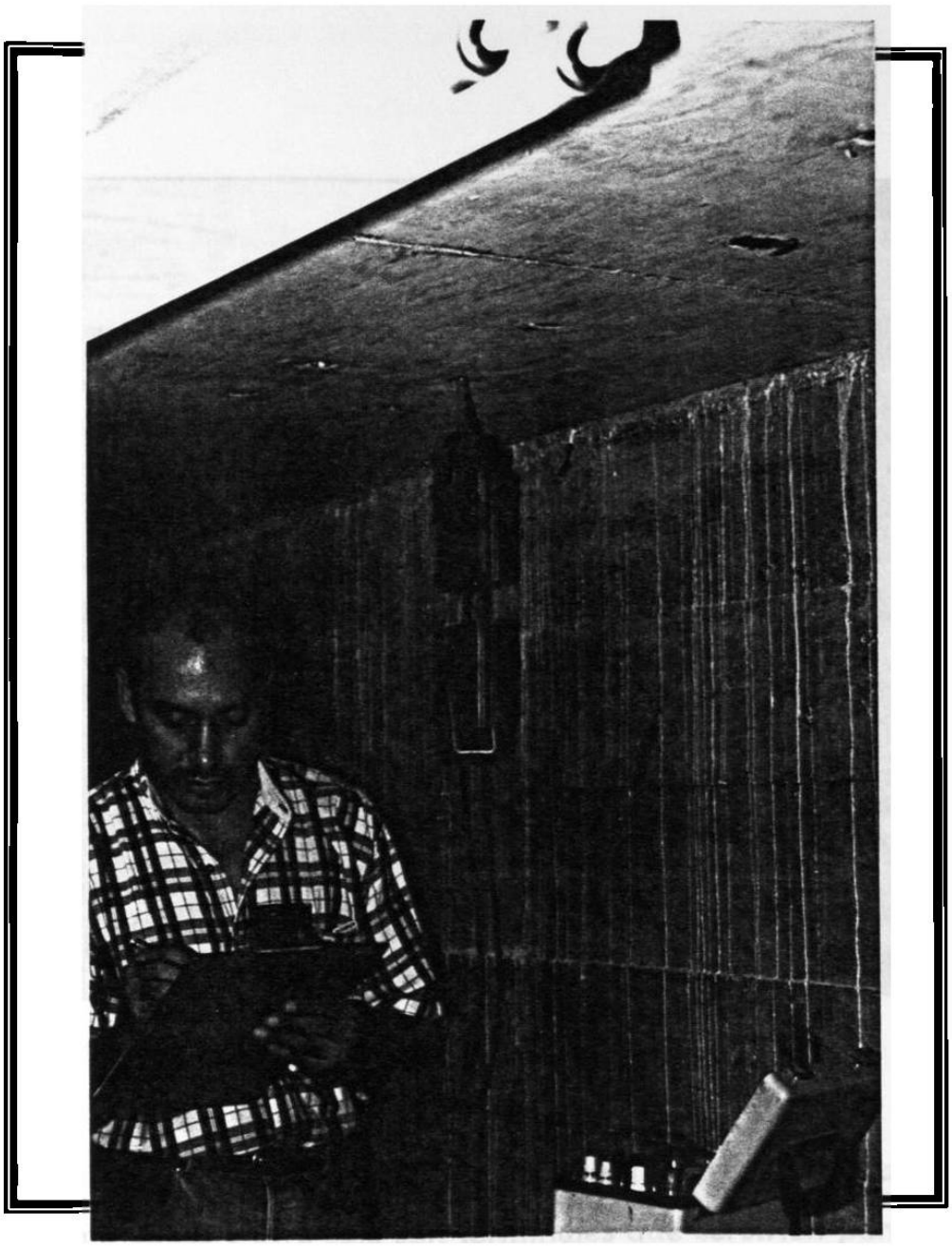
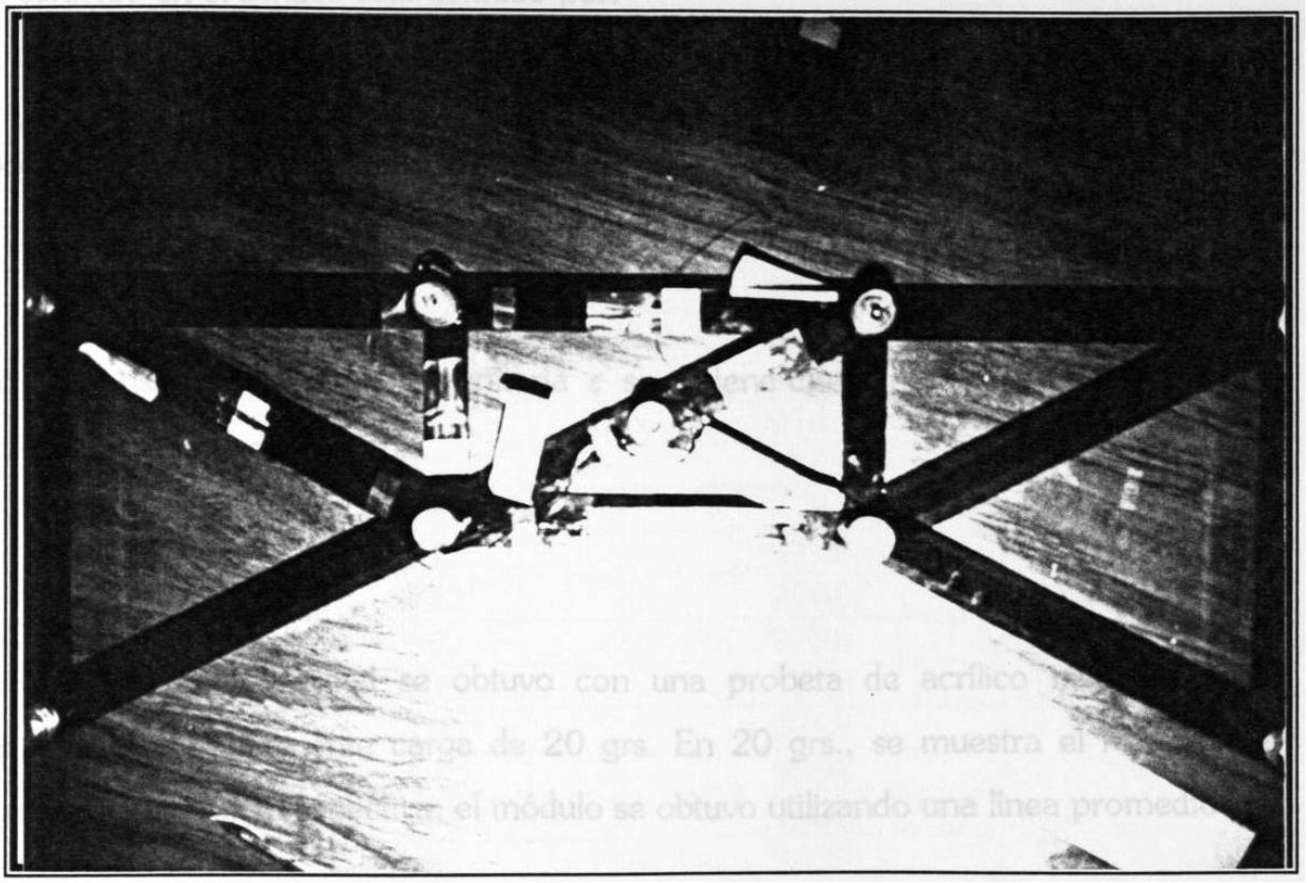


En la fotografía se aprecia la lectura en el puente por parte del instructor.

En esta fotografía se muestra la instrumentación terminada de un "strain gage", la caja de los strain gages y otra caja con terminales que servirían para realizar la instrumentación.



Esta fotografía nos muestra parte de una de las armaduras totalmente conectada.

V.4.1. Obtención del método de elasticidad del acrílico.

El esfuerzo en el acrílico esta definido por:

$$T = E\varepsilon$$

Donde:

$$T = esfuerzo\ en\ kg/cm^2$$
$$E = módulo\ de\ elasticidad\ en\ kg/cm^2$$
$$\varepsilon = deforción\ unitaria$$

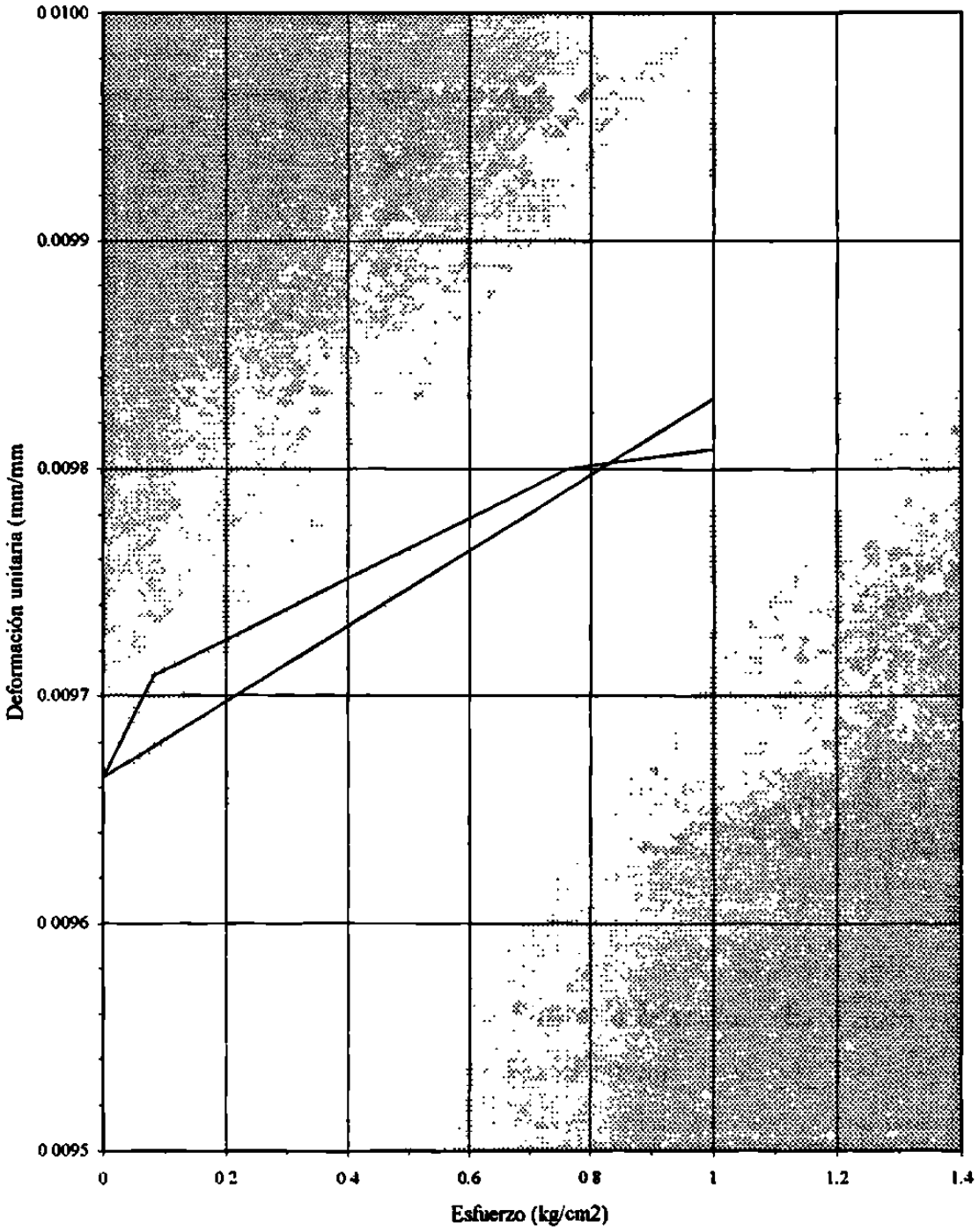
en este ensaye la deformación unitaria ε se obtiene directamente del strain gages a través del puente de Winston.

El módulo de elasticidad se obtuvo con una probeta de acrílico instrumentado aplicándole gradualmente carga de 20 grs. En 20 grs., se muestra el registro de lecturas y la gráfica respectiva, el módulo se obtuvo utilizando una línea promedio:

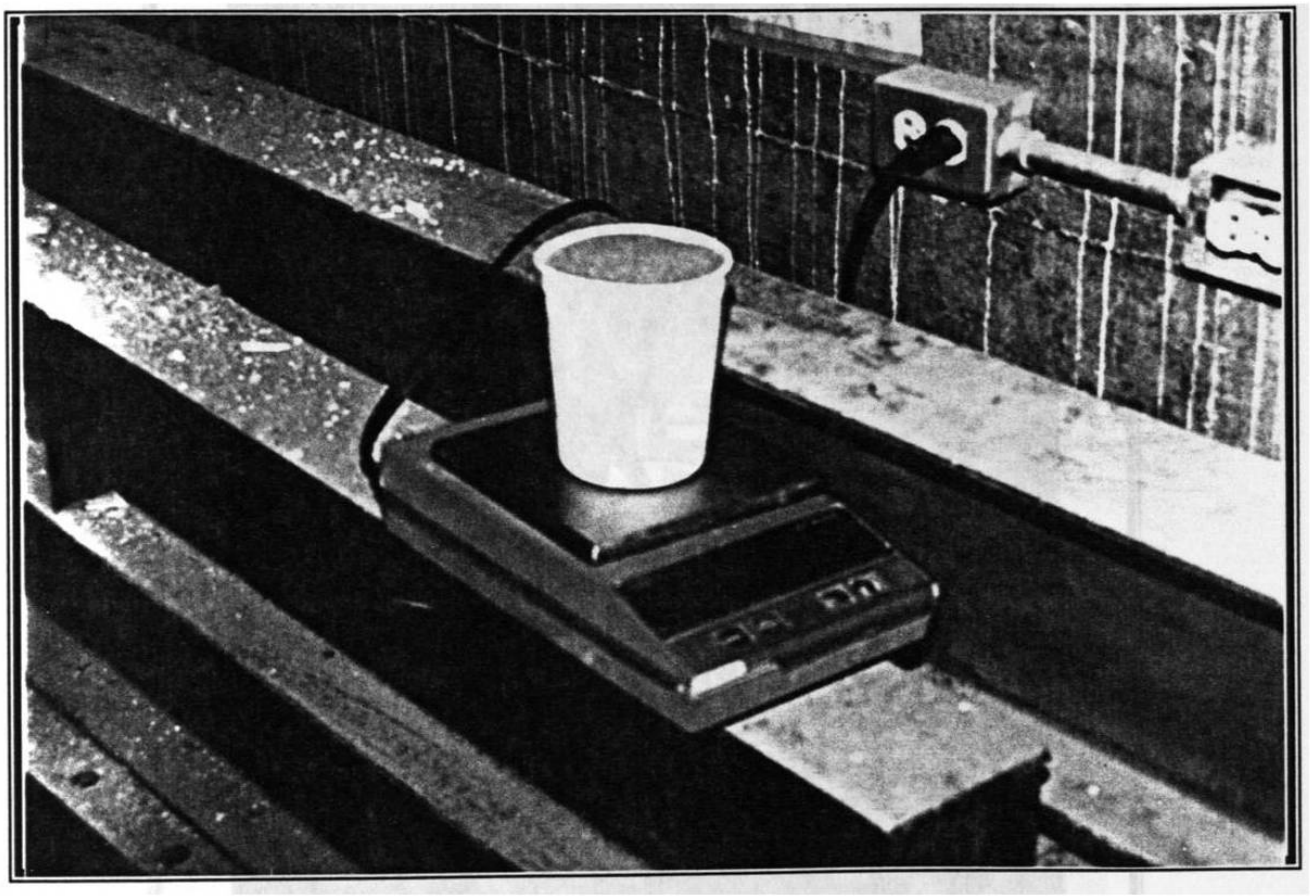
$$E = \frac{0.827 \quad 0}{0.0098 - 0.009662} = 5993 \approx 6000 kg/cm^2$$

Carga (gramos)	*Lectura X10^{-6}*
0	9662
20	9682
40	9694
60	9702
80	9712
100	9719
120	9723
140	9732
160	9736
180	9741
200	9743
220	9748
240	9753
250	9756
300	9768
350	9778
400	9789
450	9798
500	9803
550	9806
600	9807

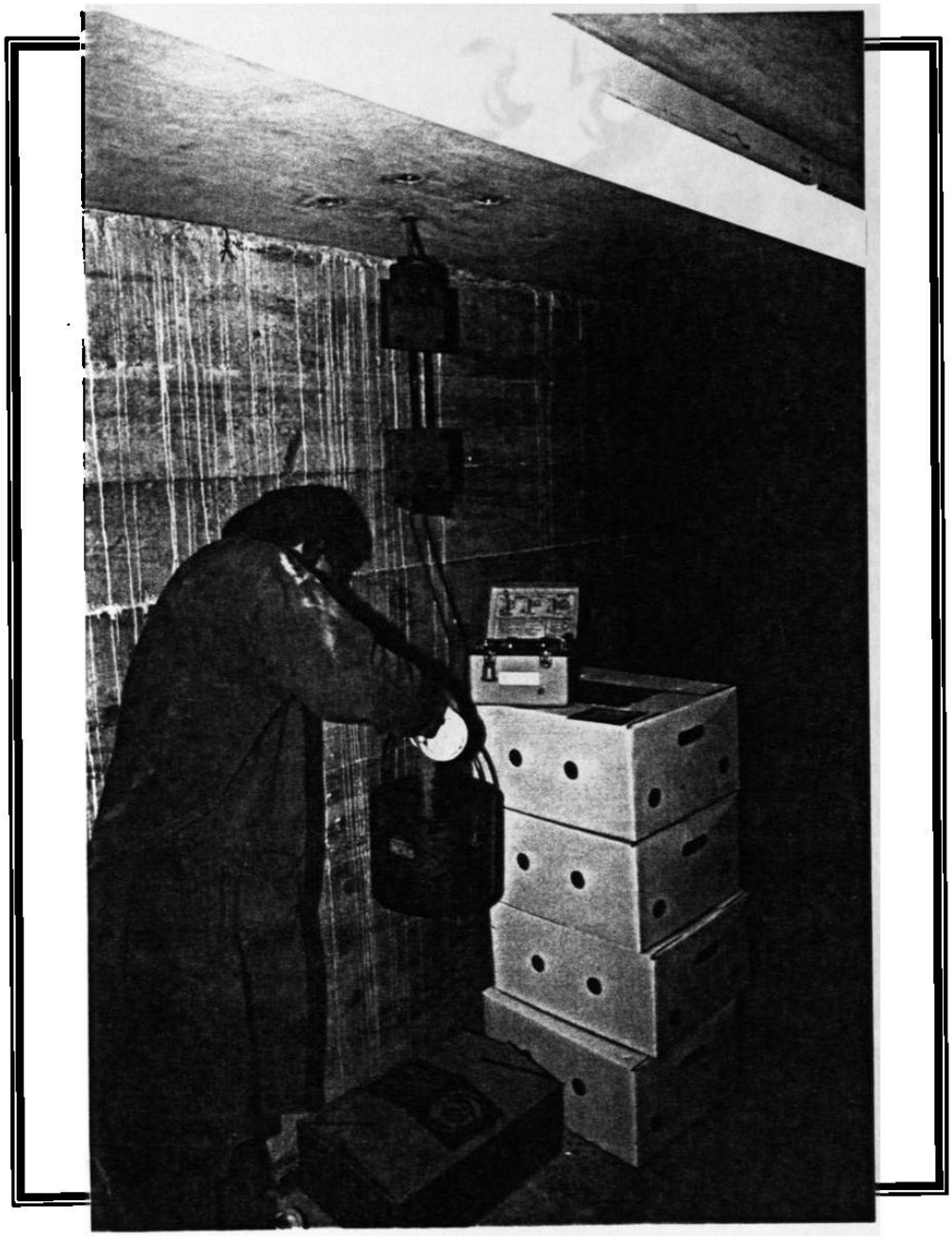
GRAFICA DE ESFUERZO vs DEFORMACION



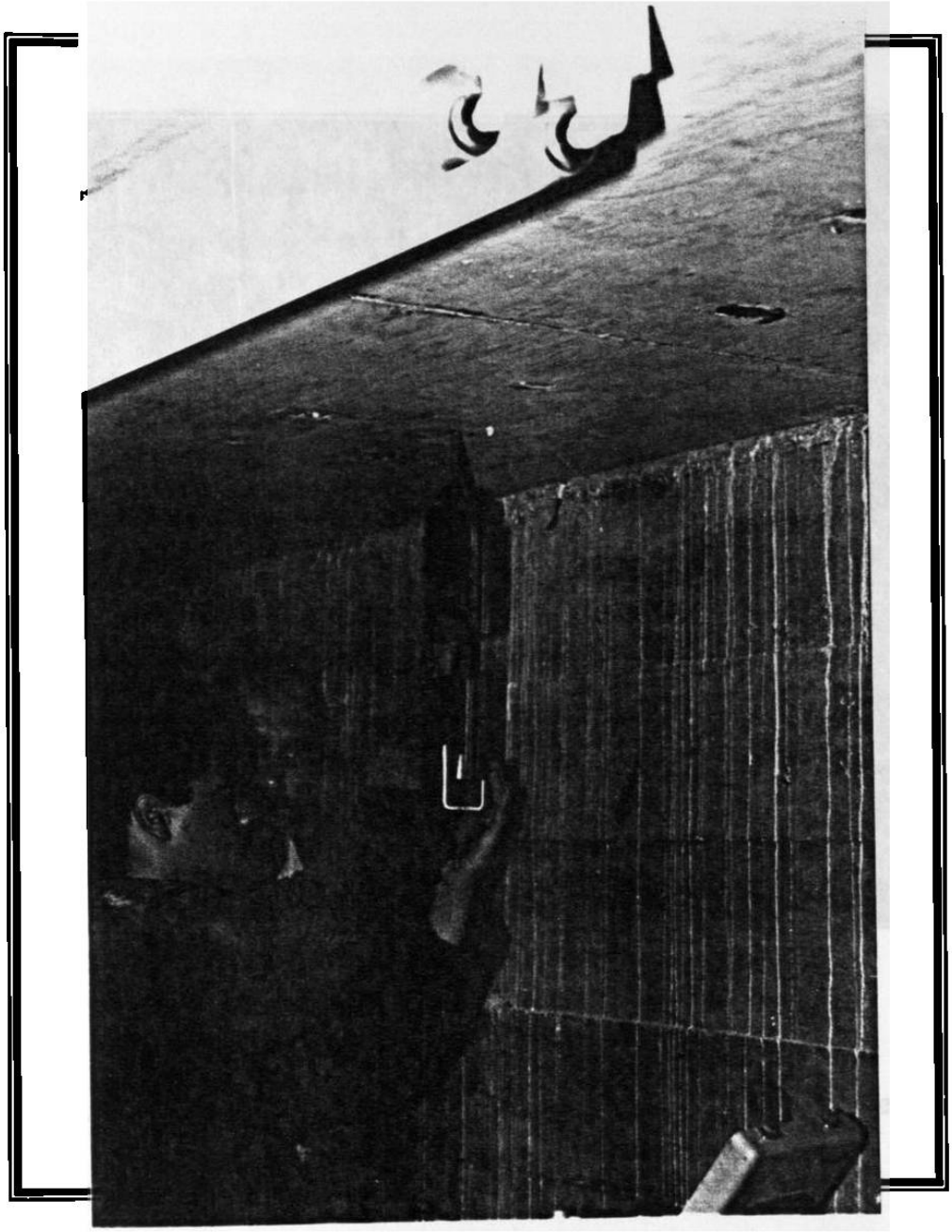
V.4.2. Obtención del módulo de elasticidad del acrílico.



