ELEMENT FLEXURAL TYPE BE2_2D command

Synopsis

The ELEMENT FLEXURAL TYPE BE2_2D command is used to describe all 2-node cubic Bernoulli-Euler ($C^1$ continuous) frame elements that are to be used in planar mechanical analyses.

Syntax

The following syntax is used to describe a typical BE2_2D frame element:

```
ELEment FLExural TYPe BE2_2D NODes #:#:#
     (MATerial #) (CONstruction #) (EXCavation #)
     (AREa #.#) (I22 #.#)
     (1_Additional #) (1_Increment #)
     (DONT_PRINT_Results)
```

Explanatory Notes

- The BE2_2D is a $C^1$ continuous frame element for planar analyses. The element
  - Contains two (2) nodes.
  - Has two (2) displacements and two (2) slope degrees of freedom at each node.
  - Employs a cubic interpolation for the transverse displacement.
- The numbering order of NODES associated with a BE2_2D elements is shown in Figure 1.
- The MATERIAL keyword is used to specify the number of the material idealization associated with the element. The default values for the MATERIAL number is one (1). The value of the elastic modulus associated with a BE2_2D element is specified in a MATERIAL FLEXURAL ELASTIC command.
- The incremental CONSTRUCTION and EXCAVATION numbers represent the time increment in which the material in this element(s) is added to or removed from the model. A CONSTRUCTION number equal to zero corresponds to a material in existence at the beginning of the analysis. Since this is the default condition, no input is required in such a case. The condition of no excavation is likewise the default.
The **AREA** keyword is used to specify the element’s cross-sectional area. The *default* **AREA** value is equal to 1.0. Over a given element, the cross-sectional area is assumed to be *constant*.

The **I22** keyword is used to specify the moment of inertia (second moment of area) for the cross-section with respect to the element $y'$-axis (Figure 1). The *default** I22 value is equal to 1.0. The moment of inertia is assumed to be *constant* over a given element.

If the body being analyzed can be divided into a layer of elements, and if the characteristics of the frame element (i.e., the **MATERIAL**, the incremental **CONSTRUCTION** and **EXCAVATION** numbers, the **AREA**, and **I22**) are the *same* for several elements along a line, and if the nodes are numbered in a *consistent* fashion, then an element data generation option can be employed. To generate a sequence of frame elements along a line, node numbers are specified only for the first element, together with appropriate values for **1_ADDITIONAL** and **1_INCREMENT**.

Specification of the keyword **DONT_PRINT_Results** indicates that the analyst does not desire to see output of secondary dependent variables (i.e., bending moments and shear force) for this element. If *generation* is performed using this **ELEMENT FLEXURAL TYPE BE2_2D** command, then all the elements generated will be affected in a like manner by the above print control commands.

**Figure 1: Node Numbering Associated with a Typical Bernoulli-Euler (BE2_2D) Frame Element**
Examples of Command Usage

Example 1

A beam of length equal to 20.0 is analyzed in this example. Both ends of the beam are fixed (i.e., both translation and rotation are prevented at the beam's ends). The loading consists of a concentrated force applied at mid-span. The associated input data file is given below.

```
ana tit "two element test case using BE2D beam elements"
ana tit "fixed-fixed beam w/conc. force @ mid-span"
ana tit ""
ana tit " exact solution for L = 20:"n
ana tit " transv. disp. @node 2 = 6.173e-04"
!
ana action anal
analysis type mechanical
analysis description linear
!
dim max material flexural elastic 1
dim max nodes 3
dim max be2_2d 2
!
echo initial off
echo grav off
echo warn off
!
fin settings
!
mat flexural elastic number 1 &
    desc "some sort of linear elastic material" &
    modulus 3.0e+06
!
nodes line number 1 x1 0.0
nodes line number 3 x1 20.0 incr 1
!
element flexural type "be2_2d" nodes 1 2 mat 1 area 3.00 i22 2.250 &
    1_add 1 1_incr 1
!
spec conc mech nodes 1:3:2 1_disp 2_disp
spec conc mech nodes 2 2_his 0 2_forc 2_val -100.0
spec conc rotation nodes 1:3:2 33_rot
!
finish data
!
solution time final 1.0 increments 1 output 1:10:1
!
finished loading
```
Using the above data in conjunction with the APES computer program, the results shown below are obtained. For clarity, the “header” that is printed at the top of the file is omitted from this file. The transverse displacement at the mid-span of the beam (node 2) is identical to that predicted by Bernoulli-Euler beam theory.

