

AN APPROXIMATE METHOD OF ANALYSIS OF
HIGH-RISE TUBULAR STRUCTURES

A Thesis
by
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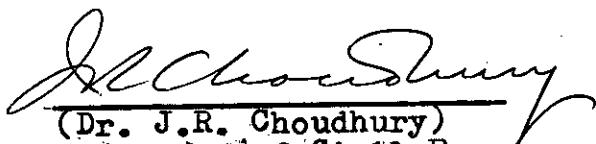


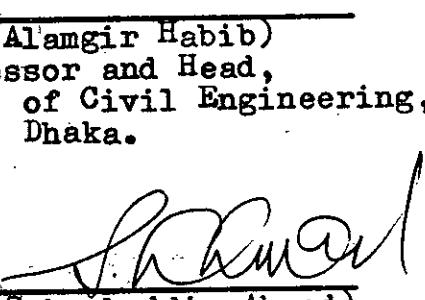
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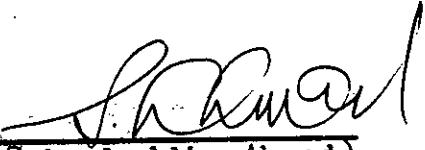
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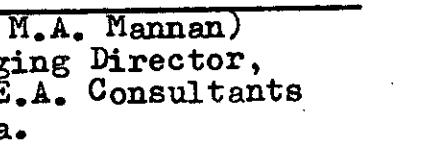
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ABSTRACT

A simplified method of analysis is developed for high-rise tubular structures, rectangular in plan, subjected to horizontal loading. The method is an extension of the continuous medium method proposed earlier by Choudhury for plane shear walls with multiple bands of openings.

The proposed method for deflection and stress analysis of a tubular structure is based on an idealisation of the discrete system of connections formed by spandrel beams as an equivalent continuous medium with equivalent stiffness properties. Based on the simplified method, a computer programme is written in FORTRAN for determination of maximum deflection, column axial forces and girder bending moments produced due to point load at top and lateral load uniformly distributed throughout the height. The shear lag effect on tubular structures is also studied for buildings with aspect ratios of 0.5, 0.75, 1.0, 1.5 and 2.0 and stiffness factors of 0.1, 1.0 and 10.0.

A comparative study of the available simplified methods, for the bending analysis of tubular structures, considering elastic behaviour is presented in graphical form. The methods are

- i) F.R. Khan method
- ii) A.H. Khan method
- iii) Coull and Bose method

Computer programmes are written on the basis of the above methods. A general computer programme for the three-dimensional analysis of tall buildings using an equivalent wide-column space frame has been used for investigating the accuracy of the different commonly used approximate methods of analysis.

The results obtained from the proposed continuous medium method agree very well with the 'exact' results obtained from the three-dimensional space frame analysis. The computer programme based on the method requires a very small computer storage and can yield acceptable results with very little computing effort. Therefore, the method may be conveniently used to rapidly evaluate the deflections and stresses for the tubular high-rise structures during preliminary design stage.

NOTATIONS

b	clear span of connecting beam
d	depth of connecting beam
H	Building height
h	storey height
i, j, k	integer variables
$l_{x,i}, a_i$	distance between centroidal axes of the two walls/columns in x-direction
$l_{y,i}, c_i$	distance between centroidal axes of the two walls/columns in y-direction
n	number of walls or opening
q	shear force intensity in connecting medium
w_x	intensity of applied horizontal loading in x-direction
w_y	intensity of applied horizontal loading in y-direction
z	vertical distance of any section from top
Y_1	horizontal deflection in x-direction
Y_2	horizontal deflection in y-direction
A_i	cross-sectional area of ith wall
E	modulus of elasticity
G	shear modulus
$I_{x,i}$	moment of inertia of ith wall about x-axis
$I_{y,i}$	moment of inertia of ith wall about y-axis
$I_{p,i}$	moment of inertia of ith connecting beam

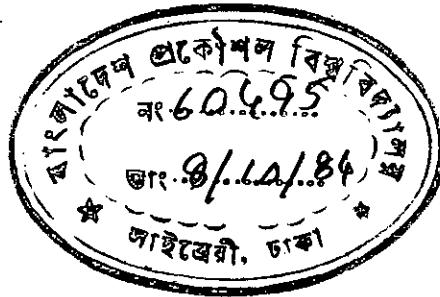
$I_{c,i}$	reduced moment of inertia of ith connecting beam
T	integral shear force
T'	$dT/dx; T'' = d^2T/dx^2$
F_i	axial force in ith wall
U_1	strain energy due to bending of beam
U_2	strain energy due to axial force of wall
U_3	strain energy due to bending of walls
U	total strain energy of the tube
M_x	bending moment in wall about x-axis
M_y	bending moment in wall about y-axis
α, β, γ	parameters defined in derivation
ν	Poisson's ratio
ξ	z/H

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CHAPTER 1
INTRODUCTION



1.1 General

The modern trend in urban planning is to build high-rise buildings in developing cities, particularly for office buildings. Low-rise buildings are often replaced by taller blocks in the more developed areas. The economy, aesthetics, efficiency and above all, the prestige associated with tall buildings have, in recent years, increased their rate of construction all over the world.

It is only in the last 30 years that reinforced concrete has found increasing use in the construction of tall buildings. In its initial development in the early parts of the twentieth century, reinforced concrete buildings were limited to only a few stories in height. The structural type used was the traditional beam-column frame system which made the construction of taller buildings relatively expensive. In the early 1950's, the introduction of shear walls opened up the possibility of using concrete in apartment and office buildings as high as 30 stories. Taller buildings still remained economically unattractive and technically inadequate, because the shear walls which were mostly used in the core of the building were relatively small in dimension compared to the height of such buildings, leading to insufficient stiffness to resist lateral loads. It was obvious that the overall dimensions of

the interior cores were too small to economically provide the stability and stiffness for buildings over 30 or 40 stories.

The natural tendency then was to find new systems of structures that would utilize the perimeter configurations of such buildings rather than to rely on the core configurations alone. The development of the special wall-frame, i.e. perforated wall structure known as a 'rigid tube', was, therefore, a logical outcome of this challenge. The modifications of the rigid tube system into a 'tube-in-tube', 'framed tube' and other variations are indeed known to offer certain advantages in planning, design and construction.

The 'rigid tube' system usually relies on 'hull-core' i.e tube-in-tube, type configurations for its basic layout; this has formed the structural backbone of almost all the tallest buildings constructed in recent years. The exterior enclosure tube or 'hull' usually consists of closely spaced columns connected together with deep spandrel beams at each floor level to form a multi-storey multi-bay box frame. For apartment buildings, this hull-tube alone or the hull with cross-walls provides the necessary stiffness against the lateral loads. For office buildings, the external hull is usually combined with an internal service 'core' through the floor system. The resulting 'hull-core' system is extremely efficient in resisting all kinds of horizontal loads, viz. winds, earthquakes or blasts.

1.2 Tubular Systems

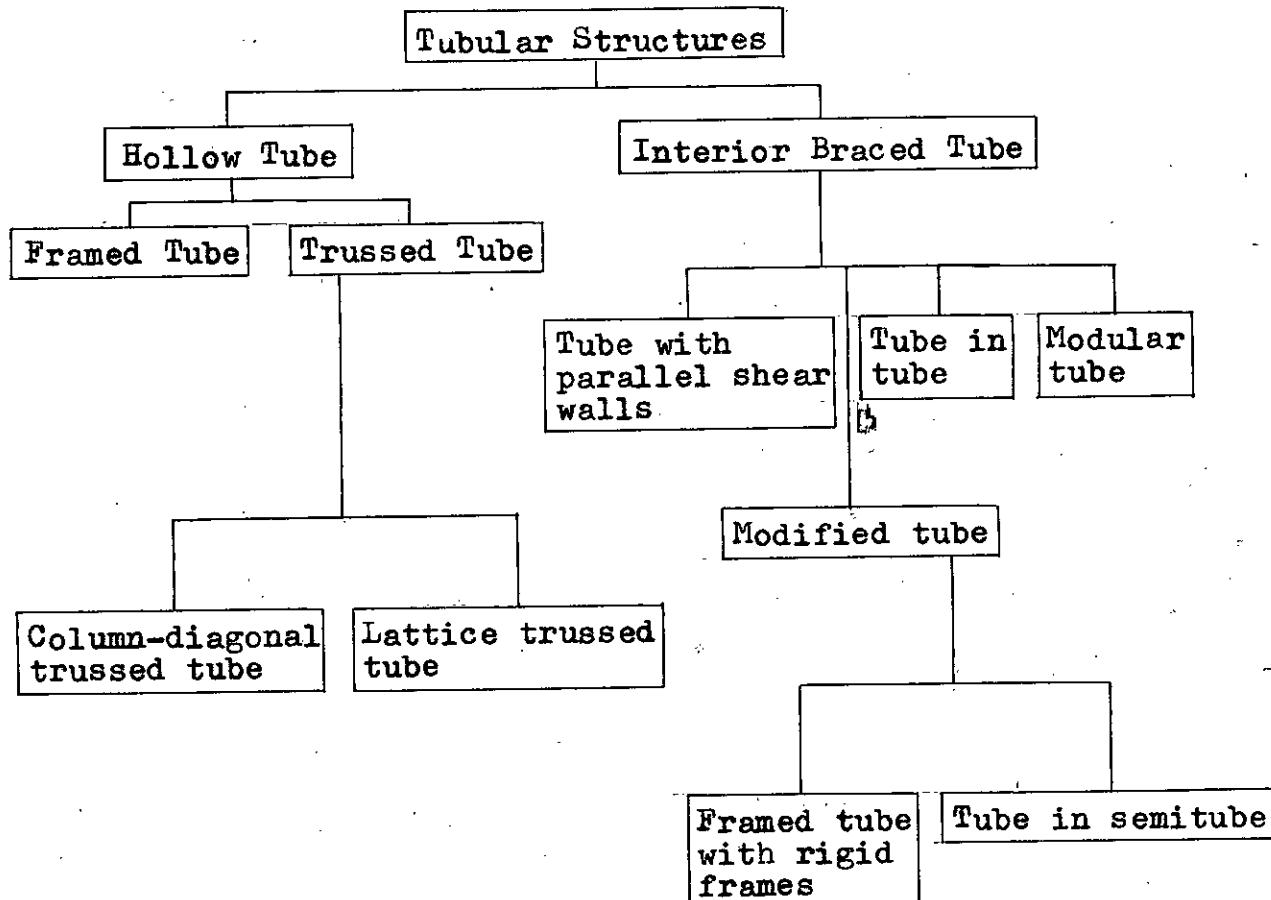
A recent development in structural design is the concept of tubular behaviour originally introduced by F.R. Khan⁽¹⁴⁾. At present (1984) four of the world's five tallest buildings use tubular systems. They are the John Hancock Building, the Sears Building, the Standard Oil Building in Chicago, and the World Trade Centre in New York (Figs. 1.1e,h,f,g, respectively). Tubular systems are so efficient that in most cases the amount of structural material used per square foot of floor space is comparable to that used in conventionally framed buildings half the height.

Tubular design assumes that the facade structure responds to lateral loads as a closed hollow box beam cantilevering out of the ground. Since the exterior walls resist all or most of the wind load, costly interior diagonal bracing or shear walls are eliminated.

The walls of the tube consist of closely spaced columns around the perimeter of the building tied together by deep spandrel beams. This facade structure looks like a perforated wall. The stiffness of the facade wall may be further increased by adding diagonal braces, causing trusslike action. The rigidity of the tube is so high that under lateral loading its behaviour is similar to a hollow cantilever beam.

The tubular structures may be subdivided into the following types as shown in Table 1.1.

Table 1.1 Classification of tubular structures
(adopted from Ref. 17)



1.2.1 Hollow Tube

(a) Framed Tube

The framed tube, the earliest application of the tubular concept, was first used by F.R. Khan in 1963 in the 43-story Dewitt Chestnut Apartment Building in Chicago. In this Vierendeel tube system, the exterior walls of the building, consisting of a closely spaced rectangular grid of beams and columns rigidly connected together, resist lateral loads through cantilever tube-action without using interior bracing.

The interior columns are assumed to carry gravity loads only and do not contribute to the exterior tube's stiffness (Fig. 1.2).

Other examples of hollow framed tube buildings are the 83-storey Standard Oil Building in Chicago and the 110 storey World Trade Centre in New York. Although these buildings have interior cores, they act as hollow tubes because the cores are not designed to resist lateral loads.

The effect of shear lag on the tube action results in nonlinear stress distribution along the column envelope; the columns at the corners of the building are forced to take a higher share of the load than the columns in between (Fig.1.5). Furthermore, the total deflection of the building no longer resembles a cantilever beam, as shear mode deformation becomes more significant.

The shear lag problem severely affects the efficiency of tubular systems, and all later developments of tubular design attempt to minimize it. The framed tube principle seems to be economical for steel buildings upto 80 stories and for concrete buildings upto 60 stories.

(b) Trussed Tube

The inherent weakness of the framed tube lies in the flexibility of its spandrel beams. Its rigidity is greatly improved by adding diagonal members. The shear is now primarily

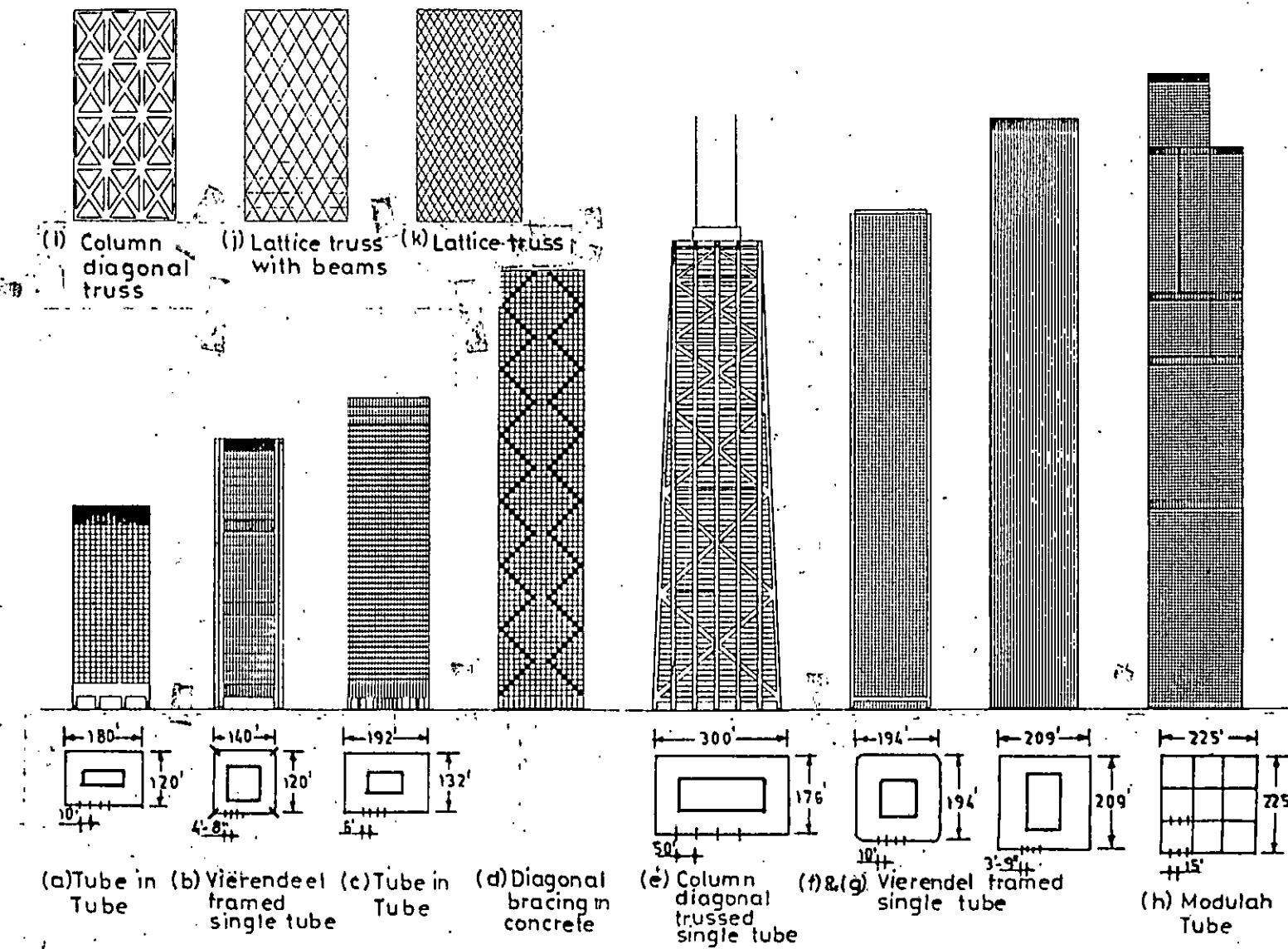


Fig. 1.1 Tubular Building Structures.

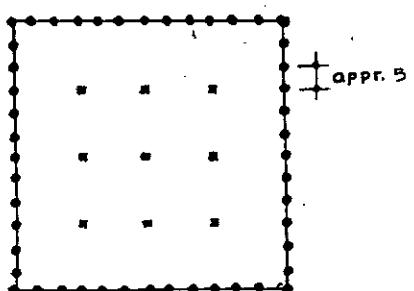


Fig. 1.2 Framed hollow tube

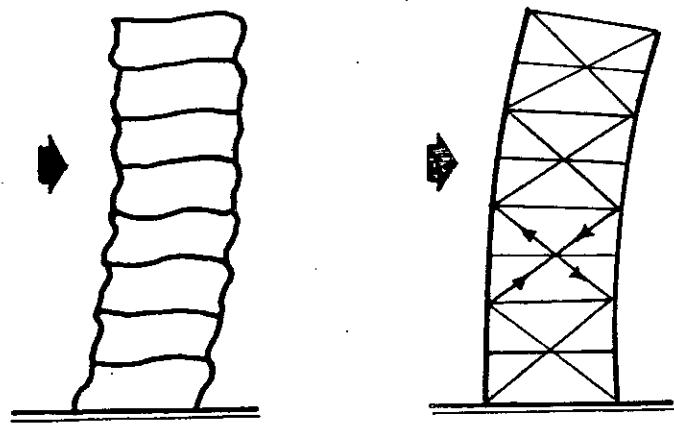


Fig. 1.3 Column-Diagonal Trussed Tube

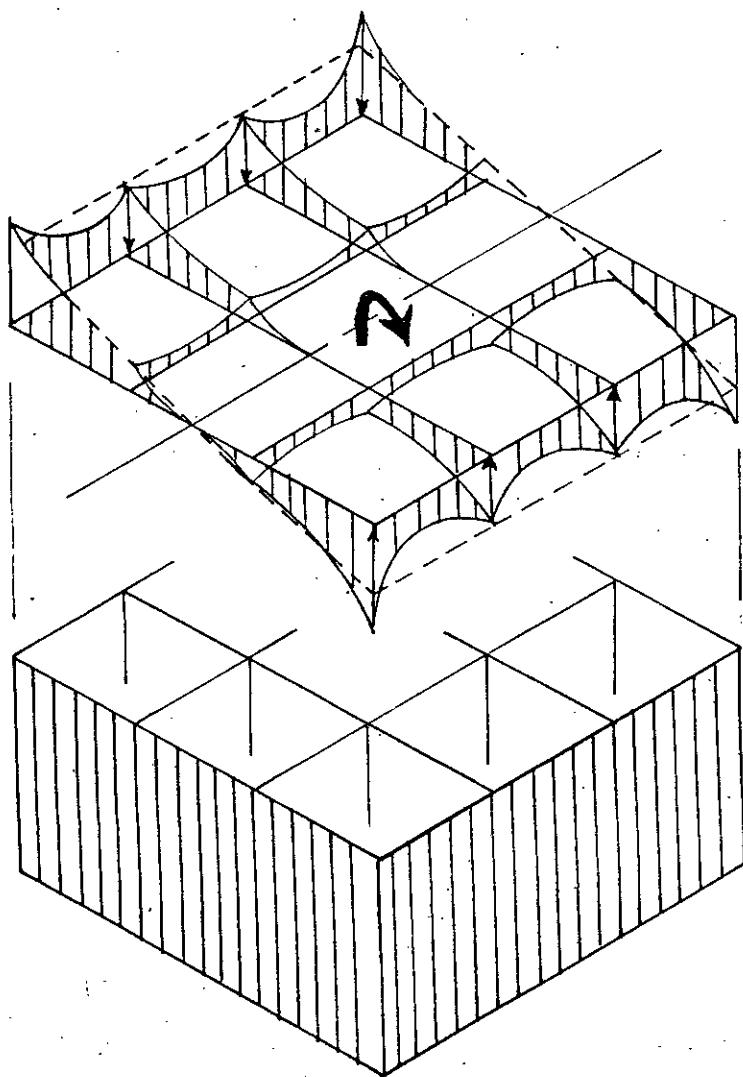


Fig. 1.4

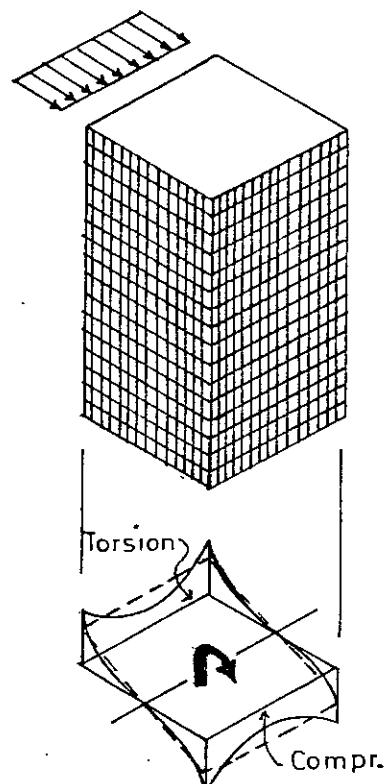


Fig. 1.5

absorbed by the diagonals, not by the spandrels. The diagonals carry the lateral forces directly in predominantly axial action. This reduction of shear lag provides for nearly pure cantilever behaviour (Fig. 1.3).

This system uses diagonals within the rectangular grid of beams and columns. The diagonals together with the spandrel beams create a wall-like rigidity against lateral loads. Not only do the diagonals carry the major portion of the wind loads, they act as inclined columns supporting gravity loads, as well.

Normally the compression induced by gravity loads is not overcome by the tension caused by lateral loads - this dual function of the diagonal members makes this system more efficient for very tall buildings (upto about 100 stories in steel). It allows much larger spacing of columns than the framed tube.

(c) Lattice Trussed Tube

In this system the tube is made up of closely spaced diagonals with no vertical columns (Figs. 1.1j,k). The diagonals act as inclined columns, carry all gravity loads, and stiffen the structure against wind. The diagonals may be tied together by horizontal beams.

The diagonals are extremely efficient in responding to lateral loads, but they are less efficient than vertical columns in transmitting gravity loads to the ground. Furthermore, the

large number of joints required between diagonals and the problems related to window details make the lattice truss system generally impractical.

1.2.2 Interior Braced Tube

The framed exterior tube may be stiffened in plane by adding diagonals, or it may be stiffened from within the building by adding shear walls or interior cores. Several approaches to interior bracings are as follows:-

(a) Modular Tube

The latest development in tubular design is the modular or bundled tube principle. This system has been used for the Sears Building in Chicago (Fig. 1.4), currently the tallest building in the world.

The exterior framed tube is stiffened by interior cross diaphragms in both directions (Fig. 1.4) an assemblage of cell tubes is thus formed. These individual tubes are independently strong, therefore may be bundled in any configuration and discontinued at any level. A further advantage of this bundled tube system lies in the extremely large floor areas that may be enclosed.

The interior diaphragms act as webs of a huge cantilever beam in resisting shear forces, thus minimizing ~~shear lag~~. In addition, they contribute strength against bending.

The behavior of this system is shown in the stress distribution diagram in Fig. 1.4. The diaphragms parallel to the wind (i.e webs) absorb shear, thereby generating points of peak stress at points of intersection with perpendicular walls (i.e. flanges) indicating the individual action of each tube.

(b) Tube-in-tube

The stiffness of a ~~hollow~~ tube system is very much improved by using the core not only for gravity loads but to resist lateral loads, as well. The floor structure ties the exterior and interior tubes together, and they respond as a unit to lateral forces.

The reaction of a tube in tube system to wind is similar to that of a frame and shear wall structure. However, the framed exterior tube is much stiffer than a rigid frame. The exterior tube resists most of the wind in the upper portion of the building, whereas the core carries most of the loads in the lower portion .

The tube in tube approach has been used by Khan⁽¹⁴⁾ in the 38-storey Brunswick Building in Chicago, and the 52-storey One Shell Plaza Building in Houston.

1.3 Objective of the Present Work

The objective of this work is

- (i) to develop a simple method for linear elastic analysis of high-rise tubular structures subjected to lateral loads.

- (ii) to compare the results obtained from different commonly used approximate methods of solution with those obtained from a 3-D analysis of the tubular structures idealised as a space frame.
- (iii) to study the shear lag effect on tubular structures with different aspect ratios and different stiffness factors.

CHAPTER 2

REVIEW OF AVAILABLE APPROXIMATE METHODS OF ANALYSIS OF TUBULAR STRUCTURES

2.1 Introduction

The approximate methods of structural analysis were developed to enable the engineer to reach quick decisions regarding the dimensions and layout of structural members and to compare different schemes of structural systems. Although the availability of powerful and sophisticated computers encourages the engineers to go for exact analysis of the structures, the final design is often accomplished by shuttling between "analysis" and "design"; the starting (i.e the preliminary design) and acceptance of the final design still require engineering judgement. In both cases, the engineer needs to make short hand calculations either to prepare "analysis" or to assure himself that the "computer results are at least realistic".

2.2 Research on Shear-lag Analysis of Box Beams

Shear lag phenomenon, resulting in a nonuniform distribution of bending stresses across wide flanges of a beam cross-section, has long been recognized. The analysis and design of box-beams with this special problem have also been investigated by aeronautical engineers. The pre and post World War II periods are especially marked for researches on

box-like components of aircraft structure and so most of the significant papers on box-beams were published during this time.

A.H. Khan⁽¹³⁾ has extensively studied the past research on shear-lag analysis of box beams. Many early works on shear-lag problems are referred to in this paper. He used energy theorems and calculus of variation to present a general solution for bending and twisting of thinwalled closed tubular structure. He assumed the spanwise displacements of a beam in the form of finite series incorporating the chordwise (transverse) displacements as some chosen and simple functions. A number of simultaneous differential equations are obtained which can be solved for stress and displacements.

D.A. Foutch and P.C. Chang⁽¹¹⁾ have reported an interesting phenomenon associated with shear-lag in the flanges of box girders that is quite contrary to well established ideas concerning this subject. If a cantilever tube is loaded laterally under non-uniform shear, a reversal of the shear lag distribution may occur at some point in the beam; the centre-line stress may exceed the edge stress.

2.3 Works on Rigid-tube Structures

Considering the number of buildings constructed all over the world using the rigid-tube concept, the published informations concerning their behaviour under load is contained in a relatively few papers. The approximate method of analysis for

their preliminary design suggested by the ACI Committee ⁽¹⁾ is probably among the first of the simplified methods of analysis. In this method, two distinct types of behaviour of a framed-tube structure are recognised, viz, the frame behaviour of two sides parallel to wind direction, and the tube behaviour of the entire structure. For the first action, the committee suggested the Portal method of analysis of two parallel frames. For the second, the whole structure is simulated by a vertical cantilevered beam with two discrete channels. To account for shear-lag effect, the 'effective flange-width' is taken as a function of the three external dimensions of the tube (Ref. 2).

Coull and Subedi's ^(4,5) method of analysis for framed-tube structures is based on a modified plane-frame computer program. By recognising that the major interaction between the frames parallel and perpendicular to the lateral loads are vertical shear forces at the corners, the two orthogonal frames are considered to lie in the same plane and are connected in series by fictitious linking members whose stiffnesses are chosen to allow only vertical forces to be transmitted between the frames. By recognizing this dominant mode of behaviour, it is possible to reduce the analysis to that of an equivalent plane frame, with a consequent large reduction in the amount of computation required in a conventional three-dimensional analysis.

Coull and Bose⁽³⁾ method of analysis for framed-tube structure provides a simple closed form solution by replacing the discrete structure by an equivalent orthotropic tube, and making simplifying assumptions regarding the stress distributions in the structure.

A simplified method is also presented by Ast and Schwaighofer⁽¹⁾ for the analysis of framed-tube structures when subjected to bending due to lateral loading. The method consists in replacing the three-dimensional tube by an equivalent two-dimensional system. Several additional simplifications are assumed and their influence on the accuracy of the results is demonstrated.

An approximate method is also available from Chan, Tso and Heidebrecht⁽¹⁰⁾ to study the interacting effect of normal frames on uniform shear walls and the shear lag effect in the normal frames. Based on the axial deformation distribution among columns, a reasonable assumption is introduced to simplify the method.

Rigorous treatment of the analysis of a framed-tube structure have been presented by F.R. Khan and Amin⁽¹⁴⁾ and A.H. Khan⁽¹³⁾.

F.R. Khan and Amin⁽¹⁴⁾ presented a graphical-analytical solution for framed tubes of any dimension and of any height. Influence curves are presented for an equivalent 10-storey tube with various ratios of bending stiffness of columns to

shearing stiffness of beams, and different aspect ratios of the building. From these curves, the axial forces in the columns and shear forces in the spandrel beams of a tube of any height can be obtained using a reduction modelling technique. A large number of computer runs on a 10-storey equivalent plane-frame were made to construct the influence curves for various factors. The effect of shear lag is taken into account by the nature of the computer analysis.

A.H. Khan⁽¹³⁾ suggested a simplified method of analysis of tube structures, which takes into account the effect of shear-lag in a tube formed by uniform plates perforated by a large number of regular openings. The effect of rigid joints is also considered in constructing the mathematical model. The range of the method is then extended to include various tubular structures of different beam-column stiffness ratios, thickness and material variations in adjacent or opposite walls. He considers the framed tube as an equivalent solid thin-walled beam. This method is limited to structures having height to width ratio greater than two and with relatively deep members. Also the properties of the structure must be constant across its width and along its height. The accuracy of the method is lost appreciably when the ratios of beam depth to storey height and column depth to bay width are less than 0.25, (Ref. 16).

A simple method for the analysis of large multistorey multibay framework has been presented by Kinh, Paul and Osama⁽¹⁶⁾.

It is based on replacing the actual structure by an elastically equivalent orthotropic membrane, which is then analysed by the finite element technique. The inflection points for the bottom storey columns are assumed at $2/3$ of the storey height from the base. The refined expressions for the equivalent elastic properties in combination with the versatility of the finite element technique make this method well adapted to a wide range of tubular structures. Out of several approximate methods, A.H. Khan, F.R. Khan, Coull and Bose methods are very popular for preliminary design purpose. The outline of these methods are discussed in the following section.

2.4. A.H. Khan Method ⁽¹³⁾

2.4.1 Assumptions

- i) In plane deformation of the section of the beam is assumed negligible. This is a reasonable assumption in view of the diaphragm actions of floor slabs at every storey level.
- ii) The properties of the structure are assumed constant across its width and along its height.
- iii) The in-plane stiffness of flanges and webs are considered; out of plane warping of the section due to torsional load is also included.
- iv) The simple functions describing the chordwise distribution of displacements are assumed so that the shear-lag effect is taken into account.
- v) The influence of grid joints are considered in using stiffness properties of the analogous plates of the equivalent tube.

2.4.2 Method of Analysis

The main features of the method are:

- a) The perforated tube is converted into an equivalent unperforated hollow tube of underformable cross-sections, with appropriate stiffness properties.
- b) The solid-walled tube is analysed by the generalised energy principles and variational methods.
- c) The stresses and displacements of the equivalent tube are then converted to the design stresses of the rigid tube structures using the stress factors.

In this method, to represent the predominant behaviour of the tube in pure bending, longitudinal and transverse displacements are assumed in the form a finite series. The parabolic distribution of axial displacements in the flanges was assumed on the basis of experience from past shear-lag analyses and the cubic distribution in the web was assumed on the basis of stress distribution predicted by finite element analysis of similar three-dimensional structures.

The final expressions for the displacement functions, longitudinal stresses, and lateral deflection of the tube for different loadings are given in Appendix A-1. From the expressions for stresses and displacements of a cantilevered tube under different loading conditions, it is observed that the problem of shear-lag has been reduced to a one-dimensional problem involving a single quantity, α (or αL). It provides a

measure of the shear-lag effect at every cross-section of the structure. A study of the parameter, αL was made in connection with deflection and stresses of tubes with a wide range of heights. The parameter study is given in Appendix A-1.

2.4.3 Computer Program

Based on the method of analysis and parameter study presented in Appendix A-1, a computer program has been written in FORTRAN. A listing of the program is given in Appendix A-1.

2.5 F.R. Khan Method⁽¹⁴⁾

2.5.1 Assumptions

a) For very preliminary analysis

- i) For a very preliminary design, the effective configuration of the tube is assumed to two equivalent channels and channel flanges normally should not be more than half the depth of web (Frames parallel to lateral load), or more than about 10% of the height of the building.

b) For more accurate analysis

- i) The points of contraflexure are at mid-height of each storey.
- ii) The frame-tube has been replaced by an equivalent plane frame for the analysis.

iii) A linearly varying ratio of bending stiffnesses of columns to spandrels was assumed 0.75 at the roof to 0.5 at ground level.

2.5.2 Method of Analysis

For a very preliminary analysis of framed tube, the effective configuration of the tube is reduced to two equivalent channels resisting the total overturning moments. This overturning moment resisted by the two equivalent channels will produce axial forces in the closely spaced columns of these channels, as well as shear forces in the connecting spandrels. The preliminary estimate of the axial forces in the columns as well as the shears in the connecting spandrel can be based on the classical beam theory and can be expressed as follows:

$$P_w = \frac{M.C.A}{I_e}$$

$$\text{and } V_s = \frac{V_w \cdot Q \cdot h}{I_e}$$

where,

P_w = axial force due to wind

M = overturning moment

I_e = effective moment of inertia of the tube

V_s = spandrel shear

V_w = total wind shear

Q = sum of first moment of column areas about the
neutral axis

C = distance of any column from the neutral axis

h = story height

A_c = cross sectional area of column

These approximate rules have generally given conservative values of shear and moment as compared to the actual forces in the exterior columns obtained by the exact analysis performed subsequently by a generalized computer program such as STRESS, STRUDL, or others.

To achieve a more accurate design than the equivalent channel method, F.R. Khan has developed influence curves which can be directly used for a relatively accurate preliminary design. These curves have been developed on the basis of a number of computer runs on a 10-story equivalent framed tube with variable nondimensional parameters representing ratios of shear stiffness, S_b , of the spandrel beam to the axial stiffness, S_c , of the columns, and a linearly varying ratio of bending stiffness of columns to spandrels. The significant structural properties of the tube structure are given in Appendix A-2.

Using the non-dimensional parameters, a total of nine nondimensional preliminary design curves are presented by F.R. Khan⁽¹⁴⁾. The design curves are shown in Appendix A-2. The main purposes of developing the curves was to provide the

design engineer a tool to determine the tubular characteristics of any given framed tube and quickly compute the total deflection and bending moments and shears in the beams caused by the tubular nature of the entire structure.

The framed tube system always has two components of its behavior: a) the frame action of the two sides parallel to the direction of the lateral load, and b) the overturning action of the entire tube causing only tension and compression in the exterior columns. All the influence curves presented by the author are for the evaluation of the tube action only, although the use of these curves will allow one to compute the approximate moments and shears in the spandrels which will define one boundary of the column moments. The other boundary of the column moments at any typical storey should be obtained by assuming the point of contraflexure at mid-height of each storey. For preliminary design the higher of the two values should be used.

To compute the total deflection, the additional deflection due to frame action must be calculated separately and added to the deflection caused by the tube action.

2.6 Coull and Bose Method⁽³⁾

2.6.1 Assumptions

- i) Out of plane deformation of the panels are neglected because of high in-plane stiffness of the floor slab.

- ii) The spacing of the beams and columns are assumed uniform throughout the height.
- iii) To simplify the expressions in the analysis, it is assumed that both beams and columns are of uniform section throughout the height.
- iv) It is assumed that the structure possesses two horizontal axes of symmetry, passing through the vertical central axes, so that the stress systems in the side panels are identical, and those in the normal panels are equal and opposite.
- v) The cross-elasticity terms, E_{yz} , E_{xz} etc. is assumed negligible.
- vi) The stresses are expressed with sufficient accuracy as a power series in the horizontal coordinate, x or y, the co-efficients of the series being arbitrary functions of the height coordinate, z;
- vii) Parabolic distribution of vertical stresses, σ_z , in the normal panel are assumed.

2.6.2 Methods of Analysis

A simplified procedure has been presented by Coull & Bose⁽³⁾ for the analysis of framed-tube structures for tall buildings subjected to lateral loading, making some simplifying assumptions regarding the stress distributions.

In the framed-tube structure shown in Fig. 2.1 the, lateral load is resisted primarily by the following actions: i) the rigidly jointed frame actions of the shear resisting panels parallel to the load (AB and DC); ii) the axial deformation of the load (AD and BC); and iii) the axial forces in the discrete corner columns. The interactions between the normal and side panels consist mainly of vertical interactive forces along corners A,B,C and D. The equivalent tube composed of orthotropic plate panels is shown in Fig. 2.1, in which the stress system on a small element on each face is given.

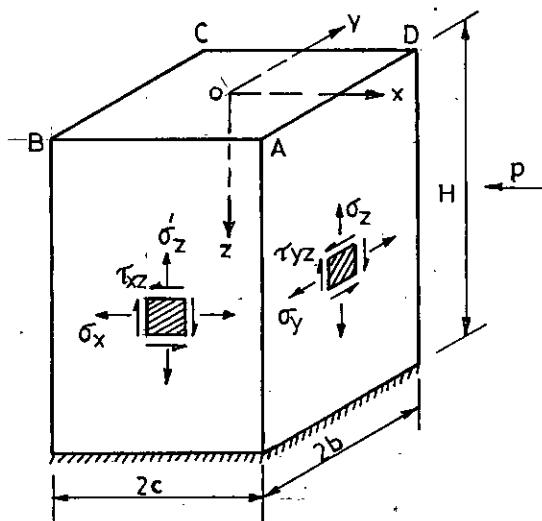


Fig. 2.1 Notation for stresses.

The stress components are expressed in the form of power series in the horizontal coordinate, the coefficients of the series being functions of the height coordinate only. It was assumed in the case of bending in the Oxz plane that the stress σ_z and σ'_z could be expressed as simply as possible as parabolic and cubic series, respectively, while in the

case of torsion the shearing stresses τ_{xz} and τ_{yz} could be approximated by parabolic forms. Statically correct distributions could then be obtained from the equilibrium conditions for the remaining stress components. After satisfying the overall equilibrium conditions and the equations of equilibrium and compatibility along the corners, all stress components could be expressed in terms of a single stress function, S . For different loading conditions, this stress function and governing equations for stresses are given in Appendix A-3.

2.6.3 Computer Program

Based on the method of analysis presented in Sec. 2.6.2, a computer program has been written in FORTRAN. A listing of the program is given in Appendix A-3.

2.7 Three-dimensional Equivalent Frame Method

2.7.1 Introduction

In this method, the tubular structure is replaced by an equivalent wide-column space frame. The frame may be conveniently analyzed by the stiffness method. The mathematical formulation and a computer program was presented by Choudhury⁽⁷⁾.

A special technique was developed by taking advantage of the sparse nature of the stiffness matrices of the frame.

To avoid the inversion of large matrices, the system coordinates of the structure are selected in such a way that the resulting matrix which must be inverted will be tridiagonal band matrix. Using the band matrix, the analysis is conducted by recursion procedure which requires the inversion of low order matrices.

2.7.2 Assumptions and Limitations

Although the method of analysis is general, it is based on certain assumptions and limitations which are outlined below:

(i) Regular rectangular building frame:

The building is laid out in a rectangular grid pattern. Storey heights, and column stiffnesses may vary arbitrarily, as may the bay widths in each direction. Departure from regularity resulting from omission of members at arbitrary locations may be accommodated by assuming zero stiffness properties for the omitted members.

(ii) Rigid floor diaphragms:

Due to the in-plane rigidity of the floor-slab, the vertical elements at any floor level undergo the same displacements (both translation and rotation) in the horizontal plane.

(iii) Rigid joints:

The jointing between the individual elements is fundamental to the integrity of the structure. Due to the linear variation of vertical deflection in the walls, the floor slabs are constrained to follow the same linearly varying deflected shape along the line of connection.

(iv) Axial and shear deformations:

Axial deformation of the columns and walls are considered in the analysis, but the girder axial deformations are neglected (as required by the rigid floor diaphragm). The shear deformations and the flexural deformations in all members are also considered in the analysis.

v) Torsional stiffness:

The non-uniform torsion of the walls is neglected. Uniform torsional stiffness of the panel components, beams, columns, walls etc. are included.

2.7.3 Method of Analysis

The approach, wide-column frame method, in which the wall and beam elements are replaced by line elements along their centroidal axis, is used for the analysis of plain frame. These elements are constrained to follow the same bending shear and axial deformation as those of the representing medium. The joints connecting the beam end to the wall

centre line are assumed to be infinitely rigid so that along the line of contact the floor plate and the wall have the same vertical deflection. Thus the above mentioned replacements are implicitly made and the equivalent frame is capable of truly representing the behaviour of the actual structure. Floor slabs flexural stiffnesses are calculated using finite element technique. The solution comprises six stages:-

- i) Computing the stiffness matrix of the whole floor system, comprising beams and plate elements.
- ii) Condensation of the stiffness matrix to conform to the degrees of freedom of the equivalent frame.
- iii) Computing the stiffness matrices of the wall and column elements of each storey.
- iv) Superposition of the matrices obtained from (ii) and (iii) to obtain the overall stiffness matrix of the equivalent frame.
- v) Solution of the equilibrium equation by recursion technique.
- vi) Computing the stress resultants in walls and columns.

The stiffness matrix of floor slab is generated using finite element techniques. The generalized procedure to use the technique can be summarized as follows:

- a) Idealization of the structure into finite number of elements.

- b) Calculation of the stiffnesses of each element of the idealized structure.
- c) Assembling the individual stiffness matrices to form the overall stiffness matrix of the structure.
- d) Calculation of the nodal force vectors.
- e) Imposition of boundary condition, and
- f) Solution of the equilibrium equations to obtain nodal displacements and finally, the stresses.

2.7.4 Computer program

A general program, based on the analysis described in the section 2.7.3 is written in FORTRAN by Choudhury M.R.⁽⁸⁾. The analysis was originally introduced by J.R. Choudhury⁽⁷⁾, in his Ph.D. thesis and he developed a computer program of this analysis using ALGOL. The programme is modified slightly by the author for the suitable solution of the framed tube structure where the total number of walls is equal to the total number of nodes. The listing of the program in FORTRAN is presented in Appendix-A4.

CHAPTER 3
SIMPLIFIED ANALYSIS OF TUBULAR STRUCTURE
BY CONTINUOUS MEDIUM METHOD

3.1 Introduction

A simplified method of solution for high-rise tubular structures is presented in this chapter. The method is an extension of the continuous medium method proposed earlier by Choudhury (Ref. 7) for plane shear walls with multiple bands of openings. The method consists in replacing the spandrel beams by a continuous medium (Fig. 3.1), obtaining a series of ordinary differential equations for the shear forces in the continuous medium by minimizing the strain energy, and solving the equations by using a weighted residual method suggested by Galerkin. The main advantage of the method is that the solution time is independent of the number of stories and depends only on the number of columns. This makes it possible to obtain approximate solutions very rapidly using a small computer.

3.2 Assumptions

i) The connecting beams do not deform axially and hence the lateral deflection of individual walls is the same at any level.

ii) The moment of inertia and cross-sectional areas of the walls and the connecting beams are constant throughout the height, except the connecting beam at the top most storey

which has half the moment of inertia and half the cross-sectional area of the other beams.

iii) The point of contraflexure of the connecting beams are at their midspan.

iv) Plane section of the wall before bending remains plane after bending, so that the moment curvature relations based on the simple engineers theory of bending (ETB) may be used.

3.3 General Formulation

The formulation technique has been adopted from Ph.D. thesis of Choudhury⁽⁷⁾. Fig. 3.3 shows a typical floor plan of a tubular structure, consisting of closely spaced columns at arbitrary locations and connected by deep spandrel beams at floor levels. It is assumed that the cross-section of column is rectangular and doubly symmetrical. The discrete connecting beams of stiffness EI_p are replaced by a continuous medium connecting the walls for the full height and having the same bending stiffness as the beams they replace. The structure is released by introducing a cut along the line of contraflexure and the integral of distributed shear forces in the connecting medium,

$$T = \int_0^Z q dz \quad (3.1)$$

is taken as the redundant function (Fig. 3.2).

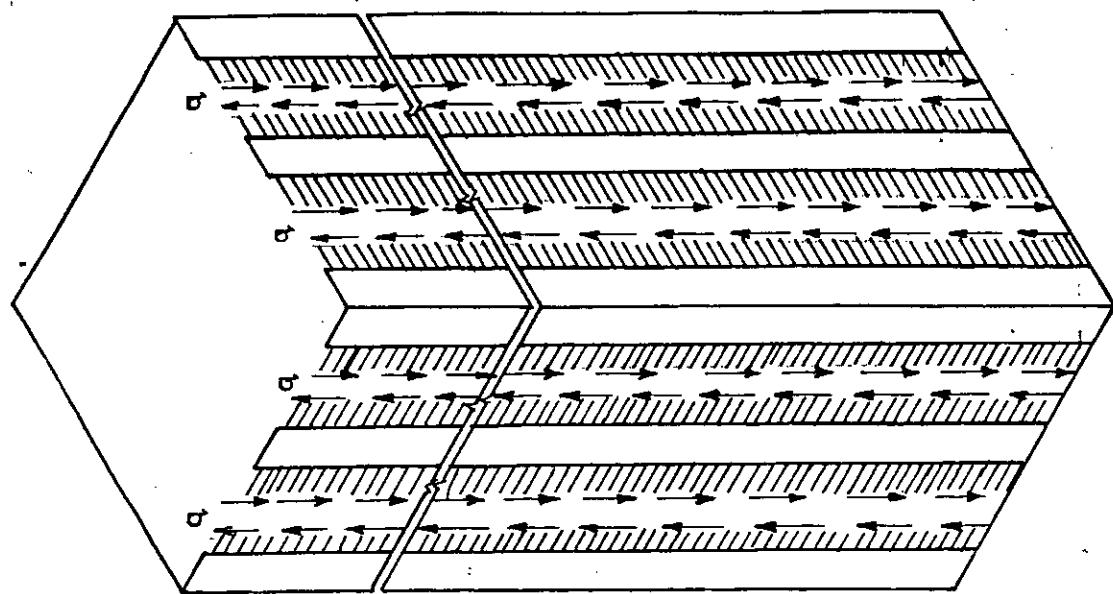
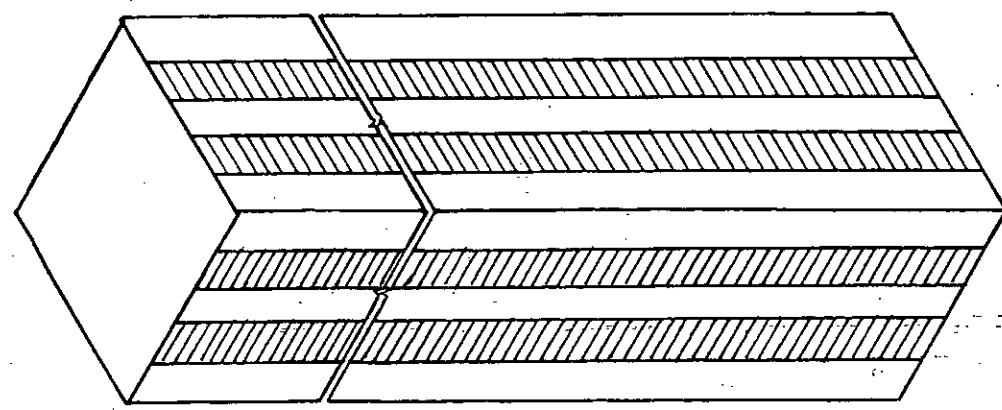
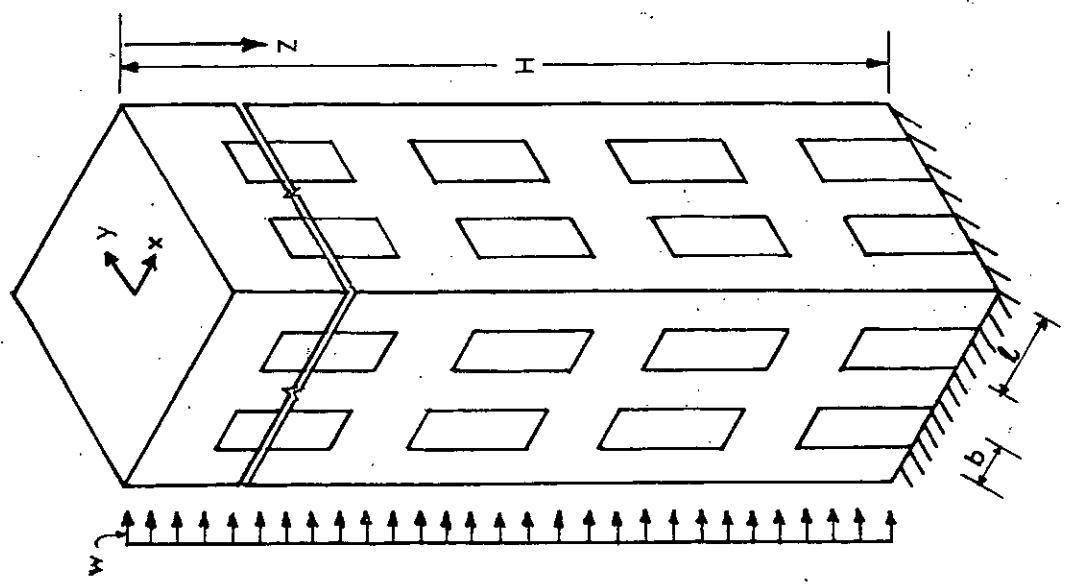


FIG. 3.2 Released Structure



(b) Beams Replaced by Continuous Medium



(a) Tube with Openings

Fig. 3.1 Tube Structure

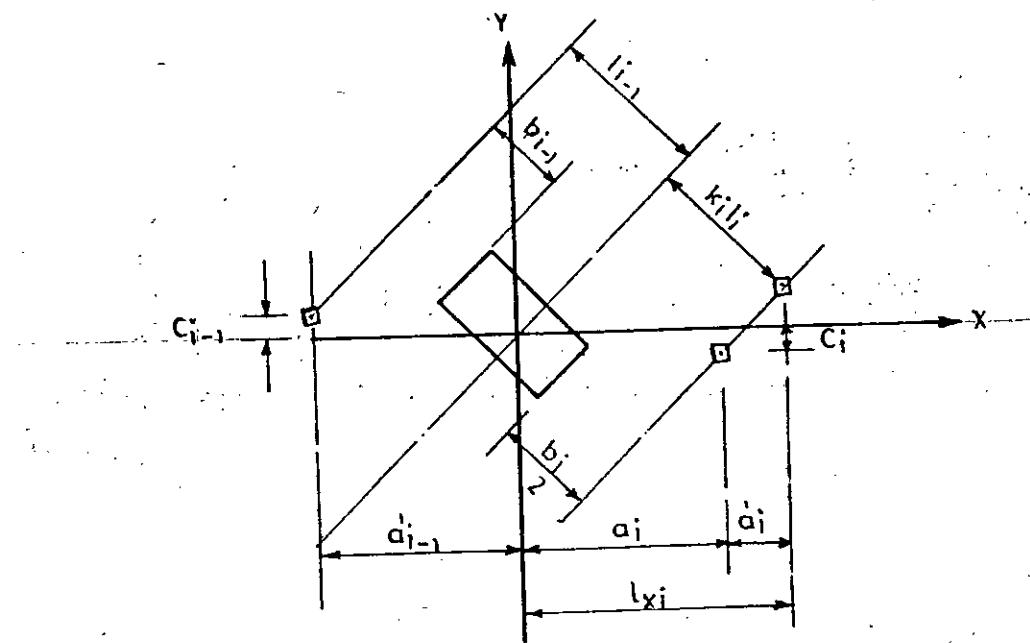
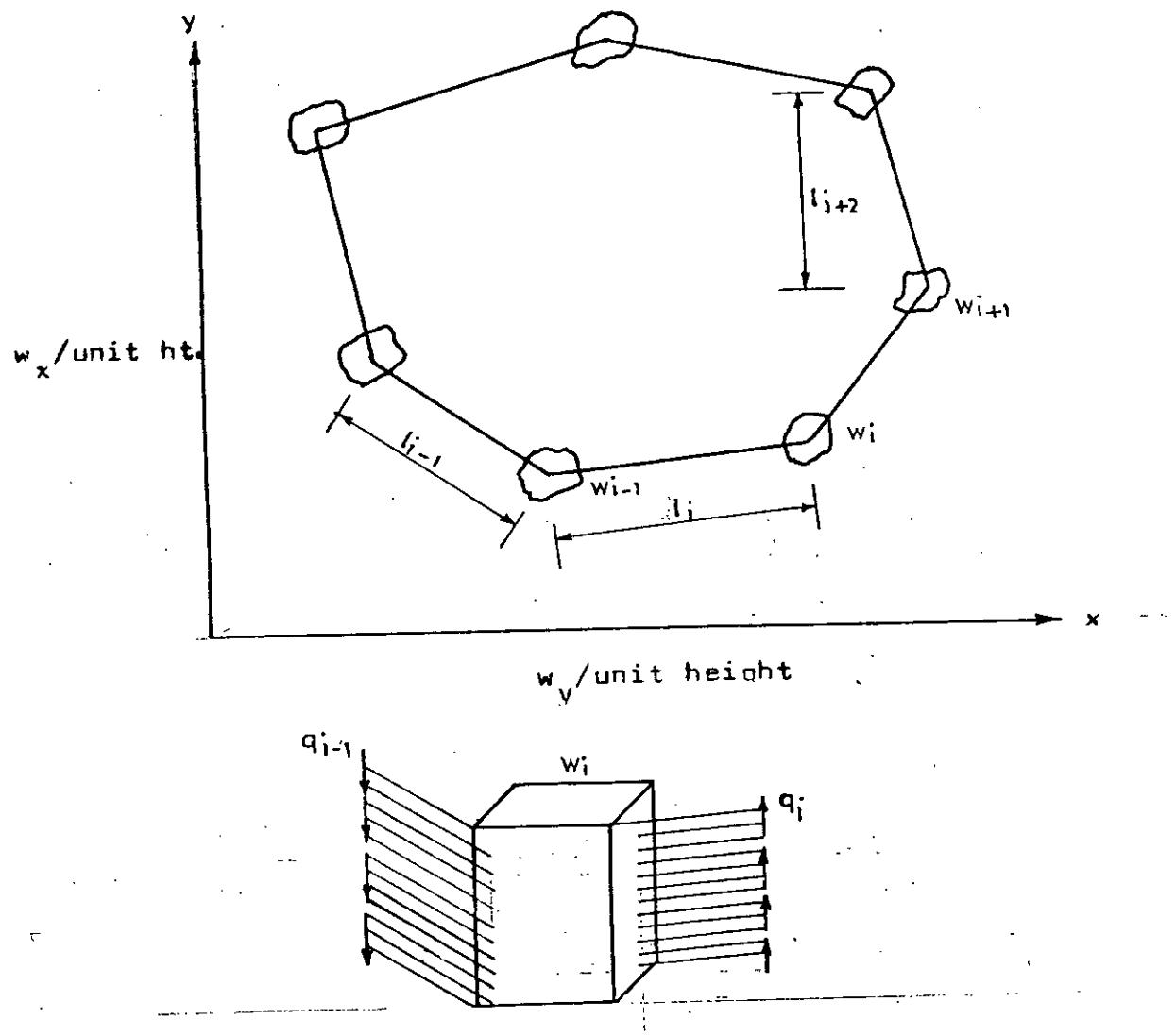


Fig. 3.3 Typical floor plan of a tubular structure.