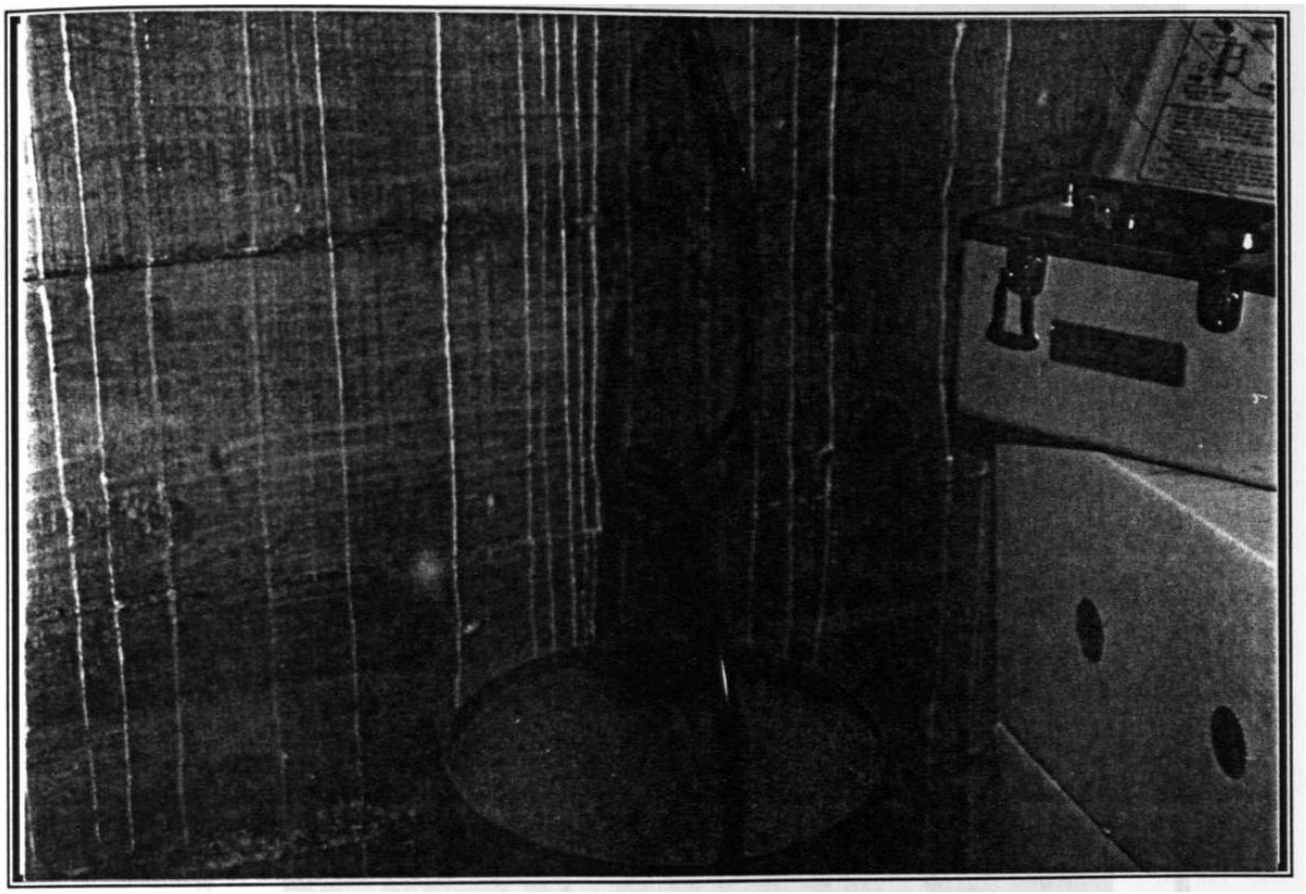
Obtención del peso de arena sílica mediante la báscula. Este dato nos ayudará para hacer un registro de cargas añadidas al ensaye.



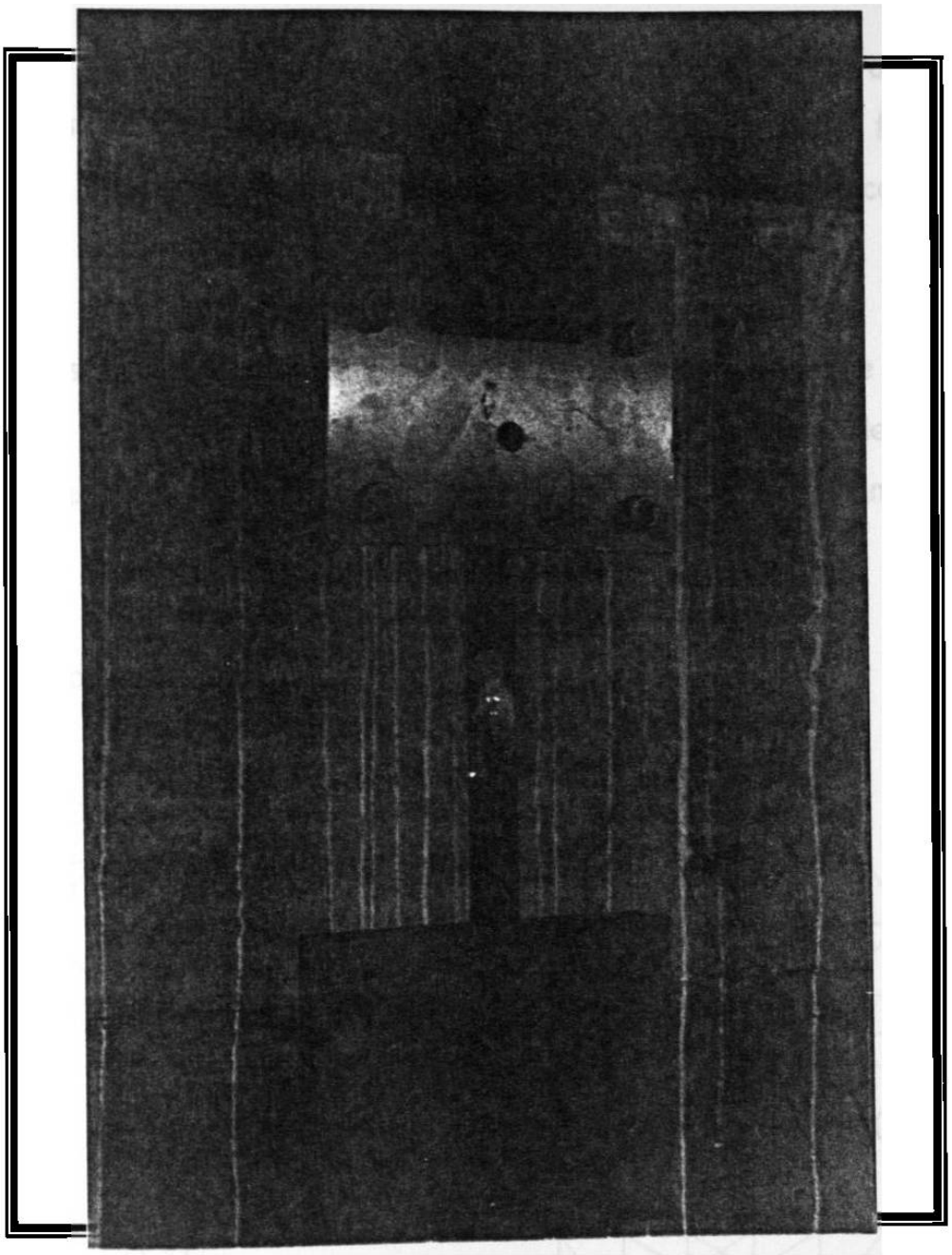
Fotografía tomada durante la aplicación de la carga mediante arena sílica.



En la fotografía se nos muestra a un ayudante realizando la sujeción de una pieza metálica que servirá para después colocarle un gancho en el que se coloca una tina para irle añadiendo la carga.



La fotografía muestra la aplicación de la carga realizada mediante arena sílica.



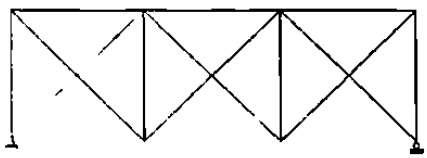
Esta fotografía se representa la probeta para realizar el ensaye a tensión para obtener el módulo de elasticidad del acrílico.

V.5. Solución analítica de armaduras.

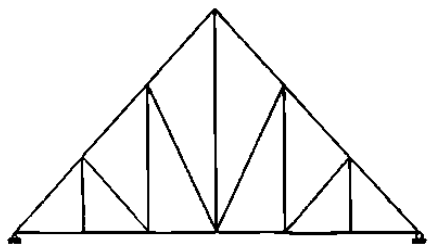
Para fases de este trabajo, se escogieron cinco armaduras y se reprodujeron a escala en acrílico, se instrumentó algunos elementos con strain gages con el fin de que éstos, a través de deformaciones nos indicarán las fuerzas de tensión o compresión en cada elemento instrumentado.

Para comparar los resultados experimentales con la referencia teórica, se analizarán cinco armaduras isostáticas, estas fueron resueltas por el método de nudos y secciones; además se analizaron con un programa computacional, llamado SAP 2000.

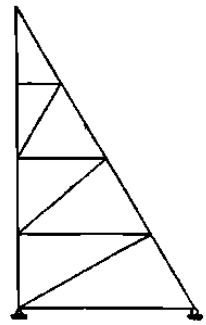
Las armaduras propuestas son:



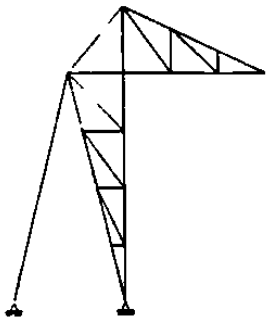
(1)



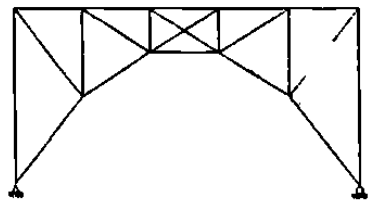
(2)



(3)

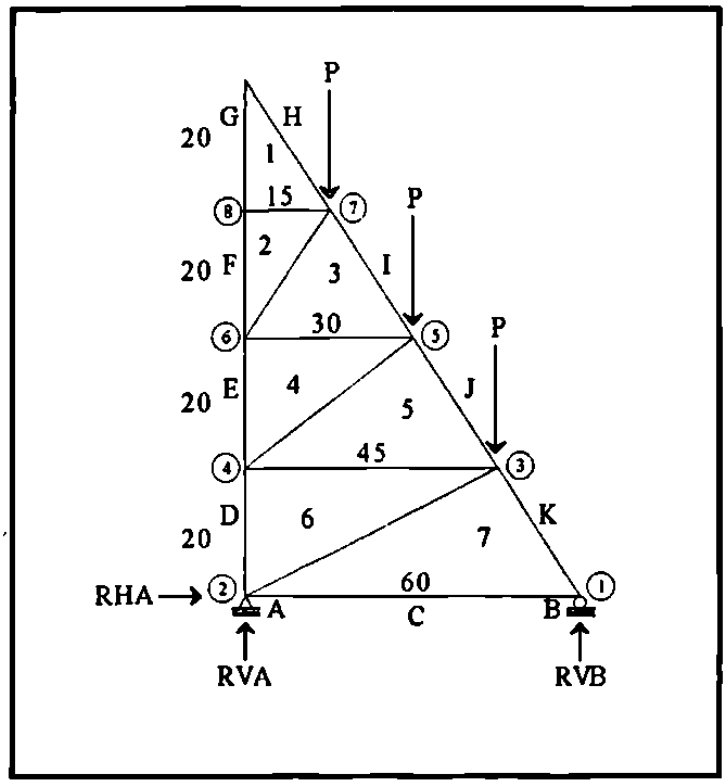


(4)



(5)

V.5.1. Armadura 1



$\Sigma Fx = 0$

$$\boxed{RH_A = 0}$$

$\Sigma M_A = 0$

$$-RV_B(60) + 45P + 30P + 15P = 0$$
$$-RV_B(60) + 90P = 0$$
$$-RV_B = -90P / 60P$$

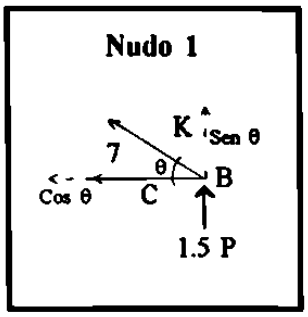
$$\boxed{RV_B = 1.5P}$$

$\Sigma Fy = 0$

$$RV_A + RV_B - 3P = 0$$
$$RV_A + 1.5P - 3P = 0$$
$$RV_A - 1.5P = 0$$

$$\boxed{RV_A = 1.5P}$$

Nota: Signo + indica tensión
signo – indica compresión.



$$\theta = arctan\frac{80}{60} = 53°$$

$$\Sigma Fy = 0$$

$$F_{7K}(\text{sen}\,53°) + 1.5P = 0$$

$$F_{7K} = -\frac{1.5P}{\text{sen}\,53°}$$

$$\boxed{F_{7K} = -1.88P}$$ compresión

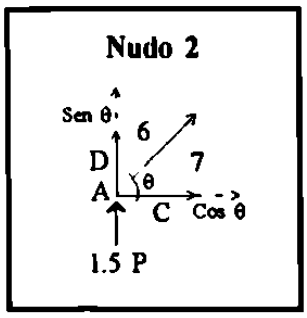
$$\Sigma Fx = 0$$

$$F_{7C} - F_{7K}\cos 53° = 0$$

$$F_{7C} - (-1.88P)(\cos 53°) = 0$$

$$F_{7C} + 1.13P = 0$$

$$\boxed{F_{7C} = 1.13P}$$ tensión



$$\theta = arctan\frac{20}{45} = 24°$$

$$\Sigma Fx = 0$$

$$F_{67}(\cos 24°) + F_{7C} = 0$$

$$F_{67}(\cos 24°) + 1.13P = 0$$

$$F_{67} = -\frac{1.13P}{\cos 24°}$$

$$\boxed{F_{67} = -1.24P}$$ compresión

$$\Sigma Fy = 0$$

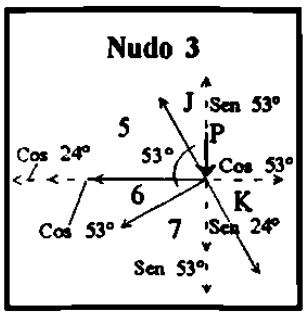
$$F_{6D} + F_{67}(\text{sen}\,24°) + 1.5P = 0$$

$$F_{6D} + (-1.24P)(\text{sen}\,24°) + 1.5P = 0$$

$$F_{6D} - 0.5P + 1.5P = 0$$

$$F_{6D} + P = 0$$

$$\boxed{F_{6D} = -P}$$ compresión

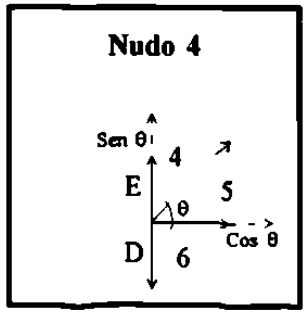


$$\Sigma Fy = 0$$
$$F_{5J}(\text{sen}53°) - F_{67}(\text{sen}24°) - F_{7K}(\text{sen}53°) - P = 0$$
$$F_{5J}(\text{sen}53°) - (-1.24P)(\text{sen}24°) - (-1.88P)(\text{sen}53°) - P = 0$$
$$F_{5J}(\text{sen}53°) + 0.5P + 1.5P - P = 0$$
$$F_{5J}(\text{sen}53°) + P = 0$$
$$F_{5J} = -P/\text{sen}53°$$

$$\boxed{F_{5J} = -1.25P}$$ compresión

$$\Sigma Fx = 0$$
$$F_{56} - F_{5J}(\cos 53°) - F_{67}(\cos 24°) + F_{7K}(\cos 53°) = 0$$
$$F_{56} - (-1.25P)(\cos 53°) - (-1.24P)(\cos 24°) + (-1.88P)(\cos 53°) = 0$$
$$F_{56} + 0.75P + 1.13P - 1.13P = 0$$

$$\boxed{F_{56} = 0.75P}$$ tensión

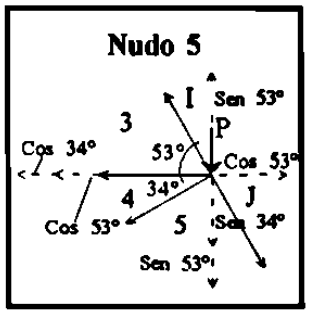


$$\Sigma Fx = 0$$
$$F_{45}(\cos 34°) + F_{56} = 0$$
$$F_{45}(\cos 34°) + F_{56} = 0$$
$$F_{45} = -\frac{0.75P}{\cos 34°}$$

$$\boxed{F_{45} = -0.9P}$$ compresión

$$\Sigma Fy = 0$$
$$F_{4E} + F_{45}(\text{sen}\,34°) - F_{6D} = 0$$
$$F_{4E} + (-0.9P)(\text{sen}\,34°) - (-P) = 0$$
$$F_{4E} - 0.5P + P = 0$$
$$F_{4E} + 0.5P = 0$$

$$\boxed{F_{4E} = -0.5P}$$ compresión

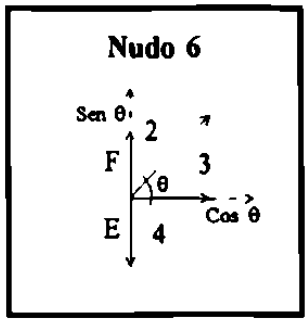


$$\Sigma Fy = 0$$
$$F_{3I}(\text{sen}\,53°) - F_{45}(\text{sen}\,34°) - F_{5J}(\text{sen}\,53°) - P = 0$$
$$F_{3I}(\text{sen}\,53°) - (-0.9)(\text{sen}\,34°) - (-1.25P)(\text{sen}\,53°) - P = 0$$
$$F_{3I}(\text{sen}\,53°) + 0.5P + P - P = 0$$
$$F_{3I} = -\frac{0.5P}{\text{sen}\,53°}$$

$$\boxed{F_{3I} = -0.63P}$$ compresión

$$\Sigma Fx = 0$$
$$F_{34} - F_{3I}(\cos 53) - F_{45}(\cos 34°) + F_{5J}(\cos 53°) = 0$$
$$F_{34} - (-0.63P)(\cos 53°) - (-0.9P)(\cos 34°) + (1.25P)(\cos 53°) = 0$$
$$F_{34} + 0.38P + 0.75P - 0.75P = 0$$

$$\boxed{F_{34} = 0.38P}$$ tensión

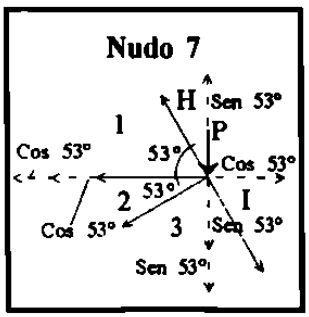


$$\theta = arcton\frac{20}{15} = 53°$$
$$\Sigma Fx = 0$$
$$F_{23}(\cos 53°) + F_{34} = 0$$
$$F_{23}(\cos 53°) + 0.38P = 0$$
$$F_{23} = -\frac{0.38P}{\cos 53°}$$

$$\boxed{F_{23} = -0.63P}$$ compresión

$$\Sigma Fy = 0$$
$$F_{2F} + F_{23}(\text{sen}\,53°) - F_{4E} = 0$$
$$F_{2F} + (-0.63P)(\text{sen}\,53°) - (-0.5P) = 0$$
$$F_{2F} - 0.5P + 0.5P = 0$$

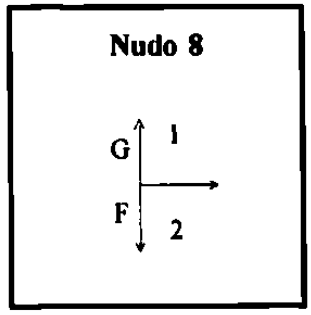
$$\boxed{F_{2F} = 0}$$



$$\Sigma Fy = 0$$
$$F_{1H}(\text{sen}53°) - F_{23}(\text{sen}53°) - F_{3I}(\text{sen}53°) - P = 0$$
$$F_{1H}(\text{sen}53°) - (0.63P)(\text{sen}53°) - 0.63P(\text{sen}53°) - P = 0$$
$$F_{1H}(\text{sen}53°) + 0.5P + 0.5P - P = 0$$

$$\boxed{F_{1H} = 0}$$

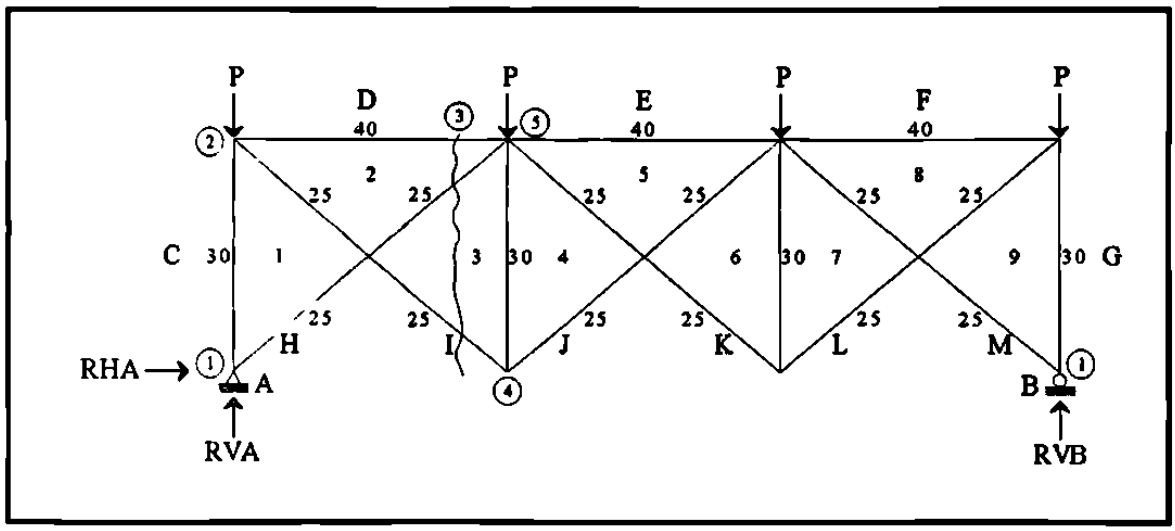
$$\Sigma Fx = 0$$
$$F_{12} - F_{1H}(\cos 53°) - F_{23}(\cos 53°) + F_{3I}(\cos 53°) = 0$$
$$F_{12} - (0)(\cos 53°) - (-0.63P)(\cos 53°) + (-0.63P)(\cos 53°) = 0$$
$$F_{12} - 0 + 0.38P - 0.38P = 0$$
$$\boxed{F_{12} = 0}$$



$$\Sigma Fy = 0$$
$$F_{1G} - F_{2F} = 0$$
$$F_{1G} - 0 = 0$$

$$\boxed{F_{1G} = 0}$$

V.5.2. Armadura 2



$\Sigma Fx = 0$

$$\boxed{RH_A = 0}$$

$\Sigma M_A = 0$

$-RV_B(120) + 40P + 80P + 120P = 0$

$-RV_B(120') + 240P = 0$

$$-RV_B = -\frac{240P}{120}$$

$$\boxed{RV_B = 2P}$$

$\Sigma Fy = 0$

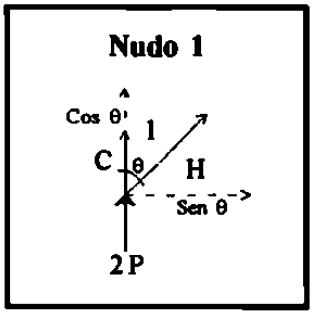
$RV_A + RV_B - 4P = 0$

$RV_A + 2P - 4P = 0$

$RV_A - 2P = 0$

$$\boxed{RV_A = 2P}$$

Nota: Signo + indica tensión
Signo – indica compresión.



$$\theta = arctan\frac{20}{15} = 53°$$

$$\Sigma Fx = 0$$

$$F_{1H}(\text{sen } 53°) = 0$$

$$\boxed{F_{1H} = 0}$$

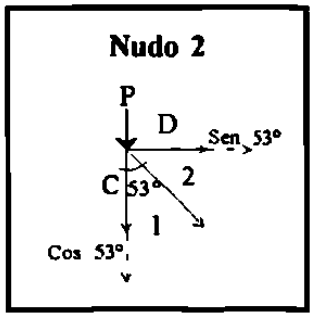
$$\Sigma Fy = 0$$

$$F_{1C} + F_{1H}(\cos 53°) + 2P = 0$$

$$F_{1C} + (0)(\cos 53°) + 2P = 0$$

$$F_{1C} + 0 + 2P = 0$$

$$\boxed{F_{1C} = 2P}$$ compresión



$$\Sigma Fy = 0$$

$$-F_{12}(\cos 53°) - F_{1C} - P = 0$$

$$-F_{12}(\cos 53°) - (-2P) - P = 0$$

$$-F_{12}(\cos 53°) + 2P - P = 0$$

$$-F_{12}(\cos 53°) + P = 0$$

$$-F_{12} = -\frac{P}{\cos 53°}$$

$$\boxed{F_{12} = 1.66P}$$ tensión

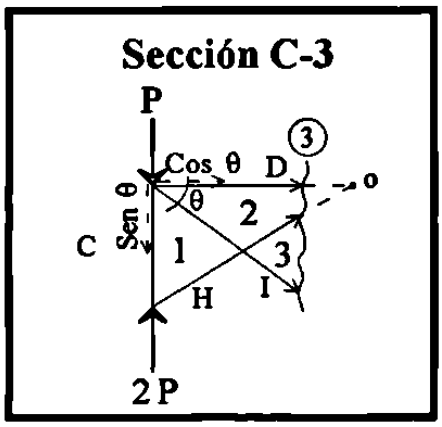
$$\Sigma Fx = 0$$

$$F_{2D} + F_{12(}\text{ sen } 53°) = 0$$

$$F_{2D} + (1.66P)(\text{sen } 53°) = 0$$

$$F_{2D} + 1.33P = 0$$

$$\boxed{F_{2D} = -1.13P}$$ compresión



Incógnitas

$F_{31} = ?$

$\theta = \arctan \dfrac{15}{20} = 37°$

$\Sigma Mo = 0$

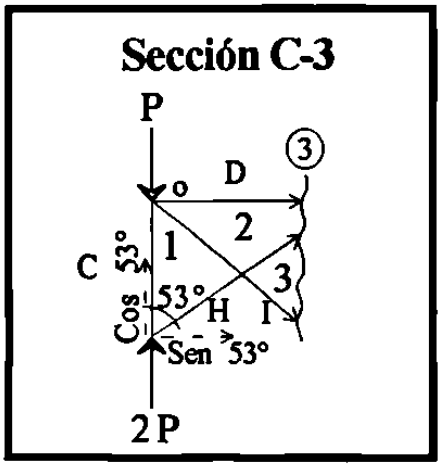
$F_{3I}(\text{sen } 37°)(40) + 40P - 2P(40) = 0$

