UNIVERSIDADE DE SÃO PAULO

ESCOLA DE ENGENHARIA DE SÃO CARLOS

Departamento de Engenharia de Estruturas

TABELAS DE VIGAS:

Deslocamentos e Momentos de Engastamento Perfeito

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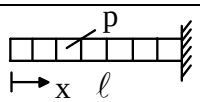
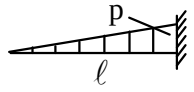
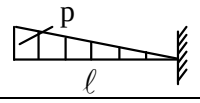
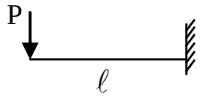
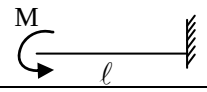
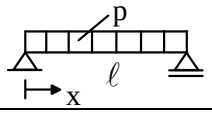
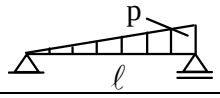
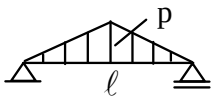
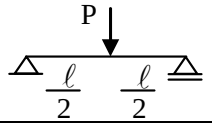
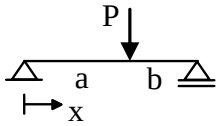
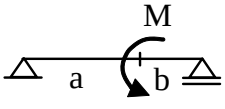
TABELA 3.1a

DESLOCAMENTOS ELÁSTICOS EM VIGAS

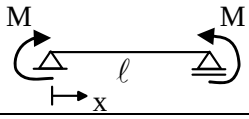
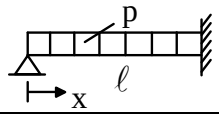
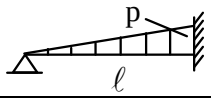
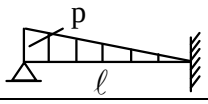
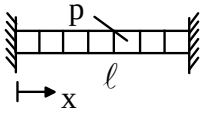
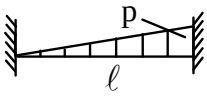
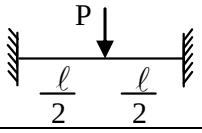
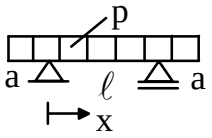
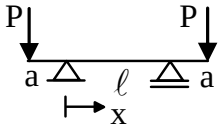
CASO	VINCULAÇÃO E CARREGAMENTO	FLECHA		EQUAÇÃO DA ELÁSTICA
		w_{max}	x	
1		$\frac{1}{8}\frac{p\ell^4}{EI}$	0	$\frac{p\ell^4}{24EI}\left(\alpha^4-4\alpha+3\right)$
2		$\frac{1}{30}\frac{p\ell^4}{EI}$	0	$\frac{p\ell^4}{120EI}\left(\alpha^5-5\alpha+4\right)$
3		$\frac{11}{120}\frac{p\ell^4}{EI}$	0	$\frac{p\ell^4}{120EI}\left(-\alpha^5+5\alpha^4-15\alpha+11\right)$
4		$\frac{1}{3}\frac{P\ell^3}{EI}$	0	$\frac{P\ell^3}{6EI}\left(\alpha^3-3\alpha+2\right)$
5		$\frac{1}{2}\frac{M\ell^2}{EI}$	0	$\frac{M\ell^2}{2EI}\left(1-\alpha\right)^2$
6		$\frac{5}{384}\frac{p\ell^4}{EI}$	$0{,}5\ell$	$\frac{p\ell^4\alpha}{24EI}\left(\alpha^3-2\alpha^2+1\right)$
7		$\frac{3}{460}\frac{p\ell^4}{EI}$ (*)	$0{,}519\ell$	$\frac{p\ell^4\alpha}{360EI}\left(3\alpha^4-10\alpha^2+7\right)$
8		$\frac{1}{120}\frac{p\ell^4}{EI}$	$0{,}5\ell$	$\frac{p\ell^4\alpha}{960EI}\left(16\alpha^4-40\alpha^2+25\right)$ (**)
9		$\frac{1}{48}\frac{P\ell^3}{EI}$	$0{,}5\ell$	$\frac{P\ell^3\alpha}{48EI}\left(-4\alpha^2+3\right)$ (**)
10		$(a \geq b)$ $\frac{Pb}{3EI\ell}\sqrt{\left(\frac{\ell^2-b^2}{3}\right)^3}$	$\sqrt{\left(\frac{\ell^2-b^2}{3}\right)}$	$x<a:\ \frac{Pbx}{6EI\ell}\left(\ell^2-b^2-x^2\right)$ $x=a:\ \frac{Pa^2b^2}{3EI\ell}$ $x>a:\ \frac{Pa(\ell-x)}{6EI\ell}\left(2\ell x-a^2-x^2\right)$
11		$\frac{1}{9\sqrt{3}}\frac{M\ell^2}{EI}$	$0{,}423\ell$	$\frac{M\ell^2\alpha}{6EI}\left(\alpha^2-3\alpha+2\right)$
12		$(a \geq 0{,}423\ell)$ $\frac{M}{3EI\ell}\sqrt{\left(\frac{\ell^2}{3}-b^2\right)^3}$	$\sqrt{\left(\frac{\ell^2}{3}-b^2\right)}$	$x<a:\ \frac{Mx}{6EI\ell}\left(\ell^2-3b^2-x^2\right)$ $x>a:\ \frac{M(\ell-x)}{6EI}\left(x^2+3a^2-2\ell x\right)$

