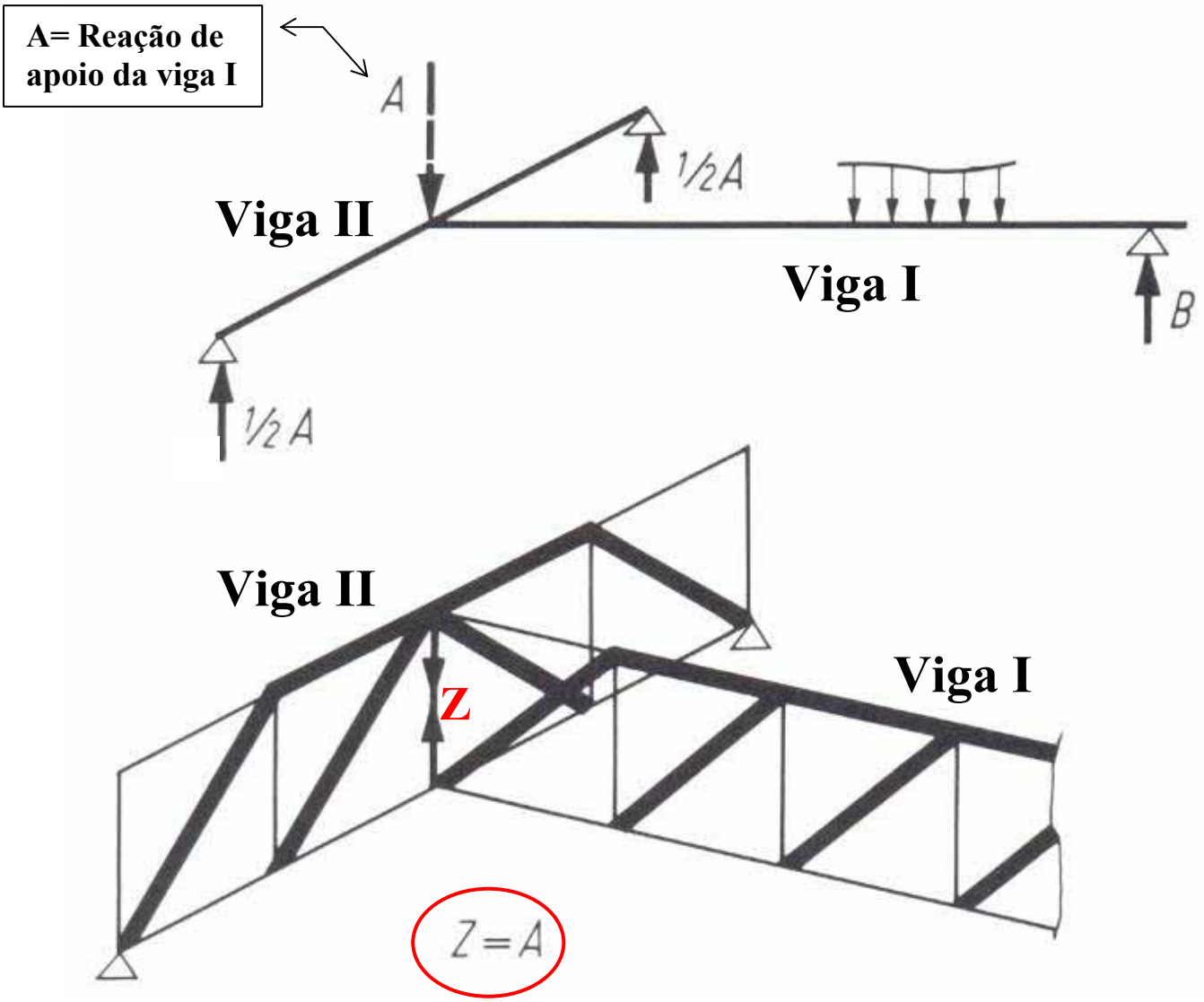
Apoio indireto no Cruzamento de Vigas ≡ Armadura de suspensão

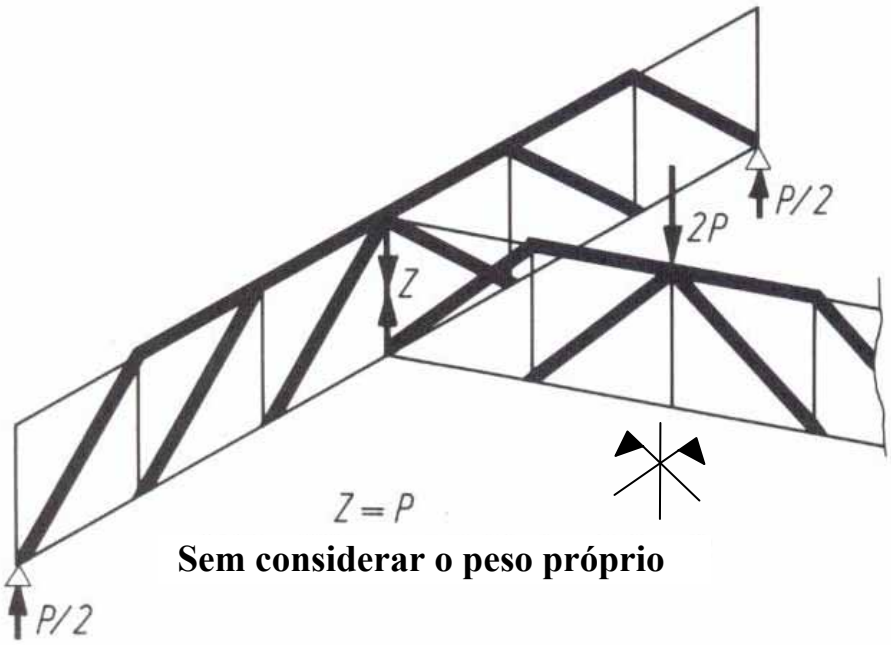


- **Modelo de treliça para o apoio indireto da Viga I na Viga II**
- **Reação de apoio da Viga I = A**
- **Armadura de suspensão Z para a reação de apoio A**

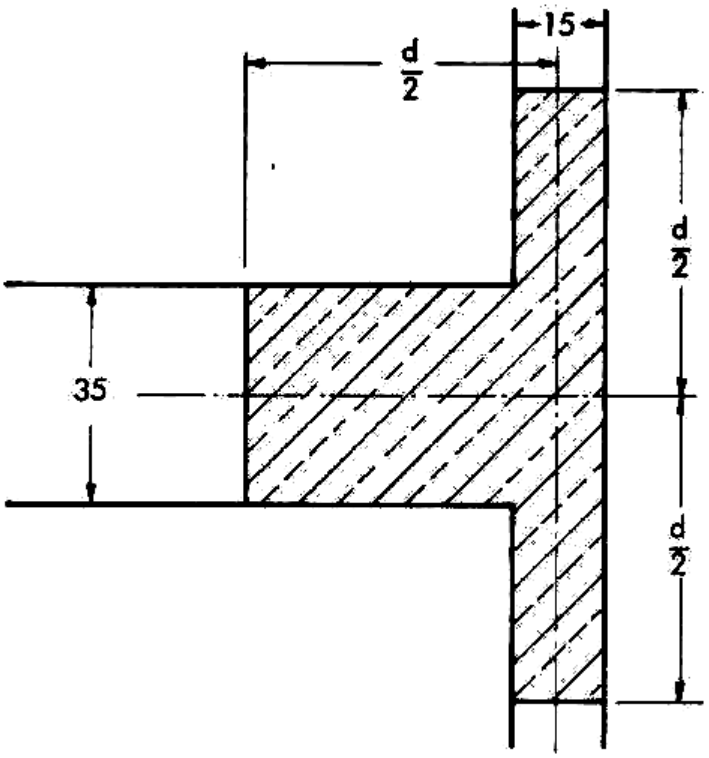
Ver Anexo 1

- Prof. Fritz Leonhardt : Ensaios D.A.f.StB – 227 – 1973 - Schubversuche an Spannbetonträger - Universität Stuttgart - *Ensaios de Cisalhamento em vigas de concreto Protendido*.

Modelo simétrico do ensaio.



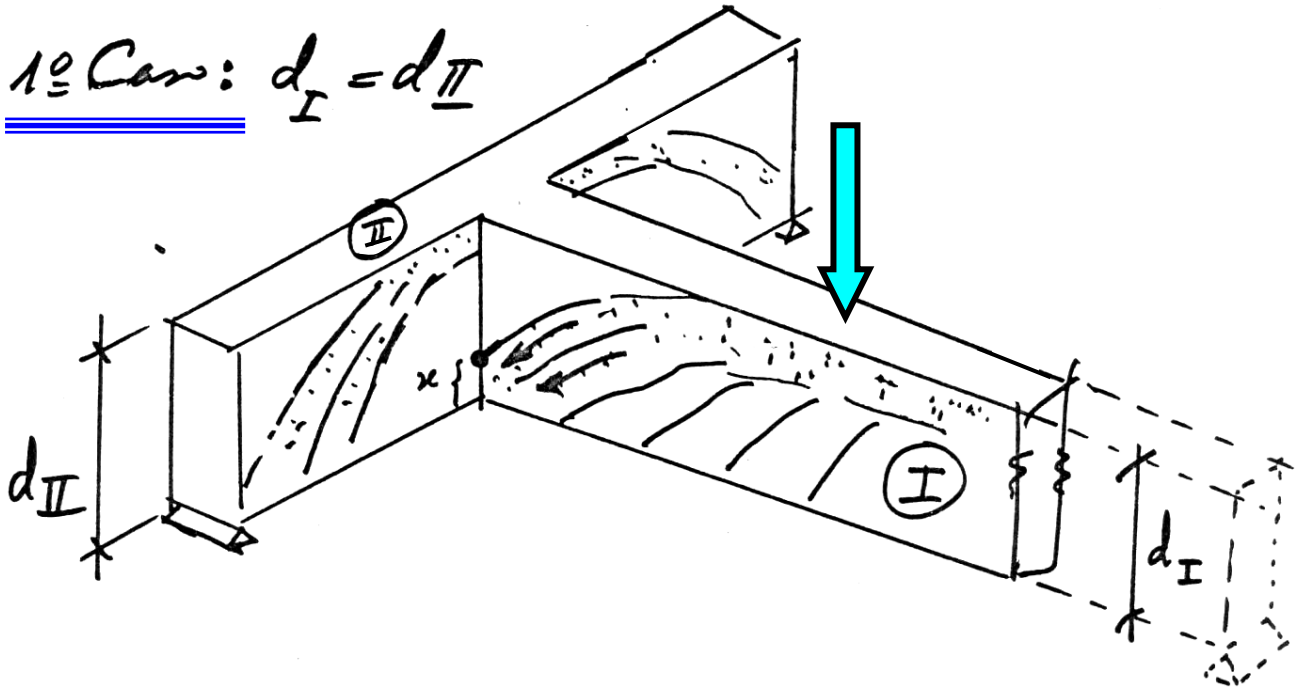
Sem considerar o peso próprio

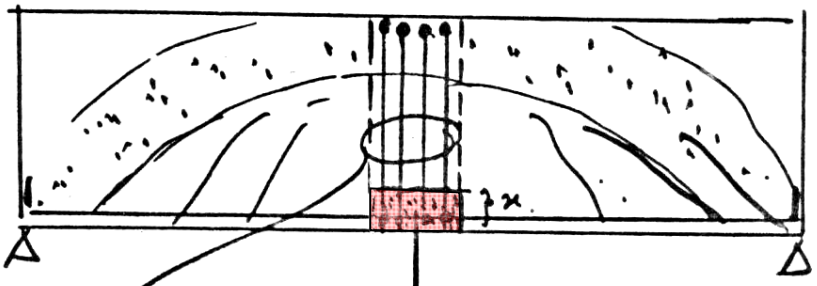


Região do cruzamento das vigas

Cruzamento de Vigas - Armadura de suspensão

1º Caso: $d_I = d_{II}$





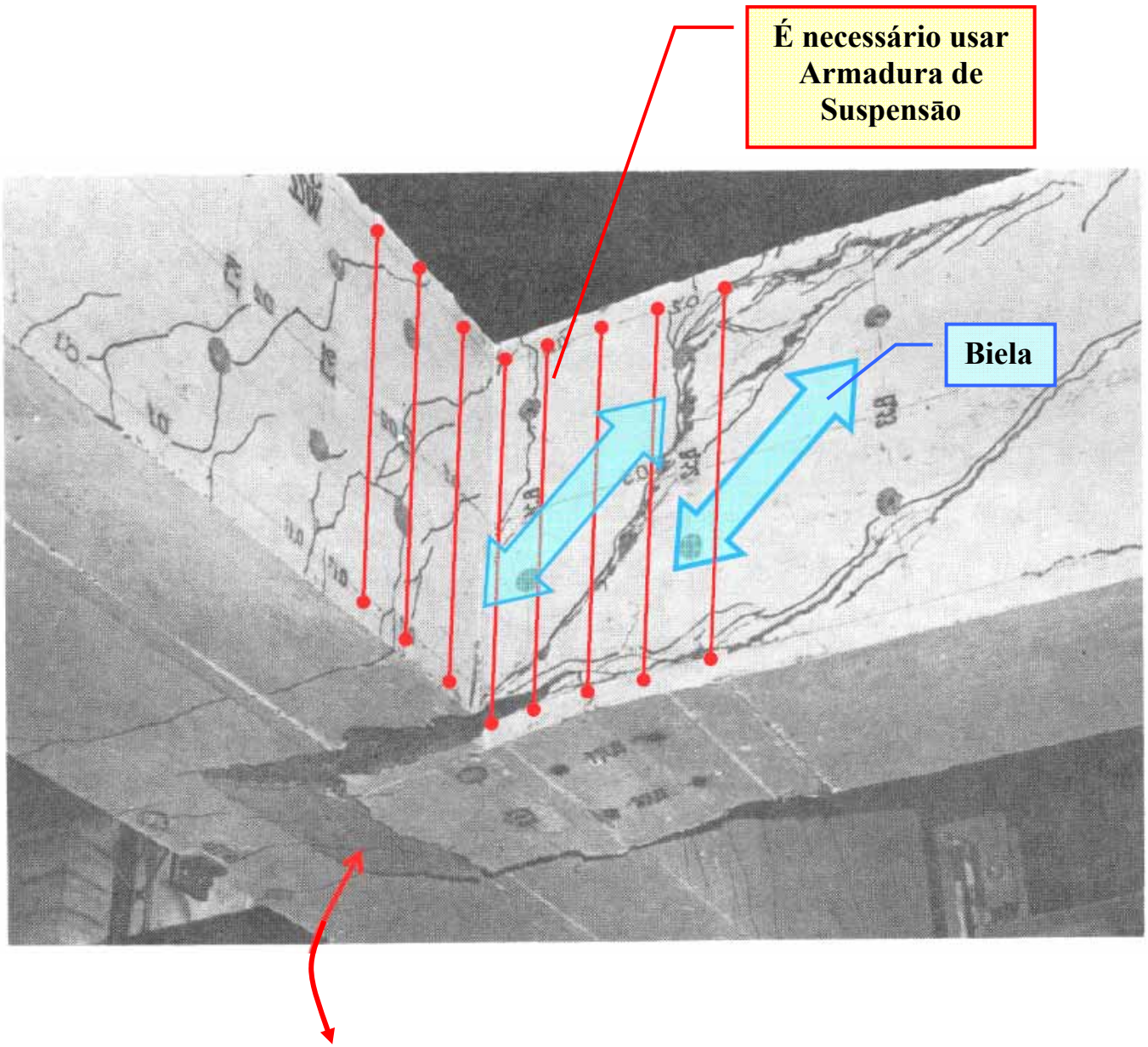
$$A_s = \frac{A_d}{f_{yd}}$$

Pendurar toda a carga.

Quando a viga que se apoia é menor que a que serve de apoio pode-se fazer uma redução da carga a pendurar.

