DETAILING RULES & SPECIAL DIMENSIONING RULES IN EUROCODE 8

DETAILING OF FLEXURAL PLASTIC HINGES, FOR CURVATURE DUCTILITY FACTOR μ_φ CONSISTENT w/ q-FACTOR

- $\mu_\varphi = 2q_o - 1$ if $T_1 \geq T_c$
- $\mu_\varphi = 1 + 2(q_o - 1)T_c/T_1$ if $T_1 < T_c$
  - T_1: fundamental period of building,
  - T_C: T at upper limit of constant spectral acceleration region,
  - q_o : q-factor unreduced for irregularity in elevation (multiplied w/ M_{Ed}/M_{Rd} at wall base).
- Derivation:
  - Relation between μ_φ & L_{pl}/L_s (L_{pl}: plastic hinge length, L_s: shear span) & μ_δ (: top displacement ductility factor) in buildings staying straight due to walls or strong columns: $\mu_\delta = 1 + 3(\mu_\varphi - 1)L_{pl}/L_s(1 - 0.5L_{pl}/L_s)$;
  - Relation q-μ_δ-T :

    $\mu_\delta = q$ if $T_1 \geq T_c$, $\mu_\delta = 1 + (q-1)T_c/T_1$ if $T_1 < T_c$;
  - Relation of L_{pl} & L_s for typical RC beams, columns & walls (for EC2 confinement model: $\varepsilon^*_{cu} = 0.0035 + 0.1\alpha\omega_w$):

    $\mu_\varphi \approx 2\mu_\delta - 1$
- For steel B (ε_u: 5-7.5%, f_t/f_y: 1.08-1.15) increase μ_φ-demand by 50%

EC8-Part 1: MEANS TO ACHIEVE μ_φ IN PLASTIC HINGES

- Members w/ axial load & symmetric reinforcement, $\omega_1=\omega_2$ (columns, ductile walls):
  - Confining reinforcement (for walls: in boundary elements) w/ (effective) mechanical volumetric ratio:

$$\alpha\omega_{wd}=30\mu_\varphi(v_d+\omega_{\nu d})\varepsilon_{yd}b_c/b_o-0.035$$

    - $v_d=N_d/b_c h f_{cd}$; $\varepsilon_{yd}=f_{yd}/E_s$;
    - b_c: width of compression zone; b_o: width of confined core;
    - ω_ν: mechanical ratio of longitudinal web reinforcement = $\rho_\nu f_{yd,\nu}/f_{cd}$
  - Columns meeting strong-column/weak-beam rule ($\Sigma M_{Rc}>1.3\Sigma M_{Rb}$), should have full confining reinforcement only at (building) base;
  - DC H strong columns ($\Sigma M_{Rc}>1.3\Sigma M_{Rb}$) also provided w/ confining reinforcement for 2/3 of μ_φ in all end regions above the base.
- Members w/o axial load & w/ asymmetric reinforcement (beams):
  - Max. mechanical ratio of tension steel:

$$\omega_1 \leq \omega_2+0.0018/\mu_\varphi\,\varepsilon_{yd}$$

Derivation:

- $\mu_\varphi = \varphi_u / \varphi_y$
- $\varphi_u = \varepsilon_{cu} / \xi_u h_o$
- $\varepsilon_{cu} = 0.0035 + 0.1 \alpha \omega_w$
- $\xi_u \sim (v_d + \omega_v + \omega_1 - \omega_2)/(1 - \varepsilon_{co}/3\varepsilon_{cu}) f_c/f_{cc} (h_c b_c)/(h_o b_o)$ (equilibrium)
- $\varphi_y = 1.75\varepsilon_y/h$ in columns, $\varphi_y = 1.44\varepsilon_y/h$ in walls, $\varphi_y = 1.54\varepsilon_y/d$ in beams (fitted to >2000 tests)
- Correction for material safety factors ($\gamma_c = 1.5$, $\gamma_s = 1.15$)