Extraída de ISNARD; GREKOW; MROZOWICZ (1971) e de SCHIEL (1976).
Revista e adaptada por Libânio M. Pinheiro, Bruna Catoia e Thiago Catoia.

$\alpha = x/\ell$ (*) Valor aproximado (**) $\alpha \leq 0{,}5$

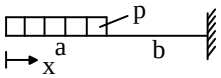
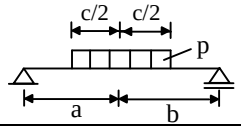
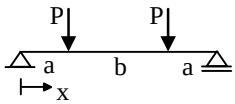
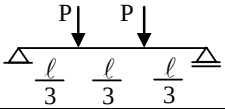
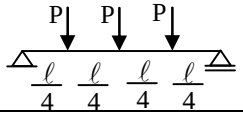
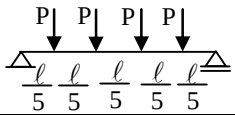
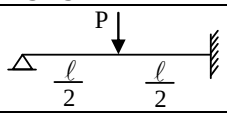
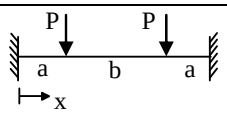
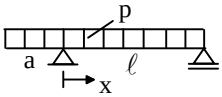
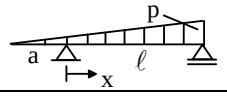
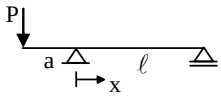
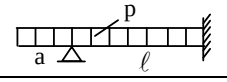
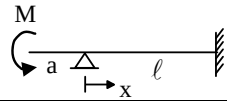
TABELA 3.1b