Ver ANEXO 2 : R. PARK and T. PAULAY - Reinforced Concrete Structures . [3]

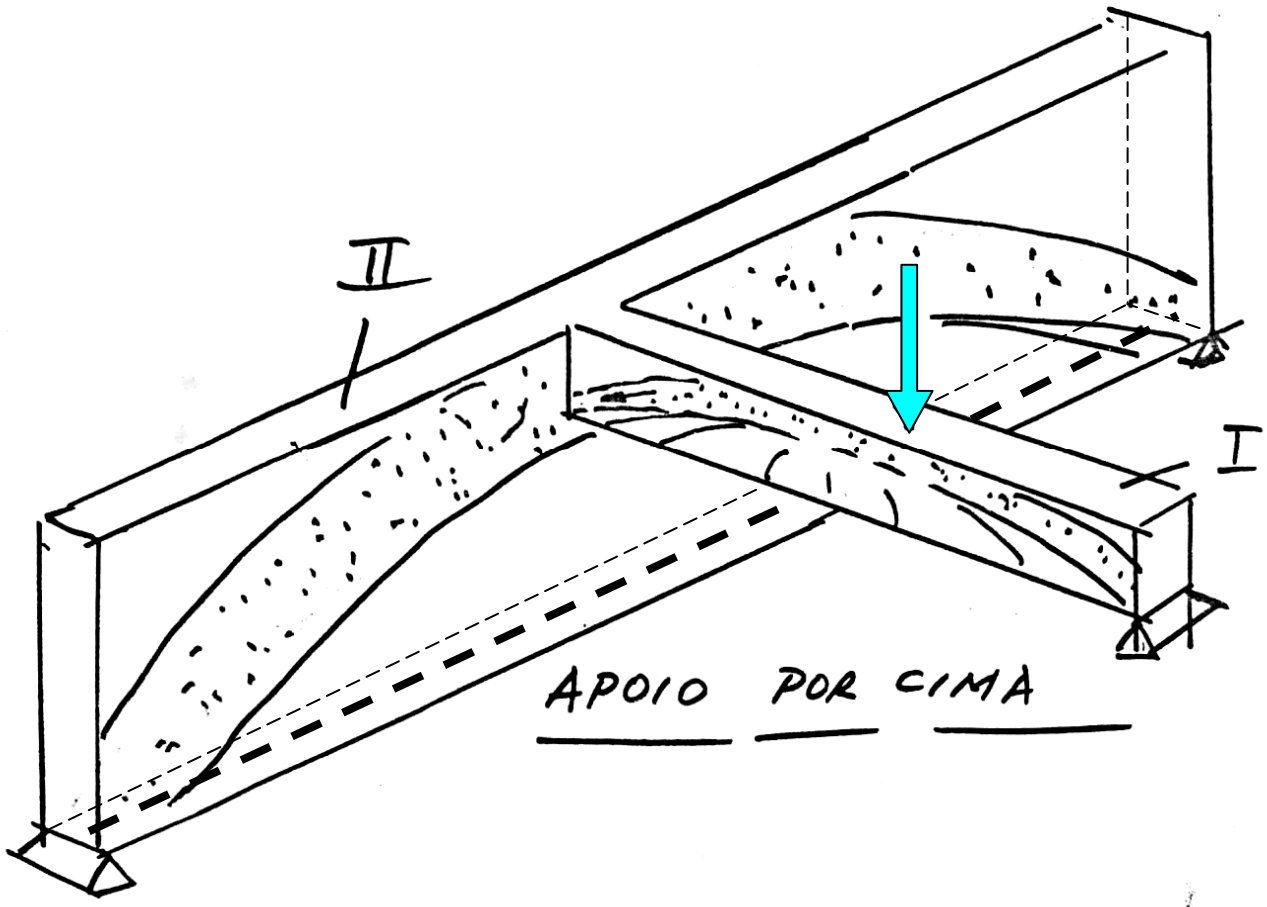
Ensaio mostrando a necessidade da armadura de suspensão.

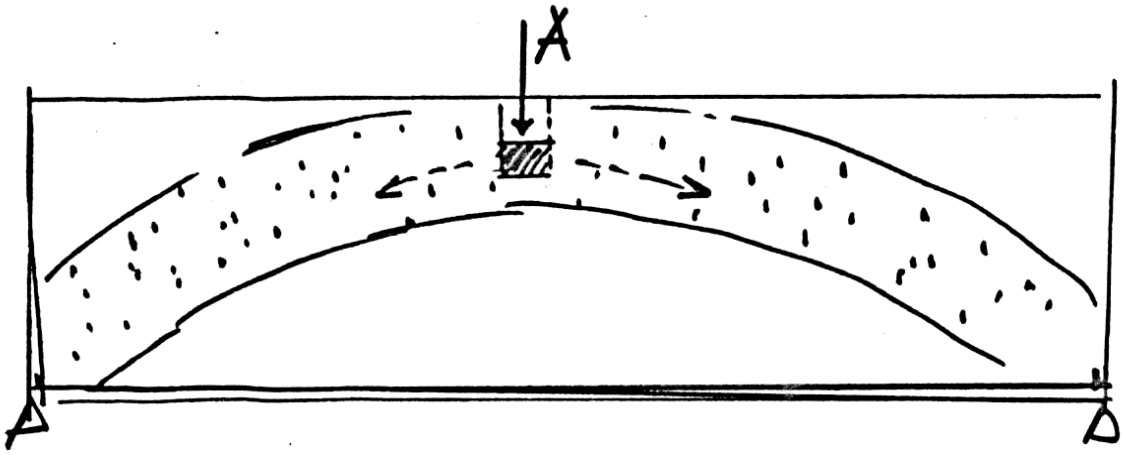


Falta de suporte para as diagonais comprimidas (bielas) .

A colocação de estribos è necessária para “suspender” a reação de apoio.

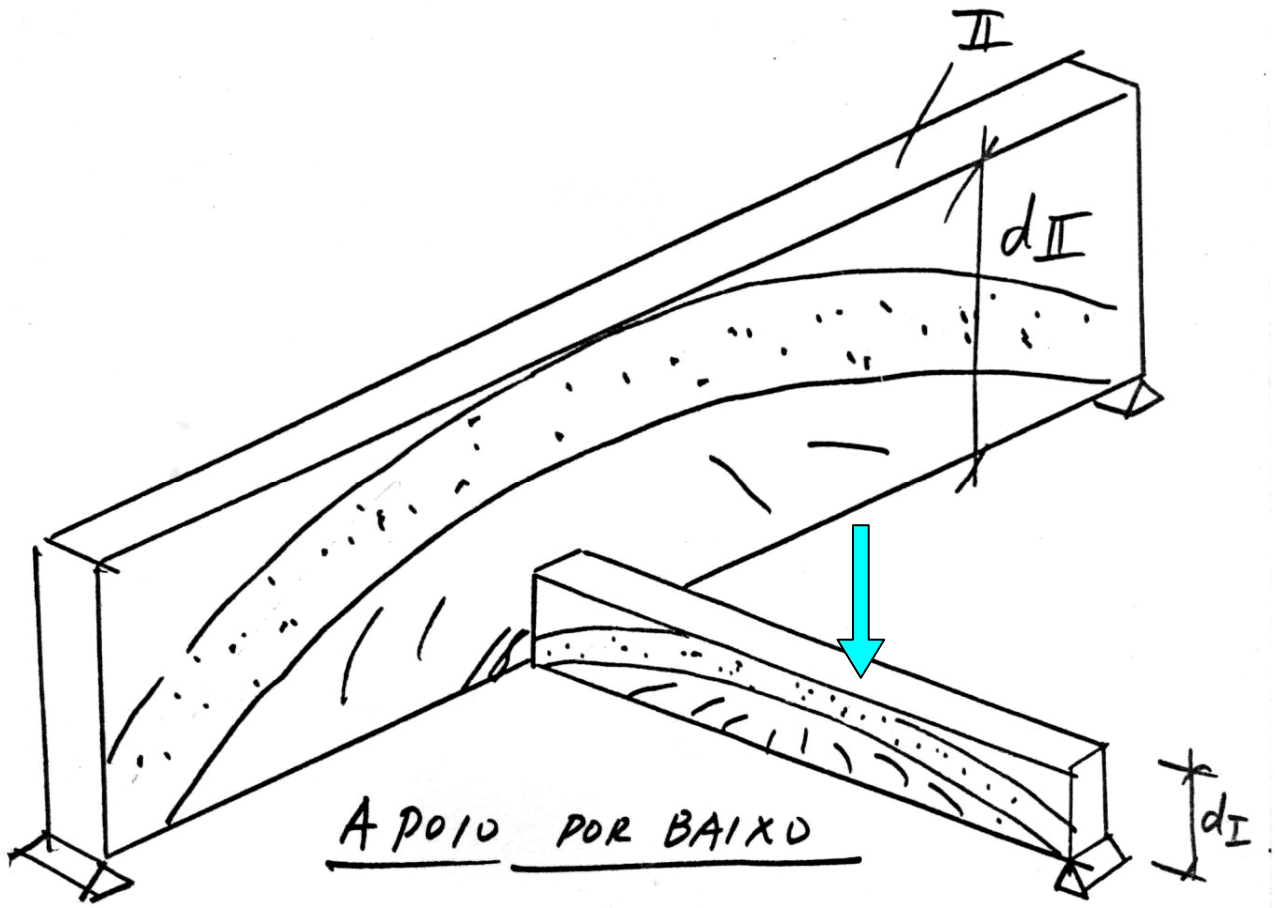
2º caso $d_I << d_{II}$

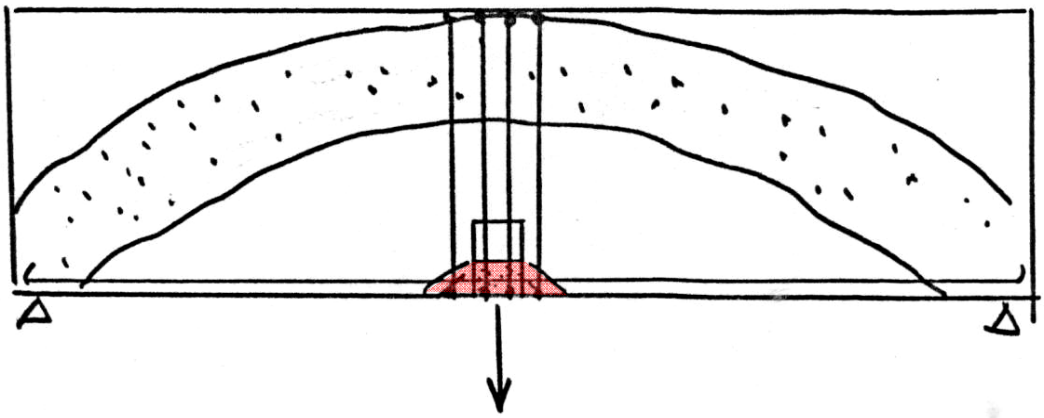




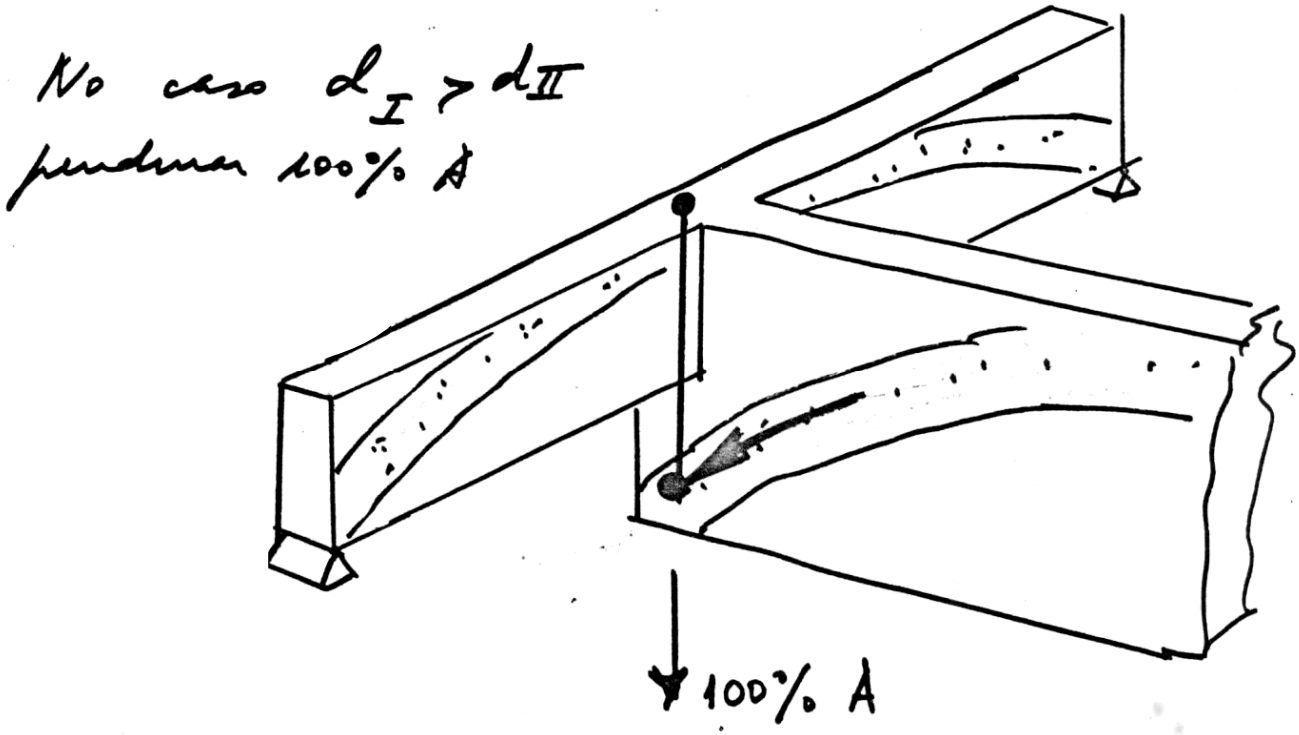
Não pendurar nenhuma carga.