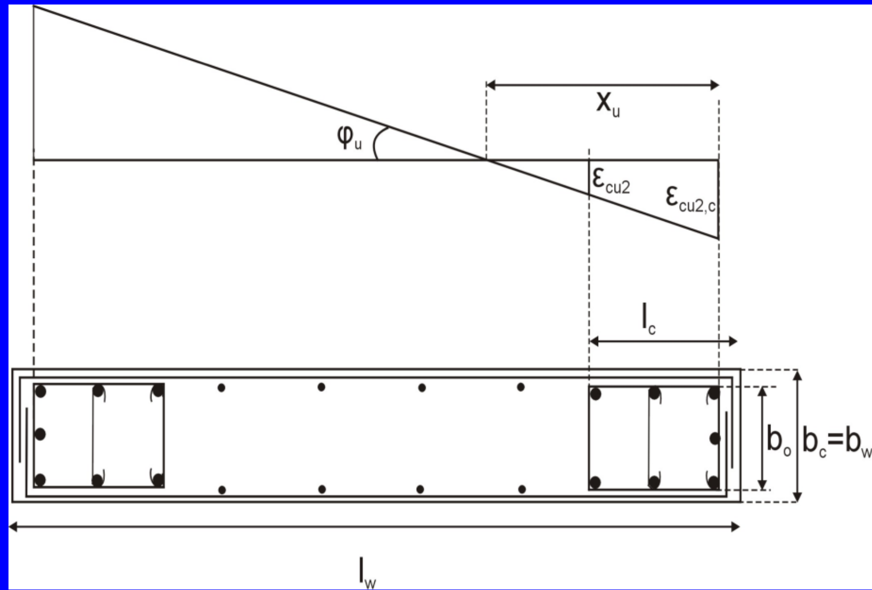
DESIGN & DETAILING OF DUCTILE WALLS

- Inelastic action limited to plastic hinge at base, so that cantilever relation between q & μ_φ can apply:
  - Wall provided with flexural overstrength above plastic hinge region (linear moment envelope with shift rule);
  - Design in shear for V from analysis, times:

    1.5 for DC M

    $[(1.2\, M_{Rd}/M_{Ed})^2+0.1(qS_e(T_c)/S_e(T_1))^2]^{1/2} < q$ for DC H

    - M_{Ed}: design moment at base (from analysis),
    - M_{Rd}: design flexural resistance at base,
    - $S_e(T)$: ordinate of elastic response spectrum,
    - T_C: upper limit T of const. spectral acc. region
    - T_1 fundamental period.



- In plastic hinge zone: boundary elements w/ confining reinforcement of effective mechanical volumetric ratio:

$$\alpha\omega_{wd}=30\mu_\varphi(v_d+\omega_{vd})\varepsilon_{yd}b_c/b_o-0.035$$

over part of compression zone depth: $x_u=(v_d+\omega_v)l_wb_c/b_o$

where strain is between: $\varepsilon^*_{cu}=0.0035+0.1\alpha\omega_w$ & $\varepsilon_{cu}=0.0035$

OVERVIEW OF DETAILING & DIMENSIONING OF PRIMARY BEAMS, COLUMNS & DUCTILE WALLS IN RC BUILDINGS OF DC H, M or L

Detailing/dimensioning of primary seismic beams (secondary ones: as in DCL)

	DC H	DCM	DCL
"critical region" length	$1.5h_w$	h_w	
Longitudinal bars (L):			
ρ_{min}, tension side	$0.5f_{ctm}/f_{yk}$		$0.26f_{ctm}/f_{yk}$, $0.13\%^{(0)}$
ρ_{max}, critical regions(1)	$\rho'+0.0018f_{cd}/(\mu_\phi\varepsilon_{sy,d}f_{yd})^{(1)}$		0.04
$A_{s,min}$, top & bottom	$2\Phi14$ ($308mm^2$)	-	
$A_{s,min}$, top-span	$A_{s,top\text{-}supports}/4$	-	
$A_{s,min}$, critical regions bottom	$0.5A_{s,top}^{(2)}$		-
$A_{s,min}$, supports bottom	$A_{s,bottom\text{-}span}/4^{(0)}$		
d_{bL}/h_c - bar crossing interior joint(3)	$\leq \frac{6.25(1+0.8\nu_d)}{(1+0.75\frac{\rho'}{\rho_{max}})}\frac{f_{ctm}}{f_{yd}}$	$\leq \frac{7.5(1+0.8\nu_d)}{(1+0.5\frac{\rho'}{\rho_{max}})}\frac{f_{ctm}}{f_{yd}}$	-
d_{bL}/h_c - bar anchored at exterior joint(3)	$\leq 6.25(1+0.8\nu_d)\frac{f_{ctm}}{f_{yd}}$	$\leq 7.5(1+0.8\nu_d)\frac{f_{ctm}}{f_{yd}}$	-

(0) NDP (Nationally Determined Parameter) per EC2. Table gives the EC2 recommended value.