two element test case using BE2D beam elements
fixed-fixed beam w/conc. force @ mid-span

exact solution for L = 20:
transv. disp. @node 2 = 6.173e-04

======================================================================
| DYNAMIC STORAGE ALLOCATION |
======================================================================

| Largest NODE number which can used in the mesh = 3
Max. no. of ISOTROPIC, ELASTIC (flexural) materials = 1
Max. no. planar Bernoulli-Euler (BE2_2D) elements = 2

======================================================================
= GENERAL ANALYSIS INFORMATION =
======================================================================

---> MECHANICAL analysis shall be performed
---> Fluid flow is NOT accounted for in the analysis
---> Thermal effects are NOT accounted for in analysis

---> TWO-DIMENSIONAL solution domain assumed
   (PLANE STRESS idealization)
---> Nodal coordinates will NOT be updated
---> solver type used: SKYLINE

---> storage type: SYMMETRIC

---> "Isoparametric" scheme used for native mesh generation (if applicable)

======================================================================
= INTEGRATION OPTIONS =
======================================================================
In approximating time derivatives, the value of "THETA" = 6.667E-01

======================================================================
= NONLINEAR ANALYSIS INFORMATION =
======================================================================

--> LINEAR analysis

======================================================================
= HISTORY FUNCTION INFORMATION =
======================================================================

<<< NONE >>>

======================================================================
= MATERIAL IDEALIZATIONS =
======================================================================

--> Material number: 1

----------
type : isotropic, linear elastic idealization for beams
info. : some sort of linear elastic material

  Modulus of Elasticity = 3.000E+06
  Poisson's ratio = 0.000E+00
  Winkler rotational stiffness = 0.000E+00
  Winkler translational stiffness = 0.000E+00

======================================================================
= NODAL COORDINATES =
======================================================================

node :  1  x1 =  0.000E+00  x2 =  0.000E+00
node :  2  x1 =  1.000E+01  x2 =  0.000E+00
node :  3  x1 =  2.000E+01  x2 =  0.000E+00
--- ELEMENT INFORMATION ---

--> number: 1 (type: BE2_2D ) (kind: FLEXURAL )
   nodes:
   1 2
   integration rule: exactly integrated element
   material no. = 1
   material type: isotropic, linear elastic idealization for beams
   cross-sectional area = 3.000E+00
   moment of inertia (I_22) = 2.250E+00

--> number: 2 (type: BE2_2D ) (kind: FLEXURAL )
   nodes:
   2 3
   integration rule: exactly integrated element
   material no. = 1
   material type: isotropic, linear elastic idealization for beams
   cross-sectional area = 3.000E+00
   moment of inertia (I_22) = 2.250E+00

--- NODE POINT SPECIFICATIONS ---

Node Number      ( c o o r d i n a t e s )                      specification:  ~~~~~~~~~~

1 : ( x1 = 0.000E+00, x2 = 0.000E+00 )
   displacement-1 = 0.000E+00 ; history no. = -2
   displacement-2 = 0.000E+00 ; history no. = -2
   rotation-33 = 0.000E+00 ; history no. = -2

2 : ( x1 = 1.000E+01, x2 = 0.000E+00 )
   force-1 = 0.000E+00 ; history no. = -2
   force-2 = -1.000E+02 ; history no. = 0
   moment-33 = 0.000E+00 ; history no. = -2

3 : ( x1 = 2.000E+01, x2 = 0.000E+00 )
   displacement-1 = 0.000E+00 ; history no. = -2
   displacement-2 = 0.000E+00 ; history no. = -2
   rotation-33 = 0.000E+00 ; history no. = -2
At time 1.000E+00 (step no. 1): NO iteration was required

= ELEMENT STRAINS & STRESSES =

--> element 1 (type = BE2_2D):

@ (x1 = 0.000E+00, x2 = 0.000E+00):
axial force = 0.000E+00, shear force = 5.000E+01, moment = 2.500E+02
@ (x1 = 1.000E+01, x2 = 0.000E+00):
axial force = 0.000E+00, shear force = 5.000E+01, moment = 2.500E+02

--> element 2 (type = BE2_2D):

@ (x1 = 1.000E+01, x2 = 0.000E+00):
axial force = 0.000E+00, shear force = -5.000E+01, moment = -2.500E+02
@ (x1 = 2.000E+01, x2 = 0.000E+00):
axial force = 0.000E+00, shear force = -5.000E+01, moment = -2.500E+02

At time 1.000E+00 (step no. 1):