$F_{3I}(24.07) + 40P - 80P = 0$

$F_{3I}(24.07) - 40P = 0$

$F_{3I} = \dfrac{40P}{24.07}$

$\boxed{F_{3I} = 1.66P}$ tensión



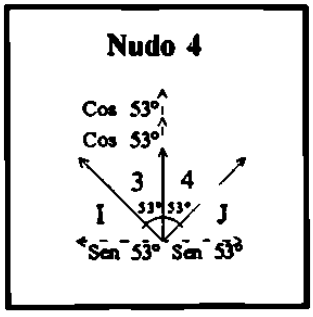
Incógnitas

$F_{23} = ?$

$\Sigma Mo = 0$

$-F_{23}(\text{sen } 53°) = 0$

$\boxed{F_{23} = 0}$



$\Sigma Fx = 0$

$F_{4J}(\text{sen } 53°) - F_{3I}(\text{sen } 53°) = 0$

$F_{4J}(\text{sen } 53°) - (1.66P)(\text{sen } 53°) = 0$

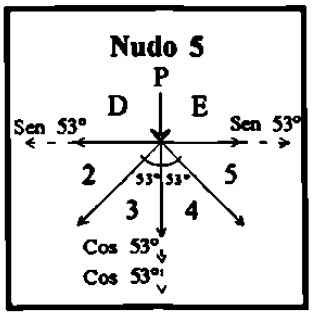
$F_{4J}(\text{sen } 53°) - 1.33P = 0$

$F_{4J} = \dfrac{1.33P}{\text{sen } 53°}$

$\boxed{F_{4J} = 1.67P}$ tensión

$$\Sigma Fy = 0$$
$$F_{34} + F_{3J}(\cos 53°) + F_{4J}(\cos 53°) = 0$$
$$F_{34} + 1.66P(\cos 53°) + 1.67P(\cos 53°) = 0$$
$$F_{34} + P + P = 0$$
$$F_{34} + 2P = 0$$

$$\boxed{F_{34} = 2P}$$ compresión



$$\Sigma Fy = 0$$
$$F_{45}(\cos 53°) - F_{23}(\cos 53°) - F_{34} - P = 0$$
$$F_{45}(\cos 53°) - (0)(\cos 53°) - (-2P) - P = 0$$
$$F_{45}(\cos 53°) - (0) + 2P - P = 0$$
$$F_{45}(\cos 53) - 0 + P = 0$$
$$F_{45} = \frac{-P}{\cos 53°}$$

$$\boxed{F_{45} = -1.66P}$$ compresión

$$\Sigma Fx = 0$$
$$F_{5E} + F_{45}(\text{sen } 53°) - F_{23}(\text{sen } 53°) - F_{2D} = 0$$
$$F_{5E} + (1.66P)(\text{sen } 53) - (0)(\text{sen } 53°) - (-1.33P) = 0$$
$$F_{5E} - 1.33P - 0 + 1.33P = 0$$

$$\boxed{F_{5E} = 0}$$

Nota: como la armadura es simétrica, entonces:

$F_{1C} = F_{9G} = 2P$ compresión

$F_{1H} = F_{9M} = 0$

$F_{12} = F_{89} = 1.66P$ tensión

$F_{2D} = F_{8F} = 1.33P$ compresión

$F_{23} = F_{78} = 0$

$F_{3J} = F_{7L} = 1.66P$ tensión

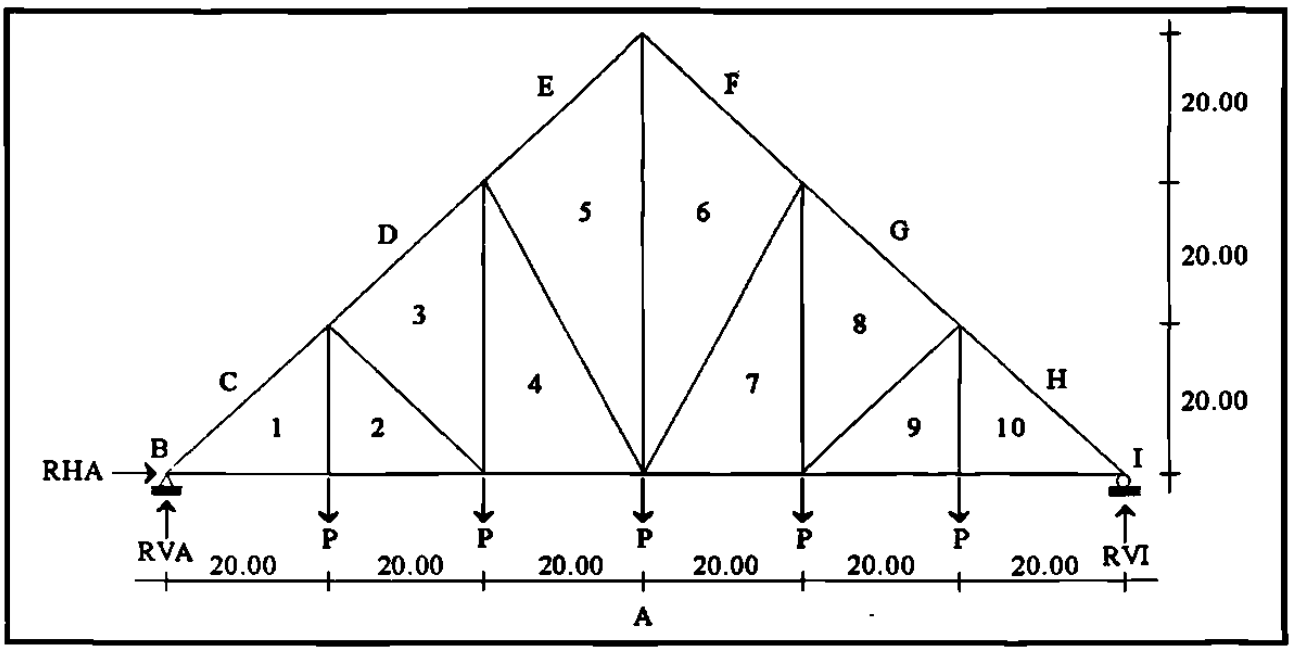
$F_{4J} = F_{6K} = 1.67P$ tensión

$F_{45} = F_{56} = 1.66P$ compresión

$F_{34} = F_{67} = 2P$ compresión

$F_{E5} = 0$

V.5.3. Armadura 3



$$\Sigma M_A = P(20) + P(40) + P(60) + P(80) + P(100) - R_{VI}(120) = 0$$

$$P(300) - RV_I(120) = 0$$

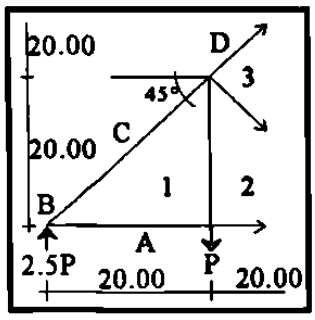
$$R_{VI} = \frac{300}{120}P \qquad RV_I = 2.5P$$

$$\Sigma Fy = 5P - RV_A - 2.5P = 0$$

$$RV_A = 5P - 2.5P \qquad RV_A = 2.5P$$

$$\Sigma Fx = RH_A = 0 \qquad \boxed{RH_A = 0}$$

Nota: Signo + indica tensión.
Signo – indica compresión.



$$\Sigma M_{C-1} 0 = 2.5P(20) + (F_{1A})(20) = 0$$

$$F_{1A} = \frac{-2.5P(20)}{(20)}$$

$$\boxed{F_{1A} = -2.5P}$$ compresión

$$\Sigma M_{A-1} = 2.5P(20) + [F_{1C} \cos 45°(20)] = 0$$

$$50P + F_{1C}\ 14.14 = 0$$

$$F_{1C} = \frac{50P}{14.14}$$

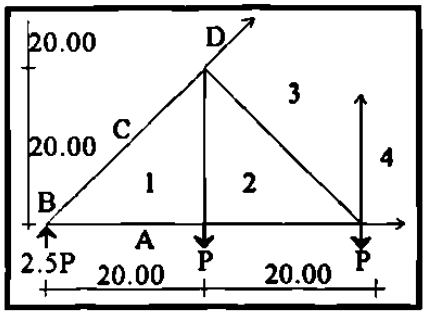
$$\boxed{F_{1C} = 3.54P}$$ tensión

$$\Sigma M_{A-2} = 2.5P(40).P(20) + F_{12}(20) - F_{1C}(\text{sen } 45°)(40) = 0$$

$$80P + F_{12}(20) - (100) = 0$$

$$F_{12} = \frac{(100 - 80(P}{20} = \frac{20P}{20}$$

$$\boxed{F_{12} = 1P}$$ tensión



$$\Sigma M_A = P(20) + F_{23} \text{ sen } 45°(40) = 0$$

$$F_{23} = \frac{20P}{28.28} = 0.71P$$

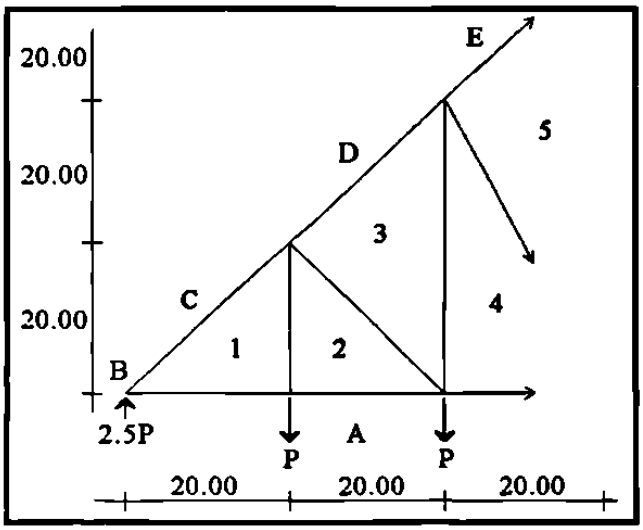
$$\boxed{F_{23} = 0.71P}$$ tensión

$$\Sigma M_{A-3} = 2.5P(40) - P(40) + F_{3D}(\sqrt{800}) = 0$$

$$F_{3D} = \frac{80P}{\sqrt{800}}$$

$$\boxed{F_{3D} = 2.83P}$$

tensión



$$\Sigma M_{C-1} = 2.5P(20) - F_{2A}(20) = 20$$

$$F_{2A} = \frac{2.5P(20)}{20}$$

$$\boxed{F_{2A} = 2.5P}$$ tensión

$$\Sigma M_A = -P(20) - P(40) - F_{34}(40) = 0$$

$$F_{34} = \frac{60P}{40}$$

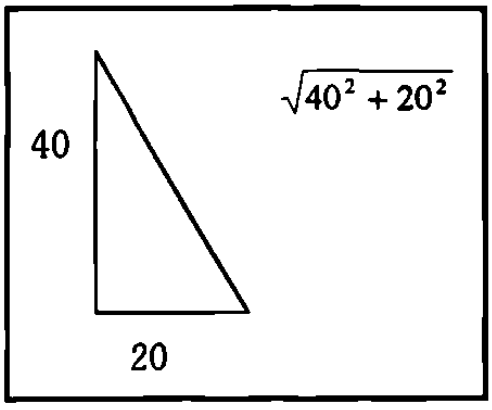
$$\boxed{F_{34} = 1.5P}$$ tensión

$$\Sigma M_{A-4} = 2.5P(60) - P(40) - P(20) + (F_E)(\sqrt{2000}) = 0$$

$$150P - 60P + F_E(\sqrt{2000}$$

$$F_E = \frac{-90P}{\sqrt{40^2 + 20^2}}$$

$$\boxed{F_E = 2.01P}$$



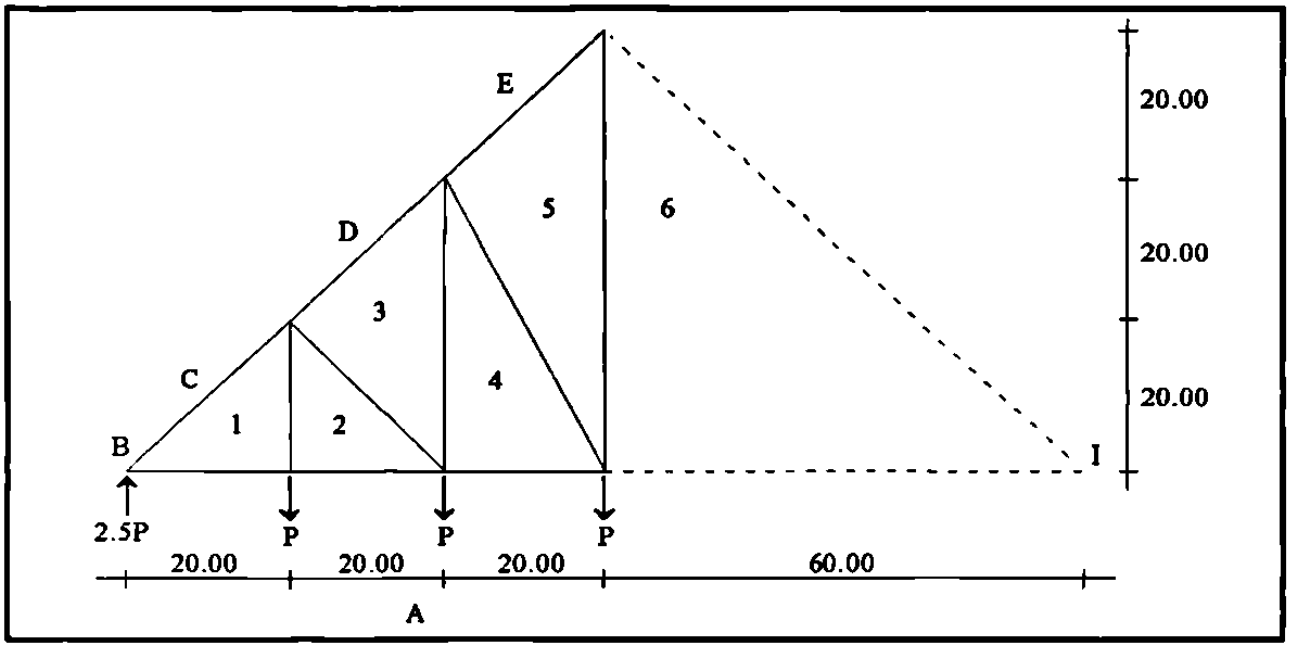
$$\text{tg}\,\theta = \frac{40}{20}$$

$$\theta = 63°26'$$

$$\Sigma M_A = 0$$
$$\Sigma M_A = -P(20) - P(40) - F_{45} \text{ sen } 63°26^1(60) = 0$$
$$-60P + F_{45}(53.66) = 0$$
$$F_{45} - \frac{60p}{53.66}$$
$$\boxed{F_{45} = 1.12P}$$

$$\Sigma M_{E-5} = 2.5P(40) - 20P - F_{4A}(40) = 0$$
$$100P - 20P - F_{4A}(40) = 0$$
$$80P - F_{4A}(40) = 0$$
$$F_{4A} = \frac{80P}{40}$$
$$\boxed{F_{4A} = 2P}$$

V.5.4. Armadura 4



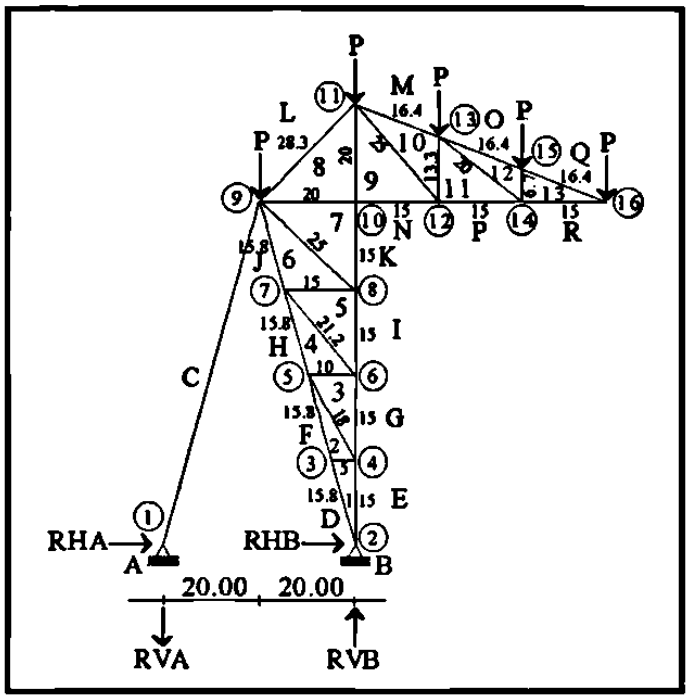
$$\Sigma M_I = 0 \Rightarrow 2.5P(120) - P(100) - P(80) - P(60) + F_{56}60$$

$$300P - 240P + F_{56}60$$

$$F_{56} = \frac{60P}{60}$$

$$\boxed{F_{56} = 1P}$$

RV_A	RH_A	RV_I	F_{1A}	F_{1C}	F_{12}	F_{2A}	F_{23}	F_{3D}	F_{34}	F_{4A}	F_{45}	F_{5E}	F_{56}
2.5 P	0	2.5P	-2.5P	3.53P	1P	2.5P	.707p	2.82P	1.5P	2P	1.12P	2.01P	1P

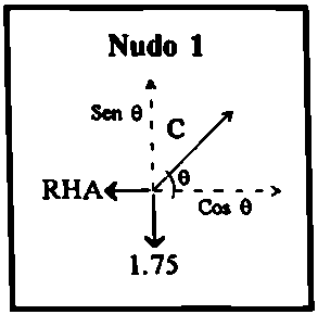


$$\Sigma M_A = 0$$
$$-RV_B(40) + 20P + 40P + 55P + 70P + 85P = 0$$
$$-RV_B(40) + 270P = 0$$
$$-RV_B = \frac{-270P}{40}$$

$$\boxed{RV_B = 6.75P}$$

$$\Sigma Fy = 0$$
$$-RV_A + RV_B - 5P = 0$$
$$-RV_A + 6.75P - 5P = 0$$
$$-RV_A + 1.75P = 0$$

$$\boxed{RV_A = 1.75P}$$



$$\theta = arcton\frac{60}{20} = 72°$$

$$\Sigma Fy = 0$$

$$F_C \text{ sen } 72°) - 1.75P = 0$$

$$F_C = -\frac{1.75P}{\text{sen } 72°}$$

$$\boxed{F_C = 1.84P}$$ tensión

$$\Sigma Fx = 0$$

$$-RH_A + F_C(\cos 72°) = 0$$

$$-RH_A + (1.84P(\cos 72°) = 0$$

$$-RH_A + 0.57P = 0$$

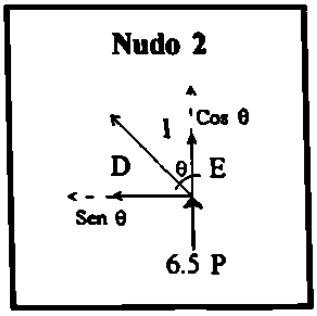
$$\boxed{RH_A = 0.57P}$$

$$\Sigma Fx = 0$$

$$-RH_A + RH_B = 0$$

$$-0.57P + RH_B = 0$$

$$\boxed{RH_B = 0.57P}$$



$$\theta = arcton\frac{5}{15} = 18°$$

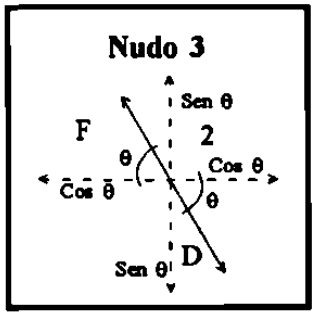
$$\Sigma Fx = 0$$

$$F_{1D}(\text{sen } 18°) + 0.57P = 0$$

$$F_{1D} = -\frac{0.57P}{\text{sen } 18°}$$

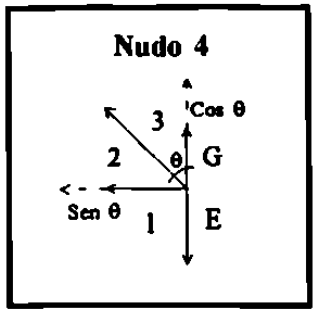
$$\boxed{F_{1D} = -1.84P}$$ tensión

$$\Sigma Fy = 0$$
$$F_{1E} + F_{1D}(\cos 18°) + 6.75P = 0$$
$$F_{1E} + (1.84P)(\cos 18°) + 6.75P = 0$$
$$F_{1E} + 1.75 + 6.75P = 0$$
$$F_{1E} + 8.5P = 0$$
$$\boxed{F_{1E} = -8.5P}$$ compresión



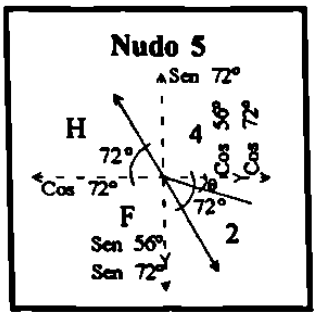
$$\theta = arcton\frac{15}{5} = 72°$$
$$\Sigma Fy = 0$$
$$F_{2F}(\text{sen } 72°) - F_{1D}(\text{sen } 72°) = 0$$
$$F_{2F}(\text{sen } 72°) - (1.84P)(\text{sen } 72°) = 0$$
$$\boxed{F_{2F} = 1.84P}$$ tensión

$$\Sigma Fx = 0$$
$$F_{12} - F_{2F}(\cos 72°) + F_{1D}(\cos 72°) = 0$$
$$F_{12} - (1.84P)(\cos 72°) + (1.84P)(\cos 72°) = 0$$
$$\boxed{F_{1-2} = 0}$$



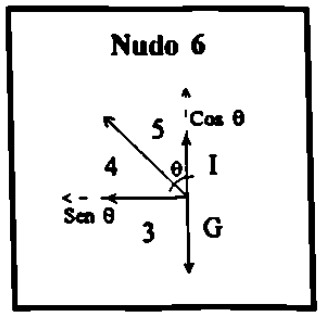
$$\theta = arctan = \frac{10}{15} = 34°$$
$$\Sigma Fx = 0$$
$$F_{23}(\text{sen } 34°)F_{12} = 0$$
$$F_{23}(\text{sen } 34°) - 0 = 0$$
$$\boxed{F_{23} = 0}$$

$$\Sigma Fy = 0$$
$$F_{3G} + F_{23}(\cos 34°) - F_{1E} = 0$$
$$F_{3G} + (0)(\cos 34°) - (-8.5P) = 0$$
$$F_{3G} + 0 + 8.5P = 0$$
$$\boxed{F_{3G} = -8.5P}$$ compresión