(1) μ_ϕ: value of the curvature ductility factor corresponding to the basic value, q_o, of behavior factor used in the design

(2) The minimum area of bottom steel, $A_{s,min}$, is in addition to any compression steel that may be needed for the verification of the end section for the ULS in bending under the (absolutely) maximum negative moment from the analysis for the seismic design situation, M_{Ed}.

(3) h_c: column depth in the direction of the bar, $\nu_d = N_{Ed}/A_c f_{cd}$: column axial load ratio for the algebraically minimum axial load in the seismic design situation (compression: positive).

Detailing & dimensioning of primary seismic beams *(cont'd)*

	DC H	DCM	DCL
Transverse bars (w):			
(i) outside critical regions			
spacing $s_w \leq$	0.75d		
$\rho_w \geq$	$0.08\sqrt{(f_{ck}(MPa)}/f_{yk}(MPa)^{(0)}$		
(ii) in critical regions:			
$d_{bw} \geq$	6mm		
spacing $s_w \leq$	$6d_{bL}$, $\frac{h_w}{4}$, $24d_{bw}$, 175mm	$8d_{bL}$, $\frac{h_w}{4}$, $24d_{bw}$, 225mm	-

Detailing & dimensioning of primary seismic beams *(cont'd)*

	DC H	DCM	DCL
Shear design:			
V_{Ed}, seismic[(4)]	$1.2\frac{\sum M_{Rb}}{l_{cl}} \pm V_{o,g+\psi_2 q}$ [(4)]	$\frac{\sum M_{Rb}}{l_{cl}} \pm V_{o,g+\psi_2 q}$ [(4)]	from analysis for design seismic action plus gravity
$V_{Rd,max}$ seismic [(5)]	As in EC2: $V_{Rd,max}=0.3(1-f_{ck}(MPa)/250)b_{wo}zf_{cd}\sin 2\delta$ [(5)], $1\leq\cot\delta\leq 2.5$		
$V_{Rd,s}$, outside critical regions[(5)]	As in EC2: $V_{Rd,s}=b_w z\rho_w f_{ywd}\cot\delta$ [(5)], $1\leq\cot\delta\leq 2.5$		
$V_{Rd,s}$, critical regions[(5)]	$V_{Rd,s}=b_w z\rho_w f_{ywd}$ ($\delta=45°$)	As in EC2: $V_{Rd,s}=b_w z\rho_w f_{ywd}\cot\delta$, $1\leq\cot\delta\leq 2.5$	
If $\zeta\equiv V_{Emin}/V_{Emax}$[(6)] <-0.5: inclined bars at angle $\pm\alpha$ to beam axis, with cross-section A_s/direction	If $V_{Emax}/(2+\zeta)f_{ctd}b_w d>1$: $A_s=0.5V_{Emax}/f_{yd}\sin\alpha$ & stirrups for $0.5V_{Emax}$	-	

(4) At a member end where the moment capacities around the joint satisfy: $\Sigma M_{Rb}>\Sigma M_{Rc}$, M_{Rb} is replaced in the calculation of the design shear force, V_{Ed}, by $M_{Rb}(\Sigma M_{Rc}/\Sigma M_{Rb})$

(5) z: internal lever arm, taken equal to 0.9*d* or to the distance between the tension and the compression reinforcement, $d-d_1$.

(6) V_{Emax}, $V_{E,min}$ are the algebraically maximum and minimum values of V_{Ed} resulting from the $\pm$ sign; V_{emax} is the absolutely largest of the two values, and is taken positive in the calculation of ζ; the sign of V_{Emin} is determined according to whether it is the same as that of V_{Emax} or not.

