text{N/mm}^2$

MS reinforcement $f_y = 250\,\text{N/mm}^2$

Ultimate bending moment $M_u = 140\,\text{kN m} = 140 \times 10^6\,\text{N mm}$

Consider the BS 8110 formulae. First $K = M/bd^2 f_{cu}$, from which an expression for d may be derived. In addition, for singly reinforced beams $K \leqslant K' = 0.156$. Hence

$$d \text{ required} = \sqrt{\left(\frac{M}{Kbf_{cu}}\right)} = \sqrt{\left(\frac{M}{0.156bf_{cu}}\right)}$$

Also, if $K = K' = 0.156$,

$$z = d[0.5 + \sqrt{(0.25 - K/0.9)}] = d[0.5 + \sqrt{(0.25 - 0.156/0.9)}] = 0.777d \not> 0.95d$$

Hence

$$A_s = \frac{M}{0.87f_y z} = \frac{M}{0.87f_y 0.777d}$$

Apply these expressions to the beam in question:

$$d \text{ required} = \sqrt{\left(\frac{M}{0.156bf_{cu}}\right)} = \sqrt{\left(\frac{140 \times 10^6}{0.156 \times 250 \times 30}\right)} = 345.92\,\text{mm:} \quad \text{use } 350\,\text{mm}$$

$$A_s \text{ required} = \frac{M}{0.87f_y 0.777d} = \frac{140 \times 10^6}{0.87 \times 250 \times 0.777 \times 350} = 2367\,\text{mm}^2$$

Provide three 25 mm diameter and three 20 mm diameter MS bars in two layers ($A_s = 1474 + 942 = 2416\,\text{mm}^2$).

It should be appreciated that since a larger effective depth d than that required has been adopted, strictly speaking a revised value of K and z should be calculated. However, this would have no practical effect on the solution as the same size and number of bars would still be provided.

To determine the beam depth (see Figure 3.9):

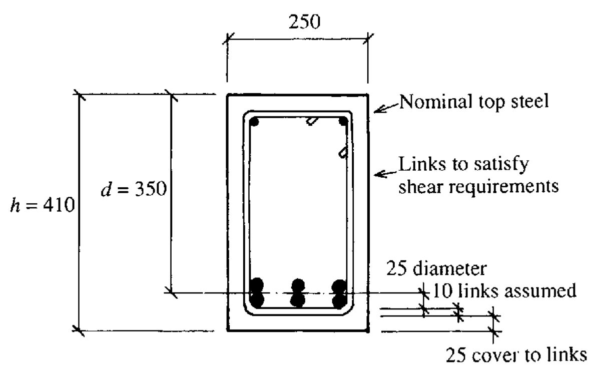

Figure 3.9 *Beam cross-section: grade 30 concrete, MS reinforcement*