technologies for the construction industry

Shearail®

Design Manual to BS8110
(BS 8110-1:1997 *Amendments Nos. 1,2 & 3*)

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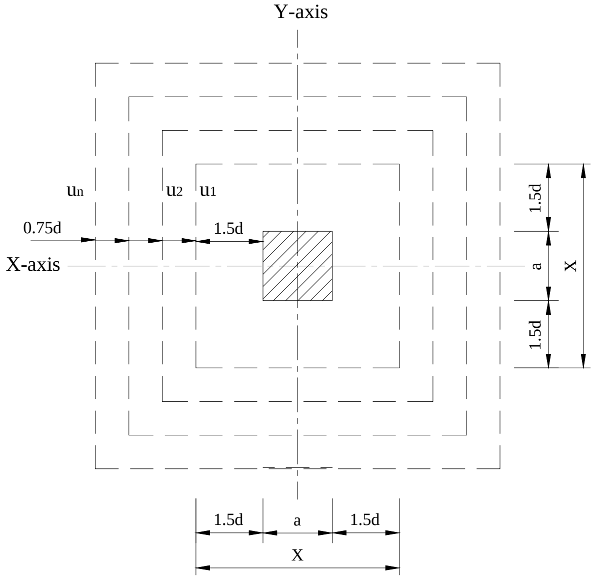
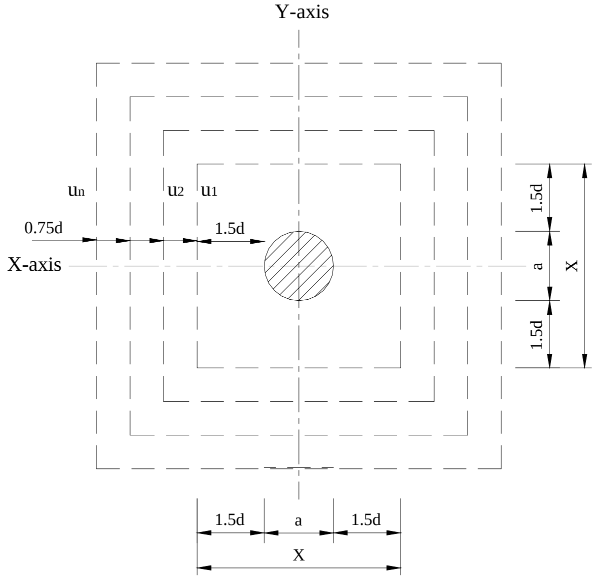
Contents

Symbols	*Units*	*Description*
a	*mm*	*Width of column or pile.*
A_{sv}	*mm^2/m*	*Area of shear reinforcement.*
b	*mm*	*Breadth of column or pile.*
c	*mm*	*Dimension to edge of slab from face of column or pile (see diagrams).*
d	*mm*	*Effective depth.*
h	*mm*	*Overall slab depth.*
e	*mm*	*Dimension to edge of slab from face of column or pile (see diagrams).*
f_{cu}	*N/mm^2*	*Characteristic strength of concrete.*
f_{yv}	*N/mm^2*	*Characteristic strength of shear reinforcement. (not to be taken more than 500 N/mm^2)*
M_t	*kN/m*	*Design moment transferred between slab and column at the connection.*
u_0	*mm*	*Effective length of the perimeter which touches a loaded area.*
u_1 ,$u_{2....}$	*mm*	*Effective length of the perimeter.*
u_n	*mm*	*The effective perimeter where $v<=v_c$*
v	*N/mm^2*	*Design shear stress.*
v_c	*N/mm^2*	*Design concrete shear stress.*
V_{eff}	*kN*	*Design effective shear including allowance for moment transfer.*
V_t	*kN*	*Design shear transferred to column*
X	*mm*	*The length of the side of the perimeter considered parallel to axis of bending.*
		Note. X is always taken as the length of the side of u_1 at 1.5d from the column or pile face for each perimeter. When calculating the direct shear with a moment at the column or pile face, X can be calculated as the length of the side of u_0 as worst case, but it is normal practice to use 1.5d as stated.

