

PRFELB

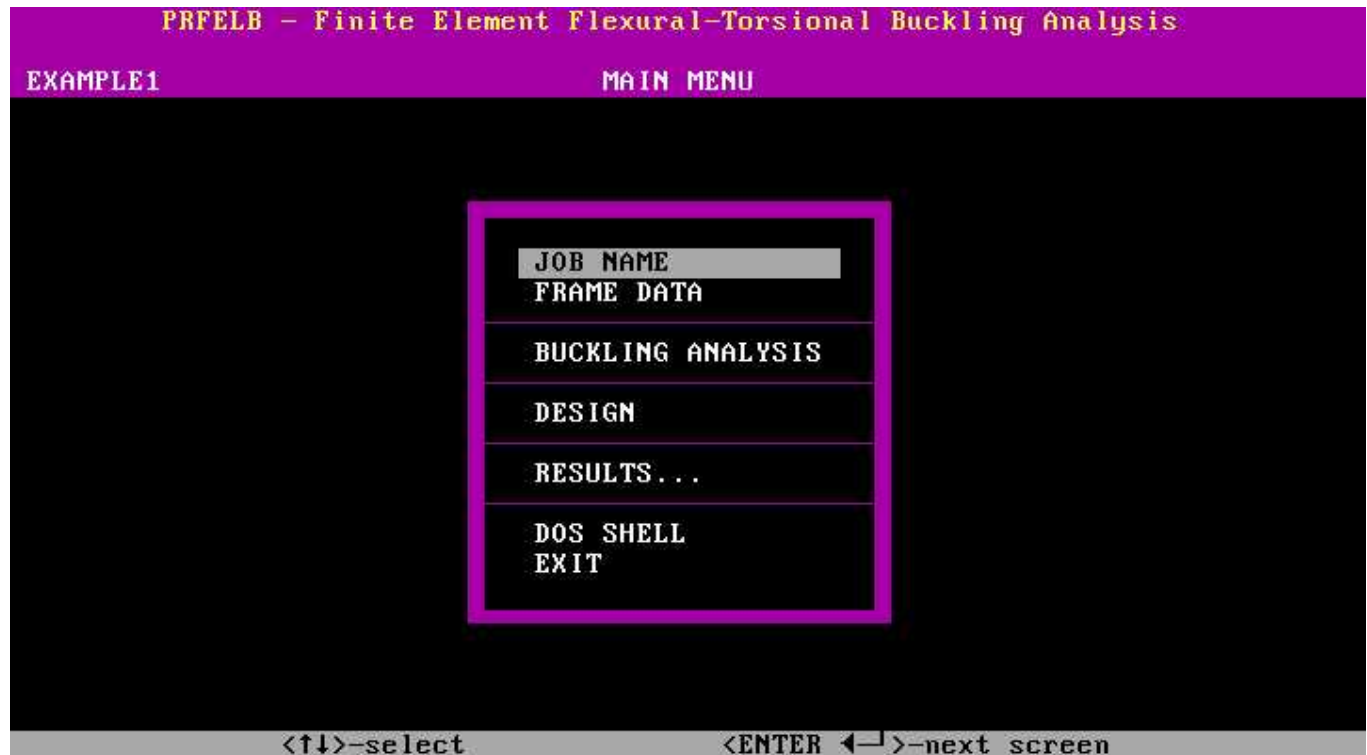


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<http://www.civil.usyd.edu.au/case/software.shtml>

Introduction

PRFELB is a user-friendly computer program for predicting the elastic flexural-torsional buckling load factor of beams and plane rigid frames. The frame can be subjected to point forces and moments and uniformly distributed loads in its plane. The frame can be restrained by rigid or elastic restraints, or continuous elastic restraints. The members may be monosymmetric such that their plane of symmetry is the plane of the structure. PRFELB can also analyse the flexural-torsional buckling of beams of any cross-section, provided the axial forces are zero. PRFELB first performs a 1st order elastic analysis of a plane rigid frame. It calculates the in-plane pre-buckling stress resultants which are then used in the flexural-torsional buckling analysis. The results of the 1st order elastic analysis include the in-plane deformations and stress resultants at buckling. The results of the flexural-torsional buckling analysis include the buckling load factor and the buckled shape. Simply supported and continuous hot-rolled beams and cold-formed purlins can be designed with PRFELB by the methods described in the Australian Steel Structures Standard AS 4100-1990 and the Australian/New Zealand Cold-Formed Steel Structures Standard AS/NZS 4600:1996.





