Specified imposed load = 5 kN/m^2

Specified imposed load UDL = 5 × 6 × 5 = 150 kN

Total ULS design load = γ_f × specified dead load + γ_f × specified imposed load

$$= 1.4 \times 112 + 1.6 \times 150 = 156.8 + 240 = 396.8\,\text{kN}$$

Ultimate bending moment $M_u = \dfrac{WL}{8} = \dfrac{396.8 \times 6}{8}$

$$= 297.6\,\text{kN m} = 297.6 \times 10^6\,\text{N mm}$$

The ultimate design strength p_y for grade 43 steel sections, from Table 5.1, is 275 N/mm^2 provided that the flange thickness does not exceed 16 mm. If the flange thickness was greater than 16 mm, p_y would reduce to 265 N/mm^2. Hence the plastic modulus is

$$S_x \text{ required} = \frac{M_u}{p_y} = \frac{297.6 \times 10^6}{275} = 1\,082\,182\,\text{mm}^3 = 1082\,\text{cm}^3$$

It should be appreciated that the plastic modulus property is always tabulated in cm^3 units.

By reference to Table 5.2, the lightest UB section with a plastic modulus greater than that required is a 457 × 152 × 60 kg/m UB with an S_x of 1280 cm^3. It should be noted that the flange thickness of the selected section is 13.3 mm; this is less than 16 mm, and it was therefore correct to adopt a p_y of 275 N/mm^2 in the design. It should also be noted that the self-weight of the section is less than that assumed and therefore no adjustment to the design is necessary; that is,

$$\text{SW} = \frac{60}{100} \times 6 = 3.6\,\text{kN} < 4\,\text{kN assumed}$$

This section would be adopted provided that it could also satisfy the shear and deflection requirements which will be discussed later.

The design approach employed in Example 5.1 only applies to beams which are fully restrained laterally and are subject to low shear loads. When plastic and compact beam sections are subject to high shear loads their moment capacity reduces because of the interaction between shear and bending. Modified expressions are given in BS 5950 for the moment capacity of beams in such circumstances. However, except for heavily loaded short span beams, this is not usually a problem and it will therefore not be given any further consideration here.

5.10.3 Bending ULS of laterally unrestrained beams

Laterally unrestrained beams are susceptible to lateral torsional buckling failure, and must therefore be designed for a lower moment capacity known as the buckling resistance moment M_b. It is perhaps worth reiterating that torsional buckling is not the same as local buckling, which also needs to be taken into account by reference to the section classification of plastic, compact, semi-compact or slender.

For rolled universal sections or joists BS 5950 offers two alternative approaches – rigorous or conservative – for the assessment of a member's lateral torsional buckling resistance. The rigorous approach may be applied to any form of section acting as a beam, whereas the conservative approach applies only to UB, UC and RSJ sections. Let us therefore consider the implications of each of these approaches with respect to the design of rolled universal sections.

Laterally unrestrained beams, rigorous approach

Unlike laterally restrained beams, it is the section's buckling resistance moment M_b that is usually the criterion rather than its moment capacity M_c. This is given by the following expression:

$$M_b = p_b S_x$$

where p_b is the bending strength and S_x is the plastic modulus of the section about the major axis, obtained from section tables.

The bending strength of laterally unrestrained rolled sections is obtained from BS 5950 Table 11, reproduced here as Table 5.5. It depends on the steel design strength p_y and the equivalent slenderness λ_{LT}, which is derived from the following expression:

$$\lambda_{LT} = nuv\lambda$$

where

- n slenderness correction factor from BS 5950
- u buckling parameter of the section, found from section tables or conservatively taken as 0.9
- v slenderness factor from BS 5950
- λ minor axis slenderness: $\lambda = L_E/r_y$
- L_E effective unrestrained length of the beam
- r_y radius of gyration of the section about its minor axis, from section tables

The effective length L_E should be obtained in accordance with one of the following conditions:

Condition (a). For beams with lateral restraints at the ends only, the value of L_E should be obtained from BS 5950 Table 9, reproduced here as Table 5.6, taking L as the span of the beam. Where the restraint conditions at each end of the beam differ, the mean value of L_E should be taken.

Condition (b). For beams with effective lateral restraints at intervals along their length, the value of L_E should be taken as $1.0L$ for normal loading conditions or $1.2L$ for destabilizing conditions, taking L as the distance between restraints.

Condition (c). For the portion of a beam between one end and the first intermediate restraint, account should be taken of the restraint conditions