= NODAL QUANTITIES =

node: 1 (x1 = 0.000E+00, x2 = 0.000E+00)
u_1 = 0.000E+00, u_2 = -6.173E-24, rot_33 = -9.259E-25

node: 2 (x1 = 1.000E+01, x2 = 0.000E+00)
\[ u_1 = 0.000E+00, u_2 = -6.173E-04, \text{rot}_{33} = 3.551E-41 \]

node: 3 ( \( x_1 = 2.000E+01, x_2 = 0.000E+00 \) )

\[ u_1 = 0.000E+00, u_2 = -6.173E-24, \text{rot}_{33} = 9.259E-25 \]

apes -> end of analysis . . . . . . .
Example 2

A beam of length equal to 10.0 that is loaded at its mid-span is analyzed in this example. The end at \( x = 0 \) is fixed (i.e., both translation and rotation are prevented at this location). A translational spring is specified at \( x = 10 \). By varying the stiffness of this spring from zero to a large value (e.g., \( 1.0 \times 10^10 \)), the beam will vary from a cantilever to a propped cantilever. The input data file associated with a spring stiffness of \( 1.0 \times 10^5 \) is given below.

```
ana tit " two element test case using BE_2D beam elements"
ana tit "with TRANSLATIONAL spring"
ana tit "cantilever beam w/conc. force @ mid-span"
ana tit " "
ana tit "exact solution for cantilever beam:"
ana tit "transv. disp. @node 2 = PL**3/24EI = 1.389"
ana tit "exact solution for propped cantilever beam:"
ana tit "transv. disp. @node 2 = 7PL**3/768EI = 0.3038"
!
ana action analyze
ana analysis type mechanical
ana analysis description linear
!
dim max material flexural elastic 1
dim max nodes 3
dim max be2_2d 2
!
echo initial off
echo grav off
echo warn off
!
fin settings
!
flexural elastic number 1 &
   desc "exotic linear elastic material for beam elements" &
      modulus 3.0e+05
!
nodes line number 1 x1 0.0
nodes line number 3 x1 10.0 incr 1
!
element flexural type "be2_2d" nodes 1 2 mat 1 area 0.50 i22 0.010 &
   1_add 1 1_incr 1
!
spec conc mech nodes 1 1_disp 2_disp
spec conc mech nodes 2 2_his -1 2_forc 2_val 100.0
spec conc mech nodes 3 2_spring 2_value 1.0e+05 2_hist -1
spec conc rot node 1 33_rot 33_value 0.0
!
finish data
```
solution time final 1.0 increments 1 output 1:10:1

finished loading

Using the above data in conjunction with the APES computer program, the results shown below are obtained. For clarity, the “header” that is printed at the top of the file is omitted from this file.

two element test case using BE_2D beam elements
with TRANSLATIONAL spring cantilever beam w/conc. force @ mid-span

exact solution for cantilever beam: transv. disp. @node 2 = PL**3/24EI = 1.389 exact solution for propped cantilever beam:
transv. disp. @node 2 = 7PL**3/768EI = 0.3038

======================================================================
| DYNAMIC STORAGE ALLOCATION |
======================================================================

Largest NODE number which can used in the mesh = 3

Max. no. of ISOTROPIC, ELASTIC (flexural) materials = 1

Max. no. planar Bernoulli-Euler (BE2_2D) elements = 2

======================================================================
= GENERAL ANALYSIS INFORMATION =
======================================================================

--> MECHANICAL analysis shall be performed
--> Fluid flow is NOT accounted for in the analysis
--> Thermal effects are NOT accounted for in analysis

--> TWO-DIMENSIONAL solution domain assumed
    (PLANE STRESS idealization)
--> Nodal coordinates will NOT be updated
--> solver type used: SKYLINE

--> storage type: SYMMETRIC

--> "Isoparametric" scheme used for native mesh generation (if applicable)
In approximating time derivatives, the value of "THETA" = 6.667E-01

--> LINEAR analysis

<<< NONE >>>

--> Material number: 1

            type : isotropic, linear elastic idealization for beams
            info. : exotic linear elastic material for beam elements

            Modulus of Elasticity = 3.000E+05
            Poisson’s ratio = 0.000E+00
            Winkler rotational stiffness = 0.000E+00
            Winkler translational stiffness = 0.000E+00
node : 1 x1 = 0.000E+00 x2 = 0.000E+00
node : 2 x1 = 5.000E+00 x2 = 0.000E+00
node : 3 x1 = 1.000E+01 x2 = 0.000E+00

---

E X A M P L E   I N F O R M A T I O N   E

---

--> number: 1 (type: BE2_2D ) (kind: FLEXURAL )
nodes:
   1  2
integration rule: exactly integrated element
material no.  = 1
material type: isotropic, linear elastic idealization for beams
cross-sectional area = 5.000E-01
moment of inertia (I_22) = 1.000E-02

