ADAPTIC

User Manual

Revision 1.3b

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Chapter 1. INTRODUCTION

ADAPTIC is an adaptive static and dynamic structural analysis program which has been developed to provide an efficient tool for the nonlinear analysis of steel and composite frames, slabs, shells and integrated structures. The program features are described briefly hereafter.

The initial development of ADAPTIC was driven by the needs of the offshore industry for an accurate yet efficient nonlinear analysis of offshore jackets subject to extreme static and dynamic loading. This motivated the development of pioneering adaptive nonlinear dynamic analysis techniques for framed structures, accounting for geometric and material nonlinearity, which formed the basis of Prof. Izzuddin's PhD thesis, and which were extensively applied in nonlinear structural analysis under earthquake loading. Since then the program has been extensively developed to deal with other extreme loading, such as fire and blast, as well as numerous additional structural forms, such as R/C and steel-decked composite slabs, cable and membrane structures, and curved shells. Most of these novel developments have been published in leading international scientific and professional journals as well as in international conferences (see http://www.imperial.ac.uk/people/b.izzuddin/publications).

This version of the manual (V1.1) covers mainly the frame analysis capabilities of ADAPTIC. The more recent developments dealing with slabs and shells will be described in forthcoming versions of the manual. Therefore, the following discussions focus on the nonlinear analysis of plane and space frames.

Inelastic analysis of steel frames may be performed by either of two methodologies. The first is an approximate solution using ideal plastic hinge elements, while the second is a more accurate solution employing elements which account for the spread of plasticity across the section depth and along the member length. For reinforced concrete and composite frames, inelastic analysis is performed using the second approach only.

The loading can be either applied forces or prescribed displacements/accelerations at nodal points. The loads can vary proportionally under static conditions, or can vary independently in the time or pseudo-time domains. The latter variation can be utilised for static or dynamic analysis.

1.1 Types of Analysis

Loads can be applied at the nodal positions for the translational and rotational freedoms in the three global directions (X, Y, Z). A load can be an applied force or a prescribed displacement/acceleration. The only restriction on the application of loads is that a load corresponding to a structural freedom should only be specified once, and that the loaded freedom should not be restrained. This requires that ground excitation, for example, should be specified as an applied acceleration at the ground nodal freedoms, and that these freedoms should not be restrained.

Static loads applied only once to the structure at the start of analysis. Any further loads applied during proportional or time-history loading are applied incrementally on top of these loads.

The initial loads are useful for modelling the structure dead weight. Also, they can model initial support settlement through using a displacement load at a support nodal freedom.

1.1.1 Static analysis – proportional loading

These are loads which vary proportionally according to one load factor. The behaviour of a structure under proportional loading can be studied in the post-ultimate range using the displacement control strategy. These loads cannot be applied with time-history loads within the same analysis.

1.1.2 Static analysis – time-history loading

These are loads which can vary independently in the time or pseudo-time domain. As such, if the structure has reached a stage where the loads cannot be incremented as specified by the user, the analysis is terminated since the program cannot establish how the user would want to continue the analysis.

Time-history loads are useful for modelling cyclic loading under various force or displacement regimes.

1.1.3 Dynamic analysis

Dynamic loads can be specified in a similar way to time-history loads and can be applied forces or prescribed accelerations. Note that the latter allow the modelling of ground excitation, which is different from the case of static analysis where support motion is indicated by means of prescribed displacements. The ability to model loads varying independently in the time domain allows asynchronous excitation to be represented with relative ease.

1.1.4 Eigenvalue analysis

Eigenvalue analysis is performed using the efficient Lanczos algorithm, which requires as input the number of modes within the range of frequencies of interest as well as the number of iterative steps. This algorithm can also be used with dynamic analysis, where the frequencies and modes are obtained during analysis using the tangent stiffness.

1.2 Structural Modelling

The following sections describe how various analysis assumptions can be modelled using the ADAPTIC elements, which are discussed in detail in Chapter 6. Note that different assumptions can be utilised in the same analysis for different members of the structure. Note also that similar element types usually exist for 2D and 3D analysis, distinguished by the last number in the element type identifier (e.g. **qph2** & **qph3**)

1.2.1 Elastic Modelling

Quartic elastic elements (**qel2**, **qel3**) can be used to model the beam-column effect and large displacements for selected structural members. One quartic element is capable of representing the beam-column action and large displacements for a whole member.

1.2.2 Plastic Hinge Modelling

Quartic plastic hinge element (**qph2**, **qph3**) have the same elastic representation power of elements (**qel2**, **qel3**) but can represent material inelasticity through the utilisation of zero-length plastic hinges at the element end nodes. The introduction of these plastic hinges depends on the interaction between the bending moments at the element ends and the axial force, established from the specification of the element cross-section.

1.2.3 Elasto-Plastic Modelling

Detailed elasto-plastic modelling, based on the inelastic uniaxial material response, can be performed using cubic elasto-plastic elements (**cbp2**, **cbp3**), which accurately model the spread of plasticity across the cross-section through the utilisation of material monitoring point. To represent the spread of inelasticity along the member length, a number of cubic elements, usually over 5, are required per member.

1.2.4 Adaptive Elasto-Plastic Modelling

Adaptive analysis can be applied in the elasto-plastic analysis of steel frames to reduce the modelling task, which previously required a fine mesh of cubic elements all over the structure, and to enable the analysis to be performed quite efficiently. The concept of adaptive analysis entails the utilisation of elastic quartic element (**qdp2**, **qdp3**) which would sub-divide into inelastic cubic elements (**cbp2**, **cbp3**) when inelasticity is detected during analysis. The analysis is started using only one quartic element per member, with element refinement performed automatically when necessary in zones along the element which are pre-defined by the user.

1.2.5 Joints and Boundary Conditions

Joint behaviour can be modelled by means of joint elements (**jel2**, **jel3**) with de-coupled axial, shear and moment actions. These joint elements can have any orientation, and may utilise a number of force-displacement relationships described in Chapter 4.

The joint elements may also be used to model special boundary conditions, such as inclined supports, soil-structure interaction and structural gaps, through choosing appropriate terms for the force-displacement relationships.

1.2.6 Dynamic Characteristics Modelling

The dynamic characteristics of the structure, namely mass and damping, are modelled by means of non-structural elements which must be included for dynamic analysis to be performed. The dynamic element types are:

Type	Description
cnm2, **cnm3**	Lumped mass elements
lnm2, **lnm3**	Linear distributed mass elements
cbm2, **cbm3**	Cubic distributed mass elements
cnd2, **cnd3**	Dashpot damping elements
rld2, **rld3**	Rayleigh damping elements

Chapter 2. Using ADAPTIC

2.1 ADAPTIC Data File

In order to perform nonlinear structural analysis using ADAPTIC, the problem data is stored in a data file which the program reads and processes. Such data specifies the structural configuration and the loading applied to structure, and must follow the syntax described in the **Data Syntax** chapter.

All ADAPTIC data files must have a ".dat" extension (e.g. one_storey.dat , SW_2.1.dat). A new data file may be created through modifying an existing data file or through typing the data from scratch. The former approach is usually more convenient, especially for parametric studies when only some data entries require modification.

2.2 Starting ADAPTIC

ADAPTIC currently runs on Linux workstations, where it is started using the following command:

```
{prompt} adaptic filename
```

Note that the *filename* does not include the ".dat" extension (e.g. adaptic one_storey).

ADAPTIC can also be run in the background using the following command:

```
{prompt} adaptic filename > filename.log &
```

where `filename.log` is a file which stores the job progress.

The execution of ADAPTIC invokes two successive stages. The first is a data reading stage, where the problem details are read from the data file, and several temporary files are created which incorporate problem and plotting information. The second is the analysis stage, where the information is retrieved from the temporary files and the nonlinear analysis is undertaken as specified. If the program seems to hang up before entering the reading stage, make sure that the two files `param.inc` and `stat.x` are removed from the working directory.

2.3 ADAPTIC Output Files

Upon successful completion of an ADAPTIC run, three additional files corresponding to *filename* should exist (`filename.out`, `filename.num` & `filename.plt`). The first file echoes the data file and contains the solution progress log. The second file contains the numerical results at all requested load/time steps. The third file is a plot file used by the post-processing programs.

Numerical results may be obtained through direct extraction from `filename.num`. Graphical visualisation of the results is also available through a number of post-processing programs described in the **Post-Processing** chapter.

Chapter 3. MATERIAL MODELS

The ADAPTIC library includes a number of uniaxial material models which can be used to model steel, concrete and other materials with similar behavioural characteristics. The models and their applicability are briefly described below, with full details given in next pages:

Model	Applicability
stl1	Bilinear steel model with kinematic strain-hardening
stl2	Multisurface steel model
con1	Simple trilinear concrete model
con2	Constant confinement concrete model
con3	Variable confinement concrete model

Cubic elasto-plastic formulations (**cbp2**, **cbp3**) utilise the full inelastic characteristics of the above models.

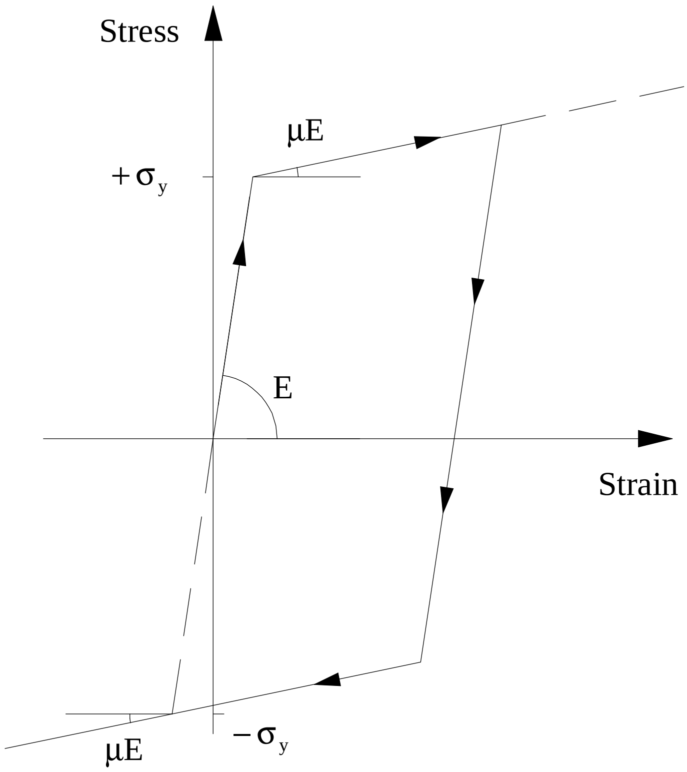
Quartic plastic hinge formulations (**qph2**, **qph3**) utilise only the yield characteristics of the models.

The elastic formulations utilise only the elastic characteristics of the models.

This section describes the material models available in ADAPTIC. Each model is referred to by a unique name, displayed at the top of the following pages, and requires the specification of a number of properties in the order indicated.

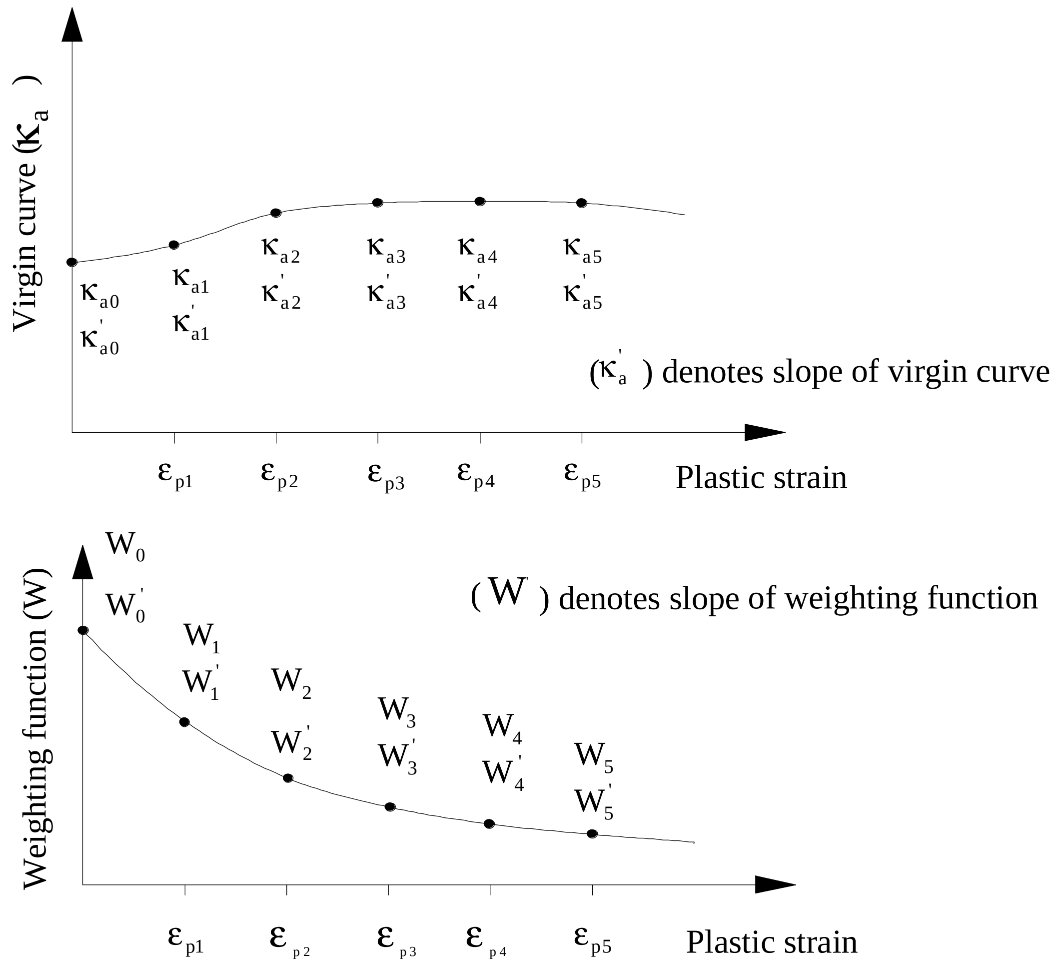
stl1

Description	Bilinear elasto-plastic model with kinematic strain hardening.	
No. of properties	3	
Properties	Young's modulus	(E)
	Yield strength	(σ_y)
	[Strain-hardening factor	(μ)]
Application	Uniaxial modelling of mild steel	



Material model ***stl1***

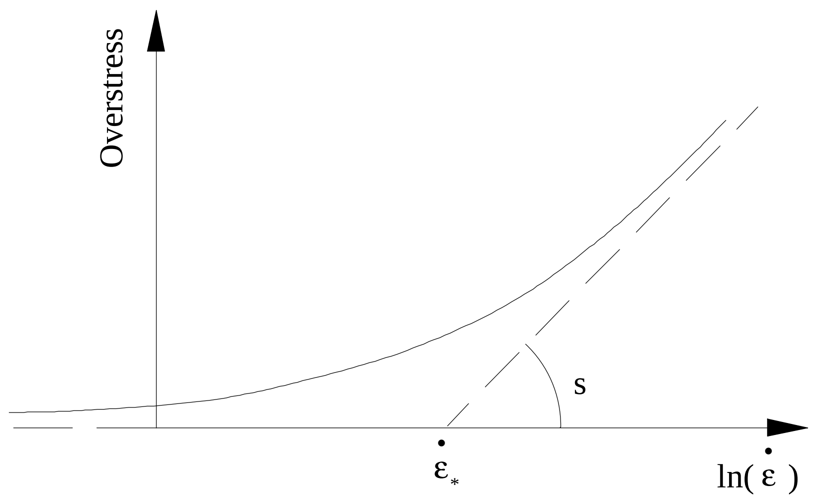
Description	Multi-surface model for cyclic plasticity.
No. of properties	42
Properties	Young's modulus (E)
	Plastic strains used for curves description
	$(\varepsilon_{p1}, \varepsilon_{p2}, ..., \varepsilon_{p5})$
	Virgin stress-plastic strain properties
	$(\kappa_{a0}, \kappa'_{a0}, \kappa_{a1}, \kappa'_{a1}, ..., \kappa_{a5}, \kappa'_{a5})$
	Cyclic stress-plastic strain properties
	$(\kappa_{b0}, \kappa'_{b0}, \kappa_{b1}, \kappa'_{b1}, ..., \kappa_{b5}, \kappa'_{b5})$
	Weighting function properties
	$(W_0, W'_0, W_1, W'_1, ..., W_5, W'_5)$
Application	Cyclic behaviour of steel modelling hardening, softening and mean stress relaxation.
Restrictions	No descending branch beyond ultimate point (i.e $\kappa'_{a5} > 0$, $\kappa'_{b5} > 0$).



Material model ***stl2***

stl3

Description	Rate-sensitive bilinear elasto-plastic model with kinematic strain hardening.	
No. of properties	5	
Properties	Young's modulus	(E)
	Yield strength	(σ_y)
	Strain-hardening factor	(μ)
	Rate-sensitive parameter	(s)
	Rate-sensitive parameter	($\dot{\varepsilon}$)
Application	Uniaxial modelling of mild steel	



Material model ***stl3***

stl4

Description Bilinear material model

No. of properties 20

Properties Young's modulus and temperatures used for trilinear description:

$$(E_1, E_2, T_1, T_2, T_3)$$

Yield strength and temperatures for trilinear description

$$(\sigma_{y1}, \sigma_{y2}, T_{\sigma 1}, T_{\sigma 2}, T_{\sigma 3})$$

Strain-hardening factor and temperatures for trilinear description:

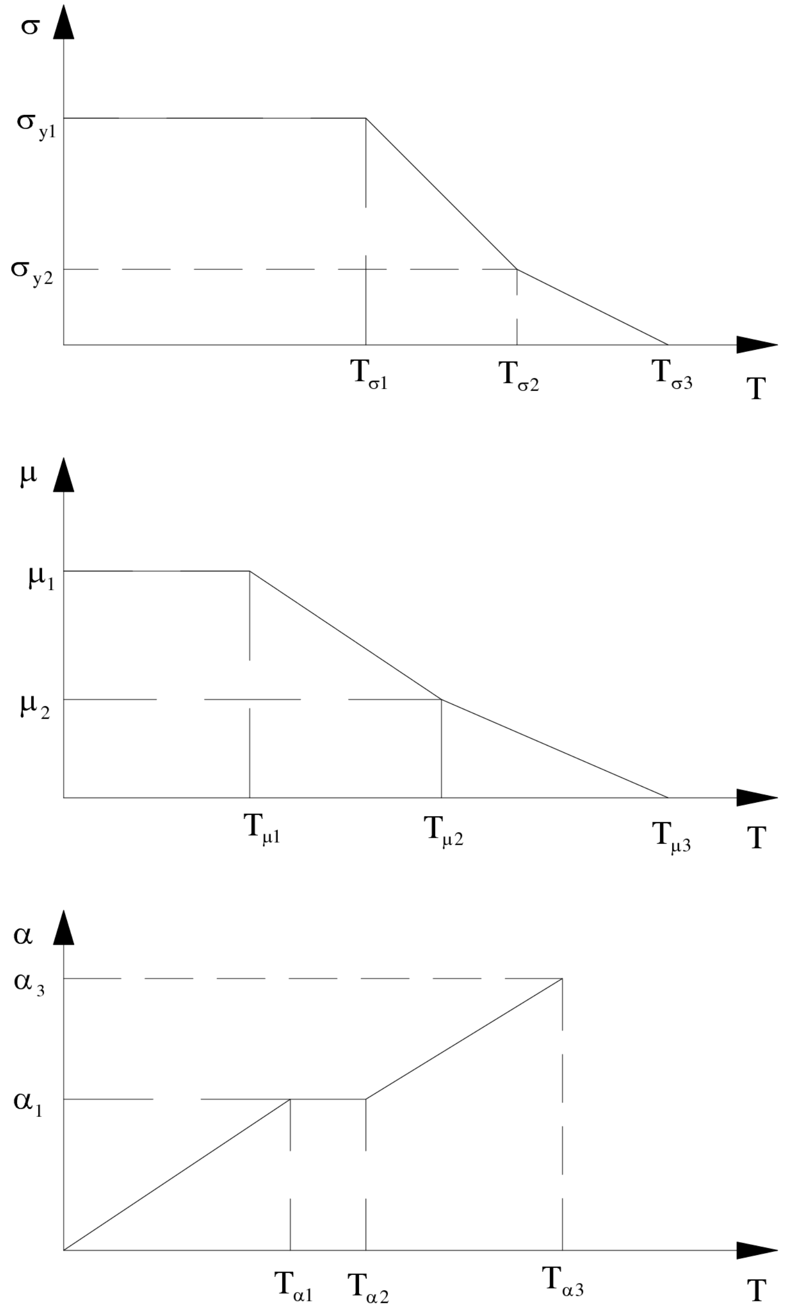
$$(\mu_1, \mu_2, T_{\mu 1}, T_{\mu 2}, T_{\mu 3})$$

Thermal strain and temperatures

$$(\alpha_1, \alpha_3, T_{\alpha 1}, T_{\alpha 2}, T_{\alpha 3})$$

Application Requires the specification of Young's modulus, the yield strength, the strain-hardening factor, the thermal strain and their variations with temperature.

Restrictions

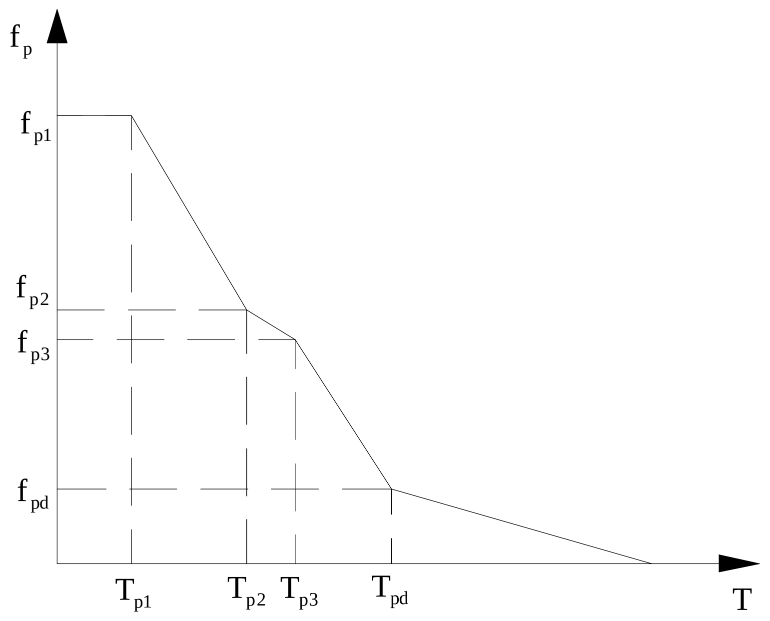


Material model ***stl4***

stl5

Description	Creep model
No. of properties	28
Properties	The first 20 properties are the same as those of the bilinear model. Material constants for modelling creep (A, B, C, D, F, G, ΔH, R, σ^*)
Application	In addition to the 20 parameters for the bilinear material model, 8 more parameters are required to specify the creep response of the material
Restrictions	

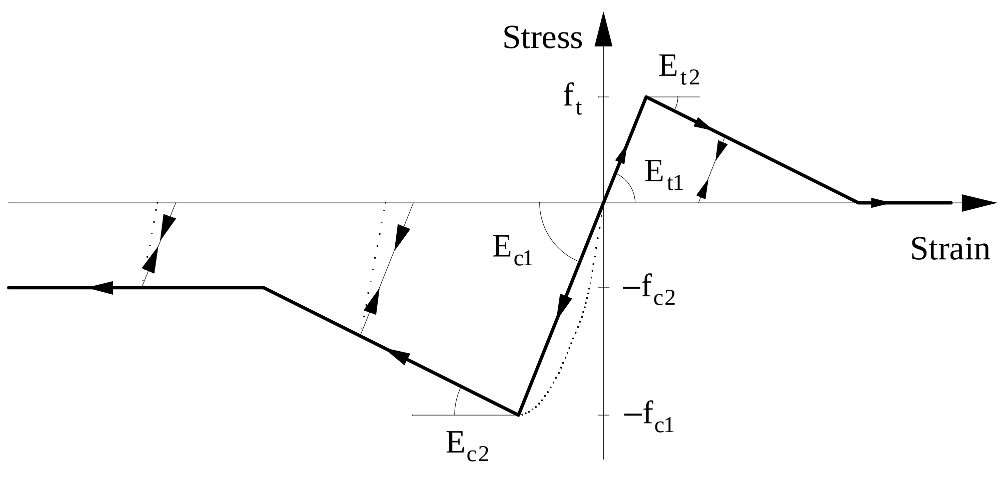
Description	Elliptical model
No. of properties	36
Properties	Young's modulus and corresponding temperatures $(E_1, E_2, E_3, E_4, T_1, T_2, T_3, T_4, T_5)$ Yield strength and corresponding temperatures $(f_{y1}, f_{y2}, f_{y3}, f_{y4}, T_{y1}, T_{y2}, T_{y3}, T_{y4}, T_{y5})$ Proportional limit and corresponding temperatures $(f_{p1}, f_{p2}, f_{p3}, f_{p4}, T_{p1}, T_{p2}, T_{p3}, T_{p4}, T_{p5})$ Thermal strain and corresponding temperatures $(\alpha_1, \alpha_2, \alpha_3, \alpha_4, T_{\alpha 1}, T_{\alpha 2}, T_{\alpha 3}, T_{\alpha 4}, T_{\alpha 5})$
Application	requires 36 parameters in total to describe Young's modulus, the proportional limit, the yield strength, the thermal strain and their variations with temperature. The nine parameters used to define the proportional limit and its variation with temperature is illustrated in figure. The other parameters are defined in the same sequence.
Restrictions	



Material model ***stl10***

con1

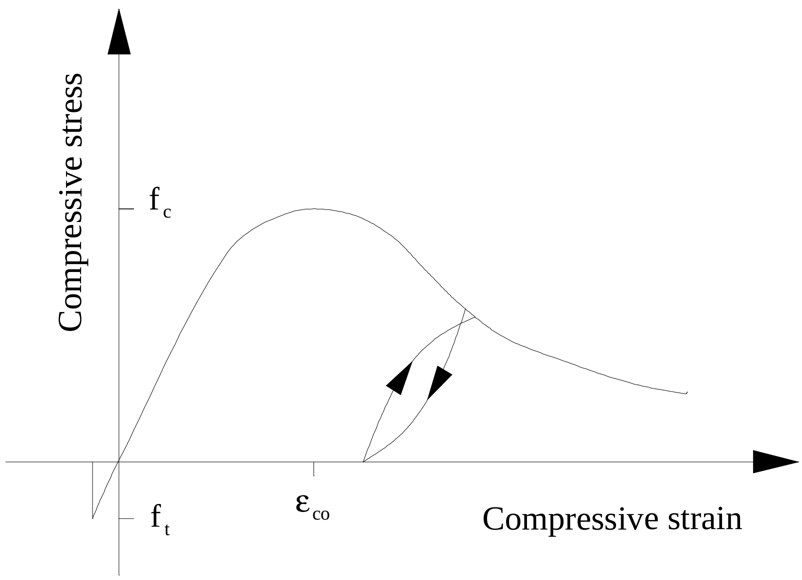
Description	Trilinear concrete model, with optional tensile response and quadratic initial compressive response.	
No. of properties	4	
Properties	Secant compressive stiffness	(E_{c1})
	Compressive strength	(f_{c1})
	Compressive softening stiffness	(E_{c2})
	Residual compressive strength	(f_{c2})
	[Initial tensile stiffness	(E_{t1})
	Tensile strength	(f_t)
	Tensile softening stiffness	(E_{t2})
	[Value of $\alpha = \left(E^t_{c1} - E_{c1}\right) / E_{c1}$	([0,1])]]
Application	Simplified uniaxial modelling of concrete material.	
Notes	E^t_{c1} is the initial tangent modulus in compression.	
	$\alpha > 0$ implies a quadratic initial compressive response.	



Material model ***con1***

con2

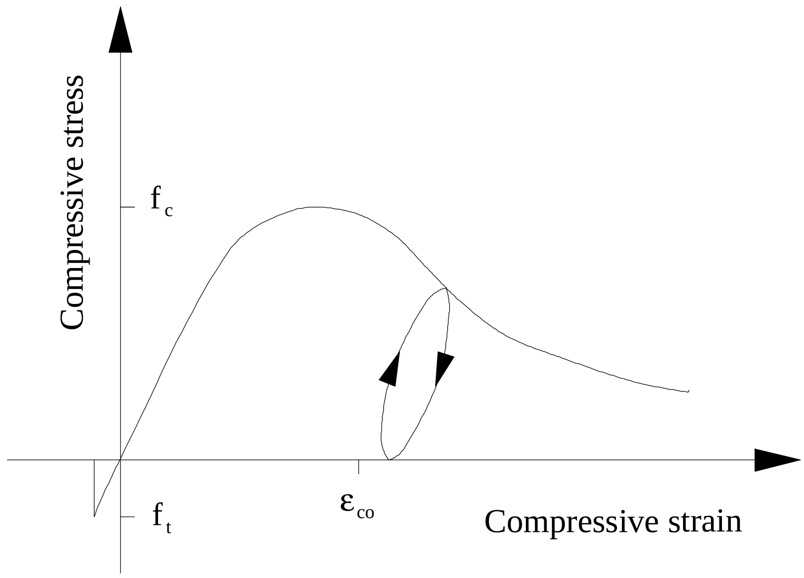
Description	Uniaxial constant confinement concrete model.	
No. of properties	4	
Properties	Concrete compressive strength	(f_c)
	Concrete tensile strength	(f_t)
	Crushing strain	(e_{co})
	Confinement factor	(k)
Application	Uniaxial modelling of concrete assuming constant confinement.	
Restrictions	Parameter units must be in Newtons and Millimetres.	
	The confinement factor must be greater or equal to 1.	



Material model ***con2***

con3

Description	Uniaxial variable confinement concrete model.	
No. of properties	10	
Properties	Concrete compressive strength	(f_c)
	Concrete tensile strength	(f_t)
	Crushing strain	(e_{co})
	Poisson's ratio of concrete	(ν)
	Yield stress of stirrups	(σ_y)
	Young's modulus of stirrups	(E)
	Strain hardening of stirrups	(μ)
	Diameter of stirrups	(ϕ)
	Stirrups spacing	(s)
	Diameter of concrete core	(Φ_c)
Application	Uniaxial modelling of concrete accounting for variable confinement effects, which are influenced by the core area within the stirrups, stirrups size and material, and stirrups spacing.	
Restrictions	Parameter units must be in Newtons and Millimetres.	



Material model ***con3***

con6

Description Trilinear compressive concrete model for elevated temperature, with zero tensile response.

No. of properties 28

Properties Compressive strength and its reduction factors $\left(r_1 = \frac{f_{c1(T)}}{f_{c1(0)}} \right)$:

$$(f_{c1},\ T_{r1,1},\ r_{1,1},\ T_{r2,1},\ r_{2,1},\ T_{r3,1},\ r_{3,1})$$

Peak compressive strain and temperature factors $\left(r_2 = \frac{\varepsilon_{c1(T)}}{\varepsilon_{c1(0)}} \right)$

$$(\varepsilon_{c1},\ T_{r1,2},\ r_{1,2},\ T_{r2,2},\ r_{2,2},\ T_{r3,2},\ r_{3,2})$$

Limit compressive strain and temperature factors $\left(r_3 = \frac{\varepsilon_{c2(T)}}{\varepsilon_{c2(0)}} \right)$

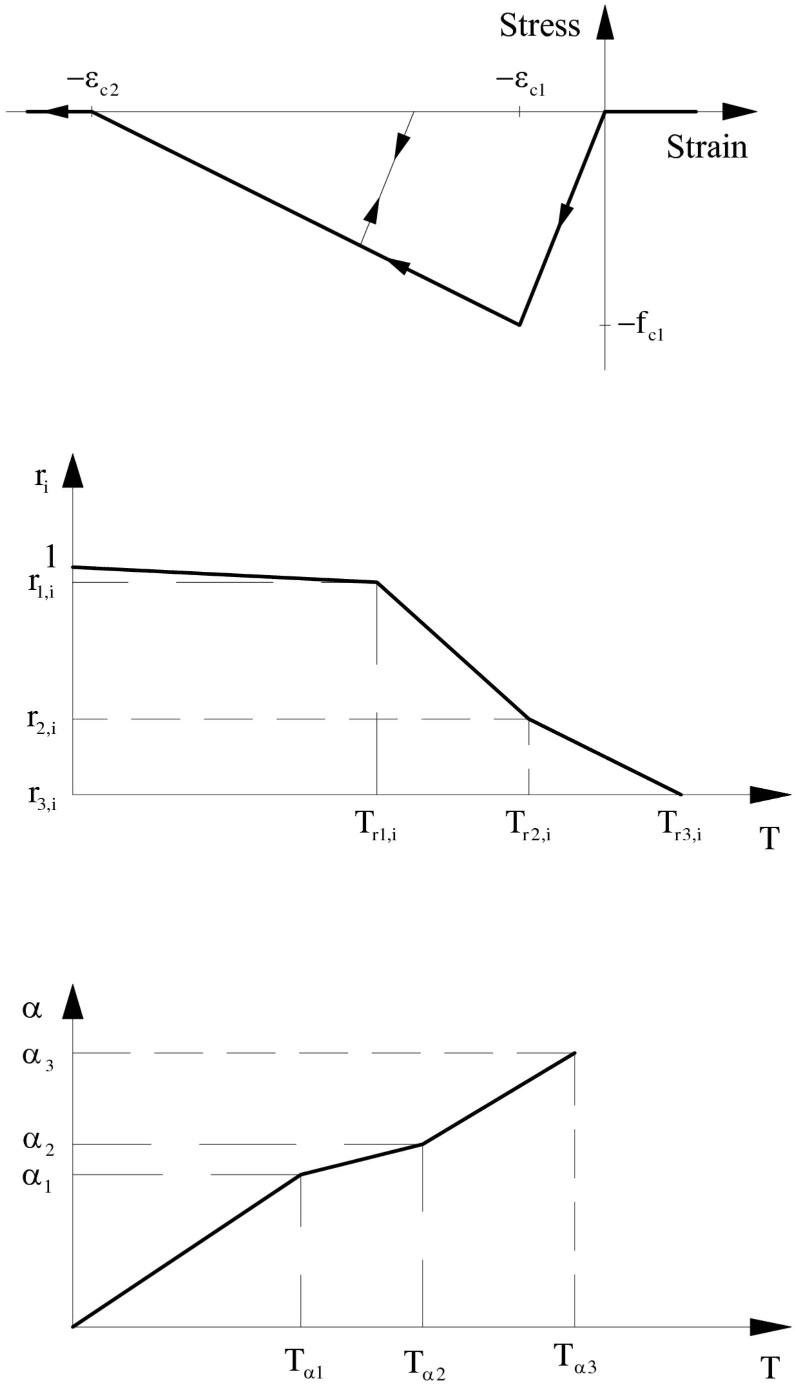
$$(\varepsilon_{c2},\ T_{r1,3},\ r_{1,3},\ T_{r2,3},\ r_{2,3},\ T_{r3,3},\ r_{3,3})$$

Thermal strain and temperatures

$$(0\,(\text{unused}),\ T_{\alpha 1},\ \alpha_1,\ T_{\alpha 2},\ \alpha_2,\ T_{\alpha 3},\ \alpha_3)$$

Application Requires the specification of the compressive strength, the peak compressive strain, the limit compressive strain at zero stress, the thermal strain and their variations with temperature. Note that r_2 and r_3 can be greater than 1.

Restrictions



Material model ***con6***

con9

Description Rotating-crack elevated-temperature model for concrete with linear compressive response.

No. of properties 25

Properties Young's modulus and temperatures:

$(E_0, r_2, T_1, T_2, T_3)$

Possion's ratio and temperatures:

$(\nu_0, r_2, T_1, T_2, T_3)$

Tensile strength and temperatures:

$(f_{to}, r_2, T_1, T_2, T_3)$

Softening slope and temperatures:

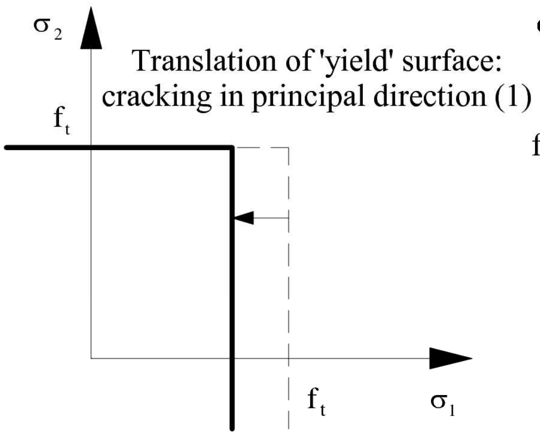
$(E_{cr0}, r_2, T_1, T_2, T_3)$

Thermal strain and temperatures

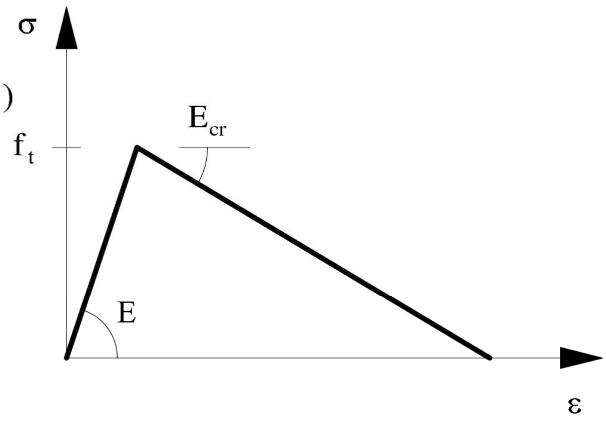
$(\varepsilon_{th1}, r_3, T_1, T_2, T_3)$

Application Plasticity-based model of concrete taking account of tensile cracking and elevated temperature.

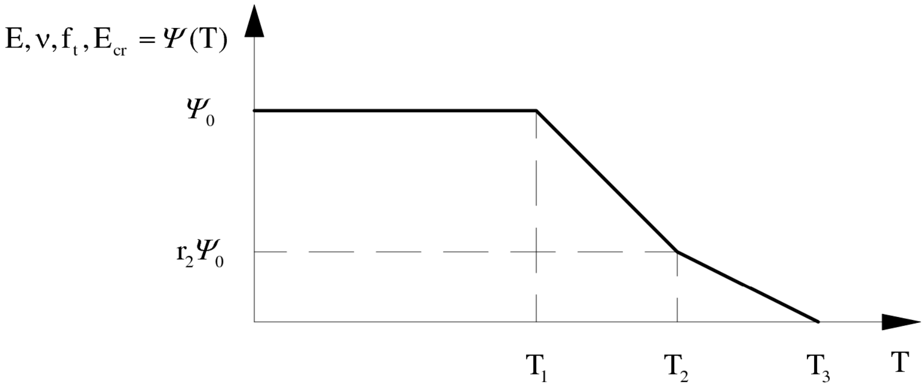
Restrictions

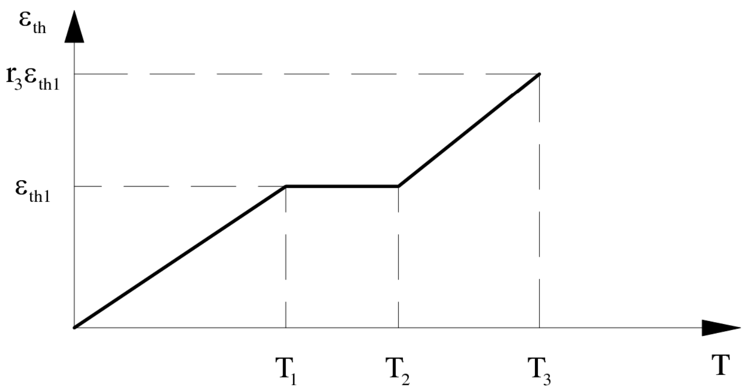


Tensile 'yield' surface in principal plane



Post-craking softening response





Material model ***con9***

con10

Description	Uniaxial Concrete model for long term analysis.	
No. of properties	6	
Properties	Type of analysis	1 (linear viscoelastic)
		2 (brittle viscoelastic)
	Time of casting	[days]
	Compressive strength	[N/mm^2]
	Tensile strength	[N/mm^2]
	Relative humidity of environment	[%]
	Notional size of member *	[mm]

Application

The long-term concrete model can be employed for long-term analysis. Two different options are allowed:

- Linear viscoelastic concrete
- Brittle viscoelastic concrete

In the linear viscoelastic analysis both creep and shrinkage phenomena are evaluated according to the CEB-FIP Model Code 90[1]. The Volterra's integral equation is solved by developing the relaxation function in series of exponential functions and applying the trapezoidal rule[2,3].

In the brittle viscoelastic analysis, the concrete is considered linear viscoelastic in compression and in tension before cracking. In cracked phase a brittle law is assumed and both creep and shrinkage are not taken into account.

References

[1] CEB 1993, CEB Bull. N°213/214: CEB-FIP Model Code 90. Comité Euro-Internetional du Béton, Lausanne, Switzerland, 1993.

[2] Amadio, C., Fragiacomo, M., and Macorini, L., "A New Effective F.E. Formulation for Studying the Long-Term Behaviour of Continuous Steel-Concrete Composite Beams", Proceedings of the Fifth World Congress on Computational Mechanics (WCCM V), July 7-12, 2002, Vienna, Austria, Editors: Mang, H.A. *et al.*, Publisher: Vienna University of Technology, Austria.

[3] Fragiacomo, M., "A finite element model for long-term analysis of timber-concrete composite beams", submitted to *Computer & Structures*.

(*) Given by the ratio $2A_c/u$, where A_c is the cross section and u is the perimeter of the member in contact with the atmosphere.

con11

Description	Fixed-crack elevated-temperature model for concrete.
No. of properties	37
Properties	Young's modulus and temperatures:

$(E_0, r_2, T_1, T_2, T_3)$

Possion's ratio and temperatures:

$(\nu_0, r_2, T_1, T_2, T_3)$

Tensile strength and temperatures:

$(f_{t0}, r_2, T_1, T_2, T_3)$

Tensile softening slope and temperatures:

$(a_{t0}, r_2, T_1, T_2, T_3)$

Thermal strain and temperatures

$(\varepsilon_{th1}, r_3, T_1, T_2, T_3)$

Compressive strength and temperatures:

$(f_{c0}, r_2, T_1, T_2, T_3)$

Normalised initial compressive strength:	(s_c)
Normalised residual compressive strength:	(r_c)
Normalised strain increment beyond ε_c:	(m_c)
Factor for biaxial compressive interaction:	(b_c)
Elastic shear retention factor:	(β_s)
Factor scaling direct tensile stresses for shear interaction:	(Φ_s)
Normalised shear softening relative to direct tensile softening:	(γ_s)

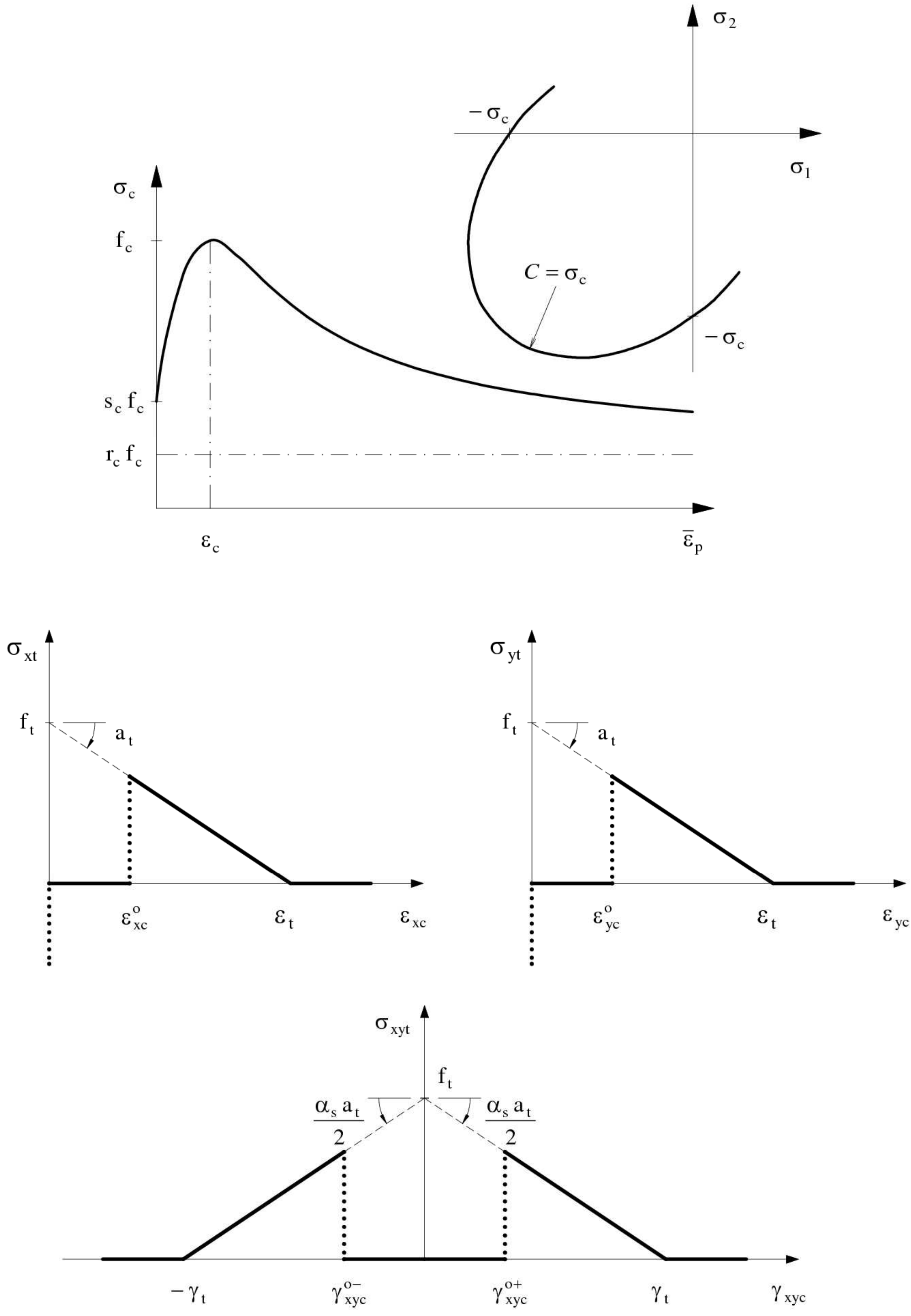
Application

Representation of tensile cracking and compressive nonlinearity, including softening effects.

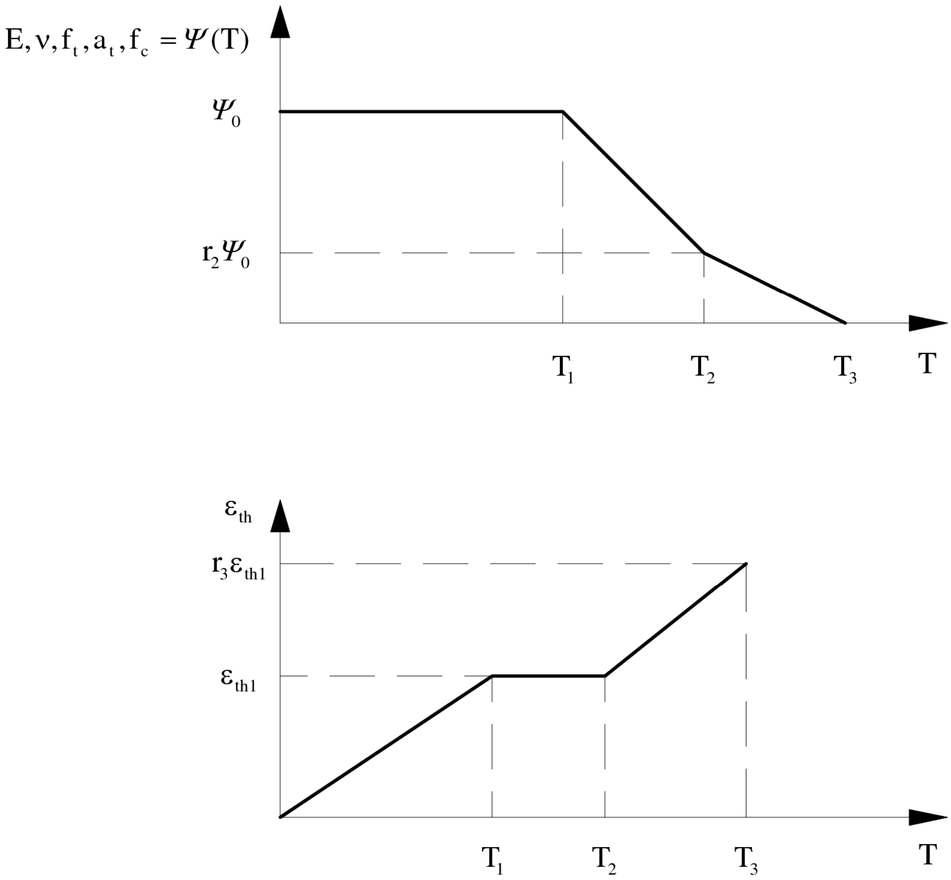
Modelling of crack opening and closure, the latter being an important requirement under dynamic loading and fire conditions

Consideration of the effects of elevated temperature, both in terms of the resulting thermal strains and the change of material properties

Restrictions



*Material model **con11** (Cont'd…)*



Material model ***con11***

gen1

Description Material properties for connection components/connected member at elevated temperature.

