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REINFORCED MASONRY WALL OUT-OF-PLANE AXIAL, BENDING AND SHEAR FORCES;

Referance and notes: Reinforced Masonry Handbook use static equilibrium and strain compatiblity. Enter forces per length of wall then use length of wall as center to center spacing of reinforcement. the reinforcement is not tied it will not be considered effective in for axial load. Uses PΔ method considering the wall as a single span simply supported member.

Wall Geometry and Forces;

Height of wall;	H=23ft;	
Center to Center spacing of reinforcement;	b=40in;	
Reinforcment size (bar number);	b_{num}=6;	A_s=pi/4*(b_{num}*1in/8)^2=**0.442**in^2;
Shear reinforcement Reinforcment size diameter;	DIA=0in;	A_v=pi/4*(DIA)^2=**0.000**in^2;
Spacing of shear reinforcment;	S=16in;	
Mortar Type (N(1), S(2), M (3));	MT=2;	
Unfactored Loads per foot of wall;		"Total over distance=spacing"
Self Weight of Masonry at location of max moment;	P_{SW}=0.610 kip/ft;	P_{SWT}=b*P_{SW}=**2.033**kip;
Axial load due to dead load;	P_{DL}=0.5 kip/ft;	P_{DLT}=b*P_{DL}=**1.667**kip;
Axial load due to live loads;	P_{LL}=0.5 kip/ft;	P_{LLT}=b*P_{LL}=**1.667**kip;
Axial load due to snow loads;	P_{SL}=0.25 kip/ft;	P_{SLT}=b*P_{SL}=**0.833**kip;
Moment due to lateral load;	M_{SER}=1.051 kip_ft/ft;	M_{SERT}=b*M_{SER}=**3.503**kip_ft;
Eccentricity of dead load;	e_{DL}=7.3in;	
Eccentricity of Snow/Live Load;	e_{LLSL}=7.3in;	

Factored Loads per foot of wall (set load factors);		Per Foot;	"Total over distance=spacing"
Self weight;	LF_{SW}=0.9;	P_{USW}=LF_{SW}*P_{SW}=**0.549**kip/ft;	P_{USWT}=b*P_{USW}=**1.830**kip;
Dead Load;	LF_{DL}=0.9;	P_{UDL}=LF_{DL}*P_{DL}=**0.450**kip/ft;	P_{UDLT}=b*P_{UDL}=**1.500**kip;
Live Load;	LF_{LL}=0;	P_{ULL}=LF_{LL}*P_{LL}=**0.000**kip/ft;	P_{ULLT}=b*P_{ULL}=**0.000**kip;
Snow Load;	LF_{SL}=0;	P_{USL}=LF_{SL}*P_{SL}=**0.000**kip/ft;	P_{USLT}=b*P_{USL}=**0.000**kip;
Moment due to lateral load;	LF_M=1.0;	M_U=LF_M*M_{SER}=**1.051**kip_ft/ft;	M_{UT}=b*M_U=**3.503**kip_ft;
Shear;		V_U=0.2kip/ft;	V_{UT}=b*V_U=**0.667**kip;
Reduction factors;		ϕ_v=0.8; ϕ_{ab}=0.9;	

Wall Properties (compare to Table GN-8b) Geometry;

(assumes face shells, cell at bar and webs each side of bar are grouted)

Nominal thickness of unit (height of x-section);	h=7.625in;		
Depth to reinforcement;	d=3.81in;		
Flange thickness;	t_f=1.25in;		
Web thickness;	t_w=1.0in;		
Width of unit and width of grout;	b_{unit}=15.625in;	b_{grout}=0.375in;	
Nominal width of unit;	b_{nunit}=b_{unit}+b_{grout}=**16.000**in;		
Width of web cell;	b_{cell}=(b_{unit}-3*t_w)/2=**6.313**in;		
Width of web;	b_w=b_{cell}+2*t_f=**8.813**in;		
Height of web;	h_w=h-2*t_f=**5.125**in;		
Total area based on rebar spacing;	A=2*b*t_f+h_w*b_w=**145.164**in^2;	Gross;	A_g=b*h=**305.000**in^2
Area of web;	A_{web}=h_w*b_w=**45.164**in^2;		
Percent of cells grouted;	%gc=A_{web}/A=**0.311**;		
Total moment of inertia based on rebar spacing;	I=b*h^3/12-(b-b_w)/2*h_w^3/12*2=**1127.892**in^4;		
Radius of gryation;	r=(I/A)$^{0.5}$=**2.787**in;		

