



ESTRUCTURA HIPERESTÁTICA ASIMÉTRICA

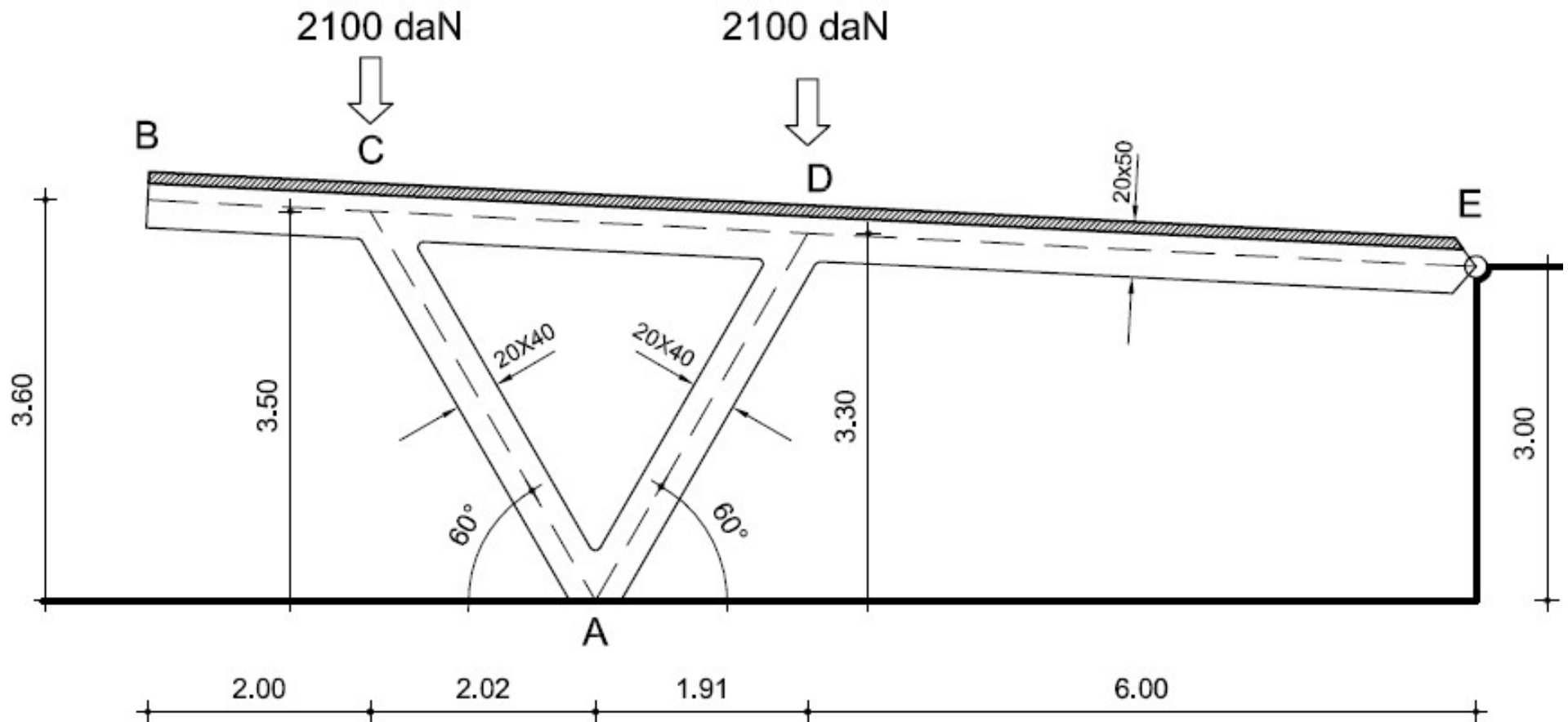
ESTRUCTURA HIPERESTATICA ASIMETRICA

Sección Tramos:

BC, CD y DE = 20 x 50 cm
AC y AD = 20 x 40 cm

Cubierta:

Losa maciza H.A., $e=10\text{cm}$
Descarga en B-C-D-E: 1300 daN/m



Estudiar el pórtico por el método de Cross, trazando los diagramas de solicitaciones de todas las barras e indicando las reacciones en los apoyos.

ESTRUCTURA HIPERESTATICA ASIMETRICA

- 1** Coeficientes de Repartición
- 2** Momentos Empotramiento Perfecto (M.E.P.)
- 3** **ARTIFICIO DE CROSS**
(momentos en los extremos de las barras)
- 4** Descargas Tramo por Tramo
- 5** Caminos Materiales
- 6** Reacciones en los Apoyos
- 7** Diagramas de Solicitaciones

ESTRUCTURA HIPERESTATICA ASIMETRICA

1 Coeficientes de Repartición

- Inercias Relativas
- Rigidez (κ)
- Rigidez Flexional ($\alpha\kappa$)
- Coef. Transmisión (β)

2 Momentos Empotramiento Perfecto (M.E.P.)

3 ARTIFICIO DE CROSS (momentos en los extremos de las barras)

4 Descargas Tramo por Tramo

5 Caminos Materiales

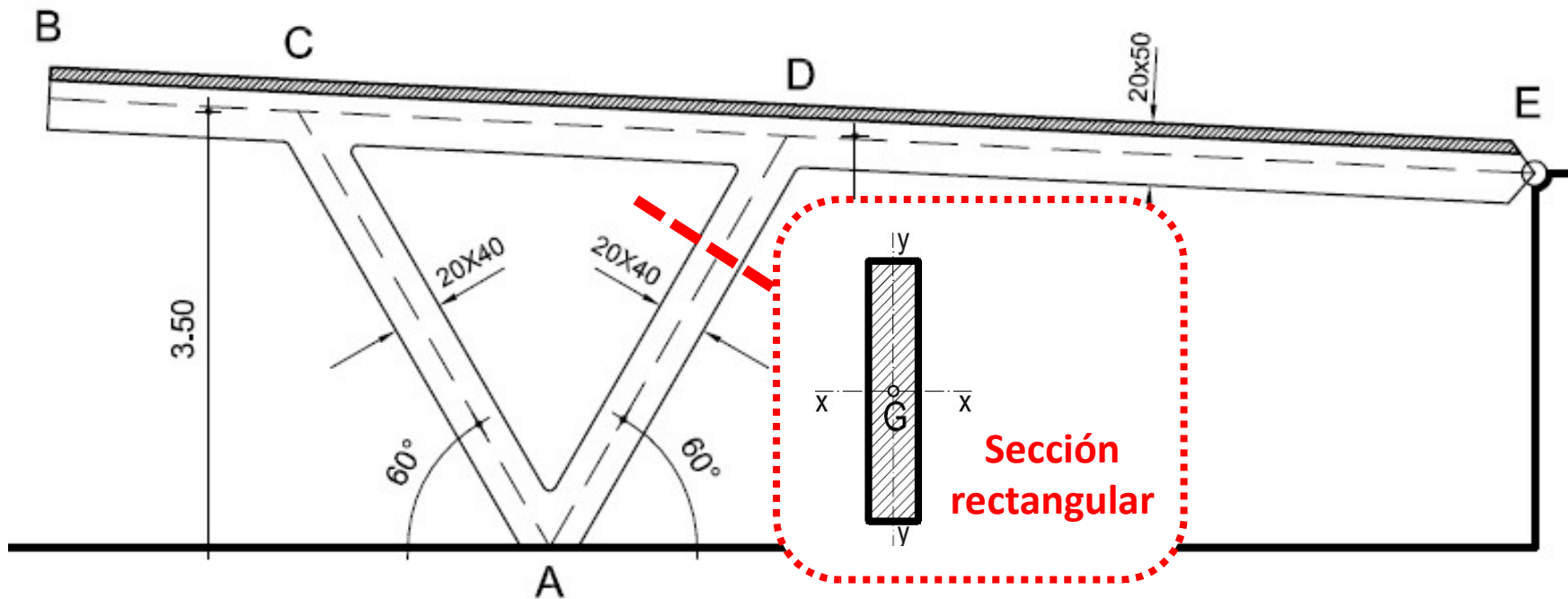
6 Reacciones en los Apoyos

7 Diagramas de Solicitaciones

TRAMO	L (m)	I_r	α	χ	$\alpha\chi$	β
AC	4,04					
AD	3,81					
CD	3,94					
DE	6,01					

Sección Rectangular: Tramos AC y AD

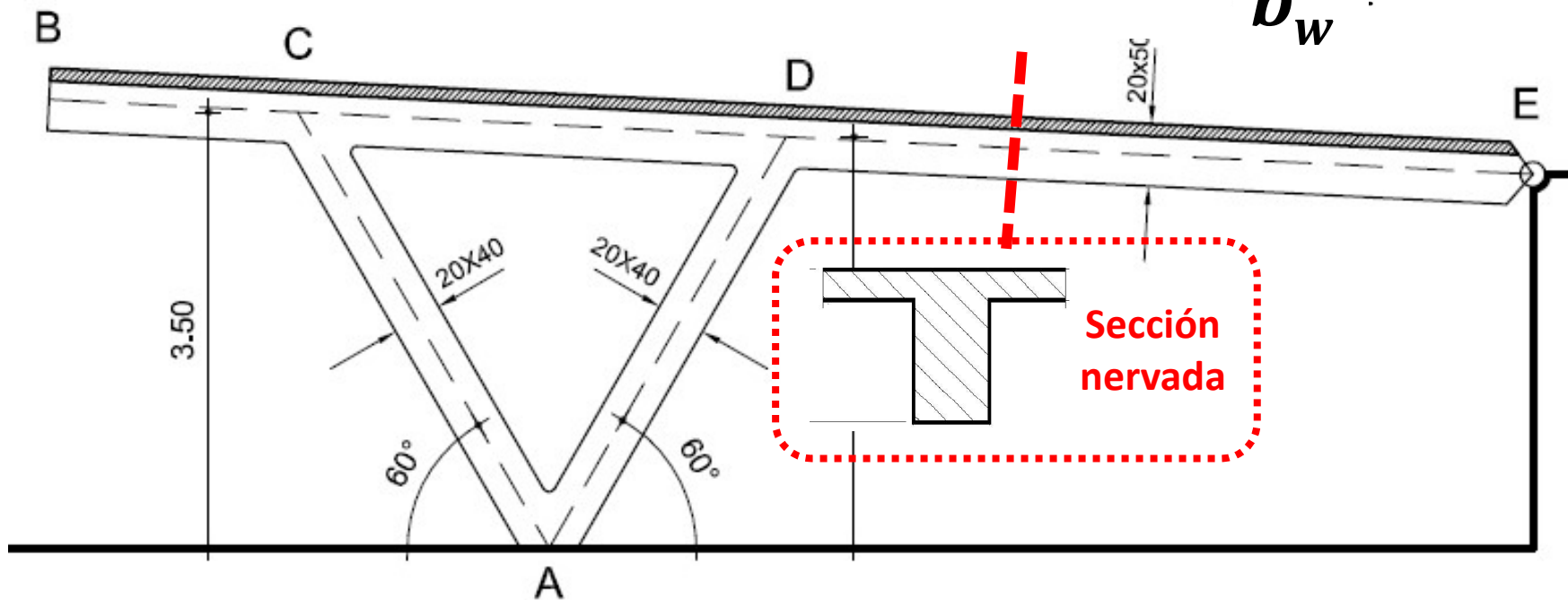
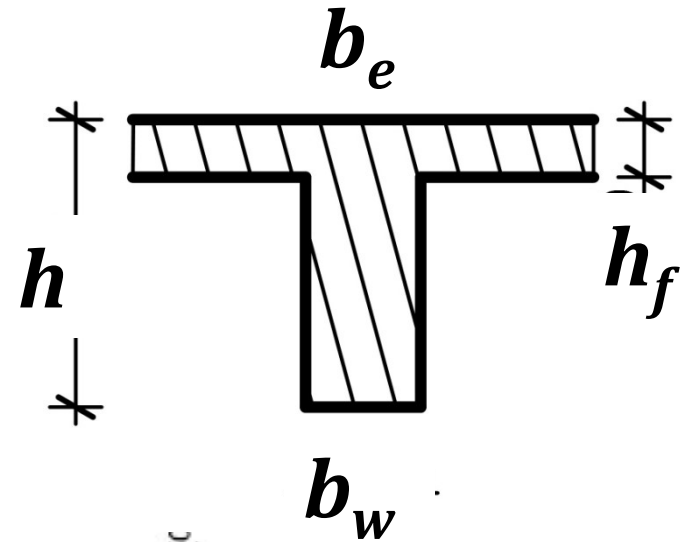
$$I_x = \frac{b \times h^3}{12} = \frac{20 \times 40^3}{12} = 106.667 \text{ cm}^4$$



¿Sección Nervada: Tramos CD y DE? Condiciones geométricas

$$h_f \geq 7 \text{ cm}$$

$$h_f / h \geq 10\%$$

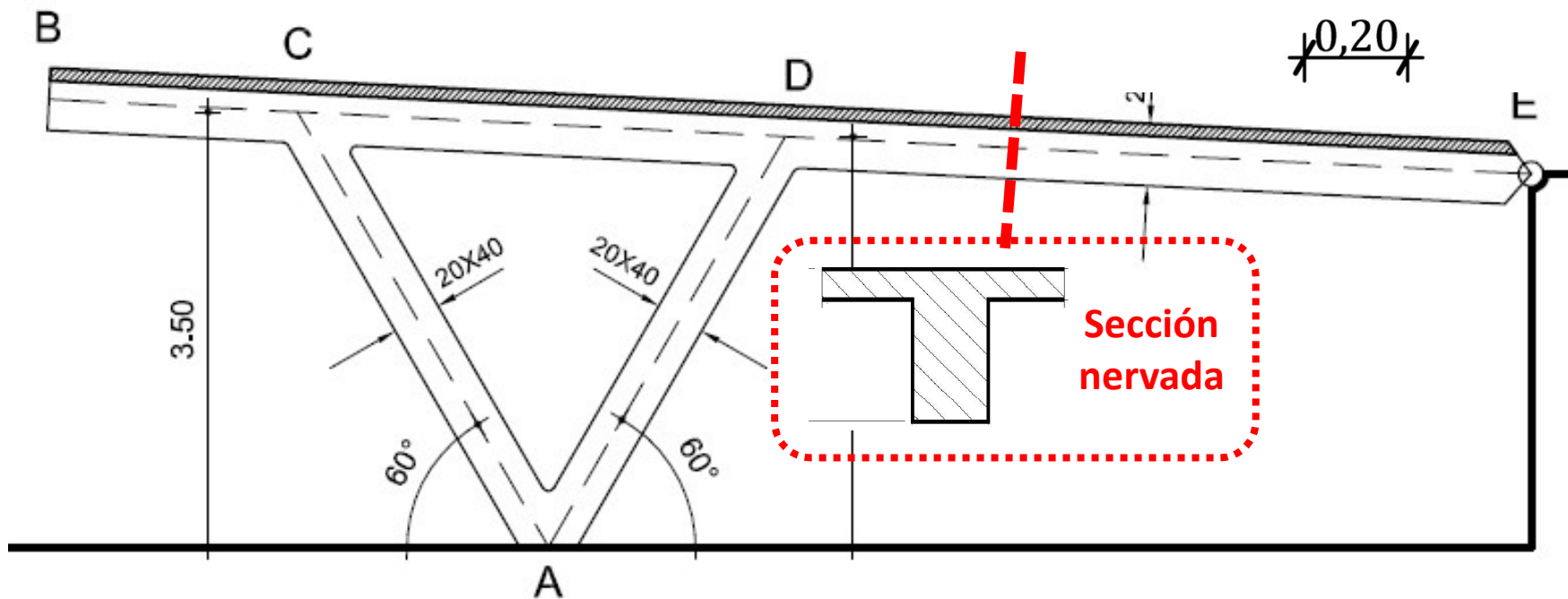
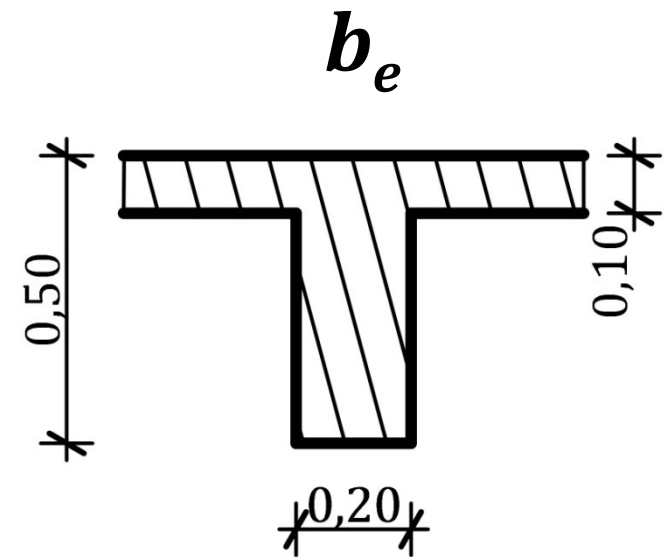


Sección Nervada: Tramos CD y DE

Condiciones geométricas

$$h_f = 10 \text{ cm} \geq 7 \text{ cm} \quad \checkmark$$

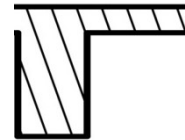
$$\frac{h_f}{h} = \frac{10}{50} = 20\% \geq 10\% \quad \checkmark$$



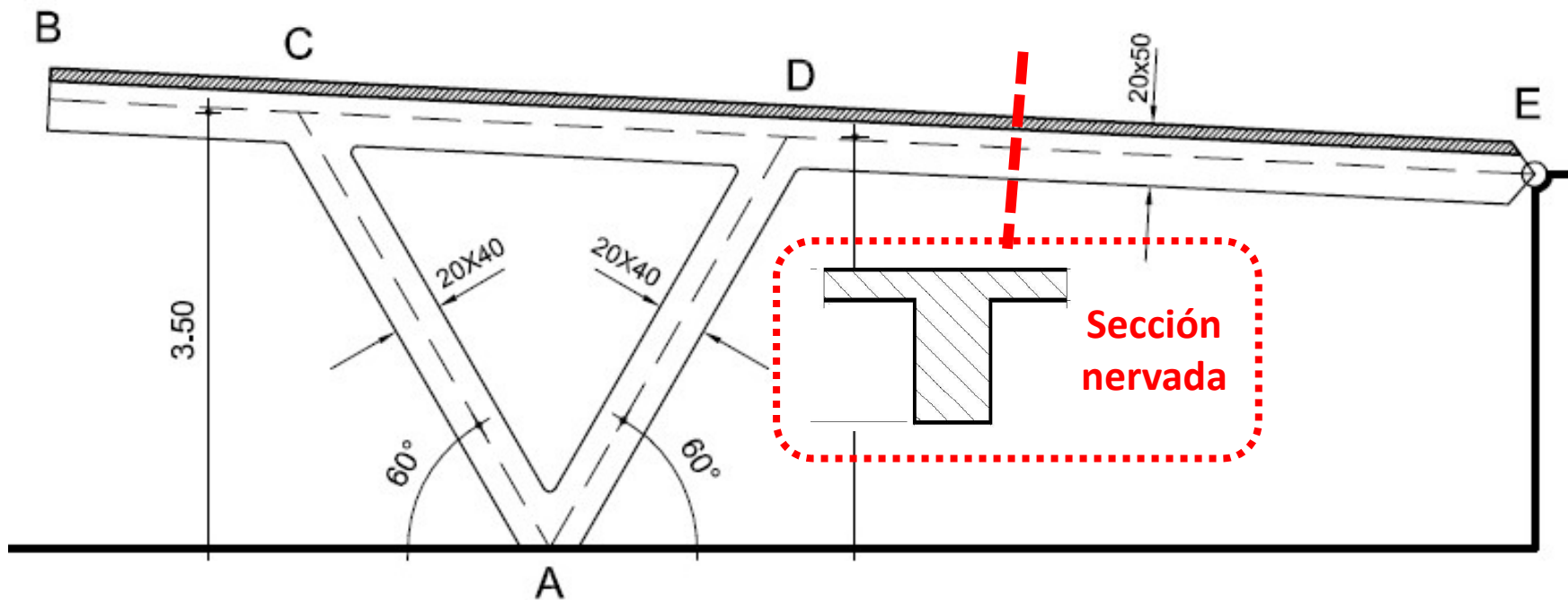
Sección Nervada

Definición de la forma

$$b_e = 2,25 \times h_f + b_w$$



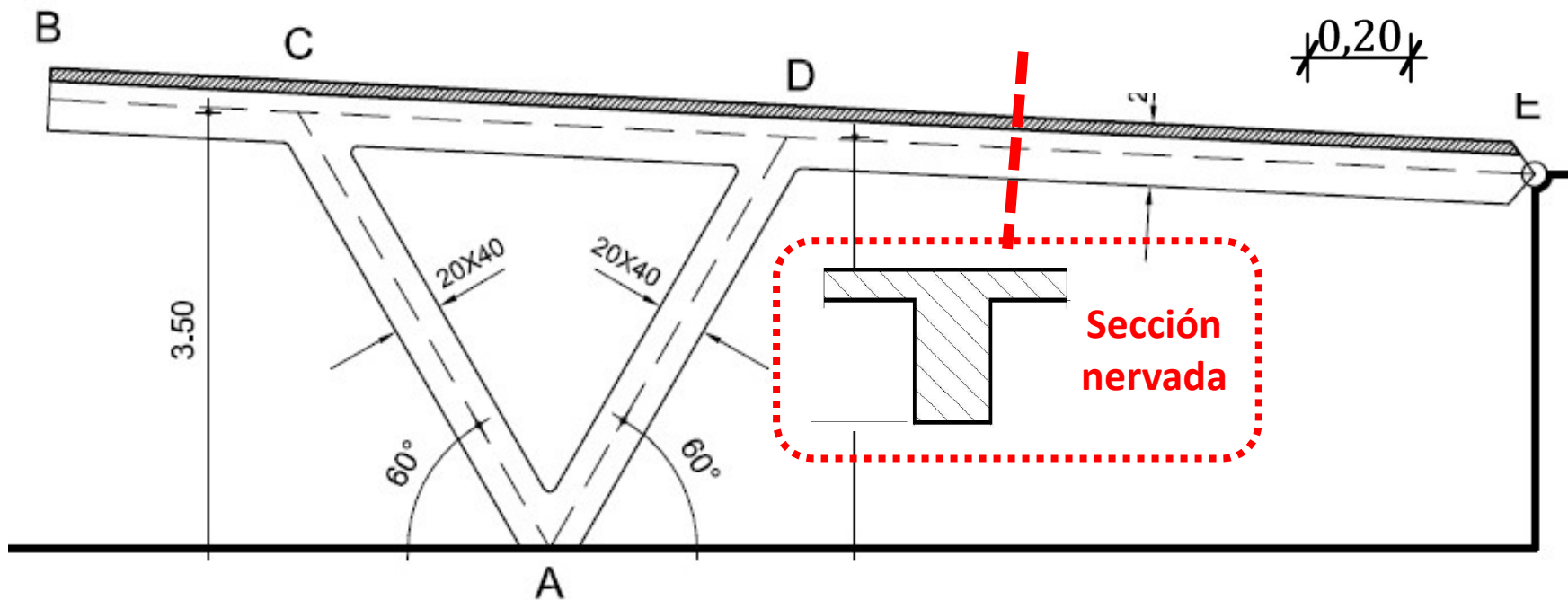
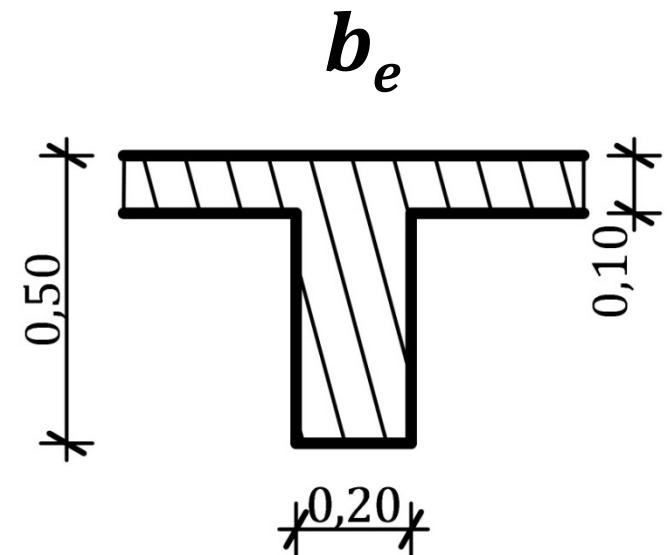
$$b_e = 6 \times h_f + b_w$$



Sección Nervada: Tramos CD y DE

Definición de la forma

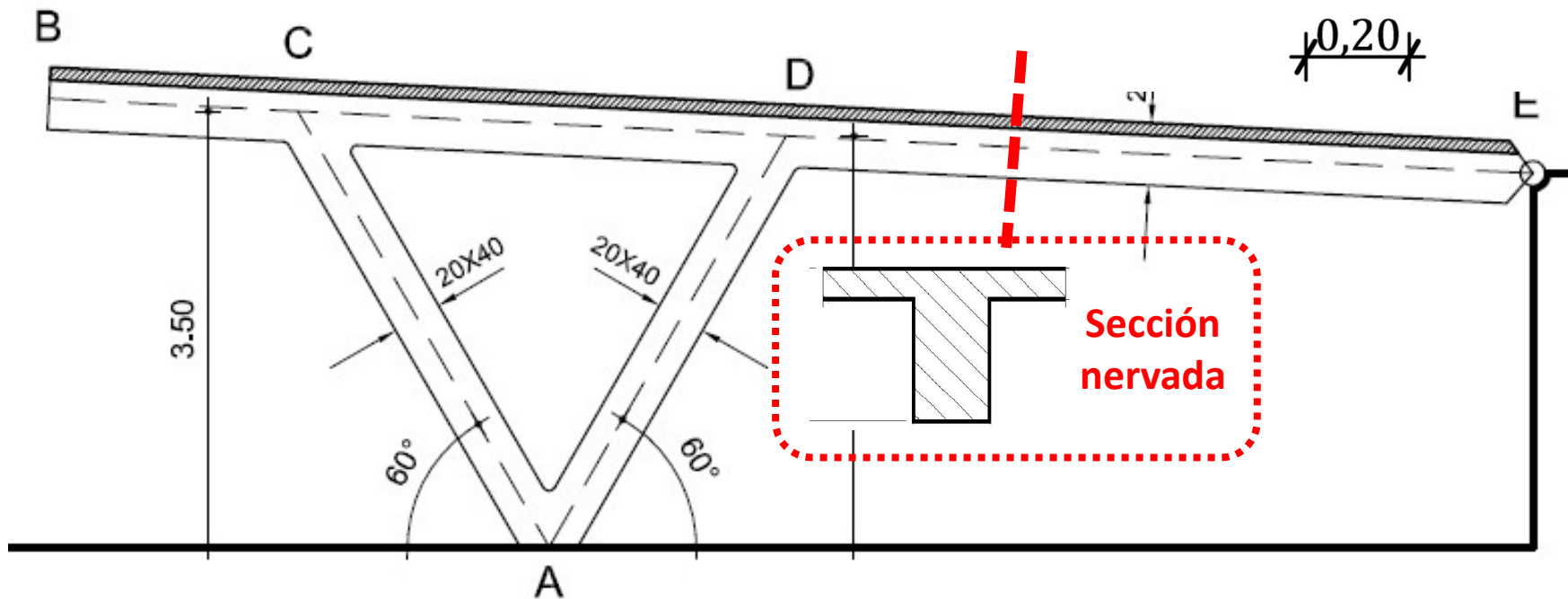
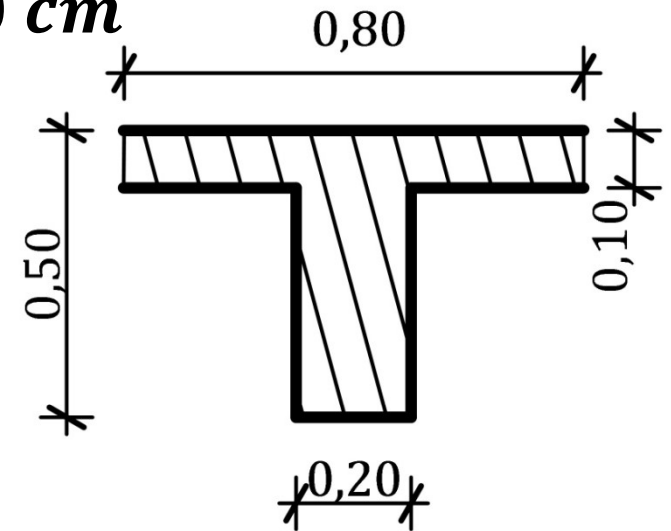
$$b_e = 6 \times h_f + b_w =$$