The governing equation for the function T will be derived from energy considerations (as originally suggested by Rosman). Neglecting the effect of axial forces, the strain energy due to bending of the continuous medium of height dz is

$$\delta U_1 = 2 \left[\int_0^{b_i} \frac{(q_i x)^2}{2 I_{p,i}} dx + \frac{1.2 q_i^2 h_i}{2 A_{p,i} G} \right] dz \quad (3.2)$$

Substituting the value of $G = \frac{E}{2(1+\nu)}$

$$\begin{aligned} \delta U_1 &= \frac{q_i^2 b_i^3 h_i}{24 E I_{p,i}} \left[1 + 2.4 \left(\frac{d_i}{b_i} \right)^2 (1 + \nu) \right] dz \\ &= (T')^2 \frac{b_i^3 h_i}{24 E I_{c,i}} dz \end{aligned} \quad (3.3)$$

$$\text{where } I_{c,i} = \frac{I_{p,i}}{1 + 2.4 \left(\frac{d_i}{b_i} \right)^2 (1 + \nu)} \quad (3.4)$$

Strain energy due to axial deformation in ith wall

$$\delta U_2 = \frac{(T_i - T_{i-1})^2}{2 E A_i} dz \quad (3.5)$$

Strain energy of ith wall due to bending deformation

$$\delta U_3 = \int_0^H \left\{ \frac{(M_{x,i})^2}{2 E I_{x,i}} + \frac{(M_{y,i})^2}{2 E I_{y,i}} \right\} dz \quad (3.6)$$

The bending moment $M_{x,i}$ and $M_{y,i}$ for any height z measuring from top of the tube, are expressed by -

$$M_{x,i} = \frac{-\frac{w_y z^2}{2} + \sum_{j=1}^n (T_j c_j + T_{j-1} c'_{j-1}) I_{xi}}{\sum_{j=1}^n I_{x,j}} \quad (3.7)$$

$$M_{y,i} = \frac{\frac{w_x z^2}{2} - \sum_{j=1}^n (T_j a_j + T_{j-1} a'_{j-1}) I_{y,i}}{\sum_{j=1}^n I_{y,j}} \quad (3.8)$$

For the tubular structures; due to continuity of beams

$$T_0 = T_n \text{ and } a'_0 = a'_n \quad (3.9)$$

$$\therefore \sum_{j=1}^n (T_j a_j + T_{j-1} a'_{j-1}) = (T_1 a_1 + T_0 a'_0) + (T_2 a_2 + T_1 a'_1) + \dots + (T_n a_n + T_{n-1} a'_{n-1}) \quad (3.10)$$

$$= \sum_{j=1}^n T_j \ell_{x,j} \quad (3.11)$$

$$\text{Similarly } \sum_{j=1}^n (T_j c_j + T_{j-1} c'_{j-1}) = \sum_{j=1}^n (T_j \ell_{y,j}) \quad (3.12)$$

Putting the values of $M_{x,i}$ and $M_{y,i}$ in Eqn. 3.6 and integrating

we get

$$\begin{aligned}
 U_3 &= \sum_{i=1}^n \left\{ \frac{-w_y z^2}{2} + \frac{(T_j l_{y,j})}{\sum_{j=1}^n I_{y,j}} \times I_{y,i} \right\}^2 / 2EI_{y,i} \\
 &\quad + \sum_{i=1}^n \left\{ \frac{w_x z^2}{2} - \frac{(T_j l_{x,j})}{\sum_{j=1}^n I_{x,j}} \times I_{x,i} \right\}^2 / 2EI_{x,i} \\
 &= \frac{\left(-\frac{w_y z^2}{2} + \sum_{j=1}^n T_j l_{y,j} \right)^2}{2E \sum I_{y,i}} + \frac{\left(\frac{w_x z^2}{2} - \sum_{j=1}^n T_j l_{x,j} \right)^2}{2E \sum I_{x,i}} \quad (3.13)
 \end{aligned}$$

\therefore Total strain energy of the system

$$U = U_1 + U_2 + U_3 = F(z, T, T') dz \quad (3.14)$$

The Euler equation of the calculus of variations states that,

if

$\oint = F(x, y, y') dx$, then for \oint to be minimum

$$\frac{\partial F}{\partial y} - \frac{d}{dz} \left(\frac{\partial F}{\partial y'} \right) = 0 \quad (3.15)$$

Applying this to minimize the strain energy of the system,

we will have

$$\frac{\partial U}{\partial T_i} - \frac{d}{dz} \left(\frac{\partial U}{\partial T'_i} \right) = 0 \quad (3.16)$$

$$\text{Now, } \frac{\partial U}{\partial T_i} = \frac{\partial U_1}{\partial T_i} + \frac{U_2}{T_i} + \frac{U_3}{T_i} \quad (3.17)$$

$$\text{and } \frac{d}{dz} \left(\frac{\partial U}{\partial T_i} \right) = \frac{d}{dz} \left(\frac{\partial U_1}{\partial T_i} \right) + \frac{d}{dz} \left(\frac{\partial U_2}{\partial T_i} \right) + \frac{d}{dz} \left(\frac{\partial U_3}{\partial T_i} \right)$$

$$\therefore \frac{\partial U_3}{\partial T_i} = \frac{\left(-\frac{Wz^2}{2} + \sum_{j=1}^n T_j \ell_{y,j} \right)}{E \sum I_{x,i}} x \ell_{y,i} + \frac{\left(\frac{Wz^2}{2} - \sum_{j=1}^n T_j \ell_{x,j} \right)}{E \sum I_{y,i}} x (-\ell_{xi})$$

$$\frac{\partial U_3}{\partial T_i} = 0 \quad (3.18)$$

$$\text{Similarly } \frac{\partial U_2}{\partial T_i} = \sum_{i=1}^n \frac{(T_i - T_{i-1})}{A_i E}$$

$$\frac{\partial U_2}{\partial T_i} = 0 \quad (3.19)$$

$$\text{and } \frac{\partial U_1}{\partial T_i} = 0$$

$$\frac{\partial U_1}{\partial T_i} = \frac{T_i b_i 3h_i}{12 E I_{ci}}$$

$$\therefore \frac{d}{dz} \left(\frac{\partial U_1}{\partial T_i} \right) = \frac{T_i'' b_i^3 h_i}{12 E I_{ci}} \quad (3.20)$$

Substituting the above expressions in eqn. (3.16) yields

$$\frac{-\frac{W}{2}z^2 \cdot l_{y,i}}{E \sum I_{x,i}} - \frac{\frac{W}{2}z^2 l_{x,i}}{E \sum I_{y,i}} + \frac{(T_i l_{y,i})}{E \sum I_{x,i}} x l_{y,i} \\ (3.21)$$

$$\frac{\sum (T_j l_{x,i})}{E \sum I_{y,i}} \cdot l_{x,i} - \left(\frac{T_{i+1} - T_i}{E A_{i+1}} \right) + \left(\frac{T_i - T_{i-1}}{E A_i} \right) - \frac{T''_i b_i^3 h_i}{12 E I_{c,i}} = 0$$

Rearranging the terms,

$$T''_i - \frac{12 I_{c,i}}{b_i^3 h_i} \left[\frac{\sum_{j=1}^n T_j \cdot l_{y,j}}{\sum I_{x,i}} \cdot l_{y,i} + \frac{\sum_{j=1}^n T_j l_{x,j}}{\sum I_{y,i}} \cdot l_{x,i} \right. \\ \left. + T_i \left(\frac{1}{A_i} + \frac{1}{A_{i+1}} \right) - \frac{T_{i-1}}{A_i} \left(\frac{T_{i+1}}{A_{i+1}} \right) + \right. \\ \left. + \left(\frac{W}{2} \cdot \frac{l_{x,i}}{\sum I_{y,i}} + \frac{W}{2} \cdot \frac{l_{y,i}}{\sum I_{x,i}} \right) \cdot \frac{12 I_{c,i}}{b_i^3 h_i} \cdot z^2 = 0 \right] \\ (3.22)$$

where $i = 1, 2, 3, \dots, n$

The above system of simultaneous second order differential equations may be written as

$$T''_1 - \alpha_{11}^2 T_1 - \alpha_{12}^2 T_2 \dots \dots \dots - \alpha_{1j}^2 T_j + \beta_1 z^2 = 0 \\ T''_2 - \alpha_{21}^2 T_1 - \alpha_{22}^2 T_2 \dots \dots \dots - \alpha_{2j}^2 T_j + \beta_2 z^2 = 0 \\ T''_i - \alpha_{i1}^2 T_1 - \alpha_{i2}^2 T_2 \dots \dots \dots - \alpha_{ij}^2 T_j + \beta_j z^2 = 0 \\ (3.23)$$

Where

$$\alpha_{ij}^2 = \left(\frac{l_{y,j} \cdot l_{y,i}}{\sum I_{x,i}} + \frac{l_{x,j} \cdot l_{x,i}}{\sum I_{y,i}} \right) \cdot \frac{12 I_{p,i}}{b_i^3 h_i} \quad \begin{array}{l} \text{when } j \neq i \\ \neq i+1 \\ \neq i-1 \end{array}$$

$$\alpha_{ij}^2 = \left(\frac{l_{y,j}^2}{\sum I_{x,i}} + \frac{l_{x,i}^2}{\sum I_{y,i}} + \frac{1}{A_i} + \frac{1}{A_{i+1}} \right) \cdot \frac{12 I_{c,i}}{b_i^3 h_i}$$

$$\alpha_{i,i+1}^2 = \left(\frac{l_{y,i+1} \cdot l_{y,i}}{\sum I_{x,i}} + \frac{l_{x,i+1} \cdot l_{x,i}}{\sum I_{y,i}} - \frac{1}{A_{i+1}} \right) \cdot \frac{12 I_{c,i}}{b_i^3 h_i}$$

$$\alpha_{i,i-1}^2 = \left(\frac{l_{y,i-1} \cdot l_{y,i}}{\sum I_{x,i}} + \frac{l_{x,i-1} \cdot l_{x,i}}{\sum I_{y,i}} - \frac{1}{A_i} \right) \cdot \frac{12 I_{c,i}}{b_i^3 h_i}$$

(3.24)

$$\text{and } \beta_i = \frac{12 I_{c,i}}{b_i^3 h_i} \cdot \left(\frac{W_x \cdot l_{x,i}}{2 \sum I_{y,i}} + \frac{W_y \cdot l_{y,i}}{2 \sum I_{x,i}} \right)$$

Written in matrix notation, eqn. (3.21) becomes

$$\frac{d^2}{dz^2} \begin{bmatrix} T_1 \\ T_2 \\ \vdots \\ T_n \end{bmatrix} = \begin{bmatrix} \alpha_{11}^2 & \alpha_{12}^2 & \cdots & \alpha_{1n}^2 \\ \alpha_{21}^2 & \alpha_{22}^2 & \cdots & \alpha_{2n}^2 \\ \vdots & \vdots & & \vdots \\ \alpha_{n1}^2 & \alpha_{n2}^2 & \cdots & \alpha_{nn}^2 \end{bmatrix} \begin{bmatrix} T_1 \\ T_2 \\ \vdots \\ T_n \end{bmatrix} + z^2 \begin{bmatrix} \beta_1 \\ \beta_2 \\ \vdots \\ \beta_n \end{bmatrix}$$

$$\text{or } \frac{d^2 T}{dz^2} = A \cdot T + \beta \cdot z^2 \quad (3.25)$$

An analytical solution of the above system of equations is too tedious for more than two bands of openings.

The boundary conditions for the equations are:

$$\text{at } z = 0 \quad T_i = 0 \quad (i = 1, 2, \dots, n)$$

$$\text{at } z = H, \quad \frac{dT_i}{dz} = 0 \quad (i = 1, 2, \dots, n) \quad (3.26)$$

Assuming the family of solutions

$$T_j = \sum_{i=1,3,5}^{\alpha} a_{ij} \sin \frac{i\pi z}{2H} \quad (j = 1, 2, \dots, n) \quad (3.27)$$

each term of which satisfies the boundary conditions Eqn. 3.26) and applying Galerkin's method to minimize the residuals, the following system of simultaneous equations in the a_{ij} 's are obtained:

$$1 \begin{bmatrix} \frac{i^2\pi^2}{4H^2} + \alpha_{11}^2 & \alpha_{12}^2 & \dots & \alpha_{1n}^2 \\ \alpha_{21}^2 & \frac{i^2\pi^2}{4H^2} + \alpha_{22}^2 & \dots & \alpha_{2n}^2 \\ \alpha_{n1}^2 & \alpha_{n2}^2 & \dots & \frac{i^2\pi^2}{4H^2} + \alpha_{nn}^2 \end{bmatrix} \begin{bmatrix} a_{i,1} \\ a_{i,2} \\ \vdots \\ a_{i,n} \end{bmatrix} = \frac{16H^2}{\pi_i^3} (\pi_i \sin \frac{\pi i}{2} - 2) \begin{bmatrix} \beta_1 \\ \beta_2 \\ \vdots \\ \beta_n \end{bmatrix}$$

X

$i = 1, 3, 5, \dots$ (3.28)

In matrix form:

$$\begin{bmatrix} \underline{C} \\ \underline{D}_i \end{bmatrix} \times \begin{bmatrix} \underline{D}_i \\ \underline{K} \end{bmatrix} = \begin{bmatrix} \underline{K} \end{bmatrix}$$

the solution of which gives the a_{ij} 's

$$\begin{bmatrix} \underline{D}_i \\ \underline{K} \end{bmatrix} = \begin{bmatrix} \underline{C}^{-1} \\ \underline{K} \end{bmatrix} \quad (3.29)$$

Once the a_{ij} 's are determined, the values of the T's at different heights may be evaluated by summing the series,

For wall i, at height z,

$$M_{x,i} = \frac{\frac{w_y z^2}{2} + \sum_{j=1}^n (T_j \cdot I_{x,j})}{\sum_{j=1}^n I_{y,j}} \cdot I_{y,i} \quad (3.30)$$

$$M_{y,i} = \frac{\frac{w_x z^2}{2} - \sum_{j=1}^n (T_j \cdot I_{y,j})}{\sum_{j=1}^n I_{x,j}} \cdot I_{x,i}$$

where T_j 's are calculated at height z.

Axial force in wall i at height z,

$$F_i = T_i - T_{i-1} \quad (3.31)$$

Deflections:

Using the moment curvature relationship

$$EI \frac{d^2 y_x}{dz^2} = \left(\frac{w_x z^2}{2} - \sum_{i=1}^n T_i I_{x,i} \right)$$

$$EI \frac{d^2y_x}{dz^2} = \left(\frac{w_x z^2}{2} - \sum_{i=1}^n T_i l_{y,i} \right) \text{ and}$$

Substituting the values of T_i 's from eqn. 3.27.

$$EI \frac{d^2y_x}{dz^2} = \frac{w_x z^2}{2} - \sum_{j=1}^n \left(\sum_{i=1,3,5}^{\alpha} a_{ij} \sin \frac{i\pi z}{2H} \right) l_{x,j} \quad (3.32)$$

$$\text{and } EI \frac{d^2y_y}{dz^2} = \frac{w_y z^2}{2} - \sum_{j=1}^n \left(\sum_{i=1,3,5}^{\alpha} a_{ij} \sin \frac{i\pi z}{2H} \right) l_{y,j}$$

Integrating twice, and substituting the appropriate boundary conditions,

$$(at z = H, y_x = y_y = \frac{dy_x}{dz} = \frac{dy_y}{dz} = 0)$$

$$\therefore EI y_x = w_x \left(\frac{z^4}{12} - \frac{H^3 z}{3} + \frac{H^4}{4} \right) - \frac{4H^2}{\pi^2} \sum_{j=1}^n \left[\sum_{i=1,3,5}^{\alpha} \left(\frac{\sin \frac{i\pi}{2} - \sin \frac{i\pi z}{2H}}{i^2} \right) \right] \cdot l_{x,j}$$

$$\text{and } EI y_y = w_y \left(\frac{z^4}{12} - \frac{H^3 z}{3} + \frac{H^4}{4} \right) - \frac{4H^2}{\pi^2} \sum_{j=1}^n \left[\sum_{i=1,3,5}^{\alpha} \left(\frac{\sin \frac{i\pi}{2} - \sin \frac{i\pi z}{2H}}{i^2} \right) \right] \cdot l_{y,j} \quad (3.33)$$

For point load at top:

The derivation follows exactly the same pattern as for the uniformly distributed load, the only difference is in the values of the loading terms in eqn. (3.25) expressed by $[B] \cdot z^2$, which is now replaced by

$$[B] \cdot z \quad \text{where} \quad [B] = \begin{bmatrix} \beta_1 \\ \beta_2 \\ \vdots \\ \vdots \\ \beta_n \end{bmatrix} \quad \text{and} \quad (3.34)$$

$$\beta_i = \frac{12 I_{ci}}{b_i^3 h_i} \left(\frac{P_x \cdot l_{x,i}}{\sum I_{y,i}} - \frac{P_y \cdot l_{y,i}}{\sum I_{x,i}} \right)$$

where P_x and P_y is the concentrated load applied horizontally at top.

In eqn. (3.28) the K matrix becomes

$$[K] = \frac{8H}{i\pi^2} \sin \frac{i\pi}{2} \begin{bmatrix} \beta_1 \\ \beta_2 \\ \vdots \\ \vdots \\ \beta_n \end{bmatrix} \quad (3.35)$$

and eqn. for moment (3.30) is modified to

$$M_{x,i} = (P_x \cdot z - \sum_{i=1}^n T_i \cdot l_{x,i}) \cdot \frac{l_{x,i}}{\sum I_{x,i}} \quad (3.36)$$

$$M_{y,i} = (P_y \cdot z - \sum_{i=1}^n T_i \cdot l_{y,i}) \cdot \frac{l_{y,i}}{\sum I_{y,i}}$$

and eqn. for deflection becomes

$$EIy_x = p_x \left(\frac{z^3}{6} - \frac{H^2 z}{2} + \frac{H^3}{3} \right) - \frac{4H^2}{2} \sum_{j=1}^n \left[\sum_{i=1,3,5}^{\alpha} d_{ij} \cdot \frac{\sin \frac{i\pi}{2} - \sin \frac{i\pi z}{2H}}{i^2} \right] \cdot l_{x,j} \quad (3.37)$$

$$EIy_y = p_y \left(\frac{z^3}{6} - \frac{H^2 z}{2} + \frac{H^3}{3} \right) - \frac{4H^2}{2} \sum_{j=1}^n \left[\sum_{i=1,3,5}^{\alpha} d_{ij} \cdot \frac{\sin \frac{i\pi}{2} - \sin \frac{i\pi z}{2H}}{i^2} \right] \cdot l_{y,j}$$

3.4 Computer Program

A computer programme, based on the theory presented in sections 3.2 and 3.3, has been written in FORTRAN. The sequence of operations followed in the programme is outlined in the flow diagram presented in Appendix-B. The number of terms to be considered in the series solution for the T's is read in as data. In Fig. 3.4, it is shown that the series for T's converge rapidly and only a few terms give sufficient accurate result.

The matrix formulation of the analysis automatically divides the programme into suitable sections. The A, B, C and K matrices have to be formed for each term of the series and the D_i's are obtained by solving Eqn. (3.26): $[D_i] = [C^{-1}] [K]$.

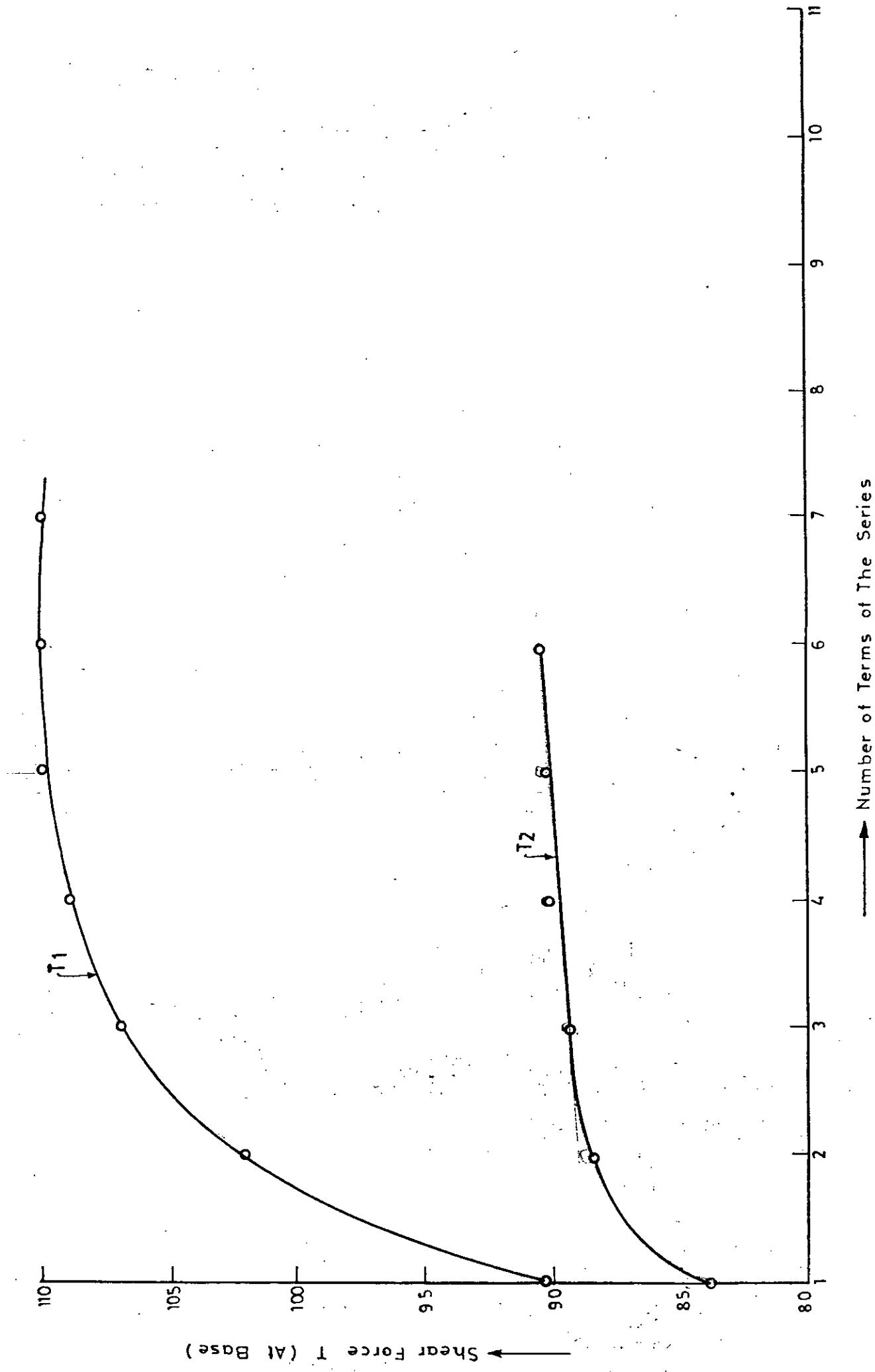


Fig. 3.4 Convergence of Shear Force in Connecting Medium.

The size of the matrices to be handled, dependent only on the number of bands of openings, are usually small viz. $(n \times n)$ and do not present any storage problems. A listing of the programme, together with a more detailed discussion of procedures and form of data input, is given in Appendix-B.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

In this chapter the results of three example problems are presented in graphical and tabular form. The example problem 1 (Fig. 4.1) is analysed by F.R. Khan method⁽¹⁴⁾, A.H. Khan method⁽¹³⁾, Coull and Bose method⁽¹³⁾, proposed Continuous medium method and the results compared with those obtained from a three-dimensional equivalent frame method. The example problem 2, (Fig. 4.2) is extensively studied by the proposed method and 3-D equivalent frame method. In the third set of example problems (Fig. 4.3), a series of 20-storied tubular structures, is analysed by the proposed simplified method to investigate the shear-lag effect on tubular structure.

A 18-storey concrete rigid-tube structure 40'x72' in plan, (Fig. 4.1) is chosen as the 1st example tubular structure. The structure is similar in dimensions to that analysed by A.H. Khan⁽¹³⁾. The total height of the tube is 216 ft and it has 5-bands and 9-bands of regular window-openings in each of the webs and flanges respectively. The other properties of the above tube are:

Storey height	= 12.0 ft
Beam size	= 1.2'x7.2'
Column size	= 1.2'x4.8'
Aspect ratio	= 1.8

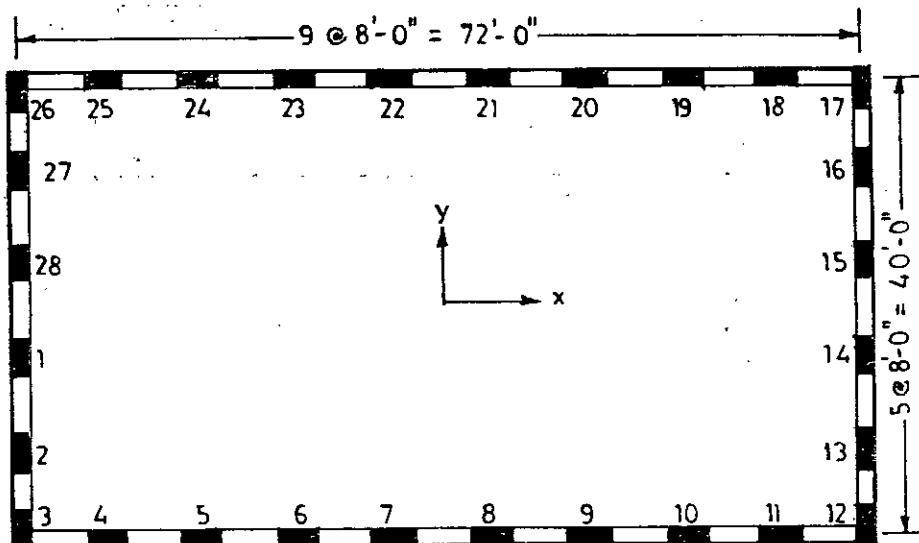


Fig. 4.1 Plan of Example Problem 1

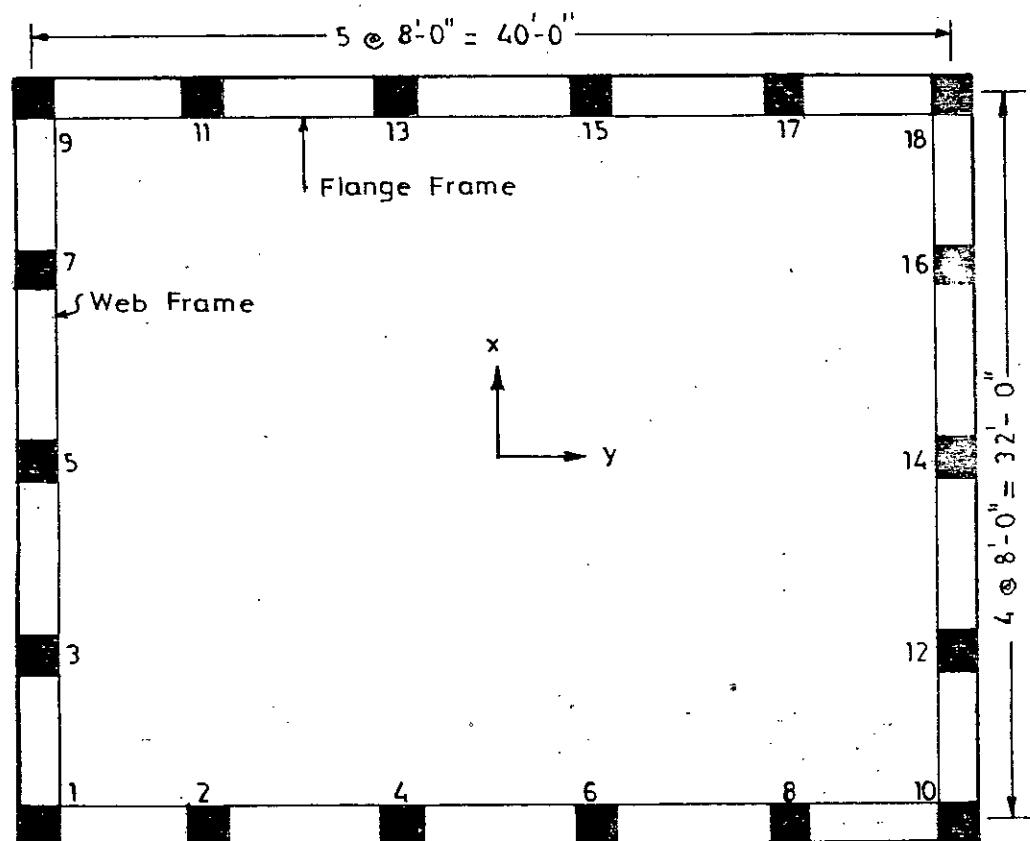


Fig. 4.2 Plan of Example Problem 2

Poisson's ratio = 0.18

Modulus of Elasticity = 432,000 ksf

Two leading cases are considered, viz. a) Point load at the top, and b) Uniformly distributed load.

4.2 Comparison between Different Approximate Methods

4.2.1 Deflection

Figs. 4.4 and 4.5 show the deflected shapes of the structure due to a point load and a distributed load respectively. The deflected shapes of the proposed simplified method agree very well with those predicted by 3-D equivalent frame analysis and A.H. Khan Method. Compared with 3-D equivalent frame method, the continuous medium method underestimates the deflection at all heights of the tube. The maximum deviation is 12% at top from that of 3-D equivalent frame analysis. F.R. Khan and Coull and Bose have not given any governing equations for the horizontal deflections, so it is not possible to compare results with those two methods.

4.2.2 Stresses

The distribution of stresses in the example tube structure for a point load and for a distributed load are shown in Figs. 4.6 and 4.7 respectively. From the stress diagrams, it is observed that the pattern of distribution of stress is predicted fairly accurately by the proposed method. The stresses at all points on the web and flange of the tubular structure calculated by the Continuous medium method are higher

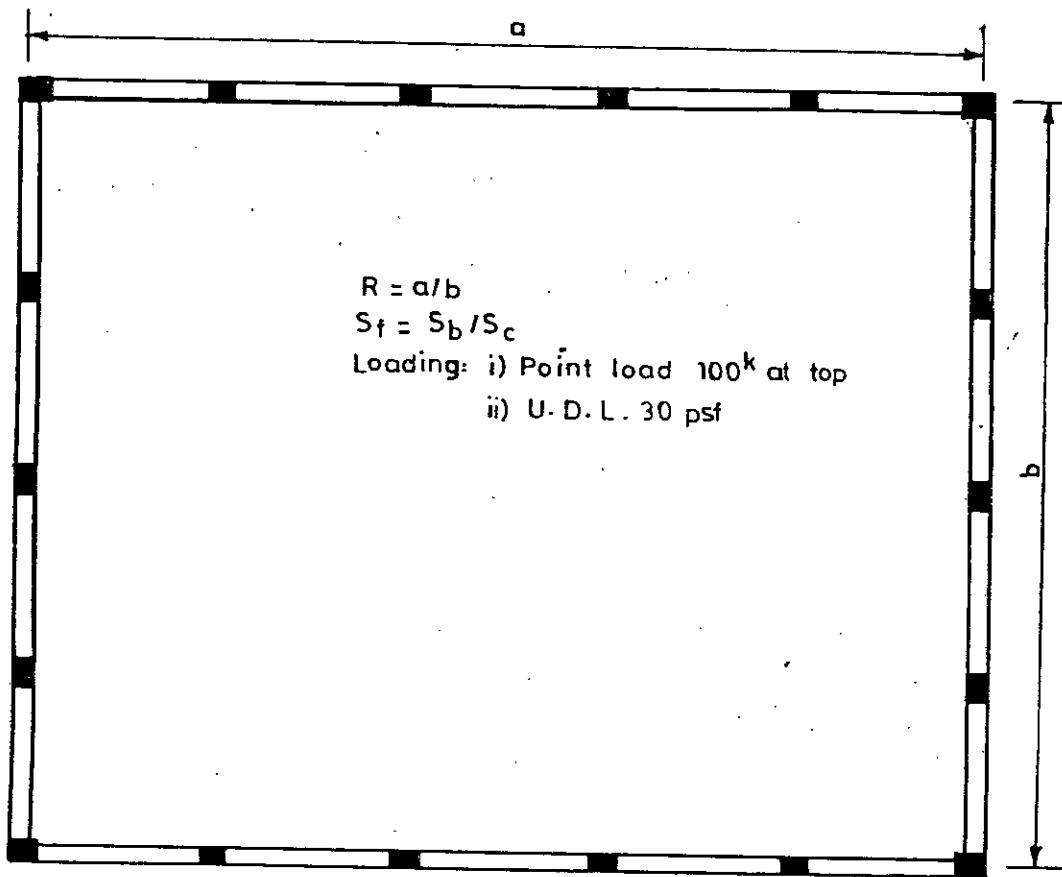


Fig. 4.3 Typical Plan of the Tubes Analyzed.

Table 4.2 Properties of the Tube.

Figures	a	b	R	Beam width ft.	Beam depth ft.	Beam moment of inertia ft ⁴	c/c dis bein column ft.	S _b /E	Column area ft ²	Storey height ft.	S _c /E	S _f	No. of Storey	S _{f10}
64	128	0.5	125	6.42	27.78	8.0	0.651	3.125	12.0	0.26	2.5	20	10.0	
64	128	0.5	1.25	3.00	2.778	8.0	0.065	3.125	12.0	0.26	0.25	20	1.0	
64	128	0.5	1.25	1.39	0.278	8.0	0.006	3.125	12.0	0.26	0.025	20	0.1	
64	96	0.75	1.25	6.42	27.78	8.0	0.651	3.125	12.0	0.26	2.5	20	10.0	
64	96	0.75	1.25	3.00	2.778	8.0	0.065	3.125	12.0	0.26	0.25	20	1.0	
64	96	0.75	1.25	1.39	0.278	8.0	0.006	3.125	12.0	0.26	0.25	20	0.1	
64	64	1.0	1.25	6.42	27.78	8.0	0.651	3.125	12.0	0.26	2.5	20	10.0	
64	64	1.0	1.25	3.00	2.778	8.0	0.065	3.125	12.0	0.26	0.25	20	1.0	
64	64	1.0	1.25	1.39	0.27	8.0	0.006	3.125	12.0	0.26	0.025	20	0.1	
96	64	1.5	1.25	6.42	27.78	8.0	0.651	3.125	12.0	0.26	2.5	20	10.0	
96	64	1.5	1.25	3.00	2.778	8.0	0.065	3.125	12.0	0.26	0.25	20	1.0	
96	64	1.5	1.25	1.39	0.278	8.0	0.006	3.125	12.0	0.26	0.025	20	0.1	

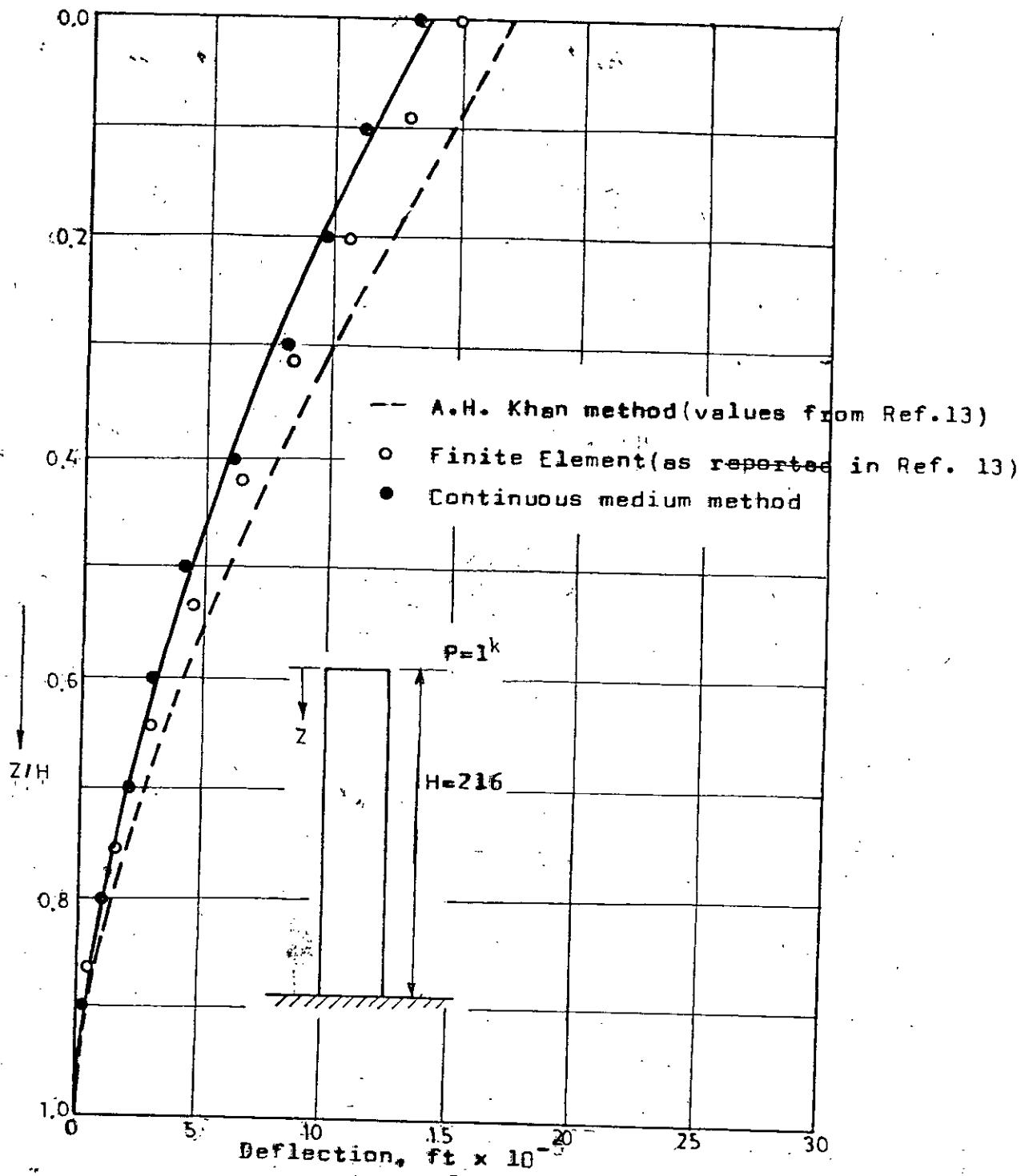


Fig. 4.4 Deflected Shapes of the Framed Tube due to Point Load.

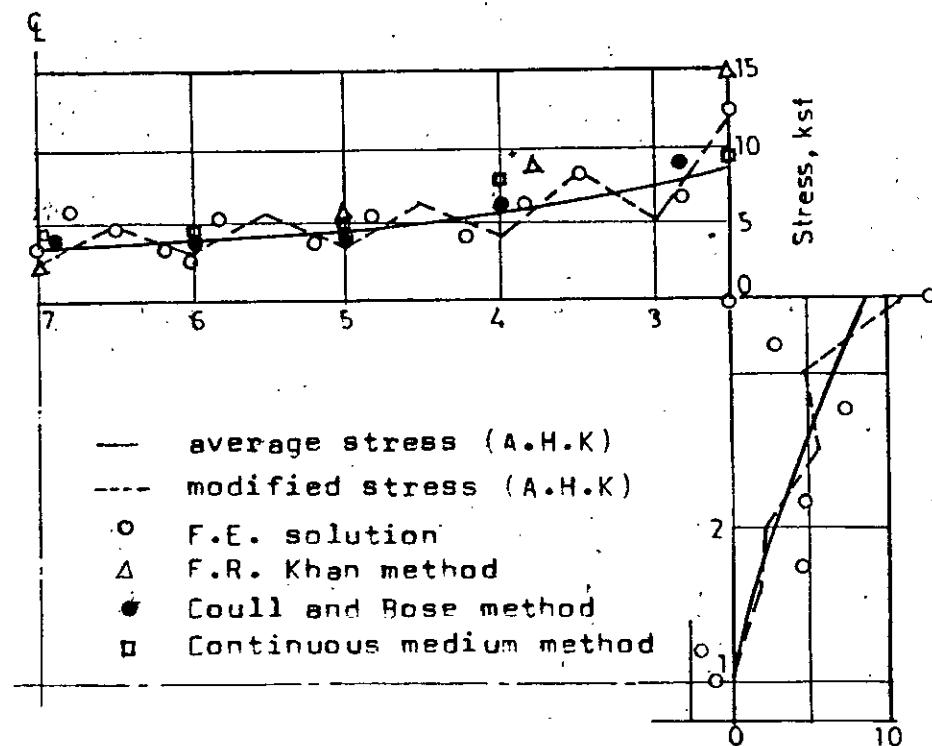


Fig. 4.6 Stress distribution at the base due to u.d.l.

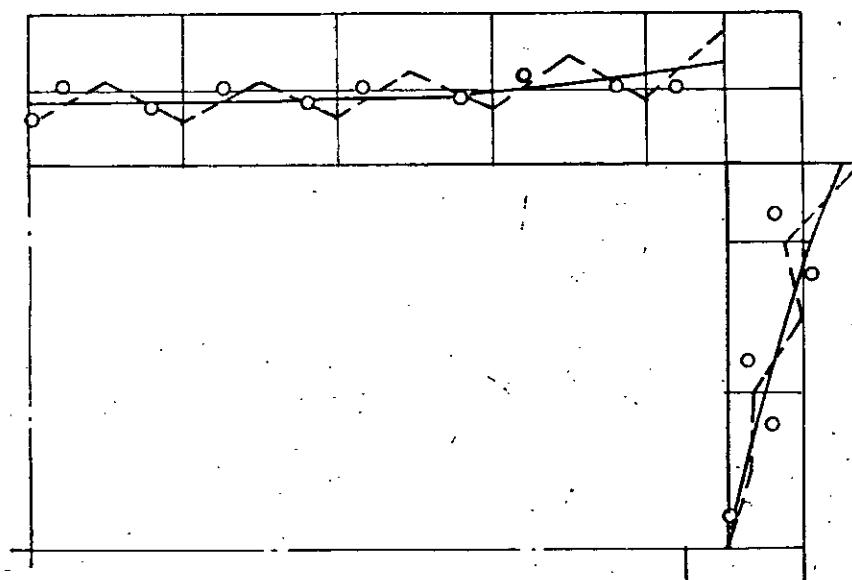


Fig. 4.7 Stress distribution at the base due to point load in the framed tube.

