ments are highest near the center of the dam (Sta. 0). When tensile stress normal to the dam/foundation contact is disallowed, the shear strength required on the portion of the dam/foundation contact that is not cracked increases. The shear strength of the portion of the dam foundation contact that is cracked is assumed to be 0. Finally, shear stress re-distribution is allowed and load is transferred up the abutments. When the shear strength is reduced to 31° and no cohesion, the non-linear finite element solution fails to achieve force equilibrium.

11-5.6.2 Buckling Failure Modes

Over and above the determination of stresses and displacements in arch dams, under some extreme dam geometries such as thin, single curvature dams with large radii, the question of buckling stability of an arch dam structure may arise. Figure 11-5.25 and the corresponding equation describe the buckling mechanism of circular arches subject to uniform compressive load, q_{cr}

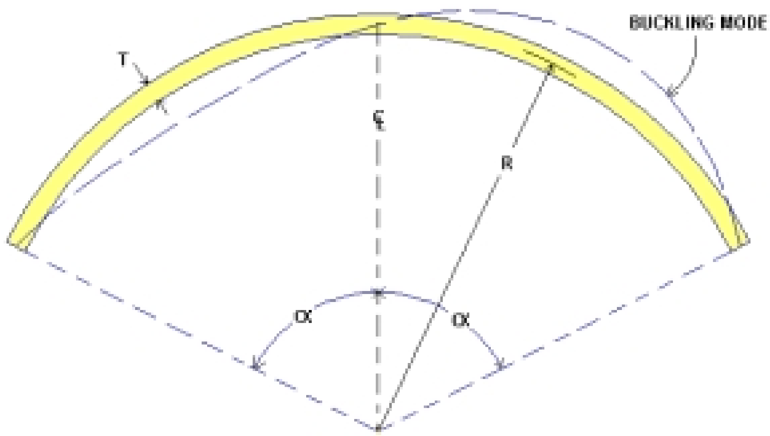

Fig. 11-5.25 Snap through buckling of a simply supported circular arch under uniform load.

$$q_{cr} = \frac{EI}{R^3}\left(\frac{\pi^2}{\alpha^2} - 1\right)$$

The critical uniform load in the above equation can be related to the average compressive arch stress σ_{cr} given by

$$\sigma_{cr} = \frac{EI}{TR^2}\left(\frac{\pi^2}{\alpha^2} - 1\right) \qquad (11\text{-}5.1)$$

General formulas for different types of arches with different boundary and load conditions can be found in “The Theory of Elastic Stability” by Timoshenko and Gere.

While this arch analogy provides some insight into how arch dams could fail in buckling, it is overly simplistic since it treats the problem in only two dimensions. It also ignores the cantilever resistance of an arch dam and thus is very conservative. If the dam has double curvature, equation 11-5.1 is even more conservative. The equation is of some value however, since if the average computed compressive arch stress is less than σ_{cr} predicted by the equation, buckling failure can be ruled out.

Rigorous determination of the buckling stability of a general shell under variable load such as a double curvature arch dam requires the use of non-linear finite element analysis. If buckling instability is a concern, simple conservative analysis techniques such as that discussed above should be used if possible.