No. of properties 45

Properties Ultimate strength, temperatures and reduction factors for quadlinear description:

$$(\sigma_u, T_{r1,1}, r_{1,1}, T_{r2,1}, r_{2,1}, T_{r3,1}, r_{3,1}, T_{r4,1}, r_{4,1})$$

Young's modulus, temperatures and reduction factors:

$$(E, T_{r1,2}, r_{1,2}, T_{r2,2}, r_{2,2}, T_{r3,2}, r_{3,2}, T_{r4,2}, r_{4,2})$$

Reduced strain hardening coefficient, temperatures and reduction factors:

$$(\mu_r, T_{r1,3}, r_{1,3}, T_{r2,3}, r_{2,3}, T_{r3,3}, r_{3,3}, T_{r4,3}, r_{4,3})$$

Yield strength , temperatures and reduction factors:

$$(\sigma_y, T_{r1,4}, r_{1,4}, T_{r2,4}, r_{2,4}, T_{r3,4}, r_{3,4}, T_{r4,4}, r_{4,4})$$

Strain hardening coefficient, temperatures and reduction factors:

$$(\mu, T_{r1,5}, r_{1,5}, T_{r2,5}, r_{2,5}, T_{r3,5}, r_{3,5}, T_{r4,5}, r_{4,5})$$

Application Requires the specification of the compressive strength, the peak compressive strain, the limit compressive strain at zero stress, the thermal strain and their variations with temperature. Note that r_2 and r_3 can be greater than 1.

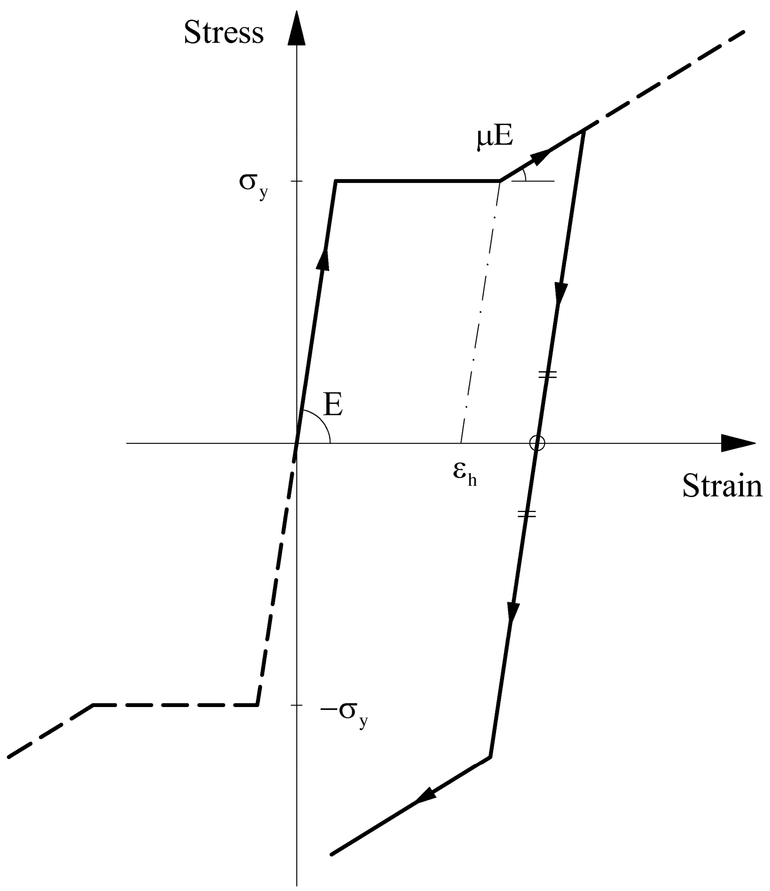
Restrictions Can be used to define material properties for joint element jbc2.

beth

Description	Elastic isotropic material model with thermal strains.	
No. of properties	3	
Properties	Young's modulus	(E)
	Possion's ratio	(ν)
	[Coefficient of thermal expansion	(α)]
Application	Can be used for 1D, 2D and 3D elements.	

bnsi

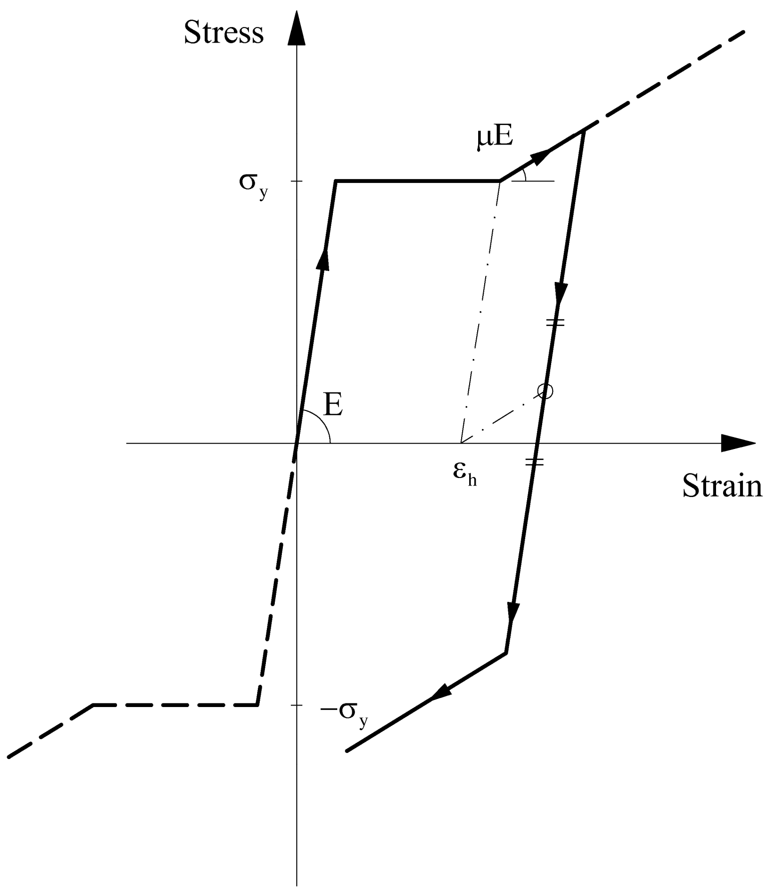
Description	Biaxial/triaxial elasto-plastic material model with *isotropic* strain-hardening.	
No. of properties	5	
Properties	Young's modulus	(E)
	Possion’s ratio	(ν)
	Yield strength	(σ_y)
	Strain-hardening parameter	(μ)
	Plastic strain at onset of hardening	(ε_h)
Application	Can be used for 1D, 2D and 3D elements	



Material model ***bnsi***

bnsk

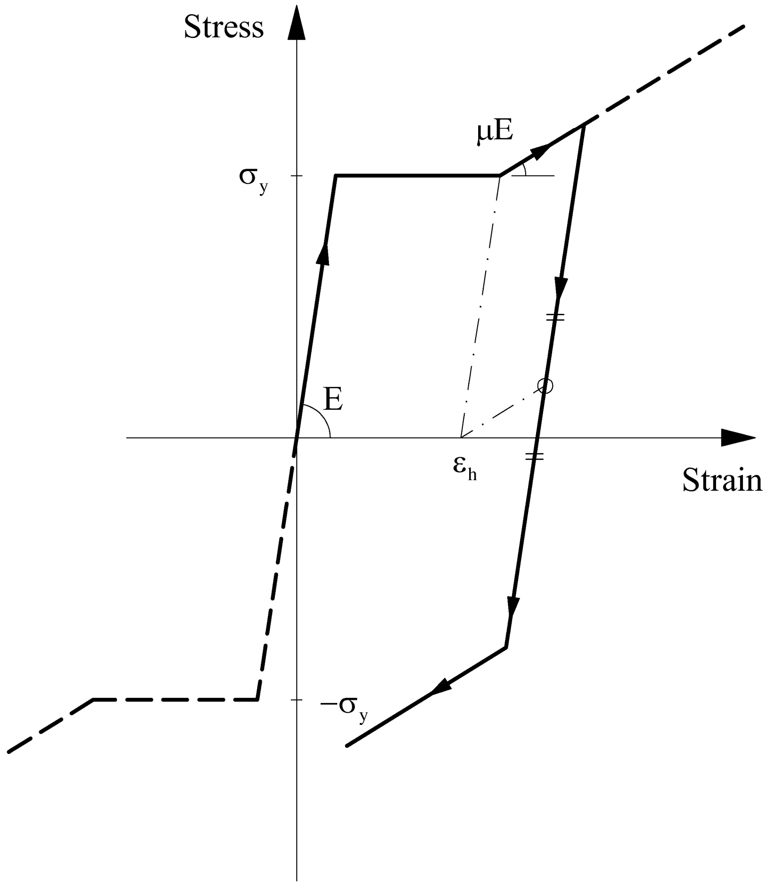
Description	Biaxial/triaxial elasto-plastic material model with *kinematic* strain-hardening.	
No. of properties	5	
Properties	Young's modulus	(E)
	Possion's ratio	(ν)
	Yield strength	(σ_y)
	Strain-hardening parameter	(μ)
	Plastic strain at onset of hardening	(ε_h)
Application	Can be used for 1D, 2D and 3D elements	



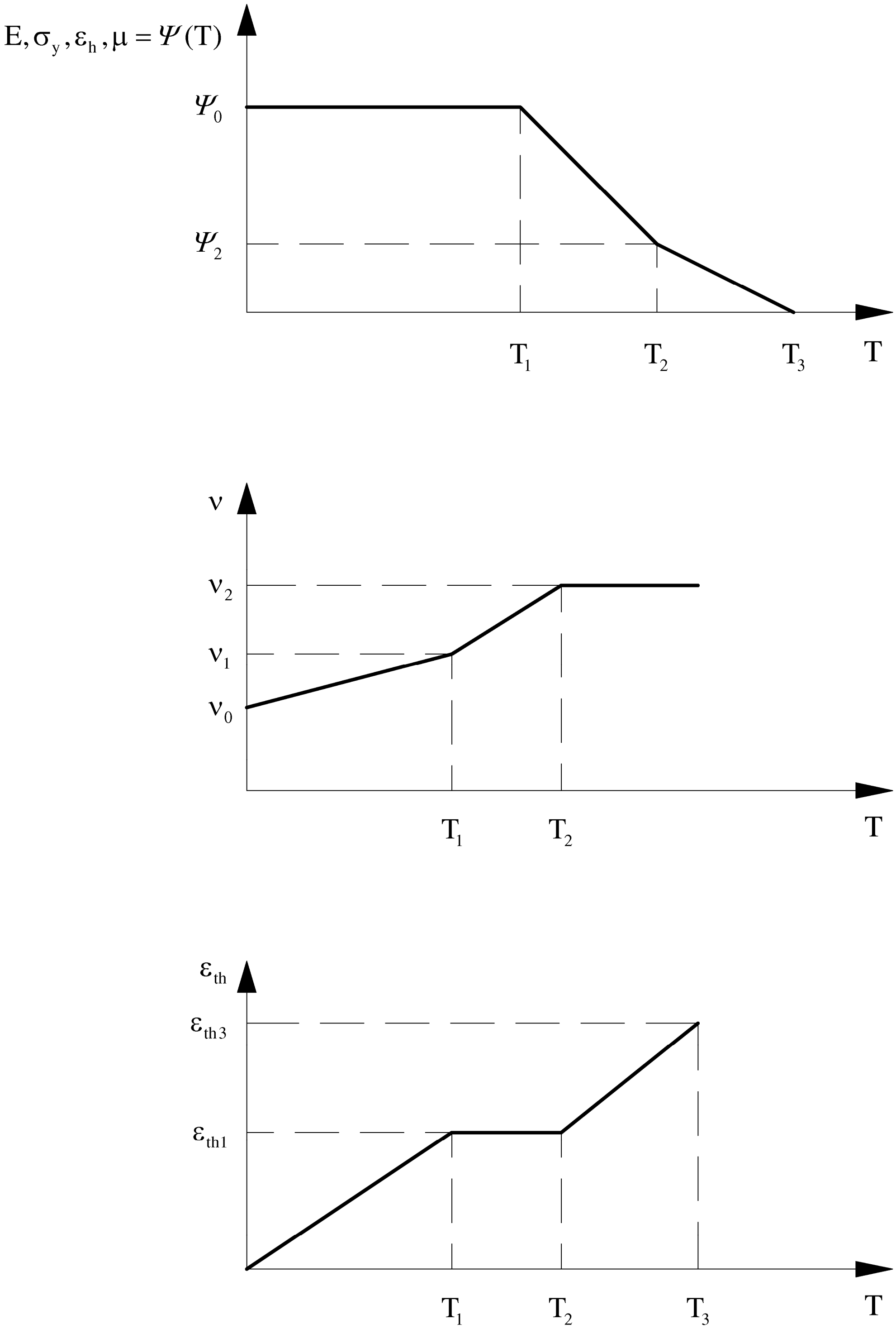
Material model ***bnsk***

tpth

Description	Triaxial elasto-plastic material model with *kinematic* strain-hardening and elevated temperature effects.
No. of properties	30
Properties	Young's modulus and temperatures:
	$(E_0, E_2, T_1, T_2, T_3)$
	Yield strength and temperatures
	$(\sigma_{y0}, \sigma_{y2}, T_1, T_2, T_3)$
	Plastic strain at onset of hardening
	$(\varepsilon_{h0}, \varepsilon_{h2}, T_1, T_2, T_3)$
	Strain-hardening parameter
	$(\mu_0, \mu_2, T_1, T_2, T_3)$
	Possion’s ratio and temperatures:
	$(\nu_0, \nu_1, \nu_2, T_1, T_2)$
	Thermal strain and temperatures
	$(\varepsilon_{th1}, \varepsilon_{th3}, T_1, T_2, T_3)$
Application	3D brick elements



*Material model **tpth** (Cont'd…)*



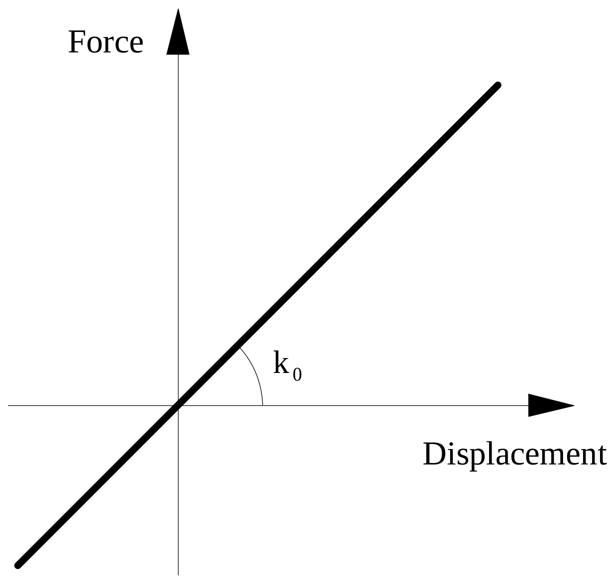
Material model ***tpth***

Chapter 4. JOINT ELEMENT CURVES

This section describes the force-displacement curves available in ADAPTIC for use by joint elements. Each curve is referred to by a unique name, displayed at the top of the following pages, and requires the specification of a number of parameters.

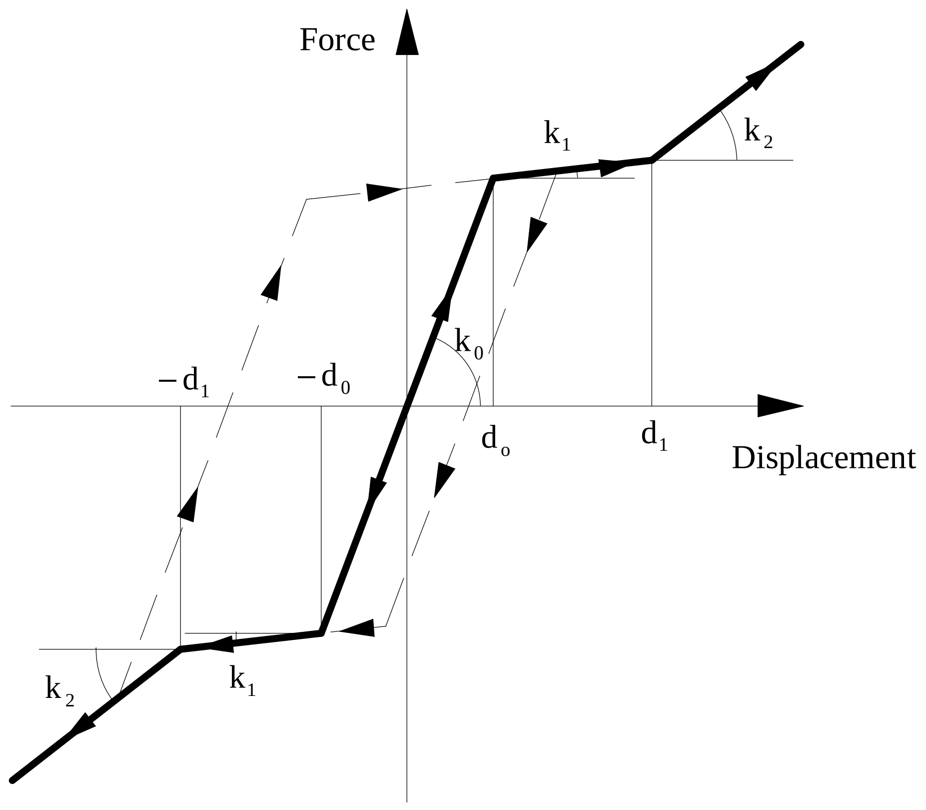
lin

Description	Linear elastic curve type.
Parameters	k_0
Characteristics	Linear elastic curve.
Application	Elastic joint action characteristics.
Restrictions	



Force-displacement curve ***lin***

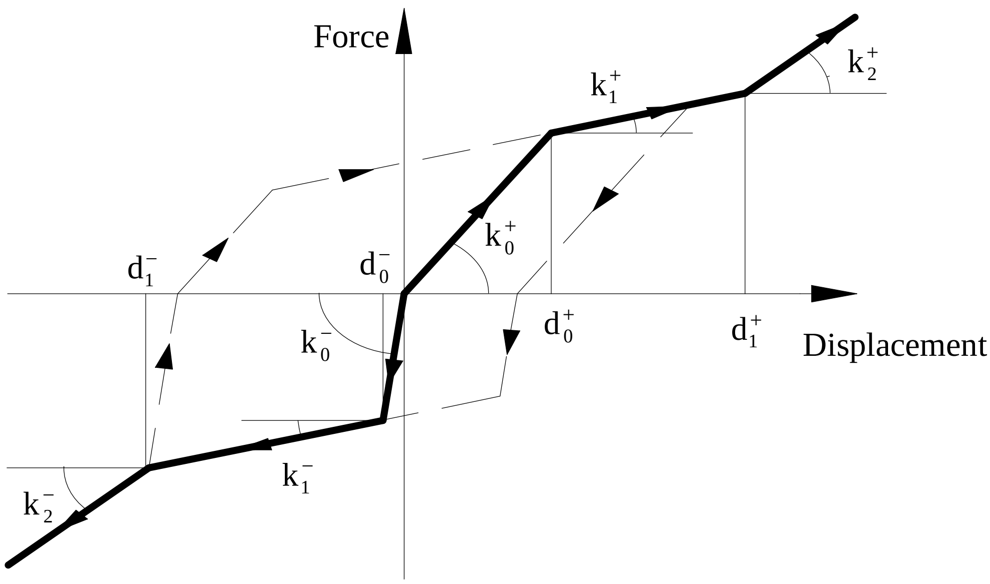
Description	Trilinear symmetric elasto-plastic curve type.
Parameters	k_0, d_0, k_1, d_1 & k_2, specified in this order.
Characteristics	Trilinear symmetric elasto-plastic curve.
	Unloading is performed kinematically to the extension of the second branch of the curve.
Application	Elasto-plastic joint action.
Restrictions	All k's must be positive.
	k_1 & k_2 must not be more than k_0.



Force-displacement curve ***smtr***

astr

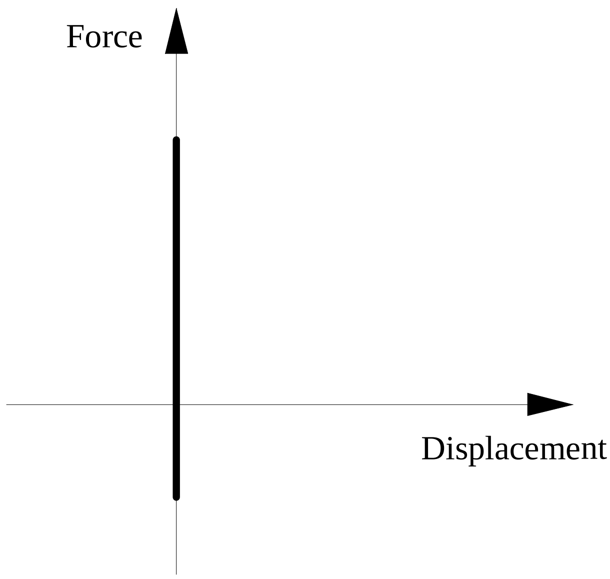
Description	Trilinear asymmetric elasto-plastic curve type.
Parameters	$(k_0, d_0, k_1, d_1, k_2)^+$ & $(k_0, d_0, k_1, d_1, k_2)^-$ specified in this order.
Characteristics	Trilinear asymmetric elasto-plastic curve. Unloading is performed kinematically to the extension of the second branch of the reloading curve.
Application	Elasto-plastic joint action. Structural gaps. The following parameters represent a curve with zero resistance until a specific negative displacement –D is achieved: (?, 0, 0, ?, 0, ?, 0, 0, -D, ?)
Restrictions	All k's must be positive. k_1 & k_2 must not be more than k_0 for the positive and negative displacement regions.



Force-displacement curve ***astr***

rigid

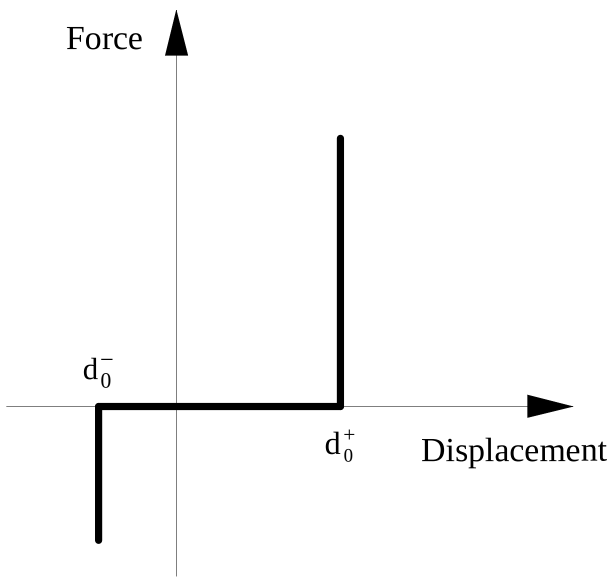
Description	Rigid curve type.
Parameters	None.
Characteristics	Rigid curve.
Application	Constrains a local freedom to zero.
	Avoids numerical problems that can occur with the **lin** curve type using a large stiffness.
Restrictions	



Force-displacement curve ***rigid***

contact

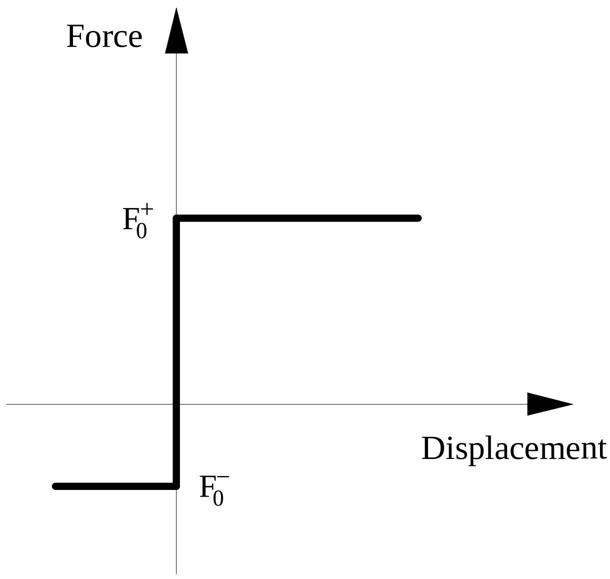
Description	Contact curve type.
Parameters	d_0^- & d_0^+.
Characteristics	Gap-contact curve, with a gap between d_0^- and d_0^+.
Application	Modelling of gaps with arbitrary lower/upper limits.
Restrictions	



Force-displacement curve ***contact***

plastic

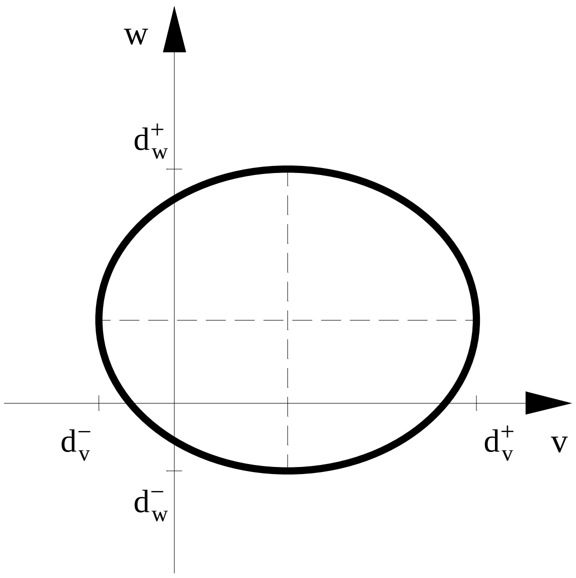
Description	Plastic curve type.
Parameters	F_0^- & F_0^+.
Characteristics	Rigid plastic curve, with plastic limits F_0^- & F_0^+.
Application	Modelling of rigid response with arbitrary lower/upper plastic limits.
Restrictions	



Force-displacement curve ***plastic***

radcont

Description	Radial contact curve.
Parameters	$(d_v^- \ \& \ d_v^+)$ or $(d_w^- \ \& \ d_w^+)$.
Characteristics	Coupled gap-contact curve between local v and w freedoms.
	Elliptical gap.
Application	Contact between concentric circular tubular members, for which the gap is defined by a circle.
Restrictions	Element type **jel3**.
	To be used simultaneously for local v and w freedoms.



Contact gap for curve ***radcont***

Chapter 5. CROSS-SECTION TYPES

The ADAPTIC library also includes a number of pre-defined cross-section types described briefly below:

Type	Description
rss	Rectangular solid section
chs	Circular hollow section
isec	General purpose I- or T-section
pnci	Partially encased composite I-section
fnci	Fully encased composite I-section
rccs	Reinforced concrete column section
rcts	Reinforced concrete T-section
flxw	Reinforced concrete flexural wall section

The degree of accuracy in modelling the above sections depends on the formulation utilising the cross-section.

Cubic formulations (**cbp2**, **cbp3**) provide detailed modelling of a cross-section through its discretisation into a number of areas where the uniaxial material response is monitored according to the previous material models.

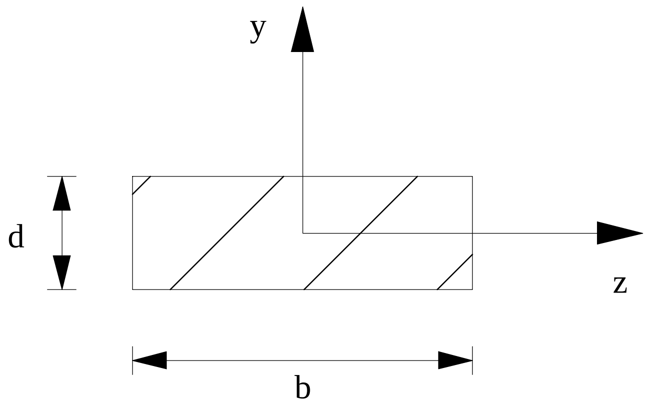
Plastic-hinge formulations (**qph2**, **qph3**) derive a plastic interaction surface between the cross-sectional bending moments and axial force, which is combined with the associated flow rule to provide approximate modelling of steel members. The plastic hinge capability is not extended to reinforced concrete sections.

Elastic formulations utilise constant elastic rigidities for bending, axial and torsional actions derived for given cross-sectional configurations. As such they are only accurate for steel members, since they do not account for concrete cracking.

This section describes the cross-section types available in ADAPTIC. Each type is referred to by a unique name, displayed at the top of the following pages, and requires the specification of a number of materials and dimensions in the order indicated.

rss

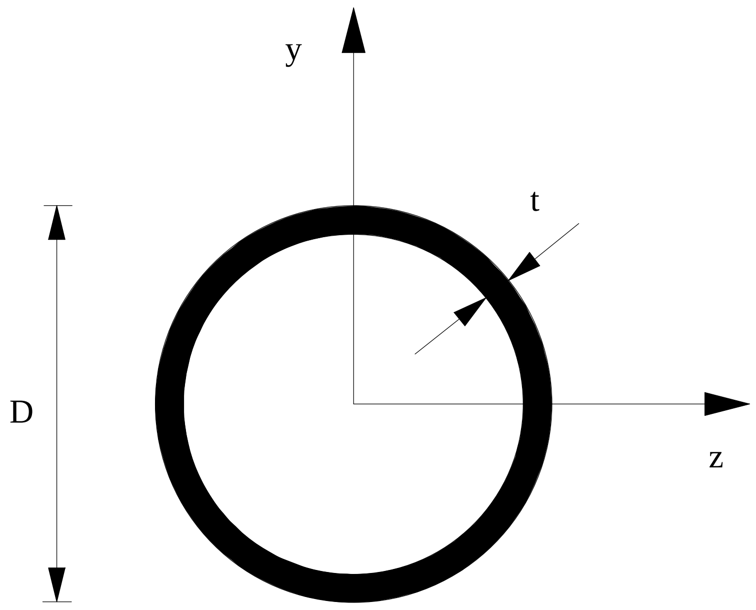
Description	Rectangular solid section.
No. of materials	1
No. of dimensions	2
Dimensions	Width (b)
	Depth (d)
Application	Rectangular solid sections of uniform material.



Section ***rss***

chs

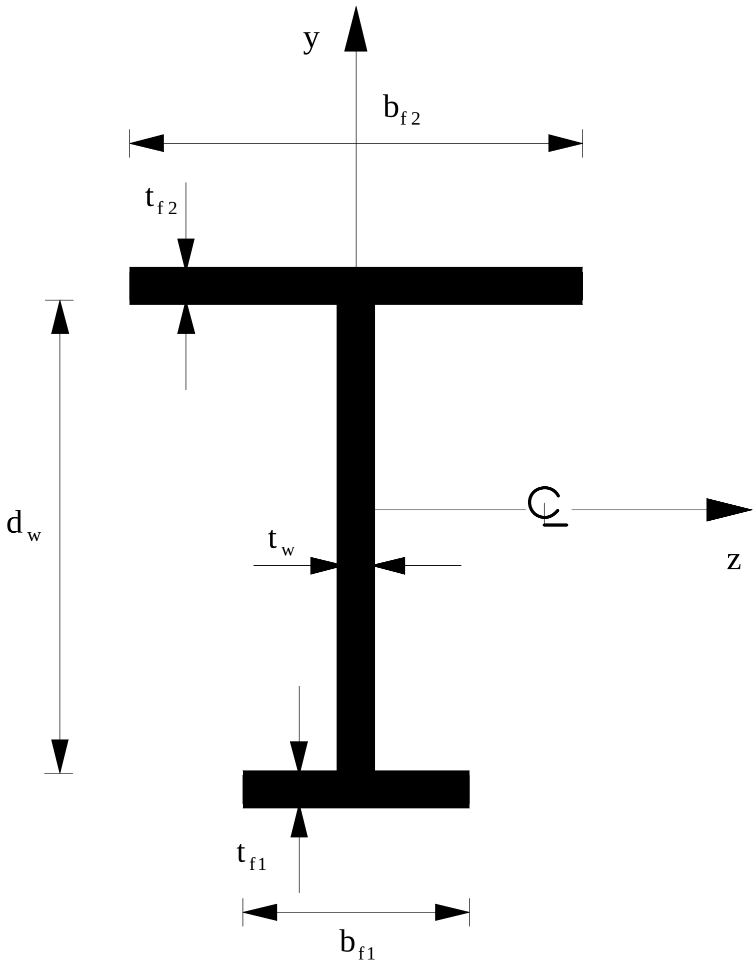
Description	Thin circular hollow section.
No. of materials	1
No. of dimensions	2
Dimensions	Outer diameter (D)
	Tube thickness (t)
Application	Circular hollow sections of uniform material.



Section ***chs***

isec

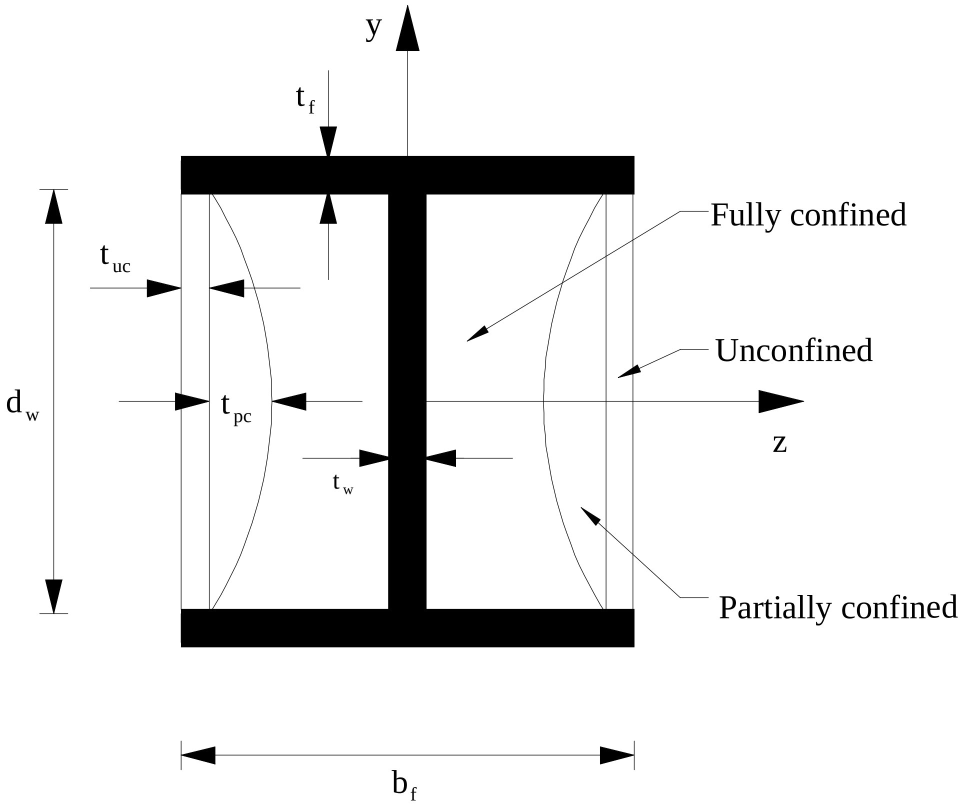
Description	General purpose I- or T-section.	
No. of materials	1	
No. of dimensions	6	
Dimensions	Bottom flange width	(b_{f1})
	Bottom flange thickness	(t_{f1})
	Top flange width	(b_{f2})
	Top flange thickness	(t_{f2})
	Web depth	(d_w)
	Web thickness	(t_w)
Application	I- or T-sections of uniform material.	



Section ***isec***

Description	Partially encased composite I-section.	
No. of materials	4, specified in this order: I-section Unconfined region Partially confined region Fully confined region	
No. of dimensions	6	
Dimensions	Flange width	(b_f)
	Flange thickness	(t_f)
	Web depth	(d_w)
	Web thickness	(t_w)
	Unconfinement ratio	(r_{uc})*
	Partial confinement ratio	(r_{pc})*
Application	Partially encased composite I-sections, with three different concrete materials to represent confinement effects.	

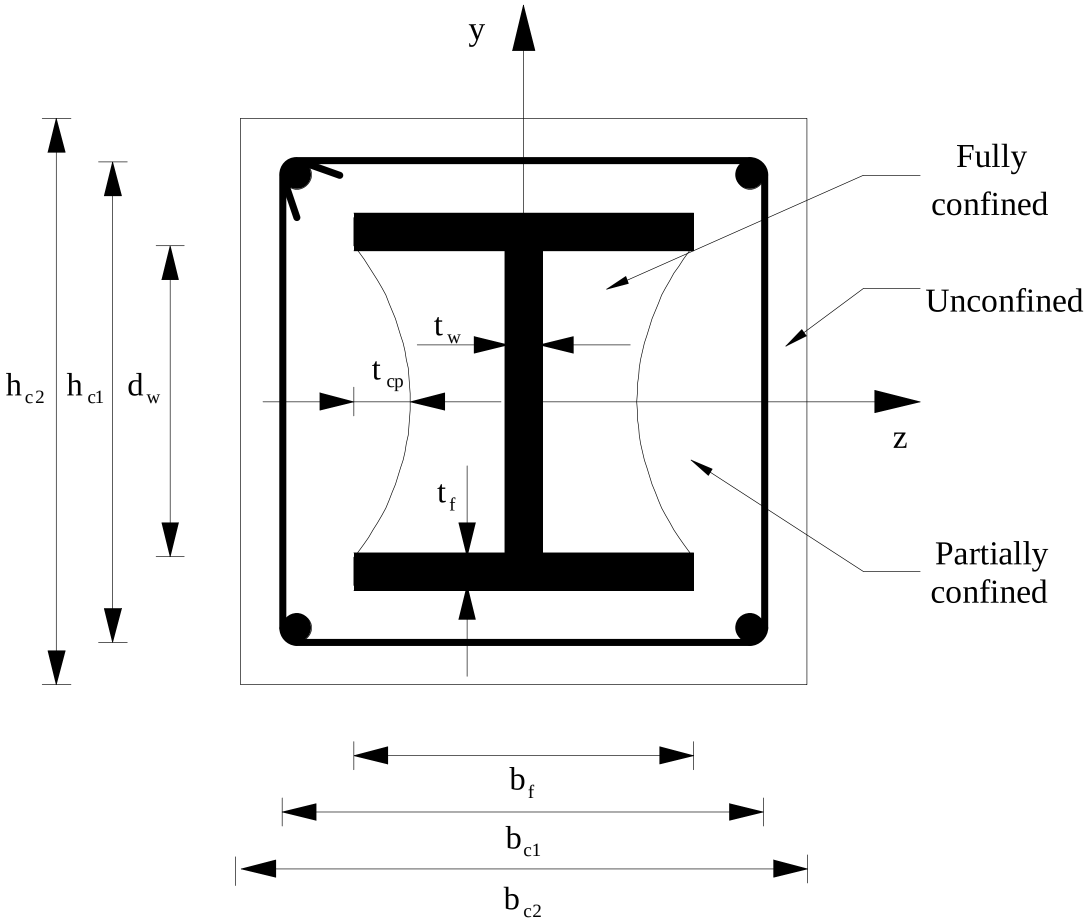
(*) $r_{uc} = 2\ t_{uc}\ /\ (b_f - t_w)$ & $r_{pc} = 2\ t_{pc}\ /\ (b_f - t_w)$, where t_{uc} and t_{pc} are the thickness of the unconfined and confined parts of the section, respectively.



*Section **pnci***

Description	Fully-encased composite I-section.	
No. of materials	4, specified in this order: I-section Unconfined region Partially confined region Fully confined region	
No. of dimensions	9	
Dimensions	Flange width	(b_f)
	Flange thickness	(t_f)
	Web depth	(d_w)
	Web thickness	(t_w)
	Partial confinement ratio	(r_{pc})*
	Stirrup width	(b_{c1})
	Section width	(b_{c2})
	Stirrup depth	(h_{c1})
	Section depth	(h_{c2})
Application	Fully encased composite I-sections, with three different concrete materials to represent confinement effects.	

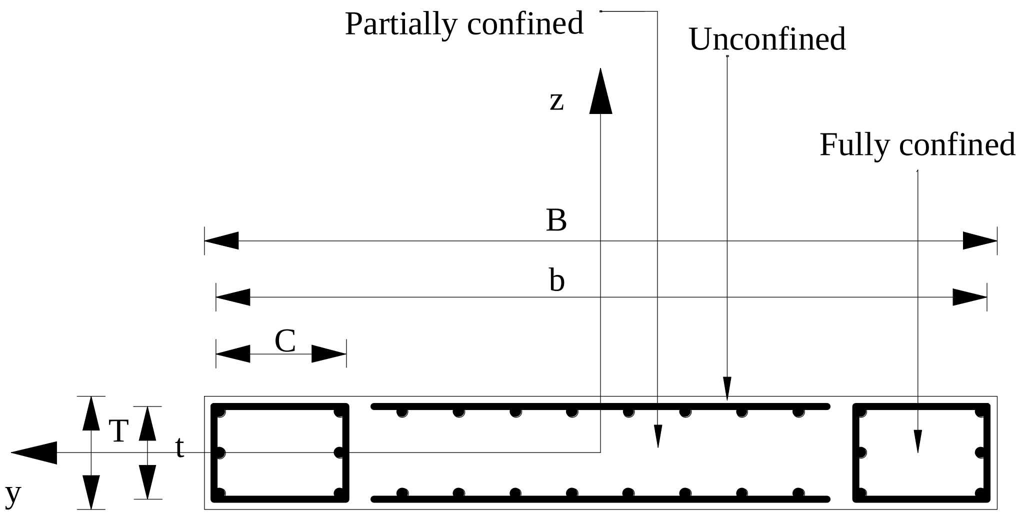
(*) $r_{pc} = 2\ t_{pc}\ /\ (b_f\ -\ t_w)$, where t_{pc} is the depth of the partially confined part beyond the section flange.



Section ***fnci***

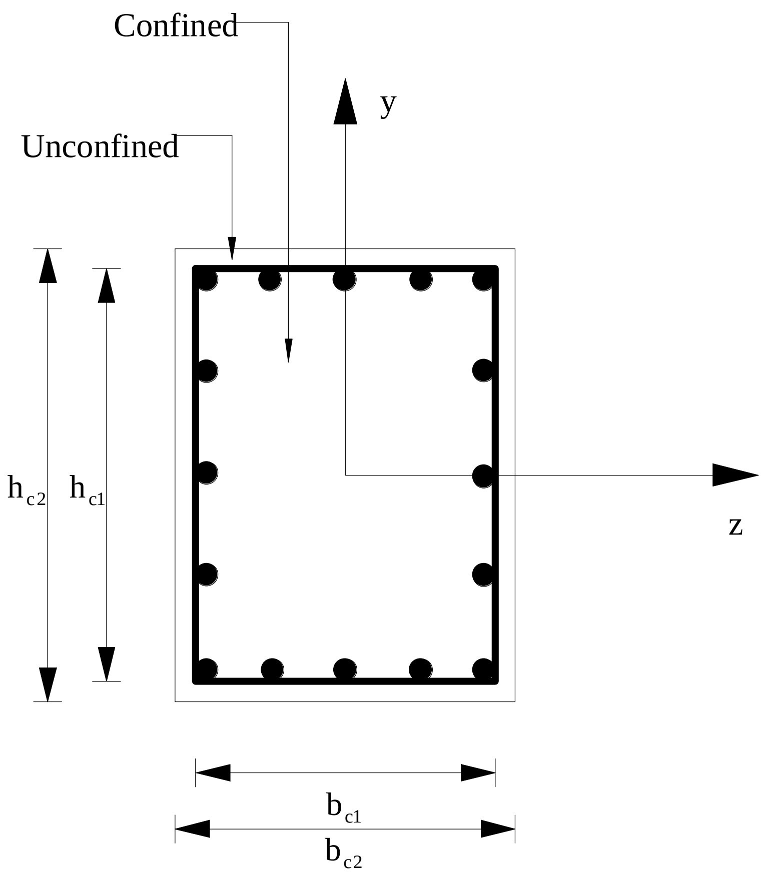
flxw

Description	Flexural wall section.
No. of materials	4, specified in this order: Reinforcement Unconfined region Partially confined region Fully confined region
No. of dimensions	2D analysis: 5 + 2 (Reinforcement layers on one side of z-axis) 3D analysis: 5 + 3 (Reinforcement bars in one y-z quadrant)
Dimensions	Wall width (B) Confined width (b) Wall thickness (T) Confined thickness (t) Depth of fully confined region (C) 2D analysis: (A_i, y_i) for each reinforcement layer on one side of the z-axis. 3D analysis: (A_i, y_i, z_i) for each reinforcement bar in the positive y-z quadrant.
Application	Symmetric flexural walls.
Restrictions	Section is assumed symmetric about the y-z origin, hence only one side of the reinforcement need to be specified.



Section ***flxw***

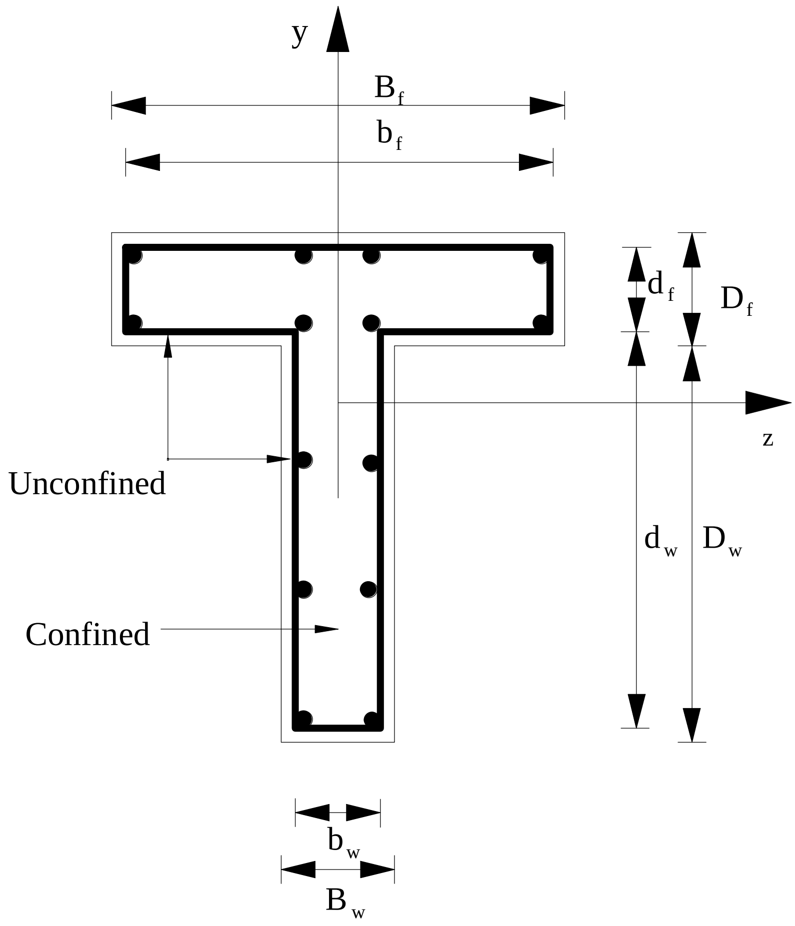
Description	Reinforced concrete column section.
No. of materials	3, specified in this order: Reinforcement Unconfined region Confined region
No. of dimensions	2D analysis: 4 + 2 (Reinforcement <u>layers</u> on one side of z-axis) 3D analysis: 4 + 3 (Reinforcement <u>bars</u> in one y-z quadrant)
Dimensions	Section depth (h_{c1}) Stirrup depth (h_{c2}) Section width (b_{c1}) Stirrup width (b_{c2}) 2D analysis: (A_i, y_i) for each reinforcement <u>layer</u> on one side of the z-axis. 3D analysis: (A_i, y_i, z_i) for each reinforcement <u>bar</u> in the positive y-z quadrant.
Application	Symmetric reinforced concrete columns.
Restrictions	Section is assumed symmetric about the y-z origin, hence only one side of the reinforcement need to be specified.