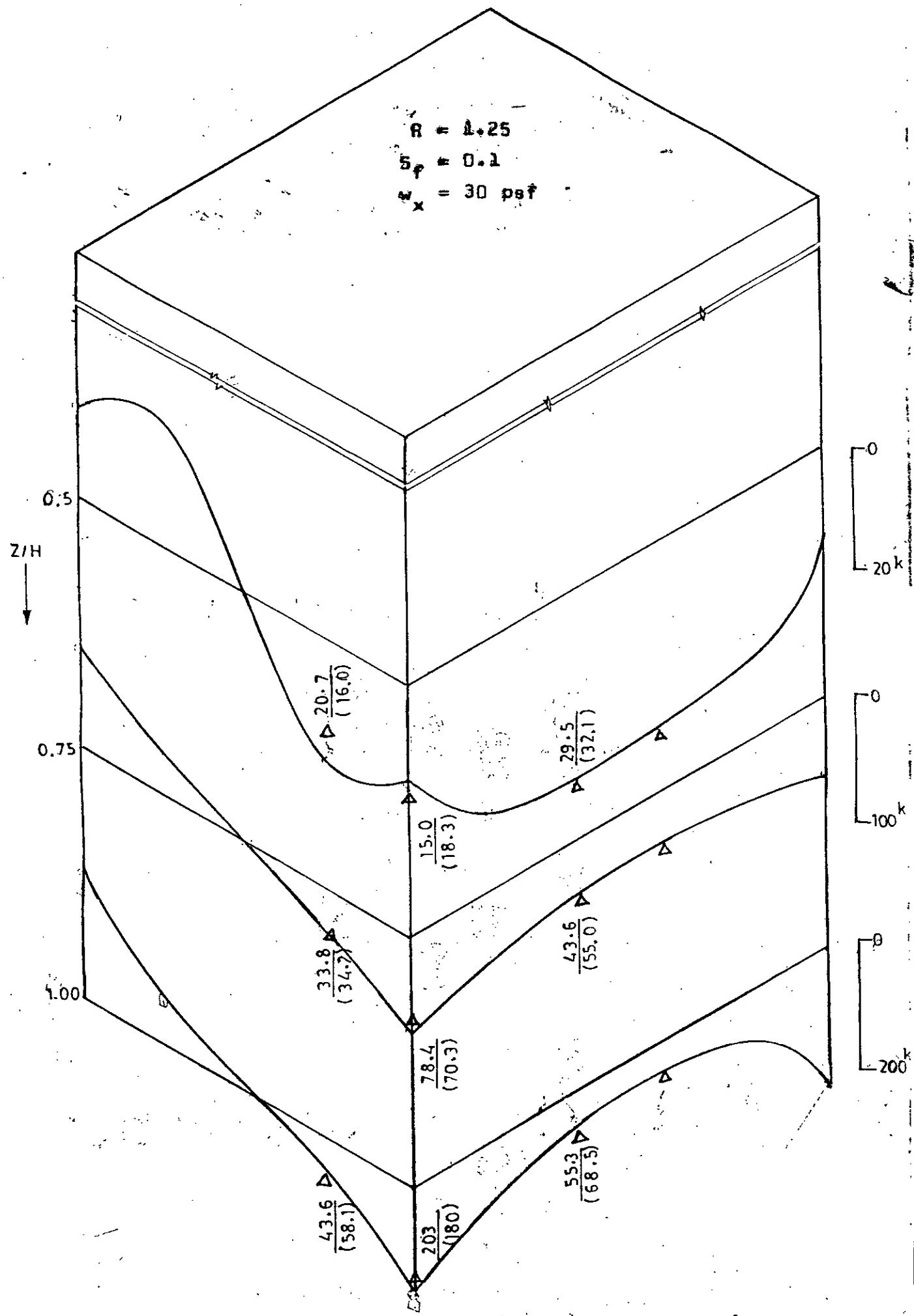
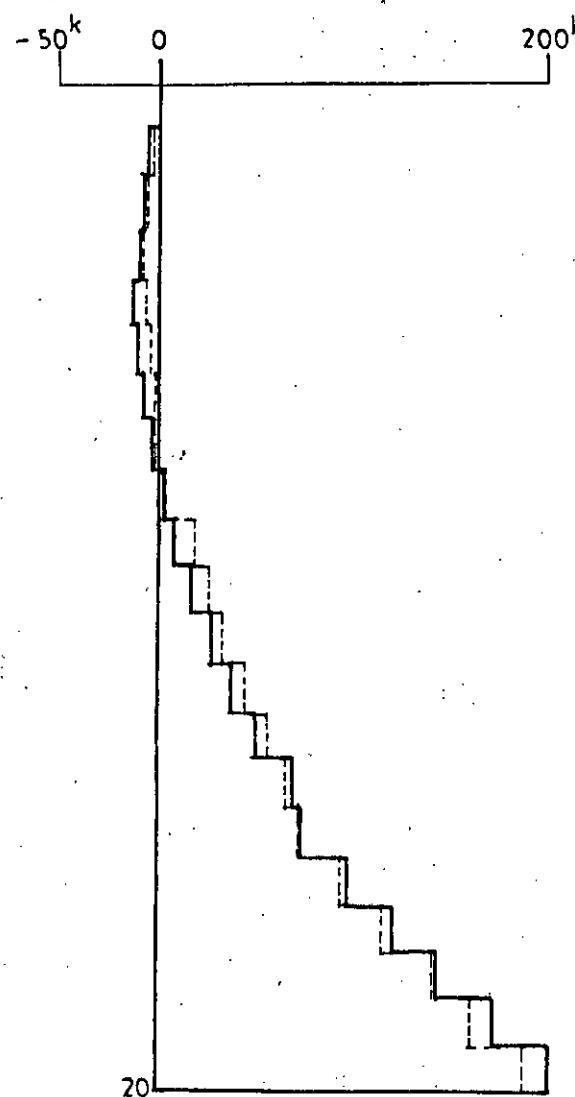
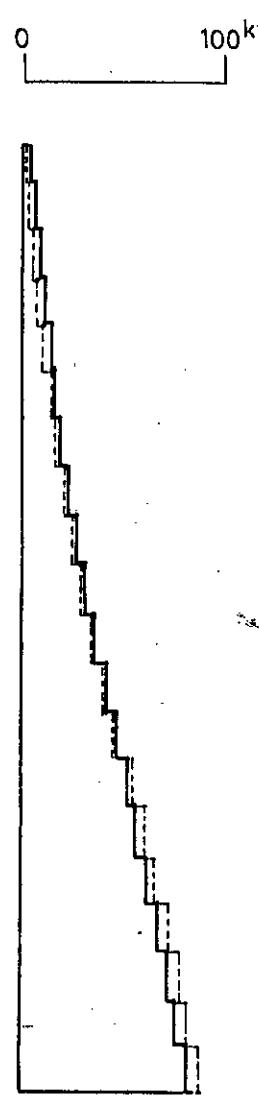


Fig. 4.8 Shear load effect on tubular structure.

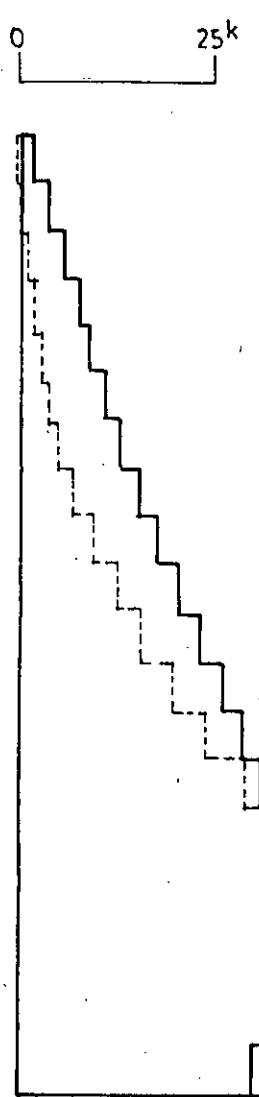
— 3-D Equivalent Frame Method
- - - Continuous Medium Method



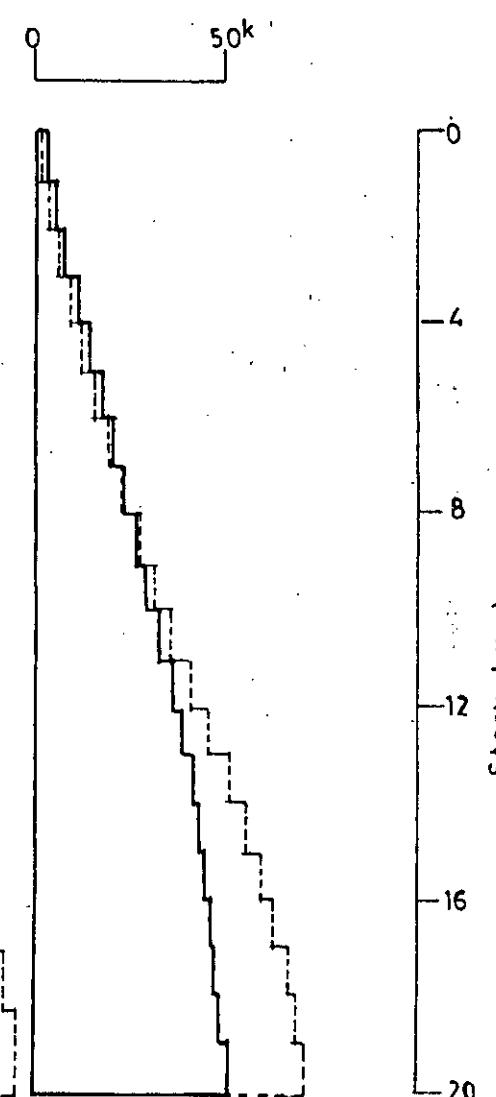
Col. 1, 9, 10, 18



Col. 2, 8, 11, 17



Col. 3, 7, 12, 16



Col. 4, 6, 13, 15

Fig. 4.9 Distribution of Axial Force in 20 Storey Building. (Fig. 4.2)

than those obtained from A.H. Khan method and Coull and Bose method. F.R. Khan method gives greater stress for corner column and the column next to corner in both web and flange of the structure. For the remaining columns, the simplified method gives higher stresses. The stress results obtained from different methods are shown in the following Table 4.1 for example problem 1 (Fig. 4.1).

Table 4.1 Stresses at bases (in ksf) due to U.D.L.

Methods	Column position						
	1	2	3	4	5	6	7
3-D space frame	2.3	5.30	9.95	8.50	5.00	4.50	4.00
F.R. Khan	1.96	3.75	15.00	8.44	5.16	3.75	3.25
A.H. Khan	2.92	5.20	7.50	6.27	5.36	4.75	4.44
Coull & Bose	1.05	3.88	8.83	6.39	4.56	3.34	2.73
Continuous medium	1.91	5.88	10.05	7.77	7.00	6.70	6.50

4.3 Comparison between Continuous Medium Method and 3-D Space Frame Method

In order to check the accuracy of the Continuous medium method, a 20-storey rigid-tube structure, example problem 2, 32 ft x 40 ft in plan, (Fig. 4.2), is analysed by three-dimensional equivalent frame method and by continuous medium method. The structure has 5-bands and 4-bands of regular

openings in each of the flanges and webs respectively. The total height of the tube is 200 ft and it has a uniform wall thickness 1.2 ft. The stiffness factor (S_f) for the structure is 0.1. The beam size is 1.2'x1.46' and the column size is 1.2'x2.4'. Poisson's ratio and modulus of elasticity are taken as 0.18 and 432000 ksf respectively. Two loading cases were considered viz. a) 100^k point load at the top applied in y-direction and b) 30 psf uniformly distributed load. The column axial forces calculated by 3-D space frame are compared in Fig. 4.8 with those obtained from Continuous medium method. The nature of the shear-lag effect on tube structure is observed to be the same from both the analysis.

An interesting effect is observed at $z/H = 0.5$ when the building is subjected to UDL. Normally, one would expect that the corner columns would have the maximum axial force. However from Fig. 4.8, it may be observed that the maximum axial force occurs not in the corner columns but in the column adjacent to the corner.

From Fig. 4.9, it is found that the axial forces calculated by Continuous medium method in corner columns 1,9,10,18 and in columns 2,8,11,17 agree well with those obtained from 3-D equivalent frame method. In the columns 3,7,12 and 16 of the web frame, the values of axial force obtained from Continuous medium method are less than 3-D equivalent frame method from top to 15th storey level, and from 15th storey to base.

the values are higher. From 3-D equivalent frame analysis, it is found that the maximum axial force occurs in the columns of web frame at 17th storey level, whereas, from Continuous medium method of analysis, the maximum axial force occurs at base, which is 36.8% higher than 3-D equivalent frame result. In columns 4,6,13 and 15 of the flange frame, the values of axial forces obtained from Continuous medium method are higher (maximum deviation 28% at base) than those obtained from 3-D equivalent frame analysis.

4.4 Discussion on Shear-lag Effect on Tubular Structures

To investigate the shear-lag effect on tubular structures, a series of twenty-storied tubular structures are analysed by continuous medium method for point load at top and lateral load uniformly distributed throughout the height, (Fig. 4.3). The properties of the tubes are tabulated in Table 4.2.

Two non-dimensional parameters

$$\text{i) aspect ratio } R = \frac{\text{width of flange frame}}{\text{width of web frame}}$$

$$\text{and ii) stiffness factor } S'_{f10} = S_f \times \left(\frac{N}{10}\right)^2$$

$$\text{where, } S_f = S_b/S_c$$

have been selected and tubes with S'_{f10} varying from 0.1 to 10.0 have been analysed by Continuous medium method for aspect

ratios 0.5, 0.75, 1.0, 1.5 and 2.0. The column axial forces obtained from these analyses are shown in Fig. 4.10 to 4.36. For all the tubes, idealised as an unperforated hollow tube, the column axial forces are also calculated by the simple bending theory and the values are shown in parenthesis. The dotted lines shown in Figs. 4.10 to 4.36 show the stress distribution in the columns for the ideal tube. It is observed that from top down to level $= z/H = 0.5$, for $S_f = 10.0$, the shape of the axial force distribution curve is concave upward for uniformly distributed load and at lower levels the shape of the curve is concave downward. This may be due to the fact that in the upper portion of the tube, the bending deformation is more prominent than the shear deformation and hence the shape of the curve is concave upward. While in the lower levels of the tube, the shear deformation being more prominent than the bending deformation causes the shear-lag curve to become concave downward.

The shear-lag effect is found almost negligible from top down to level $= z/H = 0.5$ for $S_f = 10.0$ under point loading at top.

The pronounced effect of shear-lag on the stress distribution is observed at base level for all aspect ratios under point loading as well as uniformly distributed loading.

The abnormal shape of the axial force distribution curve for $S_f = 0.1$ and for all aspect ratios under uniformly distributed

loading is observed from Fig. 4.12, 4.18, 4.24, 4.30 and 4.36. Here the maximum axial force occurs not in the corner columns but in the columns adjacent to the corner in the web frame and in the 2nd or 3rd columns in flange frame. From the above figures, it is found that the axial forces in remaining columns of the flange frame gradually decrease upto centre line of the frame following the shape of the ~~usual~~ shear-lag curve.

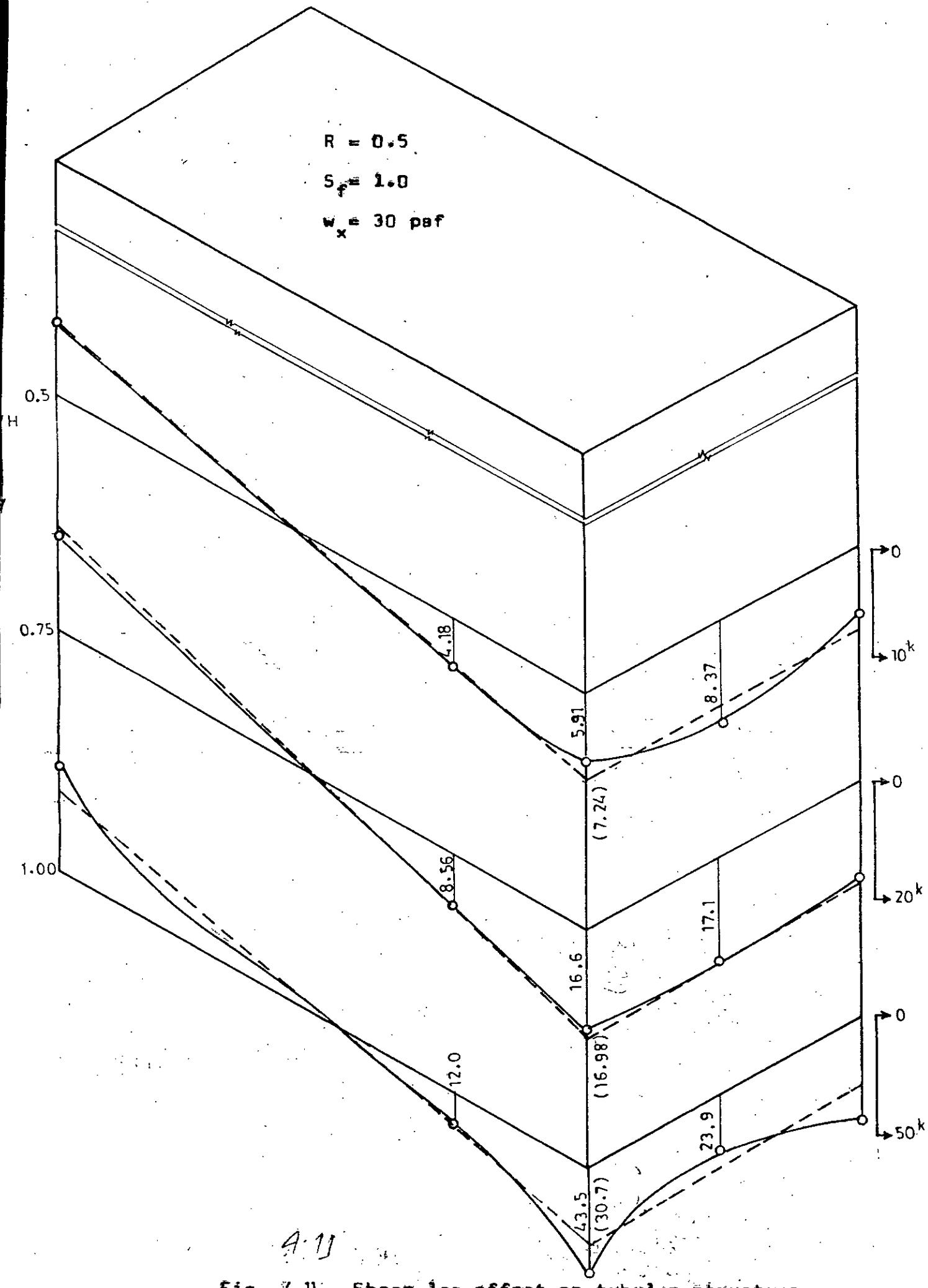


Fig. 4.11. Shear lag effect on tubular structure.

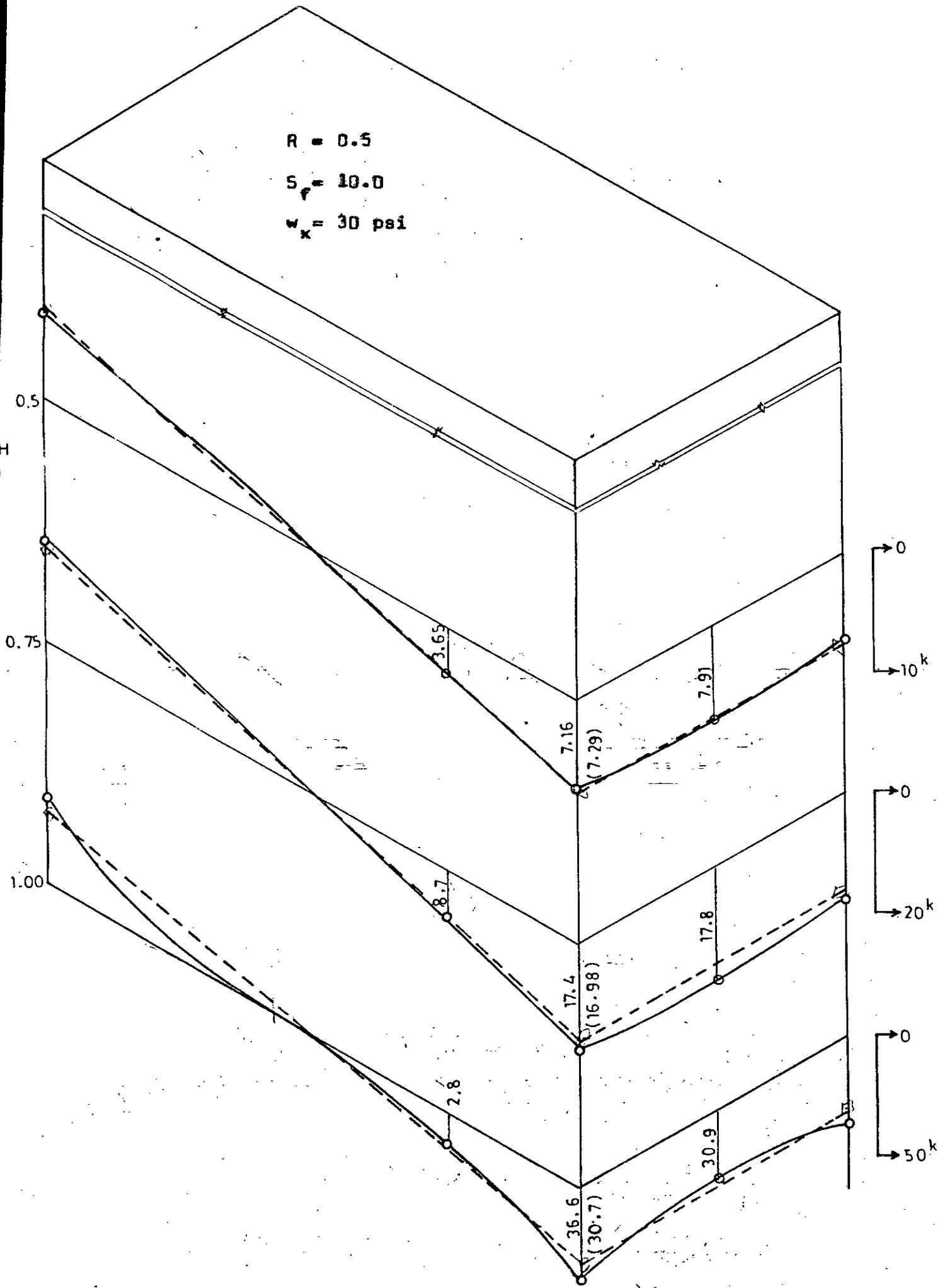


Fig. 4.12 Shear lag effect on tubular structure.

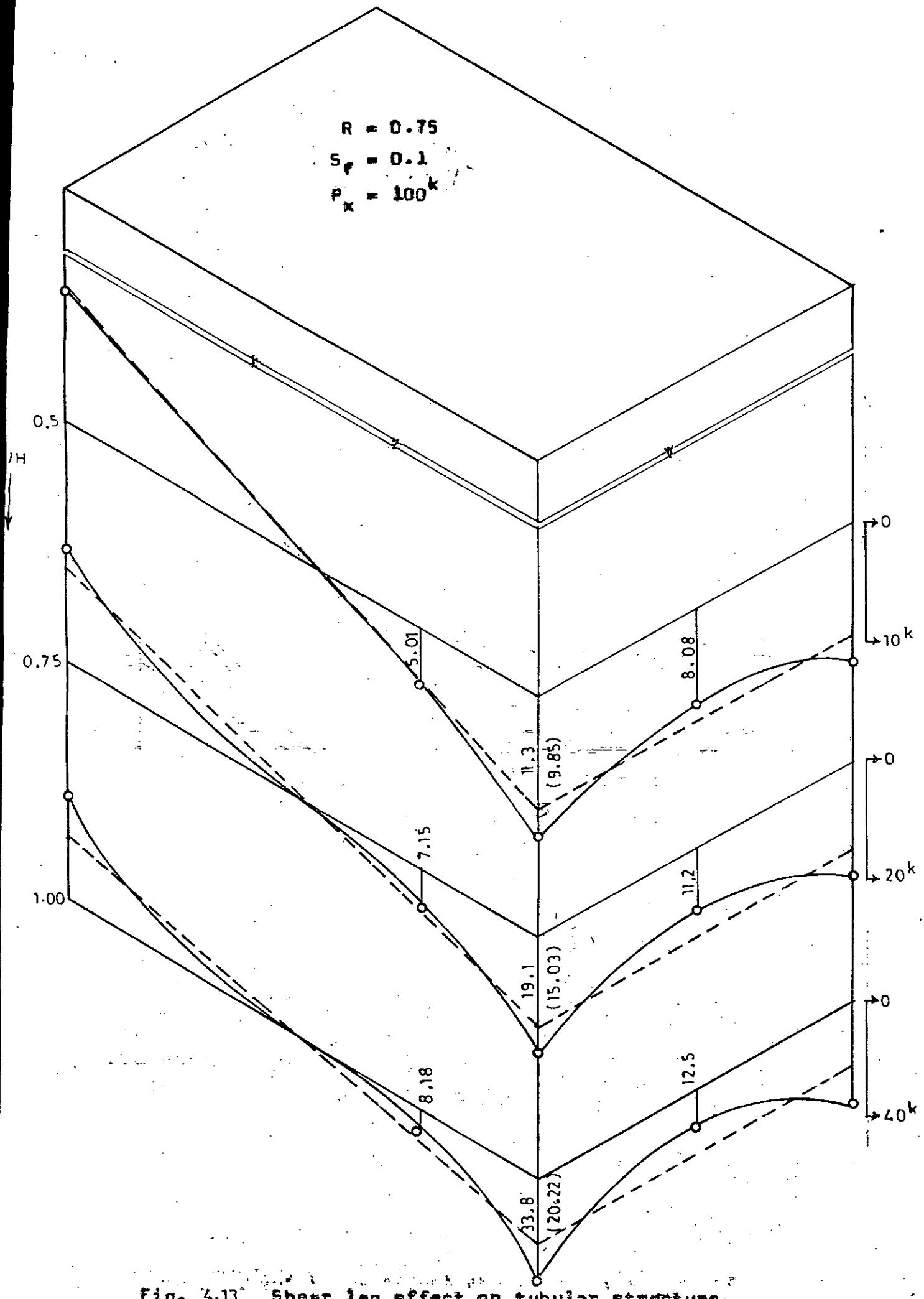


Fig. 4.13 Shear lag effect on tubular structure.

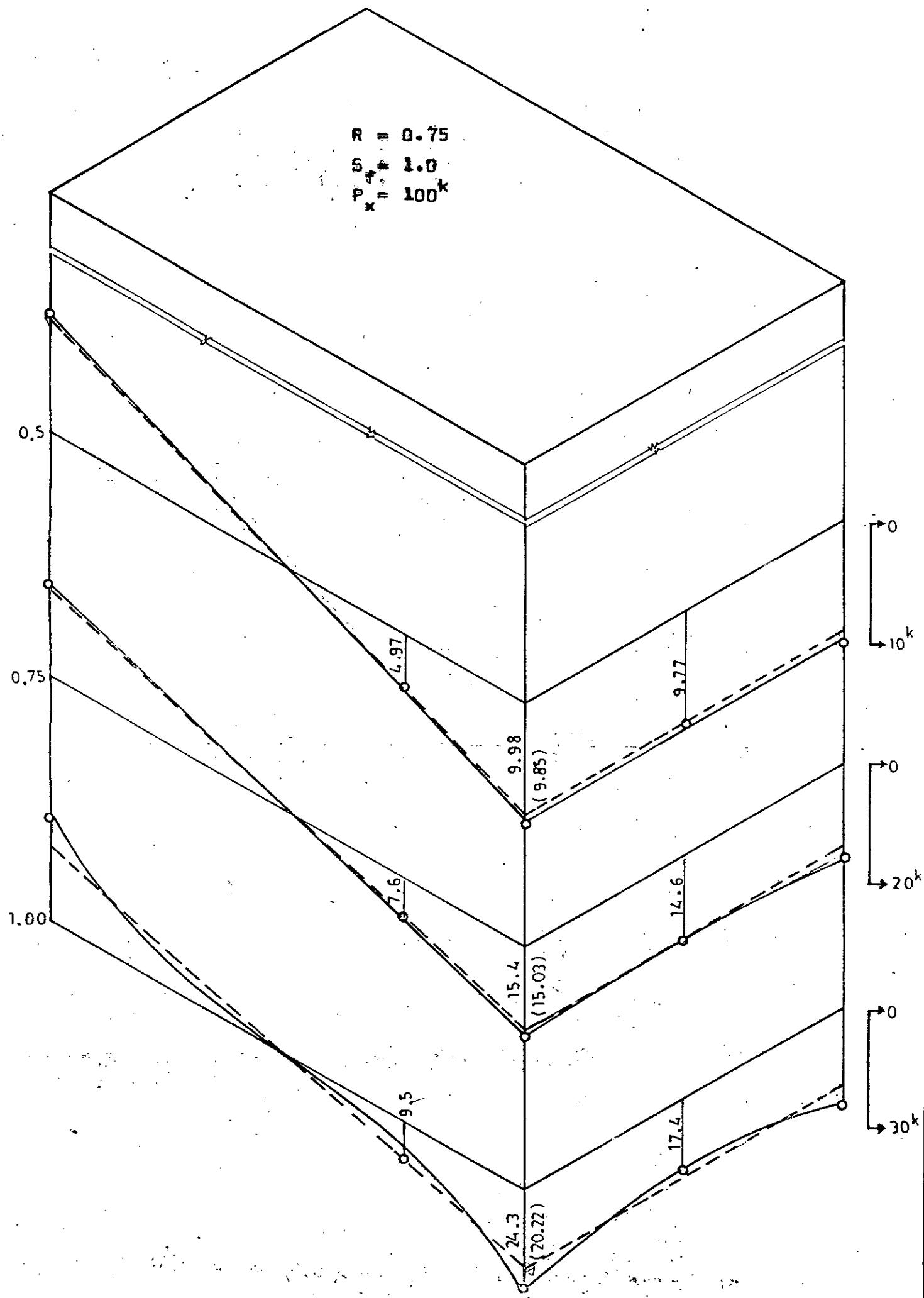


Fig. 4:14 - Shear lag effect on frame structure.

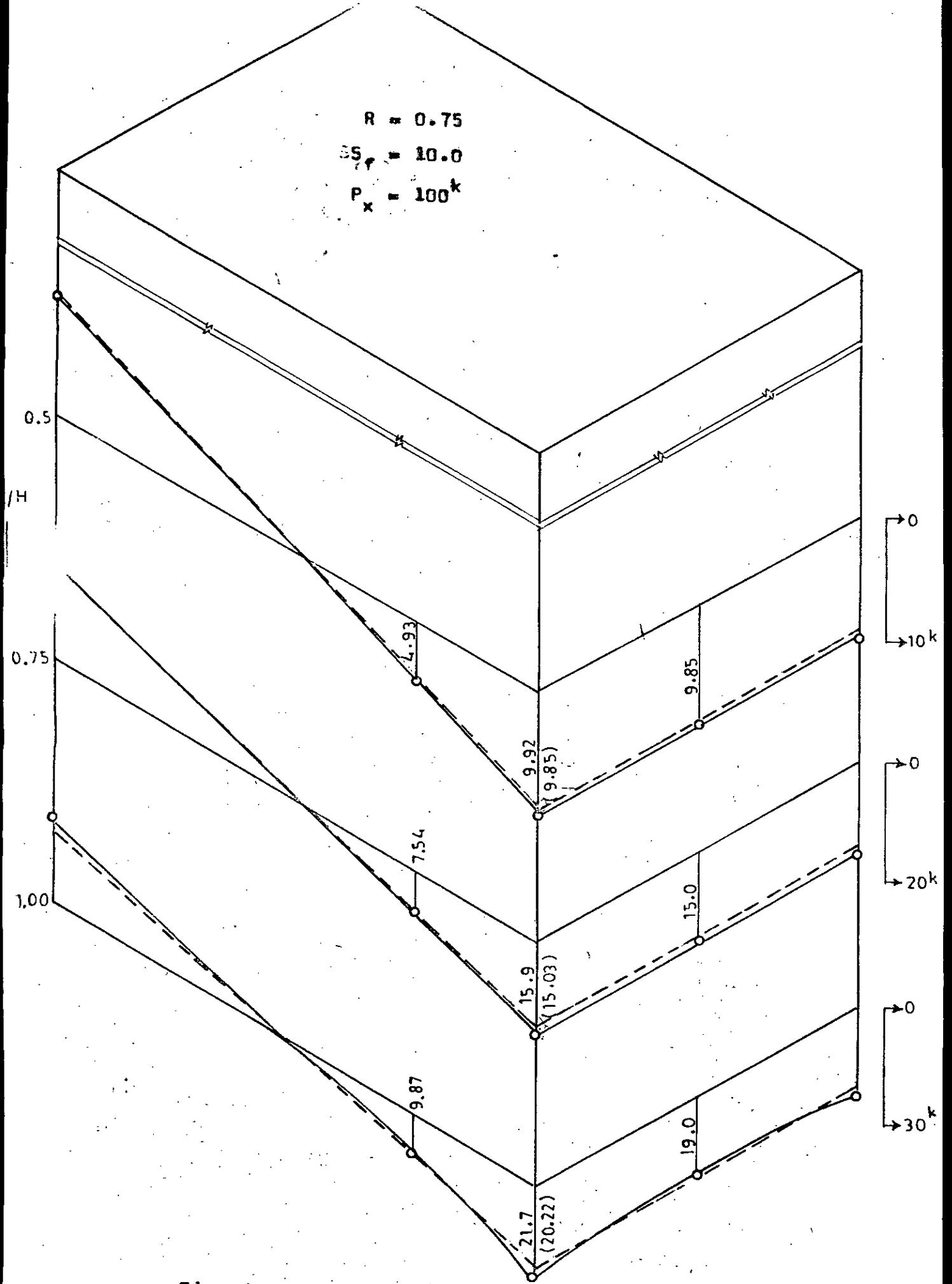


Fig. 4.15 Shear lag effect on tubular structure.

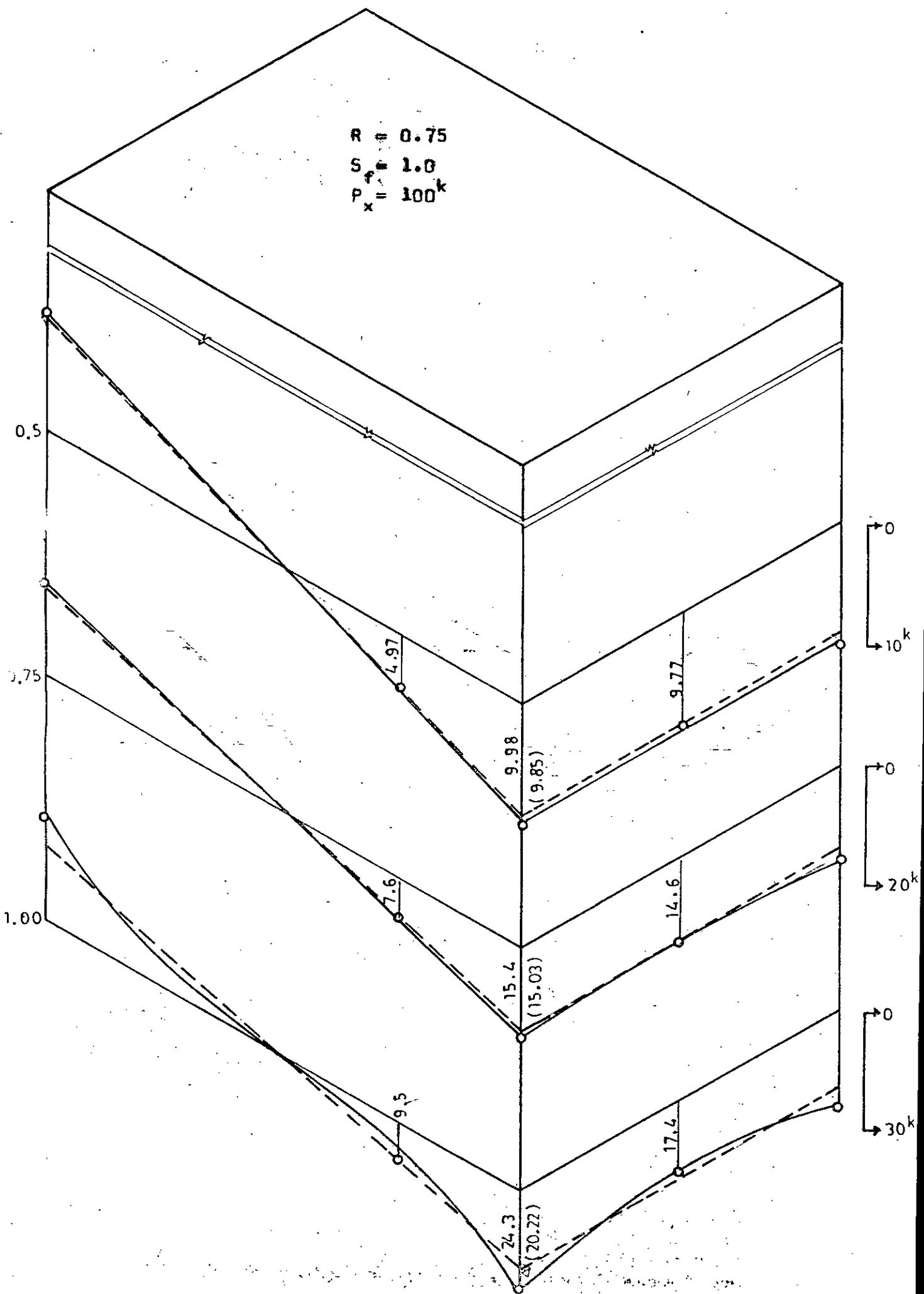


Fig. 4.16 Shear leg effect on tubular structure.

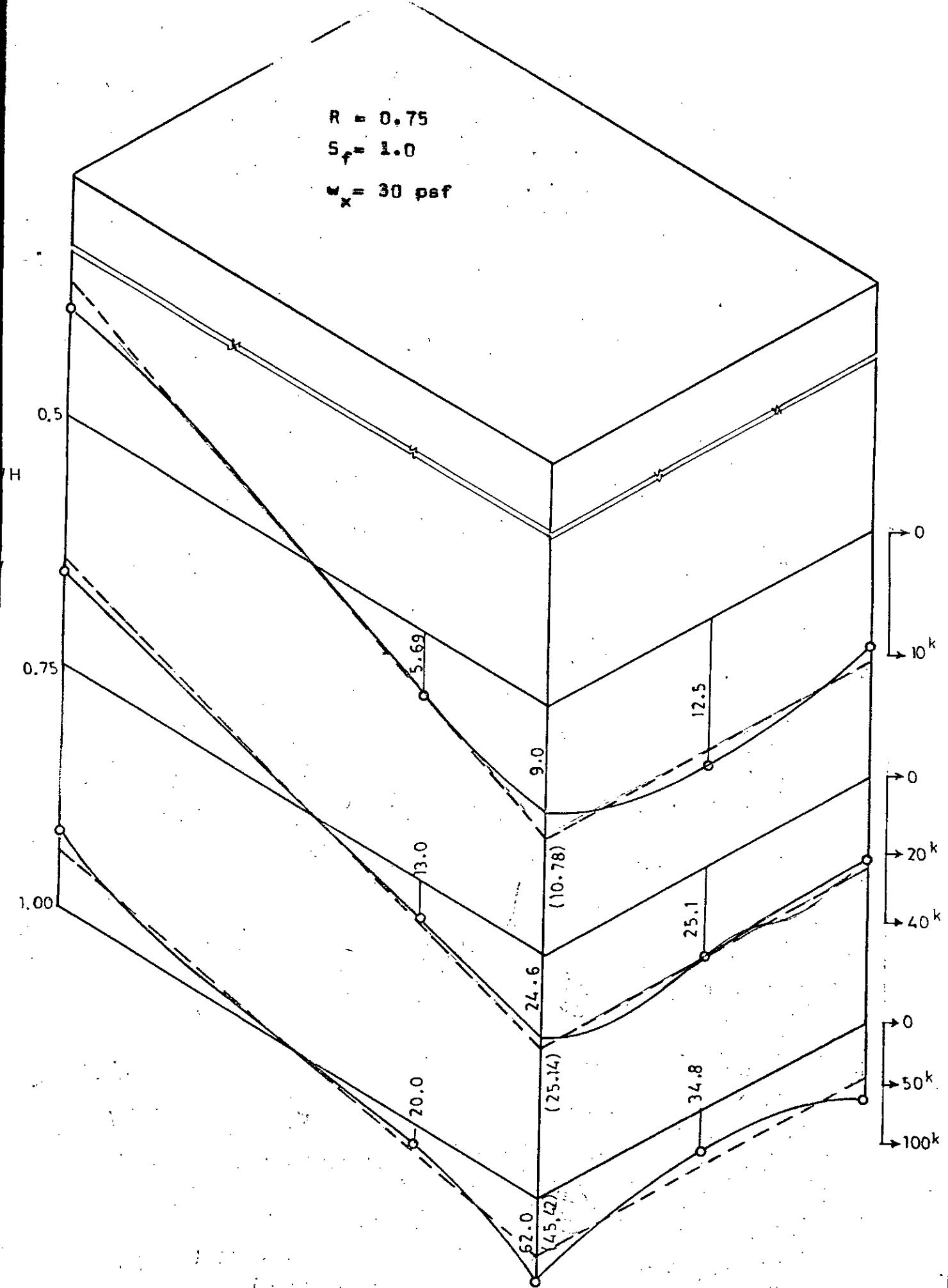


Fig. 4.17 Shear leg effect on tubular structure.

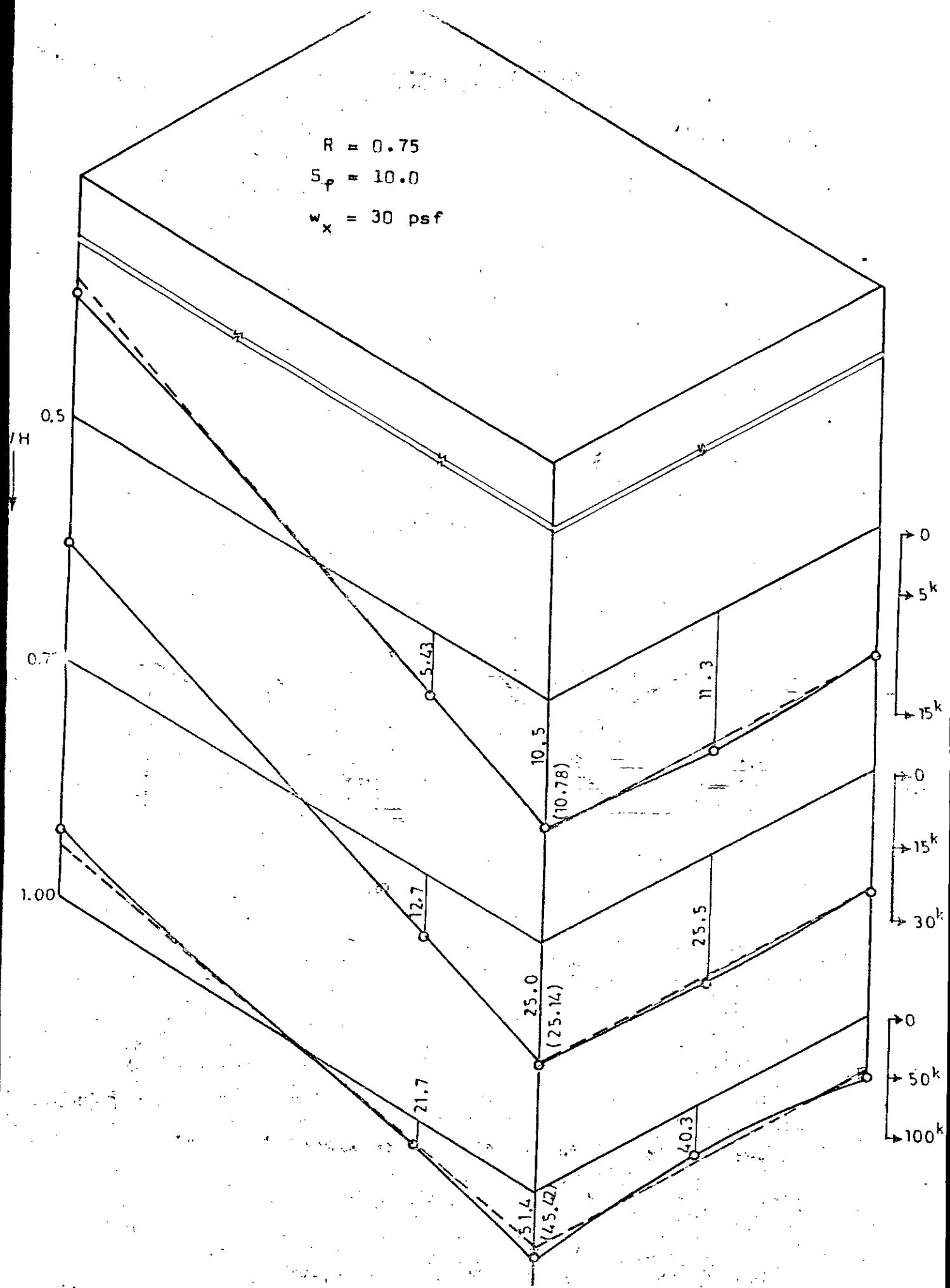


Fig. 4.18 Effect of shear lag on tubular structures

$$R = 2.0$$

$$S_f = 0.1$$

$$P_x = 100^k$$

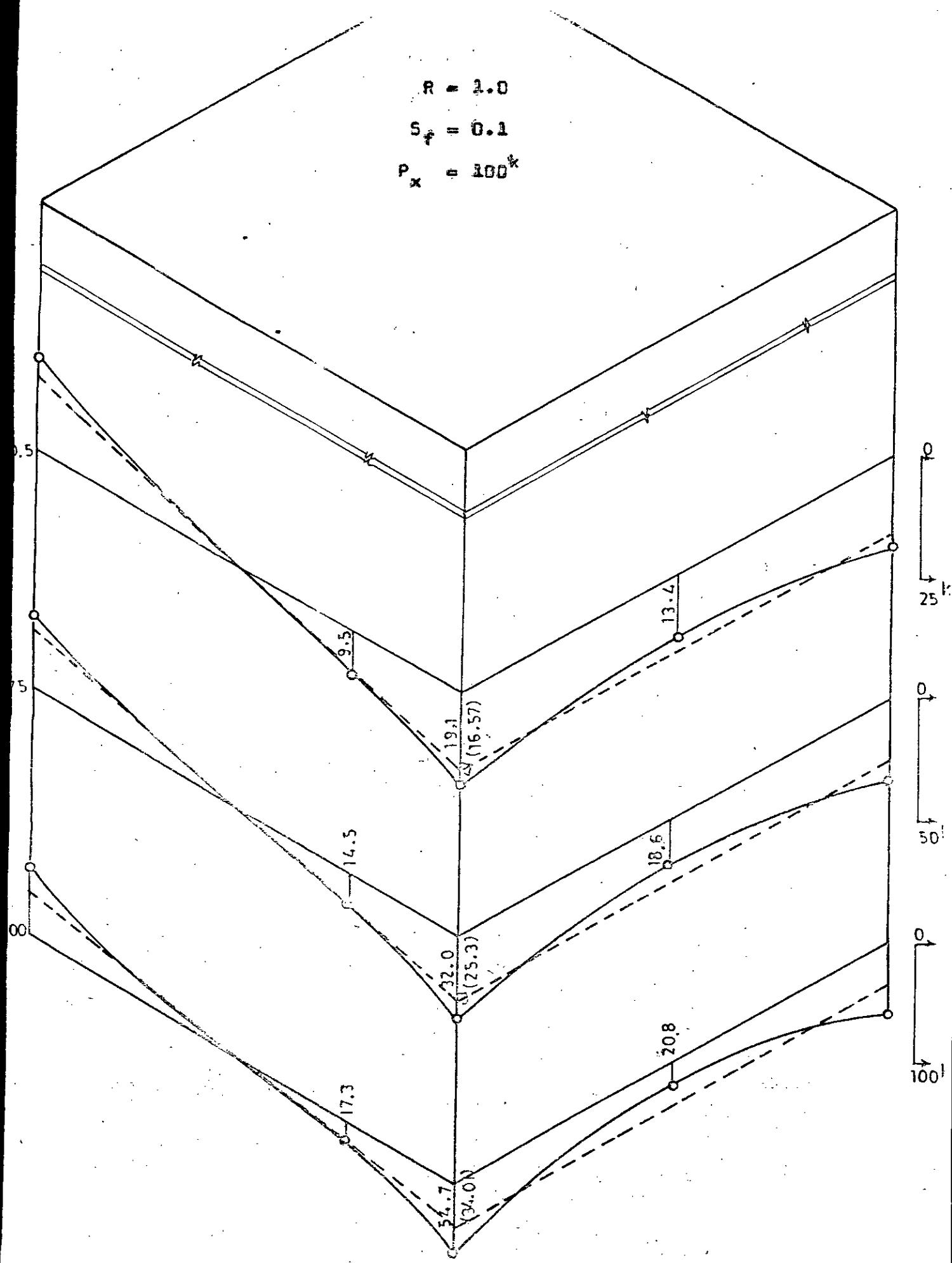


Fig. 4.19 Shear lag effect on tubular structure.

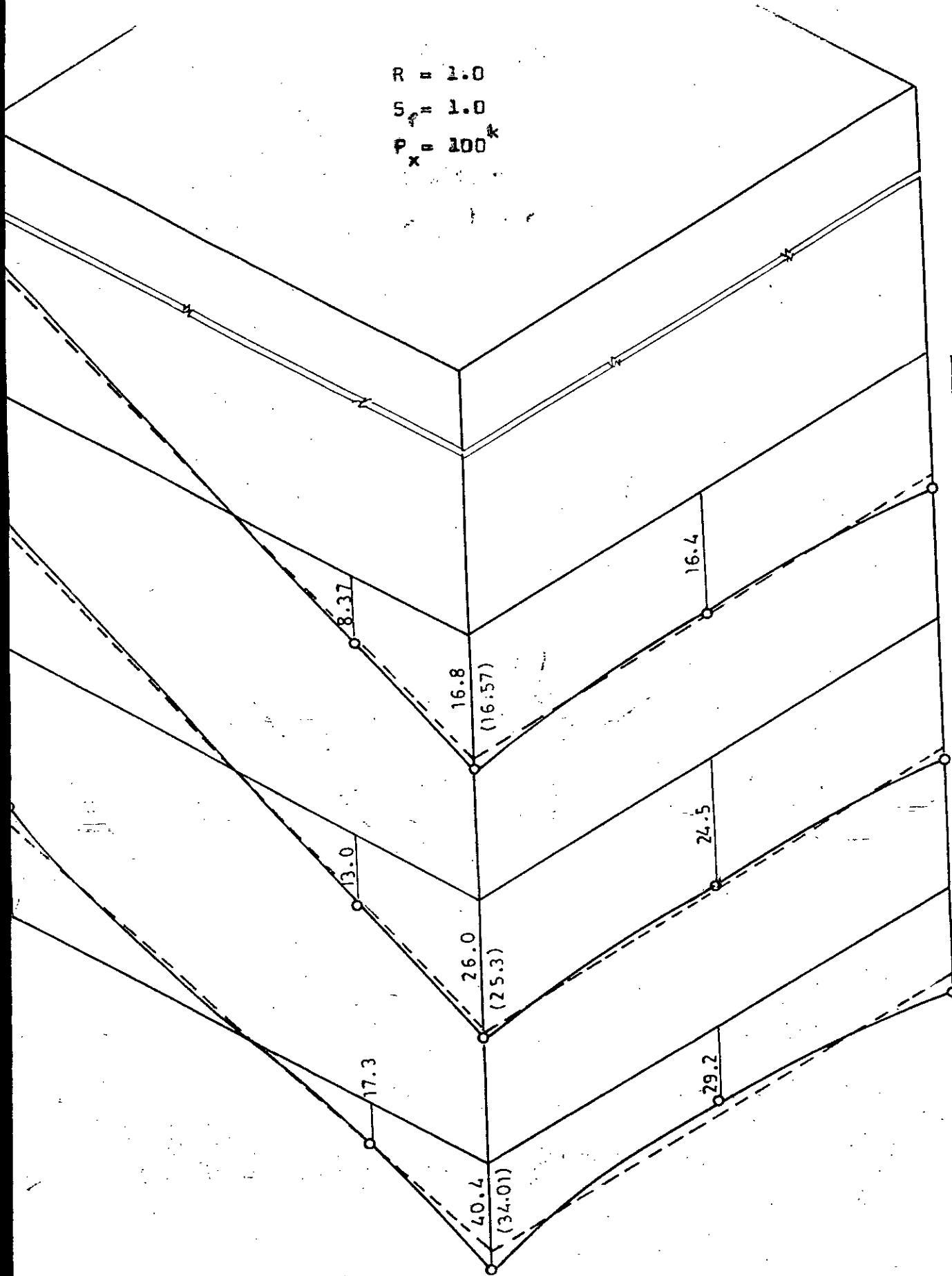
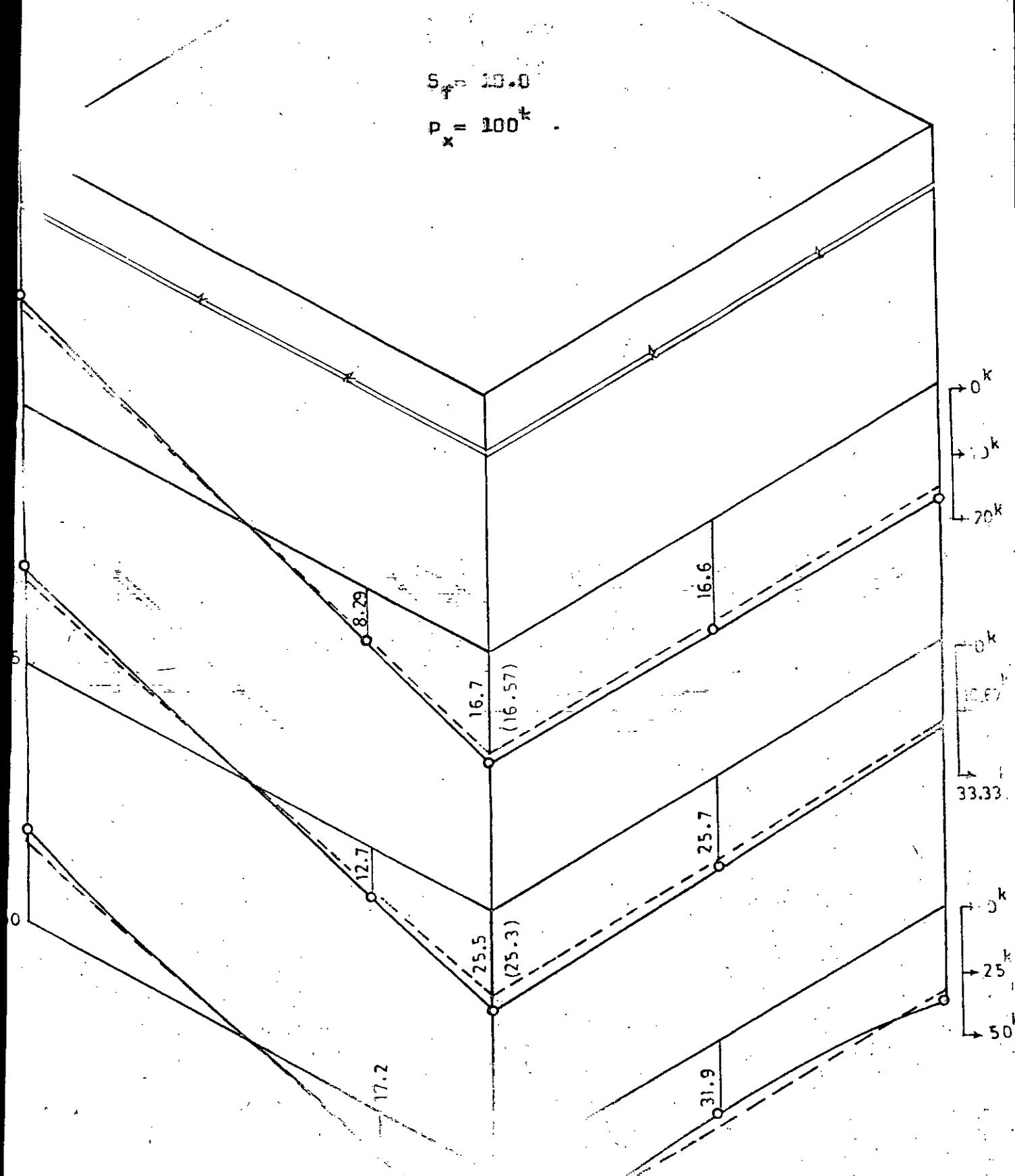


Fig. 4.20 Shear lag effect on tubular structure.