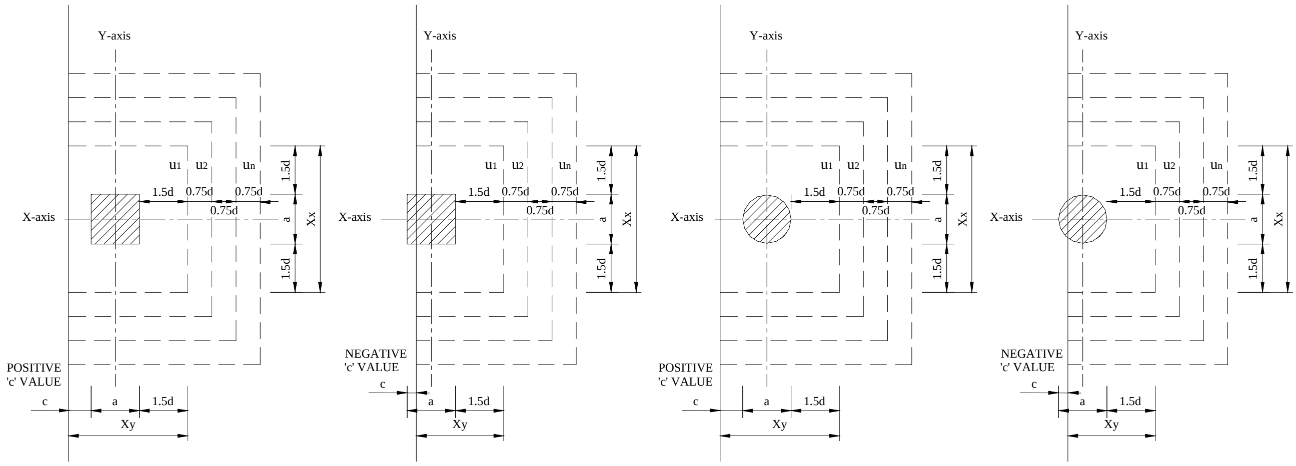
Square/Circular Loaded Areas - INTERNAL





Reference to BS8110 part1	$d = h$ – top cover – T1 Bars size / 2 – T2 Bars size / 2(average in both directions)
Figure 3.14	$X = a + (2 \times 1.5d)$ (required only when there is a moment in the slab)
3.7.7.2	$u_0 = 4a$ (Square column/pile) or $a\pi$ (Circular column/pile)
Figure 3.15	$V_{eff} = 1.15V_t$ (direct shear) or $V_{eff} = V_t\,(1 + 1.5M_t / (V_t \times X))$ (moment present)
Design at face	$v = V_{eff} / (u_0 \times d)$
Equation 27	Check v is not greater than $0.8 \times \sqrt{f_{cu}}$ or 5 N/mm ²
3.7.6.4 & 3.7.7.2	f_{cu} should not to be taken greater than 40 N/mm ²
Design at Perimeters	Design each perimeter u_1, u_2, …u_n - starting 1.5d from the column/pile face and at 0.75d thereafter until v_c is greater than or equal to v.
3.7.7.3	$u_1 = ((1.5d \times 2) + a) \times 4$ ….$u_2 = ((2.25d \times 2) + a) \times 4$ …… $u_3 = ((3d \times 2) + a) \times 4$ ..& so on
Table 3.8	$100A_s / (1000 \times d)$ Not to be taken more than 3
	$400 / d$ Not to be taken less than 1
	$v_c = 0.79 \times (((100A_s / (1000 \times d))^{1/3} \times (400 / d)^{1/4}) / 1.25) \times (f_{cu}/25)^{1/3}$
Equation 28	$v = V_{eff} / (u_1 \times d)$
3.7.7.4	$v' < 'v_c'$ ➢ No Shear reinforcement is required
3.7.7.5	$'v' > '2v_c'$ ➢ Redesign using: deeper slab, increase grade or top reinforcement.
Equation 29a	$'v' \leq '1.6v_c'$ ➢ $A_{sv} = (v - v_c)\,u_1\,d / (0.87f_{yv})$ Note: Sin 90º =1 for vertical bars
Equation 29b	$'1.6vc' < 'v' \leq '2v_c'$ ➢ $A_{sv} = 5(0.7\,v - v_c)\,u_1\,d / (0.87f_{yv})$ Note: Sin 90º =1 for vertical bars
Figure 3.17	Check against minimum Steel = $(0.4\,u_1\,d) / (0.87f_{yv})$ …. (altering u_1 to u_2,etc…accordingly)
	Note : 'A_{sv}' is for TWO perimeters of studs/links at a maximum of 0.75d centres.
	The first perimeter of studs located at 0.5d should contain 40% of the calculated area of the reinforcement required in u_1
	Repeat 'design at perimeters'… until $'v' < 'v_c'$ hence no more reinforcement is required.