*Section **rccs***

Description	Reinforced concrete T-section.
No. of materials	3, specified in this order: Reinforcement Unconfined region Confined region
No. of dimensions	2D analysis: 8 + 2 (Reinforcement layers) 3D analysis: 8 + 3 (Reinforcement bars on one side of y-axis)
Dimensions	Slab thickness (D_f) Beam depth (D_w) Confined depth in slab (d_f) Confined depth in beam (d_w) Slab effective width (B_f) Beam width (B_w) Confined width in slab (b_f) Confined width in beam (b_w) 2D analysis: (A_i, d_i^*) for each reinforcement layer. 3D analysis: (A_i, d_i^*, z_i) for each reinforcement bar on one side of the y-axis.
Application	Modelling of R/C beams with an effective slab width.
Restrictions	Symmetric section about the y-axis.

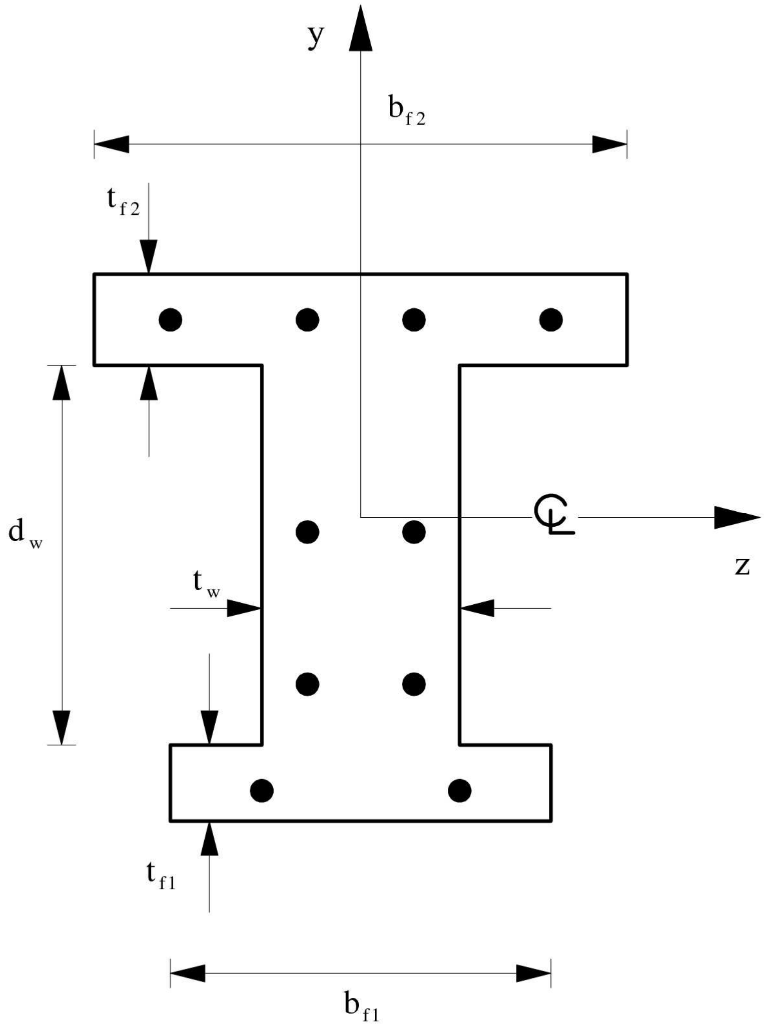
(*) d_i is the distance of reinforcement layer/bar (i) from the bottom fibre of the section.



Section ***rcts***

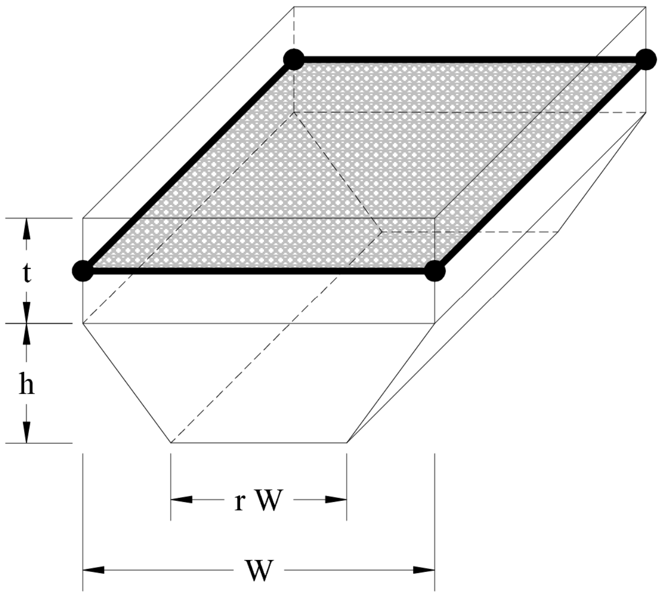
Description	General purpose reinforced concrete I- or T-section.	
No. of materials	1	
No. of dimensions	2D analysis:	
	6 + 2 (Reinforcement layers)	
Dimensions	Bottom flange width	(b_{f1})
	Bottom flange thickness	(t_{f1})
	Top flange width	(b_{f2})
	Top flange thickness	(t_{f2})
	Web depth	(d_w)
	Web thickness	(t_w)
	2D analysis:	
	(A_i, d_i^*) for each reinforcement layer.	
Application	General reinforced concrete I- or T-sections.	
Restrictions	Symmetric section about the y-axis.	

(*) d_i is the distance of reinforcement layer/bar (i) from the bottom fibre of the section.



Section ***rcgs***

Description	Composite floor slab section	
No. of materials	4 specified in this order: Deck parallel to the rib Deck perpendicular to the rib Reinforcement Concrete	
No. of dimensions	12	
Dimensions	Depth of cover:	(t)
	Depth of rib	(h)
	Rib geometric ratio	(r)
	Thickness of steel deck	(t_d)
	Reinforcement area per unit length in local x-direction	(t_x)
	Location of reinforcement in x-direction above (+)/below (-) reference mid-plane	(d_x)
	Reinforcement area per unit length in local y-direction	(t_y)
	Location of reinforcement in y-direction above (+)/below (-) reference mid-plane	(d_y)
	The remaining 4 dimesions are for two additional reinforcement layers in x and y-directions.	
Application	Composite floor slab cross-section consisting of ribbed reinforced concrete acting compositely with trapezoidal steel decking.	



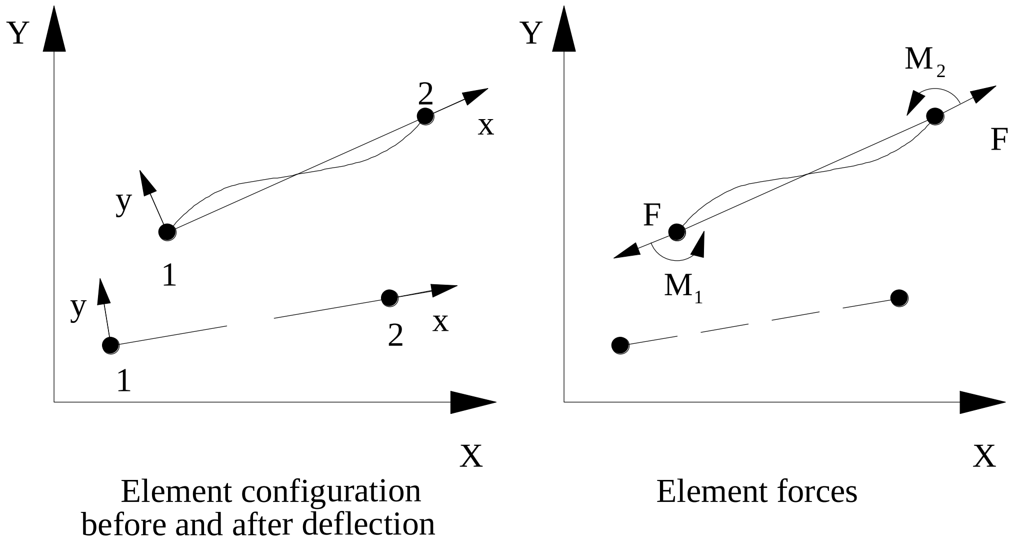
Section ***cslb***

Chapter 6. ELEMENT TYPES

This section describes the element types available in ADAPTIC. Each type is referred to by a unique name, displayed at the top of the following pages, and requires the specification of a number of entries for its groups, connectivity and other modules.

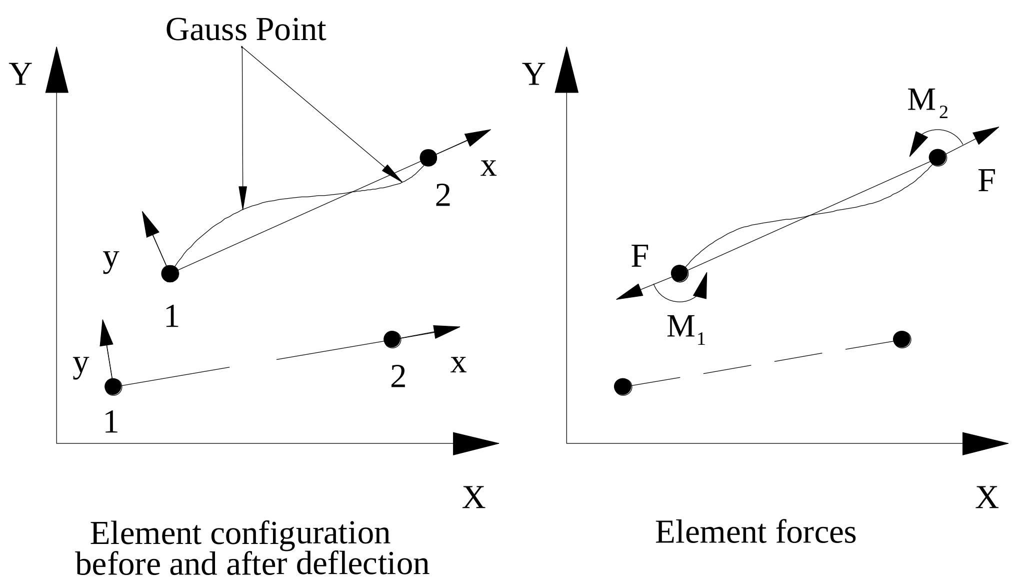
cbe2

Description	Cubic 2D elastic element with uncoupled bending and axial actions.
Nodes	2
Characteristics	Accounts for large nodal displacements, but requires a number of elements to represent a member with significant beam-column action.
Application	Elastic analysis of plane frames
Restrictions	Unable to model concrete cracking.
Group header	`sec.name`: An identifier referring to one of the cross-sections declared in the **sections** module.



*Configuration and forces in local system of element type **cbe2***

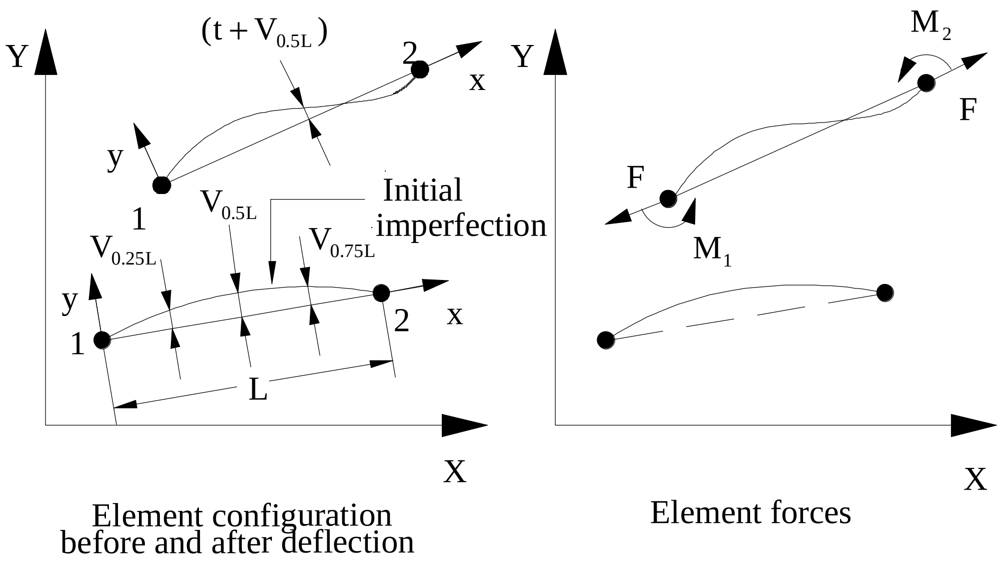
Description	Cubic elasto-plastic 2D beam-column element.
Monitoring points	25 points usually adequate; depends on section type.
Nodes	2
Characteristics	Geometric and material nonlinearities. Numerical integration performed over two Gauss points. A number of monitoring areas used at each Gauss section to monitor material direct stress and strains. Predicts global member behaviour based on a material stress-strain relationship. A number of elements per member, usually over 5, must be used for reasonable accuracy in inelastic modelling.
Application	Modelling of inelastic members in plane frames.
Restrictions	
Group header	`sec.name`: An identifier referring to one of the cross-sections declared in the **sect**ions module. `monitoring.points`: Defines the number of points for monitoring stresses and strains within a cross-section.



Configuration and forces in local system of element type ***cbp2***

qel2

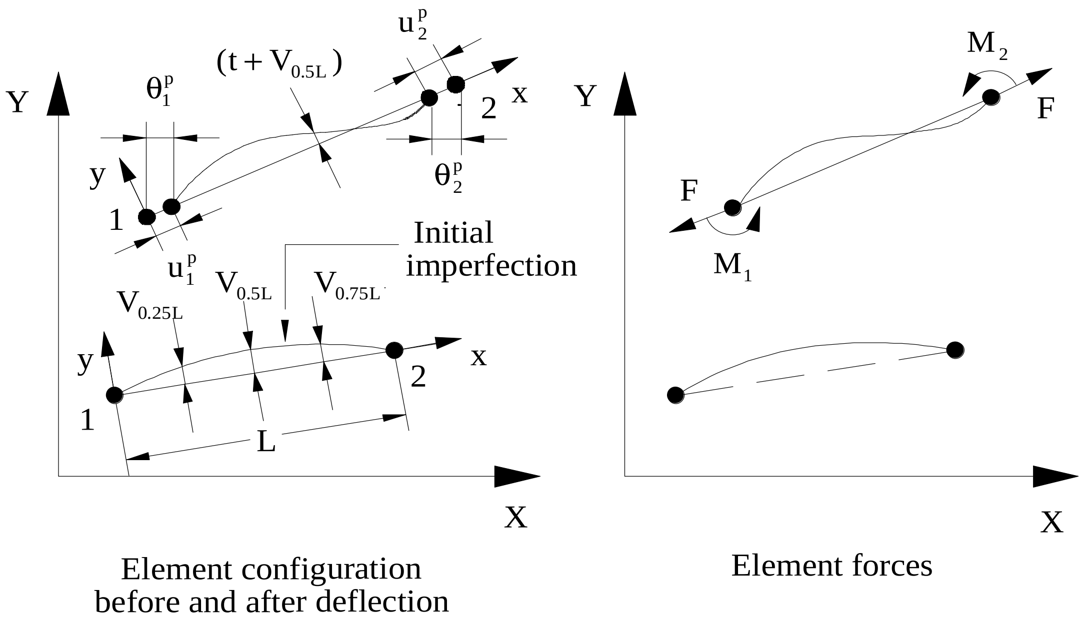
Description	Quartic elastic 2D beam-column element.
Nodes	2
Imperfections	$V_{0.25L}$, $V_{0.5L}$, $V_{0.75L}$ can be specified.
Characteristics	Geometric nonlinearities. Large displacements and beam-column effect of perfect/imperfect members. One element type ***qel2*** is usually sufficient to represent the beam-column effect and large displacement response of a whole elastic member.
Application	Geometric nonlinearities in elastic plane frames.
Restrictions	Unable to model concrete cracking.
Group header	**`sec.`**`name`: An identifier referring to one of the cross-sections declared in the **sect**ions module.



Configuration and forces in local system of element type ***qel2***

qph2

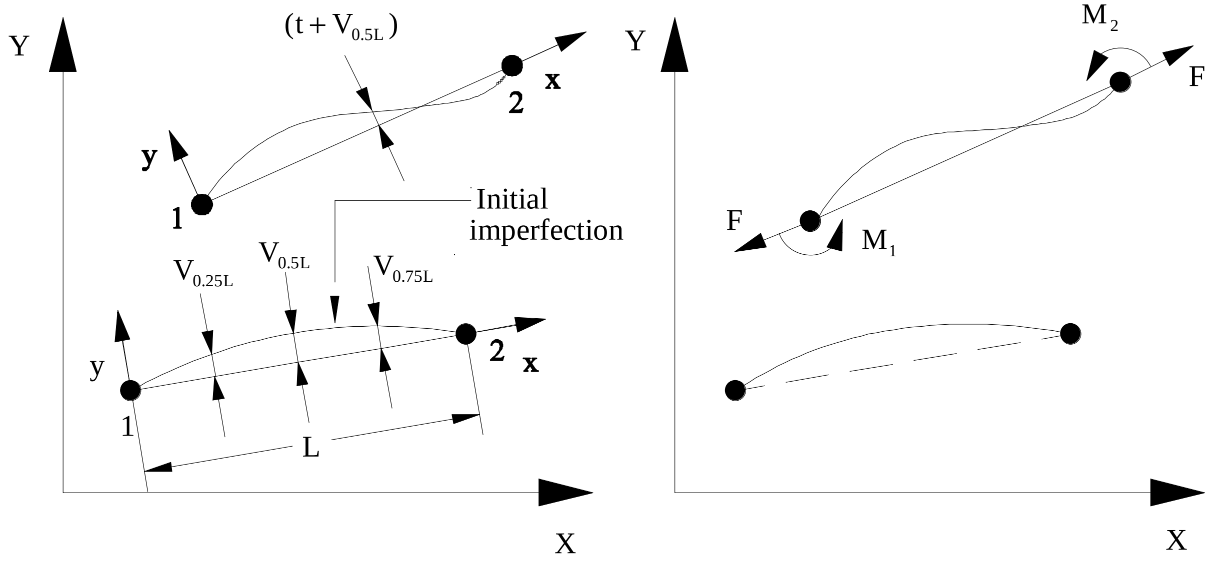
Description	Quartic plastic hinge 2D beam-column element with an option for automatic subdivision.
Nodes	2
Subdivision	Automatic subdivision into two elements if a plastic hinge is detected within the element may be requested.
Imperfections	$V_{0.25L}$, $V_{0.5L}$, $V_{0.75L}$ can be specified.
Characteristics	Geometric and material nonlinearities. Suitable for members in which the spread of plasticity is not important and the section response is elastic-plastic without strain-hardening. Rotational and axial plastic hinge displacements are allowed at the two ends of the element. One element type ***qph2*** is usually sufficient to model a whole member, and the option of subdivision allows for the case of member buckling.
Application	Large displacement plastic-hinge analysis of plane frames
Restrictions	Not applicable to reinforced concrete or composite members.
Group header	**`sec`**`.name`: An identifier referring to one of the cross-sections declared in the **sect**ions module. **`Subd`**`ivision`**:** Gives the option for automatic subdivision plastic hinge elements: =(**t** | **true**) consider element subdivision =(**f** | **false**) ignore element subdivision



Configuration and forces in local system of element type ***qph2***

qdp2

Description	Quartic elastic 2D beam-column element utilising automatic q mesh refinement.
Subdivision pattern	Relative lengths in ratio form of zones where inelasticity is checked for automatic mesh refinement.
Nodes	2
Imperfections	$V_{0.25L}$, $V_{0.5L}$, $V_{0.75L}$ can be specified
Characteristics	Geometric and material nonlinearities. Large displacement and beam-column effect of perfect/imperfect members. One element type ***qdp2*** is usually sufficient to represent a whole member. Element ***qdp2*** subdivides into elements **cbp2**, specified under **cbp2.grp.name**, if inelasticity is detected in the zones defined by the subdivision pattern **pat.name**. Accuracy increases with the number of sub-elements type **cbp2** specified in the subdivision pattern. After subdivision, elements **cbp2** are inserted in the inelastic zones, while the elastic zones are kept as element type ***qdp2***.
Application	Adaptive modelling of inelastic members in plane frames.
Restrictions	Applies only to cross-sections with materials **stl1**, **stl2** & **stl3**.
Group header	`cbp2.grp.name:` Specifies the group identifier of elements type **cbp2** used in automatic mesh refinement. `pat.name:` An identifer referring to a subdivision pattern in the **patt**erns module.

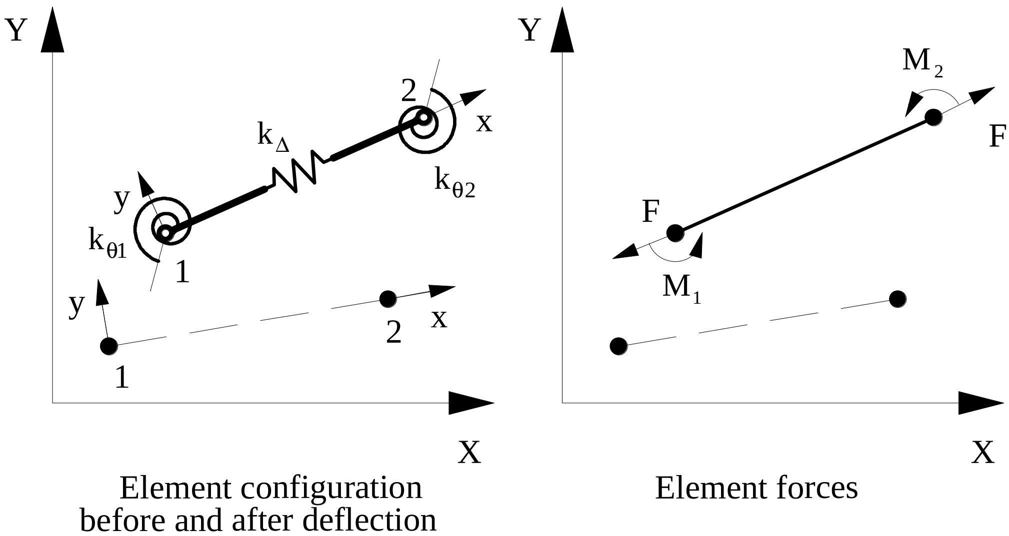


Element configuration
before and after deflection

Element forces

*Configuration and forces in local system of element type **qdp2***

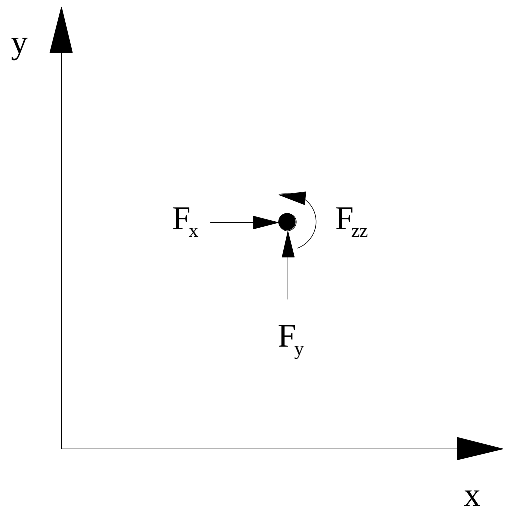
Description	2D link element with discrete axial/rotational springs.
Nodes	2
Characteristics	Geometric nonlinearity.
	3 independent spring stiffnesses, each taking either a constant numerical value or a `rigid` value.
Application	Rigid link.
	Elastic bar with pinned ends.
Restrictions	
Group header	`stiffness.parameters`: numerical or `rigid` values for each of the spring stiffnesses, $k_{\theta 1}$, $k_{\theta 2}$ and k_{Δ}, in this order.



Configuration and forces in local system of element type ***lnk2***

spe2

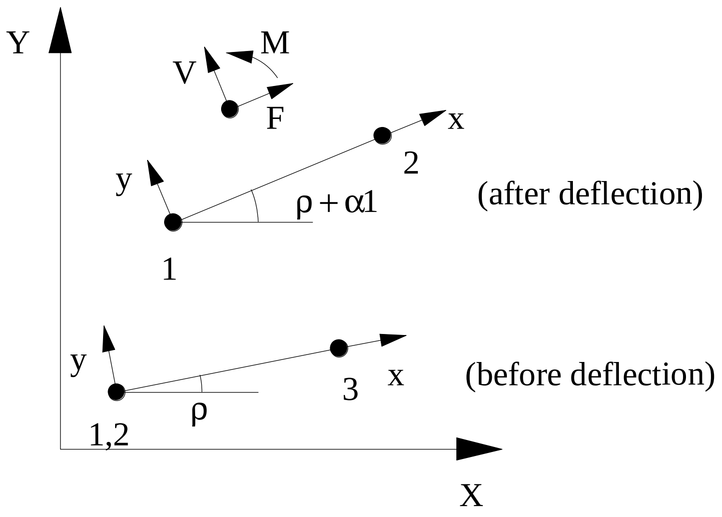
Description	Linear 2D nodal spring element.
Stiffness parameters	Two global translational stiffnesses and one rotational stiffness can be specified in the following order: K_x, K_y , K_{zz}
Nodes	1
Characteristics	Models elastic boundaries for plane frame analysis. Requires the definition of only one node, with the other node assumed fixed against translation and rotation.
Application	Plane frame boundaries.
Restrictions	Cannot be used to join two elements. For that purpose use **jel2**.
Group header	`stiffness.parameters:` Defines stiffness parameters.



Forces for element type ***spe2***

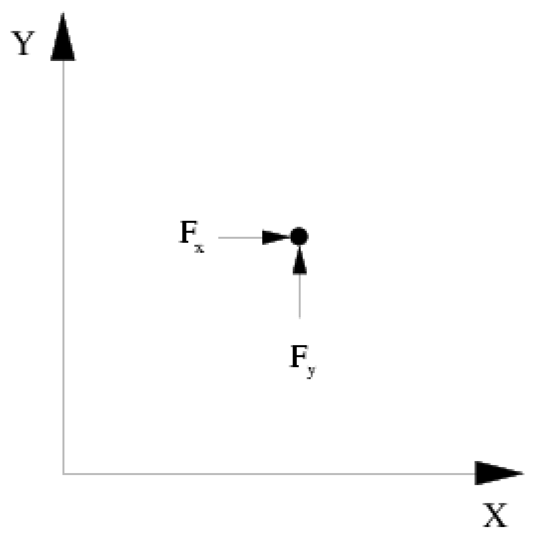
jel2

Description	2D joint element with uncoupled axial, shear and moment actions.
Curve types	Models used for the joint force-displacement curves, specified for F (axial), V (shear) and M (moment), respectively. Each of these models may be any of those described in Chapter 4.
Parameters	Parameters for each of the three models specified for F, V and M.
Nodes	3
Characteristics	Nodes (1) and (2) must be initially coincident. Node (3) is only used to define the x-axis of the joint and can be a non-structural node. The orientation of the joint x-axis after deformation is determined by its initial orientation and the global rotation of node (1).
Application	Plane frame analysis. Can be used to model pin joints, inclined supports, elasto-plastic joint behaviour, soil-structure interaction and structural gaps, through employing appropriate joint curves.
Restrictions	Element has a zero initial length, since nodes (1) and (2) must be coincident. Cannot be used to model coupled axial, shear and moment actions.
Group header	`curve.types`: Defines curve types for joint elements. `parameters:` Defines parameters for the joint elements.



Forces for element type ***jel2***

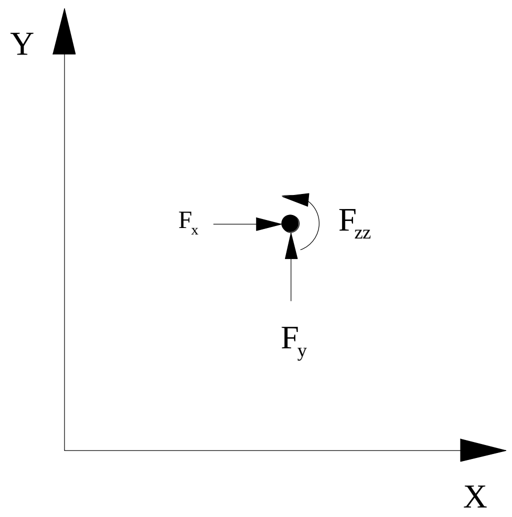
Description	Concentrated (lumped) 2D mass element.
Nodes	1
Characteristics	Models lumped mass for dynamic analysis.
	Allows full 2×2 translational mass matrix to be defined.
	Lumped element mass, specified according to one of:
	M_x (default $M_y = M_x$ & $M_{xy} = 0$)
	M_x, M_y (default $M_{xy} = 0$)
	M_x, M_y, M_{xy}
	Allows specification of mass-proportional damping at group level.
Application	Dynamic analysis of plane frames.
Restrictions	
Group header	`mass`: Element mass.
	`[damping.parameter]`: optional parameter for mass-proportional Rayleigh damping; defaults to the value of `mass.damping.parameter` specified in the default.parameters module.



Forces for element type ***cnm2***

cnd2

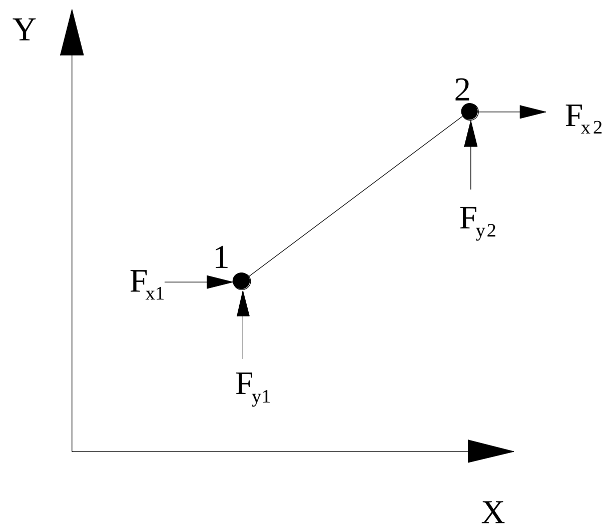
Description	Concentrated (dashpot) 2D viscous damping element.
Damping parameters	Two translational and one rotational damping coefficients, specified in this order: C_x , C_y , C_{zz}
Nodes	1
Characteristics	Models nodal viscous damping for dynamic analysis.
Application	Dynamic analysis of plane frames.
Restrictions	
Group header	`damping.parameters:` Defines dashpot damping parameters.



Forces for element type ***cnd2***

lnm2

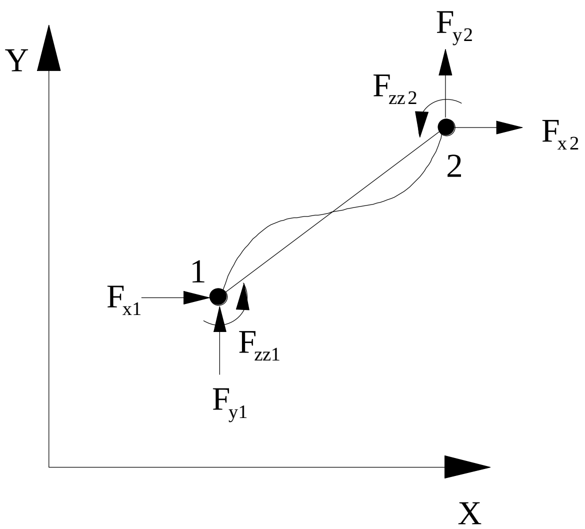
Description	Linear 2D mass element.
Nodes	2
Characteristics	Simplified modelling of uniformly distributed mass for dynamic analysis. Assumes the mass to lie on a rigid straight line between the two end nodes. Allows specification of mass-proportional damping at group level.
Application	Dynamic analysis of plane frames.
Restrictions	
Group header	`mass/length:` Mass per unit length. `[damping.parameter]`: optional parameter for mass-proportional Rayleigh damping; defaults to the value of `mass.damping.parameter` specified in the default.parameters module.



Forces for element type ***lnm2***

cbm2

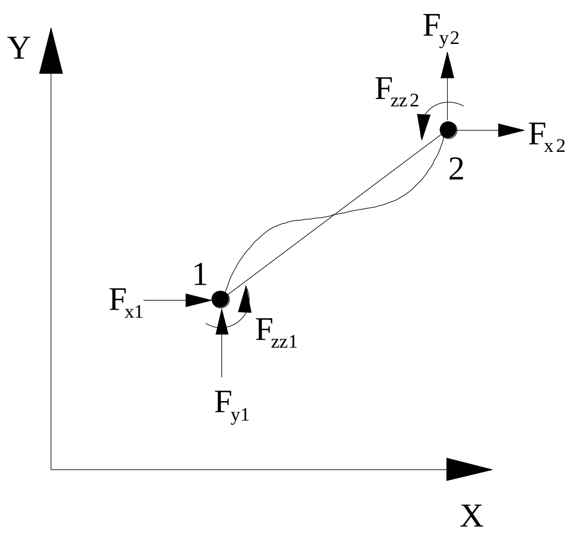
Description	Cubic 2D distributed mass element
Nodes	2
Characteristics	Models uniformly distributed mass in dynamic analysis. Uses an Updated Lagrangian formulation with a cubic shape function for the transverse displacement and a linear distribution for the axial displacement. Allows different axial (m_a) and transverse (m_t) distributed mass. Mass per unit length, specified according to one of: m_a (default $m_t = m_a$) m_a, m_t Allows specification of mass-proportional damping at group level.
Application	Dynamic analysis of plane frames.
Restrictions	
Group header	`mass/length:` Mass per unit length. `[damping.parameter]`: optional parameter for mass-proportional Rayleigh damping; defaults to the value of `mass.damping.parameter` specified in the default.parameters module.



Forces for element type ***cbm2***

rld2

Description	Rayleigh damping 2D element
Mass/length	Mass per unit length
Parameters	Two proportionality constants (a_1 & a_2) of mass and stiffness respectively, specified in that order.
Nodes	2
Characteristics	Models Rayleigh damping effects. All ***rld2*** elements must have the same constant (a_1 & a_2) to model conventional Rayleigh damping.
Application	Dynamic analysis of plane frames.
Restrictions	(a_1) should be set to zero for dynamic analysis involving ground excitation, otherwise damping would be proportional to absolute rather than relative frame velocity.
Group header	`sec.name` :An identifier referring to one of the cross-sections declared in the **sect**ions module. `mass/length`: Mass per unit length. `parameters`: Defines parameters of Rayleigh damping elements.



Forces for element type ***rld2***

Description

2D/3D joint element with coupling between axial force and moment but uncouple with shear.

Types

Three entries are required:

1) 'steel' for bare steel or 'composite' for composite connection.

2) connection type:
'flush.endplate'
'extended.endplate'
'web.angles'
'top.and.seat'
'combined.web/top/seat'
'finplate'

3) behaviour of panel zone, either 'rigid' if panel zone behaviour is omitted or 'flexible' if the flexibility of the panel zone is included.

Material name

Three material properties are required by using material model gen1. The first material provides the properties of the connecting elements e.g. plates, angle. The second material is the properties of bolts. The thirds material is the properties of the connected member i.e. column and beam.

Parameters

Number of parameters vary according to connection type:

- Flush endplate (13 parameters)
- Extended endplate (26 parameters)
- Double web angles (12 parameters)
- Top and seat angles (23 parameters)
- Combination of top, seat and web angles (34 parameters)
- Finplate (8 parameters)

1. Flush end plate

- Bolt diameter,
- Area of bolt shank,
- Thickness of bolt head,
- Thickness of nut,
- Thickness of washer,
- Distance from endplate edge to bolt head/nut/washer edge,
- Distance of bolt head/nut /washer whichever is appropriate,
- Distance from edge of bolt head/nut/ washer to fillet of endplate to beam web,
- Total depth of endplate,
- Thickness of endplate,
- Endplate width,

- Minimum bolt pitch,
- Coefficient for the computation of the effective width for the bolt-row below the beam tension flange.

2. Extended end plate

The geometrical properties of the extended endplate are double the properties of the flush endplate, accounting for different orientation of the T-stub components, but the details and order are the same. The only exception is for the last parameter, where the length of the extended part of the endplate is required.

3. Double web angles

- Bolt diameter,
- Area of bolt shank,
- Total depth of angle,
- Angle thickness,
- Gauge length of beam leg,
- Bolt clearance,
- Minimum bolt pitch,
- Gauge length of column leg,
- Distance from bolt line to free edge of column leg,
- Distance from bolt line to free edge of beam leg,
- Angle radius,
- Diameter of M16 bolts.

4. Top and seat angels

For top angle (12 parameters):

- Bolt diameter,
- Area of bolt shank,
- Total depth of angle,
- Angle thickness,
- Gauge length of beam leg,
- Bolt clearance,
- Minimum bolt pitch,
- Gauge length of column leg,
- Distance from bolt line to free edge of column leg,
- Distance from bolt line to free edge of beam leg,
- Angle radius,
- Diameter of M16 bolts.

Similar dimensions are needed for seat angle (11 parameters) except for the diameter of M16 bolts.

5. Combination of top, seat and web angles

Connection parameters for this type are the combination of web angle and top and seat angles.

6. Finplate

- Bolt diameter,
- Bolt hole diameter,
- Total depth of plate,
- Plate thickness,
- Gauge length,
- Width of plate,
- Minimum bolt pitch,
- Diameter of M16 bolts.

After the connection parameters are entered, another 14 parameters are needed: 11 parameters for the connected members, followed by Poisson ratio, number of layers and a flag to indicate preload or non-preload condition of the bolts. Connected member parameters are:

- Column depth,
- Column flange width,
- Thickness of column flange,
- Thickness of column web,
- Column radius,
- Bolt pitch in column,
- Distance from bolt line to free edge of column flange,
- Distance from bolt line to fillet of column flange,
- Beam depth,
- Thickness of beam flange,
- Thickness of beam web.

Nodes

3 (2D) used similar to jel2
4 (3D) used similar to jel3

Application

Plane frame analysis.

Space frame analysis.

Can be used to model steel and composite joints.

Restrictions

Element has a zero initial length, since nodes (1) and (2) must be coincident.

Group header

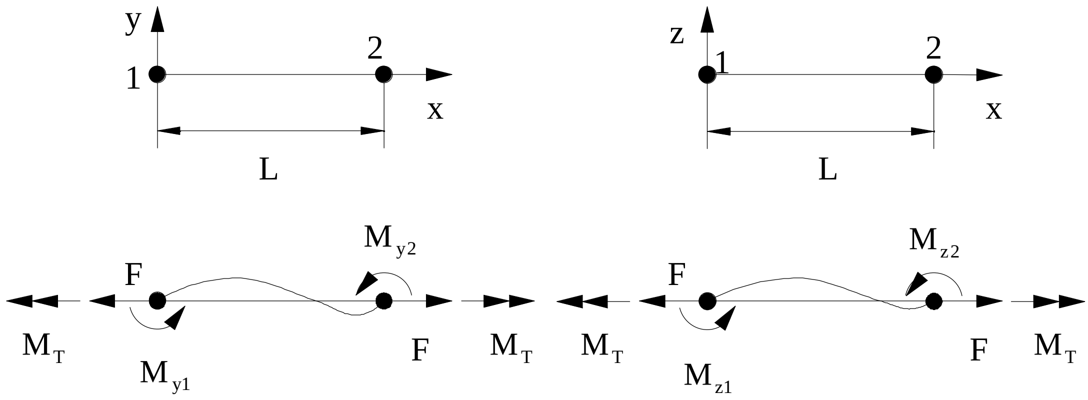
`type`: Defines the type of connection and contribution of shear panel

`mat.name(s)`: Defines the material for the connecting elements, bolts and connected member

`parameters`: Defines parameters for the joint and depends on the connection types.

cbp3

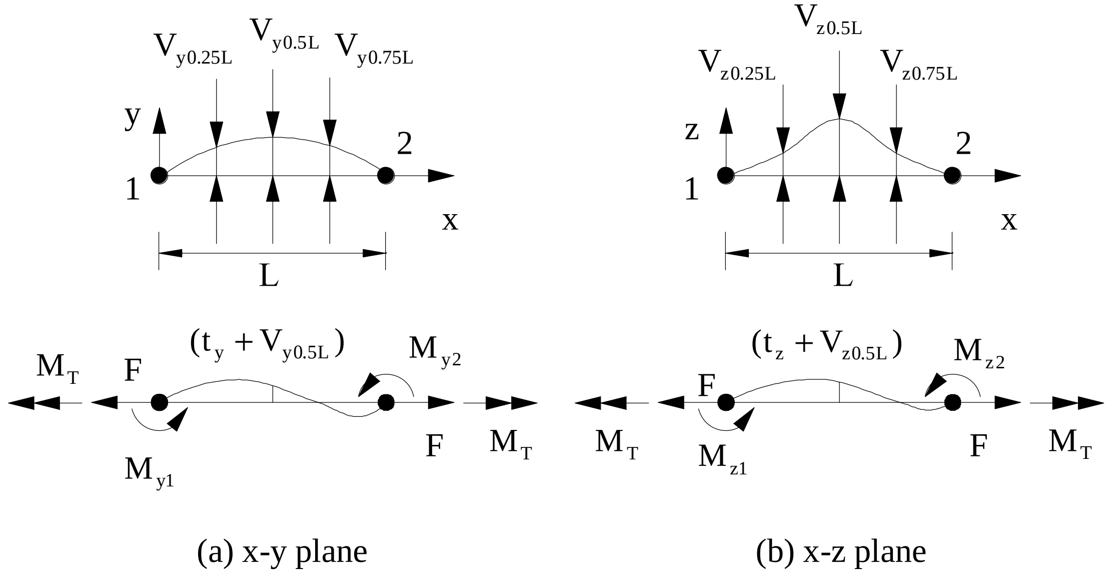
Description	Cubic elasto-plastic 3D beam-column element.
Monitoring points	100 points usually adequate; depends on section type.
Nodes	3
Characteristics	Geometric and material nonlinearities. Numerical integration performed over two Gauss points. A number of monitoring areas used at each Gauss section to monitor material direct stress and strains. Predicts global member behaviour based on a material stress-strain relationship. A number of elements per member, usually over 5, must be used for reasonable accuracy in inelastic modelling. Nodes (1) and (2) define the element connectivity and its local x-axis. The y-axis lies in a plane defined by the x-axis and node (3), which can be a non-structural node.
Application	Modelling of inelastic members in space frames.
Restrictions	The elastic torsional rigidity is used, which is approximate for composite and R/C sections.Warping strains are not accounted for.
Group header	`sec.name` :An identifier referring to one of the cross-sections declared in the **sect**ions module. `monitoring.points` Defines the number of points for monitoring stresses and strains within a cross-section.



(a) x-y plane (b) x-z plane

Forces in local system of element type ***cbp3***

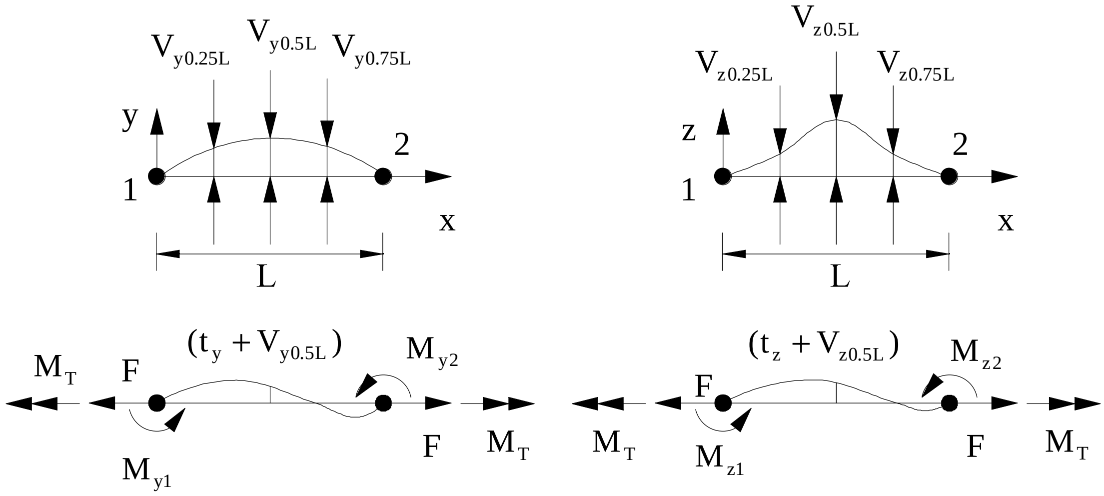
Description	Quartic elastic 3D beam-column element.
Nodes	3
Imperfections	$V_{y0.25L}$, $V_{y0.5L}$, $V_{y0.75L}$, $V_{z0.25L}$, $V_{z0.5L}$, and $V_{z0.75L}$ can be specified.
Characteristics	Geometric nonlinearities.
	Large displacements and beam-column effect of perfect/imperfect members.
	One element type ***qel3*** is usually sufficient to represent the beam-column effect and large displacement response of a whole elastic member.
	Nodes (1) and (2) define the element connectivity and its local x-axis. The y-axis lies in a plane defined by the x-axis and node (3), which can be a non-structural node.
Application	Geometric nonlinearities in elastic space frames.
Restrictions	Unable to model concrete cracking.
	Warping strains are not accounted for.
Group header	`sec.name` :An identifier referring to one of the cross-sections declared in the **sect**ions module.