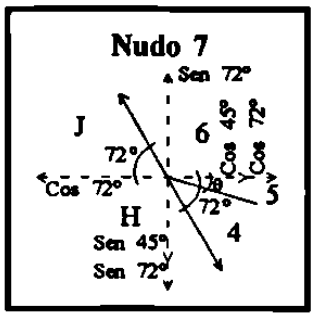
$$\theta = arcton\frac{5}{10} = 56°$$
$$\Sigma Fy = 0$$
$$F_{4H}(\text{sen } 72°) - F_{23}(\text{sen } 56°) - F_{2F}(\text{sen } 72°) = 0$$
$$F_{4H}(\text{sen } 72°) - (0)(\text{sen } 56°) - (1.84P)(\text{sen } 72) = 0$$
$$F_{4H}(\text{sen } 72°) - 0 - (1.84P)(\text{sen } 72°) = 0$$
$$\boxed{F_{4H} = 1.84P}$$ tensión

$$\Sigma Fx = 0$$
$$F_{34} - F_{4H}(\cos 72°) - F_{2F}\cos 72° - F_{23}(\cos 56°) = 0$$
$$F_{34} - (1.84P)(\cos 72°) + (1.84P)(\cos 72°) + -(0)(\cos 56°) = 0$$
$$\boxed{F_{34} = 0}$$



$$\theta = arctan\frac{15}{15} = 45°$$
$$\Sigma Fx = 0$$
$$-F_{45}(\text{sen } 45°) - F_{34} = 0$$
$$-F_{45}(\text{sen } 45°) - 0 = 0$$
$$\boxed{F_{45} = 0}$$

$$\Sigma Fy = 0$$
$$F_{5I} + F_{45}(\cos 45°) - F_{3G} = 0$$
$$F_{5I} + (0)(\cos 45°) - (-8.5P) = 0$$
$$F_{5I} + 0 + 8.5P = 0$$
$$\boxed{F_{5I} = 8.5P}$$ compresión



$$\theta = arcton\frac{15}{15} = 45°$$

$$\Sigma fY = 0$$

$$F_{6J}(\text{sen } 72°) - F_{4H}(\text{sen } 72°) - F_{45}(\text{sen } 45°) = 0$$

$$F_{6J}(\text{sen } 72°)0(1.84P)(\text{sen } 72°) - (0)(\text{sen } 45°) = 0$$

$$F_{6J}(\text{sen } 72°) - (1.84P)(\text{sen } 72°) - 0 = 0$$

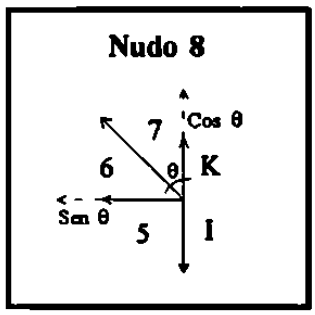
$$\boxed{F_{6J} = 1.84P}$$ tensión

$$\Sigma Fx = 0$$

$$F_{56} - F_{6J}(\cos 72°) + F_{4H}(\cos 72°) + F_{45}(\cos 45°) = 0$$

$$F_{56} - 1.84P(\cos 72°) + (1.84P)(\cos 72°) + (0)(\cos 45°) = 0$$

$$\boxed{F_{56} = 0}$$



$$\theta = arcton\frac{20}{15} = 53°$$

$$\Sigma Fx = 0$$

$$F_{67}(\text{sen } 53°) - F_{56} = 0$$

$$F_{67}(\text{sen } 53° - 0 = 0$$

$$\boxed{F_{67} = 0}$$

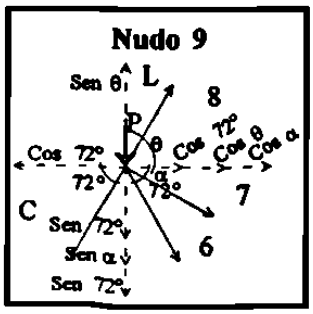
$$\Sigma Fy = 0$$

$$F_{7K} + F_{67}(\cos 53°) - F_{5I} = 0$$

$$F_{7K} + (0)(\cos 53°) - (-8.5P) = 0$$

$$F_{7K} + 0 + 8.5P = 0$$

$$\boxed{F_{7K} = 8.5P}$$ compresión



$$\theta = arctan\frac{20}{20} = 45°$$

$$\alpha = arctan\frac{15}{20} = 37°\alpha$$

$$\Sigma Fy = 0$$

$$F_{8L}(\text{sen } 45°) - F_{6J}(\text{sen } 72°) - F_{67}(\text{sen } 37°) - (F_C)(\text{sen } 72°) - P = 0$$

$$F_{8L}(\text{sen } 45°) - (1.84P)(\text{sen } 72°) - (0)(\text{sen } 37°) - (1.84P)(\text{sen } 72°) - P = 0$$

$$F_{8L}(\text{sen } 45°) - 1.75P - 0 - 1.75P - P = 0$$

$$F_{8L} = \frac{4.5P}{\text{sen } 45°}$$

$$\boxed{F_{8L} = 6.36}$$ tensión

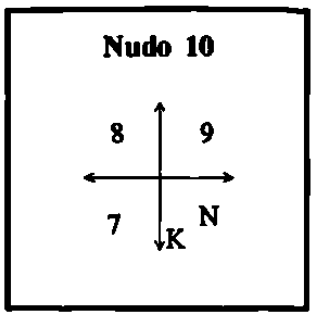
$$\Sigma Fx = 0$$

$$F_{78} + F_{8L}(\cos 45°) + F_{67}(\cos 37°) + F_{6J}(\cos 72°) - (F_C)(\cos 72°) = 0$$

$$F_{78} + (6.36P)(\cos 45°) + (0)(\cos 37) + (1.84P)(\cos 72°) - (1.84P)(\cos 72°) = 0$$

$$F_{78} + 4.5P = 0$$

$$\boxed{F_{78} = -4.5P}$$ compresión



$$\Sigma Fx = 0$$

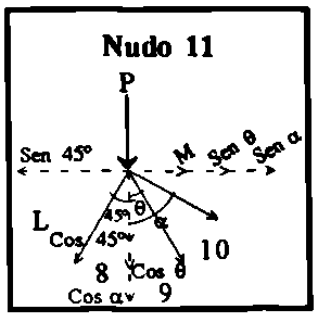
$$F_{78} + F_{9N} = 0$$

$$-(-4.5P) + F_{9N} = 0$$

$$4.5P + F_{9N} = 0$$

$$\boxed{F_{9N} = -4.5P}$$ compresión

$$\Sigma Fy = 0$$
$$F_{89} - F_{7K} = 0$$
$$F_{89}(-8.5P) = 0$$
$$F_{89} + 8.5P = 0$$
$$\boxed{F_{89} = -8.5P}$$ compresión



$$\theta = arctan\frac{15}{20} = 37°$$
$$\alpha = arctan\frac{45}{20} = 66°$$

$$\Sigma Fx = 0$$
$$F_{9-10}(\text{sen } 37°) + F_{10M}(\text{sen } 66°) - F_{8L}(\text{sen } 45°) = 0$$
$$F_{9-10}(\text{sen } 37°) + F_{10M}(\text{sen } 66°) - (6.36P)(\text{sen } 45°) = 0$$
$$F_{9-10}(\text{sen } 37°) + F_{10M}(\text{sen } 66°) = 4.5P$$
$$F_{9-10} = \frac{4.5P - F_{10M}(\text{sen } 66°)}{\text{sen } 37°}$$

$$\Sigma Fy = 0$$
$$F_{9-10}(\cos 37°) - F_{10M}(\cos 66°) - (F_{8L})(\cos 45°) - F_{89} - P = 0$$
$$-\left(\frac{4.5P - F_{10M}(\text{sen } 66°)}{\text{sen } 37°}\right)(\cos 37°) - F_{10M}(\cos 66°) - (6.36P)(\cos 45°) - (-8.5P) - P = 0$$
$$-5.97P + 1.21F_{10M} - 0.41(F_{10M})(\cos 66°) - (6.36P)(\cos 45°) - (-8.5P) - P = 0$$
$$-5.97P + 1.21F_{10M} - 0.41(F_{10M}) - 4.5 + 8.5P - P = 0$$
$$0.8F_{10M} - 2.97P = 0$$
$$(F_{10M}) = \frac{2.97P}{0.8}$$
$$\boxed{F_{10M} = 3.7P}$$ tensión

$$F_{910} = \frac{4.5P - F_{10M}(\text{sen } 6°)}{\text{sen } 37°}$$

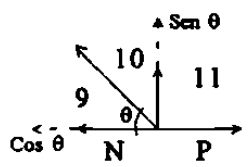
$$F_{910} = \frac{4.5P(3.7P)(\text{sen } 66°)}{\text{sen } 37°}$$

$$F_{910} = \frac{4.5P - 3.38P}{\text{sen } 37°}$$

$$F_{910} = \frac{1.12P}{\text{sen } 37°}$$

$$\boxed{F_{910} = 1.86P}$$ tensión

Nudo 12



$$\theta = arcton\frac{20}{15} = 53°$$

$$\Sigma Fy = 0$$

$$F_{10-11} + F_{910}(\text{sen } 53°) = 0$$

$$F_{10-11} + (1.86P)(\text{sen } 53°) = 0$$

$$F_{10-11} + 1.49P = 0$$

$$\boxed{F_{10-11} = -1.49P}$$ compresión

$$\Sigma Fx = 0$$

$$F_{11P} - F_{910}(s53°) - F_{9N} = 0$$

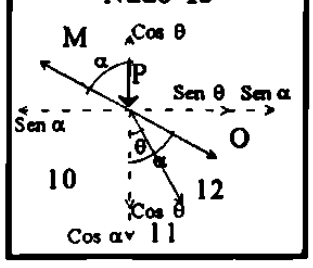
$$F_{11P} - (1.86P)(\cos 53°) - (-4.5P) = 0$$

$$F_{11P} - 1.12P + 4.5P = 0$$

$$F_{11P} + 3.38P = 0$$

$$\boxed{F_{11P} = -3.38P}$$ compresión

Nudo 13



$$\theta = arctan\frac{15}{13.3} = 48°$$

$$\alpha = arctan\frac{30}{13.3} = 66°$$

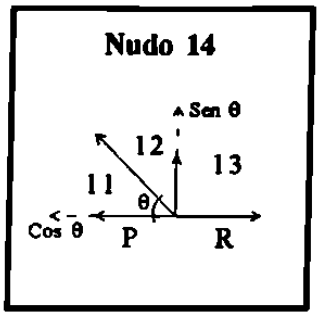
$$\Sigma Fx = 0$$
$$F_{11-12}(\text{sen } 48°) + F_{120}(\text{sen } 66°) - F_{10M}(\text{sen } 66°) = 0$$
$$F_{11-12}(\text{sen } 48°) + F_{120}(\text{sen } 66°) - (3.7P)(\text{sen } 66°) = 0$$
$$F_{11-12}(\text{sen } 48°) + F_{120}(\text{sen } 66°) = 3.38P$$
$$F_{11-12} = \frac{3.38P - F_{120}(\text{sen } 66°)}{\text{sen } 48°}$$

$$\Sigma Fy = 0$$
$$-F_{11-12}(\cos 48°) - F_{120}(\cos 66°) + F_{10M}(\cos 66°) - F_{10-11} - P = 0$$
$$-\left(\frac{38P - F_{120}(\text{sen } 66°)}{\text{sen } 48}\right)(\cos 48°) - F_{120}(\cos 66°) + (3.7P) - (-1.49P) - P = 0$$
$$-3.04P + 0.82F_{120} - 0.41F_{120} + 1.5P + 1.49P - P = 0$$
$$0.41(F_{120}) - 1.05P = 0$$
$$F_{120} = \frac{1.05P}{0.41}$$

$$\boxed{F_{120} = 2.56P}$$ tensión

$$F_{11-12} = \frac{3.38P - F_{120}(\text{sen } 66°)}{\text{sen } 48°}$$
$$F_{11-12} = \frac{3.38P - (2.56P)(\text{sen } 66°)}{\text{sen } 48°}$$
$$F_{11-12} = \frac{3.38P - 2.34P}{\text{sen } 48°}$$
$$F_{11-12} = \frac{1.04P}{\text{sen } 48°}$$

$$\boxed{F_{11-12} = 1.4P}$$ tensión



$$\theta = arcton\frac{13.3}{15} = 42°$$

$$\Sigma Fx = 0$$

$$F_{11-12}(\cos 42°) - F_{11P} + F_{13R} = 0$$

$$F_{13R} - (1.4P)(\cos 42°) - (-3.38P) = 0$$

$$F_{13R} - 1.04P + 3.38P = 0$$

$$F_{13R} + 2.34P = 0$$

$$\boxed{F_{13R} = -2.34P}$$ compresión

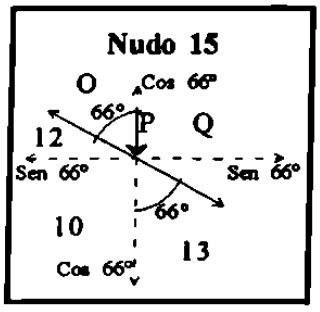
$$\Sigma Fy = 0$$

$$F_{12-13} + F_{11-12}(\text{sen } 42°) = 0$$

$$F_{12-13} + 1.4P(\text{sen } 42°) = 0$$

$$F_{12-13} + 0.94P = 0$$

$$\boxed{F_{12-13} = -0.94P}$$ compresión



$$\Sigma Fx = 0$$

$$F_{13Q}(\text{sen } 66°) - F_{120}(\text{sen } 66°) = 0$$

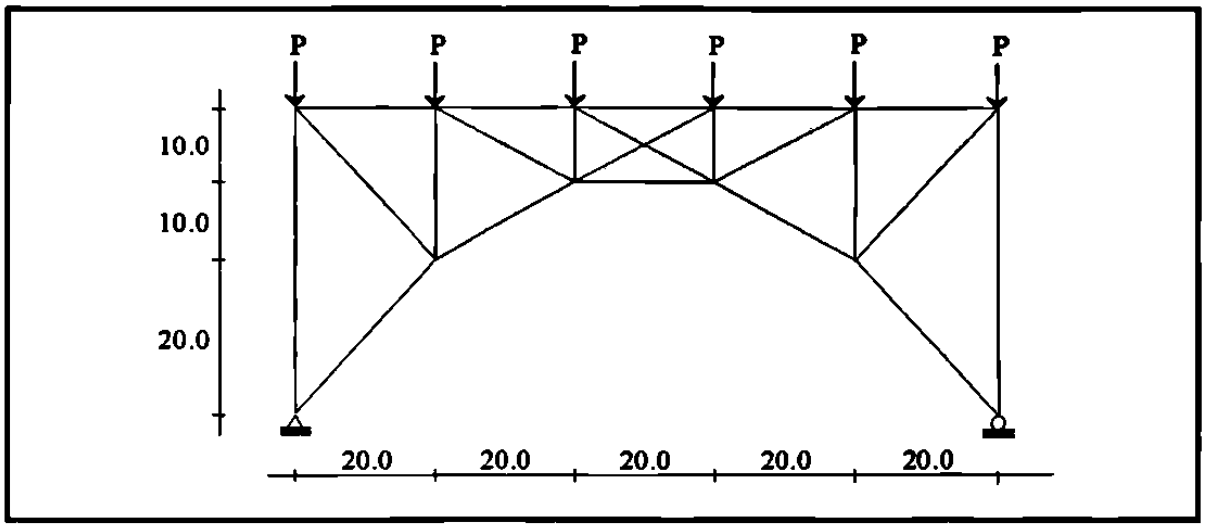
$$F_{13Q}(\text{sen } 66°) - 2.56P(\text{sen } 66°) = 0$$

$$F_{13Q}(\text{sen } 66°) - 2.34P = 0$$

$$F_{13Q} = \frac{2.34P}{\text{sen } 66°}$$

$$\boxed{F_{13Q} = 2.56P}$$

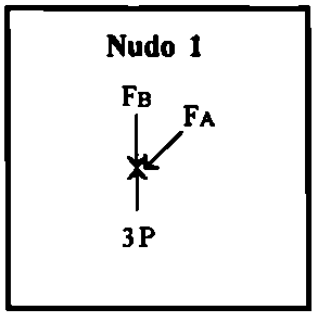
V.5.5. Armadura
Armadura 5



$R_1 = 3P$

$R_2 = 3P$

Nudo 1



$\Sigma Fx = 0$

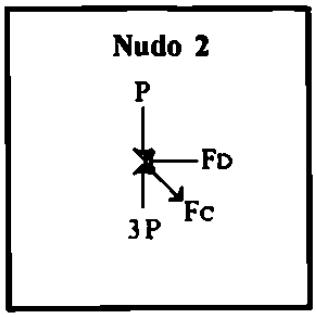
$F_A = 0$

$\Sigma Fy = 0$

$3P + 0 - F_B = 0$

$F_B = 3P$

Nudo2



$\Sigma Fy = 0$

$3P - P - F_C\left(\frac{1}{\sqrt{2}}\right) = 0$

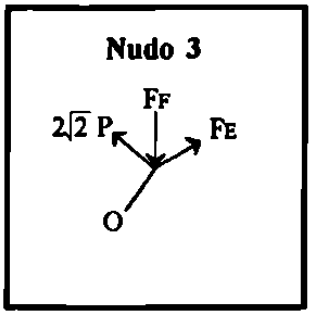
$FC = 2\sqrt{2}P$

$\Sigma Fx = 0$

$2\sqrt{2}P\left(\frac{1}{\sqrt{2}}\right) - F_D = 0$

$F_D = 2P$

Nudo 3



$$\Sigma Fx = 0$$

$$F_E \frac{2}{\sqrt{5}} - 2\sqrt{2}P\left(\frac{1}{\sqrt{2}}\right) = 0$$

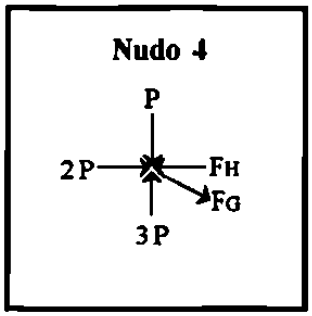
$$F_E = \sqrt{5}P$$

$$\Sigma Fy = 0$$

$$2\sqrt{2}P\left(\frac{1}{\sqrt{2}}\right) + \sqrt{5}P\left(\frac{1}{\sqrt{5}}\right) - F_F = 0$$

$$F_F = 3P$$

Nudo 4



$$\Sigma Fy = 0$$

$$3P - P - F_G\left(\frac{1}{\sqrt{5}}\right) = 0$$

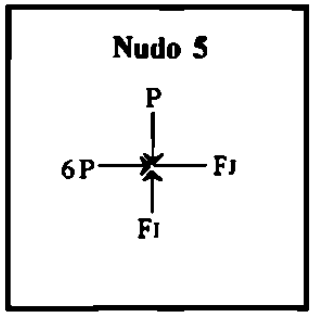
$$FG = 2\sqrt{5}P$$

$$\Sigma Fx = 0$$

$$2P + 2\sqrt{5}P\left(\frac{2}{\sqrt{5}}\right) - F_H = 0$$

$$F_H = 6P$$

Nudo 5



$$\Sigma Fx = 0$$

$$6P - F_J = 0$$

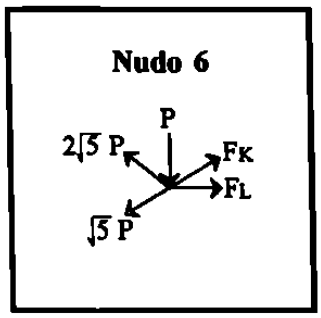
$$F_J = 6P$$

$$\Sigma Fy = 0$$

$$F_I - P = 0$$

$$F_I = P$$

Nudo 6



$$\Sigma Fy = 0$$

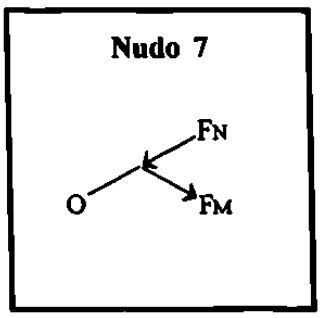
$$2\sqrt{5}P\left(\frac{1}{\sqrt{5}}\right) - \sqrt{5}P\left(\frac{1}{\sqrt{5}}\right) - P + F_K = 0$$

$$FK = 0$$

$$-2\sqrt{5}P\left(\frac{2}{\sqrt{5}}\right) - \sqrt{5}P\left(\frac{2}{\sqrt{5}}\right) + F_L = 0$$

$$F_L = 6P$$

Nudo 7



$$\Sigma Fx = 0$$

$$F_M\left(\frac{2}{\sqrt{5}}\right) - F_N\left(\frac{2}{\sqrt{5}}\right) = 0 \qquad (1)$$

$$\Sigma Fy = 0$$

$$-F_M\left(\frac{1}{\sqrt{5}}\right) - F_N\left(\frac{1}{\sqrt{5}}\right) = 0 \qquad (2)$$

Multiplicando (2) por 2

$$-F_M\left(\frac{2}{\sqrt{5}}\right) - F_N\left(\frac{2}{\sqrt{5}}\right) = 0 \qquad (3)$$

Sumando (1) y (3)

$$-F_N\left(\frac{4}{\sqrt{5}}\right) = 0$$

$$F_N = 0$$

Sustituyendo F_N en (1)

$$F_M = 0$$

Y como la armadura es simétrica

$$F_A=F_V=0$$
$$F_B=F_W=3P$$
$$F_C=F_U=2\sqrt{2}\,P$$
$$F_D=F_T=2P$$
$$F_E=F_R=\sqrt{5}\,P$$
$$F_F=F_S=3P$$
$$F_G=F_Q=2\sqrt{5}\,P$$
$$F_H=F_P=6P$$
$$F_I=F_O=P$$
$$F_J=6P$$
$$F_L=6P$$
$$F_K=0$$
$$F_M=0$$
$$F_N=0$$

V.6. Solución de armaduras por medio del programa SAP 2000

Las cinco armaduras en estudio, ahora se analizan por medio de un programa computacional llamado SAP 2000. Estos resultados coinciden con los análisis efectuados por medio del método de nudos y secciones.

```
                    S A P 2 0 0 0 (R)

                Structural Analysis Programs

                  Educational Version 6.13

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                    All rights reserved

        This copy of SAP2000 is for the exclusive use of

                       THE LICENSEE

      Unauthorized use is in violation of Federal copyright laws

          It is the responsibility of the user to verify all
                   results produced by this program

                        26 Aug 1998  15:11:16
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 D I S P L A C E M E N T   D E G R E E S   O F   F R E E D O M

         (A) = Active DOF, equilibrium equation
         (-) = Restrained DOF, reaction computed
         (+) = Constrained DOF
         ( ) = Null DOF

  JOINTS              UX  UY  UZ  RX  RY  RZ
       1               -       -
       2               A       -
       3 TO       9    A       A
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 T O T A L   A S S E M B L E D   J O I N T   M A S S E S

 IN GLOBAL COORDINATES

                   UX          UY          UZ          RX          RY
RZ
   TOTAL     .000000     .000000     .000000     .000000     .000000
.000000


 T O T A L   A C C E L E R A T E D   M A S S   A N D   L O C A T I O N

 TOTAL MASS ACTIVATED BY ACCELERATION LOADS, IN GLOBAL COORDINATES
```

```
                UX          UY          UZ
   MASS      .000000     .000000     .000000
  X-LOC      .000000     .000000     .000000
  Y-LOC      .000000     .000000     .000000
  Z-LOC      .000000     .000000     .000000
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 J O I N T   D I S P L A C E M E N T S

 TRANSLATIONS AND ROTATIONS, IN GLOBAL COORDINATES

 COMB   UNICA ------------------ MAX

  JOINT          UX          UZ
      1     .000000     .000000
      2    2.25E-05     .000000
      3   -1.57E-05   -6.67E-06
      4   -4.45E-06   -3.97E-05
      5   -3.89E-06   -1.00E-05
      6   -1.42E-07   -4.95E-05
      7    2.43E-05   -1.00E-05
      8    2.43E-05   -3.77E-05
      9    6.13E-05   -1.00E-05

 COMB   UNICA ------------------ MIN

  JOINT          UX          UZ
      1     .000000     .000000
      2    2.25E-05     .000000
      3   -1.57E-05   -6.67E-06
      4   -4.45E-06   -3.97E-05
      5   -3.89E-06   -1.00E-05
      6   -1.42E-07   -4.95E-05
      7    2.43E-05   -1.00E-05
      8    2.43E-05   -3.77E-05
      9    6.13E-05   -1.00E-05
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 A P P L I E D   L O A D S

 FORCES AND MOMENTS ACTING ON JOINTS, IN GLOBAL COORDINATES

 COMB   UNICA ------------------ MAX

  JOINT          FX          FZ
      4     .000000   -0.200000
      6     .000000   -0.200000
      8     .000000   -0.200000

 COMB   UNICA ------------------ MIN
```

```
   JOINT          FX          FZ
       4     .000000   -0.200000
       6     .000000   -0.200000
       8     .000000   -0.200000
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 R E S T R A I N T   F O R C E S   ( R E A C T I O N S )

 FORCES AND MOMENTS ACTING ON JOINTS, IN GLOBAL COORDINATES

 COMB   UNICA ----------------- MAX

   JOINT          FX          FZ
       1   -5.55E-17    0.300000
       2     .000000    0.300000

 COMB   UNICA ----------------- MIN

   JOINT          FX          FZ
       1   -5.55E-17    0.300000
       2     .000000    0.300000
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 G L O B A L   F O R C E   B A L A N C E

 TOTAL FORCE AND MOMENT AT THE ORIGIN, IN GLOBAL COORDINATES

 LOAD    VIVA -----------------

                  FX          FY          FZ          MX          MY
MZ
 APPLIED     .000000     .000000   -0.600000     .000000   18.000000
.000000
 REACTNS   -5.55E-17     .000000    0.600000     .000000  -18.000000
.000000

   TOTAL   -5.55E-17     .000000   -2.22E-16     .000000   -7.11E-15
.000000

 COMB   UNICA ----------------- MAX

                  FX          FY          FZ          MX          MY
MZ
 APPLIED     .000000     .000000   -0.600000     .000000   18.000000
.000000
 REACTNS   -5.55E-17     .000000    0.600000     .000000  -18.000000
.000000

   TOTAL   -5.55E-17     .000000   -2.22E-16     .000000   -7.11E-15
```

.000000

COMB UNICA ---------- MIN

	FX	FY	FZ	MX	MY	MZ
APPLIED	.000000	.000000	-0.600000	.000000	18.000000	000000
REACTNS	-5.55E-17	.000000	0.600000	.000000	-18.000000	.000000
TOTAL	-5.55E-17	.000000	-2.22E-16	.000000	-7.11E-15	.000000

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F R A M E E L E M E N T I N T E R N A L F O R C E S

ELEM 1 ========== LENGTH = 20.000000

COMB UNICA ---------- MAX

REL DIST	P	V2	V3	T	M2	M3
0.00000	-0.200000	.000000	.000000	.000000	.000000	.000000
1.00000	-0.200000	.000000	.000000	.000000	.000000	.000000

COMB UNICA ---------- MIN

REL DIST	P	V2	V3	T	M2	M3
0.00000	-0.200000	.000000	.000000	.000000	.000000	.000000
1.00000	-0.200000	.000000	.000000	.000000	.000000	.000000

ELEM 2 ========== LENGTH = 20.000000

COMB UNICA ---------- MAX

REL DIST	P	V2	V3	T	M2	M3
0.00000	-0.100000	.000000	.000000	.000000	.000000	.000000
1.00000	-0.100000	.000000	.000000	.000000	.000000	.000000

COMB UNICA ---------- MIN

REL DIST	P	V2	V3	T	M2	M3
0.00000	-0.100000	.000000	.000000	.000000	.000000	.000000
1.00000	-0.100000	.000000	.000000	.000000	.000000	

.000000

ELEM 3 ========== LENGTH = 20.000000

COMB UNICA ---------- MAX

REL DIST	P	V2	V3	T	M2	M3
0.00000	-7.60E-17	.000000	.000000	.000000	.000000	.000000
1.00000	-7.60E-17	.000000	.000000	.000000	.000000	.000000