DESLOCAMENTOS ELÁSTICOS EM VIGAS

CASO	VINCULAÇÃO E CARREGAMENTO	FLECHA		EQUAÇÃO DA ELÁSTICA
		w_{max}	x	
13		$\frac{M\ell^2}{8EI}$	$0{,}5\ell$	$\frac{M\ell^2\alpha}{2EI}(1-\alpha)$
14		$\frac{3}{554}\frac{p\ell^4}{EI}$ (*)	$0{,}422\ell$	$\frac{p\ell^4}{48EI}(2\alpha^4-3\alpha^3+\alpha)$
15		$\frac{3}{1258}\frac{p\ell^4}{EI}$ (*)	$0{,}447\ell$	$\frac{p\ell^4}{120EI}(\alpha^5-2\alpha^3+\alpha)$
16		$\frac{1}{328}\frac{p\ell^4}{EI}$ (*)	$0{,}402\ell$	$\frac{p\ell^4}{240EI}(-2\alpha^5+10\alpha^4-11\alpha^3+3\alpha)$
17		$\frac{M\ell^2}{27EI}$	$\frac{1}{3}\ell$	$\frac{M\ell^2}{4EI}(\alpha^3-2\alpha^2+\alpha)$
18		$\frac{1}{384}\frac{p\ell^4}{EI}$	$0{,}5\ell$	$\frac{p\ell^4}{24EI}(\alpha^4-2\alpha^3+\alpha^2)$
19		$\frac{1}{764}\frac{p\ell^4}{EI}$ (*)	$0{,}525\ell$	$\frac{p\ell^4}{120EI}(\alpha^5-3\alpha^3+2\alpha^2)$
20		$\frac{7}{3840}\frac{p\ell^4}{EI}$	$0{,}5\ell$	$\frac{p\ell^4}{960EI}(16\alpha^5-40\alpha^3+25\alpha^2)$ (**)
21		$\frac{1}{192}\frac{P\ell^3}{EI}$	$0{,}5\ell$	$\frac{P\ell^3}{48EI}(-4\alpha^3+3\alpha^2)$ (**)
22		$\frac{pa}{24EI}(6a^2\ell+3a^3-\ell^3)$ $\frac{p\ell^2}{384EI}(5\ell^2-24a^2)$	$-a$ $0{,}5\ell$	$x<0$: $\frac{px}{24EI}(x^3+4ax^2+6a^2x+\ell^3-6a^2\ell)$ $0<x<\ell$: $\frac{px}{24EI}(x^3-2\ell x^2+6a^2x-6a^2\ell+\ell^3)$
23		$\frac{Pa^2}{6EI}(2a+3\ell)$ $-\frac{Pa\ell^2}{8EI}$	$-a$ $0{,}5\ell$	$x<0$: $\frac{Px}{6EI}(x^2+3ax-3a\ell)$ $0<x<\ell$: $\frac{Pa}{2EI}x(x-\ell)$

Extraída de ISNARD; GREKOW; MROZOWICZ (1971) e de SCHIEL (1976).
Revista e adaptada por Libânio M. Pinheiro, Bruna Catoia e Thiago Catoia.

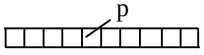
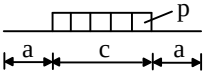
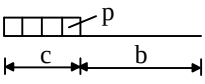
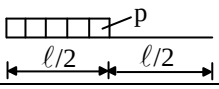
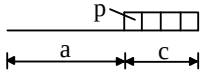
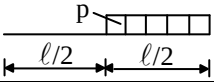
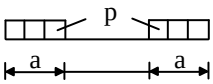
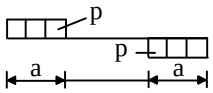
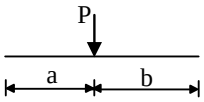
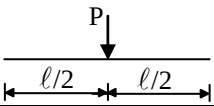
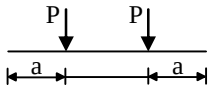
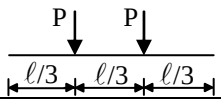
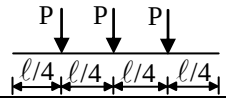
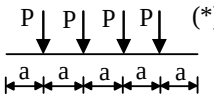
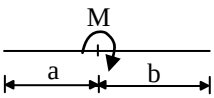
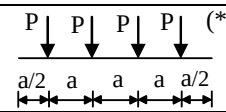
$\alpha = x/\ell$ (*) Valor aproximado (**) $\alpha \le 0{,}5$

TABELA 3.1c			
DESLOCAMENTOS ELÁSTICOS EM VIGAS			
CASO	**VINCULAÇÃO E CARREGAMENTO**	**FLECHA**	
		w_{max}	**x**
24		$\frac{p}{24EI}\left(3\ell^4 - 4b^3\ell + b^4\right)$	0
25		$\frac{pa}{120EI}\left(20\ell^3 - 10a\ell^2 + a^3\right)$	0
26		$\frac{pc}{6EI}\left[\frac{ab}{\ell}\left(2a\ell - 2a^2 - \frac{c^2}{4}\right)\right] + \frac{c^3}{64}$ (*)	a
27		$\frac{Pa}{24EI}\left(3\ell^2 - 4a^2\right)$	$0{,}5\ell$
28		$\frac{23}{648}\frac{P\ell^3}{EI}$	$0{,}5\ell$
29		$\frac{19}{384}\frac{P\ell^3}{EI}$	$0{,}5\ell$
30		$\frac{63}{1000}\frac{P\ell^3}{EI}$	$0{,}5\ell$
31		$\frac{\sqrt{5}}{240}\frac{P\ell^3}{EI}$	$0{,}447\ell$
32		$\frac{1}{24}\frac{Pa^2b}{EI}$	$0{,}5\ell$
33		$\frac{pa}{24EI}\left(3a^3 + 4a^2\ell - \ell^3\right)$	$-a$
34		$\frac{p\ell}{360EI(a+\ell)}\left(20a^4 - 15a^2\ell^2 - 7a\ell^3 + 12\right)$	$-a$
35		$\frac{Pa^2}{3EI}(a+\ell)$	$-a$
36		$\frac{pa}{48EI}\left(6a^3 + 6a^2\ell - \ell^3\right)$	$-a$
37		$\frac{Pa^2}{6EI}(4a+3)$	$-a$
38		$\frac{Ma}{4EI}(\ell + 2a)$	$-a$

