Outriggers

The lateral stiffness of 22 Bishopsgate is increased in the direction of the narrow dimension of the concrete core by mobilising the perimeter columns. Richard Henderson of the SCI discusses some of the issues.

The lateral stiffness of a building with a narrow core can be increased by connecting the core to the perimeter columns by means of stiff beams known as outriggers. In 22 Bishopsgate these are provided at two levels and are double storey-height trusses. Under lateral load, the bending moment in the building core increases rapidly with distance from the top of the building. The effect of the outriggers is to apply a bending moment of the opposite sense to the core using the steel perimeter columns (see the figure).

The magnitude of the moment transferred depends on the bending stiffnesses of the core and outrigger and the axial stiffness of the columns. The intended result is that the overall stiffness of the building is increased and the maximum deflection at the top significantly reduced.

The deflection of a building is made up of the sum of shear deflection and bending deflection. The outriggers reduce the contribution of the bending deflection to the total but do not affect the shear deflection. This is because the slope of the core at the relevant level results in a vertical deflection at the ends of the outrigger which is resisted by axial forces in the perimeter columns. Under the shear deformation, the outriggers remain horizontal and no axial forces develop in the columns.

Some of these effects can be explored at concept design stage by considering the deflection of a cantilever under lateral load with a discrete moment applied at the appropriate position. For example, the maximum bending deflection δ of a vertical cantilever of height H under a uniform load with an opposing applied moment M at mid height is given by:

$$\delta = \frac{H^2}{8E_c I}(WH - 3M)$$

if W is the total lateral load on the cantilever. The perimeter columns extend and shorten by an amount equal to the deflection of the end of the outrigger. If the outrigger is at mid height and is assumed to be rigid, the building width is b and the outriggers are $b/2$ long, the vertical deflection of the outrigger ends can be calculated from the slope of the cantilever at mid height due to the lateral load and applied moment. The vertical deflection is given by

$$x = \pm\frac{bH}{96E_c I}(7WH - 24M)$$

and is equal to $FH/(2AE_s)$ (either lengthening or shortening) where A is the column area. Using these expressions, the force F in the column is given by:

$$F = \frac{7WbHm}{24I}\left(\frac{AI}{2I + mb^2A}\right)$$

where m is the modular ratio. The moment and the deflection can then be estimated. A similar expression can be developed which takes account of the deflection of the outrigger.