Ainda $d_I << d_{II}$

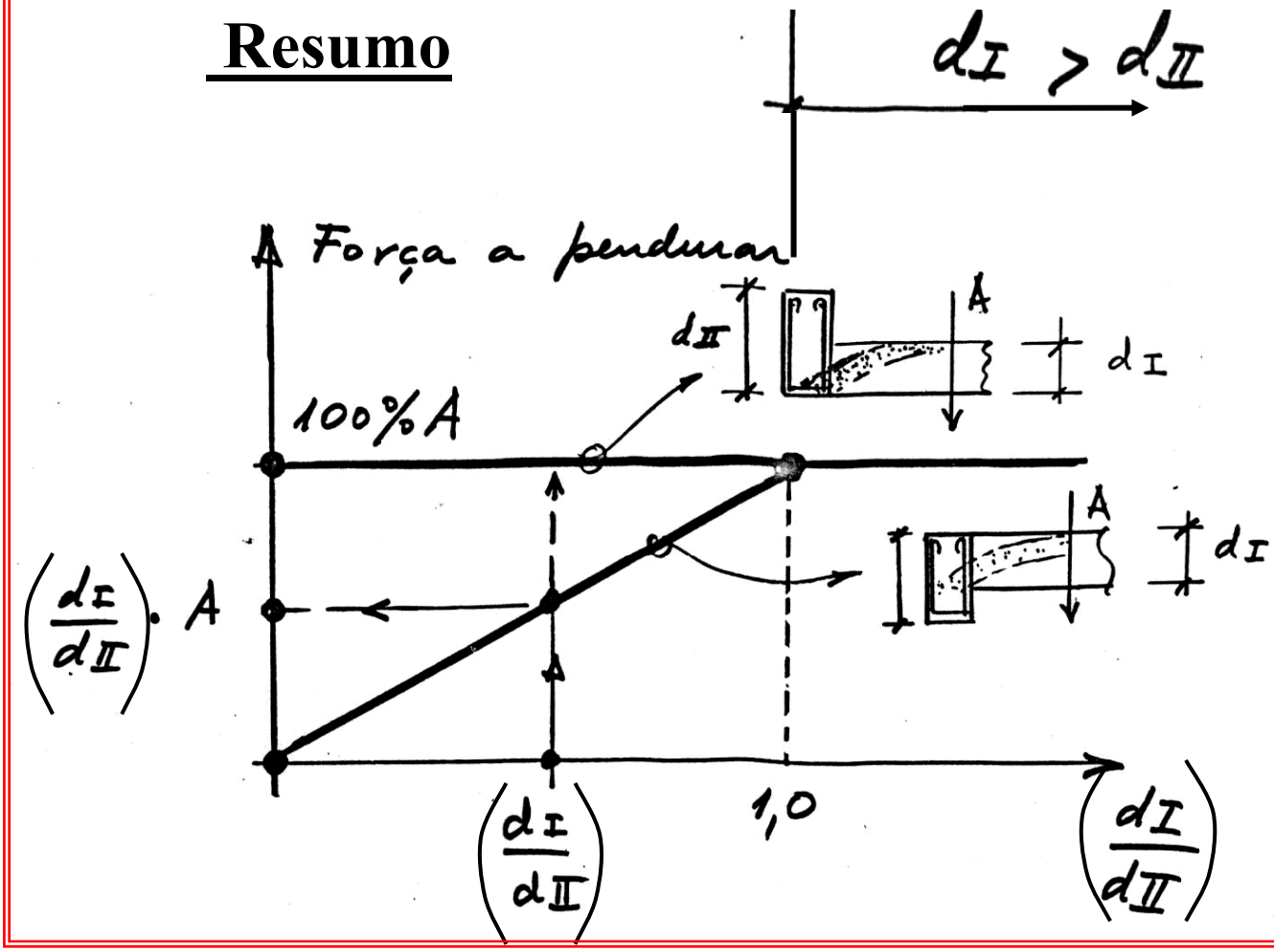




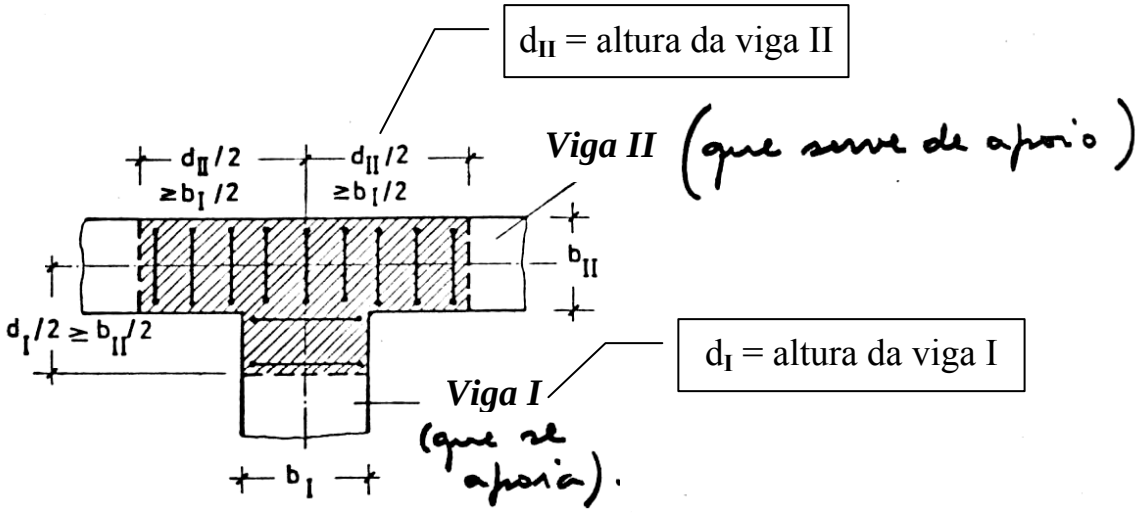
Pendurar 100% da carga.


No caso $d_I > d_{II}$
pendurar 100% A
100% A

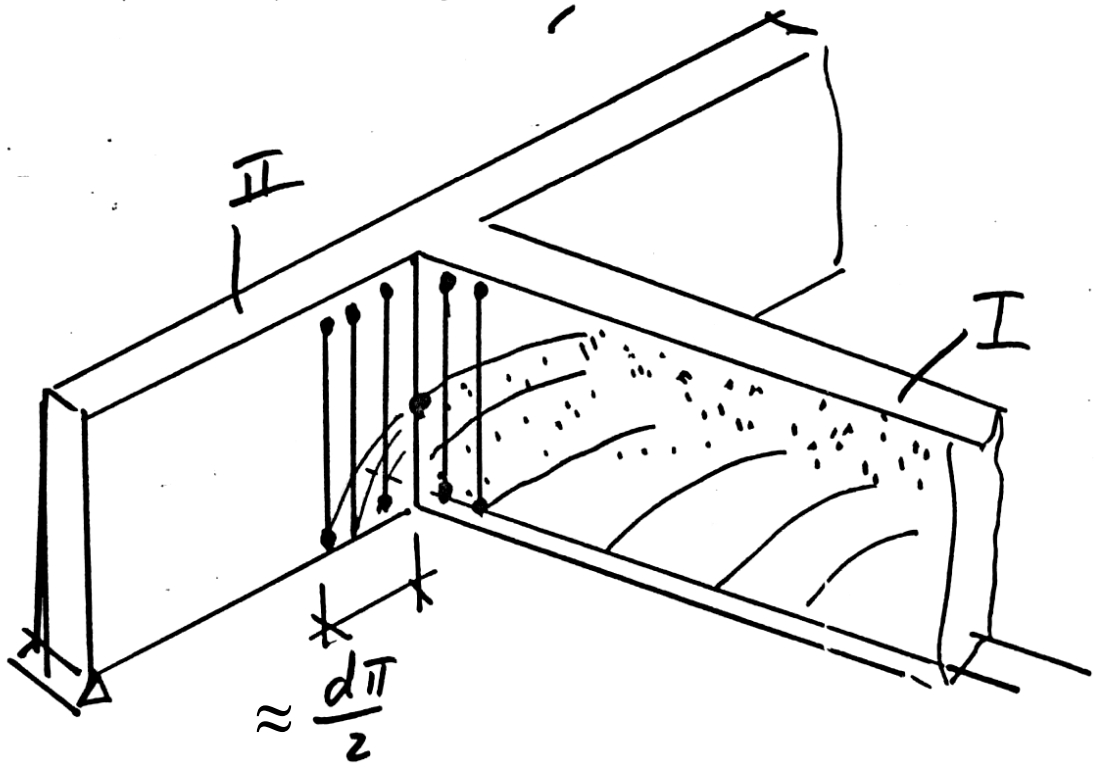
Resumo

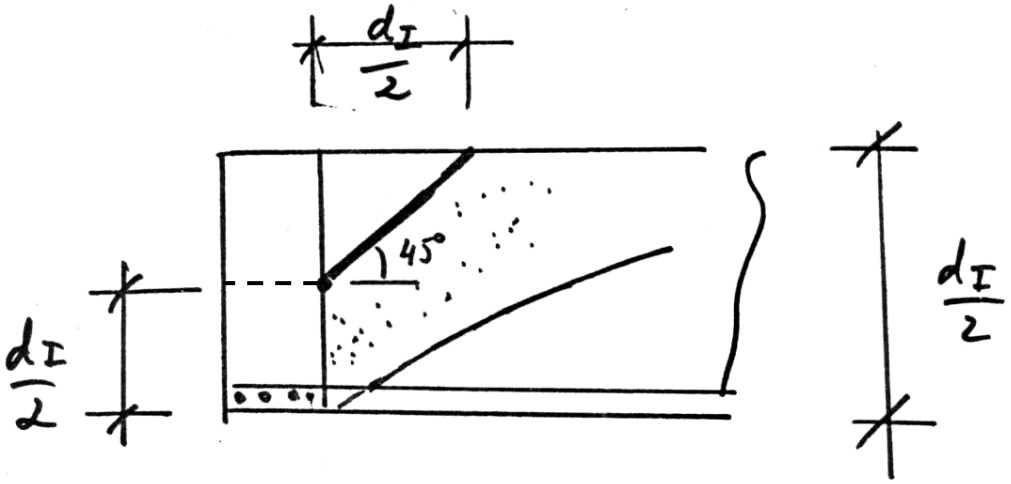

$d_I > d_{II}$
Força a pendurar
d_{II}
A
d_I
100% A
$\left(\frac{d_I}{d_{II}}\right) \cdot A$
A
d_I
$\left(\frac{d_I}{d_{II}}\right)$
1,0
$\left(\frac{d_I}{d_{II}}\right)$

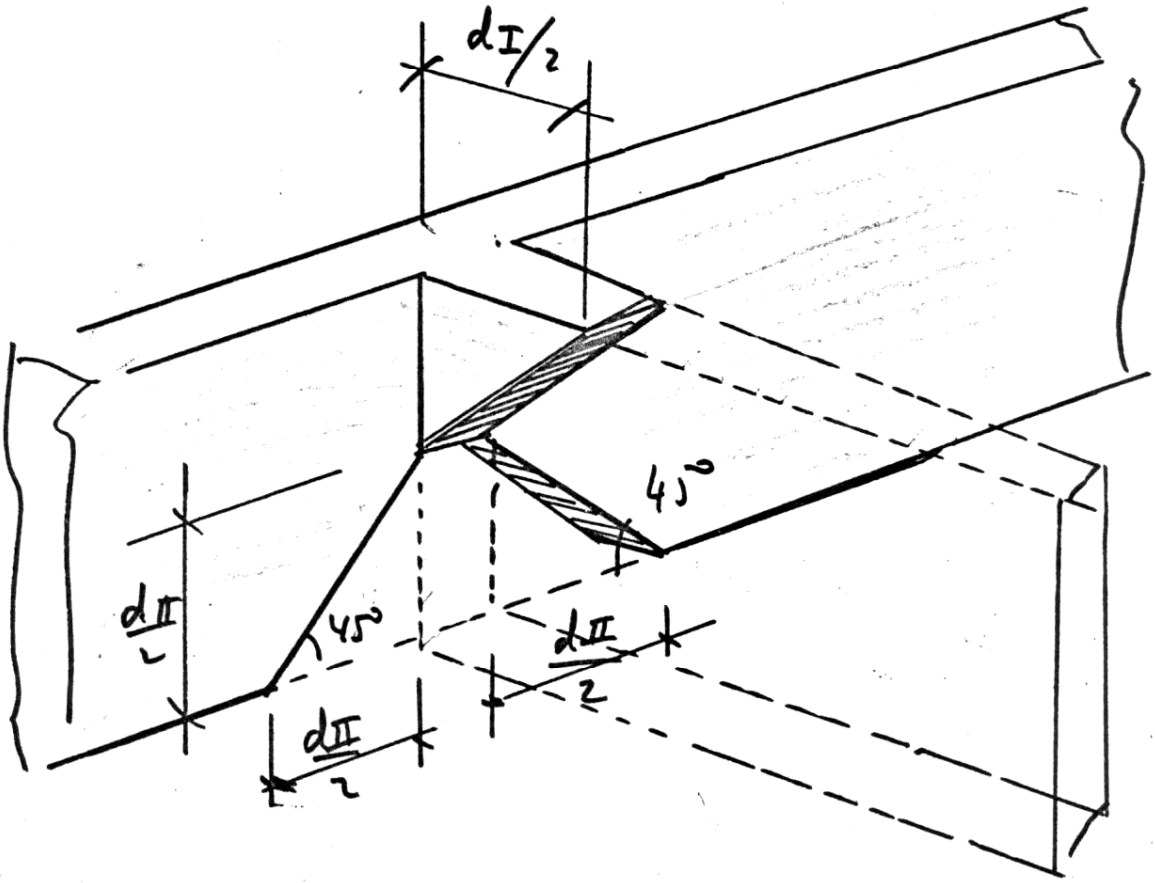
Zona onde deve ser colocado o estribo de suspensão.

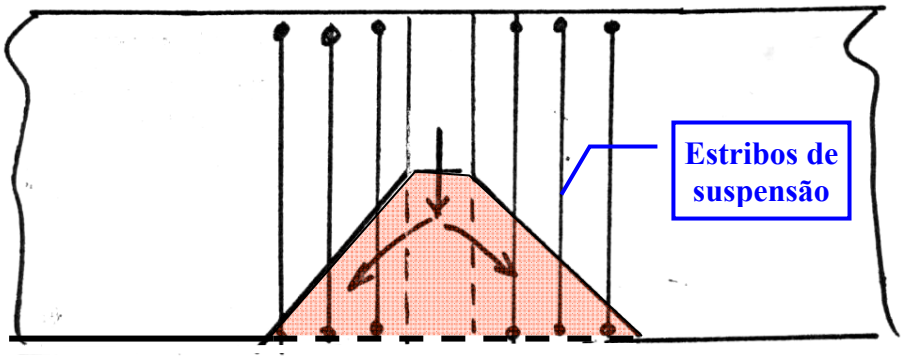


É fácil compreender o porque desta recomendação.

