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TASK 3. TWO-WAY SLAB SUPPORTED BY COLUMNS (FLAT SLAB)

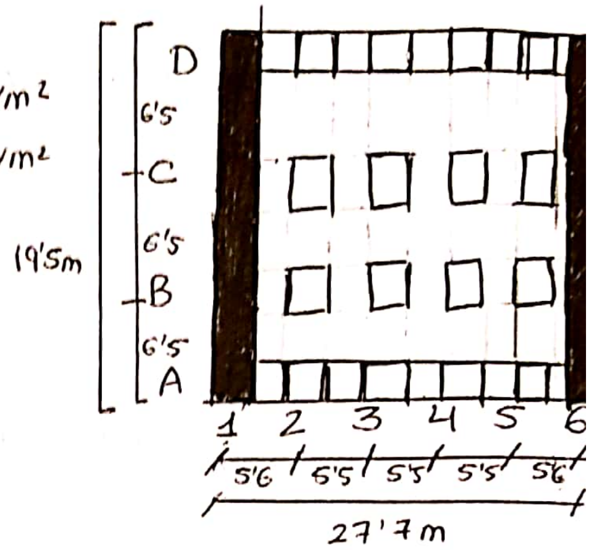
- DATA -

$a = 5'6\,m$
$b = 5'5\,m$
$d = 6'5\,m$

- Loads -
$(g-g_0)_{floor,k} = 1'1\,KN/m^2$
$q_{floor,k} = 2'9\,KN/m^2$

- Material -
C 25/30
B500

weight of concrete = 25 KN/m³
Thickness of the wall = 250 mm



1. PRELIMINARY DESING OF DIMENSIONS OF LOAD-BEARING ELEMENTS

1.1. DEPTH OF THE SLAB hs

- $l_{n,max} = 6'5\,m$ (the longest clear span)
- $c = 20\,mm$ (from Task 1)
- $\phi = 10\,mm$ (estimate)

$$h_s = \frac{1}{33} \cdot l_{n,max} = \frac{1}{33} \cdot 6'5\,m = 0'196\,m = 196\,mm$$

$$d = h_s - c - \frac{\phi}{2} = 196 - 20 - \frac{10}{2} = 171\,mm$$

But, we are not designing for $h_s < 200\,mm$, so I will take $h_s = 200\,mm$

$$d = 200 - 20 - 10/2 = 175\,mm$$

DEFLECTION CONTROL

l = longer of the axial spans.
$K_{c1} = 1$ (Effect of shape)
$K_{c2} = 1$ (Effect span)
$K_{c3} = 1'2$ (Effect reinforcemt)

$$\lambda = \frac{l}{d} \leq \lambda_{lim} = K_{c1} \cdot K_{c2} \cdot K_{c3} \cdot \lambda_{d,tab}$$

For C 25/30 and $\rho = 0'5\% \rightarrow \lambda_{d,tab} = 22'2$

ρ %	Concrete class						
	12/15	16/20	20/25	25/30	30/37	40/50	50/60
0,5	17,5	19,0	20,4	22,2	24,6	30,9	38,4
1,5	14,6	15,1	15,6	16,2	16,8	18,0	19,2

$\lambda = \frac{6'5}{0'175} = 37'15 \not\leq 1'2 \cdot 22'2 = 26'64$

So, I will try with $h_s = 300$ mm
$d = 275$ mm

$\lambda = \frac{6'5}{0'275} = 23'6 \leq \lambda_{lim} = 26'64$ ✓

1.2. LOADS

PERMANENT	K-value [KN/m²]	γ	d-value [KN/m²]
self-weight $25\frac{KN}{m^3} \cdot 0'3$ m	7'5	1'35	10'13
$(g-g_0)_{floor,K}$	1'1	1'35	1'485
VARIABLE			
$q_{floor,K}$	2'9	1'5	4'35
	11'5 KN/m²		15'97 KN/m²

So, my $f_d = 15'97$ KN/m²

1.3. DESING OF THE COLUMN

Tributing area $= 6'5 \times 5'55 = 36$ m²

Therefore, the load of the slab:

I will take into consideration the number of floors. From TASK 1 → $n = 7$.

