TITLE :	DESIGN OF Shear Wall with Boundary Element					
SUB -TITLE :	DESIGN OF WALL FOR FLEXURE AND SHEAR					
CODE OF PRACTICE :	IS 456-2000 + 13920-2016					
DESIGN TYPE :	LIMIT STATE DESIGN					

NOTE :- 1) User to Input data in cell marked as Blue.

2) Design follows Limit State Method.

User Input						**Reference / Comments**
PARAMETERS :	RCDC	SYMBOL		INPUT	UNITS	
Wall				W7		
Level				4.2 m To 7.858 m		
Width of Wall	Wall B	B	=	300	mm	User Input
Depth of Wall	Wall D	D	=	1,500	mm	User Input
Grade of Concrete	Grade Of Concrete	fck	=	25	N/mm^2	User Input
Grade of Steel	Grade Of Steel	fy	=	415	N/mm^2	User Input
Cover to reinforcement	Clear Cover	Cc	=	50	mm	User Input
Floor to floor height of the wall		hw	=	3,658	mm	User Input
Beam depth along D (left side)		db1	=	800	mm	User Input
Beam depth along D (Right side)		db2	=	800	mm	User Input
Beam depth along B (left side)		bb1	=	800	mm	User Input
Beam depth along B (right side)		bb2	=	800	mm	User Input
Maximum % steel		ptmax	=	4.00	%	User Input
Partial Factor of Safety for Material Concrete		γ_c	=	1.50	constant	User Input
Partial Factor of Safety for Material Steel		γ_s	=	1.15	constant	User Input
Wall Type	Wall Type		=	UnBraced		User Input
Minimum eccentricity check	Minimum eccentricity check		=	One Axis at a Time		User Input
Code defined D/B ratio	Code defined D/B ratio		=	4		
Effective Length Factor along Major Axis			=	0.92		User Input
Effective Length Factor along Minor axis			=	0.57		User Input
Minimum % reinforcement in wall (User defined)			=	0.25	%	
Spacing Round Factor for Links			=	25.00	mm	
Clear Floor Height @ B	Clear Floor Height @ B		=	2,858	mm	=H-(bb1,bb2)
Clear Floor Height @ D	Clear Floor Height @ D		=	2,858	mm	=H-(db1,db2)
Flexural Design (Analysis Forces)						
Critical Analysis Load Combination				19		
Load Combination			=	[9] : 1.5 (LOAD 1: LOAD CASE 1) -1.5 (LOAD 4: LOAD CASE 4 EQ-Y)		
Critical Location			=	Top Joint		
Axial force		Pu	=	2,261.28	kN	User Input
Bending Moment along D		Mux	=	-12.08	kNm	User Input
Bending Moment along B		Muy	=	158.44	kNm	User Input
Shear force from Analysis along D		Vux	=	82.43	kN	User Input
Shear force from Analysis along B		Vuy	=	1.05	kN	User Input
Load Combination for Boundary Element Length						
Load Combination Containing EQ where Axial Force is Maximum.						
Axial force		Pu	=	2,566.22	kN	User Input
% reinforcement considered for BE length calculation			=	0.80	%	
Load Combination for Boundary Element Check						
Most Favouring Pu		Pu (Fav)	=	2,370.99	kN	User Input
Bending Moment along D		Mux	=	-257.13	kNm	User Input
Most Un-favouring Pu		Pu (Un-fav)	=	1,265.43	kN	User Input
Bending Moment along D		Mux	=	-255.60	kNm	User Input