--> number: 2 (type: BE2_2D ) (kind: FLEXURAL )
nodes:
   2  3
integration rule: exactly integrated element
material no.  = 1
material type: isotropic, linear elastic idealization for beams
cross-sectional area = 5.000E-01
moment of inertia (I_22) = 1.000E-02

---

N O D E   P O I N T   S P E C I F I C A T I O N S

---

Node Number ( c o o r d i n a t e s ) specification:
---- -------------
  1 : ( x1 = 0.000E+00, x2 = 0.000E+00 )
       displacement-1 = 0.000E+00 ; history no. = -2
       displacement-2 = 0.000E+00 ; history no. = -2
       rotation-33 = 0.000E+00 ; history no. = -2

  2 : ( x1 = 5.000E+00, x2 = 0.000E+00 )
       force-1 = 0.000E+00 ; history no. = -2
       force-2 = 1.000E+02 ; history no. = -1
       moment-33 = 0.000E+00 ; history no. = -2

  3 : ( x1 = 1.000E+01, x2 = 0.000E+00 )
At time 1.000E+00 (step no. 1): NO iteration was required

======================================================================
=E L E M E N T S T R A I N S & S T R E S S E S =
======================================================================

--> element 1 ( type = BE2_2D ):
                      .........................
@ (x1 = 0.000E+00, x2 = 0.000E+00):
    axial force = 0.000E+00 , shear force = -6.875E+01 , moment = -1.875E+02
@ (x1 = 5.000E+00, x2 = 0.000E+00):
    axial force = 0.000E+00 , shear force = -6.875E+01 , moment = -1.562E+02

--> element 2 ( type = BE2_2D ):
                      .........................
@ (x1 = 5.000E+00, x2 = 0.000E+00):
    axial force = 0.000E+00 , shear force = 3.125E+01 , moment = 1.562E+02
@ (x1 = 1.000E+01, x2 = 0.000E+00):
    axial force = 0.000E+00 , shear force = 3.125E+01 , moment = 2.174E-14

At time 1.000E+00 (step no. 1):

======================================================================
= N O D A L Q U A N T I T I E S =
======================================================================

node: 1 ( x1 = 0.000E+00, x2 = 0.000E+00 )
u_1 = 0.000E+00, u_2 = 2.387E-21, rot_33 = 7.814E-22

node: 2 ( x1 = 5.000E+00, x2 = 0.000E+00 )
   u_1 = 0.000E+00, u_2 = 3.039E-01, rot_33 = 2.608E-02

node: 3 ( x1 = 1.000E+01, x2 = 0.000E+00 )
   u_1 = 0.000E+00, u_2 = 3.125E-04, rot_33 = -1.041E-01

apes -> end of analysis . . . . . . . .
Example 3

A simply-supported beam that is loaded at its mid-span is analyzed in this example. The beam is assumed to rest on an elastic (Winkler) foundation that is characterized by a translational stiffness equal to 100.0. The associated input data file is given below.

```plaintext
! ana tit " example to test the Winkler foundation option in BE2_2D elements"
anal title " simply supported beam with concentrated load at mid-span"
anal title " rectangular cross-section (3 units wide; 10 units deep)"
anal title " the coordinate origin is placed at mid-span"
anal title " to be identical to the closed-form solution"
!
anal action analyze
analysis type mechanical
analysis description linear
!
dim max material flexural elastic 1
dim max nodes 17
dim max be2_2d 16
!
echo initial off
echo grav off
echo warn off
!
fin settings
!
the Winkler foundation translational stiffness
!
mat flexural elastic number 1 &
   desc "elastic foundation" modulus 3.0E+03 winkler_trans 100.0
!
nodes line number 1 x1 -100.0

nodes line number 17 x1 100.0 incr 1
!
(element flexural type "be2_2d" nodes 1 2 mat 1 area 30.0 i22 250.0 &
   1_add 15 1_incr 1
!
   specification conc mech node 1:17:16 1_disp 2_disp
   specification conc mech node 9 2_force 2_value -10.0 2_hist 0
!
finish data
!
solution time final 1.0 increments 1 output 1:10:1
!
finished loading
```
Using the above data in conjunction with the APES computer program, the results shown below are obtained. For clarity, the “header” that is printed at the top of the file is omitted from this file.