Detailing/dimensioning of primary seismic columns (secondary ones: as in DCL)

	DCH	DCM	DCL
Cross-section sides, h_c, $b_c \geq$	0.25m; $h_v/10$ if $\theta = P\delta/Vh > 0.1$ (1)	-	
"critical region" length (1) $\geq$	$1.5h_c$, $1.5b_c$, 0.6m, $l_c/5$	h_c, b_c, 0.45m, $l_c/6$	h_c, b_c
Longitudinal bars (L):			
ρ_{min}	1%		$0.1N_d/A_c f_{yd}$, 0.2% (0)
ρ_{max}	4%		4% (0)
$d_{bL} \geq$	8mm		
bars per side $\geq$	3		2
Spacing between restrained bars	$\leq$150mm	$\leq$200mm	-
distance of unrestrained bar from	$\leq$150mm		

(1) h_v is the distance of the inflection point to the column end further away, for bending within a plane parallel to the side of interest; l_c is the column clear length.

Detailing & dimensioning of primary seismic columns *(cont'd)*

	DCH	DCM	DCL
Transverse bars (w):			
Outside critical regions:			
$d_{bw} \geq$	6mm, $d_{bL}/4$		
spacing $s_w \leq$	$20d_{bL}$, h_c, b_c, 400mm		$12d_{bL}$, $0.6h_c$, $0.6b_c$, 240mm
at lap splices, if d_{bL}>14mm: $s_w \leq$	$12d_{bL}$, $0.6h_c$, $0.6b_c$, 240mm		
Within critical regions:(2)			
$d_{bw} \geq$ (3)	6mm, $0.4(f_{yd}/f_{ywd})^{1/2}d_{bL}$	6mm, $d_{bL}/4$	
$s_w \leq$ (3),(4)	$6d_{bL}$, $b_o/3$, 125mm	$8d_{bL}$, $b_o/2$, 175mm	-
$\omega_{wd} \geq$ (5)	0.08	-	
$\alpha\omega_{wd} \geq$ (4),(5),(6),(7)	$30\mu_{\phi}^{*}\nu_d\varepsilon_{sy,d}b_c/b_o-0.035$	-	
In critical region at column base:			
$\omega_{wd} \geq$	0.12	0.08	-
$\alpha\omega_{wd} \geq$ (4),(5),(6),(8),(9)	$30\mu_{\phi}\nu_d\varepsilon_{sy,d}b_c/b_o-0.035$		-

(2) For DCM: If q ≤ 2 used in the design, the transverse reinforcement in critical regions of columns with axial load ratio ν_d not greater than 0.2 may follow the rules applying to DCL columns.

(3) For DCH: In the two lower storeys of the building, the requirements on d_{bw}, s_w apply over a distance from the end section not less than 1.5 times the critical region height.

(4) c denotes full concrete section; o the confined core (to centreline of perimeter hoop); b_o is the smallest side of this core.

(5) ω_{wd}: volume ratio of confining ties to confined core (to centreline of perimeter hoop) times f_{yd}/f_{cd}

Detailing & dimensioning of primary seismic columns *(cont'd)*

	DCH	DCM	DCL
Transverse bars (w):			
Outside critical regions:			
$d_{bw} \geq$	$6mm, d_{bL}/4$		
spacing $s_w \leq$	$20d_{bL}, h_c, b_c$, 400mm		$12d_{bL}, 0.6h_c, 0.6b_c$, 240mm
at lap splices, if d_{bL}>14mm: $s_w \leq$	$12d_{bL}, 0.6h_c, 0.6b_c$, 240mm		
Within critical regions:(2)			
$d_{bw} \geq$ (3)	$6mm, 0.4(f_{yd}/f_{ywd})^{1/2}d_{bL}$	$6mm, d_{bL}/4$	
$s_w \leq$ (3),(4)	$6d_{bL}, b_o/3$, 125mm	$8d_{bL}, b_o/2$, 175mm	-
$\omega_{wd} \geq$ (5)	0.08	-	
$\alpha\omega_{wd} \geq$ (4),(5),(6),(7)	$30\mu_\phi^* \nu_d \varepsilon_{sy,d} b_c/b_o - 0.035$	-	
In critical region at column base:			
$\omega_{wd} \geq$	0.12	0.08	-
$\alpha\omega_{wd} \geq$ (4),(5),(6),(8),(9)	$30\mu_\phi \nu_d \varepsilon_{sy,d} b_c/b_o - 0.035$		-

(6) α : confinement effectiveness factor, $\alpha=\alpha_s\alpha_n$; where $\alpha_s=(1-s/2b_o)(1-s/2h_o)$ for hoops, $\alpha_s=(1-s/2b_o)$ for spirals; α_n=1 for circular hoops, $\alpha_n=1-\{b_o/((n_h-1)h_o)+h_o/((n_b-1)b_o)\}/3$ for rect. hoops with n_b legs parallel to side of the core with length b_o and n_h legs parallel to the one with length h_o.