$R = 1.0$

$S_f = 0.1$

$w_x = 30 \text{ psf}$

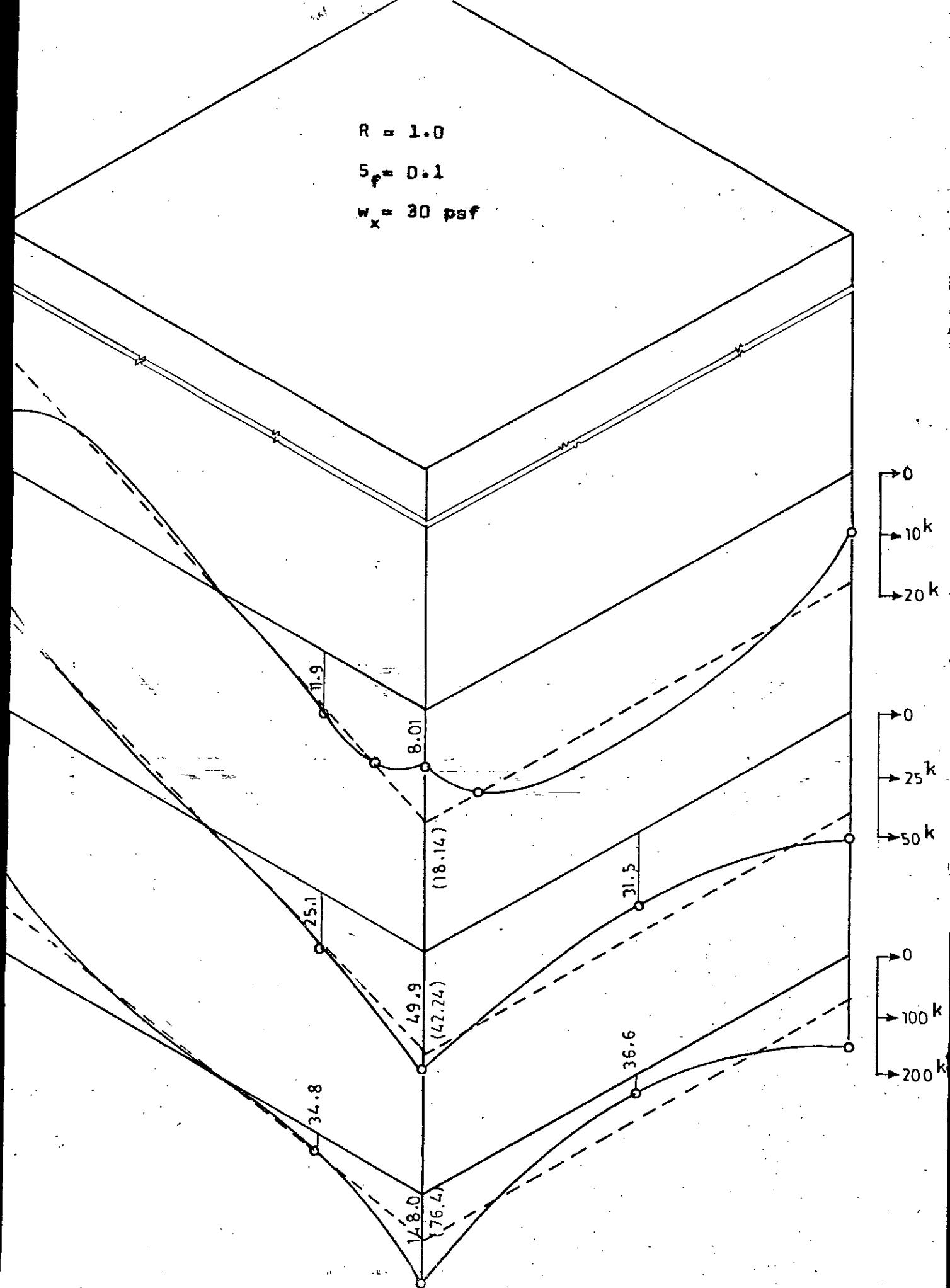
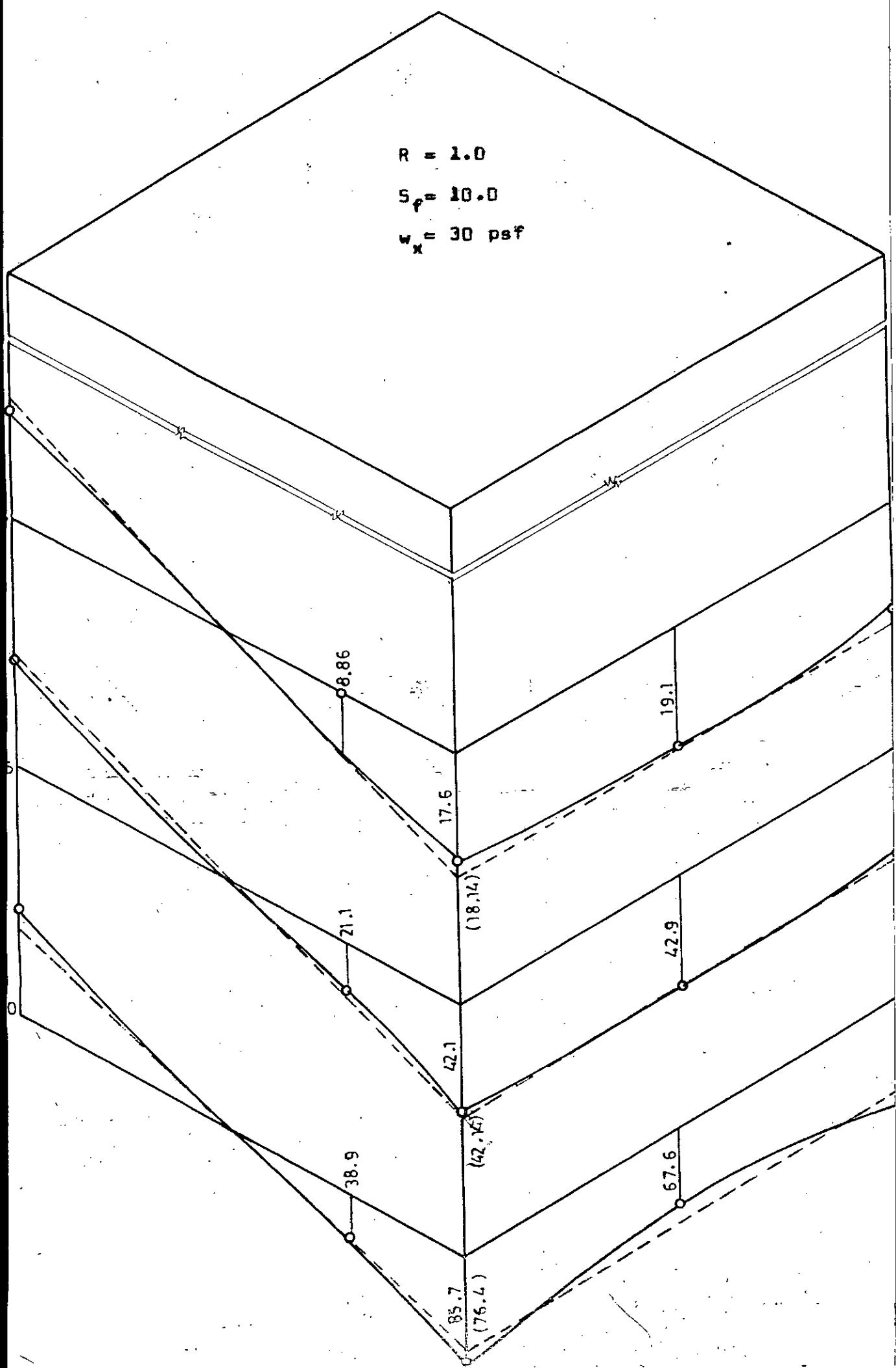


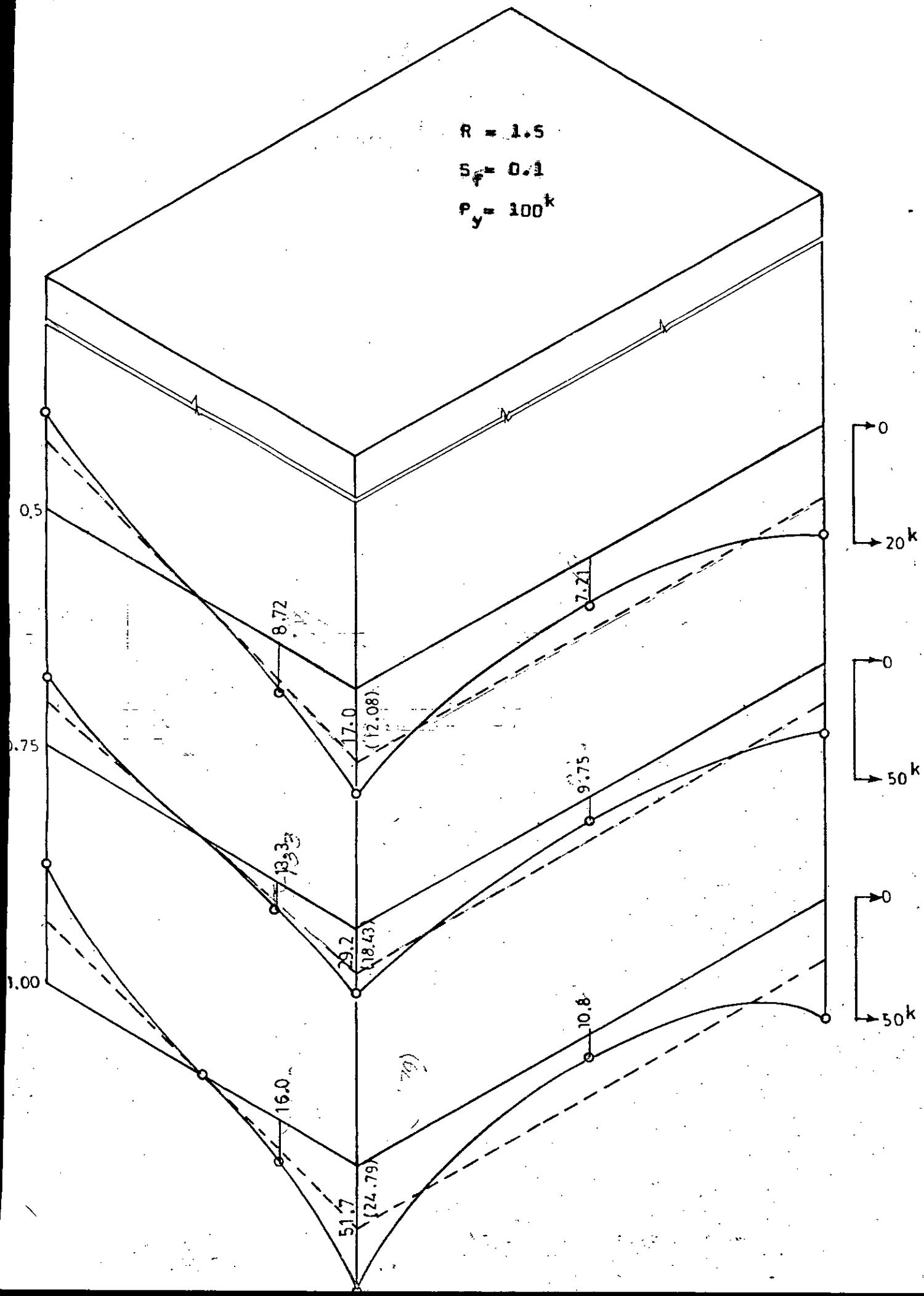
Fig. 4.22. Shear lag effect on tubular structure.



$R = 1.5$

$S_f = 0.1$

$P_y = 100^k$



$R = 1.5$

$S_f = 1.0$

$P_y = 100^k$

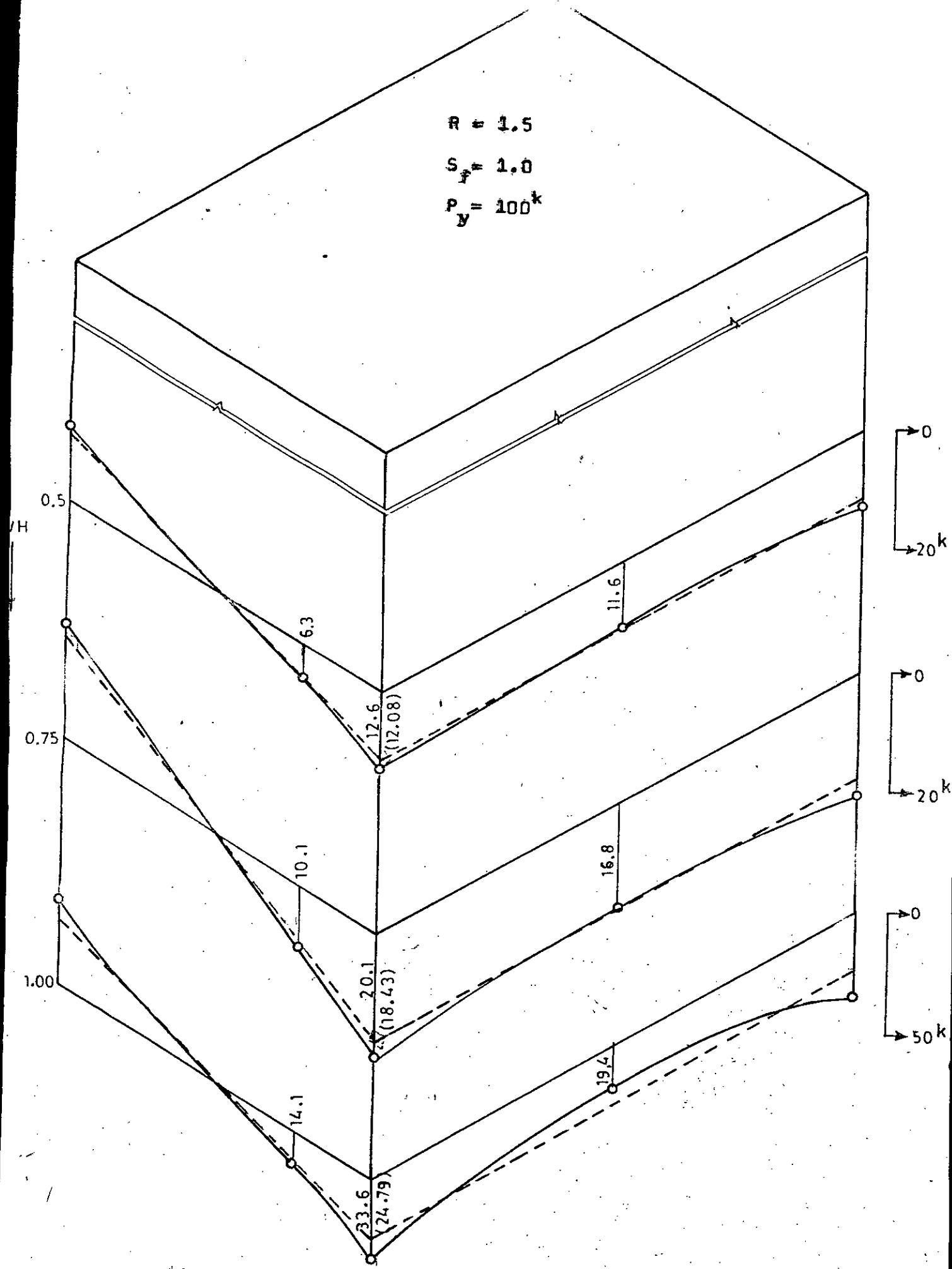


Fig. 4.26 Shear lag effect on tubular structure.

$$R = 1.5$$

$$S_f = 10.0$$

$$P_y = 100 k$$

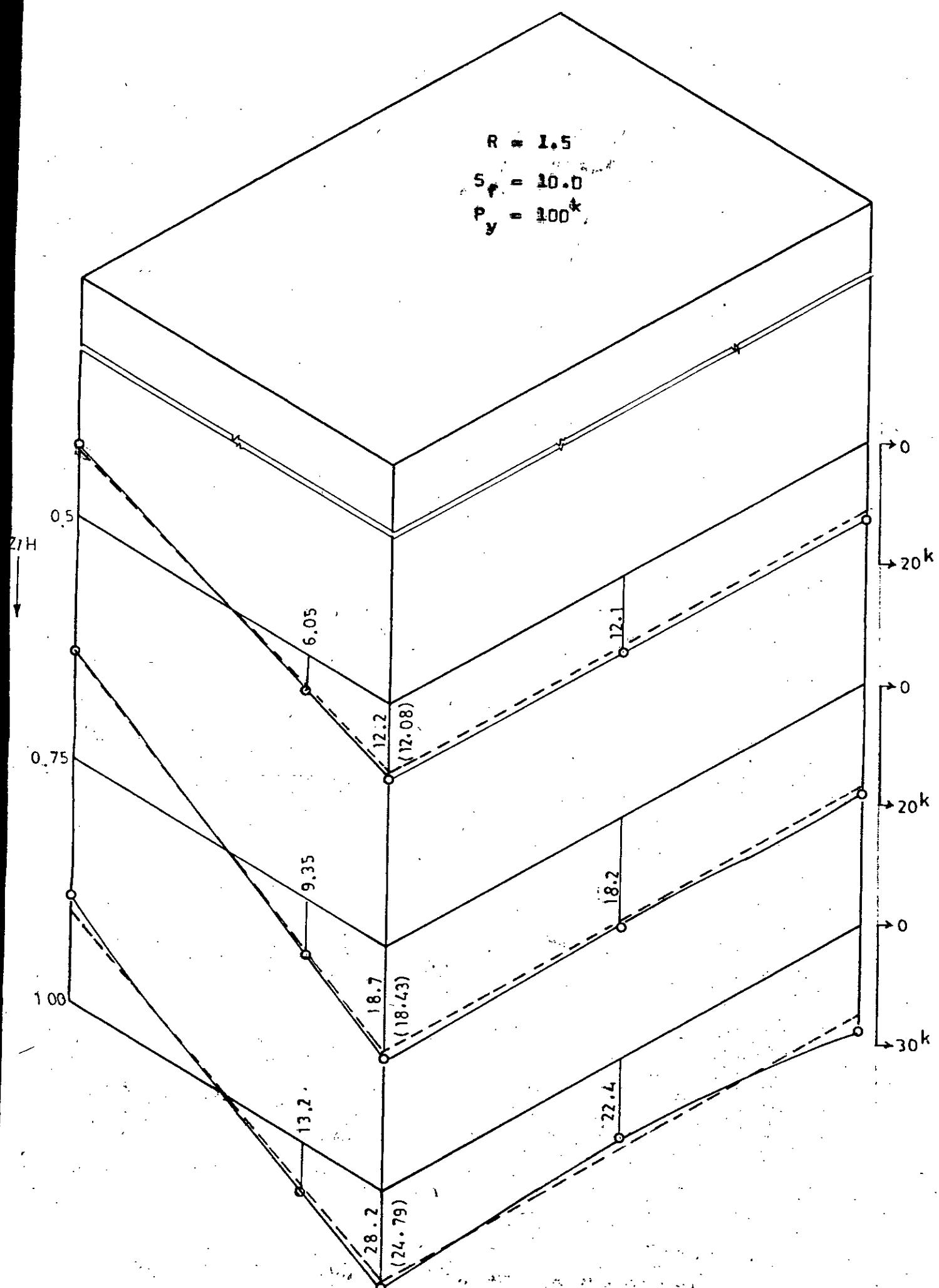


Fig. 4.27. Shear lag effect on tubular structure.

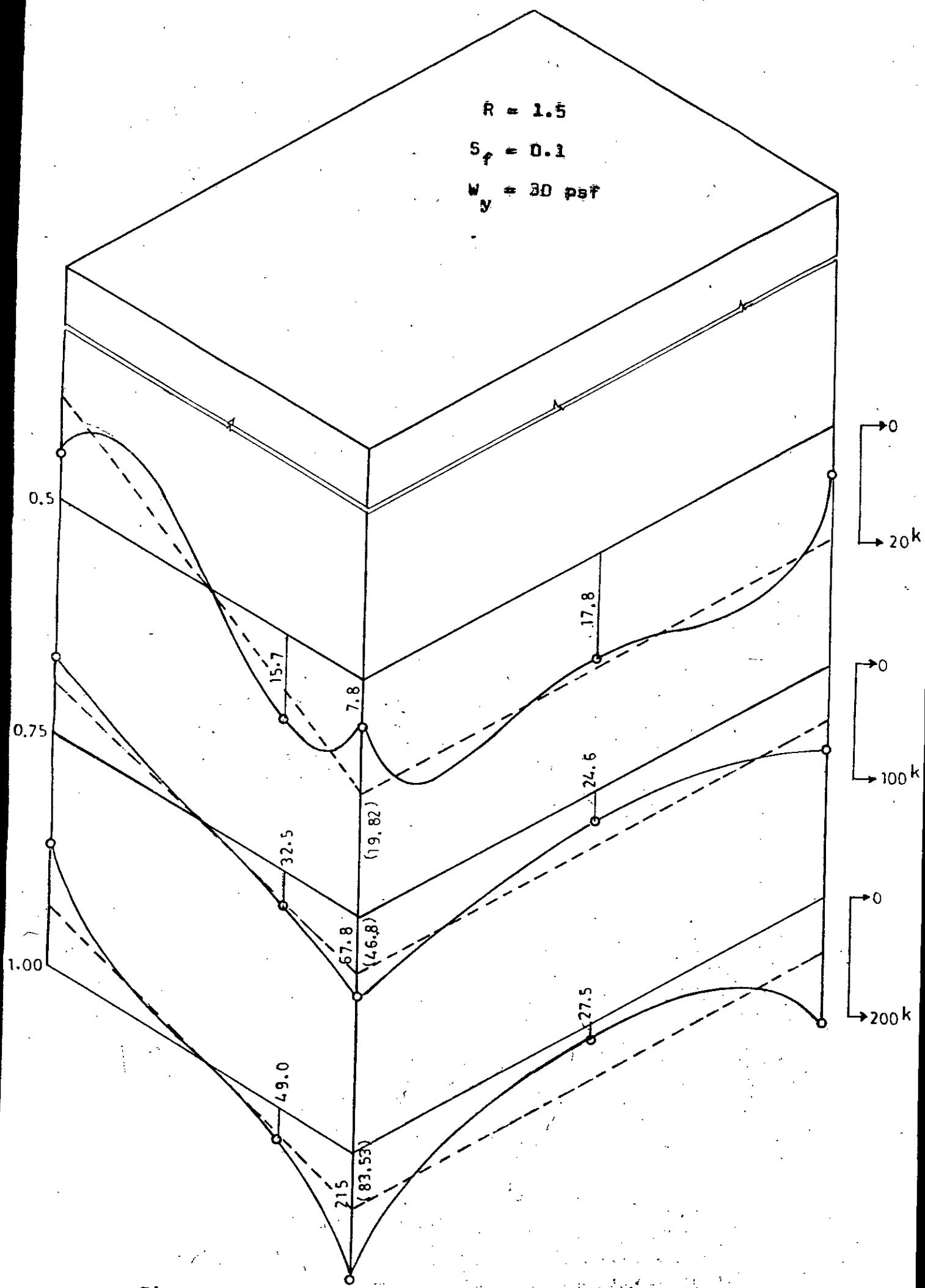


Fig. 4.78 Shear load effect on truss members

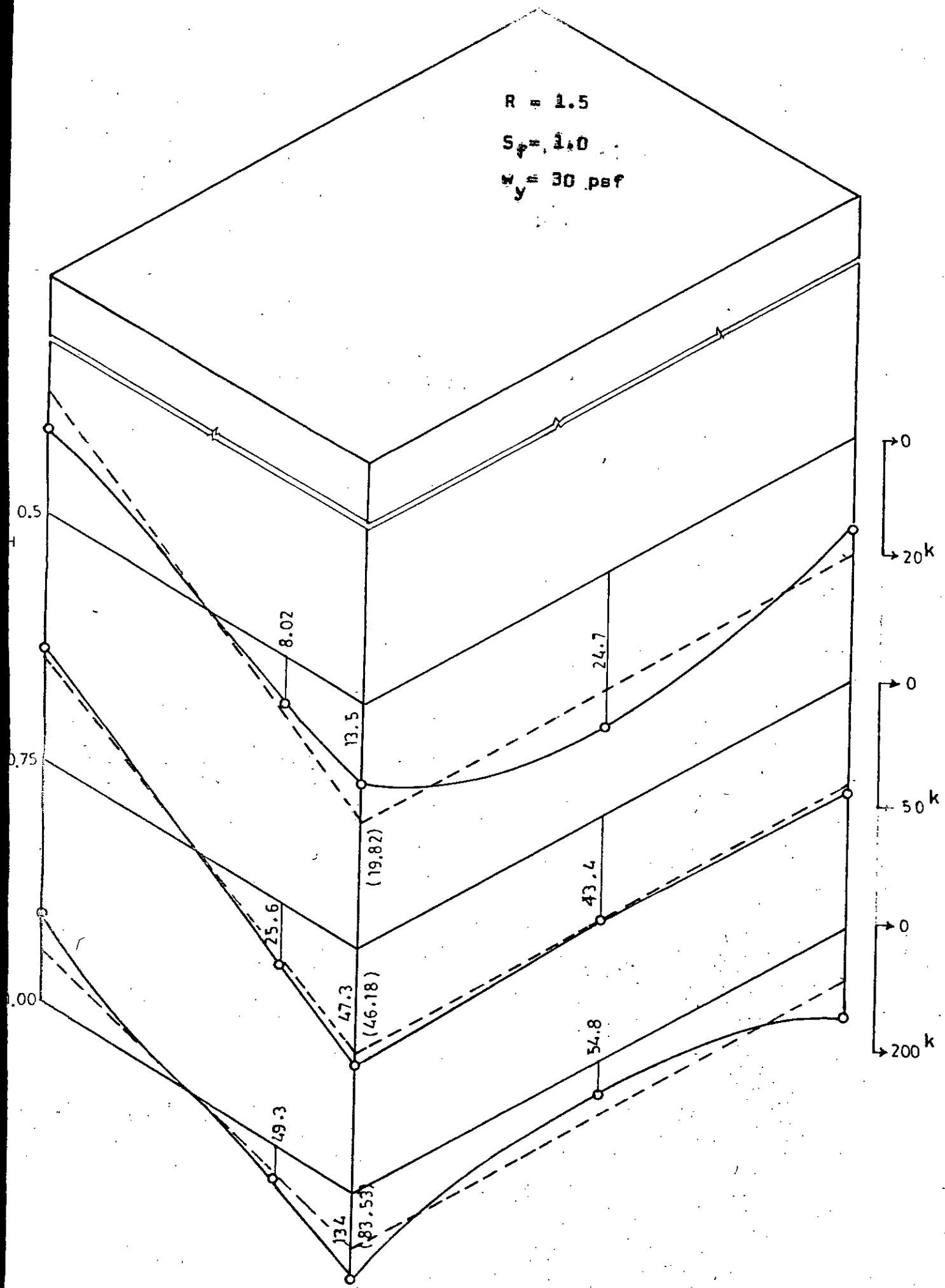


Fig. 4.29 Shear lag effect on tubular structure.

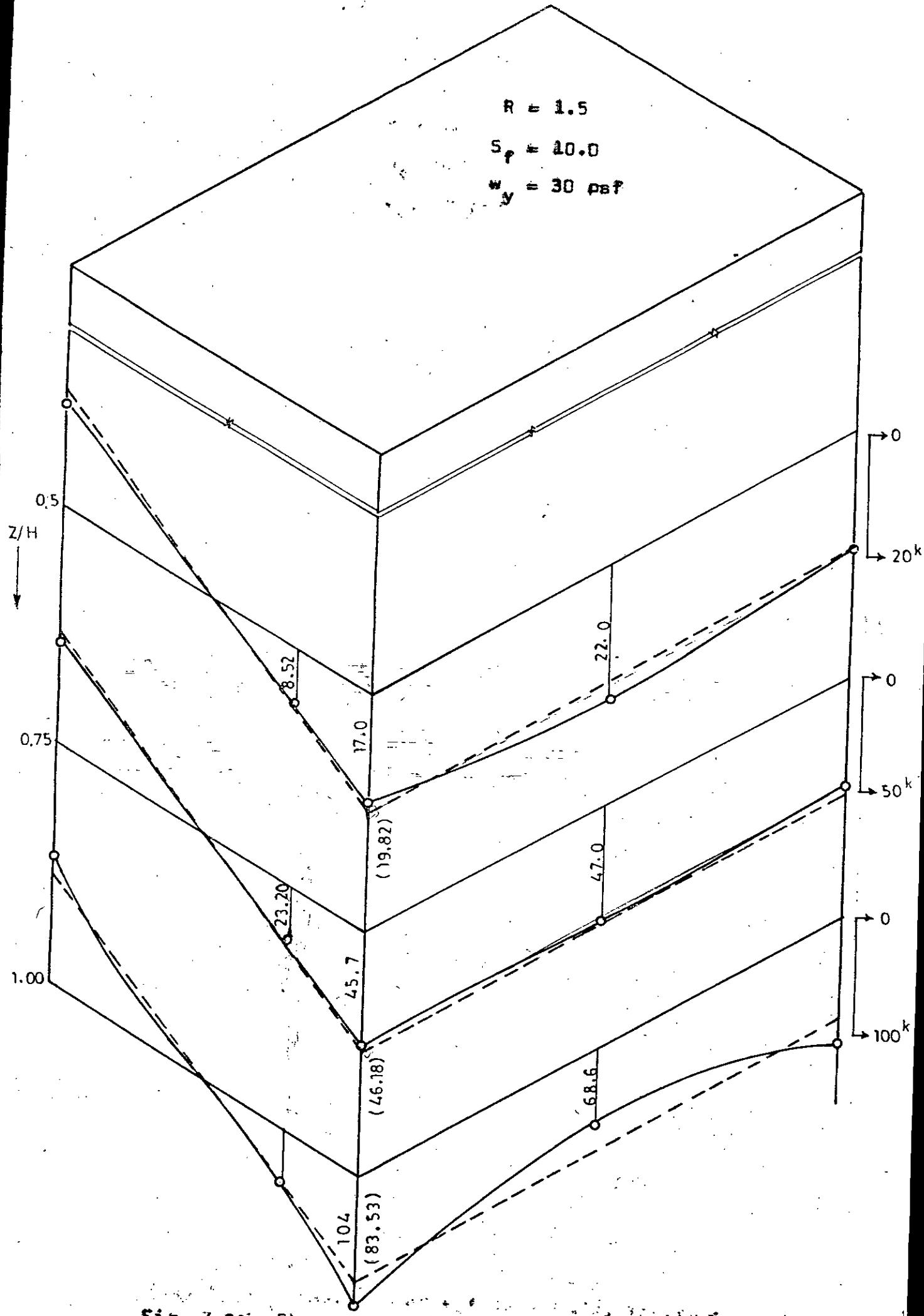


Fig. 4.30 Shear lag effect on tubular structure.

$R = 2.0$

$S_f = 0.1$

$P_x = 100^k$

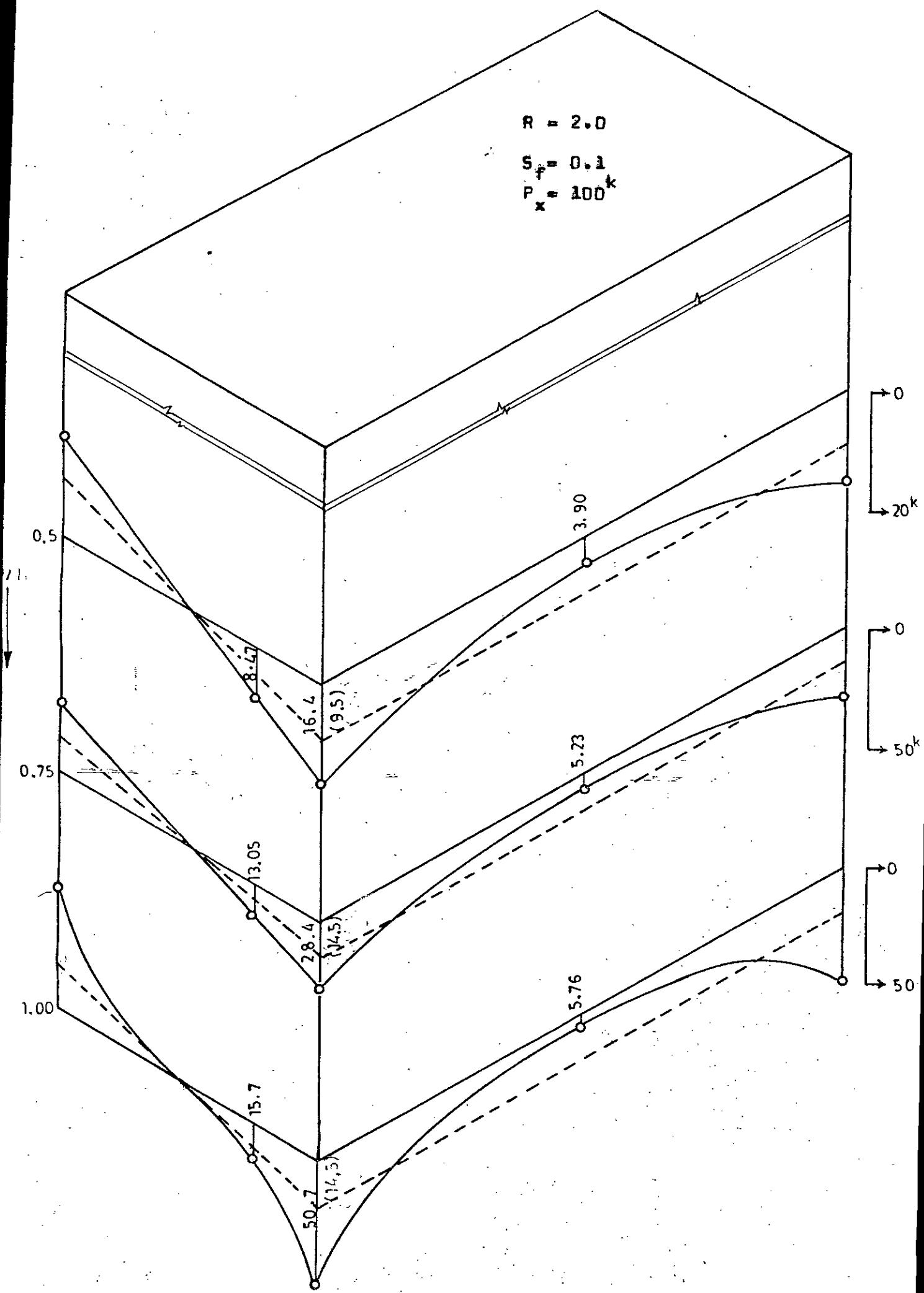


Fig. 4.31 Shear lag effect on tubular structure.

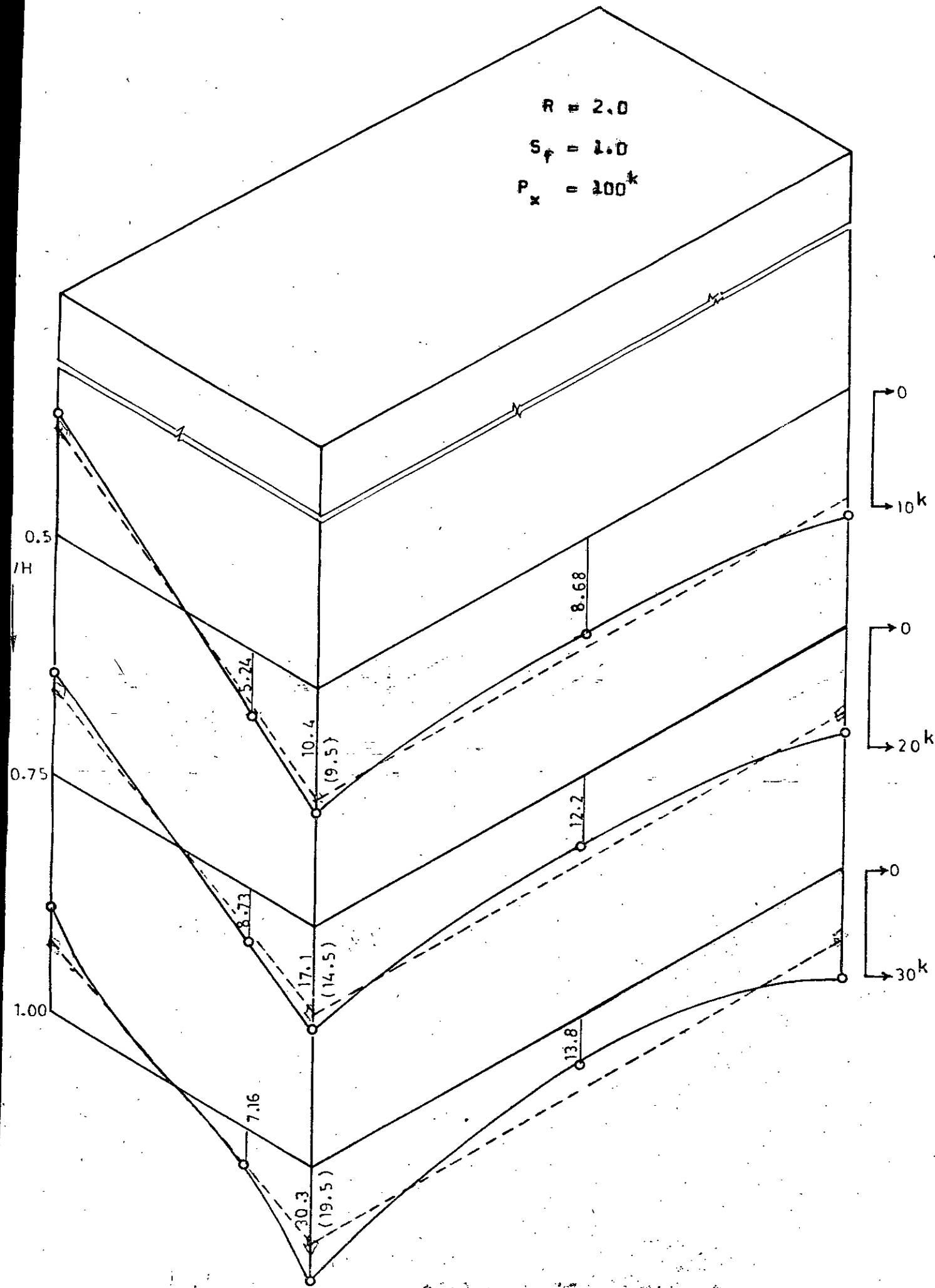


Fig. 4.32. Shear lag effect on tubular structure.

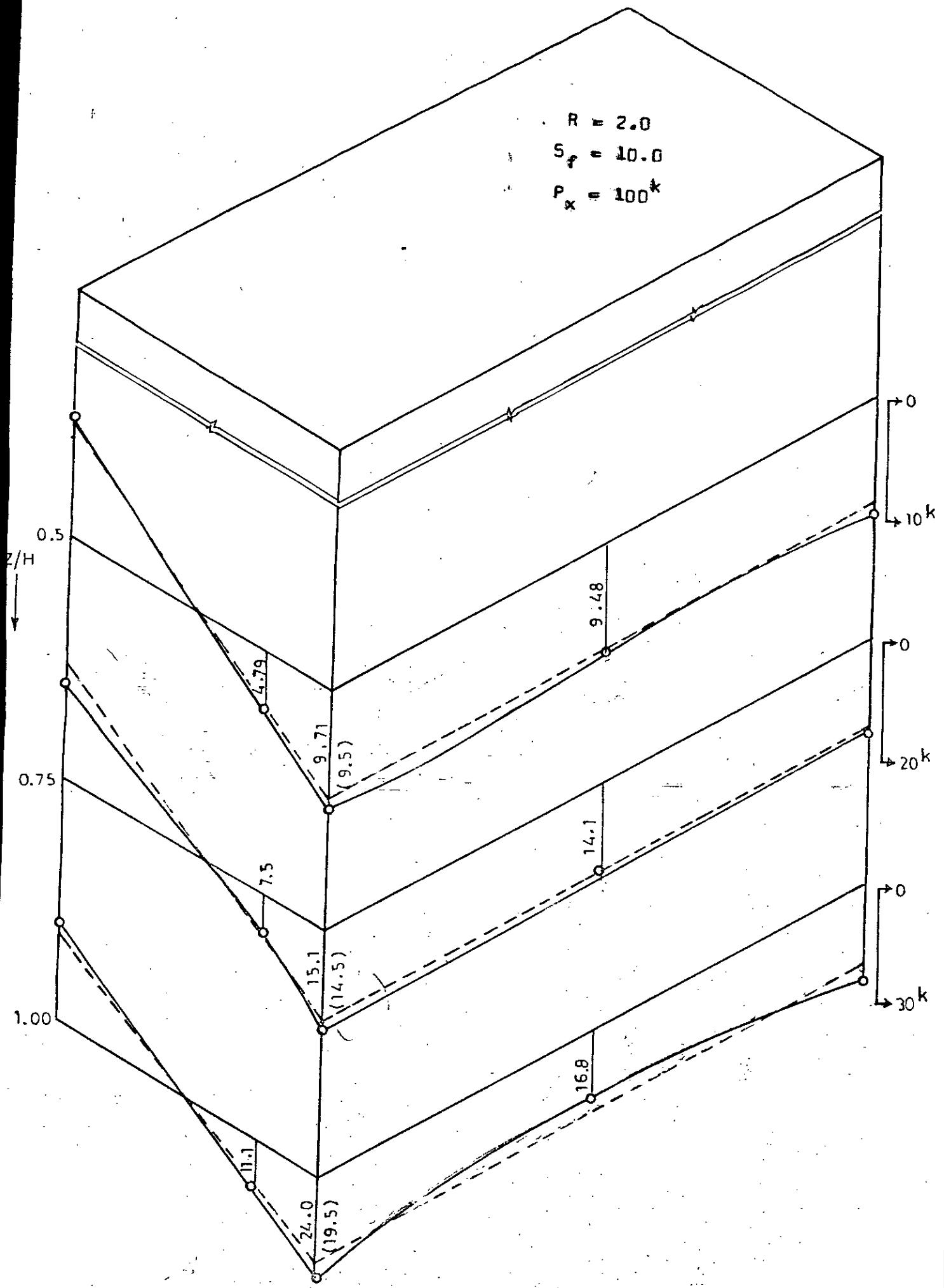


Fig. 4.33: Shear lag effect on tubular structure.

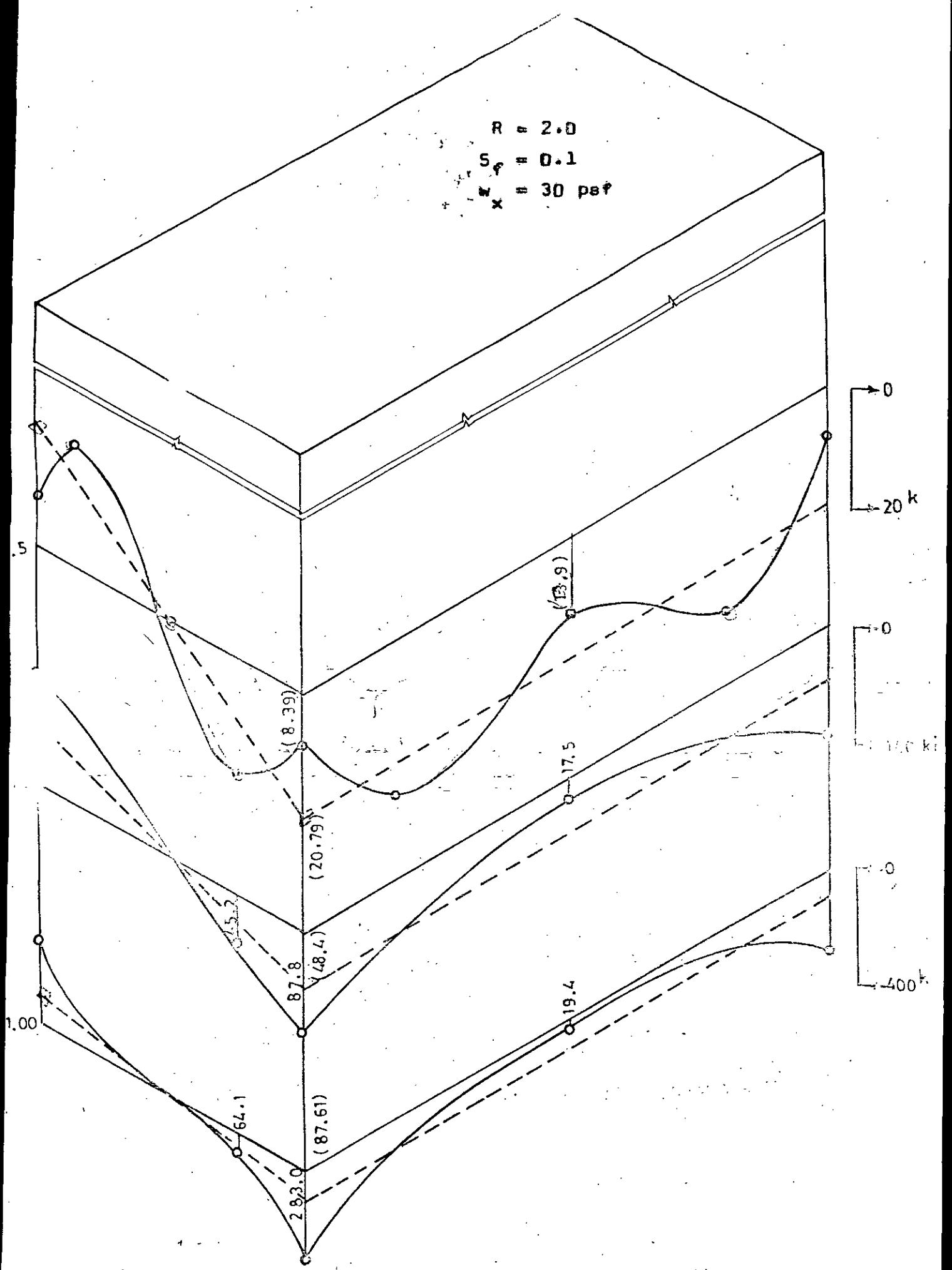


Fig. 4.34. Shear lag effect on tubular structures.