Shear Design (Analysis Forces)						
Along D						
Critical Analysis Load Combination				20		
Load Combination				[10] : 0.9 (LOAD 1: LOAD CASE 1) +1.5 (LOAD 3: LOAD CASE 3 EQ-X		
Shear force from Analysis along D		Vux	=	120.57	kN	
Axial force		Pu	=	1,382.45	kN	
Along B						
Critical Analysis Load Combination				23		
Load Combination				[13] : 0.9 (LOAD 1: LOAD CASE 1) -1.5 (LOAD 4: LOAD CASE 4 EQ-Y)		
Shear force from Analysis along D		Vux	=	73.53	kN	
Axial force		Pu	=	1,338.35	kN	
Reinforcement Provided in Wall						
Boundary Zone						
Diameter of longitudinal reinforcement		dia	=	16	mm	User Input
Numbers of Rebars at Each End Zone		Nos	=	10	Nos	User Input
No of Rebars Along B		Nos	=	3	Nos	User Input
No of Rebars Along B		Nos	=	4	Nos	User Input
Mid Zone						
Diameter of longitudinal reinforcement		dia	=	10	mm	User Input
Numbers of Rebars at Each End Zone		Nos	=	8	Nos	User Input
Shear Links						
Boundary zone Links						
Link Diameter			=	8	mm	
Link Spacing			=	100	mm	
Other Links						
Link Diameter			=	8	mm	
Link Spacing			=	100	mm	
Step 1) Check Code Defined D/B Ratio						
D/B Ratio				5		
Check	D/B Ratio		=	Hence, Design as Wall		
Step 2) Check For Requirement Of Boundary Element						
Check For Maximum Compressive Stress Along Height of Wall						
Level where Maximum Stress exists				At level (4.2 m)		
Load Combination				[7] : 1.5 (LOAD 1: LOAD CASE 1) -1.5 (LOAD 3: LOAD CASE 3 EQ-X)		
Axial Force		Pu	=	2634.38	kN	
Moment along Major Axis		Mx	=	-617.13	kNm	
Area Of Concrete (BxD)		A	=	450000	sqmm	
Section Modulus (B x D^2/6)		Zxx	=	112500000	mm3	
Pu/A			=	5.854	N/mm^2	
Mx/Zxx			=	5.49	N/mm^2	
Maximum Stress (P/A +Mx/Zxx)			=	11.34	N/mm^2	
0.2 x Fck			=	5	N/mm^2	
Check For Maximum Compressive Stress				Maximum Stress in Wall > 0.2 x Fck		
Check For Maximum Compressive Stress at level Considered						
Load Combination				[7] : 1.5 (LOAD 1: LOAD CASE 1) -1.5 (LOAD 3: LOAD CASE 3 EQ-X)		
Axial Force		Pu	=	2370.99	kN	
Moment along Major Axis		Mx	=	-257.13	kNm	
Pu/A			=	5.27	N/mm^2	
Mx/Zx			=	2.29	N/mm^2	
Maximum Stress (P/A +Mx/Zxx)			=	7.55	N/mm^2	
0.15 x Fck			=	3.75	N/mm^2	
Check For Maximum Compressive Stress				Hence Boundary Element is applicable		

10 SPECIAL SHEAR WALLS

10.1 General Requirements

10.1.3 The minimum ratio of length of wall to its thickness shall be 4.

10.4 Boundary Elements

Boundary elements are portions along the wall edges that are strengthened by longitudinal and transverse reinforcement even if they have the same thickness as that of the wall web. It is advantageous to provide boundary elements with dimension greater than thickness of the wall web.

10.4.1 Boundary elements shall be provided along the vertical boundaries of walls, when the extreme fibre compressive stress in the wall exceeds $0.2 f_{ck}$ due to factored gravity loads plus factored earthquake force. Boundary elements may be discontinued at elevations where extreme fiber compressive stress becomes less than $0.15 f_{ck}$. Extreme fibre compressive stress shall be estimated using a linearly elastic model and gross section properties.

Step 2) Calculation of Boundary Element Length			
Load Combination		1.2 (LOAD 1: LOAD CASE 1) +1.2 (LOAD 2: LOAD CASE 2) +1.2 (LOAD 4: LOAD CASE 4 EQ-Y)	
Axial force	Pu	2566.22	kN
Ast for for BE length calculation (0.8% assumed)	pt	3600	sqmm
Maximum Possible Axial Force in the wall	Po	0.8 x (0.85 x Fck x Ac + Fy x Ast)	
		8784	kN
Ratio of Design axial force / Maximum axial force Permissible	Pu/Po	0.292	
Ratio for Boundary		0.221	
Boundary Element Length at Each End	BE Length	375	mm

Ductile Wall design

Boundary elements are provided for ductile walls as per IS 13920. Zoning of reinforcement is done around the boundary element. The initial length of the boundary element is arrived at as per following procedure:

i. Value Po is calculated Po = 0.8 x (0.85 x Fck x Ac + Fy x Ast)
ii. The largest axial force Pu in earthquake combination is determined
iii. Length of boundary element is determined based on the above two values as
   a. If Pu< 0.15 x Po then length of the boundary element = 0.15 x Lw.
   b. If Pu> 0.35 x Po then length of the boundary element = 0.25 x Lw.
   c. If 0.15 x Po <Pu< 0.35 x Po the interpolate between 0.15 to 0.25 Lw .

