V_b design shear resistance of bent-up bars
v design shear stress at a cross-section
v_c design concrete shear stress (from BS 8110 Table 3.9)
θ angle of shear failure plane from the horizontal
α angle between a bent-up bar and the axis of a beam
β angle between the compression strut of a system of bent-up bars and the axis of the beam

Compression

A_c net cross-sectional area of concrete in a column
A_{sc} area of vertical reinforcement
b width of column
f_{cu} characteristic strength of concrete
f_y characteristic strength of reinforcement
h depth of section
l_e effective height
l_{ex} effective height in respect of major axis
l_{ey} effective height in respect of minor axis
l_o clear height between end restraints
N design ultimate axial load on a column

3.3 Design philosophy

The design of timber in Chapter 2 was based on permissible stress analysis, whereas the design analysis for concrete employed in BS 8110 is based on limit state philosophy. Its object is to achieve an acceptable probability that the structure being designed will not become unfit for its intended purpose during its expected life. Therefore the various ways in which a structure could become unfit for use are examined.

The condition of a structure when it becomes unfit for use or unserviceable is called a limit state. This can by definition be further subdivided into the following two categories:

(a) Ultimate limit state (ULS)
(b) Serviceability limit state (SLS).

3.3.1 Ultimate limit state

If a ULS is reached, collapse of the member or structure will occur. Therefore the design must examine all the ULSs likely to affect a particular member. Some of the ULSs that may have to be considered are as follows:

(a) ULS due to bending
(b) ULS due to shear
(c) ULS due to direct compression or tension
(d) ULS due to overturning.

3.3.2 Serviceability limit state

If an SLS is reached the appearance of the member or structure will be disrupted. Whilst this will not cause collapse it may render the member unfit for its intended service use. Some of the SLSs that may have to be considered are as follows:

(a) SLS due to deflection: this should not adversely affect the appearance of the structure.
(b) SLS due to cracking: this should not adversely affect the appearance or the durability of the structure. For example, excessive cracks would allow the ingress of moisture with subsequent corrosion and/or frost damage.
(c) SLS due to vibration: this should not produce structural damage or cause discomfort or alarm to occupants of the building. Special precautions may be necessary to isolate the source of such vibration.

Other serviceability considerations that may have to be taken into account in the design of a particular member or structure are durability, fatigue, fire resistance and lightning.

Having identified the various limit states, the basic design procedure to ensure that they are not exceeded may be summarized as follows.

3.3.3 Limit state basic design procedure

When designing a particular concrete element it is usual to first ensure that the ULS is not exceeded and then to check that the relevant SLSs are also satisfied.

In order to ensure that the ULS is not exceeded, safety factors are applied as discussed in the next section.

The serviceability requirements for routine design are usually met by compliance with certain dimensional ratios or detailing rules given in BS 8110 Part 1. They will be referred to later in the relevant sections of this chapter. If it were considered necessary to examine the deflection or cracking SLSs in more detail then reference may be made to the more rigorous method of analysis given in BS 8110 Part 2.

3.4 Safety factors

In previous codes of practice the design of reinforced concrete members was based on either elastic theory or load factor theory. The fundamental difference between the two methods is the application of safety factors: for elastic analysis they were applied to the material stresses, and for load factor analysis they were applied indirectly to the loads.

Limit state philosophy acknowledges that there can be variation in both the loads and the materials. Therefore in limit state analysis, partial safety factors are applied separately to both the loads and the material stresses.