COMB UNICA ---------- MIN

REL DIST	P	V2	V3	T	M2	M3
0.00000	-7.60E-17	.000000	.000000	.000000	.000000	.000000
1.00000	-7.60E-17	.000000	.000000	.000000	.000000	.000000

ELEM 4 ========== LENGTH = 20.000000

COMB UNICA ---------- MAX

REL DIST	P	V2	V3	T	M2	M3
0.00000	-1.22E-16	.000000	.000000	.000000	.000000	.000000
1.00000	-1.22E-16	.000000	.000000	.000000	.000000	.000000

F R A M E E L E M E N T I N T E R N A L F O R C E S

COMB UNICA ---------- MIN

REL DIST	P	V2	V3	T	M2	M3
0.00000	-1.22E-16	.000000	.000000	.000000	.000000	.000000
1.00000	-1.22E-16	.000000	.000000	.000000	.000000	.000000

ELEM 5 ========== LENGTH = 25.000000

COMB UNICA ---------- MAX

REL DIST	P	V2	V3	T	M2	M3
0.00000	-0.375000	.000000	.000000	.000000	.000000	.000000
1.00000	-0.375000	.000000	.000000	.000000	.000000	.000000

```
 COMB   UNICA ------------------ MIN

 REL DIST          P          V2          V3          T          M2
M3
 0.00000   -0.375000     .000000     .000000     .000000     .000000
.000000
 1.00000   -0.375000     .000000     .000000     .000000     .000000
.000000

 ELEM       6 ================== LENGTH =   25.000000

 COMB   UNICA ------------------ MAX

 REL DIST          P          V2          V3          T          M2
M3
 0.00000   -0.250000     .000000     .000000     .000000     .000000
.000000
 1.00000   -0.250000     .000000     .000000     .000000     .000000
.000000

 COMB   UNICA ------------------ MIN

 REL DIST          P          V2          V3          T          M2
M3
 0.00000   -0.250000     .000000     .000000     .000000     .000000
.000000
 1.00000   -0.250000     .000000     .000000     .000000     .000000
.000000

 ELEM       7 ================== LENGTH =   25.000000

 COMB   UNICA ------------------ MAX

 REL DIST          P          V2          V3          T          M2
M3
 0.00000   -0.125000     .000000     .000000     .000000     .000000
.000000
 1.00000   -0.125000     .000000     .000000     .000000     .000000
.000000

 COMB   UNICA ------------------ MIN

 REL DIST          P          V2          V3          T          M2
M3
 0.00000   -0.125000     .000000     .000000     .000000     .000000
.000000
 1.00000   -0.125000     .000000     .000000     .000000     .000000
.000000
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 F R A M E   E L E M E N T   I N T E R N A L   F O R C E S

 ELEM       8 ================== LENGTH =   25.000000
```

```
 COMB    UNICA ------------------ MAX

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    1.31E-17     .000000     .000000     .000000     .000000
.000000
 1.00000    1.31E-17     .000000     .000000     .000000     .000000
.000000

 COMB    UNICA ------------------ MIN

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    1.31E-17     .000000     .000000     .000000     .000000
.000000
 1.00000    1.31E-17     .000000     .000000     .000000     .000000
.000000

 ELEM        9 ================== LENGTH =   60.000000

 COMB    UNICA ------------------ MAX

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    0.225000     .000000     .000000     .000000     .000000
.000000
 1.00000    0.225000     .000000     .000000     .000000     .000000
.000000

 COMB    UNICA ------------------ MIN

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    0.225000     .000000     .000000     .000000     .000000
.000000
 1.00000    0.225000     .000000     .000000     .000000     .000000
.000000

 ELEM       10 ================= LENGTH =   49.244289

 COMB    UNICA ------------------ MAX

 REL DIST          P          V2          V3          T          M2
M3
 0.00000   -0.246221     .000000     .000000     .000000     .000000
.000000
 1.00000   -0.246221     .000000     .000000     .000000     .000000
.000000

 COMB    UNICA ------------------ MIN

 REL DIST          P          V2          V3          T          M2
M3
 0.00000   -0.246221     .000000     .000000     .000000     .000000
.000000
 1.00000   -0.246221     .000000     .000000     .000000     .000000
.000000

 ELEM       11 ================= LENGTH =   45.000000
```

```
 COMB   UNICA ------------------ MAX

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    0.150000     .000000     .000000     .000000     .000000
.000000
 1.00000    0.150000     .000000     .000000     .000000     .000000
.000000
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 F R A M E   E L E M E N T   I N T E R N A L   F O R C E S

 COMB   UNICA ------------------ MIN

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    0.150000     .000000     .000000     .000000     .000000
.000000
 1.00000    0.150000     .000000     .000000     .000000     .000000
.000000

 ELEM      12 ================== LENGTH =   36.055513

 COMB   UNICA ------------------ MAX

 REL DIST          P          V2          V3          T          M2
M3
 0.00000   -0.180278     .000000     .000000     .000000     .000000
.000000
 1.00000   -0.180278     .000000     .000000     .000000     .000000
.000000

 COMB   UNICA ------------------ MIN

 REL DIST          P          V2          V3          T          M2
M3
 0.00000   -0.180278     .000000     .000000     .000000     .000000
.000000
 1.00000   -0.180278     .000000     .000000     .000000     .000000
.000000

 ELEM      13 ================== LENGTH =   30.000000

 COMB   UNICA ------------------ MAX

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    0.075000     .000000     .000000     .000000     .000000
.000000
 1.00000    0.075000     .000000     .000000     .000000     .000000
.000000

 COMB   UNICA ------------------ MIN

 REL DIST          P          V2          V3          T          M2
```

```
M3
 0.00000     0.075000      .000000      .000000      .000000      .000000
.000000
 1.00000     0.075000      .000000      .000000      .000000      .000000
.000000

 ELEM       14 ================= LENGTH =   25.000000

 COMB    UNICA ------------------ MAX

 REL DIST          P          V2          V3           T          M2
M3
 0.00000    -0.125000      .000000      .000000      .000000      .000000
.000000
 1.00000    -0.125000      .000000      .000000      .000000      .000000
.000000

 COMB    UNICA ------------------ MIN

 REL DIST          P          V2          V3           T          M2
M3
 0.00000    -0.125000      .000000      .000000      .000000      .000000
.000000
 1.00000    -0.125000      .000000      .000000      .000000      .000000
.000000
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 F R A M E   E L E M E N T   I N T E R N A L   F O R C E S

 ELEM       15 ================= LENGTH =   15.000000

 COMB    UNICA ------------------ MAX

 REL DIST          P          V2          V3           T          M2
M3
 0.00000    -4.32E-17      .000000      .000000      .000000      .000000
.000000
 1.00000    -4.32E-17      .000000      .000000      .000000      .000000
.000000

 COMB    UNICA ------------------ MIN

 REL DIST          P          V2          V3           T          M2
M3
 0.00000    -4.32E-17      .000000      .000000      .000000      .000000
.000000
 1.00000    -4.32E-17      .000000      .000000      .000000      .000000
.000000
```

S A P 2 0 0 0 (R)

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D I S P L A C E M E N T D E G R E E S O F F R E E D O M

(A) = Active DOF, equilibrium equation
(-) = Restrained DOF, reaction computed
(+) = Constrained DOF
( ) = Null DOF

JOINTS			UX	UY	UZ	RX	RY	RZ
1			-		-			
2	TO	9	A		A			
10			A		-			
11			A		A			

T O T A L A S S E M B L E D J O I N T M A S S E S

IN GLOBAL COORDINATES

	UX	UY	UZ	RX	RY	RZ
TOTAL	.000000	.000000	.000000	.000000	.000000	.000000

T O T A L A C C E L E R A T E D M A S S A N D L O C A T I O N

TOTAL MASS ACTIVATED BY ACCELERATION LOADS, IN GLOBAL COORDINATES

	UX	UY	UZ
MASS	.000000	.000000	.000000
X-LOC	.000000	.000000	.000000
Y-LOC	.000000	.000000	.000000
Z-LOC	.000000	.000000	.000000

J O I N T D I S P L A C E M E N T S

TRANSLATIONS AND ROTATIONS, IN GLOBAL COORDINATES

COMB UNICA ---------- MAX

JOINT	UX	UZ
1	.000000	.000000
2	0.000186	-2.00E-05
3	0.000109	-0.000145
4	8.25E-05	-0.000204
5	0.000168	-0.000224
6	0.000150	-0.000271
7	0.000217	-0.000204
8	0.000132	-0.000224
9	0.000191	-0.000145
10	0.000300	.000000
11	0.000114	-2.00E-05

COMB UNICA ---------- MIN

JOINT	UX	UZ
1	.000000	.000000
2	0.000186	-2.00E-05
3	0.000109	-0.000145
4	8.25E-05	-0.000204
5	0.000168	-0.000224
6	0.000150	-0.000271
7	0.000217	-0.000204
8	0.000132	-0.000224
9	0.000191	-0.000145
10	0.000300	.000000
11	0.000114	-2.00E-05

A P P L I E D L O A D S

FORCES AND MOMENTS ACTING ON JOINTS, IN GLOBAL COORDINATES

COMB UNICA ---------- MAX

JOINT	FX	FZ

```
      5      .000000   -0.200000
      8      .000000   -0.200000
     11      .000000   -0.200000

 COMB   UNICA ------------------ MIN

   JOINT          FX          FZ
      2      .000000   -0.200000
      5      .000000   -0.200000
      8      .000000   -0.200000
     11      .000000   -0.200000
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 Armadura  - EXAMPLE 2 - TWO-DIMENSIONAL TRUSS
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 R E S T R A I N T   F O R C E S   ( R E A C T I O N S )

 FORCES AND MOMENTS ACTING ON JOINTS, IN GLOBAL COORDINATES

 COMB   UNICA ------------------ MAX

   JOINT          FX          FZ
      1    2.47E-15    0.400000
     10     .000000    0.400000

 COMB   UNICA ------------------ MIN

   JOINT          FX          FZ
      1    2.47E-15    0.400000
     10     .000000    0.400000
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 G L O B A L   F O R C E   B A L A N C E

 TOTAL FORCE AND MOMENT AT THE ORIGIN, IN GLOBAL COORDINATES

 LOAD    VIVA ------------------

                  FX          FY          FZ          MX          MY
MZ
 APPLIED     .000000     .000000   -0.800000     .000000   48.000000
.000000
 REACTNS    2.47E-15     .000000    0.800000     .000000  -48.000000
.000000

   TOTAL    2.47E-15     .000000    3.33E-15     .000000   -1.71E-13
.000000

 COMB   UNICA ------------------ MAX

                  FX          FY          FZ          MX          MY
```

```
MZ
 APPLIED      .000000      .000000    -0.800000      .000000    48.000000
.000000
 REACTNS     2.47E-15      .000000     0.800000      .000000   -48.000000
.000000

   TOTAL     2.47E-15      .000000     3.33E-15      .000000    -1.71E-13
.000000

 COMB    UNICA ------------------ MIN

                  FX           FY           FZ           MX           MY
MZ
 APPLIED      .000000      .000000    -0.800000      .000000    48.000000
.000000
 REACTNS     2.47E-15      .000000     0.800000      .000000   -48.000000
.000000

   TOTAL     2.47E-15      .000000     3.33E-15      .000000    -1.71E-13
.000000
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 F R A M E   E L E M E N T   I N T E R N A L   F O R C E S

 ELEM        1 ================= LENGTH =    30.000000

 COMB    UNICA ------------------ MAX

 REL DIST          P           V2           V3            T           M2
M3
 0.00000    -0.400000      .000000      .000000      .000000      .000000
.000000
 1.00000    -0.400000      .000000      .000000      .000000      .000000
.000000

 COMB    UNICA ------------------ MIN

 REL DIST          P           V2           V3            T           M2
M3
 0.00000    -0.400000      .000000      .000000      .000000      .000000
.000000
 1.00000    -0.400000      .000000      .000000      .000000      .000000
.000000

 ELEM        2 ================= LENGTH =    40.000000

 COMB    UNICA ------------------ MAX

 REL DIST          P           V2           V3            T           M2
M3
 0.00000    -0.266667      .000000      .000000      .000000      .000000
.000000
 1.00000    -0.266667      .000000      .000000      .000000      .000000
.000000
```

```
 COMB   UNICA ------------------ MIN

 REL DIST          P          V2          V3          T          M2
M3
 0.00000   -0.266667     .000000     .000000     .000000     .000000
.000000
 1.00000   -0.266667     .000000     .000000     .000000     .000000
.000000

 ELEM       3 ================== LENGTH =   25.000000

 COMB   UNICA ------------------ MAX

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    0.333333     .000000     .000000     .000000     .000000
.000000
 1.00000    0.333333     .000000     .000000     .000000     .000000
.000000

 COMB   UNICA ------------------ MIN

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    0.333333     .000000     .000000     .000000     .000000
.000000
 1.00000    0.333333     .000000     .000000     .000000     .000000
.000000

 ELEM       4 ================== LENGTH =   25.000000

 COMB   UNICA ------------------ MAX

 REL DIST          P          V2          V3          T          M2
M3
 0.00000   -3.41E-15     .000000     .000000     .000000     .000000
.000000
 1.00000   -3.41E-15     .000000     .000000     .000000     .000000
.000000
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 Armadura  - EXAMPLE 2 - TWO-DIMENSIONAL TRUSS
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 F R A M E   E L E M E N T   I N T E R N A L   F O R C E S

 COMB   UNICA ------------------ MIN

 REL DIST          P          V2          V3          T          M2
M3
 0.00000   -3.41E-15     .000000     .000000     .000000     .000000
.000000
 1.00000   -3.41E-15     .000000     .000000     .000000     .000000
.000000

 ELEM       5 ================== LENGTH =   25.000000

 COMB   UNICA ------------------ MAX
```

```
 REL DIST          P          V2          V3          T          M2
M3
 0.00000   -2.83E-15     .000000     .000000     .000000     .000000
.000000
 1.00000   -2.83E-15     .000000     .000000     .000000     .000000
.000000

 COMB   UNICA ------------------ MIN

 REL DIST          P          V2          V3          T          M2
M3
 0.00000   -2.83E-15     .000000     .000000     .000000     .000000
.000000
 1.00000   -2.83E-15     .000000     .000000     .000000     .000000
.000000

 ELEM       6 ================== LENGTH =   25.000000

 COMB   UNICA ------------------ MAX

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    0.333333     .000000     .000000     .000000     .000000
.000000
 1.00000    0.333333     .000000     .000000     .000000     .000000
.000000

 COMB   UNICA ------------------ MIN

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    0.333333     .000000     .000000     .000000     .000000
.000000
 1.00000    0.333333     .000000     .000000     .000000     .000000
.000000

 ELEM       7 ================== LENGTH =   30.000000

 COMB   UNICA ------------------ MAX

 REL DIST          P          V2          V3          T          M2
M3
 0.00000   -0.400000     .000000     .000000     .000000     .000000
.000000
 1.00000   -0.400000     .000000     .000000     .000000     .000000
.000000

 COMB   UNICA ------------------ MIN

 REL DIST          P          V2          V3          T          M2
M3
 0.00000   -0.400000     .000000     .000000     .000000     .000000
.000000
 1.00000   -0.400000     .000000     .000000     .000000     .000000
.000000
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```

Armadura - EXAMPLE 2 - TWO-DIMENSIONAL TRUSS
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F R A M E E L E M E N T I N T E R N A L F O R C E S

ELEM 8 ========== LENGTH = 40.000000

COMB UNICA ---------- MAX

REL DIST	P	V2	V3	T	M2	M3
0.00000	-0.533333	.000000	.000000	.000000	.000000	.000000
1.00000	-0.533333	.000000	.000000	.000000	.000000	.000000

COMB UNICA ---------- MIN

REL DIST	P	V2	V3	T	M2	M3
0.00000	-0.533333	.000000	.000000	.000000	.000000	.000000
1.00000	-0.533333	.000000	.000000	.000000	.000000	.000000

ELEM 9 ========== LENGTH = 25.000000

COMB UNICA ---------- MAX

REL DIST	P	V2	V3	T	M2	M3
0.00000	0.333333	.000000	.000000	.000000	.000000	.000000
1.00000	0.333333	.000000	.000000	.000000	.000000	.000000

COMB UNICA ---------- MIN

REL DIST	P	V2	V3	T	M2	M3
0.00000	0.333333	.000000	.000000	.000000	.000000	.000000
1.00000	0.333333	.000000	.000000	.000000	.000000	.000000

ELEM 10 ========== LENGTH = 25.000000

COMB UNICA ---------- MAX

REL DIST	P	V2	V3	T	M2	M3
0.00000	0.333333	.000000	.000000	.000000	.000000	.000000
1.00000	0.333333	.000000	.000000	.000000	.000000	.000000

COMB UNICA ---------- MIN

REL DIST	P	V2	V3	T	M2	M3

```
 0.00000     0.333333      .000000      .000000      .000000      .000000
.000000
 1.00000     0.333333      .000000      .000000      .000000      .000000
.000000

 ELEM       11 ================= LENGTH =    25.000000

 COMB    UNICA ------------------ MAX

 REL DIST            P           V2           V3            T           M2
M3
 0.00000     0.333333      .000000      .000000      .000000      .000000
.000000
 1.00000     0.333333      .000000      .000000      .000000      .000000
.000000
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 Armadura  - EXAMPLE 2 - TWO-DIMENSIONAL TRUSS
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 F R A M E   E L E M E N T   I N T E R N A L   F O R C E S

 COMB    UNICA ------------------ MIN

 REL DIST            P           V2           V3            T           M2
M3
 0.00000     0.333333      .000000      .000000      .000000      .000000
.000000
 1.00000     0.333333      .000000      .000000      .000000      .000000
.000000

 ELEM       12 ================= LENGTH =    25.000000

 COMB    UNICA ------------------ MAX

 REL DIST            P           V2           V3            T           M2
M3
 0.00000     0.333333      .000000      .000000      .000000      .000000
.000000
 1.00000     0.333333      .000000      .000000      .000000      .000000
.000000

 COMB    UNICA ------------------ MIN

 REL DIST            P           V2           V3            T           M2
M3
 0.00000     0.333333      .000000      .000000      .000000      .000000
.000000
 1.00000     0.333333      .000000      .000000      .000000      .000000
.000000

 ELEM       13 ================= LENGTH =    30.000000

 COMB    UNICA ------------------ MAX

 REL DIST            P           V2           V3            T           M2
M3
 0.00000    -0.400000      .000000      .000000      .000000      .000000
```

```
.000000
 1.00000    -0.400000      .000000      .000000      .000000      .000000
.000000

 COMB   UNICA ------------------ MIN

 REL DIST           P           V2           V3            T           M2
M3
 0.00000    -0.400000      .000000      .000000      .000000      .000000
.000000
 1.00000    -0.400000      .000000      .000000      .000000      .000000
.000000

 ELEM       14 ================== LENGTH =   40.000000

 COMB   UNICA ------------------ MAX

 REL DIST           P           V2           V3            T           M2
M3
 0.00000    -0.266667      .000000      .000000      .000000      .000000
.000000
 1.00000    -0.266667      .000000      .000000      .000000      .000000
.000000

 COMB   UNICA ------------------ MIN

 REL DIST           P           V2           V3            T           M2
M3
 0.00000    -0.266667      .000000      .000000      .000000      .000000
.000000
 1.00000    -0.266667      .000000      .000000      .000000      .000000
.000000
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 F R A M E   E L E M E N T   I N T E R N A L   F O R C E S

 ELEM       15 ================== LENGTH =   25.000000

 COMB   UNICA ------------------ MAX

 REL DIST           P           V2           V3            T           M2
M3
 0.00000    -3.97E-16      .000000      .000000      .000000      .000000
.000000
 1.00000    -3.97E-16      .000000      .000000      .000000      .000000
.000000

 COMB   UNICA ------------------ MIN

 REL DIST           P           V2           V3            T           M2
M3
 0.00000    -3.97E-16      .000000      .000000      .000000      .000000
.000000
 1.00000    -3.97E-16      .000000      .000000      .000000      .000000
.000000
```

```
 ELEM       16 ================= LENGTH =   25.000000

 COMB   UNICA ----------------- MAX

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    0.333333    .000000    .000000    .000000    .000000
.000000
 1.00000    0.333333    .000000    .000000    .000000    .000000
.000000

 COMB   UNICA ----------------- MIN

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    0.333333    .000000    .000000    .000000    .000000
.000000
 1.00000    0.333333    .000000    .000000    .000000    .000000
.000000

 ELEM       17 ================= LENGTH =   25.000000

 COMB   UNICA ----------------- MAX

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    0.333333    .000000    .000000    .000000    .000000
.000000
 1.00000    0.333333    .000000    .000000    .000000    .000000
.000000

 COMB   UNICA ----------------- MIN

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    0.333333    .000000    .000000    .000000    .000000
.000000
 1.00000    0.333333    .000000    .000000    .000000    .000000
.000000

 ELEM       18 ================= LENGTH =   25.000000

 COMB   UNICA ----------------- MAX

 REL DIST          P          V2          V3          T          M2
M3
 0.00000   -1.13E-15    .000000    .000000    .000000    .000000
.000000
 1.00000   -1.13E-15    .000000    .000000    .000000    .000000
.000000
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 F R A M E   E L E M E N T   I N T E R N A L   F O R C E S
```

COMB UNICA ---------- MIN

REL DIST	P	V2	V3	T	M2	M3
0.00000	-1.13E-15	.000000	.000000	.000000	.000000	.000000
1.00000	-1.13E-15	.000000	.000000	.000000	.000000	.000000

ELEM 19 ========== LENGTH = 30.000000

COMB UNICA ---------- MAX

REL DIST	P	V2	V3	T	M2	M3
0.00000	-0.400000	.000000	.000000	.000000	.000000	.000000
1.00000	-0.400000	.000000	.000000	.000000	.000000	.000000

COMB UNICA ---------- MIN

REL DIST	P	V2	V3	T	M2	M3
0.00000	-0.400000	.000000	.000000	.000000	.000000	.000000
1.00000	-0.400000	.000000	.000000	.000000	.000000	.000000

S A P 2 0 0 0 (R)

Structural Analysis Programs

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 D I S P L A C E M E N T   D E G R E E S   O F   F R E E D O M

         (A) = Active DOF, equilibrium equation
         (-) = Restrained DOF, reaction computed
         (+) = Constrained DOF
         ( ) = Null DOF

  JOINTS              UX  UY  UZ  RX  RY  RZ
       1               -       -
       2 TO      11    A       A
      12               A       -
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 T O T A L   A S S E M B L E D   J O I N T   M A S S E S

 IN GLOBAL COORDINATES

                   UX          UY          UZ          RX          RY
RZ
   TOTAL     .000000     .000000     .000000     .000000     .000000
.000000


 T O T A L   A C C E L E R A T E D   M A S S   A N D   L O C A T I O N

 TOTAL MASS ACTIVATED BY ACCELERATION LOADS, IN GLOBAL COORDINATES
```

	UX	UY	UZ
MASS	.000000	.000000	.000000
X-LOC	.000000	.000000	.000000
Y-LOC	.000000	.000000	.000000
Z-LOC	.000000	.000000	.000000

J O I N T D I S P L A C E M E N T S

TRANSLATIONS AND ROTATIONS, IN GLOBAL COORDINATES

COMB UNICA ---------- MAX

JOINT	UX	UZ
1	.000000	.000000
2	0.000656	-0.006418
3	0.004300	-0.006156
4	0.001312	-0.008772
5	0.004644	-0.007984
6	0.001837	-0.008654
7	0.001837	-0.006291
8	0.002362	-0.008772
9	-0.000969	-0.007984
10	0.003018	-0.006418
11	-0.000625	-0.006156
12	0.003675	.000000

COMB UNICA ---------- MIN

JOINT	UX	UZ
1	.000000	.000000
2	0.000656	-0.006418
3	0.004300	-0.006156
4	0.001312	-0.008772
5	0.004644	-0.007984
6	0.001837	-0.008654
7	0.001837	-0.006291
8	0.002362	-0.008772
9	-0.000969	-0.007984
10	0.003018	-0.006418
11	-0.000625	-0.006156
12	0.003675	.000000

