ELEMENT FLEXURAL TYPE TB2_2D command

Synopsis

The ELEMENT FLEXURAL TYPE TB2_2D command is used to describe all 2-node linear "Timoshenko" \(C^0\) continuous) frame elements that are to be used in planar mechanical analyses.\(^1\)

Syntax

The following syntax is used to describe a typical TB2_2D frame element:

```
ELEment FLExural TYPE TB2_2D NODes #:##:#
  (MATerial #) (CONstruction #) (EXCavation #)
  (AREa #.##) (I22 #.##) (SHEar_factor #.##)
  (1_Additional #) (1_Increment #)
  (DONT_PRINT_Results)
```

Explanatory Notes

- The **TB2_2D** is a \(C^0\) continuous frame element for planar analyses. The element
  - Contains two (2) nodes.
  - Has two (2) displacements and two (2) rotation degrees of freedom at each node.
  - Employs a *linear* interpolation for the transverse displacement and rotation.

- The numbering order of **NODES** associated with a **TB2_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 **TB2_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

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\(^1\) The range of applicability of standard Bernoulli-Euler beam theory was extended by S. P. Timoshenko [2, 3], who accounted for the effects of transverse shear deformations and, in the case of dynamic excitations and vibrating beams, rotary inertia.
Figure 1: Node Numbering Associated with a Typical Linear “Timoshenko” (TB2.2D) Frame Element

**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’s **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.

- The **SHEAR_FACTOR** keyword is used to specify a value for shear area correction factor [1] for the cross-section.