$R = 2.0$
 $S_f = 1.0$
 $w_x = 30 \text{ psf}$

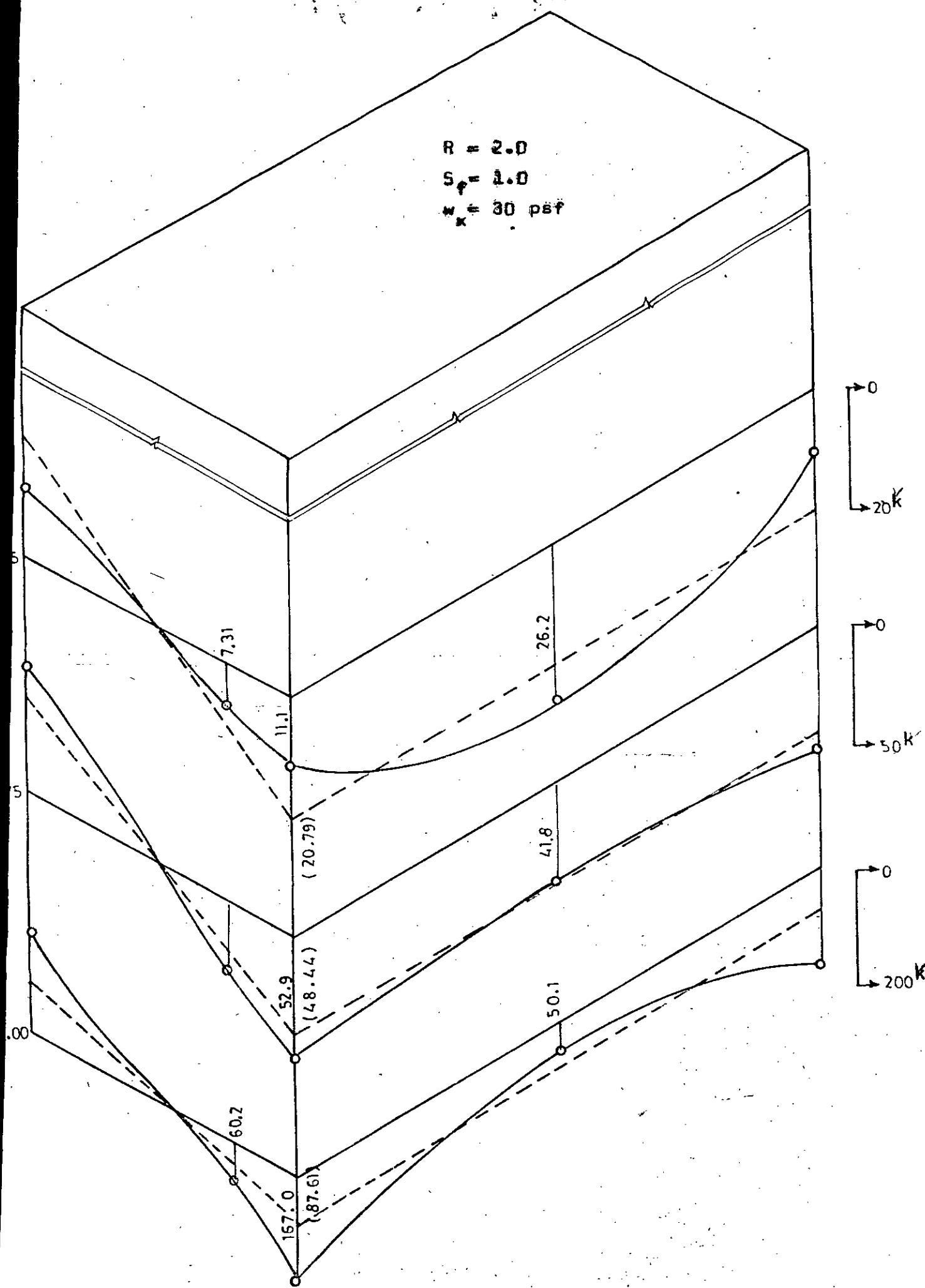


Fig. 4.35 Shear lag effect on tubular structure.

$$R = 2.0$$

$$S_f = 10.0$$

$$w_x = 30 \text{ psf}$$

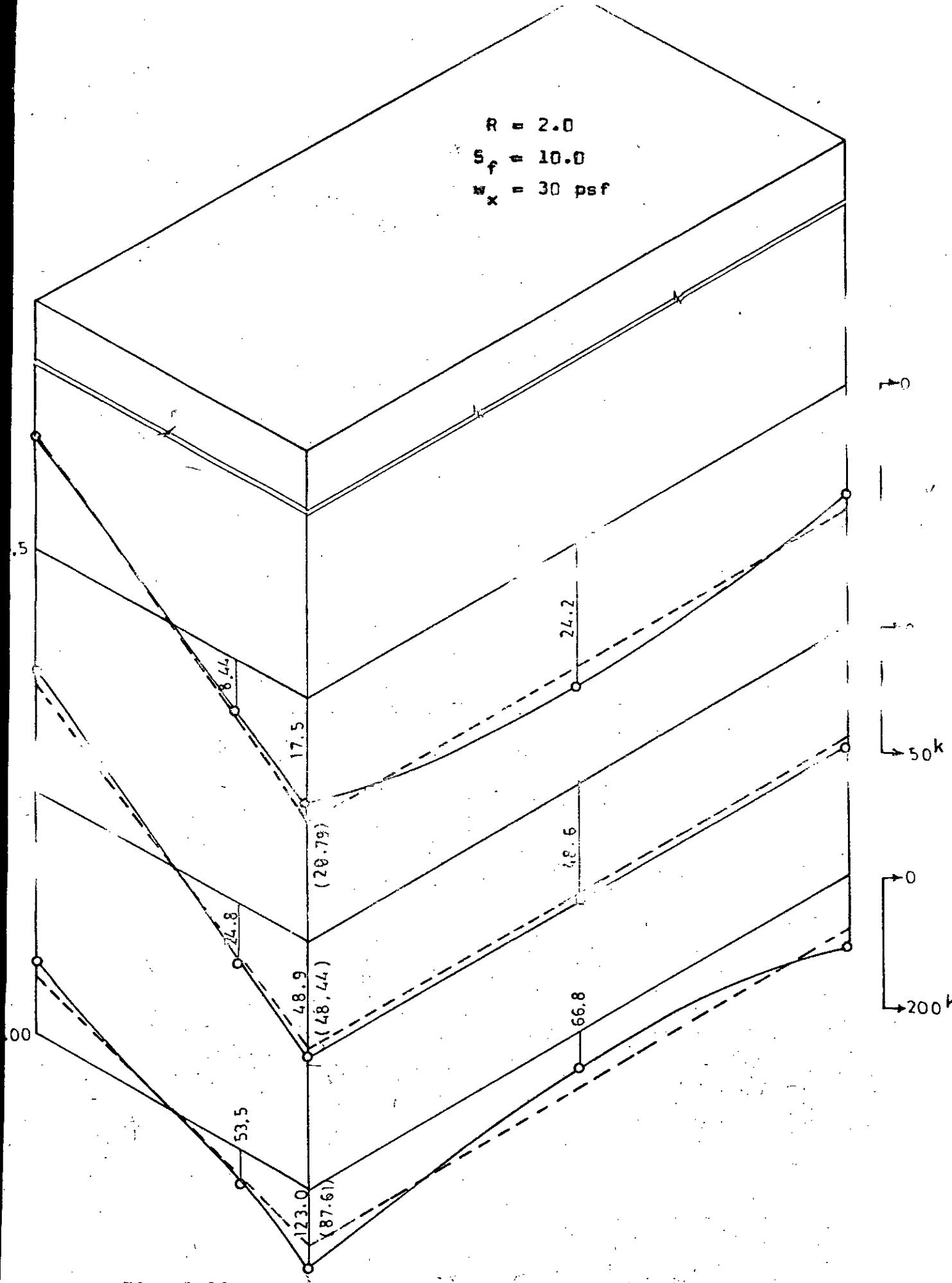


Fig. 4.36 Shear lag effect on tubular structures.

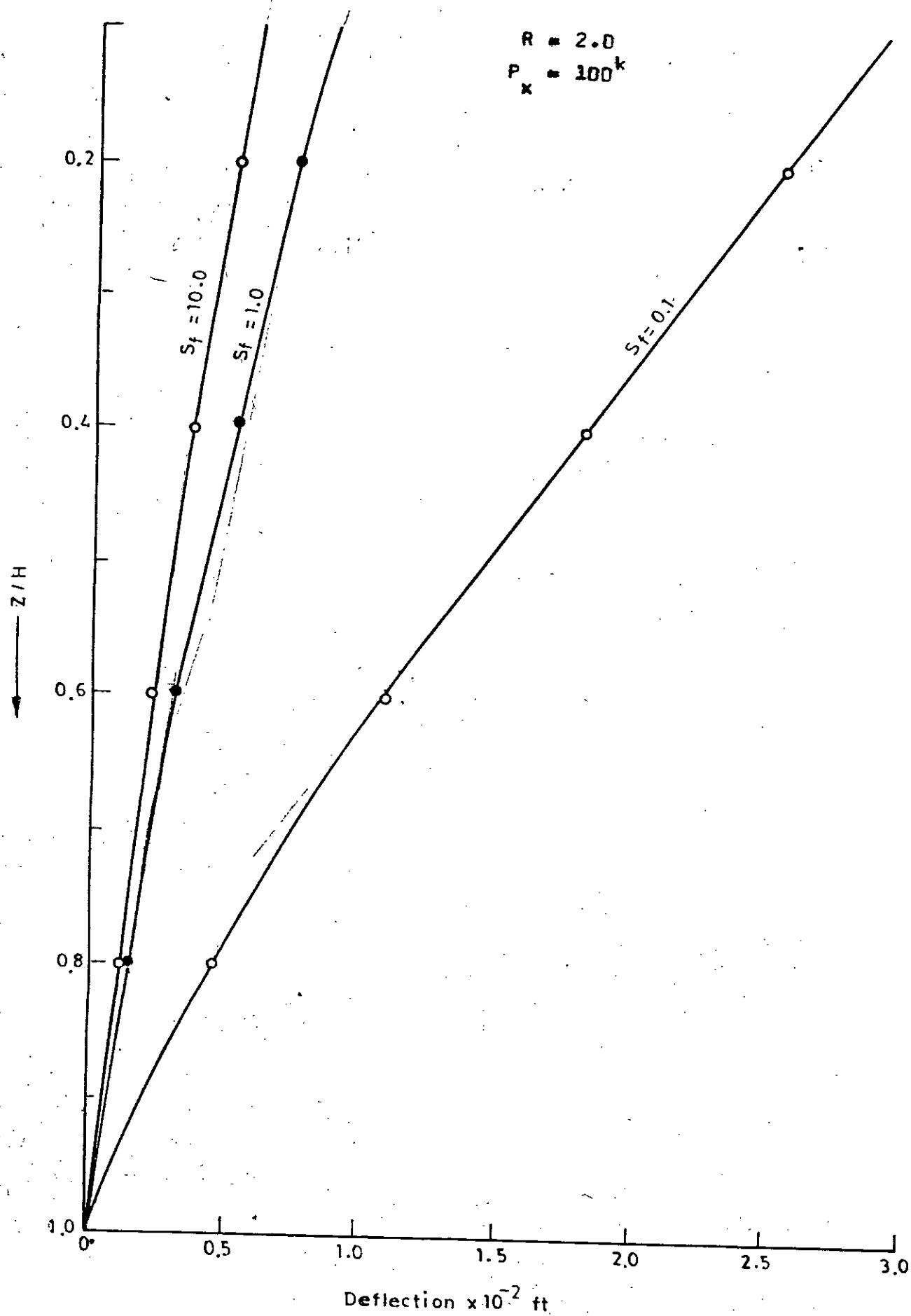


Fig. 4.38 Deflected shapes of the tubular structure.

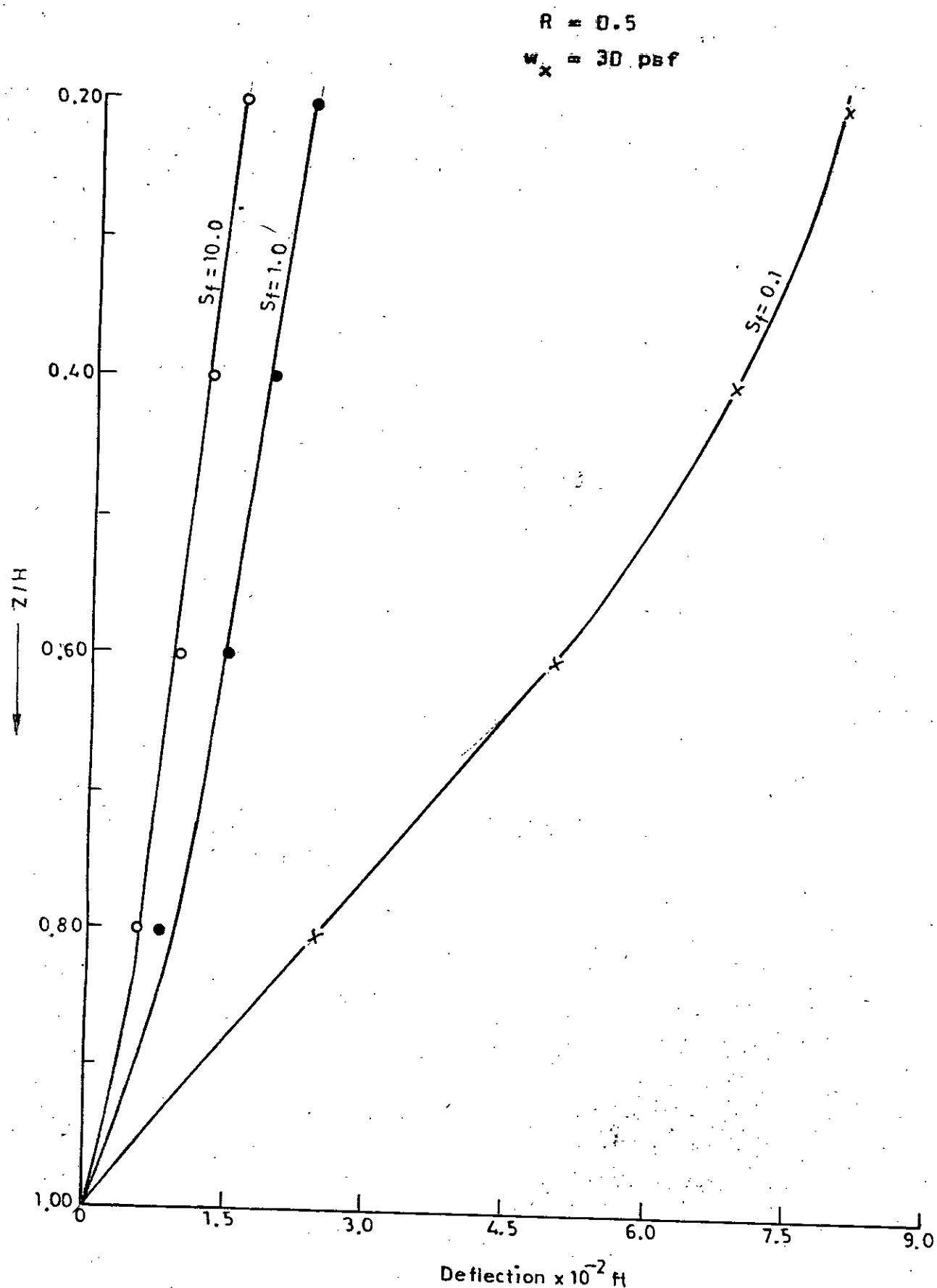


Fig. 2.39 Deflected shapes of the tubular structure.

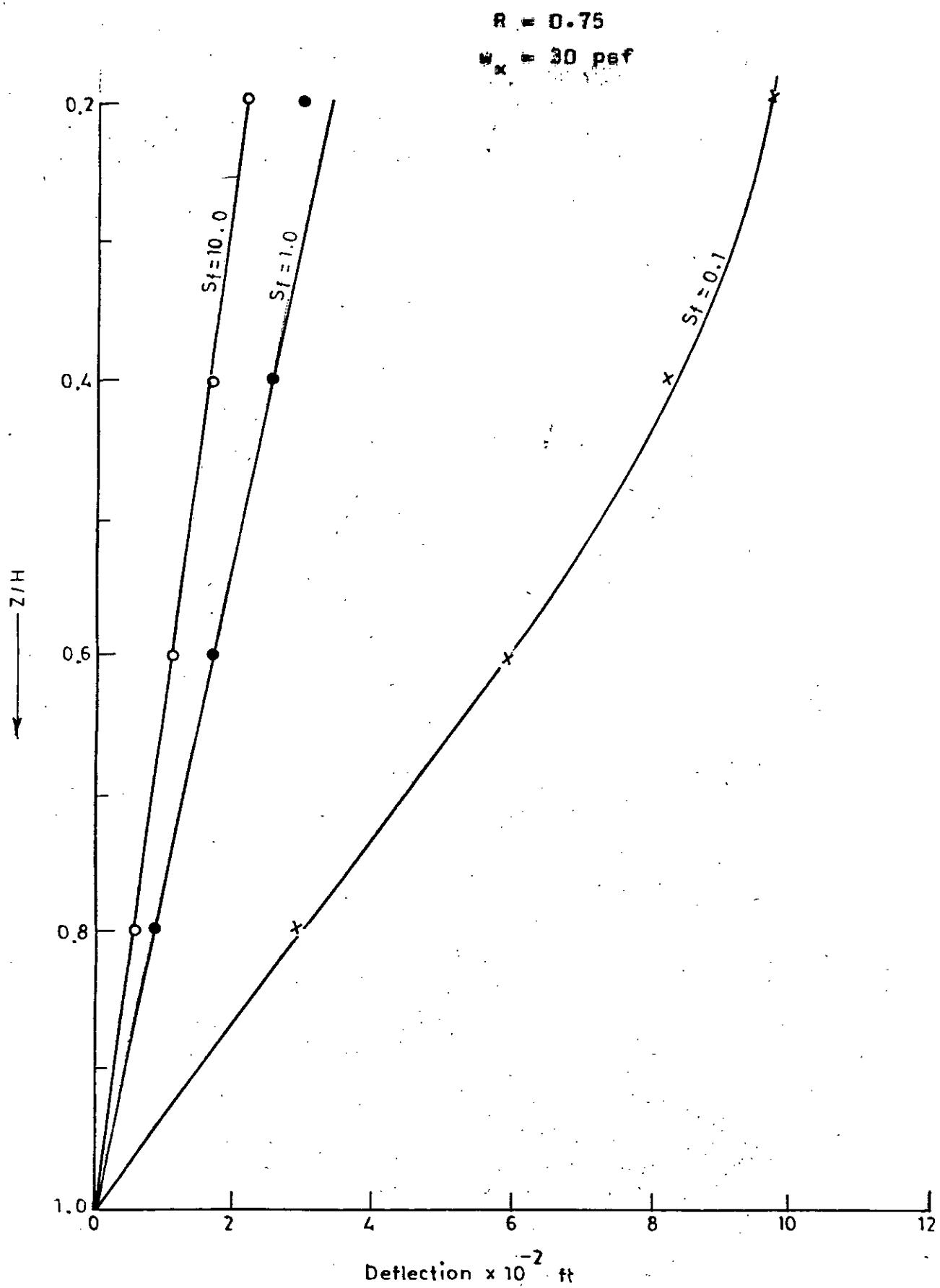


Fig. 4.40 Deflected shapes of the tubular structure.

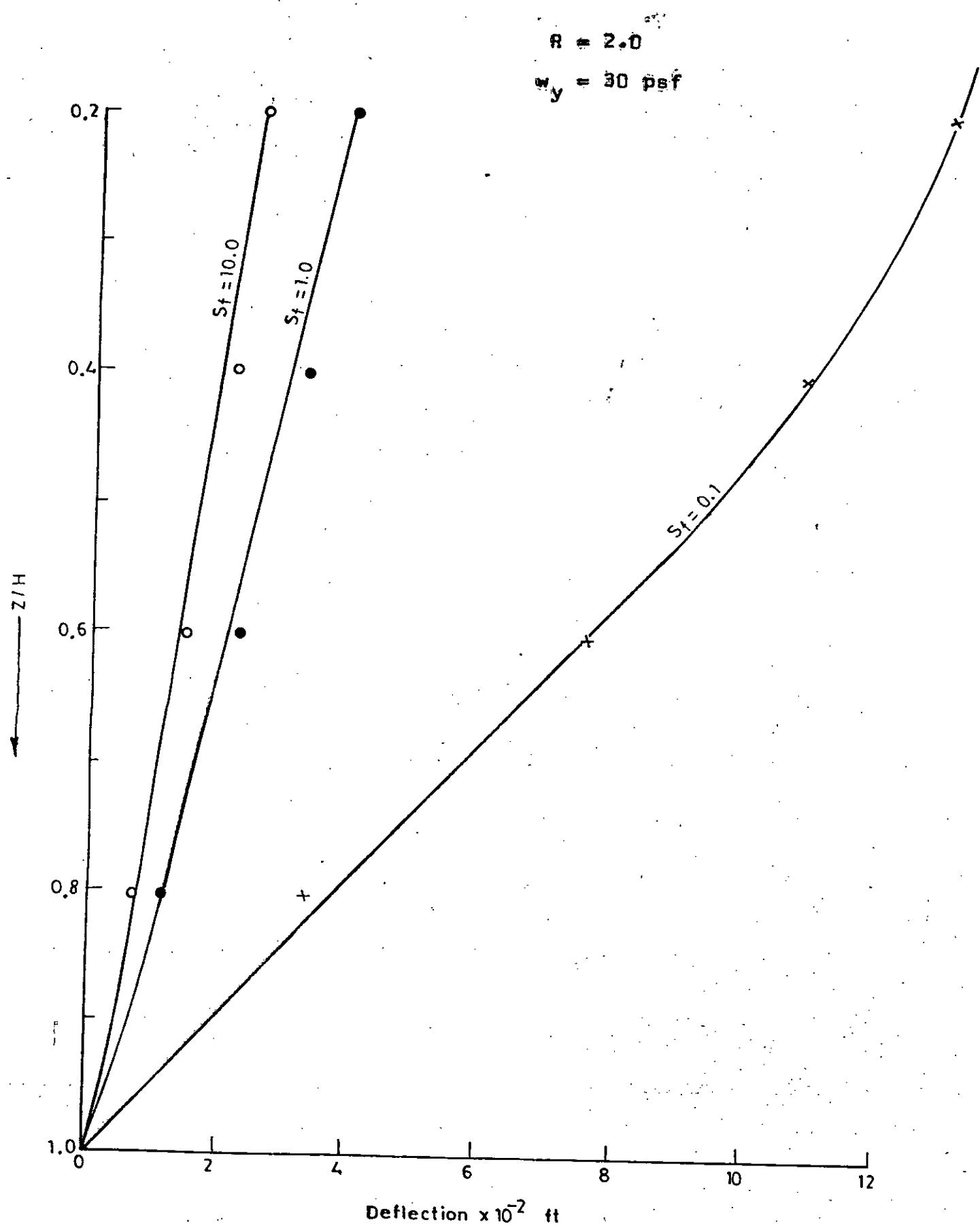


Fig. 4.41 Deflected shapes of the tubular structure.

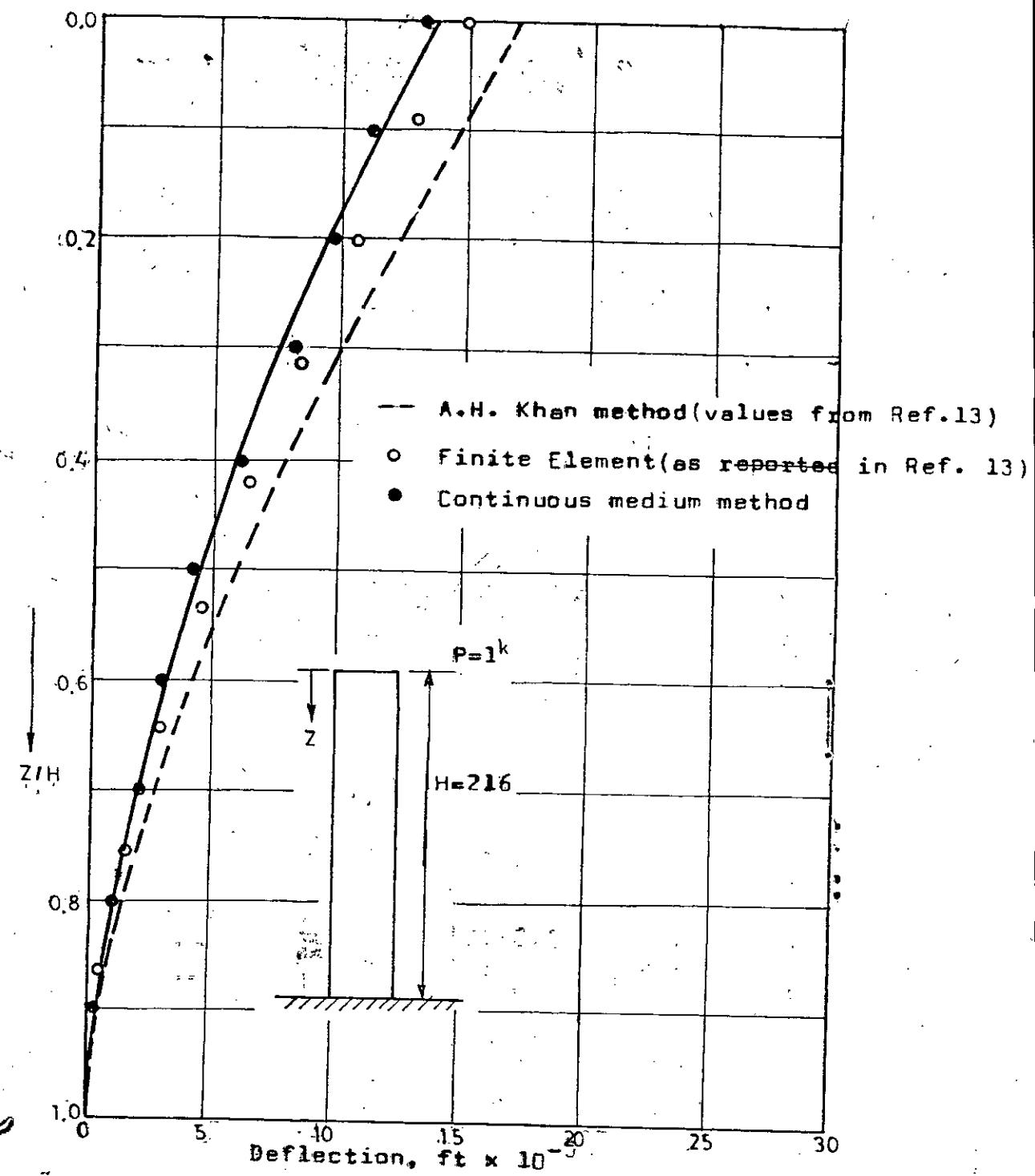


Fig. 4.4 Deflected Shapes of the Framed Tube due to Point Load.

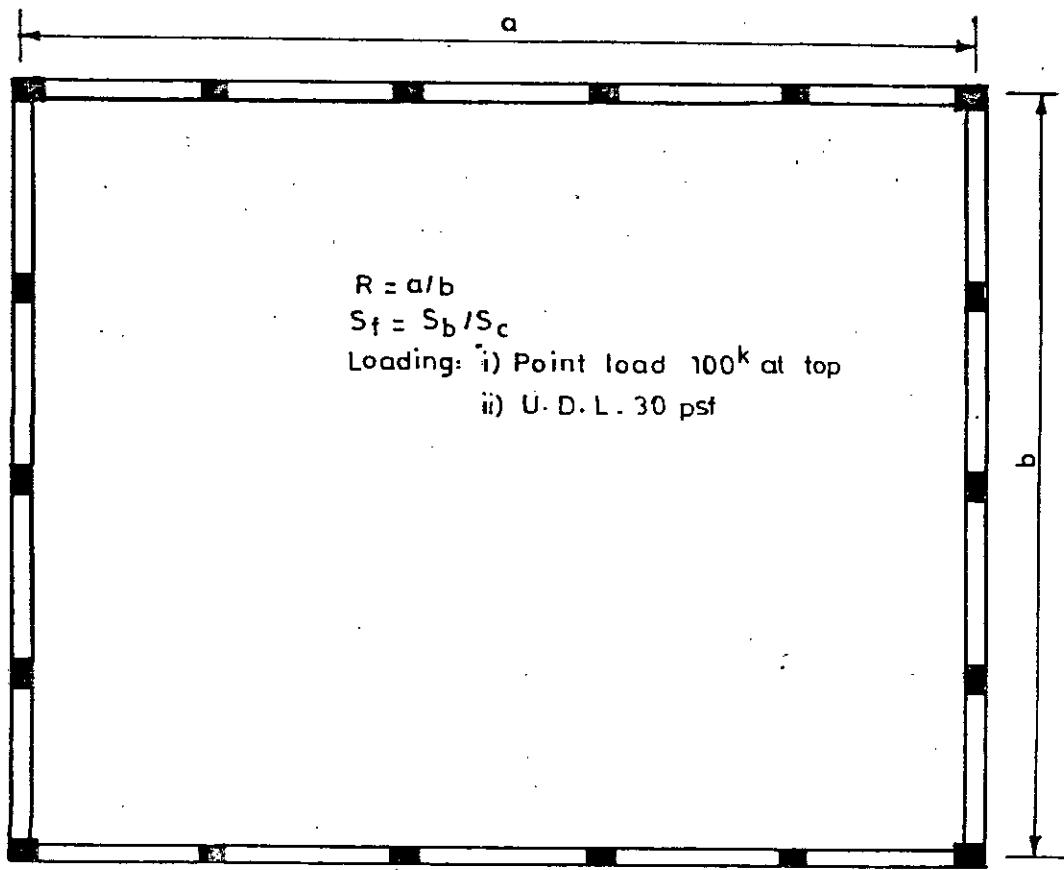
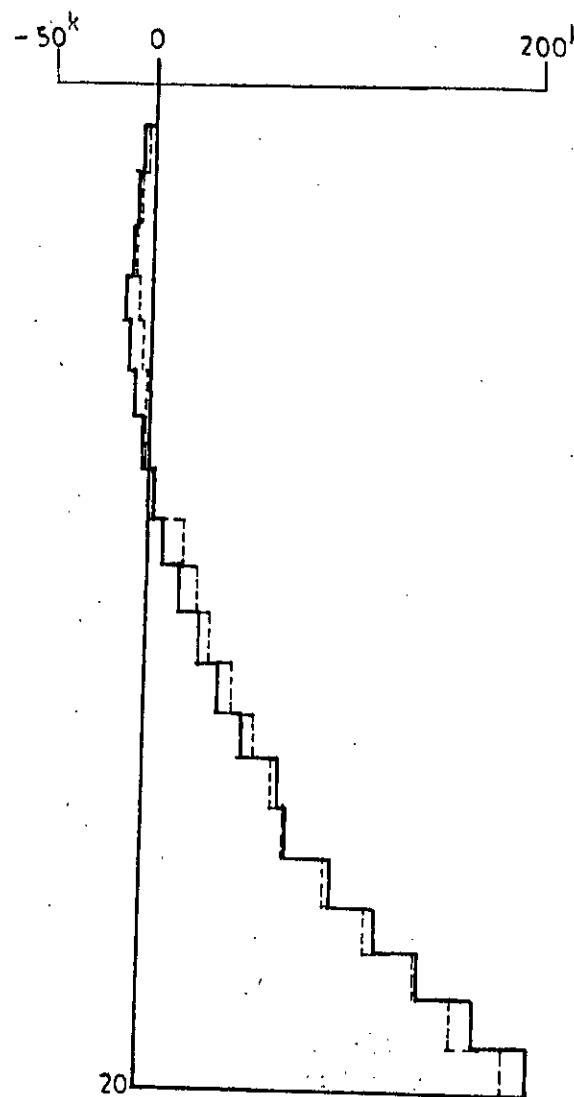


Fig. 4.3 Typical Plan of the Tubes Analyzed.

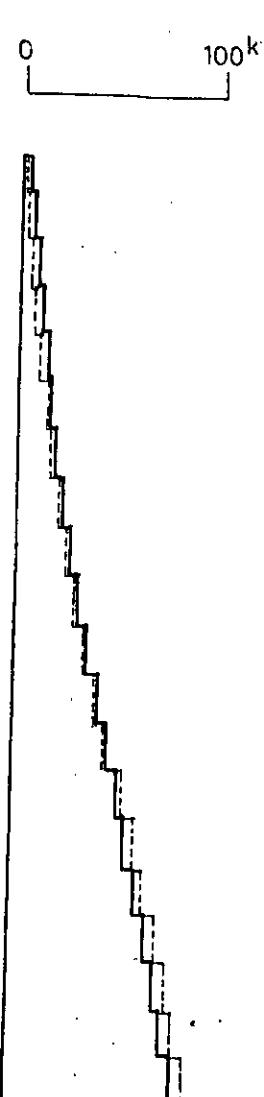
Table 4.2 Properties of the Tube.

Figures	a	b	R	Beam width ft.	Beam depth ft.	Beam moment of inertia ft ⁴	c/c distance between column ft.	S _b /E	Column area ft ²	Storey height ft.	S _c /E	S _f	No. of Storey	S _{f10}
64	128	0.5	125	6.42	27.78	8.0	0.651	3.125	12.0	0.26	2.5	20	10.0	
64	128	0.5	1.25	3.00	2.778	8.0	0.065	3.125	12.0	0.26	0.25	20	1.0	
64	128	0.5	1.25	1.39	0.278	8.0	0.006	3.125	12.0	0.26	0.025	20	0.1	
64	96	0.75	1.25	6.42	27.78	8.0	0.651	3.125	12.0	0.26	2.5	20	10.0	
64	96	0.75	1.25	3.00	2.778	8.0	0.065	3.125	12.0	0.26	0.25	20	1.0	
64	96	0.75	1.25	1.39	0.278	8.0	0.006	3.125	12.0	0.26	0.25	20	0.1	
64	64	1.0	1.25	6.42	27.78	8.0	0.651	3.125	12.0	0.26	2.5	20	10.0	
64	64	1.0	1.25	3.00	2.778	8.0	0.065	3.125	12.0	0.26	0.25	20	1.0	
64	64	1.0	1.25	1.39	0.27	8.0	0.006	3.125	12.0	0.26	0.025	20	0.1	
96	64	1.5	1.25	6.42	27.78	8.0	0.651	3.125	12.0	0.26	2.5	20	10.0	
96	64	1.5	1.25	3.00	2.778	8.0	0.06	3.125	12.0	0.26	0.25	20	1.0	
96	64	1.5	1.25	1.39	0.278	8.0	0.006	3.125	12.0	0.26	0.025	20	0.1	

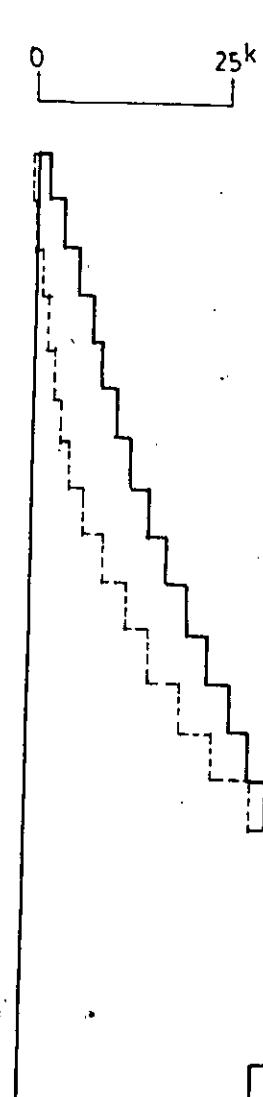
—— 3-D Equivalent Frame Method
 - - - Continuous Medium Method



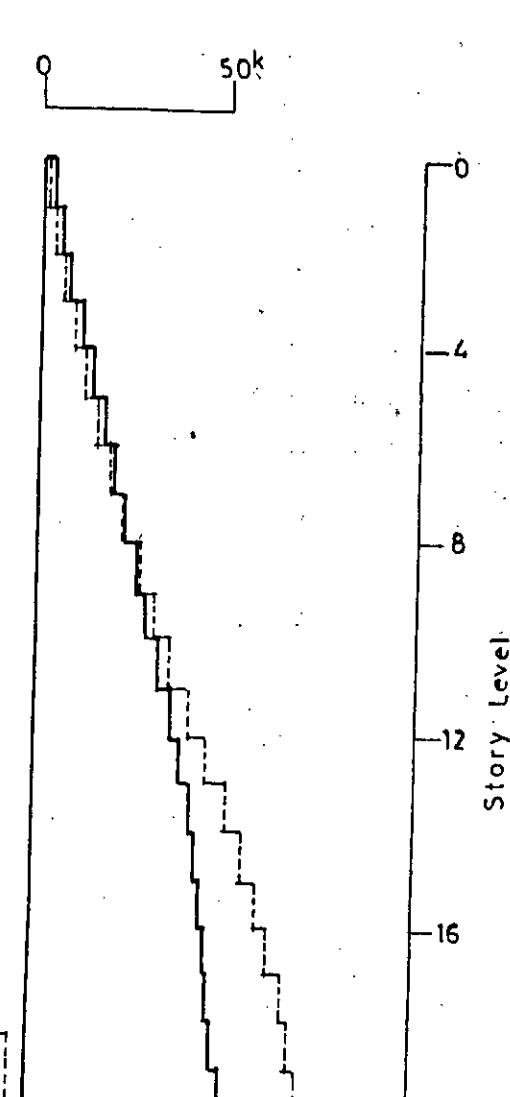
Col. 1, 9, 10, 18



Col. 2, 8, 11, 17



Col. 3, 7, 12, 16



Col. 4, 6, 13, 15

Fig. 4.9 Distribution of Axial Force in 20 Storey Building. (Fig. 4.2)

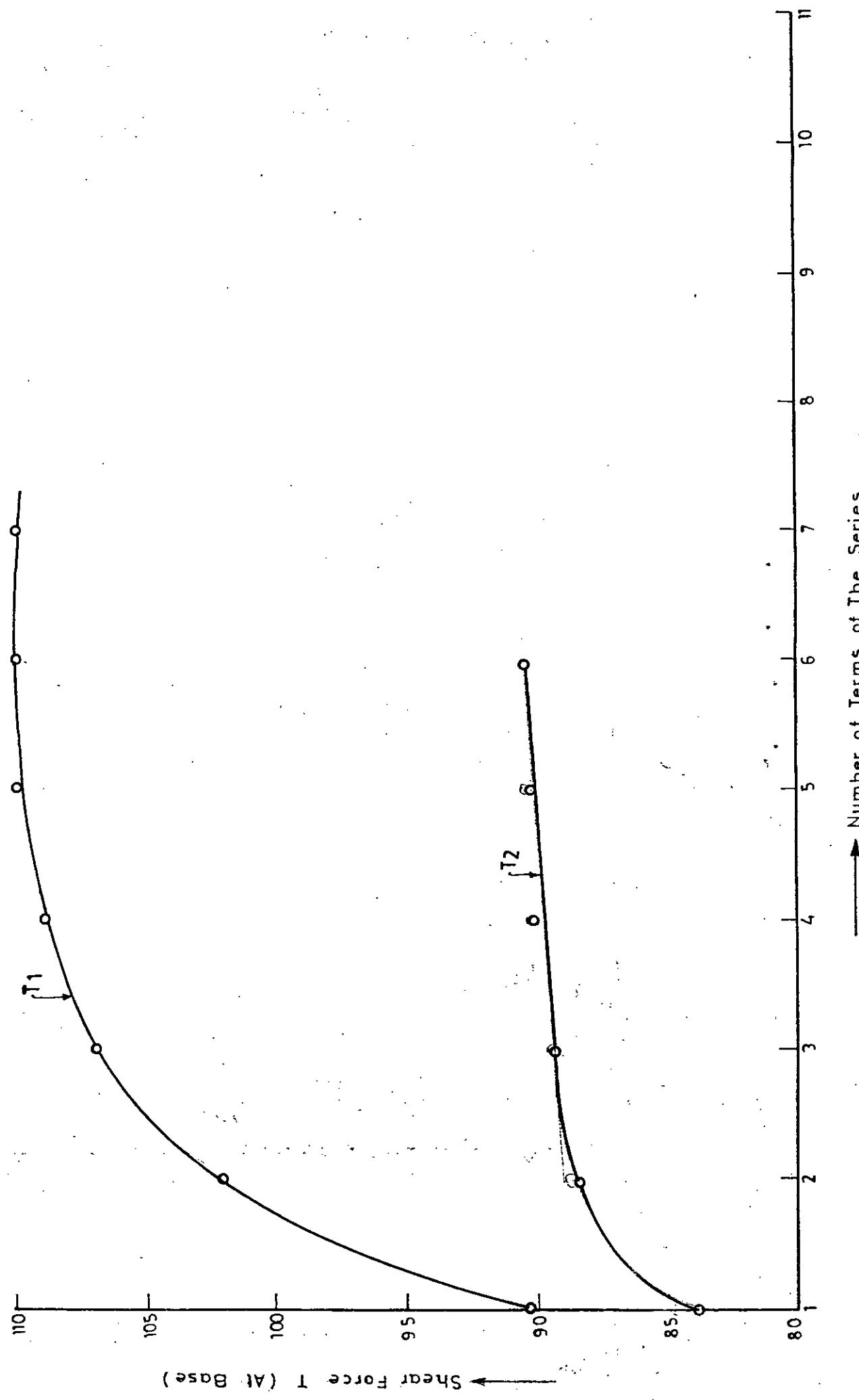


Fig. 3.4 Convergence of Shear Force in Connecting Medium.

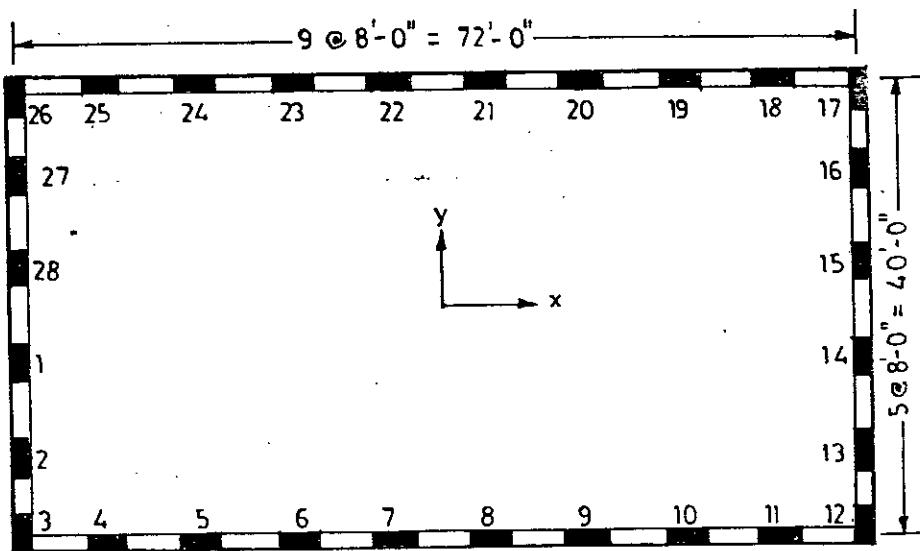


Fig. 4.1 Plan of Example Problem 1

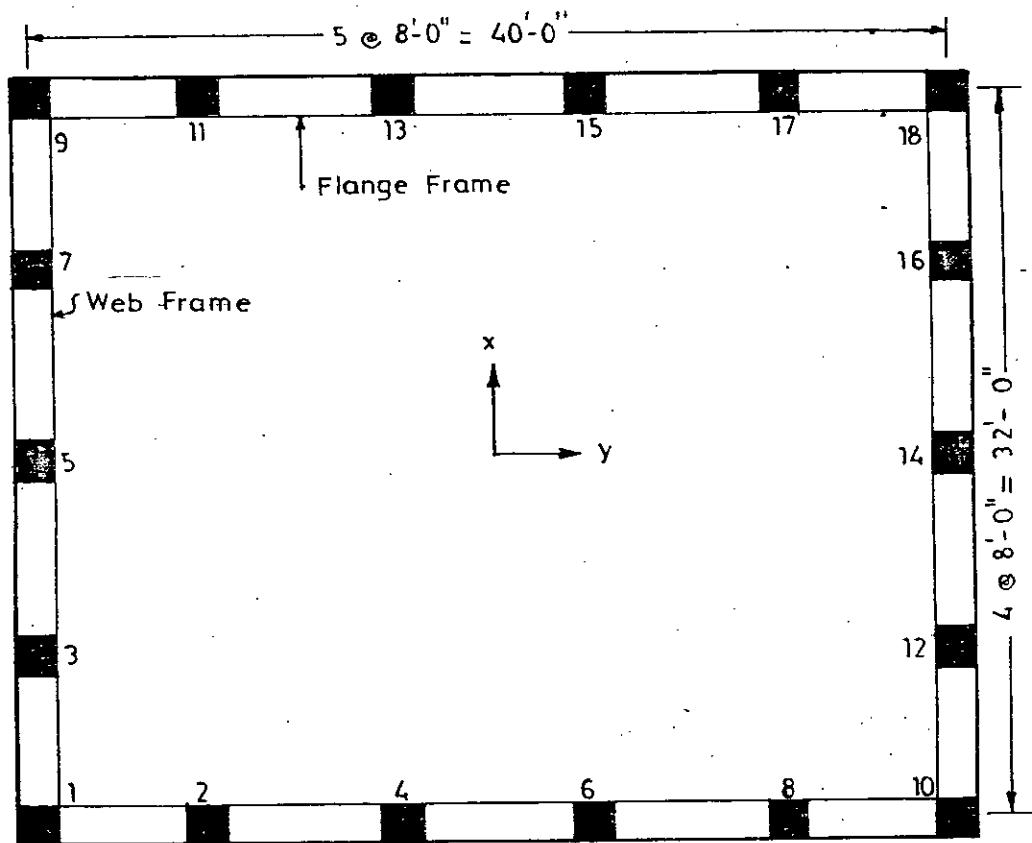


Fig. 4.2 Plan of Example Problem 2

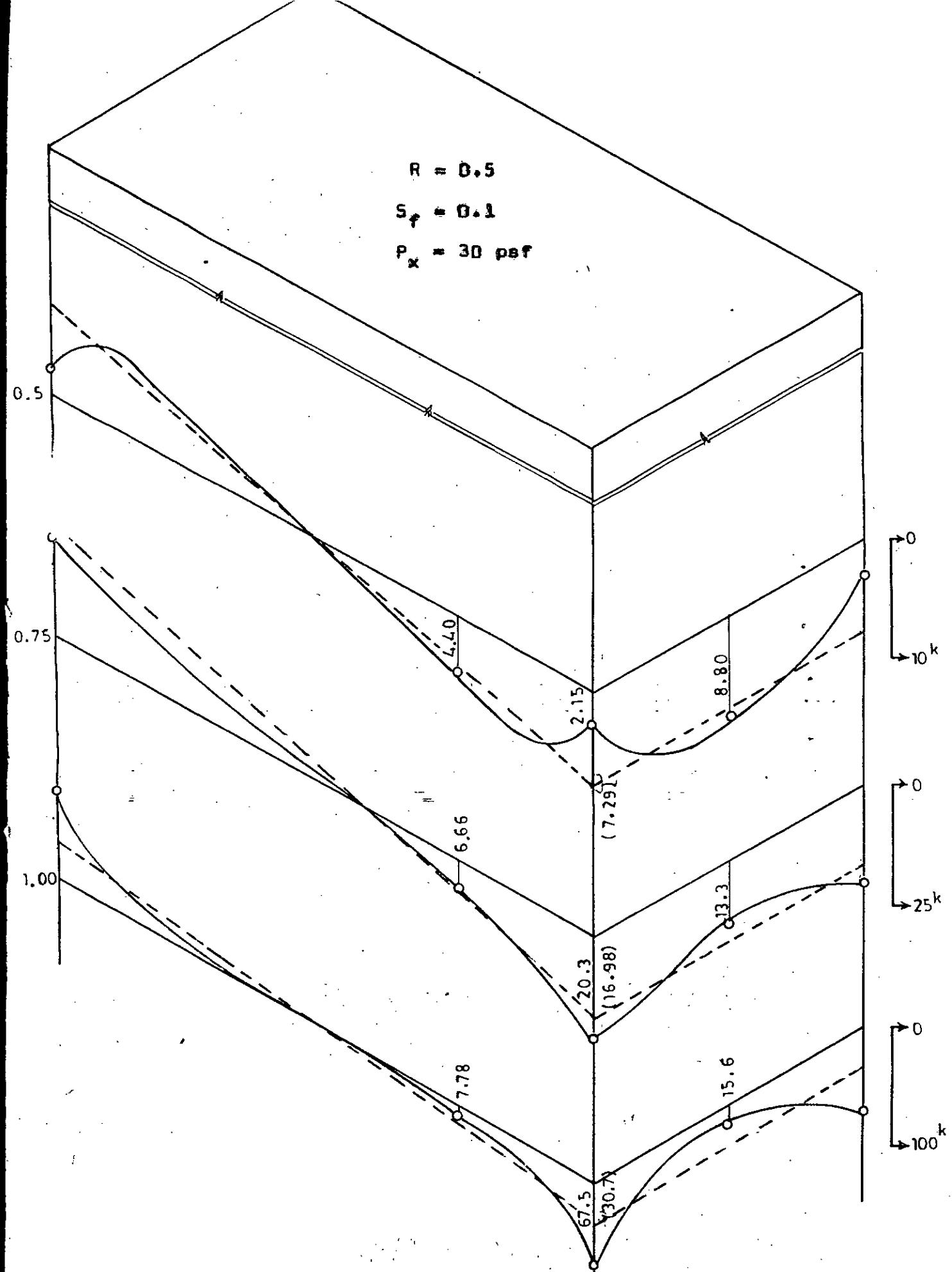


Fig. 4.10 Shear leg effect on tubular structures.

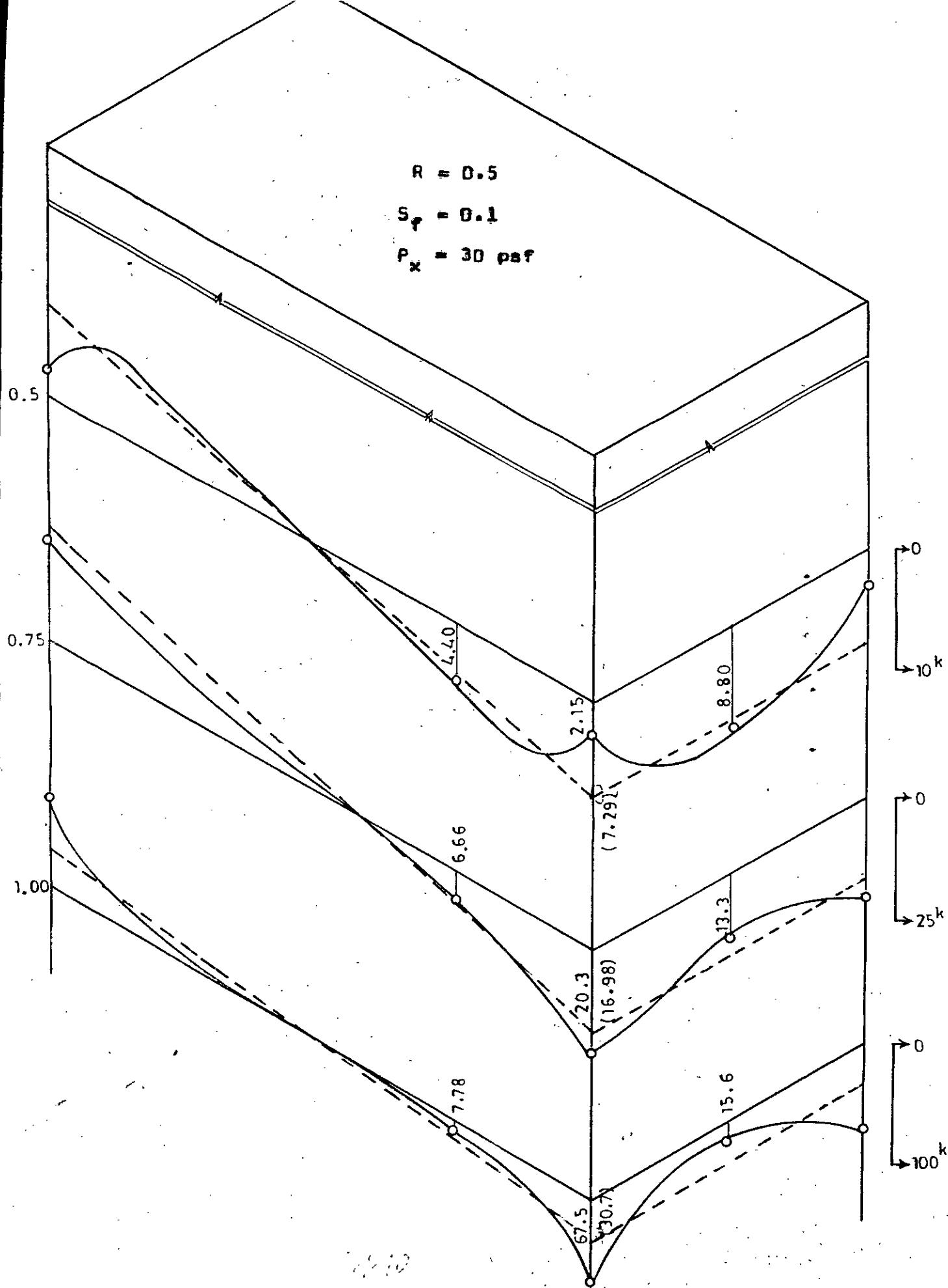


Fig. 4.10 Shear lag effect on tubular structure.

