AD 419: Composite beams with different positions of web openings

SCI publication P355 is widely used to design beams with large web openings. It is adopted in the development of software to design hot rolled and fabricated steel sections with openings of various shapes and sizes.

The purpose of this Advisory Desk note is to address some common practical problems related to adjacent openings of different heights and positions.

1. Unequal adjacent opening heights

In P355 and in the AD 418, the buckling length of the web post for buckling between closely spaced openings on the same horizontal axis is given by:

$\ell_w = 0.7(h_o^2 + s_o^2)^{0.5} \le h_o$ for rectangular openings (1)

$\ell_w = 0.5(h_o^2 + s_o^2)^{0.5} \le 0.7h_o$ for circular or elongated openings (2)

where:

h_o is the opening height (or average height, as defined below)

s_o is the edge-to-edge distance between the openings

For unequal adjacent opening heights, it is proposed that the average height of the openings, $h_{o,eff}$, may be used to determine the slenderness for web post buckling with a lower limit of 0.75 of the larger opening height. This corresponds to the smaller opening height being taken as not less than half the larger opening height. Therefore, the effective opening height, $h_{o,eff}$ replaces h_o in the above equations and is taken as:

$h_{o,eff} = 0.5\,(h_{o,1} + h_{o,2}) \ge 0.75\,h_{o,1}$ (3)

where:

$h_{o,1}$ is the height of the larger opening

$h_{o,2}$ is the height of the smaller opening

2. Different eccentricities of adjacent openings

The eccentricity of the opening, e_o, is defined as positive when the centre line of the opening is above the centre line of the beam and negative when it is below. For the checks on web-post buckling, the effective opening height in the above equations for web-post buckling should include the worst case of the difference in eccentricities, which is as follows:

$h_{o,eff} = 0.5\,(h_{o,1} + h_{o,2}) + |\,e_{o,1} - e_{o,2}\,| \ge\ 0.75\,h_{o,1} + |\,e_{o,1} - e_{o,2}\,|$ (4)

where:

$|\,e_{o,1} - e_{o,2}\,|$ is taken as its absolute value, in which $e_{o,1}$ and e_{o2} can have different signs depending on the position of adjacent openings relative to the centre line of the beam and the heights of the adjacent openings are defined as above.

The use of the absolute value of $|\,e_{o,1} - e_{o,2}\,|$ is the worst case for checking web-post buckling. A more precise treatment that takes account of the buckling length is given below.

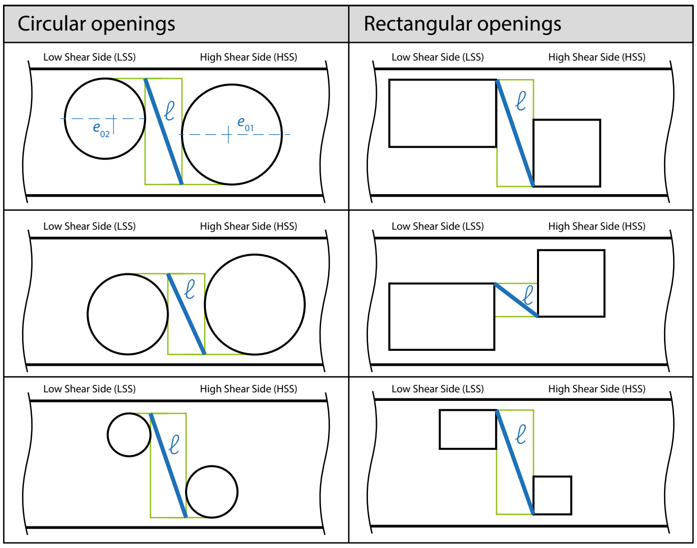

Figure 1:
Treatment of the diagonal distance for web-post buckling between adjacent openings

3. More precise treatment of eccentricities or unequal adjacent opening heights

For unequal adjacent opening heights and positions, the buckling length should be calculated from the dimension, ℓ which is the diagonal distance from the low edge of the opening in the High Shear Side (HSS) to the high edge of the opening at the Low Shear Side (LSS). Various cases are shown in Figure 1. The buckling length for web-post buckling is taken as:

For circular or elongated openings: $\ell_w = 0.5\ell$

For rectangular openings: $\ell_w = 0.7\ell$

For adjacent circular and rectangular openings: $\ell_w = 0.6\ell$

The dimension ℓ should be calculated by taking $h_{o,2} \ge 0.5h_{o,1}$ to be consistent with the limit in equation (4).

For adjacent rectangular openings, it is also necessary to check the in plane bending resistance of the web-post due to the horizontal force acting at the mid height of the beam. The position of the critical section will depend on the relative position of the openings in the beam depth. For simplicity, the in plane moment in the case of symmetric steel sections is determined from:

$M_{wp,Ed} = 0.5\,(0.5(h_{o,1} + h_{o,2}) + e_{o,1} + e_{o,2}\,)\,V_{wp,Ed}$

where:

$V_{wp,Ed}$ is the horizontal shear force acting at the mid height of the beam

This moment should not exceed the elastic bending resistance of the web post which is given by:

$M_{wp,Ed} = t_w\,s_o^{\,2}\,f_y\,/(6\gamma_{M0})$

where:

s_o is the edge to edge spacing of the openings

t_w is the web thickness

f_y is the yield strength of the steel

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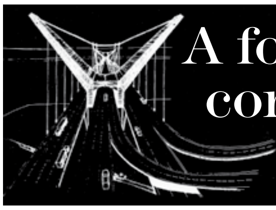

A forward looking concept in bridge design

The problem is not an unfamiliar one: an interharbour bridge is to be built as part of an interchange between interstate highways in the United States – in Baltimore, Maryland, to be precise. Considerable investigation has been carried out and unusual thoughts have been forthcoming. The bridge envisaged consists of three decks at approximately the same level: two decks each with five lanes, the third having four lanes. Pedestrians would have rights of way through this third deck.

All decks would be of orthrotropic design, constructed of steel and be equipped with resilient asphalt driving surfaces: the decks to be supported by steel cables similar to suspension bridges, but in a very different manner. The design allows for criss-crossing cables in various planes, supported by Y-shaped abutments at each end of the bridge. Considerably less steel per sq ft is required than for a conventional bridge, bringing desirable economies. The decks are approximately 800 ft long terminating at the first concrete supports of the approaches.

The Y-shaped abutments are narrow and straddle only the middle deck: they are more economical to build than the more usual vertical towers but are less bulky than four towers situated at the faces of the three decks. Since they do not obstruct the view of the bridge at its entrance, not only does the approach to the bridge become more convenient but the abutments also add lightness and grace.