- 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**
**TB2.2D** command, then all the elements generated will be affected in a like manner by the above print control commands.
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 simply-supported. The loading consists of two concentrated forces applied to the member so as to load it in “four-point” bending. The associated input data file is given below.

```
ana tit " TB2_2D beam elements used to simulate 4-point bending"
ana tit " square cross-section of unit dimension"

! ana action analyze
analysis type mechanical
analysis description linear
!
dim max material flexural elastic 1
dim max nodes 17
dim max tb2_2d 16
!
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+07
!
nodes line number 1 nodes line number 5 x1 5.0 incr 1
nodes line number 12 x1 15.0 incr 1
nodes line number 17 x1 20.0 incr 1
!
element flexural type "tb2_2d" nodes 1 2 mat 1 area 1.00 i22 0.083 int 1 &
   1_add 15 1_incr 1
!
spec conc mech nodes 1 1_disp 2_disp
spec conc mech nodes 17 2_disp
!
spec conc mech nodes 5:12:7 2_his 0 2_forc 2_val -1100.0
!
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.

TB2_2D beam elements used to simulate 4-point bending square cross-section of unit dimension

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

Largest NODE number which can used in the mesh = 17

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

Max. no. 2-node Timoshenko frame (TB2_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

======================================================================
= 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+07
            Poisson’s ratio = 0.000E+00
            Winkler rotational stiffness = 0.000E+00
            Winkler translational stiffness = 0.000E+00

-- NODAL COORDINATES

<table>
<thead>
<tr>
<th>node</th>
<th>x1</th>
<th>x2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.000E+00</td>
<td>0.000E+00</td>
</tr>
<tr>
<td>2</td>
<td>1.250E+00</td>
<td>0.000E+00</td>
</tr>
<tr>
<td>3</td>
<td>2.500E+00</td>
<td>0.000E+00</td>
</tr>
<tr>
<td>4</td>
<td>3.750E+00</td>
<td>0.000E+00</td>
</tr>
<tr>
<td>5</td>
<td>5.000E+00</td>
<td>0.000E+00</td>
</tr>
<tr>
<td>6</td>
<td>6.429E+00</td>
<td>0.000E+00</td>
</tr>
<tr>
<td>7</td>
<td>7.857E+00</td>
<td>0.000E+00</td>
</tr>
<tr>
<td>8</td>
<td>9.286E+00</td>
<td>0.000E+00</td>
</tr>
<tr>
<td>9</td>
<td>1.071E+01</td>
<td>0.000E+00</td>
</tr>
<tr>
<td>10</td>
<td>1.214E+01</td>
<td>0.000E+00</td>
</tr>
</tbody>
</table>
node: 11  x1 = 1.357E+01  x2 = 0.000E+00
node: 12  x1 = 1.500E+01  x2 = 0.000E+00
node: 13  x1 = 1.600E+01  x2 = 0.000E+00
node: 14  x1 = 1.700E+01  x2 = 0.000E+00
node: 15  x1 = 1.800E+01  x2 = 0.000E+00
node: 16  x1 = 1.900E+01  x2 = 0.000E+00
node: 17  x1 = 2.000E+01  x2 = 0.000E+00

--> number: 1  (type: TB2_2D  )  (kind: FLEXURAL  )
    nodes:
      1  2
    integration rule: 2-point quadrature used on entire element
    material no. = 1
    material type: isotropic, linear elastic idealization for beams
    cross-sectional area = 1.000E+00
    shear area factor (k) = 8.333E-01
    moment of inertia (I_22) = 8.300E-02

--> number: 2  (type: TB2_2D  )  (kind: FLEXURAL  )
    nodes:
      2  3
    integration rule: 2-point quadrature used on entire element
    material no. = 1
    material type: isotropic, linear elastic idealization for beams
    cross-sectional area = 1.000E+00
    shear area factor (k) = 8.333E-01
    moment of inertia (I_22) = 8.300E-02

--> number: 3  (type: TB2_2D  )  (kind: FLEXURAL  )
    nodes:
      3  4
    integration rule: 2-point quadrature used on entire element
    material no. = 1
    material type: isotropic, linear elastic idealization for beams
    cross-sectional area = 1.000E+00
    shear area factor (k) = 8.333E-01
    moment of inertia (I_22) = 8.300E-02

--> number: 4  (type: TB2_2D  )  (kind: FLEXURAL  )
    nodes:
      4  5
    integration rule: 2-point quadrature used on entire element
    material no. = 1
material type: isotropic, linear elastic idealization for beams
  cross-sectional area = 1.000E+00
  shear area factor (k) = 8.333E-01
  moment of inertia (I_22) = 8.300E-02

--> number: 5 (type: TB2_2D ) (kind: FLEXURAL )
  nodes:
  5  6
  integration rule: 2-point quadrature used on entire element
