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STRUCTURAL ANALYSIS AND DESIGN AT BASE OF RISER WITH CONDUIT OPENINGS IN BOTH ENDWALLS

This discussion is concerned with procedures for structural analysis and design of portions of risers at and near the wall-to-footing connection assuming openings framed by wall fittings having inside diameters equal to D in both endwalls. Except as modified in this Technical Release, the nomenclature, proportions, criteria, and procedures of Technical Release No. 30, "Structural Design of Standard Covered Risers", continue to apply. The page, figure, and table numbers referred to herein are those in TR-30.

In accordance with Note 3 contained on drawings ES-150 and ES-151, the designs and National Standard Detail Drawings of Standard Covered Risers and Standard Open Risers have been made assuming no opening in the upstream endwall. The introduction of any opening in the upstream endwall near the top of the footing decreases the endwall stiffness, increases sidewall deflections, and thus causes an increase in vertical bending in the sidewall. The introduction of a significant opening invalidates the conditions assumed in TR-30 and necessitates a re-evaluation of the required concrete thickness and steel in the vicinity of the riser wall-to-footing connection. It is improper and unsafe to simply delete from the standard drawings the concrete and steel which occupy the space of the proposed opening in the upstream endwall.

The general philosophy and theory of vertical bending presented in TR-30 apply equally well to sidewall bending when there are equal size openings in both endwalls and hence is not redeveloped here. Values of the deflection coefficient, K_y, must be determined for the structural behavior existent with equal size openings in the endwalls. The horizontal structural behavior of the riser sidewalls at and near the endwall openings is assumed that of a simply supported span. This assumption results in conservative K_y values because small, indeterminate negative end moments exist at the supports. Further, it is assumed the wall fittings provide adequate supports for the simple span reactions. This assumption eliminates the need of analyzing vertical reaction beams such as is presented in TR-31, "Structural Analysis and Design at Low Stage Inlets."

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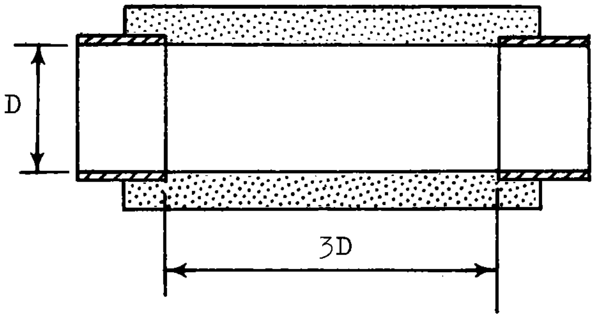
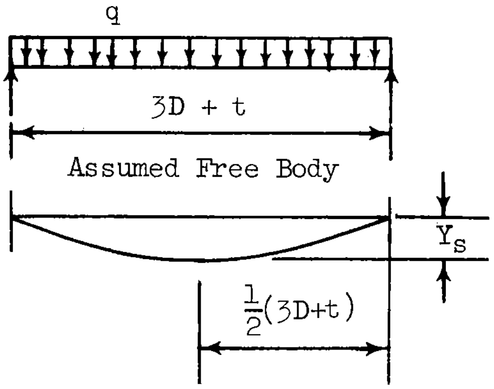


Section of Riser at Openings



Deflected Shape of Sidewall

Sketches for determination of K_y at center of sidewall.

The deflection at the center of a uniformly loaded simple span is given by

$$Y_s = \frac{5}{384}\frac{q}{EI}(3D+t)^4 = \frac{5}{384}\frac{qD^4}{EI}(3+t/D)^4$$

so that

$$K_y = \frac{EI}{qD^4} Y_s = \frac{5}{384}(3+t/D)^4$$

Values of the deflection coefficient are given below.

t/D	0.00	0.25	0.50	0.75	1.00
K_y	1.055	1.453	1.954	2.575	3.333

A comparison of these K_y values with those of Table 2-9 is revealing. Obviously M_{VO} and V_{VO} will be considerably larger than when no upstream opening exists. The example on page 2-26 is used for illustration.

$q = 3.74$ klf/ft

$t/D = 24/48 = 0.50 \qquad \therefore K_y = 1.954$

$$\beta^4 = \frac{1}{4K_yD^4}$$

$$\beta^4 = \frac{1}{4 \times 1.954 \times (4)^4} = \frac{1}{2000}$$

$$\beta^2 = \frac{1}{44.7}$$

$$\beta = \frac{1}{6.7} = 0.149$$

$$M_{VO} = \frac{q}{2\beta^2}\left(1 - \frac{0.1074}{q\beta}\right)$$

$$V_{VO} = \frac{q}{\beta}\left(1 - \frac{0.1074}{2q\beta}\right)$$

$$M_{VO} = \frac{3.74 \times 44.7}{2}\left(1 - \frac{0.1074}{3.74 \times 0.149}\right) = 67.5 \text{ ft kips/ft}$$

$$V_{VO} = \frac{3.74}{0.149}\left(1 - \frac{0.1074}{2 \times 3.74 \times 0.149}\right) = 22.7 \text{ kips/ft}$$

The values on page 2-26 for a riser having an upstream endwall without an opening, are:

