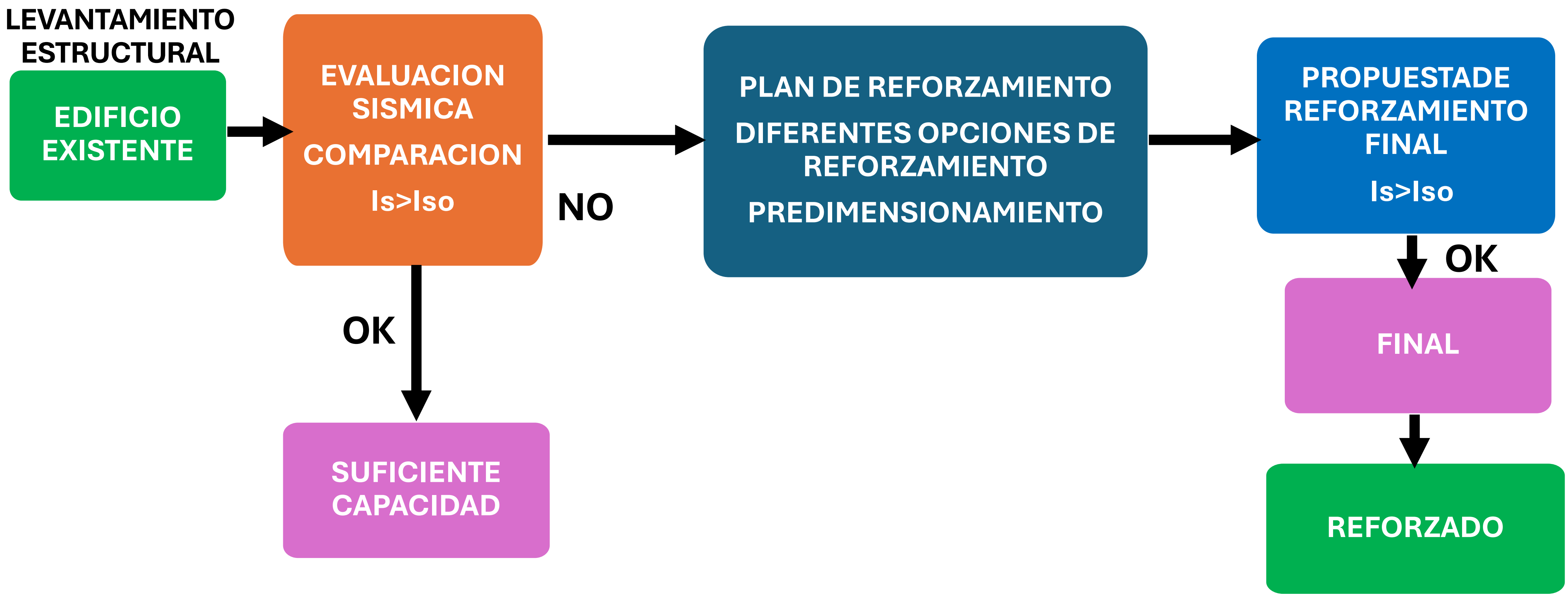
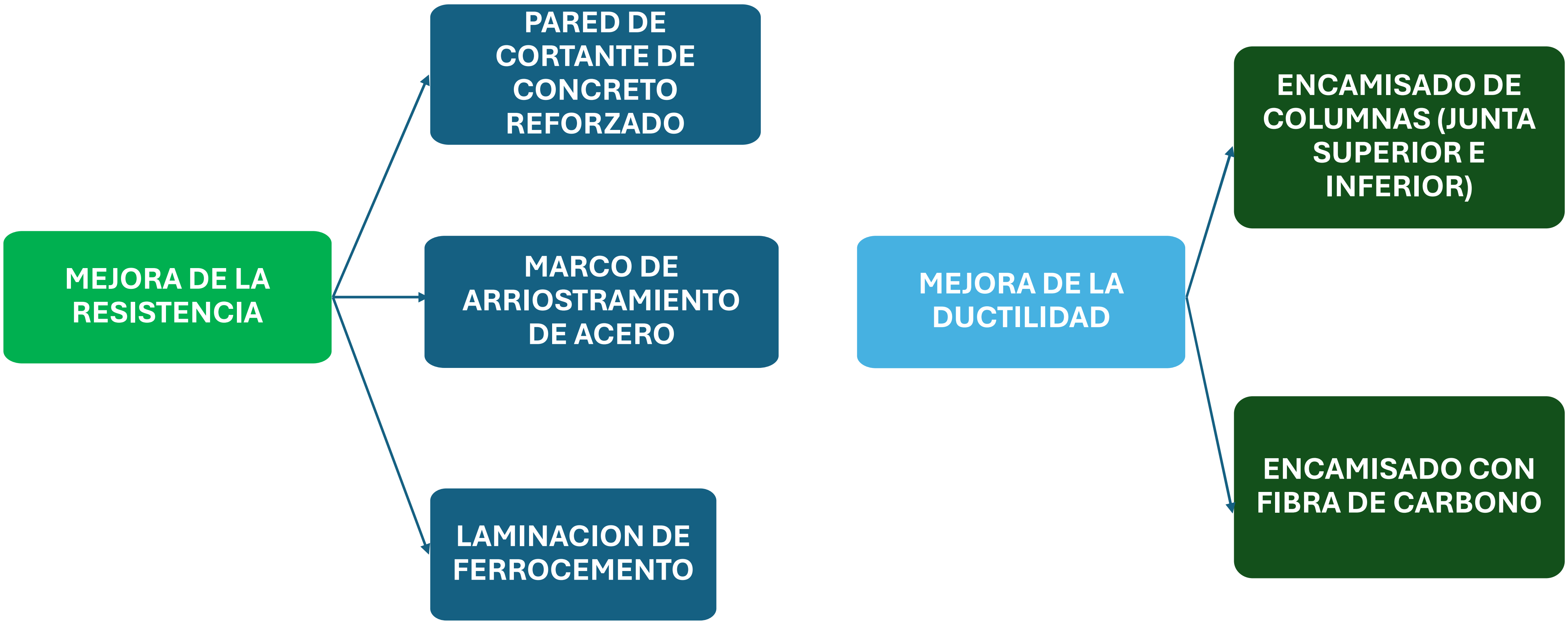
MANUAL PARA EL DISEÑO DE REFORZAMIENTO SISMICO DE EDIFICIOS EXISTENTES DE CONCRETO REFORZADO