Square/Circular Loaded Areas - EDGE



Reference to BS8110 part1	***Cantilever edges (c) are restricted to a maximum of 3d, lengths greater than 3d are ignored.***
	d = h – top cover – T1 Bars size / 2 – T2 Bars size / 2(average in both directions)
	$Xy = a + c + 1.5d$ or $Xx = a + (2 \times 1.5d)$ *(required only when there is a moment in the slab)*
Figure 3.14	*Square column* $u_0 = a \times 3$ or $u_0 = a \times 3 + c \times 2$ *Whichever is the smallest.*
3.7.7.2	*Circular column* $u_0 = a\pi$ or *when there is a negative value for 'c'* $u_0 = a\pi + (c\pi)$.
	use X as Xx or Xy as appropriate
Figure 3.15	$V_{eff} = 1.4V_t$ or $1.25V_t$ *(direct shear)* or $V_{eff} = V_t(1.25 + 1.5M_t / (V_t \times X))$ *(moment present)*
Design at face	$v = V_{eff} / (u_0 \times d)$
Equation 27	*Check v is not greater than* $0.8 \times \sqrt{f_{cu}}$ or $5\ N/mm^2$
3.7.6.4 & 3.7.7.2	f_{cu} *should not to be taken greater than 40 N/mm²*
Design at Perimeters	*Design each perimeter* $u_1, u_2, \ldots u_n$ *- starting 1.5d from the column/pile face and at 0.75d thereafter until* v_c *is greater than or equal to v.*
3.7.7.3	$u_1 = (1.5d \times 4) + 3a + 2c$ .. $u_2 = (2.25d \times 4) + 3a + 2c$ .. $u_3 = (3d \times 2) \times 4 + 3a + 2c$ ..& so on
Table 3.8	$100A_s / (1000 \times d)$ *Not to be taken more than 3*
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	$v_c = 0.79 \times (((100A_s / (1000 \times d))^{1/3} \times (400/d)^{1/4}) / 1.25) \times (f_{cu}/25)^{1/3}$
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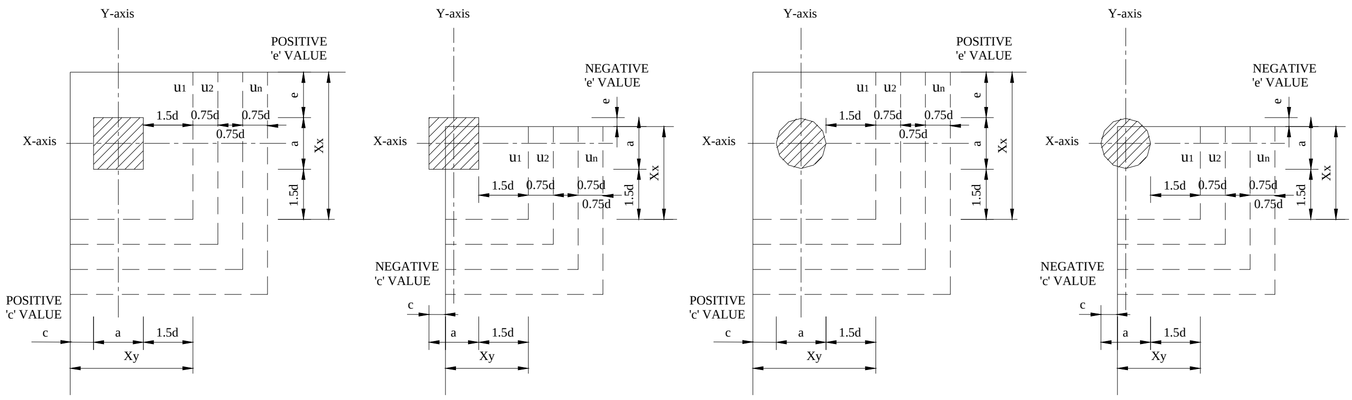
Equation 29a	$'v' \leq '1.6v_c'$ ➢ $A_{sv} = (v - v_c) u_1 d / (0.87f_{yv})$ *Note: Sin 90º =1 for vertical bars*
Equation 29b	$'1.6v_c' < 'v' \leq '2v_c'$ ➢ $A_{sv} = 5(0.7v - v_c) u_1 d / (0.87f_{yv})$ *Note: Sin 90º =1 for vertical bars*
Figure 3.17	*Check against minimum Steel =* $(0.4 u_1 d) / (0.87f_{yv})$ *…. (altering* u_1 *to* u_2 *,etc…accordingly)*
	Note : 'A_{sv}*' is for TWO perimeters of studs/links at a maximum of 0.75d centres.*
	The first perimeter of studs located at 0.5d should contain 40% of the calculated area of the reinforcement required in u_1
	Repeat 'design at perimeters'… until 'v' < ' v_c *' hence no more reinforcement is required.*