Sección Nervada: Tramos CD y DE

Definición de la forma

$$b_e = 6 \times h_f + b_w = 6 \times 10 + 20 = 80 \text{ cm}$$



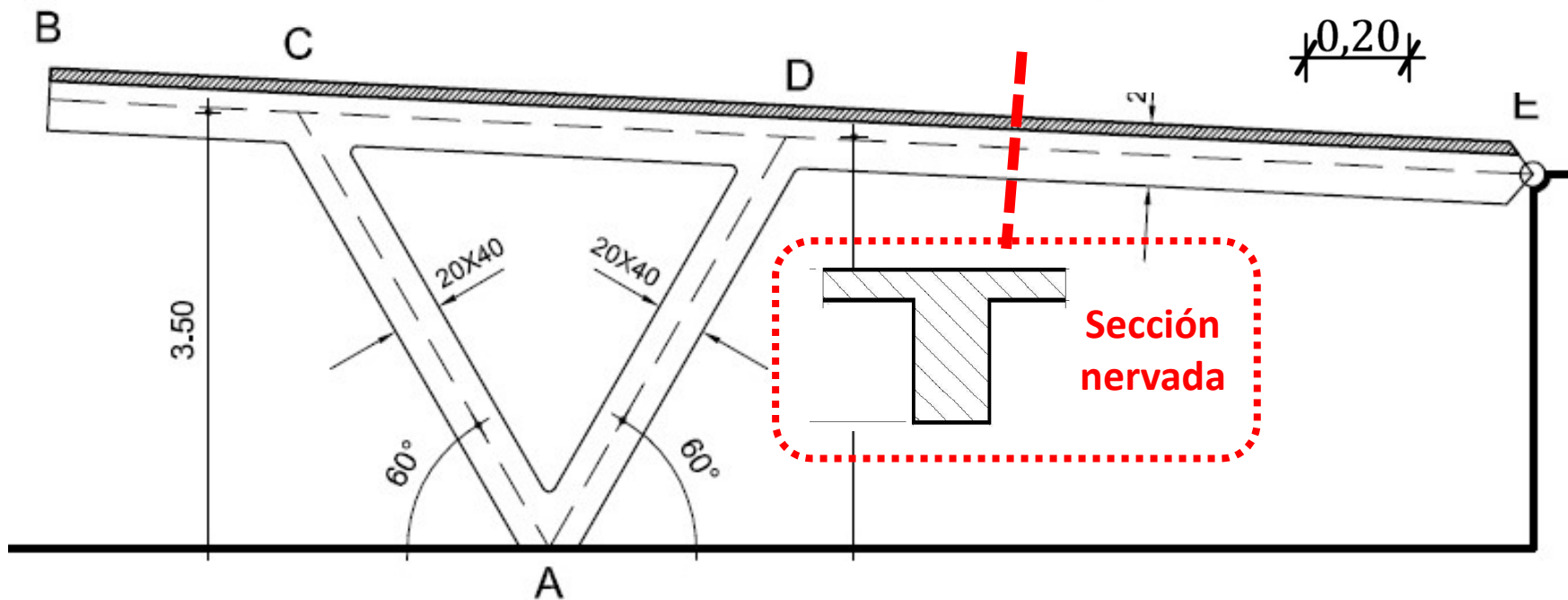
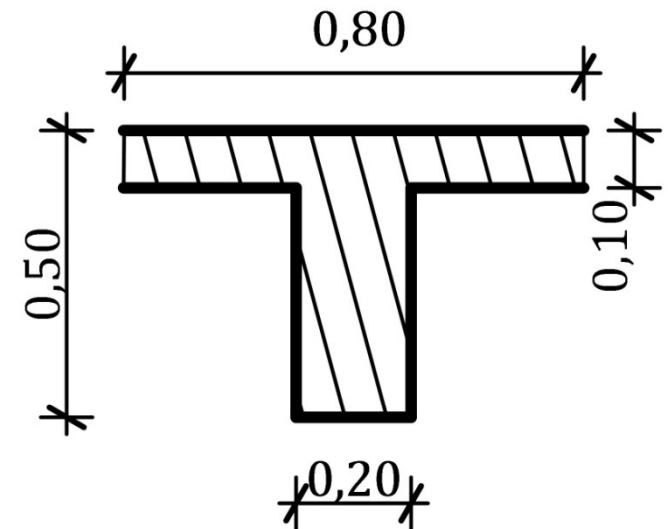
Sección Nervada: Tramos CD y DE

Coeficiente ψ

$$\xi = \frac{b_w}{b_e} = \frac{20}{80} = 0,25$$

$$\xi' = \frac{h_f}{h} = \frac{10}{50} = 0,20$$

Tabla III-4

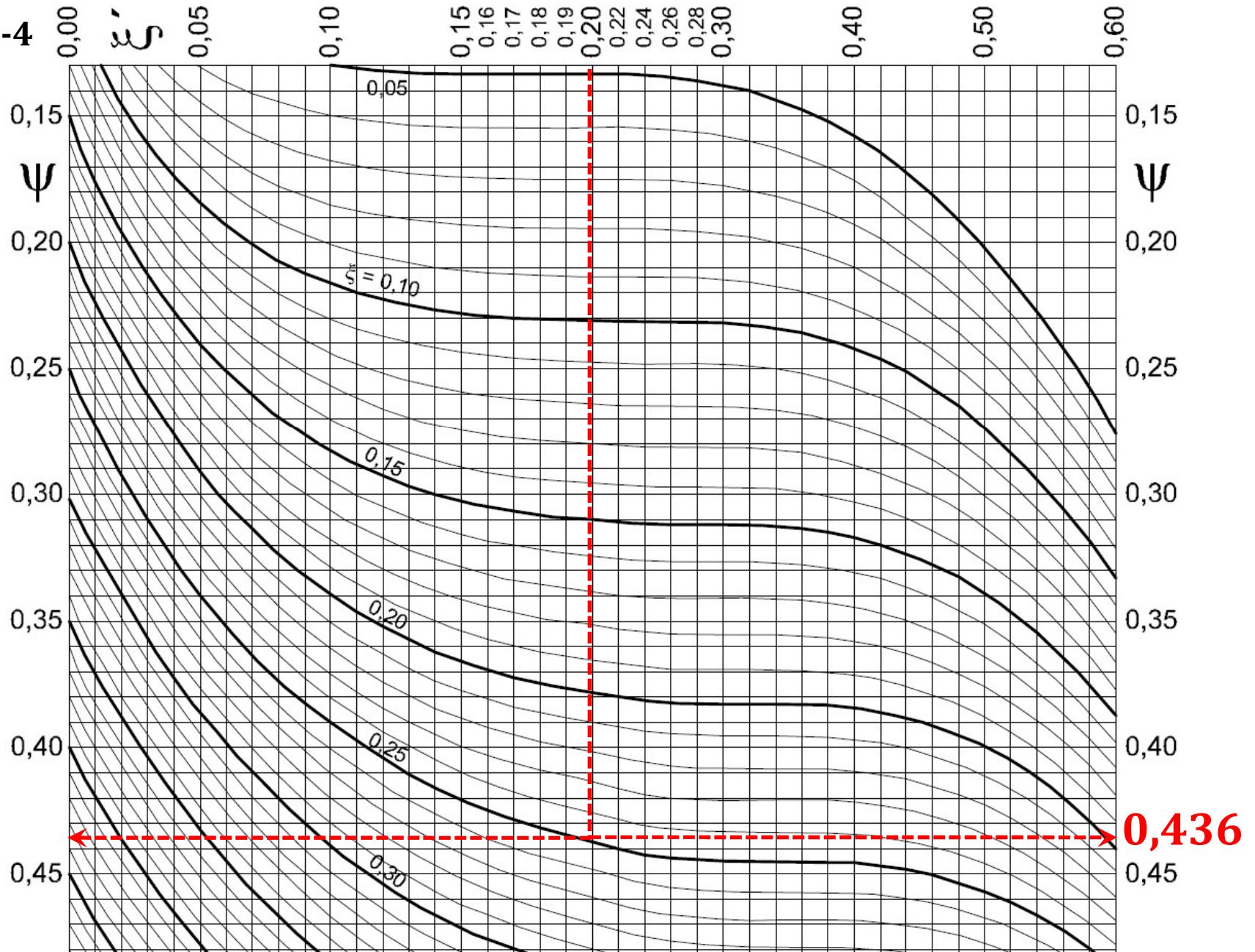


1

COEFICIENTES DE REPARTICIÓN

Cálculo de inercias

Tabla III-4



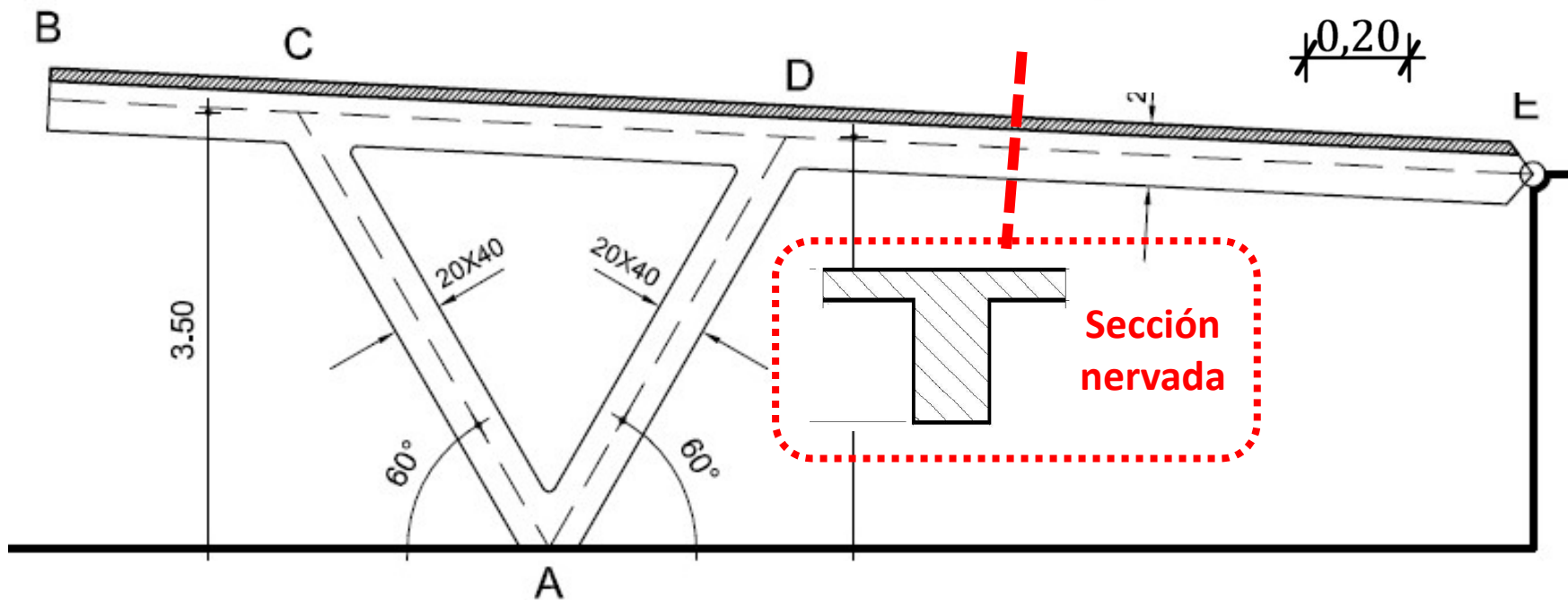
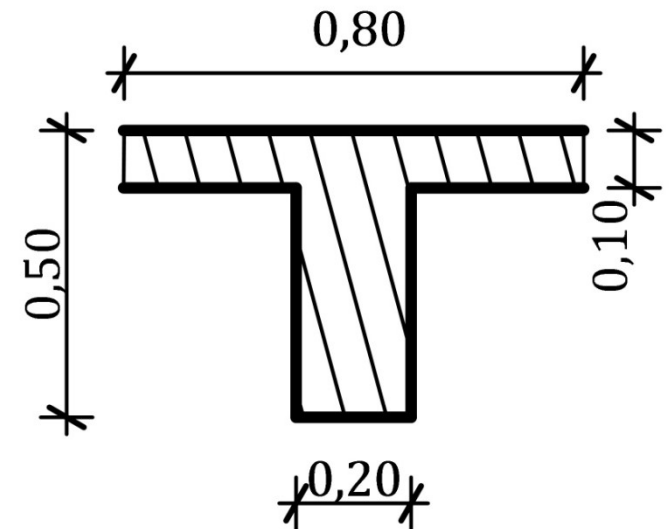
Sección Nervada: Tramos CD y DE

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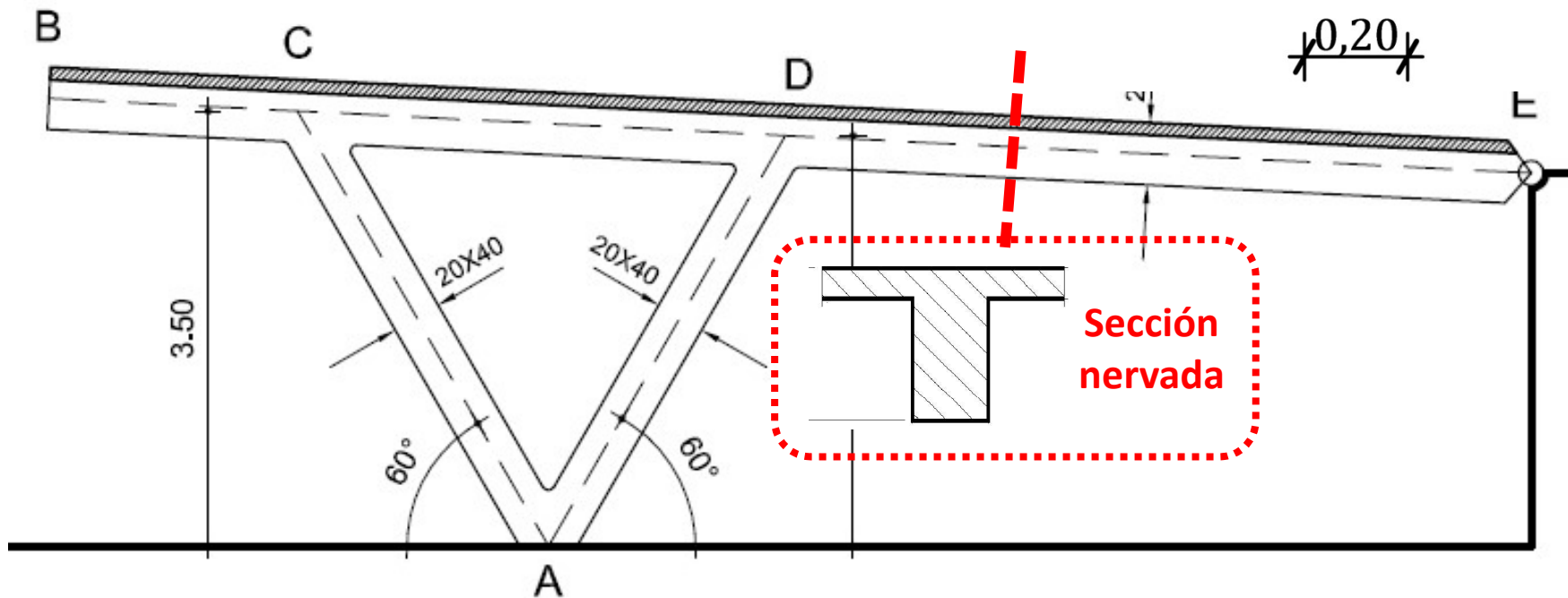
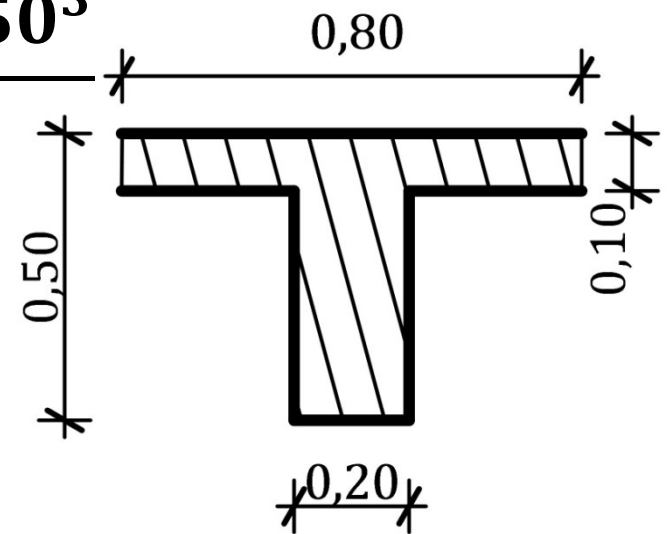
$$\psi = 0,436$$



Sección Nervada: Tramos CD y DE

$$I_x = \Psi \times \frac{b_e \times h^3}{12} = 0,436 \times \frac{80 \times 50^3}{12}$$

$$I_x = 363.333 \text{ cm}^4$$



TRAMO	L (m)	I_r	α	χ	$\alpha\chi$	β
AC	4,04					
AD	3,81					
CD	3,94					
DE	6,01					

Tramos AC y AD (inercia mínima)

$$I_x = \frac{b \times h^3}{12} = \frac{20 \times 40^3}{12} = 106.667 \text{ cm}^4$$

$$I_r = \frac{\frac{b \times h^3}{12}}{\frac{b \times h^3}{12}} = \frac{20 \times 40^3}{20 \times 40^3} = 1$$

$$I_{r \text{ AC-AD}} = 1$$

Tramos CD y DE

$$I_x = \Psi \times \frac{b_e \times h^3}{12} = 0,436 \times \frac{80 \times 50^3}{12} = 363.333 \text{ cm}^4$$

$$I_r = \frac{\Psi \times \frac{b_e \times h^3}{12}}{\frac{b \times h^3}{12}} = \frac{0,436 \times \frac{80 \times 50^3}{12}}{\frac{20 \times 40^3}{12}} = \frac{363.333 \text{ cm}^4}{106.667 \text{ cm}^4} = 3,41$$

$$I_{r \text{ CD-DE}} = 3,41$$

TRAMO	L (m)	I_r	α	χ	$\alpha\chi$	β
AC	4,04					
AD	3,81					
CD	3,94					
DE	6,01					


1

COEFICIENTES DE REPARTICIÓN

Cálculo Rigidez Flexional ($\alpha\chi$)

TRAMO	L (m)	I_r	α	χ	$\alpha\chi$	β
AC	4,04	1	1	0,248	0,248	0,5
AD	3,81	1	1	0,262	0,262	0,5
CD	3,94	3,41	1	0,865	0,865	0,5
DE	6,01	3,41	0,75	0,567	0,426	-

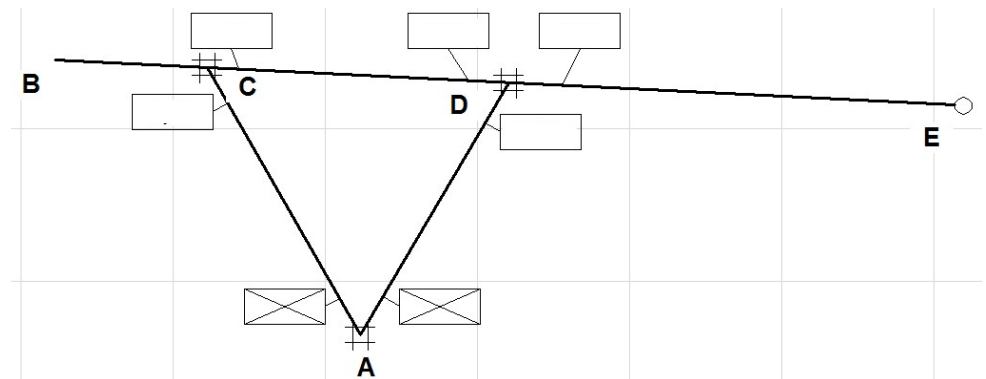
Coeficientes α y β (inercia constante):

 $\alpha = 1$ $\beta = 0,5$

 $\alpha = 0,75$ $\beta = 0$

Rigidez:

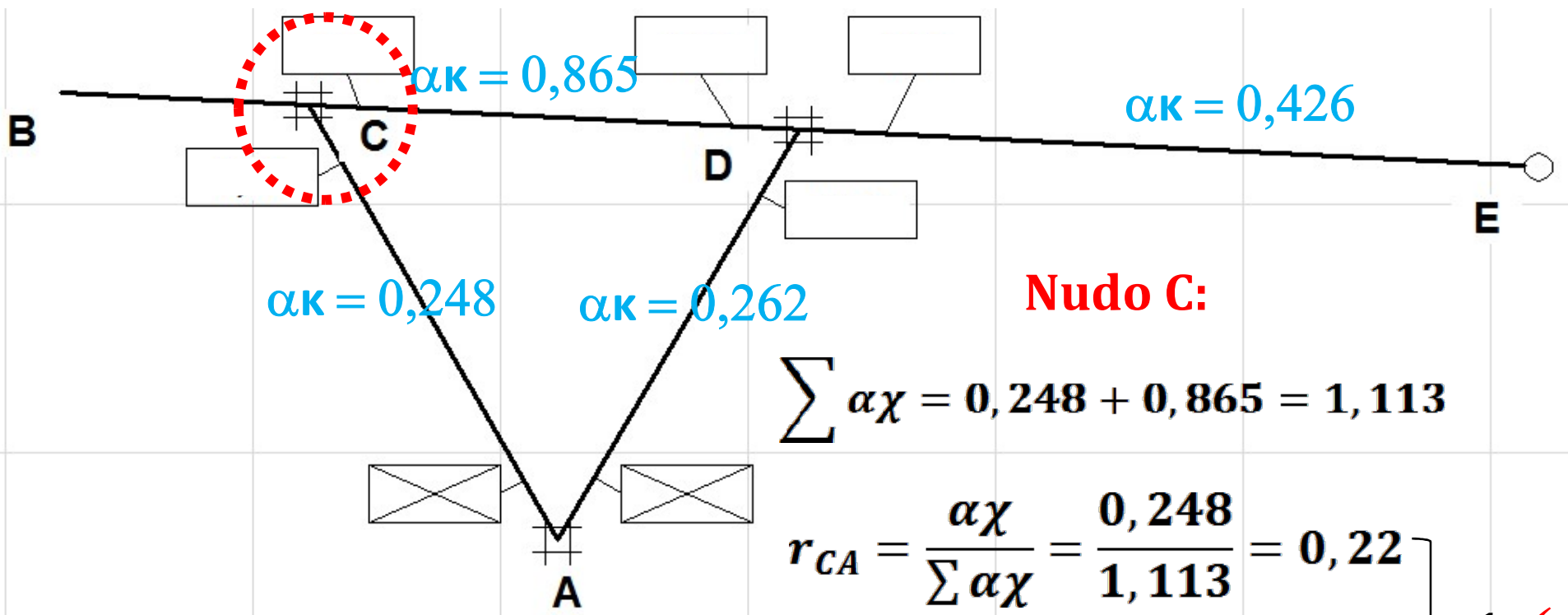
$$\chi = \frac{E \times I_r}{L}$$



1

COEFICIENTES DE REPARTICIÓN

$$\sum \alpha_{\kappa_c} = 1,113$$



Nudo C:

$$\sum \alpha_{\chi} = 0,248 + 0,865 = 1,113$$

$$r_{CA} = \frac{\alpha_{\chi}}{\sum \alpha_{\chi}} = \frac{0,248}{1,113} = 0,22$$

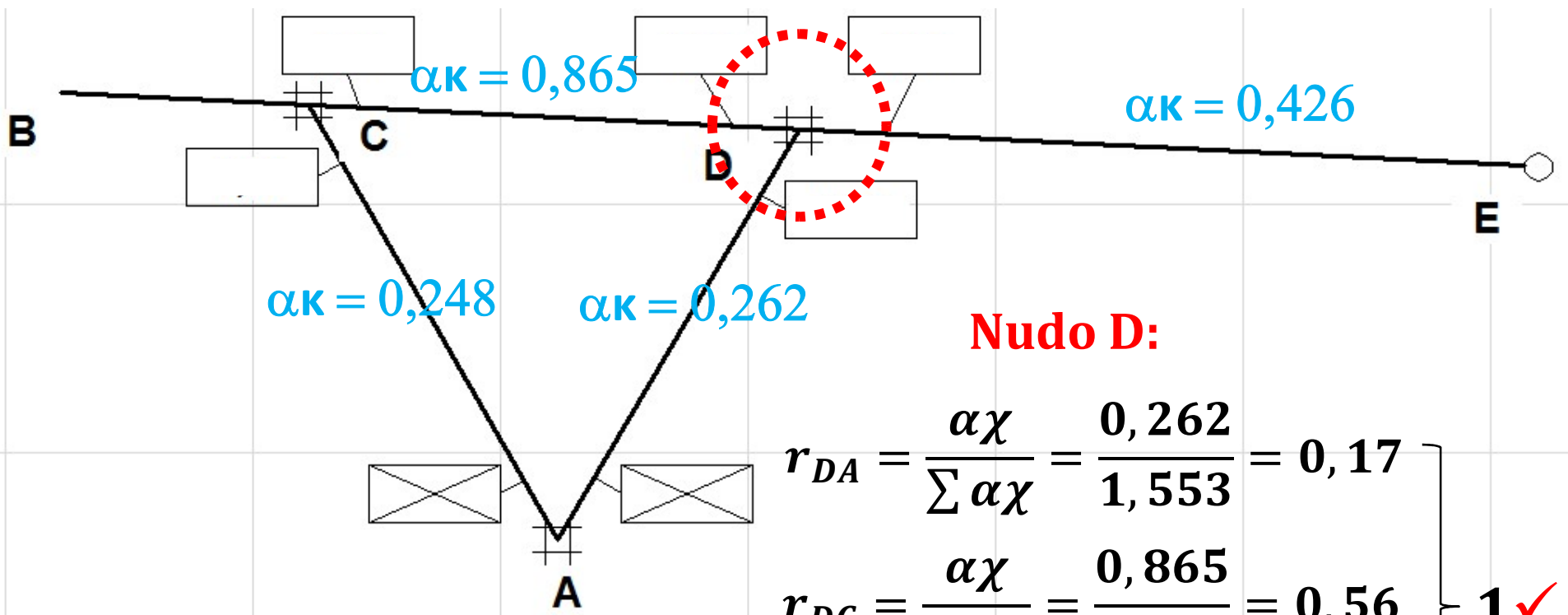
$$r_{CD} = \frac{\alpha_{\chi}}{\sum \alpha_{\chi}} = \frac{0,865}{1,113} = 0,78$$

1 ✓

1

COEFICIENTES DE REPARTICIÓN

$$\sum \alpha_{\kappa_D} = 1,553$$



Nudo D:

$$r_{DA} = \frac{\alpha_{\chi}}{\sum \alpha_{\chi}} = \frac{0,262}{1,553} = 0,17$$

$$r_{DC} = \frac{\alpha_{\chi}}{\sum \alpha_{\chi}} = \frac{0,865}{1,553} = 0,56$$

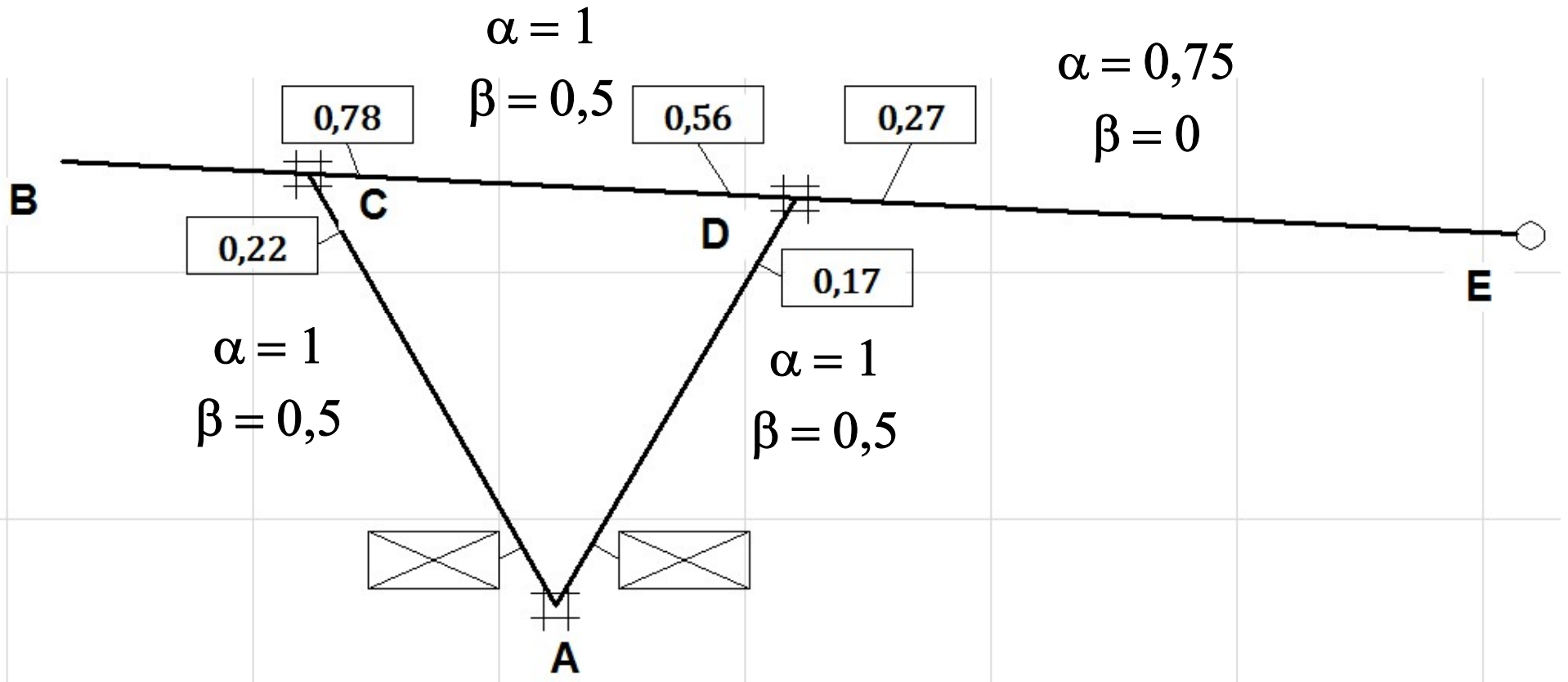
$$r_{DE} = \frac{\alpha_{\chi}}{\sum \alpha_{\chi}} = \frac{0,567}{1,553} = 0,27$$

} **1 ✓**

1

COEFICIENTES DE REPARTICIÓN

Resumen:



ESTRUCTURA HIPERESTATICA ASIMETRICA

1 Coeficientes de Repartición

2 Momentos Empotramiento Perfecto (M.E.P.)

3 **ARTIFICIO DE CROSS**
(momentos en los extremos de las barras)

4 Descargas Tramo por Tramo

5 Caminos Materiales

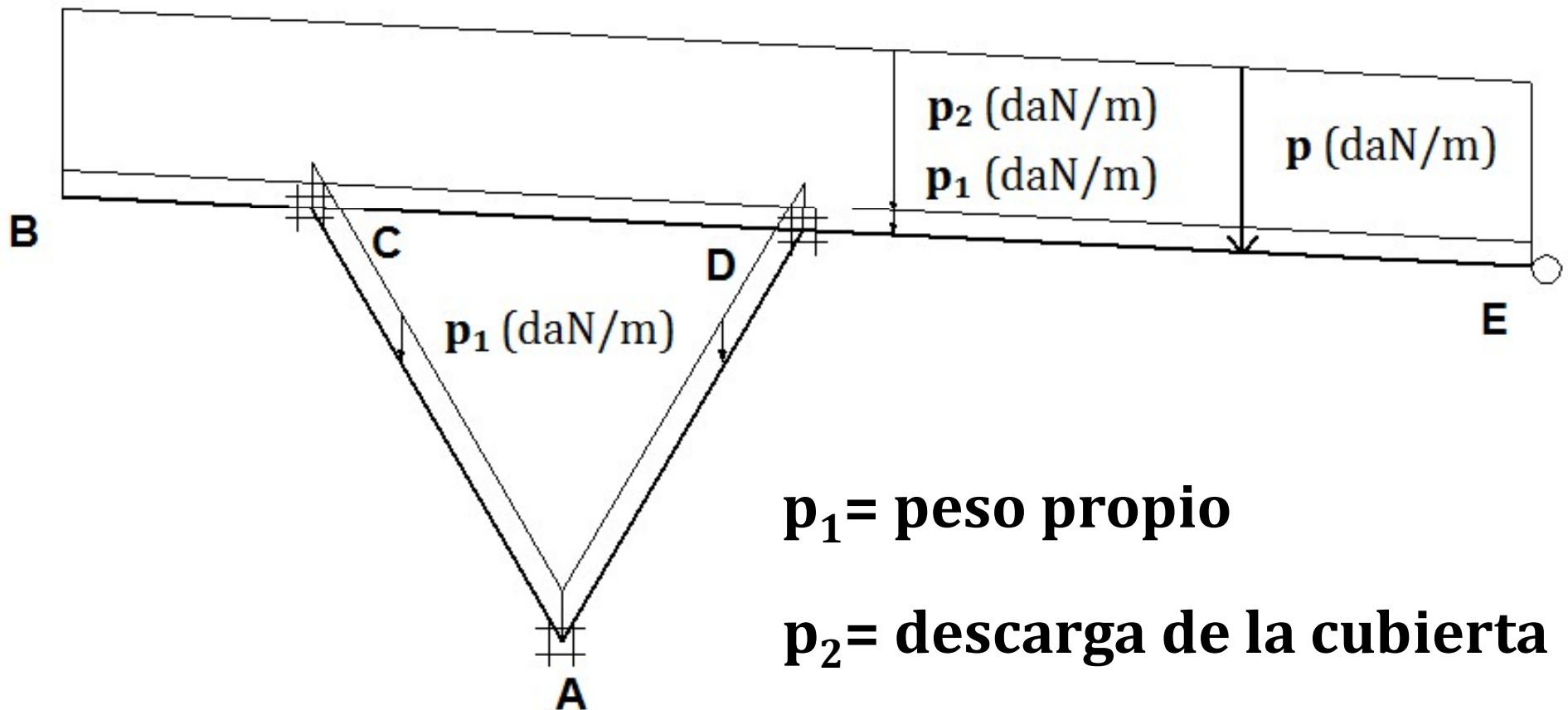
6 Reacciones en los Apoyos

7 Diagramas de Solicitaciones

2

MOMENTOS DE EMPOTRAMIENTO PERFECTO (M.E.P.)