$7 \cdot 36 m^2 \cdot 15'97 \,KN/m^2 = 4024'4$ KN
$+ \quad 25$ KN → weight of the column

$N_{Ed} \simeq 4050$ KN

$A_c \geq \frac{N_{Ed}}{0'8 \cdot f_{cd} + 0'02 \sigma_s} = \frac{4050}{0'8 \cdot 16'67e^3 + 0'02 \cdot 400e^3} = 0'121$ m² (minimum area)

$A_s = 0'02 \cdot A_c$

$N_{Rd} = 0'8 \cdot A_c \cdot f_{cd} + 0'02 \cdot A_c \sigma_s \geq N_{Ed}$

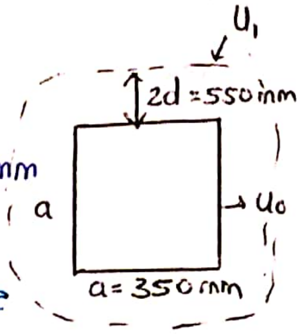
$N_{Rd} = 0'8 \cdot 0'12 \cdot 16'67e^3 + 0'12 \cdot 0'021 \cdot 400e^3$

$N_{Rd} = 2560$ KN

So, the dimensions of the column:

350×350 mm ($A = 0'1225 m^2$)

1.4. PRELIMINARY CHECK OF PUNCHING



$u_0 = 4 \cdot a = 4 \cdot 350\text{mm} = 1400$ mm

$u_1 = 4a + 2\pi \cdot 2d = 4 \cdot 350 + 2\pi \cdot 2 \cdot 275 = 4855'8$ mm

1.4.1. Maximum punching shear resistance

$\beta = 1'15$ (coeff refer. to position of the column)

$$V_{Ed,0} = \frac{\beta \cdot V_{Ed}}{u_0 \cdot d} \leq V_{Rd,max} = 0'4\left[0'6 \cdot \left(1 - \frac{f_{ck}}{250}\right)\right] f_{cd}$$

$$V_{Ed} = f_d \cdot A_T = 36\ m^2 \cdot 15'97 = 574'9 \simeq 575\ KN$$

$$V_{Ed,0} = \frac{1'15 \cdot 575}{1'4 \cdot 0'275} = 1717'5\ KN/m^2$$

$$V_{Rd,max} = 0'4\left[0'6\left(1 - \frac{25}{250}\right)\right] \cdot 16'67e^3 = 3600'7\ KN/m^2$$

$$1717'5 = V_{Ed,0} \leq V_{Rd,max} = 3600'7\ KN/m^2\ ✓$$

1.4.2. Maximum resistance with reinforcement

- where $K_{max} = 1'8$ for double-headed studs connected to a spacer bar.
- $C_{Rd,c} = 0'12$ (Reduction factor)
- $\hat{\rho}_l = 0'005$ (estimated)

$$V_{Ed,1} = \frac{\beta \cdot V_{Ed}}{u_1 \cdot d} \leq K_{max} \cdot C_{Rd,c} \cdot K \cdot \sqrt[3]{(100\rho_l \cdot f_{ck})}$$

$$K = 1 + \sqrt{\frac{200}{d}} \leq 2\ ;\ K = 1 + \sqrt{\frac{200}{275}} = 1'85$$

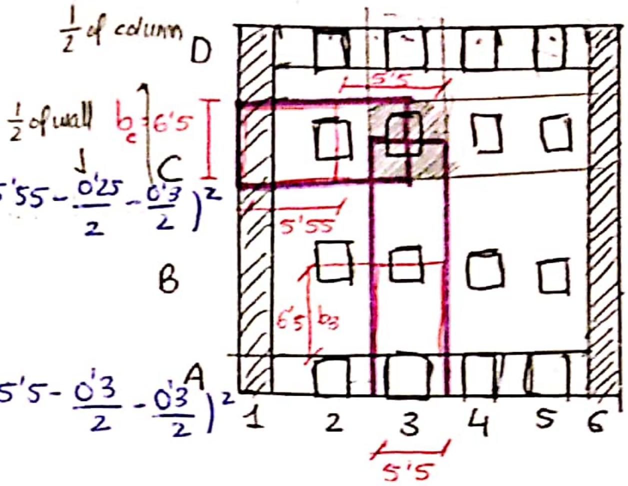
$$1'8 \cdot 0'12 \cdot 1'85 \cdot \sqrt[3]{(100 \cdot 0'005) \cdot 25(MPa)} = 0'927\ MPa$$

$$V_{Ed,1} = \frac{1'15 \cdot 575}{4855'8 \cdot 275} = 0'495\ MPa$$

$$V_{Ed,1} = 0'495 \leq 0'927 = K_{max} \cdot V_{Rd,c}\ ✓$$

2. CALCULATION OF BENDING MOMENTS (DDM)

STEP 1. TOTAL MOMENTS



$$M_{TOT} = \frac{1}{8} fd \cdot b \cdot L_n^2$$

Panel Couts : $M_{TOT} = \frac{1}{8} \cdot 15'97 \cdot 6'5 \cdot \left(5'55 - \frac{0'25}{2} - \frac{0'3}{2}\right)^2$