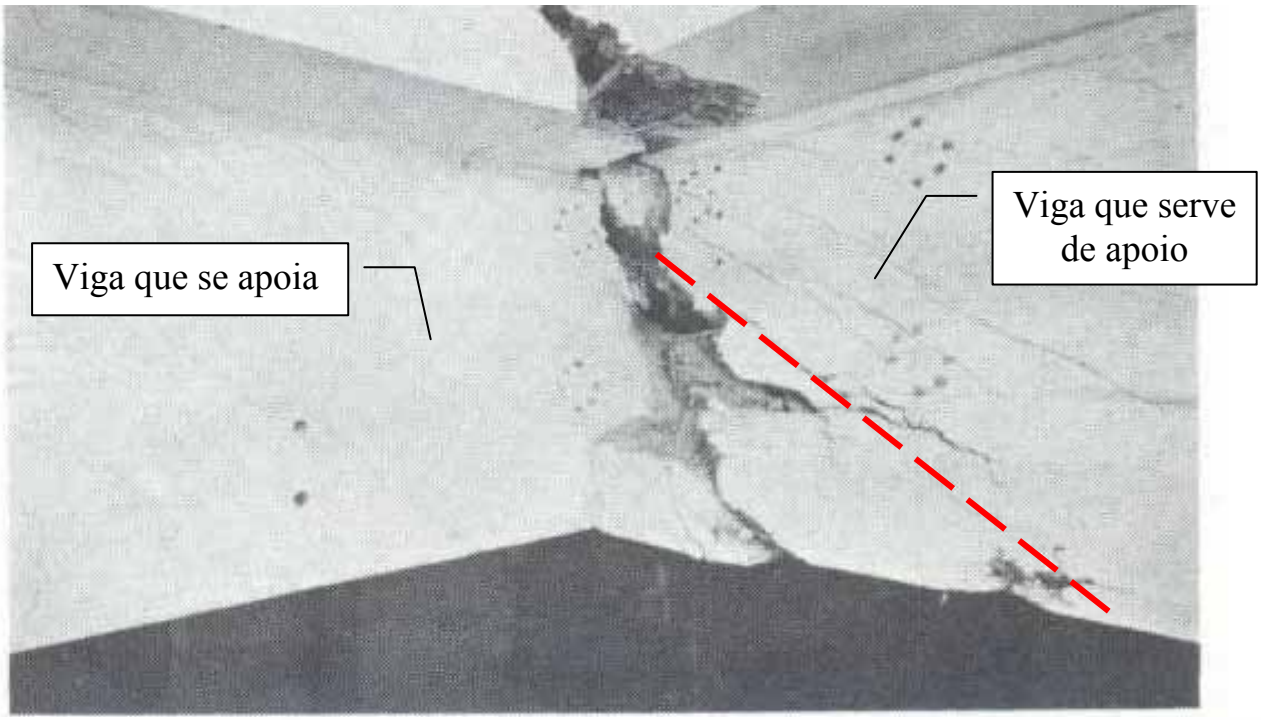


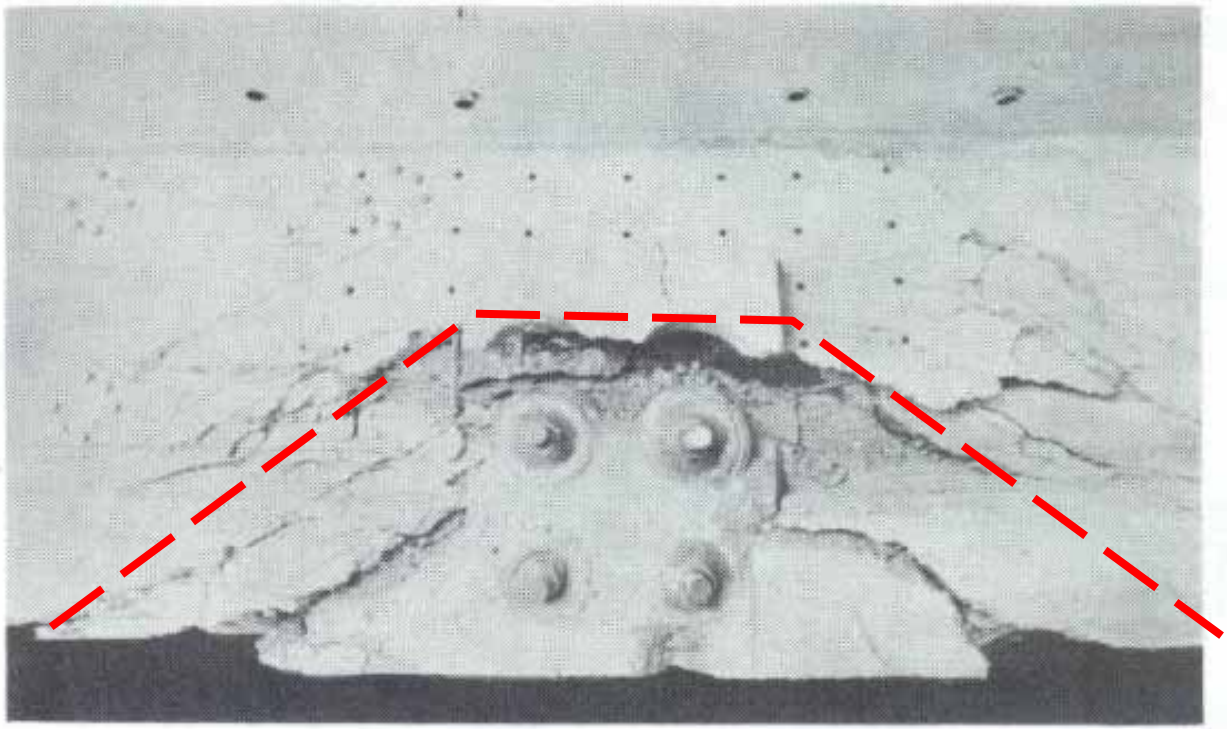

dI/2
45°
dI/2
dI/2


dI/2
45°
dII/2
45°
dII/2
dII/2


Estribos de suspensão

Ver Anexo 1 - Linhas de ruptura



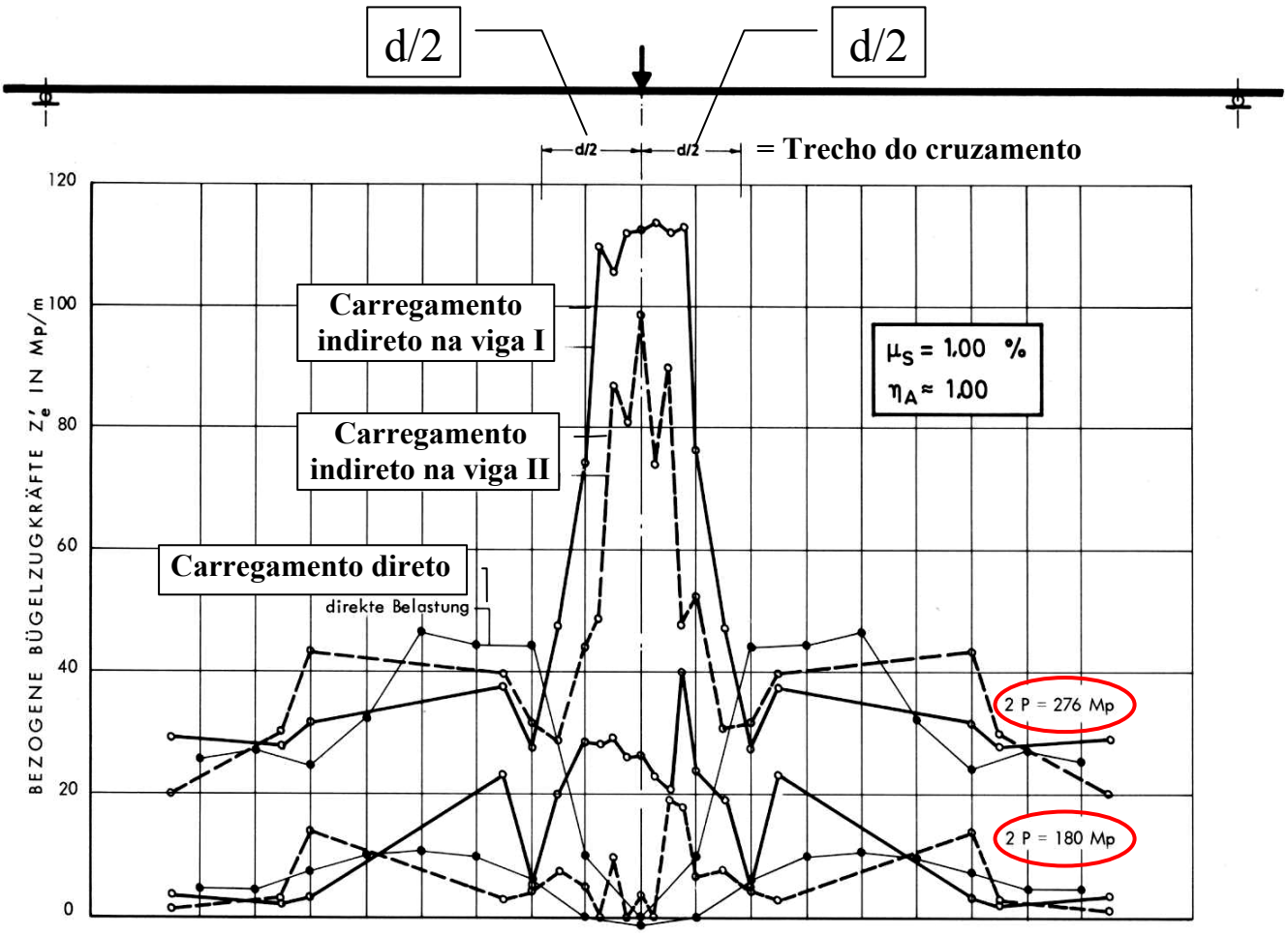


Ruptura - Viga Lateral II para a carga 2P =319 ton

- Ensaios Prof. Fritz Leonhardt : Ensaios D.A.f.StB – 227 – 1973 - Schubversuche an Spannbetonträger - Universität Stuttgart - *Ensaios de Cisalhamento em vigas de concreto Protendido.*

Ver Anexo 1

Zona de cruzamento de vigas



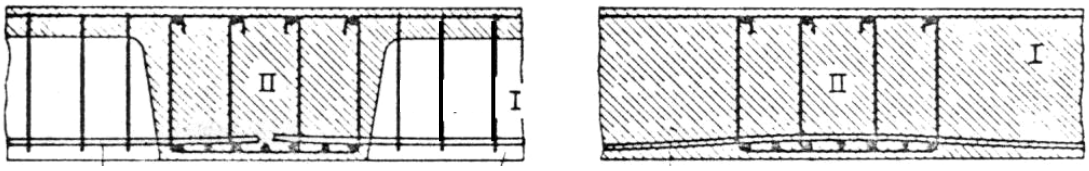
- Variação da força no estribo ao longo da viga que serve de apoio , em (ton /m) para a carga 2P=180 ton e para a carga 2P=276 ton

- Observa-se que apenas no trecho **d/2**, para cada lado do cruzamento das vigas, a tensão no estribo é alta.

que se apoia

As armaduras da viga I devem ficar sobre as da viga II

que serve de apoio



Recomendações :

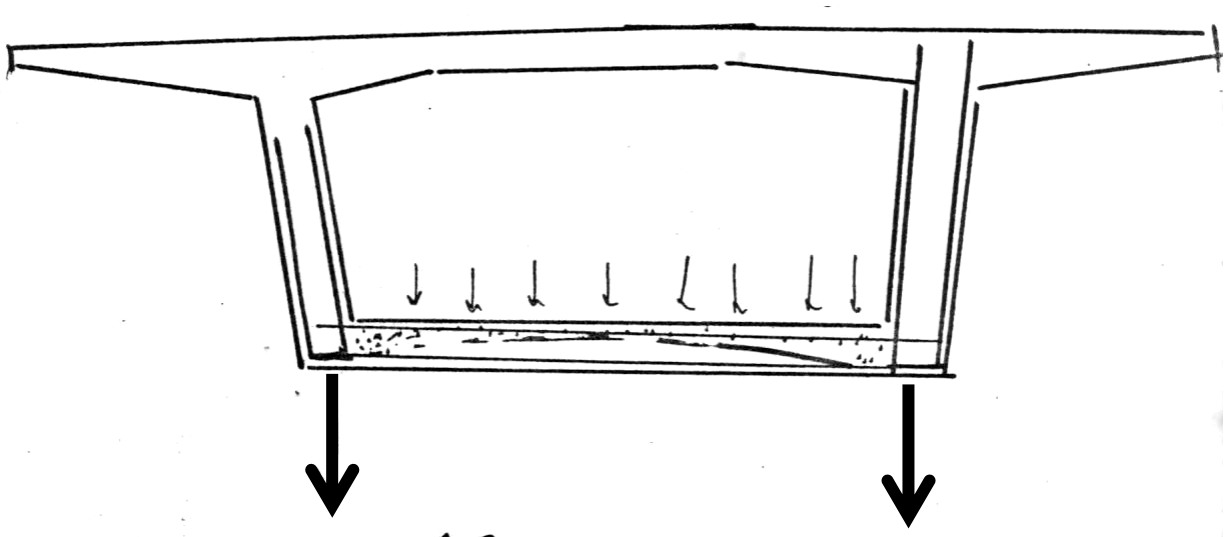
1 -

Na viga que se apoia, a armadura de suspensão não precisa ser adicionada à armadura de cisalhamento

2 -

Na viga que serve de apoio, a armadura de suspensão deve ser somada ao estribo devido ao cortante.