Example to test the Winkler foundation option in BE2_2D elements
simply supported beam with concentrated load at mid-span
rectangular cross-section (3 units wide; 10 units deep)
the coordinate origin is placed at mid-span
to be identical to the closed-form solution

======================================================================
| DYNAMIC STORAGE ALLOCATION |
======================================================================

Largest NODE number which can used in the mesh = 17
Max. no. of ISOTROPIC, ELASTIC (flexural) materials = 1
Max. no. planar Bernoulli-Euler (BE2_2D) elements = 16

======================================================================
= GENERAL ANALYSIS INFORMATION =
======================================================================

--> MECHANICAL analysis shall be performed
--> Fluid flow is NOT accounted for in the analysis
--> Thermal effects are NOT accounted for in analysis

--> TWO-DIMENSIONAL solution domain assumed
    (PLANE STRESS idealization)
--> Nodal coordinates will NOT be updated
--> solver type used: SKYLINE

--> storage type: SYMMETRIC

--> "Isoparametric" scheme used for native mesh generation (if applicable)

======================================================================
= INTEGRATION OPTIONS =
======================================================================

In approximating time derivatives, the value of "THETA" = 6.667E-01
-- LINEAR analysis

-- HISTORY FUNCTION INFORMATION

<<< NONE >>>

-- MATERIAL IDEALIZATIONS

-- Material number: 1

  type: isotropic, linear elastic idealization for beams
  info.: elastic foundation

  Modulus of Elasticity = 3.00E+03
  Poisson's ratio = 0.00E+00
  Winkler rotational stiffness = 0.00E+00
  Winkler translational stiffness = 1.00E+02

-- NODAL COORDINATES

  node :  1  x1 = -1.00E+02  x2 = 0.00E+00
  node :  2  x1 = -8.75E+01  x2 = 0.00E+00
  node :  3  x1 = -7.50E+01  x2 = 0.00E+00
  node :  4  x1 = -6.25E+01  x2 = 0.00E+00
  node :  5  x1 = -5.00E+01  x2 = 0.00E+00
  node :  6  x1 = -3.75E+01  x2 = 0.00E+00
node : 7  x1 = -2.500E+01  x2 = 0.000E+00
node : 8  x1 = -1.250E+01  x2 = 0.000E+00
node : 9  x1 =  0.000E+00  x2 = 0.000E+00
node : 10  x1 =  1.250E+01  x2 = 0.000E+00
node : 11  x1 =  2.500E+01  x2 = 0.000E+00
node : 12  x1 =  3.750E+01  x2 = 0.000E+00
node : 13  x1 =  5.000E+01  x2 = 0.000E+00
node : 14  x1 =  6.250E+01  x2 = 0.000E+00
node : 15  x1 =  7.500E+01  x2 = 0.000E+00
node : 16  x1 =  8.750E+01  x2 = 0.000E+00
node : 17  x1 = 1.000E+02  x2 = 0.000E+00

---

--- ELEMENT INFORMATION ---

---

--> number:  1 (type: BE2_2D ) (kind: FLEXURAL )
nodes:
  1  2
integration rule: exactly integrated element
  material no. =  1
  material type: isotropic, linear elastic idealization for beams
cross-sectional area = 3.000E+01
moment of inertia (I_22) = 2.500E+02

---

--> number:  2 (type: BE2_2D ) (kind: FLEXURAL )
nodes:
  2  3
integration rule: exactly integrated element
  material no. =  1
  material type: isotropic, linear elastic idealization for beams
cross-sectional area = 3.000E+01
moment of inertia (I_22) = 2.500E+02

---

--> number:  3 (type: BE2_2D ) (kind: FLEXURAL )
nodes:
  3  4
integration rule: exactly integrated element
  material no. =  1
  material type: isotropic, linear elastic idealization for beams
cross-sectional area = 3.000E+01
moment of inertia (I_22) = 2.500E+02

---

--> number:  4 (type: BE2_2D ) (kind: FLEXURAL )
nodes:
  4  5
integration rule: exactly integrated element
material no. = 1
material type: isotropic, linear elastic idealization for beams
cross-sectional area = 3.000E+01
moment of inertia (I_{22}) = 2.500E+02

--> number: 5  (type: BE2_2D )  (kind: FLEXURAL )
nodes: 5  6
integration rule: exactly integrated element
material no. = 1
material type: isotropic, linear elastic idealization for beams
cross-sectional area = 3.000E+01
moment of inertia (I_{22}) = 2.500E+02

--> number: 6  (type: BE2_2D )  (kind: FLEXURAL )
nodes: 6  7
integration rule: exactly integrated element
material no. = 1
material type: isotropic, linear elastic idealization for beams
cross-sectional area = 3.000E+01
moment of inertia (I_{22}) = 2.500E+02