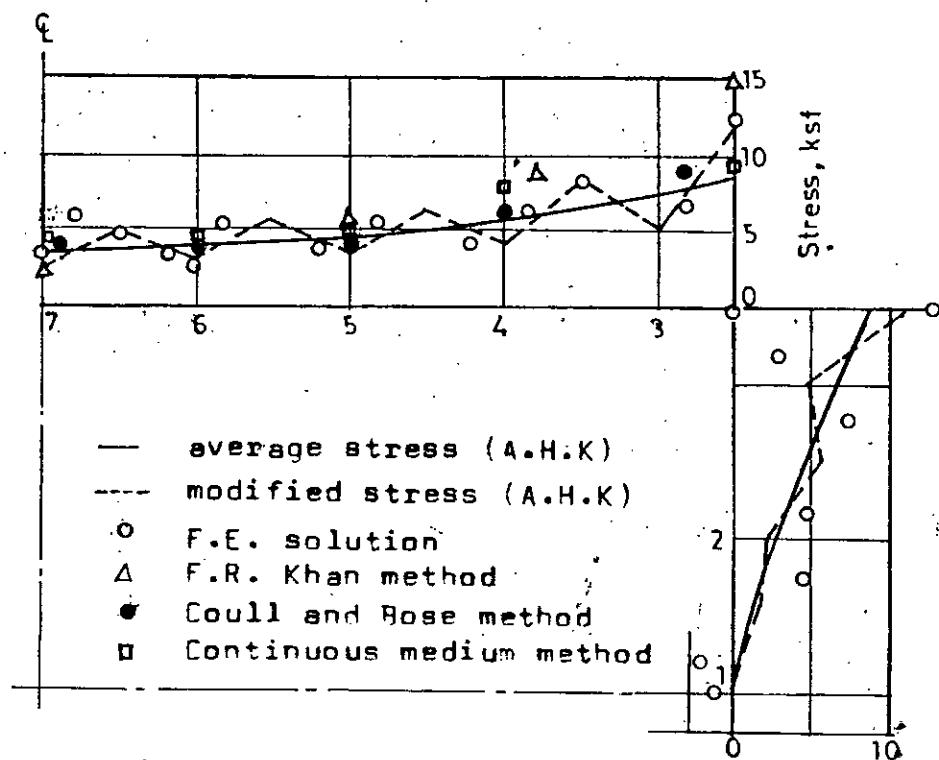


Fig. 4.6 Stress distribution at the base due to u.d.l.

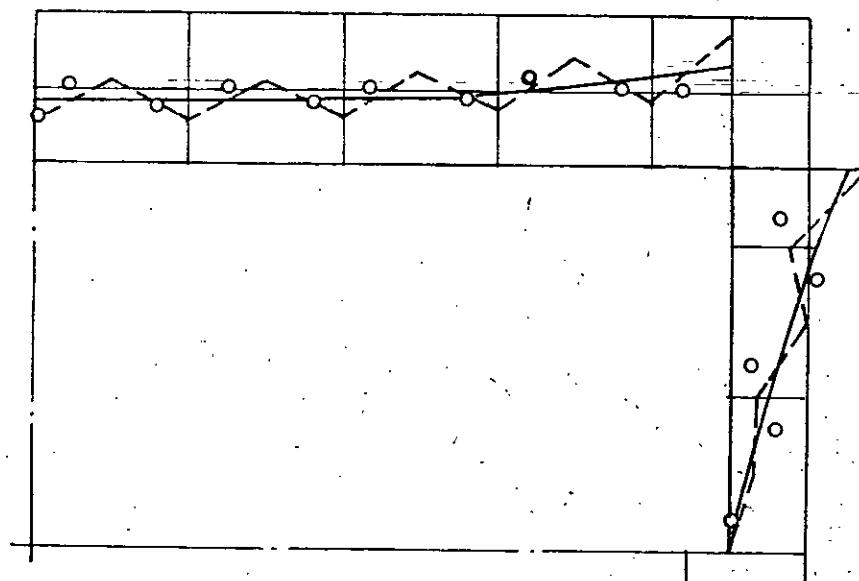


Fig. 4.7 Stress distribution at the base due to point load in the framed tube.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATION FOR FURTHER STUDY

5.1 Conclusions

The results of a preliminary investigation into the accuracy of a simplified method of analysis of high-rise rectangular tubular structures, using a Continuous medium technique, have been presented in this thesis. From the series of investigations it may be concluded that the method yields acceptable levels of accuracy for column axial forces for a wide range of stiffness factors (s_f) (i.e., $s_f = 0.5, 0.75, 1.0, 1.5$ and 2.0).

The results obtained from the proposed method are compared with those obtained from

- i) A.H. Khan method
- ii) F.R. Khan method
- iii) Coull & Bose method, and
- iv) 3-D equivalent frame analysis

The method (iv) is an 'exact' solution for the idealised tubular structure. The accuracy of the proposed method is verified by comparing the results with those obtained from analysis of a 20-storey rigid-tube structure by 3-D equivalent frame programme.

From the comparative study, it is observed that for a preliminary analysis, F.R. Khan method provides an easy

solution, amenable to manual computation, for the tubular structure. However, the stress at corner columns is about 50% higher than the method (iv).

The stresses and deflections, of the example problem 1, obtained from the governing differential equation of A.H. Khan method are found less than the values reported in Ref. 13. From Fig. 4.5 it is found that the value of horizontal deflection at top of the structure (Fig. 4.1) calculated from the governing differential equations of A.H. Khan method is about 28% less than the values obtained from Ref. 13. From the stress diagram (Fig. 4.6) it is observed that the stresses correspond very well to those predicted by 3-D equivalent frame solution.

The stress in the corner column (Fig. 4.1) obtained by Coull and Bose method is 11% less and that in the middle column of the flange frame is about 32% less than the values obtained by 3-D equivalent frame method.

In deriving the governing equations for continuous medium method, one of the assumptions made was that the points of contraflexure are at the midspan of the connecting beams, but from example problem 2 (Fig. 4.8), investigated by the 3-D equivalent frame program, it was found that no points of contraflexure in the connecting media of the flange frame and web frame except the middle beam of the web frame. Though the assumption is quite wrong, the results obtained from the proposed method agree well with those

obtained from 3-D equivalent frame method. The values of axial forces in the corner columns obtained by the simplified method are found to be within 90-95 percent of the results obtained by the more accurate three-dimensional equivalent frame method.

On the basis of the results obtained for different example problems, it may be concluded that the simplified method of analysis proposed in the study may be conveniently used to rapidly evaluate the deflections and stresses for the tubular structures investigated.

5.2 Recommendations for Further Study

In this study, the accuracy of the continuous medium method has been studied using only regular rectangular shape of tube structure. A comparative study may be done for irregular viz. octagonal shape of tubular structure. The principal axes of all columns including the corner columns are assumed to be parallel to the faces of the rectangular tube. The torsion in the beam has been neglected. A more general method may be developed including torsional effect in the connecting media and irregular shape of column cross-section.

3-D equivalent frame program is modified for suitability of the framed tube structure analysis without reducing the total memory requirements. This may be done by using direct access input/output statements.

From the series of analysis of shear-lag effect on tubular structures, (Figs. 4.10 to 4.36), a series of influence curves may be drawn for different aspect ratios, varying stiffness factor from 0.1 to 10.0.

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APPENDIX A
GOVERNING EQUATIONS, DESIGN CURVES OF
DIFFERENT METHODS AND LISTING OF THE PROGRAMMES

A.1 A.H. Khan Method Details

A.1.1 Notations

- U_1 rotational displacement
 U_2 modification of simple beam displacements
due to shear-lag
 V_1 spanwise transverse displacement
 Q point load at top
 q intensity of distributed load
 I_x moment of Inertia about x-axis
 J_2 bimoment inertia of bending
 E' modified value of E
 G' modified value of G
 z distance of the tube measured from bottom
 L total height of the tube
 α parameter defining shear lag
 ϕ_1, ϕ_2 orthogonal functions
 ϕ'_1, ϕ'_2 derivatives of orthogonal functions
 b clear span of beam
 d depth of beam
 A cross-sectional area of column

A.1.2 Governing Equations

The final expressions for the displacement functions, longitudinal stresses and lateral deflection of the tube by A.H. Khan method⁽¹³⁾ are:

a) For Point Load

Displacement functions

$$U_1 = \frac{Qz}{E I_x} \left(1 - \frac{z}{2}\right)$$

$$U_2 = \frac{bQ}{\alpha^2 E J_2} \left[\frac{\sinh \alpha l}{\cosh \alpha l} \sinh \alpha z - \cosh \alpha z + 1 \right]$$

$$V_1 = \frac{Q}{6 E I I_x} \left[z^3 - 3z^2 l \right] - \frac{zQ}{2 G A_1}$$

$$- \frac{b^2 Q}{\alpha^3 E J_2} \left[\frac{\sin \alpha l}{\cosh \alpha l} (\cosh \alpha z - 1) - \sinh \alpha z + \alpha z \right]$$

Longitudinal stresses

$$\sigma_z(z) = \frac{Q(1-z)}{I_x} \phi_1(s) + \frac{bQ}{\alpha J_2} \left[\frac{\sinh \alpha l}{\cosh \alpha l} \cosh \alpha z - \sinh \alpha z \right] \phi_2(s)$$

$$\tau_{zs} = \frac{G}{E} \cdot \frac{Qz}{I_x} (l-z) \phi_1'(s) + \frac{G}{E} \cdot \frac{bQ}{\alpha J_2} \left[\frac{\sinh \alpha l}{\cosh \alpha l} \cosh \alpha z - \sinh \alpha z \right] \phi_2'(s)$$

$$+ \frac{G}{E} \cdot Q \left(\frac{z^2}{2 I_x} - \frac{z}{I_x} \right) - \frac{Q}{2 A_1} - \frac{G}{E} \cdot \frac{b^2 Q}{\alpha^2 J_2}$$

$$\left[\frac{\sinh \alpha l}{\cosh \alpha l} \sinh \alpha z - \cosh \alpha z \right] \psi_1$$

Deflections

$$y = v(z, s) = \frac{Q}{6EI_x} \cdot [z^3 - 3z^2 l] - \frac{Qz}{2GA_1}$$

$$- \frac{b^2 Q}{\alpha^3 E J_2} \left[\frac{\sinh \alpha l}{\cosh \alpha l} (\cosh \alpha z - 1) - \sinh \alpha z + \alpha z \right]$$

b) For Uniformly Distributed Load

Displacement function

$$U_1(z) = \frac{q_1 z}{6EI_x} \left[z^2 - 3zl + 3l^2 \right]$$

$$U_2(z) = \frac{q_1 bl}{E J_2} \left[\frac{1 + \alpha l \sinh \alpha l}{\alpha l \cosh \alpha l} \sinh \alpha z - \cosh \alpha z + (1 - z/l) \right]$$

$$v_1(z) = - \frac{q_1 (z^2)}{24EI_x} (z^2 - 4lz + 6l^2) + \frac{q_1 (z)}{4GA_1} (z - 2l)$$

$$- \frac{q_1 b^2 l}{3E J_2} \left[\frac{\alpha l \sinh \alpha l + 1}{\alpha l \cosh \alpha l} (\cosh \alpha z - 1) - \sinh \alpha z \right.$$

$$\left. + \alpha l \left\{ \frac{z}{l} - \frac{1}{2} \frac{z^2}{l^2} \right\} \right]$$

Longitudinal stress

$$\sigma_z = \frac{q_1}{2I_x} (1-z)^2 \phi_1(s) + \frac{bq_1}{\alpha^2 J_2} \left[\frac{1 + \alpha l \sinh \alpha l}{\cosh \alpha l} \cosh \alpha z \right.$$

$$\left. - \alpha l \sinh \alpha z - 1 \right] \phi_2(s)$$

Deflection

$$y = v(z, s) = v_1(z)$$

A.1.3 Parameter study

From the expressions for stresses and displacements of a cantilevered tube under different loading conditions, it is observed that the problem of shear-lag has been reduced to a one-dimensional problem involving a single quantity, α (or αL).

It provides a measure of the shear-lag effect at every cross-section of the structure.

Let the expression for deflection of a tube be given by,

$$y = y_{ETB} + y_c$$

where y_{ETB} = portion of deflection calculated by Engineer's theory of bending

$$= - \frac{QL^3}{6EI_x} (3\xi^2 - \xi^3) - \frac{QL}{2GA_1} \xi, \text{ for a point load, } - Q$$

$$= - \frac{q_1 L^4}{24EI_x} (\xi^4 - 4\xi^3 + 6\xi^2) - \frac{q_1 L^2}{4GA_1} (2\xi - \xi^2), \text{ for a U.D.L., } - q_1$$

where $\xi = z/L$

y_c = correction due to shear-lag effect

y_c can be expressed as

$$y_c = k_y y_m$$

$$\text{where } y_m = - \frac{QL^3}{3EI_x}, \text{ for a point load, } - Q$$

$$= \frac{q_1 L^4}{8EI_x}, \text{ for a UDL, } - q_1$$

The expressions for K_y are

$$K_y = \frac{I_x}{J_2} \cdot \frac{3b^2}{(\alpha L)^2} \left[\frac{\sinh \alpha L}{\cosh \alpha L} (\cosh \alpha L \xi - 1) - \sinh \alpha L \xi + \alpha L \xi \right]$$

for concentrated load,

$$= \frac{I_x}{J_2} \cdot \frac{8b^2}{(\alpha L)^4} \left[\frac{1 + \alpha L \sinh \alpha L}{\cosh \alpha L} (\cosh \alpha L \xi - 1) - \alpha L \sinh \alpha L \xi - (\alpha L)^2 \left\{ \frac{\xi^2}{2} - \xi \right\} \right], \text{ for U.D.L}$$

The parametric equations for longitudinal stresses in a tube can be written as,

$$\sigma_z = K_\sigma \cdot \sigma_b$$

$$\text{where, } \sigma_b = \frac{QL(1-\xi)}{I_x} \phi_1(s), \text{ for a concentrated load, } Q$$

$$= \frac{q_1 L^2 (1-\xi)^2}{2 I_x} \phi_1(s), \text{ for a UDL, } q_1$$

$$\text{and } K_\sigma = 1 + \frac{I_x}{J_2} \cdot \frac{b \left[\frac{\sinh \alpha L}{\cosh \alpha L} \cosh \alpha L \xi - \sinh \alpha L \xi \right] \phi_2}{(\alpha L)(1-\xi) \phi_1}$$

for a concentrated load, Q

$$= 1 + \frac{I_x}{J_2} \cdot \frac{2b \left[\frac{1 + \alpha L \sinh \alpha L}{\cosh \alpha L} \cosh \alpha L \xi - \alpha L \sinh \alpha L \xi - 1 \right] \phi_2}{(\alpha L)^2 (1-\xi)^2 \phi_1}$$

for UDL, q

APPENDIX A-1
LISTING OF THE PROGRAMME
(A.H. Khan Method)

```

/LOAD FFFORTRAN
/OPTION LIST,LOG
C      ANALYSIS OF TUBULAR STRUCTURE BY ALI HOSSAIN KHAN METHOD
C      ****+-----+-----+-----+-----+-----+-----+-----+
C      DIMENSION PHI1(50),PHI2(50),SIGMAZ(12,36),SIGMAT(12,20)
C      READ(1,10) D2,D1,T1,Q1
C      READ(1,10)XL,E1,G1,ECSI
10   FORMAT( 4F10.2)
      WRITE (3,12) D2,D1,T1,Q1,XL,E1,G1
12   FORMAT(//T10,'WIDTH OF THE FLANGE',F9.3/T10,'WIDTH OF WEB=',F9.3/
     .T9,'THICKNESS OF WALL=',F9.3/T9,'U.D.L.=',F9.3/T9,'HEIGHT OF THE BU-
     .ILDING=',F10.3,/T9,'MODULUS OF ELASTICITY=',F10.3,/T9,'SHEAR MODUL-
     .LUS=',F10.3//)
      WRITE(3,15)
15   FORMAT(//T10,'DEFLECTION TABLE',/T10,20('*'),/T10,'Z/H',12X,
     .'DEFLECTION')
      DO 45 K = 1,11
      ECSI = ECSI + 0.10
      A1=T1*D1
      A2=T1*D2
      XI=D1**2*(A1/6+A2/2)
      B=D1/30*(A1*D1**2+5*A2*D2**2)/XI
      XEMDA=A2*D2**2/3+(B**2+D1**2/5)*A1
      XJ=(A1*D1**4+7*A2*D2**4)/105-(B**2)*XI
      ALPHA=(2*G1*(XEMDA-(B**2)*A1)/(E1*XJ))**0.5
      AL=ALPHA*XL
C      WRITE(3,71) A1,A2,XI,B,XEMDA,XJ,ALPHA,AL
C71   FORMAT(T10,'A1=',F15.4,'A2=',F15.4,'IX=',F15.4,'B=',F15.4,//T10,
     .'LEMDA=',F15.4,'J2=',F15.4,'ALPHA=',F15.4,'AL=',F15.4,//)
      YK=(XI/XJ)*(8*B**2)/(AL**4)*((1+AL*SINH(AL))/COSH(AL))*(COSH(AL*ECSI)-1)-AL*SINH(AL*ECSI)-AL**2*(ECSI**2/2-ECSI))
      YM=Q1*XL**4/(8*E1*XI)
      YC=YK*YM
      YETB=Q1*XL**4/(24*E1*XI)*(ECSI**4-4*ECSI**3+6*ECSI**2)+Q1*XL**2/(4
     .*G1*A1)*(2*ECSI-ECSI**2)
      Y= YETB+YC
      WRITE (3,36) ECSI,Y
36   FORMAT(10X,F4.2,12X,F12.4,5X,G10.3,5X,G10.3,5X,G10.3,5X,G10.3)
C      WRITE(3,26) Y
C26   FORMAT(//T9,'DEFLECTION=',F15.7,//T10,'COLUMN POSITION',10X,'SIGMA
     .Z'//)
C      I=0
      DO 30 IX= 4,36,8
C      I = I+1
      PHI2(IX) = ABS(D2**2/4-IX**2-B*D1/2)
      IF(IX.LT.36) GO TO 21
      DO 30 IY = 4,20,8
      IY=20
      PHI1(IY) = IY
      GO TO 19
      PHI1(IY) = D1/2
      XSIGMA = 1+ XI/XJ*2*B*((1+AL*SINH(AL))/COSH(AL)*COSH(AL*ECSI)-AL
     .*SINH(AL*ECSI)-1)*PHI2(IX) /(AL**2*(1-ECSI)**2*PHI1(IY))
      SIGMAB = Q1*XL**2*(1-ECSI)**2*PHI1(IY)/(2*XI)
      SIGMAZ(K,IX) = SIGMAB*XSIGMA
C      WRITE(3,35) I,SIGMAB,XSIGMA
C35   FORMAT(14X,I5,5X,E15.5,5X,E15.5)
30   CONTINUE
      DO 40 IY = 4,20,8
      I = I+1
      IX = 36

```

```

PHI2(IX) = ABS (D2**2/4-IX**2-B*D1/2)
PHI1(IY) = IY
XSIGMA = 1+XI/XJ*2*B*(( 1+AL*SINH(AL))/COSH(AL)*COSH(AL*ECSI)-AL
    *SINH(AL*ECSI)-1)*PHI2(IX) /(AL**2*(1-ECSI)**2*PHI1(IY))
SIGMAR = Q1*XL**2*(1-ECSI)**2*PHI1(IY)/(2*XI)
SIGMAT(K,IY) = SIGMAR*XSIGMA
WRITE (3,35) I,SIGMAR,XSIGMA
CONTINUE
CONTINUE

ECS2=-0.10
DO 55 K = 1,11
ECS2 = ECS2 + 0.10
WRITE (3,62) ECS2
62 FORMAT(//T10,'ECS2 = 'F5.2,//T10,'COLUMN POSITION',10X,'SIGMAZ')
I = 0
DO 54 IX = 4,36,8
I = I+ 1
WRITE (3,56) I, SIGMAZ(K,IX)
56 FORMAT(14X,I5,E15.5)
54 CONTINUE
DO 52 IY = 4,20,8
I = I+1
WRITE(3,56) I, SIGMAT(K,IY)
52 CONTINUE
55 CONTINUE
STOP
END
DATA
72.0      40.0      1.2      1.00
216.0     312940.3   252658.3   -0.10
END PRINT

```

A.2 F.R. Khan Method Details

A.2.1 Governing Equations

The significant structural properties of the tube of F.R. Khan method⁽¹⁴⁾ are:

1. Bending stiffness:

$$K_c \text{ for column} = \frac{I_c}{H}$$

$$K_b \text{ for spandrel beam} = \frac{I_b}{L}$$

2. Shear stiffness of the spandrel beams (defined as the force required to displace one end of the spandrel a unit distance at right angles to the axis of the beam):

$$S_b = \frac{12 EI_b}{L^3}$$

3. Axial stiffness of the column (defined as the axial force required to shorten the column a unit distance along the axis of the column):

$$S_c = \frac{A E}{c}$$

where

I_c = moment of inertia of the column

I_b = moment of inertia of the spandrel beam

A_c = cross-sectional area of the column

H = height of column

L = effective span of the spandrel beam

E = modulus of elasticity

The controlling parameters of framed tubes are:

$$\text{Stiffness ratio} = \frac{K_e}{K_b}$$

$$\text{Stiffness factor, } S_f = \frac{S_b}{S_c}$$

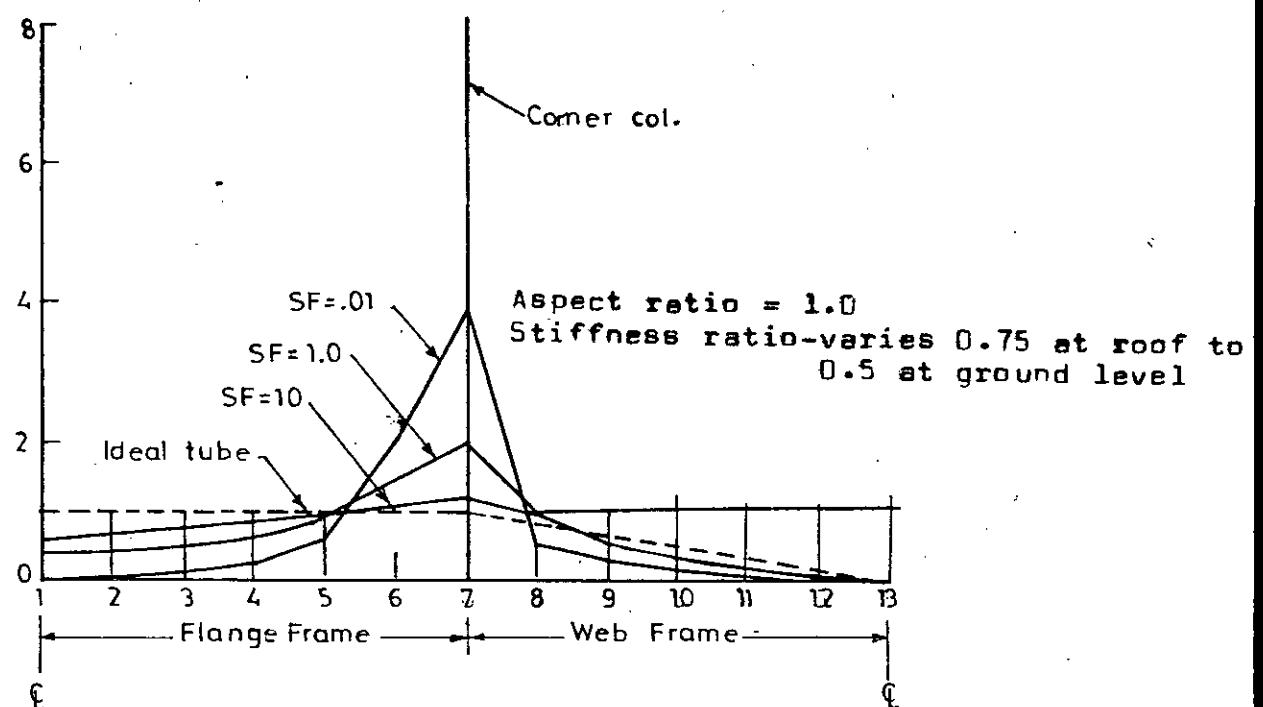
$$\text{Aspect ratio, } R = \frac{\text{width of flange frame}}{\text{width of web frame}}$$

Actual stiffness factor of the structure is transformed to a 10-storey equivalent stiffness factor S'_{f10}

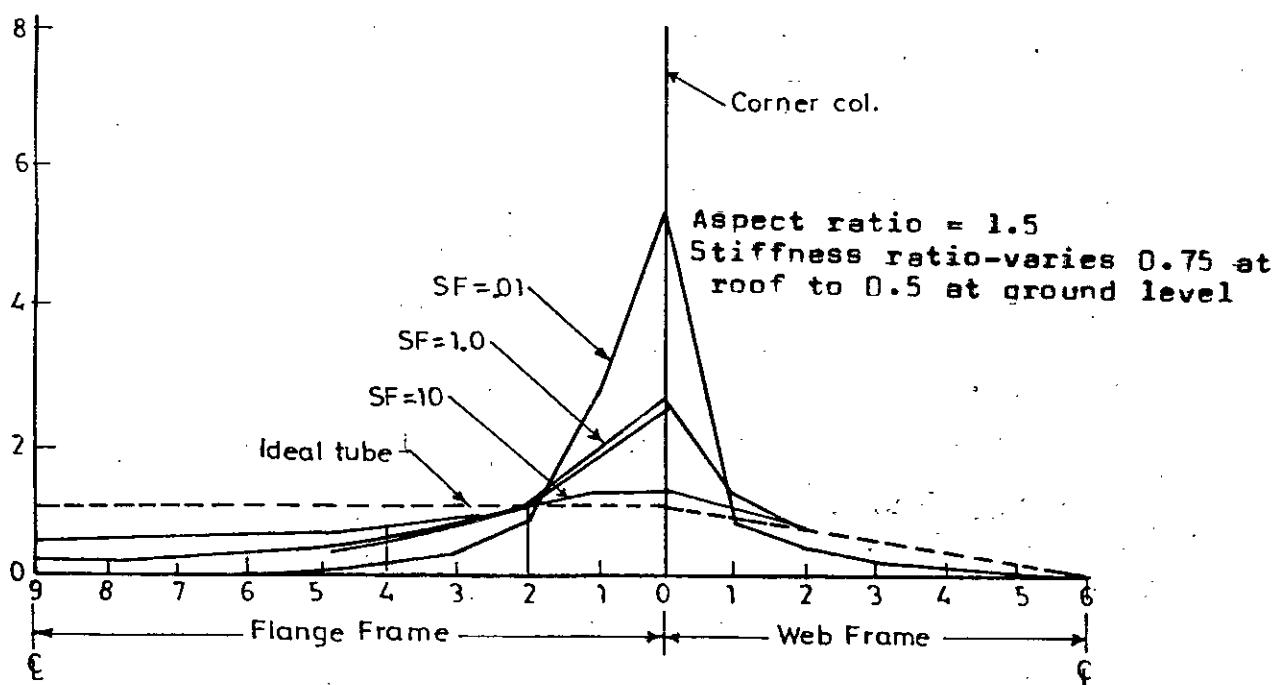
where

$$S'_{f10} = S_f \times (N/10)^2$$

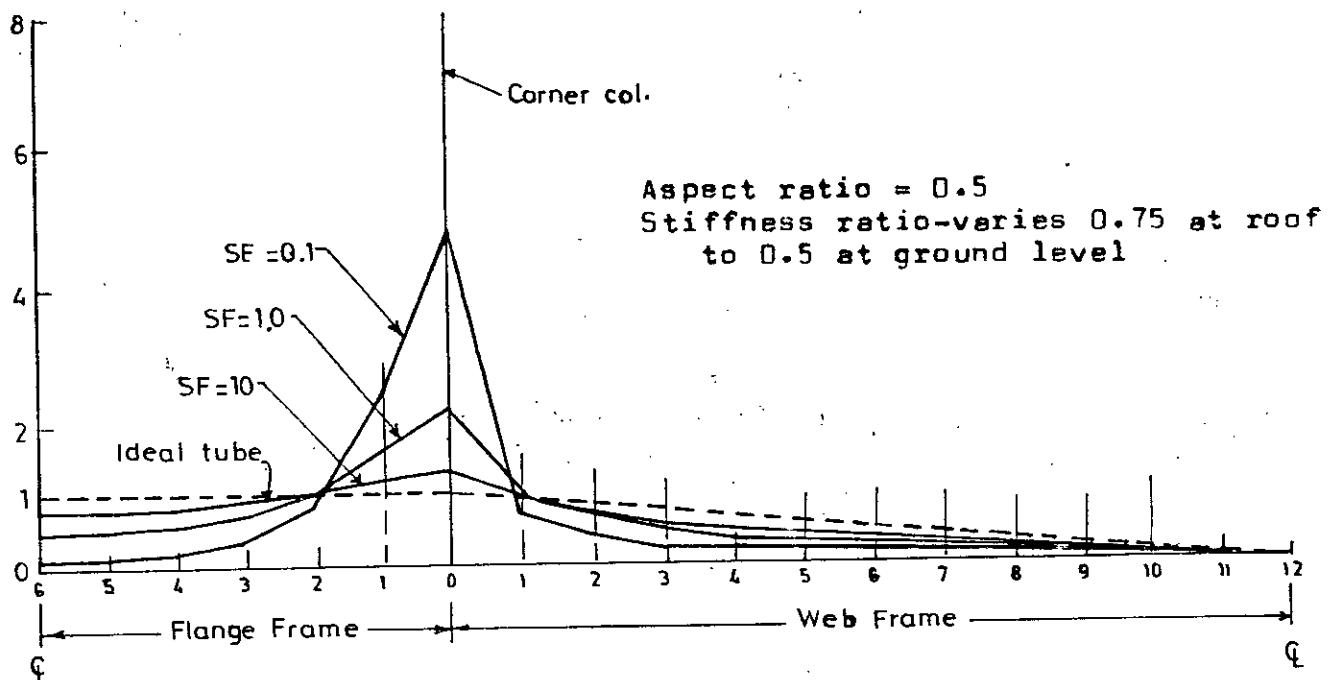
A.2.2 The non-dimensional preliminary design curves presented by F.R. Khan⁽¹⁴⁾ are as follows:



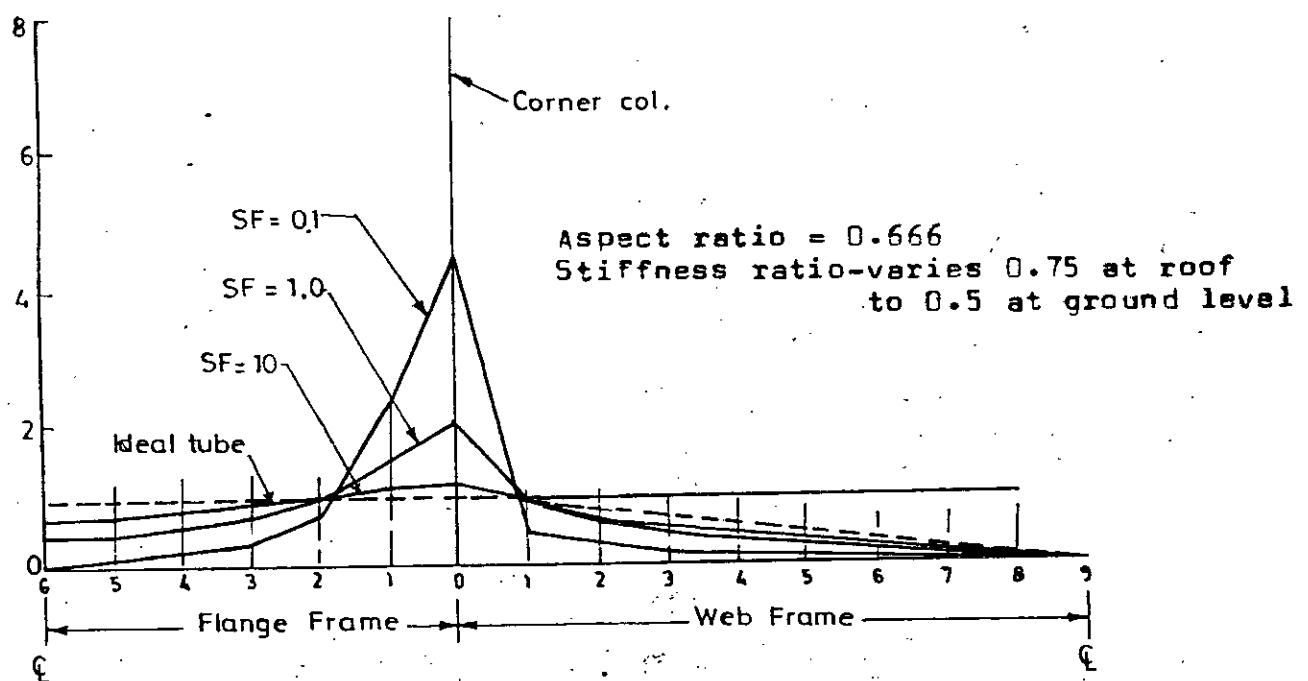
2.7 Column axial force coefficients-level 1



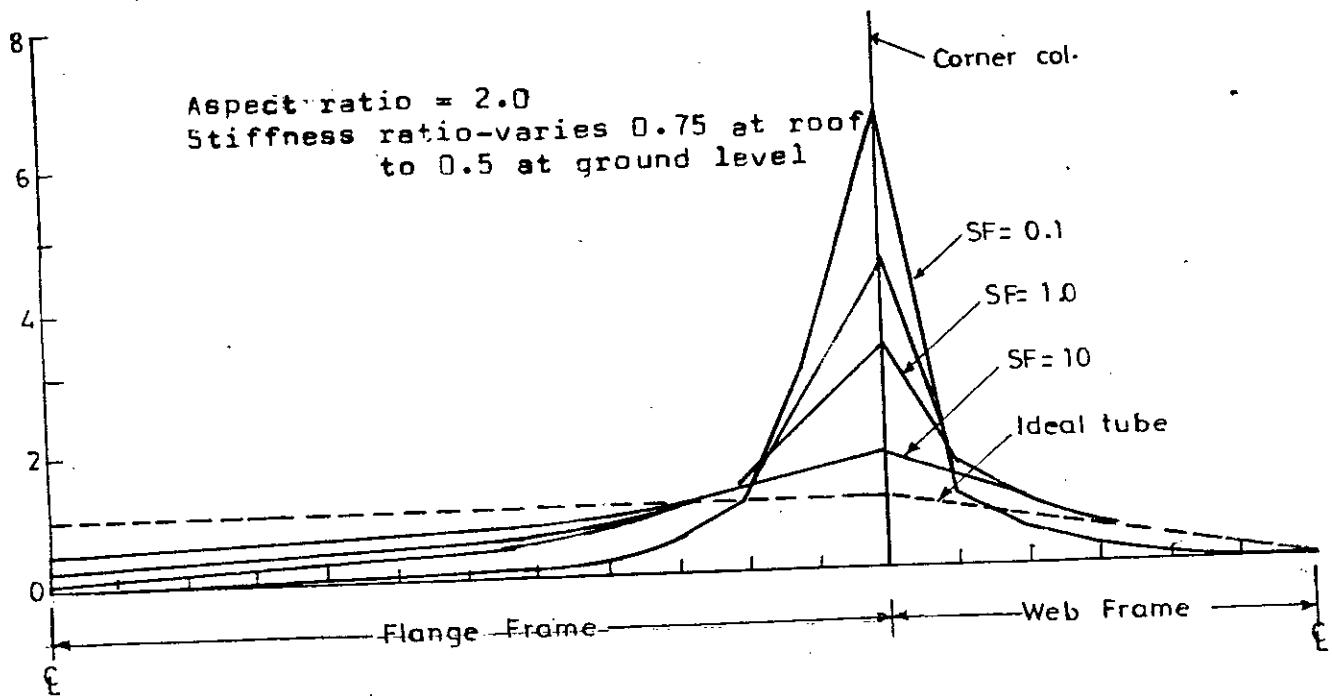
2.8 Column axial force coefficients-level 1



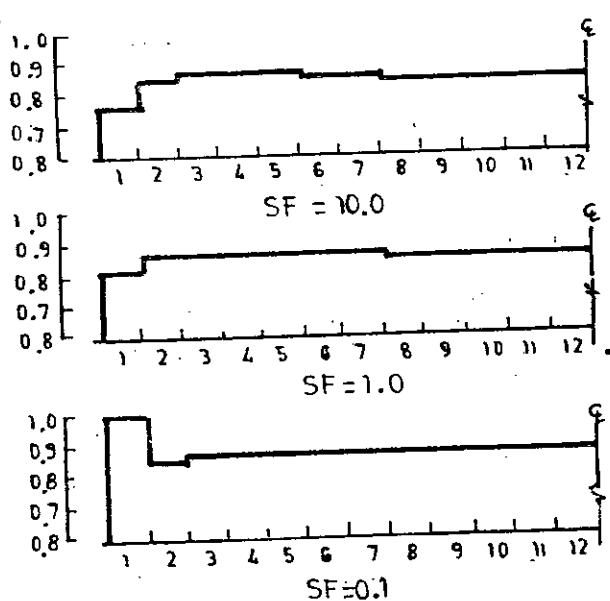
Column axial force coefficients-level 1.



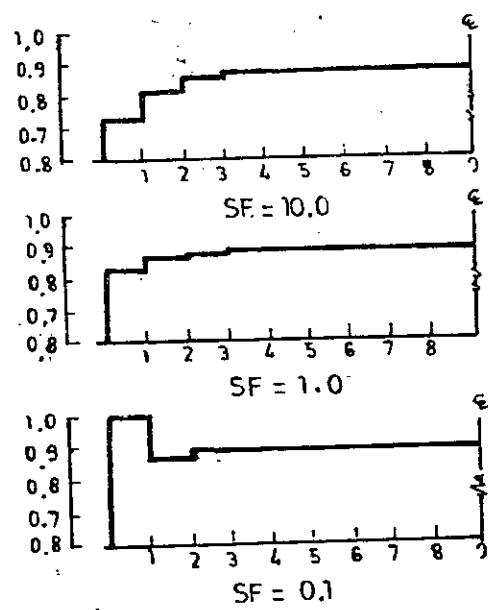
Column axial force coefficients-level 1.



Column axial force coefficients-level 1.



Shear force coefficients in web-frame beams, aspect ratio = 0.5



Shear force coefficients in web-frame beams, aspect ratio=0.666

A.3 Coull and Bose Method Details

A.3.1 Notations

A_c	area of corner column
b	half breadth of framed tube
c	half depth of framed tube
d	bay width
E	elastic modulus
G	shear modulus
H	total height of building
h	story height
I	second moment of area of framed tube
I_d	second moment of area of beam
I_h	second moment of area of column
k	structural parameter
M	applied moment at any level
m	geometrical ratio
P	concentrated load at top
p	intensity of lateral loading per unit height
S	stress functions
t	thickness of equivalent plate
x	horizontal coordinate
y	horizontal coordinate
z, z'	vertical coordinate
γ	shear strain
δ	lateral deflection at top of structure

- $\xi = z/H$ nondimensional height coordinate
 λ geometrical ratio
 τ shear stress
 σ_t direct stress and
 σ_b direct stress according to ~~Engineer's~~ beam theory

A.3.2 Governing Equations

For concentrated load P at $z = 0$ the stress functions is given by

$$S(\xi) = \frac{\lambda^2}{k} \sigma_b(H) \frac{\sinh k\xi}{\cosh k}$$

where $\xi = z/H$; and $\sigma_b(H) = (\frac{Pc}{I})z$

For uniformly distributed load p throughout height

$$S(\xi) = 2 \frac{\lambda^2}{K^2} \sigma_b(H) \left[\frac{\cosh k(1 - \xi) + K \sinh k\xi}{\cosh k} \right]$$

where $\sigma_b(H) = pc H^2/2I$

The vertical stress, σ_z and $\sigma_{z'}$ may thus be expressed in terms of S as

$$\sigma_z = \frac{Mc}{I} - \left[\frac{1}{3}m - \left(\frac{x}{b} \right)^2 \right] S$$

$$\sigma_{z'} = \frac{Mx}{I} + \left(1 - \frac{1}{3}m \right) \left(\frac{x}{c} \right)^3 S$$

The stress in the corner column then becomes

$$\sigma_c = (\sigma_z)_{y=b} = \frac{M}{I}C + (1 - \frac{1}{3}m)s$$

the remaining stress components are

$$\begin{aligned}\sigma_y &= \frac{b^2c}{2I} \left[\left(\frac{y}{b} \right)^2 - 1 \right] \frac{d^2M}{dz^2} - \frac{b^2}{12} \left[2m \left(\frac{y}{b} \right)^2 - \left(\frac{y}{b} \right)^4 \right. \\ &\quad \left. - (2m - 1) \right] \frac{d^2s}{dz^2}\end{aligned}$$

$$\tau_{yz} = y \left\{ \frac{c}{I} \frac{dM}{dz} - \frac{1}{3} \left[m - \left(\frac{y}{b} \right)^2 \right] \frac{ds}{dz} \right\}$$

$$\begin{aligned}\sigma_x &= - \frac{c^3}{2I} \left[2 \left(\frac{1}{3} + \frac{b}{c} + \frac{A}{ct} \right) + \left(1 + \frac{2b}{c} + \frac{2Ac}{ct} \right) \frac{x}{c} \right. \\ &\quad \left. - \frac{1}{3} \left(\frac{x}{c} \right)^3 \right] \frac{d^2M}{dz^2} - (1 - \frac{1}{3}m) \frac{c^2}{20} \left[\left(\frac{x}{c} \right)^2 - \left(\frac{x}{c} \right)^5 \right] \frac{d^2s}{dz^2}\end{aligned}$$

$$\begin{aligned}\tau_{xz} &= \frac{c^3}{2I} \left[1 + 2 \frac{b}{c} + \frac{2Ac}{ct} - \left(\frac{x}{c} \right)^2 \right] \frac{dM}{dz} \\ &\quad + (1 - \frac{1}{3}m) \frac{c}{4} \left[\frac{1}{5} - \left(\frac{x}{c} \right)^4 \right] \frac{ds}{dz}\end{aligned}$$

APPENDIX A-3
LISTING OF THE COMPUTER PROGRAMME
(Coulle and Bose Method)

APPENDIX A-4

LISTING OF THE PROGRAMME

(3-D Equivalent Frame Method)

LIST

SI SYS004 IS 04D - 3540 - BLKSIZE IS 0080 - RECSIZE IS 80

JOE JNM=CT98JRF,DISP=D,CLASS=A

LSI DISP=D

```
*****  

UCE CT98JFF CT98  

SSGN SYS005,X*161*  

OLEL UOUT,* IJSYS05*  

EXTENT SYS005,,,2705,100  

EXEC CLRDK  

UCL E=(K=0,D=2361,X*00*,GY,E=(3340)  

END  

OLEL IJSYS05,* IJSYS05*  

XTENT SYS005,,,2705,100  

OLEL IJSYS06,*REFERENCE-9*,1,SD  

XTENT SYS006,,,2805,100  

OLEL IJSYS07,*REFERENCE-10*,1,SD  

XTENT SYS007,,,2905,100  

SSGN SYS006,X*161*  

SSGN SYS007,X*161*  

CFTICK LINK,LIST,LOG  

LFSI 11  

EXEC FFORTAN  

OLEL COUT,* IJSYS07*  

EXTENT SYS007,,,2429,05  

EXEC CLRDK  

UCL E=(K=0,D=108),X*00*,GY,E=(3340)  

END  

OLEL IJSYS07,* IJSYS07*  

EXTENT SYS007,,,2429,05  

CFTICK LINK,NOLIST,LCG  

EXEC FFORTAN
```

CC PROGRAMME FOR THE ANALYSIS OF SHEAR WALL/FRAME STRUCTURES TAKING INTO ACCOUNT THEIR THREE-DIMENSIONAL BEHAVIOUR AND THE STIFFENING EFFECT OF FLOOR SLABS.

CC SCOPE THE PROGRAMME ANALYSIS THE BEHAVIOUR OF BUILDINGS CONSISTING OF SHEAR WALLS AND/ OR FRAMES INTERCONNECTED THROUGH FLOOR SLABS AND/CR BEAMS , SUJECTED TO HORIZONTAL LOADS APPLIED AT FLOOR LEVEL'S OR VERTICAL LOADS APPLIED AT FLOOR WALL INTERSECTIONS.

CC THEORY ANALYSIS OF WALLS IS BASED ON THE EQUIVALENT WIDE-COLUMN FRAME METHOD AND THE BENDING STIFFNESS IS CALCULATE FROM A FINITE ELEMENT ANALYSIS.

CC SIGNIFICANCE OF THE SYMBOLS USED IN THIS PROGRAMME AND THE SEQUENTIAL ARRANGEMENTS OF INPUTS IN THE DATA SET LEVEL ARE EXPLICITLY DEFINED IN CHAPTER 4 (DESCRIPTION OF PROGRAMME)

C THE STORAGE LOCATION REQUIRED FOR EACH BLOCK OR MATRICES DEPENDS ON THE CHARACTERISTICS OF THE BUILDINGS.

* THE VARIABLE STORAGE LOCATION FOR BLOCKS AND MATRICES ARE AS FOLLOWS.

* THE SYMBOLS USED ARE OF USUAL MEANING AS IN THE MAIN PROGRAMME.

* TO USE THE PROGRAMME THE ONLY CHANGE WILL HAVE TO MAKE IN THE DIMENSION

OF THE MATRICES AND THE VARIATIONS SHOULD BE MADE ACCORDINGLY.

ELOCK MATRICES WITH REQUIRED CAPACITY

/ KF{3*M,3*N}

1/ ELCOR(NN,2),BP(NBE,3),CON(NEL,4),CONB(NBE,3),RSM(NRN,2),PREDIS(3*N,2)

*CON(NN+M,2)

2/ TH(NEL*,WALLNO(M),NODARR(3*M)

*TH(3*M+3),WALLNO(M),NCDARR(3*M+3)

3/ KGE(3*NN,HW+1)

* HW=((MAXDIF+1)*2*NDF+1)/2

4/ C(3*M+3,3*M+3),D(3*M+3,3*M+3),DO(3*M+3,3*M+3),B(3*M+3,3*M)

*C(NS*NDF,NS*NDF).

*NS=NC. OF SIDES OF NODES OF EACH ELEMENT.