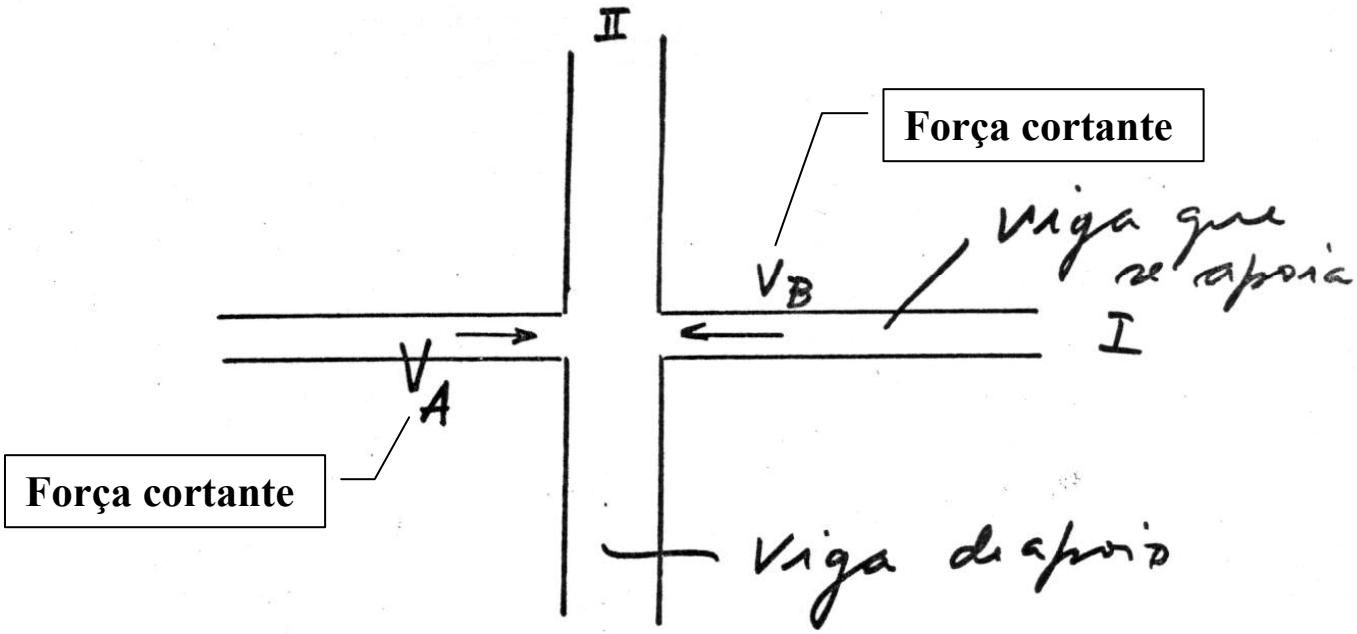
Em pontes com laje inferior

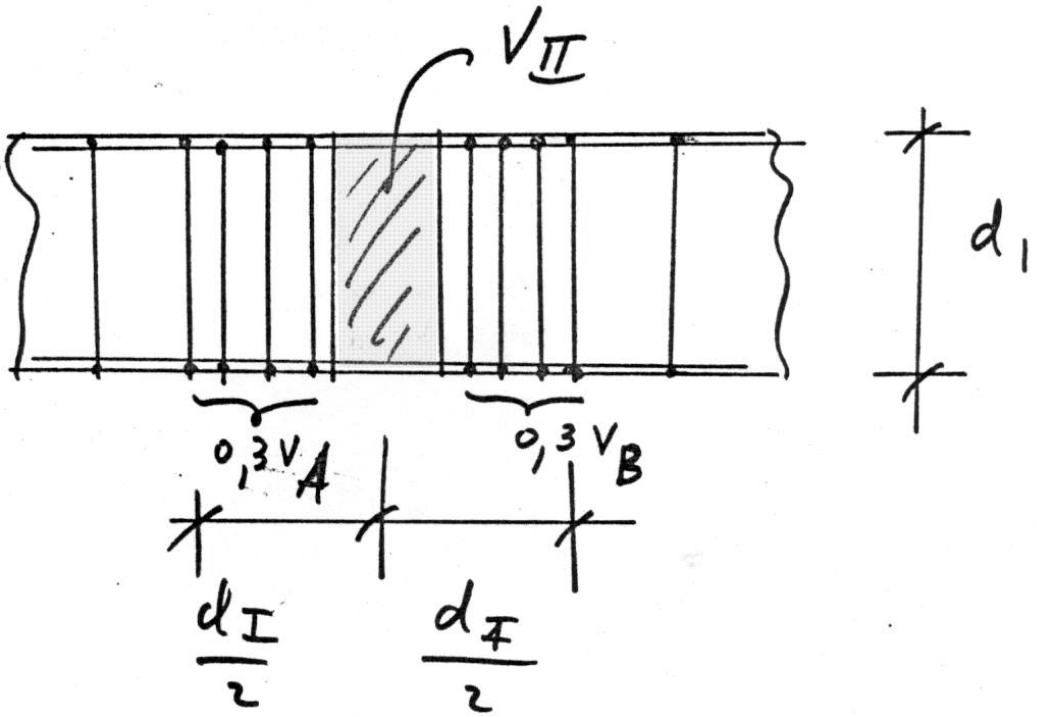


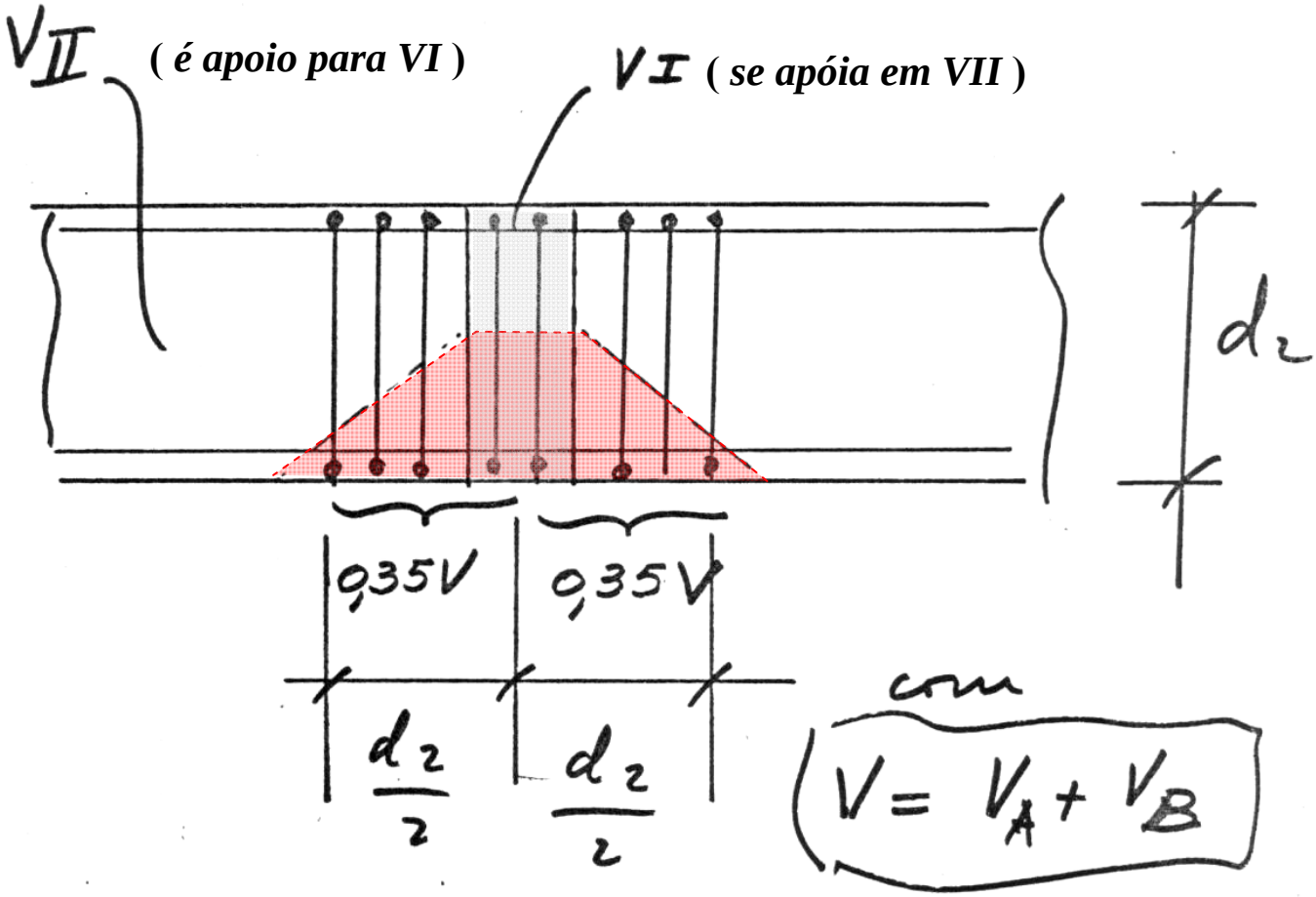
A laje está pendurada na viga.

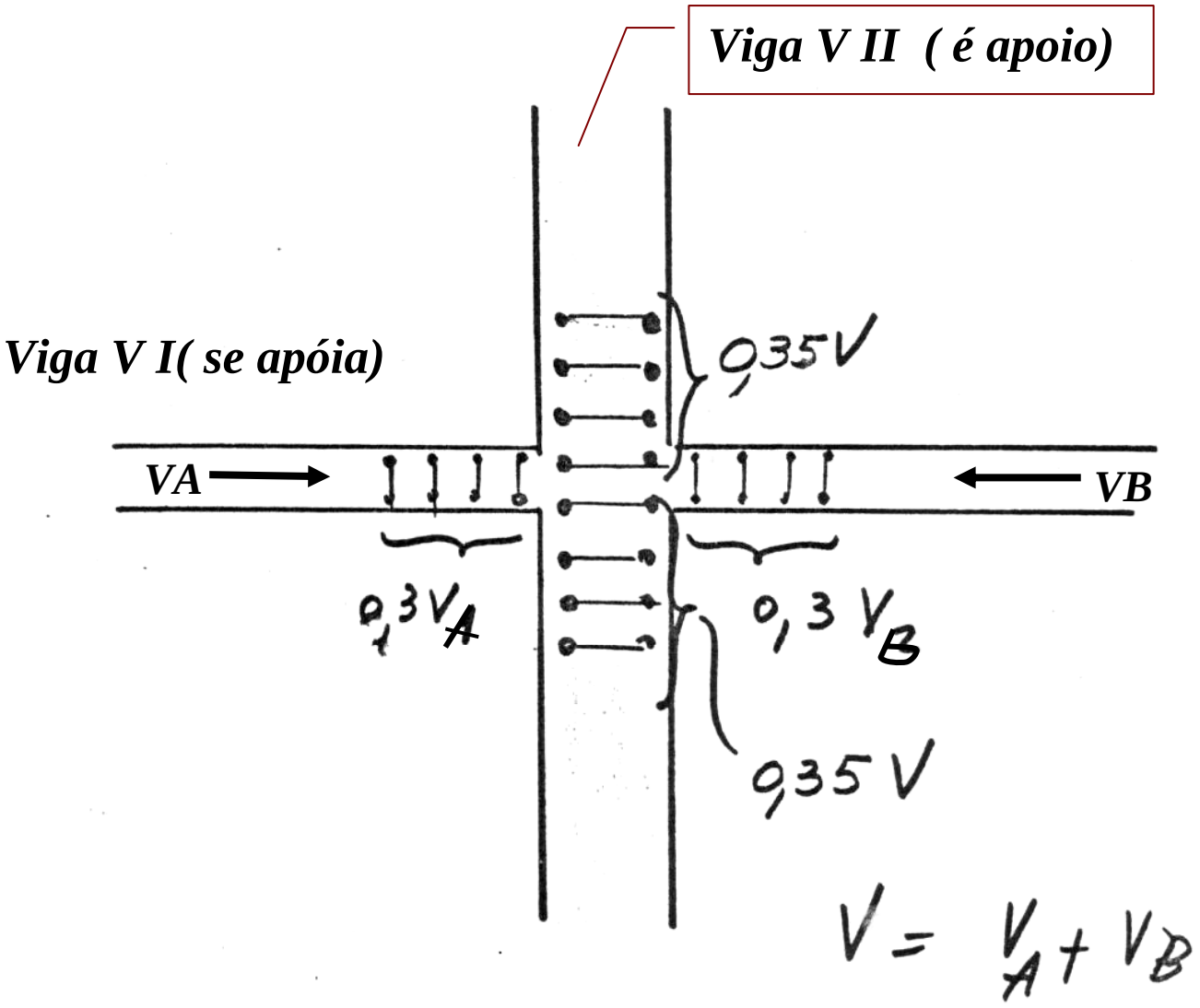
Neste caso, ao estribo de cizalhamento somar a armadura de suspensão da laje do fundo.

Quanto pendurar em cada trecho do cruzamento?



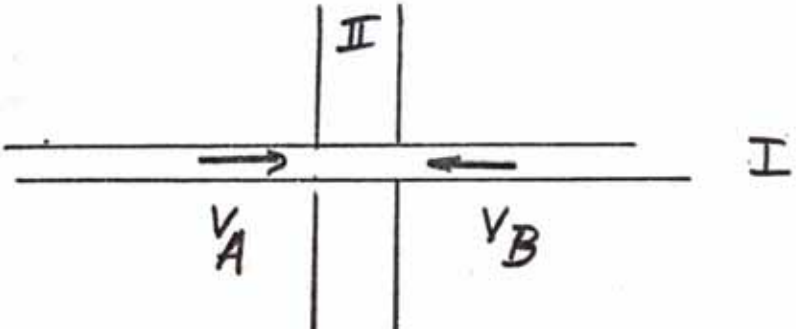


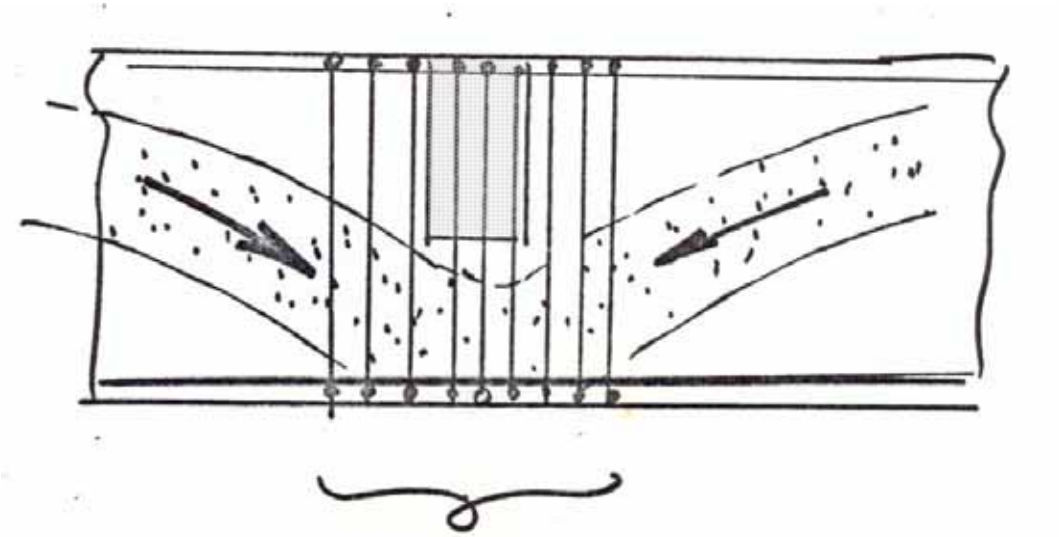

VII
(é apoio para VI)
VI (se apóia em VII)
d2
0,35V
0,35V
d2/2
d2/2
com
V = VA + VB


Viga V II (é apoio)
Viga V I(se apóia)
0,35V
VA
VB
0,3 VA
0,3 VB
0,35 V
V = VA + VB

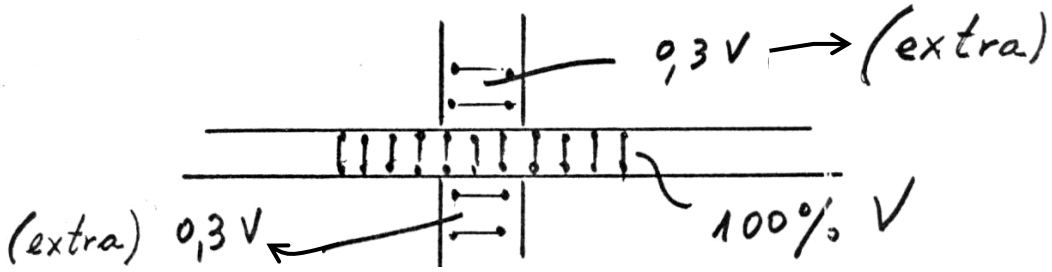
Em planta

Se $d_1 > d_2$ pendura 100%



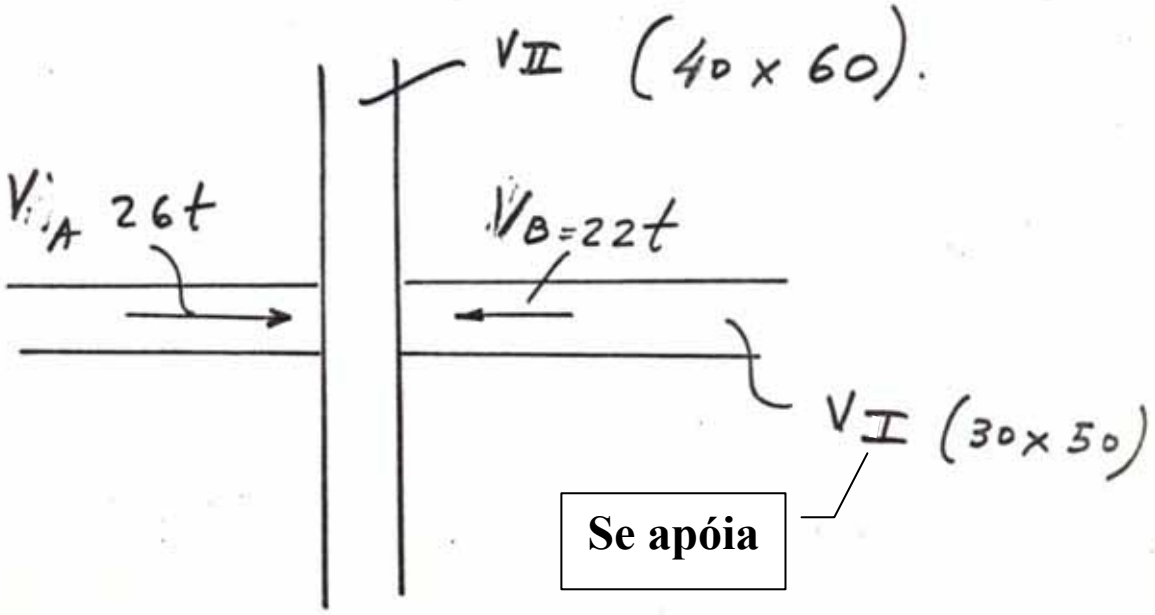


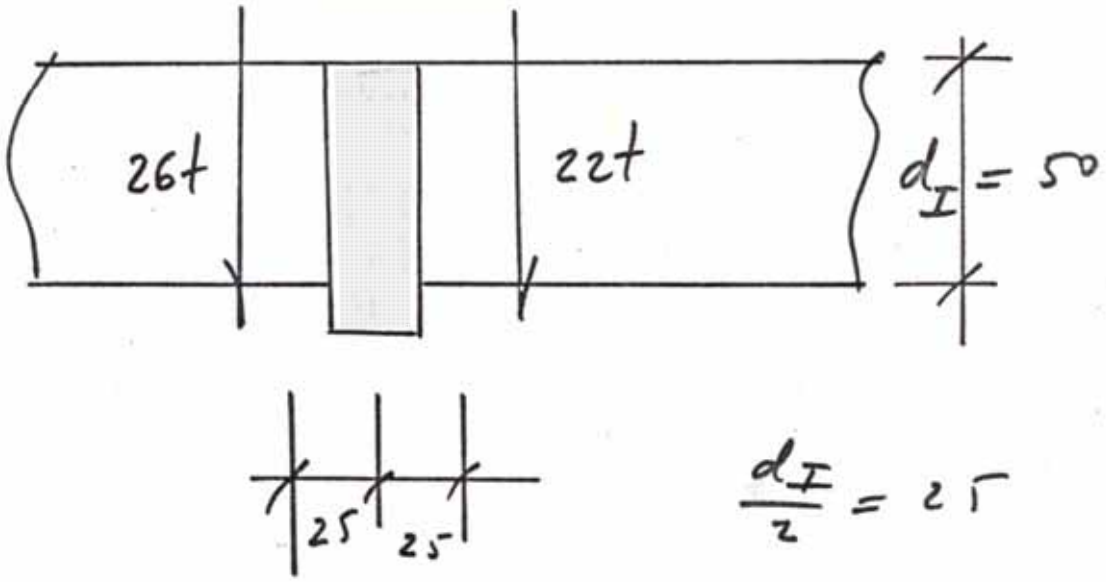
$$V = V_A + V_B$$



Colocar, também na Viga II, uma armadura extra.

Exemplo.


