

Calculation of Voided Slabs Rigidities

Gee-Cheol Kim, Joo-Won Kang

Abstract—A theoretical study of the rigidities of slabs with circular voids oriented in the longitudinal and in the transverse direction is discussed. Equations are presented for predicting the bending and torsional rigidities of the voided slabs. This paper summarizes the results of an extensive literature search and initial review of the current methods of analyzing voided slab. The various methods of calculating the equivalent plate parameters, which are necessary for two-dimensional analysis, are also reviewed. Static deflections on voided slabs are shown to be in good agreement with proposed equation.

Keywords—voided slab, bending rigidity, torsional rigidity, orthotropic plate.

I. INTRODUCTION

AN orthotropic plate is defined as one which has different rigidities in two orthogonal directions. In general two forms of orthotropic plate are identified, namely, material orthotropic plate and shape orthotropic plate. Most of the actual orthotropic plates are of the latter type, as like ribbed slabs and voided slabs. As voided slabs, voids running in the longitudinal direction are frequently introduced into concrete slabs in order to reduce their self weight. Such voids are often of circular shape because they are simple then to fabricate, and it is relatively easy to ensure that compaction of the concrete under the void takes place during casting. Circular voided slabs of this nature are used both for floor slabs and for medium span slab bridge.

An approach commonly used is to assume the concrete is uncracked and linearly elastic, and thus ignore the reinforcement. This approach has the advantage of simplicity and of closely modeling the behavior of a slab. And the concept of converting an actual slab into an equivalent orthotropic plate for the purpose of determining the distributions of stresses is well established. Numerous investigators have suggested expressions of the determination of these bending rigidities but few have compared them. In this paper, the bending rigidities are derived from finite element analyses of cross sections of voided slabs, with the voids symmetrical with respect to the slab middle surface. And this paper summarizes the results of literature research and the review process, giving details of the various methods of analysis and calculating the properties of simplified mathematical models.

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II. GOVERNING EQUATION OF PLATE

The governing equation of the plate ignoring the extensibility of the middle surface is given by

$$D_x \frac{\partial^4 w}{\partial x^4} + (D_{xy} + D_{yx} + D_z + D_y) \frac{\partial^4 w}{\partial x^2 \partial y^2} + D_y \frac{\partial^4 w}{\partial y^4} = p(x, y) \quad (1)$$

In which D_x and D_y denote the bending rigidities, D_{xy} and D_{yx} are the torsional rigidities and D_z and D_y are the coupling rigidities. The values of solid slab are defined as follows:

Bending rigidity is

$$D = \frac{Et^3}{12(1-\nu^2)} \quad (2)$$

Torsional rigidity is

$$D_{xy} = \frac{Gt^3}{12} \quad (3)$$

The elasticity modulus, shear elasticity modulus and Poisson's ratio are denoted by E , G and ν respectively.

It becomes necessary to calculate the equivalent parameters for a two-dimensional analysis. The various parameters may be required for all two-dimensional analyses of voided slab. The orthotropic plate rigidities are required for the orthotropic plate and two dimensional finite element analyses.

The cross section and the notation of voided slab are as shown in Fig. 1.

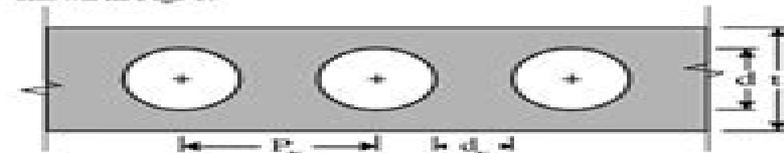


Fig. 1 Section of voided slab

III. BENDING AND TORSIONAL RIGIDITIES

Bending rigidities (D_x and D_y) in the longitudinal direction and in the transverse direction and torsional rigidities (D_{xy} and D_{yx}) can be obtained by treating the structure as equivalent stiffnesses.

For uncracked concrete voided slabs, [1] proposed the following equation for calculation of D_x and D_y .

$$D_x = E \left[\frac{r^4}{12} - \frac{\pi d^4}{64\rho^2} \right] \quad (4)$$

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