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Shear Area (disregard c dimension as max shear will not occur at max moment);	A_v= $b*t_f+b_w*(d-t_f)$=**72.560**in^2;	
<u>Wall Properties Material (See Tbl 2.2B or IBC 2105.2.2.1.2);</u>		
Maximum masonry compressive strain;	ε_m=0.0025;	(“Clay=0.0035”);
Max masonry compressive stress;	f'_m=1500psi;	
Steel yeild stress;	F_y=60ksi;	
Modulus of Elasticity – steel;	E_s=29000ksi;	
Ductility factor for strain in steel (MSJC 3.3.3.5);	aε=1.5;	
Steel yeild strain;	$\varepsilon_y=F_y/E_s$=**0.002**in/in;	
Modulus of Elasticity – masonry;	$E_m=900*f'_m$=**1350.000**ksi;	(use 700 for clay)
Modular ratio;	$n=E_s/E_m$=**21.481**;	
Slenderness Ratio;	γ=H/h=**36.197**	
Max allow. Comp. stress based on slenderness;	F_a=if(γ<=30,0.2*f'_m,0.05*f'_m)=**0.075**ksi;	
Modulus of rupture type N (MSJC Tbl 3.1.8.2.1);	f_{rn}=%gc*(158psi-48psi)+48psi=**82.224**psi;	
Modulus of rupture type M,S;	f_{rms}=%gc*(163psi-63psi)+63psi=**94.112**psi;	
Modulus of rupture;	f_r=if(MT==1, f_{rn},f_{rms})=**94.112**psi;	
<u>Shear Strength of Section;</u>		
Moment and shear interaction;	MV=$M_U/(V_U*d)$=**16.551**;	
Max Nominal Shear Strength for “MV<0.25”;	MV1=6*A_v*1psi*(f'_m/1psi)$^{0.5}$=**16.861**kip;	
Max Nominal Shear Strength for “MV>1.0”;	MV2=4*A_v*1psi* (f'_m/1psi)$^{0.5}$=**11.241**kip;	
Max Nominal Shear Strength;	V_{nmax}=InterpLinear(MV, 0.25, MV1, 1.0, MV2)=**11.241**kip;	
Allowable masonry shear strength;	V_m=(4-1.75*min(1,MV))*A_v*1psi* (f'_m/1psi)$^{0.5}$=**6.323**kips;	
Steel shear strength;	V_s=0.5*A_v/S*F_y*d=**518.351**kips;	
Shear strength;	$V_c=\phi_v$*min(V_m+V_s,V_{nmax})=**8.993**kips;	
<u>Analysis of Stess and Strain;</u>		
Assume location of NA;	c=0.9 in;	
Maximum allowable compressive strain of MSRY;	ε_m=**0.003**;	
Depth of compression block;	a=0.8*c=**0.720**in;	
Effective flange thickness (strength , deflection);	t'_f=min(t_f,a)=**0.900**in;	$t'_{f\Delta}$=min(t_f,c)=**0.900**in;
Effective height of web (strength, deflection);	y_{cw}=max(0in,a-t'_f)=**0.000**in;	$y_{cw\Delta}$=max(0in,c-$t'_{f\Delta}$)=**0.000**in;
Strain in steel based on compatibility;	$\varepsilon_s=\varepsilon_m$/c*(d-c)=**0.008**in/in;	
Stress in steel;	$f'_s=E_s*\varepsilon_s$ =**234.417**ksi;	
Usable steel stress;	f_s=min(F_y,f'_s)=**60.000**ksi;	
Compressive force on flange;	C_f=0.8*f'_m*t'_f*b=**34.560**kip;	
Compressive force on web;	C_w=0.8*f'_m *y_{cw} *b_w=**0.000**kip;	
Tension force;	T=max(0kip,A_s*f_s)=**26.507**kip;	
Momemt Arm – Flange;	X_{cf}=h/2-t'_f/2=**3.452**in;	
Moment strength;	$M_{cf}=X_{cf}*C_f$=**9.943**kip_ft;	
Moment Arm – Web;	X_{cw}=h/2-(t'_f+y_{cw}/2)=**3.093**in;	
Moment strength – Web;	$M_{cw}=X_{cw}*C_w$=**0.000**kip_ft;	
Moment Arm – Steel;	X_{s1}=h/2-d=**0.002**in;	