Square/Circular Loaded Areas – INTERNAL CORNER



Reference to BS8110 part1	***<u>Cantilever edges (c,d) are restricted to a maximum of 3d, lengths greater than 3d are ignored.</u>***
	d = h – top cover – T1 Bars size / 2 – T2 Bars size / 2(average in both directions)
Figure 3.14	*Xy = a + c + 1.5d or Xx = a + e + 1.5d (required only when there is a moment in the slab)*
	Square column u_0 = 2a + any negative value for ‘c’ or ‘e’.
3.7.7.2	*Circular column u_0 = 2/3 x a π or when there is a negative value for ‘c’ or ‘e’ use*
	u_0 = 2/3 x aπ+(cπ/2) u_0 = 2/3 x aπ +(eπ/2) u_0 = 2/3 x aπ+(cπ/2) +(eπ/2) accordingly
Figure 3.15	*use X as Xx or Xy as appropriate*
<u>Design at face</u>	*$V_{eff} = 1.25V_t$ (direct shear) or $V_{eff} = V_t$ (1.25 + 1.5M_t / (V_t x X)) (moment present)*
Equation 27	*$v = V_{eff}$ / (u_0 x d)*
3.7.6.4 & 3.7.7.2	*Check v is not greater than 0.8 x $\sqrt{f_{cu}}$ or 5 N/mm ²*
	f_{cu} should not to be taken greater than 40 N/mm ²
<u>Design at Perimeters</u>	*Design each perimeter u_1, u_2, …u_n - starting 1.5d from the column/pile face and at 0.75d thereafter until v_c is greater than or equal to v.*
3.7.7.3	*u_1 = (1.5d x 2) + 2a + c + e ..u_2 = (2.25d x 2) + 2a + c + e ..u_3 = (3d x 2) + 2a + c + e...& so on*
Table 3.8	*100A_s / (1000 x d) Not to be taken more than 3*
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	$v_c = 0.79 \times (((100A_s / (1000 \times d))^{1/3} \times (400 / d)^{1/4}) / 1.25) \times (f_{cu}/25)^{1/3}$
Equation 28	*$v = V_{eff}$ / (u_1 x d)*
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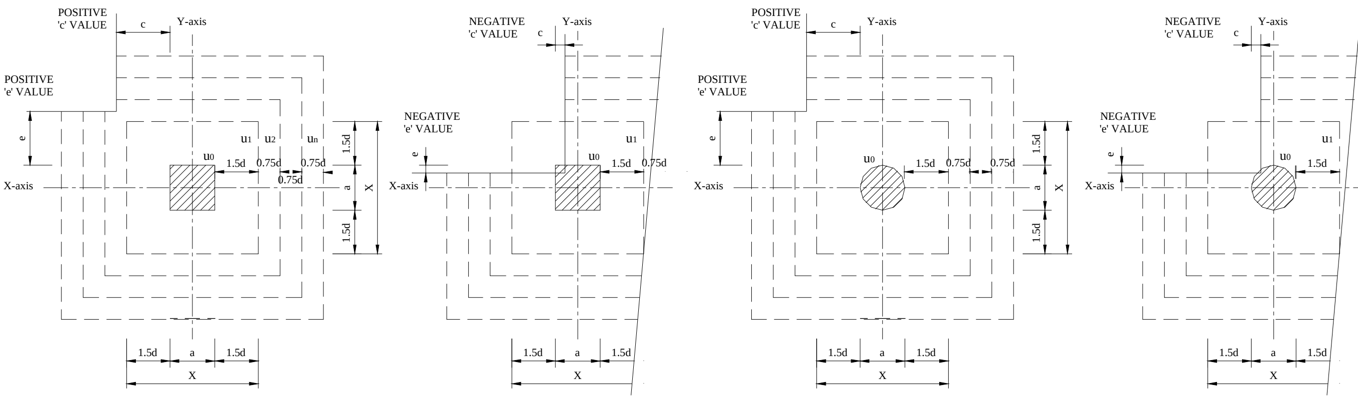
Equation 29a	*‘v’ ≤ ‘1.6v_c’ ➢ A_{sv} = (v – v_c) u_1 d / (0.87f_{yv}) Note: Sin 90º =1 for vertical bars*
Equation 29b	*‘1.6vc’ < ‘v’ ≤ ‘2v_c’ ➢ A_{sv} = 5(0.7 v – v_c) u_1 d / (0.87f_{yv}) Note: Sin 90º =1 for vertical bars*
Figure 3.17	*Check against minimum Steel = (0.4 u_1 d) / (0.87f_{yv}) …. (altering u_1 to u_2 ,etc…accordingly)*
	Note : ‘A_{sv}’ is for TWO perimeters of studs/links at a maximum of 0.75d centres.
	The first perimeter of studs located at 0.5d should contain 40% of the calculated area of the reinforcement required in u_1.
	Repeat ‘design at perimeters’… until ‘v’ < ‘ v_c’ hence no more reinforcement is required.