(7) For DCH: at column ends protected from plastic hinging by capacity design of the column, μ_ϕ^* is the curvature ductility factor corresponding to 2/3 of the basic value q_o of the behaviour factor used in the design; at column ends where plastic hinging is not prevented due to the exemptions in Note (10) below, μ_ϕ^* is the full value corresponding to q_o; $\varepsilon_{sy,d}= f_{yd}/E_s$.

(8) Note (1) of the Beams Table applies.

(9) For DCH: Requirement applies also in the critical regions at the ends of columns where plastic hinging is not prevented, because of the exemptions in Note (10) below.

Detailing & dimensioning of primary seismic columns *(cont'd)*

	DCH	DCM	DCL
Capacity design check at beam-column joints: (10)	$1.3\sum M_{Rb} \leq \sum M_{Rc}$ No moment in transverse direction of column		-
Verification for M_x-M_y-N:	Truly biaxial, or uniaxial with (M_z/0.7, N), (M_y/0.7, N)		
Axial load ratio $\nu_d = N_{Ed}/A_c f_{cd}$	≤ 0.55	≤ 0.65	-
Shear design:			
V_{Ed} seismic(11)	$1.3\frac{\sum M_{Rc}^{ends}}{l_{cl}}$ (11)	$1.1\frac{\sum M_{Rc}^{ends}}{l_{cl}}$ (11)	from analysis for design seismic action plus gravity
$V_{Rd,max}$ seismic (12), (13)	As in EC2: $V_{Rd,max}=0.3(1-f_{ck}(MPa)/250)b_{wo}zf_{cd}\sin2\delta$, $1\leq\cot\delta\leq2.5$		
$V_{Rd,s}$ seismic (12), (13), (14)	As in EC2: $V_{Rd,s}=b_w z \rho_w f_{ywd}\cot\delta+N_{Ed}(h-x)/l_{cl}$ (13), $1\leq\cot\delta\leq2.5$		

(10) The capacity design rule does not need to be met at beam-column joints: (a) of the top floor, (b) of the ground storey in two-storey buildings with axial load ratio $\nu_d \leq 0.3$ in all columns, (c) if shear walls resist ≥ 50% of base shear parallel to the plane of the frame (wall buildings or wall-equivalent dual), or (d) in one-out-of-four columns of plane frames with columns of similar size.

(11) At a member end where the moment capacities around the joint satisfy: $\sum M_{Rb} < \sum M_{Rc}$, M_{Rc} is replaced by $M_{Rc}(\sum M_{Rb}/\sum M_{Rc})$.

(12) z is the internal lever arm, equal to 0.9*d* or to the distance between the tension and the compression reinforcement, d-d_1.

(13) The axial load, N_{Ed}, and its normalized value, ν_d, are taken with their most unfavorable values for the shear verification in the seismic design situation (considering both demand and capacity)

(14) *x* is the neutral axis depth at the end section in the ULS of bending with axial load.

Detailing & dimensioning of ductile walls

	DCH	DCM	DCL
Web thickness, $b_{wo} \geq$	max(150mm, $h_{storey}/20$)		-
critical region length, h_{cr}	$\geq \max(l_w, H_w/6)$ (1) $\leq \min(2l_w, h_{storey})$ if wall $\leq$6 storeys $\leq \min(2l_w, 2h_{storey})$ if wall > 6 storeys		-

(0) Notes (0) of the Beam & Column Tables apply.

(1) l_w is the long side of the rectangular wall section or rectangular part thereof; H_w is the total height of the wall; h_{storey} is the storey height.