$M_{TOT} = 360'4$ KN·m

Panel Cinsd : $M_{TOT} = \frac{1}{8} \cdot 15'97 \cdot 6'5 \left(5'5 - \frac{0'3}{2} - \frac{0'3}{2}\right)^2$

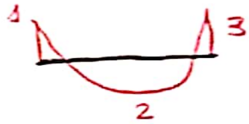
$M_{TOT} = 350'2$ KN·m

Panel 3out : $M_{TOT} = \frac{1}{8} \cdot 15'97 \cdot 5'5 \cdot \left(6'5 - \frac{0'3}{2} - \frac{0'3}{2}\right)^2$

$M_{TOT} = 421'25$ KN·m

Panel 3insd : $M_{TOT} = 421'25$ KN·m (same as 3out)

STEP 2. POSITIVE AND NEGATIVE MOMENTS



negative = support
positive = midspan

Panel Cout

γ_{Cout} coefficients for outer panel supported by wall.

$M_1 = \gamma_1 \cdot M_{TOT} = 0'65 \cdot 360'4$ KN·m $= 234'3$ KN·m
$M_2 = \gamma_2 \cdot M_{TOT} = 0'35 \cdot 360'4$ KN·m $= 126'14$ KN·m
$M_3 = \gamma_3 \cdot M_{TOT} = 0'65 \cdot 360'4$ KN·m $= 234'3$ KN·m

Panel Cinsd

γ_{Cinsd} coefficients for inner panel

$M_1 = 0'65 \cdot 350'2 = 227'6$ KN·m
$M_2 = 0'35 \cdot 350'2 = 122'57$ KN·m
$M_3 = 0'65 \cdot 350'2 = 227'6$ KN·m

Panel 3out

γ_{3out} coeff for outter panel with edge beam

$M_1 = 0'3 \cdot 421'25 = 126'4$ KN·m
$M_2 = 0'5 \cdot 421'25 = 210'6$ KN·m
$M_3 = 0'7 \cdot 421'25 = 294'87$ KN·m

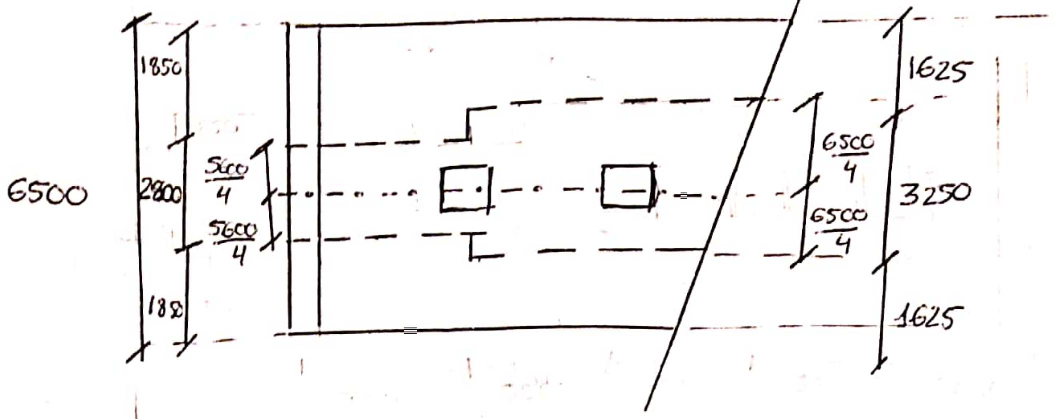
Panel 3in ·

γ_{3in} coefficients for inner panel.