Imperfection and forces in local system of element type ***qel3***

qph3

Description	Quartic plastic hinge 3D beam-column element with an option for automatic subdivision.
Nodes	3
Subdivision	Automatic subdivision into two elements if a plastic hinge is detected within the element may be requested.
Imperfections	$V_{y0.25L}$, $V_{y0.5L}$, $V_{y0.75L}$, $V_{z0.25L}$, $V_{z0.5L}$, and $V_{z0.75L}$ can be specified.
Characteristics	Geometric and material nonlinearities. Suitable for members in which the spread of plasticity is not important and the section response is elastic-plastic without strain-hardening. Rotational and axial plastic hinge displacements are allowed at the two ends of the element. One element type ***qph3*** is usually sufficient to model a whole member, and the option of subdivision allows for the case of member buckling. Nodes (1) and (2) define the element connectivity and its local x-axis. The y-axis lies in a plane defined by the x-axis and node (3), which can be a non-structural node.
Application	Large displacement plastic-hinge analysis of space frames
Restrictions	Not applicable to reinforced concrete or composite members. Warping strains are not accounted for.
Group header	**sec**.name: An identifier referring to one of the cross-sections declared in the **sect**ions module. **subd**ivision**:** Gives the option for automatic subdivision plastic hinge elements: =(**t** | **true**) consider element subdivision =(**f** | **false**) ignore element subdivision

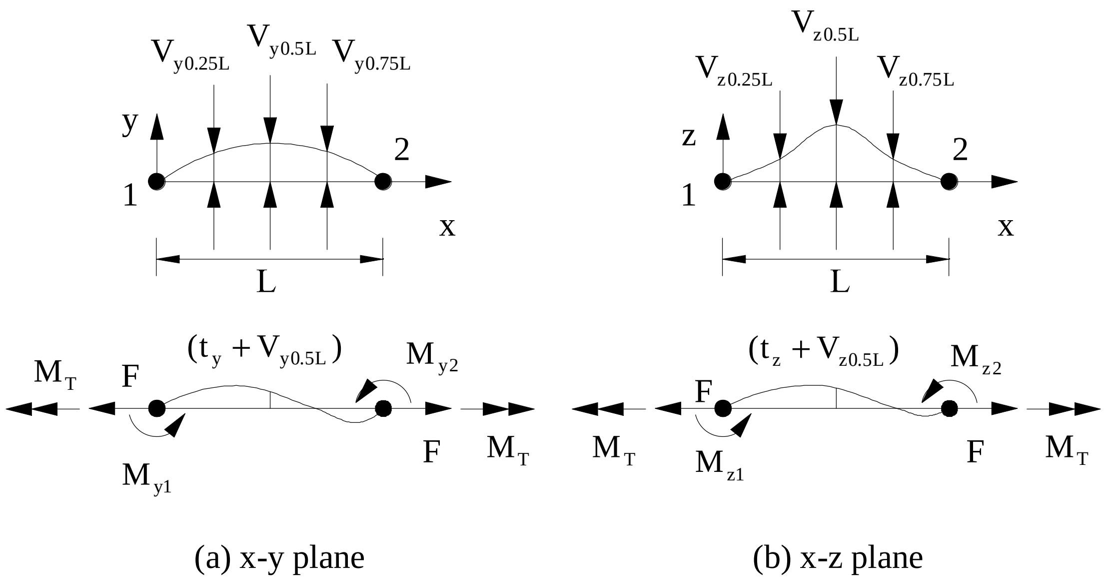


(a) x-y plane

(b) x-z plane

*Imperfection and forces in local system of element type **qph3***

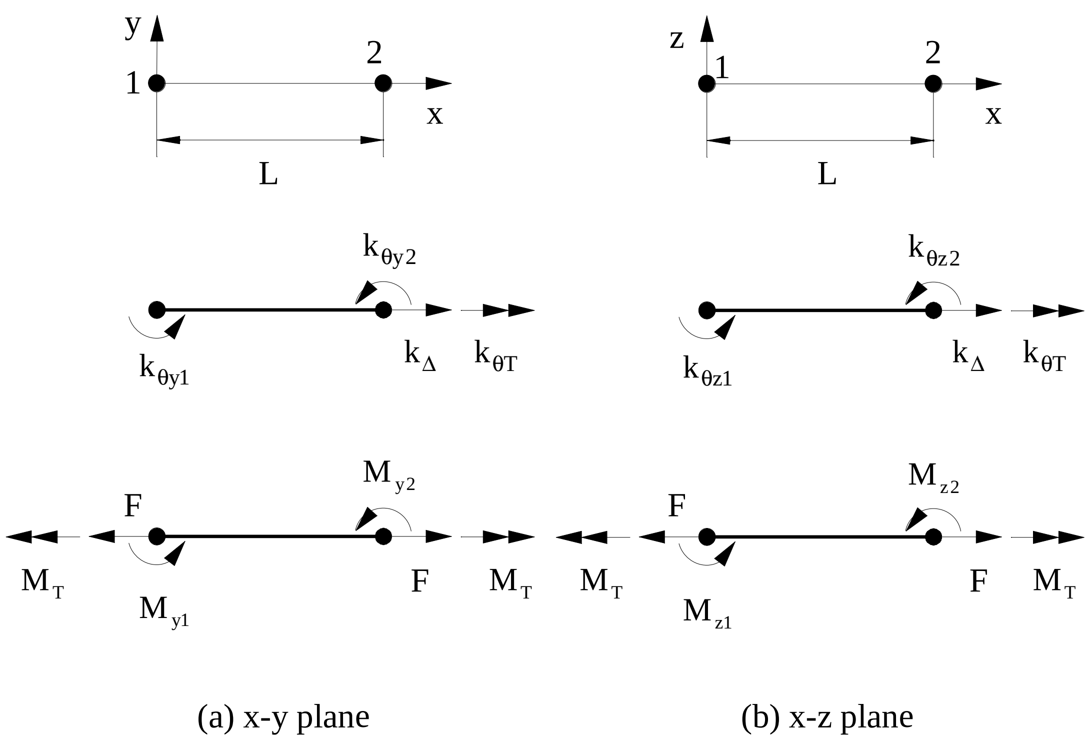
Description	Quartic elastic 3D beam-column element utilising automatic mesh refinement.
Subdivision pattern	Relative lengths in ratio form of zones where inelasticity is checked for automatic mesh refinement.
Nodes	3
Imperfections	$V_{y0.25L}$, $V_{y0.5L}$, $V_{y0.75L}$, $V_{z0.25L}$, $V_{z0.5L}$, and $V_{z0.75L}$ can be specified.
Characteristics	Geometric and material nonlinearities.
	Large displacement and beam-column effect of perfect/imperfect members.
	One element type ***qdp3*** is usually sufficient to represent a whole member.
	Element ***qdp3*** subdivides into elements **cbp3**, specified under **cbp3.grp.name**, if inelasticity is detected in the zones defined by the subdivision pattern **pat.name**.
	Accuracy increases with the number of sub-elements type **cbp3** specified in the subdivision pattern.
	After subdivision, elements **cbp3** are inserted in the inelastic zones, while the elastic zones are kept as element type ***qdp3***.
	Nodes (1) and (2) define the element connectivity and its local x-axis. The y-axis lies in a plane defined by the x-axis and node (3), which can be a non-structural node.
Application	Adaptive modelling of inelastic members in space frames.
Restrictions	Applies only to cross-sections with materials **stl1**, **stl2** & **stl3**.
	Warping strains are not
Group header	`cbp3.grp.name:` Specifies the group identifier of elements type **cbp3** used in automatic mesh refinement.
	`pat.name:` An identifer referring to a subdivision pattern in the **patt**erns module.



*Imperfection and forces in local system of element type **qdp3***

lnk3

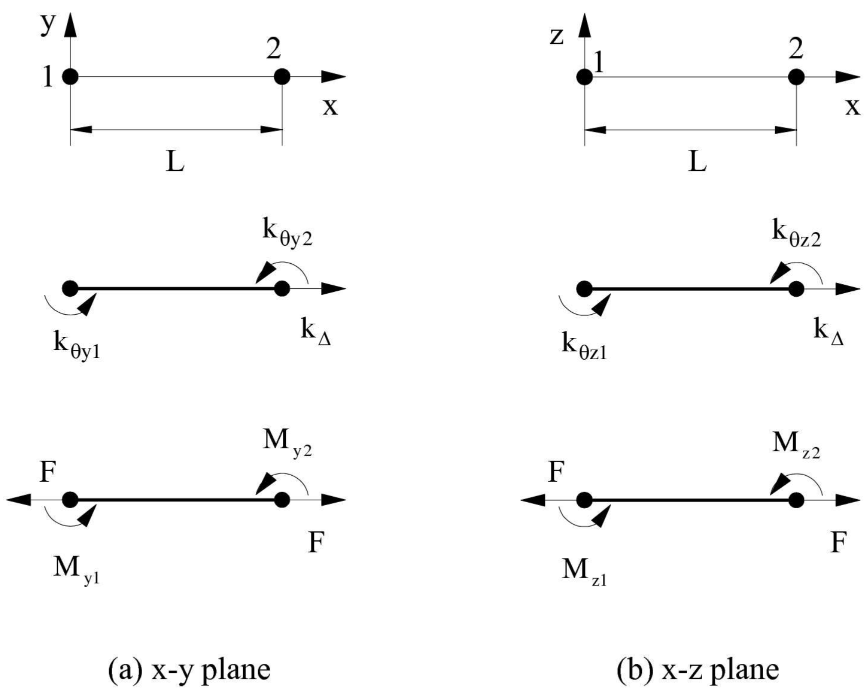
Description	3D link element with discrete axial/rotational springs.
Nodes	3
Characteristics	Geometric nonlinearity.
	Nodes (1) and (2) define the element connectivity and its local x-axis. The y-axis lies in a plane defined by the x-axis and node (3), which can be a non-structural node.
Application	Rigid link.
	Elastic bar with pinned ends.
Restrictions	
Group header	`stiffness.parameters`: numerical or `rigid` values for each of the spring stiffnesses, $k_{\theta y1}$, $k_{\theta z1}$, $k_{\theta y2}$, $k_{\theta z2}$, k_{Δ} and $k_{\theta T}$ in this order.



*Stiffness parameters and forces in local system of element type **lnk3***

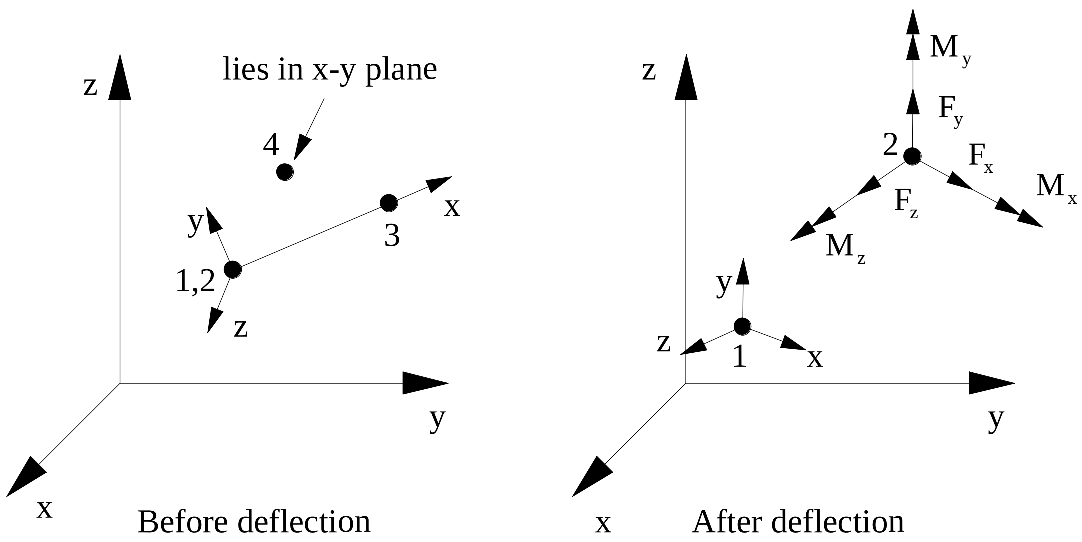
lnks

Description	3D link element linking 6 DOF to 5 DOF nodes.
Nodes	3.
Characteristics	Geometric nonlinearity. Nodes (1) and (2) define the element connectivity and its local x-axis. The y-axis lies in a plane defined by the x-axis and node (3), which can be a non-structural node.
Application	Beam to slab connection. The second node is a 5 DOF node belonging to plate/shell elements with only two rotational DOF's, including ***csl4*** elements.
Restrictions	
Group header	`stiffness.parameters`: numerical or `rigid` values for each of the spring stiffnesses, $k_{\theta y1}$, $k_{\theta z1}$, $k_{\theta y2}$, $k_{\theta z2}$ and k_{Δ} in this order.



Stiffness parameters and forces in local system of element type ***lnks***

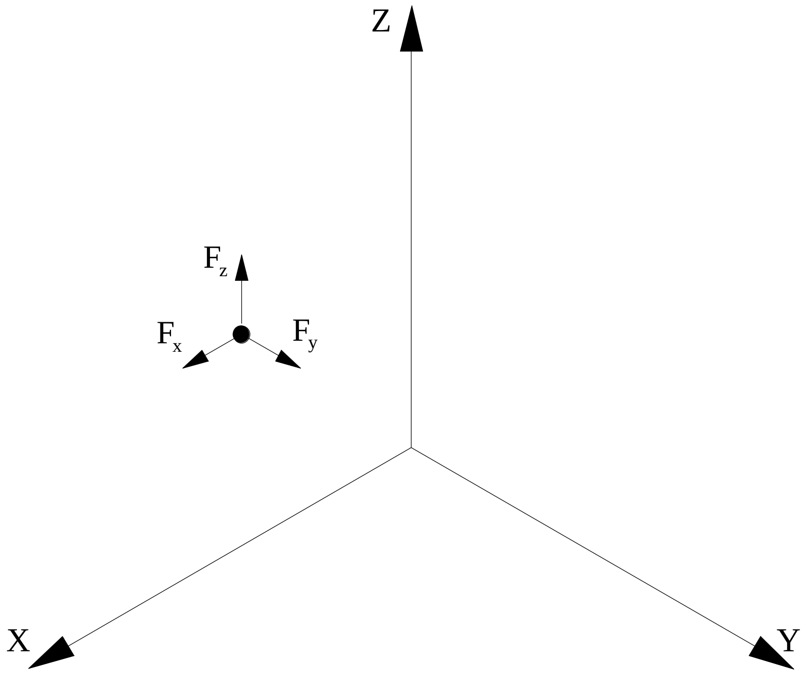
Description	3D joint element with uncoupled axial, shear and moment actions.
Curve types	Models used for the joint force-displacement curves, specified for F_x (axial), F_y & F_z (shear) and M_x, M_y & M_z (moment), respectively. Each of these models may be any of those described in Chapter 4.
Parameters	Parameters for each of the six models specified for F_x, F_y, F_z, M_x, M_y, M_z.
Nodes	4
Characteristics	Nodes (1) and (2) must be initially coincident. Node (3) is only used to define the x-axis of the joint and can be a non-structural node. The y-axis lies in a plane defined by the x-axis and node (4), which also can be a non-structural node. The orientation of the joint x-axis after deformation is determined by its initial orientation and the global rotations of node (1).
Application	Space frame analysis. Can be used to model pin joints, inclined supports, elasto-plastic joint behaviour, soil-structure interaction and structural gaps, through employing appropriate joint curves.
Restrictions	Element has a zero initial length, since nodes (1) and (2) must be coincident. Cannot be used to model coupled axial, shear and moment actions.
Group header	`curve.types`: Defines curve types for joint elements. `parameters:` Defines parameters for the joint elements.



Configuration and forces for element type ***jel3***

cnm3

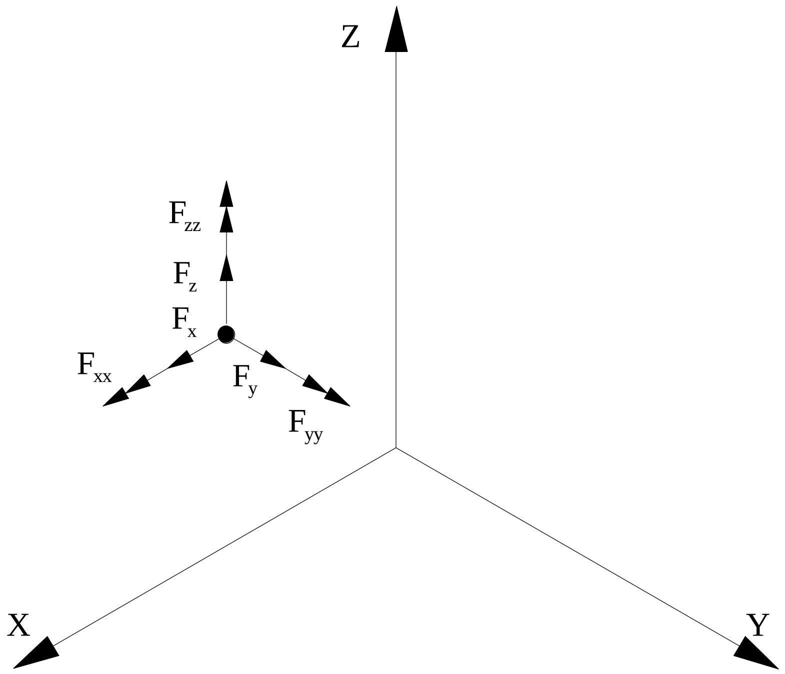
Description	Concentrated (lumped) 3D mass element.
Nodes	1
Characteristics	Models lumped mass for dynamic analysis. Allows full 3×3 translational mass matrix to be defined. Lumped element mass, specified according to one of: M_x (default $M_y = M_z = M_x$ & $M_{xy} = M_{xz} = M_{yz} = 0$) M_x, M_y, M_z (default $M_{xy} = M_{xz} = M_{yz} = 0$) $M_x, M_y, M_z, M_{xy}, M_{xz}, M_{yz}$ Allows specification of mass-proportional damping at group level.
Application	Dynamic analysis of space frames, shells and 3D continuum/membrane structures.
Restrictions	
Group header	**`mass:`** Element mass. `[damping.parameter]`: optional parameter for mass-proportional Rayleigh damping; defaults to the value of `mass.damping.parameter` specified in the default.parameters module.



Forces for element type ***cnm3***

cnd3

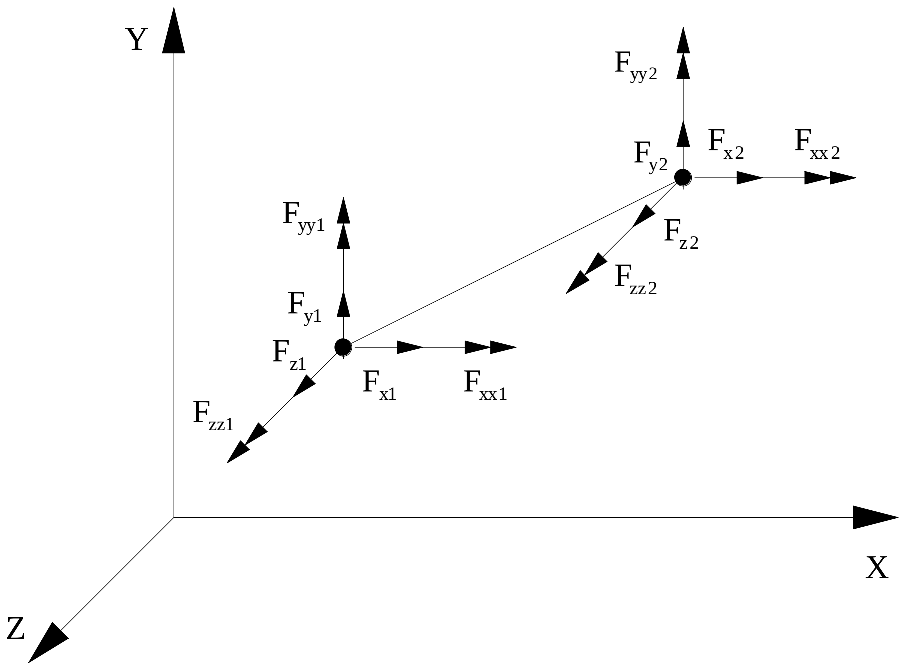
Description	Concentrated (dashpot) 3D viscous damping element.
Damping parameters	Three translational and three rotational damping coefficients, specified in this order: C_x , C_y , C_z [C_{xx} , C_{yy} , C_{zz}]
Nodes	1
Characteristics	Models nodal viscous damping for dynamic analysis.
Application	Dynamic analysis of space frames and shells. Dynamic analysis of 3D continuum/membrane structures.
Restrictions	C_{xx} , C_{yy} , C_{zz} should be specified as zero for shell nodes. [C_{xx} , C_{yy} , C_{zz}] should not be specified for 3D continuum/membrane analysis.
Group header	`damping.parameters:` Defines dashpot damping parameters.



Forces for element type ***cnd3***

lnm3

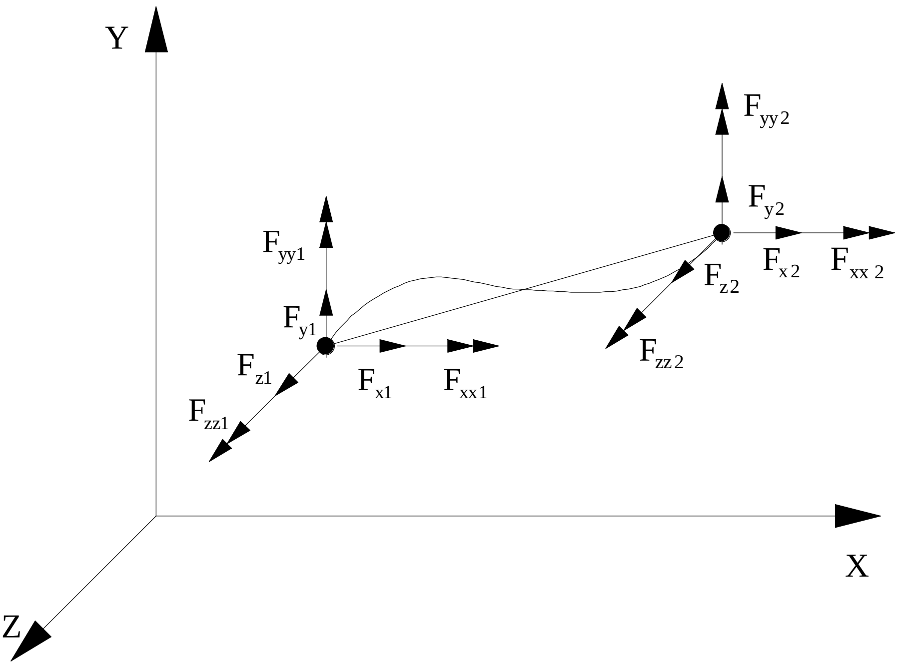
Description	Linear 3D mass element.
Nodes	2
Characteristics	Simplified modelling of uniformly distributed mass for dynamic analysis. Assumes the mass to lie on a rigid straight line between the two end nodes. Allows specification of mass-proportional damping at group level.
Application	Dynamic analysis of space frames.
Restrictions	
Group header	`mass/length:` Mass per unit length. `[damping.parameter]`: optional parameter for mass-proportional Rayleigh damping; defaults to the value of `mass.damping.parameter` specified in the default.parameters module.



Forces for element type ***lnm3***

cbm3

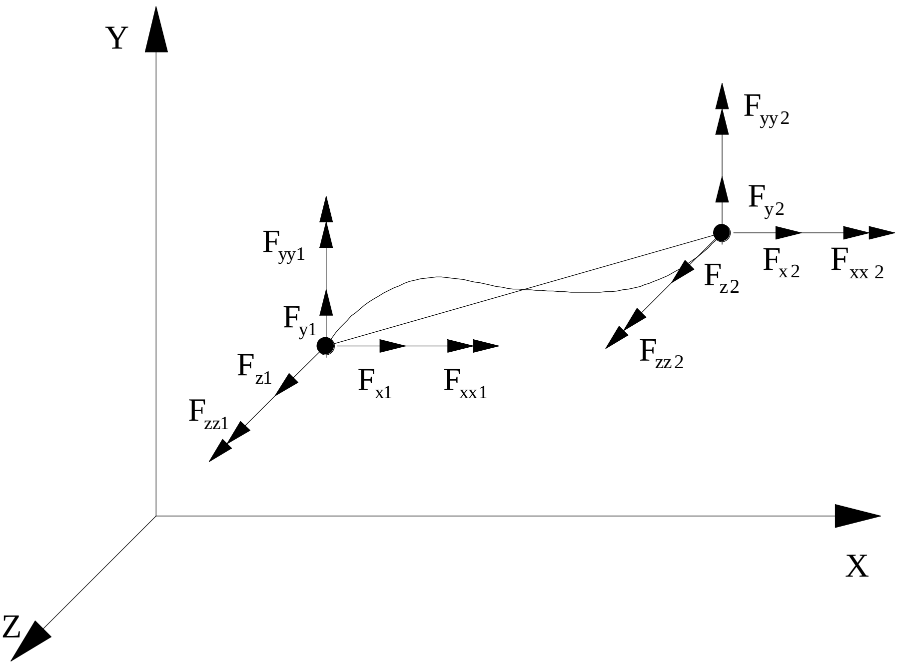
Description	Cubic 3D distributed mass element.
Nodes	2
Characteristics	Models uniformly distributed mass in dynamic analysis. Uses an Updated Lagrangian formulation with a cubic shape function for the transverse displacement and a linear distribution for the axial displacement. Allows different axial (m_a) and transverse (m_t) distributed mass. Mass per unit length, specified according to one of: m_a (default $m_t = m_a$) m_a, m_t Allows specification of mass-proportional damping at group level.
Application	Dynamic analysis of space frames.
Restrictions	
Group header	`mass/length`: Mass per unit length. `[damping.parameter]`: optional parameter for mass-proportional Rayleigh damping; defaults to the value of `mass.damping.parameter` specified in the default.parameters module.



*Forces for element type **cbm3***

rld3

Description	Rayleigh damping 3D element
Mass/length	Mass per unit length
Parameters	Two proportionality constants (a_1 & a_2) of mass and stiffness respectively, specified in that order.
Nodes	3
Characteristics	Models Rayleigh damping effects. All ***rld3*** elements must have the same constant (a_1 & a_2) to model conventional Rayleigh damping. Nodes (1) and (2) define the element connectivity and its local x-axis. The y-axis lies in a plane defined by the x-axis and node (3), which can be a non-structural node.
Application	Dynamic analysis of plane frames.
Restrictions	(a_1) should be set to zero for dynamic analysis involving ground excitation, otherwise damping would be proportional to absolute rather than relative frame velocity.
Group header	`sec.name` :An identifier referring to one of the cross-sections declared in the **sect**ions module. `mass/length`: Mass per unit length. `parameters`: Defines parameters of Rayleigh damping elements.



Forces for element type ***rld3***

csl4

Description 2-D flat shell element for composite floor slabs.

Nodes 4

Characteristics Geometrically orthotropic slab.

4-noded composite and R/C slab element with additional rib and cover freedoms. It deals with the nonlinear analysis of composite floor slabs, enabling the modelling of material nonlinearities and geometric orthotropy through a modification of the Reissner-Mindlin hypothesis.

The element can be used in a basic form employing bilinear shape functions or in a higher-order form employing quadratic shape functions for the normal rotations. This is achieved through the use of hierarchic additional freedoms, which are defined in this order:

$$f_a = \left\langle (\bar{\mathbf{w}})_{1\to4}, (\mathbf{u}_r, \mathbf{v}_r)_{1\to2}, (\bar{\mathbf{u}}, \bar{\mathbf{v}}, \bar{\bar{\mathbf{w}}}, \bar{\boldsymbol{\theta}}_x, \bar{\boldsymbol{\theta}}_y)_{1\to4}, (\bar{\mathbf{u}}_r, \bar{\mathbf{v}}_r)_{1\to3} \right\rangle^T$$

For the bilinear form, only the first 8 additional freedoms are used, with the remaining 26 additional freedoms employed in addition for the quadratic form. Individual additional freedoms may be restrtained as described in the ***restraints*** module.

Elevated temperature may be specified using element load type ***tmp7*** specified in this order:

$$\langle T_1, \Delta T_1, T_2, \Delta T_2, T_3, \Delta T_3, T_4, \Delta T_4, T_5, \Delta T_5, T_6, \Delta T_6, T_7, T_8 \rangle$$

where T_i and ΔT_i indicate respectively temperatures and temperature increments between the bottom of the cover and the top of the slab.

Application Realistic modeling of composite floor slabs under extreme loading, including fire conditions.

Restrictions

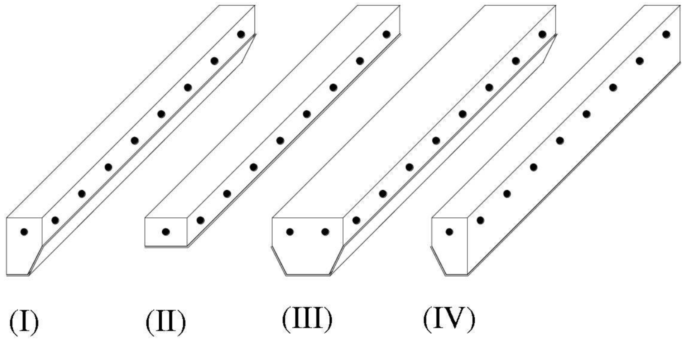
Group header

sec.name: An identifier referring to a cross-section of type ***cslb*** declared in the sections module.

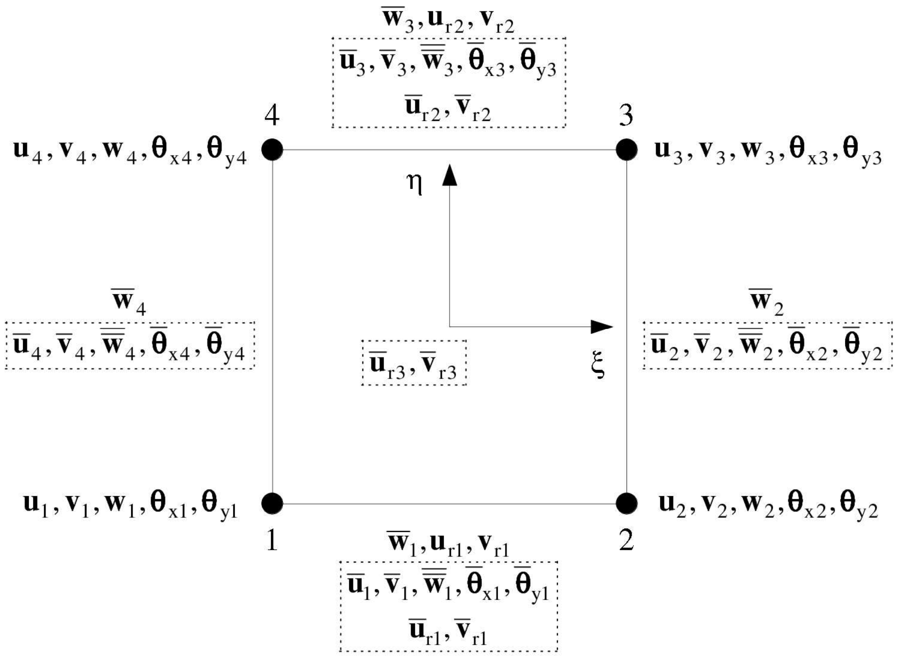
type: one of the following: **left**.edge.rib, **cove**r, **centr**al.rib, and **right**.edge.rib.

gauss.points: 3 entries representing number of gauss points in the local x, y and z directions, respectively.

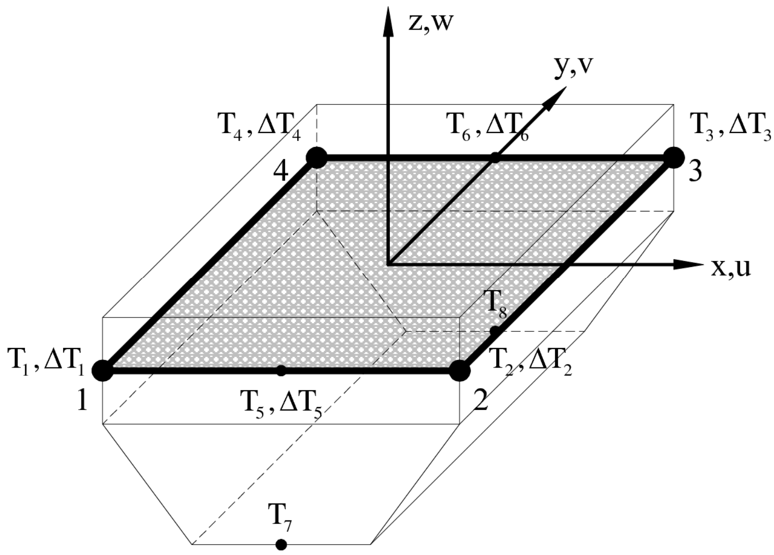
[options]: optional parameter indicating the element order **[bilinear|quad**ratic**]**; defaults to **bilin**ear.



Element types for ***csl4:*** *(I) left.edge.rib; (II) cover; (III) central.rib; (IV) right.edge.rib*



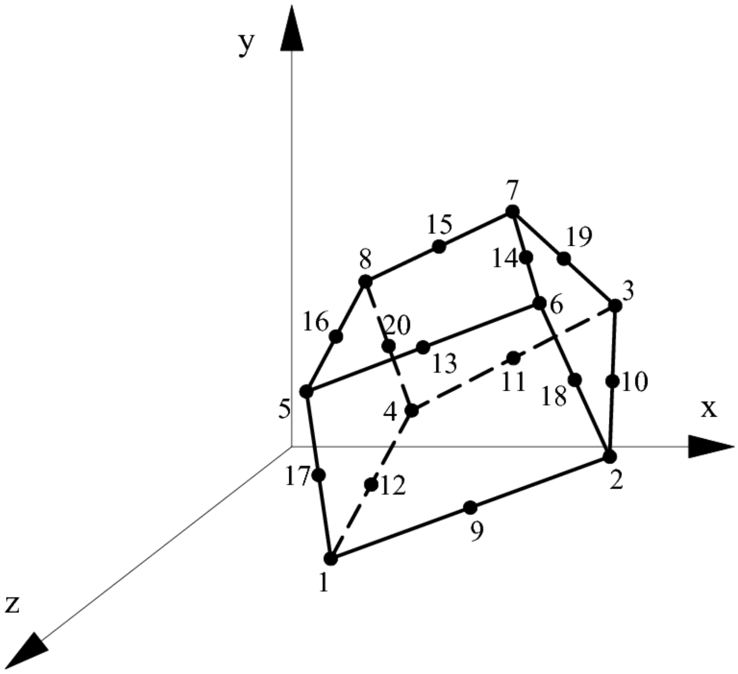
Additional freedoms for element ***csl4***



Temperature distribution for ***csl4***

bk20

Description	20 noded 3D brick element.
Nodes	20
Characteristics	Models 3D continuum large displacement problems using Green's strain. Applies to static, dynamic and elevated temperature analysis. Allows direct specification of material density and Rayleigh damping parameters for dynamic analysis.
Application	Static/dynamic analysis of 3D continuum problems.
Restrictions	Works with material models **beth**, **bnsi**, **bnsk** and **tpth**.
Group header	`mat.name` :An identifier referring to one of the materials declared in the **mate**rials module. `[gauss.points]`: optional total number of gauss points; defaults to 27 (ie. 3×3×3). `[density]`: optional material density used for dynamic analysis; defaults to zero. `[damping.parameter]`: two optional parameters for mass- and stiffness-proportional Rayleigh damping, respectively; default to the values of `mass.damping.parameter` and `stiffness.damping.parameter` specified in the default.parameters module.



*Nodal ordering for **bk20***

Chapter 7. DATA SYNTAX

7.1 Introduction

A header-oriented syntax is utilized in ADAPTIC data files. Data modules are identified by means of unique headers, and only the first four characters in the header key words are necessary. However, if more than four characters of a key word are employed, the ADAPTIC data input module checks for the consistency of all characters.

Names or numbers employed, for example, as identifiers for elements or nodes can be up to 8 character long. However, if this number is exceeded only the first 8 characters are considered.

The following symbols are used for describing the ADAPTIC data syntax. Note that these symbols are used in the rest of this manual only for delivering information, and they must not be used within an ADAPTIC data file.

Symbol	**Description**
(......)	Parantheses used to include a list of items.
		Exclusive OR. For example (**2d** | **3d**) is equivalent to a single entry which can be either 2d or 3d.
[......]	Brackets used to include optional item(s). For example [**z**] means that entry z is optional.
< entry >	Specifies the entry type. For example < integer > indicates an integer data entry.
^	Indicates that the entries for the previous key word in the header can be defined by assignment outside the header line. For example,

```
mat.name     model^     properties
```

indicates that the following two data modules,

```
mat.name     model     properties
  m1          stl1      210e9  300e6  0.01
```

and,

```
model = stl1
mat.name     properties
  m1          210e9  300e6  0.01
```

are equivalent.

7.2 General Facilities

This sections describes general facilities which are available with all data modules, unless indicated otherwise.

7.2.1 Continuation

The ampersand (**&**) symbol can be used to continue data entry on the next line.

7.2.2 Comments

Comments can be added anywhere in the data file using the hash (#) symbol. All entries following a (#) on the current line are ignored.

7.2.3 Incrementation

The automatic incrementation facility can be used with some data modules. This is indicated where applicable. The general syntax is given below:

f	< entry {1} >	. . . .	< entry {n} >
r	< inc. {1,1} >	. . . .	< inc. {n,1} > < rep. {1} >
r [<range{2}>]	< inc. {1,2} >	. . . .	< inc. {n,2} > < rep. {2} >
r [<range{m}>]	< inc. {1,m} >	. . . .	< inc. {n,m} > < rep. {m} >

<entry {i}> ith entry on the first data line used for generation.

<range {j}> Range of previously generated lines to be used for further incrementation.
Syntax of <range {j}> is ([<first {j}>] **:** [<last {j}>]), for example 4:8.

<inc. {i,j}> The increment to be used in the generation of the ith entries.
If <entry {i}> is a character string then <inc{i,j}> must be a dash (**–**).

<rep. {j}> The number of times each line in the range <range {j}> is incremented.

Notes The defaults for optional arguments are:

<range {j}> = **1:**(total number of lines generated so far)

<first {j}> = **1**

<last{j}> = total number of lines generated so far

7.3 Input Modules

This sections describes the input modules available within ADAPTIC.

7.3.1 Analysis

This module specifies the analysis type.

```
analysis  ( 2d | 3d )  ( eigenvalue | dynamic | static )
```

`2d`	Two dimensional analysis.
`3d`	Three dimensional analysis.
`eigenvalue`	Eigenvalue analysis.
`dynamic`	Dynamic analysis.
`static`	Static analysis.

Notes

7.3.2 Default.parameters

This module specifies some default parameters.

```
default.parameters
mass.damping.parameter = < real >
stiffness.damping.parameter = < real >
```

`mass.damping.parameter`	Parameter used to specify mass-proportional damping, without the need for damping elements. Applies to mass elements **cnm2**, **lnm2**, **cbm2**, **cnm3**, **lnm3**, **cbm3** and **bk20**.
`stiffness.damping.parameter`	Parameter used to specify stiffness-proportional damping, without the need for damping elements. Applies to elements **bk20**.

Notes

7.3.3 Materials

This module specifies material identifiers referring to a particular model and model properties.

```
materials
mat.name        model^          properties
```

mat.name	A material identifier referring to the specified model and properties. The material name can be any alphanumeric string.
model	The material model used. The model should be one of those specified in Chapter 3.
properties	The material model properties. The number of properties must be as indicated in Chapter 3 for the corresponding model.

Notes

7.3.4 Sections

This module specifies cross-section identifiers referring to a section type, constituent materials and section dimensions.

sections			
sec.name	**type^**	**mat.**name^	**dime**nsions

sec.name — The name of the section which has the given properties. The name can be any alphanumeric string.

type — The section type. This must be one of the available types given in Chapter 5.

mat.name — Specifies the material(s) used. The specified entry(s) should be one of the material identifiers declared in the **mate**rials module.

dimensions — Dimensions of the section. The number of dimension must be as defined in Chapter 5 for the corresponding section type.

Notes

7.3.5 Patterns

This modules defines subdivision patterns utilised in automatic mesh refinement. The specified ratios indicate the number of potential subelements and their relative lengths.

patterns	
pat.name	**rati**os

pat.name	A pattern identifier.
ratios	Integer values denoting relative lengths of zones where inelasticity is checked. The number of integers implicitly defines the number of zones.

Notes

7.3.6 Groups

This module defines properties for element groups. The number and nature of group properties depend on the type of elements for which the group is being established.

groups	
type.of.element = < element type >	**grp.**name = <group header>

7.3.7 Structural.nodal.coordinates

This module defines coordinates of structural nodes.

```
structural.nodal.coordinates
nod.name     x^        y^          [z^]
```

nod.name	A node identifier which can be any alphanumeric string.
x, **y**, **z**	Global nodal coordinates.

Notes **z** is only required for 3D analysis.

Incrementation can be used with this module.

7.3.8 Non.structural.nodal.coordinates

This module defines coordinates of structural nodes.

```
non.structural.nodal.coordinates
nod.name    x^        y^            [z^]
```

nod.name	A node identifier which can be any alphanumeric string.
x, **y**, **z**	Global nodal coordinates.

Notes **z** is only required for 3D analysis.

Incrementation can be used with this module.

7.3.9 Element.connectivity

This module defines the connectivity of elements in a mesh configuration.

element.connectivity		
elm.name	**grp.**name^	**nod.**name(s)

elm.name	An element identifier which can be any alphanumeric string.
grp.name	An identifier referring to one of the groups declared in the `groups` module.
nod.name(s)	The element end nodes defined in the **stru**ctural.nodal.coordinates or **non.**structural.nodal.coordinates modules.

Notes Incrementation can be used with this module.

7.3.10 Imperfections

This module specifies imperfection levels within elements of specific types.

```
imperfections
elm.name        values^
```

elm.name	The element which has the specified imperfection values.
values	The imperfection values for the element.

Notes

7.3.11 Restraints

This module defines nodal restraints.

```
        restraints
        [ nod.name              direction^] |
        [ elm.name              freedom^]
```

nod.name	The node to be restrained.
direction	Specifies the direction in which the defined node is restrained.
	= **x** displacement along global X-axis.
	= **y** displacement along global Y-axis.
	= **z** displacement along global Z-axis.
	= **rx** rotation about global X-axis.
	= **ry** rotation about global Y-axis.
	= **rz** rotation about global Z-axis.
elm.name	The element to be restrained.
freedom	The element additional freedom to be restrained.
	= **fa##** (e.g. fa5 and fa12 for freedoms 5 and 12).

Notes In two dimensional analysis, only **x**, **y** and **rz** directions can be specified.

Multiple freedoms can be specified by one entry (e.g. x+y+ry indicates restraints in the three directions x, y and ry).

Incrementation can be used with this module.

7.3.12 Conditions

This module specifies the conditions which govern the termination of the automatic control phase under a proportional static loading regime. These conditions are expressed in terms of limits on the load factor or displacements at specific freedoms.

```
conditions
(  ( lf.cnd.name  limits ) |
   ( disp.cnd.name  nod.name  direction  limits )  )
```

`lf.cnd.name`	Used for the load factor condition option, with the entry representing the condition identifier.
`limits`	Specifies the minimum and maximum limits.
`disp.cnd.name`	Used for the displacement condition option, with the entry representing the condition identifier.
`nod.name`	The node name for which the displacement condition applies.
`direction`	The direction for which the displacement condition applies. = **x** displacement along global X-axis. = **y** displacement along global Y-axis. = **z** displacement along global Z-axis. = **rx** rotation about global X-axis. = **ry** rotation about global Y-axis. = **rz** rotation about global Z-axis.

Notes Multiple direction specification is not allowed in this module.

This module is only applicable when using `proportional.loads` in the `applied.loading` module.

7.3.13 Linear.curves

This module specifies piecewise linear load curves for dynamic or time history loading.

```
linear.curves
start.time  =  < real >
crv.name =  < name >
      (  ( time load.factor ) |
         ( file            =      < file name > ]
            [ delay        =      < real > ]
            [ first.line   =      < integer > ]
            [ last.line    =      < integer > ]
            [ format       =      < format specification > ] )
```

start.time — Specifies the start time at which all load curves have a zero value. This entry must be less than the first **TIME** entry of all load curves

crv.name — A curve identifier.

time — Time or pseudo-time column of entries.

load.factor — Load factor column entries corresponding to the **time** enteries.

file — The name of the file in which the load curve is stored. This option can be used if the load curve is stored in a file.

delay — The time delay from the start time before the load curve is applied.

Default = **0**

first.line — The line number in **file** corresponding to the first entry of the load curve.

Default = **1**

last.line — The line number in **file** corresponding to the last entry of the load curve.

Default = <end of file>

format — A FORTRAN format specification by which the load curve entries are read from `file`.

Default = <free format>

Notes Load factors of all load curves are taken as zero at the start time.

The time entries of a load curve recalled from a **file** are shifted by the value of **delay** which must always be positive. The load factor for such curves is zero between `start.time` and (`start.time` + `delay`).

This module is only applicable when using `time.history.loads` or `dynamic.loads` defined in the `applied.loading` module.

7.3.14 Integration.scheme

This module specifies the time integration scheme for dynamic analysis and its parameters.

```
integration.scheme
   ( scheme = newmark
     [ beta     =     < real > ]
     [ gamma    =     < real > ] ) |
   ( scheme = hilber.hughes.taylor
     [ alpha    =     < real > ]
     [ beta     =     < real > ]
     [ gamma    =     < real > ])
```

scheme	The time integration scheme.
alpha	HHT α parameter (>-1/3).
	Default = **0.0** (Newmark)
beta	Newmark/HHT β parameter.
	Default = $\mathbf{0.25(1-\alpha)^2}$
gamma	Newmark/HTT γ parameter.
	Default = $\mathbf{0.5-\alpha}$

Notes This module is only applicable for dynamic analysis defined by the existence of **dyna**mic.loads in the **appl**ied.loading module.

7.3.15 Applied.loading

This module specifies the type and the value of the applied loads.

```
applied.loading
   [ initial.loads
     ( nod.name direction^ type^ value^ ) |
     ( elm.name type^ value^ ) ]
(  ( proportional.loads
     nod.name direction^ type^ value^ ) |
   ( time.history.loads
     ( nod.name direction^ type^ crv.name^ value^ ) |
     ( elm.name type^ crv.name^ value^ ) ) |
   ( dynamic.loads
     ( nod.name direction^ type^ crv.name^ value^ ) |
     ( elm.name type^ crv.name^ value^ ) ) )
```

`initial.loads`	These are static loads that are applied prior to any variable load. They can be forces or prescribed displacements applied at nodes in the global directions.
`proportional.loads`	These are static loads having proportional variation. The magnitude of a load at any step is given by the product of its nominal value and the current load factor. Proportional loads may be forces or prescribed displacements applied at nodes in the global directions.
`time.history.loads`	These are static loads varying according to different load curves in the pseudo-time domain. The magnitude of a load at any given pseudo-time is given by the product of its nominal value and the load factor obtained from its load curve at that pseudo-time. Time history loads may be forces or prescribed displacements applied at nodes in the global directions.
`dynamic.loads`	These are dynamic loads varying according to different load curves in the real time domain. The magnitude of a load at any given time is given by the product of its nominal value and the load factor obtained from its load curve at that time. Dynamic loads can be forces or

	accelerations applied at the nodes in the global directions.
`nod.name`	The node at which the load is applied.
`nod.name`	The node at which the load is applied.
`direction`	The direction of the applied load:
	= `x` displacement along global X-axis.
	= `y` displacement along global Y-axis.
	= `z` displacement along global Z-axis.
	= `rx` rotation about global X-axis.
	= `ry` rotation about global Y-axis.
	= `rz` rotation about global Z-axis.
`type`	Defines the type of the applied load
	= (`force` | `f`) applied force.
	= (`displacement` | `d`) applied displacement.
	= (`velocity` | `v`) applied velocity.
	= (`acceleration` | `a`) applied acceleration.
	= element specific keyword for element loads.
`elm.name`	The element subjected to loading.
`value`	Nominal value of the applied load.
`crv.name`	The load curve defining the variation of dynamic or time history loads. The load curve must be declared in the `linear.curves` module.

Notes

`proportional.loads`, `time.history.loads` and `dynamic.loads` cannot be used in the same analysis.

`initial.loads` can be used in static or dynamic analysis, but the module is optional. The load `type` can either be `force` or `displacement` for both static and dynamic analysis. In dynamic analysis only, `velocity` and `acceleration` can be used to indicate initial conditions, but these are only applicable to dynamic freedoms (i.e. those associated with mass/damping elements or support excitation).

`proportional.loads` or `time.history`. loads must be used in static analysis, for which the load `type` can either be `force` or `displacement`.

`dynamic.loads` must be used in dynamic analysis, for which the load `type` can either be `force` or `acceleration`.

Element loads cannot be applied as `proportional.loads`.

7.3.16 Equilibrium.stages

This module defines stages of time intervals at which structural equilibrium is established.

equilibrium.stages	
end.of.stage	**step**s

end.of.stage	Defines the end time of a stage.
steps	The number of steps within a stage.

Notes The time-step size for a stage is equal to the difference between the end time of the current stage and that of the previous stage divided by the number of steps of the current stage. For the first stage, the time step size is equal to the difference between the end of the first stage and the **star**t.time defined in **line**ar.curves.

This module is only applicable when using **time.**history.loads or **dyna**mic.loads defined in the **appl**ied.loading module.

7.3.17 Phases

This module defines the control phases used to trace the load deflection curve for proportional loading. Three types of control are available: load, displacement and automatic control.

```
phases
(  ( load.control
     increment       path              steps ) |
   ( displacement.control
     [( nod.name | elm.name )] direction increment path steps ) |
   ( automatic.control
     type            path        cnd.name ) )
```

load.control	Represents the load-control option.
displacement.control	Represents the displacement-control option.
automatic.control	Represents the automatic displacement-control option.
increment	Specifies the increment in the load factor for **load**.control, the increment of displacement for **disp**lacement.control, or the increment of arc length.
path	Specifies the sign of the increment (**cont**inue | **c**) = follow the previous loading path. (**reve**rse | **r**) = unload relative to the previous loading path (**keep** | **k**) = keep the sign of the increment as specified. This cannot be used for arc-length control.
steps	The number of steps used to apply the increment.
(**nod**.name | **elm**.name)	The name of the node or element used for displacement control. Omission of this implies arc-length control. Note that arc-length control cannot be used for the first phase.
direction	The global direction in which the displacement control will be applied.
type	The **auto**matic.control type:

(**nod.**control | **elm.**control | **arc.**length.control)

(**tran**slation | **rota**tion | x+y+z).

The direction specification x+y+z is used only for **arc.**length.control, and can represent any combination of the available translational freedoms (x, y and/or z).

cnd.name	The name of the stopping condition used in the automatic-control option. The specified condition should be declared in the **cond**itions module.

Notes The **path** entry, always be **keep** for the first phase.

automatic.control can not be the first phase.

7.3.18 Iterative.strategy

This module specifies the iterative strategy applied during a load or a time step.

```
iterative.strategy
[ number.of.iterations      =   < integer > ]
[ initial.reformations      =   < integer > ]
[ step.reduction            =   < integer > ]
[ divergence.iteration      =   < integer > ]
[ scaled.iterations         =   < integer > ]
[ tol.relax.level           =   < integer > ]
[ maximum.convergence       =   < real > ]
[ arc.flow.iteration        =   < integer > ]
```

number.of.iterations	The maximum number of iterations performed for each increment. `Default = 10`
initial.reformations	The number of initial reformations of the tangent stiffness matrix within an increment. `Default = 10`
step.reduction	The step reduction factor used when convergence is not achieved. `Default = 5`
divergence.iteration	The iteration after which divergence checks are performed. `Default = 6`
scaled.iterations	Number of iterations (> 2) after divergence over which the iterative displacement corrections are gradually scaled from zero to their full value. `Default = 1` (scaling off)
tol.relax.level	Step-reduction level (0 to 3) from and above which tolerance relaxation (between **tole**rance and **maxi**mum.tolerance) is allowed. `Default = 0`
maximum.convergence	The maximum convergance value allowed for any iteration `Default = 1000`

`arc.flow.iteration`	Iteration number after which the normal flow method is appled with arc-length control. Default = `number.of.iterations`

Notes

Using a number of `initial.reformations` equal to the `number.of.iterations` is equivalent to the Newton- Raphson strategy.