VII (40 x 60).
VA 26t
VB=22t
VI (30x50)
Se apóia


26t
22t
dI = 50
25
25
dI/2 = 25

$$A_{s\,B} = \frac{1{,}4 \times 22000}{4000} = 7{,}7\ cm^2$$

$$f_{yd} \leq \begin{cases} \dfrac{5000}{1{,}15} \\ 4000 \end{cases} = 4000$$

Tensão limite para evitar fissuras com grande abertura

$$\begin{cases} \text{Viga I} \rightarrow 0{,}3 \times 7{,}7 = 2{,}31\ cm^2 \\ \text{Viga II} \rightarrow 0{,}7 \times 7{,}7 = \underline{5{,}39\ cm^2} \end{cases}$$

$$7{,}70\ cm^2$$

$$A_{s\,A} = \frac{1{,}4 \times 26000}{4000} = 9{,}1\ cm^2$$

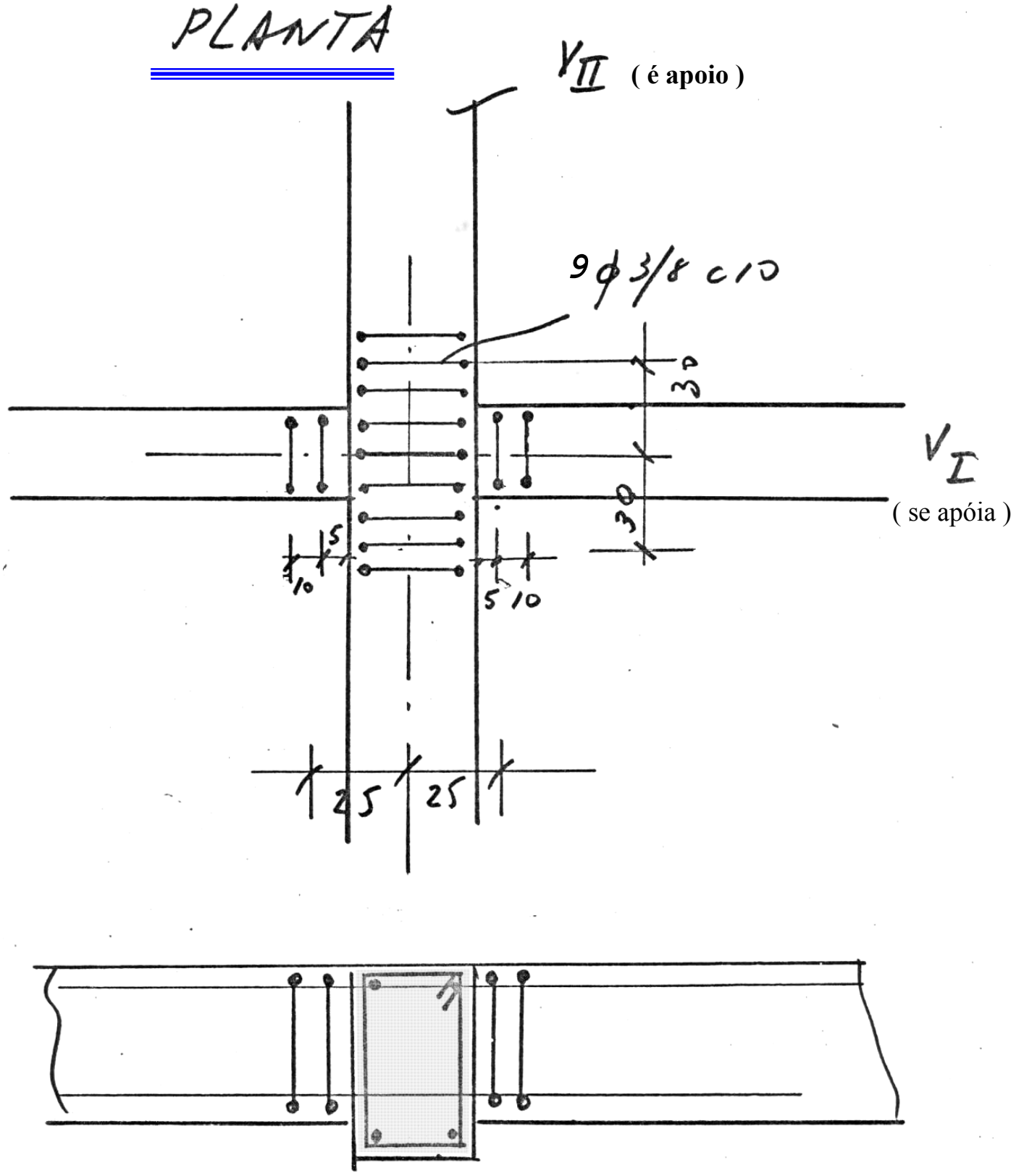
$$\text{Viga I} \rightarrow 0{,}3 \times 9{,}1 = 2{,}73\ cm^2$$

$$\text{Viga II} \rightarrow 0{,}7 \times 9{,}1 = \underline{6{,}37\ cm^2}$$

$$9{,}10\ cm^2$$

$$\text{I} \begin{cases} 2{,}31\ cm^2 = 4 \cdot \phi\ 3/8 = 2{,}84\ cm^2 \\ 2{,}73\ cm^2 \rightarrow 4\ \phi\ 3/8 = 2{,}84\ cm^2 \end{cases}$$

$$\text{II} \begin{cases} 5{,}39 + 6{,}37 = 11{,}76\ cm^2 = \begin{cases} 9\ \phi\ 1/2 \\ 16\ \phi\ 3/8 \end{cases} \end{cases}$$


PLANTA
V_{II} (é apoio)
9 φ 3/8 c/10
30
30
V_I
(se apóia)
5
10
5 10
25
25

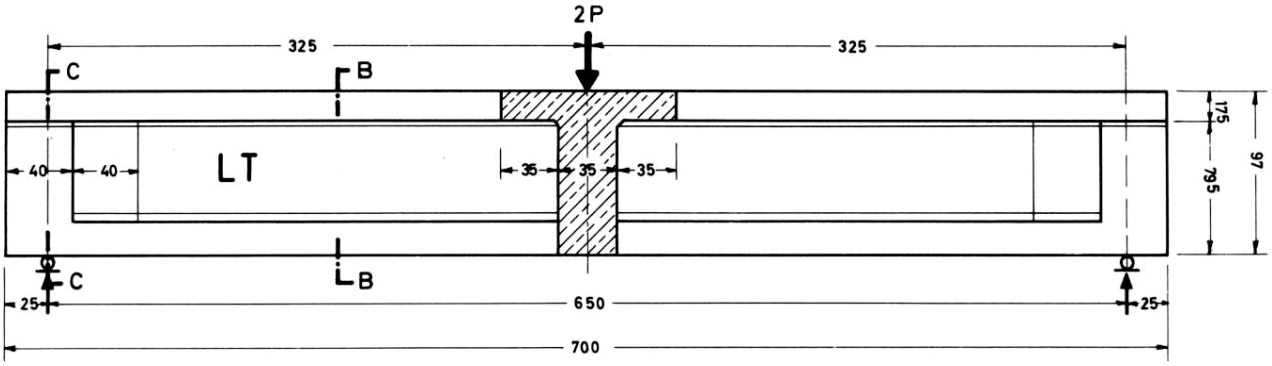
†††

Anexo 1

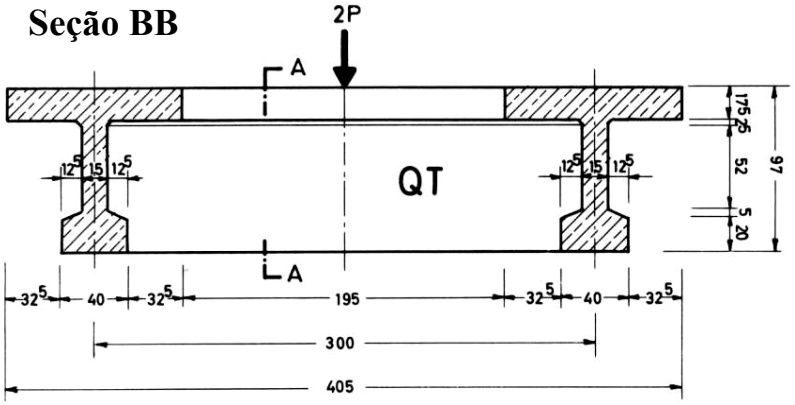
- Ensaios do Prof. Fritz Leonhardt : Ensaios D.A.f.StB – 227 – 1973 - Schubversuche an Spannbetonträger - Universität Stuttgart - *Ensaios de Cisalhamento em vigas de concreto Protendido*.

