AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING

ELASTIC STABILITY OF BRACED AND UNBRACED MULTI BAY-MULTI STOREY FRAMES

BY

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A THESIS

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بسم الله الرحمن الرحيم

STATEMENT

This dissertation is submitted to Ain Shams University for the degree of Master of Science in Structural Engineering.

The work included in this thesis was carried out by the author in the department of Structural Engineering, Ain Shams University, from Nov., 1984 to Sep., 1989.

No part of this thesis has been submitted for a degree or a qualification at any other University or Institution.

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Abstract:

The effect of providing knee braces on the stability of different types of frames is studied. The critical buckling loads of rectangular multi-bay frames and multi-storey frames provided with knee braces are investigated. The study is extended to include non-rectangular frames provided with knee braces, frames with stepped column sections carrying crane loads and multi-bay frames with different bay heights. Different knee braing distributions inside the frames are treated in order to obtain the optimum distribution of knee braces of each type of frames. The excluding of knee braces from any storey of multi-storey frames has been carried out to investigate the effect of such elimination on the critical buckling load of the frame. The study includes the mathematical procedure to deduce "Theory of Multiples" for multi-bay frames provided with knee braces. Computer programmes are prepared to calculate the critical buckling loads using direct method and stiffness method of analysis.

Key Words:

buckling load - knee brace - stability - bending stiffness ratio - length ratio.

TABLE OF CONTENTS

LIST OF NOTATIONS

The following symbols are used in this thesis. Other symbols not listed below are defind where they are used:

A_b = Cross sectinal area of a beam

A_c = Cross sectional area of a column

A_k = Cross sectional area of knee brace member

a = Knee brace height

B = Length of beam or span of frame

b = Knee brace width

c = Carry-over factor for fixed end member when sidesway is prevented

E = Young's modulus of elasticity

F = Force in knee brace member

$G_1, G_2, G_3, G_4, G_5, G_6$ and G_7 = Elements of member stiffness matrix

H = Secondary force causing shear on columns produced due to sidesway of frame

I_b = Moment of interia of frame beam

I_c = Moment of interia of frame column

$\bar{K}$ = Member stiffness matrix corresponding to the general coordinates of the system

K = Member stiffness matrix corresponging to the local coordinates of the member, or

= EI/L = Bending stiffness of a member

K_b = EI_b/B = Bending stiffness of frame beam

T = Transformation matrix

u = Displacement in X-direction

v = displacement in Y-direction

W = Disturbing agent

X and Y = General coordinates of the system

x and y = Local coordinates of the member

β = $A_k L^2 \sin^2\psi \cos\psi / I_c$ = Stiffness of Knee brace member

θ = Angle of rotation

Δ = Displacement of a frame, or

= Relative translation of a member

Δ_o = Displacement of a frame due to disturbing agent only

Δ_1 = Displacement of a frame due to applied load only

Δ_2 = Displacement of a frame due to applied load plus disturbing agent

ϕ = Angle of translation for the member

= Angle of inclination of a column to the vertical

ψ = Angle of inclination of a knee brace member with the column

λ = Angle at which local coordinates is inclined to the system coordinates

μ = $\sqrt{P/EI}$, or $\sqrt{P/EI_c}$

ρ = P/P_E = Ratio of axial load Euler's load

ρ_{cr} = P_{cr}/P_E = Critical load parameter

K_c = EI_c/L = Bending stiffness of column

L = Height of column

M = Bending moment

m = Magnification factor for moments produced at ends of fixed member which is in a state of pure-shear sway due to axial force effect

N = Number of storeys in a frame, or

= Moment of inertia ratio for column protions

n = Stiffness factor for fixed end member which is in a state of no-shear sway

O = Carry-over factor for fixed end member which is in a state of no-shear sway

P = External virtical load acting on a frame

P_{cr} = Elastic critical load

P_E = $\pi^2 EI_c/L^2$=Euler's load of a column

P_x and P_y = Nodal forces at X and Y directions respectively

Q = Stiffness of a frame at any load parameter

Q_o = Stiffness of a frame at the absence of the vertical applied load

R = Column height ratio, or

= Bay height ratio

r = Beam length ratio

S = stiffness factor for fixed end member when side-sway is prevented

INTRODUCTION

The theory of Elastic Stability is considered to be the most effective aspect which governs the safety of structural frameworks. Timoshenko (1)investigated the isolated struts under different loading, geometry and boundary conditions. He, also treated the single bay-single storey rectangular frames. Single bay-multi storey rectangular frames were studied by Merchant (5,6). Livesly and Chandler (2) introduced the main stability coefficients which helped in simplifying the analysis. Salem (3,7,11) remarkably continued to the understanding of the phenomenon and the methods of analysis. His study is extended to single and multi-storey rectangular frames with different loading patterns and boundary conditions taking axial deformation of columns in the analysis. He, also treated trapezoidal frames as well as rectangular frames provided with bracing members. Korashy (10) studied several cases of multi- storey braced rectangular frames including the effect of axial deformation of bracing members as well as the columns. Zidan (9) studied the effect of the change of geometry under the increasing load. Saad (12) investigated single bay-single storey rectangular frames provided with knee braces. G.F.Iskandar (15) studied the effect of knee bracing on the stability of some cases of pitched roof frames. The present study in the thesis is concentrated on t e effect of knee bracing elements on the stability of different types of rectangular frames. Rectangular single storey- multi bay frames, multi storey-single bay frames and multi storey- multi bay frames provided with knee braces are investigated taking the axial deformation of knee braces in the consideration. Various systems of knee braces having the same total area are applied on the frames treated in order to compare the results of buckling loads and obtain the cases of optimum distribution of knee braces dimensions, density and positions in cases of various beam to column stiffness ratio. "Theory of Multiples" for multi-bay frames provided with knee braces is proved mathematically. The effect of excluding of knee braces from any intermediate storey of multi-storey frames on the stability of such frames is studied. The study is extended to investigate the same effects on the stability of trapezoidal frames as well as non-rectangular frames with unequal-vertical columns provided with knee braces. The effect of variation of bay heights and the level of portions included by knee braces on the buckling loads of multi-bay frames are investigated. Frames with stepped column sections carrying crane loads provided with knee braces are also treated . Several computer programs in BASIC language are prepared for each of the above cases . The results are illustrated on the attached curves, in a manner, to facilitate the design and optimize the proportioning of structural frameworks.

CHAPTER -I-

METHOD OF ANALYSIS

1-1 Introduction.

1-2 General Assumptions.

1-3 Direct Method For The Determination Of The Elastic Critical Buckling Load Of Frames.

1-4 Stiffness Method For The Determination Of The Elastic Critical Buckling Loads Of Frames.

1-1 Introduction

The main object of this chapter is to describe in details the different methods used for obtaining the elastic critical buckling loads of structural frameworks.

These methods are quite different in dealing with the problem, but all are based on the same main simplifying assumptions considered in the analysis. These assumptions will be discussed first. The direct elastic stability analysis will be described together with the operations for the general sway problem. The stiffness method for the determination of the elastic critical buckling loads will also be tackled.

1-2 General Assumptions :

The analysis of structural frameworks carried out in this thesis is based on the following main assumptions :

1- The frame material is perfectly elastic, i.e the stress-strain relationship is to be indefinitely elastic.

2- Buckling outside the plane of the frame is prevented when studying the in-plane buckling of frame and vice-versa. This means that any member of the frame is undergoing flexure about one principal axis only and that bending about the other principal axis does not occur.