Data

The frame is modelled by subdividing it into a series of straight line elements. The ends of the elements intersect at nodes. The input data for the frame includes the geometry of the frame, the in-plane supports and out-of-plane restraints, the section and material properties of the frame elements, and the loading. The out-of-plane restraints include discrete rigid or elastic restraints (eg fly bracing) and continuous elastic restraints (eg roof sheeting). The loads can be applied above or below the centroid of a section. A user-friendly data processor can be used for the creation of data for a new frame or for the modification of data for an existing frame. Help screens provide advice concerning the nature of the data required, and a facility exists for the automatic generation of the node and element numbers for some standard frames. A section library is also available for the selection of many standard hot-rolled and cold-formed sections.

PRFELB - Finite Element Flexural-Torsional Buckling Analysis

EXAMPLE1 **NODE DATA**

PRIMARY **NODES** **ELEMENTS** **PROPERTIES** **NODE REST** **CONT REST** **LOADS** **GRAPHICS**

EXAMPLE PORTAL FRAME kN m

node no	Z	Y	in-plane			buckling				PR (°)
			δZ	δY	θX	δX	θY	θZ	$\theta Z'$	
1	0	0	0	0	1	0	0	1	1	0
2	0	-3	1	1	1	1	1	1	1	0
3	0	-6	1	1	1	0	1	1	0	0
4	5	-6.75	1	1	1	1	1	1	1	0
5	10	-7.5	1	1	1	1	1	1	1	0
6	15	-8.25	1	1	1	1	1	1	1	0
7	20	-9	1	1	1	0	1	1	0	0
8	20	-6	1	1	1	1	1	1	1	0
9	20	-3	1	1	1	1	1	1	1	0
10	20	0	0	0	1	0	0	1	1	0

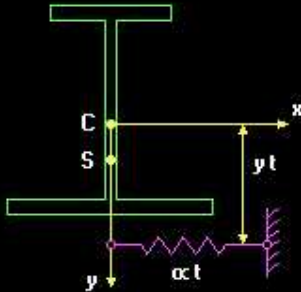
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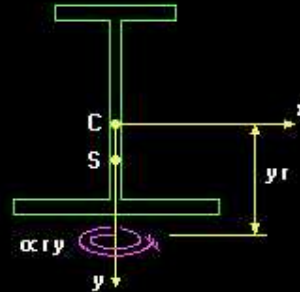
PRFELB - Finite Element Flexural-Torsional Buckling Analysis

EXAMPLE1

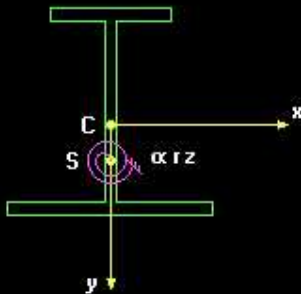
ELASTIC NODAL RESTRAINT DATA



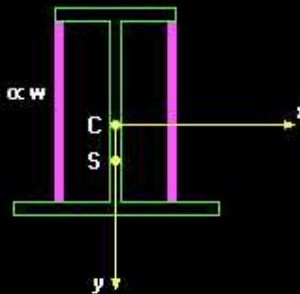
TRANSLATIONAL RESTRAINT



MINOR AXIS ROTATIONAL RESTRAINT



TORSIONAL RESTRAINT



WARPING RESTRAINT

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EXAMPLE1

STANDARD SECTION TYPES

I-SECTIONS

- UB - universal beams
- UC - universal columns
- UBP - universal bearing piles
- CC - column core sections
- TFB - taper flange beams
- WB - welded beams
- WC - welded columns

CHANNELS

- PFC - parallel flange channels
- TFC - taper flange channels

ANGLES

- EA - equal angles
- UA - unequal angles

HOLLOW SECTIONS

- RHS - rectangular hollow sections
- SHS - square hollow sections
- CH2 - circular hollow sections C250
- CH3 - circular hollow sections C350