Extraída de ISNARD; GREKOW; MROZOWICZ (1971).
Revista e adaptada por Libânio M. Pinheiro, Bruna Catoia e Thiago Catoia.
(*) Não corresponde necessariamente ao deslocamento máximo

TABELA 3.2a

MOMENTOS DE ENGASTAMENTO PERFEITO

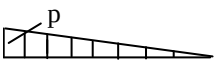
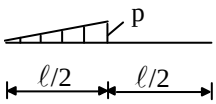
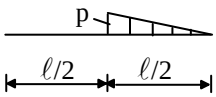
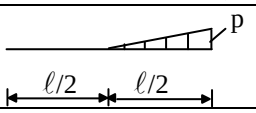
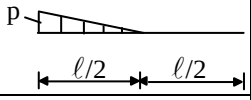
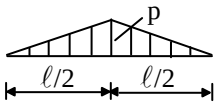
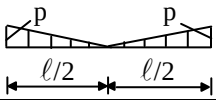
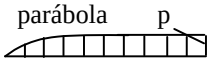
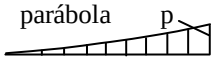
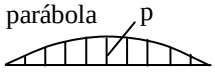
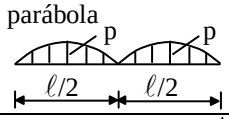
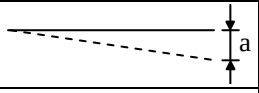
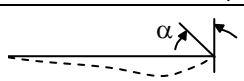
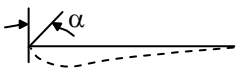
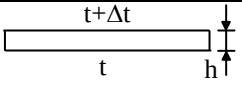
	CARREGAMENTO	A ℓ B	C ℓ D		E ℓ F
		M_{BA}	M_{CD}	M_{DC}	M_{EF}
1		$-\frac{p\ell^2}{8}$	$\frac{p\ell^2}{12}$	$-\frac{p\ell^2}{12}$	$\frac{p\ell^2}{8}$
2		$-\frac{pc}{16\ell}\left(3\ell^2-c^2\right)$	$\frac{pc}{24\ell}\left(3\ell^2-c^2\right)$	$-\frac{pc}{24\ell}\left(3\ell^2-c^2\right)$	$\frac{pc}{16\ell}\left(3\ell^2-c^2\right)$
3		$-\frac{pc^2}{8\ell^2}\left(2\ell^2-c^2\right)$	$\frac{pc^2}{12\ell^2}\left(6b^2+4bc+c^2\right)$	$-\frac{pc^2}{12\ell^2}\left(4bc+c^2\right)$	$\frac{pc^2}{8\ell^2}(\ell+b)^2$
4		$-\frac{7}{128}p\ell^2$	$\frac{11}{192}p\ell^2$	$-\frac{5}{192}p\ell^2$	$\frac{9}{128}p\ell^2$
5		$-\frac{pc^2}{8\ell^2}(\ell+a)^2$	$\frac{pc^2}{12\ell^2}\left(4ac+c^2\right)$	$-\frac{pc^2}{12\ell^2}\left(6a^2+4ac+c^2\right)$	$\frac{pc^2}{8\ell^2}\left(2\ell^2-c^2\right)$
6		$-\frac{9}{128}p\ell^2$	$\frac{5}{192}p\ell^2$	$-\frac{11}{192}p\ell^2$	$\frac{7}{128}p\ell^2$
7		$-\frac{pa^2}{4\ell}(3\ell-2a)$	$\frac{pa^2}{6\ell}(3\ell-2a)$	$-\frac{pa^2}{6\ell}(3\ell-2a)$	$\frac{pa^2}{4\ell}(3\ell-2a)$
8		$-\frac{pa^2}{4\ell}(3\ell-2a)$	$\frac{pa^2}{2\ell^2}(\ell-a)^2$	$-\frac{pa^2}{2\ell^2}(\ell-a)^2$	$\frac{pa^2}{4\ell}(3\ell-2a)$
9		$-\frac{Pab}{2\ell^2}(\ell+a)$	$\frac{Pab^2}{\ell^2}$	$-\frac{Pa^2b}{\ell^2}$	$\frac{Pab}{2\ell^2}(\ell+b)$
10		$-\frac{3P\ell}{16}$	$\frac{P\ell}{8}$	$-\frac{P\ell}{8}$	$\frac{3P\ell}{16}$
11		$-\frac{3Pa}{2\ell}(\ell-a)$	$\frac{Pa}{\ell}(\ell-a)$	$-\frac{Pa}{\ell}(\ell-a)$	$\frac{3Pa}{2\ell}(\ell-a)$
12		$-\frac{P\ell}{3}$	$\frac{2P\ell}{9}$	$-\frac{2P\ell}{9}$	$\frac{P\ell}{3}$
13		$-\frac{15P\ell}{32}$	$\frac{5P\ell}{16}$	$-\frac{5P\ell}{16}$	$\frac{15P\ell}{32}$
14	 (*)	$-\frac{P\ell}{8n}\left(n^2-1\right)$	$\frac{P\ell}{12n}\left(n^2-1\right)$	$-\frac{P\ell}{12n}\left(n^2-1\right)$	$\frac{P\ell}{8n}\left(n^2-1\right)$
15		$-\frac{M}{2\ell^2}\left(\ell^2-3a^2\right)$	$\frac{Mb}{\ell^2}(3b-2\ell)$	$-\frac{Ma}{\ell^2}(2\ell-3a)$	$\frac{M}{2\ell^2}\left(3b^2-\ell^2\right)$
16	 (*)	$-\frac{P\ell}{16n}\left(2n^2+1\right)$	$\frac{P\ell}{24n}\left(2n^2+1\right)$	$-\frac{P\ell}{24n}\left(2n^2+1\right)$	$\frac{P\ell}{16n}\left(2n^2+1\right)$