EDWARD QUINTANILLA

Plan de Reforzamiento

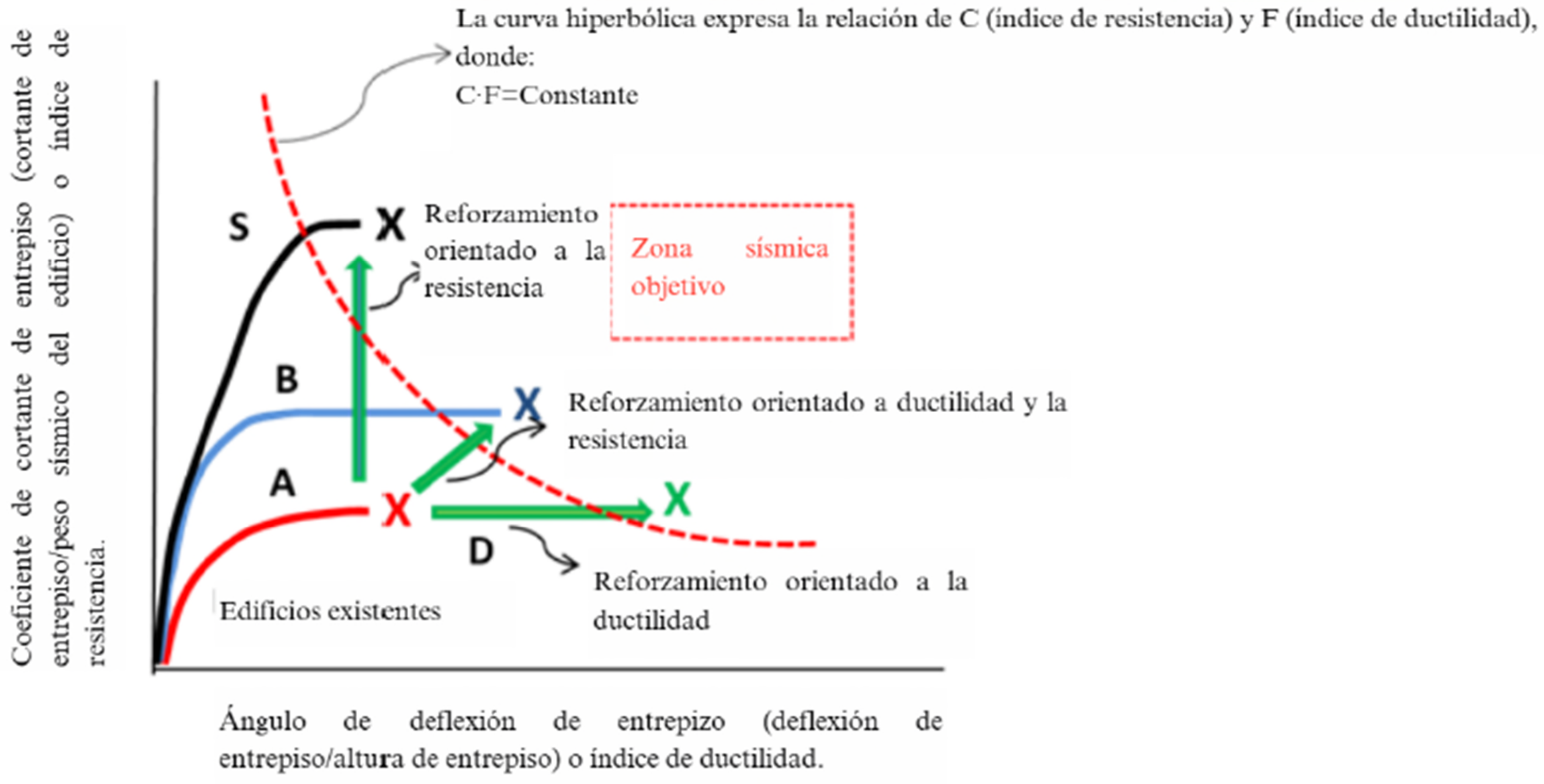


Plan de Reforzamiento



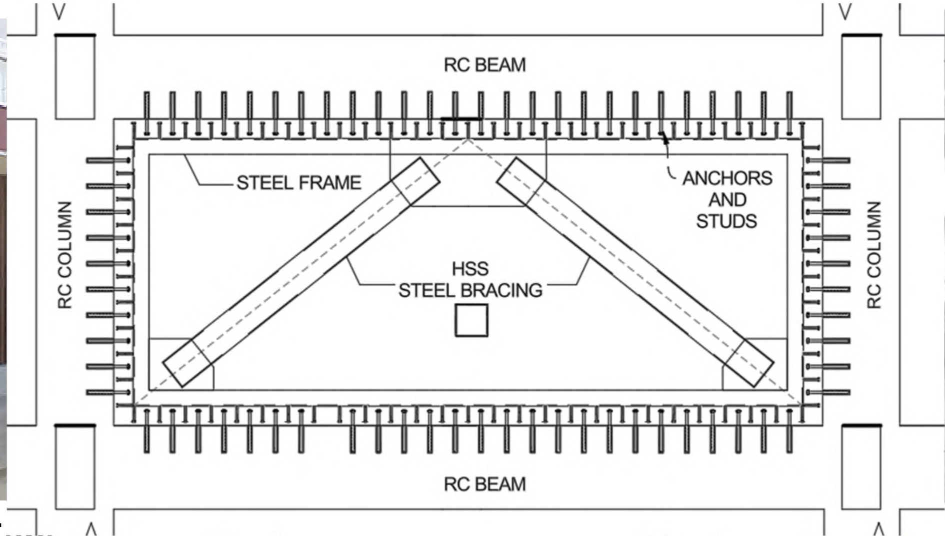
Fuente: MANUAL PARA EL DISEÑO Y REFORZAMIENTO SISMICO DE EDIFICIOS EXISTENTES DE CONCRETO REFORZADO, PAGINA 26

Plan de Reforzamiento



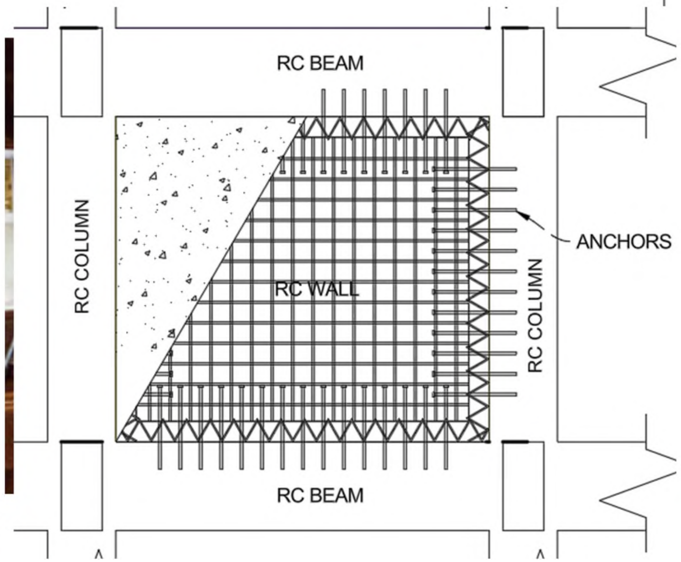
Fuente: MANUAL PARA EL DISEÑO Y REFORZAMIENTO SISMICO DE EDIFICIOS EXISTENTES DE CONCRETO REFORZADO, PAGINA 27

