AD 528:
Lateral restraint forces for beams

SCI's Advisory Desk has received queries from designers as to what restraint forces should be used to restrain the compression flange of a beam. This AD Note compares the lateral restraint force requirements for BS EN 1993-1-1[1] and BS 5950-1[2].

To use a steel beam economically, the compression flange needs to be restrained laterally against buckling and two requirements may be identified for all restraint systems[3,4]:

1. The restraint should have sufficient stiffness to increase the buckling load of the restrained member to the desired level by limiting the buckling deformations.
2. The restraint should have sufficient strength to resist the loads transmitted as a result of restricting the buckling deformations.

The relationship between stiffness and strength is such that the greater the stiffness of the restraint, the smaller its required strength. Despite the importance of both strength and stiffness, many structural design codes provide only strength requirements (e.g. BS 5950-1) and it is assumed that a member of such strength will also possess sufficient stiffness. Long span structures will develop large restraint forces and additional checks may be required.

In BS 5950-1, the restraint force required is straightforward, in BS EN 1993-1-1, the approach is more detailed.

BS EN 1993-1-1

In BS EN 1993-1-1, restraint is dealt with by assuming an initial geometric imperfection. The initial geometric imperfection may be replaced by an equivalent stabilising force q_d, defined by Equation 5.13 of BS EN 1993-1-1, which is applied as a uniformly distributed load on the member to be resisted by a bracing system.

The equivalent stabilising force q_d is defined in clause 5.3.3(2) of BS EN 1993-1-1 as:

$$q_d = \sum N_{Ed} 8 \frac{e_0 + \delta_q}{L^2}$$

Where:

N_{Ed} is the axial force in the compression flange of the beam, taken as:

$$N_{Ed} = \frac{M_{Ed}}{h}$$

M_{Ed} is the maximum moment in the beam
h is the overall beam height

Where a beam is subjected to external compression N_{Ed}, it should include the part of the compression force carried by the flange.

e_0 is the member imperfection defined by Equation 5.12 of BS EN 1993-1-1 as:

$e_0 = \alpha_m L/500$

α_m is a reduction factor when multiple beams are being restrained by a bracing system, given in clause 5.3.3(1) of BS EN 1993-1-1 as:

$$\alpha_m = 0.5\left(1 + \frac{1}{m}\right)$$

m is the number of members to be restrained
L is the length of the beam
δ_q is the inplane deflection of the bracing system under q_d plus any external loads. The in-plane deflection of the bracing system could have a significant impact on the stabilising force. SCI's P360 suggests that the deflections of typical bracing systems in buildings are unlikely to exceed $L/2000$ and a useful approach is to assume initially (and subsequently confirm) that the deflection of the bracing system δ_q will be less than this conservative value. The total resulting equivalent stabilising force $(q_d L)$ is then 2% of N_{Ed}.

Where two or more intermediate lateral restraints are provided, P360 suggests that each restraint should be capable of resisting a force of not less than $5q_d L/8$. Provided that the actual deflection of the bracing system δ_q is less than the L/2000, the restraint force equals 1.25% of N_{Ed}.

The restraints should also be capable of resisting any additional forces due to external actions and it must be ensured that sum of the restraint forces for the individual beams are transferred to some 'stiff' point in the structure, for example, to in-plane bracing or concrete core walls.

BS 5950-1

BS 5950-1, clause 4.2.2 says that full lateral restraint may be assumed to exist if the frictional or positive connection of a floor (or other) construction to the compression flange of the member is capable of resisting a lateral force of not less than 2.5% of the maximum force in the compression flange of the member.

Similarly, clause 4.3.2.2 says that where intermediate lateral restraint is required at intervals within the length of a beam, the intermediate lateral restraints should be capable of resisting a total force of not less than 2.5% of the maximum value of the factored force in the compression flange within the relevant span, divided between the intermediate lateral restraints in proportion to their spacing.

Where three or more intermediate lateral restraints are provided, each intermediate lateral restraint should be capable of resisting a force of not less than 1% of the maximum value of the factored force in the compression flange within the relevant span.

The intermediate lateral restraints should either be connected to an appropriate system of bracing capable of transferring the restraint forces to the effective points of support of the member, or else connected to an independent robust part of the structure capable of fulfilling a similar function.

The bracing system should be capable of resisting each of the following alternatives:

a) the 1% restraint force considered as acting at only one point at a time and
b) the 2.5% restraint force divided between the intermediate lateral restraints in proportion to their spacing

Clause 4.3.2.2.3 requires that bracing systems that supply intermediate lateral restraint to more than one member should be designed to resist the sum of the lateral restraint forces from each member that they restrain, reduced by the factor k_r obtained from:

$k_r = (0.2 + 1/N_r)^{0.5}$

N_r is the number of parallel members restrained.

Conclusion

Both BS EN 1993-1-1 and BS 5950-1 result in similar lateral restraint forces, for full lateral restraint a force equal to 2% and 2.5% of the axial force in the compression flange respectively and for intermediate lateral restraints a force equal to 1.25% and 1% of the axial force in the compression flange respectively. However, in BS EN 1993-1-1 the determination of restraint forces is an iterative process, due to the dependence of the forces on the level of deflection of the bracing system.

Both approaches include a reduction factor on the restraint forces to bracing systems when multiple beams are being restrained.

Long span structures will develop large restraint forces and additional checks may be required.

1 BS EN 1993-1-1:2005
Eurocode 3 - Design of steel structures - General rules and rules for buildings, BSI

2 BS 5950-1:2000
Structural use of steelwork in building. Code of practice for design. Rolled and welded sections

3 Nethercot, D.A. and Lawson, R.M.
Lateral stability of steel beams and columns (P093),
SCI, 1992

4 Gardner, L.
Stability of steel beams and columns (P360),
SCI, 2011

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