Montagem do Ensaio

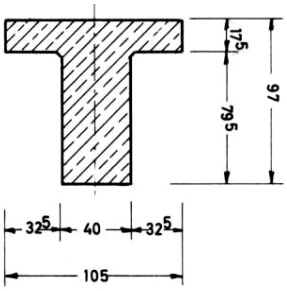
Seção AA



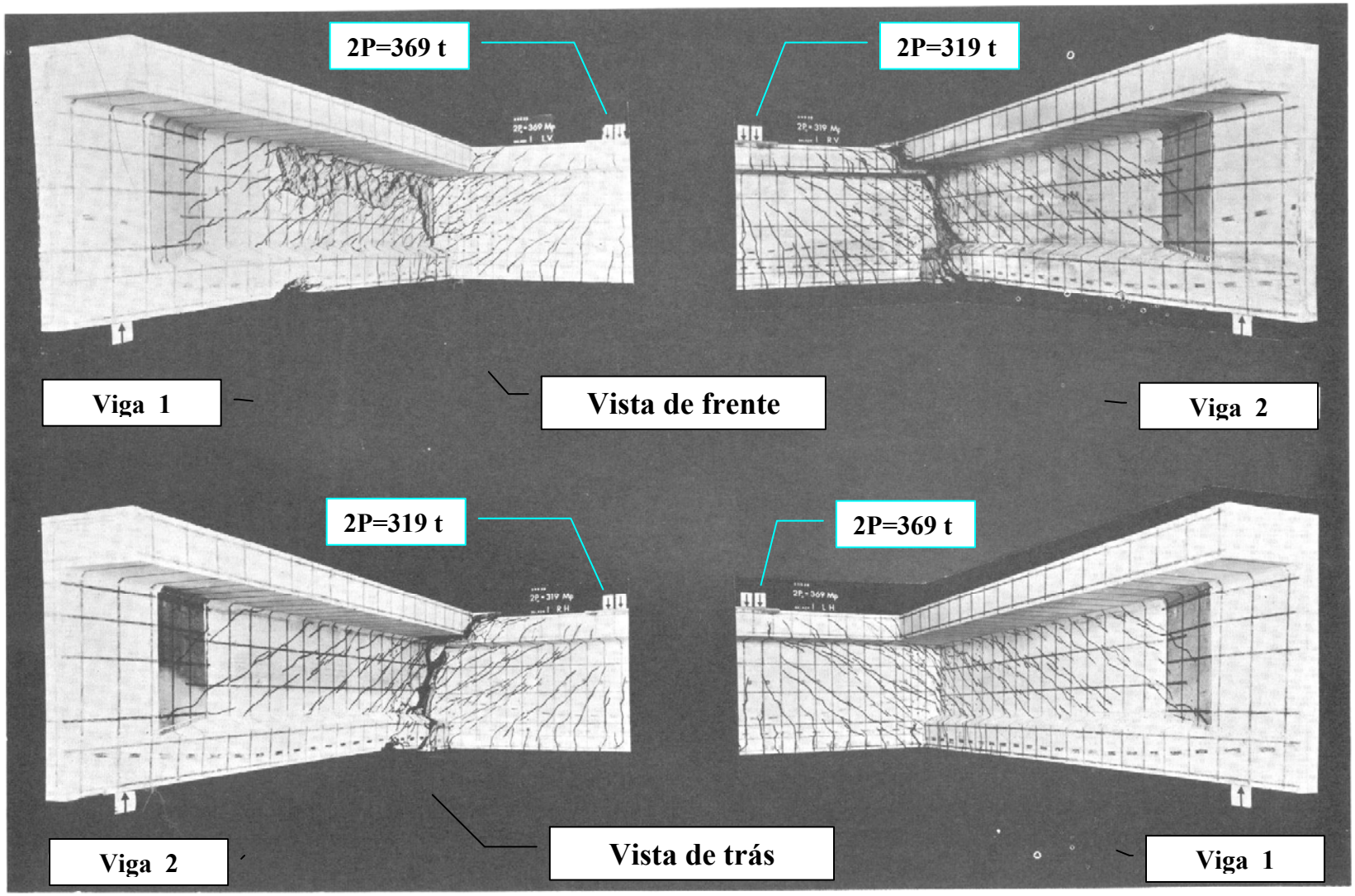
Seção BB



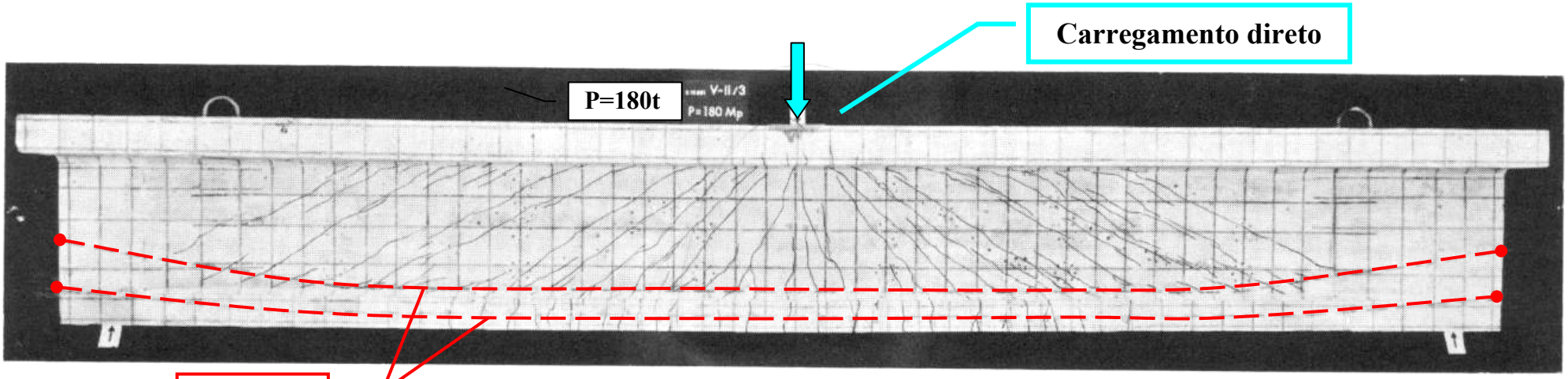
Seção CC

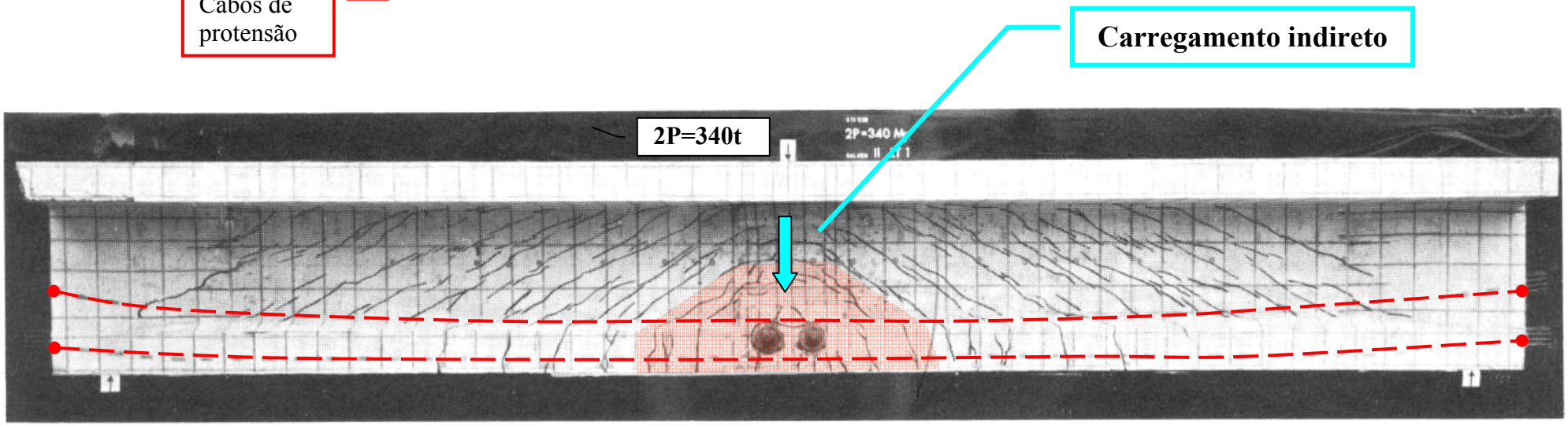


Dimensões em centímetros

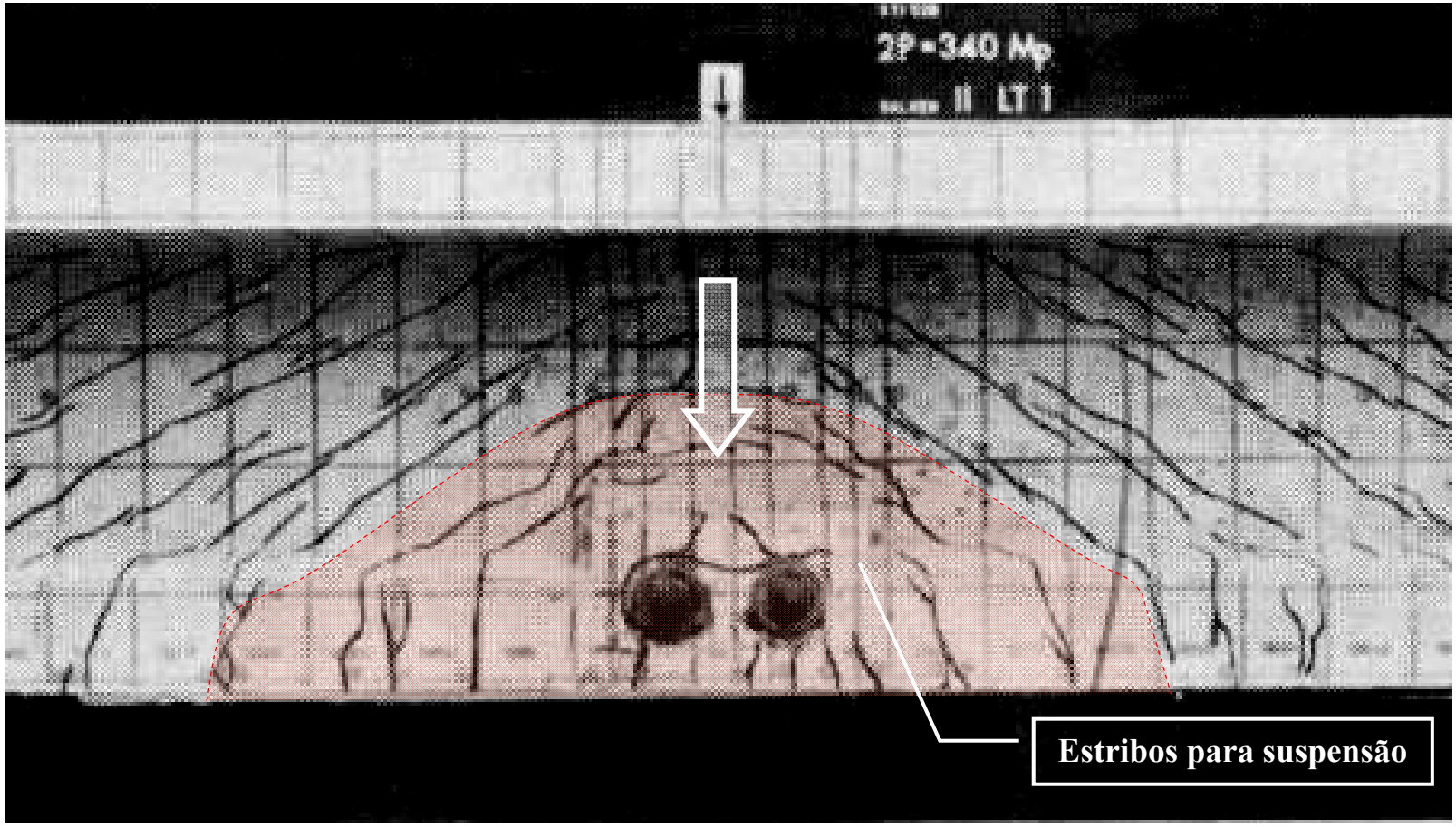


Fissuração na ruptura



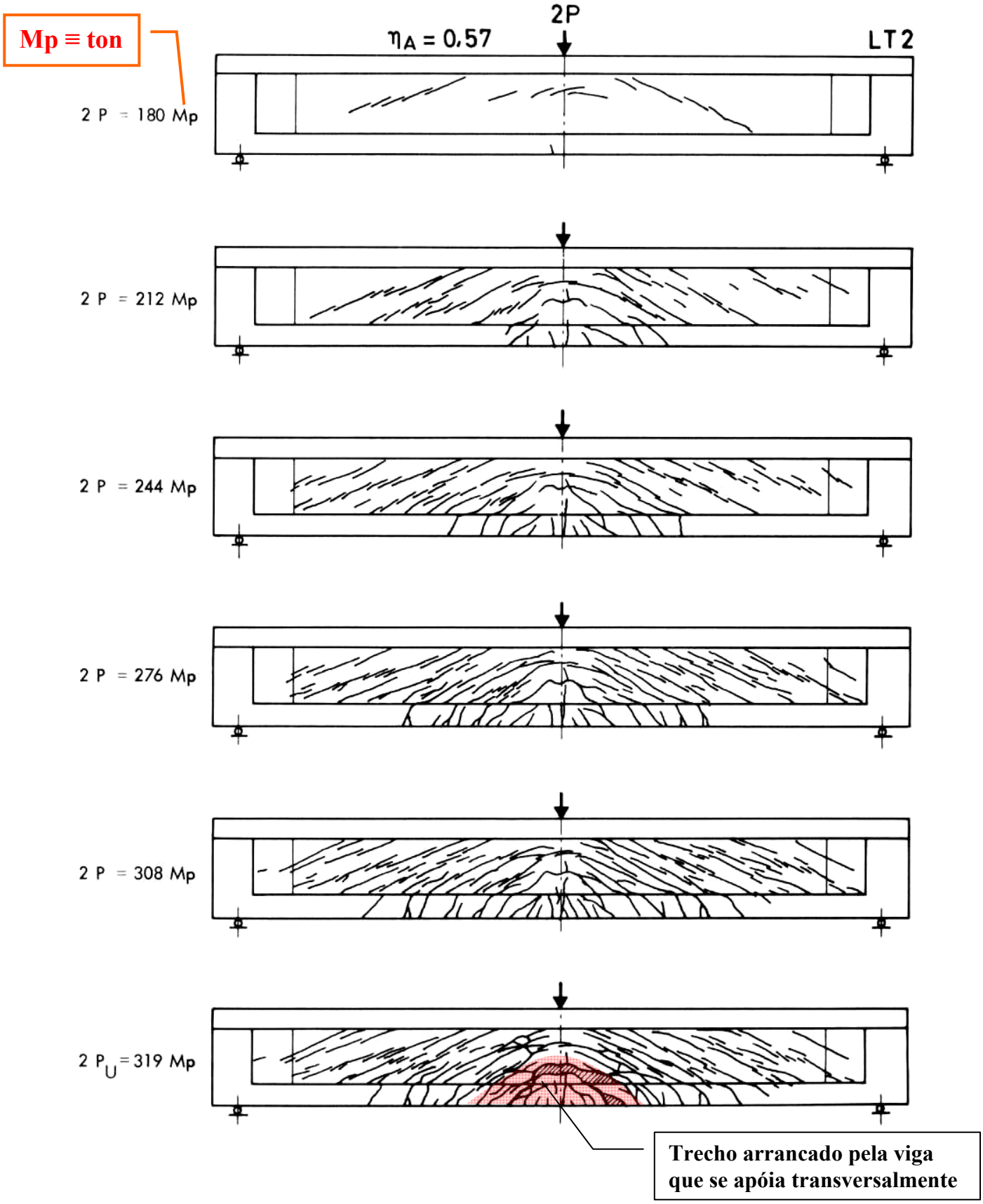


Nota-se que a diferença na fissuração ocorre apenas na zona inferior assinalada (com forma trapezoidal).

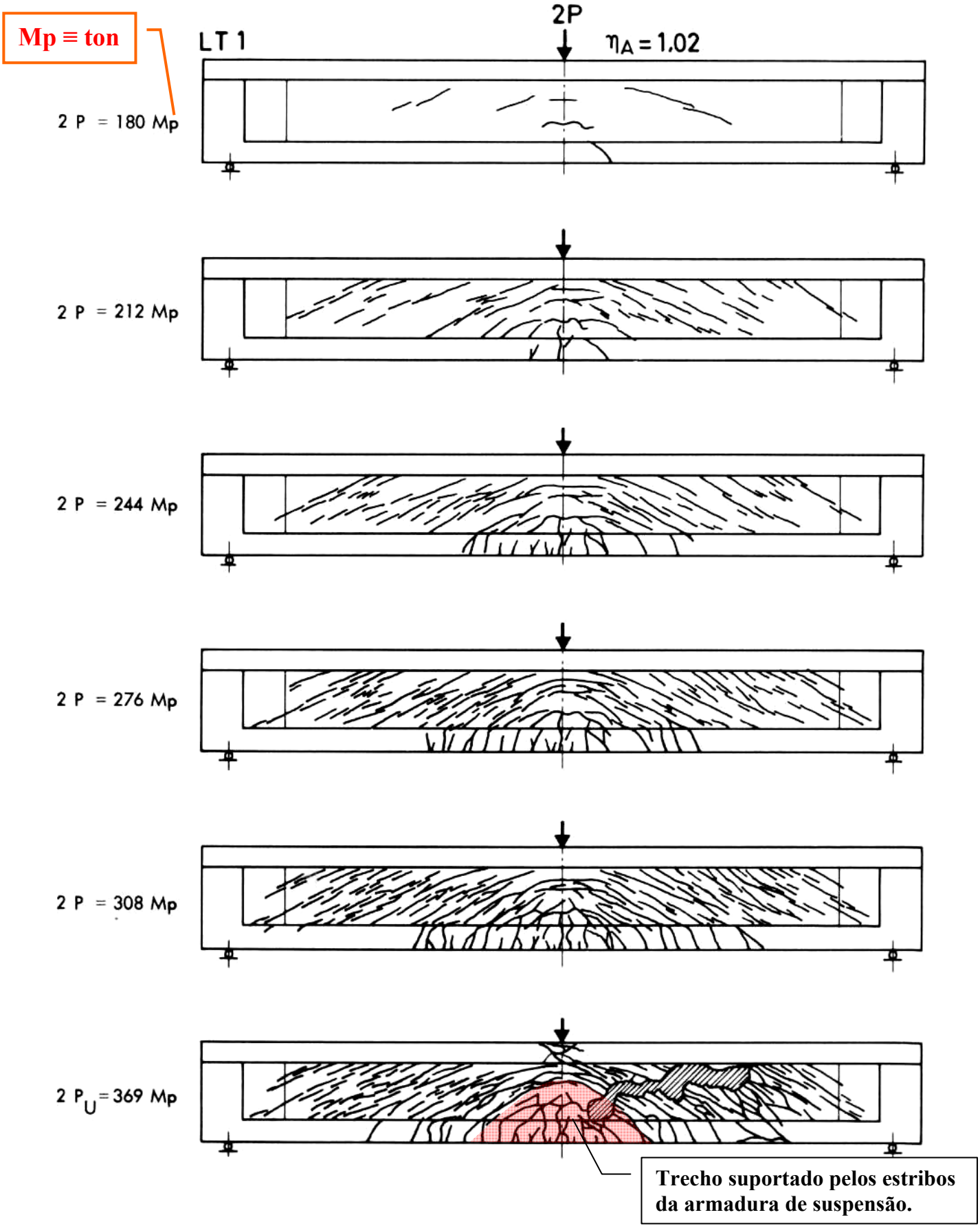


Detalhe da Zona de Cruzamento das Vigas no Carregamento indireto

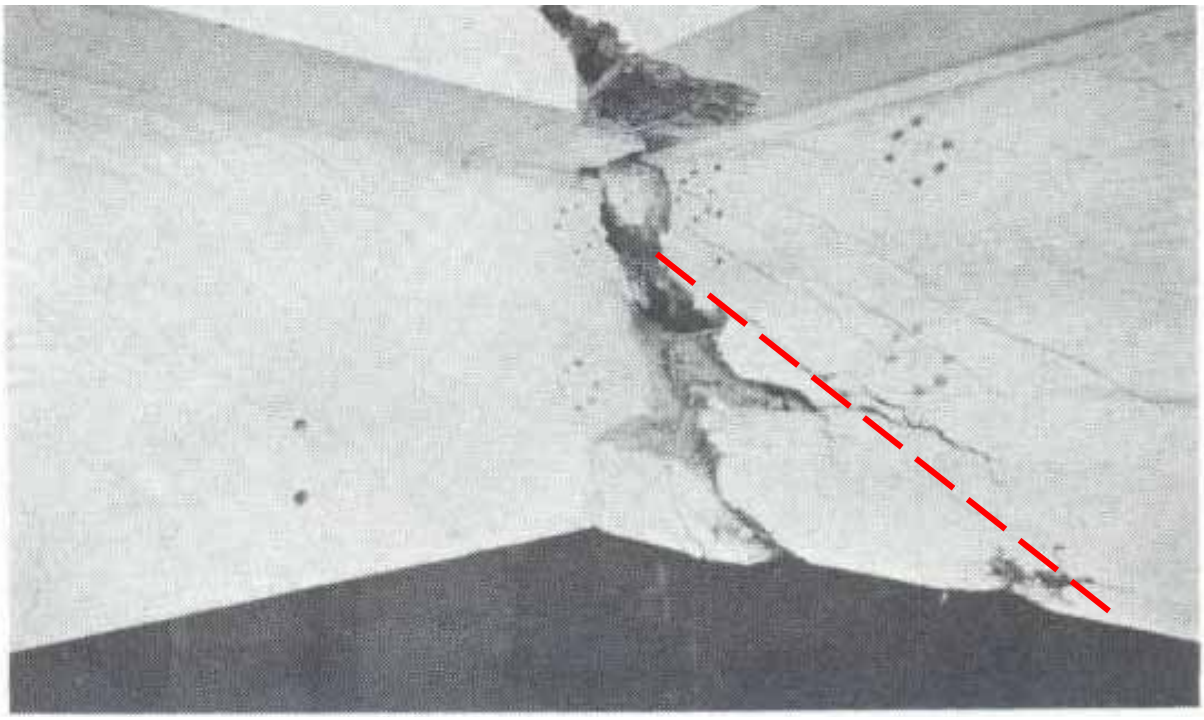
Viga com pouco estribo e com carregamento indireto