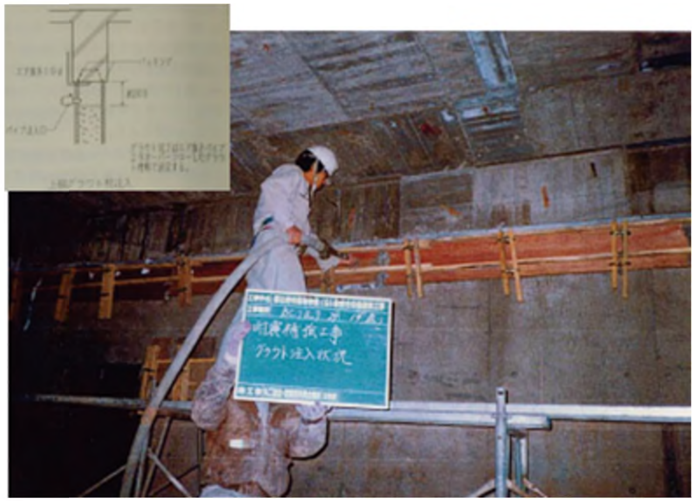
Plan de Reforzamiento



Source: https://www.design-fit.jp/

Source: Seismic Evaluation and Seismic Rehabilitation by M. Sakashita

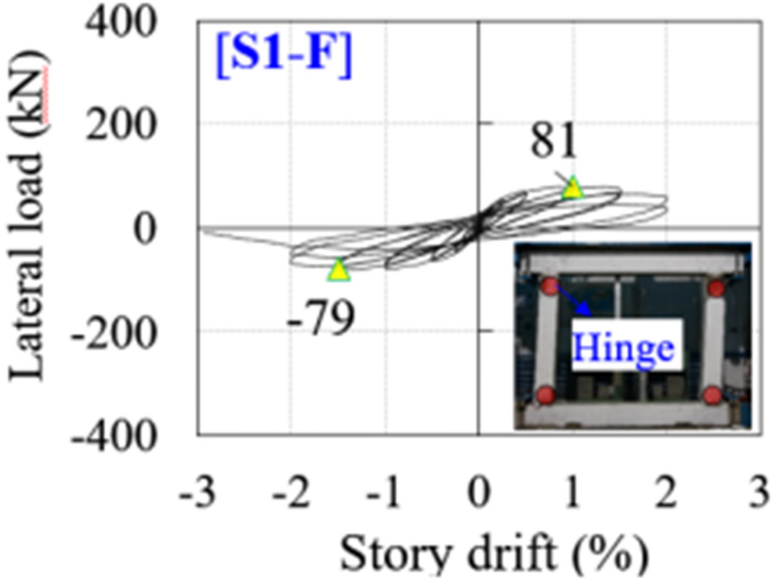


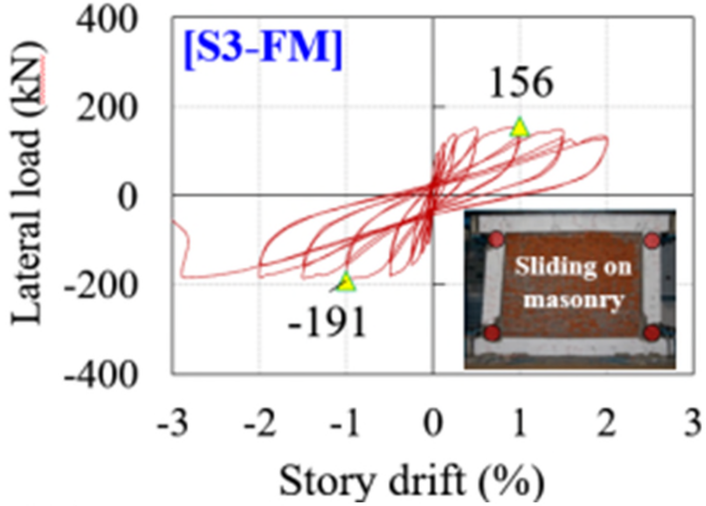


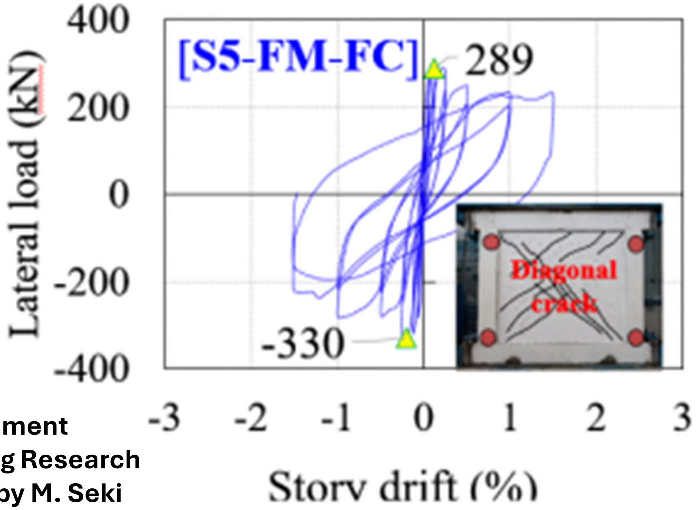
Plan de Reforzamiento

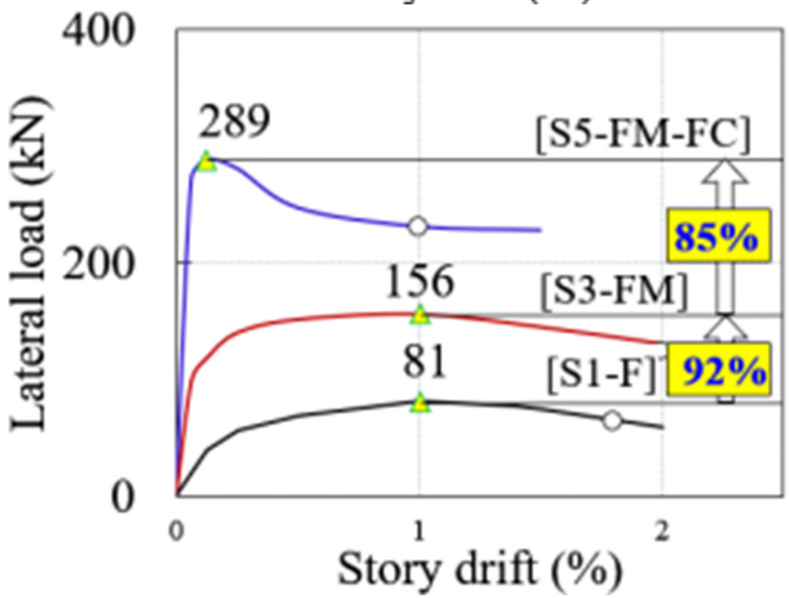
Source: Manual for Ferrocement Lamination retrofit, Building Research Institute (BRI, IISEE JAPAN by M. Seki