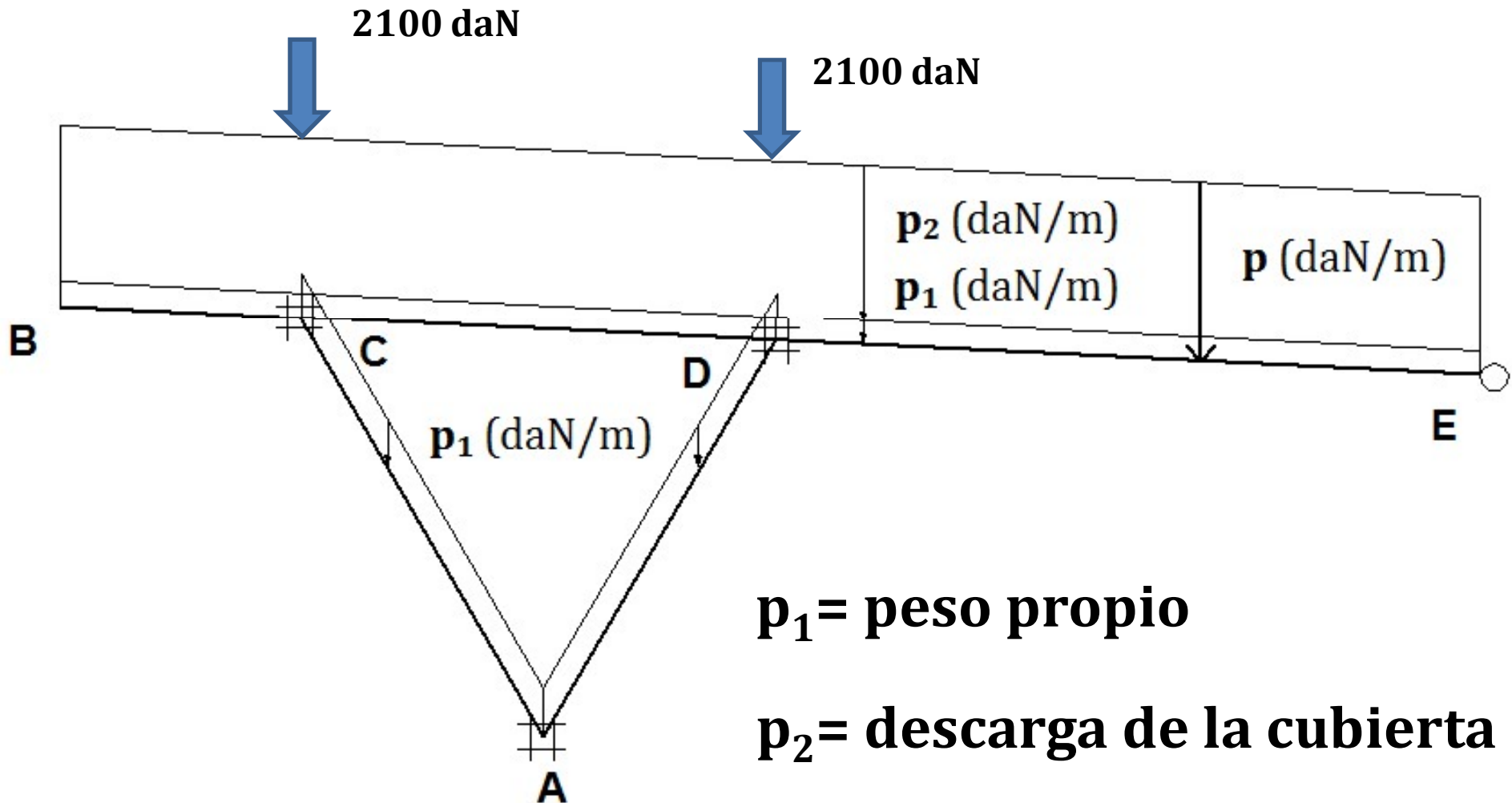
Esquema de cargas de la estructura



2

MOMENTOS DE EMPOTRAMIENTO PERFECTO (M.E.P.)

Esquema de cargas de la estructura



2

MOMENTOS DE EMPOTRAMIENTO PERFECTO (M.E.P.)

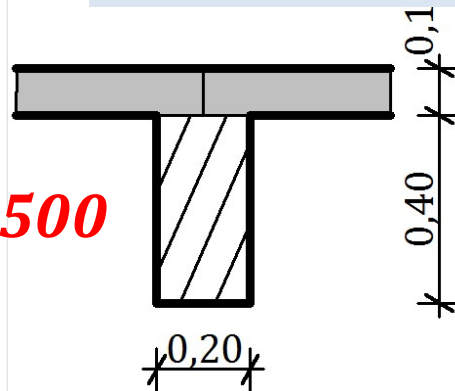
Determinación de cargas

TRAMO	PESO PROPIO	DESCARGA DE LOSA	CARGA TOTAL
BC CD DE	$0,20 \text{ m} \times (0,50 - 0,10) \text{ m} \times 2500 \text{ daN/m}^3$ $= 200 \text{ daN/m}$ $h-h_f$	1300 daN/m	1500 daN/m
AC AD	$0,20 \text{ m} \times 0,40 \text{ m} \times 2500 \text{ daN/m}^3 =$ 200 daN/m		200 daN/m

¿Cuándo descontar p.p. losa?

Pórticos intermedios

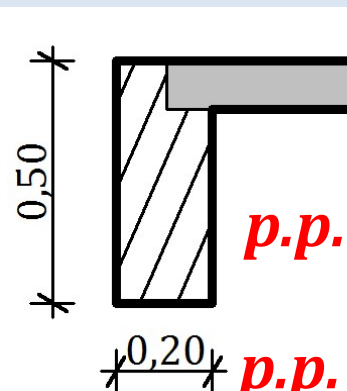
$$p.p. = b \cdot (h - h_f) \cdot 2500$$



Pórtico de borde

~~$$p.p. = b \cdot (h - h_f) \cdot 2500$$~~

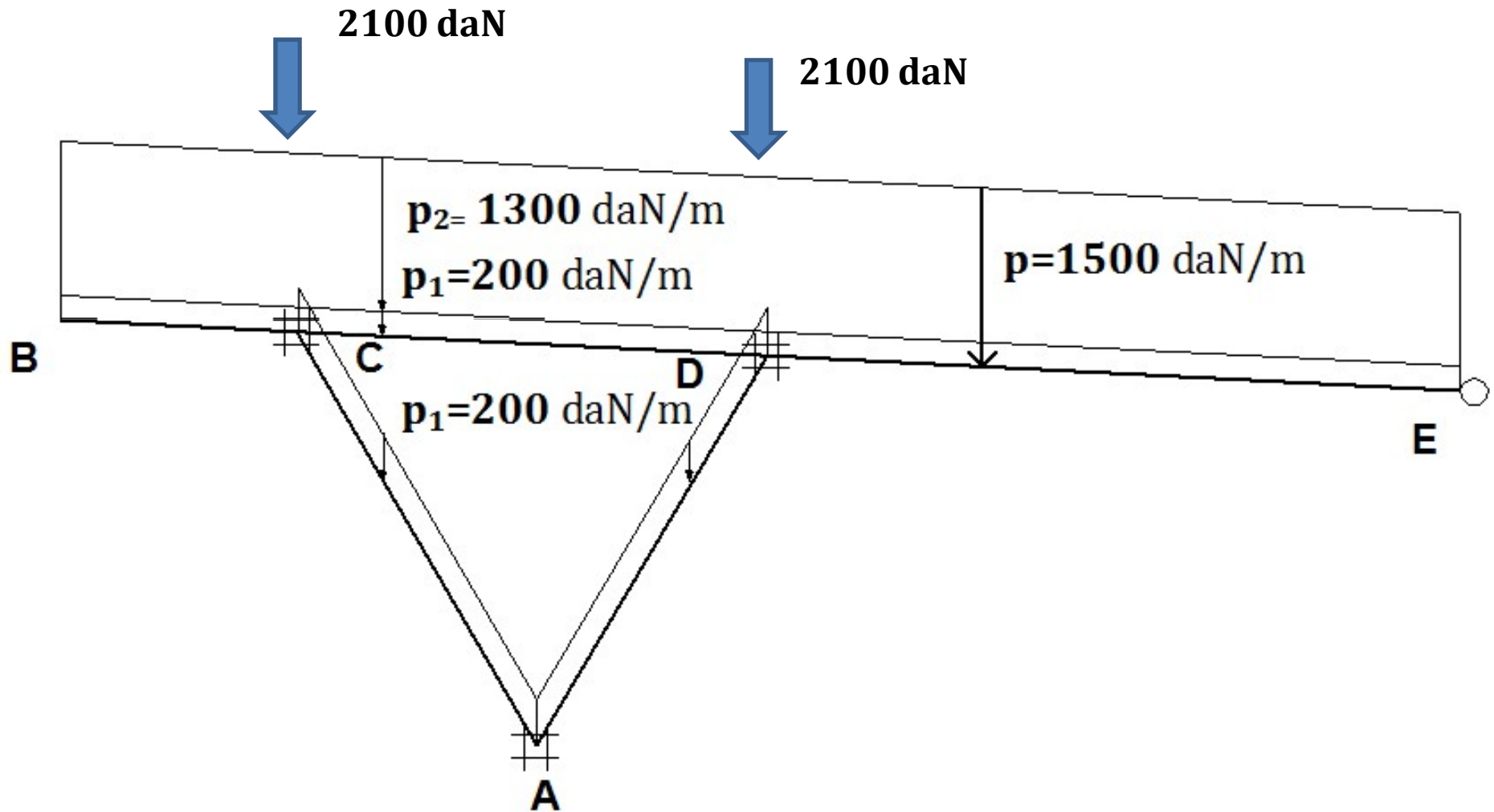
$$p.p. = b \cdot h \cdot 2500$$



2

MOMENTOS DE EMPOTRAMIENTO PERFECTO (M.E.P.)

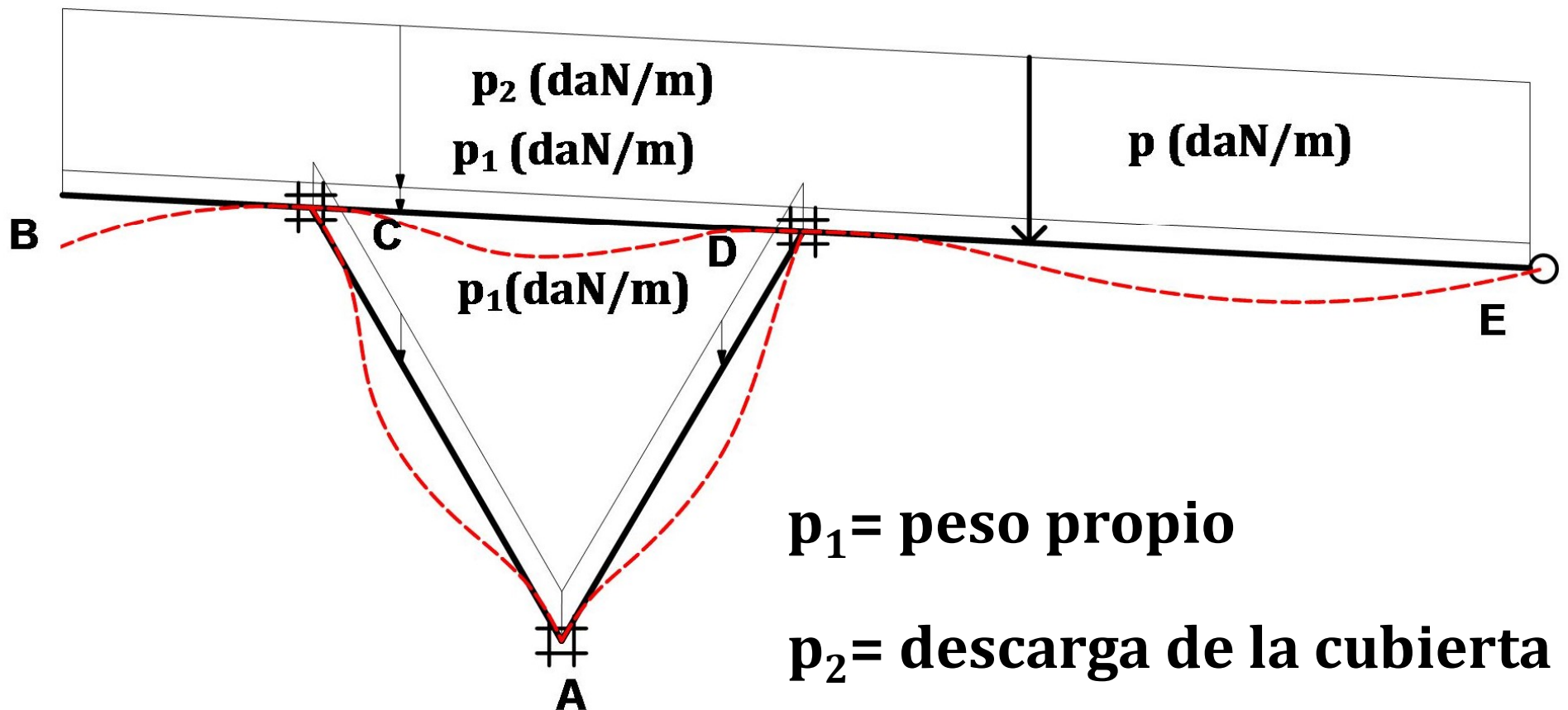
Resumen de determinación de cargas



2

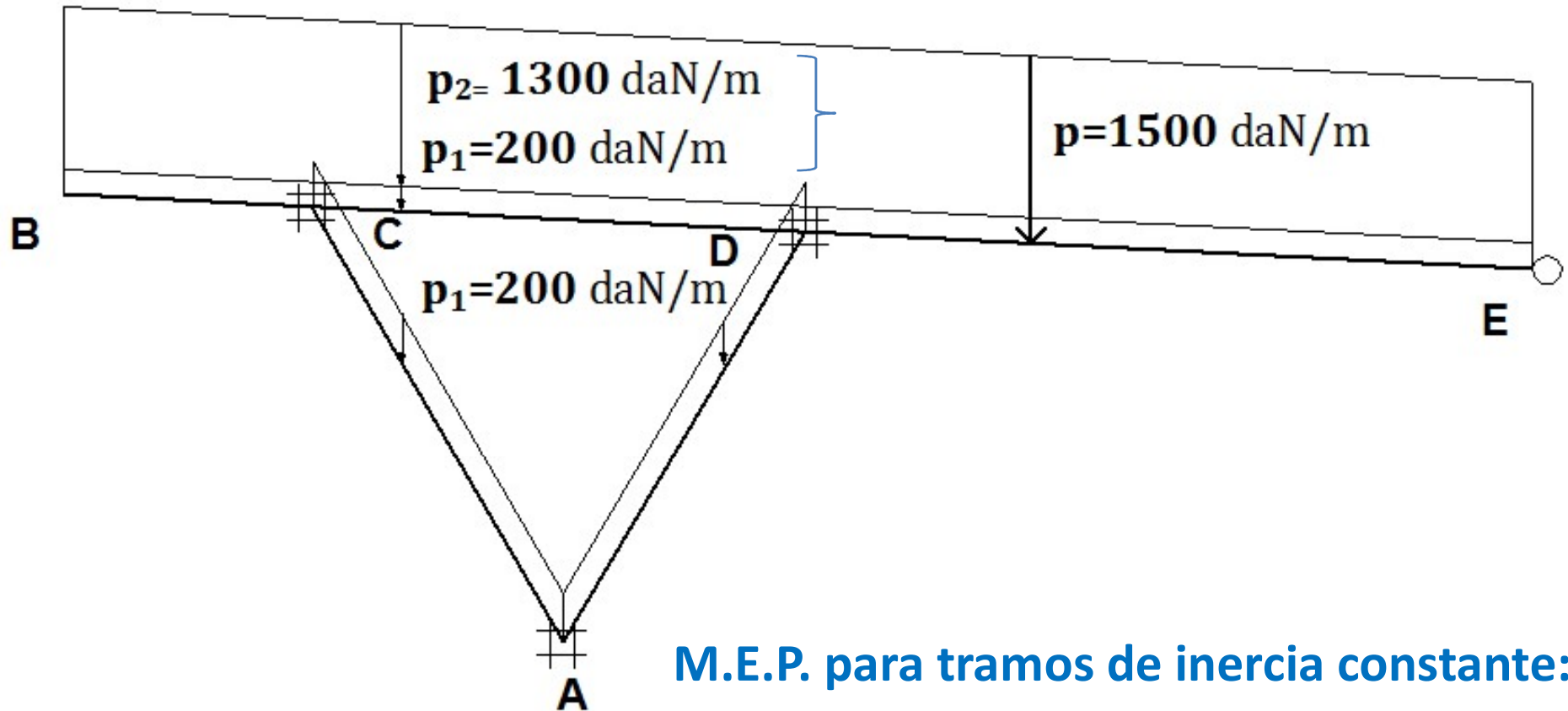
MOMENTOS DE EMPOTRAMIENTO PERFECTO (M.E.P.)

Los MEP son generados por cargas perpendiculares al eje de la barra.



2

MOMENTOS DE EMPOTRAMIENTO PERFECTO (M.E.P.)

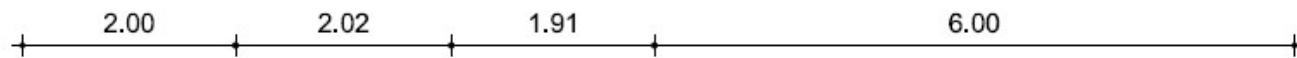
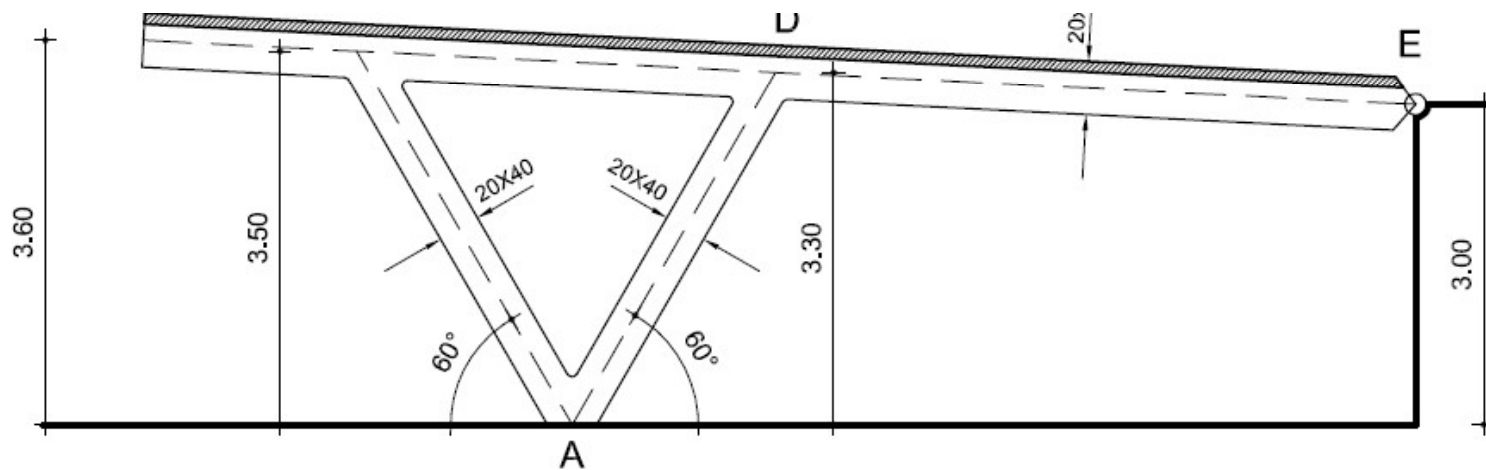
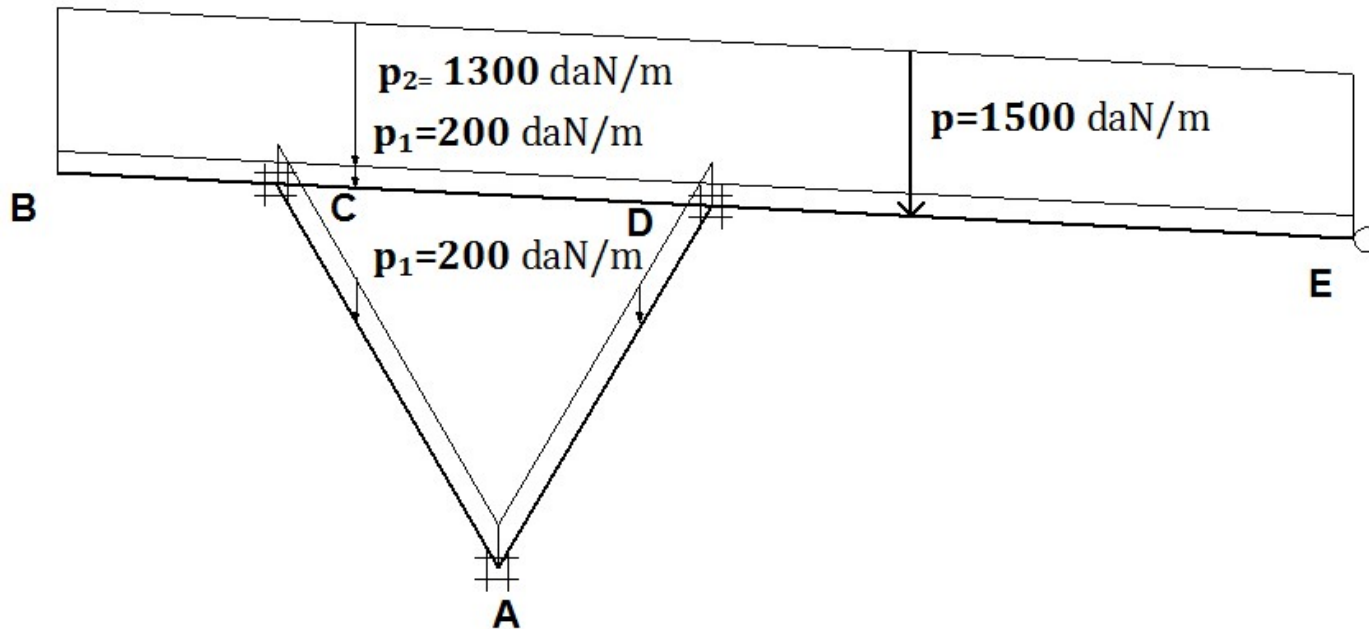


M.E.P. para tramos de inercia constante:

$$M_m = \frac{p \times l_i \times l_h}{2}$$

$$M = \frac{p \times l_i \times l_h}{8}$$

$$M = \frac{p \times l_i \times l_h}{12}$$



$$M_m = \frac{p \times l_i \times l_h}{2}$$



$$M = \frac{p \times l_i \times l_h}{8}$$



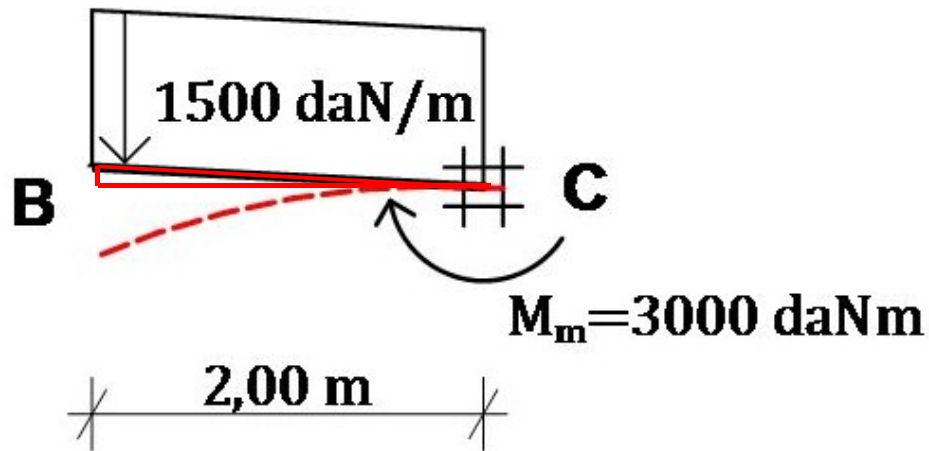
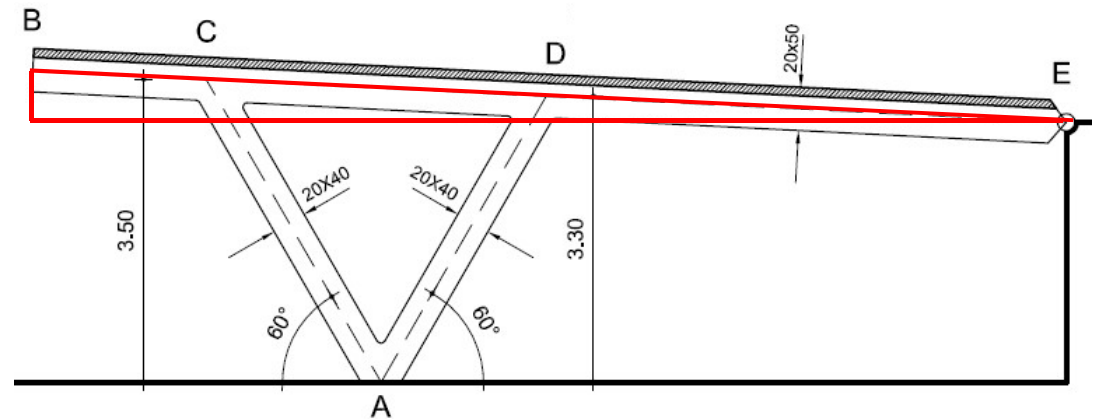
$$M = \frac{p \times l_i \times l_h}{12}$$



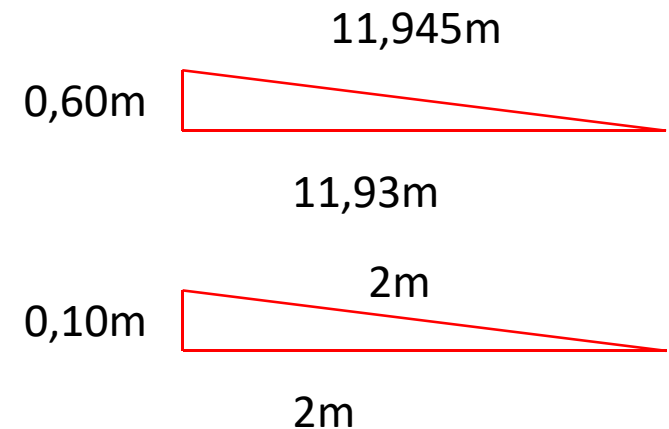
TRAMO	L (m)
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2

MOMENTOS DE EMPOTRAMIENTO PERFECTO (M.E.P.)



Semejanza de Triángulos:

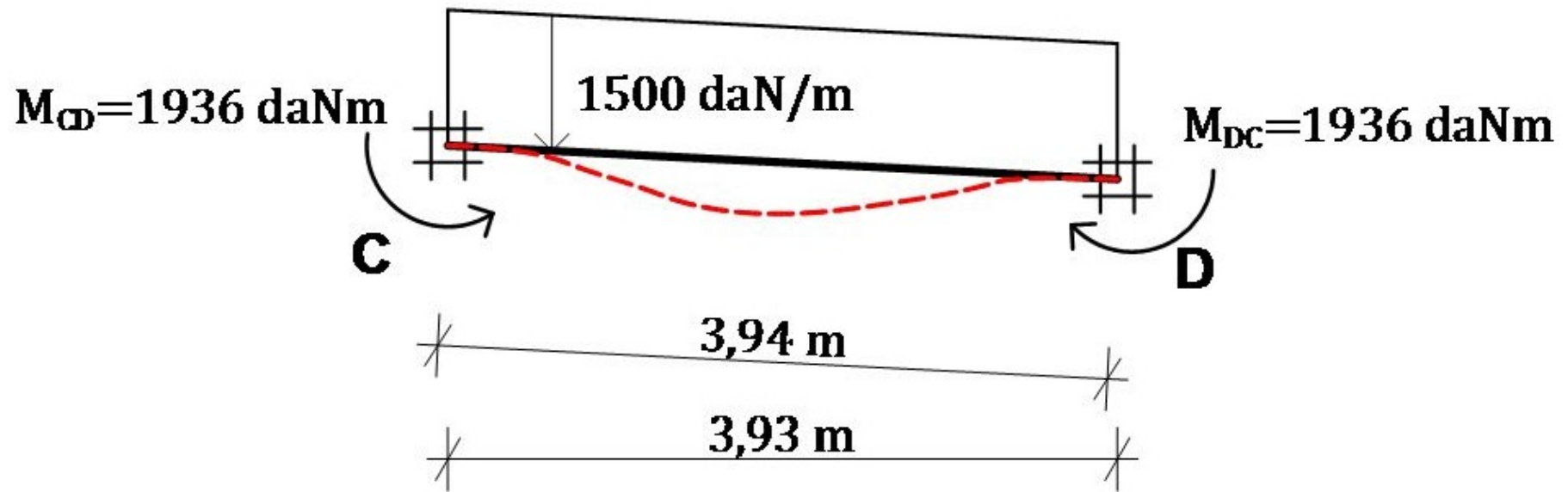


$$M_m = \frac{p \times l_i \times l_h}{2}$$

$$M_m = \frac{1500 \times 2^2}{2} = 3000 \text{ daNm}$$

2

MOMENTOS DE EMPOTRAMIENTO PERFECTO (M.E.P.)

