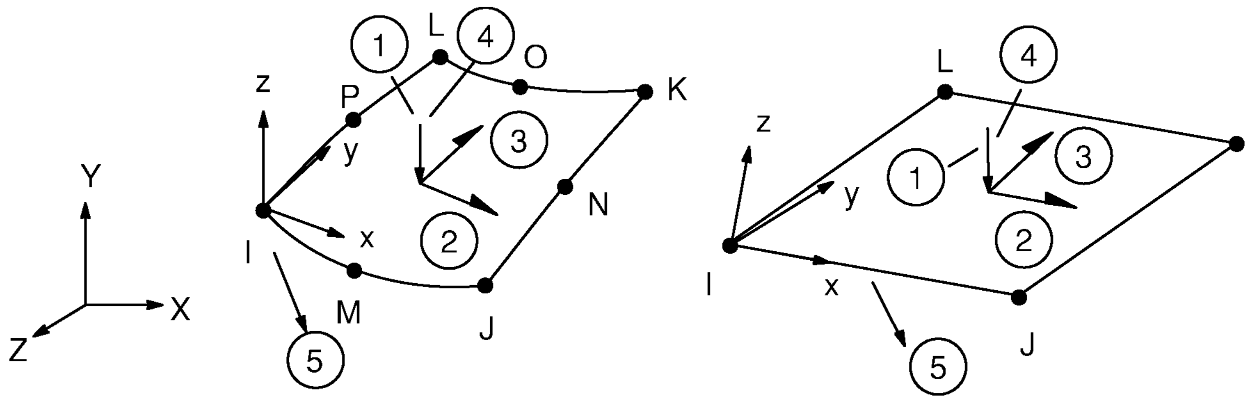
14.154 SURF154 — 3–D Structural Surface Effect



Matrix or Vector	Geometry	Midside Nodes	Shape Functions	Integration Points
Convection Surface Matrix and Load Vector	Quad	If KEYOPT(4)=0 (has midside nodes)	Equations (12.5.10–1), (12.5.10–2), and (12.5.10–3)	3 x 3
		If KEYOPT(4)=1 (has no midside nodes)	Equations (12.5.8–1), (12.5.8–2), and (12.5.8–3)	2 x 2
	Triangle	If KEYOPT(4)=0 (has midside nodes)	Equations (12.5.5–1), (12.5.5–2), and (12.5.5–3)	6
		If KEYOPT(4)=0 (has no midside nodes)	Equations (12.5.3–1), (12.5.3–2), and (12.5.3–3)	3

Matrix or Vector	Geometry	Midside Nodes	Shape Functions	Integration Points
Damping Matrix	Same as stiffness matrix			
Mass Matrix	Same as stiffness matrix			
Stress Stiffness Matrix	Same as stiffness matrix			
Pressure Load Vector	Same as stiffness matrix			
Surface Tension Load Vector	Same as stiffness matrix			

Load Type	Distribution
All Loads	Same as shape functions

The stiffness matrix is:

$$[K_e^f] = \text{element foundation stiffness matrix}$$

$$= k^f \int_A \{N_z\} \{N_z\}^T \, dA \tag{14.154–1}$$

k^f = foundation stiffness (input as EFS on **R** command)

A = area of element

$\{N_z\}$ = vector of shape functions representing motions normal to the surface

The mass matrix is:

$$[M_e] = \text{element mass matrix}$$

$$= \rho \int_A t_h \{N\}\{N\}^T \, dA + A_d \int_A \{N\}\{N\}^T dA \tag{14.154–2}$$

where: t_h = thickness (input as TKI, TKJ, TKK, TKL on **RMORE** command)

ϱ	=	density (input as DENS on **MP** command)
{N}	=	vector of shape functions
A_d	=	added mass per unit area (input as ADMSUA on **R** command)

If the command **LUMPM**,ON is used, $[M_e]$ is diagonalized as described in Section 13.2.

The element damping matrix is:

$$[C_e] = \text{element damping matrix} = \mu \int_A \{N\}\{N\}^T \, dA \qquad (14.154\text{–}3)$$

where: μ = dissipation (input as VISC on **MP** command)

The element stress stiffness matrix is:

$$[S_e] = \text{element stress stiffness matrix} = \int_A [S_g]^T [S_m][S_g] \, dA \qquad (14.154\text{–}4)$$

where: $[S_g]$ = derivatives of shape functions of normal motions

$$[S_m] = \begin{bmatrix} s & 0 & 0 \\ 0 & s & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

s = in–plane force per unit length (input as SURT on **R** command)

If pressure is applied to face 1, the pressure load stiffness matrix is computed as described in Section 3.3.4.

The element load vector is:

$$\{F_e\} = \{F_e^{st}\} + \{F_e^{pr}\} \qquad (14.154\text{–}5)$$

where: $\{F_e^{st}\}$ = surface tension force vector

$$= s \int_E \{N_p\} \, dE$$

$\{N_p\}$	=	vector of shape functions representing in–plane motions normal to the edge
E	=	edge of element
$\{F_e^{pr}\}$	=	pressure load vector

$$= \int_A \Big(\{N_x\} P_x + \{N_y\} P_y - \{N_z\} P_z$$

$$+ P_v Z_f \left(p_x \{N_X\} + p_y \{N_Y\} + p_z \{N_Z\} \right) \Big) dA$$

$\{N_x\}$ = vector of shape functions representing motion in element x direction

$\{N_y\}$ = vector of shape functions representing motion in element y direction

P_x, P_y, P_z = distributed pressures over element in element x, y, and z directions (input quantities *VAL1* thru *VAL4* with *LKEY* = 2, 3, 1, respectively, on **SFE** command)

P_v = uniform pressure magnitude

$$P_v = \begin{cases} P_1 \cos\theta & \text{if KEYOPT(11) = 0 or 1} \\ P_1 & \text{if KEYOPT(11) = 2} \end{cases}$$

P_1 = input quantity VAL1 with LKEY = 5 on **SFE** command

θ = angle between element normal and applied load direction

$$Z_f = \begin{cases} 1.0 & \text{if KEYOPT(12) = 0 or } \cos\theta \le 0.0 \\ 0.0 & \text{if KEYOPT(12) = 1 and } \cos\theta > 0.0 \end{cases}$$

$$p_x = \begin{cases} D_x / \sqrt{D_x^2 + D_y^2 + D_z^2} & \text{if KEYOPT(11)} \neq 1 \\ 0.0 & \text{if KEYOPT(11) = 1} \end{cases}$$

$$p_y = \begin{cases} D_y / \sqrt{D_x^2 + D_y^2 + D_z^2} & \text{if KEYOPT(11)} \neq 1 \\ 0.0 & \text{if KEYOPT(11) = 1} \end{cases}$$

$$p_z = D_z / \sqrt{D_x^2 + D_y^2 + D_z^2}$$

D_x, D_y, D_z = vector directions (input quantities VAL2 thru VAL4 with LKEY = 5 on **SFE** command)

$\{N_X\}, \{N_Y\}, \{N_Z\}$ = vectors of shape functions in global Cartesian coordinates

The integration used to arrive at $\{F_c^{pr}\}$ is the usual numerical integration, even if KEYOPT(6) $\neq$ 0. The output quantities “average face pressures” are the average of the pressure values at the integration points.