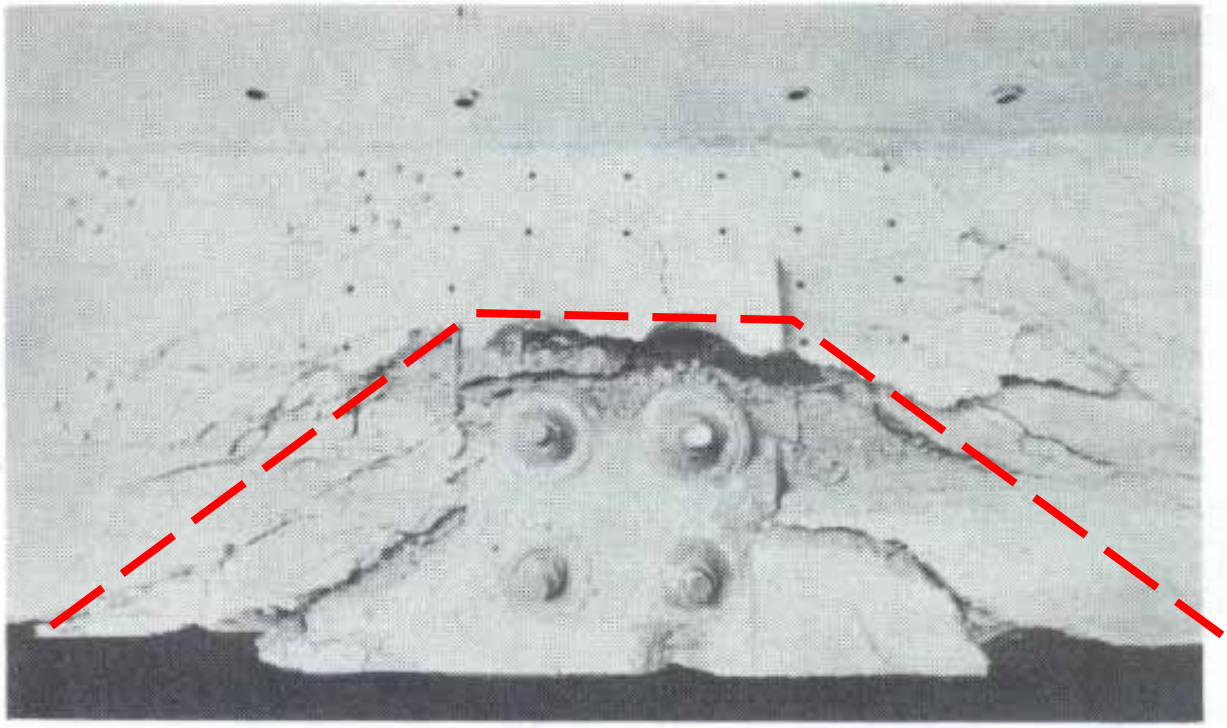


Viga com muito estribo e com carregamento indireto



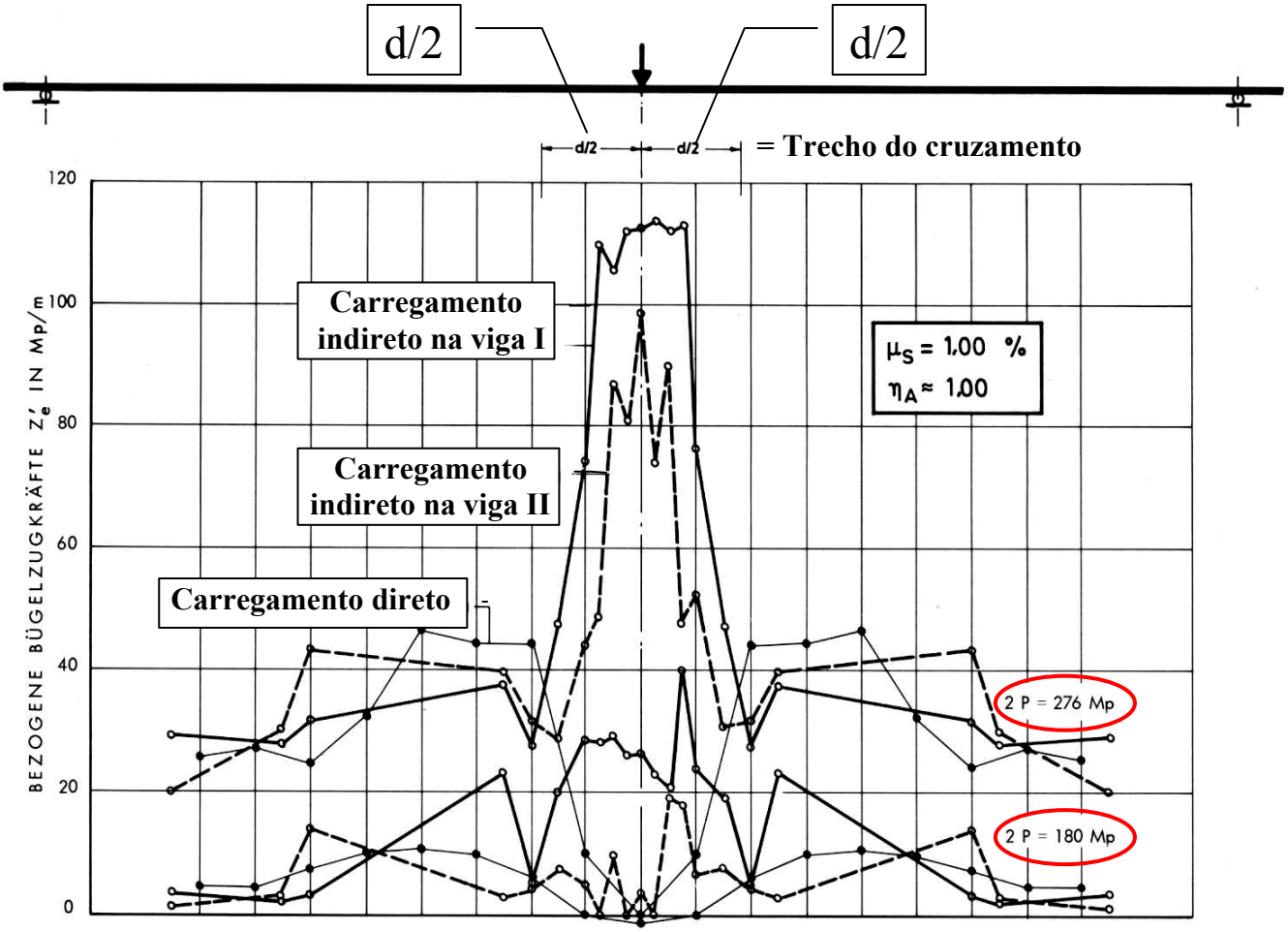
ANEXO 1 – Foto da zona rompida por escoamento dos estribos





Ruptura da viga 2 com a carga 2P = 319 t

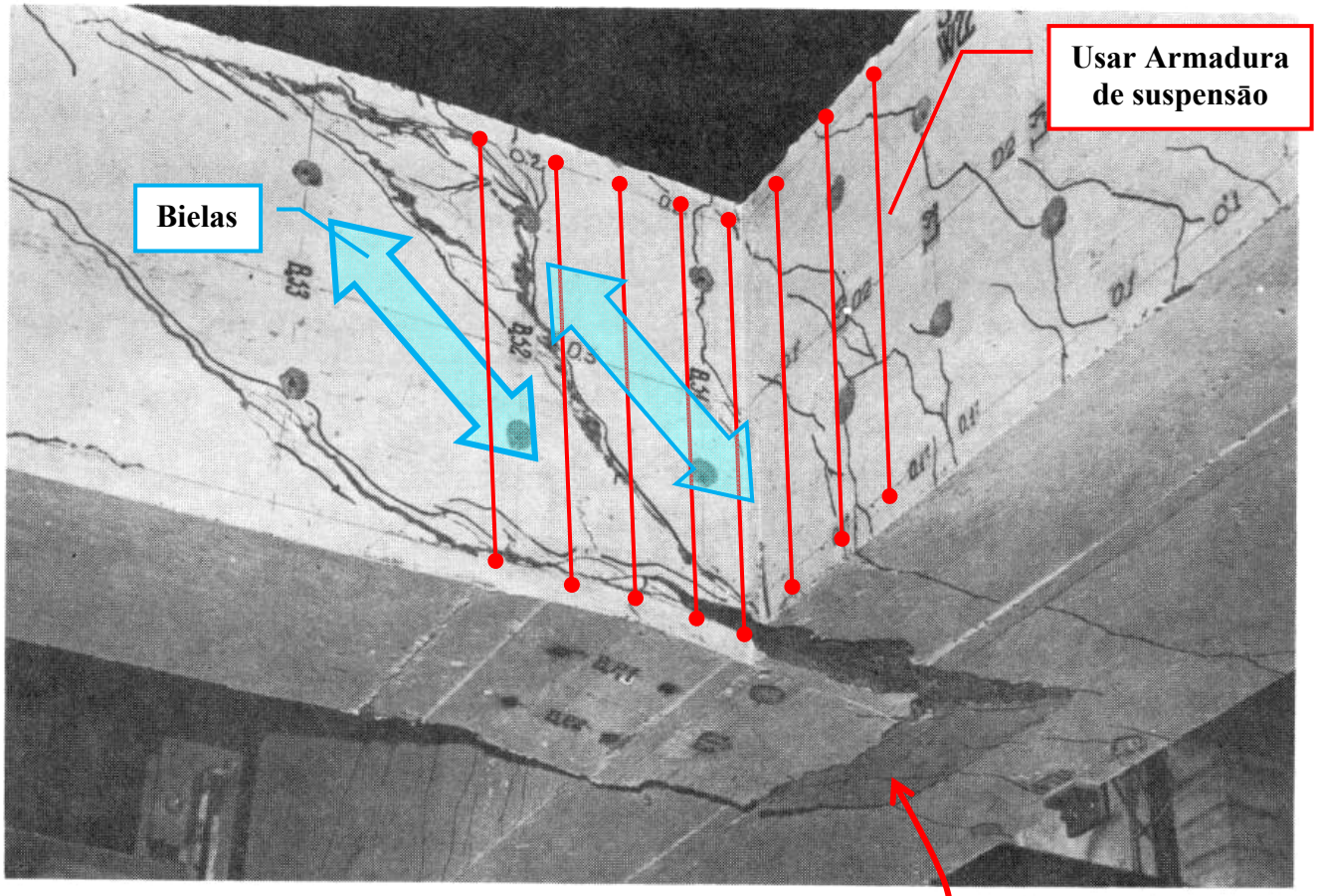
Carga nos estribos na zona de cruzamento das vigas.



- Variação da força no estribo ao longo da viga em (ton /m) para a carga 2P=180 ton e para a carga 2P=276 ton

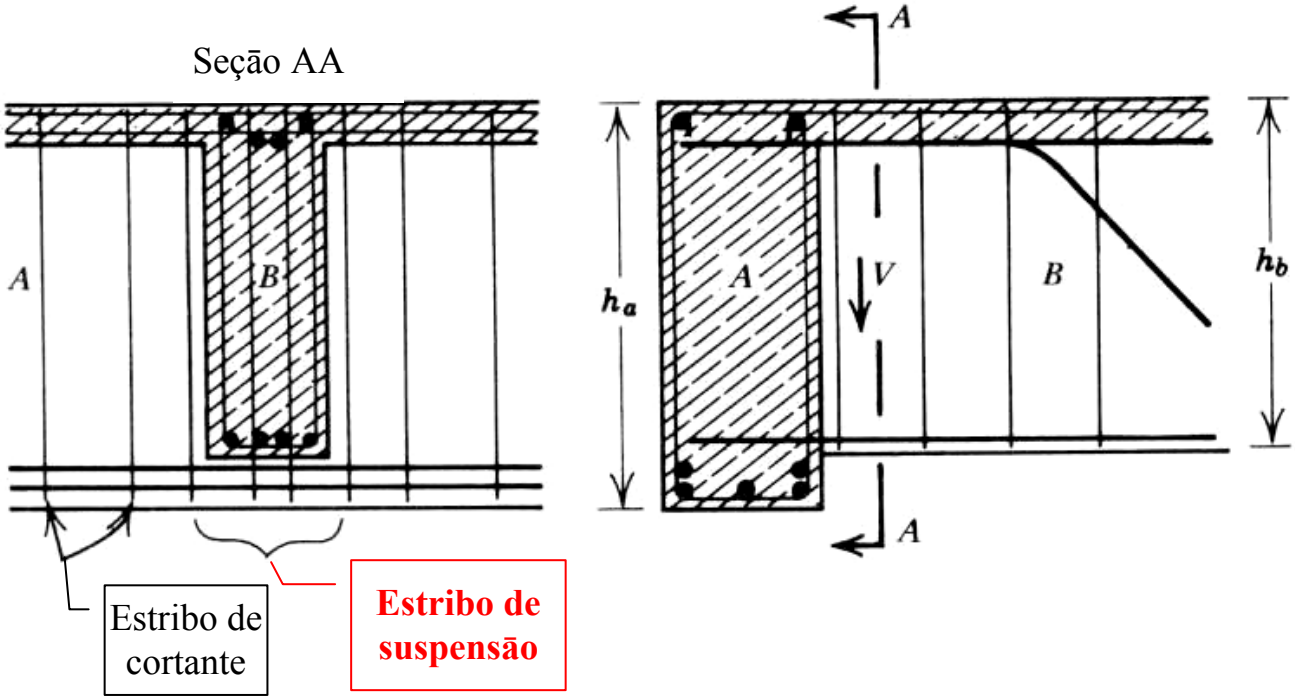
- Observa-se que apenas no trecho **d/2**, para cada lado do cruzamento das vigas, a força nos estribos é alta.

ANEXO 2 : R. PARK and T. PAULAY - Reinforced Concrete Structures



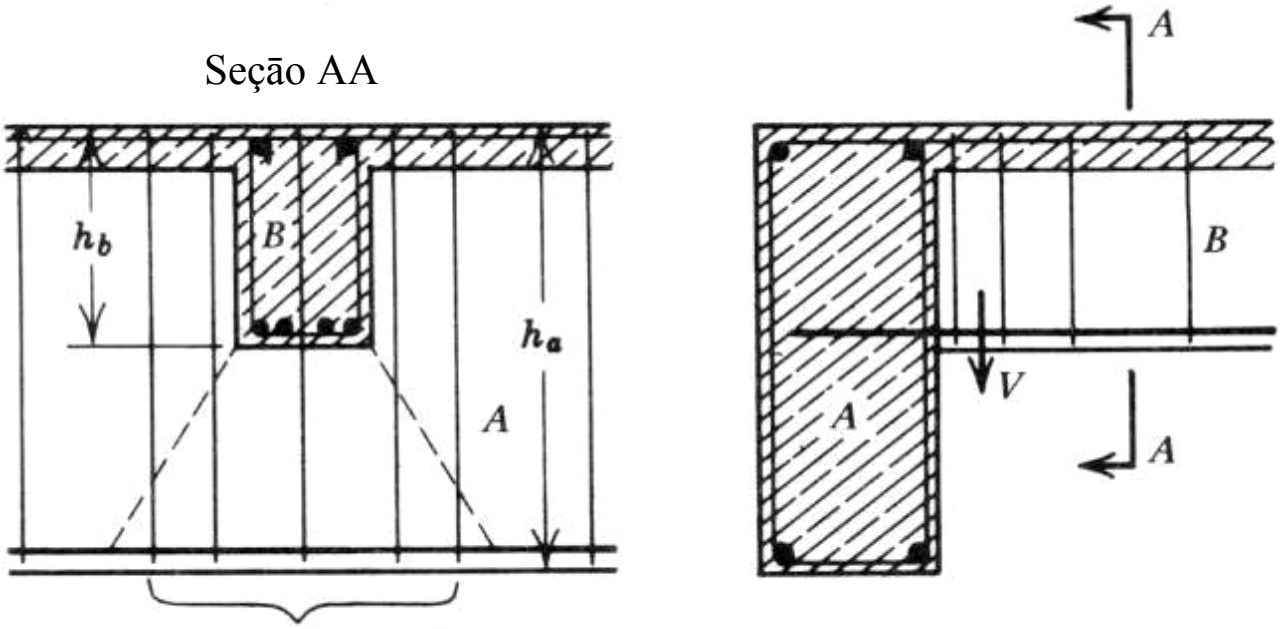
Falta de suporte para as diagonais comprimidas (bielas) .
A colocação de estribos é necessária para suspender a reação de apoio.

Vigas com alturas quase iguais : $h_a \approx h_b$



Vigas com alturas diferentes

Seção AA



Estribo de suspensão para $V_s^* = \frac{h_b}{h_a} V$

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