although there are certain subtle differences. The design of beams will therefore be studied first and then compared with the design of slabs.

3.9 Beams

There are a number of dimensional requirements and limitations applicable to concrete beams which the designer needs to consider since they can affect the design:

(a) Effective span of beams
(b) Deep beams
(c) Slender beams
(d) Main reinforcement areas
(e) Minimum spacing of reinforcement
(f) Maximum spacing of reinforcement.

Certain other aspects such as bond, anchorage, and if applicable the curtailment and lap lengths of reinforcement, require consideration at the detailing stage.

The main structural design requirements for which concrete beams should be examined are as follows:

(a) Bending ULS
(b) Cracking SLS
(c) Deflection SLS
(d) Shear ULS.

Let us now consider how each of these dimensional and structural requirements influences the design of beams.

3.9.1 Effective span of beams

The effective span or length of a simply supported beam may be taken as the lesser of:

(a) The distance between the centres of bearing
(b) The clear distance between supports plus the effective depth *d*.

The effective length of a cantilever should be taken as its length to the face of the support plus half its effective depth *d*.

3.9.2 Deep beams

Deep beams having a clear span of less than twice their effective depth *d* are outside the scope of BS 8110. Reference should therefore be made to specialist literature for the design of such beams.

3.9.3 Slender beams

Slender beams, where the breadth of the compression face b_c is small compared with the depth, have a tendency to fail by lateral buckling. To prevent such failure the clear distance between lateral restraints should be limited as follows:

(a) For simply supported beams, to the lesser of $60b_c$ or $250b_c^2/d$
(b) For cantilevers restrained only at the support, to the lesser of $25b_c$ or $100b_c^2/d$.

These slenderness limits may be used at the start of a design to choose preliminary dimensions. Thus by relating the effective length of a simply supported beam to $60b_c$, an initial breadth can be derived. This can then be substituted in the bending design formula, given in Section 3.9.7, and an effective depth d determined. Finally this can be compared with the second slenderness limit of $250b_c^2/d$.

Example 3.3

A simply supported beam spanning 8 m is provided with effective lateral restraints at both ends. If it has an effective depth of 450 mm, what breadth would be satisfactory?

To avoid lateral buckling failure the distance between lateral restraints should be the lesser of $60b_c$ or $250b_c^2/d$. Hence either

$$\text{Effective span} = 60b_c$$
$$8000 = 60b_c$$
$$b_c = \frac{8000}{60} = 133\,\text{mm}$$

or

$$\text{Effective span} = \frac{250b_c^2}{d}$$
$$8000 = \frac{250b_c^2}{450}$$
$$b_c = \sqrt{\left(\frac{8000 \times 450}{250}\right)} = 120\,\text{mm}$$

Hence the minimum breadth of beam to avoid lateral buckling would have to be 133 mm.

3.9.4 Main reinforcement areas

Sufficient reinforcement must be provided in order to control cracking of the concrete. Therefore the minimum area of tension reinforcement in a beam should not be less than the following amounts:

(a) 0.24 per cent of the total concrete area, when $f_y = 250\,\text{N/mm}^2$
(b) 0.13 per cent of the total concrete area, when $f_y = 460\,\text{N/mm}^2$.