Using a number of `initial.reformations` equal to 0 is equivalent to the modified Newton- Raphson strategy.

The solution is considered to be diverging if after the `divergence.iteration` the convergence of the current iteration is greater than that of the previous iteration. This check is not applied during the `scaled.iterations` stage and for a number of subsequent iterations equal to `divergence.iteration`, or if a relaxed solution within `maximum.tolerance` has been found. Scaling of iterative displacement corrections is applied after divergence if the remaining number of iterations exceeds `scaled.iterations`; this technique can be used to overcome convergence oscillations.

The increment is reduced by the `step.reduction` factor if convergence (full or relaxed) is not achieved, divergence occurs or `maximum.convergence` is exceeded. The original increment can be reduced for up to three levels.

The normal flow option for arc-length control can improve convergence characteristics, but does not guarantee that the displacement increments correspond exactly to the specified arc length.

7.3.19 Convergence.criteria

This module defines convergence criteria for the iterative procedures. The convergence criteria is based either on the out-of-balance norm or the maximum iterative displacement increment.

```
convergence.criteria
tolerance               =    < real >
( force.ref             =    < real >
  moment.ref            =    < real > ) |
( displacement.ref      =    < real >
  rotation.ref          =    < real > ) |
( work.ref              =    < real > )
[ maximum.tolerance     =    < real > ]
```

tolerance	The required convergence tolerance for each load or time step.
force.ref	The force reference value used in calculating the convergence. Applicable to convergence criteria based on the out-of-balance norm.
moment.ref	The moment reference value used in calculating the convergence. Applicable to convergence criteria based on the out-of-balance norm.
displacement.ref	The displacement reference value used in calculating the convergence. Applicable to convergence criteria based on the maximum iterative displacement increment.
rotation.ref	The rotation reference value used in calculating the convergence. Applicable to convergence criteria based on the maximum iterative displacement increment.
work.ref	The work reference value used in calculating the convergence. Applicable to convergence criteria based on the energy norm.
maximum.tolerance	The maximum tolerance to which a solution may be relaxed to if the specified **tole**rance could not be satisfied with the **iter**ative.strategy. This is used in conjunction with **tol**.relax.level. Default = **0**

Notes A **tole**rance and **maxi**mum.tolerance equal to zero is equivalent to an iterative procedure in which a fixed **numb**er.of.iterations is performed for each load or time step without consideration of convergence.

7.3.20 Output

This module specifies the frequency of numerical output.

```
output
frequency <integer> [stress] [local.displacements|
   no.local.displacements] eigenvalue.interval <integer>
```

frequency	Provides the frequency of the numerical output. = **0** all equilibrium steps including step reduction levels. = **1** all equilibrium steps without step reduction levels. = **n** output every "n" equilibrium steps.
stress	Specified if element stresses are required. Applicable only to specific element types.
[no.]local.displacements	Indicates whether the local displacements of elements are output, which is true by default.
eigenvalue.interval	Indicates the output interval for eigenvalue analysis during dynamic analysis.

7.3.21 Lanczos.eigenvalue

This module specifies the number of required eigenvalues and the range of natural frequencies of interest. The Lanczos eigenvalue algorithm is utilized.

```
lanczos.eigenvalue
number.of eigenvalues   = < integer >
steps                   = < integer >
w.min                   = < real >
w.max                   = < real >
shift                   = < real >

[ starting.vector
   nod.name        direction^        value^]
```

`number.of eigenvalues`	The number of required eigenvalues.
`steps`	The number of Lanczos steps to converge to the eigenvectors.
`w.min`	Minimum natural frequency of interest.
`w.max`	Maximum natural frequency of interest.
`shift`	The frequency shift during the solution of the eigenvalue problem.
`starting.vector`	Initial vector used by the Lanczos algorithm to derive eigenvectors.
`nod.name`	Node name considered in the starting vector.
`direction`	The global direction which is given the specified values.
`value`	The value of the entry in the starting vector corresponding to the `nod.name` in the global `direction`.

Notes The number of steps must be less or equal to the total number of freedoms for the structure.

`w.min`, `w.max` and `shift` are in rd/sec.

`shift` must be between `w.min` and `w.max`.

A random starting vector is generated if the starting vector module is not specified.

Chapter 8. POST-PROCESSING

8.1 Start-Up

After the analysis has been *completed*, a post-processing application may be started to study the structural response graphically. Two graphics post-processing applications are available:

1) **ADAPTIC_graphs** for plotting X-Y graphs. This is activated as follows

```
{prompt} adaptic -g [filename[.dat|.svg]]
```

2) **ADAPTIC_shapes** for plotting deflected shapes. This is activated as follows

```
{prompt} adaptic -s [filename[.dat|.svs]]
```

The above applications are discussed separately in the following sections.

8.2 ADAPTIC_graphs

8.2.1 General Facilities

The main items of the graphics region in the ADAPTIC_graphs application are shown in Figure 8.2.1. The mouse buttons can be used to manipulate the appearance, size and position of each of the components, as discussed below.

Moving

Each of the items may be moved using the left mouse button with a single click to activate moving followed by a click and drag to move to the desired position.

Resizing

This facility only applies to the "Graph Area" item. It can be performed using the right mouse button with a single click to active resizing followed by a click and drag of the bottom right corner to the desired position.

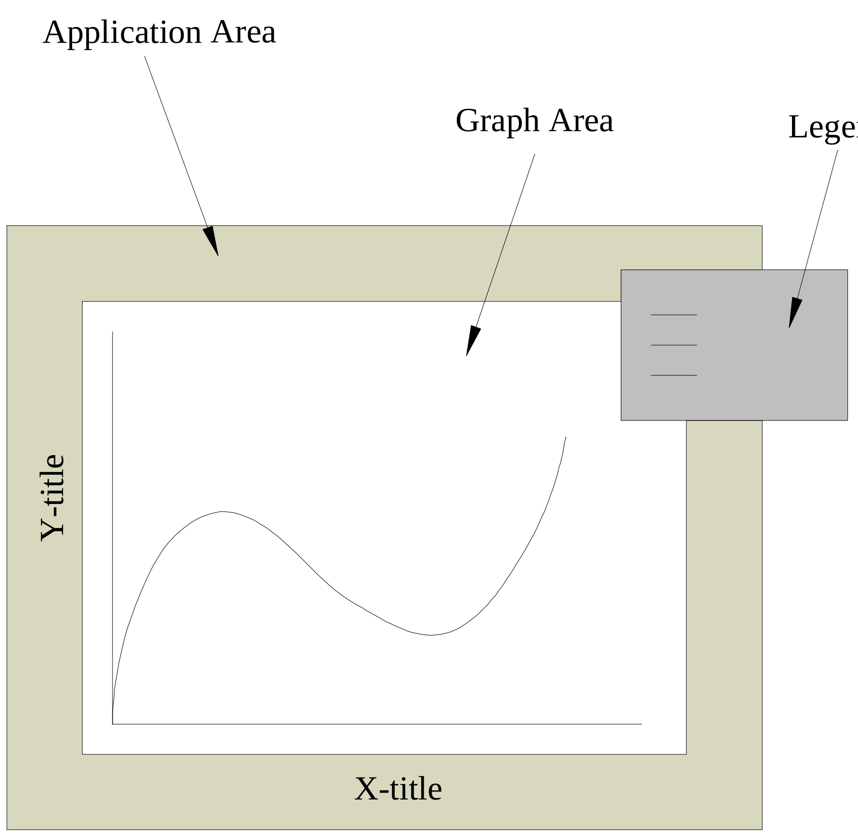


Figure 8.2.1. Graphics region of ADAPTIC_graphs application

8.2.2 File

This menu option offers the following facilities discussed with reference to the initiating buttons.

Data File

This invokes a form which allows the selection of the data file corresponding to the analysis that has been performed. Select the file `*filename*.dat` from the list of files in the directory where the analysis has been performed, where `*filename*` stands for the file identifier (e.g. `one_storey`).

Save

This button provides the means for storing plot information in a plot file for later retrieval. This is quite important for storing a permanent description of the plot, so that future modification can be performed with relative ease. Save files for the ADAPTIC_graphs application are automatically given a "`.svg`" extension.

Retrieve

This button retrieves "`.svg`" plot files that have been previously saved.

Print/Export

This button allows i) the output of the plot description to an Encapsulated PostScript (EPS) file, which can be imported into word processing applications, or ii) the export of numerical data as X-Y columns within a text file, which can be used for further processing and plotting in spreadsheet applications.

Exit

This allows the ADAPTIC_graphs application to be terminated. Before exiting, make sure you have saved your plot file, if necessary.

8.2.3 Graphs

Three facilities can be accessed using this menu option, as discussed below.

New Curve

This allows the selection of X and Y entities for a new line graph. After selecting the entities, described hereafter, the *Done* button must be pressed followed by the *Plot* button for displaying the new line graph.

TIME/LOAD FACTORS: Allows the selection of time or load factor, depending on the type of analysis, as well as CPU time and output number for plotting. The output numbers are explicitly indicated for the various steps of the nonlinear analysis in the output file `filename.out`.

FORCES AT PRESCRIBED FREEDOMS: Allows the selection of forces at restrained or prescribed freedoms. The latter are defined as any freedom subject to a displacement or time-history acceleration load.

NODAL ENTITIES: This covers nodal displacements, velocities and accelerations. The last two should only be requested for dynamic analysis.

ELEMENT ENTITIES: This covers i) local element entities (e.g. element forces and local displacements which depend on the element type), and ii) stresses and strains, the availability of which depend on the element type.

ENERGY GROUPS: This allows the selection of energy components determined for pre-defined energy groups.

ARITHMETIC EXPRESSIONS: This is a general utility which allows the combination of entities corresponding to previous line graphs in arithmetic expressions. The following definitions are valid combinations, referring to the Y coordinate of line graph 1, the X coordinate of line graph 3 and the Y coordinate of line graph 2:

Y1-2-X3/6

Y2**2-Y1*X3

Y2-Y1

Such expressions should be typed in the dialogue box.

One application of this utility is for generating entities representing relative displacements rather than absolute nodal displacements.

Delete Curves

This allows previous line graphs to be deleted. This may be desirable if a curve is no longer required, especially if it was originally intended for providing X and Y coordinates to be manipulated by the ARITHMETIC EXPRESSIONS utility described above.

Clear All

This facility clears the contents of the current plot. This allows the construction of a new plot.

8.2.4 Customize

This option facilitates the customisation of the graph characteristics.

Fonts

This allows the modification of the font name, size and style for the axes titles, axes labels and legend text.

Axes

This facility can be used to modify the axes attributes, including thickness, colour, etc. It also allows individual axes to be modified in terms of minimum and maximum values, step size, scaling factor, etc.

Lines

Each line graph can be customised using this facility with regard to thickness, style, colour, the use of points, activation/de-activation, the output range of interest, the corresponding legend text, etc.

Legend

The legend can be customised with regard to visibility as well as the number of legend columns.

8.3 ADAPTIC_shapes

8.3.1 General Facilities

The main components of the ADAPTIC_shapes application are shown in Figure 8.3.1. The functionality of each component is described hereafter.

<u>*Graphics Display Area*</u>

This is the main graphics area where the structure is displayed. Each of the three mouse buttons has a *click-and-drag* functionality, which is modified by the Shift key, and which depend on whether normal or perspective **view** is selected.

For normal view:

Lef button:	rotate about planar axes, origin centred in structure.
Lef button + Shift:	rotate about out-of-plane axis.
Right button:	zoom in.
Right button + Shift:	zoom out.
Middle button:	move.
Middle button + Shift:	pan.

For prespective view:

Lef button:	rotate camera about planar axes, origin centred at focal point.
Lef button + Shift:	rotate camera about out-of-plane axis.
Right button:	move camera forwards/backwards.
Right button + Shift:	zoom camera in/out.
Middle button:	pan camera in plane.
Middle button + Shift:	move scene in plane.

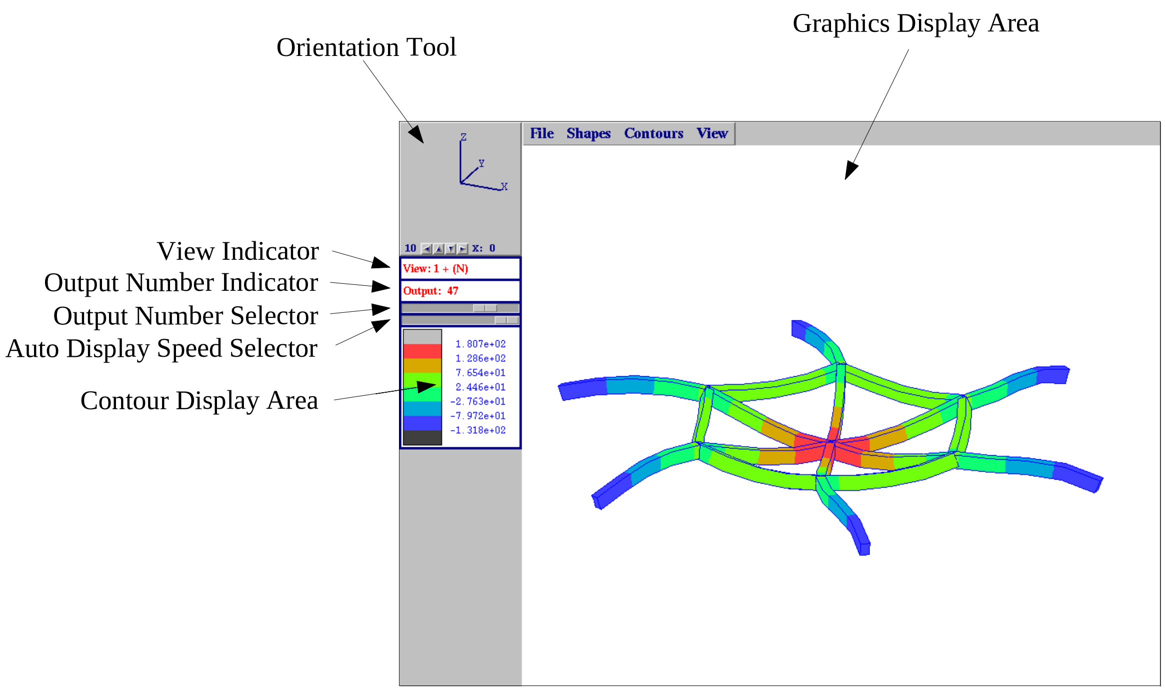


Figure 8.3.1. Components of ADAPTIC_shapes application

Orientation Tool

This tool displays the orientation of the global structural reference axes in the current view. The four arrow buttons can be used to change this orientation by i) selecting a global axis for incremental rotation, ii) specifying the increment of rotation, iii) applying positive rotation increments, and/or iv) applying negative rotation increments.

A single click with the mouse buttons on the orientation display area has the following functionality:

Lef button: controlled customisation of current **view**.
Right button: turn on/off axes orientation in the Graphics Display Area.

View Indicator

This displays the current view number (1, 2 or 3). The presence of (+) indicates that the current view is a subsequent modification of a stored view, whereas (–) indicates that the current view is a precursor to a stored view. Furthermore, (N) indicates a normal view, whereas (P) indicates a perspective view.

Output Number Indicator

This displays the current output number, as well as the corresponding eigenvalue mode if any, in view. For example, “Output: 3” refers to the actual deflected shape in output number 3, “Output: 5 [M2]” refers to mode 2 of output number 5 with auto display/slider contol given to varying the output number, while “Output: [5] M2” refers to the same mode and output number with auto display/slider contol given to varying the mode number.

A single click with the left mouse button enables specification of output number and eigenvalue mode.

Output Number Selector

This allows output number selection using a slider, which is more convenient for a quick browse through the deflected shapes.

Auto Display Speed Selector

This enable the speed of automatic display for deflected shapes to be controlled using a slider.

Contour Display Area

This area displays the contour colours and scale, and is activated by the **General Settings** button.

A single click with the mouse buttons on the contour display area has the following functionality:

Lef button: customisation of **contours**.
Right button: turn on/off contour information in the Graphics Display Area.

8.3.2 File

This menu option offers the following facilities discussed with reference to the initiating buttons.

Data File

This allows the selection of the data filename, provided the application is started on the command line without a filename specification, i.e.:

```
{prompt} adaptic -s
```

Save

This button provides the means for storing plot information in a plot file for later retrieval. This is quite important for storing a permanent description of the plot, so that future modification can be performed with relative ease. Save files for the ADAPTIC_shapes application are automatically given a "`.svs`" extension.

Retrieve

This button retrieves "`.svs`" plot files that have been previously saved.

Print

This button allows the output of the plot description to an Encapsulated PostScript (EPS) file, which can be imported into word processing applications.

General Settings

This button enables/disables the display of i) the initial shape alongside the deflected shape, ii) node and element labels, iii) contours, and iv) customisation of auto display/slider control.

The initial shape and labels are enabled by default for the undeflected configuration.

Control can be given to **Auto Display** and the **Output Number Selector (Slider)** to vary either the output number for a specific mode or the mode number for a specific output number. Also, a increment of output/mode numbers can be specified for Auto Display.

Exit

This allows the ADAPTIC_shapes application to be terminated. Before exiting, make sure you have saved your plot file, if necessary.

8.3.3 Shapes

This menu option offers the following facilities discussed with reference to the initiating buttons.

Output Number

This specifies the output and mode numbers to be displayed.

Output number 0 refers to the initial undeflected configuration, with other numbers referring to various equilibrium states obtained during nonlinear analysis.

For a specific output number, mode number 0 refers to the actual deflected shape of the equilibrium state, while other mode numbers refer to eigenvalue modes if any have been obtained for this equilibrium state.

Auto Display

This enabes an animation of the structural response or the eigenvalue modes through sequential automatic display of deflected shapes/modes.

Animation control can be given in the **General Settings** over varying the output numbers for a specific mode (0 for the deflected shape) or the mode numbers for a specific output number (0 for the initial configuration).

The speed of animation is controlled by the **Auto Display Speed Selector**. The animation can be interrupted with a single mouse click with any button anywhere within the application window.

Customize

This allows the display of various element types to be customised, mainly in terms of i) basic or full plotting, ii) range of element to be excluded from view, iii) plotting divisions over element, iv) line colour, v) fill colour, vi) line thickness and vii) appearance of nodal and element labels. The customisation can be applied selectively for individual element types or uniformly for all element types.

8.3.4 Contours

This menu option offers the following facilities discussed with reference to the initiating buttons.

Select Entities

This allows the selection of entities associated with specific element types for contour plotting. Note that this facility may not be available for some element types. Furthermore, the plotting of contours in the Graphics Display Area is controlled by the specification under **General Settings**.

Customize

This enables the specification of the number of contours, the associated colours and the corresponding numerical range, whether manual or automatic. An automatic contour range is established from the maximum and minimum values of the entities to be plotted.

8.3.5 View

This menu option offers the following facilities discussed with reference to the initiating buttons.

Scale

This specifies the displacement/mode scale to be used.

Two independent scale values can be specified for plotting the deflected shape (i.e. mode = 0) and the eigenvalue modes (i.e. mode > 0).

For large displacement analysis, the scale for the deflected shape (mode = 0) is normally specified as (1).

For eigenvalue analysis, a large scale (>>1) may need to be specified to distinguish the mode shape from the initial undeflected shape.

Select

This allows the selection of any of the three stored views in addition to the previous view. By default, the three views correspond to normal views of the i) X-Y, ii) X-Z and iii) Y-Z planes.

Store

This allows the storage of the current view into one of the three available views.

Customize

This enables customisation of the current view, including i) axes orientation, ii) zoom centre, iii) zoom scale, and iv) normal/perspective specification.

Chapter 9. EXAMPLES

9.1 Space dome subject to vertical apex load

The dome space structure shown in the figure has been widely considered in the verification of nonlinear analysis methods for 3D frames. The aim here is to be able to predict the lowest buckling mode of the dome.

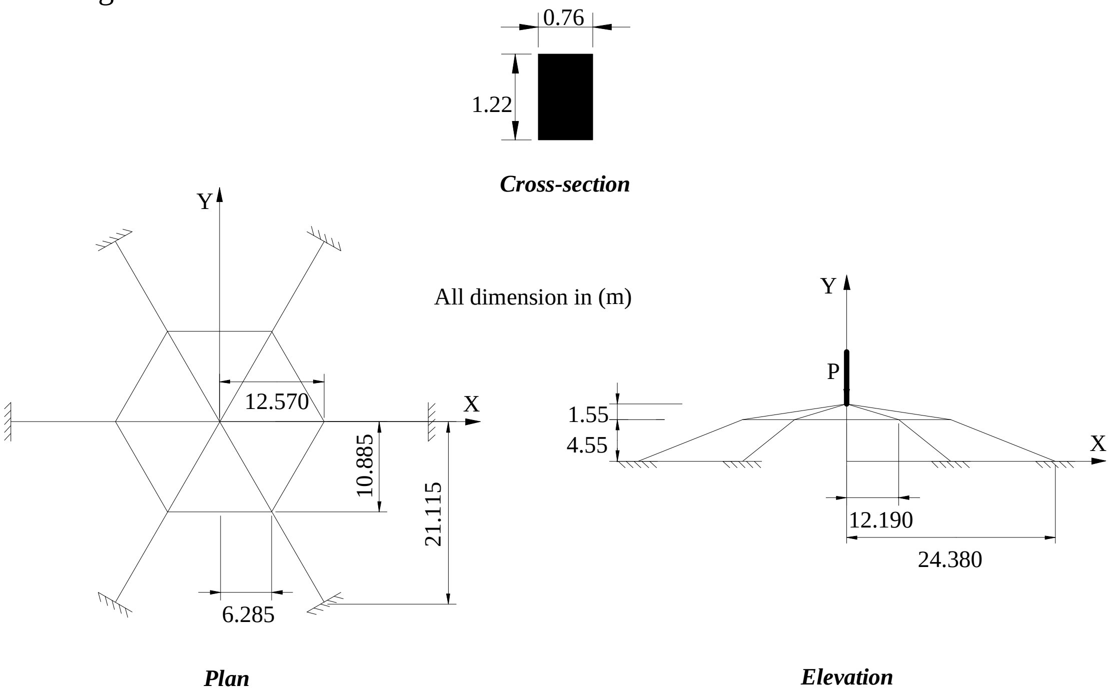


figure 9.1. Configuration of space dome subject to vertical apex load.

In order to illustrate the behaviour of the structure under a increasing load, here is going to be use ADAPTIC, which has the capability of predicting the large displacements static and dynamic behaviour of elastic and inelastic plane and space frames.

9.1.1 Data file

```
#
analysis 3d static                                                (a)
#
materials                                                         (b)
  mat.name    model          properties
   mat1       beth       20690  0.172  0.0
sections                                                          (c)
  type = rss
  sec.name    mat.name   dimensions
   sect1      mat1       0.76  1.22
#
groups                                                            (d)
type = qel3
 grp.name       sec.name
   gp1            sect1
#
structural                                                        (e)
   nod.n      x          y         z
      1       0          0         0
      11      6.286   -10.886   -1.551
      12     12.572     0.002   -1.552
      13      6.288    10.888   -1.553
      14     -6.287    10.887   -1.552
      15    -12.573     0.003   -1.553
      16     -6.286   -10.886   -1.551
      21     12.190   -21.115   -6.10
      22     24.380     0       -6.10
      23     12.190    21.115   -6.10
      24    -12.190    21.115   -6.10
      25    -24.380     0       -6.10
      26    -12.190   -21.115   -6.10
#
non.structural                                                    (f)
  nod.name    x          y         z
    1011      6.286   -10.886   10
    1012     12.572     0.002   10
    1013      6.288    10.888   10
    1014     -6.287    10.887   10
    1015    -12.573     0.003   10
    1016     -6.286   -10.886   10
#
restraints                                                        (g)
  direction = x+y+z+rx+ry+rz
   nod.name
f    21
r     1    5
#
element.connectivity                                              (h)
  grp.name = gp1
  elm.name   nod.name
f    1        21    11    1011
r    1         1     1       1   5
#
f   11        11     1    1011
r    1         1     0       1   5
#
f   21        11    12    1011
r    1         1     1       1   4
```

```
    26        16    11    1016
#
applied.loading                                            (i)
 proportional
  type = force
        nod.name        direction   value
           1               z          -1
#
phases                                                     (j)
load.control
  increment     path    steps
    70            k       14
displacement.control
      nod.name   dire   increment   path  steps
         1        rz      -0.24       k     30
         1         z      -3          k     20
#
iterative.strategy                                         (k)
number = 10
initial.reformations = 10
step.reduction = 10
divergence.iteration = 8
maximum.convergence =  1e+8
#
convergence.criteria                                       (l)
 tolerance = 0.1e-5
 force.ref = 1
 moment.ref = 1
#
output                                                     (m)
frequency 1 local
#
end
```

9.1.2 Structural behaviour

The nonlinear analysis is undertaken using one element per member, the response shown in the figure illustrate the ability of this method to predict the lowest buckling mode and to trace the associated post buckling path when an imperfect dome is considered.

Here is been obtained how the vertical apex deflection varies while the load increases.

figure 9.1.2.a. Response of space dome structure.

As is shown in the figure there is a first path where the displacements of the structure are almost proportional to the load, but when is arrived to a certain value of load, the displacement are nonlinear, and they increase more than the load.

It is evident that the introduction of small imperfections activates the lowest buckling mode, which involves a planar rotational mode, like is shown in the *figure*. In the absence of these imperfections the dome deflects fully symmetric about the dome apex (*papers*).

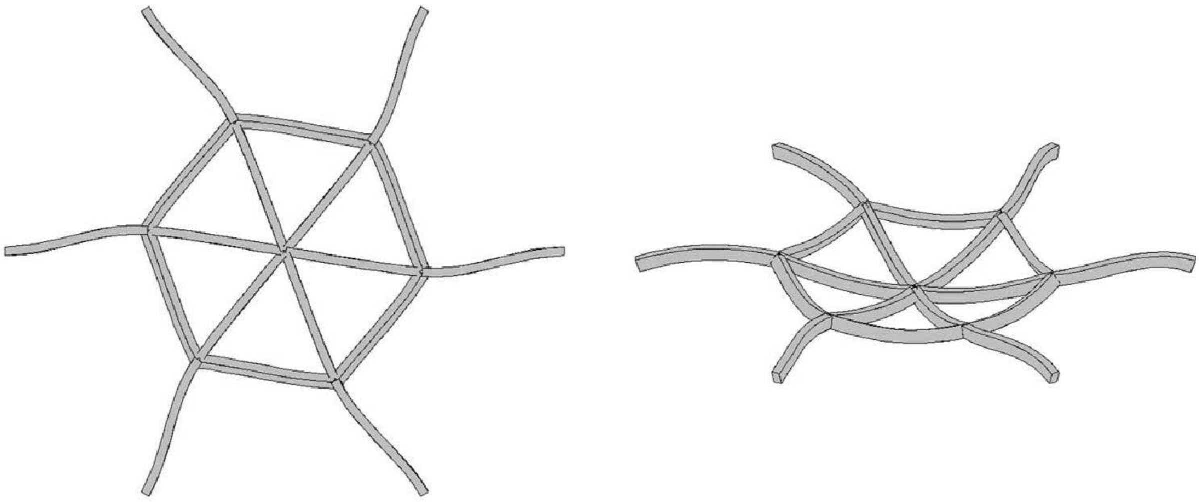


figure 9.1.2.b.Final deflected shape of space imperfect dome.

9.1.3 Output file

ADAPTIC also give an output file, where can be found the way that the program calculates the structure.

```
                  ELEMENT ASSEMBLY ORDER
 ---->>>> ---->>>> ---->>>> ---->>>> ---->>>> ---->>>> ---->>>> ---->>>>
 1        11       21       26       2        12       22       13
 14       15       16       6        25       3        23       4
 24       5

 MAXIMUM FRONT: (NODAL =    5) - (ADDITIONAL FREEDOMS =   0)
 +++++++++++++


                 V A R I A B L E   L O A D I N G
                 ++++++++++++++++++++++++++++++++

          PHASE NUMBER =   1
          TYPE = LOAD CONTROL
          INCREMENT FACTOR =0.700000E+02
          NUMBER OF STEPS =  14

                VARIABLE
                  LOAD
 OUTPUT          FACTOR       LEVEL    CONV.-NORM   ITERATIONS
     1       0.50000000E+01    0      0.546E-10         2
     2       0.10000000E+02    0      0.883E-10         2
     3       0.15000000E+02    0      0.162E-09         2
     4       0.20000000E+02    0      0.293E-09         2
     5       0.25000000E+02    0      0.568E-09         2
     6       0.30000000E+02    0      0.118E-08         2
     7       0.35000000E+02    0      0.266E-08         2
     8       0.40000000E+02    0      0.659E-08         2
     9       0.45000000E+02    0      0.185E-07         2
    10       0.50000000E+02    0      0.613E-07         2
    11       0.55000000E+02    0      0.255E-06         2
    12       0.60000000E+02    0      0.860E-11         3
    13       0.65000000E+02    0      0.918E-11         3
    14       0.70000000E+02    0      0.325E-08         3

          PHASE NUMBER =   2
          NODAL DISPLACEMENT CONTROL
          GLOBAL DIRECTION = RZ
          CONTROLLED NODE = 1

          DISPLACEMENT INCREMENT =-.240000E+00
          NUMBER OF STEPS =  30

                                  VARIABLE
              DISPLACEMENT          LOAD
 OUTPUT         INCREMENT          FACTOR       LEVEL    CONV.-NORM
ITERATIONS
     0        -.80000000E-03    0.74819797E+02    1      0.188E-07         8
     0        -.80000000E-03    0.75170596E+02    1      0.871E-11         3
     0        -.80000000E-03    0.75299433E+02    1      0.604E-06         2
     0        -.80000000E-03    0.75366635E+02    1      0.150E-07         2
     0        -.80000000E-03    0.75407861E+02    1      0.891E-09         2
     0        -.80000000E-03    0.75435665E+02    1      0.921E-10         2
```

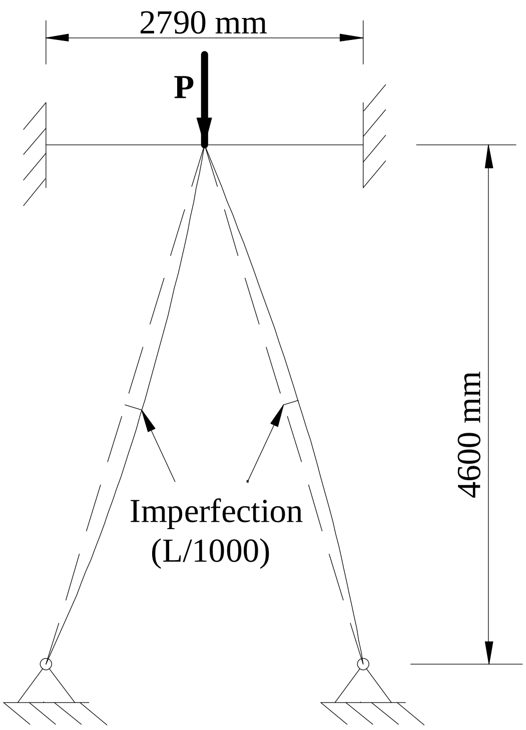
```
    0      -.80000000E-03    0.75455610E+02     1     0.155E-10       2
    0      -.80000000E-03    0.75470539E+02     1     0.650E-11       2
    0      -.80000000E-03    0.75482060E+02     1     0.838E-11       2
   15      -.80000000E-03    0.75491151E+02     1     0.800E-11       2
   16      -.80000000E-02    0.75524591E+02     0     0.594E-07       2
   17      -.80000000E-02    0.75521580E+02     0     0.938E-07       2
   18      -.80000000E-02    0.75503625E+02     0     0.108E-06       2
   19      -.80000000E-02    0.75474865E+02     0     0.130E-06       2
   20      -.80000000E-02    0.75436480E+02     0     0.161E-06       2
   21      -.80000000E-02    0.75388739E+02     0     0.203E-06       2
   22      -.80000000E-02    0.75331551E+02     0     0.260E-06       2
   23      -.80000000E-02    0.75264686E+02     0     0.338E-06       2
   24      -.80000000E-02    0.75187920E+02     0     0.446E-06       2
   25      -.80000000E-02    0.75101171E+02     0     0.599E-06       2
   26      -.80000000E-02    0.75004682E+02     0     0.820E-06       2
   27      -.80000000E-02    0.74899266E+02     0     0.694E-11       3
   28      -.80000000E-02    0.74786682E+02     0     0.629E-11       3
   29      -.80000000E-02    0.74670196E+02     0     0.106E-10       3
   30      -.80000000E-02    0.74555445E+02     0     0.885E-11       3
   31      -.80000000E-02    0.74451780E+02     0     0.843E-11       3
   32      -.80000000E-02    0.74374309E+02     0     0.462E-11       3
   33      -.80000000E-02    0.74346913E+02     0     0.996E-11       3
   34      -.80000000E-02    0.74406363E+02     0     0.492E-11       3
   35      -.80000000E-02    0.74607289E+02     0     0.875E-11       3
   36      -.80000000E-02    0.75027175E+02     0     0.149E-10       3
   37      -.80000000E-02    0.75770907E+02     0     0.351E-10       3
   38      -.80000000E-02    0.76977822E+02     0     0.792E-10       3
   39      -.80000000E-02    0.78843610E+02     0     0.182E-09       3
   40      -.80000000E-02    0.81695491E+02     0     0.723E-09       3
   41      -.80000000E-02    0.86304315E+02     0     0.138E-07       3
    0      -.80000000E-03    0.86954218E+02     1     0.269E-09       2
    0      -.80000000E-03    0.87640899E+02     1     0.566E-09       2
    0      -.80000000E-03    0.88387322E+02     1     0.911E-09       2
    0      -.80000000E-03    0.89206621E+02     1     0.155E-08       2
    0      -.80000000E-03    0.90117991E+02     1     0.273E-08       2
    0      -.80000000E-03    0.91151485E+02     1     0.496E-08       2
    0      -.80000000E-03    0.92359318E+02     1     0.273E-07       2
    0      -.80000000E-03    0.93849297E+02     1     0.670E-06       2
    0      -.80000000E-03    0.95940853E+02     1     0.391E-10       3
    0      -.80000000E-04    0.96260563E+02     2     0.129E-09       2
    0      -.80000000E-04    0.96572169E+02     2     0.103E-08       2
    0      -.80000000E-04    0.96917884E+02     2     0.345E-08       2
    0      -.80000000E-04    0.97312732E+02     2     0.186E-07       2
    0      -.80000000E-04    0.97785290E+02     2     0.182E-06       2
    0      -.80000000E-04    0.98411526E+02     2     0.918E-11       3
    0      -.80000000E-05    0.98520476E+02     3     0.146E-10       2
    0      -.80000000E-05    0.98609176E+02     3     0.365E-09       2
    0      -.80000000E-05    0.98703536E+02     3     0.417E-09       2
    0      -.80000000E-05    0.98806745E+02     3     0.109E-08       2
    0      -.80000000E-05    0.98921952E+02     3     0.363E-08       2
    0      -.80000000E-05    0.99054545E+02     3     0.171E-07       2
    0      -.80000000E-05    0.99215707E+02     3     0.145E-06       2
    0      -.80000000E-05    0.99438530E+02     3     0.636E-10       3
Phase (2) terminated
+++++++++++++++++++++++


         PHASE NUMBER =   3
         NODAL DISPLACEMENT CONTROL
         GLOBAL DIRECTION = Z
         CONTROLLED NODE = 1
```

DISPLACEMENT INCREMENT =-.300000E+01
NUMBER OF STEPS = 20

OUTPUT ITERATIONS	DISPLACEMENT INCREMENT	VARIABLE LOAD FACTOR	LEVEL	CONV.-NORM	
42	-.15000000E+00	0.10110066E+03	0	0.224E-08	2
43	-.15000000E+00	0.10278682E+03	0	0.230E-08	2
44	-.15000000E+00	0.10449112E+03	0	0.233E-08	2
45	-.15000000E+00	0.10621060E+03	0	0.238E-08	2
46	-.15000000E+00	0.10794230E+03	0	0.247E-08	2
47	-.15000000E+00	0.10968333E+03	0	0.258E-08	2
48	-.15000000E+00	0.11143082E+03	0	0.273E-08	2
49	-.15000000E+00	0.11318196E+03	0	0.293E-08	2
50	-.15000000E+00	0.11493396E+03	0	0.318E-08	2
51	-.15000000E+00	0.11668410E+03	0	0.352E-08	2
52	-.15000000E+00	0.11842972E+03	0	0.395E-08	2
53	-.15000000E+00	0.12016827E+03	0	0.452E-08	2
54	-.15000000E+00	0.12189727E+03	0	0.527E-08	2
55	-.15000000E+00	0.12361439E+03	0	0.630E-08	2
56	-.15000000E+00	0.12531749E+03	0	0.772E-08	2
57	-.15000000E+00	0.12700463E+03	0	0.972E-08	2
58	-.15000000E+00	0.12867421E+03	0	0.127E-07	2
59	-.15000000E+00	0.13032502E+03	0	0.171E-07	2
60	-.15000000E+00	0.13195645E+03	0	0.240E-07	2
61	-.15000000E+00	0.13356868E+03	0	0.355E-07	2

9.2 K-frame subject to vertical load

The k-frame, shown in the figure, is subjected to an end force **P**, where load application in the middle of the upper frame. The buckling forces for this frame where also obtained with ADAPTIC, where the following values were reported using 4 elements.



Transverse beam:

$\Phi 219 \times 4.37\text{mm}^2$

$E = 210 \times 10^3 \, N/mm^2$

$\sigma_y = 414 N/mm^2$

Diagonal members:

$\Phi 101.7 \times 3.30\text{mm}^2$

$E = 210 \times 10^3 \, N/mm^2$

$\sigma_y = 335 N/mm^2$

figure 9.2.a Geometric configuration of K-frame.

9.2.1 Data file

```
#
analysis 2d statics                                                     (a)
#
materials
  mat.name     model     properties
   mat1        stl1     0.210e6 0.335e3 0.00                            (b)
   mat2        stl1     0.210e6 0.414e3 0.00
#
sections                                                                (c)
  type = chs
  sec.name     mat.name    dimensions
   sect1       mat1        101.7   3.30
   sect2       mat2        219.0   4.37
#
groups                                                                  (d)
type = qph2
 grp.name        sec.name       subdivision
   grp1           sect1           t
   grp2           sect2           f
#
structural.nodal                                                        (e)
   nod.n        x          y
    f 1     0000.0      0000.0
    r 1     2790.0      0000.0 1
    f 3     0000.0      4600.0
    r 1     1395.0      0000.0 2
#
restraints                                                              (g)
 nod.name        direction
  f 1               x+y
  r 1                -      1
  f 3              x+y+rz
  r 2                 -      1
#
element.connectivity                                                    (h)
  elm.name       grp.name         nod.name
     f 1           grp1           1   4
     r 1            -             3 -2    1
     f 3           grp2           3   4
     r 1            -             1   1   1
#
imperfection                                                            (n)
elm.name                values
    1             -3.6   -4.8  -3.6
    2              3.6    4.8   3.6
#
applied.loading                                                         (i)
 proportional
       nod.name        direction        type       value
           4               y            force    -0.100e+7
#
condition                                                               (o)
 disp.cnd.name  nod.name        direction       limits
       1          4                y            -300.0 0.0
#
phases                                                                  (j)
load.control
  increment     path     steps
```

```
    1.0         k       25
automatic.control
      type                    path    cnd.name
  nodal translation             c       1
#use default iterative strategy
#iterative.strategy                                              (k)
#number = 10
#initial.reformations = 10
#step.reduction = 10
#divergence.iteration = 6
#maximum.convergence =  0.1e5
#
convergence.criteria                                             (l)
 tolerance = 0.1e-5
 force = 0.5e+6
 moment = 0.1e+8
#
output                                                           (m)
frequency 0
#
end
```

Note The following picture shows the names that have been given to the nodes and elements in the data file.

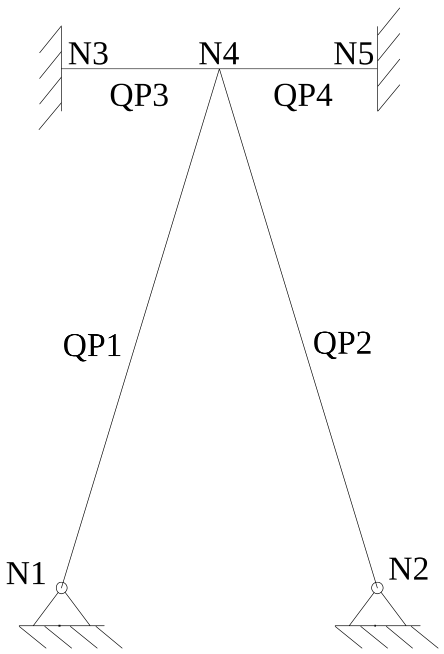


figure 9.2.1 Nodes and elements of the K-frame.

9.2.2 Structural behaviour

The nonlinear analysis is undertaken using one element per member, the response shown in the figure 9.2.2a shows the static response of K-frame.

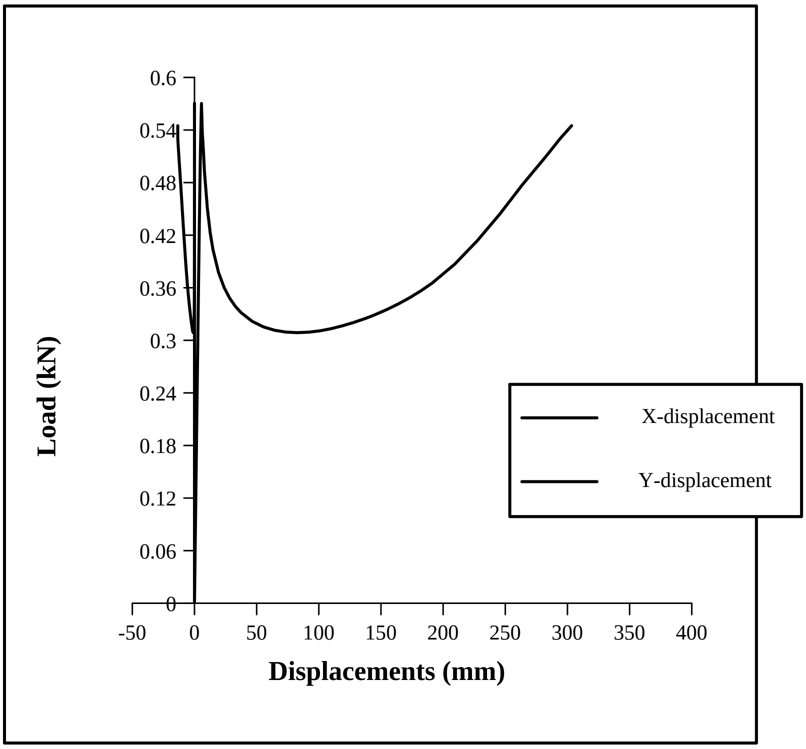


figure 9.2.2a Static response of K-frame

Here is shown the ability of this method to predict the lowest buckling mode and to trace the associated post-buckling path when an imperfect K-frame is considered.

The figure illustrates that the higher displacements of the structure are in the X-direction of the frame. When is arrived to a certain value of load, the displacement increase with fewer loads, and with minor load you can obtain higher displacements.

The following figure illustrates the response of modelling K-frame with the plastic-hinge approach.

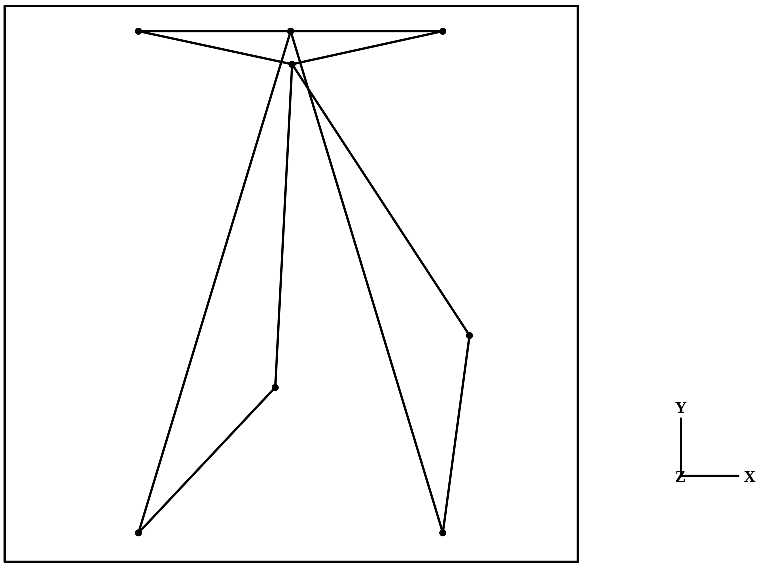


Figure 9.2.2b Deformed shape modelling with the plastic-hinge approach.

It is evident that the introduction of small imperfections activates the lowest buckling mode, which involves a deflection shape, like is shown in the figure. In the absence of these imperfections the K-frame deflects fully symmetric about symmetry axes.

9.2.3 Output file

This is the output file given by ADAPTIC.