5/ K1{M,6,6},K2T{M,6,6},K3{M,6,6},A{M,3*M+3,6}

6/ LLOAD((3*M+3)*N,NLOAD),X((3*M+3)*N,NLOAD)

7/ I (YN). LENGTH OF THE XN DIVISIONS, IN ORDER X(I),LENGTH OF I THE YN DIVISIONS, IN ORDER Y(I) I

I (X(I),I=1,XN) I 10F8.2

I (Y(I),I=1,YN) I 10F8.2

I CON(I,1),CON(I,2),TH(I) I 2I4,F10.4 (NEL

I CO-ORDINATES OF PLATE NODES I,J,AND THICKNES SETS OF VALUE

I S (T) ARE RESPECTIVELY (CON(I,1),CON(I,2) & T(I)

I ELCOR(I,J),J=1,2),I=1,NN) I 10F8.2

I ELEMENT CO-ORDINATES (ELCOR(I,J)) I X CO-ORD. J Y CO-ORD.

```

C      CALL MULTI(A,B,D1,I+1,I+1,I+1,M,N,N,M1,M2,N1,N2, 7 +54)
C      CALL TRANS(A,D2,M,N,M1,M2,E4,E7 )
C      CALL MULTI(D1,D2,C,I+1,I+1,I+1,1,M,N,M,E7 ,54,E4,57 ,L1,L2)
C      DC 1 I=1,N
C      DC 1 J=1,N
C 2 FORMAT(/* D1=*,F10.4,*D2=*,F10.4,*C=*,F10.4/)
      RETURN
      DEBUG SUECHK
      END
      SUBROUTINE COPY32(A,B,M,N,P,M1,M2,M3,N1,N2)
      INTEGER P
      DIMENSION A(M1,M2,M3), B(N1,N2)
C
      DC 601 I=1,N
      DC 601 J=1,P
 601  B(I,J)=A(M,I,J)
      RETURN
      END
      SUBROUTINE CLEAR(A,M,N,M1,M2)
      DIMENSION A(M1,M2)
      COMMON A
      DC 701 I=1,M
      DC 701 J=1,N
 701  A(I,J)=0.
      RETURN
      END
      SUBROUTINE CLEAR3(A,M,N,P,M1,M2,M3)
      INTEGER P
      DIMENSION A(M1,M2,M3)
      DC 801 I=1,M
      DC 801 J=1,N
      DC 801 K=1,P
 801  A(I,J,K)=0.
      RETURN
      END
      SUBROUTINE PRINTM(A,M,N,P,Q,M1,M2)
      INTEGER P,G,C1,C2,C5
      DIMENSION A(M1,M2),ROWNO(54),JX(18),SF(18),G1(18),G2(18),WX(18),
+     WY(18),AX(18)
      COMMON /B9/ROWNO,AX,JX,SF,G1,G2,WX,WY
      C6=M/12.
      C7=M/12
      C5=C7
      IF((C6-C7) .GT. .0001) C5=C5+1
      C1=1
      C5=(N-1)/LW
      IC51=C5+1
      DC 14 L1=1,12
 14   ROWNO(L1)=L1
      C1=1+L*LW
      IF (C5 .EQ.0) GO TO 15
      C2=C1+LW-1
      IF (L .EQ. C5) C2=N
      GO TO 16
 15   C2=N
 16   WRITE (3,17)
 17   FFORMAT( /*, ROW NO.,IX,12FS.0,           /7X,120(*-*)/* COL. *,*I*,,
+/* NO. *,*I*,//)
      LW110=110/LW
 18   WRITE(3,19) K,LW110
      DC 20 L=1,CS
      C2=12*L
      IF(L .EQ. C5) C2=M
      WRITE(3,15)      (ROWNO(J) ,J=C1,C2)
      DC 21 K=1,N
 21   WRITE(3,22) K,(A(J,K),J=C1,C2)
      C1=C2+1
 20   CONTINUE
 22   FFORMAT(IX,I3,3X,*I*,12E10.3)
      RETURN
      DEBUG SUECHK
      END
      SUBROUTINE OUTARR(A, M,N,P,Q,TITLE1,TITLE2,TITLE3,M1,M2)
      INTEGER P,Q
      DIMENSION A(M1,M2)
      COMMON A
      WRITE (3,1001) TITLE1,TITLE2,TITLE3
      SUB. NC. =11 { OUTPUT ARRAY}
 1001 FFORMAT(/2X,3A4/)
      CALL PRINTM(A,M,N,P,Q,M1,M2)

```

```

C
      RETURN
      END
      REAL FUNCTION INP(U,      S,F,L,P,M1,M2,N1)
      INTEGER S,F,P
      DIMENSION U(M1,M2),V(L,N1)
      H=0.
      IF(P .EQ. 0) GO TO 11
      IF (F .LT. S) GO TO 13
      DC 10 K=S,F
10   H=H+U(L,K)*U(K,P)
      GO TO 13
11   IF (F .LT. S) GO TO 13
      DC 12 K=S,F
12   H=H+U(L,K)*V(K)
      GO TO 13
      GO TO 13
C 16   H=U(L,S)*V(S)
13   INP=H
      RETURN
      END
      SUBROUTINE SOLVEH(      HB,N,NL)
      INTEGER HE
      DIMENSION A(54 , 9 ),B(57 ,54 ),B1K3(54,57)
      COMMON /B3/A/E7/B1K3,E
      NHB=N-HB+1
      NHB2=N-HB+2
      N1=N-1
      IF (HE-1) 101,102,101
102  DC 103 K=1,N
      DC 103 L=1,NL
103  B(K,L)=B(K,L)/A(K,1)
      GO TO 124
101  DC 105 K=1,NHB
      K1=K+1
      K2=K+HB-1
      DC 105 I=K1,K2
      DC 106 L=1,NL
106  B(I,L)=B(I,L)-B(K,L)*A(K,I-K+1)/A(K,1)
      K2I=K+HB-I
      DC 107 J=1,K2I
107  A(I,J)=A(I,J)-A(K,I-K+J)*A(K,I-K+1)/A(K,1)
105  CONTINUE
      IF (HE-2) 108,109,108
108  DC 110 K=NHB2,N1
      K1=K+1
      DC 110 I=K1,N
      IK1=I-K+1
      N2=N-I+1
      DC 111 L=1,NL
111  E(I,L)=B(I,L)-B(K,L)*A(K,IK1)/A(K,1)
      DC 112 J=1,N2
112  A(I,J)=A(I,J)-A(K,I-K+J)*A(K,I-K+1)/A(K,1)
110  CONTINUE
C      END OF TRIANGULATION
109  DC 104 L=1,NL
      E(N,L)=B(N,L)/AIN,1
      IF (HB-2) 114,115,114
114  I=N-1
117  SOM=0.
      N1=N-I+1
      DC 116 J=2,N1
116  SOM=SOM+A(I,J)*B(I+J-1,L)
      B(I,L)=(E(I,L)-SOM)/A(I,1)
      I=I-1
      IF (I-N+HE-1) 117,118,117
118  CONTINUE
115  I=NHB
120  SOM=0
      DC 119 J=2,HB
119  SOM=SOM+A(I,J)*B(I+J-1,L)
      E(I,L)=(B(I,L)-SOM)/A(I,1)
      I=I-1
      IF (I) 120,104,120
104  CONTINUE
124  RETURN
      END
      SUBROUTINE CRCUT2(A,      N,M1,M2,DET,REPEAT,*)
      INTEGER PIVOT, WALLNO
      REAL INP
      LOGICAL REPEAT

```

```

      DIMENS 57, 57, 57, 57, 57, 57, 57
      COMMON /B2/X, WALLNO, PIVOT
      DET=1.
      DC 25 I=1,N
      E(I)=Y(I)
      IF (REPEAT) GO TO 16
      DC 15 K=1,N
      TEMP=0.
      DC 11 I=K,N
      A(I,K)=A(I,K)-INP(A      ,B      ,I,K-1,I,K,M1,M2,N)
      IF (ABS(A(I,K)) .LE. TEMP) GO TO 11
      TEMP=AES(A(I,K))
      IMAX=I
11   CONTINUE
      PIVOT(K)=IMAX
      IF (IMAX .EQ. K) GO TO 10
      DET=-DET
      DC 12 J=1,N
      TEMP=A(K,J)
      A(K,J)=A(IMAX,J)
      A(IMAX,J)=TEMP
12   CONTINUE
      TEMP=E(K)
      E(K)=E(IMAX)
      E(IMAX)=TEMP
10   CONTINUE
      IF (A(K,K) .EQ. 0.) GO TO 21
      GUCT=1./A(K,K)
      KP1=K+1
      DC 13 I=KP1,N
13   A(I,K)=GUCT*A(I,K)
      DC 14 J=KP1,N
      KN1=K-1
14   A(K,J)=A(K,J)-INP(A      ,B      ,I,KM1,K,J,M1,M2,N)
      E(K)=B(K)-INP(A      ,B      ,I,KM1,K,O,M1,M2,N)
15   CONTINUE
      GC TC 17
16   CONTINUE
      DC 18 K=1,N
      TEMP=B(PIVOT(K))
      E(PIVOT(K))=B(K)
      B(K)=TEMP
      B(K)=B(K)-INP(A      ,B      ,I,K-1,K,O,M1,M2,N)
18   CONTINUE

17   NP1=N+1
      DC 20 IK=1,N
      K=NP1-IK
      IF (.NOT. REPEAT) DET=A(K,K)*DET
20   Y(K)=(B(K)-INP(A      ,Y      ,K+1,N,K,O,M1,M2,N))/A(K,K)
      CONTINUE
      RETURN
21   RETURN 1
      DEBUG UNIT(3), INIT(DET,Y)
      END
      SUBROUTINE SOLVE (A,B,C,M,N,M1,M2,N1,N2)
      INTEGER PIVOT,WALLNO
      LOGICAL REPEAT
      DIMENSION A(M1,M2),B(N1,N2),C(N1,N2), PIVOT(57),WALLNO(18),X(57)
      SUB NO. = 15 (SOLVE(A,E,C,M,N))
      COMMON /B2/X,WALLNO,PIVOT
      REPEAT=.FALSE.
      DC 52 J=1,N
      DC 51 K=1,M
51   X(K)=B(K,J)
51   Z(K)=X(K)
      CALL CROUT2(A,      M,M1,M2,DET,REPEAT,854)
      ARRAY "X" IS STORED IN ARRAY NAMED "Z" (Z IS DIRECTLY TRANSFERRED TO "B" IN
      "CROUT" SUBROUTINE & "X" THROUGH COMMON BLOCK B2 IN THE SAME)
      REPEAT=.TRUE.
      DC 52 K=1,M
      C(K,J)=X(K)
      IF (J .NE. 1) C(K,J)=Z(K)
52   CONTINUE
      GC TC 50
54   #RITE(3,53#M
53   FORMAT(//2X,"SINGULAR MATRIX OF ORDER--",I4/)
      STCP
50   J=1
      RETURN

```

```

*N,N+NRHS)
CALL SUB1(BIGD,D2,X,M*(I-1)+1,M+1,1,1,M*(I-1)+1,1,N, NRHS,
+150,30,18,20,198,2)
CALL SUB1(D1,D2,X,1,N+1,1,1,M*(I-1)+1,1,M, NRHS, M, M+NRHS, N, M+NRHS,
+N*N, NRHS)
C CONTINUE
RETURN
DEBUG SUBCHK
END
SUBROUTINE FEFLR(NPD)
REAL KF,MU,KGB
INTEGER CCN,CONB,RSM,PREDIS,WALLNO,BW,HBW
DIMENSION KF(54,54),ELCOR(57,2),TH(57),BP(18,3),KGB(54,5),
+CCN(18,4),CONB(18,3),RSM(1,2),PREDIS(54,2),WALLNO(18),NODARR(57)
CCMOM //KF /B1/ELCOR,BP,CON,CONB,RSM,PREDIS/B2/TH,WALLNO,NODARR
CCMEN /B3/KGB /B1/UNIT(3)

READ (1,10) NEL,NN,NRN,NBE
10 FORMAT(4I5)
N3=NRN
IF(NRN .EQ.0) N3=1
N2=NNE
IF(NBE .EQ.0) N2=1
N4=NEL
IF (NEL .EQ. 0) N4=1
CALL READFL(NEL,NN,E,MU,NRN,NPD,NBE)

CALL PRINTF(NEL,NN,E,MU,NRN,NPD,NBE)

NN1=0
NN2=0
IF (NEL .NE.0) CALL BANDWH(NEL,4,3,MM1)
IF(NBE .NE.0) CALL BANDWH(NBE,2,3,MM2)
EM= MAX0(MM1,MM2)
HEW=(EW-1)/2
WRITE(3,100) MM1,MM2,HEW
100 FORMAT//T10,*MM1=*,18,*MM2=*,18,*HBW=*,18
CALL CLEAR(KGB,3*NN,HBW+1,3*NN,HBW+1)

IF (NEL .NE. 0) CALL ASSEMB(3,NEL,4,1,E,MU)
WRITE(3,25) ((KGB(I,L),L=1,15),I=1,27)
C25 FORMAT//T10,*VALUES OF KGB-MATRIX*,/T8,24(***)//([15E8.2])
DC 20 II=1,NBE
DC 20 JJ=1,3
20 CCN(II,JJ)=CONB(II,JJ)
IF (NBE .NE.0) CALL ASSEMB(3,NBE,2,2,E,MU)
NN3 = 3*NN
IF (NN3.NE.NPD) GO TO 35
DO 11 IK = 1,NN3
DC 11 JK = IK,NN3
IF (JK.LT.(IK+HBW+1)) GO TO 12
KF (IK,JK) = 0.0
GO TO 11
12 JK22 = JK-IK+1
KF (IK,JK) = KGB( IK,JK22)
11 CONTINUE
DC 14 IK = 1,NN3
DC 14 JK = 1,IK
14 KF (IK,JK) = KF (JK,IK)
GO TO 36
C
C
C 440 WRITE(3,440) ((KGB(I,L),L=1,15),I=1,27 )
C 440 FORMAT//T10,*VALUES OF KGB MATRIX*,/T8,24(***)//([15E8.2])
C WRITE(3,230) ((CON(I,J),J=1,3),I=1,NBE)
C
C GO TO 36
35 CALL CCNSM( NPD,NN, BW)
36 RETURN
END
SUBROUTINE READFL(NEL,NN,E,MU, NRN, NPD,NBE)
INTEGER CCN,RSM,PREDIS,CONB,WALLNO,XN,YN,ELNO
REAL MU
DIMENSION ELCOR(57,2),TH(57),BP(18,3),X(54),Y(18),CON(1E,4)
DIMENSION CONB(18,3), RSM(1,2),PREDIS(54,2), WALLNO(18),
+NODARR(57),JX(18),SF(18),G1(18),G2(18),WX(18),WY(18)
CCMEN //B1/ELCOR,BP,CON,CONB,RSM,PREDIS/B2/TH,WALLNO,NODARR
CCMEN /E1/UNIT(3)
CCMEN /BS/X,Y,JX,SF,G1,G2,WX,WY
21 FORMAT(1B)

```

```

      WRITE(3,513) IN1
513  FORMAT(13.5X)
      DC 512 IN2=1,M
      J=IN2+3
C     IF(IN2 .NE. 1) GO TO 516
514  FORMAT(10X,14.3X)
C   15  FORMAT(1H ,15F8.3)
      WRITE(3,514) IN2
      WRITE(3,518) X(3+I+IN2,IN3),X(3+M+I+IN2,IN3),X(3+2*M+I+IN2,IN3)
518  FORMAT(24X, E13.6,6X,E13.6,5X,E13.6)
512  CCNTINUE
507  CCNTINUE
      CALL CALSTR(NZONE,NSTR, M,N,NLOAD)
      GC TC 500
560  STOP
C     DEEUG SUBCHK
END
SUBROUTINE ADD1(A,B,C,AR1,AC1,BR1,BC1,CR1,CC1,M,N,M1,M2,N1,N2)
INTEGER AR1,AC1,BR1,BC1,CR1,CC1
DIMENSION A(M1,M2),B(N1,N2),C(N1,N2)
DC 101 II=1,M
I=II-1
DC 101 JI=1,N
J=JI-1
101 C(I+CR1,J+CC1)=A(I+AR1,J+AC1)+B(I+BR1,J+BC1)
      RETURN
END
SUBROUTINE SUE1 (A,B,C,AR1,AC1,BR1,BC1,CR1,CC1,M,N,MA1,MA2,MB1,
+NE2,MC1,MC2)
INTEGER AR1,AC1,BR1,BC1,CR1,CC1
DIMENSION A(MA1,MA2),B(MB1,MB2),C(MC1,MC2)
DC 201 II=1,M
I=II-1
DC 201 JI=1,N
J=JI-1
201 C(I+CR1,J+CC1)=A(I+AR1,J+AC1)-B(I+BR1,J+BC1)
      RETURN
END
SUBROUTINE COPY1(A,B,AR1,AC1,BR1,BC1,M,N,MA1,MA2,MB1,MB2)
INTEGER AR1,AC1,BR1,BC1
DIMENSION A(MA1,MA2),B(MB1,MB2)
CCMNCR A,B
SUB =3 (COPYING P FROM F )
DC 301 II=1,M
I=II-1
DC 301 JI=1,N
J=JI-1
301 A(I+AR1,J+AC1)=B(I+BR1,J+BC1)
      RETURN
C     DEEUG INIT
END
SUBROUTINE MULTI(A,B,C,AR1,AC1,BR1,BC1,CR1,CC1,M,N,P,MA1,MA2,MB1,
+NE2,MC1,MC2)
INTEGER AR1,AC1,BR1,BC1,CR1,CC1,P
DIMENSION A(MA1,MA2),B(MB1,MB2),C(MC1,MC2)
SUB =4 (MULTIPLICATION OF MATRIX A&B (C=A*B))
DC 401 II=1,M
I=II-1
DC 401 JI=1,P
J=JI-1
SUM=0.
DC 402 KI=1,N
K=K1-1
402 SUM=SUM+A(I+AR1,K+AC1)*B(K+BR1,J+BC1)
401 C(I+CR1,J+CC1)=SUM
      RETURN
END
SUBROUTINE TRANS(A,B,M,N,M1,M2,N1,N2)
DIMENSION A(M1,M2), B(N1,N2)
C     SUE =5 (TRANSPOSE OF MATRIX A INTO B)
DC 501 J=1,N
DC 501 I=1,M
501 B(J,I)=A(I,J)
      RETURN
END
SUBROUTINE TRANSM(A,B,C,M,N,M1,M2,N1,N2,L1,L2)
DIMENSION A(M1,M2),B(N1,N2), D2(54,57),D1( 57,54),C(L1,L2)
CCMNCR /E7/D2,D1
CCMNCR A,B,D1
SUB. NC. =6 (TRANSPOSE OF A MULTIPLICATION & THEN MULT. BY OTHER)

```

```

H=EP(M,3)
I=E*H**3/12.
G=E/2/(1+NU)
F=E/H
IF (B .GT .H) R=H/E
J=(1/3.-.21*R*(1-R**4/12))*(B*H)**2*R
DO 70 N=1,6
DO 70 G=1,6
70 KE(N,G)=0.
DO 71 I=1,4,3
71 KE(I,I)=12*E*I/L**3
KE(1,4)=-KE(1,1)
IF (CCNB(M,3) .NE. 1) GO TO 72
KB(1,3)=6*E*I/L**2
KE(1,6)=KE(1,3)
KE(2,2)= G*j/L
KE(5,5)=KE(2,2)
KE(2,5)=-G*j/L
KE(3,3)= 4*E*I/L
KE(6,6)=KE(3,3)
KE(3,4)=-E*I/L**2
KE(4,6)=KE(3,4)
KB(3,6)=2*E*I/L
GO TO 73
72 KE(1,2)=-6*E*I/L**2
KE(1,5)=KE(1,2)
KB(2,2)=4*E*I/L
KE(5,5)=KE(2,2)
KB(2,4)=6*E*I/L**2
KE(4,5)=KE(2,4)
KE(2,5)=2*E*I/L
KE(3,3)=G*j/L
KB(6,6)=KE(3,3)
KE(3,6)=-G*j/L
73 CONTINUE
WRITE(3,100) M
100 FORMAT(//'* STIFFNESS MATRIX OF BEAM ELEMENT (6X6) //,* I=*,I4)
WRITE(3,101) ((KBIMM,N), N=1,6),MM=1,6)
101 FORMAT( 6F12.3)
RETURN
END
SUBROUTINE PREBC(      NRN,NN,BW,NPD)
INTEGER RSM,BW,HBW,HBW1,CON,CONB
REAL KGB
DIMENSION KGB(54 , 9 ),ELCOR(57 ,2),BP(18,3),CON(18 ,4),CONB(18,3)
+ ,RSM( 1,2),PREDIS(54,2)
COMMON /B1/ELCOR,EP,CON,CONB,RSM,PREDIS /B3/KGB

```

```

HEW=(E-1)/2
HEW1=HEW+1
DO 80 I=1,NRN
K=(RSM(I,1)-1)*3+RSM(I,2)
DO 81 J=2,HBW1
81 KEE(K,J)=0.
KEB(K,1)=1.
80 CONTINUE
END OF PRESCRIBED BOUNDARY CONDITION
RETURN
DEBUG SUBCHK
END
SUBROUTINE CONSM(      NPD,NN,          BW)
INTEGER PREDIS,WALLNO,BW,ROW,COL,HBW,          FREEN,HBW1,CONB
REAL KF,KEE,KIK3,K1,K3K1
DIMENSION WALLNO(18), NODARR(57), NODEW(18 ,4),  FREEN(18 )
DIMENSION KIK3(54,57 ), K1(12,12),  K3K1(57 ,54)
+ ,KF(54,54),KGB(54 , 9 ), ELCOR(57 ,2),  PREDIS(54,2),B(57,54)
DIMENSION BP(18,3),CONB(18,3),RSM( 1,2),TH(57 ),C(57,57),DO(57,57)
COMMON //KF /B1/ELCOR,EP,NCDEW,CONB,RSM,PREDIS
COMMON /B2/TH,WALLNO,NODARR /B3/KGB /B4/C,K1,DO,B /B7/K1K3,K3K1

```

```

500 FORMAT(//T10,*NW1 = * ,I3)
M=NPD/3
HEW=(E-1)/2
NW1=0

```

```

DC 120 KB=1,3
120 KGB((I-1)*3+KA,1+KB-KA+3*KC)=KGB((J-1)*3+KA,1+KB-KA+3*(KC+KD))
KE=KE+1
GC TC 117
121 KD=KD+1
122 GC TC 117
115 CONTINUE
C      WRITE(3,205)
C      CALL TRANS(KIK3,K3K1,NPD,3*(NN-NW1-M),NPD ,3*NN,3*(NN-NW1-M),
C      +NPD )
C      DC 204 JRC=1,NPD
C      204 WRITE(3,205) (KIK3(JRC,JRM),JRM=1,10),(K3K1(JRC,JRN1,JRN=1,10)
C      205 FORMAT(//,* POSITION IS PRIOR TO STAT.NO.211 (I=)',I3)
C      *WRITE(3,211)
C      211 FORMAT(/// THIS POSITION IS PRIOR TO STAT.NO.123//)
C
C      CALL SOLVEH(      HBW+1,3*(NN-NW1-M),NPD )
C      CALL MULTI(KIK3,K3K1,K1,1,1,1,1,1,NPD,3*(NN-NW1-M),NPD,
C      +NPD ,3*NN,3*(NN-NW1-M),NPD ,NPD,NPD)
C
C      CALL SUB1(KF,K1,KF,1,1,1,1,1,1,NPD,NPD,NPD,NPD,NPD,NPD)
C      READ(1,123) J
123 FCFM4T(I4)
      IF (J .NE.0) GO TO TC 127
      CALL CLEAF(K1,NPD,NPD,NPD,NPD)
      DC 124 I=1,NPD
124 K1(I,I)=1
      DC 125 I=1,M
      I133=(I-1)*3+3
      I131=(I-1)*3+1
      I132=(I-1)*3+2
      READ(1,126)K1(I133,I131),K1(I132,I131)
126 FCFM4T(2F7.3)
      K1(I133,I131)=ELCOR(WALLNO(I),1)-K1(I133,I131)
125 K1(I132,I131)=K1(I132,I131)-ELCOR(WALLNO(I),2)
      CALL TRANS(K1,KF,KF,NPD,NPD,18,18,15,15,15,15)
C      DO 230 JR1=1,NPD
C      230 WRITE(3,231) (K1(JR1,JR2),JR2=1,NPD),(KF(JR1,JR2),JR2=1,NPD)
      CALL TRANSM(K1,KF,KF,NPD,NPD,NPD,NPD,NPD,NPD,NPD)
127 CONTINUE
C      231 FCFM4T(5),1GF10.2),5X,16F10.2)
C      WRITE(3,232)
C      232 FCFM4T(// THIS POSITION IS WITHIN SUB. CONSM,LAST //)
C      DC 234 JR1=1,NPD
C      234 WRITE(3,231) (K1(JR1,JT),JT=1,NPD),(KF(JR1,JT),JT=1,NPD)
C
C      WRITE(3,81)
81 FCFM4T(// STIFFNESS MATRIX (KF) ((LOAD/DEFL. OR ROT.)X1000) )
      DO 82 I=1,NPD
82 WRITE(3,83) (KF(I,J),J=1,NPD)
83 FCFM4T(7S,12F10.3)
      RETURN
      DEBUG SUBCHK
      END
      SUBROUTINE FORMWS(NZONE,NS, M,N)
      INTEGER DFOS
      FEAL K1,K2T,K3,IX,IY,JX,MU
      DIMENSION K1(18,6,6), K2T(18,6,6),K3(18,6,6),A(1E,57,6)
      DIMENSION B(57,54), C(57,57),D(57,57),DO(57,57),IX(57),IY(54)
      DIMENSION AX(18),JX(18),SF(18),G1(18),G2(18),WX(18),WY(18)
      DIMENSION NS(NZONE),WALLNO(18),NODARR(57)
      COMMON /B4/C,D,DO,B /B5/K1,K2T,K3,A /B9/IX,JX,SF,G1,G2,
      +WX,WY/B11/UNIT(3)/B2/IX,WALLNO,NODARR
C      DEFINE FILE 9(50,72,L)
      REWIND 9
      READ (1,155) NZONE,(NS(IA),IA=1,NZONE)
155 FCFM4T(13,514)
      *WRITE(3,158) N,NZONE
      DC 154 NN=1,NZONE
C
      NSCP1=1
      IF (NN .NE. 1) NSCP1=NS(NN-1)
      NSCP2=NS(NN)
      WRITE(3,157) NSCP1,NSCP2
C 157 FCFM4T(//9*'WALL DATA'),//5X,*THE FOLLOWING SECTIONAL PROPERTIES
C      +OF WALL ARE CONSTANT FROM STORY NO.',I4,*TO STORY NO.',I4,/5X,*ST
      CALL READWD(          H,           E,M,N,           MU)
      CALL CLEAR3(K1,M,6,6,M,6,6)
      CALL CLEAR3(K2T,M,6,6,M,6,6)
      CALL CLEAR3(K3,M,6,6,M,6,6)
      G=E/2./{1.+MU}

```

```

K(7,9)=K(4,6)
K(2,3)=-Z*(A*B*B)
K(8,9)=K(2,3)
K(5,6)=-K(2,3)
K(11,12)=K(5,6)
K(1,4)=Z*(2*R**2-4/R**2+(4*U-14.)/5.)
K(7,10)=K(1,4)
K(2,5)=Z*(2./3.*A**2-4./15.*B**2*(1.-U))
K(8,11)=K(2,5)
K(3,6)=Z*(2/3.*E**2-A**2/15.* (1.-U))
K(9,12)=K(3,6)
K(2,4)=-Z*(A**2/B-B/5*(1+4*U))
K(1,5)=K(2,4)
K(8,10)=-K(2,4)
K(7,11)=K(8,10)
K(3,4)=-Z*(2*B**2/A+A/5*(1-U))
K(7,12)=K(3,4)
K(1,6)=-K(3,4)
K(9,10)=K(1,6)
K(1,7)=Z*(-2/R**2-2*R**2+(14-4*U)/5.)
K(4,10)=K(1,7)
K(2,8)=Z*(A**2/3+E**2/15*(1-U))
K(5,11)=K(2,8)
K(3,9)=Z*(B**2/3+A**2/15*(1-U))
K(6,12)=K(3,9)
K(2,7)=Z*(A**2/B-B/5*(1-U))
K(5,10)=K(2,7)
K(1,8)=-K(2,7)
K(4,11)=K(1,8)
K(1,9)=Z*(B**2/A-A/5*(1-U))
K(6,10)=K(1,9)
K(3,7)=-K(1,9)
K(4,12)=K(3,7)
K(4,7)=Z*(2/R**2-4*R**2+(4*U-14.)/5.)
K(1,10)=K(4,7)
K(5,8)=Z*(2./3.*A**2-B**2/15.* (1.-U))
K(2,11)=K(5,8)
K(6,9)=Z*(2./3.*B**2-4./15.*A**2*(1.-U))
K(3,12)=K(6,9)
K(5,7)=Z*(2*A**2/B+B/5*(1-U))
K(2,10)=K(5,7)
K(4,8)=-K(5,7)
K(1,11)=K(4,8)
K(3,10)=Z*(B**2/A-A/5*(1+4*U))
K(1,12)=K(3,10)
K(6,7)=-K(3,10)
K(4,9)=K(6,7)
K(3,5)=0.
K(2,6)=0.
K(3,8)=0.
K(6,8)=0.
K(2,9)=0.
K(5,9)=0.
K(3,11)=0.
K(6,11)=0.
K(9,11)=0.
K(2,12)=0.
K(5,12)=0.
K(8,12)=0.

C
      WRITE(3,100)
100 FORMAT(//'* STIFFNESS MATRIX OF PLATE ELEMENT IN BENDING*',//++)
      WRITE(3,101)((K(I,J),J=1,12),I=1,12)
101 FORMAT( 12F10.3)
      RETURN
C      DEBUG SUECHK
      END
      SUBROUTINE STIFB(      NBE,      E, MU,      M)
      INTEGER CONE,Q,CON
      REAL MU,I,L,J,KB
C
      DIMENSION KX2(12,12),KX3(12,12),KX2T(12,12)
      DIMENSION CONB(18,3),      KB(12,12),      BP(18,3),ELCOR(57 ,2),
      +CCN(18 ,4),RSM(1,2),PREDIS(54,2)
      COMMON /BI/ELCOF,BP,CON,CONB,RSM,PREDIS /BA/KB,KX2,KX3,KX2T
      WRITE(3,172) NEE,M
C 172 FORMAT(/////////* OH ALLAH SAVE ME*, //* NBE=*,I5,* I=*,I5)
C
      L=EP(M,1)
      E=EP(M+2)

```

```

C 15 FFORMAT(6F7.3,4X,12F7.3)
C   WRITE(3,12) ((K1(I,J,K),K=1,6),J=1,6),I=1,6
C   1 WRITE(3,21) (K1(I,MNN,KM),KM=1,6),(K2T(I,MNN,KM),KM=1,6),
C   + (K3(I,MNN,KM),KM=1,6)
C   J=3*N+3
C     CALL CLEAR(D1,J,J,J,J)
C     CALL CLEAR(C,J,J,J,J)
C     CALL CLEAR(D,J,J,J,J)
C     CALL CLEAR(D0,J,J,J,J)
C   WRITE(3,21) ((C(K,L),L=1,15),K=1,15)
C 21 FFORMAT(/T10,*VALUES OF C MATRIX*,/T8,25(* * *),//(15F8.4))
C   WRITE(3,22) ((D(K,L),L=1,15),K=1,15)
C 22 FFORMAT(/T10,*VALUES OF D MATRIX*,/T8,25(* * *),//(15F8.4))
C   WRITE(3,23) ((D0(K,L),L=1,15),K=1,15)
C 23 FFORMAT(/T10,*VALUES OF DOMATRIX*,/T8,25(* * *),//(15F8.4))
C   WRITE(3,24) ((D1(K,L),L=1,15),K=1,15)
C 24 FFORMAT(/T10,*VALUES OF DIMATRIX*,/T8,25(* * *),//(15F8.4))
C DC 180 I=1,M
C   CALL CCPY32(K2T,KX1,I,6,6,M,6,6,6,6)
C   CALL COPY32(K3,KX2,I,6,6,M,6,6,6,6)
C   CALL CCPY32(K1,KX3,I,6,6,M,6,6,6,6)
C   CALL COPY32(A,AX1,I,J,6,M,J,6,J,6)
C   WRITE(3,25) ((K1(I,L,K),K=1,6),L=1,6),((K2T(I,L,K),K=1,6),L=1,6),
C   + (K3(I,L,K),K=1,6),L=1,6)
C 25 FFORMAT(/T10,*VALUES OF K1,K2T,K3 MATRIX*,/T8,25(* * *),//(6F7.3,2X,
C   + 6F7.3,2X,6F7.3))
C   WRITE(3,41) ((KX1(K,L),L=1,6),K=1,6)
C 41 FFORMAT(/T10,*VALUES OF KX1 MATRIX*,/T6,30(* * *),//(6F12.5))
C   WRITE(3,42) ((KX2(K,L),L=1,6),K=1,6)
C 42 FFORMAT(/T10,*VALUES OF KX2 MATRIX*,/T6,30(* * *),//(6F12.5))
C   WRITE(3,43) ((KX3(K,L),L=1,6),K=1,6)
C 43 FFORMAT(/T10,*VALUES OF KX3 MATRIX*,/T6,30(* * *),//(6F12.5))
C   WRITE(3,44) ((AX1(K,L),L=1,6),K=1,15)
C 44 FFORMAT(/T10,*VALUES OF AX1 MATRIX*,/T6,30(* * *),//(6F12.5))
C   WRITE(3,45) ((A1(I,L,K),K=1,6),L=1,15)
C 45 FFORMAT(/T10,*VALUES OF -A- MATRIX*,/T6,30(* * *),//(6F12.5))
C   IF (NN .EQ. 1) GO TO 1S2
C   CALL COPY32(D01,D1,I,J,J,M,J,J,J)
C 1S2 CALL TRANSM(AX1,KX1,A1,J,6,J,6,6,6,J,J)
C   WRITE(3,46) ((A1(K,L),L=1,15),K=1,15)
C 46 FFORMAT(/T10,*VALUES OF A1 MATRIX*,/T8,25(* * *),//(15F8.4))
C   CALL ADD1(A1,C,C,1,1,1,1,1,J,J,J,J)
C   WRITE(3,47) ((C(K,L),L=1,15),K=1,15)
C 47 FFORMAT(/T10,*VALUES OF C MATRIX*,/T8,25(* * *),//(15F8.4))
C   CALL TRANSM(AX1,KX2,A1,J,6,J,6,6,J,J)
C   WRITE(3,46) ((A1(K,L),L=1,15),K=1,15)
C   WRITE(3,44) ((AX1(K,L),L=1,6),K=1,15)
C   WRITE(3,9) I
C 7 WRITE(3,8) (A1(K,L),L=1,9)-(D1(K,L),L=1,9)
C 8 FFORMAT(/2X,9F7.4,2X,9F7.4)
C 9 FFORMAT(///* MATRICES A1 & D1 ARE AS FOLLOWS I=*,13//)
C 2 FFORMAT(2X,18F7.4)
C DC 191 K=1,J
C DC 191 L=1,J
C 1S1 D01(I,K,L)=A1(K,L)
C   CALL ADD1(A1,D,D,1,1,1,1,1,J,J,J,J,J)
C   WRITE(3,22) ((D(K,L),L=1,15),K=1,15)
C   WRITE(3,46) ((A1(K,L),L=1,15),K=1,15)
C
C   CALL TRANSM(AX1,KX3,A1,J,6,J,6,6,6,J,J)
C   WRITE(3,44) ((AX1(K,L),L=1,6),K=1,15)
C   WRITE(3,41) ((KX1(K,L),L=1,6),K=1,6)
C   WRITE(3,46) ((A1(K,L),L=1,15),K=1,15)
C   CALL ADD1(A1,D,D,1,1,1,1,1,J,J,J,J,J)
C   WRITE(3,46) ((A1(K,L),L=1,15),K=1,15)
C   WRITE(3,22) ((D(K,L),L=1,15),K=1,15)
C   CALL ADD1(A1,D0,D0,1,1,1,1,1,J,J,J,J,J)
C   WRITE(3,46) ((A1(K,L),L=1,15),K=1,15)
C   WRITE(3,23) ((D0(K,L),L=1,15),K=1,15)
C   CALL ADD1(D1,D0,D0,1,1,1,1,1,J,J,J,J,J)
C   WRITE(3,31) ((D0(K,L),L=1,15),K=1,15)
C 31 FFORMAT(/T10,*VALUES OF D0 MATRIX*,/T8,25(* * *),//(15F8.4))
C   WRITE(3,32) ((D(K,L),L=1,15),K=1,15)
C 32 FFORMAT(/T10,*VALUES OF D MATRIX*,/T8,25(* * *),//(15F8.4))
C   WRITE(3,34) ((C(K,L),L=1,15),K=1,15)
C 34 FFORMAT(/T10,*VALUES OF C MATRIX*,/T8,25(* * *),//(15F8.4))
C   WRITE(3,36) ((A1(K,L),L=1,15),K=1,15)
C 36 FFORMAT(/T10,*VALUES OF A1 MATRIX*,/T8,25(* * *),//(15F8.4))
C 180 CONTINUE
C   CALL TRANSM(B,KF,A1,J,3*M,J,3*M,3*M,3*M,J,J)
C   CALL ADD1(A1,D,D,1,1,1,1,1,J,J,J,J,J)

```



```

1 READ(1,172) WALLT
2 FORMAT(15)
3 IF (WALLT .NE. 0) GO TO 173
4 READ(1,174) BX,BY
5 FORMAT(3F12.6)
6 IX(I)=BY*3*BX/12.
7 IY(I)=BX*3*BY/12.
8 AX(I)=EX*EY
9 IF (AX(I) .EQ. 0) GO TO 273
10 R=BX/BY
11 IF (BX .GE. BY) R=EY/BX
12 JX(I)=(1/3--.21*R*(1-R**4/12))*AX(I)**2*R
13 GO TO 274
14 JX(I)=0
15 SF(I)=1.2
16 CONTINUE
17 IF (WALLT .NE. 1) GO TO 175
18 READ(1,176) IX(I),IY(I),AX(I),JX(I),SF(I)
19 FORMAT(5F12.4)
20 READ(1,177) WX(I),WY(I)
21 FORMAT(2F12.6)
22 IF (AX(I) .EQ. 0) GO TO 275
23 G1(I)=6*E*IY(I)*SF(I)/G/AX(I)/H**2
24 G2(I)=6*E*IX(I)*SF(I)/G/AX(I)/H**2
25 GO TO 171
26 G1(I)=0
27 G2(I)=0
28 G2(I)=0
29 CONTINUE
30 WRITE(3,178) M,E,MU,F
31 FORMAT(1 /
32 *E OF WALL=* ,14/, * MODULUS OF ELASTICITY =*,E12.4/, * POISSENS RATIO
33 *=*,E10.5/, * HEIGHT OF STORY =*,F12.4//, * PROPERTIES OF WALLS*
34 + //,* WALLS*,8X,* I*,13X,* I*.14X,* AREA OF *,12X,* J*,10X,* SHAPE*,2X,
35 + 5X,* SHEAR CENTRE CO ORD.* ,/, * NO*,11X,* X*,13X,* Y*,11X,* CROSS SECT
36 + TICN*,9X,* X*,9X,* Y*/ ,
37 + 5X,* X*,9X,* Y*/ ,
38 DC 179 I=1,M
39 WRITE(3,180) I,IX(I),IY(I),AX(I),JX(I),SF(I),WX(I),WY(I)

40 FORMAT(14, F13.4,3X,F12.4,10X,F8.2,9X,F8.2,5X,F6.2,6X,F8.2,2X,
41 +F8.2//)
42
43 CONTINUE
44 END OF READ WALL DATA (SUBROUTINE NUMBER = 27)
45 RETURN
46 DEBUG SUBCHK
47 END
48
49 SUBROUTINE FORMCD(NZONE,NS,M).
50 REAL K1,K2T,K3,KF,KX1,KX2,KX3
51 NO. OF RECORD={NZONE*(3*M+3)}                                RECORD LENGTH=6*M*NZONE (FILE 10)
52 REWIND 9
53 DIMENSION C(57,57),D(57,57),DO(57,57),B(57,54),KF(54,54)
54 DIMENSION K1(18,6,6),K2T(18,6,6),K3(18,6,6),A(18,57,6)
55 DIMENSION A1(57,57),AX1(57,6),KX3(6,6),KX1(6,6),KX2(6,6)
56 +,DO1(18,57,57),D1(57,57),NS(NZONE),KX4(6,6),KX2T(6,6)
57 COMMON //KF /E4/C,D,DO,B /B5/K1,K2T,K3,A /B/E/AX1,A1,KX3/BA/KX1,KX2
58 +KX4,KX2T /E10/D1
59 REWIND 9
60 REWIND 10
61 CALL CLEAR(DO1,M,3*M+3,3*M+3,M,3*M+3,3*M+3)
62 DC 190 NN=1,NZONE
63 WRITE(3,3) NN
64 3 FORMAT(//, K1,K2T AND K3 FOR ZONE NO. = *,I3//)
65 DC 90 MN=1,M
66 DO 90 MNN=1,6
67 90 READ(9) (K1(MN,MNN,KM),KM=1,6),(K2T(MN,MNN,KM),KM=1,6),(K3
68 +(MN,MNN,KM),KM=1,6)
69 WRITE(3,12) (((K1(I,J,K),K=1,6),J=1,6),I=1,4),(((K2T(I,J,K),K=1,
70 +6),J=1,6),I=1,4),(((K3(I,J,K),K=1,6),J=1,6),I=1,4)
71 FORMAT(/T10,*VALUES OF K1,K2T,K3 MATRIX SUBROUTINE FORMCD*,/T8,
72 +32(**)/,//(6F7.3,2X,6F7.3,2X,6F7.3))
73 WRITE(3,13)
74 FORMAT(/T10,*VALUES OF A , B MATRIX*,/T8,25(**)/,//)
75 DC 14 I = 1,4
76 DC 14 J = 1,15
77 14 WRITE(3,15) (A (I,J,K),K=1,6),(B (J,K),K=1,12)

```

```

201 CONTINUE
C
C      RETURN
C      DEBUG SUBCHK
C      END
C      SUBROUTINE CALSTR(NZCNE,NS, M,N,NLOAD)
C      REAL K1,K2T,K3,KF,KX1,KX2T,KX3,KX2
C      INTEGER DFOS
C      DIMENSION KF(54,54),BI(57,57),FA(54,2),FB(54,2),B(57,54),
C      +K1(18,6,6),K2T(18,6,6),K3(18,6,6),A(18,57,6),LOAD(1140,2),
C      +X(1140,2),
C      +A(57,57), A2(57,57),SR1(6,2),
C      +DV1(6,2), DV2(6,2),SRT(6,2),SRB(6,2),SR2(6,2),
C      +NS(NZCNE),KX2T( 6, 6)
C
C      COMMON //KF//B11/UNIT(3)           /B4/B1,A1,A2,B
C      COMMON //B5/K1,K2T,K3,A /B6/LOAD,X /BA/KX1,KX2,KX3,KX2T
C      REWIND 9
C      KFC5=1
C      WRITE(3,216) UNIT(2),UNIT(3),UNIT(2),UNIT(3),UNIT(1),UNIT(2),UNIT(
C      +3),UNIT(1)
C      DC 190 MN=1,M
C      DC 190 M,N=1,6
190  READ(9)          (K1(MN,MNN,KM),KM=1,6),(K2T(MN,MNN,KM),KM=1,6),(K3
+ (MN,MNN,KM),KM=1,6)
        L=1
        K=3#N+3
        DC 210 I=1,N
        IF(I .EQ. (NS(L)+1)) GO TO 10
        GO TO 15
10   CONTINUE
        L=L+
C      2 FORMAT(//** K1,K2T,K3 ARE AS FOLLOWS & I=*,I4/)
        DC 191 MN=1,N
        DC 191 MNN=1,6
191  READ(9)          (K1(MN,MNN,KM),KM=1,6),(K2T(MN,MNN,KM),KM=1,6),(K3
+ (MN,MNN,KM),KM=1,6)
        WRITE(3,211)
        DC 5 MNN=1,6
C      5 WRITE(3,11(K1(1,MNN,KM),KM=1,6),(K2T(1,MNN,KM),KM=1,6),(K3(1,MNN,
C      +KM),KM=1,6)
        1 FORMAT(18F7.3)
15   CONTINUE
        WRITE(3,211) I
211  FORMAT(//** STRESS RESULTTENTS IN WALLS ** /IX,25(*-*),//IX,
+                      * STOREY NO.* ,I4/)
        +
        DO 212 J=1,M
        CALL COPY32(A,A1,J,K,6,M,K,6,K,K)
        CALL COPY32(K1,KX1,J,6,6,M,6,6,6,6)
        CALL COPY32(K2T,KX2T,J,6,6,M,6,6,6,6)
        CALL COPY32(K3,KX3,J,6,6,M,6,6,6,6)
        CALL TRANS(A1,A2,K,6,K,K,K,K)
        CALL MULTI(A2,X,DV1,1,1,(I-1)*K+1,1,1,1,6,K,NLOAD,
+K,K,K*N,NLOAD,6,NLOAD)
        IF (I .EQ. N) GO TO 213
        CALL MULTI(A2,X,DV2,1,1,I*K+1,1,1,1,6,K,NLOAD,
+K,K,K*N,NLOAD,6,NLOAD)
        GO TO 214
213  CALL CLEAR(DV2,6,NLOAD,6,NLOAD)
214  CALL MULTI(KX1,DV1,SR1,1,1,1,1,1,1,6,6,NLOAD,6,6,NLOAD,6,NLOAD)
        CALL TRANS(KX2T,KX2,6,6,6,6,6)
        CALL MULTI(KX2,DV2,SR2,1,1,1,1,1,1,6,6,NLOAD,6,6,NLOAD,6,NLOAD)
        CALL ADD1(SR1,SR2,SRT,1,1,1,1,1,1,6,NLOAD,6,NLOAD,6,NLOAD)
        CALL MULTI(KX2T,DV1,SR1,1,1,1,1,1,1,1,6,6,NLOAD,
+6,6,6,NLOAD,6,NLOAD)
        CALL MULTI(KX3,DV2,SR2,1,1,1,1,1,1,1,6,6,NLOAD,6,6,NLOAD,6,NLOAD)

```

```

CC 150 I=1,M
K1(I,1,1)=12*E*IY(I)/H**3/(1+2*G1(I))
K1(I,1,5)=-K1(I,1,1)*H/2.
K1(I,5,1)=K1(I,1,5)
K1(I,2,2)=12*E*IX(I)/H**3/(1+2*G2(I))
K1(I,2,4)=K1(I,2,2)*H/2.
K1(I,4,2)=K1(I,2,4)
K1(I,3,3)=AX(I)*E/H
K1(I,4,4)=2*E*IX(I)/H*(2+G2(I))/(1+2*G2(I))
K1(I,5,5)=-2*E*IY(I)/H*(2+G1(I))/(1+2*G1(I))
K1(I,6,6)=G*JX(I)/H
K2T(I,1,1)=-K1(I,1,1)
K2T(I,1,5)=-K1(I,1,5)
K2T(I,2,2)=-K1(I,2,2)
K2T(I,2,4)=-K1(I,2,4)
K2T(I,3,3)=-K1(I,3,3)
K2T(I,4,2)=K1(I,4,2)
K2T(I,4,4)=2*E*IX(I)/H*(1-G2(I))/(1+2*G2(I))
K2T(I,5,1)=K1(I,5,1)
K2T(I,5,5)=2*E*IY(I)/H*(1-G1(I))/(1+2*G1(I))
K2T(I,6,6)=-G*JX(I)/H
DC 151 J=1,6
151 K3(I,J,J)=K1(I,J,J)
K3(I,1,5)=-K1(I,1,5)
K3(I,5,1)=K3(I,1,5)
K3(I,2,4)=-K1(I,2,4)
K3(I,4,2)=K3(I,2,4)
150 CONTINUE
C      WRITE(3,161) K1,K2T,K3
C      DC 1   I=1,4
C      DC 1   J=1,6
C      WRITE(3,2)
C      2 FORMAT(//10,*VALUES OF K1,K2T,K3 MATRIX*,/T8,30(* * *),//)
C      +6F7.3,2X,6F7.3)
C      DC 156 I=1,M
C      DC 156 K=1,6
156 WRITE(9) (K1(I,K,L),L=1,6),(K2T(I,K,L),L=1,6),(K3(I,K,L),
+L=1,6)
154 CONTINUE
CALL CLEAR3(A,M,3*M+3,E,M,3*M+3,E)
DC 152 I=1,M
A(I,1,1)=1.
A(I,2,2)=1.
A(I,3,6)=1.
A(I,3+I,3)=1.
A(I,3+N+I,4)=1.
A(I,I+3+2*M,5)=1.
A(I,3,1)=WY(I)
A(I,3,2)=-WX(I)
152 CONTINUE
CALL CLEAR(B,3*M+3,3*M,3*M+3,3*M)
DC 153 I=1,M
B((3+I),(I-1)*3+1)=1.
B((M+3+1,(I-1)*3+2)=1
B(2*M+3+I,3*I)=1.
153 CONTINUE
C      157 FORMAT(//1X,120(*-*), //1X,*THE FOLLOWING SECTIONAL PROPERTY
+OF WALL IS CONSTANT FROM STORY NO.* ,I4,* TO STORY NO.* ,I4,/1X,
+*STARTING FROM TOP*//)
158 FORMAT(//5X,125(*-*),//5X,*TOTAL NO. OF STORY =*, I4,//5X,120(*-*
+ *),//5X,*NO. OF ZONE WITH CONSTANT WALL PROPERTIES =*,I4//)
RETURN
C      DEBUG SUECHK
END
SUBROUTINE READWD(H, E, M, N, MU)
INTEGER WALLT
REAL MU, IX, IY, JX
DIMENSION IX(57), IY(54), AX(18), JX(18), SF(18), G1(18), G2(18),
+WX(18), WY(18), NODARR(57), WALLNO(18)
COMMON /B9/IY, AX, JX, SF, G1, G2, WX, WY/B11/UNIT(3)
COMMON /B2/ IX, WALLNO, NODARR
C      WRITE(3,181) UNIT(1)
181 FORMAT(*1*,//1X,*DATA-FOR-WALLS*,/1X, 14(*-*),/1X,****LENGTH UNIT
+IS IN *,A4)
174 FORMAT(2F12.4)
C      READ(1,170) E, MU, H
G=E/2./{1.+MU}
DC 171 I=1,M

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104 DC 105 I=1,NPD
C CCL=(PREDIS(I,1)-1)*3+PREDIS(I,2)
C CALL CCPY1(KF,KIK3,I,I,1,COL,NPD,NPD,NPD ,3*NN)
105 CONTINUE
C
C DC 202 JRC=1,NPD
C 202 WRITE(3,203) (KFI JRC,JRM),JRM=1,6 ),(KIK3(JRC,JRN),JRN=1,6 )
C 203 FFORMAT( * KF=',(6F10.2), /* KIK3=',(6F10.2)// )
C CALL COPY1(KF,KIK3,I,I,1,COL,NPD,I,15,15,15,190)
C 105 CONTINUE
IF (NW1 .EQ. 0) GO TO 107
DC 106 I=1,NW
J=NODEW(I,1)
KA=NODEW(I,2)
KE=WALLNC(KA)
X=ELCOR(J,1)-ELCOR(KB,1)
Y=ELCOR(J,2)-ELCOR(KB,2)
DC 106 KG=1,3
CCL=(J-1)*3+KG
KD=(KA-1)*3+KG
DC 106 KC=1,NPD
KF(KC,KD)=KF(KC,KD)+KIK3(KC,COL)
IF (KG .NE. 1) GO TO 106
KF(KC,KD+1)=KF(KC,KD+1)-Y*KIK3(KC,COL)
KF(KC,KD+2)=KF(KC,KD+2)+X*KIK3(KC,COL)
106 CONTINUE
107 CCL=0
J=0
K=0
KC=0
DC 108 I=1,NN
108 FREEN(I)=0
IF (NW1 .NE. 0) GO TO 109
GC TC 111
109 DC 110 I=1,NW1
110 FREEN(NODEW(I,1))=NODEW(I,2)
111 DC 112 I=1,M
112 FREEN(WALLNO(I))=I
DC 113 I=1,NN
IF (FREEN(I) .NE. 0) GO TO 114
K=K+1
FREEN(K)=I
CALL COPY1(KIK3,KIK3,1,COL+1,1,(I-1)*3+1,NPD,3,NPD ,3*NN,NPD
+3*NN)
CCL=COL+3
GC TC 113
114 J=J+1
NODDEW(J,1)=I
NODDEW(J,2)=FREEN(I)
115 CONTINUE
MAXDIF=(HEW+1)/3-1
NNNW1=NN-NW1-M
C WRITE(3,211)
DC 115 I=1,NNNW1
J=FREEN(I)
J=FREEN(I)
KC=0
KD=0
DC 116 KA=1,3
DC 116 KE=KA,3
116 KGB((I-1)*3+KA,I-KA+KE)=KGB((J-1)*3+KA,1-KA+KB)
KE=I
K=J
IF (J .EQ. NN) GO TO 115
117 K=K+1
IF (K .LE. (J+MAXDIF)) GO TO 118
IF ((KC+1) .GT. MAXDIF) GO TO 115
DC 119 KA=1,3
KAKC3=5-KA+3*KC
HEW1=HEW+1
DC 119 KB=KAKC3,HEW1
KGB((I-1)*3+KA,KB)=0.0
119 CONTINUE
GC TC 115
118 CONTINUE
C
C WRITE(3,211)
IF (KE .EQ. (NN-NW1-M)) GO TO 115
IF (K .NE. FREEN(KE+1)) GO TO 121
KC=KC+1
DC 120 KA=1,3

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      DC 90 I=1,M
90 NW1=NW1+NCDARR(I)
NW=NW1
IF(NW1 .EQ. 0) NW=1
CALL CLEARIK1K3,NFD,3*NN,NPD ,3*NN)
KA=0
C
      WRITE(3,500) NW1
      IF(NW1 .NE. 0) GO TO 91
      NCDEW(1,1)=NN+1
      NCDEW(1,2)=NODEW(1,1)
      GC TC 2
91 WRITE(3,92)
92 FORMAT(//,* WALL CONNECTIVITY*,*,* WALL*,SX,*REF*,SX,*CONNECTED
+*,/* NO*,SX,*NODE*,7X,*NODES*,/)
DC 93 I=1,M
      WRITE(3,94) I,WALLNO(I)
94 FORMAT( I4,5X,I4)
      IF(NCDARR(I) .EQ. 0) GO TO 93
      NCDARI=NCDARR(I)
      IF(NCDARI.LE.0) GO TC 93
C
      DC 97 J=1,NODARI
      KA=KA+1
      READ(1,98) NODEW(KA,1)
98 FORMAT(I4)
      NODEW(KA,2)=I
      WRITE(3,99) NODEWIKA,1)
99 FORMAT(17X,I4)
97 CONTINUE
93 CONTINUE
2 DC 100 I=1,NPD
ROW=(PREDIS(I,1)-1)*3+PREDIS(I,2)
DC 100 J=1,BW
KA=ROW-HEW+J-1
IF(KA .GT. 0 .AND. KA .LE. 3*NN)GO TO 101
GC TC 100
101 IF (J .GT. HBW) GO TO 96
      K1K3(I,KA)=KGB(KA,1-KA+ROW)
      GC TC 100
C
      96 K1K3(I,KA)=KGB(ROW,J-HEW)
100 CONTINUE
C
      MRCHY=NN-NW1-M
      WRITE(3,201) MRCHY
C 201 FORMAT(//,* THIS IS THE POSITION WITHIN SUB.CONSM,NN-NW1-M=*,I6)
C 100 CONTINUE
      IF (NW1 .EQ. 0) GO TO 104
      DC 102 I=1,NW
      J=NODEW(I,1)
      KA=NODEW(I,2)
      KB=WALLNO(KA)
      X=ELCOR(J,1)-ELCOR(KE,1)
      Y=ELCOR(J,2)-ELCOR(KE,2)
      DC 102 KG=1,3
      RCW=(J-1)*3+KG
      KD=(KA-1)*3+KG
      DC 102 KC=1,BW
      KE=RCW-HBW+KC-1
      IF (KE .GT. 0 .AND. KE .LE. 3*NN) GO TC 103
      GC TC 102
103 IF (KC .GT. HBW) GO TO 130
      XI=KGB(KE,1-KE+ROW)
      GC TC 131
130 XI=KGB(RCW,KC-HBW)
C
C
C
C
C
      131 K1K3(KD,KE)=K1K3(KD,KE)+XI
      IF (KG .NE. 1) GO TO 102
      K1K3(KD+1,KE)=K1K3(KD+1,KE)-Y*XI
      K1K3(KD+2,KE)=K1K3(KD+2,KE)+X*XI
      K1K3(KD+2,KE)=K1K3(KD+2,KE)+X*XI
C
C
C
C
      102 CONTINUE

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```

DC 100 I=1,NEL
WRITE(3,2) I,NEL
2 FORMAT( ///* THIS POSITION IS WITHIN THE SUE. ASSEMB*, *I=*,14,16*
IF( TYPE .NE. 1) GO TO 110
XN=ABS(ELCOR(CON(I,3),1)- ELCOR(CON(I,1), 1))
YN= ABS( ELCOR( CON(I,3),2)- ELCOR( CON (I,1), 2))
IF (( ABS(XN-X) .LT. 0.0001) .AND. ( ABS(YN-Y) .LT. 0.0001)) GO
+ TO 120
CALL STM5( NEL, E,MU, I)
X=XN
Y=YN
GC TO 120
110 CALL STIF8(NEL,E,MU,I)
WRITE(3,2) I,NEL
120 DO 130 J=1,NS
DC 130 L=J,NS
A=CON(I,J)
E= CON(I,L)
M1=(A-1)*NDF
M2=(B-1)*NDF
M3=( J-1) *NDF
M4=( L-1) *NDF
IF ( A .NE. B) GO TO 140
DC 150 MA=1,NDF
DC 150 N=MA,NDF
F=M1+MA
Q=1-MA+N
150 KGBH(P,Q)=KGBH(P,C)+K(M3+MA,M4+N)
GC TO 130
140 IF ( A .LT. E) GO TO 170
DC 180 MA=1,NDF
DC 180 N=1,NDF
NS=M2+N
M6= 1-M2+M1+MA-N
180 KGBH(M5,M6)=KGBH(M5,M6)+ K(M3+MA,M4+N)
GC TO 130
170 DC 190 MA=1,NDF
DC 190 N=1,NDF
NS=M1+MA
M6=1-M1+M2+N-MA
190 KGBH(M5,M6)=KGBH(M5,M6)+K(M3+MA,M4+N)
130 CONTINUE
56 WRITE(3,56) ((KGBH(M,N),N=1,15),M=1,27)
00 FORMAT(//T10,*VALUES OF KGBH-MATRIX*/T8,24(* *),//(1SE8.2))
00 CONTINUE