A P P L I E D L O A D S

FORCES AND MOMENTS ACTING ON JOINTS, IN GLOBAL COORDINATES

COMB UNICA ---------- MAX

```
   JOINT          FX          FZ
       2     .000000   -0.200000
       4     .000000   -0.200000
       6     .000000   -0.200000
       8     .000000   -0.200000
      10     .000000   -0.200000

 COMB   UNICA ------------------ MIN

   JOINT          FX          FZ
       2     .000000   -0.200000
       4     .000000   -0.200000
       6     .000000   -0.200000
       8     .000000   -0.200000
      10     .000000   -0.200000
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 R E S T R A I N T   F O R C E S   ( R E A C T I O N S )

 FORCES AND MOMENTS ACTING ON JOINTS, IN GLOBAL COORDINATES

 COMB   UNICA ------------------ MAX

   JOINT          FX          FZ
       1   -7.77E-16    0.500000
      12     .000000    0.500000

 COMB   UNICA ------------------ MIN

   JOINT          FX          FZ
       1   -7.77E-16    0.500000
      12     .000000    0.500000
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 G L O B A L   F O R C E   B A L A N C E

 TOTAL FORCE AND MOMENT AT THE ORIGIN, IN GLOBAL COORDINATES

 LOAD    VIVA ------------------

                  FX          FY          FZ          MX          MY
MZ
 APPLIED     .000000     .000000   -1.000000     .000000   60.000000
.000000
 REACTNS   -7.77E-16     .000000    1.000000     .000000  -60.000000
.000000

   TOTAL   -7.77E-16     .000000    4.00E-15     .000000   -2.56E-13
.000000
```

```
 COMB   UNICA ------------------ MAX

                  FX          FY          FZ          MX          MY
MZ
 APPLIED     .000000     .000000   -1.000000     .000000   60.000000
.000000
 REACTNS   -7.77E-16     .000000    1.000000     .000000  -60.000000
.000000

   TOTAL   -7.77E-16     .000000    4.00E-15     .000000   -2.56E-13
.000000

 COMB   UNICA ------------------ MIN

                  FX          FY          FZ          MX          MY
MZ
 APPLIED     .000000     .000000   -1.000000     .000000   60.000000
.000000
 REACTNS   -7.77E-16     .000000    1.000000     .000000  -60.000000
.000000

   TOTAL   -7.77E-16     .000000    4.00E-15     .000000   -2.56E-13
.000000
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 Armadura  - EXAMPLE 3 - TWO-DIMENSIONAL TRUSS
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 F R A M E   E L E M E N T   I N T E R N A L   F O R C E S

 ELEM       1 ================= LENGTH =   20.000000

 COMB   UNICA ------------------ MAX

 REL DIST          P          V2          V3           T          M2
M3
 0.00000    0.500000     .000000     .000000     .000000     .000000
.000000
 1.00000    0.500000     .000000     .000000     .000000     .000000
.000000

 COMB   UNICA ------------------ MIN

 REL DIST          P          V2          V3           T          M2
M3
 0.00000    0.500000     .000000     .000000     .000000     .000000
.000000
 1.00000    0.500000     .000000     .000000     .000000     .000000
.000000

 ELEM       2 ================= LENGTH =   28.284271

 COMB   UNICA ------------------ MAX

 REL DIST          P          V2          V3           T          M2
M3
 0.00000   -0.707107     .000000     .000000     .000000     .000000
.000000
```

```
 1.00000    -0.707107      .000000      .000000      .000000      .000000
.000000

 COMB    UNICA ------------------ MIN

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    -0.707107      .000000      .000000      .000000      .000000
.000000
 1.00000    -0.707107      .000000      .000000      .000000      .000000
.000000

 ELEM        3 ================== LENGTH =   20.000000

 COMB    UNICA ------------------ MAX

 REL DIST          P          V2          V3          T          M2
M3
 0.00000     0.200000      .000000      .000000      .000000      .000000
.000000
 1.00000     0.200000      .000000      .000000      .000000      .000000
.000000

 COMB    UNICA ------------------ MIN

 REL DIST          P          V2          V3          T          M2
M3
 0.00000     0.200000      .000000      .000000      .000000      .000000
.000000
 1.00000     0.200000      .000000      .000000      .000000      .000000
.000000

 ELEM        4 ================== LENGTH =   20.000000

 COMB    UNICA ------------------ MAX

 REL DIST          P          V2          V3          T          M2
M3
 0.00000     0.500000      .000000      .000000      .000000      .000000
.000000
 1.00000     0.500000      .000000      .000000      .000000      .000000
.000000
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 F R A M E   E L E M E N T   I N T E R N A L   F O R C E S

 COMB    UNICA ------------------ MIN

 REL DIST          P          V2          V3          T          M2
M3
 0.00000     0.500000      .000000      .000000      .000000      .000000
.000000
 1.00000     0.500000      .000000      .000000      .000000      .000000
.000000
```

```
ELEM        5 ================= LENGTH =    28.284271

COMB    UNICA ------------------ MAX

REL DIST          P          V2          V3          T          M2
M3
0.00000    -0.141421    .000000    .000000    .000000    .000000
.000000
1.00000    -0.141421    .000000    .000000    .000000    .000000
.000000

COMB    UNICA ------------------ MIN

REL DIST          P          V2          V3          T          M2
M3
0.00000    -0.141421    .000000    .000000    .000000    .000000
.000000
1.00000    -0.141421    .000000    .000000    .000000    .000000
.000000

ELEM        6 ================= LENGTH =    28.284271

COMB    UNICA ------------------ MAX

REL DIST          P          V2          V3          T          M2
M3
0.00000    -0.565685    .000000    .000000    .000000    .000000
.000000
1.00000    -0.565685    .000000    .000000    .000000    .000000
.000000

COMB    UNICA ------------------ MIN

REL DIST          P          V2          V3          T          M2
M3
0.00000    -0.565685    .000000    .000000    .000000    .000000
.000000
1.00000    -0.565685    .000000    .000000    .000000    .000000
.000000

ELEM        7 ================= LENGTH =    40.000000

COMB    UNICA ------------------ MAX

REL DIST          P          V2          V3          T          M2
M3
0.00000     0.300000    .000000    .000000    .000000    .000000
.000000
1.00000     0.300000    .000000    .000000    .000000    .000000
.000000

COMB    UNICA ------------------ MIN

REL DIST          P          V2          V3          T          M2
M3
0.00000     0.300000    .000000    .000000    .000000    .000000
.000000
1.00000     0.300000    .000000    .000000    .000000    .000000
.000000
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```

```
 F R A M E   E L E M E N T   I N T E R N A L   F O R C E S

 ELEM        8 ================= LENGTH =   20.000000

 COMB    UNICA ----------------- MAX

 REL DIST          P          V2          V3           T          M2
M3
 0.00000    0.400000     .000000     .000000     .000000     .000000
.000000
 1.00000    0.400000     .000000     .000000     .000000     .000000
.000000

 COMB    UNICA ----------------- MIN

 REL DIST          P          V2          V3           T          M2
M3
 0.00000    0.400000     .000000     .000000     .000000     .000000
.000000
 1.00000    0.400000     .000000     .000000     .000000     .000000
.000000

 ELEM        9 ================= LENGTH =   44.721360

 COMB    UNICA ----------------- MAX

 REL DIST          P          V2          V3           T          M2
M3
 0.00000   -0.223607     .000000     .000000     .000000     .000000
.000000
 1.00000   -0.223607     .000000     .000000     .000000     .000000
.000000

 COMB    UNICA ----------------- MIN

 REL DIST          P          V2          V3           T          M2
M3
 0.00000   -0.223607     .000000     .000000     .000000     .000000
.000000
 1.00000   -0.223607     .000000     .000000     .000000     .000000
.000000

 ELEM       10 ================= LENGTH =   28.284271

 COMB    UNICA ----------------- MAX

 REL DIST          P          V2          V3           T          M2
M3
 0.00000   -0.424264     .000000     .000000     .000000     .000000
.000000
 1.00000   -0.424264     .000000     .000000     .000000     .000000
.000000

 COMB    UNICA ----------------- MIN
```

```
 REL DIST          P          V2          V3          T          M2
M3
 0.00000   -0.424264     .000000     .000000     .000000     .000000
.000000
 1.00000   -0.424264     .000000     .000000     .000000     .000000
.000000

 ELEM      11 ================== LENGTH =   60.000000

 COMB   UNICA ------------------ MAX

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    0.600000     .000000     .000000     .000000     .000000
.000000
 1.00000    0.600000     .000000     .000000     .000000     .000000
.000000
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 F R A M E   E L E M E N T   I N T E R N A L   F O R C E S

 COMB   UNICA ------------------ MIN

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    0.600000     .000000     .000000     .000000     .000000
.000000
 1.00000    0.600000     .000000     .000000     .000000     .000000
.000000

 ELEM      12 ================== LENGTH =   20.000000

 COMB   UNICA ------------------ MAX

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    0.400000     .000000     .000000     .000000     .000000
.000000
 1.00000    0.400000     .000000     .000000     .000000     .000000
.000000

 COMB   UNICA ------------------ MIN

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    0.400000     .000000     .000000     .000000     .000000
.000000
 1.00000    0.400000     .000000     .000000     .000000     .000000
.000000

 ELEM      13 ================== LENGTH =   44.721360

 COMB   UNICA ------------------ MAX
```

```
 REL DIST          P          V2          V3          T          M2
M3
 0.00000   -0.223607     .000000     .000000     .000000     .000000
.000000
 1.00000   -0.223607     .000000     .000000     .000000     .000000
.000000

 COMB   UNICA ----------------- MIN

 REL DIST          P          V2          V3          T          M2
M3
 0.00000   -0.223607     .000000     .000000     .000000     .000000
.000000
 1.00000   -0.223607     .000000     .000000     .000000     .000000
.000000

 ELEM      14 ================= LENGTH =   28.284271

 COMB   UNICA ----------------- MAX

 REL DIST          P          V2          V3          T          M2
M3
 0.00000   -0.424264     .000000     .000000     .000000     .000000
.000000
 1.00000   -0.424264     .000000     .000000     .000000     .000000
.000000

 COMB   UNICA ----------------- MIN

 REL DIST          P          V2          V3          T          M2
M3
 0.00000   -0.424264     .000000     .000000     .000000     .000000
.000000
 1.00000   -0.424264     .000000     .000000     .000000     .000000
.000000
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 F R A M E   E L E M E N T   I N T E R N A L   F O R C E S

 ELEM      15 ================= LENGTH =   40.000000

 COMB   UNICA ----------------- MAX

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    0.300000     .000000     .000000     .000000     .000000
.000000
 1.00000    0.300000     .000000     .000000     .000000     .000000
.000000

 COMB   UNICA ----------------- MIN

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    0.300000     .000000     .000000     .000000     .000000
```

```
.000000
 1.00000     0.300000      .000000      .000000      .000000      .000000
.000000

 ELEM       16 ================= LENGTH =   20.000000

 COMB    UNICA ------------------ MAX

 REL DIST          P          V2          V3           T          M2
M3
 0.00000     0.500000      .000000      .000000      .000000      .000000
.000000
 1.00000     0.500000      .000000      .000000      .000000      .000000
.000000

 COMB    UNICA ------------------ MIN

 REL DIST          P          V2          V3           T          M2
M3
 0.00000     0.500000      .000000      .000000      .000000      .000000
.000000
 1.00000     0.500000      .000000      .000000      .000000      .000000
.000000

 ELEM       17 ================= LENGTH =   28.284271

 COMB    UNICA ------------------ MAX

 REL DIST          P          V2          V3           T          M2
M3
 0.00000    -0.141421      .000000      .000000      .000000      .000000
.000000
 1.00000    -0.141421      .000000      .000000      .000000      .000000
.000000

 COMB    UNICA ------------------ MIN

 REL DIST          P          V2          V3           T          M2
M3
 0.00000    -0.141421      .000000      .000000      .000000      .000000
.000000
 1.00000    -0.141421      .000000      .000000      .000000      .000000
.000000

 ELEM       18 ================= LENGTH =   28.284271

 COMB    UNICA ------------------ MAX

 REL DIST          P          V2          V3           T          M2
M3
 0.00000    -0.565685      .000000      .000000      .000000      .000000
.000000
 1.00000    -0.565685      .000000      .000000      .000000      .000000
.000000
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```

F R A M E E L E M E N T I N T E R N A L F O R C E S

COMB UNICA ---------- MIN

REL DIST	P	V2	V3	T	M2	M3
0.00000	-0.565685	.000000	.000000	.000000	.000000	.000000
1.00000	-0.565685	.000000	.000000	.000000	.000000	.000000

ELEM 19 ========== LENGTH = 20.000000

COMB UNICA ---------- MAX

REL DIST	P	V2	V3	T	M2	M3
0.00000	0.200000	.000000	.000000	.000000	.000000	.000000
1.00000	0.200000	.000000	.000000	.000000	.000000	.000000

COMB UNICA ---------- MIN

REL DIST	P	V2	V3	T	M2	M3
0.00000	0.200000	.000000	.000000	.000000	.000000	.000000
1.00000	0.200000	.000000	.000000	.000000	.000000	.000000

ELEM 20 ========== LENGTH = 20.000000

COMB UNICA ---------- MAX

REL DIST	P	V2	V3	T	M2	M3
0.00000	0.500000	.000000	.000000	.000000	.000000	.000000
1.00000	0.500000	.000000	.000000	.000000	.000000	.000000

COMB UNICA ---------- MIN

REL DIST	P	V2	V3	T	M2	M3
0.00000	0.500000	.000000	.000000	.000000	.000000	.000000
1.00000	0.500000	.000000	.000000	.000000	.000000	.000000

ELEM 21 ========== LENGTH = 28.284271

COMB UNICA ---------- MAX

REL DIST	P	V2	V3	T	M2	M3
0.00000	-0.707107	.000000	.000000	.000000	.000000	.000000

```
 1.00000   -0.707107     .000000     .000000     .000000     .000000
.000000

 COMB   UNICA ------------------ MIN

 REL DIST          P          V2          V3           T          M2
M3
 0.00000   -0.707107     .000000     .000000     .000000     .000000
.000000
 1.00000   -0.707107     .000000     .000000     .000000     .000000
.000000
```

```
                    S A P 2 0 0 0 (R)

                Structural Analysis Programs

                  Educational Version 6.13

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 D I S P L A C E M E N T   D E G R E E S   O F   F R E E D O M

         (A) = Active DOF, equilibrium equation
         (-) = Restrained DOF, reaction computed
         (+) = Constrained DOF
         ( ) = Null DOF

  JOINTS                UX  UY  UZ  RX  RY  RZ
       1 TO       2     -       -
       3 TO      16     A       A
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 T O T A L   A S S E M B L E D   J O I N T   M A S S E S

 IN GLOBAL COORDINATES

                   UX          UY          UZ          RX          RY
RZ
   TOTAL     .000000     .000000     .000000     .000000     .000000
.000000


 T O T A L   A C C E L E R A T E D   M A S S   A N D   L O C A T I O N

 TOTAL MASS ACTIVATED BY ACCELERATION LOADS, IN GLOBAL COORDINATES

                   UX          UY          UZ
```

MASS	.000000	.000000	.000000
X-LOC	.000000	.000000	.000000
Y-LOC	.000000	.000000	.000000
Z-LOC	.000000	.000000	.000000

J O I N T D I S P L A C E M E N T S

TRANSLATIONS AND ROTATIONS, IN GLOBAL COORDINATES

COMB UNICA ---------- MAX

JOINT	UX	UZ
1	.000000	.000000
2	.000000	.000000
3	-0.007657	-0.002149
4	-0.007657	-0.001673
5	-0.007874	-0.001818
6	-0.007874	-0.003346
7	-0.004975	-0.000448
8	-0.004975	-0.005020
9	1.49E-16	0.001614
10	-0.001181	-0.006693
11	0.013878	-0.008924
12	-0.002067	-0.021646
13	0.008955	-0.021906
14	-0.002733	-0.035694
15	0.003423	-0.035783
16	-0.003174	-0.051849

COMB UNICA ---------- MIN

JOINT	UX	UZ
1	.000000	.000000
2	.000000	.000000
3	-0.007657	-0.002149
4	-0.007657	-0.001673
5	-0.007874	-0.001818
6	-0.007874	-0.003346
7	-0.004975	-0.000448
8	-0.004975	-0.005020
9	1.49E-16	0.001614
10	-0.001181	-0.006693
11	0.013878	-0.008924
12	-0.002067	-0.021646
13	0.008955	-0.021906
14	-0.002733	-0.035694
15	0.003423	-0.035783
16	-0.003174	-0.051849

A P P L I E D L O A D S

FORCES AND MOMENTS ACTING ON JOINTS, IN GLOBAL COORDINATES

COMB UNICA ---------- MAX

JOINT	FX	FZ
9	.000000	-0.200000
11	.000000	-0.200000
13	.000000	-0.200000
15	.000000	-0.200000
16	.000000	-0.200000

COMB UNICA ---------- MIN

JOINT	FX	FZ
9	.000000	-0.200000
11	.000000	-0.200000
13	.000000	-0.200000
15	.000000	-0.200000
16	.000000	-0.200000

R E S T R A I N T F O R C E S (R E A C T I O N S)

FORCES AND MOMENTS ACTING ON JOINTS, IN GLOBAL COORDINATES

COMB UNICA ---------- MAX

JOINT	FX	FZ
1	-0.116667	-0.350000
2	0.116667	1.350000

COMB UNICA ---------- MIN

JOINT	FX	FZ
1	-0.116667	-0.350000
2	0.116667	1.350000

G L O B A L F O R C E B A L A N C E

TOTAL FORCE AND MOMENT AT THE ORIGIN, IN GLOBAL COORDINATES

LOAD VIVA ----------

	FX	FY	FZ	MX	MY	MZ
APPLIED	.000000	.000000	-1.000000	.000000	54.000000	

```
.000000
 REACTNS    -7.34E-15      .000000     1.000000      .000000  -54.000000
.000000

   TOTAL    -7.34E-15      .000000     4.00E-15      .000000   -6.39E-13
.000000

 COMB    UNICA ------------------ MAX

                   FX           FY           FZ           MX           MY
MZ
 APPLIED      .000000      .000000    -1.000000      .000000   54.000000
.000000
 REACTNS    -7.34E-15      .000000     1.000000      .000000  -54.000000
.000000

   TOTAL    -7.34E-15      .000000     4.00E-15      .000000   -6.39E-13
.000000

 COMB    UNICA ------------------ MIN

                   FX           FY           FZ           MX           MY
MZ
 APPLIED      .000000      .000000    -1.000000      .000000   54.000000
.000000
 REACTNS    -7.34E-15      .000000     1.000000      .000000  -54.000000
.000000

   TOTAL    -7.34E-15      .000000     4.00E-15      .000000   -6.39E-13
.000000
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7ErRaAuMaEEstEdLoE-MEXANPTE 4I-NTWOEDRMENAIDNALFTBUBSC E S

 ELEM        1 ================= LENGTH =    63.245553

 COMB    UNICA ------------------ MAX

 REL DIST           P           V2           V3            T           M2
M3
 0.00000     0.368932      .000000      .000000      .000000      .000000
.000000
 1.00000     0.368932      .000000      .000000      .000000      .000000
.000000

 COMB    UNICA ------------------ MIN

 REL DIST           P           V2           V3            T           M2
M3
 0.00000     0.368932      .000000      .000000      .000000      .000000
.000000
 1.00000     0.368932      .000000      .000000      .000000      .000000
.000000

 ELEM        2 ================= LENGTH =    15.811388
```

```
 COMB   UNICA ------------------ MAX

 REL DIST          P          V2          V3          T          M2
M3
 0.00000     0.368932     .000000     .000000     .000000     .000000
.000000
 1.00000     0.368932     .000000     .000000     .000000     .000000
.000000

 COMB   UNICA ------------------ MIN

 REL DIST          P          V2          V3          T          M2
M3
 0.00000     0.368932     .000000     .000000     .000000     .000000
.000000
 1.00000     0.368932     .000000     .000000     .000000     .000000
.000000

 ELEM       3 ================== LENGTH =   15.000000

 COMB   UNICA ------------------ MAX

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    -1.700000     .000000     .000000     .000000     .000000
.000000
 1.00000    -1.700000     .000000     .000000     .000000     .000000
.000000

 COMB   UNICA ------------------ MIN

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    -1.700000     .000000     .000000     .000000     .000000
.000000
 1.00000    -1.700000     .000000     .000000     .000000     .000000
.000000

 ELEM       4 ================== LENGTH =    5.000000

 COMB   UNICA ------------------ MAX

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    -3.04E-16     .000000     .000000     .000000     .000000
.000000
 1.00000    -3.04E-16     .000000     .000000     .000000     .000000
.000000
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 F R A M E   E L E M E N T   I N T E R N A L   F O R C E S

 COMB   UNICA ------------------ MIN
```

REL DIST	P	V2	V3	T	M2	M3
0.00000	-3.04E-16	.000000	.000000	.000000	. 00000	.000000
1.00000	-3.04E-16	.000000	.0000 0	.000000	000	.000000

ELEM 5 ========== LENGTH = 15.811388

COMB UNICA ---------- MAX

REL DIST	P	V2	V3	T	M2	M3
0.00000	0.368932	.000000	.000000	.000000	. 0000	.000000
1.00000	0.368932	.000000	.0000 0	.000000	. 0000	.000000

COMB UNICA ---------- MIN

REL DIST	P	V2	V3	T	M2	M3
0.00000	0.368932	.000000	.000000	.000000	. 0000	.000000
1.00000	0.368932	.000000	.000000	.000000	. 0000	.000000

ELEM 6 ========== LENGTH = 18.027756

COMB UNICA ---------- MAX

REL DIST	P	V2	V3	T	M2	M3
0.00000	-1.57E-15	.000000	.000000	.000000	. 0000	.000000
1.00000	-1.57E-15	.000000	.000000	.000000	.000000	.000000

COMB UNICA ---------- MIN

REL DIST	P	V2	V3	T	M2	M3
0.00000	-1.57E-15	.000000	.000000	.000000	.000000	.000000
1.00000	-1.57E-15	.000000	.000000	.000000	. 0000	.000000

ELEM 7 ========== LENGTH = 15.000000

COMB UNICA ---------- MAX

REL DIST	P	V2	V3	T	M2	M3
0.00000	-1.700000	.000000	.00000	.000000	. 000	.000000
1.00000	-1.700000	.000000	.000000	.000000	. 000	.000000

COMB UNICA ---------- MIN

```
 REL DIST          P          V2          V3          T          M2
M3
 0.00000   -1.700000     .000000     .000000     .000000     .000000
.000000
 1.00000   -1.700000     .000000     .000000     .000000     .000000
.000000
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 F R A M E   E L E M E N T   I N T E R N A L   F O R C E S

 ELEM       8 ================= LENGTH =   10.000000

 COMB   UNICA ----------------- MAX

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    2.15E-16     .000000     .000000     .000000     .000000
.000000
 1.00000    2.15E-16     .000000     .000000     .000000     .000000
.000000

 COMB   UNICA ----------------- MIN

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    2.15E-16     .000000     .000000     .000000     .000000
.000000
 1.00000    2.15E-16     .000000     .000000     .000000     .000000
.000000

 ELEM       9 ================= LENGTH =   15.811388

 COMB   UNICA ----------------- MAX

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    0.368932     .000000     .000000     .000000     .000000
.000000
 1.00000    0.368932     .000000     .000000     .000000     .000000
.000000

 COMB   UNICA ----------------- MIN

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    0.368932     .000000     .000000     .000000     .000000
.000000
 1.00000    0.368932     .000000     .000000     .000000     .000000
.000000

 ELEM      10 ================= LENGTH =   21.213203

 COMB   UNICA ----------------- MAX

 REL DIST          P          V2          V3          T          M2
```

```
M3
 0.00000   -1.38E-15     .000000     .000000     .000000     .000000
.000000
 1.00000   -1.38E-15     .000000     .000000     .000000     .000000
.000000

 COMB   UNICA ------------------ MIN

 REL DIST          P          V2          V3           T          M2
M3
 0.00000   -1.38E-15     .000000     .000000     .000000     .000000
.000000
 1.00000   -1.38E-15     .000000     .000000     .000000     .000000
.000000

 ELEM      11 ================== LENGTH =   15.000000

 COMB   UNICA ------------------ MAX

 REL DIST          P          V2          V3           T          M2
M3
 0.00000   -1.700000     .000000     .000000     .000000     .000000
.000000
 1.00000   -1.700000     .000000     .000000     .000000     .000000
.000000
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 F R A M E   E L E M E N T   I N T E R N A L   F O R C E S

 COMB   UNICA ------------------ MIN

 REL DIST          P          V2          V3           T          M2
M3
 0.00000   -1.700000     .000000     .000000     .000000     .000000
.000000
 1.00000   -1.700000     .000000     .000000     .000000     .000000
.000000

 ELEM      12 ================== LENGTH =   15.000000

 COMB   UNICA ------------------ MAX

 REL DIST          P          V2          V3           T          M2
M3
 0.00000    5.90E-16     .000000     .000000     .000000     .000000
.000000
 1.00000    5.90E-16     .000000     .000000     .000000     .000000
.000000

 COMB   UNICA ------------------ MIN

 REL DIST          P          V2          V3           T          M2
M3
 0.00000    5.90E-16     .000000     .000000     .000000     .000000
.000000
```

```
 1.00000     5.90E-16      .000000      .000000      .000000      .000000
.000000

 ELEM       13 ================= LENGTH =   15.811388

 COMB    UNICA ------------------ MAX

 REL DIST          P           V2           V3           T           M2
M3
 0.00000     0.368932      .000000      .000000      .000000      .000000
.000000
 1.00000     0.368932      .000000      .000000      .000000      .000000
.000000

 COMB    UNICA ------------------ MIN

 REL DIST          P           V2           V3           T           M2
M3
 0.00000     0.368932      .000000      .000000      .000000      .000000
.000000
 1.00000     0.368932      .000000      .000000      .000000      .000000
.000000

 ELEM       14 ================= LENGTH =   25.000000

 COMB    UNICA ------------------ MAX

 REL DIST          P           V2           V3           T           M2
M3
 0.00000    -2.31E-15      .000000      .000000      .000000      .000000
.000000
 1.00000    -2.31E-15      .000000      .000000      .000000      .000000
.000000

 COMB    UNICA ------------------ MIN

 REL DIST          P           V2           V3           T           M2
M3
 0.00000    -2.31E-15      .000000      .000000      .000000      .000000
.000000
 1.00000    -2.31E-15      .000000      .000000      .000000      .000000
.000000
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 F R A M E   E L E M E N T   I N T E R N A L   F O R C E S

 ELEM       15 ================= LENGTH =   15.000000

 COMB    UNICA ------------------ MAX

 REL DIST          P           V2           V3           T           M2
M3
 0.00000    -1.700000      .000000      .000000      .000000      .000000
.000000
 1.00000    -1.700000      .000000      .000000      .000000      .000000
```