--> number: 7  (type: BE2_2D )  (kind: FLEXURAL )
nodes: 7  8
integration rule: exactly integrated element
material no. = 1
material type: isotropic, linear elastic idealization for beams
cross-sectional area = 3.000E+01
moment of inertia (I_{22}) = 2.500E+02

--> number: 8  (type: BE2_2D )  (kind: FLEXURAL )
nodes: 8  9
integration rule: exactly integrated element
material no. = 1
material type: isotropic, linear elastic idealization for beams
cross-sectional area = 3.000E+01
moment of inertia (I_{22}) = 2.500E+02

--> number: 9  (type: BE2_2D )  (kind: FLEXURAL )
nodes: 9  10
integration rule: exactly integrated element
material no. = 1
material type: isotropic, linear elastic idealization for beams
cross-sectional area = 3.000E+01
moment of inertia \( (I_{22}) = 2.500E+02 \)

--> number: 10 (type: BE2_2D) (kind: FLEXURAL)

nodes:
10 11
integration rule: exactly integrated element
material no. = 1
material type: isotropic, linear elastic idealization for beams
cross-sectional area = 3.000E+01
moment of inertia \( (I_{22}) = 2.500E+02 \)

--> number: 11 (type: BE2_2D) (kind: FLEXURAL)

nodes:
11 12
integration rule: exactly integrated element
material no. = 1
material type: isotropic, linear elastic idealization for beams
cross-sectional area = 3.000E+01
moment of inertia \( (I_{22}) = 2.500E+02 \)

--> number: 12 (type: BE2_2D) (kind: FLEXURAL)

nodes:
12 13
integration rule: exactly integrated element
material no. = 1
material type: isotropic, linear elastic idealization for beams
cross-sectional area = 3.000E+01
moment of inertia \( (I_{22}) = 2.500E+02 \)

--> number: 13 (type: BE2_2D) (kind: FLEXURAL)

nodes:
13 14
integration rule: exactly integrated element
material no. = 1
material type: isotropic, linear elastic idealization for beams
cross-sectional area = 3.000E+01
moment of inertia \( (I_{22}) = 2.500E+02 \)

--> number: 14 (type: BE2_2D) (kind: FLEXURAL)

nodes:
14 15
integration rule: exactly integrated element
material no. = 1
material type: isotropic, linear elastic idealization for beams
cross-sectional area = 3.000E+01
moment of inertia \( (I_{22}) = 2.500E+02 \)

--> number: 15 (type: BE2_2D) (kind: FLEXURAL)
nodes:  
15  16
integration rule: exactly integrated element
material no. = 1
  material type: isotropic, linear elastic idealization for beams
cross-sectional area = 3.000E+01
moment of inertia (I_{22}) = 2.500E+02

--> number: 16 (type: BE2_2D ) (kind: FLEXURAL )

nodes:  
16  17
integration rule: exactly integrated element
material no. = 1
  material type: isotropic, linear elastic idealization for beams
cross-sectional area = 3.000E+01
moment of inertia (I_{22}) = 2.500E+02

======================================================================
= NODE POINT SPECIFICATIONS =
======================================================================

+-------------------------------------------+--------------------------+
| Node Number | (coordinates) | specification          |
|-------------------------------------------+--------------------------|
+-------------------------------------------+--------------------------+

  1 : ( x1 = -1.000E+02, x2 = 0.000E+00 )
  displacement-1 = 0.000E+00 ; history no. = -2
  displacement-2 = 0.000E+00 ; history no. = -2
  moment-33 = 0.000E+00 ; history no. = -2

  9 : ( x1 = 0.000E+00, x2 = 0.000E+00 )
  force-1 = 0.000E+00 ; history no. = -2
  force-2 = -1.000E+01 ; history no. = 0
  moment-33 = 0.000E+00 ; history no. = -2

  17 : ( x1 = 1.000E+02, x2 = 0.000E+00 )
  displacement-1 = 0.000E+00 ; history no. = -2
  displacement-2 = 0.000E+00 ; history no. = -2
  moment-33 = 0.000E+00 ; history no. = -2

~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
end of mathematical model data
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
At time 1.000E+00 (step no. 1): NO iteration was required

======================================================================
= ELEMENT STRAINS & STRESSES =
======================================================================

--> element  1 ( type = BE2_2D ):
                      .................
  @(x1 = -1.000E+02, x2 = 0.000E+00):  
     axial force = 0.000E+00 , shear force = 2.496E-03 , moment = 3.551E-03
  @(x1 = -8.750E+01, x2 = 0.000E+00):  
     axial force = 0.000E+00 , shear force = 2.496E-03 , moment = 2.765E-02