    material no. = 1
      material type: isotropic, linear elastic idealization for beams
          cross-sectional area = 1.000E+00
          shear area factor (k) = 8.333E-01
          moment of inertia (I_22) = 8.300E-02

--> number: 6 (type: TB2_2D ) (kind: FLEXURAL )
  nodes:
  6  7
  integration rule: 2-point quadrature used on entire element
    material no. = 1
      material type: isotropic, linear elastic idealization for beams
          cross-sectional area = 1.000E+00
          shear area factor (k) = 8.333E-01
          moment of inertia (I_22) = 8.300E-02

--> number: 7 (type: TB2_2D ) (kind: FLEXURAL )
  nodes:
  7  8
  integration rule: 2-point quadrature used on entire element
    material no. = 1
      material type: isotropic, linear elastic idealization for beams
          cross-sectional area = 1.000E+00
          shear area factor (k) = 8.333E-01
          moment of inertia (I_22) = 8.300E-02

--> number: 8 (type: TB2_2D ) (kind: FLEXURAL )
  nodes:
  8  9
  integration rule: 2-point quadrature used on entire element
    material no. = 1
      material type: isotropic, linear elastic idealization for beams
          cross-sectional area = 1.000E+00
          shear area factor (k) = 8.333E-01
          moment of inertia (I_22) = 8.300E-02

--> number: 9 (type: TB2_2D ) (kind: FLEXURAL )
  nodes:
  9 10
integration rule: 2-point quadrature used on entire element
material no. = 1
material type: isotropic, linear elastic idealization for beams
cross-sectional area = 1.000E+00
shear area factor \( k \) = 8.333E-01
moment of inertia \( I_{22} \) = 8.300E-02

--> number: 10 (type: TB2_2D ) (kind: FLEXURAL )
nodes:
10 11

integration rule: 2-point quadrature used on entire element
material no. = 1
material type: isotropic, linear elastic idealization for beams
cross-sectional area = 1.000E+00
shear area factor \( k \) = 8.333E-01
moment of inertia \( I_{22} \) = 8.300E-02

--> number: 11 (type: TB2_2D ) (kind: FLEXURAL )
nodes:
11 12

integration rule: 2-point quadrature used on entire element
material no. = 1
material type: isotropic, linear elastic idealization for beams
cross-sectional area = 1.000E+00
shear area factor \( k \) = 8.333E-01
moment of inertia \( I_{22} \) = 8.300E-02

--> number: 12 (type: TB2_2D ) (kind: FLEXURAL )
nodes:
12 13

integration rule: 2-point quadrature used on entire element
material no. = 1
material type: isotropic, linear elastic idealization for beams
cross-sectional area = 1.000E+00
shear area factor \( k \) = 8.333E-01
moment of inertia \( I_{22} \) = 8.300E-02

--> number: 13 (type: TB2_2D ) (kind: FLEXURAL )
nodes:
13 14

integration rule: 2-point quadrature used on entire element
material no. = 1
material type: isotropic, linear elastic idealization for beams
cross-sectional area = 1.000E+00
shear area factor \( k \) = 8.333E-01
moment of inertia \( I_{22} \) = 8.300E-02

--> number: 14 (type: TB2_2D ) (kind: FLEXURAL )
nodes: 14 15
integration rule: 2-point quadrature used on entire element
material no. = 1
material type: isotropic, linear elastic idealization for beams
cross-sectional area = 1.000E+00
shear area factor (k) = 8.333E-01
moment of inertia (I_{22}) = 8.300E-02

--> number: 15 (type: TB2_2D ) (kind: FLEXURAL )

nodes: 15 16
integration rule: 2-point quadrature used on entire element
material no. = 1
material type: isotropic, linear elastic idealization for beams
cross-sectional area = 1.000E+00
shear area factor (k) = 8.333E-01
moment of inertia (I_{22}) = 8.300E-02

--> number: 16 (type: TB2_2D ) (kind: FLEXURAL )

nodes: 16 17
integration rule: 2-point quadrature used on entire element
material no. = 1
material type: isotropic, linear elastic idealization for beams
cross-sectional area = 1.000E+00
shear area factor (k) = 8.333E-01
moment of inertia (I_{22}) = 8.300E-02

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

Node Number 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
moment-33 = 0.000E+00 ; history no. = -2

5 : ( x1 = 5.000E+00, x2 = 0.000E+00 )
force-1 = 0.000E+00 ; history no. = -2
force-2 = -1.100E+03 ; history no. = 0
moment-33 = 0.000E+00 ; history no. = -2
At time 1.000E+00 (step no. 1): NO iteration was required

--> element 1 ( type = TB2_2D ): ..............................................
