Engineering Notes

WELLS & SCALETTY LLC

Web Openings in Beams

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The best coordinated construction documents cannot prevent occasional conflicts between structure and mechanical/electrical items. Floor-to-floor heights are kept to a minimum for economic reasons. Space above the ceiling is always at a premium; and subcontractors don't always do a good job coordinating their work with other trades.

Sometimes there is no choice but to cut a hole through a beam. This article addressed web openings in steel beams, and a simplified way of determining what size opening is possible.

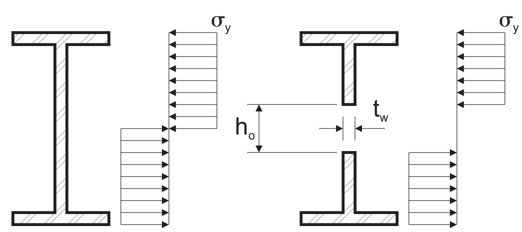
AISC's Design of Steel and Composite Beams with Web Openings[1] specifies a design procedure for placing holes in steel beam webs. The method is straight-forward, but can take some time to perform. Obviously, the size of opening is dependent upon the moments and shears present at the hole's exact location.

I've found that during construction administration, when possible resolutions to the conflict are being explored, the team needs to know how big of a hole can be cut in the beam. It isn't practical for the engineer to return to the office for lengthy calculations.

Furthermore, most conflicts are with pipes, conduits, or small round ducts. The designers have usually already coordinated equipment and larger utilities. When a hole is needed, it can usually be round. Thus, it would be nice to formulate a general rule-of-thumb for round openings.

Background

Web openings are possible because the web contributes very little to the bending strength of the beam. Also, shear and bending stresses interact weakly within the member.



Full Section — Beam with Hole in Web

Bending Stress Distribution at Plastic Moment Capacity

Beams typically have a small margin of over-design. The applied loads and the beam strength will never be exactly the same. If we set the arbitrary limit that the hole will only reduce the beam strength by 5%, then the dimensions of the opening can be calculated as follows:

$$M_n = M_p \left[1 - \frac{h_o t_w \left(\frac{h_o}{4} \right)}{Z} \right]$$

$$\frac{M_n}{M_p} = 0.95 = 1 - \frac{h_o^2 t_w}{4Z}$$

$$h_o = \sqrt{\frac{0.2Z}{t_w}}$$

On the back of this page is a chart showing this calculation for all wide-flange shapes. The ratio of opening height to beam depth clusters around 0.4.

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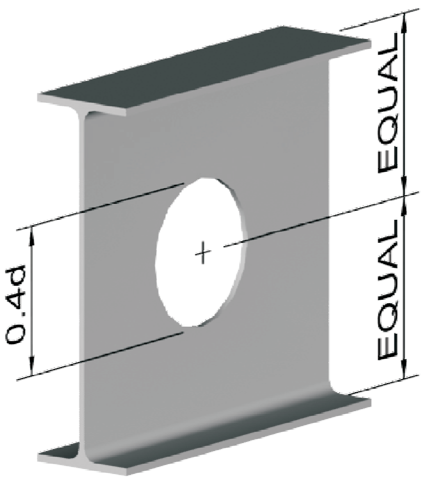
[1] Darwin, David; Design of Steel and Composite Beams with Web Openings, Steel Design Guide Series 2; American Institute of Steel Construction; Chicago, IL; 1990

The beam depth times 0.4 is an easy rule to remember. Thus, you can quickly determine in the field what sort of opening should be possible.

Note that this is a vastly simplified approach, and the engineer still needs to perform full calculations including shear and deflection checks.

I am very picky about how the holes are made. Smaller openings should be drilled whenever possible. If the hole must be flame cut, the dimensions should be carefully checked. Also, edges should be ground smooth to help relieve stress concentrations.



Restrictions:

1. *No concentrated loads can be located within a distance equal to the depth of the beam from the edge of the opening.*

2. *The beam should be a simple span supporting a nearly uniform load.*

3. *The beam is non-composite.*

4. *The top flange of the beam should have continuous lateral support.*

5. *The opening should be centered in the beam.*

6. *The opening should be as close as practical to the center of the span.*