

Beams on Elastic Foundations— Solution by Relaxation Methods

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Several pure mathematical solutions have been obtained for beams resting on elastic foundations, see, for example, Timoshenko's "Strength of Materials," but these are restricted to certain standard types of loading and to constant flexural rigidity of the beam.

A practical application of these solutions is represented by a beam (usually concrete) resting on a soil which is assumed to have a constant subgrade modulus; this modulus, being the pressure necessary to deflect the foundation unit distance, has dimensions $(\text{lb./in.}^2)/\text{in.}$

In practice, there is a considerable variation in the value of the subgrade modulus, the assumed flexural rigidity of the beam and the assumed values of load. This is, therefore, a type of problem particularly suited to solution by Relaxation Methods¹—an exact solution is unobtainable but a solution to any required degree of accuracy is easily found. In view of the uncertainty of the other data, particularly the subgrade modulus, the degree of accuracy aimed at need not be exacting.

The relaxation method is readily adaptable to any type of loading and to any variation in flexural rigidity along the beam, whereas such variations tend to make the solution by pure mathematics very complex and tedious.

Governing Equation—

The governing equation is, from the usual beam theory,

$$EI \frac{d^4 y}{dx^4} + ky = w(x) = w,$$

where

x, y are Cartesian co-ordinates
 EI = the flexural rigidity of the beam
 $w(x)$ = the loading intensity at x
 k = Subgrade Modulus.

As a test of the relaxation method, the "standard case" of a central point load acting on a beam of uniform flexural rigidity has been worked out and checked against the solution as obtained by the more conventional treatment.

RELAXATION APPROACH

The beam is divided into a number of equal parts h apart. The governing equation is then expressed in finite difference form and values of the wanted function y are guessed at each point in the range. These values are substituted in the finite difference equations for the point and the resultant error or residual found. This is then liquidated by means of suitable operations, the final residual being made as small as we please, compatible with the accuracy required. When the deflections have been found, the practically important slopes and bending moments are easily calculated.

FINITE DIFFERENCE APPROXIMATION

The governing equation is $\frac{EI d^4 y}{dx^4} + ky = W(x) = w$,

and this must be expressed in finite difference form

$$\begin{array}{ccccccc} & a & + & a & + & a & + & a & + \\ & | & & | & & | & & | & \\ & \hline & 1 & & 2 & & 3 & & 4 & \end{array}$$

Considering 5 adjacent points of subdivision, the finite

difference form of $\frac{d^4 y}{dx^4}$ at the point 2 is $h^4 \left(\frac{d^4 y}{dx^4} \right)_2 =$

$-\frac{1}{2}y_1 + y_2 + \frac{1}{2}y_3$
 Differentiating twice and multiplying by h^4

$$h^4 \left(\frac{d^4 y}{dx^4} \right)_2 = -\frac{24y_1 y_2}{h^4} + \frac{24y_2 y_3}{h^4} + \frac{24y_3 y_4}{h^4}$$

$$= -4(-4y_1 + y_2 + y_3 + y_4 + y_5) - 4y_2 + y_3 + y_4 - 4y_5$$

$$= 4y_1 - 4y_2 - 4y_3 + y_4 + y_5$$

$\therefore$ The equation expressed in finite difference form is

$$-4y_1 + 4y_2 + 4y_3 - y_4 - y_5 + \left(\frac{W h^4}{EI} \right)_2$$

$$= \frac{24y_2}{EI} = w = P_2$$

The relaxation pattern for liquidating residuals will be for the typical point 2.

$$\begin{array}{ccccccc} & + & 1 & & + & 1 & \\ & | & & | & & | & \\ & \hline & 1 & + & 2 & + & 3 & + & 4 & \\ & | & & | & & | & & | & \\ & \hline & 1 & & 2 & & 3 & & 4 & \end{array}$$

In order to interpret the boundary conditions we need

also $\frac{d^2 y}{dx^2}$ and $\frac{d^3 y}{dx^3}$ expressed in finite difference form,

as follows:—

$$h^2 \left(\frac{d^2 y}{dx^2} \right)_2 = -24y_1 + 144y_2 + 24y_3 = \frac{2}{EI} (4y_1 + y_2)$$

$$h^3 \left(\frac{d^3 y}{dx^3} \right)_2 = 4y_1 - 4y_2 + 4y_3 - 4y_4$$

¹ "Relaxation Methods in Engineering Science"—Macmillan.

Solution Manual For Beams On Elastic Medium

Kathleen Armour



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Scientific and Technical Aerospace Reports ,1995 **Modelling of Soil-Structure Interaction** V. Kolár, I. Nemec, 2012-12-02 Distributed in the East European countries China Northern Korea Cuba Vietnam and Mongolia by Academia Prague Czechoslovakia This book is based on the efficient subsoil model introduced by the authors in 1977 and applied in the last ten years in the design of foundations From the designer's point of view the model considerably reduces the extent of the calculations connected with the numerical analysis of soil structure interaction The algorithms presented are geared for use on mini and personal computers and can be used in any numerical method A special chapter is devoted to the implementation of the model in the NE XX finite element program package illustrated with diagrams tables and practical examples Besides presenting the energy definition and general theory of both 2D and 3D model forms the book also deals with practical problems such as Kirchhoff's and Mindlin's foundation plates interaction between neighbouring structures actual values of physical constants of subsoils and natural frequencies and shapes of foundation plates Today researchers and engineers can choose from a wide range of soil models some fairly simple and others very elaborate However the gap which has long existed between geomechanical theory and everyday design practice still persists The present book is intended to suit the practical needs of the designer by introducing an efficient subsoil model in which the surrounding soil is substituted by certain properties of the structure soil interface When a more precise solution is required a more sophisticated model form can be used Its additional degrees of deformation freedom can better express the behaviour of layered or generally unhomogeneous subsoil As a result designers will find that this book goes some way towards bridging the above mentioned gap between structural design theory and day to day practice *Applied Mechanics Reviews* ,1973 **Outline of Solutions Available for the Design of Raft Foundations** R. A. Fraser, 1976 **Electrical Engineering** ,1898

Telephone Magazine ,1898 Handbook On Timoshenko-ehrenfest Beam And Uflyand- Mindlin Plate Theories Isaac E Elishakoff, 2019-10-29 The refined theory of beams which takes into account both rotary inertia and shear deformation was developed jointly by Timoshenko and Ehrenfest in the years 1911 1912 In over a century since the theory was first articulated tens of thousands of studies have been performed utilizing this theory in various contexts Likewise the generalization of the Timoshenko Ehrenfest beam theory to plates was given by Uflyand and Mindlin in the years 1948 1951 The importance of these theories stems from the fact that beams and plates are indispensable and are often occurring elements of every civil mechanical ocean and aerospace structure Despite a long history and many papers there is not a

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s **Technical Paper** Commonwealth Scientific and Industrial Research Organization (Australia) Division of Geomechanics,1977 Strength of Materials Mansfield Merriman,1906 Structural Engineering & Construction ,1986
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