The above is based on a few international papers and recommendations in the ACI code.
Reference has also been made to an IIT-Kanpur publication IITK-GSDMA-EQ22-V3.03, example 9.

Step 4) Effective Length Calculation		
Effective Length Factor along Major Axis	0.92	
Effective Length Factor along Minor axis	0.57	
Step 5) Minimum Eccentricity Check		
Check	Since Axial Force is compressive, Min. Eccentricity check to be performed	
Most critical case is with Min. Eccentricity	Y-direction	
Actual Eccentricity Along D :	-	
	0	mm
	Max (Actual Eccentricity,20)	
Minimum Eccentricity Along D :	0.00	mm
Mminx	-	
	0.00	kNm
Actual Eccentricity Along B :	Clear Floor Height @ B / 500 + B / 30	
	15.72	mm
Minimum Eccentricity Along B :	Max (Actual Eccentricity,20)	
	20.00	mm
Mminy	Pu x Minimum Eccentricity	
	45.23	kNm

25.4 Minimum Eccentricity

All columns shall be designed for minimum eccentricity, equal to the unsupported length of column/ 500 plus lateral dimensions/30, subject to a minimum of 20 mm. Where bi-axial bending is considered, it is sufficient to ensure that eccentricity exceeds the minimum about one axis at a time.

25.3 Slenderness Limits for Columns

25.3.1 The unsupported length between end restraints shall not exceed 60 times the least lateral dimension of a column.

Step 5) Slenderness Check

Max Slenderness Ratio(Clear Floor Height @ B/B)	2858/300
	9.53
Check	< 6, Hence OK
Column Is Unbraced Along D	
Slenderness Check Along D:	
Effective Length Factor along Major Axis	0.92
Effective Length (Unsupported Length x Effective Length Factor)	2858X0.92
	2629.36 mm
Slenderness Ratio	Effective Length / D
	1.75
	Wall not Slender Along D
Column Is Unbraced Along B	
Slenderness Check Along B:	
Effective Length Factor along Major Axis	0.57
Effective Length (Unsupported Length x Effective Length Factor)	2858X0.57
	1629.06 mm
Slenderness Ratio	Effective Length / B
	5.43
	Wall not Slender Along B

Calculation of Design Moment

Direction	Manalysis	Mmin (Abs)	Mdesign	MsIndx (Abs)	Mdesign-final
	A	B	C	E	F
Major Axis - Mux	-12.08	0.00	-12.08	0	-12.08
Minor Axis - Muy	158.44	45.23	158.44	0	158.44

Where

A	=	Moments directly from analysis
B	=	Moments due to minimum eccentricity
C	=	Maximum of analysis moment and min. eccentricity = Max (A,B)
E	=	Moment due to slenderness effect
F	=	Final design Moment = Max(C- Top Bottom , D- Top Bottom) + E

Final Critical Design Forces

Pu	=	2,261.28	kN
Mux	=	-12.08	kNm
Muy	=	158.44	kNm

Minimum % steel

User defined pt min1		=	0.25	
Vertical reinforcement as per type of wall				
Floor to Floor height of wall	hw	=	3658	mm
Depth of Wall	Lw = D	=	1500	mm
hw/Lw	hw/Lw	=	2.44	
Type of wall			hw/Lw > 2 Hence, Slender wall	
Width of Wall	tw = B	=	300	mm
Minimum % of Horizontal Reinforcement	Ph	=	0.0025	
Minimum % of Web Reinforcement	Pvweb	=	0.0025	
Ptv min2	Ptv min2	=	0.00525	%
Ptmin	Ptmin	=	Max(Pvweb,Ptv min2)	
		=	0.00525	
		=	0.525	%

25.1.2 *Short and Slender Compression Members*

A compression member may be considered as short when both the slenderness ratios $\frac{l_{ex}}{D}$ and $\frac{l_{ey}}{b}$ are less than 12:

10.3 Design for Axial Force and Bending Moment

10.3.1 Design moment of resistance M_u of the wall section subjected to combined bending moment and compressive axial load shall be estimated in accordance with requirements of limit state design method given in IS 456, using the principles of mechanics involving equilibrium equations, strain compatibility conditions and constitutive laws.