Extraída de SOUZA; ANTUNES (1983), JIMENES MONTOYA; GARCIA MESEGUER; MORAN CABRE (1973) e de SCHREYER (1965). Convenção de GRINTER. (*) $n = \ell / a$

Revista e adaptada por Libânio M. Pinheiro, Bruna Catoia e Thiago Catoia.

TABELA 3.2b

MOMENTOS DE ENGASTAMENTO PERFEITO

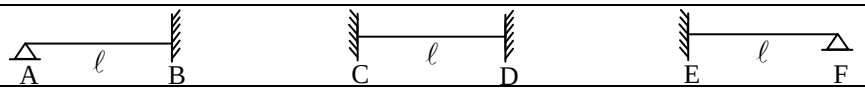
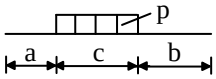
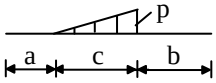
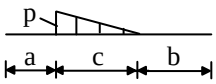
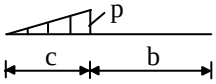
	CARREGAMENTO	A ℓ B M_{BA}	C ℓ D M_{CD}	 M_{DC}	E ℓ F M_{EF}
17		$-\frac{p\ell^2}{15}$	$\frac{p\ell^2}{30}$	$-\frac{p\ell^2}{20}$	$\frac{7p\ell^2}{120}$
18		$-\frac{7p\ell^2}{120}$	$\frac{p\ell^2}{20}$	$-\frac{p\ell^2}{30}$	$\frac{p\ell^2}{15}$
19		$-\frac{17}{480}p\ell^2$	$\frac{p\ell^2}{30}$	$-\frac{3}{160}p\ell^2$	$\frac{41}{960}p\ell^2$
20		$-\frac{41}{960}p\ell^2$	$\frac{3}{160}p\ell^2$	$-\frac{p\ell^2}{30}$	$\frac{17}{480}p\ell^2$
21		$-\frac{53}{1920}p\ell^2$	$\frac{7}{960}p\ell^2$	$-\frac{23}{960}p\ell^2$	$\frac{37}{1920}p\ell^2$
22		$-\frac{37}{1920}p\ell^2$	$\frac{23}{960}p\ell^2$	$-\frac{7}{960}p\ell^2$	$\frac{53}{1920}p\ell^2$
23		$-\frac{5}{64}p\ell^2$	$\frac{5}{96}p\ell^2$	$-\frac{5}{96}p\ell^2$	$\frac{5}{64}p\ell^2$
24		$-\frac{3}{64}p\ell^2$	$\frac{p\ell^2}{32}$	$-\frac{p\ell^2}{32}$	$\frac{3}{64}p\ell^2$
25		$-\frac{11}{120}p\ell^2$	$\frac{p\ell^2}{20}$	$-\frac{p\ell^2}{15}$	$\frac{p\ell^2}{12}$
26		$-\frac{p\ell^2}{24}$	$\frac{p\ell^2}{60}$	$-\frac{p\ell^2}{30}$	$\frac{p\ell^2}{30}$
27		$-\frac{p\ell^2}{10}$	$\frac{p\ell^2}{15}$	$-\frac{p\ell^2}{15}$	$\frac{p\ell^2}{10}$
28		$-\frac{7}{80}p\ell^2$	$\frac{7}{120}p\ell^2$	$-\frac{7}{120}p\ell^2$	$\frac{7}{80}p\ell^2$
29		$+\frac{3a}{\ell^2}EI$	$+\frac{6a}{\ell^2}EI$	$+\frac{6a}{\ell^2}EI$	$+\frac{3a}{\ell^2}EI$
30		$+\frac{3\alpha}{\ell}EI$	$+\frac{2\alpha}{\ell}EI$	$+\frac{4\alpha}{\ell}EI$	---