T-SECTIONS

- BT - tees cut from UBs
- CT - tees cut from UCs

COLD-FORMED SECTIONS

- CEE - channel sections
- ZED - zed sections

FABRICATED SECTIONS

- PWG - plate web girders
- BOX - welded box sections

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EXAMPLE1 GRAPHICAL DATA CHECK

The diagram shows a frame structure with nodes 1 through 10. Nodes 1, 2, and 3 are on the left vertical member. Nodes 4, 5, 6, and 7 are on the top horizontal member. Nodes 8, 9, and 10 are on the right vertical member. Element 1 is the bottom part of the left member, element 2 is the top part. Elements 3, 4, 5, and 6 are segments of the top member. Elements 7, 8, and 9 are segments of the right member. Node 10 is fixed. Horizontal loads are applied at nodes 2, 3, 8, and 9. Vertical loads are applied at nodes 4, 5, and 6.

FRAME

NODES

ELEMENTS

ELEMENT TYPES

SUPPORTS

RIGID RESTRAINTS

NODE RESTRAINTS

CONT RESTRAINTS

LOADS

AXES

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Flexural-Torsional Buckling Analysis

The flexural-torsional buckling analysis in PRFELB is based on the use of the finite element method to solve the energy equation for flexural-torsional buckling. This equation states that the strain energy stored in the structure during buckling is equal to the work done by the applied loads during buckling. Cubic shape functions are used to describe the variation of the buckling displacements along an element with respect to the nodal values. This allows the strain energy and work done to be described in matrix format. Equating the strain energy and work done leads to a linear eigenvalue problem in which the lowest eigenvalue (load factor) defines the load set at which the structure first buckles and the corresponding eigenvector defines the buckled shape of the structure.

The program initially carries out an in-plane (pre-buckling) 1st order elastic analysis, and then uses the results of this to carry out the flexural-torsional buckling analysis. The results of the 1st order elastic analysis (multiplied by the buckling load factor) can be displayed graphically as the in-plane deformations at buckling, and the stress resultants (moment and axial force) at buckling. The results can also be shown on the screen in text mode.



PRFELB - Finite Element Flexural-Torsional Buckling Analysis

EXAMPLE1 **RESULTS**



At buckling, maximum $\delta Z = .3198$ at node 5
maximum $\delta Y = .046186$ at node 5
maximum $\theta X = -.077732$ at node 1

Scale: 10 ▲▼

FRAME

NODES

ELEMENTS

ELEMENT TYPES

SUPPORTS

RIGID RESTRAINTS

NODE RESTRAINTS

CONT RESTRAINTS

LOADS

DEFORMATIONS

MOMENT

SHEAR

AXIAL

BUCKLED SHAPE u

BUCKLED SHAPE ϕ

AXES

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PRFELB - Finite Element Flexural-Torsional Buckling Analysis

EXAMPLE1	RESULTS
-----------------	----------------



At buckling, maximum $M = 6.1855E+02$ in element 3

FRAME

NODES

ELEMENTS

ELEMENT TYPES

SUPPORTS

RIGID RESTRAINTS

NODE RESTRAINTS

CONT RESTRAINTS

LOADS

DEFORMATIONS

MOMENT

SHEAR

AXIAL

BUCKLED SHAPE u

BUCKLED SHAPE ϕ

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PRFELB - Finite Element Flexural-Torsional Buckling Analysis

EXAMPLE1 RESULTS

At buckling, maximum N = -8.3277E+01 in element 7

FRAME

NODES

ELEMENTS

ELEMENT TYPES

SUPPORTS

RIGID RESTRAINTS

NODE RESTRAINTS

CONT RESTRAINTS

LOADS

DEFORMATIONS

MOMENT

SHEAR

AXIAL

BUCKLED SHAPE u

BUCKLED SHAPE ϕ

AXES

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The results of the flexural-torsional buckling analysis include the load factor and the buckled shape of the frame. The buckled shape is defined by the eigenvector obtained from the eigenvalue analysis. The eigenvector contains the out-of-plane deflection, lateral rotation, twist rotation, and warping at each node point. The buckled shape can be displayed graphically as the variation of the out-of plane deflection and twist rotation along each member.