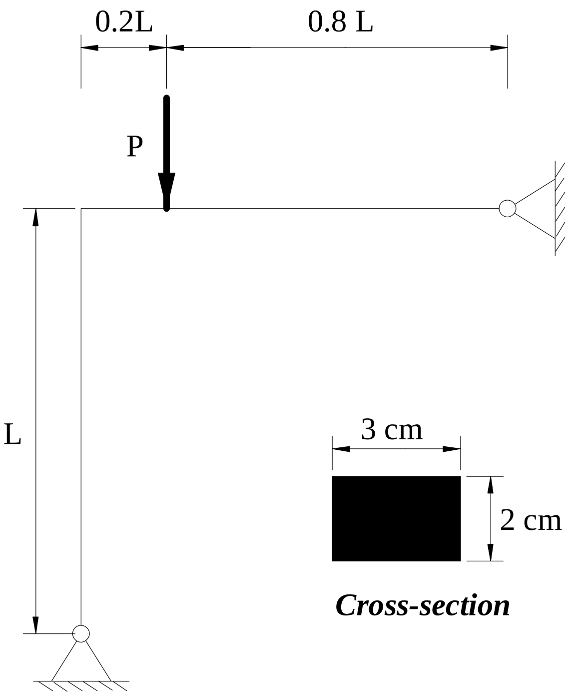
```
                   ELEMENT ASSEMBLY ORDER
 ---->>>> ---->>>> ---->>>> ---->>>> ---->>>> ---->>>> ---->>>> ---->>>>
 1        2        3        4

 MAXIMUM FRONT: (NODAL =    3) - (ADDITIONAL FREEDOMS =   0)
 +++++++++++++


                V A R I A B L E   L O A D I N G
                ++++++++++++++++++++++++++++++++

          PHASE NUMBER =   1
          TYPE = LOAD CONTROL
          INCREMENT FACTOR =0.100000E+01
          NUMBER OF STEPS =  25

               VARIABLE
                 LOAD
 OUTPUT         FACTOR      LEVEL    CONV.-NORM   ITERATIONS
     1       0.40000000E-01    0      0.155E-07        1
     2       0.80000000E-01    0      0.242E-07        1
     3       0.12000000E+00    0      0.390E-07        1
     4       0.16000000E+00    0      0.651E-07        1
     5       0.20000000E+00    0      0.114E-06        1
     6       0.24000000E+00    0      0.209E-06        1
     7       0.28000000E+00    0      0.407E-06        1
     8       0.32000000E+00    0      0.854E-06        1
     9       0.36000000E+00    0      0.135E-11        2
    10       0.40000000E+00    0      0.913E-11        2
    11       0.44000000E+00    0      0.725E-10        2
    12       0.48000000E+00    0      0.595E-09        2
    13       0.52000000E+00    0      0.414E-08        2
    14       0.56000000E+00    0      0.408E-07        2
    15       0.56800000E+00    1      0.460E-06        1
    16       0.56960000E+00    2      0.672E-09        1
    17       0.56992000E+00    3      0.965E-06        0
    18       0.57024000E+00    3      0.974E-06        0
 Phase (1) terminated
 +++++++++++++++++++++++


          PHASE NUMBER =   2
          NODAL DISPLACEMENT CONTROL
          GLOBAL DIRECTION = Y
          CONTROLLED NODE = 4

                                 VARIABLE
             DISPLACEMENT          LOAD
 OUTPUT        INCREMENT          FACTOR       LEVEL    CONV.-NORM
ITERATIONS
    19       -.58886522E-02    0.57032137E+00     0     0.993E-06         1
 Plastic hinge formed for element 2          at node 4
    20       -.35331913E-01    0.56783100E+00     0     0.303E-07         2
 Plastic hinge formed for element 1          at node 4
    21       -.14132765E+00    0.56085432E+00     0     0.228E-06         2
```

```
*******************(  SUBDIVISION OF ELEMENT 1        )***************
*                                                                   *
*NUMBER OF NODES CREATED                                            *
*           1                                                       *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n1                    0.537226E+03          0.175588E+04         *
*-------------------------------------------------------------------*
*                                                                   *
*NUMBER OF ELEMENTS CREATED                                         *
*             2                                                     *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                      *
* #e1           qph2                 1         #n1                  *
* #e2           qph2                 #n1       4                    *
*-------------------------------------------------------------------*
*                                                                   *
*NUMBER OF IMPERFECT ELEMENTS                                       *
*             2                                                     *
* ELM.NAME      TH1I          TH2I           TI                     *
* #e1       -.152581E-02  0.152581E-02  -.700432E+00                *
* #e2       -.246847E-02  0.246847E-02  -.183324E+01                *
*********************************************************************


*******************(  SUBDIVISION OF ELEMENT 2        )***************
*                                                                   *
*NUMBER OF NODES CREATED                                            *
*           1                                                       *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n2                    0.867206E+03          -.284399E+04         *
*-------------------------------------------------------------------*
*                                                                   *
*NUMBER OF ELEMENTS CREATED                                         *
*             2                                                     *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                      *
* #e3           qph2                 4         #n2                  *
* #e4           qph2                 #n2       2                    *
*-------------------------------------------------------------------*
*                                                                   *
*NUMBER OF IMPERFECT ELEMENTS                                       *
*             2                                                     *
* ELM.NAME      TH1I          TH2I           TI                     *
* #e3       0.247064E-02  -.247064E-02  0.183647E+01                *
* #e4       0.152364E-02  -.152364E-02  0.698438E+00                *
*********************************************************************

   22       -.56531062E+00    0.53452938E+00     0     0.354E-06        6
Plastic hinge formed for element #e3      at node 4
Plastic hinge formed for element #e2      at node #n1
Plastic hinge formed for element #e2      at node 4
Plastic hinge formed for element #e4      at node #n2
   23       -.56531062E+00    0.52314632E+00     0     0.100E-06        5
Plastic hinge formed for element 3        at node 4
   24       -.11306212E+01    0.49180805E+00     0     0.988E-06        5
Plastic hinge formed for element 3        at node 3
   25       -.22612425E+01    0.45116331E+00     0     0.447E-06        8
Plastic hinge formed for element 4        at node 5
   26       -.22612425E+01    0.42323379E+00     0     0.498E-06        6
   27       -.22612425E+01    0.40365272E+00     0     0.896E-06        5
   28       -.45224849E+01    0.37733661E+00     0     0.803E-06        8
   29       -.45224849E+01    0.36011033E+00     0     0.356E-06        7
   30       -.45224849E+01    0.34784546E+00     0     0.601E-06        6
```

```
    31       -.45224849E+01    0.33867433E+00     0     0.133E-06          6
    32       -.45224849E+01    0.33159941E+00     0     0.623E-06          5
    33       -.90449698E+01    0.32159929E+00     0     0.775E-06          8
    34       -.90449698E+01    0.31528570E+00     0     0.190E-06          8
    35       -.90449698E+01    0.31143394E+00     0     0.798E-06          7
    36       -.90449698E+01    0.30938842E+00     0     0.790E-06          7
    37       -.90449698E+01    0.30875711E+00     0     0.784E-06          7
    38       -.90449698E+01    0.30929004E+00     0     0.401E-06          8
    39       -.90449698E+01    0.31082759E+00     0     0.924E-06          7
    40       -.90449698E+01    0.31326084E+00     0     0.878E-06          7
 Plastic hinge closed for element #e2      at node 4
    41       -.90449698E+01    0.31650563E+00     0     0.473E-06          8
    42       -.90449698E+01    0.32032074E+00     0     0.269E-06          9
    43       -.90449698E+01    0.32469935E+00     0     0.664E-06          8
    44       -.18089940E+01    0.32565287E+00     1     0.121E-07          2
    45       -.18089940E+01    0.32663005E+00     1     0.141E-07          2
    46       -.18089940E+01    0.32763135E+00     1     0.119E-06          2
 Plastic hinge closed for element #e3      at node 4
    47       -.18089940E+01    0.32865710E+00     1     0.137E-07          2
    48       -.18089940E+01    0.32970771E+00     1     0.124E-07          2
    49       -.90449698E+01    0.33532282E+00     0     0.540E-06          7
    50       -.90449698E+01    0.34162424E+00     0     0.229E-06          7
    51       -.90449698E+01    0.34866739E+00     0     0.546E-06          6
    52       -.90449698E+01    0.35653812E+00     0     0.234E-06          6
    53       -.90449698E+01    0.36537081E+00     0     0.672E-06          5
    54       -.18089940E+02    0.38688104E+00     0     0.234E-06          6
    55       -.18089940E+02    0.41356265E+00     0     0.852E-06          8
    56       -.18089940E+02    0.44388832E+00     0     0.542E-06          8
    57       -.18089940E+02    0.47725230E+00     0     0.304E-06          6
 Plastic hinge formed for element 4        at node 4
    58       -.18089940E+02    0.50809231E+00     0     0.571E-06          9
    59       -.36179879E+01    0.51444736E+00     1     0.329E-07          2
    60       -.36179879E+01    0.52086955E+00     1     0.348E-07          2
    61       -.36179879E+01    0.52735930E+00     1     0.362E-07          2
    62       -.72359759E+00    0.52866515E+00     2     0.412E-06          1
    63       -.72359759E+00    0.52995151E+00     2     0.924E-08          2
    64       -.72359759E+00    0.53110568E+00     2     0.181E-07          1
    65       -.72359759E+00    0.53225959E+00     2     0.181E-07          1
    66       -.72359759E+00    0.53341324E+00     2     0.180E-07          1
    67       -.36179879E+01    0.53917749E+00     1     0.391E-09          2
    68       -.36179879E+01    0.54493498E+00     1     0.384E-09
```

9.3 Lee's frame

The Lee's frame, shown in the figure 9.3, is subjected to an end force P. The buckling forces for this frame where also obtained with ADAPTIC, where the following values were reported using 3 elements.



L=120cm

$E=720\ \text{ton/cm}^2$

Mass per unit length = $0.24\times10^{-5}\,\text{ton}\cdot\text{sec}^2/\text{cm}^2$

figure 9.3 Geometry and loading of Lee's frame.

9.3.1 Data file

```
#
analysis 2d statics                                        (a)
# control start
#
#
materials                                                  (b)
  mat.name    model properties
   mat1        stl1  0.720e3  0.100e1 0.00
#
sections                                                   (c)
  type = rss
  sec.name    mat.name   dimensions
   sect1      mat1        3.0 2.0
#
groups                                                     (d)
type.of.element = qel2
 grp.name       sec.name
   grp1           sect1
#
structural                                                 (e)
   nod.n     x     y
     1      0.00    0.00
     2      0.00  120.00
     3     24.00  120.00
     4    120.00  120.00
#
restraints                                                 (g)
 nod.name direction
   1     x+y
   4     x+y
#
element.connectivity                                       (h)
  elm.name   grp.name    nod.
     f 1     grp1             1  2
     r 1      -          1  1     2
#
applied.loading                                            (i)
 proportional.loads
       nod.name       direction      type    value
           3              y          force  -0.10e+1
#
condition                                                  (o)
 lf.cnd.name   limits
      1        -2.0 2.0
 disp.cnd.name nod.name       direction      limits
       2          3              x          -0.12e+3 0.12e+3
       3          3              y          -0.12e+3 0.12e+3
#
phases                                                     (j)
load.control
  increment     path    steps
  0.2e+1         k       20
automatic.control
  type                 path    cnd.name
  nodal translation     c        1 2 3
#
iterative.strategy                                         (k)
number = 5
```

```
initial.reformations = 5
step.reduction = 5
divergence.iteration = 4
maximum.convergence =  0.1e3
#
convergence.criteria                                              (l)
 tolerance = 0.1e-5
 force = 0.2e+1
 mome = 0.1e+3
#
output                                                            (m)
frequency 0
#
end
```

Note: The elements and the nodes that are used are shown in the figure 9.3.1.

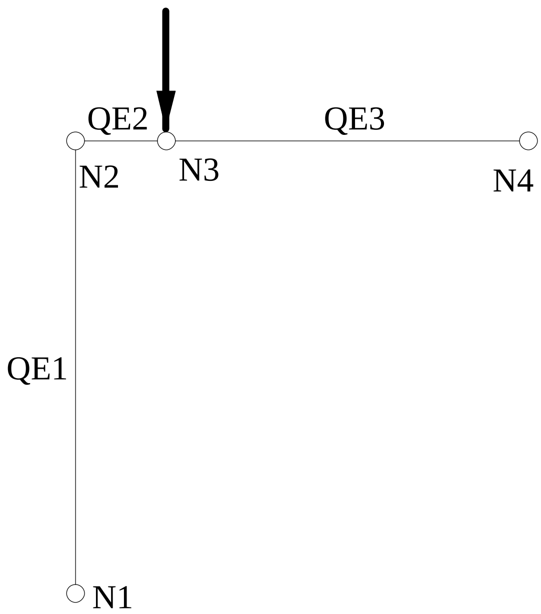


figure 9.3.1 Nodes and elements of Lee's frame.

9.3.2 Structural behaviour

The nonlinear analysis is undertaken using one element per member. The following figures show the static response of Lee's frame.

The node 1 only experiments rotation, as could be seen in the figure. It has the same behaviour as the node 4.

The nodes 2 and 3 have similar behaviour,

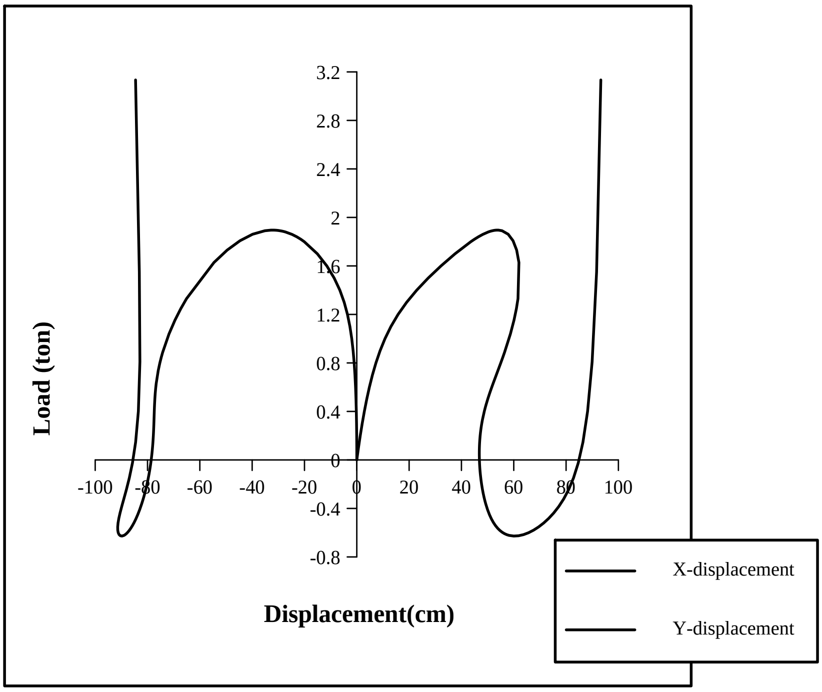


figure 9.3.2a Static response of Lee's frame at node 3.

This is the deformed shape of the Lee's frame. As it could be seen, nodes 1 and 4 only experiment rotation, and the displacements of node 2 are bigger than the displacements of node 3, even the develop in the time follows the same tendency.

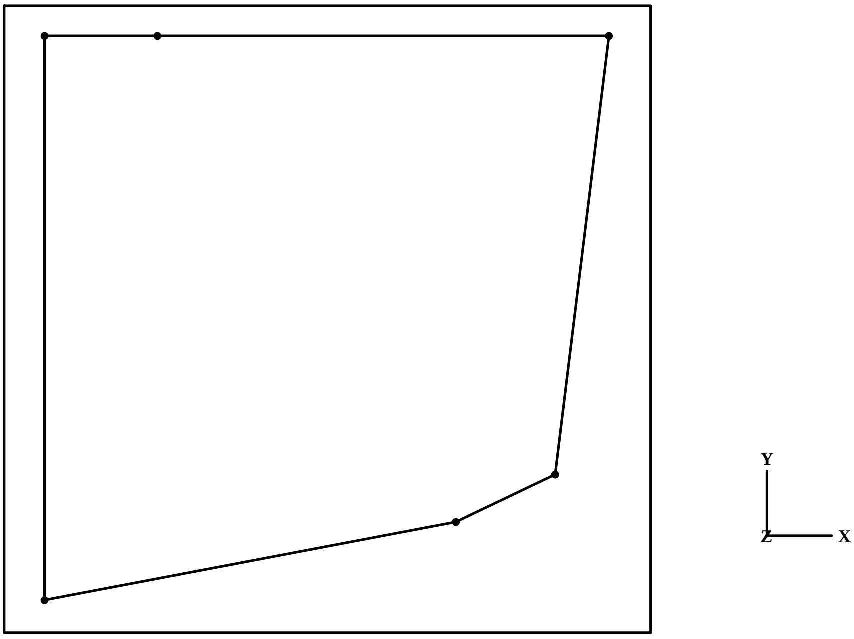


figure 9.3.2b Deflected shape of Lee’s frame.

The real deflected shape of Lee’s frame when the load increase vary like is shown in the following figure.

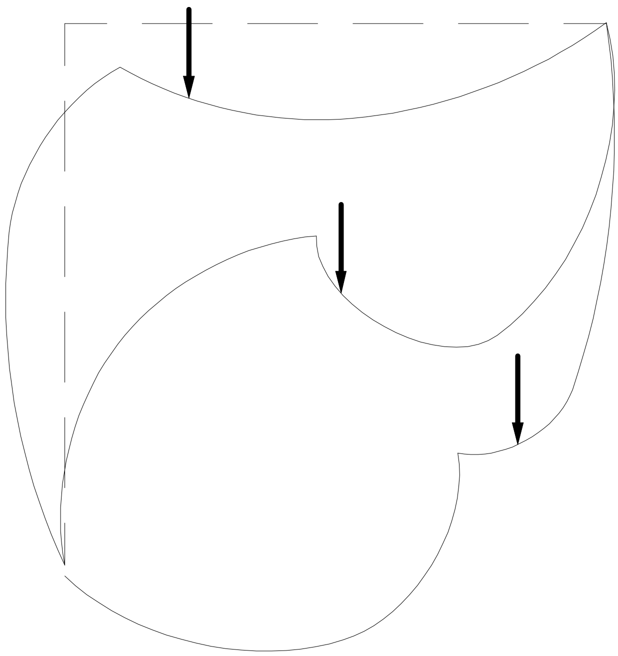


figure 9.3.2c Deflected shape of Lee’s frame during static loading.

9.3.3 Output file

```
                  ELEMENT ASSEMBLY ORDER
---->>>> ---->>>> ---->>>> ---->>>> ---->>>> ---->>>> ---->>>> ---->>>>
1        2        3

MAXIMUM FRONT: (NODAL =    2) - (ADDITIONAL FREEDOMS =   0)
+++++++++++++


                 V A R I A B L E   L O A D I N G
                 ++++++++++++++++++++++++++++++++

         PHASE NUMBER =   1
         TYPE = LOAD CONTROL
         INCREMENT FACTOR =0.200000E+01
         NUMBER OF STEPS =  20

               VARIABLE
                 LOAD
OUTPUT          FACTOR       LEVEL    CONV.-NORM   ITERATIONS
    1       0.10000000E+00    0      0.489E-09        3
    2       0.20000000E+00    0      0.926E-08        3
    3       0.30000000E+00    0      0.304E-07        3
    4       0.40000000E+00    0      0.392E-07        3
    5       0.50000000E+00    0      0.357E-07        3
    6       0.60000000E+00    0      0.314E-07        3
    7       0.70000000E+00    0      0.305E-07        3
    8       0.80000000E+00    0      0.343E-07        3
    9       0.90000000E+00    0      0.459E-07        3
   10       0.10000000E+01    0      0.711E-07        3
   11       0.11000000E+01    0      0.118E-06        3
   12       0.12000000E+01    0      0.187E-06        3
   13       0.13000000E+01    0      0.242E-06        3
   14       0.14000000E+01    0      0.244E-06        3
   15       0.15000000E+01    0      0.245E-06        3
   16       0.16000000E+01    0      0.434E-06        3
   17       0.17000000E+01    0      0.152E-11        4
   18       0.18000000E+01    0      0.100E-08        4
   19       0.18200000E+01    1      0.380E-12        3
   20       0.18400000E+01    1      0.529E-11        3
   21       0.18600000E+01    1      0.197E-09        3
   22       0.18800000E+01    1      0.803E-07        3
   23       0.18840000E+01    2      0.736E-07        2
   24       0.18880000E+01    2      0.499E-06        2
   25       0.18920000E+01    2      0.340E-09        3
   26       0.18928000E+01    3      0.144E-08        2
   27       0.18936000E+01    3      0.929E-08        2
   28       0.18944000E+01    3      0.145E-06        2
   29       0.18952000E+01    3      0.462E-07        3
Phase (1) terminated
+++++++++++++++++++++++


         PHASE NUMBER =   2
         NODAL DISPLACEMENT CONTROL
         GLOBAL DIRECTION = X
         CONTROLLED NODE = 2

                                VARIABLE
             DISPLACEMENT         LOAD
```

OUTPUT ITERATIONS	INCREMENT	FACTOR	LEVEL	CONV.-NORM	
30	0.12676487E+01	0.18951791E+01	0	0.635E-09	2
31	0.25352974E+01	0.18902504E+01	0	0.121E-06	2
32	0.50705949E+01	0.18612923E+01	0	0.114E-10	3
33	0.50705949E+01	0.18077847E+01	0	0.405E-11	3
34	0.50705949E+01	0.17303899E+01	0	0.130E-11	3
35	0.50705949E+01	0.16283372E+01	0	0.269E-06	2
36	0.10141190E+02	0.13300448E+01	0	0.612E-07	3
37	0.20282379E+01	0.12478470E+01	1	0.614E-07	2
38	0.20282379E+01	0.11529115E+01	1	0.443E-06	2
39	0.20282379E+01	0.10386773E+01	1	0.630E-11	3
40	0.20282379E+01	0.88635252E+00	1	0.357E-07	3
41	0.40564759E+00	0.84608354E+00	2	0.138E-06	2
42	0.40564759E+00	0.79871870E+00	2	0.702E-12	3
43	0.40564759E+00	0.73803157E+00	2	0.924E-09	3
44	0.40564759E+00	0.63150114E+00	2	0.342E-11	5

Current control type terminated
****

PHASE NUMBER = 2
NODAL DISPLACEMENT CONTROL
GLOBAL DIRECTION = Y
CONTROLLED NODE = 3

OUTPUT ITERATIONS	DISPLACEMENT INCREMENT	VARIABLE LOAD FACTOR	LEVEL	CONV.-NORM	
45	0.67338419E+00	0.59122201E+00	0	0.842E-12	3
46	0.67338419E+00	0.54930670E+00	0	0.341E-10	3
47	0.67338419E+00	0.50485740E+00	0	0.297E-08	3
48	0.67338419E+00	0.45652421E+00	0	0.761E-11	4
49	0.13467684E+00	0.44621774E+00	1	0.752E-08	2
50	0.13467684E+00	0.43564685E+00	1	0.145E-07	2
51	0.13467684E+00	0.42478342E+00	1	0.295E-07	2
52	0.13467684E+00	0.41359499E+00	1	0.628E-07	2
53	0.13467684E+00	0.40204378E+00	1	0.141E-06	2
54	0.67338419E+00	0.33693690E+00	0	0.905E-10	4
55	0.13467684E+00	0.32186952E+00	1	0.877E-12	3
56	0.13467684E+00	0.30581535E+00	1	0.382E-08	3
57	0.13467684E+00	0.28855344E+00	1	0.605E-07	3
58	0.13467684E+00	0.26977110E+00	1	0.122E-06	3
59	0.13467684E+00	0.24899930E+00	1	0.141E-06	3
60	0.13467684E+00	0.22547457E+00	1	0.236E-06	3
61	0.13467684E+00	0.19778790E+00	1	0.448E-11	4
62	0.13467684E+00	0.16268829E+00	1	0.454E-07	4
63	0.26935367E-01	0.15410827E+00	2	0.504E-07	2
64	0.26935367E-01	0.14468054E+00	2	0.123E-06	2
65	0.26935367E-01	0.13410380E+00	2	0.381E-06	2
66	0.26935367E-01	0.12184021E+00	2	0.594E-11	3
67	0.26935367E-01	0.10672673E+00	2	0.851E-09	3
68	0.26935367E-01	0.84875270E-01	2	0.245E-09	4
69	0.53870735E-02	0.78273464E-01	3	0.225E-06	2
70	0.53870735E-02	0.69112846E-01	3	0.146E-08	3

Current control type terminated
****

PHASE NUMBER = 2
NODAL DISPLACEMENT CONTROL
GLOBAL DIRECTION = Y
CONTROLLED NODE = 2

OUTPUT ITERATIONS	DISPLACEMENT INCREMENT	VARIABLE LOAD FACTOR	LEVEL	CONV.-NORM	
71	-.80789915E-01	0.57646662E-01	0	0.884E-08	2
72	-.16157983E+00	0.36441746E-01	0	0.848E-06	2
73	-.32315966E+00	-.97531927E-03	0	0.948E-10	3
74	-.32315966E+00	-.33812188E-01	0	0.341E-11	3
75	-.32315966E+00	-.63438327E-01	0	0.972E-12	3
76	-.32315966E+00	-.90632858E-01	0	0.581E-12	3
77	-.32315966E+00	-.11588821E+00	0	0.602E-06	2
78	-.64631932E+00	-.16182271E+00	0	0.508E-10	3
79	-.64631932E+00	-.20296138E+00	0	0.685E-11	3
80	-.64631932E+00	-.24029833E+00	0	0.100E-11	3
81	-.64631932E+00	-.27447033E+00	0	0.390E-12	3
82	-.64631932E+00	-.30591620E+00	0	0.523E-12	3
83	-.64631932E+00	-.33495588E+00	0	0.367E-12	3
84	-.64631932E+00	-.36183352E+00	0	0.935E-06	2
85	-.12926386E+01	-.40984154E+00	0	0.134E-09	3
86	-.12926386E+01	-.45112304E+00	0	0.383E-10	3
87	-.12926386E+01	-.48654527E+00	0	0.124E-10	3
88	-.12926386E+01	-.51679131E+00	0	0.451E-11	3
89	-.12926386E+01	-.54242477E+00	0	0.223E-11	3
90	-.12926386E+01	-.56392427E+00	0	0.639E-12	3
91	-.12926386E+01	-.58170326E+00	0	0.672E-12	3
92	-.12926386E+01	-.59612224E+00	0	0.356E-12	3
93	-.12926386E+01	-.60749699E+00	0	0.447E-12	3
94	-.12926386E+01	-.61610455E+00	0	0.157E-12	3
95	-.12926386E+01	-.62218784E+00	0	0.862E-06	2
96	-.25852773E+01	-.62760442E+00	0	0.252E-09	3
97	-.25852773E+01	-.62513542E+00	0	0.778E-10	3
98	-.25852773E+01	-.61580883E+00	0	0.253E-10	3
99	-.25852773E+01	-.60034713E+00	0	0.873E-11	3
100	-.25852773E+01	-.57920181E+00	0	0.269E-11	3
101	-.25852773E+01	-.55256728E+00	0	0.146E-11	3
102	-.25852773E+01	-.52037179E+00	0	0.457E-12	3
103	-.25852773E+01	-.48223868E+00	0	0.428E-12	3
104	-.25852773E+01	-.43740453E+00	0	0.246E-12	3
105	-.25852773E+01	-.38456730E+00	0	0.637E-12	3
106	-.25852773E+01	-.32161248E+00	0	0.132E-11	3
107	-.25852773E+01	-.24511144E+00	0	0.206E-11	3
108	-.25852773E+01	-.14937073E+00	0	0.499E-11	3
109	-.25852773E+01	-.24547529E-01	0	0.116E-10	3
110	-.25852773E+01	0.14728750E+00	0	0.242E-10	3
111	-.25852773E+01	0.40093190E+00	0	0.581E-10	3
112	-.25852773E+01	0.80974686E+00	0	0.339E-09	3
113	-.25852773E+01	0.15494444E+01	0	0.417E-08	3
114	-.25852773E+01	0.31338199E+01	0	0.310E-06	3

9.4 Fixed ended beam-column

The fixed ended beam-column, shown in the figure 9.4, is subjected to two vertical symmetric forces P, and to an horizontal force. The buckling forces for this frame where obtained using 3 elements.

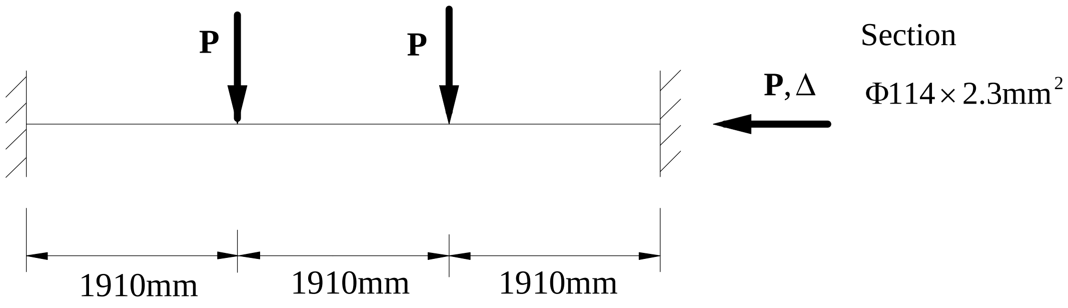


figure 9.4 Geometry of fixed ended beam-column.

9.4.1 Data file

```
#
analysis 2d statics                                                    (a)

#
materials                                                              (b)

  mat.name    model           properties
   mat1       stl2 &   # 42 properties for multisurface steel model follow
                       0.210000e+06   0.100000e-02   0.200000e-02 &
                        0.600000e-02   0.210000e-01   0.306000e-01 &
                        0.187850e+03   0.101150e+06   0.260100e+03 &
                        0.433500e+05   0.289000e+03   0.867000e+04 &
                        0.306340e+03   0.115600e+04   0.323680e+03 &
                        0.120417e+04   0.335240e+03   0.104278e+04 &
                        0.187850e+03   0.101150e+06   0.260100e+03 &
                        0.433500e+05   0.289000e+03   0.867000e+04 &
                        0.306340e+03   0.115600e+04   0.323680e+03 &
                        0.120417e+04   0.335240e+03   0.104278e+04 &
                        0.000000e+00   0.000000e+00   0.000000e+00 &
                        0.000000e+00   0.000000e+00   0.000000e+00 &
                        0.000000e+00   0.000000e+00   0.000000e+00 &
                        0.000000e+00   0.000000e+00   0.000000e+00
sections                                                               (c)
  type = chs
# circular hollow section
  sec.name    mat.name   dimensions
   sect1      mat1       114.0  2.3
#
patterns                                                               (p)
# subdivision patterns for elelments "qdp2"
 pat.name     ratios
  pat1           1 2 3 4 5     # 5 subelements; smallest near 1st node
  pat2           3 2 1 2 3     # 5 subelements; smallest in the middle
 #
groups                                                                 (d)

type = cbp2
 grp.name       sec.name      monitoring.points
   grp1          sect1                 40
#
type = qdp2
 grp.name    cbp2.grp.name    pat.name
   grp2         grp1             pat1
   grp3         grp1             pat2

#
structural.nodal                                                       (e)
        nod.name       x          y
           1            0.0        0.0
           2         1910.0        0.0
           3         3810.0        0.0
           4         5720.0        0.0
#
restraints                                                             (g)
 nod.name       direction
   1            x+y+rz
   4            y+rz
#
```

```
element.connectivity                                        (h)

  elm.name    grp.name nod.name
      1        grp2     1  2
      2        grp3     2  3
      3        grp2     4  3
#
linear.curves  # curves for time history loads
start.time = 0.0
crv.name = c1
        time    load.factor
          1          -1.0
          3           1.0
          5          -1.0
#
applied.loading                                             (i)
 initial
        nod.name       direction      type       value
         f 2               y          force    -0.1005e+4
         r 1               -            -          0.0     1
 time.history
        nod.name       direction      type     crv.name   value
            4              x          disp        c1      40.0
#
equilibrium.stages
        end.of.stage   steps
             5.0        200
# use default iterative strategy
convergence.criteria                                        (l)
 tolerance  = 0.1e-5
 force.ref  = 0.1e+6
 moment.ref = 0.1e+8
#
output                                                      (m)
frequency 0 stress     # all equilibrium steps including step reduction
levels
#
end
```

Note The following picture shows the names that have been given to the nodes and elements in the data file.

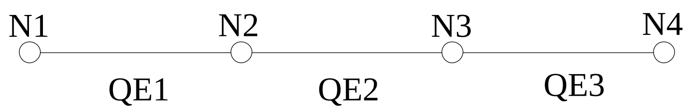


figure 9.4.1 Nodes and elements of fixed ended beam-column.

9.4.2 Structural behaviour

The nonlinear analysis is undertaken using one element per member. The following figures show the static response of fixed ended beam-column.

The nodes 1 and 4, only experiments rotation. The nodes 2 experiments a small displacement in X-axes and a bigger one in the Y-axes, and does not exist any rotation.

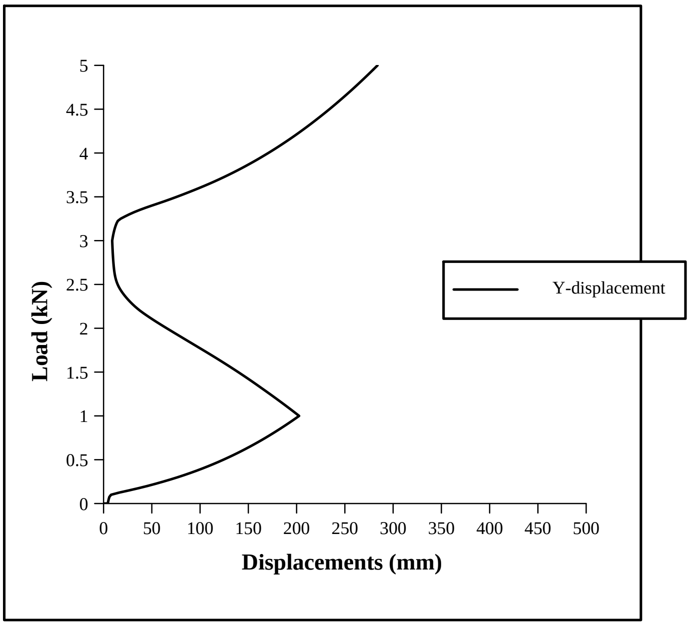


figure 9.4.2b Displacements of fixed ended beam-column.

The deformed shape that experiments the beam subject at those loads is the following one:

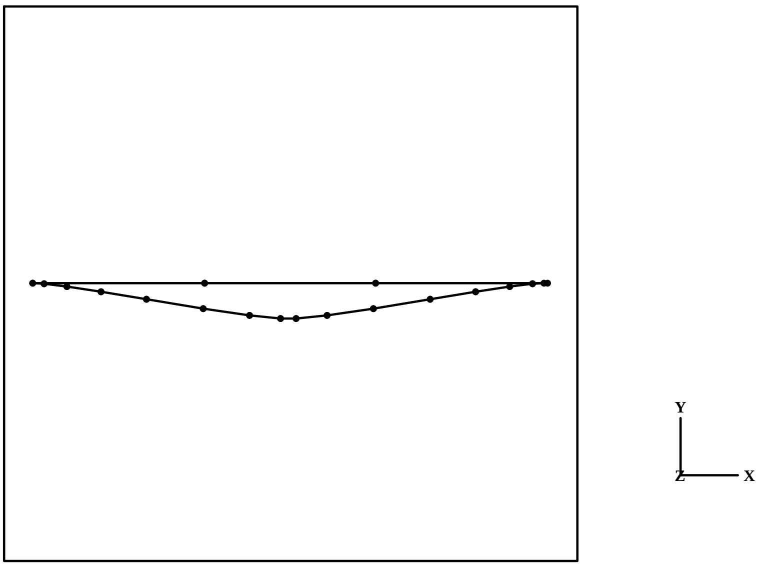


figure 9.4.2b Deflected Shape of fixed ended beam-column.

9.4.3 Output file

```
ELEMENT ASSEMBLY ORDER
 ---->>>> ---->>>> ---->>>> ---->>>> ---->>>> ---->>>> ---->>>> ---->>>>
 1        2        3

 MAXIMUM FRONT: (NODAL =    3) - (ADDITIONAL FREEDOMS =   0)
 +++++++++++++


                  I N I T I A L   L O A D I N G
                  +++++++++++++++++++++++++++++

                INITIAL
                LOADING             CURRENT
 OUTPUT         FACTOR               TIME        LEVEL   CONV.-NORM
ITERATIONS
     1       0.10000000E+01    0.00000000E+00     0     0.303E-07         1

                 V A R I A B L E   L O A D I N G
                 ++++++++++++++++++++++++++++++++

                 CURRENT
 OUTPUT            TIME       LEVEL    CONV.-NORM   ITERATIONS
     2       0.25000000E-01    0      0.326E-06         1
     3       0.50000000E-01    0      0.584E-06         1
     4       0.75000000E-01    0      0.155E-12         2

 ********************(  SUBDIVISION OF ELEMENT 1        )****************
 *                                                                      *
 *NUMBER OF NODES CREATED                                               *
 *           3                                                          *
 * NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
 * #n1                    0.127333E+03         0.000000E+00             *
 * #n2                    0.382000E+03         0.000000E+00             *
 * #n3                    0.764000E+03         0.000000E+00             *
 *----------------------------------------------------------------------*
 *                                                                      *
 *NUMBER OF ELEMENTS CREATED                                            *
 *             4                                                        *
 * ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                         *
 * #e1           cbp2                 1         #n1                     *
 * #e2           cbp2                 #n1       #n2                     *
 * #e3           cbp2                 #n2       #n3                     *
 * #e4           qdp2                 #n3       2                       *
 *----------------------------------------------------------------------*
 *                                                                      *
 *NUMBER OF IMPERFECT ELEMENTS                                          *
 *             0                                                        *
 ************************************************************************


 ********************(  SUBDIVISION OF ELEMENT 2        )****************
 *                                                                      *
 *NUMBER OF NODES CREATED                                               *
 *           4                                                          *
 * NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
 * #n4                    0.518182E+03         0.000000E+00             *
 * #n5                    0.863636E+03         0.000000E+00             *
 * #n6                    0.103636E+04         0.000000E+00             *
```

```
* #n7                   0.138182E+04          0.000000E+00            *
*---------------------------------------------------------------------*
*                                                                     *
*NUMBER OF ELEMENTS CREATED                                           *
*             5                                                       *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                        *
* #e5           cbp2                 2          #n4                   *
* #e6           cbp2                 #n4        #n5                   *
* #e7           cbp2                 #n5        #n6                   *
* #e8           cbp2                 #n6        #n7                   *
* #e9           cbp2                 #n7        3                     *
*---------------------------------------------------------------------*
*                                                                     *
*NUMBER OF IMPERFECT ELEMENTS                                         *
*             0                                                       *
***********************************************************************


*******************(  SUBDIVISION OF ELEMENT 3        )***************
*                                                                     *
*NUMBER OF NODES CREATED                                              *
*           3                                                         *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n8                   -.127333E+03          0.000000E+00            *
* #n9                   -.382000E+03          0.000000E+00            *
* #n10                  -.764000E+03          0.000000E+00            *
*---------------------------------------------------------------------*
*                                                                     *
*NUMBER OF ELEMENTS CREATED                                           *
*             4                                                       *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                        *
* #e10          cbp2                 4          #n8                   *
* #e11          cbp2                 #n8        #n9                   *
* #e12          cbp2                 #n9        #n10                  *
* #e13          qdp2                 #n10       3                     *
*---------------------------------------------------------------------*
*                                                                     *
*NUMBER OF IMPERFECT ELEMENTS                                         *
*             0                                                       *
***********************************************************************

    5       0.10000000E+00    0      0.888E-07         3

*******************(  SUBDIVISION OF ELEMENT #e4      )***************
*                                                                     *
*NUMBER OF NODES CREATED                                              *
*           1                                                         *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n11                  0.509333E+03          0.000000E+00            *
*---------------------------------------------------------------------*
*                                                                     *
*NUMBER OF ELEMENTS CREATED                                           *
*             2                                                       *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                        *
* #e14          cbp2                 #n3        #n11                  *
* #e15          cbp2                 #n11       2                     *
*---------------------------------------------------------------------*
*                                                                     *
*NUMBER OF IMPERFECT ELEMENTS                                         *
*             0                                                       *
***********************************************************************
```

```
********************(  SUBDIVISION OF ELEMENT #e13     )****************
*                                                                      *
*NUMBER OF NODES CREATED                                               *
*           1                                                          *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n12                   -.509333E+03         0.000000E+00             *
*----------------------------------------------------------------------*
*                                                                      *
*NUMBER OF ELEMENTS CREATED                                            *
*             2                                                        *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                         *
* #e16          cbp2                 #n10      #n12                    *
* #e17          cbp2                 #n12      3                       *
*----------------------------------------------------------------------*
*                                                                      *
*NUMBER OF IMPERFECT ELEMENTS                                          *
*             0                                                        *
************************************************************************
```

6	0.12500000E+00	0	0.665E-07	3
7	0.15000000E+00	0	0.219E-06	2
8	0.17500000E+00	0	0.437E-06	2
9	0.20000000E+00	0	0.195E-06	2
10	0.22500000E+00	0	0.177E-06	2
11	0.25000000E+00	0	0.161E-06	2
12	0.27500000E+00	0	0.116E-06	2
13	0.30000000E+00	0	0.349E-07	2
14	0.32500000E+00	0	0.208E-08	3
15	0.35000000E+00	0	0.206E-09	3
16	0.37500000E+00	0	0.233E-08	3
17	0.40000000E+00	0	0.508E-07	2
18	0.42500000E+00	0	0.411E-07	2
19	0.45000000E+00	0	0.731E-07	2
20	0.47500000E+00	0	0.574E-07	2
21	0.50000000E+00	0	0.254E-07	2
22	0.52500000E+00	0	0.410E-07	2
23	0.55000000E+00	0	0.841E-07	2
24	0.57500000E+00	0	0.355E-09	3
25	0.60000000E+00	0	0.478E-07	2
26	0.62500000E+00	0	0.103E-06	2
27	0.65000000E+00	0	0.138E-08	3
28	0.67500000E+00	0	0.157E-09	3
29	0.70000000E+00	0	0.481E-07	2
30	0.72500000E+00	0	0.342E-07	2
31	0.75000000E+00	0	0.191E-07	2
32	0.77500000E+00	0	0.186E-07	2
33	0.80000000E+00	0	0.183E-07	2
34	0.82500000E+00	0	0.575E-09	3
35	0.85000000E+00	0	0.173E-07	2
36	0.87500000E+00	0	0.128E-07	2
37	0.90000000E+00	0	0.133E-07	2
38	0.92500000E+00	0	0.242E-07	2
39	0.95000000E+00	0	0.425E-09	3
40	0.97500000E+00	0	0.186E-09	3
41	0.10000000E+01	0	0.263E-09	3
42	0.10250000E+01	0	0.312E-08	2
43	0.10500000E+01	0	0.829E-07	1
44	0.10750000E+01	0	0.828E-07	1
45	0.11000000E+01	0	0.822E-07	1

46	0.11250000E+01	0	0.811E-07	1
47	0.11500000E+01	0	0.795E-07	1
48	0.11750000E+01	0	0.772E-07	1
49	0.12000000E+01	0	0.743E-07	1
50	0.12250000E+01	0	0.706E-07	1
51	0.12500000E+01	0	0.692E-07	1
52	0.12750000E+01	0	0.277E-06	2
53	0.13000000E+01	0	0.250E-08	2
54	0.13250000E+01	0	0.394E-07	2
55	0.13500000E+01	0	0.102E-08	2
56	0.13750000E+01	0	0.829E-08	2
57	0.14000000E+01	0	0.215E-07	2
58	0.14250000E+01	0	0.139E-07	2
59	0.14500000E+01	0	0.226E-07	2
60	0.14750000E+01	0	0.398E-07	2
61	0.15000000E+01	0	0.120E-06	2
62	0.15250000E+01	0	0.179E-06	2
63	0.15500000E+01	0	0.105E-06	2
64	0.15750000E+01	0	0.634E-07	2
65	0.16000000E+01	0	0.234E-07	2
66	0.16250000E+01	0	0.314E-07	2
67	0.16500000E+01	0	0.202E-07	2
68	0.16750000E+01	0	0.932E-07	2
69	0.17000000E+01	0	0.182E-07	2
70	0.17250000E+01	0	0.343E-07	2
71	0.17500000E+01	0	0.450E-07	2
72	0.17750000E+01	0	0.322E-06	2
73	0.18000000E+01	0	0.359E-06	2
74	0.18250000E+01	0	0.231E-07	2
75	0.18500000E+01	0	0.204E-06	2
76	0.18750000E+01	0	0.411E-06	2
77	0.19000000E+01	0	0.124E-08	3
78	0.19250000E+01	0	0.160E-07	2
79	0.19500000E+01	0	0.516E-06	2
80	0.19750000E+01	0	0.515E-06	2
81	0.20000000E+01	0	0.174E-07	2
82	0.20250000E+01	0	0.357E-07	2
83	0.20500000E+01	0	0.145E-06	2
84	0.20750000E+01	0	0.232E-07	2
85	0.21000000E+01	0	0.532E-08	2
86	0.21250000E+01	0	0.615E-08	2
87	0.21500000E+01	0	0.134E-07	2
88	0.21750000E+01	0	0.358E-08	2
89	0.22000000E+01	0	0.134E-06	2
90	0.22250000E+01	0	0.179E-07	2
91	0.22500000E+01	0	0.372E-07	2
92	0.22750000E+01	0	0.591E-06	2
93	0.23000000E+01	0	0.411E-08	2
94	0.23250000E+01	0	0.491E-07	2
95	0.23500000E+01	0	0.557E-08	2
96	0.23750000E+01	0	0.616E-08	2
97	0.24000000E+01	0	0.508E-08	2
98	0.24250000E+01	0	0.721E-08	2
99	0.24500000E+01	0	0.134E-07	2
100	0.24750000E+01	0	0.487E-06	2
101	0.25000000E+01	0	0.224E-06	2
102	0.25250000E+01	0	0.788E-07	2
103	0.25500000E+01	0	0.223E-07	2
104	0.25750000E+01	0	0.320E-07	2
105	0.26000000E+01	0	0.467E-07	2
106	0.26250000E+01	0	0.382E-07	2

107	0.26500000E+01	0	0.483E-08	2
108	0.26750000E+01	0	0.480E-08	2
109	0.27000000E+01	0	0.457E-08	2
110	0.27250000E+01	0	0.349E-08	2
111	0.27500000E+01	0	0.184E-08	2
112	0.27750000E+01	0	0.934E-06	1
113	0.28000000E+01	0	0.542E-06	1
114	0.28250000E+01	0	0.380E-06	1
115	0.28500000E+01	0	0.542E-06	1
116	0.28750000E+01	0	0.900E-06	1
117	0.29000000E+01	0	0.261E-08	2
118	0.29250000E+01	0	0.299E-08	2
119	0.29500000E+01	0	0.249E-08	2
120	0.29750000E+01	0	0.872E-06	1
121	0.30000000E+01	0	0.512E-06	1
122	0.30250000E+01	0	0.629E-09	2
123	0.30500000E+01	0	0.215E-06	1
124	0.30750000E+01	0	0.303E-06	1
125	0.31000000E+01	0	0.437E-06	1
126	0.31250000E+01	0	0.642E-06	1
127	0.31500000E+01	0	0.967E-06	1
128	0.31750000E+01	0	0.126E-11	2
129	0.32000000E+01	0	0.114E-11	2
130	0.32250000E+01	0	0.173E-08	3
131	0.32500000E+01	0	0.813E-08	3
132	0.32750000E+01	0	0.129E-06	3
133	0.33000000E+01	0	0.670E-07	2
134	0.33250000E+01	0	0.438E-07	2
135	0.33500000E+01	0	0.108E-06	2
136	0.33750000E+01	0	0.344E-06	2
137	0.34000000E+01	0	0.216E-06	2
138	0.34250000E+01	0	0.289E-06	2
139	0.34500000E+01	0	0.232E-06	2
140	0.34750000E+01	0	0.135E-08	3
141	0.35000000E+01	0	0.126E-07	3
142	0.35250000E+01	0	0.888E-07	2
143	0.35500000E+01	0	0.649E-07	2
144	0.35750000E+01	0	0.300E-06	2
145	0.36000000E+01	0	0.357E-06	2
146	0.36250000E+01	0	0.264E-08	3
147	0.36500000E+01	0	0.194E-08	3
148	0.36750000E+01	0	0.214E-09	3
149	0.37000000E+01	0	0.420E-06	2
150	0.37250000E+01	0	0.760E-07	2
151	0.37500000E+01	0	0.408E-07	2
152	0.37750000E+01	0	0.200E-06	2
153	0.38000000E+01	0	0.268E-08	3
154	0.38250000E+01	0	0.162E-09	3
155	0.38500000E+01	0	0.202E-09	3
156	0.38750000E+01	0	0.139E-09	3
157	0.39000000E+01	0	0.126E-10	3
158	0.39250000E+01	0	0.110E-10	3
159	0.39500000E+01	0	0.614E-09	2
160	0.39750000E+01	0	0.307E-09	2
161	0.40000000E+01	0	0.225E-06	2
162	0.40250000E+01	0	0.973E-08	2
163	0.40500000E+01	0	0.653E-06	2
164	0.40750000E+01	0	0.920E-06	2
165	0.41000000E+01	0	0.256E-09	2
166	0.41250000E+01	0	0.154E-09	2
167	0.41500000E+01	0	0.113E-08	2

168	0.41750000E+01	0	0.343E-08	2
169	0.42000000E+01	0	0.348E-09	2
170	0.42250000E+01	0	0.410E-08	2
171	0.42500000E+01	0	0.139E-08	2
172	0.42750000E+01	0	0.102E-07	2
173	0.43000000E+01	0	0.602E-10	3
174	0.43250000E+01	0	0.174E-08	2
175	0.43500000E+01	0	0.148E-06	2
176	0.43750000E+01	0	0.331E-08	2
177	0.44000000E+01	0	0.256E-08	2
178	0.44250000E+01	0	0.971E-10	3
179	0.44500000E+01	0	0.592E-09	2
180	0.44750000E+01	0	0.194E-09	2
181	0.45000000E+01	0	0.930E-09	2
182	0.45250000E+01	0	0.924E-09	2
183	0.45500000E+01	0	0.946E-09	2
184	0.45750000E+01	0	0.320E-10	3
185	0.46000000E+01	0	0.104E-08	2
186	0.46250000E+01	0	0.999E-09	2
187	0.46500000E+01	0	0.332E-08	2
188	0.46750000E+01	0	0.582E-09	2
189	0.47000000E+01	0	0.398E-10	2
190	0.47250000E+01	0	0.430E-10	2
191	0.47500000E+01	0	0.175E-09	2
192	0.47750000E+01	0	0.142E-09	2
193	0.48000000E+01	0	0.729E-10	2
194	0.48250000E+01	0	0.107E-09	2
195	0.48500000E+01	0	0.164E-09	2
196	0.48750000E+01	0	0.208E-09	2
197	0.49000000E+01	0	0.130E-08	2
198	0.49250000E+01	0	0.676E-10	3
199	0.49500000E+01	0	0.486E-09	2
200	0.49750000E+01	0	0.543E-09	2
201	0.50000000E+01	0	0.137E-09	2

9.5 Two-storey

This example illustrates the influence of an earthquake on the resistance of steel frames.

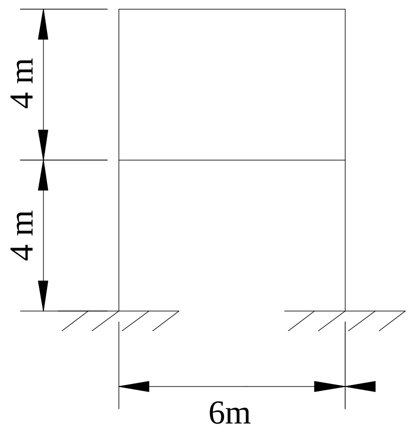


figure 9.5 Steel frames subject to earthquake.