Plan de Reforzamiento



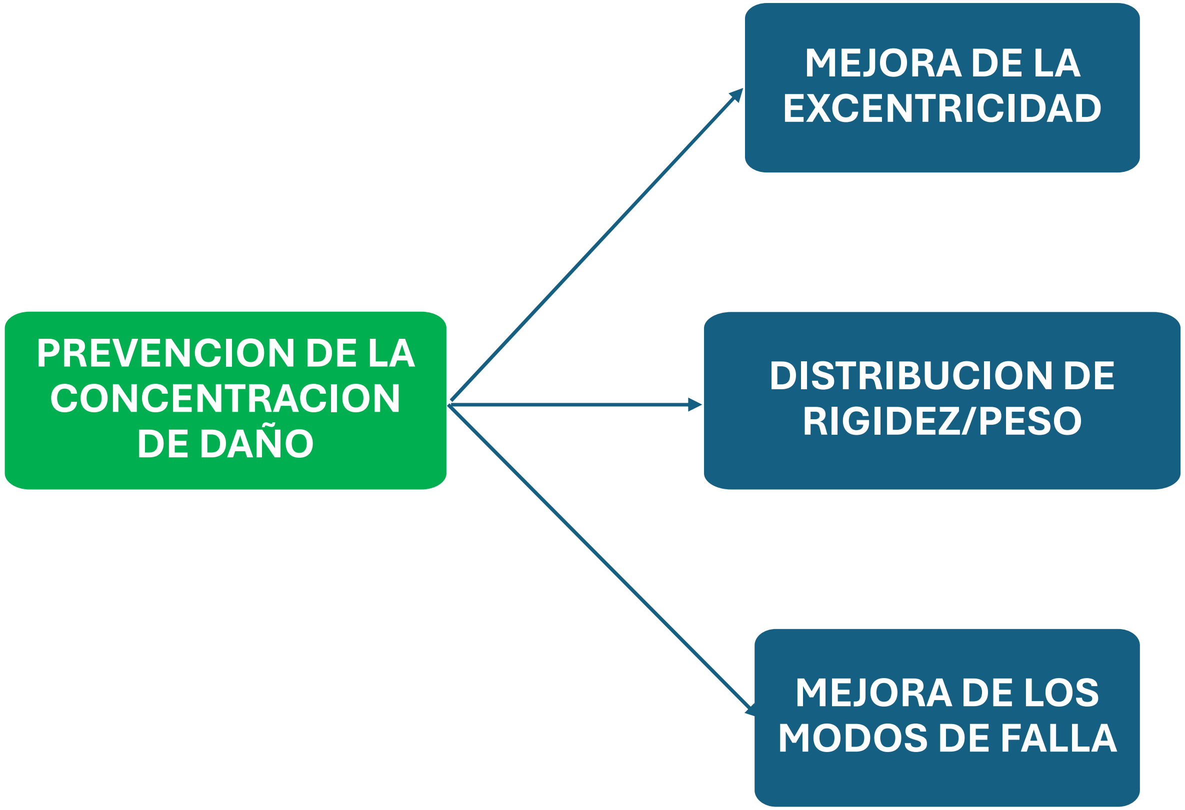






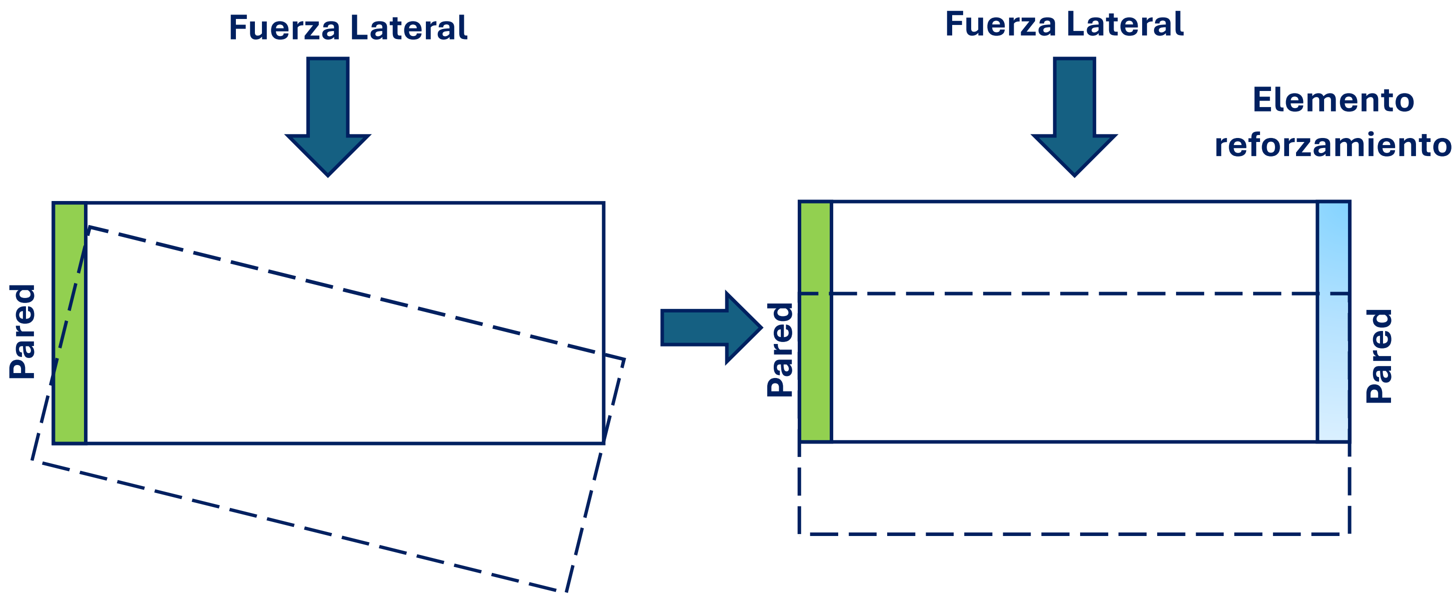
Source: Manual for Ferrocement Lamination retrofit, Building Research Institute (BRI, IISEE JAPAN by M. Seki