$M_1 = 0'65 \cdot 421'25 = 273'8$ KN·m
$M_2 = 0'35 \cdot 421'25 = 147'4$ KN·m
$M_3 = 0'65 \cdot 421'25 = 273'8$ KN·m

STEP 3: COLUMN AND MIDDLE STRIPS

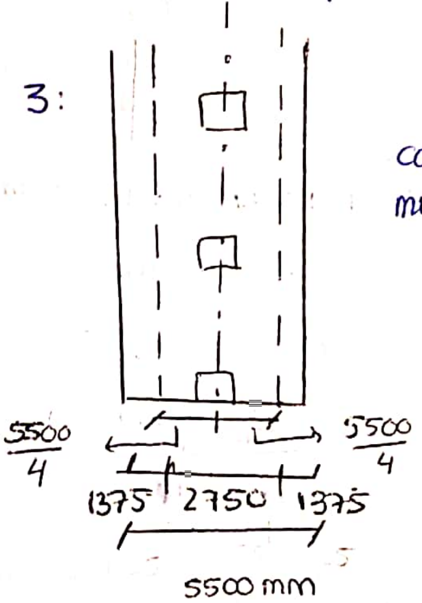
BELT C:



Panel Cout: column strip 2800 mm; middle strip 3700 mm

Panel Cins: column strip 3250 mm; middle strip 3250 mm

BELT 3:



For panels 3out and 3in:

column strip 2750 mm

middle strip 2750 mm

STEP 5. RIGIDITY OF EDGE BEAM

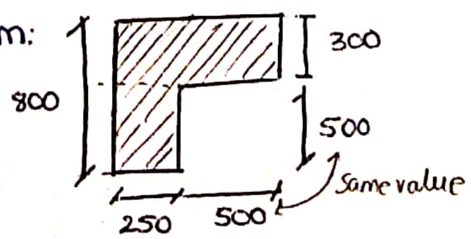
The moment of inertia of the slab in belt 3:

b = width of belt 3 =

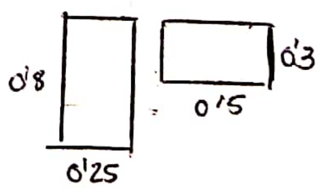
= 5500 mm

$$I_s = \frac{1}{12} \cdot b \cdot h_s^3 = \frac{1}{12} \cdot 5'5 \cdot 0'3^3 = 12'3\, e^{-3}\ m^4$$

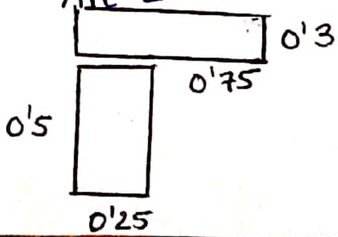
Beam:



Alt 1.



Alt 2.



$$I_t = \sum_{i=1}^{2} \left(1 - 0'63 \frac{t_i}{a_i}\right) \frac{t_i^3 \cdot a_i}{3}$$

$$I_{t1} = \left(1 - 0'63 \cdot \frac{0'25}{0'8}\right) \cdot \frac{0'25^3 \cdot 0'8}{3} + \left(1 - 0'63 \cdot \frac{0'3}{0'5}\right) \cdot \frac{0'3^3 \cdot 0'5}{3}$$

$$I_{t1} = 6'15 e^{-3} \ m^4$$

$$I_{t2} = \left(1 - 0'63 \cdot \frac{0'25}{0'5}\right) \cdot \frac{0'25^3 \cdot 0'5}{3} + \left(1 - 0'63 \cdot \frac{0'3}{0'75}\right) \cdot \frac{0'3^3 \cdot 0'75}{3}$$

$$I_{t2} = 6'8 e^{-3} \ m^4$$

We need the higher value, so : $I_t = 6'8 e^{-3} m^4$

Therefore, the rigidity coefficient of edge beam is:

$$\beta_t = \frac{I_t}{2 I_s} = \frac{6'8 e^{-3}}{2 \cdot 12'3 e^{-3}} = 0'27$$

CALCULATION OF MOMENTS : in column and middle strips

- The moment in COLUMN STRIP is:

$$M_j = u \cdot M_i$$

- And in the MIDDLE strip is:

$$M_j = (1 - u) \cdot M_i$$

- Moments per 1m of the slab are: $m_j = \frac{M_j}{S_j}$

- Values of u coefficients for negative moment on the edge with edge beam, we receive by interpolation:

$\beta_t = 0$ .... $1 = u$

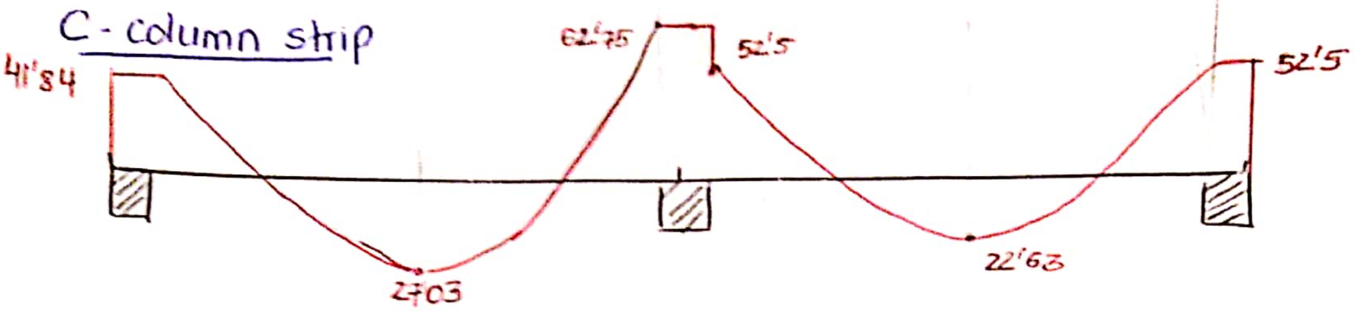
$\beta_t = 0'27$ ... $0'973 = u$

$\beta_t = 2'5$ ... $0'75 = u$

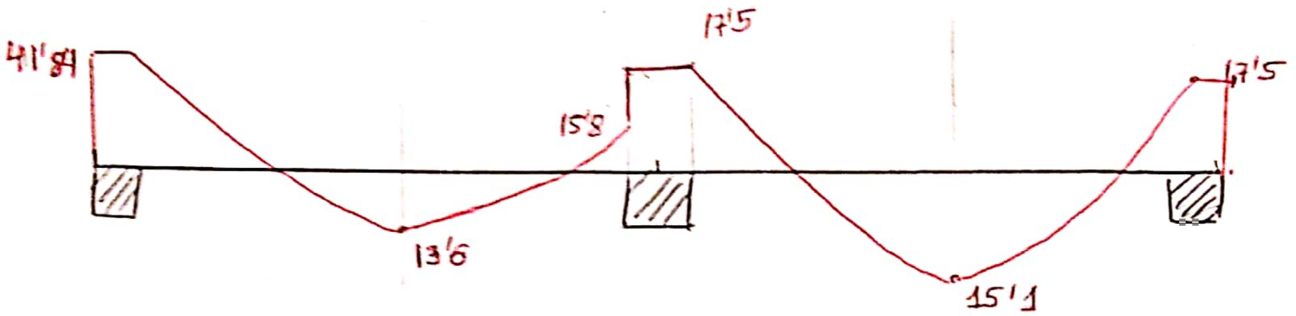
$$\frac{2'5 - 0'27}{2'5 - 0} = \frac{0'75 - u}{0'75 - 1}$$