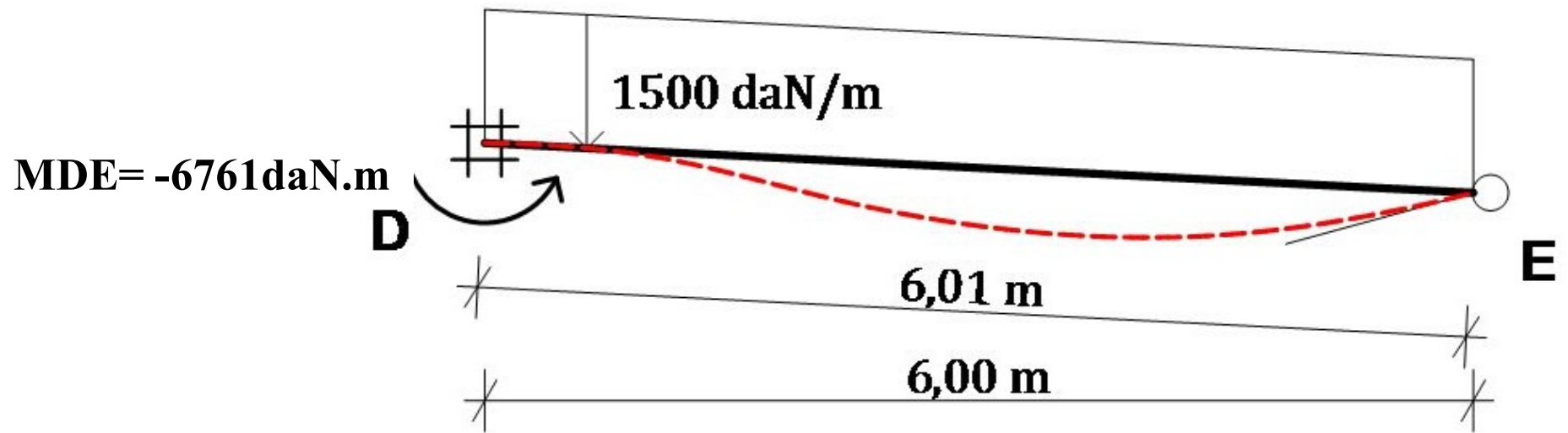


$$M = \frac{p \times l_i \times l_h}{12}$$

$$M_{CD} = M_{DC} = \frac{1500 \times 3,93 \times 3,94}{12} = 1936 \text{ daNm}$$

2

MOMENTOS DE EMPOTRAMIENTO PERFECTO (M.E.P.)

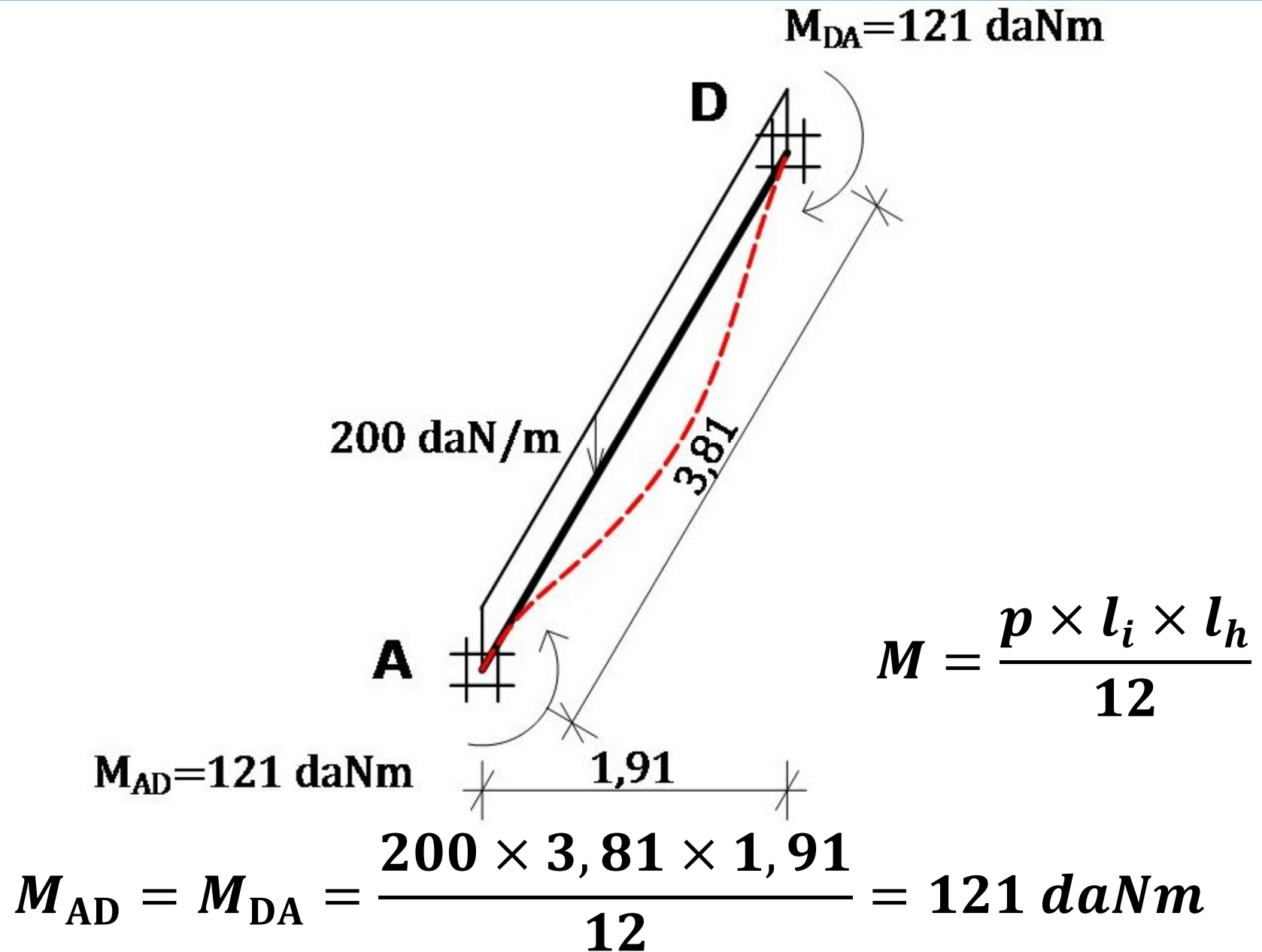


$$M = \frac{p \times l_i \times l_h}{8}$$

$$M_{DE} = M_{DC} = \frac{1500 \times 6,00 \times 6,01}{8} = 6761 \text{ daNm}$$

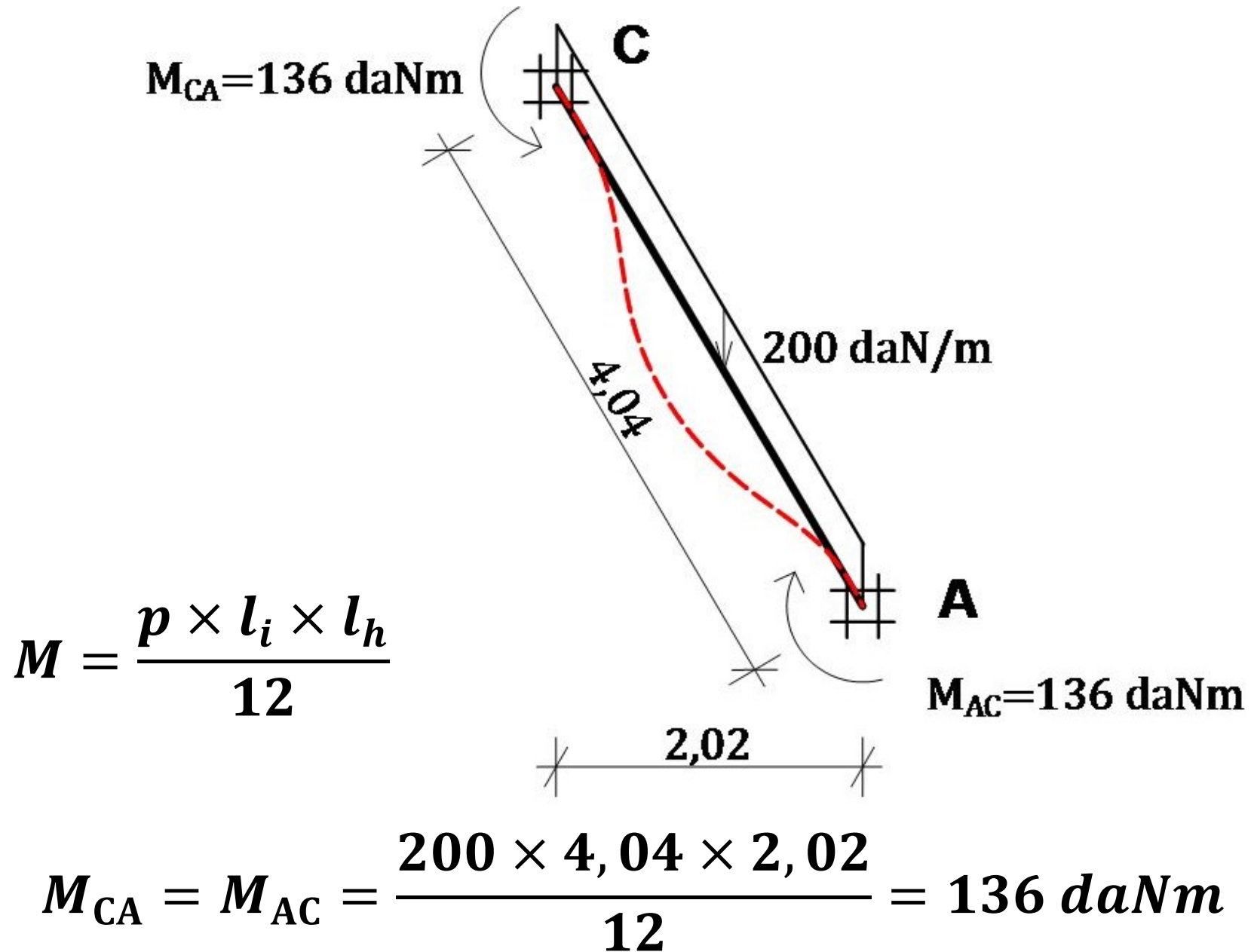
2

MOMENTOS DE EMPOTRAMIENTO PERFECTO (M.E.P.)



2

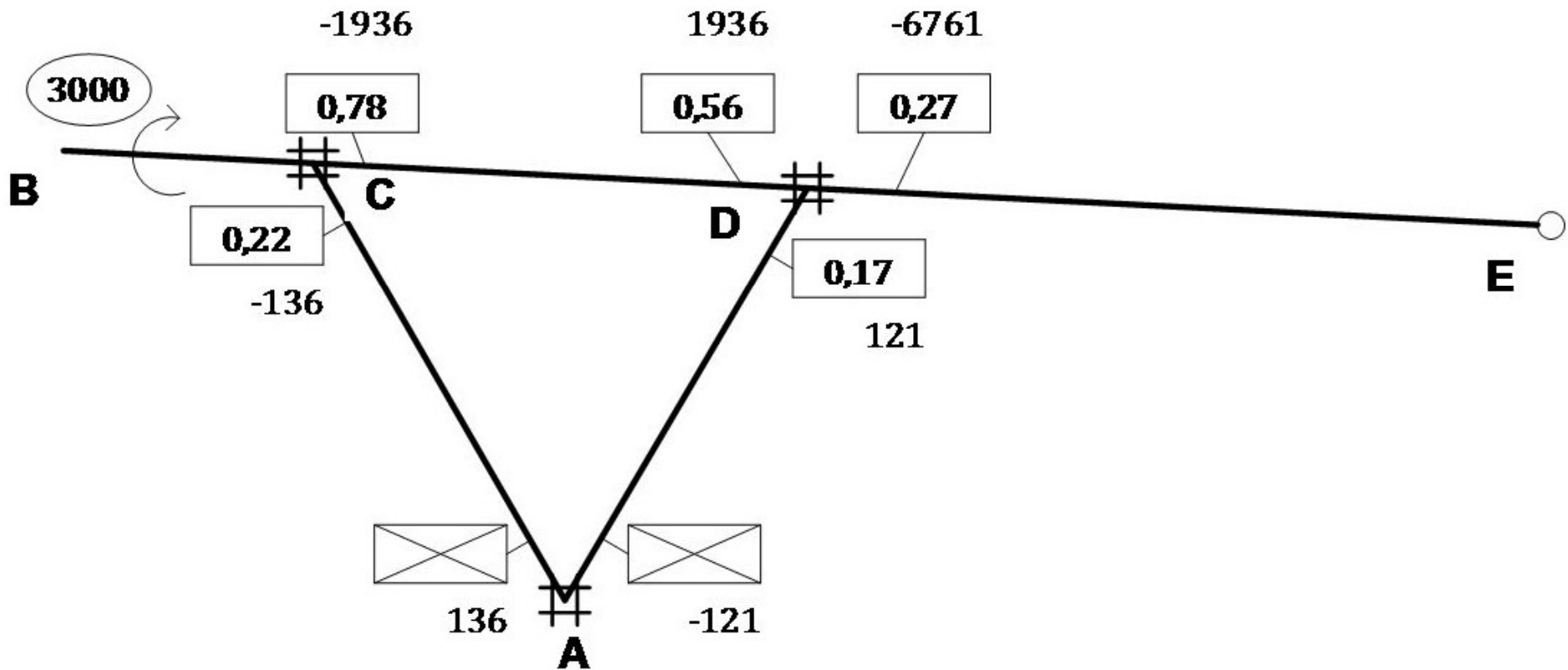
MOMENTOS DE EMPOTRAMIENTO PERFECTO (M.E.P.)



2

MOMENTOS DE EMPOTRAMIENTO PERFECTO (M.E.P.)

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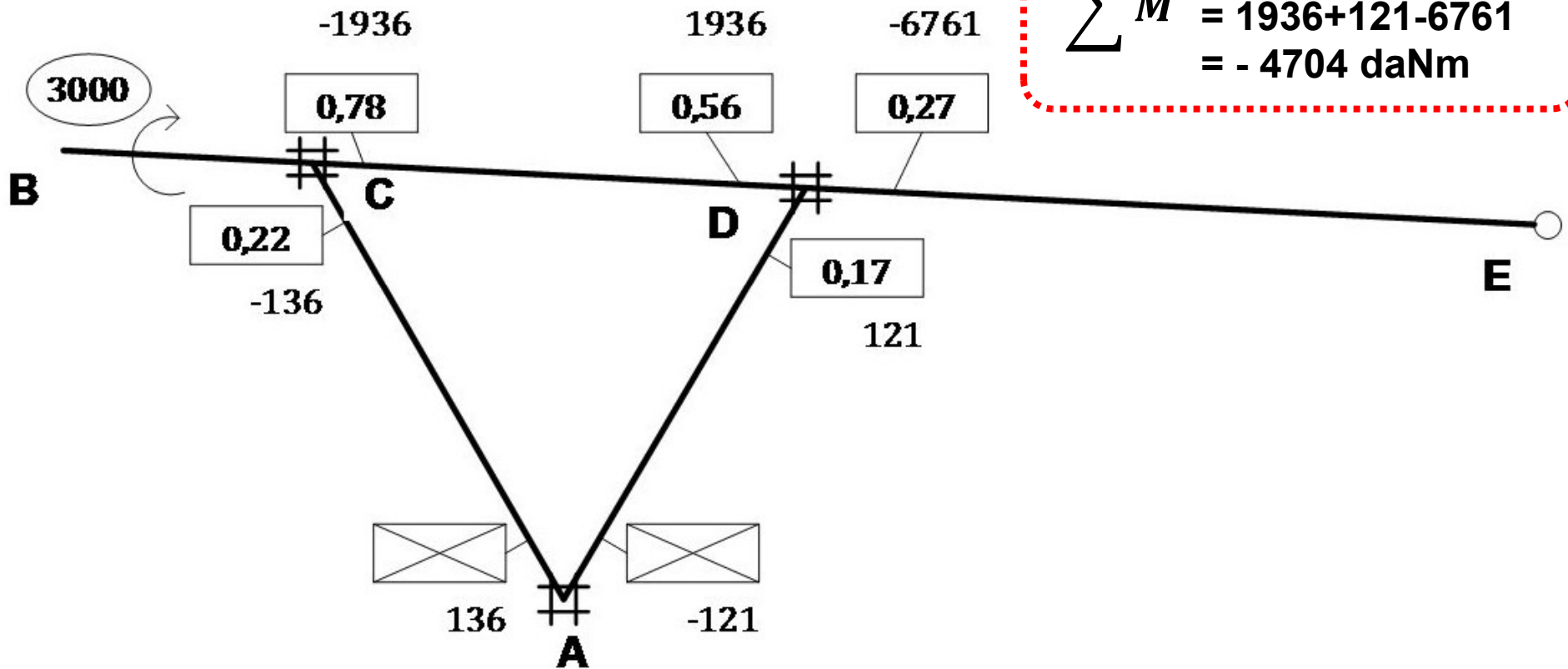
ARTIFICIO DE CROSS

$$\sum M = 3000 - 1936 - 136 = 928 \text{ daNm}$$

Nudo C

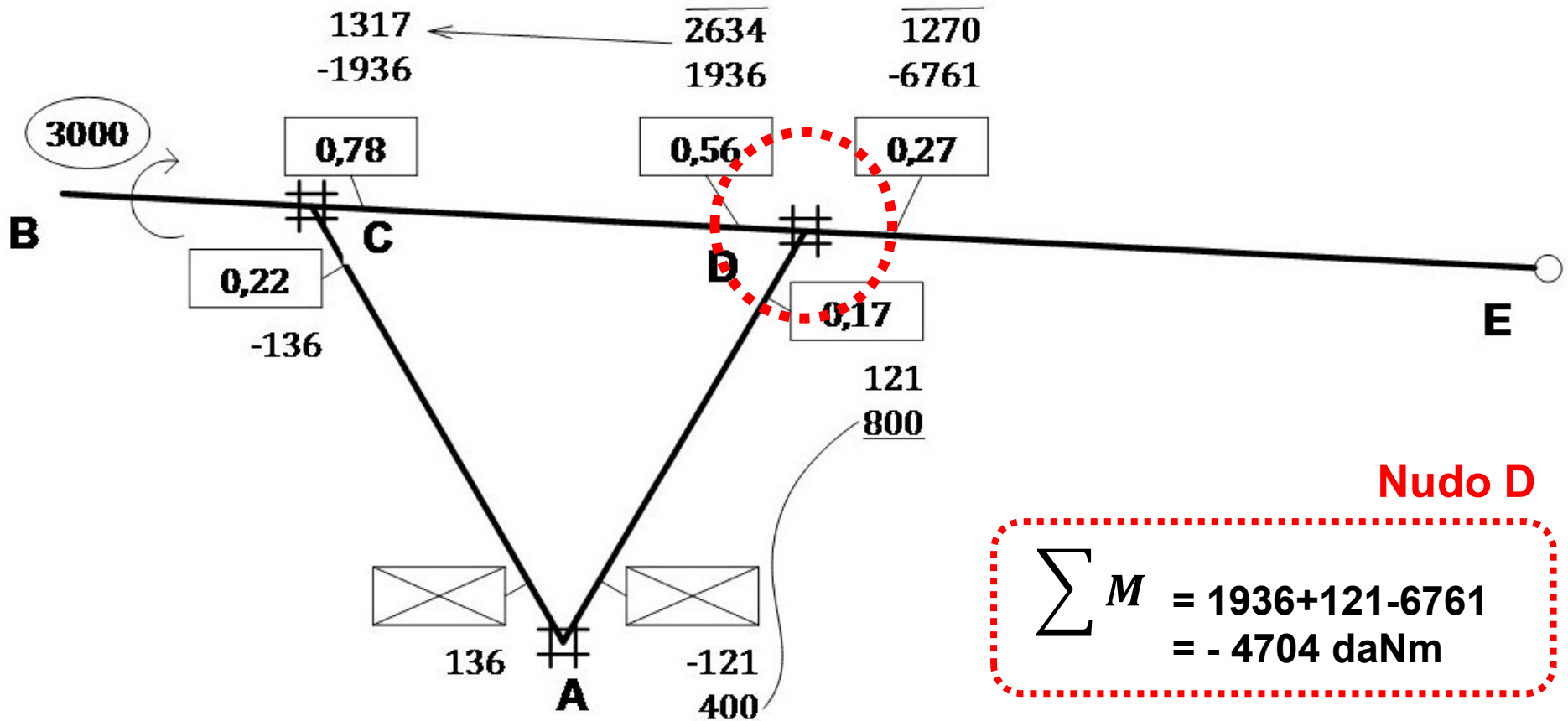
Nudo D

$$\sum M = 1936 + 121 - 6761 = -4704 \text{ daNm}$$



3

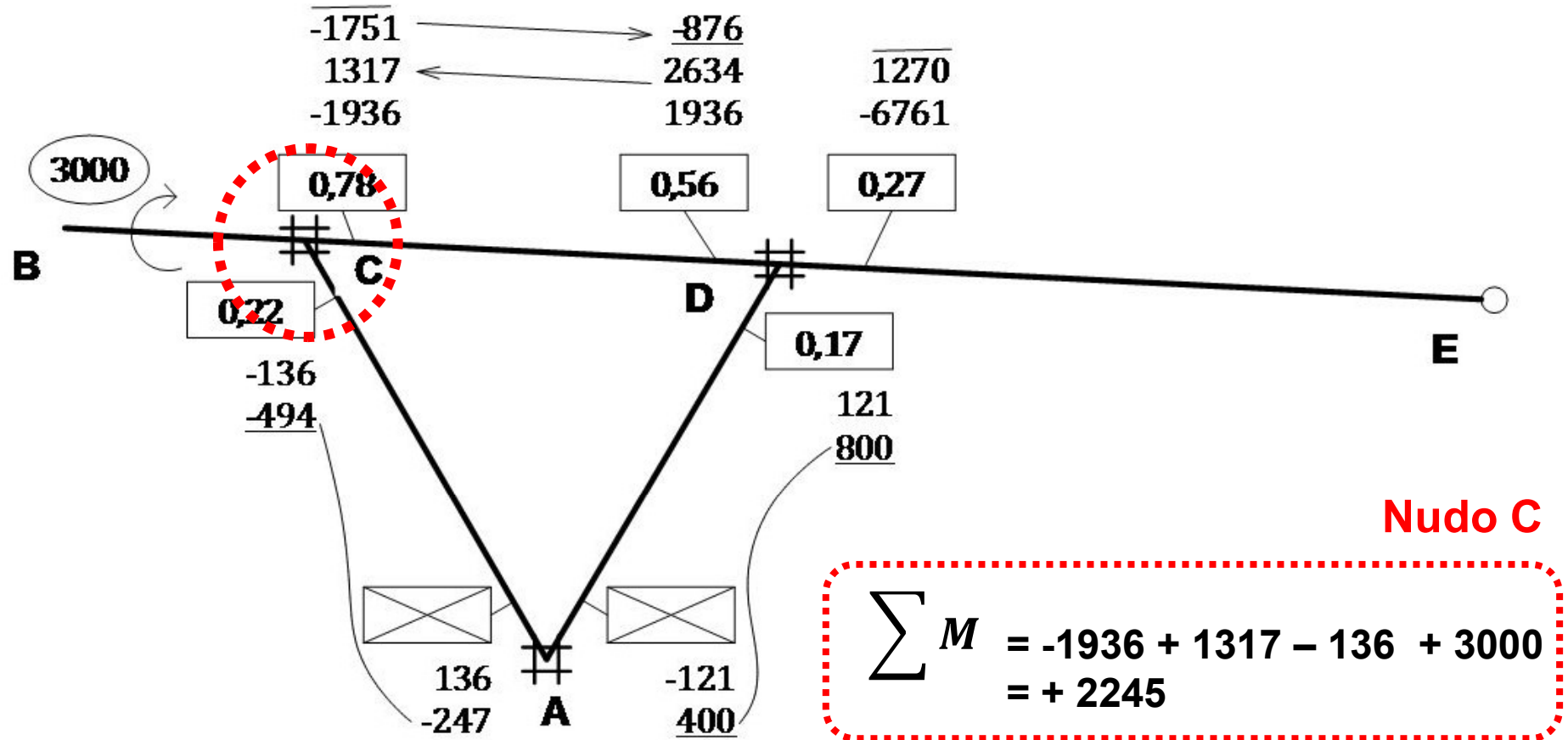
ARTIFICIO DE CROSS



NUDO	$\sum M$	$-\sum M$	r_i	M_{rep}	/	β_i	M_{trans}
D	-4704	+4704	0,56	2634	/	0,5	1317
			0,27	1270	/	-	-
			0,17	800	/	0,5	400

3

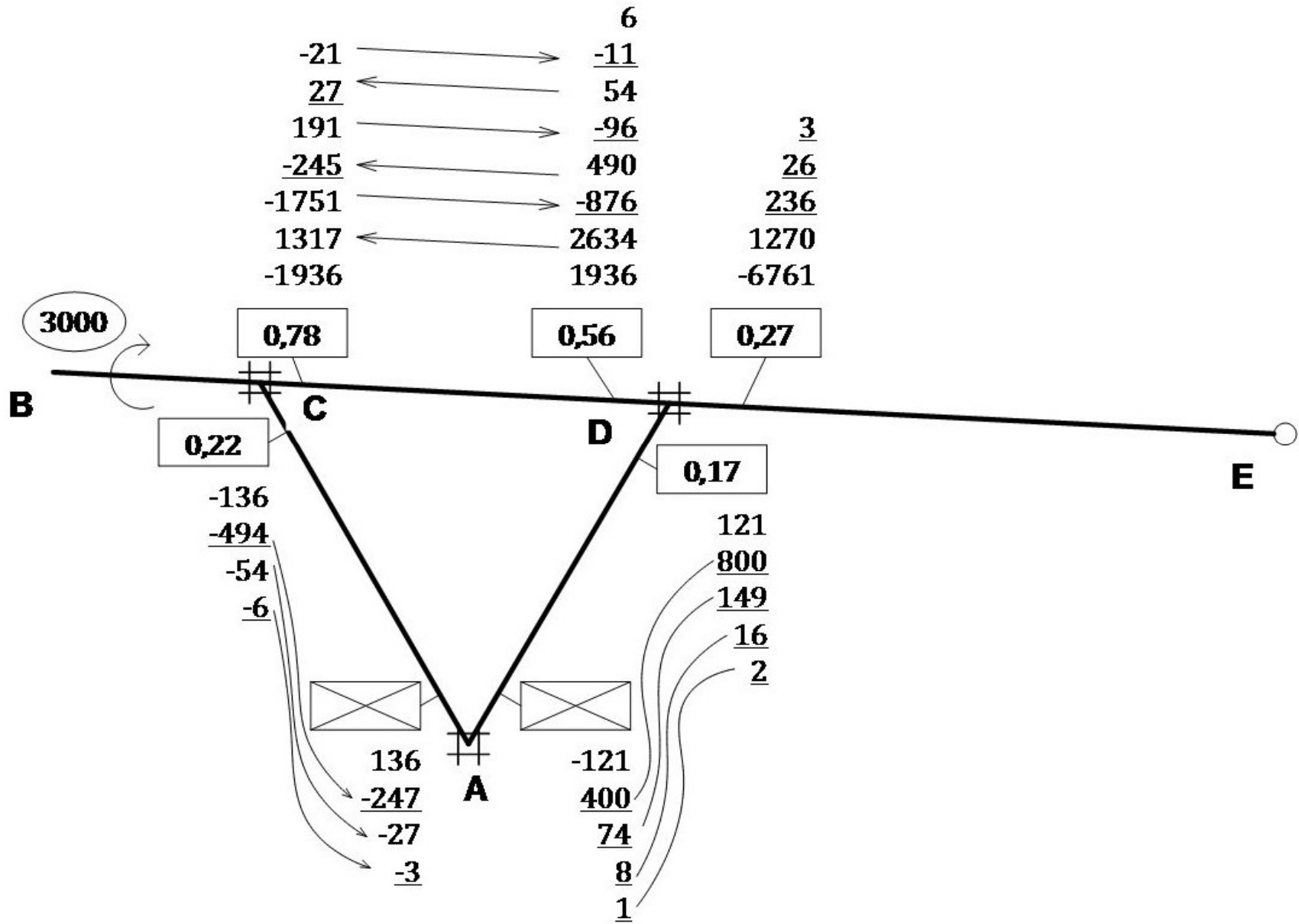
ARTIFICIO DE CROSS



NUDO	$\sum M$	$-\sum M$	r_i	M_{rep}	/	β_i	M_{trans}
C	+2245	-2245	0,78	-1751	/	0,5	-876
			0,22	-494	/	0,5	-247

