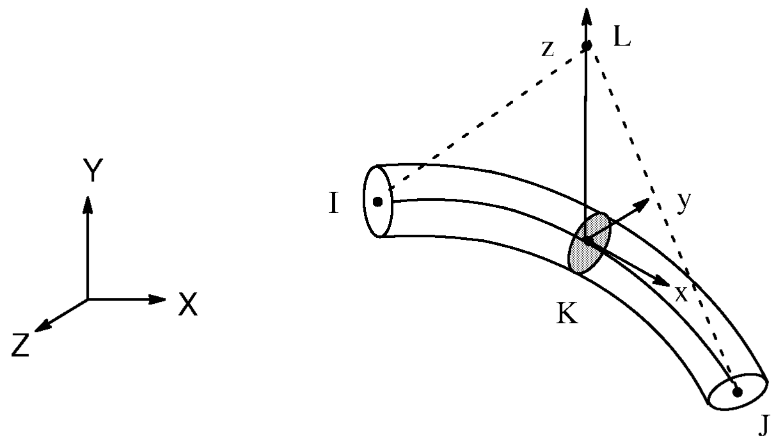
14.189 BEAM189 — 3–D Finite Strain Quadratic Beam



Matrix or Vector	Shape Functions	Integration Points
Stiffness Matrix	Equations (12.2.3–1), (12.2.3–2), (12.2.3–3), (12.2.3–4), (12.2.3–5) and (12.2.3–6)	Along the length: 2 Across the section: see text below
Mass Matrix	Same as stiffness matrix	Along the length: 3 Across the section: 1
Stress Stiffness Matrix	Same as stiffness matrix	Same as stiffness matrix
Thermal Load Matrix	Same as stiffness matrix	Same as stiffness matrix
Pressure Load Vector	Same as stiffness matrix	Same as mass matrix
Newton–Raphson Load Vector	Same as stiffness matrix	Same as stiffness matrix

Load Type	Distribution
Element Temperature	Bilinear across cross–section and linear along length (see Section 14.24.3 for details)
Nodal Temperature	Constant across cross–section, linear along length
Pressure	Linear along length. The pressure is assumed to act along the element x–axis.

References: Simo and Vu–Quoc(237), Ibrahimbegovic(238).

14.189.1 Assumptions and Restrictions

The elements are based on Timoshenko beam theory, and hence shear deformation effects are included. The element is a quadratic (3–noded) beam element in 3–D with six degrees of freedom at each node. The DOF at each node includes translations in x, y, and z directions, and rotations about the x, y, and z directions. Warping of cross sections is considered optionally (KEYOPT(1)).

This element is well–suited for linear, large rotation, and/or large strain nonlinear applications. If KEYOPT(2) = 0, the cross sectional dimensions are scaled uniformly as a function of axial strain in nonlinear analysis such that the volume of the element is preserved.

The element includes stress stiffness terms, by default, in any analysis with NLGEOM,ON. The stress stiffness terms provided enable the elements to analyze flexural, lateral and torsional stability problems (using eigenvalue buckling or collapse studies with arc length methods). Pressure load stiffness (Section 3.3.4) is included.

Transverse shear strain is constant through cross–section, i.e., cross sections remain plane and undistorted after deformation. The element can be used for slender or stout beams. Due to the limitations of first order shear deformation theory, only moderately "thick" beams may be analyzed. Slenderness ratio of a beam structure may be used in judging the applicability of the element. It is important to note that this ratio should be calculated using some global distance measures, and not based on individual element dimensions. A slenderness ratio greater than 30 is recommended.

Currently these elements support only elastic relation between transverse shear forces and transverse shear strains. Orthotropic elastic material properties with isotropic hardening plasticity options BISO, MISO may be used. User may specify transverse shear stiffnesses using real constants.

The St. Venant warping functions for torsional behavior is determined in the underformed state, and is used to define shear strain even after yielding. The element does not provide options to recalculate the torsional shear distribution on cross sections during the analysis and possible partial plastic yielding of cross section. As such, large inelastic deformation due to torsional loading should be treated with caution and carefully verified.

The elements are provided with section relevant quantities (area of integration, position, Poisson function, function derivatives, etc.) automatically at a number of section points by the use of section commands. Each section is assumed to be an assembly of predetermined number of 9 node cells (see Figure 14.189–1) which illustrates section model of a rectangular section). Each cell has 4 integration points.

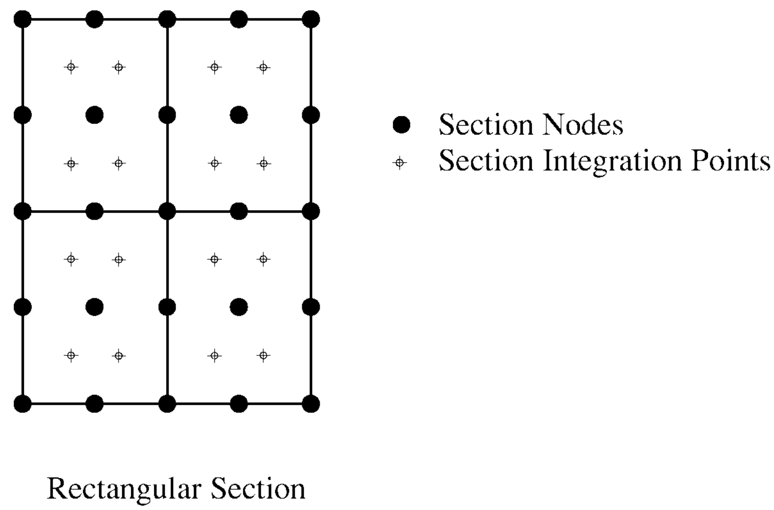


Figure 14.189–1 Section Model

When the material has inelastic behavior or the temperature varies across the section, constitutive calculations are performed at each of the section integration points. For all other cases, the element uses the pre–calculated properties of the section at each element integration point along the length. The restrained warping formulation used may be found in Timoshenko and Gere(246) and Schulz and Fillippou(247).

14.189.2 Stress Evaluation

Several stress evaluation options exist. The section strains and generalized stresses are evaluated at element integration points and then extrapolated to the nodes of the element.

If the material is elastic, stresses and strains are available after extrapolation in cross–section at the nodes of section mesh. If the material is plastic, stresses and strains are moved to the section nodes (from section integration points).