Plan de Reforzamiento



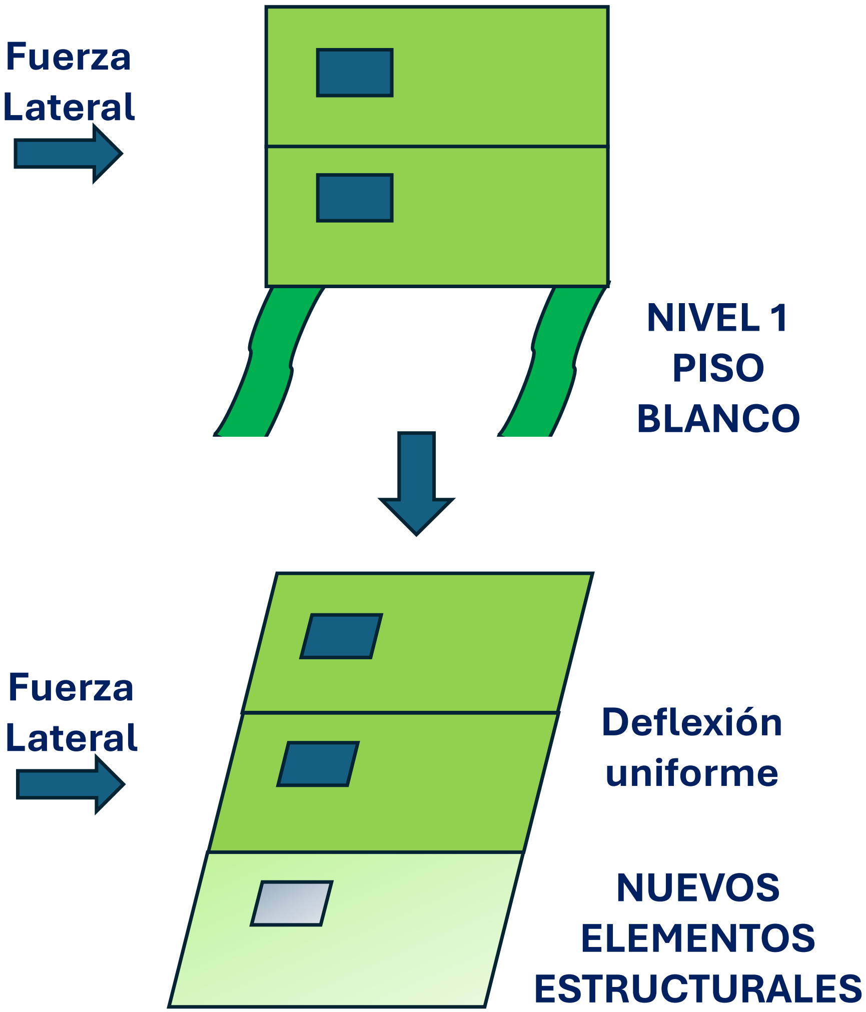
Fuente: MANUAL PARA EL DISEÑO Y REFORZAMIENTO SISMICO DE EDIFICIOS EXISTENTES DE CONCRETO REFORZADO, PAGINA 26

Plan de Reforzamiento



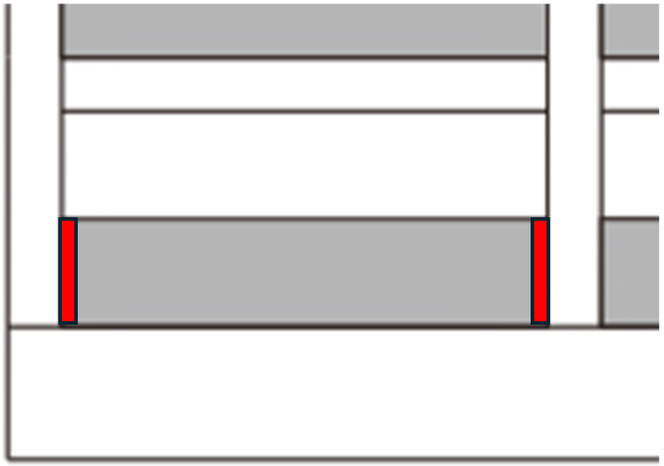
Source: Seismic Evaluation and Seismic Rehabilitation by M. Sakashita

Plan de Reforzamiento



Source: Seismic Evaluation and Seismic Rehabilitation by M. Sakashita

Plan de Reforzamiento



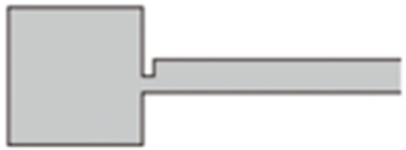
Columna Corta

Source: Seismic Evaluation and Seismic Rehabilitation by M. Sakashita

Columna exterior

Columna interior

Ranura o Junta Estructural



Procedimiento de Diseño de Reforzamiento Sismico

INDICE SISMICO TIPO 1 (SEGUNDO NIVEL DE EVALUACION)

INDICE SISMICO TIPO 2 (EVALUACION SISMICA DETALLADA)

BASADO EN EL DESEMPEÑO SISMICO (ESPECTRO DE CAPACIDAD Y METODO DE LOS COEFICIENTES)

Fuente: MANUAL PARA EL DISEÑO Y REFORZAMIENTO SISMICO DE EDIFICIOS EXISTENTES DE CONCRETO REFORZADO, PAGINA 27

SEGUNDO NIVEL DE EVALUACION

$$I_S \geq I_{SO}$$

$$I_S = E_o \times S_D \times T$$

I_S= INDICE SISMICO DE LA ESTRUCTURA

I_{SO}= INDICE SISMICO OBJETIVO (DEMANDA SISMICA OBJETIVO)