.000000

COMB UNICA ---------- MIN

REL DIST	P	V2	V3	T	M2	M3
0.00000	-1.700000	.000000	.000000	.000000	.000000	.000000
1.00000	-1.700000	.000000	.000000	.000000	.000000	.000000

ELEM 16 ========== LENGTH = 20.000000

COMB UNICA ---------- MAX

REL DIST	P	V2	V3	T	M2	M3
0.00000	-0.900000	.000000	.000000	.000000	.000000	.000000
1.00000	-0.900000	.000000	.000000	.000000	.000000	.000000

COMB UNICA ---------- MIN

REL DIST	P	V2	V3	T	M2	M3
0.00000	-0.900000	.000000	.000000	.000000	.000000	.000000
1.00000	-0.900000	.000000	.000000	.000000	.000000	.000000

ELEM 17 ========== LENGTH = 28.284271

COMB UNICA ---------- MAX

REL DIST	P	V2	V3	T	M2	M3
0.00000	1.272792	.000000	.000000	.000000	.000000	.000000
1.00000	1.272792	.000000	.000000	.000000	.000000	.000000

COMB UNICA ---------- MIN

REL DIST	P	V2	V3	T	M2	M3
0.00000	1.272792	.000000	.000000	.000000	.000000	.000000
1.00000	1.272792	.000000	.000000	.000000	.000000	.000000

ELEM 18 ========== LENGTH = 20.000000

COMB UNICA ---------- MAX

REL DIST	P	V2	V3	T	M2	M3
0.00000	-1.700000	.000000	.000000	.000000	.000000	.000000
1.00000	-1.700000	.000000	.000000	.000000	.000000	

F R A M E E L E M E N T I N T E R N A L F O R C E S

COMB UNICA ---------- MIN

REL DIST	P	V2	V3	T	M2	M3
0.00000	-1.700000	.000000	.000000	.000000	.000000	.000000
1.00000	-1.700000	.000000	.000000	.000000	.000000	.000000

ELEM 19 ========== LENGTH = 15.000000

COMB UNICA ---------- MAX

REL DIST	P	V2	V3	T	M2	M3
0.00000	-0.900000	.000000	.000000	.000000	.000000	.000000
1.00000	-0.900000	.000000	.000000	.000000	.000000	.000000

COMB UNICA ---------- MIN

REL DIST	P	V2	V3	T	M2	M3
0.00000	-0.900000	.000000	.000000	.000000	.000000	.000000
1.00000	-0.900000	.000000	.000000	.000000	.000000	.000000

ELEM 20 ========== LENGTH = 25.000000

COMB UNICA ---------- MAX

REL DIST	P	V2	V3	T	M2	M3
0.00000	0.372180	.000000	.000000	.000000	.000000	.000000
1.00000	0.372180	.000000	.000000	.000000	.000000	.000000

COMB UNICA ---------- MIN

REL DIST	P	V2	V3	T	M2	M3
0.00000	0.372180	.000000	.000000	.000000	.000000	.000000
1.00000	0.372180	.000000	.000000	.000000	.000000	.000000

ELEM 21 ========== LENGTH = 16.428329

```
 COMB   UNICA ------------------ MAX

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    0.741128     .000000     .000000     .000000     .000000
.000000
 1.00000    0.741128     .000000     .000000     .000000     .000000
.000000

 COMB   UNICA ------------------ MIN

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    0.741128     .000000     .000000     .000000     .000000
.000000
 1.00000    0.741128     .000000     .000000     .000000     .000000
.000000
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 F R A M E   E L E M E N T   I N T E R N A L   F O R C E S

 ELEM      22 ================== LENGTH =   13.300000

 COMB   UNICA ------------------ MAX

 REL DIST          P          V2          V3          T          M2
M3
 0.00000   -0.297744     .000000     .000000     .000000     .000000
.000000
 1.00000   -0.297744     .000000     .000000     .000000     .000000
.000000

 COMB   UNICA ------------------ MIN

 REL DIST          P          V2          V3          T          M2
M3
 0.00000   -0.297744     .000000     .000000     .000000     .000000
.000000
 1.00000   -0.297744     .000000     .000000     .000000     .000000
.000000

 ELEM      23 ================== LENGTH =   15.000000

 COMB   UNICA ------------------ MAX

 REL DIST          P          V2          V3          T          M2
M3
 0.00000   -0.676692     .000000     .000000     .000000     .000000
.000000
 1.00000   -0.676692     .000000     .000000     .000000     .000000
.000000

 COMB   UNICA ------------------ MIN
```

```
 REL DIST          P          V2          V3          T          M2
M3
 0.00000   -0.676692     .000000     .000000     .000000     .000000
.000000
 1.00000   -0.676692     .000000     .000000     .000000     .000000
.000000

 ELEM      24 ================= LENGTH =   20.047194

 COMB   UNICA ----------------- MAX

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    0.305961     .000000     .000000     .000000     .000000
.000000
 1.00000    0.305961     .000000     .000000     .000000     .000000
.000000

 COMB   UNICA ----------------- MIN

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    0.305961     .000000     .000000     .000000     .000000
.000000
 1.00000    0.305961     .000000     .000000     .000000     .000000
.000000

 ELEM      25 ================= LENGTH =   16.387800

 COMB   UNICA ----------------- MAX

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    0.489188     .000000     .000000     .000000     .000000
.000000
 1.00000    0.489188     .000000     .000000     .000000     .000000
.000000
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 Armadura Estadio - EXAMPLE 4 - TWO-DIMENSIONAL TRUSS
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 F R A M E   E L E M E N T   I N T E R N A L   F O R C E S

 COMB   UNICA ----------------- MIN

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    0.489188     .000000     .000000     .000000     .000000
.000000
 1.00000    0.489188     .000000     .000000     .000000     .000000
.000000

 ELEM      26 ================= LENGTH =    6.700000

 COMB   UNICA ----------------- MAX

 REL DIST          P          V2          V3          T          M2
```

```
M3
 0.00000    -0.202985      .000000      .000000      .000000      .000000
.000000
 1.00000    -0.202985      .000000      .000000      .000000      .000000
.000000

 COMB    UNICA ------------------ MIN

 REL DIST           P           V2           V3            T           M2
M3
 0.00000    -0.202985      .000000      .000000      .000000      .000000
.000000
 1.00000    -0.202985      .000000      .000000      .000000      .000000
.000000

 ELEM       27 ================== LENGTH =    15.000000

 COMB    UNICA ------------------ MAX

 REL DIST           P           V2           V3            T           M2
M3
 0.00000    -0.447761      .000000      .000000      .000000      .000000
.000000
 1.00000    -0.447761      .000000      .000000      .000000      .000000
.000000

 COMB    UNICA ------------------ MIN

 REL DIST           P           V2           V3            T           M2
M3
 0.00000    -0.447761      .000000      .000000      .000000      .000000
.000000
 1.00000    -0.447761      .000000      .000000      .000000      .000000
.000000

 ELEM       28 ================== LENGTH =    16.428329

 COMB    UNICA ------------------ MAX

 REL DIST           P           V2           V3            T           M2
M3
 0.00000     0.490398      .000000      .000000      .000000      .000000
.000000
 1.00000     0.490398      .000000      .000000      .000000      .000000
.000000

 COMB    UNICA ------------------ MIN

 REL DIST           P           V2           V3            T           M2
M3
 0.00000     0.490398      .000000      .000000      .000000      .000000
.000000
 1.00000     0.490398      .000000      .000000      .000000      .000000
.000000
```

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D I S P L A C E M E N T D E G R E E S O F F R E E D O M

(A) = Active DOF, equilibrium equation
(-) = Restrained DOF, reaction computed
(+) = Constrained DOF
( ) = Null DOF

JOINTS			UX	UY	UZ	RX	RY	RZ
1			-		-			
2	TO	11	A		A			
12			A		-			
13			A		A			

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Armadura - EXAMPLE 5 - TWO-DIMENSIONAL TRUSS
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T O T A L A S S E M B L E D J O I N T M A S S E S

IN GLOBAL COORDINATES

	UX	UY	UZ	RX	RY	RZ
TOTAL	.000000	.000000	.000000	.000000	.000000	.000000

T O T A L A C C E L E R A T E D M A S S A N D L O C A T I O N

TOTAL MASS ACTIVATED BY ACCELERATION LOADS, IN GLOBAL COORDINATES

	UX	UY	UZ
MASS	.000000	.000000	.000000
X-LOC	.000000	.000000	.000000
Y-LOC	.000000	.000000	.000000
Z-LOC	.000000	.000000	.000000

J O I N T D I S P L A C E M E N T S

TRANSLATIONS AND ROTATIONS, IN GLOBAL COORDINATES

COMB UNICA ---------- MAX

JOINT	UX	UZ
1	.000000	.000000
2	0.018584	-0.001378
3	0.009191	-0.012255
4	0.018059	-0.013043
5	0.014922	-0.022250
6	0.016484	-0.022381
7	0.015736	-0.023877
8	0.016497	-0.022355
9	0.014909	-0.022486
10	0.022254	-0.012308
11	0.013334	-0.013095
12	0.031485	.000000
13	0.012810	-0.001378

COMB UNICA ---------- MIN

JOINT	UX	UZ
1	.000000	.000000
2	0.018584	-0.001378
3	0.009191	-0.012255
4	0.018059	-0.013043
5	0.014922	-0.022250
6	0.016484	-0.022381
7	0.015736	-0.023877
8	0.016497	-0.022355
9	0.014909	-0.022486
10	0.022254	-0.012308
11	0.013334	-0.013095
12	0.031485	.000000
13	0.012810	-0.001378

A P P L I E D L O A D S

FORCES AND MOMENTS ACTING ON JOINTS, IN GLOBAL COORDINATES

```
 COMB   UNICA ------------------ MAX

   JOINT          FX          FZ
       2     .000000   -0.200000
       4     .000000   -0.200000
       6     .000000   -0.200000
       9     .000000   -0.200000
      11     .000000   -0.200000
      13     .000000   -0.200000

 COMB   UNICA ------------------ MIN

   JOINT          FX          FZ
       2     .000000   -0.200000
       4     .000000   -0.200000
       6     .000000   -0.200000
       9     .000000   -0.200000
      11     .000000   -0.200000
      13     .000000   -0.200000
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 R E S T R A I N T   F O R C E S   ( R E A C T I O N S )

 FORCES AND MOMENTS ACTING ON JOINTS, IN GLOBAL COORDINATES

 COMB   UNICA ------------------ MAX

   JOINT          FX          FZ
       1    1.83E-14    0.600000
      12     .000000    0.600000

 COMB   UNICA ------------------ MIN

   JOINT          FX          FZ
       1    1.83E-14    0.600000
      12     .000000    0.600000
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 G L O B A L   F O R C E   B A L A N C E

 TOTAL FORCE AND MOMENT AT THE ORIGIN, IN GLOBAL COORDINATES

 LOAD    VIVA ------------------

                  FX          FY          FZ          MX          MY
MZ
 APPLIED     .000000     .000000   -1.200000     .000000   60.000000
.000000
 REACTNS    1.83E-14     .000000    1.200000     .000000  -60.000000
```

```
.000000

   TOTAL     1.83E-14      .000000     4.00E-15      .000000     2.13E-13
.000000

 COMB    UNICA ------------------ MAX

                   FX           FY           FZ           MX           MY
MZ
 APPLIED      .000000      .000000    -1.200000      .000000    60.000000
.000000
 REACTNS     1.83E-14      .000000     1.200000      .000000   -60.000000
.000000

   TOTAL     1.83E-14      .000000     4.00E-15      .000000     2.13E-13
.000000

 COMB    UNICA ------------------ MIN

                   FX           FY           FZ           MX           MY
MZ
 APPLIED      .000000      .000000    -1.200000      .000000    60.000000
.000000
 REACTNS     1.83E-14      .000000     1.200000      .000000   -60.000000
.000000

   TOTAL     1.83E-14      .000000     4.00E-15      .000000     2.13E-13
.000000
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 Armadura - EXAMPLE 5 - TWO-DIMENSIONAL TRUSS
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 F R A M E   E L E M E N T   I N T E R N A L   F O R C E S

 ELEM        1 ================== LENGTH =    35.000000

 COMB    UNICA ------------------ MAX

 REL DIST           P           V2           V3            T           M2
M3
 0.00000    -0.600000      .000000      .000000      .000000      .000000
.000000
 1.00000    -0.600000      .000000      .000000      .000000      .000000
.000000

 COMB    UNICA ------------------ MIN

 REL DIST           P           V2           V3            T           M2
M3
 0.00000    -0.600000      .000000      .000000      .000000      .000000
.000000
 1.00000    -0.600000      .000000      .000000      .000000      .000000
.000000

 ELEM        2 ================== LENGTH =    25.000000

 COMB    UNICA ------------------ MAX
```

```
 REL DIST
M3                P          V2          V3          T          M2
 0.00000   -2.25E-14     .000000     .000000     .000000     .000000
.000000
 1.00000   -2.25E-14     .000000     .000000     .000000     .000000
.000000

 COMB   UNICA ------------------ MIN

 REL DIST          P          V2          V3          T          M2
M3
 0.00000   -2.25E-14     .000000     .000000     .000000     .000000
.000000
 1.00000   -2.25E-14     .000000     .000000     .000000     .000000
.000000

 ELEM       3 ================== LENGTH =   28.284271

 COMB   UNICA ------------------ MAX

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    0.565685     .000000     .000000     .000000     .000000
.000000
 1.00000    0.565685     .000000     .000000     .000000     .000000
.000000

 COMB   UNICA ------------------ MIN

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    0.565685     .000000     .000000     .000000     .000000
.000000
 1.00000    0.565685     .000000     .000000     .000000     .000000
.000000

 ELEM       4 ================== LENGTH =   20.000000

 COMB   UNICA ------------------ MAX

 REL DIST          P          V2          V3          T          M2
M3
 0.00000   -0.400000     .000000     .000000     .000000     .000000
.000000
 1.00000   -0.400000     .000000     .000000     .000000     .000000
.000000
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 Armadura - EXAMPLE 5 - TWO-DIMENSIONAL TRUSS
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 F R A M E   E L E M E N T   I N T E R N A L   F O R C E S

 COMB   UNICA ------------------ MIN

 REL DIST          P          V2          V3          T          M2
M3
```

```
 0.00000    -0.400000      .000000      .000000      .000000      .000000
.000000
 1.00000    -0.400000      .000000      .000000      .000000      .000000
.000000

 ELEM        5 ================= LENGTH =    20.000000

 COMB    UNICA ------------------ MAX

 REL DIST            P           V2           V3            T           M2
M3
 0.00000    -0.600000      .000000      .000000      .000000      .000000
.000000
 1.00000    -0.600000      .000000      .000000      .000000      .000000
.000000

 COMB    UNICA ------------------ MIN

 REL DIST            P           V2           V3            T           M2
M3
 0.00000    -0.600000      .000000      .000000      .000000      .000000
.000000
 1.00000    -0.600000      .000000      .000000      .000000      .000000
.000000

 ELEM        6 ================= LENGTH =    22.360680

 COMB    UNICA ------------------ MAX

 REL DIST            P           V2           V3            T           M2
M3
 0.00000     0.447214      .000000      .000000      .000000      .000000
.000000
 1.00000     0.447214      .000000      .000000      .000000      .000000
.000000

 COMB    UNICA ------------------ MIN

 REL DIST            P           V2           V3            T           M2
M3
 0.00000     0.447214      .000000      .000000      .000000      .000000
.000000
 1.00000     0.447214      .000000      .000000      .000000      .000000
.000000

 ELEM        7 ================= LENGTH =    22.360680

 COMB    UNICA ------------------ MAX

 REL DIST            P           V2           V3            T           M2
M3
 0.00000     0.894427      .000000      .000000      .000000      .000000
.000000
 1.00000     0.894427      .000000      .000000      .000000      .000000
.000000

 COMB    UNICA ------------------ MIN

 REL DIST            P           V2           V3            T           M2
M3
```

```
 0.00000     0.894427     .000000     .000000     .000000     .000000
.000000
 1.00000     0.894427     .000000     .000000     .000000     .000000
.000000
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 Armadura - EXAMPLE 5 - TWO-DIMENSIONAL TRUSS
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 F R A M E   E L E M E N T   I N T E R N A L   F O R C E S

 ELEM        8 ================== LENGTH =   20.000000

 COMB   UNICA ------------------ MAX

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    -1.200000     .000000     .000000     .000000     .000000
.000000
 1.00000    -1.200000     .000000     .000000     .000000     .000000
.000000

 COMB   UNICA ------------------ MIN

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    -1.200000     .000000     .000000     .000000     .000000
.000000
 1.00000    -1.200000     .000000     .000000     .000000     .000000
.000000

 ELEM        9 ================== LENGTH =   10.000000

 COMB   UNICA ------------------ MAX

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    -0.200000     .000000     .000000     .000000     .000000
.000000
 1.00000    -0.200000     .000000     .000000     .000000     .000000
.000000

 COMB   UNICA ------------------ MIN

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    -0.200000     .000000     .000000     .000000     .000000
.000000
 1.00000    -0.200000     .000000     .000000     .000000     .000000
.000000

 ELEM       10 ================== LENGTH =   20.000000

 COMB   UNICA ------------------ MAX

 REL DIST          P          V2          V3          T          M2
M3
 0.00000     1.200000     .000000     .000000     .000000     .000000
```

```
.000000
 1.00000     1.200000      .000000      .000000      .000000      .000000
.000000

 COMB    UNICA ------------------ MIN

 REL DIST            P           V2           V3            T           M2
M3
 0.00000     1.200000      .000000      .000000      .000000      .000000
.000000
 1.00000     1.200000      .000000      .000000      .000000      .000000
.000000

 ELEM       11 ================== LENGTH =   11.180340

 COMB    UNICA ------------------ MAX

 REL DIST            P           V2           V3            T           M2
M3
 0.00000    -9.81E-15      .000000      .000000      .000000      .000000
.000000
 1.00000    -9.81E-15      .000000      .000000      .000000      .000000
.000000
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 Armadura - EXAMPLE 5 - TWO-DIMENSIONAL TRUSS
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 F R A M E   E L E M E N T   I N T E R N A L   F O R C E S

 COMB    UNICA ------------------ MIN

 REL DIST            P           V2           V3            T           M2
M3
 0.00000    -9.81E-15      .000000      .000000      .000000      .000000
.000000
 1.00000    -9.81E-15      .000000      .000000      .000000      .000000
.000000

 ELEM       12 ================== LENGTH =   11.180340

 COMB    UNICA ------------------ MAX

 REL DIST            P           V2           V3            T           M2
M3
 0.00000     9.32E-16      .000000      .000000      .000000      .000000
.000000
 1.00000     9.32E-16      .000000      .000000      .000000      .000000
.000000

 COMB    UNICA ------------------ MIN

 REL DIST            P           V2           V3            T           M2
M3
 0.00000     9.32E-16      .000000      .000000      .000000      .000000
.000000
 1.00000     9.32E-16      .000000      .000000      .000000      .000000
.000000
```

```
 ELEM      13 ================= LENGTH =   20.000000

 COMB   UNICA ----------------- MAX

 REL DIST          P          V2          V3          T          M2
M3
 0.00000   -1.200000     .000000     .000000     .000000     .000000
.000000
 1.00000   -1.200000     .000000     .000000     .000000     .000000
.000000

 COMB   UNICA ----------------- MIN

 REL DIST          P          V2          V3          T          M2
M3
 0.00000   -1.200000     .000000     .000000     .000000     .000000
.000000
 1.00000   -1.200000     .000000     .000000     .000000     .000000
.000000

 ELEM      14 ================= LENGTH =   11.180340

 COMB   UNICA ----------------- MAX

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    1.21E-14     .000000     .000000     .000000     .000000
.000000
 1.00000    1.21E-14     .000000     .000000     .000000     .000000
.000000

 COMB   UNICA ----------------- MIN

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    1.21E-14     .000000     .000000     .000000     .000000
.000000
 1.00000    1.21E-14     .000000     .000000     .000000     .000000
.000000
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 Armadura - EXAMPLE 5 - TWO-DIMENSIONAL TRUSS
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 F R A M E   E L E M E N T   I N T E R N A L   F O R C E S

 ELEM      15 ================= LENGTH =   10.000000

 COMB   UNICA ----------------- MAX

 REL DIST          P          V2          V3          T          M2
M3
 0.00000   -0.200000     .000000     .000000     .000000     .000000
.000000
 1.00000   -0.200000     .000000     .000000     .000000     .000000
.000000
```

```
 COMB    UNICA ----------------- MIN

 REL DIST          P          V2          V3          T          M2
M3
 0.00000   -0.200000     .000000     .000000     .000000     .000000
.000000
 1.00000   -0.200000     .000000     .000000     .000000     .000000
.000000

 ELEM       16 ================= LENGTH =   22.360680

 COMB    UNICA ----------------- MAX

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    0.447214     .000000     .000000     .000000     .000000
.000000
 1.00000    0.447214     .000000     .000000     .000000     .000000
.000000

 COMB    UNICA ----------------- MIN

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    0.447214     .000000     .000000     .000000     .000000
.000000
 1.00000    0.447214     .000000     .000000     .000000     .000000
.000000

 ELEM       17 ================= LENGTH =   22.360680

 COMB    UNICA ----------------- MAX

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    0.894427     .000000     .000000     .000000     .000000
.000000
 1.00000    0.894427     .000000     .000000     .000000     .000000
.000000

 COMB    UNICA ----------------- MIN

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    0.894427     .000000     .000000     .000000     .000000
.000000
 1.00000    0.894427     .000000     .000000     .000000     .000000
.000000

 ELEM       18 ================= LENGTH =   20.000000

 COMB    UNICA ----------------- MAX

 REL DIST          P          V2          V3          T          M2
M3
 0.00000   -1.200000     .000000     .000000     .000000     .000000
.000000
 1.00000   -1.200000     .000000     .000000     .000000     .000000
.000000
 Program SAP2000 Educational Version 6.13
```

```
 F R A M E   E L E M E N T   I N T E R N A L   F O R C E S

 COMB   UNICA ------------------ MIN

 REL DIST          P          V2          V3          T          M2
M3
 0.00000   -1.200000     .000000     .000000     .000000     .000000
.000000
 1.00000   -1.200000     .000000     .000000     .000000     .000000
.000000

 ELEM      19 ================= LENGTH =   20.000000

 COMB   UNICA ------------------ MAX

 REL DIST          P          V2          V3          T          M2
M3
 0.00000   -0.600000     .000000     .000000     .000000     .000000
.000000
 1.00000   -0.600000     .000000     .000000     .000000     .000000
.000000

 COMB   UNICA ------------------ MIN

 REL DIST          P          V2          V3          T          M2
M3
 0.00000   -0.600000     .000000     .000000     .000000     .000000
.000000
 1.00000   -0.600000     .000000     .000000     .000000     .000000
.000000

 ELEM      20 ================= LENGTH =   25.000000

 COMB   UNICA ------------------ MAX

 REL DIST          P          V2          V3          T          M2
M3
 0.00000   -2.16E-15     .000000     .000000     .000000     .000000
.000000
 1.00000   -2.16E-15     .000000     .000000     .000000     .000000
.000000

 COMB   UNICA ------------------ MIN

 REL DIST          P          V2          V3          T          M2
M3
 0.00000   -2.16E-15     .000000     .000000     .000000     .000000
.000000
 1.00000   -2.16E-15     .000000     .000000     .000000     .000000
.000000

 ELEM      21 ================= LENGTH =   28.284271

 COMB   UNICA ------------------ MAX
```

```
 REL DIST          P          V2          V3          T          M2
M3
 0.00000    0.565685     .000000     .000000     .000000     .000000
.000000
 1.00000    0.565685     .000000     .000000     .000000     .000000
.000000

 COMB   UNICA ------------------ MIN

 REL DIST          P          V2          V3          T          M2
M3
 0.00000    0.565685     .000000     .000000     .000000     .000000
.000000
 1.00000    0.565685     .000000     .000000     .000000     .000000
.000000
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 Armadura - EXAMPLE 5 - TWO-DIMENSIONAL TRUSS
13

 F R A M E   E L E M E N T   I N T E R N A L   F O R C E S

 ELEM      22 ================= LENGTH =   20.000000

 COMB   UNICA ------------------ MAX

 REL DIST          P          V2          V3          T          M2
M3
 0.00000   -0.400000     .000000     .000000     .000000     .000000
.000000
 1.00000   -0.400000     .000000     .000000     .000000     .000000
.000000

 COMB   UNICA ------------------ MIN

 REL DIST          P          V2          V3          T          M2
M3
 0.00000   -0.400000     .000000     .000000     .000000     .000000
.000000
 1.00000   -0.400000     .000000     .000000     .000000     .000000
.000000

 ELEM      23 ================= LENGTH =   35.000000

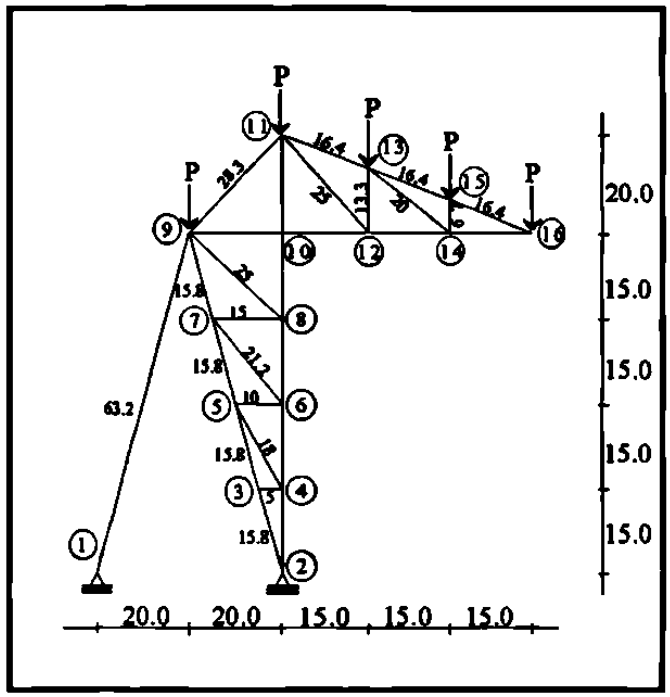
 COMB   UNICA ------------------ MAX

 REL DIST          P          V2          V3          T          M2
M3
 0.00000   -0.600000     .000000     .000000     .000000     .000000
.000000
 1.00000   -0.600000     .000000     .000000     .000000     .000000
.000000

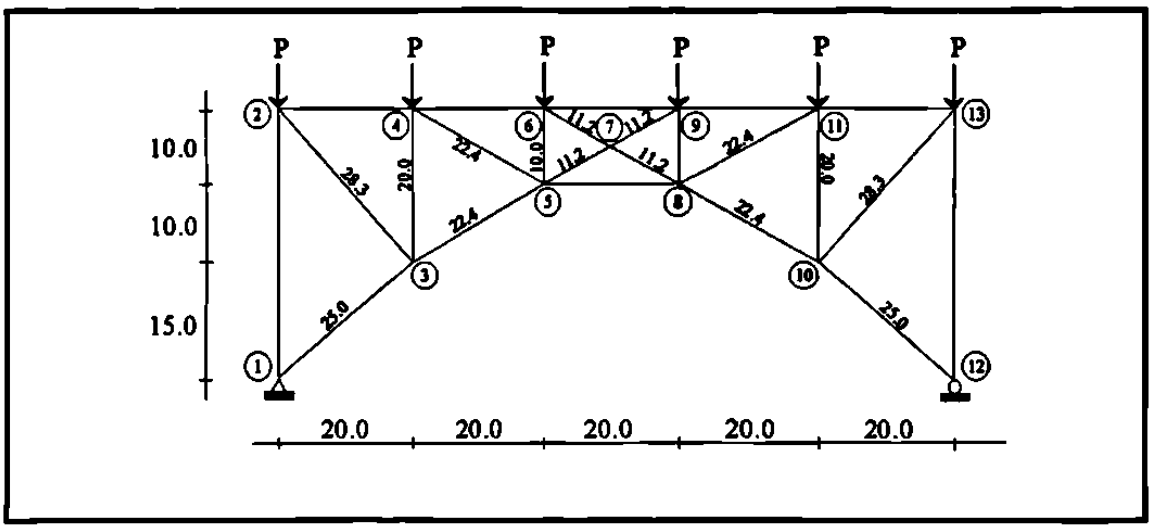
 COMB   UNICA ------------------ MIN

 REL DIST          P          V2          V3          T          M2
M3
```