Square/Circular Loaded Areas - EXTERNAL CORNER



Reference to BS8110 part1	***Cantilever edges (c,e) are restricted to a maximum of 1.5d, lengths greater are ignored.*** *d = h – top cover – T1 Bars size / 2 – T2 Bars size / 2(average in both directions)*
Figure 3.14	*Xy = a + 3d or Xx = a + 3d (required only when there is a moment in the slab)* *Square column u_0 = 4a + any negative value for 'c' or 'e'.*
3.7.7.2	*Circular column u_0 = aπ + any negative value for 'c' or 'e' using the formula (πa/2 x c/a) or (πa/2 x e/a) accordingly*
Figure 3.15	*use X as Xx or Xy as appropriate*
Design at face	*V_{eff} = 1.25V_t (direct shear) or V_{eff} = V_t (1.25 + 1.5M_t / (V_t x X)) (moment present)*
Equation 27	*v = V_{eff} / (u_0 x d)*
3.7.6.4 & 3.7.7.2	*Check v is not greater than 0.8 x $\sqrt{f_{cu}}$ or 5 N/mm ²* *f_{cu} should not to be taken greater than 40 N/mm ²*
Design at Perimeters	*Design each perimeter u1, u2, …un - starting 1.5d from the column/pile face and at 0.75d thereafter until vc is greater than or equal to v.*
3.7.7.3	*u1 = (1.5d x 6) + 4a + c + e ..u2 = (2.25d x 6) + 4a + c + e ..u3 = (3d x 6) + 4a + c + e..& so on* *Check u1, u2, etc.. Against a complete enclosed perimeter i.e. u1 = ((1.5d x 2) + a) x 4*
Table 3.8	*100As / (1000 x d) Not to be taken more than 3* *400 / d Not to be taken less than 1* *vc = 0.79 x (((100As / (1000 x d))1/3 x (400 / d)1/4) / 1.25) x (fcu /25)1/3*
Equation 28	*v = Veff / (u1 x d)*
3.7.7.4	*v' < ' v_c'* ➢ *No Shear reinforcement is required*
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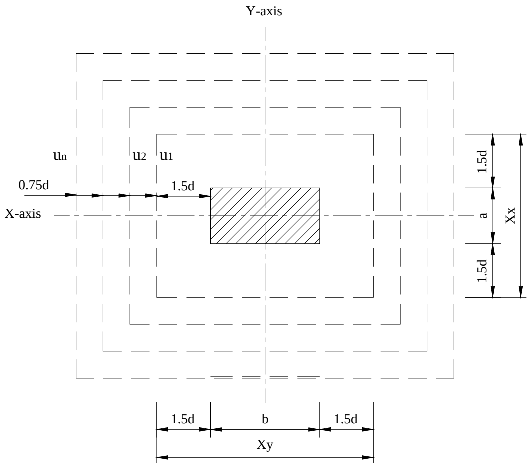
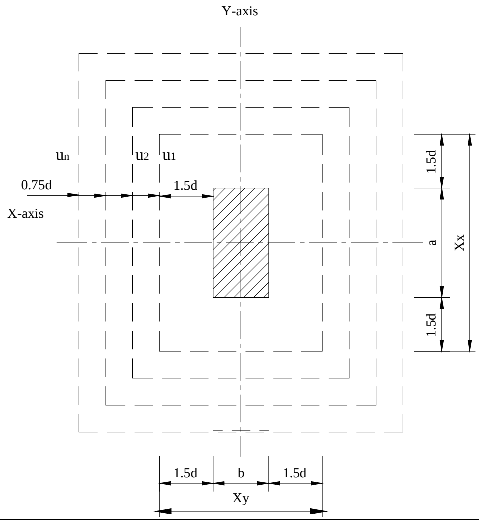
Equation 29b	*'1.6vc' < 'v' ≤ '2v_c'* ➢ *A_{sv} = 5(0.7 v – v_c) u_1 d / (0.87f_{yv}) Note: Sin 90º =1 for vertical bars*
Figure 3.17	*Check against minimum Steel = (0.4 u_1 d) / (0.87f_{yv}) …. (altering u_1 to u_2 ,etc…accordingly)* *Note : 'A_{sv}' is for TWO perimeters of studs/links at a maximum of 0.75d centres.* *The first perimeter of studs located at 0.5d should contain 40% of the calculated area of the reinforcement required in u_1.* *Repeat 'design at perimeters'… until 'v' < ' v_c' hence no more reinforcement is required.*