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Moment strength – steel;	$M_{s1}=X_{s1}*T=$**0.006**kip_ft;
Nominal compressive force based on assumed c location and Maximum masonry strain;	$P_{nsT}=C_f+C_w-T=$**8.053**kip;
Nominal moment stength;	$M_{nsT}=M_{cf}+M_{cw}-M_{s1}=$**9.938**kip_ft;;
Eccentricity of section;	$e_s=M_{nsT}/P_{nsT}=$**14.809**in;
P-D Method Ultimate Loads;	
Initial deflection estimate;	$\delta'_u=1.55$in;
Total factored axial load;	$P_{UT}= P_{USWT} + P_{UDLT} + P_{ULLT} + P_{USLT}=$**3.330**kips
Effective Load to contribute to steel area;	$P_{ueT}=P_{USWT} + P_{UDLT} +0.5*(P_{ULLT}+P_{USLT})=$**3.330**kips;
Effective steel area;	$A_{seu}=(P_{ueT}+A_s*F_y)/F_y=$**0.497**in^2;
Gross moment of inertia;	$I_g=b_w*h_w^3/12+b*t_f^3/12+2*((b*t_f)*(h/2-t_f/2)^2)=$**1121.381**in^4;
Cracked Moment;	$M_{cr}=2*I_g*f_r/h=$**2.307**kip_ft;
Gross moment of inertia and Cracked moment;	$I_g=$**1121.381**in^4; $M_{cr}=2*I_g*f_r/h=$**2.307**kip_ft;
Cracked moment of inertia;	$I_{cru}=b* t'_{f\Delta}{}^3/12+(t'_{f\Delta} *b)*(c- t'_{f\Delta} /2)^2+b_w*y_{cw\Delta}{}^3/12+(y_{cw\Delta}*b_w)*(y_{cw\Delta}/2)^2+n*A_{seu}*(d-c)^2$; $I_{cru}=$**100.180**in^4;
Moment due to offset load;	$M_{euT}=P_{UDLT}*e_{DL}/2+(P_{ULLT}+P_{USLT})*e_{LLSL}/2=$**0.456**kip_ft;
Moment due to deflection;	$M_{duT}=(P_{UDLT}+P_{ULLT}+P_{USLT}+P_{USWT})* \delta'_u=$**0.430**kip_ft;
Amplified ultimate moment;	$M_{auT}=M_{UT}+M_{euT}+M_{duT}=$**4.390**kip_ft;
Ultimate load deflection;	$\delta_u=5*M_{cr}*H^2/(48*E_m*I_g)+5*(M_{auT}-M_{cr})*H^2/(48*E_m*I_{cru})=$**1.612**in;
Convergance should be <5%;	$CS_u=(\delta_u-\delta'_u)/\delta_u*100=$**3.822**;
Eccentricity required from loads;	$e_r=M_{auT}/P_{UT}=$**15.819**in;
Eccentricity of section;	$e_s=M_{nsT}/P_{nsT}=$**14.809**in;
P-D Method Service Loads;	
Initial deflection estimate;	$\delta'_s=0.95$in;
Effective Load to contribute to steel area;	$P_{ses}=P_{SWT}+P_{DLT}+0.5*(P_{LLT}+P_{SLT})=$**4.950**kip ;
Effective steel area;	$A_{ses}=(P_{ses} +A_s*F_y)/F_y=$**0.524**in^2;
Cracked moment of inertia;	$I_{crs}=b* t'_{f\Delta}{}^3/12+(t'_{f\Delta} *b)*(c- t'_{f\Delta} /2)^2+b_w*y_{cw\Delta}{}^3/12+(y_{cw\Delta}*b_w)*(y_{cw\Delta}/2)^2+n*A_{ses}*(d-c)^2$; $I_{crs}=$**105.092**in^4;
Gross moment of inertia and Cracked moment;	$I_g=$**1121.381**in^4; $M_{cr}=2*I_g*f_r/h=$**2.307**kip_ft;
Moment due to offset load;	$M_{esT}=P_{DLT}*e_{DL}/2+(P_{LLT}+P_{SLT})*e_{LLSL}/2=$**1.267**kip_ft;;
Moment due to deflection;	$M_{dsT}=(P_{DLT}+P_{LLT}+P_{SLT}+P_{SWT})* \delta'_s=$**0.491**kip_ft;
Amplified service moment;	$M_{asT}=M_{SERT}+M_{esT}+M_{dsT}=$**5.262**kip_ft;
Service load deflection;	$\delta_s=5*M_{cr}*H^2/(48*E_m*I_g)+5*(M_{SERT}-M_{cr})*H^2/(48*E_m*I_{crs})=$**0.948**in;
Convergance should be <5%;	$CS_s=(\delta_s-\delta'_s)/\delta_s*100=$**-0.194**;
Max allowable deflection;	$\Delta_{smax}=0.007*H=$**1.932**in;

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<u>Checks;</u>

Axial Stress (gross);	$f_a=P_{UT}/A_g=$**10.918**psi;
Axial Strength;	$P_c=P_{nsT}*\phi_{ab}=$**7.248**kip;
Moment Strength;	$M_c=M_{nsT}*\phi_{ab}=$**8.944**kip_ft;
Check Axial Stress;	ChAx=if($F_a>f_a$,"OK","NG")=**"OK"**;
Check Shear stress;	ChV=if($V_c>V_{UT}$,"OK","NG")=**"OK"**;
Check Axial Strength;	ChP=if($P_c>P_{UT}$,"OK","NG")=**"OK"**;
Check Moment Strength;	ChM=if($M_c>M_{UT}$,"OK","NG")=**"OK"**;
Check Deflection;	ChD=if($\delta_s< \Delta_{smax}$,"OK","NG")=**"OK"**;
Check Ductility (minimum steel strain);	Che=if($\varepsilon_s>a\varepsilon*\varepsilon_y$,"OK","NG")=**"OK"**;
Check Convergence;	ChCn=if(and($CS_s<5,CS_u<5$),"OK","NG")=**"OK"**;