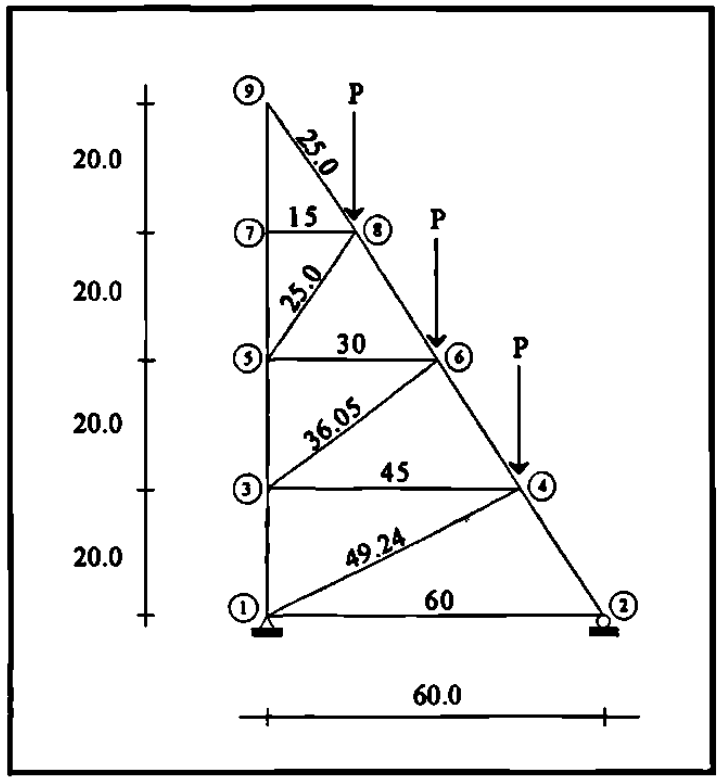
```
 0.00000   -0.600000     .000000     .000000     .000000     .000000
.000000
 1.00000   -0.600000     .000000     .000000     .000000     .000000
.000000
```



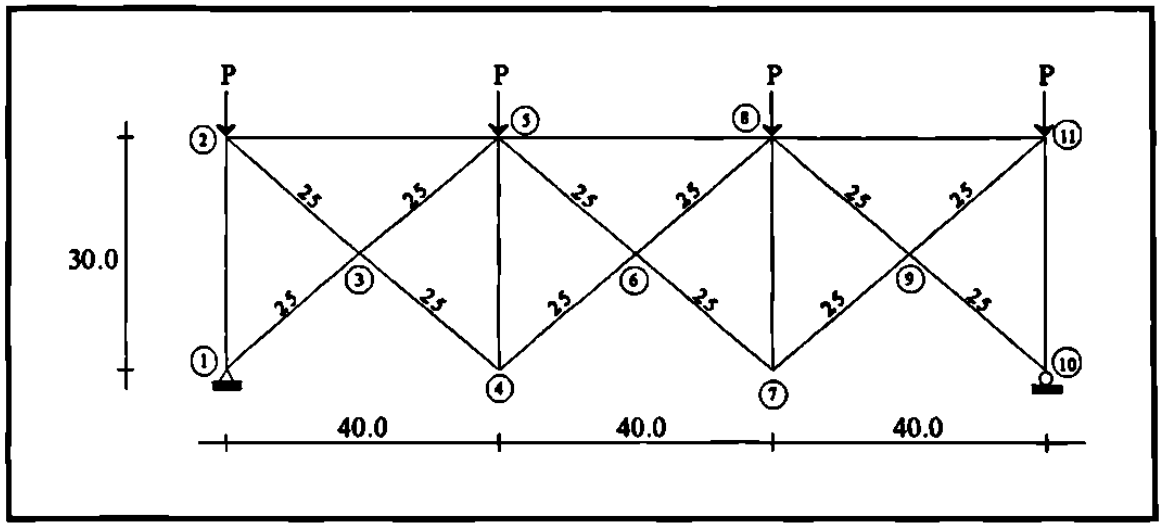
Nudo	X	Y
1.	0	0
2.	40	0
3.	35	15
4.	40	15
5.	30	30
6.	40	30
7.	25	45
8.	40	45
9.	20	60
10.	40	60
11.	40	80
12.	55	60
13.	55	73.3
14.	70	60
15.	70	66.7
16.	85	60



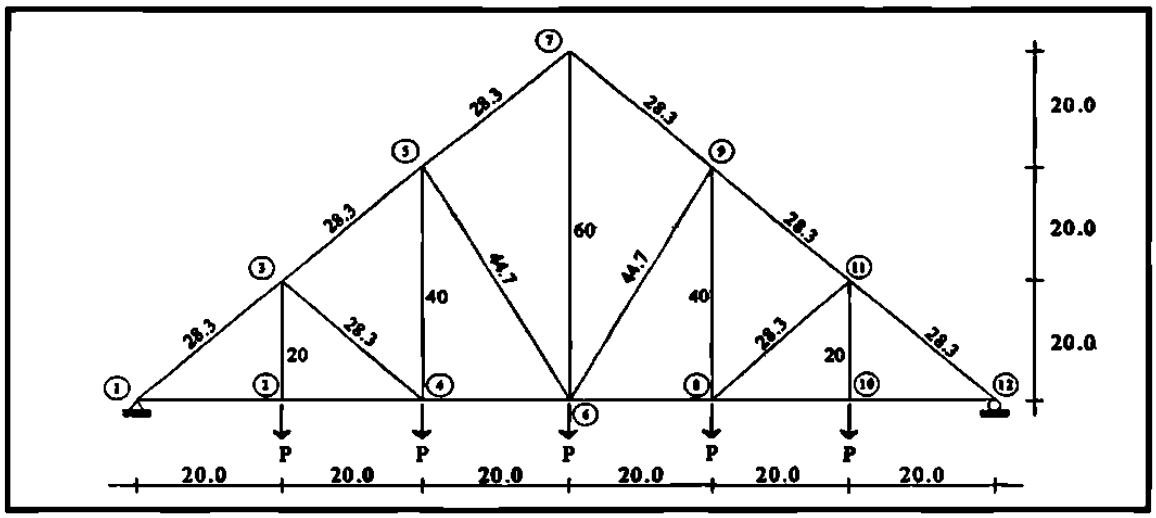
Nudo	X	Y
1.	0	0
2.	0	35
3.	20	15
4.	20	35
5.	40	25
6.	40	35
7.	50	30
8.	60	25
9.	60	35
10.	80	15
11.	80	35
12.	100	0
13.	100	35



Nudo	X	Y
1.	0	0
2.	60	0
3.	0	20
4.	45	20
5.	0	40
6.	30	40
7.	0	60
8.	15	60
9.	0	80



Nudo	*X*	*Y*
1.	0	0
2.	0	30
3.	20	15
4.	40	0
5.	40	30
6.	60	15
7.	80	0
8.	80	30
9.	100	15
10.	120	0
11.	120	30



Nudo	X	Y
1.	0	0
2.	20	0
3.	20	20
4.	40	0
5.	40	40
6.	60	0
7.	60	60
8.	80	0
9.	80	40
10.	100	0
11.	100	20
12.	120	0

V.7. Comparativa de resultados usando los modelos.

Se tomó cada una de las armaduras, cada una de ellas esta habilitada con cuatro strain gages, los cuales están indicados en cada figura, cada armadura fue cargada con una P=200 grs. en donde se indica, con excepción de la armadura 3 cuya P= 840 grs., se tomó la lectura final L_F; en la tabla aparece la diferencia entre las dos lecturas anteriores, con esta diferencia se calcula la carga axial presentada en ese elemento y se compara con la carga axial teórica.

Para poder obtener la carga axial, se obtiene la diferencia de las lecturas, esa diferencia es $x10^{-6}$ mm/mm. Se multiplica por el módulo de elasticidad y por el área

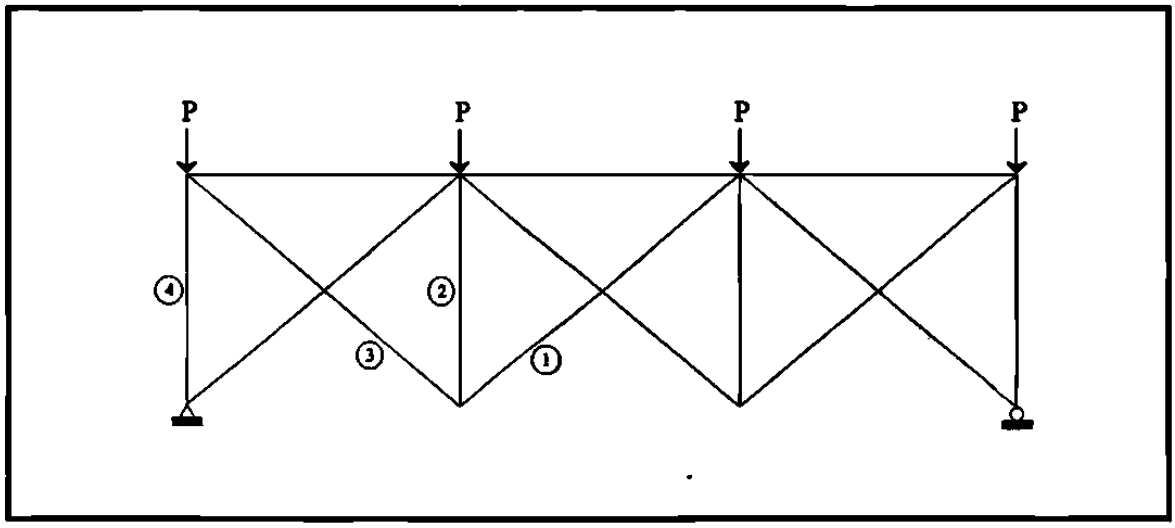
$$P = E\varepsilon A \qquad\qquad A = 0.6cm^2$$

Ejemplo :

Diferencia: 85

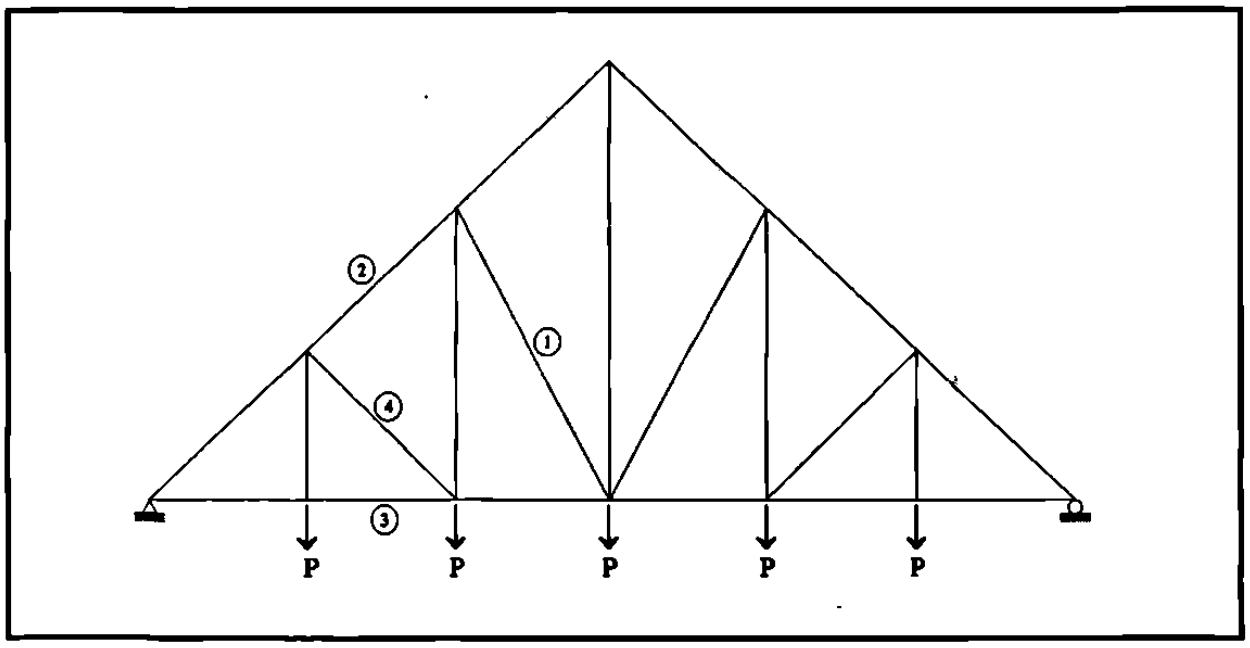
$$P = (6000kg/cm^2)(85x10^{-6})(0.6cm^2)$$
$$P = 0.306kg.$$

Armadura 1



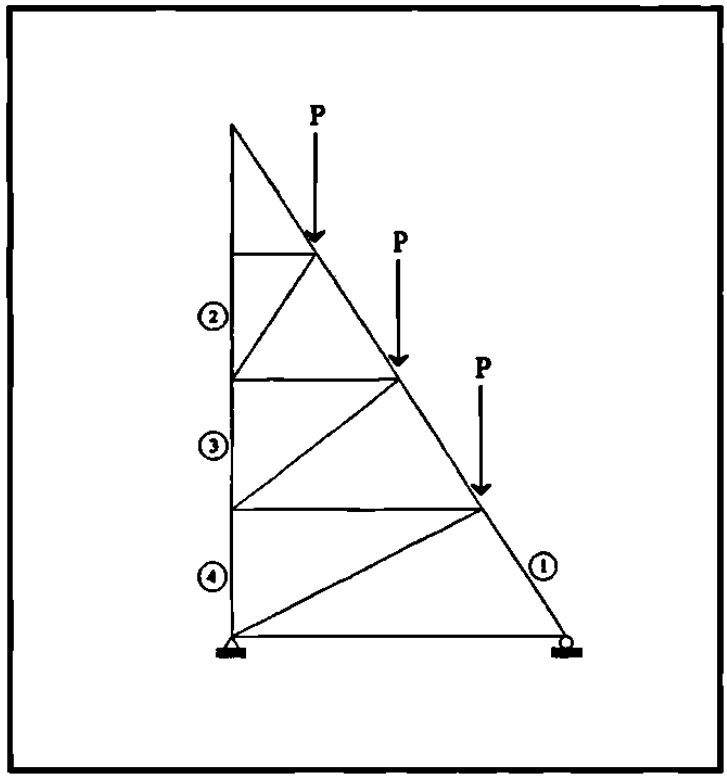
Elemento	***1***	***2***	***3***	***4***
Li	+105	-1300	+555	-310
Lf	+20	-1428	+427	-430
Diferencia	+85	-128	+128	-120
P obtenida	0.306	-0.461	0.461	-0.432
P teórica	0.334	-0.4	0.334	-0.4

Armadura 2



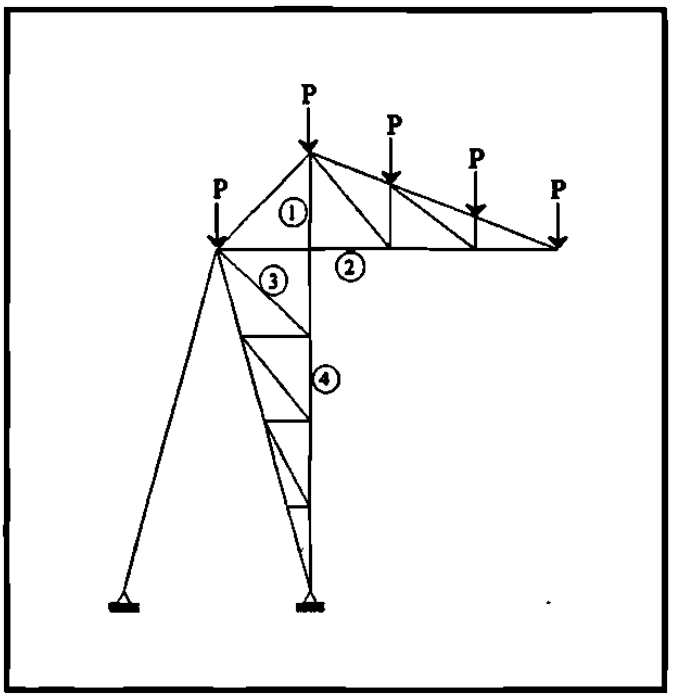
Elemento	***1***	***2***	***3***	***4***
Li	120	-6553	-2525	730
Lf	178	-6400	-2650	760
Diferencia	58	153	-125	30
P obtenida	0.2088	0.5508	-0.45	0.108
P teórica	0.224	0.564	-0.50	0.142

Armadura 3



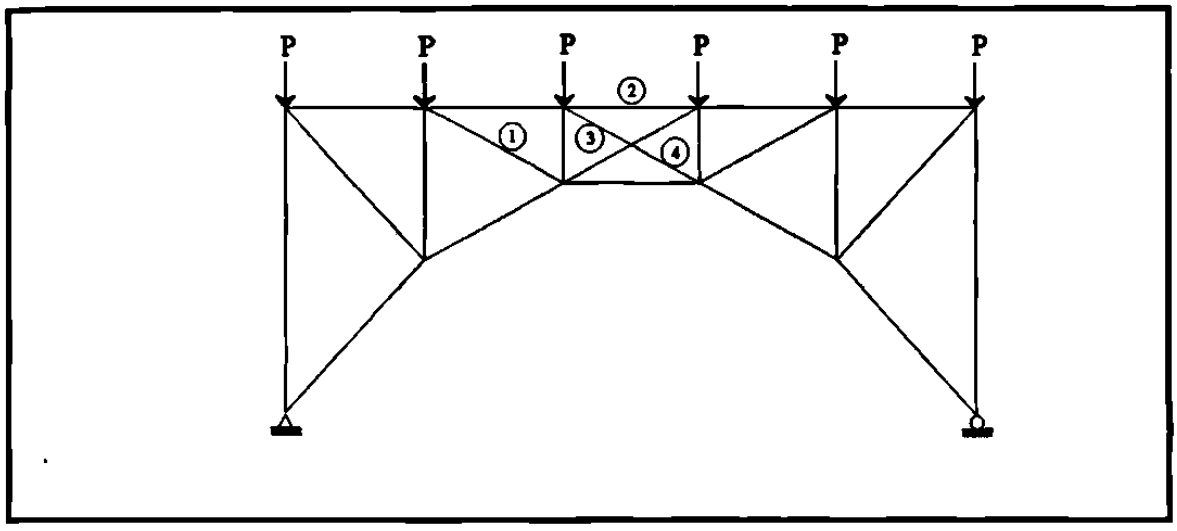
Elemento	***1***	***2***	***3***	***4***
Li	2900	-1300	-4385	-1425
Lf	2515	-1300	-4490	-1684
Diferencia	-385	0	-105	-259
P obtenida	-1.386	0	-0.378	-0.9324
P teórica	-1.5792	0	-0.420	-0.840

Armadura 4



Elemento	***1***	***2***	***3***	***4***
Li	-300	-2710	-4944	-4223
Lf	-3400	-2615	-4970	-4775
Diferencia	-400	95	-26	-552
P obtenida	-1.44	0.342	-0.0936	-1.9872
P teórica	-1.70	0.368	0	-1.70

Armadura 5



Elemento	*1*	*2*	*3*	*4*
Li	-2832	-1208	-1560	-5790
Lf	-2540	-1510	-1573	-5758
Diferencia	292	-302	-13	32
P obtenida	1.0512	-1.0781	-0.0468	-0.1152
P teórica	0.894	-1.20	0	0

V.8. Conclusiones de armaduras.

En las mediciones se han encontrado diferencias con respecto a las cargas teóricas de80 grm., según se dijo con anterioridad, en el cuerpo de la tesis, al implementar un modelo, existen errores en la medición por diversos factores, los que se han podido apreciar aquí son los siguientes:

- El módulo de elasticidad a etapas muy bajas de carga no se comporta idealmente como una línea, sino que a cada incremento presenta diferencias en variación esto lo hemos observado en diversos materiales tales como el acero, aluminio, latón y acrílico, siendo este último el que menos variaciones nos reportó. Al momento de haber variaciones en el módulo, para cargas muy bajas, la precisión se ve altamente afectada.
- En el modelo se procuró evitar las fricciones, pero como es natural no se pueden eliminar totalmente, por lo que aparece su influencia en las lecturas, tomando en cuenta además que al aplicar cargas muy pequeñas en algunos casos no son vencidas las fuerzas de fricción por las aplicadas.
- Existen algunos elementos en las armaduras específicamente esforzados, éstos han cedido a la solicitación y el strain gages nos reporta la deformación por compresión más la deformación por pandeo del elemento, esta lectura generalmente nos da errónea en el modelo, se sugiere mostrar ese elemento o darle mas capacidad de carga.
- La temperatura ambiente a la cual se realiza el ensaye afecta significativamente en las lecturas.
- El rodillo que se utilizó tiene fricción y etapas muy bajas de carga, tiende a comportarse como una articulación.

Estos errores, en la medición hasta cierto punto normales, no han impedido, significativamente, visualizar las cargas presentadas en la armadura y si se pudo lograr el objetivo de ayudar a explicar el comportamiento de las armaduras en el aula o laboratorio.

VI. MODELO DE COLUMNAS

VI.1. Generalidades

Longitud efectiva.

Expresado en términos sencillos, el concepto de longitud efectiva es un método para convertir matemáticamente el problema de evaluar la carga crítica de columnas en estructuras reticulares completas, al de una columna aislada equivalente, doblemente articulada, con extremos no desplazables.

La "carga de pandeo", "carga crítica" o "carga de bifurcación" de Eüler es el valor de referencia con respecto al cual la resistencia de columnas reales se compara mediante la sustitución de una longitud equivalente o "longitud efectiva" en lugar de la longitud real de la columna.

Cada columna individual se diseña con una ecuación de interacción deducida para columnas aisladas, en la que se incluye el factor de longitud efectiva K que le corresponde por ser parte de una estructura continua, teniendo en cuenta las restricciones en sus extremos que le proporcionan los elementos que se conectan a ella.

VI.2. Demostración de formulas de columnas

VI.2.1.Hipótesis fundamentales para la deducción:

1. La columna perfectamente recta
2. La carga axial será aplicada a través del eje centroidal de la columna.
3. Las secciones, planas antes de la deformación, permanecen planas después de la deformación.
4. Las deflexiones de la pieza son consecuencia de flexión solamente; es decir, se ignoran las deformaciones por cortante.