Rectangular Loaded Areas - INTERNAL





Reference to BS8110 part1 *1.3.4.1*	*For Rectangular loaded areas with a length exceeding four times its thickness, should be considered as a wall receiving localised punching shear at its ends, see section on Wall/Blade Column*
	d = h – top cover – T1 Bars size / 2 – T2 Bars size / 2(average in both directions)
	Xy= b + (2 x 1.5d) or Xx = a + (2 x 1.5d) (required only when there is a moment in the slab)
Figure 3.14	u_0 = 2a + 2b *use X as Xx or Xy as appropriate*
3.7.7.2	$V_{eff} = 1.15V_t$ *(direct shear) or* $V_{eff} = V_t\ (1 + 1.5M_t / (V_t \times X))$ *(moment present)*
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3.7.7.3	$u_1 = (1.5d \times 2) \times 4 + (a + b) \times 2$ .. $u_2 = (2.25d \times 2) \times 4 + (a + b) \times 2$ .. $u_3 = (3d \times 2) \times 4 + (a + b) \times 2$ *..& so on*
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Equation 29a	$'v' \leq '1.6v_c'$ ➢ $A_{sv} = (v - v_c)\ u_1\ d / (0.87f_{yv})$ *Note: Sin 90º =1 for vertical bars*
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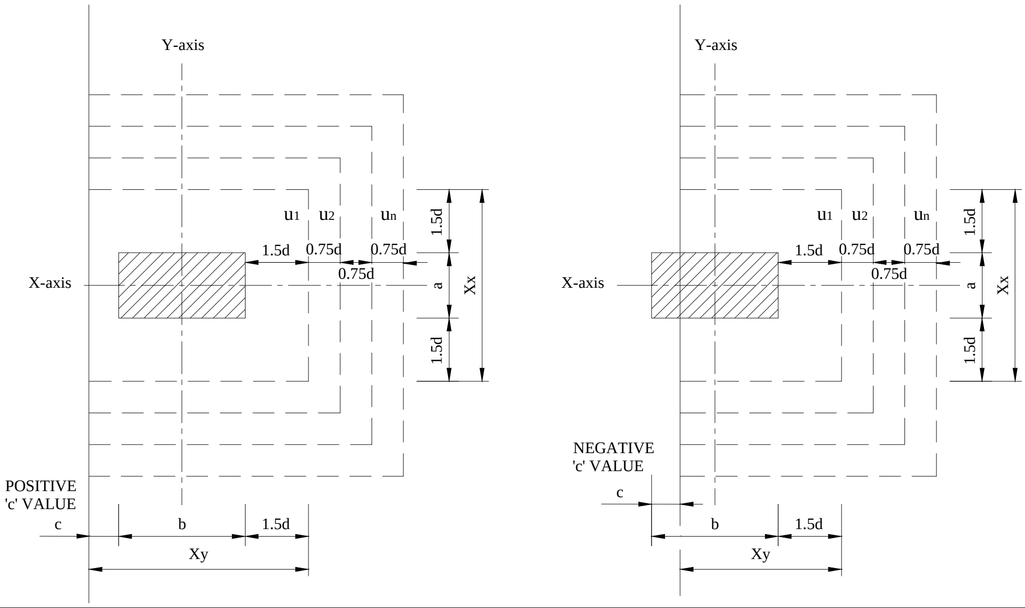
Rectangular Loaded Areas - EDGE



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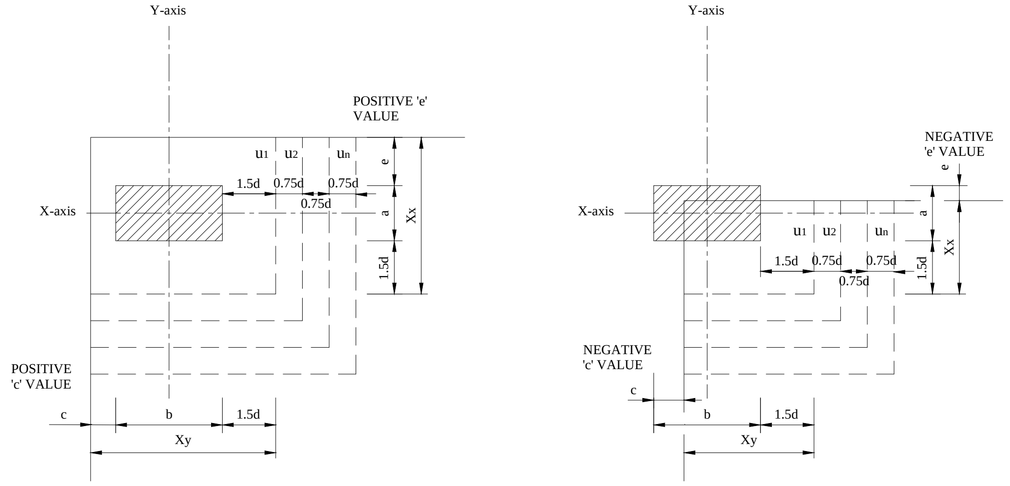
Rectangular Loaded Areas – INTERNAL CORNER