Detailing & dimensioning of ductile walls *(cont'd)*

	DCH	DCM	DCL
Boundary elements:			
a) in critical region:			
- length l_c from edge ≥	$0.15l_w$, $1.5b_w$, length over which $\varepsilon_c > 0.0035$		-
- thickness b_w over l_c ≥	0.2m; $h_{st}/15$ if $l_c \le \max(2b_w, l_w/5)$, $h_{st}/10$ if $l_c > \max(2b_w, l_w/5)$		-
- vertical reinforcement:			
ρ_{min} over $A_c = l_c b_w$	0.5%		0.2% (0)
ρ_{max} over A_c	4% (0)		
- confining hoops (w) (2):			
$d_{bw} \ge$	6mm, $0.4(f_{yd}/f_{ywd})^{1/2} d_{bL}$	6mm,	in the part of the section where $\rho_L > 2\%$: as over the rest of the wall (case b, below)
spacing $s_w \le$ (3)	$6d_{bL}$, $b_o/3$, 125mm	$8d_{bL}$, $b_o/2$, 175mm	
$\omega_{wd} \ge$ (2)	0.12	0.08	
$\alpha\omega_{wd} \ge$ (3),(4)	$30\mu_\phi(\nu_d+\omega_v)\varepsilon_{sy,d} b_w/b_o - 0.035$		
b) over the rest of the wall height:	In parts of the section where $\varepsilon_c > 0.2\%$: $\rho_{v,min} = 0.5\%$; In parts of the section where $\rho_L > 2\%$: - distance of unrestrained bar in compression zone from nearest restrained bar ≤ 150mm; - hoops with $d_{bw} \ge \max(6\text{mm}, d_{bL}/4)$ & spacing $s_w \le \min(12d_{bL}, 0.6b_{wo}, 240\text{mm})$ (0) up to a distance of $4b_w$ above or below floor beams or slabs, or $s_w \le \min(20d_{bL}, b_{wo}, 400\text{mm})$ (0) beyond that distance		

(2) For DC M: If in the seismic design situation $\nu_d = N_{Ed}/A_c f_{cd} \le 0.15$, the DCL rules may be applied to boundary elements; these rules apply also if $\nu_d \le 0.2$ but the q-value used in the design is ≤ of 85% of the value allowed if the DC M confining reinforcement is used in boundary elements.

(3) Notes (4), (5), (6) of the columns Table apply for the confined core of boundary elements.

(4) μ_ϕ is the curvature ductility factor corresponding to the product of q_o andthe ratio M_{Edo}/M_{Rdo} at the base of the wall; $\varepsilon_{sy,d} = f_{yd}/E_s$, ω_{vd} is the mechanical ratio of the vertical web reinforcement.

Detailing & dimensioning of ductile walls *(cont'd)*

	DCH	DCM	DCL
Web:			
- vertical bars (v):			
$\rho_{v,min}$	wherever ε_c>0.2%: 0.5%; elsewhere 0.2%		0.2%$^{(0)}$
$\rho_{v,max}$	4%		
$d_{bv} \geq$	8mm	-	
$d_{bv} \leq$	$b_{wo}/8$	-	
spacing $s_v \leq$	min(25d_{bv}, 250mm)	min(3b_{wo}, 400mm)	
- horizontal bars:			
ρ_{hmin}	0.2%	max(0.1%, 0.25ρ_v)$^{(0)}$	
$d_{bh} \geq$	8mm	-	
$d_{bh} \leq$	$b_{wo}/8$	-	
spacing $s_h \leq$	min(25d_{bh}, 250mm)	400mm	
axial load ratio $\nu_d = N_{Ed}/A_c f_{cd}$	≤0.35	≤0.4	-
Design moments M_{Ed}:	If $H_w/l_w \geq 2$, design moments from linear envelope of maximum moments M_{Ed} from analysis for the "seismic design situation", shifted up by the "tension shift" a_l		from analysis for design seismic action & gravity

(0) Notes (0) of the Beam & Column Tables apply.