9.5.1 Data file

```
#
analysis 2d dynamics                                                         (a)
#
materials                                                                    (b)
  mat.name    model         properties
   mat1       stl1      0.210e12 0.300e9 0.100e-1
#
sections                                                                     (c)
  type = rss
  sec.name    mat.name   dimensions
   sect1      mat1       0.10 0.10
#
patterns                                                                     (p)
 pat.name     ratios
  pat1           1 2 3 3 2 1
#
groups                                                                       (d)
type = cbp2
 grp.name      sec.name      monitoring.points
   grp1         sect1                 30

type = qdp2
 grp.name    cbp2.grp.name    pat.name
   grp2        grp1              pat1

type = cnm2
 grp.name         mass
   grp3          20000
#
structural                                                                   (e)
   nod.n      x      y
  f 1       0.0    0.0
  r 1       6.0    0.0 1
  r 2       0.0    4.0 2
#
restraints                                                                   (f)
  direction = y+rz
        nod.name
           1
           2
#
element.connectivity                                                         (g)
  grp.name = grp2
  elm.name      nod.name
    f 1          1   3
    r 1          1   1 1
    r 2          2   2 1
      5          3   4
      6          5   6
  grp.name = grp3
  elm.name     nod.name
    f 10          3
    r  1          1   3
#
integration                                                                  (r)
scheme = newmark
beta  = 0.25
gamma = 0.5
```

```
#
linear.curves                                                   (q)
start.time = 0.0
crv.name = crv1
file      = earthquake1
first.line = 1
last.line  = 1200
format    = (23x,2(e15.8,2x))
#
equilibrium.stages                                              (s)
        end.of.stage      steps
          5              500
#
applied.loading                                                 (i)
 dynamic
        nod.name        direction       type        crv.name    value
          f 1               x       acceleration      crv1     9.81
          r 1               -            -              -      0   1
#
iterative.strategy                                              (k)
number = 10
initial.reformations = 7
step.reduction = 10
divergence.iteration = 7
maximum.convergence =  1.0
#
convergence.criteria                                            (l)
 tolerance = 0.1e-3
 displacement.ref = 1.0
 rotation.ref     = 1.0
#
output                                                          (m)
frequency 2
#
end
```

Note The following picture shows the names that have been given to the nodes and elements in the data file.

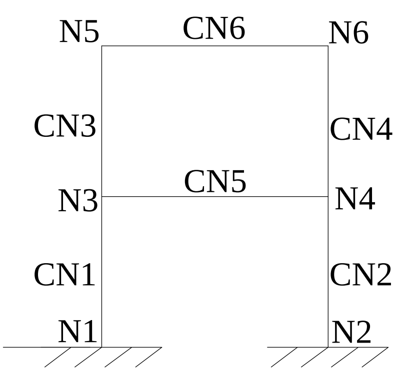


figure 9.5.1 Nodes and elements of the two-storey.

9.5.2 Structural behaviour

The nonlinear analysis is undertaken using one element per member. The following figures show the dynamic response of the structure.

The displacements of the node 121 at the Y-axes are almost inexistent compare into the ones at the X-axes, which vary with the time.

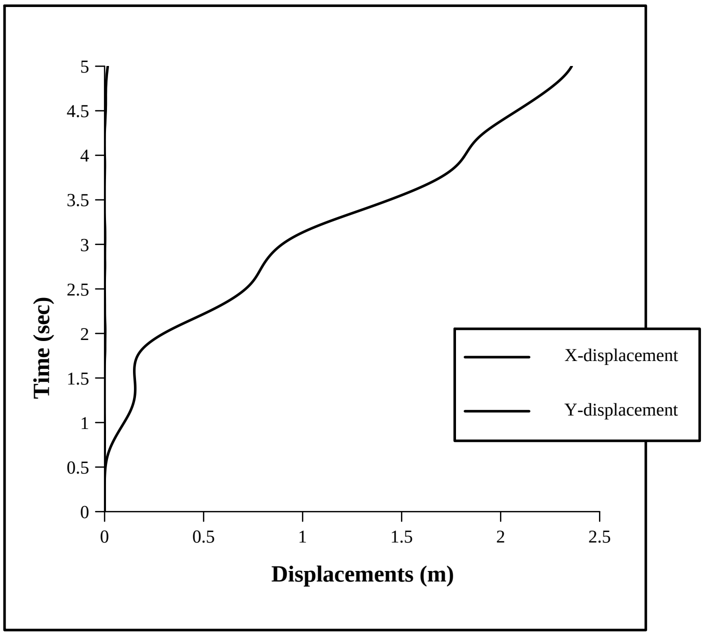


figure 9.5.2b Displacements of two-storey.

The deformed shape given by ADAPTIC is the one shown in the figure, where could be seen that the main effect of the earthquake is a translation of the structure.

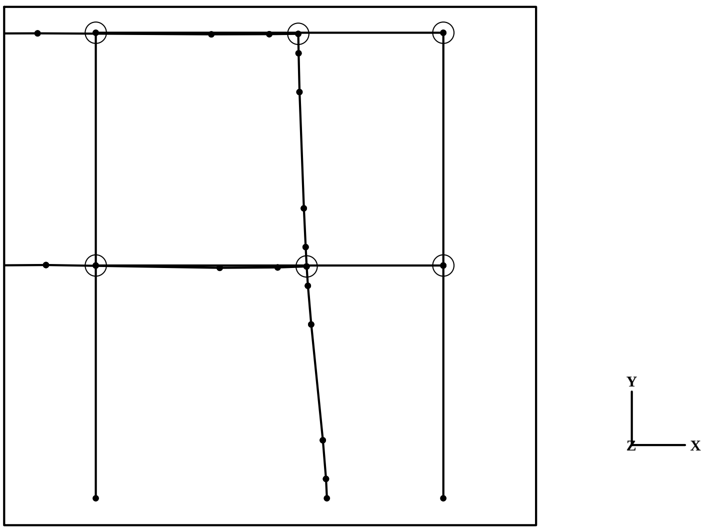


figure 9.5.2b Deflected Shape of two-storey.

9.5.3 Output file

```
    ELEMENT ASSEMBLY ORDER
----->>>> ---->>>> ---->>>> ---->>>> ---->>>> ---->>>> ---->>>> ---->>>>
1         3         5         10        6         12        4         13
2         11

MAXIMUM FRONT: (NODAL =    4) - (ADDITIONAL FREEDOMS =   0)
+++++++++++++


                V A R I A B L E   L O A D I N G
                ++++++++++++++++++++++++++++++++

                CURRENT
OUTPUT           TIME        LEVEL     CONV.-NORM   ITERATIONS
    0       0.10000000E-01    0       0.147E-06        0
    1       0.20000000E-01    0       0.736E-06        0
    0       0.30000000E-01    0       0.190E-05        0
    2       0.40000000E-01    0       0.362E-05        0
    0       0.50000000E-01    0       0.516E-05        0
    3       0.60000000E-01    0       0.511E-05        0
    0       0.70000000E-01    0       0.128E-05        0
    4       0.80000000E-01    0       0.932E-05        0
    0       0.90000000E-01    0       0.261E-04        0
    5       0.10000000E+00    0       0.449E-04        0
    0       0.11000000E+00    0       0.622E-04        0
    6       0.12000000E+00    0       0.750E-04        0
    0       0.13000000E+00    0       0.795E-04        0
    7       0.14000000E+00    0       0.716E-04        0
    0       0.15000000E+00    0       0.485E-04        0
    8       0.16000000E+00    0       0.884E-05        0
    0       0.17000000E+00    0       0.509E-04        0
    9       0.18000000E+00    0       0.860E-09        1
    0       0.19000000E+00    0       0.266E-08        1
   10       0.20000000E+00    0       0.556E-08        1
    0       0.21000000E+00    0       0.895E-08        1
   11       0.22000000E+00    0       0.116E-07        1
    0       0.23000000E+00    0       0.132E-07        1
   12       0.24000000E+00    0       0.149E-07        1
    0       0.25000000E+00    0       0.168E-07        1
   13       0.26000000E+00    0       0.178E-07        1
    0       0.27000000E+00    0       0.177E-07        1
   14       0.28000000E+00    0       0.173E-07        1
    0       0.29000000E+00    0       0.171E-07        1
   15       0.30000000E+00    0       0.166E-07        1
    0       0.31000000E+00    0       0.160E-07        1
   16       0.32000000E+00    0       0.159E-07        1
    0       0.33000000E+00    0       0.170E-07        1
   17       0.34000000E+00    0       0.199E-07        1
    0       0.35000000E+00    0       0.248E-07        1
   18       0.36000000E+00    0       0.312E-07        1
    0       0.37000000E+00    0       0.383E-07        1
   19       0.38000000E+00    0       0.450E-07        1
    0       0.39000000E+00    0       0.508E-07        1
   20       0.40000000E+00    0       0.565E-07        1
    0       0.41000000E+00    0       0.631E-07        1
   21       0.42000000E+00    0       0.722E-07        1
    0       0.43000000E+00    0       0.840E-07        1
   22       0.44000000E+00    0       0.971E-07        1
    0       0.45000000E+00    0       0.112E-06        1
```

23	0.46000000E+00	0	0.132E-06	1
0	0.47000000E+00	0	0.158E-06	1
24	0.48000000E+00	0	0.190E-06	1
0	0.49000000E+00	0	0.222E-06	1
25	0.50000000E+00	0	0.245E-06	1
0	0.51000000E+00	0	0.252E-06	1
26	0.52000000E+00	0	0.245E-06	1
0	0.53000000E+00	0	0.227E-06	1
27	0.54000000E+00	0	0.208E-06	1
0	0.55000000E+00	0	0.191E-06	1
28	0.56000000E+00	0	0.177E-06	1
0	0.57000000E+00	0	0.164E-06	1
29	0.58000000E+00	0	0.146E-06	1
0	0.59000000E+00	0	0.123E-06	1
30	0.60000000E+00	0	0.110E-06	1
0	0.61000000E+00	0	0.109E-06	1
31	0.62000000E+00	0	0.110E-06	1
0	0.63000000E+00	0	0.115E-06	1
32	0.64000000E+00	0	0.122E-06	1
0	0.65000000E+00	0	0.129E-06	1
33	0.66000000E+00	0	0.132E-06	1
0	0.67000000E+00	0	0.134E-06	1
34	0.68000000E+00	0	0.137E-06	1
0	0.69000000E+00	0	0.142E-06	1
35	0.70000000E+00	0	0.157E-06	1
0	0.71000000E+00	0	0.171E-06	1
36	0.72000000E+00	0	0.171E-06	1
0	0.73000000E+00	0	0.182E-06	1
37	0.74000000E+00	0	0.193E-06	1
0	0.75000000E+00	0	0.204E-06	1
38	0.76000000E+00	0	0.213E-06	1
0	0.77000000E+00	0	0.224E-06	1
39	0.78000000E+00	0	0.226E-06	1
0	0.79000000E+00	0	0.232E-06	1
40	0.80000000E+00	0	0.239E-06	1
0	0.81000000E+00	0	0.247E-06	1
41	0.82000000E+00	0	0.253E-06	1
0	0.83000000E+00	0	0.266E-06	1
42	0.84000000E+00	0	0.275E-06	1
0	0.85000000E+00	0	0.261E-06	1
43	0.86000000E+00	0	0.262E-06	1
0	0.87000000E+00	0	0.262E-06	1
44	0.88000000E+00	0	0.262E-06	1
0	0.89000000E+00	0	0.260E-06	1
45	0.90000000E+00	0	0.276E-06	1
0	0.91000000E+00	0	0.278E-06	1
46	0.92000000E+00	0	0.261E-06	1
0	0.93000000E+00	0	0.257E-06	1
47	0.94000000E+00	0	0.254E-06	1
0	0.95000000E+00	0	0.248E-06	1
48	0.96000000E+00	0	0.239E-06	1
0	0.97000000E+00	0	0.230E-06	1
49	0.98000000E+00	0	0.217E-06	1
0	0.99000000E+00	0	0.205E-06	1
50	0.10000000E+01	0	0.199E-06	1
0	0.10100000E+01	0	0.200E-06	1
51	0.10200000E+01	0	0.212E-06	1
0	0.10300000E+01	0	0.224E-06	1
52	0.10400000E+01	0	0.243E-06	1
0	0.10500000E+01	0	0.258E-06	1
53	0.10600000E+01	0	0.306E-06	1

0	0.10700000E+01	0	0.354E-06	1
54	0.10800000E+01	0	0.371E-06	1
0	0.10900000E+01	0	0.330E-06	1
55	0.11000000E+01	0	0.276E-06	1
0	0.11100000E+01	0	0.209E-06	1
56	0.11200000E+01	0	0.149E-06	1
0	0.11300000E+01	0	0.104E-06	1
57	0.11400000E+01	0	0.809E-07	1
0	0.11500000E+01	0	0.627E-07	1
58	0.11600000E+01	0	0.381E-07	1
0	0.11700000E+01	0	0.260E-07	1
59	0.11800000E+01	0	0.240E-07	1
0	0.11900000E+01	0	0.266E-07	1
60	0.12000000E+01	0	0.544E-07	1
0	0.12100000E+01	0	0.898E-07	1
61	0.12200000E+01	0	0.973E-07	1
0	0.12300000E+01	0	0.799E-07	1
62	0.12400000E+01	0	0.989E-07	1
0	0.12500000E+01	0	0.116E-06	1
63	0.12600000E+01	0	0.132E-06	1
0	0.12700000E+01	0	0.149E-06	1
64	0.12800000E+01	0	0.172E-06	1
0	0.12900000E+01	0	0.200E-06	1
65	0.13000000E+01	0	0.234E-06	1
0	0.13100000E+01	0	0.269E-06	1
66	0.13200000E+01	0	0.303E-06	1
0	0.13300000E+01	0	0.334E-06	1
67	0.13400000E+01	0	0.366E-06	1
0	0.13500000E+01	0	0.398E-06	1
68	0.13600000E+01	0	0.430E-06	1
0	0.13700000E+01	0	0.462E-06	1
69	0.13800000E+01	0	0.495E-06	1
0	0.13900000E+01	0	0.530E-06	1
70	0.14000000E+01	0	0.564E-06	1
0	0.14100000E+01	0	0.594E-06	1
71	0.14200000E+01	0	0.620E-06	1
0	0.14300000E+01	0	0.647E-06	1
72	0.14400000E+01	0	0.685E-06	1
0	0.14500000E+01	0	0.732E-06	1
73	0.14600000E+01	0	0.788E-06	1
0	0.14700000E+01	0	0.845E-06	1
74	0.14800000E+01	0	0.901E-06	1
0	0.14900000E+01	0	0.948E-06	1
75	0.15000000E+01	0	0.974E-06	1
0	0.15100000E+01	0	0.971E-06	1
76	0.15200000E+01	0	0.941E-06	1
0	0.15300000E+01	0	0.894E-06	1
77	0.15400000E+01	0	0.849E-06	1
0	0.15500000E+01	0	0.810E-06	1
78	0.15600000E+01	0	0.777E-06	1
0	0.15700000E+01	0	0.745E-06	1
79	0.15800000E+01	0	0.709E-06	1
0	0.15900000E+01	0	0.671E-06	1
80	0.16000000E+01	0	0.636E-06	1
0	0.16100000E+01	0	0.606E-06	1
81	0.16200000E+01	0	0.581E-06	1
0	0.16300000E+01	0	0.562E-06	1
82	0.16400000E+01	0	0.548E-06	1
0	0.16500000E+01	0	0.540E-06	1
83	0.16600000E+01	0	0.548E-06	1
0	0.16700000E+01	0	0.577E-06	1

```
   84       0.16800000E+01    0      0.621E-06         1
    0       0.16900000E+01    0      0.793E-06         1
   85       0.17000000E+01    0      0.105E-05         1
    0       0.17100000E+01    0      0.130E-05         1
   86       0.17200000E+01    0      0.147E-05         1

********************(  SUBDIVISION OF ELEMENT 1        )***************
*                                                                     *
*NUMBER OF NODES CREATED                                              *
*           1                                                         *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n1                    0.000000E+00          0.333333E+00           *
*---------------------------------------------------------------------*
*                                                                     *
*NUMBER OF ELEMENTS CREATED                                           *
*             2                                                       *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                        *
* #e1           cbp2                 1         #n1                    *
* #e2           qdp2                 #n1       3                      *
*---------------------------------------------------------------------*
*                                                                     *
*NUMBER OF IMPERFECT ELEMENTS                                         *
*             0                                                       *
***********************************************************************


********************(  SUBDIVISION OF ELEMENT 2        )***************
*                                                                     *
*NUMBER OF NODES CREATED                                              *
*           1                                                         *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n2                    0.000000E+00          0.333333E+00           *
*---------------------------------------------------------------------*
*                                                                     *
*NUMBER OF ELEMENTS CREATED                                           *
*             2                                                       *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                        *
* #e3           cbp2                 2         #n2                    *
* #e4           qdp2                 #n2       4                      *
*---------------------------------------------------------------------*
*                                                                     *
*NUMBER OF IMPERFECT ELEMENTS                                         *
*             0                                                       *
***********************************************************************

    0       0.17300000E+01    0      0.317E-04         1
   87       0.17400000E+01    0      0.374E-04         1

********************(  SUBDIVISION OF ELEMENT #e2      )***************
*                                                                     *
*NUMBER OF NODES CREATED                                              *
*           1                                                         *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n3                    0.000000E+00          0.333333E+01           *
*---------------------------------------------------------------------*
*                                                                     *
*NUMBER OF ELEMENTS CREATED                                           *
*             2                                                       *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                        *
* #e6           cbp2                 #n3       3                      *
* #e5           qdp2                 #n1       #n3                    *
```

```
*-----------------------------------------------------------------------*
*                                                                       *
*NUMBER OF IMPERFECT ELEMENTS                                           *
*             0                                                         *
*************************************************************************


********************(  SUBDIVISION OF ELEMENT #e4      )****************
*                                                                       *
*NUMBER OF NODES CREATED                                                *
*           1                                                           *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n4                    0.000000E+00          0.333333E+01             *
*-----------------------------------------------------------------------*
*                                                                       *
*NUMBER OF ELEMENTS CREATED                                             *
*             2                                                         *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                          *
* #e8           cbp2                 #n4       4                        *
* #e7           qdp2                 #n2       #n4                      *
*-----------------------------------------------------------------------*
*                                                                       *
*NUMBER OF IMPERFECT ELEMENTS                                           *
*             0                                                         *
*************************************************************************

    0       0.17500000E+01    0      0.727E-04         1
   88       0.17600000E+01    0      0.624E-04         1
    0       0.17700000E+01    0      0.327E-04         1

********************(  SUBDIVISION OF ELEMENT #e5      )****************
*                                                                       *
*NUMBER OF NODES CREATED                                                *
*           1                                                           *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n5                    0.000000E+00          0.666667E+00             *
*-----------------------------------------------------------------------*
*                                                                       *
*NUMBER OF ELEMENTS CREATED                                             *
*             2                                                         *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                          *
* #e9           cbp2                 #n1       #n5                      *
* #e10          qdp2                 #n5       #n3                      *
*-----------------------------------------------------------------------*
*                                                                       *
*NUMBER OF IMPERFECT ELEMENTS                                           *
*             0                                                         *
*************************************************************************


********************(  SUBDIVISION OF ELEMENT #e7      )****************
*                                                                       *
*NUMBER OF NODES CREATED                                                *
*           1                                                           *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n6                    0.000000E+00          0.666667E+00             *
*-----------------------------------------------------------------------*
*                                                                       *
*NUMBER OF ELEMENTS CREATED                                             *
*             2                                                         *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                          *
```

```
* #e11          cbp2                 #n2        #n6                     *
* #e12          qdp2                 #n6        #n4                     *
*-----------------------------------------------------------------------*
*                                                                       *
*NUMBER OF IMPERFECT ELEMENTS                                           *
*             0                                                         *
*************************************************************************

   89       0.17800000E+01    0      0.204E-04         1
    0       0.17900000E+01    0      0.230E-04         1
   90       0.18000000E+01    0      0.299E-04         1
    0       0.18100000E+01    0      0.122E-05         1
   91       0.18200000E+01    0      0.201E-05         1
    0       0.18300000E+01    0      0.287E-05         1
   92       0.18400000E+01    0      0.659E-05         1
    0       0.18500000E+01    0      0.993E-06         1
   93       0.18600000E+01    0      0.423E-05         1
    0       0.18700000E+01    0      0.117E-04         1
   94       0.18800000E+01    0      0.658E-06         1
    0       0.18900000E+01    0      0.102E-04         1
   95       0.19000000E+01    0      0.212E-04         1
    0       0.19100000E+01    0      0.115E-04         1
   96       0.19200000E+01    0      0.541E-05         1
    0       0.19300000E+01    0      0.254E-05         1
   97       0.19400000E+01    0      0.322E-05         1
    0       0.19500000E+01    0      0.266E-05         1
   98       0.19600000E+01    0      0.317E-05         1
    0       0.19700000E+01    0      0.370E-05         1
   99       0.19800000E+01    0      0.405E-05         1
    0       0.19900000E+01    0      0.402E-05         1
  100       0.20000000E+01    0      0.373E-05         1
    0       0.20100000E+01    0      0.268E-04         1
  101       0.20200000E+01    0      0.151E-04         1
    0       0.20300000E+01    0      0.357E-05         1
  102       0.20400000E+01    0      0.398E-05         1
    0       0.20500000E+01    0      0.424E-05         1
  103       0.20600000E+01    0      0.435E-05         1
    0       0.20700000E+01    0      0.437E-05         1
  104       0.20800000E+01    0      0.442E-05         1
    0       0.20900000E+01    0      0.464E-05         1
  105       0.21000000E+01    0      0.496E-05         1
    0       0.21100000E+01    0      0.521E-05         1
  106       0.21200000E+01    0      0.532E-05         1
    0       0.21300000E+01    0      0.525E-05         1
  107       0.21400000E+01    0      0.505E-05         1
    0       0.21500000E+01    0      0.478E-05         1
  108       0.21600000E+01    0      0.447E-05         1
    0       0.21700000E+01    0      0.423E-05         1
  109       0.21800000E+01    0      0.410E-05         1
    0       0.21900000E+01    0      0.399E-05         1
  110       0.22000000E+01    0      0.377E-05         1
    0       0.22100000E+01    0      0.343E-05         1
  111       0.22200000E+01    0      0.308E-05         1

********************(  SUBDIVISION OF ELEMENT 5        )***************
*                                                                       *
*NUMBER OF NODES CREATED                                                *
*           2                                                           *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n7                    0.500000E+00          0.000000E+00             *
* #n8                    0.550000E+01          0.000000E+00             *
```

```
*----------------------------------------------------------------------*
*                                                                      *
*NUMBER OF ELEMENTS CREATED                                            *
*             3                                                        *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                         *
* #e13          cbp2                 3         #n7                     *
* #e15          cbp2                 #n8       4                       *
* #e14          qdp2                 #n7       #n8                     *
*----------------------------------------------------------------------*
*                                                                      *
*NUMBER OF IMPERFECT ELEMENTS                                          *
*             0                                                        *
************************************************************************

    0       0.22300000E+01    0      0.809E-05         1

*******************(  SUBDIVISION OF ELEMENT 3        )***************
*                                                                      *
*NUMBER OF NODES CREATED                                               *
*           1                                                          *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n9                    0.000000E+00         0.366667E+01             *
*----------------------------------------------------------------------*
*                                                                      *
*NUMBER OF ELEMENTS CREATED                                            *
*             2                                                        *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                         *
* #e17          cbp2                 #n9       5                       *
* #e16          qdp2                 3         #n9                     *
*----------------------------------------------------------------------*
*                                                                      *
*NUMBER OF IMPERFECT ELEMENTS                                          *
*             0                                                        *
************************************************************************


*******************(  SUBDIVISION OF ELEMENT 4        )***************
*                                                                      *
*NUMBER OF NODES CREATED                                               *
*           1                                                          *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n10                   0.000000E+00         0.366667E+01             *
*----------------------------------------------------------------------*
*                                                                      *
*NUMBER OF ELEMENTS CREATED                                            *
*             2                                                        *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                         *
* #e19          cbp2                 #n10      6                       *
* #e18          qdp2                 4         #n10                    *
*----------------------------------------------------------------------*
*                                                                      *
*NUMBER OF IMPERFECT ELEMENTS                                          *
*             0                                                        *
************************************************************************


*******************(  SUBDIVISION OF ELEMENT 6        )***************
*                                                                      *
*NUMBER OF NODES CREATED                                               *
*           2                                                          *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
```

```
* #n11                   0.500000E+00          0.000000E+00            *
* #n12                   0.550000E+01          0.000000E+00            *
*----------------------------------------------------------------------*
*                                                                      *
*NUMBER OF ELEMENTS CREATED                                            *
*             3                                                        *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                         *
* #e20          cbp2                 5          #n11                   *
* #e22          cbp2                 #n12       6                      *
* #e21          qdp2                 #n11       #n12                   *
*----------------------------------------------------------------------*
*                                                                      *
*NUMBER OF IMPERFECT ELEMENTS                                          *
*             0                                                        *
************************************************************************

  112       0.22400000E+01    0      0.608E-05         1

********************(  SUBDIVISION OF ELEMENT #e16     )***************
*                                                                      *
*NUMBER OF NODES CREATED                                               *
*           1                                                          *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n13                   0.000000E+00          0.333333E+00            *
*----------------------------------------------------------------------*
*                                                                      *
*NUMBER OF ELEMENTS CREATED                                            *
*             2                                                        *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                         *
* #e23          cbp2                 3          #n13                   *
* #e24          qdp2                 #n13       #n9                    *
*----------------------------------------------------------------------*
*                                                                      *
*NUMBER OF IMPERFECT ELEMENTS                                          *
*             0                                                        *
************************************************************************


********************(  SUBDIVISION OF ELEMENT #e18     )***************
*                                                                      *
*NUMBER OF NODES CREATED                                               *
*           1                                                          *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n14                   0.000000E+00          0.333333E+00            *
*----------------------------------------------------------------------*
*                                                                      *
*NUMBER OF ELEMENTS CREATED                                            *
*             2                                                        *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                         *
* #e25          cbp2                 4          #n14                   *
* #e26          qdp2                 #n14       #n10                   *
*----------------------------------------------------------------------*
*                                                                      *
*NUMBER OF IMPERFECT ELEMENTS                                          *
*             0                                                        *
************************************************************************

    0       0.22500000E+01    0      0.183E-04         1
  113       0.22600000E+01    0      0.814E-05         1
    0       0.22700000E+01    0      0.951E-05         1
  114       0.22800000E+01    0      0.257E-04         1
```

```
    0       0.22900000E+01    0      0.200E-04         1
  115       0.23000000E+01    0      0.248E-04         1
    0       0.23100000E+01    0      0.325E-04         1
  116       0.23200000E+01    0      0.216E-04         1

********************(  SUBDIVISION OF ELEMENT #e24     )***************
*                                                                       *
*NUMBER OF NODES CREATED                                                *
*           1                                                           *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n15                   0.000000E+00          0.666667E+00             *
*-----------------------------------------------------------------------*
*                                                                       *
*NUMBER OF ELEMENTS CREATED                                             *
*             2                                                         *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                          *
* #e27          cbp2                 #n13      #n15                     *
* #e28          qdp2                 #n15      #n9                      *
*-----------------------------------------------------------------------*
*                                                                       *
*NUMBER OF IMPERFECT ELEMENTS                                           *
*             0                                                         *
*************************************************************************


********************(  SUBDIVISION OF ELEMENT #e26     )***************
*                                                                       *
*NUMBER OF NODES CREATED                                                *
*           1                                                           *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n16                   0.000000E+00          0.666667E+00             *
*-----------------------------------------------------------------------*
*                                                                       *
*NUMBER OF ELEMENTS CREATED                                             *
*             2                                                         *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                          *
* #e29          cbp2                 #n14      #n16                     *
* #e30          qdp2                 #n16      #n10                     *
*-----------------------------------------------------------------------*
*                                                                       *
*NUMBER OF IMPERFECT ELEMENTS                                           *
*             0                                                         *
*************************************************************************

    0       0.23300000E+01    0      0.115E-04         1
  117       0.23400000E+01    0      0.251E-04         1
    0       0.23500000E+01    0      0.191E-04         1
  118       0.23600000E+01    0      0.307E-04         1
    0       0.23700000E+01    0      0.562E-05         1

********************(  SUBDIVISION OF ELEMENT #e30     )***************
*                                                                       *
*NUMBER OF NODES CREATED                                                *
*           1                                                           *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n17                   0.000000E+00          0.200000E+01             *
*-----------------------------------------------------------------------*
*                                                                       *
*NUMBER OF ELEMENTS CREATED                                             *
*             2                                                         *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                          *
```

```
* #e32          cbp2                 #n17      #n10               *
* #e31          qdp2                 #n16      #n17               *
*-----------------------------------------------------------------*
*                                                                 *
*NUMBER OF IMPERFECT ELEMENTS                                     *
*             0                                                   *
*******************************************************************


*******************(  SUBDIVISION OF ELEMENT #e21     )***************
*                                                                 *
*NUMBER OF NODES CREATED                                          *
*           1                                                     *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n18                   0.100000E+01         0.000000E+00        *
*-----------------------------------------------------------------*
*                                                                 *
*NUMBER OF ELEMENTS CREATED                                       *
*             2                                                   *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                    *
* #e33          cbp2                 #n11      #n18               *
* #e34          qdp2                 #n18      #n12               *
*-----------------------------------------------------------------*
*                                                                 *
*NUMBER OF IMPERFECT ELEMENTS                                     *
*             0                                                   *
*******************************************************************

  119       0.23800000E+01    0      0.148E-04         1

*******************(  SUBDIVISION OF ELEMENT #e34     )***************
*                                                                 *
*NUMBER OF NODES CREATED                                          *
*           1                                                     *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n19                   0.300000E+01         0.000000E+00        *
*-----------------------------------------------------------------*
*                                                                 *
*NUMBER OF ELEMENTS CREATED                                       *
*             2                                                   *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                    *
* #e36          cbp2                 #n19      #n12               *
* #e35          qdp2                 #n18      #n19               *
*-----------------------------------------------------------------*
*                                                                 *
*NUMBER OF IMPERFECT ELEMENTS                                     *
*             0                                                   *
*******************************************************************

    0       0.23900000E+01    0      0.838E-05         1

*******************(  SUBDIVISION OF ELEMENT #e28     )***************
*                                                                 *
*NUMBER OF NODES CREATED                                          *
*           1                                                     *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n20                   0.000000E+00         0.200000E+01        *
*-----------------------------------------------------------------*
*                                                                 *
*NUMBER OF ELEMENTS CREATED                                       *
*             2                                                   *
```

```
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                          *
* #e38          cbp2                 #n20      #n9                      *
* #e37          qdp2                 #n15      #n20                     *
*-----------------------------------------------------------------------*
*                                                                       *
*NUMBER OF IMPERFECT ELEMENTS                                           *
*             0                                                         *
*************************************************************************

  120       0.24000000E+01    0      0.323E-05         1
    0       0.24100000E+01    0      0.379E-05         1
  121       0.24200000E+01    0      0.422E-05         1
    0       0.24300000E+01    0      0.319E-05         1
  122       0.24400000E+01    0      0.667E-06         1
    0       0.24500000E+01    0      0.412E-05         1
  123       0.24600000E+01    0      0.515E-05         1
    0       0.24700000E+01    0      0.527E-06         1
  124       0.24800000E+01    0      0.492E-05         1
    0       0.24900000E+01    0      0.217E-04         1
  125       0.25000000E+01    0      0.531E-06         1
    0       0.25100000E+01    0      0.515E-06         1
  126       0.25200000E+01    0      0.562E-06         1
    0       0.25300000E+01    0      0.546E-06         1
  127       0.25400000E+01    0      0.760E-06         1
    0       0.25500000E+01    0      0.917E-06         1
  128       0.25600000E+01    0      0.101E-05         1
    0       0.25700000E+01    0      0.136E-05         1
  129       0.25800000E+01    0      0.187E-05         1
    0       0.25900000E+01    0      0.186E-05         1
  130       0.26000000E+01    0      0.198E-05         1
    0       0.26100000E+01    0      0.225E-05         1
  131       0.26200000E+01    0      0.262E-05         1
    0       0.26300000E+01    0      0.306E-05         1
  132       0.26400000E+01    0      0.324E-05         1
    0       0.26500000E+01    0      0.332E-05         1
  133       0.26600000E+01    0      0.370E-05         1
    0       0.26700000E+01    0      0.410E-05         1
  134       0.26800000E+01    0      0.421E-05         1
    0       0.26900000E+01    0      0.435E-05         1
  135       0.27000000E+01    0      0.464E-05         1
    0       0.27100000E+01    0      0.477E-05         1
  136       0.27200000E+01    0      0.477E-05         1
    0       0.27300000E+01    0      0.491E-05         1
  137       0.27400000E+01    0      0.481E-05         1
    0       0.27500000E+01    0      0.446E-05         1
  138       0.27600000E+01    0      0.433E-05         1
    0       0.27700000E+01    0      0.451E-05         1
  139       0.27800000E+01    0      0.484E-05         1
    0       0.27900000E+01    0      0.503E-05         1
  140       0.28000000E+01    0      0.469E-05         1
    0       0.28100000E+01    0      0.393E-05         1
  141       0.28200000E+01    0      0.353E-05         1
    0       0.28300000E+01    0      0.356E-05         1
  142       0.28400000E+01    0      0.379E-05         1
    0       0.28500000E+01    0      0.387E-05         1
  143       0.28600000E+01    0      0.370E-05         1
    0       0.28700000E+01    0      0.344E-05         1
  144       0.28800000E+01    0      0.317E-05         1
    0       0.28900000E+01    0      0.292E-05         1
  145       0.29000000E+01    0      0.276E-05         1
    0       0.29100000E+01    0      0.271E-05         1
```

146	0.29200000E+01	0	0.270E-05	1
0	0.29300000E+01	0	0.253E-05	1
147	0.29400000E+01	0	0.240E-05	1
0	0.29500000E+01	0	0.250E-05	1
148	0.29600000E+01	0	0.410E-05	1
0	0.29700000E+01	0	0.113E-04	1
149	0.29800000E+01	0	0.191E-05	1
0	0.29900000E+01	0	0.153E-05	1
150	0.30000000E+01	0	0.152E-04	1
0	0.30100000E+01	0	0.146E-05	1
151	0.30200000E+01	0	0.590E-05	1
0	0.30300000E+01	0	0.722E-05	1
152	0.30400000E+01	0	0.531E-04	1
0	0.30500000E+01	0	0.745E-05	1
153	0.30600000E+01	0	0.417E-06	1
0	0.30700000E+01	0	0.315E-06	1
154	0.30800000E+01	0	0.273E-06	1
0	0.30900000E+01	0	0.270E-05	1
155	0.31000000E+01	0	0.627E-07	1
0	0.31100000E+01	0	0.102E-04	1
156	0.31200000E+01	0	0.124E-06	1
0	0.31300000E+01	0	0.136E-06	1
157	0.31400000E+01	0	0.121E-06	1
0	0.31500000E+01	0	0.147E-06	1
158	0.31600000E+01	0	0.241E-06	1
0	0.31700000E+01	0	0.410E-06	1
159	0.31800000E+01	0	0.712E-06	1
0	0.31900000E+01	0	0.104E-05	1
160	0.32000000E+01	0	0.121E-05	1
0	0.32100000E+01	0	0.117E-05	1
161	0.32200000E+01	0	0.124E-05	1
0	0.32300000E+01	0	0.146E-05	1
162	0.32400000E+01	0	0.185E-05	1
0	0.32500000E+01	0	0.218E-05	1
163	0.32600000E+01	0	0.222E-05	1
0	0.32700000E+01	0	0.219E-05	1
164	0.32800000E+01	0	0.228E-05	1
0	0.32900000E+01	0	0.225E-05	1
165	0.33000000E+01	0	0.225E-05	1
0	0.33100000E+01	0	0.240E-05	1
166	0.33200000E+01	0	0.253E-05	1
0	0.33300000E+01	0	0.251E-05	1
167	0.33400000E+01	0	0.239E-05	1
0	0.33500000E+01	0	0.225E-05	1
168	0.33600000E+01	0	0.215E-05	1
0	0.33700000E+01	0	0.205E-05	1
169	0.33800000E+01	0	0.183E-05	1
0	0.33900000E+01	0	0.155E-05	1
170	0.34000000E+01	0	0.140E-05	1
0	0.34100000E+01	0	0.135E-05	1
171	0.34200000E+01	0	0.126E-05	1
0	0.34300000E+01	0	0.116E-05	1
172	0.34400000E+01	0	0.106E-05	1
0	0.34500000E+01	0	0.104E-05	1
173	0.34600000E+01	0	0.103E-05	1
0	0.34700000E+01	0	0.960E-06	1
174	0.34800000E+01	0	0.928E-06	1
0	0.34900000E+01	0	0.997E-06	1
175	0.35000000E+01	0	0.878E-06	1
0	0.35100000E+01	0	0.692E-06	1
176	0.35200000E+01	0	0.679E-06	1

0	0.35300000E+01	0	0.579E-06	1
177	0.35400000E+01	0	0.585E-06	1
0	0.35500000E+01	0	0.668E-06	1
178	0.35600000E+01	0	0.768E-06	1
0	0.35700000E+01	0	0.591E-06	1
179	0.35800000E+01	0	0.468E-06	1
0	0.35900000E+01	0	0.439E-06	1
180	0.36000000E+01	0	0.404E-06	1
0	0.36100000E+01	0	0.504E-06	1
181	0.36200000E+01	0	0.607E-06	1
0	0.36300000E+01	0	0.677E-06	1
182	0.36400000E+01	0	0.757E-06	1
0	0.36500000E+01	0	0.756E-06	1
183	0.36600000E+01	0	0.776E-06	1
0	0.36700000E+01	0	0.906E-06	1
184	0.36800000E+01	0	0.250E-04	1
0	0.36900000E+01	0	0.914E-06	1
185	0.37000000E+01	0	0.124E-05	1
0	0.37100000E+01	0	0.338E-04	1
186	0.37200000E+01	0	0.140E-05	1
0	0.37300000E+01	0	0.236E-04	1
187	0.37400000E+01	0	0.424E-04	1
0	0.37500000E+01	0	0.134E-04	1
188	0.37600000E+01	0	0.344E-04	1
0	0.37700000E+01	0	0.188E-05	1
189	0.37800000E+01	0	0.141E-05	1
0	0.37900000E+01	0	0.165E-05	1
190	0.38000000E+01	0	0.250E-04	1
0	0.38100000E+01	0	0.345E-05	1
191	0.38200000E+01	0	0.140E-04	1
0	0.38300000E+01	0	0.621E-05	1
192	0.38400000E+01	0	0.375E-05	1
0	0.38500000E+01	0	0.647E-05	1
193	0.38600000E+01	0	0.464E-05	1
0	0.38700000E+01	0	0.472E-05	1
194	0.38800000E+01	0	0.523E-05	1
0	0.38900000E+01	0	0.280E-04	1
195	0.39000000E+01	0	0.197E-04	1
0	0.39100000E+01	0	0.566E-05	1
196	0.39200000E+01	0	0.627E-05	1
0	0.39300000E+01	0	0.649E-05	1
197	0.39400000E+01	0	0.625E-05	1
0	0.39500000E+01	0	0.581E-05	1
198	0.39600000E+01	0	0.616E-05	1
0	0.39700000E+01	0	0.621E-05	1
199	0.39800000E+01	0	0.626E-05	1
0	0.39900000E+01	0	0.639E-05	1
200	0.40000000E+01	0	0.644E-05	1
0	0.40100000E+01	0	0.632E-05	1
201	0.40200000E+01	0	0.607E-05	1
0	0.40300000E+01	0	0.577E-05	1
202	0.40400000E+01	0	0.552E-05	1
0	0.40500000E+01	0	0.515E-05	1
203	0.40600000E+01	0	0.463E-05	1
0	0.40700000E+01	0	0.436E-05	1
204	0.40800000E+01	0	0.439E-05	1
0	0.40900000E+01	0	0.433E-05	1
205	0.41000000E+01	0	0.381E-05	1
0	0.41100000E+01	0	0.382E-04	1
206	0.41200000E+01	0	0.334E-05	1
0	0.41300000E+01	0	0.962E-04	1

```
  207       0.41400000E+01    0      0.601E-04         1
    0       0.41500000E+01    0      0.369E-05         1
  208       0.41600000E+01    0      0.312E-04         1
    0       0.41700000E+01    0      0.359E-04         1
  209       0.41800000E+01    0      0.138E-04         1
    0       0.41900000E+01    0      0.165E-04         1
  210       0.42000000E+01    0      0.255E-04         1
    0       0.42100000E+01    0      0.616E-05         1
  211       0.42200000E+01    0      0.495E-05         1
    0       0.42300000E+01    0      0.145E-04         1
  212       0.42400000E+01    0      0.721E-05         1
    0       0.42500000E+01    0      0.510E-05         1
  213       0.42600000E+01    0      0.287E-04         1
    0       0.42700000E+01    0      0.544E-05         1
  214       0.42800000E+01    0      0.776E-05         1
    0       0.42900000E+01    0      0.107E-04         1
  215       0.43000000E+01    0      0.259E-04         1
    0       0.43100000E+01    0      0.139E-04         1
  216       0.43200000E+01    0      0.405E-04         1
    0       0.43300000E+01    0      0.139E-04         1
  217       0.43400000E+01    0      0.116E-04         1

********************(  SUBDIVISION OF ELEMENT #e14     )***************
*                                                                        *
*NUMBER OF NODES CREATED                                                 *
*           2                                                            *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n21                   0.100000E+01          0.000000E+00              *
* #n22                   0.400000E+01          0.000000E+00              *
*------------------------------------------------------------------------*
*                                                                        *
*NUMBER OF ELEMENTS CREATED                                              *
*             3                                                          *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                           *
* #e39          cbp2                 #n7       #n21                      *
* #e41          cbp2                 #n22      #n8                       *
* #e40          qdp2                 #n21      #n22                      *
*------------------------------------------------------------------------*
*                                                                        *
*NUMBER OF IMPERFECT ELEMENTS                                            *
*             0                                                          *
**************************************************************************

    0       0.43500000E+01    0      0.253E-04         1
  218       0.43600000E+01    0      0.844E-05         1
    0       0.43700000E+01    0      0.258E-04         1
  219       0.43800000E+01    0      0.280E-04         1
    0       0.43900000E+01    0      0.492E-05         2
  220       0.44000000E+01    0      0.956E-04         1
    0       0.44100000E+01    0      0.657E-04         1
  221       0.44200000E+01    0      0.168E-04         1
    0       0.44300000E+01    0      0.231E-04         1
  222       0.44400000E+01    0      0.218E-04         1
    0       0.44500000E+01    0      0.181E-04         1
  223       0.44600000E+01    0      0.190E-04         1
    0       0.44700000E+01    0      0.463E-04         1
  224       0.44800000E+01    0      0.983E-05         1
    0       0.44900000E+01    0      0.137E-04         1
  225       0.45000000E+01    0      0.326E-04         1
    0       0.45100000E+01    0      0.339E-04         1
  226       0.45200000E+01    0      0.130E-04         1
```

```
    0       0.45300000E+01    0      0.143E-04         1
  227       0.45400000E+01    0      0.412E-05         1
    0       0.45500000E+01    0      0.177E-05         1
  228       0.45600000E+01    0      0.160E-05         1
    0       0.45700000E+01    0      0.261E-05         1
  229       0.45800000E+01    0      0.353E-05         1
    0       0.45900000E+01    0      0.127E-04         1
  230       0.46000000E+01    0      0.126E-04         1
    0       0.46100000E+01    0      0.406E-06         1
  231       0.46200000E+01    0      0.135E-05         1
    0       0.46300000E+01    0      0.560E-04         1
  232       0.46400000E+01    0      0.954E-05         1
    0       0.46500000E+01    0      0.691E-06         1
  233       0.46600000E+01    0      0.327E-04         1
    0       0.46700000E+01    0      0.215E-04         1
  234       0.46800000E+01    0      0.927E-05         1
    0       0.46900000E+01    0      0.492E-05         1
  235       0.47000000E+01    0      0.192E-04         1
    0       0.47100000E+01    0      0.181E-04         1
  236       0.47200000E+01    0      0.403E-04         1
    0       0.47300000E+01    0      0.225E-04         1
  237       0.47400000E+01    0      0.831E-05         1
    0       0.47500000E+01    0      0.135E-04         1
  238       0.47600000E+01    0      0.316E-05         1
    0       0.47700000E+01    0      0.132E-04         1
  239       0.47800000E+01    0      0.456E-04         1
    0       0.47900000E+01    0      0.689E-05         1
  240       0.48000000E+01    0      0.684E-05         1
    0       0.48100000E+01    0      0.460E-04         1
  241       0.48200000E+01    0      0.436E-04         1
    0       0.48300000E+01    0      0.520E-05         1
  242       0.48400000E+01    0      0.196E-04         1
    0       0.48500000E+01    0      0.443E-04         1
  243       0.48600000E+01    0      0.218E-04         1
    0       0.48700000E+01    0      0.104E-04         1
  244       0.48800000E+01    0      0.256E-04         1
    0       0.48900000E+01    0      0.252E-04         1
  245       0.49000000E+01    0      0.317E-04         1

********************(  SUBDIVISION OF ELEMENT #e12     )****************
*                                                                      *
*NUMBER OF NODES CREATED                                               *
*           1                                                          *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n23                   0.000000E+00          0.200000E+01            *
*----------------------------------------------------------------------*
*                                                                      *
*NUMBER OF ELEMENTS CREATED                                            *
*             2                                                        *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                         *
* #e43          cbp2                 #n23      #n4                     *
* #e42          qdp2                 #n6       #n23                    *
*----------------------------------------------------------------------*
*                                                                      *
*NUMBER OF IMPERFECT ELEMENTS                                          *
*             0                                                        *
************************************************************************

    0       0.49100000E+01    0      0.196E-04         1

********************(  SUBDIVISION OF ELEMENT #e10     )****************
```

```
*                                                                         *
*NUMBER OF NODES CREATED                                                  *
*           1                                                             *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n24                   0.000000E+00          0.200000E+01               *
*-------------------------------------------------------------------------*
*                                                                         *
*NUMBER OF ELEMENTS CREATED                                               *
*             2                                                           *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                            *
* #e45          cbp2                 #n24       #n3                       *
* #e44          qdp2                 #n5        #n24                      *
*-------------------------------------------------------------------------*
*                                                                         *
*NUMBER OF IMPERFECT ELEMENTS                                             *
*             0                                                           *
***************************************************************************

  246       0.49200000E+01    0      0.305E-04         1
    0       0.49300000E+01    0      0.293E-04         1
  247       0.49400000E+01    0      0.583E-04         1
    0       0.49500000E+01    0      0.302E-04         1
  248       0.49600000E+01    0      0.570E-04         1
    0       0.49700000E+01    0      0.424E-04         1
  249       0.49800000E+01    0      0.915E-04         1
    0       0.49900000E+01    0      0.156E-04         1
  250       0.50000000E+01    0      0.434E-04         1
```

9.6 Steel frame subject to explosion and fire loading

This example illustrates the considerable influence of explosion on the fire resistance of steel frames, even when the extent of structural damage due to explosion is relative small.

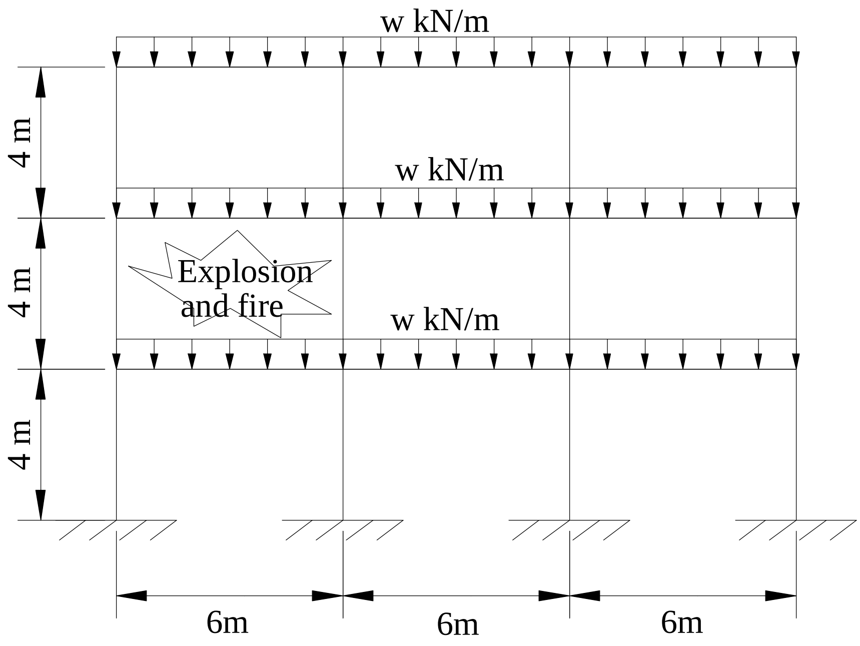


Figure 9.6 Steel frames subject to explosion and fire loading.