E_o= INDICE SISMICO BASE DE LA ESTRUCTURA

S_D = INDICE DE IRREGULARIDAD

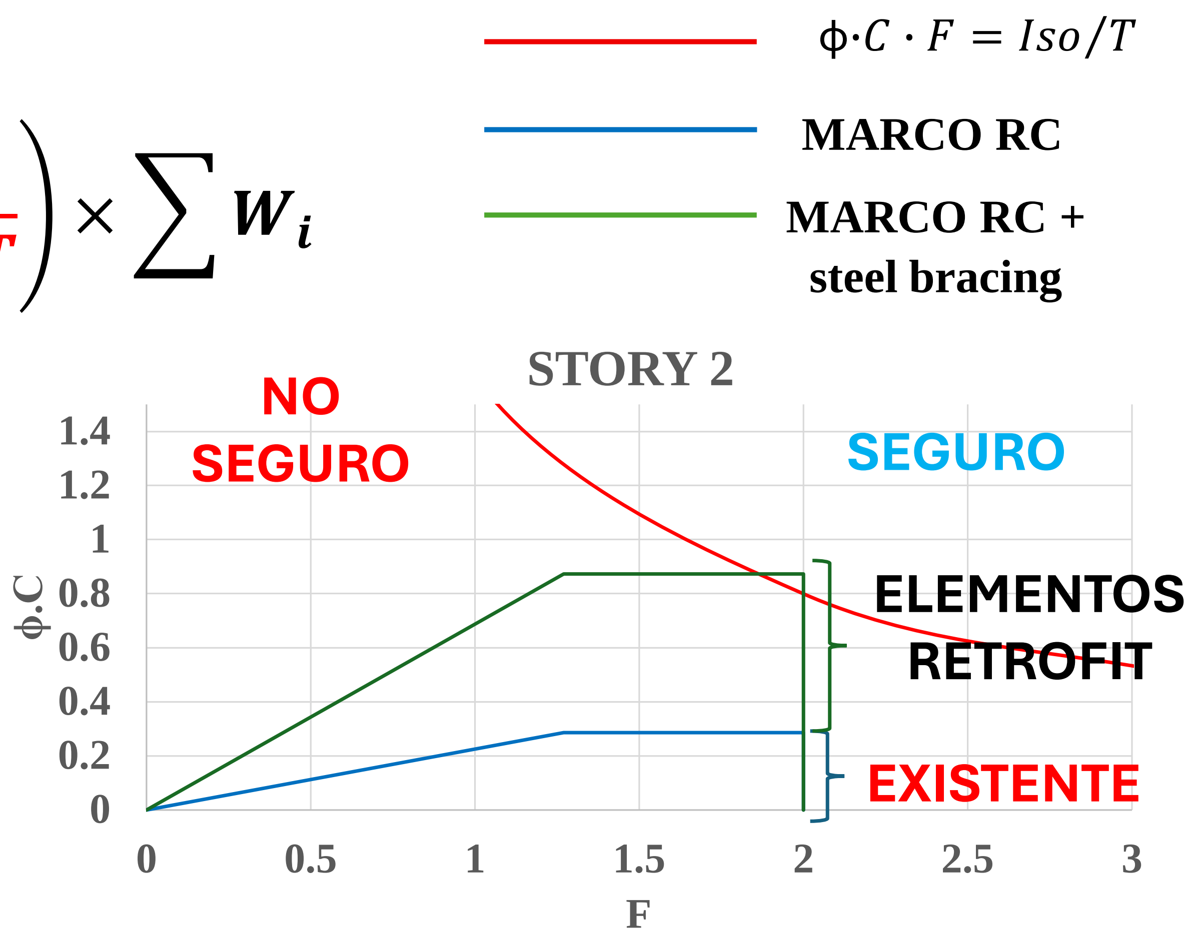
T= INDICE DE TIEMPO

SEGUNDO NIVEL DE EVALUACION

DESPUES REFORZAMIENTO

ANTES REFORZAMIENTO

$$\Delta Q_i = \left(\frac{n+i}{n+1}\right) \times \frac{1}{F}\left(\frac{{}_R I_S}{{S_D}' \cdot T'} - \frac{I_S}{S_D \cdot T}\right) \times \sum W_i$$

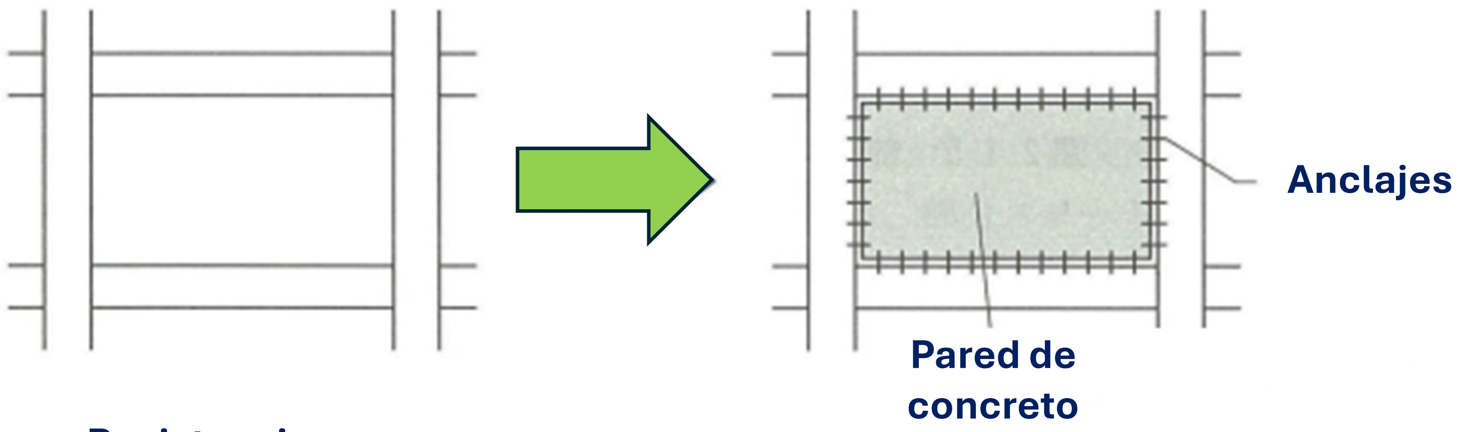


ΔQ_i= FUERZA CORTANTE REQUERIDA EN EL PISO i DEL EDIFICIO EXISTENTE PARA ALCANZAR LA DEMANDA SISMICA

${}_R I_S = I_{so} =$ INDICE SISMICO OBJETIVO

Fuente: MANUAL PARA EL DISEÑO Y REFORZAMIENTO SISMICO DE EDIFICIOS EXISTENTES DE CONCRETO REFORZADO, PAGINA 29

SEGUNDO NIVEL DE EVALUACION



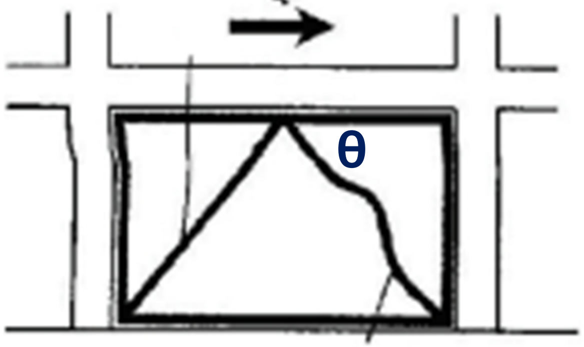
Resistencia cortante — Resistencia cortante del muro — Aporte de las columnas

$$ {}_{w}Q_{su} = \min\left\{ {}_{w}Q'_{su} + 2 \cdot \alpha \cdot Q_c \ , \ Q_j + {}_{p}Q_c + \alpha \cdot Q_c \right\} $$