Detailing & dimensioning of ductile walls *(cont'd)*

	DCH	DCM	DCL
Shear design:			
Design shear force V_{Ed} = shear force V'_{Ed} from the analysis for the design seismic action, times factor ε:	if $H_w/l_w \le 2$(5): $\varepsilon = 1.2M_{Rdo}/M_{Edo} \le q$ if $H_w/l_w > 2$(5), (6): $\varepsilon = \sqrt{\left(1.2\frac{M_{Rdo}}{M_{Edo}}\right)^2 + 0.1\left(q\frac{S_e(T_C)}{S_e(T_1)}\right)^2} \le q$	ε=1.5	ε=1.0
Design shear force in walls of dual systems with $H_w/l_w>2$, for z between $H_w/3$ and H_w: (7)	$V_{Ed}(z) = \left(\frac{0.75z}{H_w} - \frac{1}{4}\right)\varepsilon V_{Ed}(0) + \left(1.5 - \frac{1.5z}{H_w}\right)\varepsilon V_{Ed}\left(\frac{H_w}{3}\right)$		from analysis for design seismic action & gravity
$V_{Rd,max}$ outside critical region	As in EC2: $V_{Rd,max}=0.3(1-f_{ck}(MPa)/250)b_{wo}(0.8l_w)f_{cd}\sin2\delta$, with $1\le\cot\delta\le2.5$		
$V_{Rd,max}$ in critical region	40% of EC2 value	As in EC2	

(5) M_{Edo} : moment at the wall base from the analysis for the seismic design situation;
M_{Rdo} : design moment resistance at wall base for the axial force N_{Ed} from the same analysis

(6) $S_e(T_1)$: value of the elastic spectral acceleration at the period of the fundamental mode in the horizontal direction (closest to that) of the wall shear force being multiplied by ε;
$S_e(T_C)$: spectral acceleration at the corner period T_C of the elastic spectrum.

(7) A dual structural system is one where walls resist between 35 and 65% of the seismic base shear in the direction of the wall shear force considered; z is distance from the base of the wall.

Detailing & dimensioning of ductile walls *(cont'd)*

	DCH	DCM	DCL
Shear design:			
$V_{Rd,s}$ in critical region; web reinforcement ratios: ρ_h, ρ_v			
(i) if $\alpha_s=M_{Ed}/V_{Ed}l_w\geq 2$: $\rho_v=\rho_{v,min}$, ρ_h from $V_{Rd,s}$:	$V_{Rd,s}=b_{wo}(0.8l_w)\rho_h f_{ywd}$	As in EC2: $V_{Rd,s}=b_{wo}(0.8l_w)\rho_h f_{ywd}\cot\delta$, $1\leq\cot\delta\leq 2.5$	
(ii) if $\alpha_s<2$: ρ_h from $V_{Rd,s}$: (8)	$V_{Rd,s}=V_{Rd,c}+b_{wo}\alpha_s(0.75l_w)\rho_h f_{yhd}$	As in EC2: $V_{Rd,s}=b_{wo}(0.8l_w)\rho_h f_{ywd}\cot\delta$, $1\leq\cot\delta\leq 2.5$	
ρ_v from: (9)	$\rho_v f_{yvd}\geq\rho_h f_{yhd}-N_{Ed}/(0.8l_w b_{wo})$		
Resistance to sliding shear: via bars with total area A_{si} at angle $\pm\alpha$ to the horizontal (10)	$V_{Rd,s}=A_{si}f_{yd}\cos\alpha+A_{sv}\min(0.25f_{yd},\ 1.3\sqrt{(f_{yd}f_{cd})})+0.3(1-f_{ck}(\text{MPa})/250)b_{wo}xf_{cd}$		
$\rho_{v,min}$ at construction joints (9),(11)	$0.0025,\ \dfrac{1.3f_{ctd}-\dfrac{N_{Ed}}{A_c}}{f_{yd}+1.5\sqrt{f_{cd}f_{yd}}}$	-	

(8) If b_w & d in m, f_{cd} in MPa, ρ_l: tensile reinforcement ratio and N_{Ed} in kN, $V_{Rd,c}$ (in kN) is given by:

$$V_{Rd,c}=\left\{\max\left[180(100\rho_1)^{1/3},\ 35\sqrt{1+\sqrt{\frac{0.2}{d}}}f_{cd}^{1/6}\right]\left(1+\sqrt{\frac{0.2}{d}}\right)f_{cd}^{1/3}+0.15\frac{N_{Ed}}{A_c}\right\}b_w d$$

$N_{ed}>0$ for compression; min. value from analysis for seismic design situation; $V_{Rd,}=0$ for tension

(9) $N_{Ed}>0$ for compression; use its minimum value from the analysis for the seismic design situation

(10) A_{sv}: total area of web vert. bars & of additional vert. bars in boundary elements for shear sliding

(11) $f_{ctd}=f_{ctk,0.05}/\gamma_c$: design value of (5%-fractile) tensile strength of concrete.