There are going to be used elasto-plastic cubic elements to resolve this example. The material model of steel used in this example covers the effects of the elevated temperature, creep and high strain-rate.

9.6.1 Data file

```
# Here temperatures are incremental over ambient temperature (20C)
#
analysis 2d dynamics                                                      (a)
#
materials                                                                 (b)
mat.name    model             properties
  mat1       stl8             31.19  4.65e-3  20   &
                              2.1e5  0.84e5   80.  680. 1080.  &
                              399.    59.9   280.  680.  980.  &
                              0.0     0.032  280.  380.  880.  &
                              0.01022 0.01652 730. 731. 1180.
#
sections                                                                  (c)
  type = isec
mat.name = mat1
  sec.name    dimensions
   sec1       254.5 21.0 254.5 21.0 645.6 13.2
   sec2       152.4 6.8  152.4 6.8  138.8 6.1
   sec3       203.2 11.0 203.2 11.0 181.2 7.3
#
patterns                                                                  (p)
 pat.name     ratios
  pat1            1  1  1  1  1  1  1  1  1  1
#
groups                                                                    (d)
type = cbp2
  grp.name      sec.name      monitoring.points
   grp1c         sec1                  40
   grp2c         sec2                  40
   grp3c         sec3                  40
type = qdp2
 grp.name    cbp2.grp.name    pat.name
   grp1           grp1c             pat1
   grp2           grp2c             pat1
   grp3           grp3c             pat1
#
 type = cnm2
  grp.name    mass
   gpm1       23.4
   gpm2       46.8
#
structural.nodal                                                          (e)
       nod.name       x           y
        f   101         0.0        0.0
        r    10         0.0      4000.0 3
        r   100      6000.0        0.0  3
#
restraints                                                                (g)
 nod.name      direction
 f   101       x+y+rz
 r   100         -        3
#
element.connectivity                                                      (h)
elm.name   grp.name    nod.name
  f  101      grp1        111   211
  r   1        -          100   100  2
  r   3        -           10    10  2
#
```

```
  elm.name   grp.name    nod.name
  f  201      grp2        101 111
  r  1         -          10   10  2
  r  3         -          300 300  1
#
  elm.name   grp.name    nod.name
  f  301      grp3        201 211
  r  1         -          10   10  2
  r  3         -          100 100  1
#
grp.name = gpm1
  elm.name     nod.name
  f 1101         111
  r 1            10   2
  r 3            300  1
#
grp.name = gpm2
  elm.name     nod.name
  f 1201         211
  r 1            10   2
  r 3            100  1
#
linear.curves   # curves for time history loads                    (q)
start.time = 18
crv.name = c1
        time     load.factor
        18.12          1.0
        18.15          0.0
        1220           0.0
crv.name = c2
        time    load.factor
          20       0.0
        1220       1.2
#
applied.loading                                                    (i)
  initial.load
    elm.name     type       value
   f  101        udl1       0   -75
   r   1          -         0    0    2
   r   3          -         0    0    2
#
 dynamic.load
   elm.name     type    crv.name   value
     101        udl1      c1         0   -125
     104        udl1      c1         0    125
     202        udl1      c1       -125 0
     302        udl1      c1        125 0
   elm.name     type    crv.name   value
     104        tmp2      c2      875  -0.3636   875  -0.3636   875  -0.3636
     202        tmp2      c2      375  -1.6404   375  -1.6404   375  -1.6404
     302        tmp2      c2      1000  0       1000   0       1000   0
equilibrium.stages
       end.of.stage      steps
         18.2              50
          20               45
         640               62
         670               30
#
integration
scheme = hilber
alpha = -0.3
```

```
beta  = 1.21
gamma = 0.8
#
iterative
number = 10
initial = 10
step = 10
dive = 10
maxi = 0.1e8
#
 convergence.criteria                                          (l)
 tolerance  = 0.5e-3
 force.ref = 300e3
 moment.ref = 300e6
#
output                                                         (m)
frequency  2
#
end
```

Note The following picture shows the names that have been given to the nodes and elements in the data file.

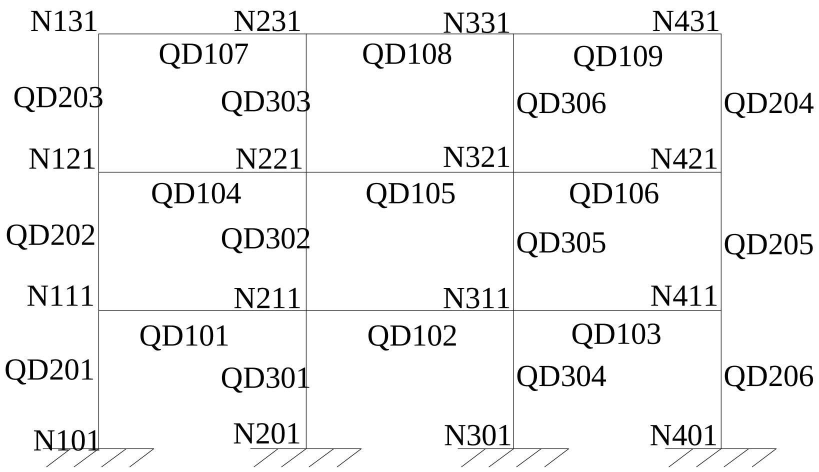
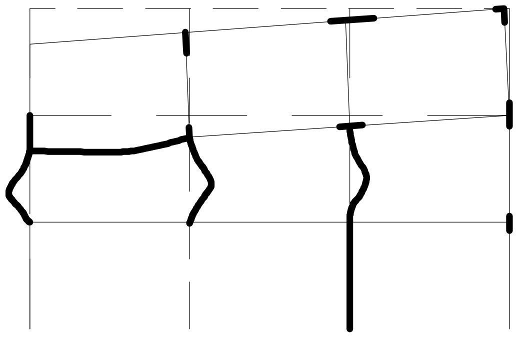


figure 9.6.1 Nodes and elements .

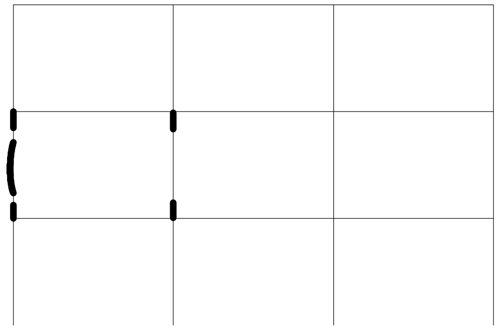
9.6.2 Structural behaviour

This example illustrates the considerable influence of explosion on the fire resistance of steel frames, even when the extent of structural damage due to explosion is relative small.

For both loading scenarios, elevated temperatures initiate buckling in the internal column at $T \approx 475^{o}C$. However, the explosion/fire scenario is associated with a much reduced overall fire resistance of $(T \approx 642^{o}C)$ in comparison with that of the fire only scenario $(T \approx 894^{o}C)$,representing a reduction of 28%. This reduction is mainly attributed to deterioration in vertical resistance of the side column due to explosion damage, leading to redistribution of vertical loading to the internal column and an earlier overall failure of the system. The deflected shapes for the two loading scenarios are shown in the following figure.



(a) fire loading



(b) explosion loading

figure 9.6.2a Final deflected shape after: (a) fire loading: (b) explosion.

The deformed shape if we consider explosion and fire loading given by ADAPTIC shows that the combination of both efforts.

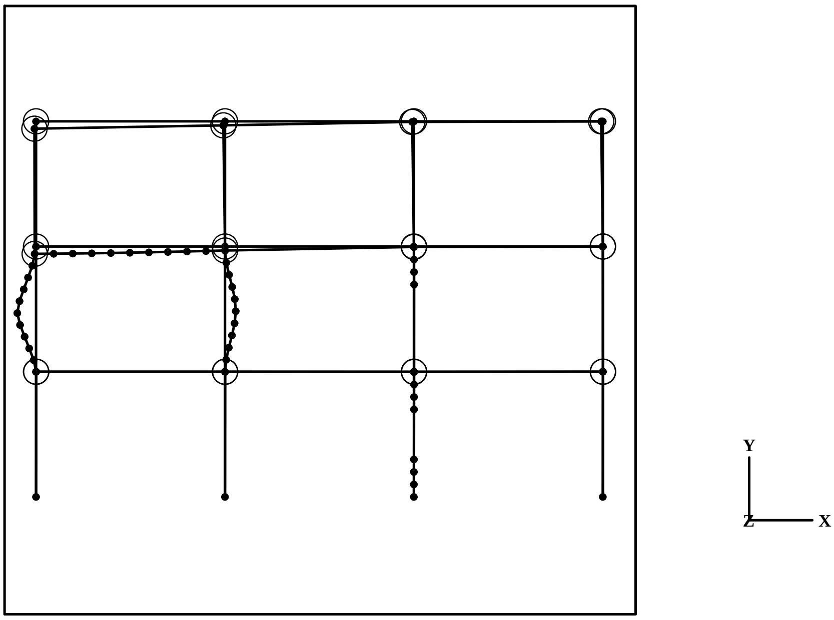


figure 9.6.2b Final deflected shape after explosion and fire loading.

In addition to the analysis of the structure it is going to be considered the CPU time demand over the displacements at the node 121, which is the one that experiments higher displacements.

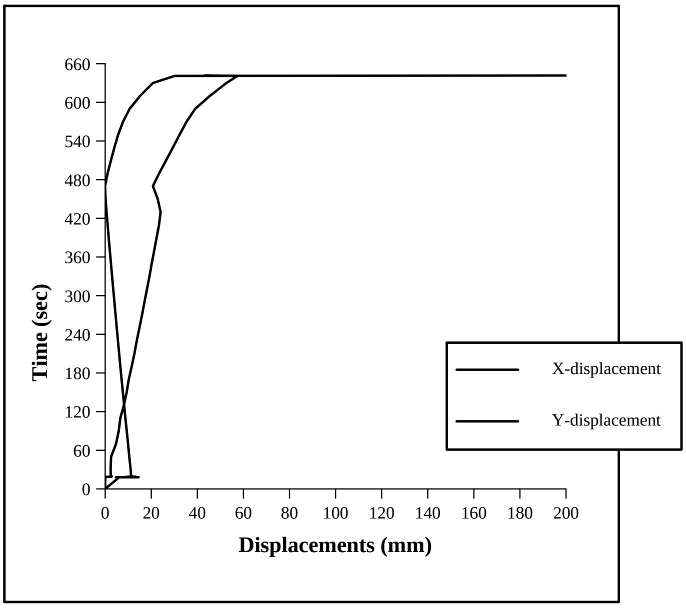


figure 9.6.2b Final deflected shape after explosion and fire loading.

9.6.3 Output file

```
  ELEMENT ASSEMBLY ORDER
----&gt;&gt;&gt;&gt; ----&gt;&gt;&gt;&gt; ----&gt;&gt;&gt;&gt; ----&gt;&gt;&gt;&gt; ----&gt;&gt;&gt;&gt; ----&gt;&gt;&gt;&gt; ----&gt;&gt;&gt;&gt; ----&gt;&gt;&gt;&gt;
201      101      202      1101     104      203      1102     107
1103     105      302      303      1202     108      1203     109
306      1206     206      1106     106      305      1205     102
301      1201     205      1105     103      304      1204     204
1104

MAXIMUM FRONT: (NODAL =    6) - (ADDITIONAL FREEDOMS =   0)
+++++++++++++


                 I N I T I A L   L O A D I N G
                 +++++++++++++++++++++++++++++

               INITIAL
               LOADING             CURRENT
OUTPUT         FACTOR               TIME        LEVEL   CONV.-NORM
ITERATIONS
    1       0.10000000E+01    0.18000000E+02     0     0.498E-07         1

                V A R I A B L E   L O A D I N G
                ++++++++++++++++++++++++++++++++

                CURRENT
OUTPUT           TIME        LEVEL    CONV.-NORM   ITERATIONS
    0       0.18004000E+02    0      0.595E-05        0
    2       0.18008000E+02    0      0.619E-05        0
    0       0.18012000E+02    0      0.663E-05        0
    3       0.18016000E+02    0      0.728E-05        0
    0       0.18020000E+02    0      0.795E-05        0
    4       0.18024000E+02    0      0.841E-05        0
    0       0.18028000E+02    0      0.856E-05        0
    5       0.18032000E+02    0      0.843E-05        0

********************(  SUBDIVISION OF ELEMENT 202      )***************
*                                                                    *
*NUMBER OF NODES CREATED                                             *
*           1                                                        *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n1                    0.000000E+00          0.400000E+03          *
*--------------------------------------------------------------------*
*                                                                    *
*NUMBER OF ELEMENTS CREATED                                          *
*             2                                                      *
* ELM.NAME   TYPE.OF.ELEMENT          NOD.NAMES                      *
* #e1           cbp2                  111       #n1                  *
* #e2           qdp2                  #n1       121                  *
*--------------------------------------------------------------------*
*                                                                    *
*NUMBER OF IMPERFECT ELEMENTS                                        *
*             0                                                      *
**********************************************************************

    0       0.18036000E+02    0      0.140E-03        0
    6       0.18040000E+02    0      0.652E-05        1
    0       0.18044000E+02    0      0.110E-05        1
```

```
*******************(  SUBDIVISION OF ELEMENT #e2      )***************
*                                                                    *
*NUMBER OF NODES CREATED                                             *
*           1                                                        *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n2                    0.000000E+00          0.320000E+04          *
*--------------------------------------------------------------------*
*                                                                    *
*NUMBER OF ELEMENTS CREATED                                          *
*             2                                                      *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                       *
* #e4           cbp2                 #n2       121                   *
* #e3           qdp2                 #n1       #n2                   *
*--------------------------------------------------------------------*
*                                                                    *
*NUMBER OF IMPERFECT ELEMENTS                                        *
*             0                                                      *
**********************************************************************

    7       0.18048000E+02    0      0.168E-04         1
    0       0.18052000E+02    0      0.367E-04         1
    8       0.18056000E+02    0      0.155E-03         1
    0       0.18060000E+02    0      0.157E-03         1
    9       0.18064000E+02    0      0.408E-03         1
    0       0.18068000E+02    0      0.233E-05         2
   10       0.18072000E+02    0      0.100E-04         2

*******************(  SUBDIVISION OF ELEMENT #e3      )***************
*                                                                    *
*NUMBER OF NODES CREATED                                             *
*           3                                                        *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n3                    0.000000E+00          0.120000E+04          *
* #n4                    0.000000E+00          0.160000E+04          *
* #n5                    0.000000E+00          0.200000E+04          *
*--------------------------------------------------------------------*
*                                                                    *
*NUMBER OF ELEMENTS CREATED                                          *
*             4                                                      *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                       *
* #e6           cbp2                 #n3       #n4                   *
* #e7           cbp2                 #n4       #n5                   *
* #e5           qdp2                 #n1       #n3                   *
* #e8           qdp2                 #n5       #n2                   *
*--------------------------------------------------------------------*
*                                                                    *
*NUMBER OF IMPERFECT ELEMENTS                                        *
*             0                                                      *
**********************************************************************

    0       0.18076000E+02    0      0.638E-04         2
   11       0.18080000E+02    0      0.130E-03         2
    0       0.18084000E+02    0      0.293E-03         2

*******************(  SUBDIVISION OF ELEMENT #e5      )***************
*                                                                    *
*NUMBER OF NODES CREATED                                             *
*           1                                                        *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n6                    0.000000E+00          0.800000E+03          *
*--------------------------------------------------------------------*
```

```
*                                                                        *
*NUMBER OF ELEMENTS CREATED                                              *
*             2                                                          *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                           *
* #e10          cbp2                 #n6       #n3                       *
* #e9           qdp2                 #n1       #n6                       *
*------------------------------------------------------------------------*
*                                                                        *
*NUMBER OF IMPERFECT ELEMENTS                                            *
*             0                                                          *
**************************************************************************


********************(  SUBDIVISION OF ELEMENT #e8      )****************
*                                                                        *
*NUMBER OF NODES CREATED                                                 *
*           1                                                            *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n7                    0.000000E+00          0.400000E+03              *
*------------------------------------------------------------------------*
*                                                                        *
*NUMBER OF ELEMENTS CREATED                                              *
*             2                                                          *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                           *
* #e11          cbp2                 #n5       #n7                       *
* #e12          qdp2                 #n7       #n2                       *
*------------------------------------------------------------------------*
*                                                                        *
*NUMBER OF IMPERFECT ELEMENTS                                            *
*             0                                                          *
**************************************************************************

   12       0.18088000E+02    0      0.759E-05         3
    0       0.18092000E+02    0      0.453E-03         2
   13       0.18096000E+02    0      0.240E-05         3
    0       0.18100000E+02    0      0.107E-04         3

********************(  SUBDIVISION OF ELEMENT 302      )****************
*                                                                        *
*NUMBER OF NODES CREATED                                                 *
*           1                                                            *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n8                    0.000000E+00          0.400000E+03              *
*------------------------------------------------------------------------*
*                                                                        *
*NUMBER OF ELEMENTS CREATED                                              *
*             2                                                          *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                           *
* #e13          cbp2                 211       #n8                       *
* #e14          qdp2                 #n8       221                       *
*------------------------------------------------------------------------*
*                                                                        *
*NUMBER OF IMPERFECT ELEMENTS                                            *
*             0                                                          *
**************************************************************************

   14       0.18104000E+02    0      0.322E-04         3

********************(  SUBDIVISION OF ELEMENT #e14     )****************
*                                                                        *
*NUMBER OF NODES CREATED                                                 *
```

```
*            1                                                            *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n9                    0.000000E+00          0.320000E+04             *
*-----------------------------------------------------------------------*
*                                                                       *
*NUMBER OF ELEMENTS CREATED                                             *
*              2                                                        *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                          *
* #e16          cbp2                 #n9       221                      *
* #e15          qdp2                 #n8       #n9                      *
*-----------------------------------------------------------------------*
*                                                                       *
*NUMBER OF IMPERFECT ELEMENTS                                           *
*              0                                                        *
*************************************************************************

    0       0.18108000E+02    0      0.335E-04         3

********************(  SUBDIVISION OF ELEMENT #e9      )****************
*                                                                       *
*NUMBER OF NODES CREATED                                                *
*            1                                                          *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n10                   0.000000E+00          0.400000E+03             *
*-----------------------------------------------------------------------*
*                                                                       *
*NUMBER OF ELEMENTS CREATED                                             *
*              2                                                        *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                          *
* #e18          cbp2                 #n10      #n6                      *
* #e17          qdp2                 #n1       #n10                     *
*-----------------------------------------------------------------------*
*                                                                       *
*NUMBER OF IMPERFECT ELEMENTS                                           *
*              0                                                        *
*************************************************************************


********************(  SUBDIVISION OF ELEMENT #e12     )****************
*                                                                       *
*NUMBER OF NODES CREATED                                                *
*            1                                                          *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n11                   0.000000E+00          0.400000E+03             *
*-----------------------------------------------------------------------*
*                                                                       *
*NUMBER OF ELEMENTS CREATED                                             *
*              2                                                        *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                          *
* #e19          cbp2                 #n7       #n11                     *
* #e20          qdp2                 #n11      #n2                      *
*-----------------------------------------------------------------------*
*                                                                       *
*NUMBER OF IMPERFECT ELEMENTS                                           *
*              0                                                        *
*************************************************************************

   15       0.18112000E+02    0      0.480E-04         3
    0       0.18116000E+02    0      0.267E-04         3
   16       0.18120000E+02    0      0.205E-04         3
    0       0.18124000E+02    0      0.583E-04         2
```

17	0.18128000E+02	0	0.485E-03	2
0	0.18132000E+02	0	0.323E-03	1
18	0.18136000E+02	0	0.595E-04	1
0	0.18140000E+02	0	0.148E-04	1
19	0.18144000E+02	0	0.385E-05	1
0	0.18148000E+02	0	0.551E-05	1
20	0.18152000E+02	0	0.290E-04	1
0	0.18156000E+02	0	0.206E-03	0
21	0.18160000E+02	0	0.119E-03	0
0	0.18164000E+02	0	0.837E-04	0
22	0.18168000E+02	0	0.171E-03	0
0	0.18172000E+02	0	0.458E-04	1
23	0.18176000E+02	0	0.268E-04	1
0	0.18180000E+02	0	0.398E-03	1
24	0.18184000E+02	0	0.270E-06	2
0	0.18188000E+02	0	0.204E-05	2
25	0.18192000E+02	0	0.165E-06	2
0	0.18196000E+02	0	0.200E-03	1
26	0.18200000E+02	0	0.560E-04	1
0	0.18240000E+02	0	0.569E-04	3
27	0.18280000E+02	0	0.263E-04	2
0	0.18320000E+02	0	0.184E-05	1
28	0.18360000E+02	0	0.186E-03	0
0	0.18400000E+02	0	0.269E-06	1
29	0.18440000E+02	0	0.133E-05	1
0	0.18480000E+02	0	0.314E-06	1
30	0.18520000E+02	0	0.474E-04	0
0	0.18560000E+02	0	0.126E-06	1
31	0.18600000E+02	0	0.352E-06	1
0	0.18640000E+02	0	0.551E-07	1
32	0.18680000E+02	0	0.353E-04	0
0	0.18720000E+02	0	0.389E-07	1
33	0.18760000E+02	0	0.106E-06	1
0	0.18800000E+02	0	0.457E-03	0
34	0.18840000E+02	0	0.379E-04	0
0	0.18880000E+02	0	0.493E-03	0
35	0.18920000E+02	0	0.438E-07	1
0	0.18960000E+02	0	0.266E-03	0
36	0.19000000E+02	0	0.312E-04	0
0	0.19040000E+02	0	0.340E-03	0
37	0.19080000E+02	0	0.487E-03	0
0	0.19120000E+02	0	0.153E-03	0
38	0.19160000E+02	0	0.215E-04	0
0	0.19200000E+02	0	0.281E-03	0
39	0.19240000E+02	0	0.314E-03	0
0	0.19280000E+02	0	0.669E-04	0
40	0.19320000E+02	0	0.366E-04	0
0	0.19360000E+02	0	0.213E-03	0
41	0.19400000E+02	0	0.202E-03	0
0	0.19440000E+02	0	0.386E-04	0
42	0.19480000E+02	0	0.513E-04	0
0	0.19520000E+02	0	0.166E-03	0
43	0.19560000E+02	0	0.121E-03	0
0	0.19600000E+02	0	0.169E-04	0
44	0.19640000E+02	0	0.403E-04	0
0	0.19680000E+02	0	0.101E-03	0
45	0.19720000E+02	0	0.577E-04	0
0	0.19760000E+02	0	0.432E-05	0
46	0.19800000E+02	0	0.375E-04	0
0	0.19840000E+02	0	0.756E-04	0
47	0.19880000E+02	0	0.458E-04	0

```
    0       0.19920000E+02    0      0.248E-04         0
   48       0.19960000E+02    0      0.497E-04         0
    0       0.20000000E+02    0      0.621E-04         0
   49       0.30000000E+02    0      0.216E-03         0
    0       0.40000000E+02    0      0.227E-03         0
   50       0.50000000E+02    0      0.184E-03         0
    0       0.60000000E+02    0      0.191E-03         0
   51       0.70000000E+02    0      0.197E-03         0
    0       0.80000000E+02    0      0.189E-03         0
   52       0.90000000E+02    0      0.187E-03         0
    0       0.10000000E+03    0      0.187E-03         0
   53       0.11000000E+03    0      0.180E-03         0
    0       0.12000000E+03    0      0.183E-03         0
   54       0.13000000E+03    0      0.183E-03         0
    0       0.14000000E+03    0      0.181E-03         0
   55       0.15000000E+03    0      0.178E-03         0
    0       0.16000000E+03    0      0.175E-03         0
   56       0.17000000E+03    0      0.173E-03         0
    0       0.18000000E+03    0      0.171E-03         0
   57       0.19000000E+03    0      0.170E-03         0
    0       0.20000000E+03    0      0.169E-03         0
   58       0.21000000E+03    0      0.166E-03         0
    0       0.22000000E+03    0      0.164E-03         0
   59       0.23000000E+03    0      0.162E-03         0
    0       0.24000000E+03    0      0.161E-03         0
   60       0.25000000E+03    0      0.160E-03         0
    0       0.26000000E+03    0      0.158E-03         0
   61       0.27000000E+03    0      0.156E-03         0
    0       0.28000000E+03    0      0.154E-03         0
   62       0.29000000E+03    0      0.152E-03         0
    0       0.30000000E+03    0      0.151E-03         0
   63       0.31000000E+03    0      0.149E-03         0
    0       0.32000000E+03    0      0.148E-03         0
   64       0.33000000E+03    0      0.146E-03         0
    0       0.34000000E+03    0      0.144E-03         0

********************(  SUBDIVISION OF ELEMENT 104      )***************
*                                                                     *
*NUMBER OF NODES CREATED                                              *
*           9                                                         *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n12                   0.600000E+03         0.000000E+00            *
* #n13                   0.120000E+04         0.000000E+00            *
* #n14                   0.180000E+04         0.000000E+00            *
* #n15                   0.240000E+04         0.000000E+00            *
* #n16                   0.300000E+04         0.000000E+00            *
* #n17                   0.360000E+04         0.000000E+00            *
* #n18                   0.420000E+04         0.000000E+00            *
* #n19                   0.480000E+04         0.000000E+00            *
* #n20                   0.540000E+04         0.000000E+00            *
*---------------------------------------------------------------------*
*                                                                     *
*NUMBER OF ELEMENTS CREATED                                           *
*            10                                                       *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                        *
* #e21          cbp2                 121       #n12                   *
* #e22          cbp2                 #n12      #n13                   *
* #e23          cbp2                 #n13      #n14                   *
* #e24          cbp2                 #n14      #n15                   *
* #e25          cbp2                 #n15      #n16                   *
* #e26          cbp2                 #n16      #n17                   *
```

```
* #e27          cbp2                #n17      #n18                      *
* #e28          cbp2                #n18      #n19                      *
* #e29          cbp2                #n19      #n20                      *
* #e30          cbp2                #n20      221                       *
*-----------------------------------------------------------------------*
*                                                                       *
*NUMBER OF IMPERFECT ELEMENTS                                           *
*             0                                                         *
*************************************************************************

    0       0.34100000E+03    1      0.265E-06         1
    0       0.34200000E+03    1      0.310E-05         0
    0       0.34300000E+03    1      0.311E-05         0
    0       0.34400000E+03    1      0.308E-05         0
    0       0.34500000E+03    1      0.295E-05         0
    0       0.34600000E+03    1      0.290E-05         0
    0       0.34700000E+03    1      0.294E-05         0
    0       0.34800000E+03    1      0.302E-05         0
    0       0.34900000E+03    1      0.303E-05         0
   65       0.35000000E+03    1      0.299E-05         0
    0       0.36000000E+03    0      0.153E-06         1
   66       0.37000000E+03    0      0.289E-03         0
    0       0.38000000E+03    0      0.284E-03         0
   67       0.39000000E+03    0      0.281E-03         0
    0       0.40000000E+03    0      0.311E-06         1

********************(  SUBDIVISION OF ELEMENT #e17     )****************
*                                                                       *
*NUMBER OF NODES CREATED                                                *
*           0                                                           *
*-----------------------------------------------------------------------*
*                                                                       *
*NUMBER OF ELEMENTS CREATED                                             *
*             1                                                         *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                          *
* #e31          cbp2                #n1       #n10                      *
*-----------------------------------------------------------------------*
*                                                                       *
*NUMBER OF IMPERFECT ELEMENTS                                           *
*             0                                                         *
*************************************************************************


********************(  SUBDIVISION OF ELEMENT #e20     )****************
*                                                                       *
*NUMBER OF NODES CREATED                                                *
*           0                                                           *
*-----------------------------------------------------------------------*
*                                                                       *
*NUMBER OF ELEMENTS CREATED                                             *
*             1                                                         *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                          *
* #e32          cbp2                #n11      #n2                       *
*-----------------------------------------------------------------------*
*                                                                       *
*NUMBER OF IMPERFECT ELEMENTS                                           *
*             0                                                         *
*************************************************************************

    0       0.40100000E+03    1      0.149E-07         2
    0       0.40200000E+03    1      0.317E-03         0
```

```
    0       0.40300000E+03    1      0.268E-05         0
    0       0.40400000E+03    1      0.269E-05         0
    0       0.40500000E+03    1      0.276E-05         0
    0       0.40600000E+03    1      0.286E-05         0
    0       0.40700000E+03    1      0.286E-05         0
    0       0.40800000E+03    1      0.276E-05         0
    0       0.40900000E+03    1      0.269E-05         0
   68       0.41000000E+03    1      0.268E-05         0
    0       0.42000000E+03    0      0.731E-08         1

********************(  SUBDIVISION OF ELEMENT #e15     )***************
*                                                                     *
*NUMBER OF NODES CREATED                                              *
*          1                                                          *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n21                   0.000000E+00         0.280000E+04            *
*---------------------------------------------------------------------*
*                                                                     *
*NUMBER OF ELEMENTS CREATED                                           *
*            2                                                        *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                        *
* #e34          cbp2                 #n21      #n9                    *
* #e33          qdp2                 #n8       #n21                   *
*---------------------------------------------------------------------*
*                                                                     *
*NUMBER OF IMPERFECT ELEMENTS                                         *
*            0                                                        *
***********************************************************************

    0       0.42100000E+03    1      0.378E-07         3
    0       0.42200000E+03    1      0.342E-04         1
    0       0.42300000E+03    1      0.659E-07         1
    0       0.42400000E+03    1      0.533E-08         1
    0       0.42500000E+03    1      0.528E-08         1
    0       0.42600000E+03    1      0.884E-09         1
    0       0.42700000E+03    1      0.395E-08         1
    0       0.42800000E+03    1      0.672E-08         1
    0       0.42900000E+03    1      0.113E-08         1
   69       0.43000000E+03    1      0.609E-07         1

********************(  SUBDIVISION OF ELEMENT #e33     )***************
*                                                                     *
*NUMBER OF NODES CREATED                                              *
*          1                                                          *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n22                   0.000000E+00         0.400000E+03            *
*---------------------------------------------------------------------*
*                                                                     *
*NUMBER OF ELEMENTS CREATED                                           *
*            2                                                        *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                        *
* #e35          cbp2                 #n8       #n22                   *
* #e36          qdp2                 #n22      #n21                   *
*---------------------------------------------------------------------*
*                                                                     *
*NUMBER OF IMPERFECT ELEMENTS                                         *
*            0                                                        *
***********************************************************************

    0       0.43100000E+03    1      0.130E-03         3
    0       0.43200000E+03    1      0.383E-08         1
```

```
    0       0.43300000E+03    1      0.133E-08         1
    0       0.43400000E+03    1      0.281E-08         1
    0       0.43500000E+03    1      0.191E-08         1
    0       0.43600000E+03    1      0.203E-08         1
    0       0.43700000E+03    1      0.185E-08         1
    0       0.43800000E+03    1      0.283E-08         1
    0       0.43900000E+03    1      0.467E-03         0
    0       0.44000000E+03    1      0.152E-05         1

********************(  SUBDIVISION OF ELEMENT #e36     )***************
*                                                                      *
*NUMBER OF NODES CREATED                                               *
*           1                                                          *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n23                   0.000000E+00          0.200000E+04            *
*----------------------------------------------------------------------*
*                                                                      *
*NUMBER OF ELEMENTS CREATED                                            *
*             2                                                        *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                         *
* #e38          cbp2                 #n23      #n21                    *
* #e37          qdp2                 #n22      #n23                    *
*----------------------------------------------------------------------*
*                                                                      *
*NUMBER OF IMPERFECT ELEMENTS                                          *
*             0                                                        *
************************************************************************

    0       0.44100000E+03    1      0.397E-04         2
    0       0.44200000E+03    1      0.335E-03         0
    0       0.44300000E+03    1      0.354E-03         0
    0       0.44400000E+03    1      0.334E-03         0
    0       0.44500000E+03    1      0.215E-05         2
    0       0.44600000E+03    1      0.458E-08         1
    0       0.44700000E+03    1      0.387E-03         0
    0       0.44800000E+03    1      0.520E-08         1
    0       0.44900000E+03    1      0.233E-05         1
   70       0.45000000E+03    1      0.458E-03         0

********************(  SUBDIVISION OF ELEMENT #e37     )***************
*                                                                      *
*NUMBER OF NODES CREATED                                               *
*           2                                                          *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n24                   0.000000E+00          0.400000E+03            *
* #n25                   0.000000E+00          0.160000E+04            *
*----------------------------------------------------------------------*
*                                                                      *
*NUMBER OF ELEMENTS CREATED                                            *
*             3                                                        *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                         *
* #e39          cbp2                 #n22      #n24                    *
* #e41          cbp2                 #n25      #n23                    *
* #e40          qdp2                 #n24      #n25                    *
*----------------------------------------------------------------------*
*                                                                      *
*NUMBER OF IMPERFECT ELEMENTS                                          *
*             0                                                        *
************************************************************************

    0       0.45010000E+03    2      0.215E-03         1
```

```
    0       0.45020000E+03    2      0.187E-04         0
    0       0.45030000E+03    2      0.925E-07         0
    0       0.45040000E+03    2      0.434E-05         0
    0       0.45050000E+03    2      0.919E-07         0
    0       0.45060000E+03    2      0.911E-07         0
    0       0.45070000E+03    2      0.420E-04         0
    0       0.45080000E+03    2      0.926E-07         0
    0       0.45090000E+03    2      0.136E-04         0
    0       0.45100000E+03    2      0.929E-07         0
    0       0.45200000E+03    1      0.846E-08         1
    0       0.45300000E+03    1      0.118E-04         1
    0       0.45400000E+03    1      0.431E-03         1
    0       0.45500000E+03    1      0.371E-04         1
    0       0.45600000E+03    1      0.477E-04         1
    0       0.45700000E+03    1      0.692E-04         1
    0       0.45800000E+03    1      0.181E-04         2
    0       0.45900000E+03    1      0.133E-03         2
    0       0.46000000E+03    1      0.440E-03         1
    0       0.46010000E+03    2      0.359E-04         3
    0       0.46020000E+03    2      0.134E-04         0
    0       0.46030000E+03    2      0.779E-05         0
    0       0.46040000E+03    2      0.321E-04         0
    0       0.46050000E+03    2      0.131E-04         0
    0       0.46060000E+03    2      0.603E-04         0
    0       0.46070000E+03    2      0.226E-04         0
    0       0.46080000E+03    2      0.163E-04         0
    0       0.46090000E+03    2      0.240E-04         0
    0       0.46100000E+03    2      0.591E-04         0

********************(  SUBDIVISION OF ELEMENT #e40     )****************
*                                                                       *
*NUMBER OF NODES CREATED                                                *
*           1                                                           *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n26                   0.000000E+00          0.400000E+03            *
*-----------------------------------------------------------------------*
*                                                                       *
*NUMBER OF ELEMENTS CREATED                                             *
*             2                                                         *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                          *
* #e42          cbp2                 #n24      #n26                     *
* #e43          qdp2                 #n26      #n25                     *
*-----------------------------------------------------------------------*
*                                                                       *
*NUMBER OF IMPERFECT ELEMENTS                                           *
*             0                                                         *
*************************************************************************

    0       0.46110000E+03    2      0.357E-05         2
    0       0.46120000E+03    2      0.197E-03         0
    0       0.46130000E+03    2      0.300E-03         0
    0       0.46140000E+03    2      0.796E-04         1
    0       0.46150000E+03    2      0.675E-04         0
    0       0.46160000E+03    2      0.607E-04         0
    0       0.46170000E+03    2      0.630E-04         0
    0       0.46180000E+03    2      0.707E-04         0
    0       0.46190000E+03    2      0.524E-04         0
    0       0.46200000E+03    2      0.911E-04         0
    0       0.46300000E+03    1      0.232E-04         2
    0       0.46400000E+03    1      0.203E-05         1
```

```
*******************(  SUBDIVISION OF ELEMENT #e43     )***************
*                                                                    *
*NUMBER OF NODES CREATED                                             *
*           1                                                        *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n27                   0.000000E+00          0.400000E+03          *
*--------------------------------------------------------------------*
*                                                                    *
*NUMBER OF ELEMENTS CREATED                                          *
*             2                                                      *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                       *
* #e45          cbp2                 #n27      #n25                  *
* #e44          qdp2                 #n26      #n27                  *
*--------------------------------------------------------------------*
*                                                                    *
*NUMBER OF IMPERFECT ELEMENTS                                        *
*             0                                                      *
**********************************************************************

    0       0.46410000E+03    2      0.417E-05         2
    0       0.46420000E+03    2      0.278E-03         0
    0       0.46430000E+03    2      0.177E-03         0
    0       0.46440000E+03    2      0.210E-03         0
    0       0.46450000E+03    2      0.151E-03         0
    0       0.46460000E+03    2      0.123E-03         0
    0       0.46470000E+03    2      0.111E-03         0
    0       0.46480000E+03    2      0.123E-03         0
    0       0.46490000E+03    2      0.119E-03         0
    0       0.46500000E+03    2      0.126E-03         0
    0       0.46600000E+03    1      0.846E-04         2

*******************(  SUBDIVISION OF ELEMENT #e44     )***************
*                                                                    *
*NUMBER OF NODES CREATED                                             *
*           0                                                        *
*--------------------------------------------------------------------*
*                                                                    *
*NUMBER OF ELEMENTS CREATED                                          *
*             1                                                      *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                       *
* #e46          cbp2                 #n26      #n27                  *
*--------------------------------------------------------------------*
*                                                                    *
*NUMBER OF IMPERFECT ELEMENTS                                        *
*             0                                                      *
**********************************************************************

    0       0.46601000E+03    3      0.131E-03         1
    0       0.46602000E+03    3      0.357E-04         0
    0       0.46603000E+03    3      0.122E-04         0
    0       0.46604000E+03    3      0.252E-05         0
    0       0.46605000E+03    3      0.347E-05         0
    0       0.46606000E+03    3      0.303E-07         0
    0       0.46607000E+03    3      0.305E-07         0
    0       0.46608000E+03    3      0.160E-05         0
    0       0.46609000E+03    3      0.115E-06         0
    0       0.46610000E+03    3      0.443E-05         0
    0       0.46620000E+03    2      0.458E-03         0
    0       0.46630000E+03    2      0.158E-03         0
    0       0.46640000E+03    2      0.109E-03         0
    0       0.46650000E+03    2      0.410E-04         0
```

0	0.46660000E+03	2	0.379E-03	0
0	0.46670000E+03	2	0.180E-04	0
0	0.46680000E+03	2	0.307E-04	0
0	0.46690000E+03	2	0.365E-04	0
0	0.46700000E+03	2	0.321E-03	0
0	0.46800000E+03	1	0.774E-04	4
0	0.46900000E+03	1	0.433E-03	2
71	0.47000000E+03	1	0.504E-04	3
0	0.48000000E+03	0	0.473E-04	5
72	0.49000000E+03	0	0.105E-03	2
0	0.50000000E+03	0	0.767E-05	2
73	0.51000000E+03	0	0.289E-05	2
0	0.52000000E+03	0	0.720E-06	2
74	0.53000000E+03	0	0.210E-06	2
0	0.54000000E+03	0	0.773E-07	2
75	0.55000000E+03	0	0.380E-03	1
0	0.56000000E+03	0	0.103E-06	2
76	0.57000000E+03	0	0.742E-04	2
0	0.58000000E+03	0	0.180E-03	1
77	0.59000000E+03	0	0.262E-03	1
0	0.60000000E+03	0	0.963E-07	2
78	0.61000000E+03	0	0.798E-06	2
0	0.62000000E+03	0	0.483E-07	2
79	0.63000000E+03	0	0.241E-07	2
0	0.64000000E+03	0	0.165E-04	3
0	0.64010000E+03	1	0.574E-04	1
0	0.64020000E+03	1	0.274E-04	0
0	0.64030000E+03	1	0.367E-04	0
0	0.64040000E+03	1	0.140E-05	1
0	0.64050000E+03	1	0.246E-03	0
0	0.64060000E+03	1	0.399E-03	1
0	0.64070000E+03	1	0.242E-04	1
0	0.64080000E+03	1	0.150E-05	1
0	0.64090000E+03	1	0.275E-05	1
80	0.64100000E+03	1	0.502E-04	1
0	0.64110000E+03	1	0.293E-03	1
0	0.64120000E+03	1	0.406E-04	1
0	0.64130000E+03	1	0.410E-03	1
0	0.64140000E+03	1	0.265E-03	2
0	0.64150000E+03	1	0.437E-05	3
0	0.64160000E+03	1	0.217E-05	4
0	0.64161000E+03	2	0.495E-03	3
0	0.64162000E+03	2	0.500E-04	2
0	0.64163000E+03	2	0.807E-04	2
0	0.64164000E+03	2	0.416E-04	2
0	0.64165000E+03	2	0.555E-04	2
0	0.64166000E+03	2	0.386E-03	1
0	0.64167000E+03	2	0.288E-04	2
0	0.64168000E+03	2	0.111E-07	3
0	0.64169000E+03	2	0.387E-04	1
0	0.64170000E+03	2	0.147E-03	1
0	0.64171000E+03	2	0.355E-04	3

```
********************(  SUBDIVISION OF ELEMENT 304       )****************
*                                                                       *
*NUMBER OF NODES CREATED                                                *
*           1                                                           *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n28                   0.000000E+00          0.400000E+03             *
*-----------------------------------------------------------------------*
*                                                                       *
```

```
*NUMBER OF ELEMENTS CREATED                                             *
*             2                                                         *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                          *
* #e47          cbp2                 301       #n28                     *
* #e48          qdp2                 #n28      311                      *
*-----------------------------------------------------------------------*
*                                                                       *
*NUMBER OF IMPERFECT ELEMENTS                                           *
*             0                                                         *
*************************************************************************

    0       0.64172000E+03    2      0.317E-03         3

********************(  SUBDIVISION OF ELEMENT #e48     )****************
*                                                                       *
*NUMBER OF NODES CREATED                                                *
*           1                                                           *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n29                   0.000000E+00         0.320000E+04              *
*-----------------------------------------------------------------------*
*                                                                       *
*NUMBER OF ELEMENTS CREATED                                             *
*             2                                                         *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                          *
* #e50          cbp2                 #n29      311                      *
* #e49          qdp2                 #n28      #n29                     *
*-----------------------------------------------------------------------*
*                                                                       *
*NUMBER OF IMPERFECT ELEMENTS                                           *
*             0                                                         *
*************************************************************************

    0       0.64173000E+03    2      0.392E-07         4

********************(  SUBDIVISION OF ELEMENT #e49     )****************
*                                                                       *
*NUMBER OF NODES CREATED                                                *
*           1                                                           *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n30                   0.000000E+00         0.400000E+03              *
*-----------------------------------------------------------------------*
*                                                                       *
*NUMBER OF ELEMENTS CREATED                                             *
*             2                                                         *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                          *
* #e51          cbp2                 #n28      #n30                     *
* #e52          qdp2                 #n30      #n29                     *
*-----------------------------------------------------------------------*
*                                                                       *
*NUMBER OF IMPERFECT ELEMENTS                                           *
*             0                                                         *
*************************************************************************


********************(  SUBDIVISION OF ELEMENT 305      )****************
*                                                                       *
*NUMBER OF NODES CREATED                                                *
*           1                                                           *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n31                   0.000000E+00         0.360000E+04              *
*-----------------------------------------------------------------------*
```

```
*                                                                        *
*NUMBER OF ELEMENTS CREATED                                              *
*             2                                                          *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                           *
* #e54          cbp2                 #n31      321                       *
* #e53          qdp2                 311       #n31                      *
*------------------------------------------------------------------------*
*                                                                        *
*NUMBER OF IMPERFECT ELEMENTS                                            *
*             0                                                          *
**************************************************************************

    0       0.64174000E+03    2      0.101E-06         4

********************(  SUBDIVISION OF ELEMENT #e53     )***************
*                                                                        *
*NUMBER OF NODES CREATED                                                 *
*           1                                                            *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n32                   0.000000E+00         0.320000E+04               *
*------------------------------------------------------------------------*
*                                                                        *
*NUMBER OF ELEMENTS CREATED                                              *
*             2                                                          *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                           *
* #e56          cbp2                 #n32      #n31                      *
* #e55          qdp2                 311       #n32                      *
*------------------------------------------------------------------------*
*                                                                        *
*NUMBER OF IMPERFECT ELEMENTS                                            *
*             0                                                          *
**************************************************************************

    0       0.64175000E+03    2      0.172E-06         4

********************(  SUBDIVISION OF ELEMENT #e52     )***************
*                                                                        *
*NUMBER OF NODES CREATED                                                 *
*           1                                                            *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n33                   0.000000E+00         0.240000E+04               *
*------------------------------------------------------------------------*
*                                                                        *
*NUMBER OF ELEMENTS CREATED                                              *
*             2                                                          *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                           *
* #e58          cbp2                 #n33      #n29                      *
* #e57          qdp2                 #n30      #n33                      *
*------------------------------------------------------------------------*
*                                                                        *
*NUMBER OF IMPERFECT ELEMENTS                                            *
*             0                                                          *
**************************************************************************

    0       0.64176000E+03    2      0.243E-06         4
    0       0.64177000E+03    2      0.436E-03         1
    0       0.64178000E+03    2      0.723E-05         2

********************(  SUBDIVISION OF ELEMENT #e55     )***************
*                                                                        *
*NUMBER OF NODES CREATED                                                 *
```

```
*           1                                                         *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n34                   0.000000E+00          0.280000E+04           *
*---------------------------------------------------------------------*
*                                                                     *
*NUMBER OF ELEMENTS CREATED                                           *
*             2                                                       *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                        *
* #e60          cbp2                 #n34      #n32                   *
* #e59          qdp2                 311       #n34                   *
*---------------------------------------------------------------------*
*                                                                     *
*NUMBER OF IMPERFECT ELEMENTS                                         *
*             0                                                       *
***********************************************************************

    0       0.64179000E+03    2      0.127E-03         4
    0       0.64180000E+03    2      0.319E-04         2
    0       0.64181000E+03    2      0.396E-03         4

********************(  SUBDIVISION OF ELEMENT #e57     )****************
*                                                                     *
*NUMBER OF NODES CREATED                                              *
*           2                                                         *
* NOD.NAME      COORD'S (X,Y) RELATIVE TO END(1) OF SUBDIVIDED ELEMENT *
* #n35                   0.000000E+00          0.400000E+03           *
* #n36                   0.000000E+00          0.200000E+04           *
*---------------------------------------------------------------------*
*                                                                     *
*NUMBER OF ELEMENTS CREATED                                           *
*             3                                                       *
* ELM.NAME   TYPE.OF.ELEMENT         NOD.NAMES                        *
* #e61          cbp2                 #n30      #n35                   *
* #e63          cbp2                 #n36      #n33                   *
* #e62          qdp2                 #n35      #n36                   *
*---------------------------------------------------------------------*
*                                                                     *
*NUMBER OF IMPERFECT ELEMENTS                                         *
*             0                                                       *
***********************************************************************

    0       0.64182000E+03    2      0.122E-08         6
   81       0.64182000E+03    4      0.191E+00        10
```

9.7 Apexes

(a)	Indicates the kind of analysis required.
(b)	Introduces the characteristics of the materials: the name, the material model, and the properties, which are different for each material model (Chapter 3).
(c)	Introduces the type of section, the name, material and the dimensions.
(d)	Defines the groups. There you define the element type, the group name and the name give to the section.
(e)	Defines the coordinates of the structural nodes.
(f)	Defines the global coordinates of the structural nodes (non.structural.nodes).
(g)	Defined the nodal restraints. The f-command indicates the name of the first nodes which has restraints, and the r-command is refereed to the increment of this and how many times it has to increment the nod.name.
(h)	Defines the connectivity of elements in a mesh configuration. First is indicated the group name. At the f-command is the name of the element and the extreme nodes of it and at the r-command is defined the increment of the nod.name, the extreme nodes and when it has to stop.
(i)	Indicates the kind of load and the direction of each one.
(j)	This module, phases, is used to trace the load deflection curve for the proportional loading.
(k)	This module specifies the iterative strategy applied during a load or time step.
(l)	Defines the tolerance at the iterative calculating process, and the reference value in calculating the convergence.
(m)	Specifies the frequency of numerical output.
(n)	This module specifies levels within elements of specific types **(*)**.
(o)	This module specifies the conditions which govern the termination of the automatic control phrase under a proportional static loading regime **(**)**.
(p)	This modules defines subdivision patterns utilised in automatic mesh refinement.
(q)	This module specifies piecewise linear load curves for dynamic or time history loading.
(r)	This module specifies the time scheme for dynamic analysis and its parameters **(***)**.

(s)	This module defines of intervals at which structural equilibrium is established **(****)** .