MOMENT CURVES

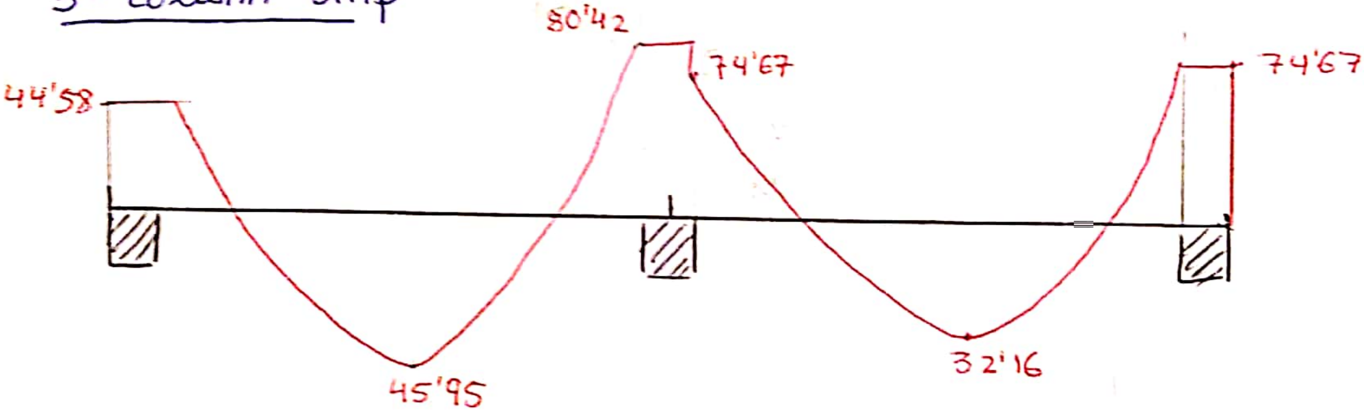
C - column strip



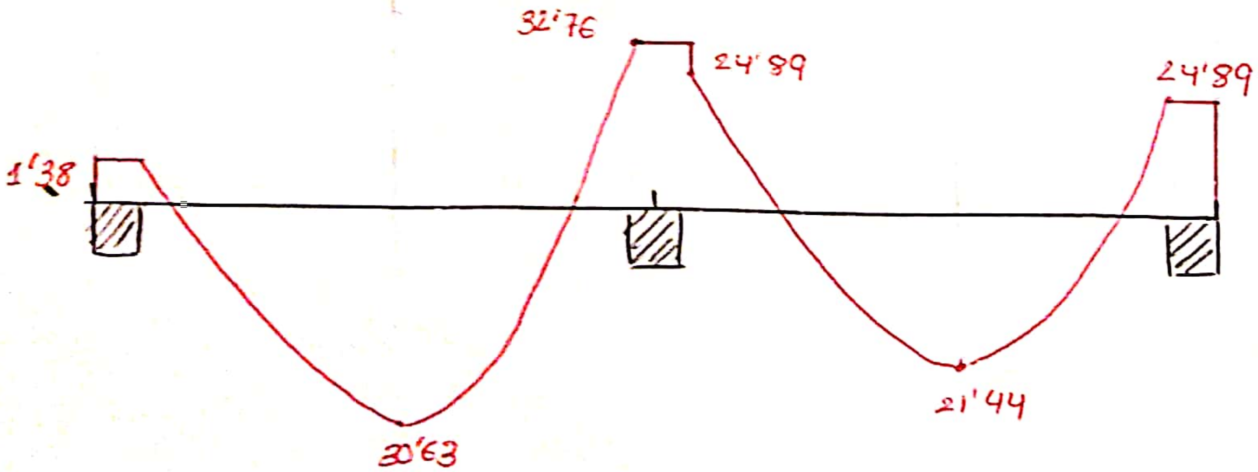
C - middle strip



3 - column strip



3 - middle strip



Moments in column and middle strips							
Panel	**Cross-section**	**Positive/negative moment Mi [kNm]**	**Strip**	**ω**	**Moment in column/middle strip Mj [kNm]**	**Width of the strip sj [m]**	**Moment per 1 m of the slab mj [kNm/m]**
Cout	1 (left support)	234,3	no division	1	234,3	5,6	41,84
	2 (midspan)	126,14	Column	0,6	75,684	2,8	27,03
			Middle		50,456	3,7	13,64
	3 (right support)	234,3	Column	0,75	175,725	2,8	62,76
			Middle		58,575	3,7	15,83
Cin	1 (left support)	227,6	Column	0,75	170,7	3,25	52,52
			Middle		56,9	3,25	17,51
	2 (midspan)	122,57	Column	0,6	73,542	3,25	22,63
			Middle		49,028	3,25	15,09
	3 (right support)	227,6	Column	0,75	170,7	3,25	52,52
			Middle		56,9	3,25	17,51
3out	1 (left support)	126,4	Column	0,97	122,608	2,75	44,58
			Middle		3,792	2,75	1,38
	2 (midspan)	210,6	Column	0,6	126,36	2,75	45,95
			Middle		84,24	2,75	30,63
	3 (right support)	294,87	Column	0,75	221,1525	2,75	80,42
			Middle		73,7175	2,25	32,76
3in	1 (left support)	273,8	Column	0,75	205,35	2,75	74,67
			Middle		68,45	2,75	24,89
	2 (midspan)	147,4	Column	0,6	88,44	2,75	32,16
			Middle		58,96	2,75	21,44
	3 (right support)	273,8	Column	0,75	205,35	2,75	74,67
			Middle		68,45	2,75	24,89