The moment of resistance of slender rectangular structural wall section with uniformly distributed vertical reinforcement may be estimated using expressions given in Annex A. Expressions given in Annex A are not applicable for structural walls with boundary elements.

39.6 Members Subjected to Combined Axial Load and Biaxial Bending

The resistance of a member subjected to axial force and biaxial bending shall be obtained on the basis of assumptions given in 39.1 and 39.2 with neutral axis so chosen as to satisfy the equilibrium of load and moments about two axes. Alternatively such members may be designed by the following equation:

10.1.4 Special shear walls shall be classified as squat, intermediate or slender depending on the overall height h_w to length L_w ratio as

a) Squat walls: $h_w / L_w < 1$,

b) Intermediate walls: $1 \le h_w / L_w \le 2$, and

c) Slender walls: $h_w / L_w > 2$.

<u>Resultant Moment (Combined Action)</u>					
Moment Capacity Check					
Pt Calculated		=	1.03		
Reinforcement Provided		=	20-T16 + 8-T10		
Load Angle		=	Tan^{-1}(Muy/Mux)		
		=	85.64	deg	
MRes		=	158.90	kNm	
MCap		=	286.96	kNm	
Capacity Ratio		=	MRes/ MCap		
		=	0.55		
Check			0.55<=1		
<u>Check For Boundary Element</u>					
Calculation of vertical reinforcement in BE zone					
Area Of Concrete (BxD)	A	=	450000	sqmm	
Section Modulus (B x D^2/6)	Z	=	112500000	mm3	
Maximum Compressive Force in BE					
Most Favouring Pu	P (Fav)		2,370.99	kN	
Bending Moment along D	M		-257.13	kNm	
P/A	P/A	=	5.27	N/mm^2	
M/Z	M/Z	=	-2.29	N/mm^2	
Depth of Wall	Lw = D	=	1500	mm	
Stress Slope,S1		=	((P/A + M/Z) - (P/A - M/Z)) / Lw		
		=	-3.05	N/mm^2	
Stress - 1		=	(P/A + M/Z) - S1 X (BE length) / 2		
		=	3.55	N/mm^2	
Stress - 2		=	(P/A - M/Z) + S1 X (BE length) / 2		
		=	6.98	N/mm^2	
Maximum compressive force		=	Maximum (Stress-1, Stress-2) x BE length		
		=	785.60	kN	
Pt required	pt1	=	0	%	
Maximum Tensile Force in BE					
Most Un-Favouring Pu	Pu (Un-Fav)		1,265.43	kN	
Bending Moment along D	Mux		-255.60	kNm	
Pu/A	Pu/A	=	2.81	N/mm^2	
Mx/Zx	M/Z	=	-2.27	N/mm^2	
Stress Slope,S1		=	((P/A + M/Z) - (P/A - M/Z)) / Lw		
		=	-3.03	N/mm^2	
Stress - 1		=	(P/A + M/Z) - S1 X (BE length) / 2		
		=	1.11	N/mm^2	
Stress - 2		=	(P/A - M/Z) + S1 X (BE length) / 2		
		=	4.52	N/mm^2	
Maximum compressive force		=	Minimum (Stress-1, Stress-2) x BE length		
		=	124.66	kN	
Pt required	pt2	=	0	%	
<u>Design pt in BE</u>					
Minimum pt		=	0.8	% (Constant)	Clause 10.4.3 (IS 13920-2016)
Pt required in BE		=	=Maximum (0.8, pt1, pt2)		
		=	0.8	%	
<u>Check For Compression Capacity Of BE</u>					
PT provided in BE		=	1.79	%	
Ast provided in BE	Ast	=	2010.62	sqmm	
Capacity of BE in compression		=	0.4 x Fck x Aconcrete + 0.67 x Fy x Ast		
		=	1663.95	kN	
			1663.95 > 785.6		
			1663.95 Hence OK		

Table 1 Minimum Reinforcement in RC Shear Walls

(*Clause* 10.1.6)