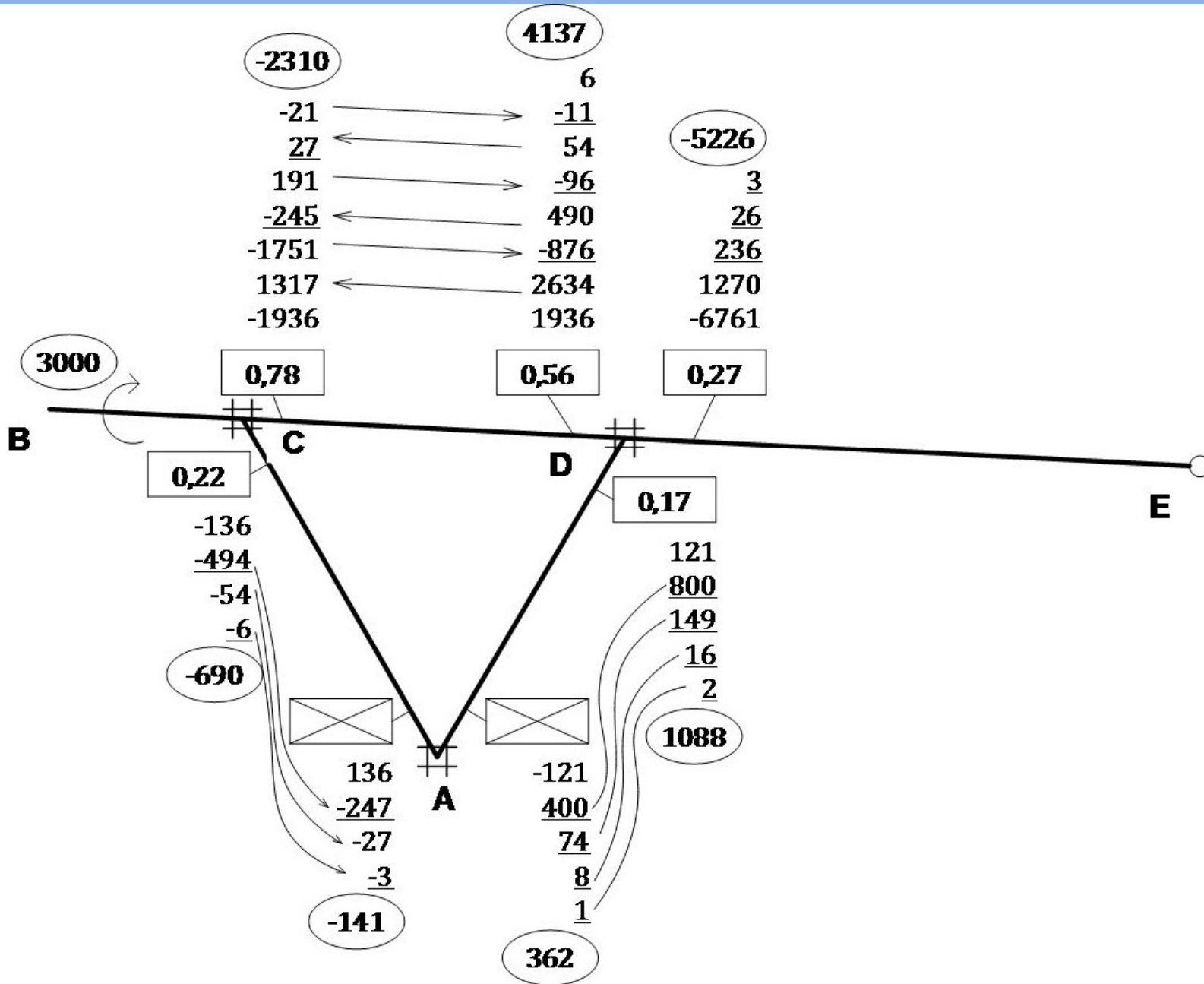
3

ARTIFICIO DE CROSS



3

ARTIFICIO DE CROSS

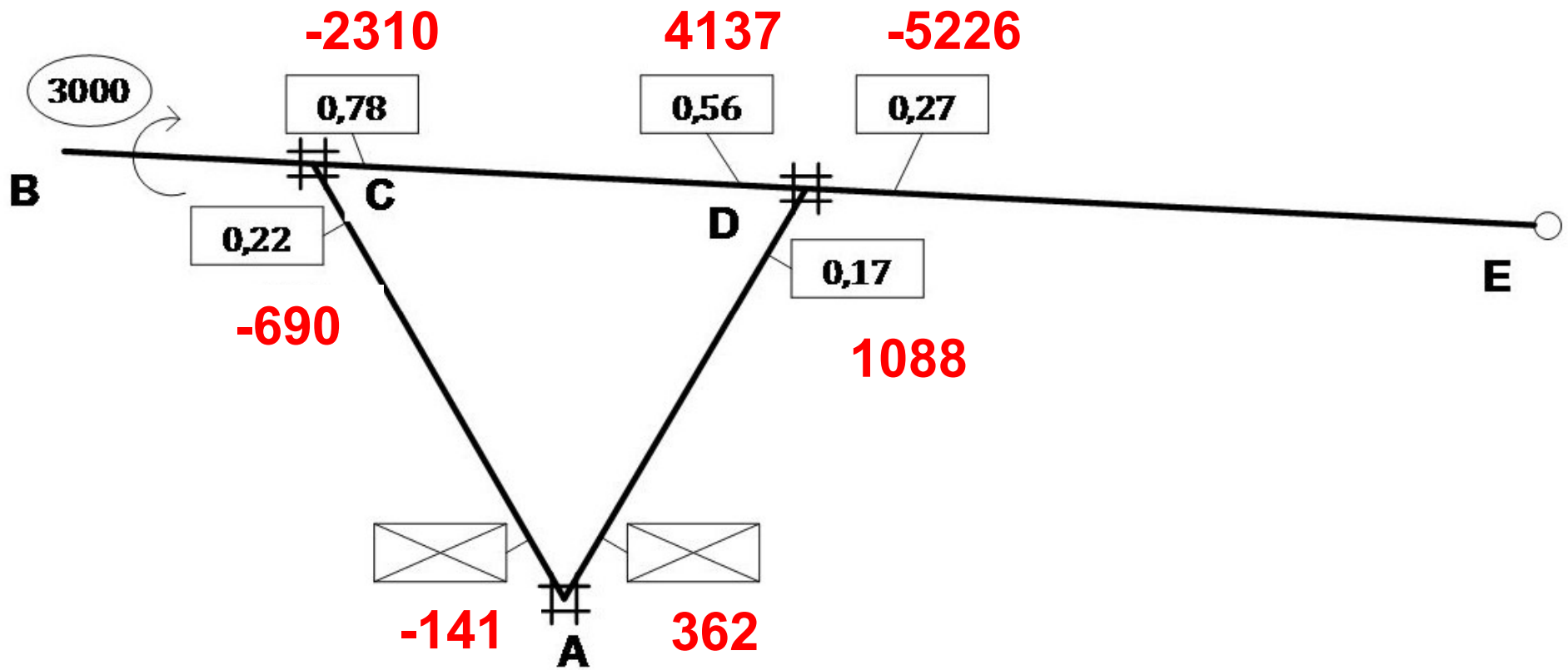


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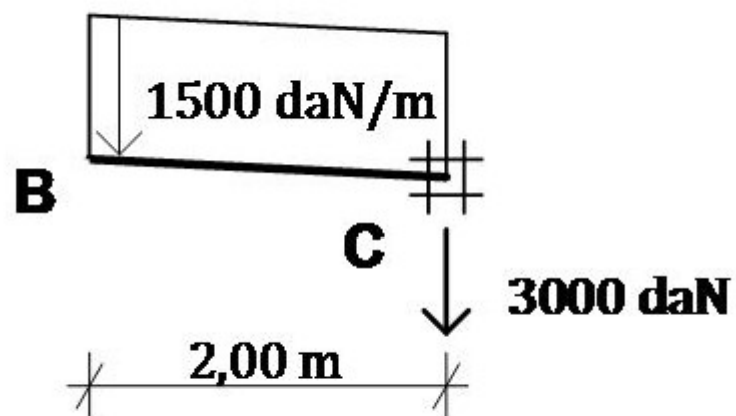
4

DESCARGAS TRAMO POR TRAMO



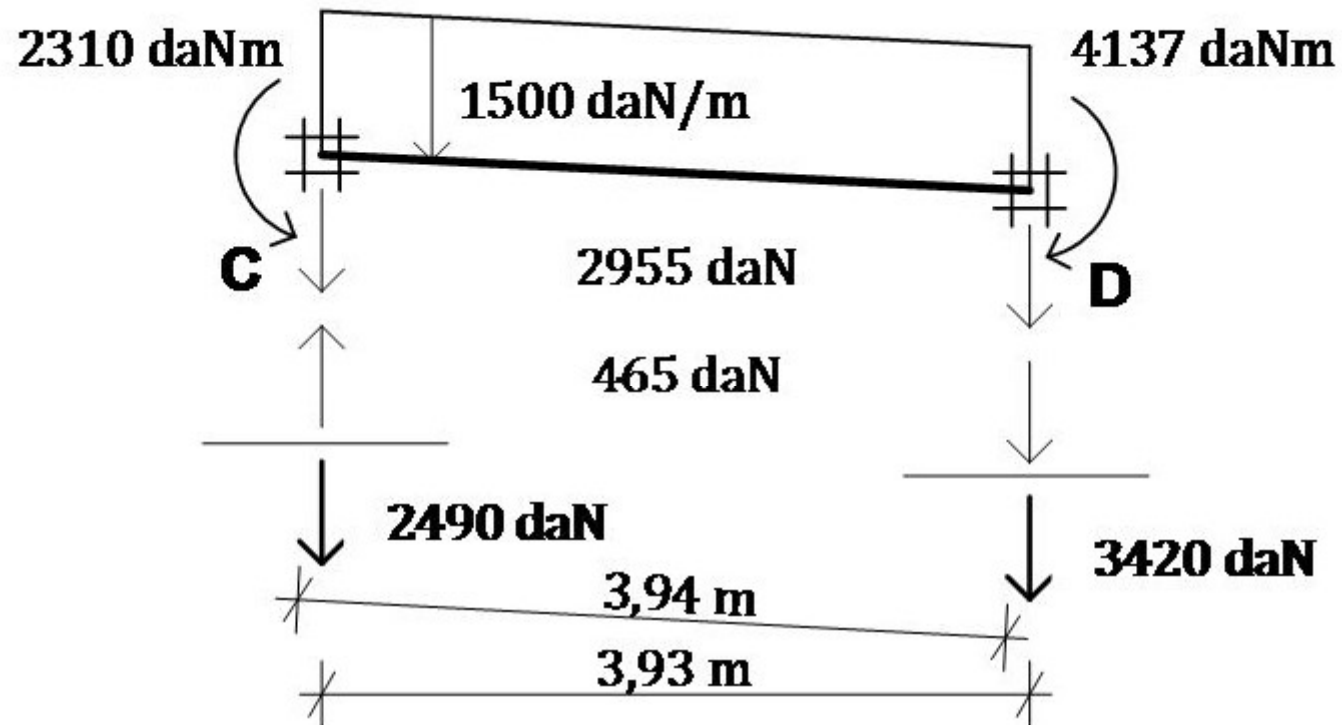
4

DESCARGAS TRAMO POR TRAMO



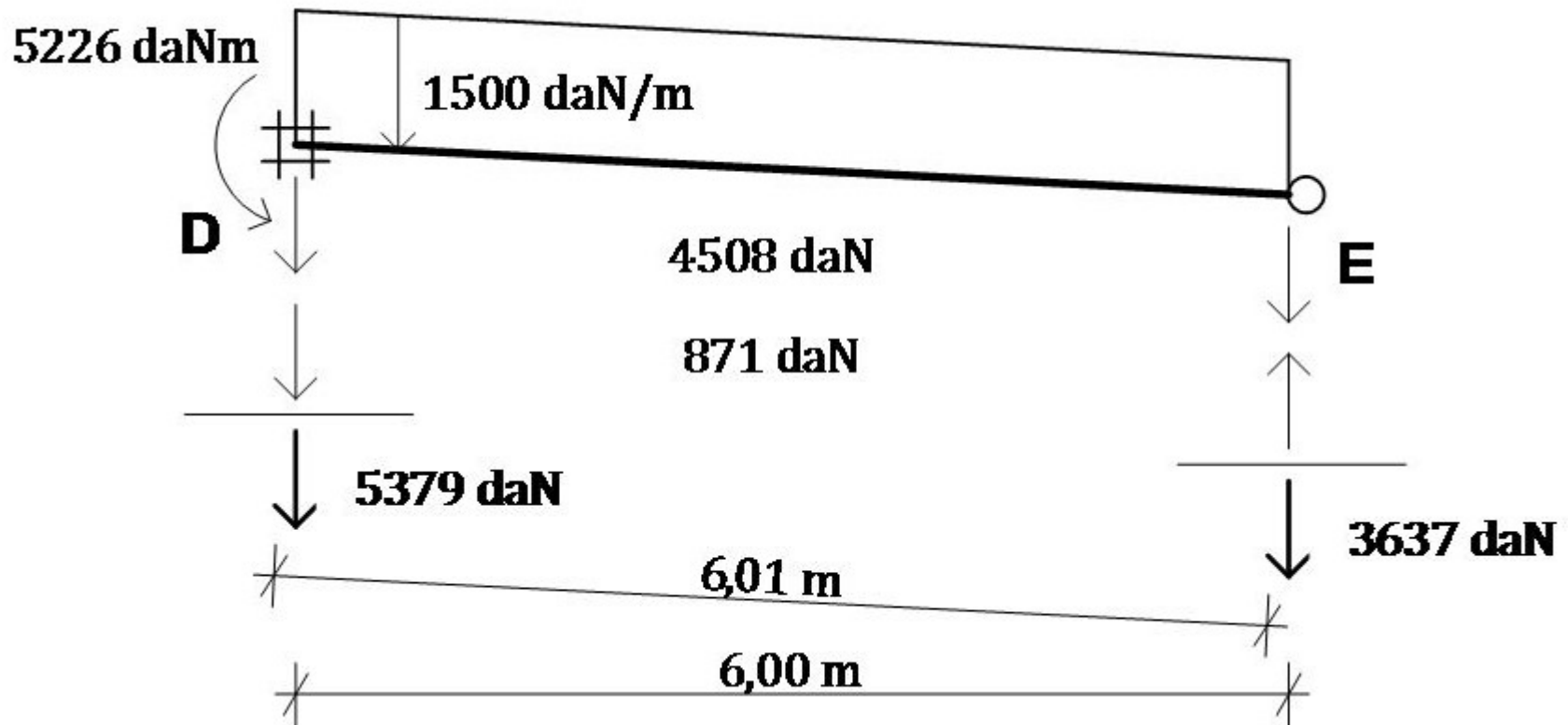
4

DESCARGAS TRAMO POR TRAMO



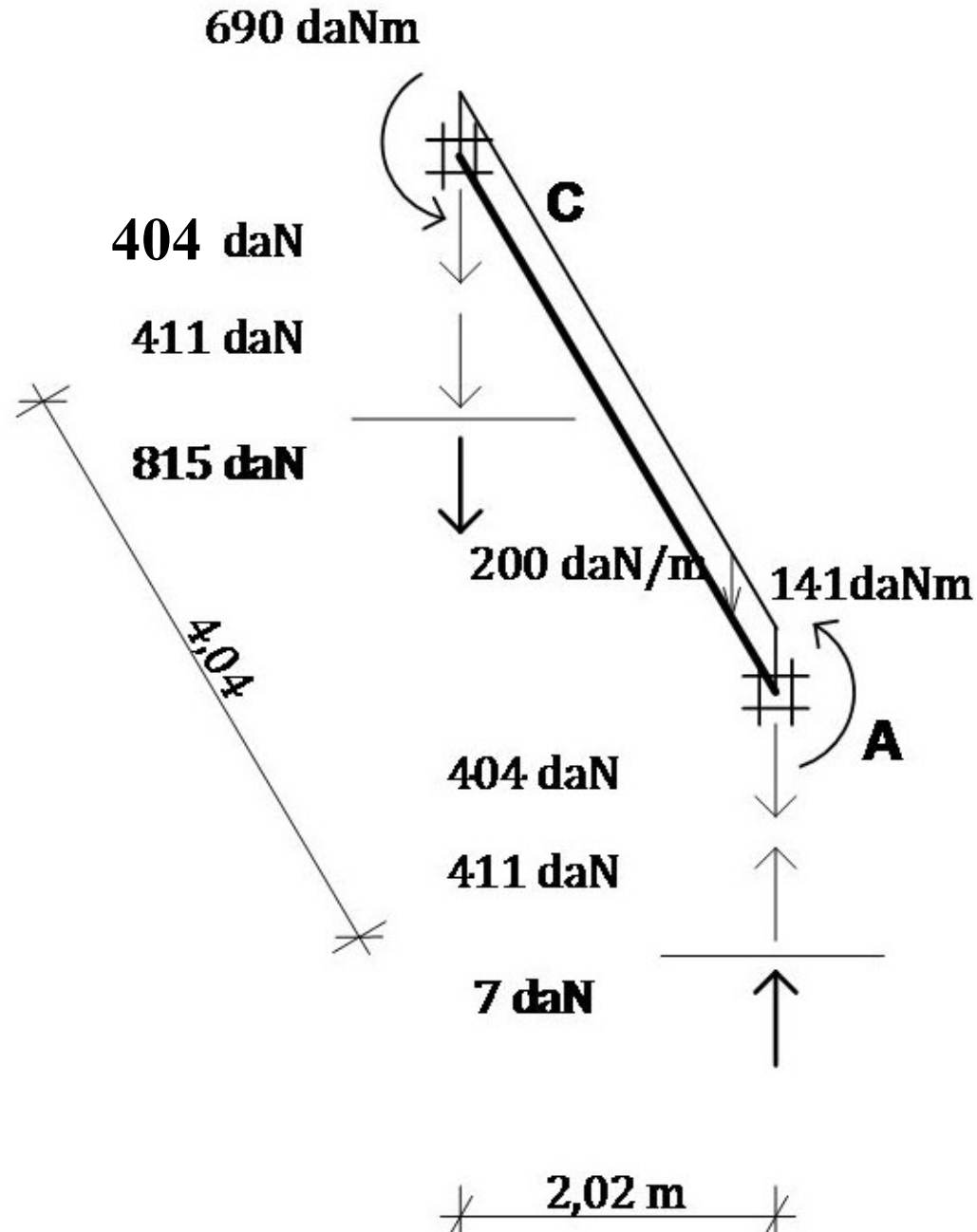
4

DESCARGAS TRAMO POR TRAMO



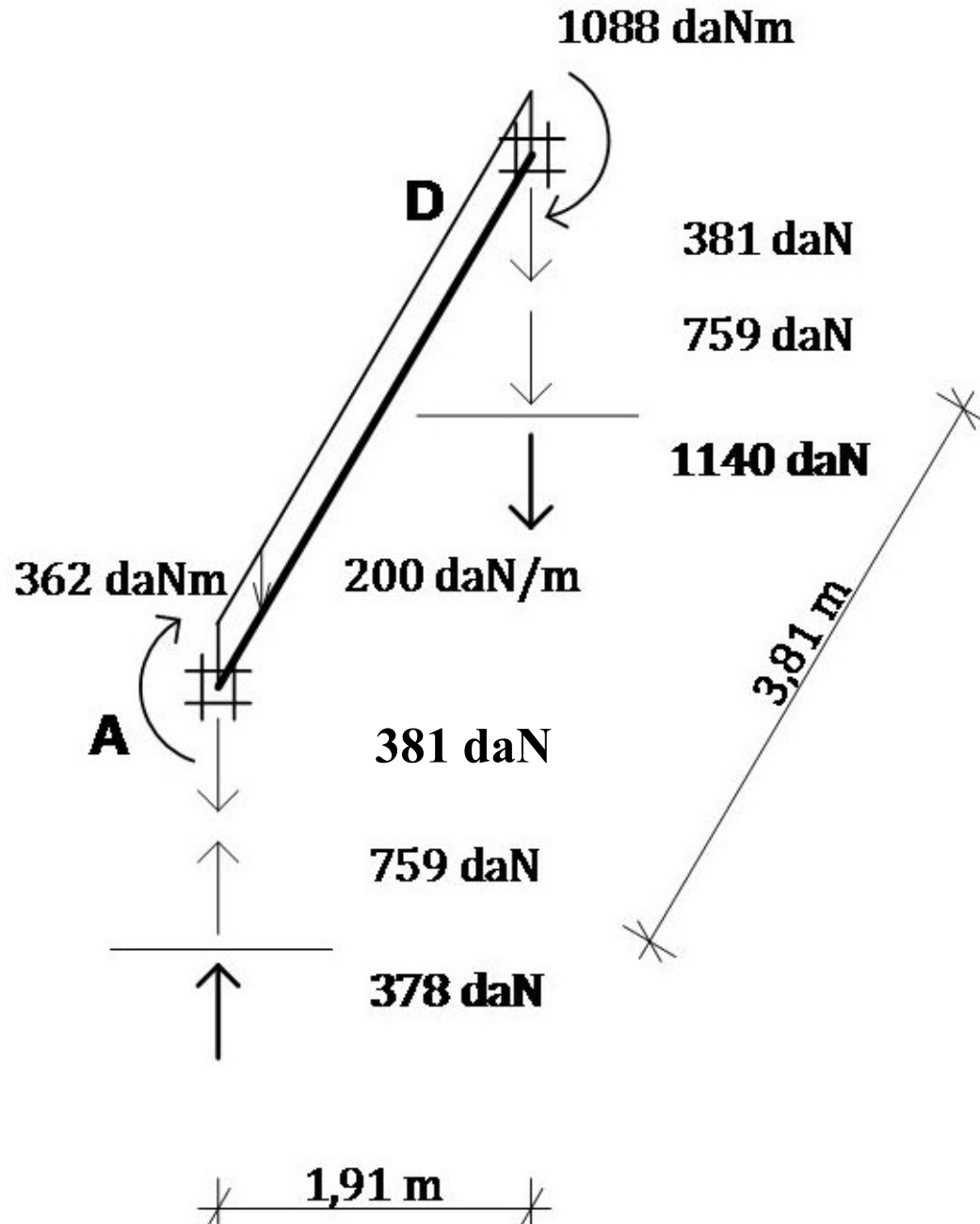
4

DESCARGAS TRAMO POR TRAMO



4

DESCARGAS TRAMO POR TRAMO

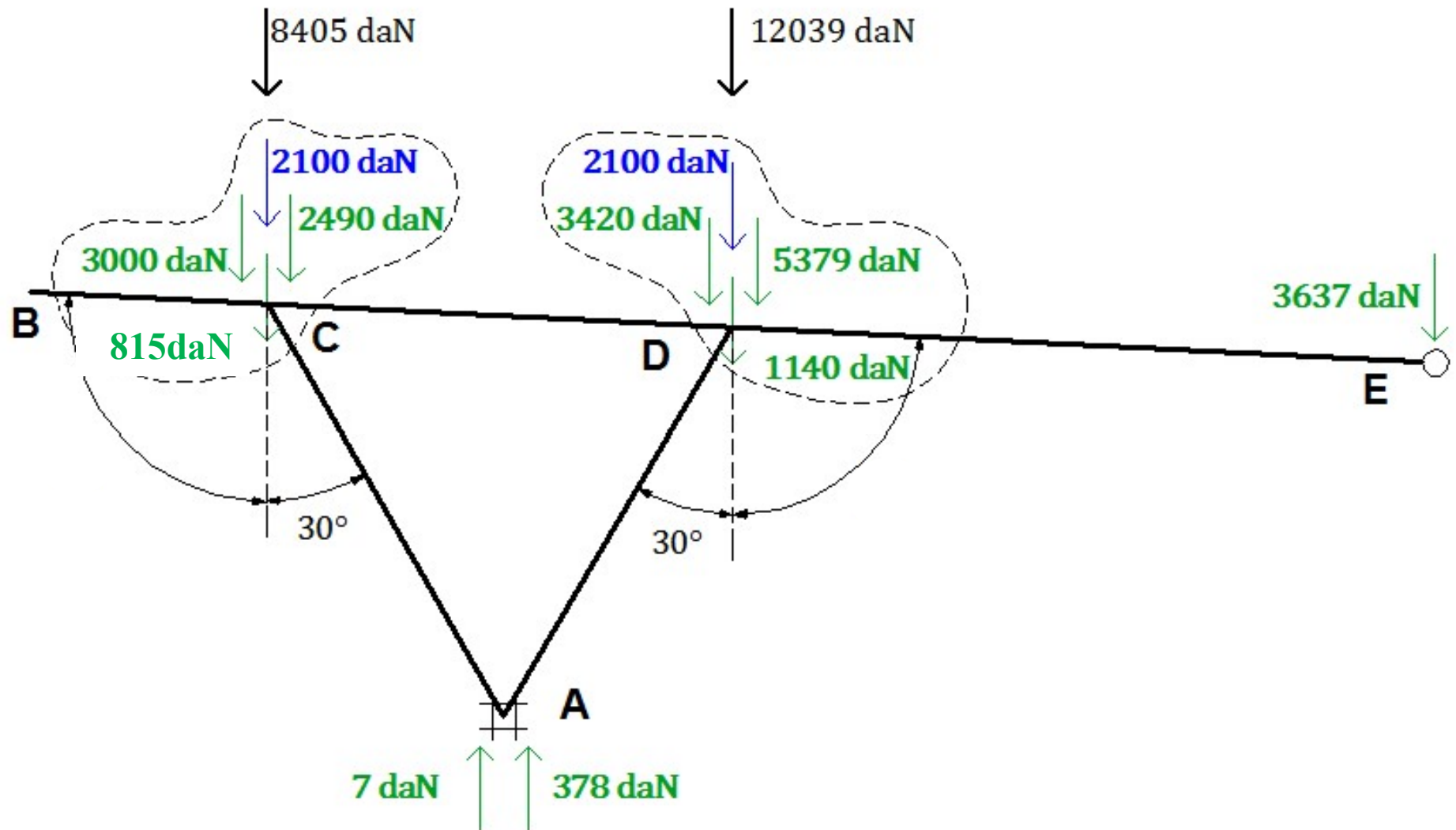


ESTRUCTURA HIPERESTATICA ASIMETRICA

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- 5** Caminos Materiales
- 6** Reacciones en los Apoyos
- 7** Diagramas de Solicitaciones

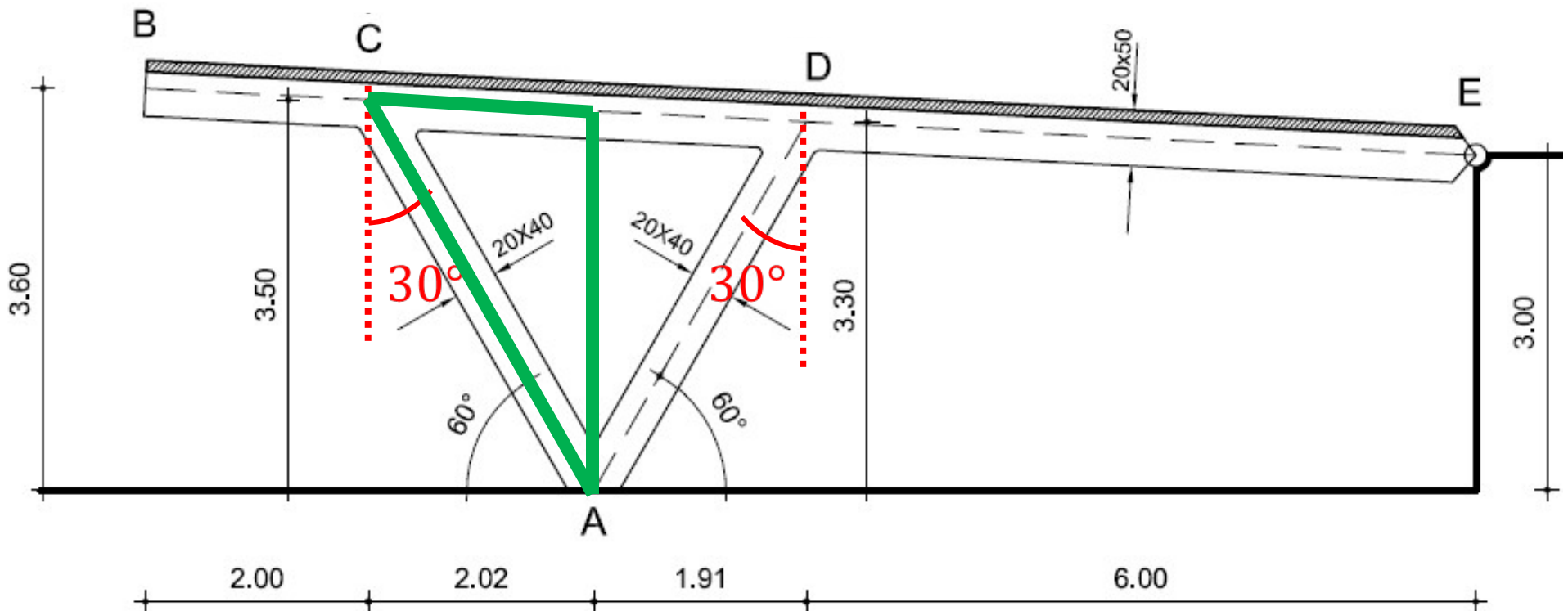
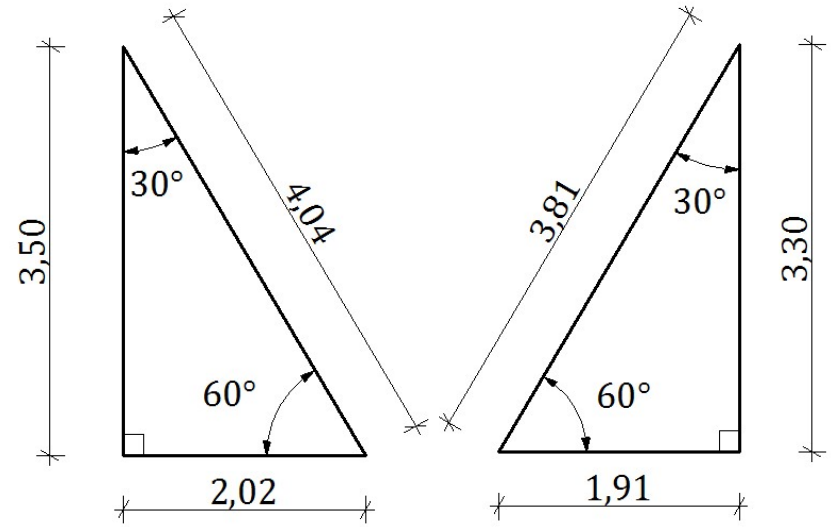
5