```

```

RETURN
DEUG SUBCHK
END
SUBROUTINE STM5( NEL, E, U, IX)
INTEGER CON,CONB,RSM,PREDIS,WALLNO
REAL K,KX2,KX3,KX2T
DIMENSION K(12,12),ELCCR(57,2),TH(57),CON(18,4),BP(18,3),CONB
+(18,3),
PREDIS(54,2),WALLNO(18),NODARR(57),REN(1,2),
+KX2(12,12),KX3(12,12),KX2T(12,12)
COMMON /B1/ELCOR,BP,CON,CONB,RSM,PREDIS/B2/TH,WALLNO,NODARR/BA/K,
+KX2,KX3,KX2T

```

```

A=ABS(ELCCR(CON(IX,3),1)- ELCOR(CON(IX,1),1))
E=ABS(ELCCR(CON(IX,3),2) - ELCOR(CON(IX,1),2))
Z=E*TH(IX)** 3/12./ ( 1-U**2)/(A*B)
R=A/E
DC 10 I=1,10,3
K(I,1)=Z*( 4*R**2+4./R**2+(14 -4*U)/5)
I1=I+1
K(I1,1)=Z*(4./3.*A**2+4./15.* ( 1.-U)*B**2)
I2=I1+1
K(I2,1)=Z*(4/3.*E**2+4./15.* ( 1.-U)*A**2)
10 CONTINUE
K(1,2)= (2*A**2/B+8/5*(1+4*U))*(-Z)
K(4,5)=K(1,2)
K(7,8)=-K(1,2)
K(10,11)=K(7,8)
K(1,3)=Z*(2*B**2/A+A/5*(1+4*U))
K(10,12)=K(1,3)
K(4,6)=-K(1,3)

```

```

      WRITE(3,14) UNIT(1)
14 FORMAT('1',//'* FINITE ELEMENT ANALYSIS OF FLOOR SLAB*',/1X,40('*'))
+,*//1X,***UNIT OF LENGTH USED FOR THIS ANALYSIS IS IN *,A4)
DATA A,B/*X*,*Y*/
WRITE (3,10) NEL,NBE,NN,NPD,NRN,E,MU
10 FORMAT ( //1X,*NUMBER OF PLATE ELEMENTS=*,I4,*
+ * NUMBER OF BEAM ELEMENTS=*,I4,*
+ * NUMBER OF NODES=*,I4,*
+ * NUMBER OF PRESCRIBED DISPLACEMENTS=*,I4,*
+ * NUMBER OF TOTAL RESTRAINT APPLIED AT NODES=*,I4,*
+ * MODULUS OF EL
+ * STIFFNESS=*,F12.2/,* POISSON'=*,* S RATIO=*,F6.2)
IF (NEL .EQ. 0) GO TO 20
WRITE(3,11)
11 FORMAT(//,* CONNECTIVITY AND CO-ORDINATES OF PLATE ELEMENTS*,/1X,
+ 50(*''),//,
+ * EL. NO. *,20X,* NODE NO. *,29X,* NODAL CO-ORDINATES*,18X,* THICKNES
+ * S*,//,*26X,* I*,5X,* J*,5X,* K*,5X,* L*,13X,* X1*,7X,* Y1*,5X,* XJ*,5X,
+ * YJ*,5X,* XK*,5X,* YK* //)
DC 21 I=1,NEL
21 WRITE(3,12) I,(CON(I,J),J=1,4),((ELCOR(CON(I,J),K),K=1,2),J=1,3),
+ TH(I)
12 FORMAT(16.15X,416,10X,F7.2,6X,F6.2)
20 IF(NEE .EQ.0) GO TO 25
WRITE(3,22)
22 FORMAT(//,* CONNECTIVITY AND DIMENSIONS OF BEAM ELEMENTS*,/1X,
+ 50(*''),//,* ELEMENT NO. *,
+ * 4X,* NODE NO. *,8X,* LENGTH*,5X,* WIDTH*,5X,* DEPTH*,3X,* DIRECTION
+ * //)
DC 23 I=1,NBE
XA=B
IF( CONB(I,3) .EQ. 1) XA=A
23 WRITE(3,24) I, (CONB(I,J),J=1,2),(BP(I,J),J=1,3),XA
24 FORMAT(1X,17,7X,13,4X,13,7X,F7.2,4X,F5.2,5X,F5.2,5X,A4)
25 IF( NRN .EQ.0) GO TO 26
WRITE(3,27)
27 FORMAT(//,* TOTALLY RESTRAINED NODES *,//,* NODE NO ---- SENSE-RESTRA
+ INED*,//)
WRITE(3,28) ((RSM(I,J),J=1,2),I=1,NRN)
28 FORMAT(16,8X,I4)
26 WRITE(3,29)
29 FORMAT(//,* PRESCRIBED DISPLACEMENTS*//,* NODE NO.----SENSE*//)
WRITE(3,30) ((PREDIS(I,J),J=1,2),I=1,NPD)
30 FORMAT(15,8X,I3)
C END OF PRINT FLOOR DATA
RETURN
END
SUBROUTINE BANDWH( NEL,NS,NDF,BW)
INTEGER BW,CON,BW1,BW2,CONB
DIMENSION PREDIS(54,2)
DIMENSION CON(18,4),BP(18,3),ELCOR(57,2),CONB(18,3),RSM(1,2)
COMMON /EI/ ELCOR,BP,CON,CONB,RSM,PREDIS
C
BW2=0
NS1=NS-1
DO 100 I=1,NEL
DO 100 J=1,NS1
J1=J+1
DO 100 K=J1,NS
BW1 { FOR BOTH CON AND CONB MATRIX}
BW1=CON(I,J)-CON(I,K)
IF (NS .EQ.2) BW1=CONB(I,J)-CONB(I,K)
IF (BW1 .LT. 0) BW1=-BW1
IF (BW1 .GT. BW2) BW2= BW1
100 CONTINUE
BW=(BW2+1)*NDF*2-1
RETURN
END
SUBROUTINE ASSEMB( NDF,NEL, NS,TYPE, E,MU )
INTEGER CON,TYPE,A,B,P,Q,CONB,RSM,PREDIS,WALLNO
REAL MU,KGBH,K,KX2,KX3,KX2T
DIMENSION KGBH(54, 9 ),ELCOR(57,2),BP(18,3),CON(18,4),RSM(1,2)
+ , CONB(18,3),TH(57),K(12,12),PREDIS(54,2),WALLNO(18),
+ KX2(12,12),KX3(12,12),KX2T(12,12),NODARR(57)
COMMON /B1/ ELCOR,BP,CON,CONB,RSM,PREDIS /B2/ TH,WALLNO,NODARR /B3/
+ KGBH /EA/K,KX2,KX3,KX2T
C
C
C
```

X=0.
Y=0.

```

      READ(1,20) E,MU
20  FCFMFORMAT(F10.1,F5.2)
      IF(NEL .EQ.0) GO TO 12
C     CC 11 N=1,3
      READ(1,21) K
      IF (K .EQ.1) GO TO 11
      READ(1,22) XN,YN,T
      READ(1,23) (X(I), I=1,XN)
      READ(1,23) (Y(I), I=1,YN)
23  FCFMFORMAT(8F10.2)
22  FCFMFORMAT(2I3,F10.4)
      DC 24 I=1,XN
      DC 24 J=1,YN
      K=(I-1)*YN+J
      L=K
      CCN(L,1)= ((YN+1)*K-1)/YN
      CCN(L,2)=CON(L,1)+YN+1
      CCN(L,3)=CON(L,2)+1
      CCN(L,4)=CON(L,1)+1
24  TH(L)=T
      X1=0.
      N1=XN+1
      N2=YN+1
      DC 25 I=1,N1
      IF (I.EQ.1) GO TO 330
      X1=X1+X(I-1)
330  Y1=0.0
      DC 26 J=1,N2
C
      IF(J .EQ.1) GO TO 331
      Y1=Y1+Y(J-1)
331  K=(I-1)*(YN+1)+J
      ELCOR(K,1)=X1
      ELCOR(K,2)=Y1
      26 CONTINUE
      25 CONTINUE
      GC TC 12
      11 CONTINUE
C
      61 FCFMFORMAT(3F5.2)
C
29  FCFMFORMAT(4I4,F10.4)
      DC 28 I=1,NEL
      READ(1,29) CON(I,1),CON(I,2),CON(I,3),CON(I,4),TH(I)
      28 CONTINUE
C     CCN(I,3)=CON(I,2)+1
C     CCN(I,4)=CON(I,1)+1
      READ(1,23)((ELCOR(I,J),J=1,2),I=1,NN)
      12 IF(NBE .EQ.0) GO TO 6
      DC 30 I=1,NBE
      READ(1,31) (CONE(I,J),J=1,2)
31  FCFMFORMAT(3I4)
      K=2
      IF((CONB(I,3)-1) .EQ. 0) K=1
      BP(I,1)=AES(ELCOR(CONB(I,1).K)- ELCOR(CONB(I,2),K))
      READ(1,61) (BP(I,J),J=1,3)
      30 CONTINUE
      6 IF(NRN .EQ. 0) GO TO 7
      READ(1,32) ((RSM(I,J),J=1,2),I=1,NRN)
32  FCFMFORMAT(2I4)
      7 NDI=NPD/3
      DC 60 I=1,NDI
      READ(1,32) J,NODARR(I)
      WALLNO(I)=J
      NCDARR(I)=NODARR(I)-1
      DC 34 K=1,3
      PREDIS(3*I-3+K,1)=J
34  PREDIS(3*I-3+K,2)=K
      60 CONTINUE
      READ(1,27) UNIT(1),UNIT(2),UNIT(3)
C     27 FCFMFORMAT(3A4)
      RETURN
      END
      SUBROUTINE PRINTF(NEL,NN,E,MU, NRN, NPD,NBE)
C
      INTEGER CCN,RSM,PREDIS,CONB
      REAL MU
      DIMENSION ELCOR(57,2),TH(57),BP(18,3),CON(18,4),CONB(18,3)
      DIMENSION RSM( 1,2),PREDIS(54,2),NODARR(57),WALLNO(18)
      COMMON /B1/ELCOR,EP,CON,CONB,RSM,PREDIS/B2/TH,WALLNO,NCDARR
      COMMON /B3/UNIT(3)

```

CEBUG SUBCHK

END

SUBROUTINE FORMB3(N,M, NRHS,NZONE,NS)

DIMENSION A(57,57),B(57,57),BO(57,57),P(1140,2),X(1140,2),C(57,55)
+ , BP(18,3),C1(57,54),C(57,59),D2(57,59),CON(18,4),CONE(18,4),
+ RSM(1,2), PN(57,2),T(57,57),NS(NZONE),PREDIS(54,2)

(T=A)

SUBROUTINE NO = 16 (FCRMBPN3(A,B,BO,N,M,P,X,NRHS))

CMMCN /B8/C,DI,D2/B4/A,B,BO,C1/B6/P,X/B1/PN,BP,CON,CONB,FSM,PREDI

+S /E10/T

REWIND 10

MNRHS=M+NRHS

DC 16 JL=1,M

16 READ(10) (A(JL,KL),KL=1,M),(B(JL,KL),KL=1,M),(BO(JL,KL),KL=1,M)

NN=2

WRITE(3,22) A,B,BO,C1

2 FCFMAT(15E8.4)

WRITE(3,31) ((A(I,J),J=1,15),I=1,15)

31 FORMAT(1T10,*VALUES OF A-MATRIX*,/T8,22(***),//(15F8.4))

WRITE(3,32) ((B(I,J),J=1,15),I=1,15)

32 FORMAT(1T10,*VALUES OF B-MATRIX*,/T8,22(***),//(15F8.4))

WRITE(3,33) ((BO(I,J),J=1,15),I=1,15)

33 FORMAT(1T10,*VALUES OF BO-MATRIX*,/T8,24(***),//(15F8.4))

WRITE(3,34) ((C1(I,J),J=1,12),I=1,15)

34 FORMAT(1T10,*VALUES OF C1-MATRIX*,/T8,22(***),//(12F8.4))

DC 61 KK=1,NZONE

NS1=NS(KK)+1

IF (KK .EQ. NZONE) NS1=N

IF (KK .NE. 1) GO TO 11

CALL CCPY1(D2,BO,1,1,1,1,M,M,M,M+NRHS,M,M)

CALL CCPY1(D2,P,1,M+1,1,1,M,NRHS,M,M+NRHS,M,N,NRHS)

GO TO 15

11 CALL CCPY1(A,T,1,1,1,1,M,M,M,M,M)

CALL CCPY1(T,BO,1,1,1,1,M,M,M,M,M)

CALL CCPY1(BO,E,1,1,1,1,M,M,M,M,M)

CALL CCPY1(E,T,1,1,1,1,M,M,M,M,M)

15 CALL TRANS(A,C,M,M,M,M,M+NRHS)

DEFINE FILE 8(1960,55 ,U,MIN2)

F ND (8*1)

IF (KK .NE. 1) NN=NTEMP

IF (NN .GT. NS1) GO TO 62

DC 61 I=NN,NS1

5 CALL CCPY1(C,BO,1,M+1,1,M+1,M,NRHS,M,M+NRHS,M,M+NRHS)

CALL SOLVE(D2,C,DI,M,M+NRHS,M,M+NRHS,M,M+NRHS)

CALL CCPY1(BIGD,DI,M*(I-2)+1,1,1,1,M,M+NRHS,190,30,1E,20)

MIN2=M*(I-2)+1

WRITE(3,20) MIN2

- FIND (8*MIN2)

DC=9-K=1,M

9 WRITE(8*MIN2) (D1(K,L),L=1,MNRHS)

IF (I .NE. NS1) GO TO 13

IF (KK .EQ. NZONE) GO TO 64

IF ((NS(KK+1))-NS(KK)) .EQ. 1) GO TO 63

64 IF (I .EQ. N) GO TO 13

63 DC 14 JL=1,M

14 READ(10) (T(JL,KL),KL=1,M),(BO(JL,KL),KL=1,M),(B(JL,KL),

+KL=1,M)

12 CONTINUE

NTEMP=NS1+1

3 WRITE(3,2) (D1(K,L),L=1,11)

CALL MULT1(A,D1,D2,1,1,1,1,1,1,M,M,M+NRHS,M,M,M,M+NRHS,M,M+NRHS)

CALL SUB1(B,D2,D2+1,1,1,1,1,1,M,M,M,M,M+NRHS,M,M+NRHS)

CALL SUB1(P,D2,D2,M*(I-1)+1,1,1,1,M+1,1,M+1,M,NRHS,M*N,NRHS,M,

+ N*NRHS,M,M+NRHS)

61 CONTINUE

62 CALL CCPY1(PN,D2,1,1,1,M+1,M,NRHS,M,MRHS,M,M+NRHS)

CALL SOLVE(D2,PN,PN,M,MRHS,M,M+NRHS,M,MRHS)

CALL COPY1(X,PN,M*(N-1)+1,1,1,1,M,MRHS,M*N,MRHS,M,MRHS)

5 WRITE(3,2) (PN(K,L),L=1,2)

N1=N-1

DC 60 II=1,N1

I=N-II

MIN2=M*(I-1)+1

FIND (8*MIN2)

DC 6 K=1,M

6 READ(8*MIN2) (D1(K,L),L=1,MNRHS)

CALL MULT1(BIGD,X,D2,M*(I-1)+1,1,M*I+1,1,1,1,M,M,MRHS)

+190,30,198,2,18,20)

CALL MULT1(D1,X,D2,1,1,M*I+1,1,1,1,M,M,MRHS,M,M+NRHS,M*N,MRHS).

```

001 IF EACH I (CONB(I,J),J=1,3) I 314
001 AN EL.1 I BP(I,J),J=2,3 I 2F5.2
001 I CONNECTIVITY OF BEAMS (CONB(I,J)),(1.NODE NO. I,2.NODE NC. J &
001 I 3. DIRECTION ( 1 FOR X-DIR. 2 FOR Y DIR.) I
001 I BEAMS PARAMETER (BP(I,J)), (1ST. ONE FOR WIDTH & 2ND ONE FOR
001 I DEPTH OF BEAM) I NBE SETS OF VALUE
001 I (RSM(I,J),J=1,2),I=1,NRN) I 214
001 FOR EACH I RESTRAINT APPLIED AT NODES (RSM(I,J)),(1ST. ONE FOR NODE NC. &
001 I INTEGER FLOOR,CON,CONB,RSM,PREDIS,WALLNO

002 REAL LOAD, K1K3, K3K1,IY,JX,KF,K1,K2T,K3,KGB,KX3

003 DIMENSION KF(54,54),ELCOR( 57,2),BP(1E,3),CON( 18,4),CONB(18,3)
003 DIMENSION RSM( 1,2),PREDIS(54,2),TH(57 ),WALLNO(1E),NCDARF(57 ),
003 +KGB(54 , 9 ),C(57,57),D(57,57),DO(57,57),B(57,57),K1(18,6,6),K2T(
003 +1E,6,6),K3(18,6,6),A(18,57,6),LOAD(1140,2),NSTR(3),X(1140,2),
003 +K1K3(54,57 ), UNIT(3), K3K1(57 ,54),IY(54),AX(18),JX(18),SF(18)
003 +,G1(18),G2(18),WX(18),WY(18),AX1(57 , 6),A1(57,57),KX3( 6, 6)
003 CCMON //KF /B1/ELCOR,BP,CON,CONB,RSM,PREDIS /B2/TH,WALLNC,NCDARF
003 CCMEN /B3/KGB /B4/C,D,DO,B /B5/K1,K2T,K3,A/B6/LOAD,X /B7/
003 + K1K3,K3K1 /B9/IY,AX,JX,SF,G1,G2,WX,WY/B8/AX1,A1,KX3/B11/UNIT
004 READ(1,501) M,UNIT(1),UNIT(2),UNIT(3)
004 FCFMAT(14,3A4)
004 IF (M .LT. 0) GO TO 560
004 READ(1,502) N,NLOAD,FLOOR
005 FCFMAT(2I6,I4)
005 IF(FLCERT .NE. 0) GO TO 505
005 MINTC3=3*N
005 READ(1,503) ((KF(IN1,IN2),IN2=IN1,MINT03),IN1=1,MINTC3)
005 FCFMAT(25X,6F7.4)
005 DC 504 IN1=1,MINT03
005 DC 504 IN2=1,IN1
005 KF(IN1,IN2)=KF(IN2,IN1)
005 GE TC 506
006 CALL FEFLR(3*M)
006 LENTINUE
006 DATA TITL 1,TITL 2,TITL 3 /*STIF*,*OF F*,*LCOR*/
006 IF(M .EQ.2) GO TO 560
006 CALL OUTARR(KF,3*M,3*M,0,5,TITL 1,TITL 2,TITL 3,3*M,3*M)
006 CALL FCRM$S(NZONE,NSTR,M,N)
006 DC 1 I=1,4
006 DC 1 J=1,6
006 WRITE(3,2) (K1(I,J,K),K=1,6),(K2T(I,J,K),K=1,6),(K3(I,J,K),K=1,6)
006 FCFMAT(6F7.3,2X,6F7.3,2X,6F7.3)
006 DC 3 I=1,4
006 DC 3 J=1,15
007 WRITE(3,3) (A(I,J,K),K=1,6),(B(J,K),K=1,12)
007 FCFMAT(6F7.3,4X,12F7.3)
007 CALL FCRMCD(NZONE,NSTR,M)
007 DC 5 I=1,15
008 WRITE(3,4) (C(I,J),J=1,15),(D(I,J),J=1,15)
008 FCFMAT(1H ,15F8.4)
008 DC 7 I=1,15
009 WRITE(3,5) (DO(I,J),J=1,15)
009 FCFMAT(1H ,15F8.4)
009 CALL READlw( NLOAD,M,N)
009 CALL TEST(M,N,NLOAD)

010 CALL FCRME3(N,3*M+3,NLOAD,NZONE,NSTR)
010 DC 9 I=1,15
011 WRITE(3,6) (C(I,J),J=1,15),(D(I,J),J=1,15)
011 DC 11 I=1,15
012 WRITE(3,15) (DO(I,J),J=1,15)
012 WRITE(3,15) ((LOAD(I,J),I=1,150),J=1,21
012 DC 507 IN3=1,NLOAD
012 WRITE(3,508) IN3,UNIT(1)
013 50E FORMAT('1',//1X,*LOAD CASE*,16//1X,*FLOOR DISPLACEMENTS*,/1X,20(*
013 +**),/1X,*** UNIT OF DISPL. IS. IN*,*(1,A4,* / 1000)*,//* FLOOR*,5X
013 +,* HORIZONTAL DEFLECTION*,15X,*ROTATION*,/,1X,*NO.* ,EX,
013 +,* X-DIRE*,8X,*Y-DIRE*,16X,*XY-PLANE*,/)
013 DC 609 IN1=1,N
013 IN2=(IN1-1)*(3*M+3)
014 WRITE(3,509) IN1,X(IN2+1,IN3),X(IN2+2,IN3),X(IN2+3,IN3)
014 FCFMAT(13,5X,E13.7,5X,E13.7,8X,E13.7)
014 WRITE(3,511)
015 511 FCFMAT(///,* WALL DISPLACEMENTS*/1X,20(***),//1X,*FLOOR NO.--WALL
015 +NC,* ,5X,
015 +*VERT. DEF.* ,9X,*THETA-X*,9X,*THETA-Y*/)
016 DC 512 IN1=1,N
016 I=(IN1-1)*(3*M+3)

```

```

CALL ADD1(SR1,SR2,SRB,I,1,I,1,I,1,6,NLOAD,6,NLOAD,E,NLOAD)
WRITE(3,215) J
215 FORMAT(//,* WALL NO=*,I4)
DATA TLE1, TLE2, TLE3 //TOP*, * NOD*,*ES *
C   TITLE2=XXXX
C   TITLE3=XXXX
CALL CUTARR(SRT,6,NLOAD,0,5, TLE1, TLE2, TLE3,6,NLOAD)
DATA TTLE1, TTLE2, TTLE3//BOT*, *OM N*,*ODES*
C   TITLE2=OMXX
C   TITLE3=XXXX
CALL CUTARR(SRB,6,NLOAD,0,5, TTLE1, TTLE2, TTLE3,6,NLOAD)
212 CONTINUE
CALL TRANS(B,BI,K,3*M,K,3*M, K,K)
CALL MULT1(BI,X,FA,1,1,(I-1)*K+1,1,1,1,3*M,K,NLOAD,
+ K,K,K*N,NLOAD,3*M,NLOAD)
CALL MULT1(KF,FA,FE,1,1,1,1,1,1,3*M,3*M,NLOAD,
+3*M,3*M,NLOAD,3*M,NLOAD)
DATA TITLE1,TITLE2,TITLE3 //FLOO*,*R AC*,*TION*
216 FORMAT(*1*,///1X,*STRESS RESULTANTS AT TOP AND BOTTOM OF WALLS AND
+COLUMNS OF EACH STOREY ARE PRESENTED IN THE FOLLOWING TABLE*//1X,
+99(***),/1X,*SIX COLUMNS OF THE TABULATED STRESSES ARE FOR EACH
+NODE*,/1X,* & THE STRESS ARE AS FOLLOWS*,/1X,68(***),/1X,*AXIAL
+LOAD*,5X,*MOMENT ABOUT X-AXIS*,5X,*MOMENT ABOUT Y-AXIS*,/1X,68(***
+),/1X,*(*,2A4,*1*,8X,*(*,2A4,*-,A4,* )*,5X,*1*,2A4,*-,A4,* )*)*/
CALL CUTARR(FE,3*M,NLOAD,0,5,TITLE1,TITLE2,TITLE3,3*M,NLOAD)
210 CONTINUE
C   END OF CALCULATE STRESS RESULTANT (SUBROUTINE NUMBER =30)
C
C
C   RETURN
C   DEBUG SUBCHK
END

/*
// EXEC LNKECT
// EXEC
18FEET KIPS
 20      2      1
 0    18    00    18
 4.32     .18
 1      2      1
 8.0    1.2    1.46
 2      4      1
 8.0    1.2    1.46
 4      6      1
 8.0    1.2    1.46
 6      8      1
 8.0    1.2    1.46
 8      10     1
 8.0    1.2    1.46
 10     12     2
 8.0    1.2    1.46
 12     14     2
 8.0    1.2    1.46
 14     16     2
 8.0    1.2    1.46
 16     18     2
 8.0    1.2    1.46
 1      2
 8.0    1.2    1.46
 3      5
 8.0    1.2    1.46
 5      7
 8.0    1.2    1.46
 7      9
 8.0    1.2    1.46
 9      11
 8.0    1.2    1.46
 11     13
 8.0    1.2    1.46
 13     15
 8.0    1.2    1.46
 15     17
 8.0    1.2    1.46
 17     18
 8.0    1.2    1.46
 1      1
 2      1
 3      1
 4      1
 5      1
 6      1

```

APPENDIX B
LISTING OF THE PROGRAMME
(Continuous Medium Method)

NW NUMBER OF WALLS/COLUMNS
NO NUMBER OF OPENINGS
NT NUMBER OF TERMS CONSIDERED IN SERIES
SOLUTION FOR 'T'

CARD TYPE 1(B)

ONE CARD WITH BH, SH, E, PR . . . 4F10.3

BH TOTAL HEIGHT OF THE TUBE

SH STOREY HEIGHT OF THE TUBE

E MODULUS OF ELASTICITY

PR POISSON'S RATIO

2. WALL/COLUMN DATA

NW SETS OF CARDS WITH (A(I),XI(I),YI(I)) 3F10.4

A(I) AREA OF WALLS/COLUMNS

XI(1) MOMENT OF INERTIA OF WALLS/COLUMNS
 ABOUT X-AXIS

**YI(I) MOMENT OF INERTIA OF WALLS/COLUMNS
 ABOUT Y-AXIS**

3. BEAM DATA

CARD TYPE 3(A)

NO. SETS OF CARDS WITH SPECIES B132 2E12, 4

XIP(I) MOMENT OF INERTIA OF BEAM

(C) CLEAR SPAN OF BEAM

CARD TYPE 3(B)

NO. SETS OF CARDS WITH $(XII(i,j), j=1,2)$ 214

XII(I) CONNECTIVITY OF BEAMS

CARD TYPE 3(C)

ONE CARD WITH (BD) F10.4

RD DEPTH OF BEAM

4. LOADING ON THE BUILDING

ONE CARD WITH (WX,WY,PX,PY) 4F10.3

WX U.D.L. IN X-DIRECTION

BY U.D.L. IN Y-DIRECTION

PX POINT LOAD IN X-DIRECTION

PX	POINT LOAD IN X-DIRECTION	C
PY	POINT LOAD IN Y-DIRECTION	C
E	MODULUS OF ELASTICITY	C
PR	POISSON'S RATIO	C
Z	VERTICAL DISTANCE OF ANY SECTION	C
	FROM TOP	C
Y1	HORIZONTAL DEFLECTION IN X-DIRECTION	C
Y2	HORIZONTAL DEFLECTION IN Y-DIRECTION	C
F	AXIAL FORCE OF WALLS/COLUMNS	C
ECSI	Z/BH NONDIMENSIONAL PARAMETER	C
XI	MOMENT OF INERTIA OF WALLS/COLUMNS IN X-DIRECTION	C
YI	MOMENT OF INERTIA OF WALLS/COLUMNS IN Y-DIRECTION	CC
BD	BEAM DEPTH	CCC

PROGRAMME DESCRIPTION

- I. PROCEDURE FOR STANDARD MATRIX OPERATIONS AND FOR THE EVALUATION OF EXPONENTIAL FUNCTIONS C
1. SINH(A) CALCULATES SINH C
2. COSH(A) CALCULATES COSH C
3. SOLVE (A,B,X,N) C

II. OTHER PROCEDURES :

4. DATAINPUT : READS THE DATA FOR WALLS/COLUMNS AND C
CONNECTING BEAMS. READS APPLIED LOADING. C
 5. FORMALPHA2 : FORMS THE A-MATRIX IN EQN. 3-24 C
 6. FORMBETA : FORMS B-MATRIX IN EQN. 3-24
 7. FORMC : FORMS C-MATRIX IN EQN. 3-28
 8. FORMD : FORMS D-MATRIX IN EQN. 3-29
 9. DEFLECTION : CALCULATES THE HORIZONTAL DEFLECTION OF
THE TUBE IN BOTH X AND Y DIRECTION.
 10. ACTUAL STRESS : CALCULATES THE VALUES OF ACTUAL STRESS
AT THE EDGES OF THE WALLS, AT SPECIFIED
HEIGHTS, RESULTING FROM A CONTINUOUS
MEDIUM ANALYSIS.

- ## PART OF BRIEF

CARD TYPE 1(A)

```

CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
      INTEGER XII
      DIMENSION A(18),XI(18),YI(18),ELCOR(18,2),XIP(18),B(18),XIC(18),XL
      +(18),YL(18),BETA(18),ALPHA(18,18),C(18,18),BK(18),D(18,39),ZZ(39)
      +,YS(39,18),T(39,18),YL1(39),YL2(39),F(39,18),BMX(39,18),BMY(39,18)
      +,X(18),XII(18,2),BSH(39,18),GM(39,18),WMT(39,18),WMB(39,18)
      +,WS(39,18)
      READ (1,15) NW,NO,NT
15   FORMAT (3I5)
      READ (1,5) SH,BH,E,PR
5    FORMAT(4F10.3)
      READ*(1,16) (A(I),XI(I),YI(I),I=1,NW)
16   FORMAT(3F10.5)
      READ (1,17) ((ELCOR(I,J),J=1,2),I=1,NW)
17   FORMAT( 2F10.4)
      READ (1,21) (XIP(I),B(I),I=1,NO)
21   FORMAT( 2F10.4)
      READ(1,20) ((XII(I,J),J=1,2 ),I=1,NO)
20   FORMAT (2I4)
      READ (1,901) BD
901  FORMAT( F10.4)
      READ (1,902) WX,WY,PX,PY
902  FORMAT(4F10.4)
      WRITE(3,81) NW,NO,SH,BH,WX,WY,PX,PY,BD,E,PR
81   FORMAT(//T15,'ANALYSIS OF TUBULAR STRUCTURES BY CONTINUOUS MEDIUM
      +METHOD',//T12,60('*'),//T10,'UNIT OF LENGTH USED FOR ANALYSIS IS IN
      + FEET',//T10,'UNIT OF LOAD APPLIED IS IN KIPS',
      + //T10,'TOTAL NO OF (WALLS+COLUMNS)=',I3,/T10,'TOTAL NO OF OP
      +ENINGS=',I3,/T10,'STOREY HEIGHT=',F10.3,/T10,'BUILDING HEIGHT=',
      +F10.3,/T10,'U.D.L. IN X-DIRECTION=',F10.3,/T10,'U.D.L. IN Y-DIRECT
      +ION=',F10.3,/T10,'POINT LOAD IN X-DIRECTION=',F10.3,/T10,'POINT LO
      +AD IN Y-DIRECTION=',F10.3,/T10,'BEAM DEPTH = ',F10.3,
      + //T10,'MODULUS OF ELASTICITY=',F10.3,/T10,
      +'POISSON S RATIO=',F10.3,//)
      WRITE(3,82)
82   FORMAT(/T10,'PROPERTIES AND CO-ORDINATES OF WALLS/COLUMNS',//T8,48('*'),//T10,'(COLUMN+WALL)',5X,'(COLUMN+WALL)',5X,'MOMENT OF
      +INERTIA',5X,'MOMENT OF INERTIA', 5X,'C.G. OF WALLS/COLUMNS'
      +/T15,'NO',13X,'AREA',12X,'IN X-DIRECTION',8X,'IN Y-DIRECTION',10X,
      +'X',15X,'Y',//)
      DO 84 I=1,NW
84   WRITE(3,85) I,A(I),XI(I),YI(I),(ELCOR(I,J),J=1,2)
85   FORMAT(12X,I3,10X,F8.4, 11X,F10.4,11X,F10.4,10X,F10.4,8X,F10.4)
      WRITE(3,87)
87   FORMAT(/T10,'CONNECTIVITY AND PROPERTIES OF BEAMS',//T8,40('*'),//T3,
      +'OPENING/BEAM',6X,'CONNECTIVITY', 7X,
      +'MOMENT OF INERTIA',4X,'CLEAR SPAN', 6X,'C/C DISTANCE BETWEEN',5X,
      +'C/C DISTANCE BETWEEN', //T7,'NO',12X,'FROM',5X,' TO ',
      +10X,'OF BEAM ', 12X,'OF BEAM ', 9X,'WALLS/COLUMNS',9X,
      +'WALLS/COLUMNS',//T21,'WALL',7X,'WALL',//T22,'NO',8X,'NO',//)
86   FORMAT(8X,I3,8X,I3,8X,I3,6X,F12.4,10X,F10.4,10X,F10.4,10X,
      +F12.4)
      NW1=NW-1
      XIT = 0.0
      YIT = 0.0
      DO 18 I = 1,NW
      XIT = XIT + XI(I)
      YIT = YIT + YI(I)
18   XIC(I) = XIP(I)/(1+2.4*(1+PR)*(BD /B(I))**2)
      DO 89 I = 1,NO
      IF (I.EQ.NW) GO TO 208
      IK = I+1
      GO TO 207
89   T1= -4.0
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      T788= 0.0
      T789= 0.0
      T790= 0.0
      T791= 0.0
      T792= 0.0
      T793= 0.0
      T794= 0.0
      T795= 0.0
      T796= 0.0
      T797= 0.0
      T798= 0.0
      T799= 0.0
      T800= 0.0
      T801= 0.0
      T802= 0.0
      T803= 0.0
      T804= 0.0
      T805= 0.0
      T806= 0.0
      T807= 0.0
      T808= 0.0
      T809= 0.0
      T810= 0.0
      T811= 0.0
      T812= 0.0
      T813= 0.0
      T814= 0.0
      T815= 0.0
      T816= 0.0
      T817= 0.0
      T818= 0.0
      T819= 0.0
      T820= 0.0
      T821= 0.0
      T822= 0.0
      T823= 0.0
      T824= 0.0
      T825= 0.0
      T826= 0.0
      T827= 0.0
      T828= 0.0
      T829= 0.0
      T830= 0.0
      T831= 0.0
      T832= 0.0
      T833= 0.0
      T834= 0.0
      T835= 0.0
      T836= 0.0
      T837= 0.0
      T838= 0.0
      T839= 0.0
      T840= 0.0
      T841= 0.0
      T842= 0.0
      T843= 0.0
      T844= 0.0
      T845= 0.0
      T846= 0.0
      T847= 0.0
      T848= 0.0
      T849= 0.0
      T850= 0.0
      T851= 0.0
      T852= 0.0
      T853= 0.0
      T854= 0.0
      T855= 0.0
      T856= 0.0
      T857= 0.0
      T858= 0.0
      T859= 0.0
      T860= 0.0
      T861= 0.0
      T862= 0.0
      T863= 0.0
      T864= 0.0
      T865= 0.0
      T866= 0.0
      T867= 0.0
      T868= 0.0
      T869= 0.0
      T870= 0.0
      T871= 0.0
      T872= 0.0
      T873= 0.0
      T874= 0.0
      T875= 0.0
      T876= 0.0
      T877= 0.0
      T878= 0.0
      T879= 0.0
      T880= 0.0
      T881= 0.0
      T882= 0.0
      T883= 0.0
      T884= 0.0
      T885= 0.0
      T886= 0.0
      T887= 0.0
      T888= 0.0
      T889= 0.0
      T890= 0.0
      T891= 0.0
      T892= 0.0
      T893= 0.0
      T894= 0.0
      T895= 0.0
      T896= 0.0
      T897= 0.0
      T898= 0.0
      T899= 0.0
      T900= 0.0
      T901= 0.0
      T902= 0.0
      T903= 0.0
      T904= 0.0
      T905= 0.0
      T9
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YL(I) = ELCOR(IK,2)-ELCOR(I,2)
WRITE(3,86) I,(XII(I,J),J=1,2),XIP(I),B(I),XL(I),YL(I)
C BETA(I) = 12*XIC(I)/B(I)**3/SH*(WX*XL(I)/2/YIT+WY*YL(I)/2/XIT)
BETA(I) = 12*XIC(I)/B(I)**3/SH*(PX*XL(I)/YIT+PY*YL(I)/XIT)
89 CONTINUE
C WRITE(3,70)(XL(I),YL(I),BETA(I),I=1,NW)
98 FORMAT(/T10,'DEFLECTION TABLE',/T8,24('*'),//T10,'Z/H',12X,
+'DEFLECTION IN',10X,'DEFLECTION IN',/T25,'X-DIRECTION',
+12X,'Y-DIRECTION'//)
DO 22 I=1,NW
DO 22 J=1,NW
IF((I.EQ.1).AND.(J.EQ.NW)) GO TO 77
IF((I.EQ.NW).AND.(J.EQ.1)) GO TO 77
IF (I.EQ.NW) GO TO 300
IIK = I+1
GO TO 301
300 IIK = 1
301 IF (I.NE.J) GO TO 23
ALPHA(I,J) = 12*XIC(I)/SH/B(I)**3*(YL(I)**2/XIT+XL(I)**2/YIT
++1/A(I)+1/A(IIK))
GO TO 22
23 IF ( J.EQ.(I-1)) GO TO 24
IF ( J.EQ.(I+1)) GO TO 25
ALPHA(I,J) = 12*XIC(I)/SH/B(I)**3*(YL(J)*YL(I)/XIT+XL(I)*
+XL(J)/YIT)
GO TO 22
24 ALPHA(I,J) = 12*XIC(I)/SH/B(I)**3*(YL(I)*YL(I-1)/XIT+XL(I)*
+XL(I-1)/YIT-1/A(I))
GO TO 22
25 ALPHA(I,J) = 12*XIC(I)/SH/B(I)**3*(YL(I)*YL(IIK)/XIT+XL(I)*
+XL(IIK)/YIT-1/A(IIK))
GO TO 22
77 ALPHA(I,J) = 12*XIC(I)/SH/B(I)**3*(YL(I)*YL(J)/XIT+XL(I)*
+XL(J)/YIT-1/A(J))
22 CONTINUE
PI = 3.14159
DO 39 KK=1,NT
K = KK*2-1
R = PI**2/4/BH**2
DO 36 I= 1,NO
DO 35 J= 1,NO
IF(J.NE.I) GO TO 34
C(I,J) = ALPHA(I,J)+R*K**2
GO TO 35
34 C(I,J) = ALPHA(I,J)
35 CONTINUE
C BK(I)= BETA(I)*16*BH**2/PI**3/K**3*(PI*K*SIN(K*PI/2)-2)
BK(I)= BETA(I)*8*BH/PI**2/K**2*SIN(K*PI/2)
36 CONTINUE
CALL BARI (C,BK,X,NW)
DO 10 I= 1,NW
10 D(I,KK) = X(I)
39 CONTINUE
WRITE(3,98)
DO 40 L= 1,19,2
Z = L*SH/2
DO 41 I = 1,NO
YS(L,I) = 0.0
T(L,I) = 0.0
DO 42 KK= 1,8
K = KK*2-1
YS(L,I)= YS(L,I)+D(I,KK)*((SIN(K*PI/2)-SIN(K*PI*Z/2/BH))/K**2)
T(L,I)= T(L,I)+D(I,KK)*SIN(K*PI*Z/BH/2)
42 CONTINUE
44 CONTINUE

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      YI = 0.0
      YX = 0.0
      DO 43 I=1,N0
      YX = YX+YS(L,I)*XL(I)
      YY = YY+YS(L,I)*YL(I)
  43  CONTINUE
      C   Y1=(WX*(Z**4/24-BH**3*Z/6+BH**4/8)-4*BH**2/PI**2*YX)/E/XIT
      C   Y2=(WY*(Z**4/24-BH**3*Z/6+BH**4/8)-4*BH**2/PI**2*YY)/E/YIT
      C   Y1=(PX*(Z**3/6-BH**2*Z/2+BH**3/3)-4*BH**2/PI**2*YX)/E/XIT
      C   Y2=(PY*(Z**3/6-BH**2*Z/2+BH**3/3)-4*BH**2/PI**2*YY)/E/YIT
      YL1(L) = Y1
  42  YL2(L) = Y2
      WRITE(3,97) Z ,YL1(L),YL2(L)
  97  FORMAT(10X,F6.2,10X,G12.4,12X,G12.4)
      DO 44 I=1,NW
      IF (I.EQ.1) GO TO 401
      IK1 = I-1
      GO TO 402
  C
  401 IK1 = NW
  402 F(L,I)=T(L,I)-T(L,IK1)
  44  CONTINUE
      TSL1=0
      TSL2=0
      DO 48 I=1,N0
      TSL1=TSL1+T(L,I)*XL(I)
      TSL2=TSL2+T(L,I)*YL(I)
  48  CONTINUE
      DO 49 I=1,NW
      BMX(L,I)=(WY*Z**2/2-TSL2)*XI(I)/XIT
      BMY(L,I)=(WX*Z**2/2-TSL1)*YI(I)/YIT
      BMX(L,I)=(PY*Z-TSL2)*XI(I)/XIT
      BMY(L,I)=(PX*Z-TSL1)*YI(I)/YIT
  49  CONTINUE
  62  FORMAT(/T10,'VALUES OF BEAM SHEAR FORCES',/T15,'T-MATRIX',/T5,
  +35('*'),//(/ 6E15.6))
  40  CONTINUE
      WRITE(3,62)((T(L,I),I=1,NW),L=1,39)
      DO 90 I= 1,39,2
      WRITE(3,91)
  91  FORMAT(/T10,'TABLE FOR BENDING MOMENT AND AXIAL FORCES',/T9,42
  +'*'),//T10,'Z ',20X,'WALL-1',20X,'WALL-2',20X,'WALL-3',20X,
  +'WALL-4',/T18,'MX',8X,'MY',8X,'F',9X,'MX',8X,'MY',8X,'F',9X,
  +'MX',8X,'MY',8X,'F',9X,'MX',8X,'MY',8X,'F')
      Z = I*SH/2
      WRITE(3,92) Z , (BMX(I,K),BMY(I,K),F(I,K),K=1,NW)
  92  FORMAT( /8X,F6.2,( /T12,12E10.3))
  90  CONTINUE
      DO 105 I = 1,NW
      DO 101 L = 1,39,2
      IF (L.EQ.1) GO TO 102
      LL = L-2
      BSH(L,I) = F(L,I)-F(LL,I)
      GM(L,I) = BSH(L,I)*B(I)/2
      GO TO 101
  102 BSH(L,I) = F(L,I)
      GM(L,I) = BSH(L,I)*B(I)/2
  101 CONTINUE
      L = 1
      WMT(L,I) = GM(L,I)
      WS(L,I) = (WMT(L,I)+BMY(L,I))*2/SH
      WMB(L,I) = WS(L,I)*SH/2+BMY(L,I)
      DO 103 L=3,39,2
      LL = L-2
      WMT(L,I) = GM(L,I)-WMB(LL,I)
      WMT(I,T) = WMT(I,T)+BMY(I,T)*SH/2+BMY(I,T)*SH/2

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103 CONTINUE
105 CONTINUE
    WRITE(3,110) ((BSH(L,I),I=1,NW),L=1,10)
    WRITE(3,111) (( GM(L,I),I=1,NW),L=1,10)
    WRITE(3,112) ((WMT(L,I),I=1,NW),L=1,10)
    WRITE(3,113) ((WMB(L,I),I=1,NW),L=1,10)
110 FORMAT(/T10,' TABLE FOR BEAM SHEAR ',/T8,22('*'),/( 4E12.5))
111 FORMAT(/T10,' TABLE FOR GIRDER MOMENT ',/T8,22('*'),/( 4E12.5))
112 FORMAT(/T10,' TABLE FOR WALL MOMENT TOP ',/T8,22('*'),/( 4E12.5))
113 FORMAT(/T10,' TABLE FOR WALL MOMENT BOT ',/T8,22('*'),/( 4E12.5))
    STOP
    END

SUBROUTINE BARI(A,B,X,N)
DIMENSION A(18,18),B(18),X(18)
NMI = N-1
DO 30 K= 1,NMI
    KPI = K+1
    L = K
C     SEARCH FOR LARGEST PIVOT
    DO 40 I = KPI,N
        IF (ABS(A(I,K))-ABS(A(L,L))) 40,40,50
50    L = I
40    CONTINUE
        IF (L-K) 60,60,70
C     ROW INTERCHANGE
70    DO 80 J= K,N
        TEMP = A(K,J)
        A(K,J) = A(L,J)
        A(L,J) = TEMP
        TEMP = B(K)
        B(K) = B(L)
        B(L) = TEMP
50    DO 30 I= KPI,N
        XM= A(I,K)/A(K,K)
        A(I,K) = 0.0
        DO 9 J=KPI,N
            A(I,J)= A(I,J)-XM*A(K,J)
30    B(I) = B(I)-XM*B(K)
C     END OF ELIMINATION AND START OF BACK-SUBSTITUTION
    X(N) = B(N)/A(N,N)
    I = NMI
12    IPI = I+1
    SUM = 0.0
    DO 20 J= IPI,N
        SUM = SUM+A(I,J)*X(J)
        X(I) = (B(I)-SUM)/A(I,I)
        I = I-1
        IF(I) 11,11,12
11    RETURN
    END

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2.88	0.3456	1.3824	
2.88	0.3456	1.3824	
2.88	0.3456	1.3824	
2.88	0.3456	1.3824	
2.88	0.3456	1.3824	
-20.0	-16.0		
-12.0	-16.0		
-4.0	-16.0		
4.0	-16.0		
12.0	-16.0		
20.0	-16.0		
20.0	-8.0		
20.0	0.0		
20.0	8.0		
20.0	16.0		
12.0	16.0		
-4.0	16.0		
-4.0	16.0		
-12.0	16.0		
-20.0	16.0		
-20.0	8.0		
-20.0	0.0		
-20.0	-8.0		
0.3112	5.6		
0.3112	5.6		
0.3112	5.6		
0.3112	5.6		
0.3112	5.6		
0.3112	5.6		
0.3112	5.6		
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0.3112	5.6		
0.3112	5.6		
0.3112	5.6		
0.3112	5.6		
0.3112	5.6		
0.3112	5.6		
1	2		
2	3		
3	4		
4	5		
5	6		
6	7		
7	8		
8	9		
9	10		
10	11		
11	12		
12	13		
13	14		
14	15		
15	16		
16	17		
17	18		
18	1		
	4.32		
0.0	0.0	100.0	0.0

*END PRINT

*READY

