

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 plane 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 modelling 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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Joo-Won Kang is with the Department of Architectural Engineering, Yeungnam University, Kyeongsan, Korea (corresponding author to provide phone: 053-810-2429; fax: 053-810-4625; e-mail: kangjw@yu.ac.kr).

II. GOVERNING EQUATION OF PLATE

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

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

In which D_x and D_y denote the bending rigidities, D_{xy} and D_{yx} are the torsional rigidities and D_x 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.

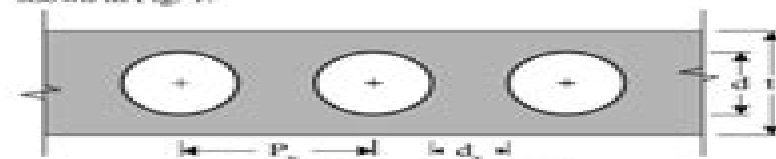


Fig. 1 Section of voided slab

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 .

$$D_x = E \left[\frac{I'}{12} - \frac{\pi d^4}{64F_y} \right] \quad (4)$$

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Load Distribution in Concrete Bridge Decks Anthony Ralph Cusens, 1974 Bridge Analysis Simplified Baidar Bakht, Leslie G. Jaeger, 1985 *Seismic Design and Assessment of Bridges* Andreas J Kappos, M. Saiid Saiidi, M. Nuray Aydinoglu, Tatjana Isaković, 2012-04-17 The book focuses on the use of inelastic analysis methods for the seismic assessment and design of bridges for which the work carried out so far albeit interesting and useful is nevertheless clearly less than that for buildings Although some valuable literature on the subject is currently available the most advanced inelastic analysis methods that emerged during the last decade are currently found only in the specialised research oriented literature such as technical journals and conference proceedings Hence the key objective of this book is two fold first to present all important methods belonging to the aforementioned category in a uniform and sufficient for their understanding and implementation length and to provide also a critical perspective on them by including selected case studies wherein more than one methods are applied to a specific bridge and by offering some critical comments on the limitations of the individual methods and on their relative efficiency The book should be a valuable tool for both researchers and practicing engineers dealing with seismic design and assessment of bridges by both making the methods and the analytical tools available for their implementation and by assisting them to select the method that best suits the individual bridge projects that each engineer and or researcher faces *Magazine of Concrete Research* ,1976 *Bridges* Baidar Bakht, Aftab Mufti, 2015-10-09 This book offers a valuable guide for practicing bridge engineers and graduate students in structural engineering its main purpose is to present the latest concepts in bridge engineering in fairly easy to follow terms The book provides details of easy to use computer programs for Analysing slab on girder bridges for live load distribution Analysing slab and other solid bridge components for live load distribution Analysing and designing concrete deck slab overhangs of girder bridges under vehicular loads Determining the failure loads of concrete deck slabs of girder bridges under concentrated wheel loads In addition the book includes extensive chapters dealing with the design of wood bridges and soil steel bridges Further a unique chapter on structural health monitoring SHM will help bridge engineers determine the actual load carrying capacities of bridges as opposed to their perceived analytical capacities The chapter addressing structures made with fibre reinforced polymers will allow engineers to design highly durable economical and sustainable structures This chapter also provides guidance on rehabilitating deteriorated structures with these new materials The book also deals with the philosophy of bridge design without resorting to complex equations Additional material to this book can be downloaded from <http://extras.springer.com> **The Finite-strip Method in Bridge Engineering** Yew-Chaye Loo, Anthony Ralph Cusens, 1978 *Transactions of the American Society of Civil Engineers* American Society of Civil Engineers, 1983 Vols 29 30 contain papers of the International Engineering Congress Chicago 1893 v 54 pts A F papers of the International Engineering Congress St Louis 1904 **Ontario Highway Bridge Design Code** Ontario. Highway Engineering Division, 1983

Applied Mechanics Reviews ,1994 **Ontario Highway Bridge Design Code: Bridge Code** Ontario. Ministry of Transportation. Quality and Standards Division,1991 *Applied Science & Technology Index* ,1984 Elastic Rigidities of Circularly Voided Slabs Ricardo P. Pama,Sayan Imsom-Somboon,Seng-Lip Lee,1972 **Plastic Voided Slab Systems** Corey J. Midkiff,2013 Reinforced concrete slabs are one of the most common components in modern building construction Reinforced concrete slabs with plastic voids slabs are a new and innovative type of structural concrete slab system developed to allow for lighter self weight of the structure while maintaining similar load carrying capacity of a solid slab Plastic voided slabs are capable of reducing the amount of concrete necessary to construct a building by 30 percent or more This reduction can be beneficial in terms of financial savings as well as building performance This report examines a two way reinforced concrete slab with plastic voids construction in comparison to traditional flat plate reinforced concrete slab construction The design process for plastic voided slabs is directly compared with traditional two way flat plate reinforced concrete slabs through a design comparison of typical bays of 20 by 20 6m by 6m 25 by 25 7 6m by 7 6m 30 by 30 9m by 9m and 35 by 35 10 7m by 10 7m The traditional slab design process follows the ACI 318 11 Building Code Requirements for Structural Concrete chapter 13 Direct Design Method while the plastic voided slab design process is modified from the BubbleDeck Design Guide for compliance with BCA using AS3600 and EC2 Sizes of traditional slab bays are compared to sizes of plastic voided slab bays Results of the comparison study are presented **Yield-line Formulae for Slabs** K.W. Johansen,1972-01-01 This E F N Spon title is now distributed by Routledge in the US and Canada This book was the first attempt to establish a simple formulae for the calculation of various slab types A large number of examples are included Flat Plate Voided Slabs Hunter Wheeler,2018 In structural engineering it can be challenging to incorporate a sustainable design without sacrificing structural integrity However flat plate voided slabs are an interesting alternative to standard flat plate concrete slab systems due to the reduction in concrete and the recycled plastic void formers that are located inside the slab This research is necessary because an increased use of voided slabs in concrete structures would help fight climate change by reducing the CO2 emissions caused from cement production This report will discuss the advantages and disadvantages of implementing plastic void formers into solid flat plate slabs and examine a parametric study comparing voided flat plate slabs to solid flat plate slabs The design of the voided slabs follows the CRSI Design Guide for Voided Concrete Slabs while also referencing the ACI 318 14 Building Code Requirements for Structural Concrete Three different slabs for typical square bay sizes of 25 feet 30 feet and 35 feet are designed to compare the effectiveness of voided slabs to traditional solid slabs Bridge Analysis Simplified Baidar Bakht,Leslie G. Jaeger,1985 **Quality assurance of hollow core slab floors** FIB – International Federation for Structural Concrete,1992-01-01 Model Studies for Voided Posttensioned Concrete Slab Bri P. Meades,R. Green,Ontario Ministry of Transportation and Communications University of,1974 *The Application of the Yield-line Theory to Calculation of the Flexural Strength of Slabs and Flat-slab Floors*

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