Sl. No.	Type of Wall	Reinforcement Details
i)	Squat walls	$(\rho_h)_{min} = 0.0025$ $(\rho_v)_{min} = 0.0025 + 0.5\left(1 - \frac{h_w}{t_w}\right)(\rho_h - 0.0025)$ $(\rho_{v,net}) = (\rho_{v,web}) + \left(\frac{t_w}{L_w}\right)\cdot\left[0.02 - 2.5(\rho_{v,web})\right]$ $(\rho_v)_{provided} < (\rho_h)_{provided}$
ii)	Intermediate walls	$(\rho_h)_{min} = 0.0025$ $(\rho_{v,be})_{min} = 0.0080$ $(\rho_{v,web})_{min} = 0.0025$ $(\rho_{v,net})_{min} = 0.0025 + 0.01375\left(\frac{t_w}{L_w}\right)$.
iii)	Slender walls	$(\rho_h)_{min} = 0.0025 + 0.5\left(\frac{h_w}{L_w} - 2\right)(\rho_h - 0.0025)$ $(\rho_{v,be})_{min} = 0.0080$ $(\rho_{v,web})_{min} = 0.0025$ $(\rho_{v,net})_{min} = 0.0025 + 0.01375\left(\frac{t_w}{L_w}\right)$.

10.4.2 A boundary element shall have adequate axial load carrying capacity, assuming short column action, so as to enable it to carry axial compression arising from factored gravity load and lateral seismic shaking effects.

10.4.2.1 The load factor for gravity load shall be taken as 0.8, if gravity load gives higher axial compressive strength of the boundary element.

10.4.3 The vertical reinforcement in the boundary elements shall not be less than 0.8 percent and not greater than 6 percent; the practical upper limit would be 4 percent to avoid congestion.

Check For Tension Capacity Of BE

PT provided in BE		=	1.79	%
Ast provided in BE	Ast	=	2010.62	sqmm
Capacity of BE in Tension		=	0.87 x Ast X Fy	
		=	725.93	kN

Wall Configuration

	Boundary Element	Mid	Boundary Element
Length (mm)	375	750	375
Reinforcement	10-T16	8-T10	10-T16
Ast provided	2010.62	628.32	2010.62
Pt as % of entire wall	0.45%	0.14%	0.45%
Pt as % of zone	1.79%	0.28%	1.79%

Shear Design (Analysis Forces)

Design for shear along D

Critical Analysis Load Combination		:	20	
Critical Load Combination	[10] : 0.9 (LOAD 1: LOAD CASE 1) +1.5 (LOAD 3: LOAD CASE 3 EQ			
Design shear force	Vuy	=	120.57	kN
Axial Force	Pu	=	1,382.45	kN
Shear Stress	Tvy	=	Vuy / (0.8 x B X D))	
		=	0.3349	N/mm^2
Pt (20% of vertical reinforcement)		=	0.207	%
Beta		=	14.047	
Design shear strength,	Tc	=	0.3356	N/mm^2
Shear Strength Enhancement Factor		=	1 + 3 x Pu / (B x D x Fck)	
		=	1.3687	
Shear Strength Enhancement Factor (max)		=	1.50	
Shear Strength Enhancement Factor		=	1.3687	
Enhanced shear strength (Tc x Enhancement Factor)	Tc-e	=	0.459	N/mm^2
Design shear check		=	Tvy < Tc x Enhancement factor	
			Link for Shear Design along D are not required	

Design for shear along B

Critical Analysis Load Combination		:	23	
Critical Load Combination	[13] : 0.9 (LOAD 1: LOAD CASE 1) -1.5 (LOAD 4: LOAD CASE 4 EQ-Y)			
Design shear force	Vux	=	73.53	kN
Axial Force	Pu	=	1338.35	kN
Shear Stress	Tvx	=	Vux / (0.8 x B X D))	
		=	0.2043	N/mm^2
Pt (20% of vertical reinforcement)		=	0.207	%
Beta		=	14.047	
Design shear strength,	Tc	=	0.3356	N/mm^2
Shear Strength Enhancement Factor		=	1 + 3 x Pu / (B x D x Fck)	
		=	1.3569	
Shear Strength Enhancement Factor (max)		=	1.50	
Shear Strength Enhancement Factor		=	1.3569	
Enhanced shear strength (Tc x Enhancement Factor)	Tc-e	=	0.455	N/mm^2
Design shear check		=	Tvy > Tc x Enhancement factor	
			Shear Reinforcement required along B	

10.2 Design for Shear Force

10.2.1 Nominal shear stress demand τ_v on a wall shall be estimated as:

$$\tau_v = \frac{V_u}{t_w d_w},$$

where V_u is factored shear force, t_w thickness of the web, and d_w effective depth of wall section (along the length of the wall), which may be taken as 0.8 L_w for rectangular sections.