   @(x1 = 0.000E+00, x2 = 0.000E+00):
      axial force = 0.000E+00 , shear force = -1.100E+03 , moment = -4.157E+02

--> element 2 ( type = TB2_2D ): ..............................................
   @(x1 = 1.250E+00, x2 = 0.000E+00):
      axial force = 0.000E+00 , shear force = -1.100E+03 , moment = -1.247E+03

--> element 3 ( type = TB2_2D ): ..............................................
   @(x1 = 2.500E+00, x2 = 0.000E+00):
      axial force = 0.000E+00 , shear force = -1.100E+03 , moment = -2.079E+03

--> element 4 ( type = TB2_2D ): ..............................................
@(x1 = 3.750E+00, x2 = 0.000E+00):
axial force = 0.000E+00 , shear force = -1.100E+03 , moment = -2.910E+03

--> element 5 ( type = TB2_2D ):

@(x1 = 5.000E+00, x2 = 0.000E+00):
axial force = 0.000E+00 , shear force = 9.307E-11 , moment = -2.967E+03

--> element 6 ( type = TB2_2D ):

@(x1 = 6.429E+00, x2 = 0.000E+00):
axial force = 0.000E+00 , shear force = 6.955E-11 , moment = -2.967E+03

--> element 7 ( type = TB2_2D ):

@(x1 = 7.857E+00, x2 = 0.000E+00):
axial force = 0.000E+00 , shear force = 3.302E-11 , moment = -2.967E+03

--> element 8 ( type = TB2_2D ):

@(x1 = 9.286E+00, x2 = 0.000E+00):
axial force = 0.000E+00 , shear force = 2.738E-11 , moment = -2.967E+03

--> element 9 ( type = TB2_2D ):

@(x1 = 1.071E+01, x2 = 0.000E+00):
axial force = 0.000E+00 , shear force = -1.240E-11 , moment = -2.967E+03

--> element 10 ( type = TB2_2D ):

@(x1 = 1.214E+01, x2 = 0.000E+00):
axial force = 0.000E+00 , shear force = -1.587E-11 , moment = -2.967E+03

--> element 11 ( type = TB2_2D ):

@(x1 = 1.357E+01, x2 = 0.000E+00):
axial force = 0.000E+00 , shear force = -3.794E-11 , moment = -2.967E+03

--> element 12 ( type = TB2_2D ):
@ (x1 = 1.500E+01, x2 = 0.000E+00):
axial force = 0.000E+00 , shear force = 1.100E+03 , moment = -3.490E+03

--> element  13 ( type = TB2_2D ):
..................................

@ (x1 = 1.600E+01, x2 = 0.000E+00):
axial force = 0.000E+00 , shear force = 1.100E+03 , moment = -2.714E+03

--> element  14 ( type = TB2_2D ):
..................................

@ (x1 = 1.700E+01, x2 = 0.000E+00):
axial force = 0.000E+00 , shear force = 1.100E+03 , moment = -1.939E+03

--> element  15 ( type = TB2_2D ):
..................................

@ (x1 = 1.800E+01, x2 = 0.000E+00):
axial force = 0.000E+00 , shear force = 1.100E+03 , moment = -1.163E+03

--> element  16 ( type = TB2_2D ):
..................................

@ (x1 = 1.900E+01, x2 = 0.000E+00):
axial force = 0.000E+00 , shear force = 1.100E+03 , moment = -3.878E+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 = -1.100E-24, rot_33 =  9.392E-03

node:  2 ( x1 =  1.250E+00, x2 =  0.000E+00 )
u_1 =  0.000E+00, u_2 = -1.172E-02, rot_33 =  9.183E-03

node:  3 ( x1 =  2.500E+00, x2 =  0.000E+00 )
u_1 =  0.000E+00, u_2 = -2.292E-02, rot_33 =  8.557E-03

node:  4 ( x1 =  3.750E+00, x2 =  0.000E+00 )
u₁ = 0.000E+00, u₂ = -3.307E-02, rot₃₃ = 7.513E-03

node: 5 ( x₁ = 5.000E+00, x₂ = 0.000E+00 )
u₁ = 0.000E+00, u₂ = -4.166E-02, rot₃₃ = 6.052E-03

node: 6 ( x₁ = 6.429E+00, x₂ = 0.000E+00 )
u₁ = 0.000E+00, u₂ = -4.909E-02, rot₃₃ = 4.350E-03

node: 7 ( x₁ = 7.857E+00, x₂ = 0.000E+00 )
u₁ = 0.000E+00, u₂ = -5.409E-02, rot₃₃ = 2.648E-03

node: 8 ( x₁ = 9.286E+00, x₂ = 0.000E+00 )
u₁ = 0.000E+00, u₂ = -5.665E-02, rot₃₃ = 9.456E-04

node: 9 ( x₁ = 1.071E+01, x₂ = 0.000E+00 )
u₁ = 0.000E+00, u₂ = -5.799E-02, rot₃₃ = -7.566E-04

node: 10 ( x₁ = 1.214E+01, x₂ = 0.000E+00 )
u₁ = 0.000E+00, u₂ = -5.449E-02, rot₃₃ = -2.459E-03

node: 11 ( x₁ = 1.357E+01, x₂ = 0.000E+00 )
u₁ = 0.000E+00, u₂ = -5.665E-02, rot₃₃ = -4.161E-03

node: 12 ( x₁ = 1.500E+01, x₂ = 0.000E+00 )
u₁ = 0.000E+00, u₂ = -5.679E-02, rot₃₃ = -5.863E-03

node: 13 ( x₁ = 1.600E+01, x₂ = 0.000E+00 )
u₁ = 0.000E+00, u₂ = -5.595E-02, rot₃₃ = -7.265E-03

node: 14 ( x₁ = 1.700E+01, x₂ = 0.000E+00 )
u₁ = 0.000E+00, u₂ = -2.805E-02, rot₃₃ = -8.355E-03

node: 15 ( x₁ = 1.800E+01, x₂ = 0.000E+00 )
u₁ = 0.000E+00, u₂ = -1.922E-02, rot₃₃ = -9.134E-03

node: 16 ( x₁ = 1.900E+01, x₂ = 0.000E+00 )
u₁ = 0.000E+00, u₂ = -9.767E-03, rot₃₃ = -9.601E-03

node: 17 ( x₁ = 2.000E+01, x₂ = 0.000E+00 )
u₁ = 0.000E+00, u₂ = -8.800E-25, rot₃₃ = -9.757E-03

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