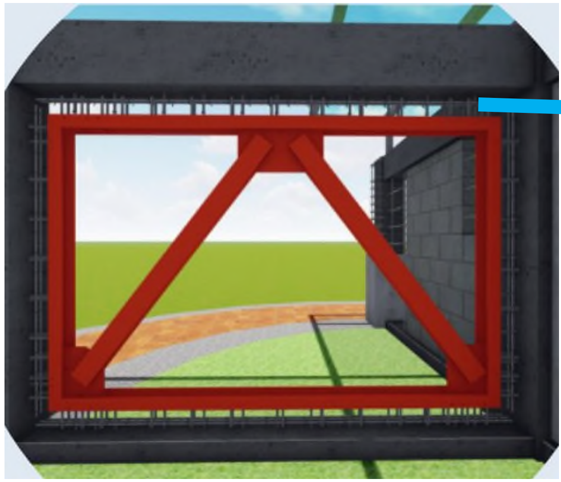
∑Resistencia Cortante conectores bajo la viga — Resistencia Cortante parte superior columna — Aporte columna

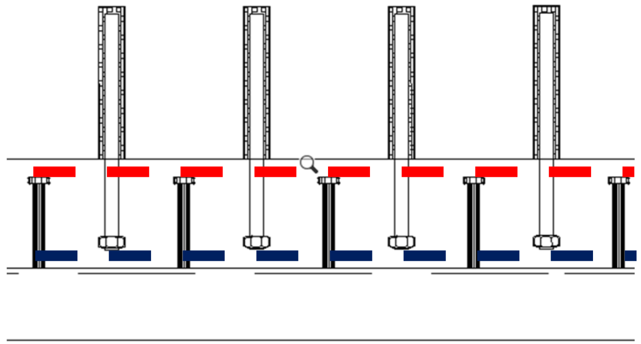
CAPITULO 3, SECCION 3.3
PAGINAS 60-81

Arriostramiento Trabajando a tensión



Pandeo del arriostramiento a compresión





$$Q_{suAnclaje} = Q_{jAnclje} + {}_pQ_c + \alpha \cdot Q_c$$

$$Q_{suPerno} = Q_{jPerno} + {}_pQ_c + \alpha \cdot Q_c$$

$$\min \{Q_{su},\ Q_{suAnclaje},\ Q_{suPerno}\}$$

$$Q_{su} = (N_c + N_0)\cos\theta$$

Capacidad Ultima

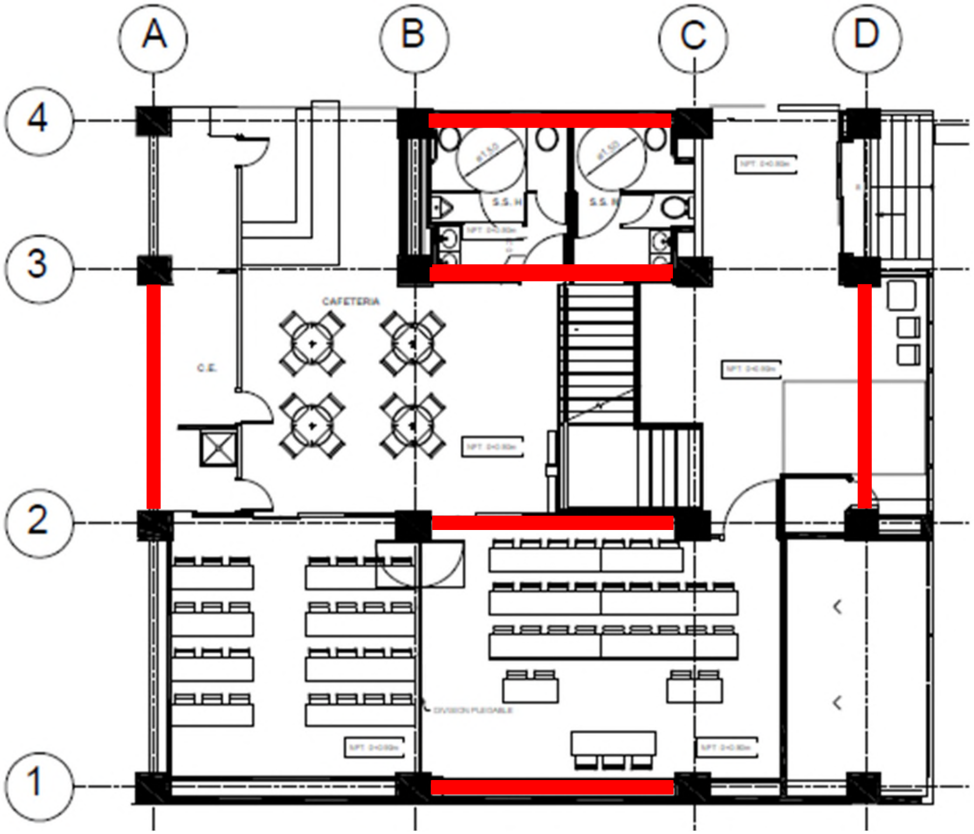
$$Q_u = 2Q_{cu} + Q_{su}$$

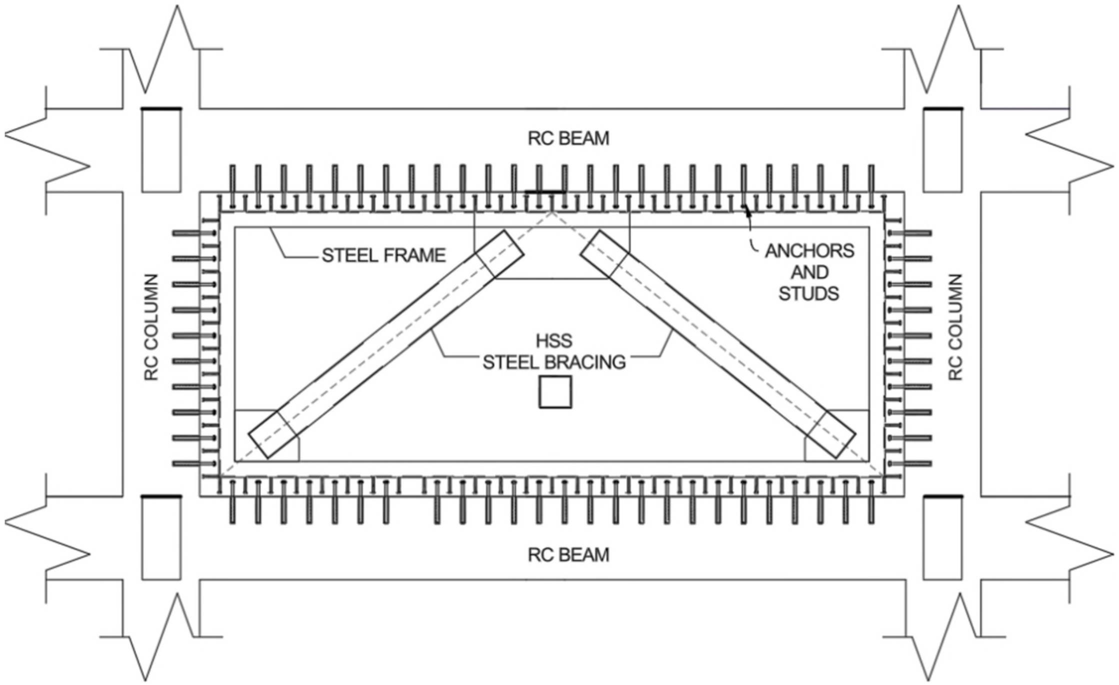
Aporte columnas — Aporte Sistema de arriostramiento