39.2 Design Shear Strength of Concrete

SP 24

$$\tau_c = \frac{0.85\sqrt{0.8 f_{ck}}\,(\sqrt{1.+5\beta}-1)}{6\beta}$$

where $\beta = 0.8\, f_{ck}/6.89\, p_t$, but not less than 1, and

$$P_t = \frac{100\, A_s}{b_w d}$$

40.2.2 ***Shear Strength of Members under Axial Compression***

For members subjected to axial compression P_u, the design shear strength of concrete, given in Table 19, shall be multiplied by the following factor :

$$\delta = 1 + \frac{3P_u}{A_g f_{ck}} \text{ but not exceeding 1.5}$$

where

P_u = axial compressive force in Newtons,

A_g = gross area of the concrete section in mm², and

f_{ck} = characteristic compressive strength of concrete.

Design Of Links

Main Links

Links in the zone where special confining links are not required

Normal Links

Horizontal reinforcement as per type of wall

hw		=	3,658	mm
Lw		=	1,500	mm
hw/Lw		=	2.44	
Type of wall			hw/Lw > 2 Hence, Slender wall	
tw		=	300	mm
Ph		=	0.0025	
Pvweb		=	0.0025	
Ptv min		=	0.525	%
Area of Horizontal Links			750	sqmm
Diameter of main horizontal steel		=	8	mm
Spacing Required for Links			134	mm
Thus, Spacing		=	125	mm
Spacing of horizontal reinforcement is minimum of following				
D / 5		=	300	mm
3 x B		=	900	mm
Maximum		=	450	mm
Spacing considered		=	125	mm
Special confining reinforcement as per IS 13920 - 2016				
Min. Lateral dimension of column, B		=	300	mm
B/3		=	100	mm
6 X Smallest Longitudinal Bar Dia		=	60	mm
Spacing		=	150	mm
Hence Link spacing, Sv		=	100	mm
Hoop dimension, h	(B - 2 x Cover + 2 x Link Dia) / (No of Rebars Along B -1)			
Along B		=	108.00	mm
Along D	(BE Zone - Cover + Link Dia + Main Rebar Dia / 2 + Link Dia) / (No of Rebars Along D -1)			
		=	116.33	mm
	Max (Along B, Along D)		116.33	mm
Area of special confining link, Ash		=	0.05 x Sv x h x (Fck/Fy)	
		=	35.040	sqmm
Diameter of special confining link		=	8	mm
		=	Max. longitudinal bar dia / 4	
		=	4	mm
Area of horizontal steel provided			Area of bar provided x 1000 x 2 / spacing	
		=	1005.31	(sqmm)/ m height
		=	0.3351	
			> min. steel required 0.25%	

Special confining links to be provided along full height in BE.

Table For Links

Note: Ductile Design Of Links Is Applicable Only For Boundary Elements

	Required			Provided	
	Normal Design	Shear Design	Ductile Design	Normal Zone	Ductile Zone
Link Dia.	8	---	8	8	8
Spacing	125	---	100	125	100

Secondary Links:

In Boundary element	T8@100c/c
In Mid-zone	T8@125c/c

10.1.8 The largest diameter of longitudinal steel bars used in any part of a wall shall not exceed 1/10th of the thickness of that part.

10.1.9 The maximum spacing of vertical or horizontal reinforcement shall not exceed smaller of:

a) 1/5th horizontal length L_w of wall;

b) 3 times thickness t_w of web of wall; and

c) 450 mm.

10.4.4 Boundary elements, where required as per **10.4.1**, shall be provided with special confining reinforcement throughout their height, given by

$$A_{sh} = 0.05\ s_v\ h\ \frac{f_{ck}}{f_y}$$

and have a spacing not more than,

a) 1/3 of minimum member dimension of the boundary element;

b) 6 times diameter of the smallest longitudinal reinforcement bars; and

c) 100 mm but may be relaxed to 150 mm, if maximum distance between cross-ties/parallel legs of links or ties is limited to 200 mm,

but need not be less than 100 mm.