PRFELB - Finite Element Flexural-Torsional Buckling Analysis

EXAMPLE1	RESULTS	
 <p>OUT-OF-PLANE DEFLECTION u</p> <p>Load factor = 2.1491 Mode number 1</p>		FRAME
		NODES
		ELEMENTS
		ELEMENT TYPES
		SUPPORTS
		RIGID RESTRAINTS
		NODE RESTRAINTS
		CONT RESTRAINTS
		LOADS
		DEFORMATIONS
		MOMENT
		SHEAR
		AXIAL
BUCKLED SHAPE u		
BUCKLED SHAPE ϕ		
AXES		

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Design by Buckling Analysis to AS 4100

A method of designing hot-rolled beams against flexural-torsional buckling by using the results of an elastic buckling analysis is allowed explicitly in the Australian Steel Structures Standard AS 4100. This method is known as design by buckling analysis and its use can lead to more economical sections over those obtained from conventional design. In PRFELB, the design by buckling analysis procedure involves dividing the beam into segments between lateral restraints and checking the out-of-plane member capacity of each segment. For this, the maximum moment in the segment at buckling is found from the elastic flexural-torsional buckling analysis. In addition, the section capacity is checked at every cross-section of the beam and the in-plane member capacity is checked for the beam length. The results of the design by buckling analysis include the design load factor and various quantities from AS 4100. The design load factor is the factor by which the design loads must be multiplied so that the design load effect is equal to the controlling design capacity. If the design load factor is less than 1.0, then the beam is unsafe.



PRFELB - Finite Element Flexural-Torsional Buckling Analysis

EXAMPLE2 DESIGN BY BUCKLING ANALYSIS TO AS 4100

EXAMPLE BEAM kN m

Design results for Segment 4 (critical segment)

410 UB 53.7	Compact section		
Grade 250	M* = 234.4	Mob = 571.0	$\alpha_m = 1.078$
Length = 3.000	Msx = 275.6	Mos = 525.6	$\alpha_s = .7728$
Zex = 0.106E-02	Uvm = 432.1	Moo = 487.3	Mbx = 229.7

Section capacity design load factor = 1.235
Member capacity design load factor = .8820

Governing failure criterion : Flexural-torsional buckling (5.6)

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Design of Cold-Formed Purlins to AS/NZS 4600

The Australian/New Zealand Cold-Formed Steel Structures Standard AS/NZS 4600 is based on the limit states method of design. The standard allows the results of an elastic flexural-torsional buckling analysis to be used to compute the member capacity of the section. In addition to yielding and flexural-torsional buckling, PRFELB can design cold-formed lipped C-section purlins for distortional buckling, shear, combined bending and shear, bearing, combined bending and bearing, purlin bearing and bolt shear. Both lapped and unlapped purlins can be designed. Z-sections laterally restrained by roof sheeting can be designed by treating the Z-section as an equivalent C-section.



PRFELB - Finite Element Flexural-Torsional Buckling Analysis

EXAMPLE3 DESIGN OF COLD-FORMED PURLINS TO AS/NZS 4600

3 SPAN LAPPED Z-PURLIN

Failure Criterion	Design Load Factor	Location
Section moment capacity	2.6899	Node 5
Flexural-torsional buckling capacity	2.1187	Node 5
Distortional buckling capacity	2.2221	Node 5
Purlin fastened to sheeting	2.1661	Node 5
Shear	4.0684	Node 10
Combined bending and shear	2.3885	Node 12
Bearing	2.1817	Node 1
Combined bending and bearing	2.6900	Node 11
Purlin bearing	4.1815	Node 11
Bolt shear	4.4344	Node 11

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System Requirements

Although PRFELB is a DOS program, it can be run under Windows 95/98/ME/NT/2000/XP.

Download a Demonstration Copy & Demo

Visit our website: <http://ww.civil.usyd.edu.au/case/software.shtml>

SALES INQUIRIES

Information about computer software and prices is available from:

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