M_{VO} = 54.1 ft kips/ft

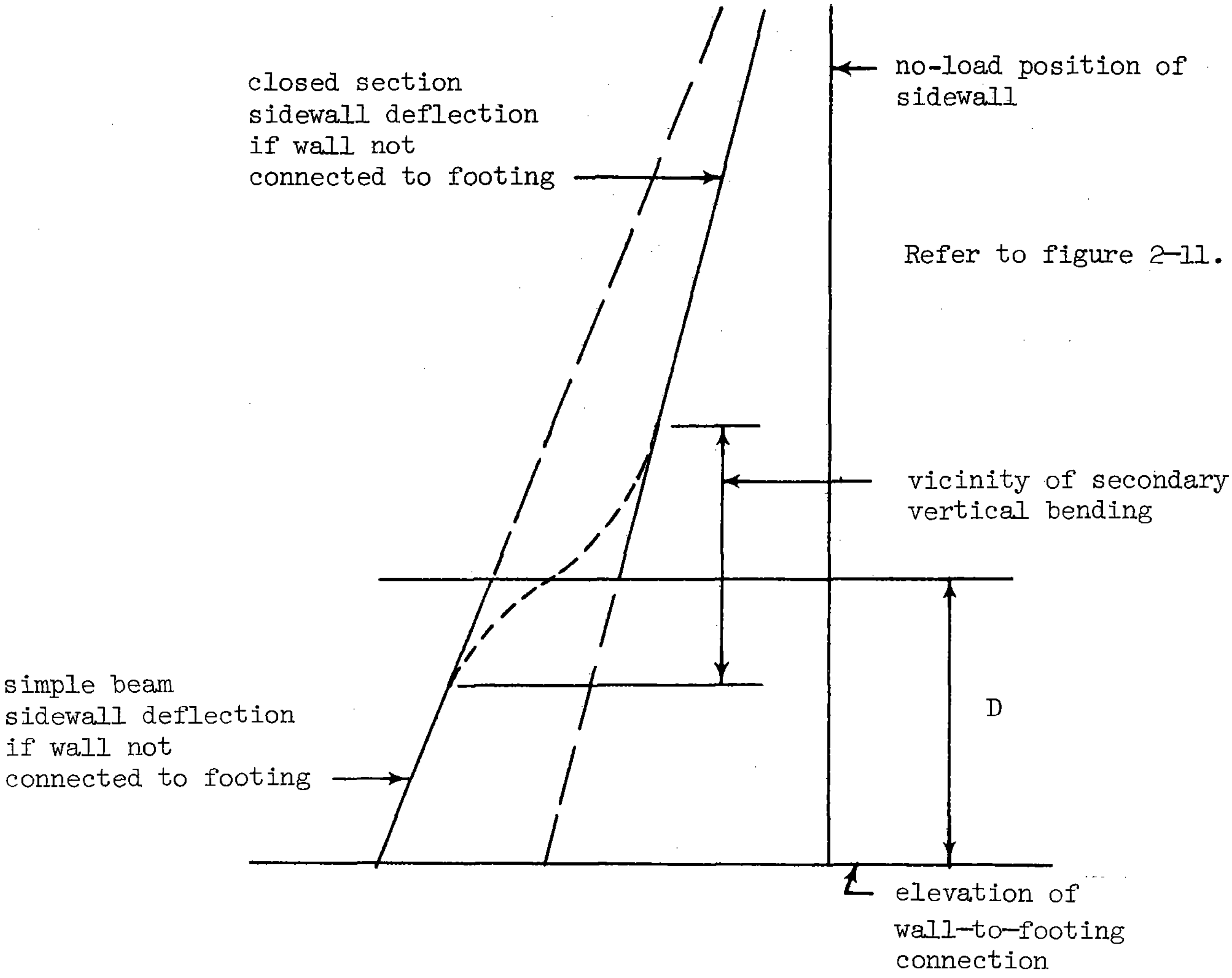
V_{VO} = 20.3 kips/ft

This represents a 25% increase in moment and a 12% increase in shear.

The increase in the values of M_{VO} and V_{VO} often requires an increase in sidewall vertical steel or wall thickness or both. Similarly, the footing thickness between the sidewalls or the footing steel for M_{VO} and V_{VO} or both, may require modification.

The loading on the riser walls is divided between that producing vertical bending and that producing horizontal bending. This division is as described on pages 2-27 and 2-28. Hence the procedure given on page 2-17 for determination of required amounts of horizontal steel is still satisfactory. However, the RH2 bars in Figure 2-10 would be replaced by RH4 bars.

Although the wall-to-footing connection is the primary discontinuity of section producing vertical bending, it should be recognized that there is still another discontinuity present in the risers in addition to wall thickness change locations mentioned in TR-30. Specifically, the difference between horizontal deflections of closed sections above the conduits and horizontal deflections of assumed simple span sections at the level of the conduits causes vertical bending in the vicinity of a distance D above the conduit inverts. This discontinuity of deflection is also present, but to a lesser extent, in a riser without an opening in the upstream endwall. The discontinuity is secondary in that it can be shown to produce relatively small vertical moments and shears. Hence it need not be considered further. The following sketch indicates qualitatively the action involved.



Sketch illustrating presence of secondary vertical bending.