--> element  2 ( type = BE2_2D ):
                      .................
  @(x1 = -8.750E+01, x2 = 0.000E+00):  
     axial force = 0.000E+00 , shear force = 9.698E-03 , moment = -2.372E-02
  @(x1 = -7.500E+01, x2 = 0.000E+00):  
     axial force = 0.000E+00 , shear force = 9.698E-03 , moment = 1.449E-01

--> element  3 ( type = BE2_2D ):
                      .................
  @(x1 = -7.500E+01, x2 = 0.000E+00):  
     axial force = 0.000E+00 , shear force = 1.198E-02 , moment = -1.604E-01
  @(x1 = -6.250E+01, x2 = 0.000E+00):  
     axial force = 0.000E+00 , shear force = 1.198E-02 , moment = 3.102E-01

--> element  4 ( type = BE2_2D ):
                      .................
  @(x1 = -6.250E+01, x2 = 0.000E+00):  
     axial force = 0.000E+00 , shear force = -3.195E-02 , moment = -3.755E-01
  @(x1 = -5.000E+01, x2 = 0.000E+00):  
     axial force = 0.000E+00 , shear force = -3.195E-02 , moment = -2.395E-02

--> element  5 ( type = BE2_2D ):
                      .................
  @(x1 = -5.000E+01, x2 = 0.000E+00):  
     axial force = 0.000E+00 , shear force = -1.776E-01 , moment = -6.790E-02
axial force = 0.000E+00, shear force = -1.776E-01, moment = -2.152E+00

--> element 6 (type = BE2_2D):
........................................
@ (x1 = -3.750E+01, x2 = 0.000E+00):
  axial force = 0.000E+00, shear force = -3.201E-01, moment = 2.312E+00
@ (x1 = -2.500E+01, x2 = 0.000E+00):
  axial force = 0.000E+00, shear force = -3.201E-01, moment = -6.314E+00

--> element 7 (type = BE2_2D):
........................................
@ (x1 = -2.500E+01, x2 = 0.000E+00):
  axial force = 0.000E+00, shear force = 2.269E-01, moment = 7.408E+00
@ (x1 = -1.250E+01, x2 = 0.000E+00):
  axial force = 0.000E+00, shear force = 2.269E-01, moment = -4.572E+00

--> element 8 (type = BE2_2D):
........................................
@ (x1 = -1.250E+01, x2 = 0.000E+00):
  axial force = 0.000E+00, shear force = 2.826E+00, moment = 6.794E+00
@ (x1 = 0.000E+00, x2 = 0.000E+00):
  axial force = 0.000E+00, shear force = 2.826E+00, moment = -2.854E+01

--> element 9 (type = BE2_2D):
........................................
@ (x1 = 0.000E+00, x2 = 0.000E+00):
  axial force = 0.000E+00, shear force = -2.826E+00, moment = -2.854E+01
@ (x1 = 1.250E+01, x2 = 0.000E+00):
  axial force = 0.000E+00, shear force = -2.826E+00, moment = -6.794E+00

--> element 10 (type = BE2_2D):
........................................
@ (x1 = 1.250E+01, x2 = 0.000E+00):
  axial force = 0.000E+00, shear force = -2.269E-01, moment = 4.572E+00
@ (x1 = 2.500E+01, x2 = 0.000E+00):
  axial force = 0.000E+00, shear force = -2.269E-01, moment = -7.408E+00

--> element 11 (type = BE2_2D):
........................................
@ (x1 = 2.500E+01, x2 = 0.000E+00):
  axial force = 0.000E+00, shear force = 3.201E-01, moment = 6.314E+00
@ (x1 = 3.750E+01, x2 = 0.000E+00):
axial force = 0.000E+00 , shear force = 3.201E-01 , moment = -2.312E+00

--> element  12 ( type = BE2_2D ):

.................................
@ (x1 = 3.750E+01, x2 = 0.000E+00):
  axial force = 0.000E+00 , shear force = 1.776E-01 , moment = 2.152E+00
@ (x1 = 5.000E+01, x2 = 0.000E+00):
  axial force = 0.000E+00 , shear force = 1.776E-01 , moment = 6.790E-02

--> element  13 ( type = BE2_2D ):

.................................
@ (x1 = 5.000E+01, x2 = 0.000E+00):
  axial force = 0.000E+00 , shear force = 3.195E-02 , moment = 2.395E-02
@ (x1 = 6.250E+01, x2 = 0.000E+00):
  axial force = 0.000E+00 , shear force = 3.195E-02 , moment = 3.755E-01