31		---	$-\frac{4\alpha}{\ell}EI$	$-\frac{2\alpha}{\ell}EI$	$-\frac{3\alpha}{\ell}EI$
32		$+\frac{3EI}{2h}\alpha_t\Delta t$	$-\frac{EI}{h}\alpha_t\Delta t$	$+\frac{EI}{h}\alpha_t\Delta t$	$-\frac{3EI}{2h}\alpha_t\Delta t$

Extraída de SOUZA; ANTUNES (1983), JIMENES MONTOYA; GARCIA MESEGUER; MORAN CABRE (1973) e de SCHREYER (1965). Convenção de GRINTER.

Revista e adaptada por Libânio M. Pinheiro, Bruna Catoia e Thiago Catoia.

TABELA 3.2c

MOMENTOS DE ENGASTAMENTO PERFEITO

CARREGAMENTO		
33		$M_{BA} = -\frac{p}{8\ell^2}\left[a^4 - (a+c)^4 + 2c\ell^2(2a+c)\right]$
		$M_{CD} = \frac{p}{12\ell^2}\left\{4\ell\left[(b+c)^3 - b^3\right] - 3\left[(b+c)^4 - b^4\right]\right\}$
		$M_{DC} = -\frac{p}{12\ell^2}\left\{4\ell\left[(a+c)^3 - a^3\right] - 3\left[(a+c)^4 - a^4\right]\right\}$
		$M_{EF} = \frac{p}{8\ell^2}\left[b^4 - (b+c)^4 + 2c\ell^2(2b+c)\right]$
34		$M_{BA} = -\frac{pc}{108\ell^2}(3a+2c)\left[9(\ell^2 - a^2) - 12ac - c^2\left(4 + \frac{45a+28c}{30a+20c}\right)\right]$
		$M_{CD} = \frac{pc}{540\ell^2}\left[10(3b+c)^2(3a+2c) - 15c^2(3b-\ell) - 17c^3\right]$
		$M_{DC} = -\frac{pc}{540\ell^2}\left[10(3b+c)(3a+2c)^2 - 15c^2(3a-\ell) - 28c^3\right]$
		$M_{EF} = \frac{pc}{108\ell^2}(3b+c)\left[9(\ell^2 - b^2) - 6bc - c^2\left(1 + 9\frac{45b+17c}{270b+90c}\right)\right]$
35		$M_{BA} = -\frac{pc}{108\ell^2}(3a+c)\left[9(\ell^2 - a^2) - 6ac - c^2\left(1 + 9\frac{45a+17c}{270a+90c}\right)\right]$
		$M_{CD} = \frac{pc}{540\ell^2}\left[10(3a+c)(3b+2c)^2 - 15c^2(3b-\ell) - 28c^3\right]$
		$M_{DC} = -\frac{pc}{540\ell^2}\left[10(3a+c)^2(3b+2c) - 15c^2(3a-\ell) - 17c^3\right]$
		$M_{EF} = \frac{pc}{108\ell^2}(3b+2c)\left[9(\ell^2 - b^2) - 12bc - c^2\left(4 + \frac{45b+28c}{30b+20c}\right)\right]$
36		$M_{BA} = -\frac{p}{30\ell^2}c^2(5\ell^2 - 3c^2)$
		$M_{CD} = \frac{p}{30\ell^2}c^2(10\ell^2 - 15c\ell + 6c^2)$
		$M_{DC} = -\frac{p}{20\ell^2}c^2(5c\ell - 4c^2)$
		$M_{EF} = \frac{p}{120\ell^2}c^2(40\ell^2 - 45c\ell + 12c^2)$