CAMINOS MATERIALES



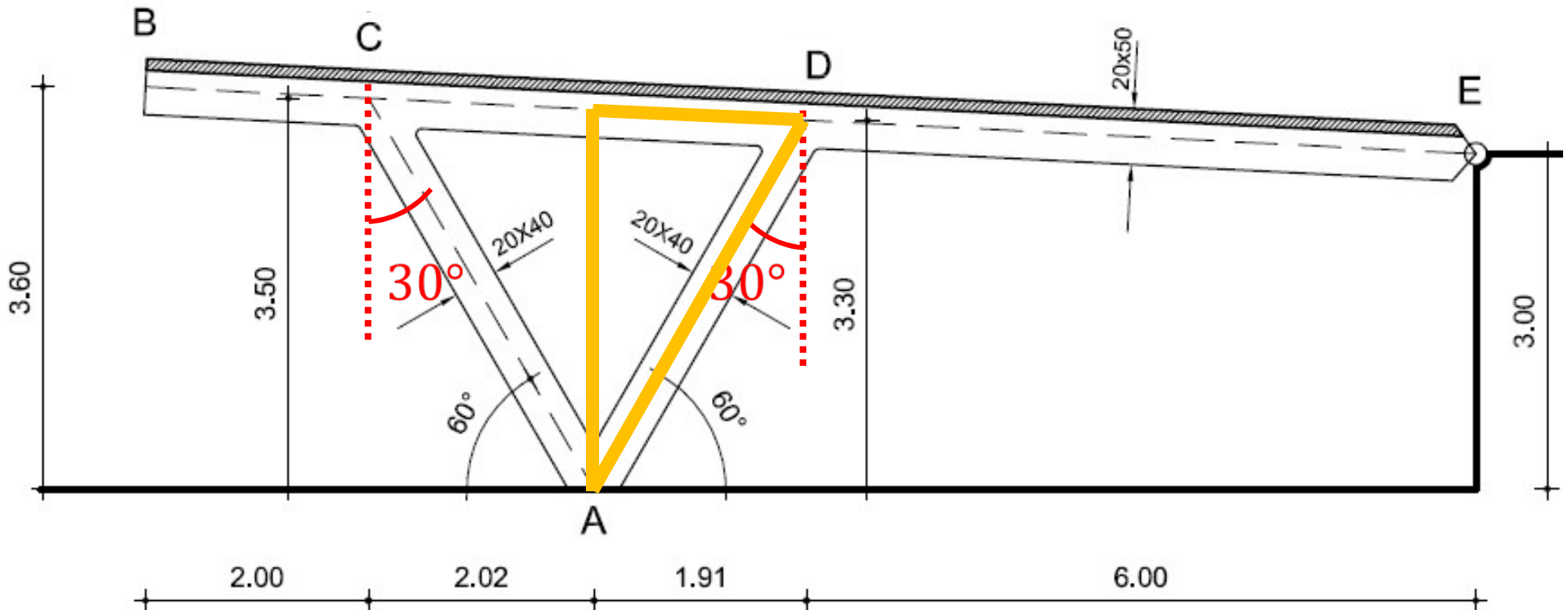
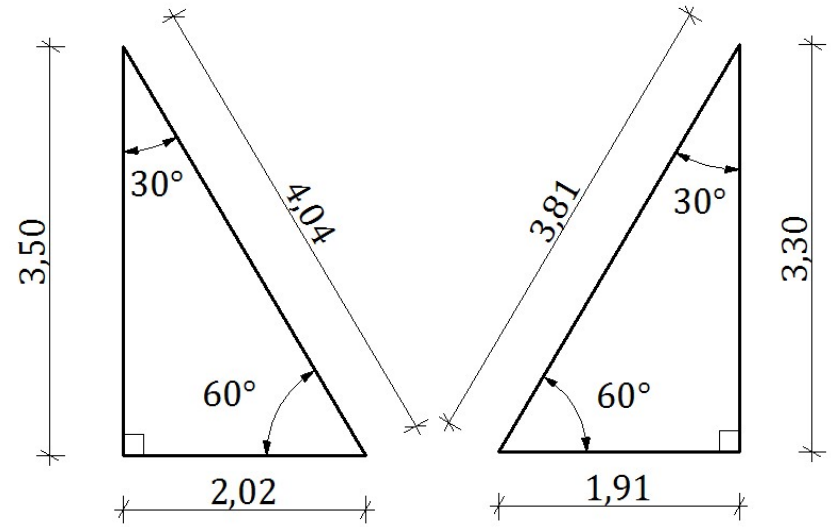
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CAMINOS MATERIALES



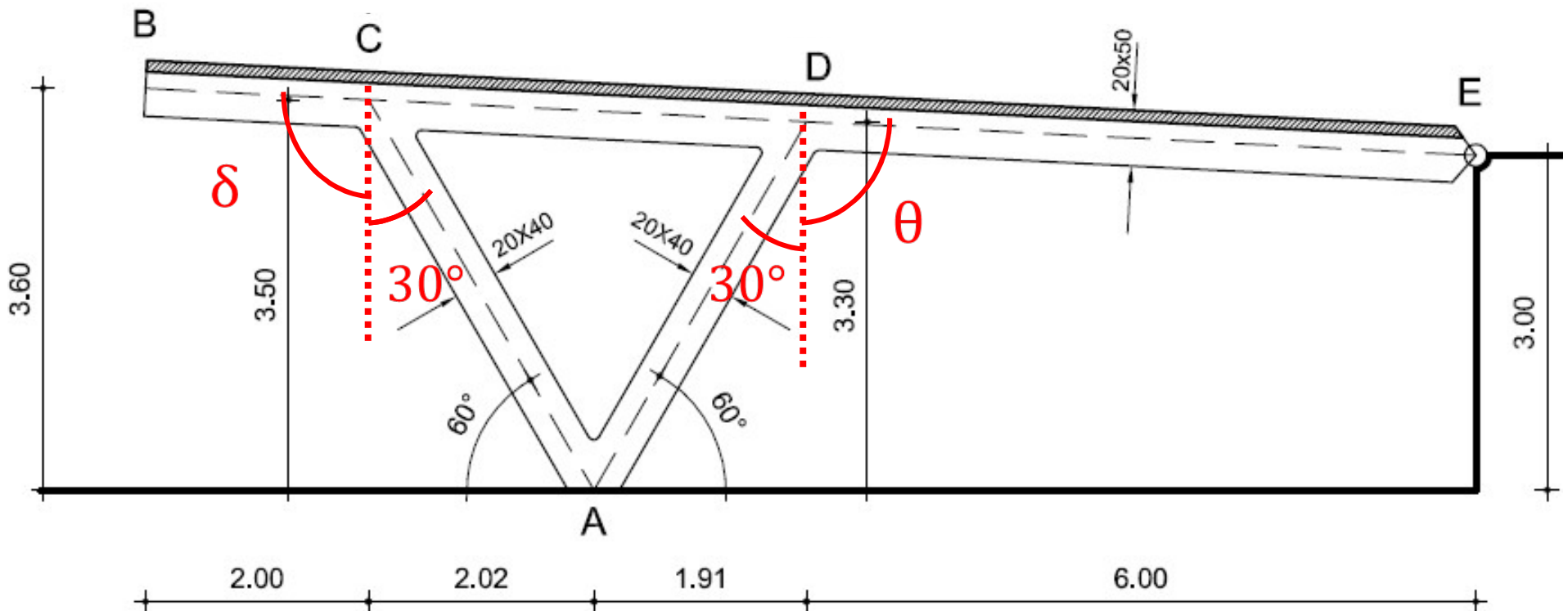
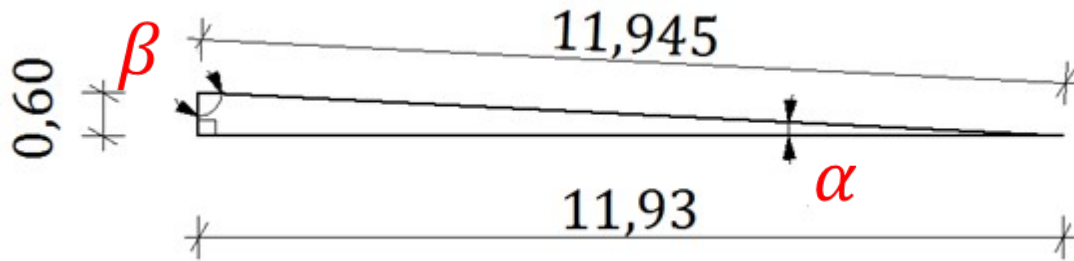
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CAMINOS MATERIALES



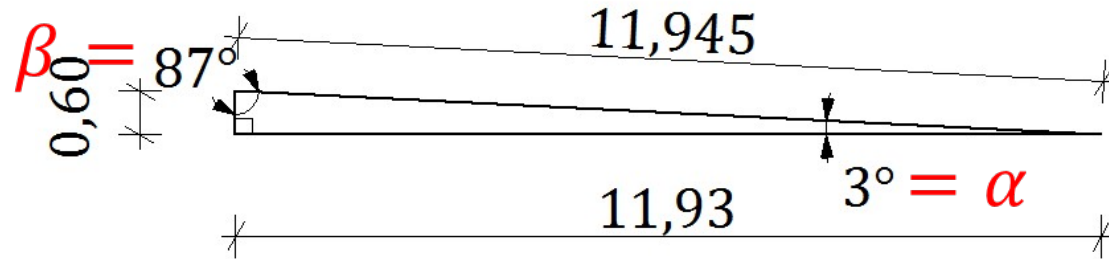
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CAMINOS MATERIALES



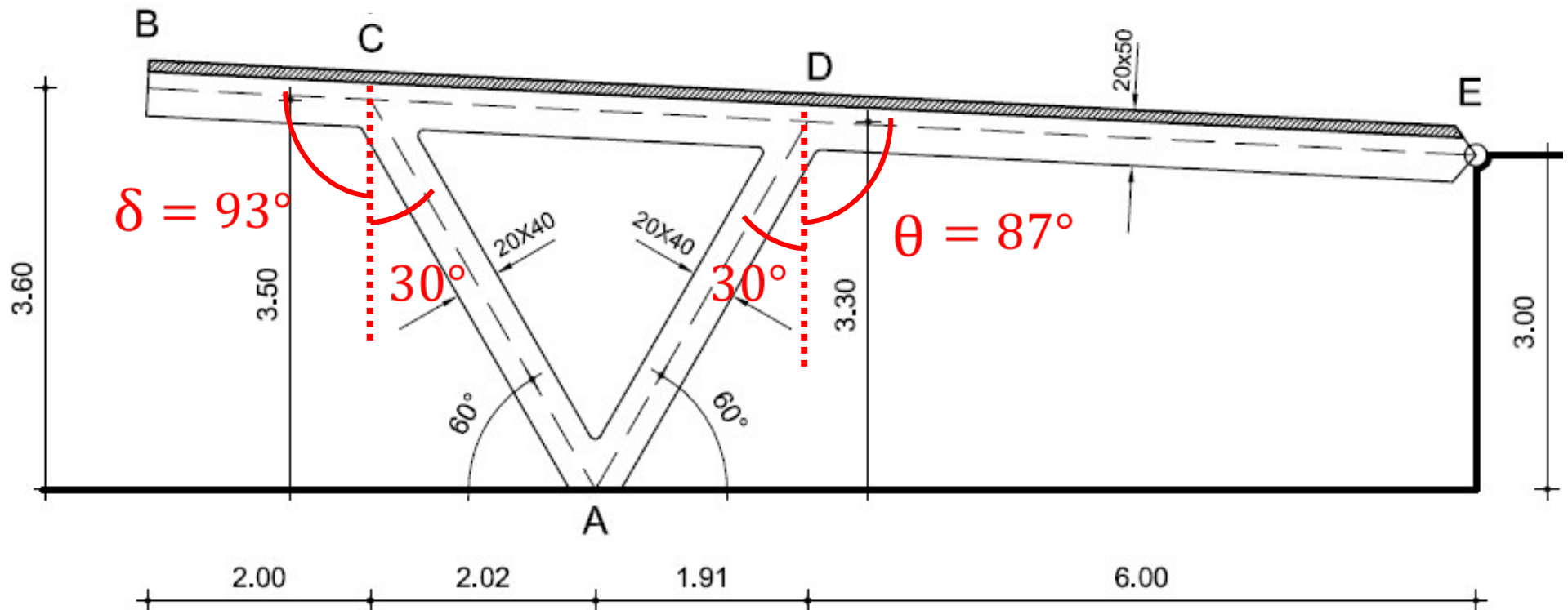
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CAMINOS MATERIALES



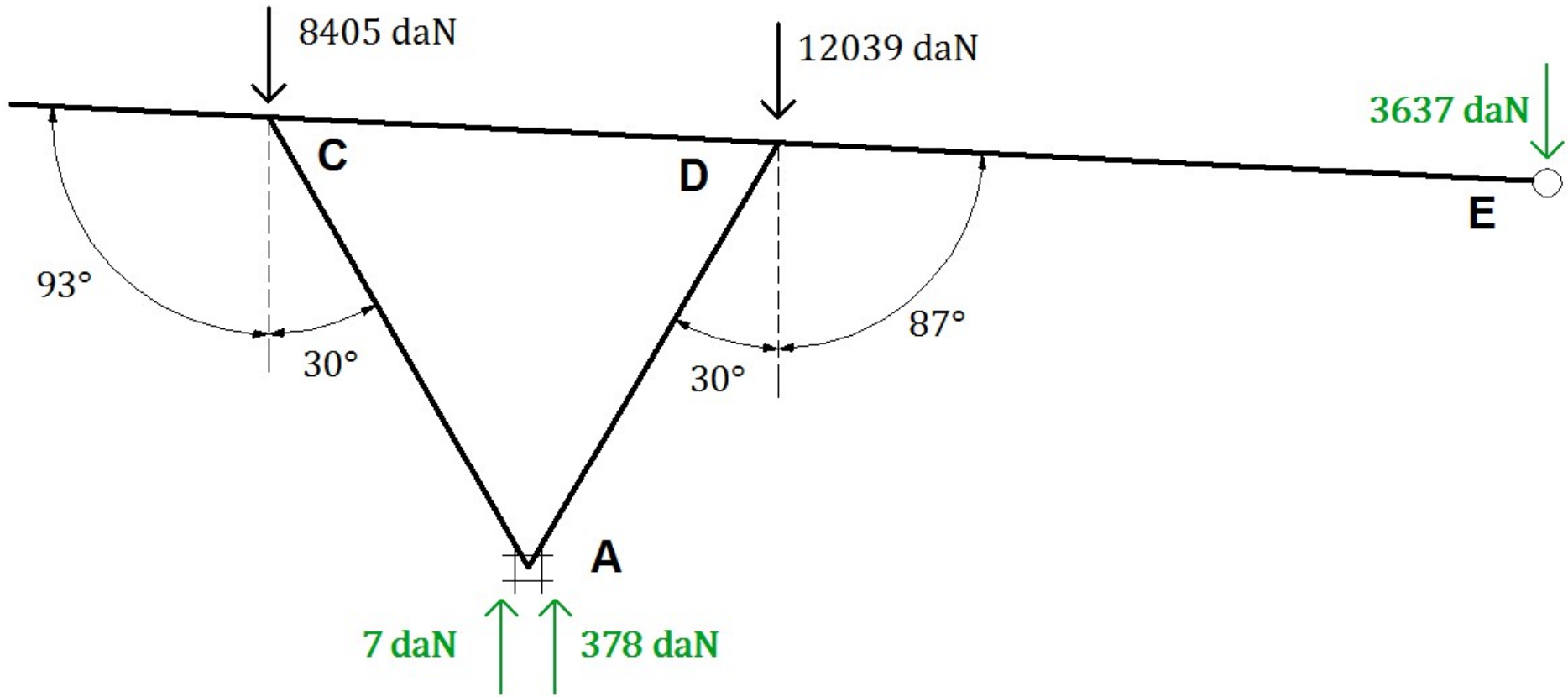
$$\tan \alpha = \frac{op}{adj} = \frac{0,60}{11,93} \rightarrow$$

$$inv. \tan \alpha \cong 3^\circ$$



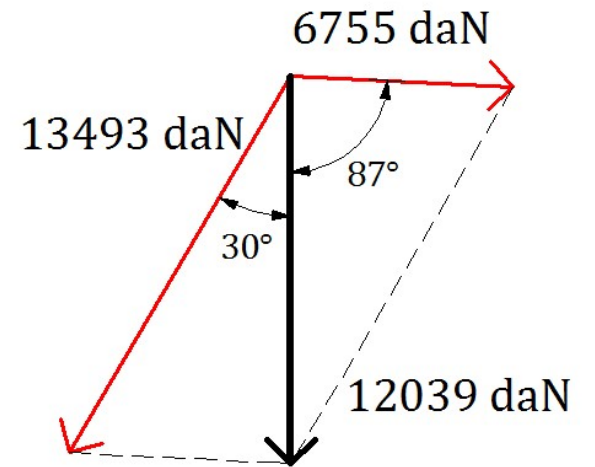
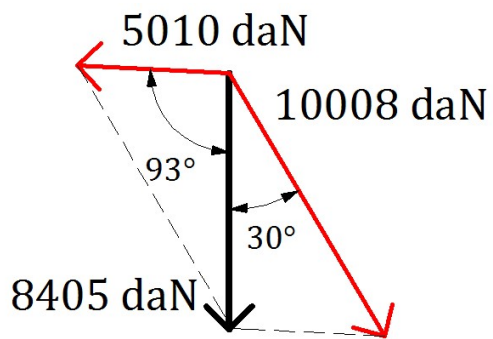
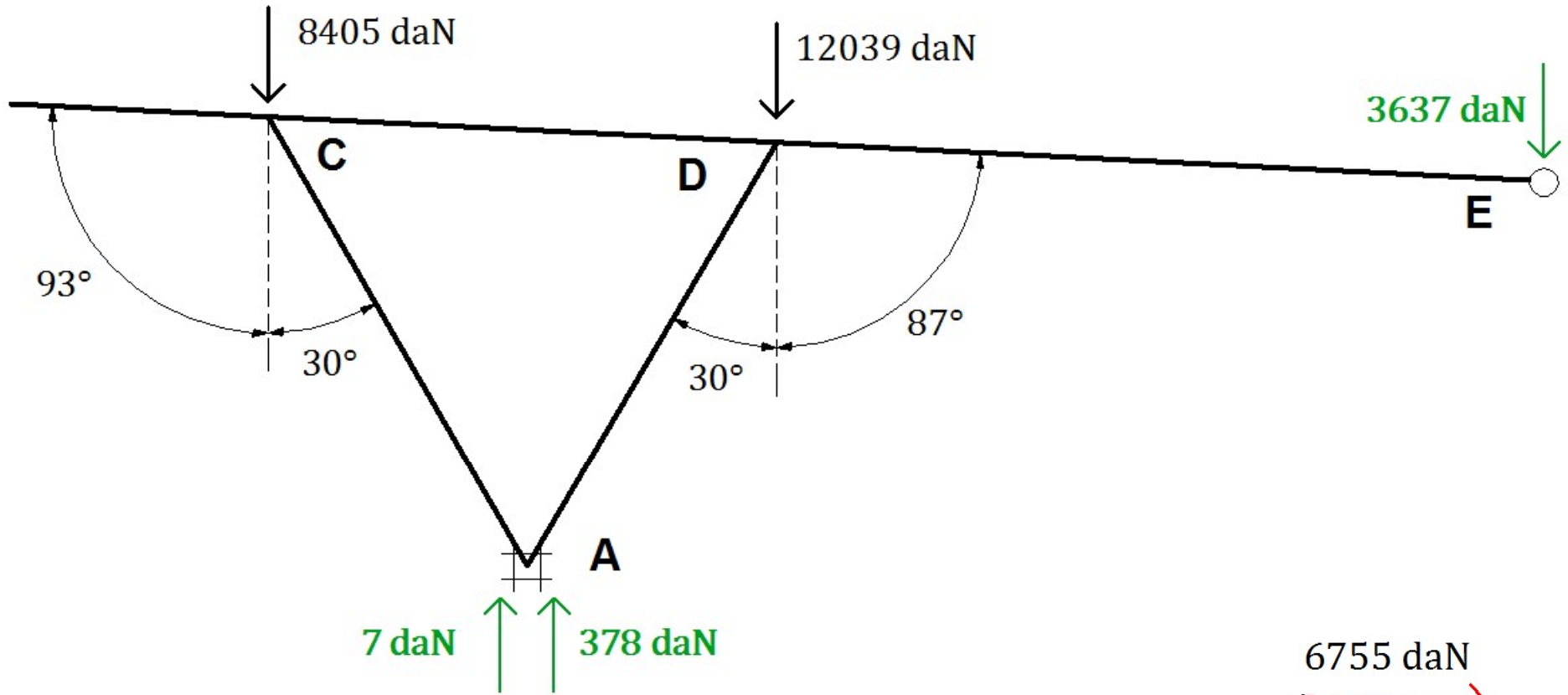
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CAMINOS MATERIALES



5

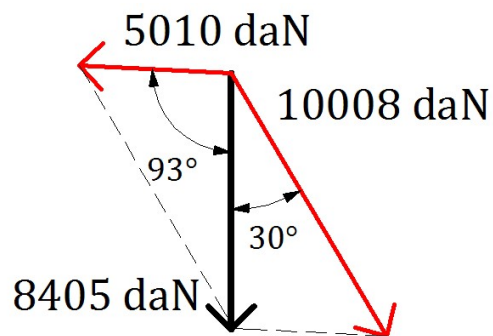
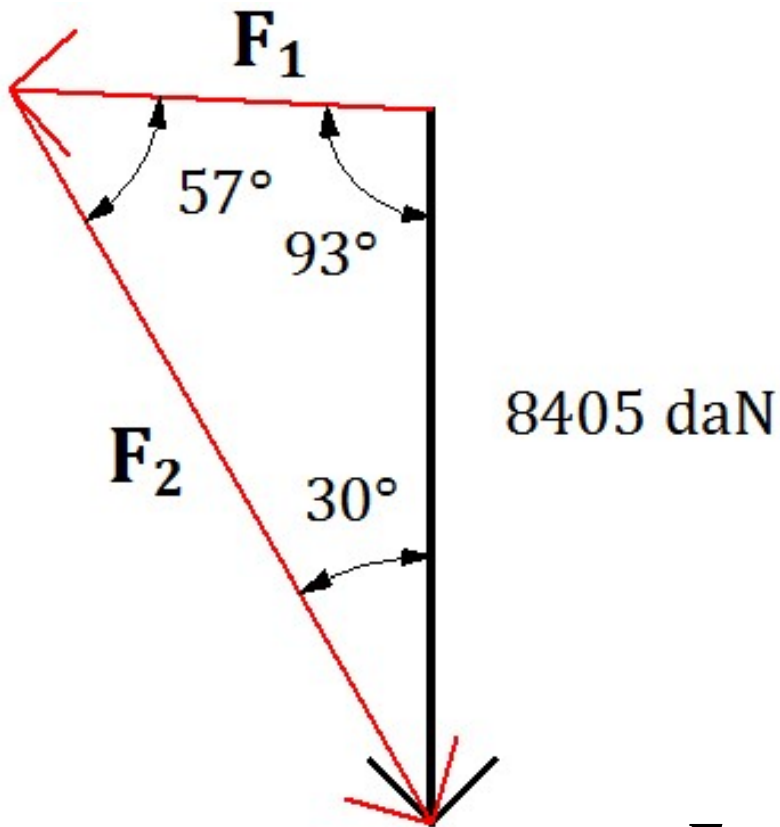
CAMINOS MATERIALES



5

CAMINOS MATERIALES

Aplicación del Teorema del seno para la descomposición de fuerzas



$$\frac{8405}{\text{sen } 57^\circ} = \frac{F_1}{\text{sen } 30^\circ} = \frac{F_2}{\text{sen } 93^\circ}$$

$$F_1 = \frac{8405 \times \text{sen } 30^\circ}{\text{sen } 57^\circ} = 5010 \text{ daN}$$

$$F_2 = \frac{8405 \times \text{sen } 93^\circ}{\text{sen } 57^\circ} = 10008 \text{ daN}$$

5

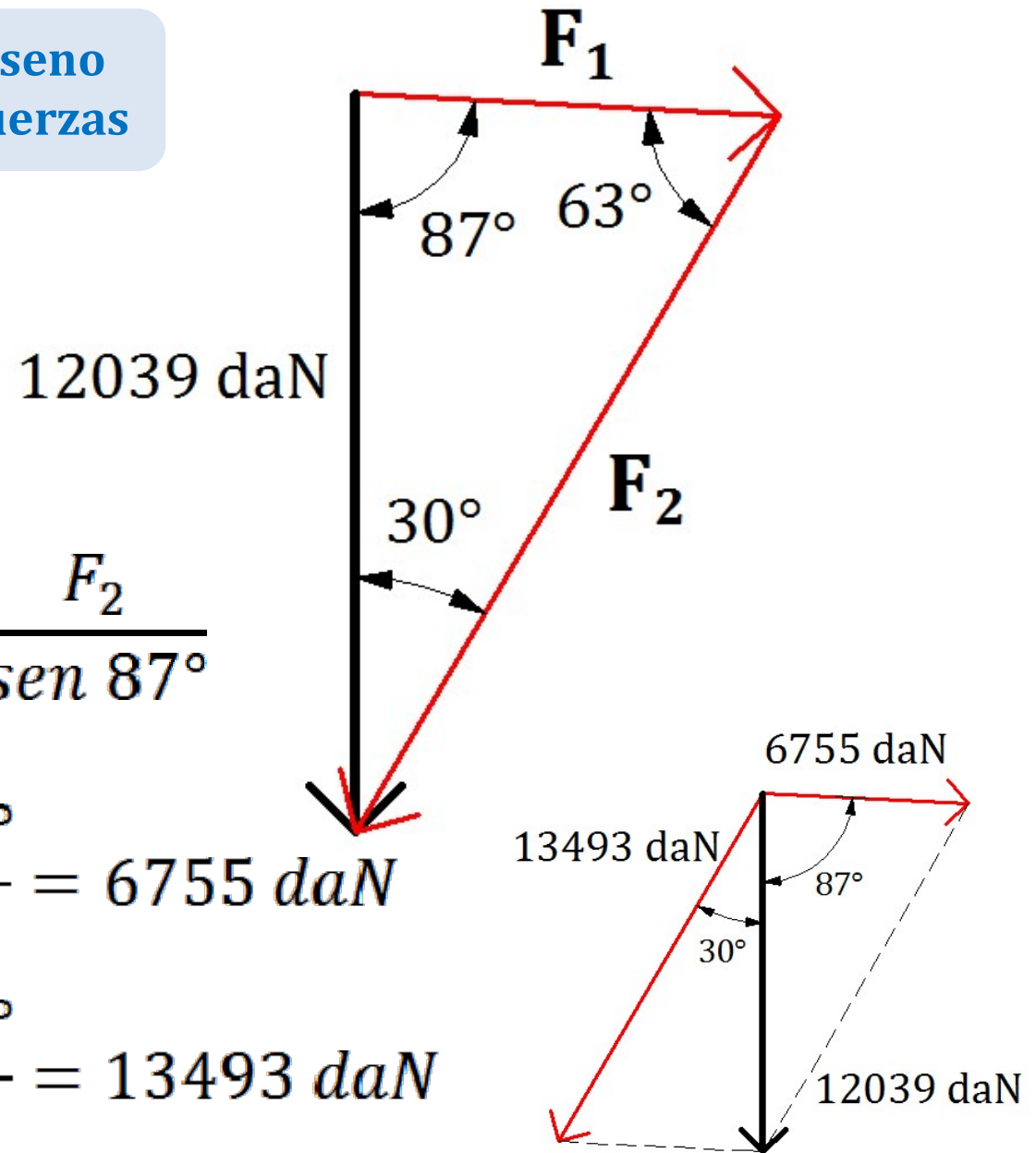
CAMINOS MATERIALES

Aplicación del Teorema del seno para la descomposición de fuerzas

$$\frac{12039}{\text{sen } 63^\circ} = \frac{F_1}{\text{sen } 30^\circ} = \frac{F_2}{\text{sen } 87^\circ}$$

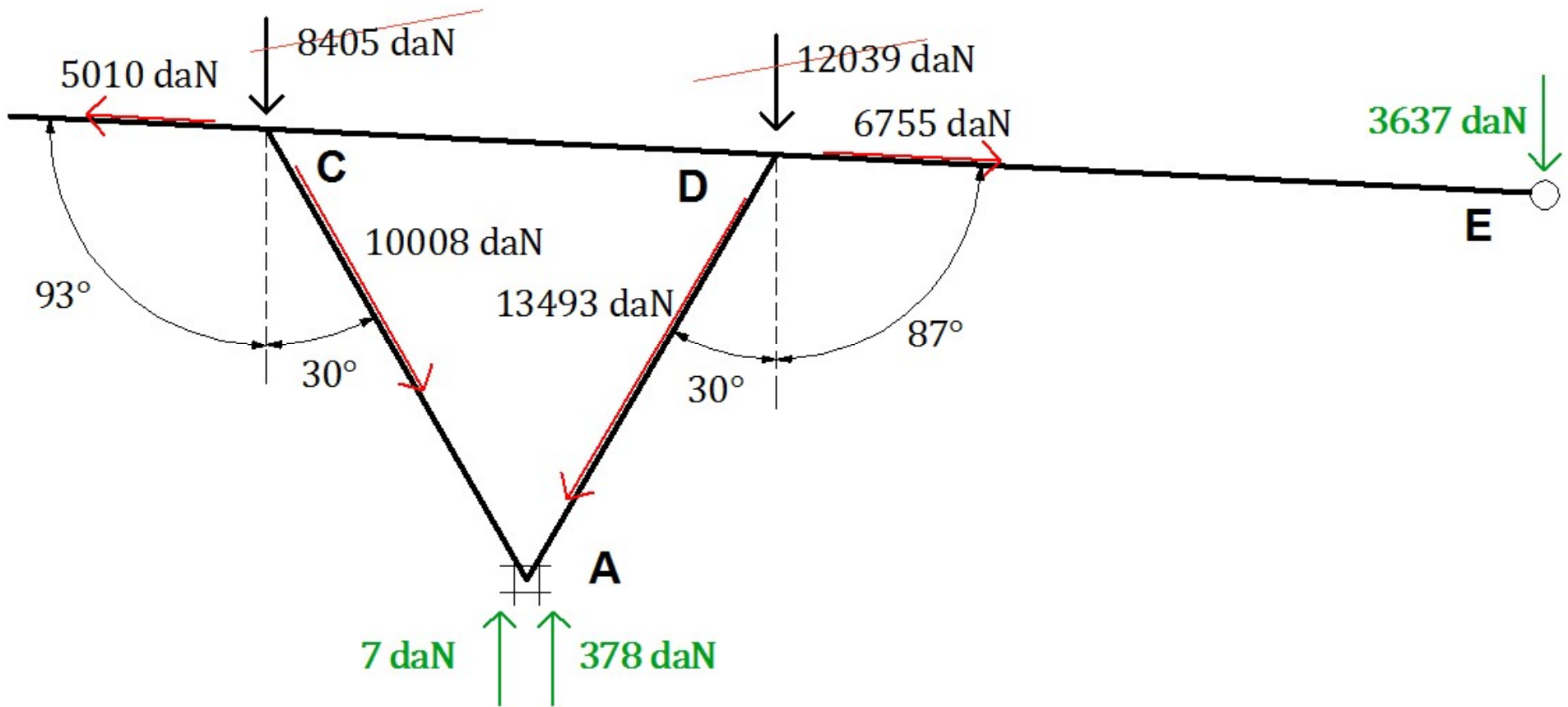
$$F_1 = \frac{12039 \times \text{sen } 30^\circ}{\text{sen } 63^\circ} = 6755 \text{ daN}$$

$$F_2 = \frac{12039 \times \text{sen } 87^\circ}{\text{sen } 63^\circ} = 13493 \text{ daN}$$