--> element  14 ( type = BE2_2D ):

.................................
@ (x1 = 6.250E+01, x2 = 0.000E+00):
  axial force = 0.000E+00 , shear force = -1.198E-02 , moment = -3.102E-01
@ (x1 = 7.500E+01, x2 = 0.000E+00):
  axial force = 0.000E+00 , shear force = -1.198E-02 , moment = 1.604E-01

--> element  15 ( type = BE2_2D ):

.................................
@ (x1 = 7.500E+01, x2 = 0.000E+00):
  axial force = 0.000E+00 , shear force = -9.698E-03 , moment = -1.449E-01
@ (x1 = 8.750E+01, x2 = 0.000E+00):
  axial force = 0.000E+00 , shear force = -9.698E-03 , moment = 2.372E-02

--> element  16 ( type = BE2_2D ):

.................................
@ (x1 = 8.750E+01, x2 = 0.000E+00):
  axial force = 0.000E+00 , shear force = -2.496E-03 , moment = -2.765E-02
@ (x1 = 1.000E+02, x2 = 0.000E+00):
  axial force = 0.000E+00 , shear force = -2.496E-03 , moment = -3.551E-03

At time 1.000E+00 (step no.  1):
<table>
<thead>
<tr>
<th>node</th>
<th>x1</th>
<th>x2</th>
<th>u_1</th>
<th>u_2</th>
<th>rot_33</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-1.000E+02</td>
<td>0.000E+00</td>
<td>0.000E+00</td>
<td>-2.389E-27</td>
<td>-5.555E-07</td>
</tr>
<tr>
<td>2</td>
<td>-8.750E+01</td>
<td>0.000E+00</td>
<td>0.000E+00</td>
<td>-6.230E-06</td>
<td>-3.546E-07</td>
</tr>
<tr>
<td>3</td>
<td>-7.500E+01</td>
<td>0.000E+00</td>
<td>0.000E+00</td>
<td>-3.983E-06</td>
<td>1.051E-06</td>
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<tr>
<td>4</td>
<td>-6.250E+01</td>
<td>0.000E+00</td>
<td>0.000E+00</td>
<td>3.107E-05</td>
<td>4.973E-06</td>
</tr>
<tr>
<td>5</td>
<td>-5.000E+01</td>
<td>0.000E+00</td>
<td>0.000E+00</td>
<td>1.185E-04</td>
<td>7.902E-06</td>
</tr>
<tr>
<td>6</td>
<td>-3.750E+01</td>
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<td>0.000E+00</td>
<td>1.472E-04</td>
<td>-9.466E-06</td>
</tr>
<tr>
<td>7</td>
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<td>0.000E+00</td>
<td>0.000E+00</td>
<td>-3.509E-04</td>
<td>-8.134E-05</td>
</tr>
<tr>
<td>8</td>
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<td>0.000E+00</td>
<td>-2.041E-03</td>
<td>-1.812E-04</td>
</tr>
<tr>
<td>9</td>
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<td>0.000E+00</td>
<td>-3.787E-03</td>
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</tr>
<tr>
<td>10</td>
<td>1.250E+01</td>
<td>0.000E+00</td>
<td>0.000E+00</td>
<td>-2.041E-03</td>
<td>1.812E-04</td>
</tr>
<tr>
<td>11</td>
<td>2.500E+01</td>
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<td>0.000E+00</td>
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<td>8.134E-05</td>
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<tr>
<td>12</td>
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<td>0.000E+00</td>
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<tr>
<td>13</td>
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<td>0.000E+00</td>
<td>1.185E-04</td>
<td>-7.902E-06</td>
</tr>
<tr>
<td>14</td>
<td>6.250E+01</td>
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<td>0.000E+00</td>
<td>3.107E-05</td>
<td>-4.973E-06</td>
</tr>
<tr>
<td>15</td>
<td>7.500E+01</td>
<td>0.000E+00</td>
<td>0.000E+00</td>
<td>4.183E-20</td>
<td></td>
</tr>
</tbody>
</table>
u_1 = 0.000E+00, u_2 = -3.983E-06, rot_33 = -1.051E-06

node: 16 (x1 = 8.750E+01, x2 = 0.000E+00)
u_1 = 0.000E+00, u_2 = -6.230E-06, rot_33 = 3.546E-07

node: 17 (x1 = 1.000E+02, x2 = 0.000E+00)
u_1 = 0.000E+00, u_2 = -2.389E-27, rot_33 = 5.555E-07

apes -> end of analysis . . . . . . .
References