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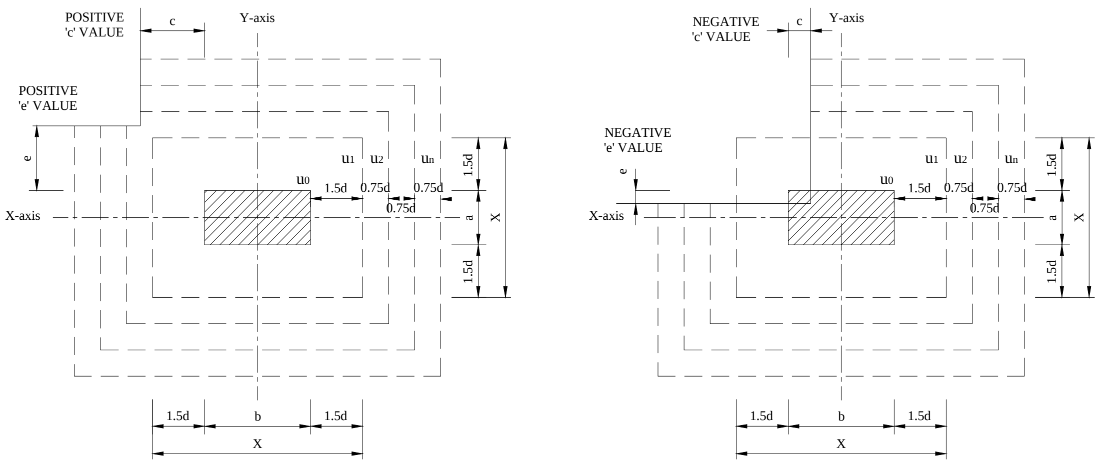
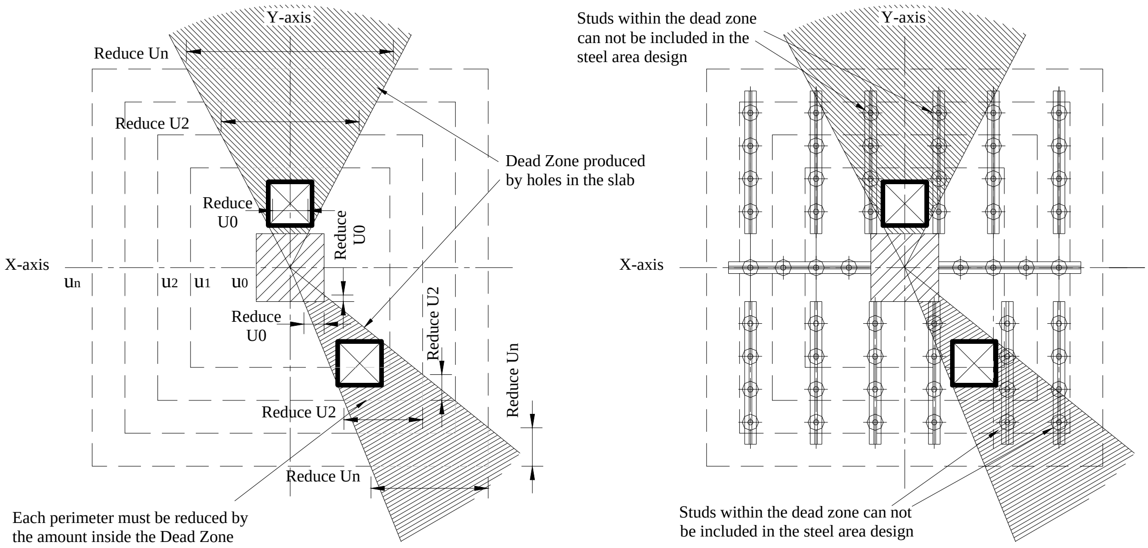
	Note : 'A_{sv}*' is for TWO perimeters of studs/links at a maximum of 0.75d centres.*
	The first perimeter of studs located at 0.5d should contain 40% of the calculated area of the reinforcement required in u_1*.*
	Repeat 'design at perimeters'… until 'v' < ' v_c *' hence no more reinforcement is required.*