5

CAMINOS MATERIALES

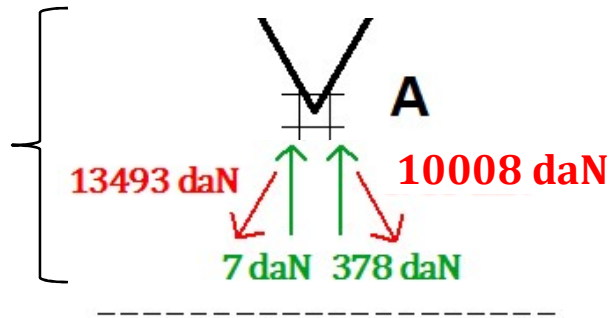


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- 7** Diagramas de Solicitaciones

Descargas

(obtenidas
s/caminos
materiales)



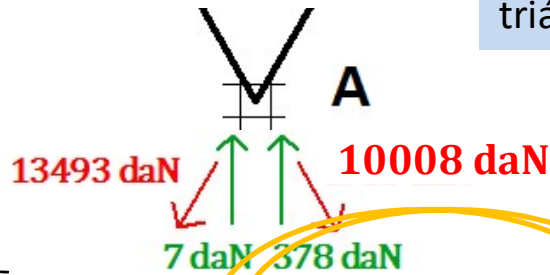
6

REACCIONES EN LOS APOYOS

Apoyo A

Descargas

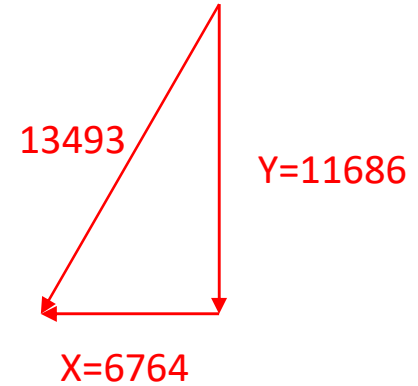
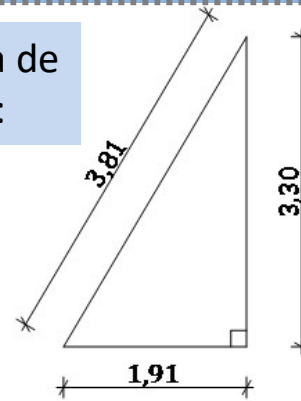
(obtenidas s/caminos materiales)



(s/ componente vertical y horizontal)



Semejanza de triángulos:



$$\frac{13493}{3,81} = \frac{X}{1,91} = \frac{Y}{3,30} \left\{ \begin{array}{l} X = \frac{13493 \times 1,91}{3,81} \\ Y = \frac{13493 \times 3,30}{3,81} \end{array} \right.$$

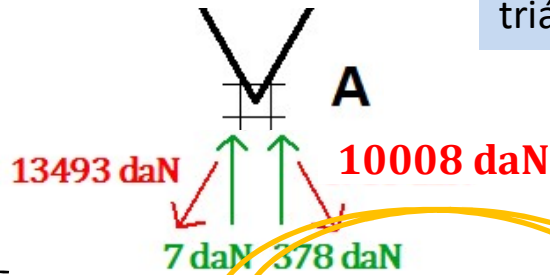
6

REACCIONES EN LOS APOYOS

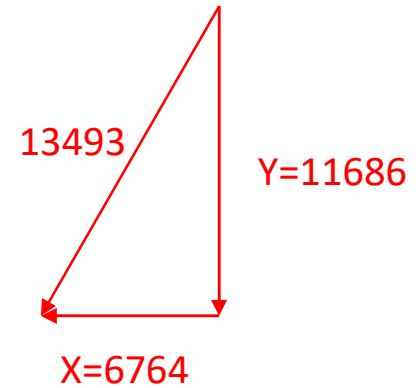
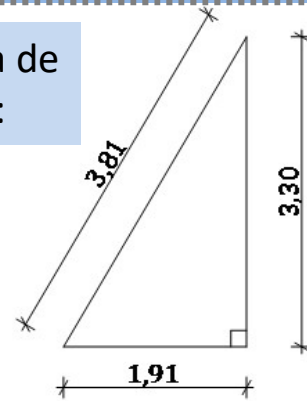
Apoyo A

Descargas

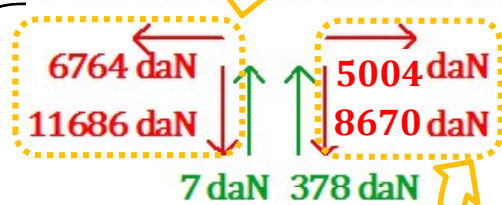
(obtenidas s/caminos materiales)



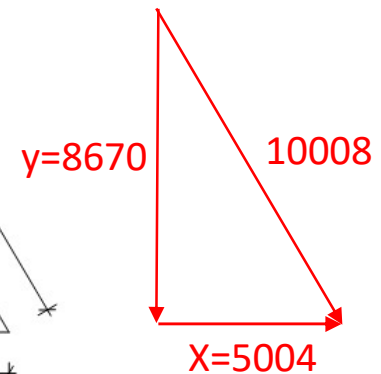
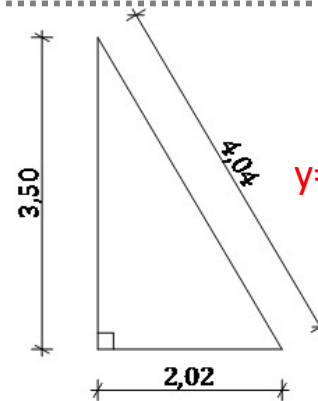
Semejanza de triángulos:



(s/ componente vertical y horizontal)



$$\frac{13493}{3,81} = \frac{X}{1,91} = \frac{Y}{3,30} \left\{ \begin{array}{l} X = \frac{13493 \times 1,91}{3,81} \\ Y = \frac{13493 \times 3,30}{3,81} \end{array} \right.$$



$$\frac{10008}{4,04} = \frac{X}{2,02} = \frac{Y}{3,5} \left\{ \begin{array}{l} X = \frac{10008 \times 2,02}{4,04} \\ Y = \frac{10008 \times 3,5}{4,04} \end{array} \right.$$

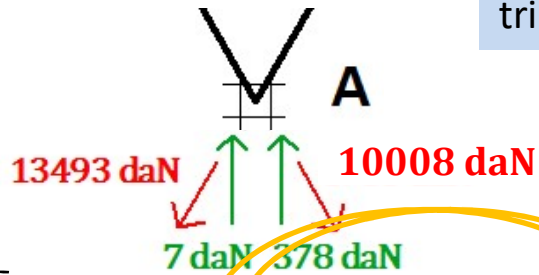
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REACCIONES EN LOS APOYOS

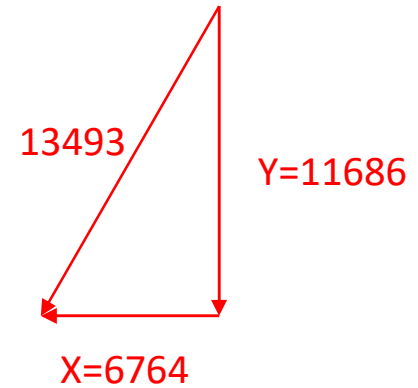
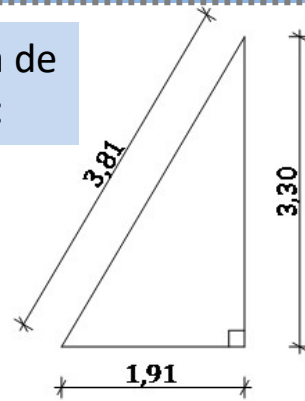
Apoyo A

Descargas

(obtenidas s/caminos materiales)

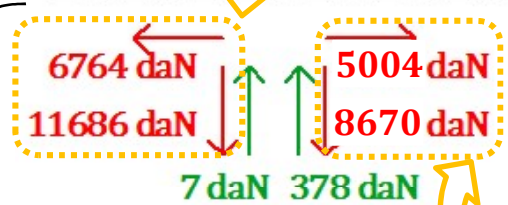


Semejanza de triángulos:

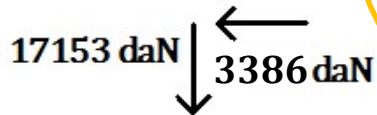


$$\frac{13493}{3,81} = \frac{X}{1,91} = \frac{Y}{3,30} \left\{ \begin{array}{l} X = \frac{13493 \times 1,91}{3,81} \\ Y = \frac{13493 \times 3,30}{3,81} \end{array} \right.$$

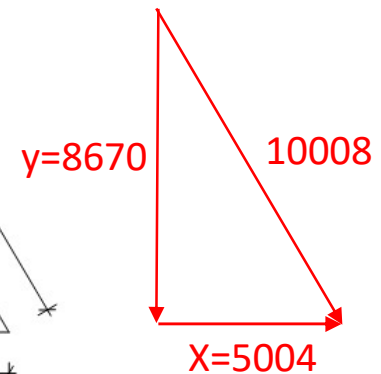
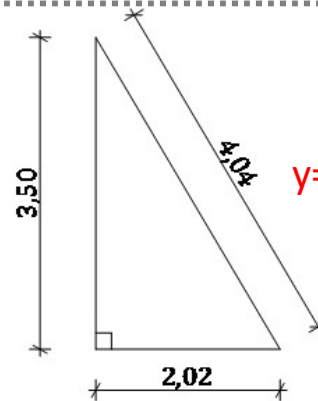
(s/ componente vertical y horizontal)



(totales)



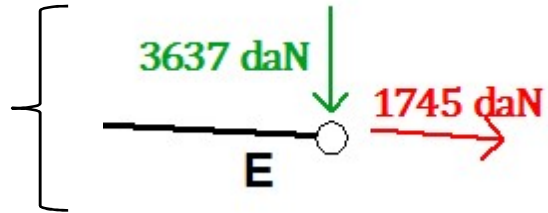
Reacciones



$$\frac{10008}{4,04} = \frac{X}{2,02} = \frac{Y}{3,5} \left\{ \begin{array}{l} X = \frac{10008 \times 2,02}{4,04} \\ Y = \frac{10008 \times 3,5}{4,04} \end{array} \right.$$

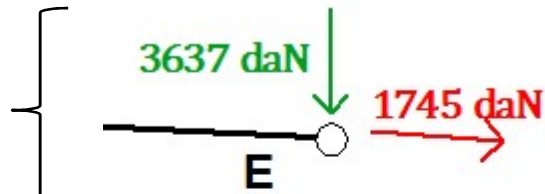
Descargas

(obtenidas
s/caminos
materiales)

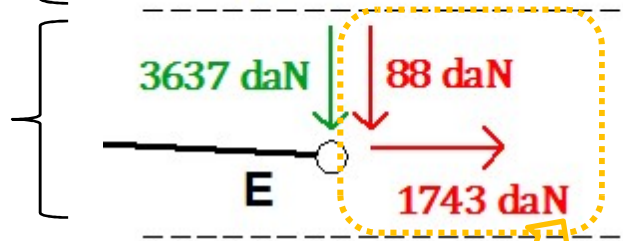


Descargas

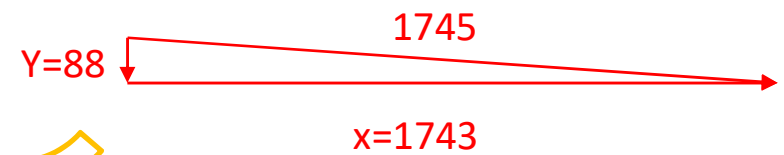
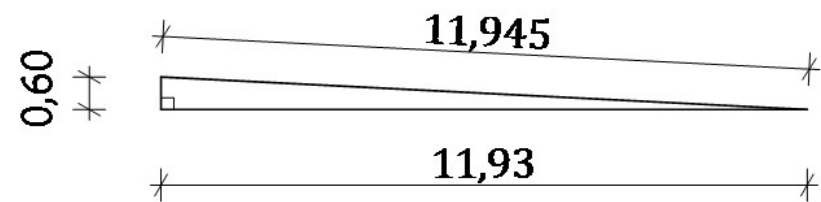
(obtenidas
s/caminos
materiales)



(s/ componente
vertical y
horizontal)

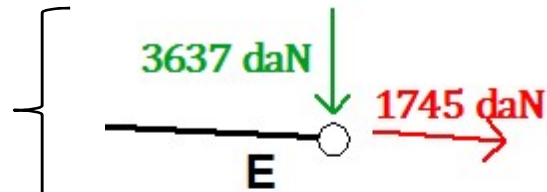
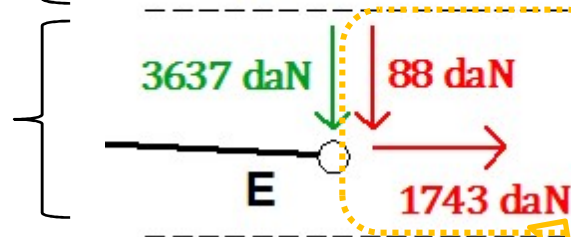


Semejanza de
triángulos:

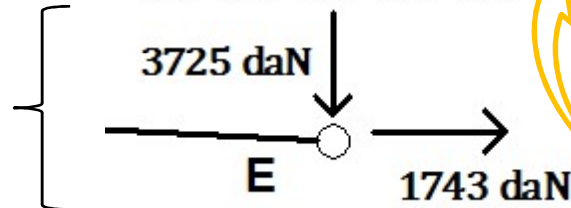
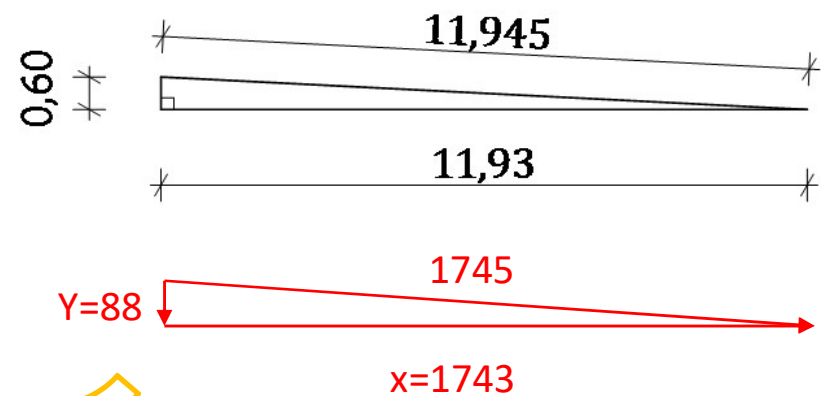


$$\frac{1745}{11,945} = \frac{X}{11,93} = \frac{Y}{0,60} \left\{ \begin{array}{l} X = \frac{1745 \times 11,93}{11,945} \\ Y = \frac{1745 \times 0,60}{11,945} \end{array} \right.$$

Descargas

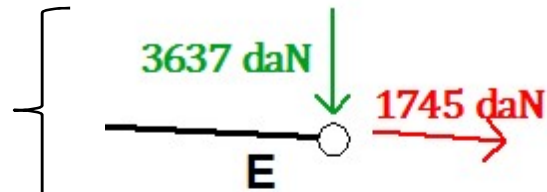
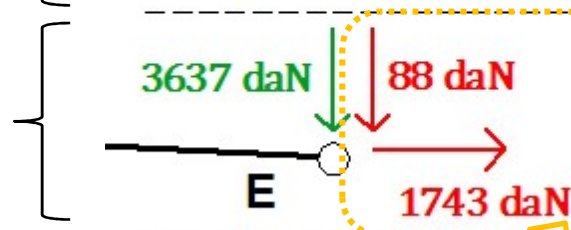
(obtenidas
s/caminos
materiales)(s/ componente
vertical y
horizontal)

(totales)

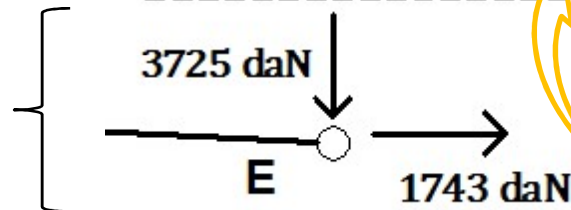
Semejanza de
triángulos:

$$\frac{1745}{11,945} = \frac{X}{11,93} = \frac{Y}{0,60} \begin{cases} X = \frac{1745 \times 11,93}{11,945} \\ Y = \frac{1745 \times 0,60}{11,945} \end{cases}$$

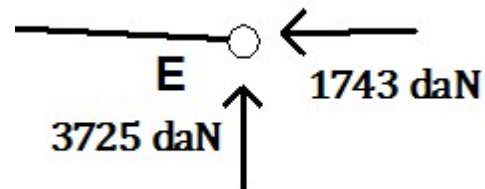
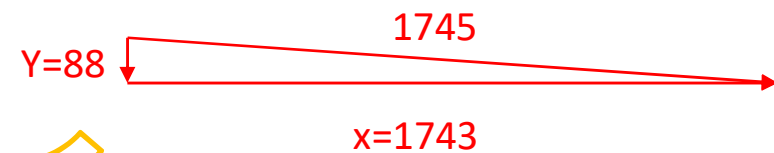
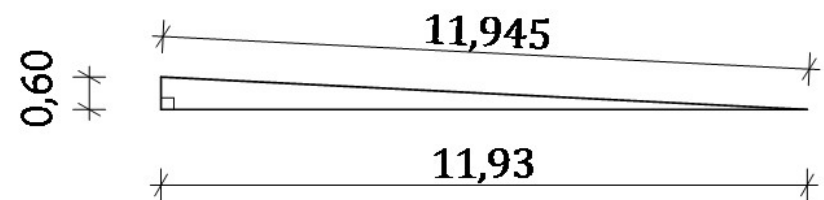
Descargas

(obtenidas
s/caminos
materiales)(s/ componente
vertical y
horizontal)

(totales)



Reacciones

Semejanza de
triángulos:

$$\frac{1745}{11,945} = \frac{X}{11,93} = \frac{Y}{0,60} \left\{ \begin{array}{l} X = \frac{1745 \times 11,93}{11,945} \\ Y = \frac{1745 \times 0,60}{11,945} \end{array} \right.$$

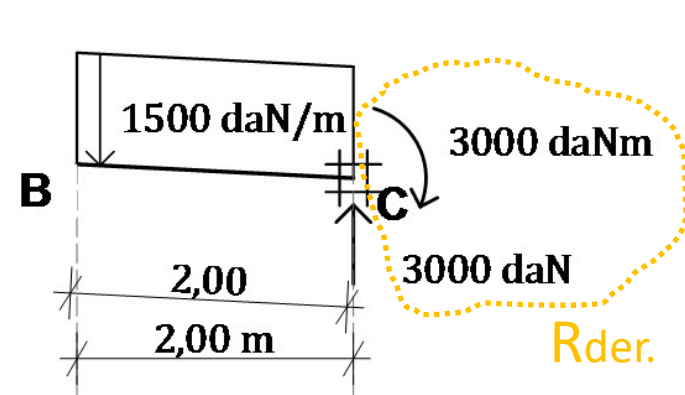
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Tramo BC

Tramo aislado
y en equilibrio:

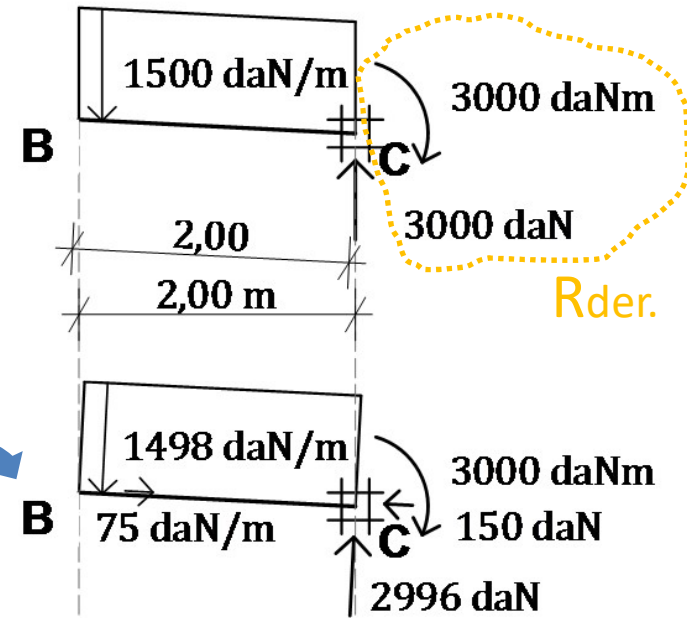
$$\begin{aligned}\sum F_v &= 0 \\ \sum F_H &= 0 \\ \sum M &= 0\end{aligned}$$



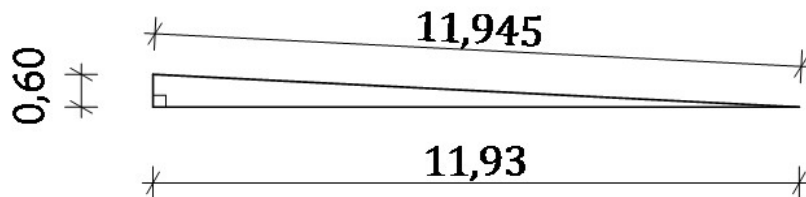
Tramo BC

Tramo aislado
y en equilibrio:

$$\begin{aligned}\sum F_v &= 0 \\ \sum F_H &= 0 \\ \sum M &= 0\end{aligned}$$



Descomposición de fuerzas según
componente córtate y axil
(usando semejanza de triángulos):

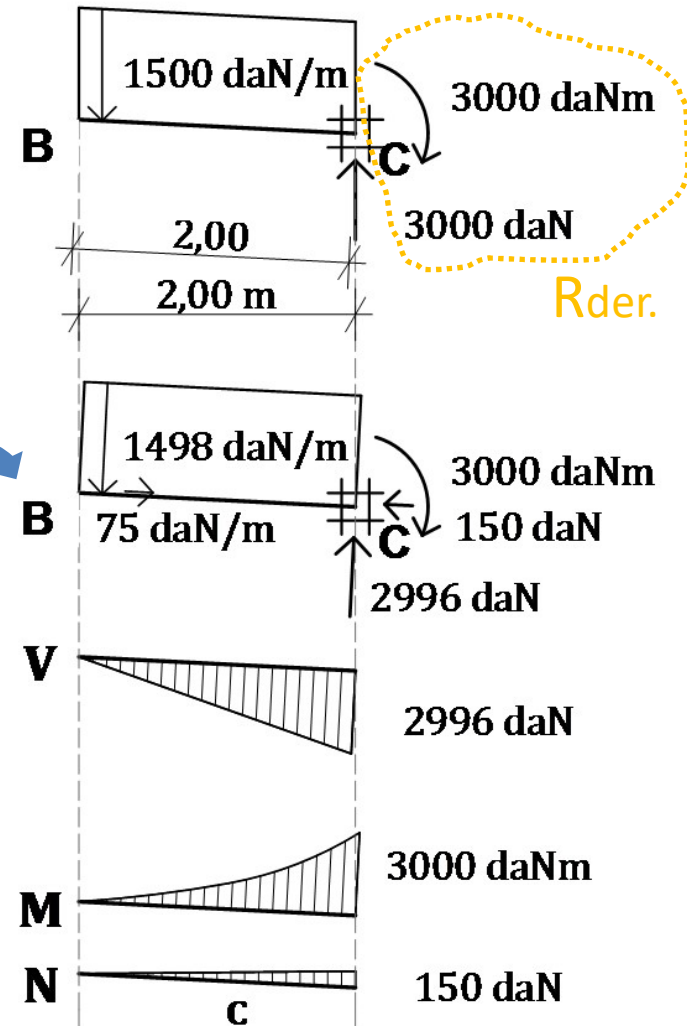
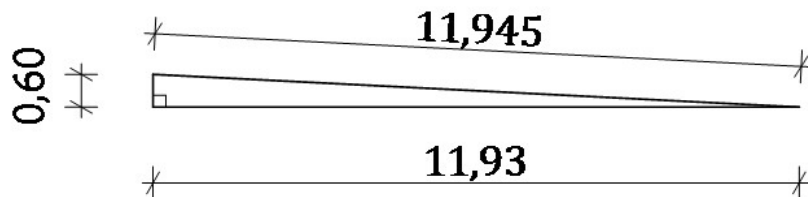


Tramo BC

Tramo aislado
y en equilibrio:

$$\begin{aligned}\sum F_v &= 0 \\ \sum F_H &= 0 \\ \sum M &= 0\end{aligned}$$

Descomposición de fuerzas según
componente córtate y axil
(usando semejanza de triángulos):



7

SOLICITACIONES

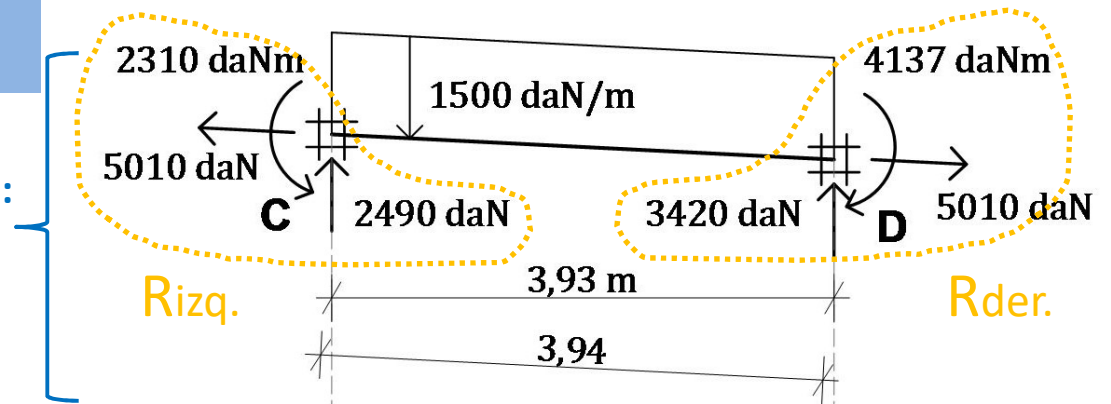
Tramo CD

Tramo aislado
y en equilibrio:

$$\sum F_V = 0$$

$$\sum F_H = 0$$

$$\sum M = 0$$



7

SOLICITACIONES

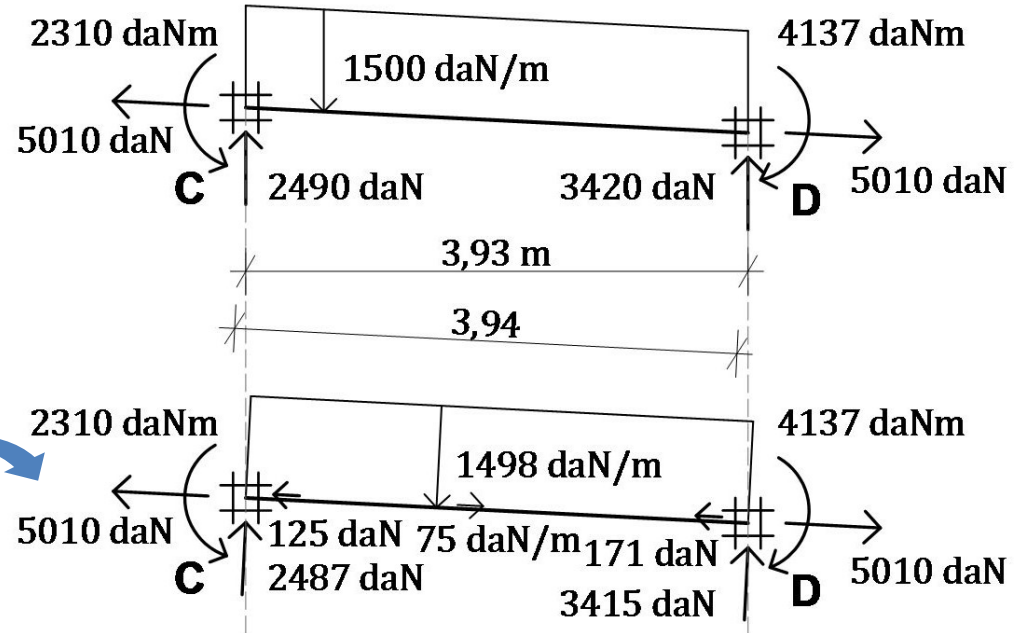
Tramo CD

Tramo aislado y en equilibrio:

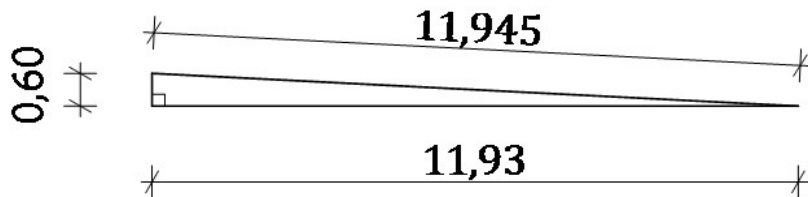
$$\sum F_v = 0$$

$$\sum F_h = 0$$

$$\sum M = 0$$



Descomposición de fuerzas según componente córtate y axil (usando semejanza de triángulos):