Extraída de SCHREYER (1965). Convenção de GRINTER.
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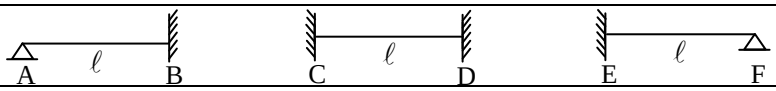
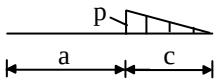
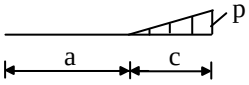
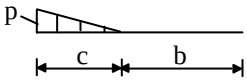
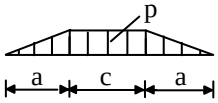
TABELA 3.2d		
MOMENTOS DE ENGASTAMENTO PERFEITO		
CARREGAMENTO		
37		$M_{BA} = -\frac{p}{120\ell^2}c^2\left(40\ell^2 - 45c\ell + 12c^2\right)$
		$M_{CD} = \frac{p}{20\ell^2}c^2\left(5c\ell - 4c^2\right)$
		$M_{DC} = -\frac{p}{30\ell^2}c^2\left(10\ell^2 - 15c\ell + 6c^2\right)$
		$M_{EF} = \frac{p}{30\ell^2}c^2\left(5\ell^2 - 3c^2\right)$
38		$M_{BA} = -\frac{p}{120\ell^2}c^2\left(20\ell^2 - 15c\ell + 3c^2\right)$
		$M_{CD} = \frac{p}{60\ell^2}c^2\left(5c\ell - 3c^2\right)$
		$M_{DC} = -\frac{p}{60\ell^2}c^2\left(10a\ell + 3c^2\right)$
		$M_{EF} = \frac{p}{120\ell^2}c^2\left(10\ell^2 - 3c^2\right)$
39		$M_{BA} = -\frac{p}{120\ell^2}c^2\left(10\ell^2 - 3c^2\right)$
		$M_{CD} = \frac{p}{60\ell^2}c^2\left(10b\ell + 3c^2\right)$
		$M_{DC} = -\frac{p}{60\ell^2}c^2\left(5c\ell - 3c^2\right)$
		$M_{EF} = \frac{p}{120\ell^2}\left(20\ell^2 - 15c\ell + 3c^2\right)$
40		$M_{BA} = -\frac{p}{8\ell}\left(\ell^3 - 2a^2\ell + a^3\right)$
		$M_{CD} = \frac{p}{12\ell}\left(\ell^3 - 2a^2\ell + a^3\right)$
		$M_{DC} = -\frac{p}{12\ell}\left(\ell^3 - 2a^2\ell + a^3\right)$
		$M_{EF} = \frac{p}{8\ell}\left(\ell^3 - 2a^2\ell + a^3\right)$
Extraída de SCHREYER (1965). Convenção de GRINTER. Revista e adaptada por Libânio M. Pinheiro, Bruna Catoia e Thiago Catoia.		

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