Rectangular Loaded Areas – EXTERNAL CORNER



Reference to BS8110 part1	***Cantilever edges (c,e) are restricted to a maximum of 1.5d, lengths greater are ignored.***
	d = h – top cover – T1 Bars size / 2 – T2 Bars size / 2(average in both directions)
Figure 3.14	*Xy = b + 3d or Xx = a + 3d (required only when there is a moment in the slab)*
3.7.7.2	u_0 *= 2a + 2b + any negative value for 'c' or 'e'.*
Figure 3.15	*use X as Xx or Xy as appropriate*
Design at face	$V_{eff} = 1.25V_t$ *(direct shear) or* $V_{eff} = V_t\,(1.25 + 1.5M_t / (V_t \times X))$ *(moment present)*
Equation 27	$v = V_{eff} / (u_0 \times d)$
3.7.6.4 & 3.7.7.2	*Check v is not greater than* $0.8 \times \sqrt{f_{cu}}$ *or 5 N/mm²*
	f_{cu} *should not to be taken greater than 40 N/mm²*
Design at Perimeters	*Design each perimeter u1, u2, …un - starting 1.5d from the column/pile face and at 0.75d thereafter until vc is greater than or equal to v.*
3.7.7.3	*u1 =(1.5d x 6) +2a +2b +c +e ..u2 =(2.25d x 6) +2a +2b +c +e ..u3 =(3d x 6) +2a +2b +c +e..& so on*
	Check u1, u2, etc.. Against a complete enclosed perimeter i.e. u1 = ((1.5d x 2) x 4 + 2a + 2b)
Table 3.8	*100As / (1000 x d) Not to be taken more than 3*
	400 / d Not to be taken less than 1
	vc = 0.79 x (((100As / (1000 x d))1/3 x (400 / d)1/4) / 1.25) x (fcu /25)1/3
Equation 28	*v = Veff / (u1 x d)*
3.7.7.4	*v' < ' v_c'* ➢ *No Shear reinforcement is required*
3.7.7.5	*'v' > '2v_c'* ➢ *Redesign using: deeper slab, increase grade or top reinforcement.*
Equation 29a	*'v' ≤ '1.6v_c'* ➢ $A_{sv} = (v - v_c)\,u_1\,d / (0.87f_{yv})$ *Note: Sin 90° =1 for vertical bars*
Equation 29b	*'1.6vc' < 'v' ≤ '2v_c'* ➢ $A_{sv} = 5(0.7\,v - v_c)\,u_1\,d / (0.87f_{yv})$ *Note: Sin 90° =1 for vertical bars*
Figure 3.17	*Check against minimum Steel =* $(0.4\,u_1\,d) / (0.87f_{yv})$ *…. (altering* u_1 *to* u_2 *,etc…accordingly)*
	Note : 'A_{sv}' is for TWO perimeters of studs/links at a maximum of 0.75d centres.
	The first perimeter of studs located at 0.5d should contain 40% of the calculated area of the reinforcement required in u_1.
	Repeat 'design at perimeters'… until 'v' < ' v_c' hence no more reinforcement is required.

Design Guidance for Holes in Slabs



BS8110 part 1 1997 3.7.7.6 *Modification of effective perimeter to allow for holes.*

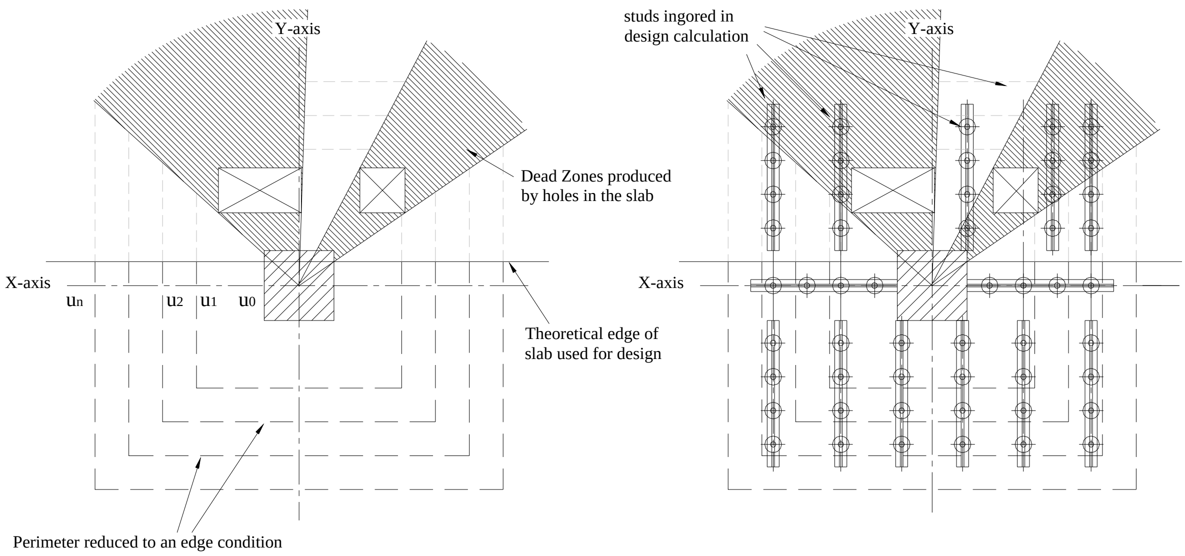
When a hole or holes are within 6d from the face of the column/pile, part of the perimeter that is enclosed by the radial projections (dead zone) from the centre of the column/pile to the edges of the hole/s are considered ineffective.

Each perimeter (uo, u1, etc..) must be reduced accordingly and any studs/reinforcement ignored when calculating the area of steel required/used, care should be taken when repositioning rails to miss holes that it has not moved into another perimeter without adjusting the calculation likewise.

A single hole can be ignored if its largest width is less than the smaller of:

1. *One-quarter of the column side*
2. *Half the slab depth*

It may be desirable or quicker to consider a worst-case design ignoring the part of the slab with the hole/s and design as an edge or corner condition, supplying additional rails to the disregarded area of slab that will be receiving load from the slab.



Alternatively, a percentage reduction of the perimeters can be used, but care must be taken, as the percentage will vary due to the position around the column/pile and with the distance between the column/pile to the hole.