7

SOLICITACIONES

Tramo CD

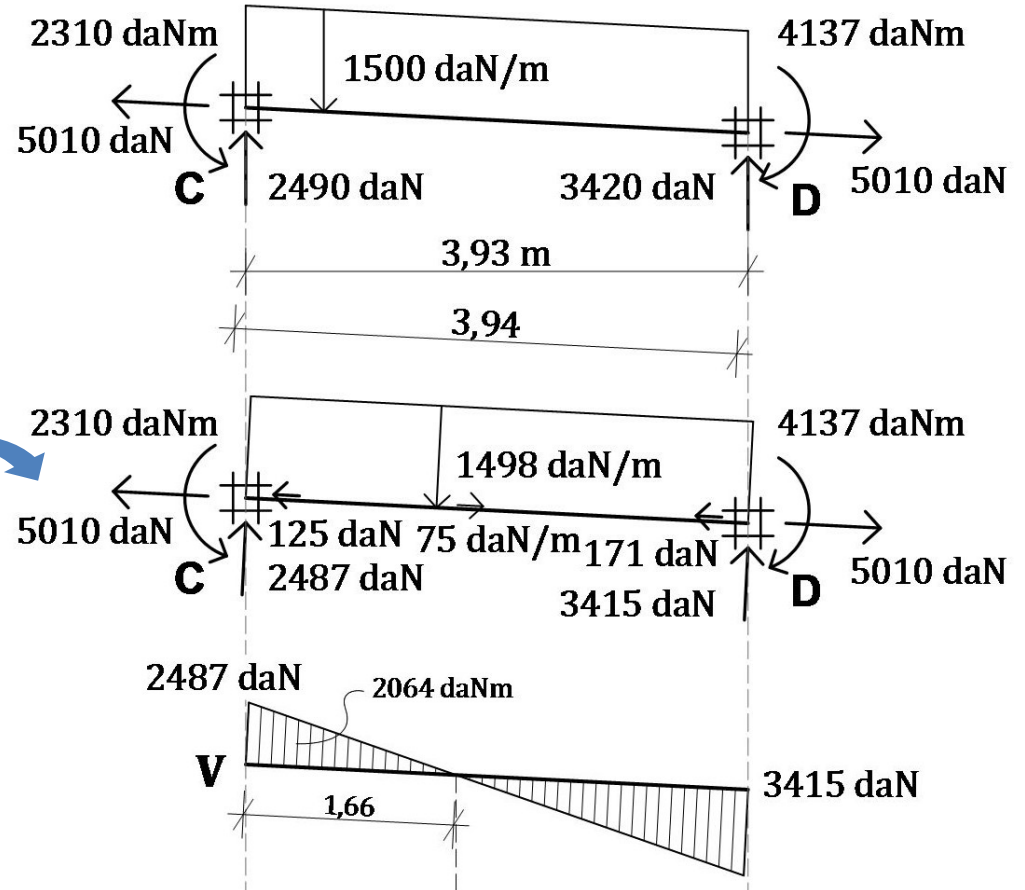
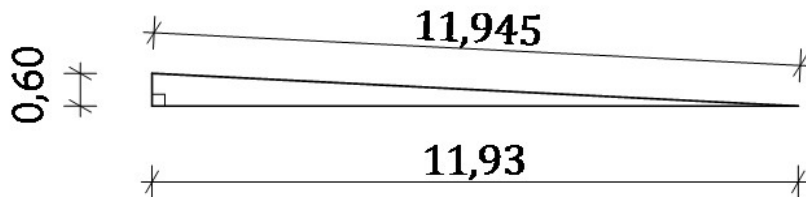
Tramo aislado y en equilibrio:

$$\sum F_v = 0$$

$$\sum F_h = 0$$

$$\sum M = 0$$

Descomposición de fuerzas según componente córtate y axil (usando semejanza de triángulos):



7

SOLICITACIONES

Tramo CD

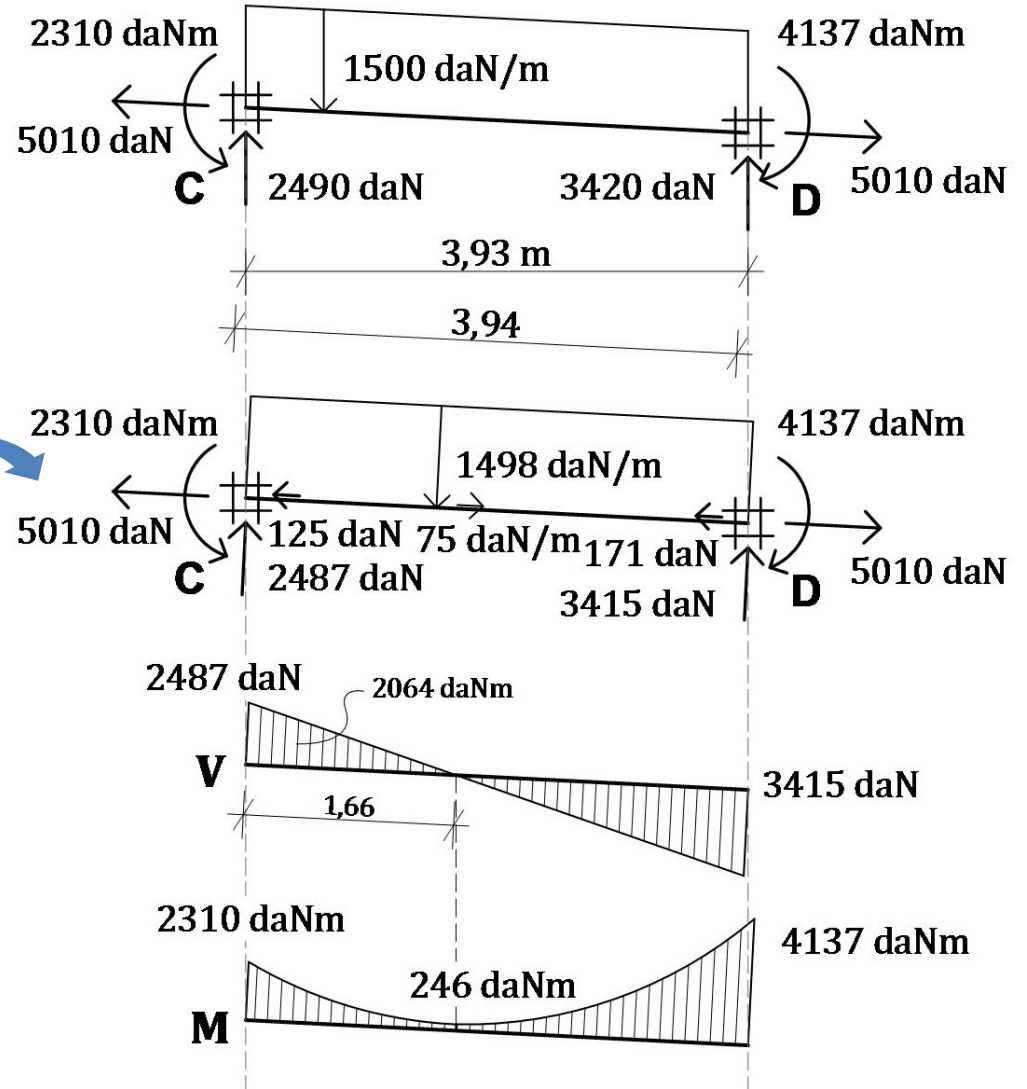
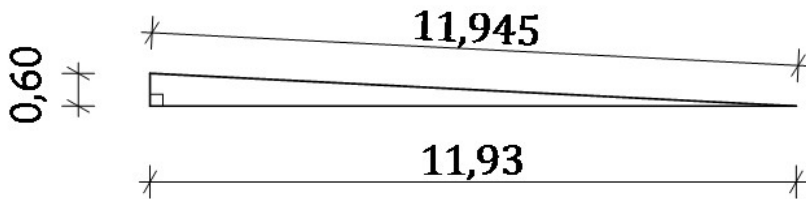
Tramo aislado y en equilibrio:

$$\sum F_V = 0$$

$$\sum F_H = 0$$

$$\sum M = 0$$

Descomposición de fuerzas según componente córtate y axil (usando semejanza de triángulos):



7

SOLICITACIONES

Tramo CD

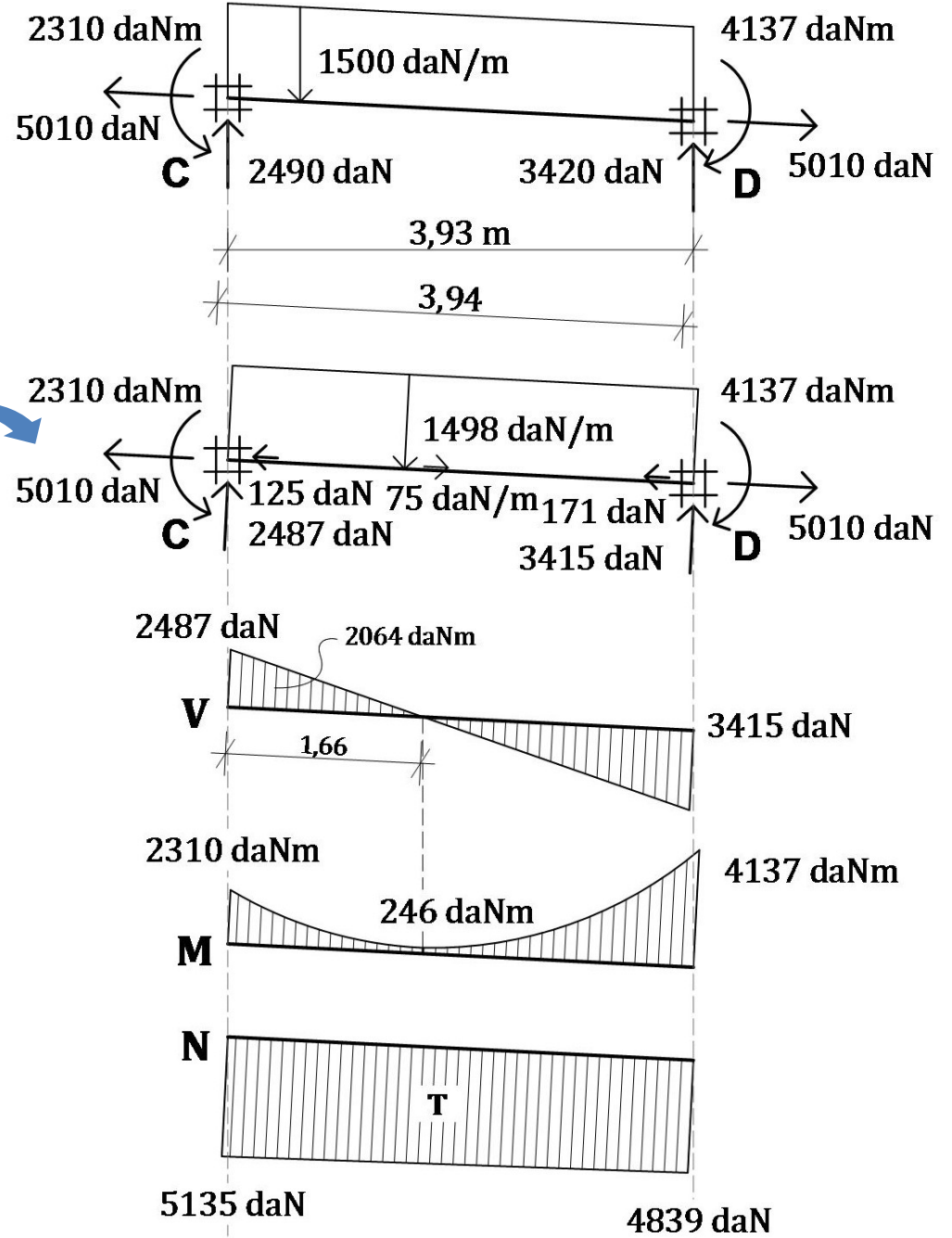
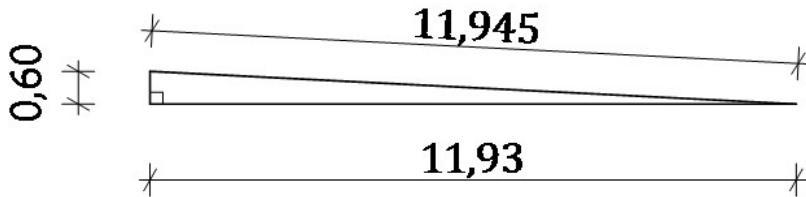
Tramo aislado y en equilibrio:

$$\sum F_v = 0$$

$$\sum F_h = 0$$

$$\sum M = 0$$

Descomposición de fuerzas según componente córtate y axil (usando semejanza de triángulos):



7

SOLICITACIONES

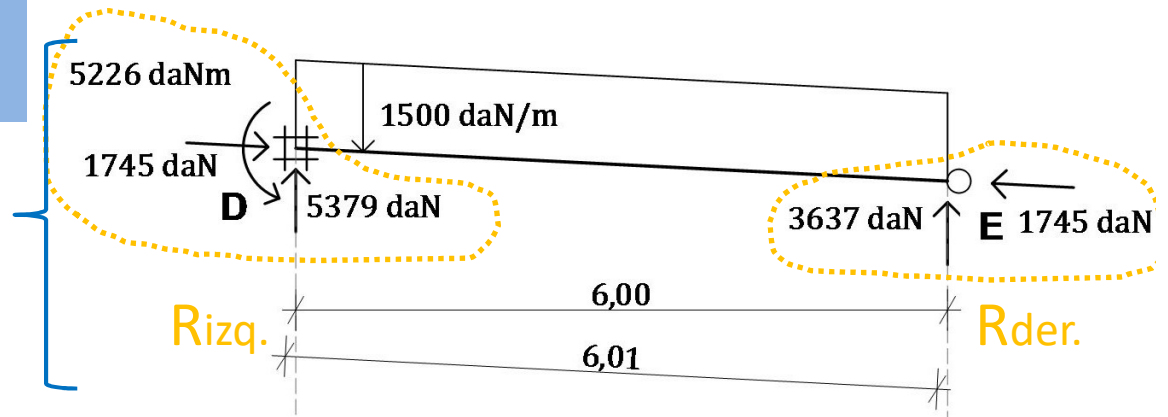
Tramo DE

Tramo aislado
y en equilibrio:

$$\sum F_v = 0$$

$$\sum F_H = 0$$

$$\sum M = 0$$



7

SOLICITACIONES

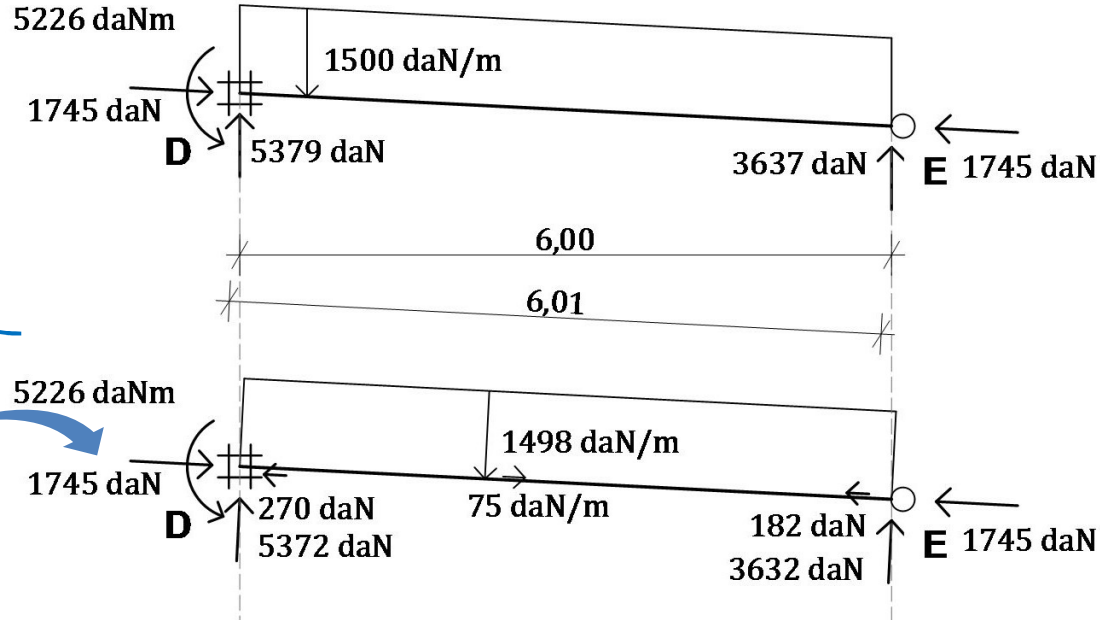
Tramo DE

Tramo aislado
y en equilibrio:

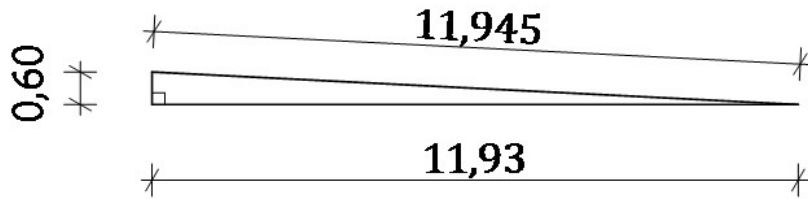
$$\sum F_v = 0$$

$$\sum F_H = 0$$

$$\sum M = 0$$



Descomposición de fuerzas según
componente córtate y axil
(usando semejanza de triángulos):



7

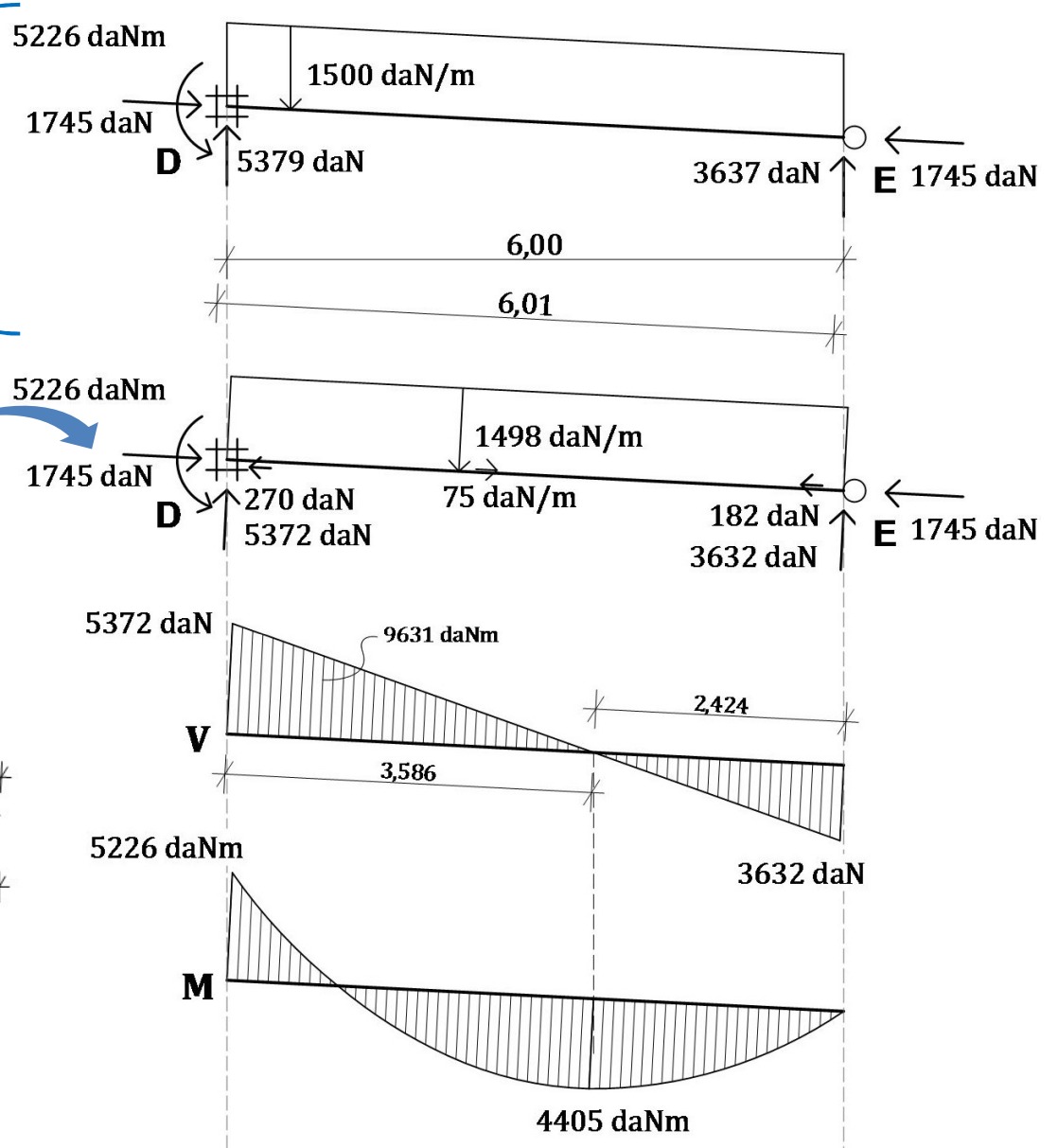
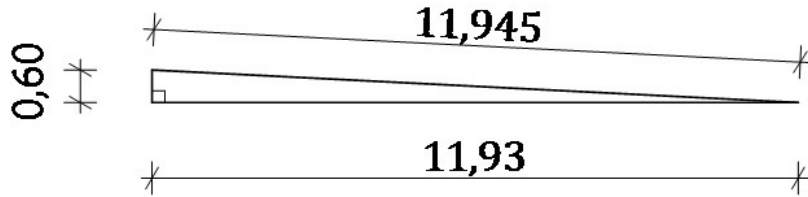
SOLICITACIONES

Tramo aislado
y en equilibrio:

Tramo DE

$$\begin{aligned} \sum F_v &= 0 \\ \sum F_H &= 0 \\ \sum M &= 0 \end{aligned}$$

Descomposición de fuerzas según
componente córtate y axil
(usando semejanza de triángulos):



7

SOLICITACIONES

Tramo aislado
y en equilibrio:

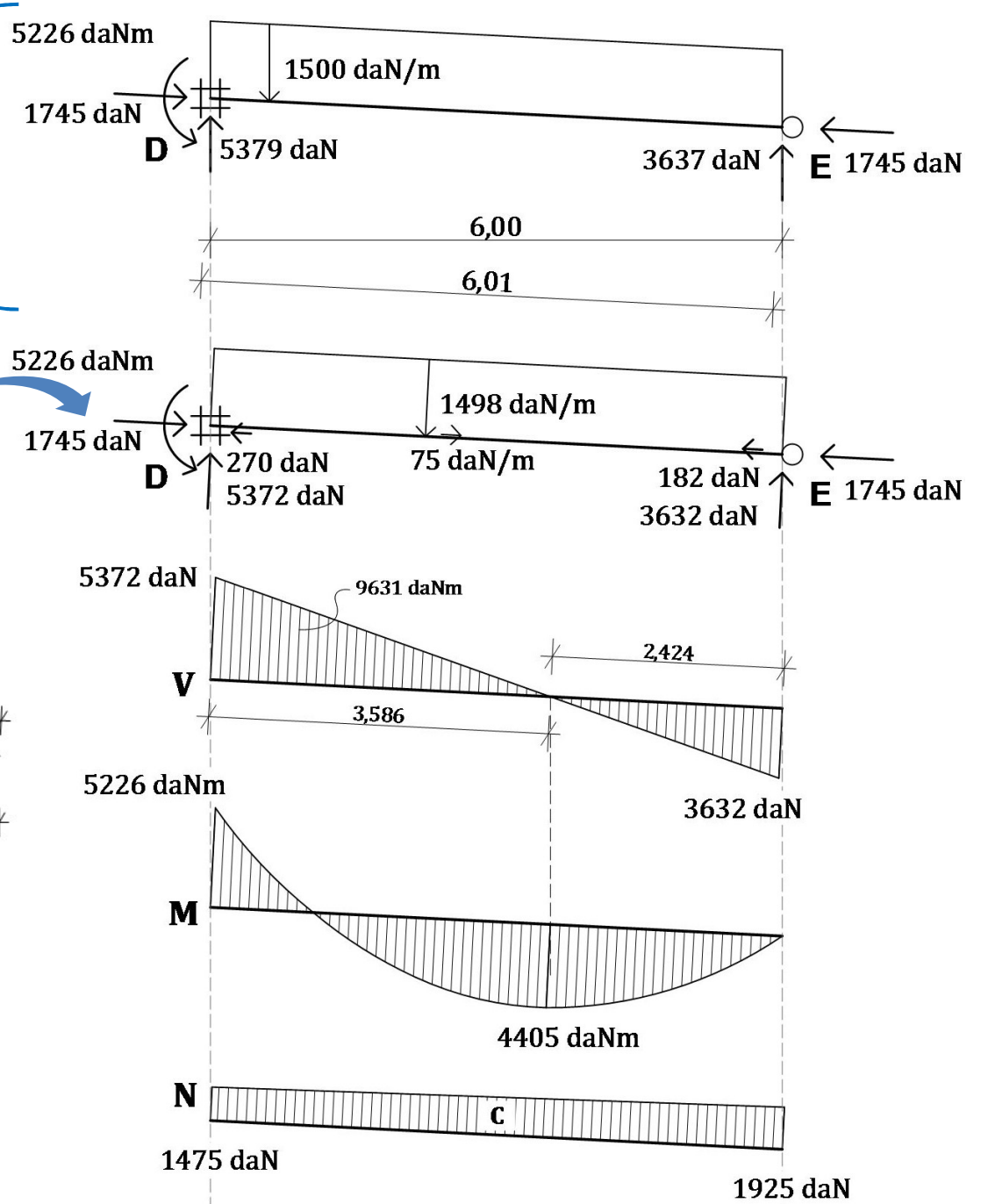
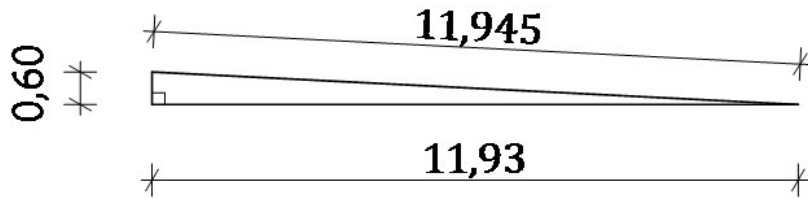
Tramo DE

$$\sum F_v = 0$$

$$\sum F_H = 0$$

$$\sum M = 0$$

Descomposición de fuerzas según
componente córtate y axil
(usando semejanza de triángulos):



Tramo CA

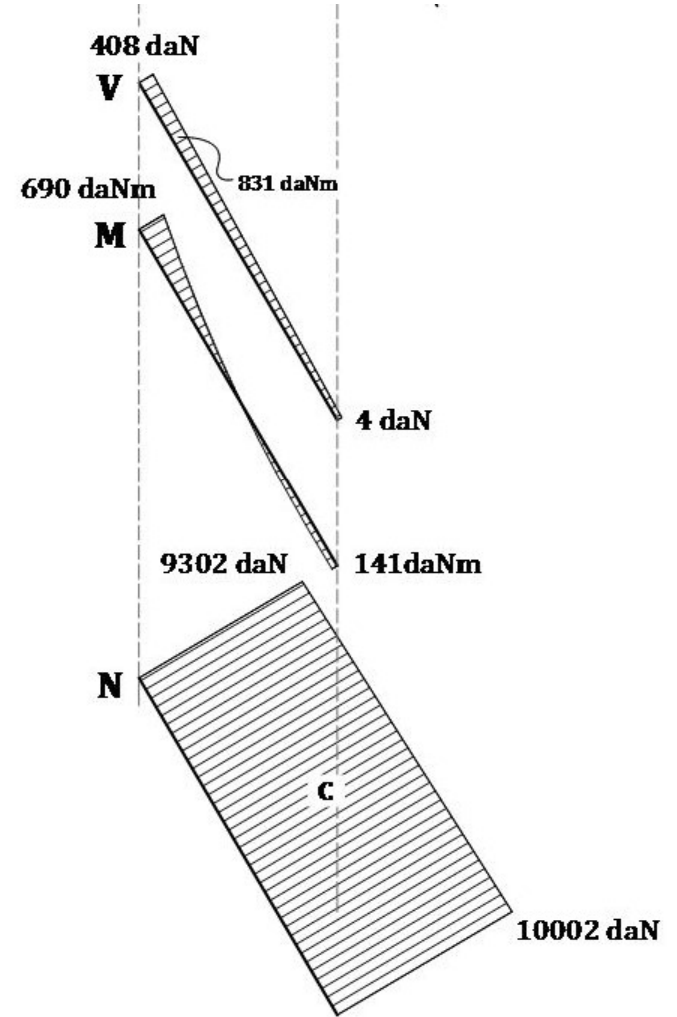
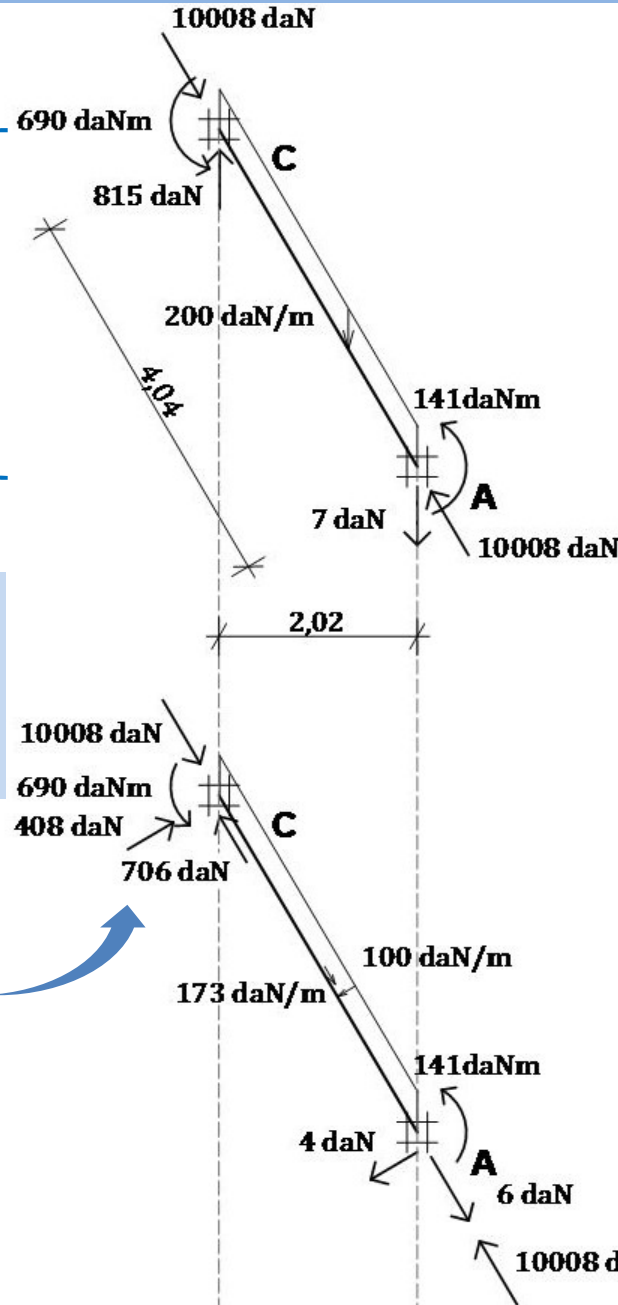
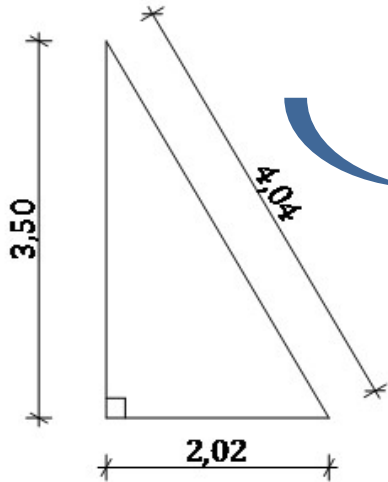
Tramo aislado y en equilibrio:

$$\sum F_v = 0$$

$$\sum F_H = 0$$

$$\sum M = 0$$

Descomposición de fuerzas según componente cortante y axil (usando semejanza de triángulos):



Tramo AD

Tramo aislado y en equilibrio:

$$\sum F_v = 0$$

$$\sum F_h = 0$$

$$\sum M = 0$$

Descomposición de fuerzas según componente cortante y axil (usando semejanza de triángulos):