CAPITULO 3, SECCION 3.4
PAGINAS 82-100

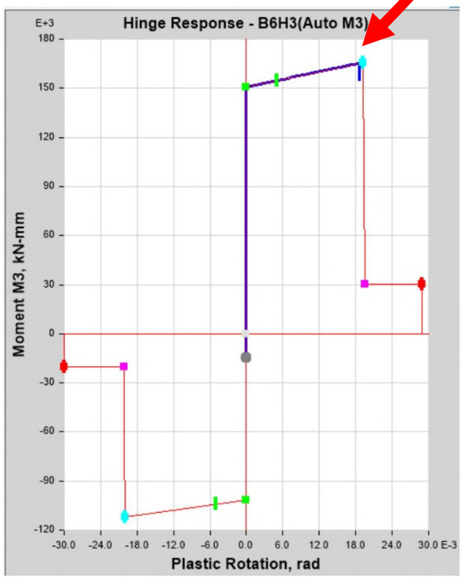
SEGUNDO NIVEL DE EVALUACION

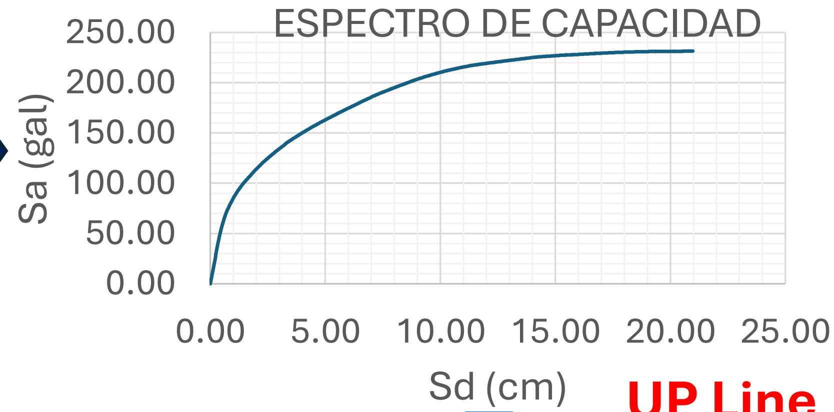
SISTEMA DE STEEL BRACING	Qsb (kN)	ΔQi (kN)	ΔQi/Qsb	#	RETROFIT
HSS 6X6X1/4	1631.29		3.28	4	
HSS 8X8X1/4	2185.41	5348.48	2.45	3	2 HSS 10x10x1/4
HSS 10X10X1/4	2770.48		1.93	2	

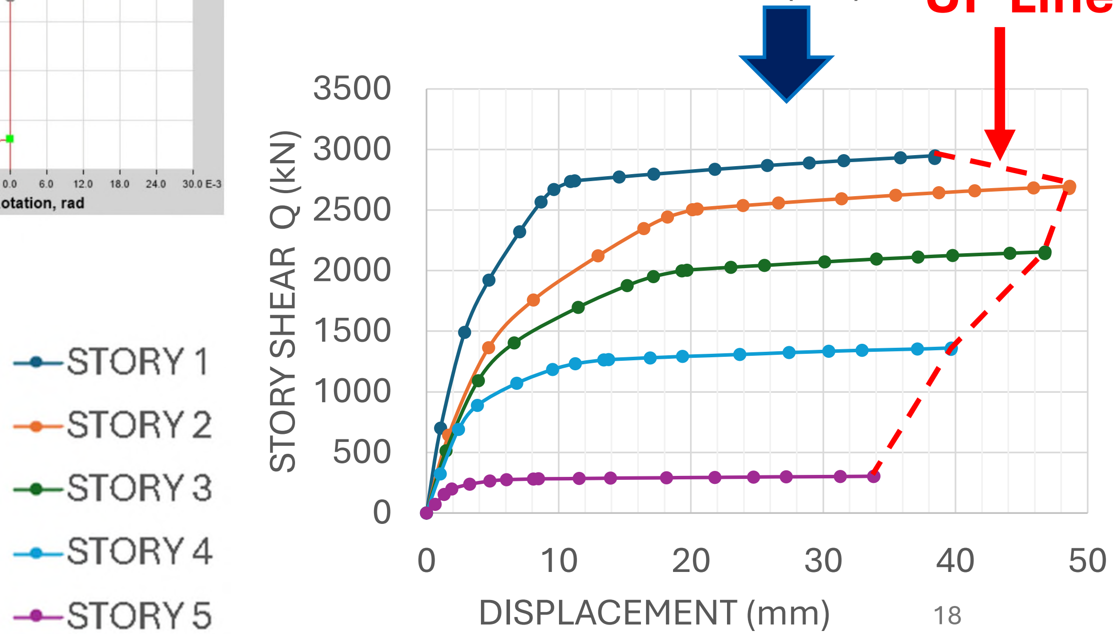




PATRON DE CARGAS



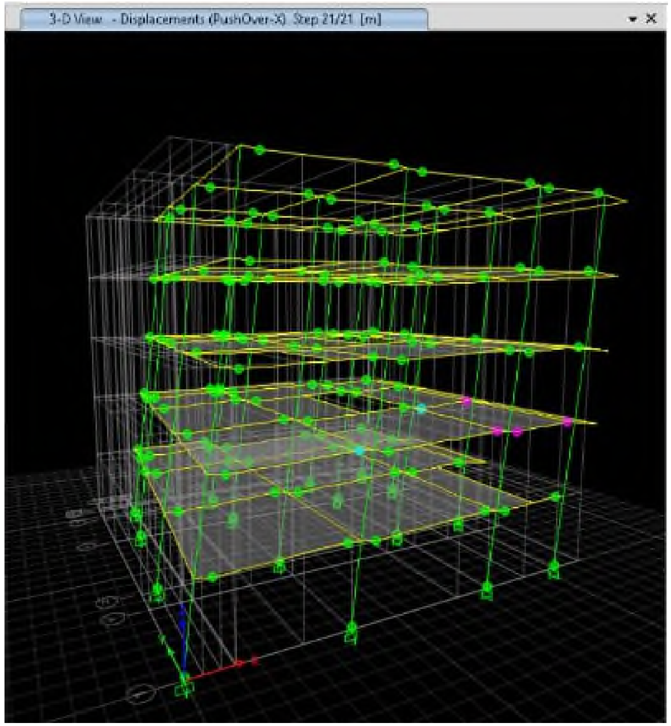


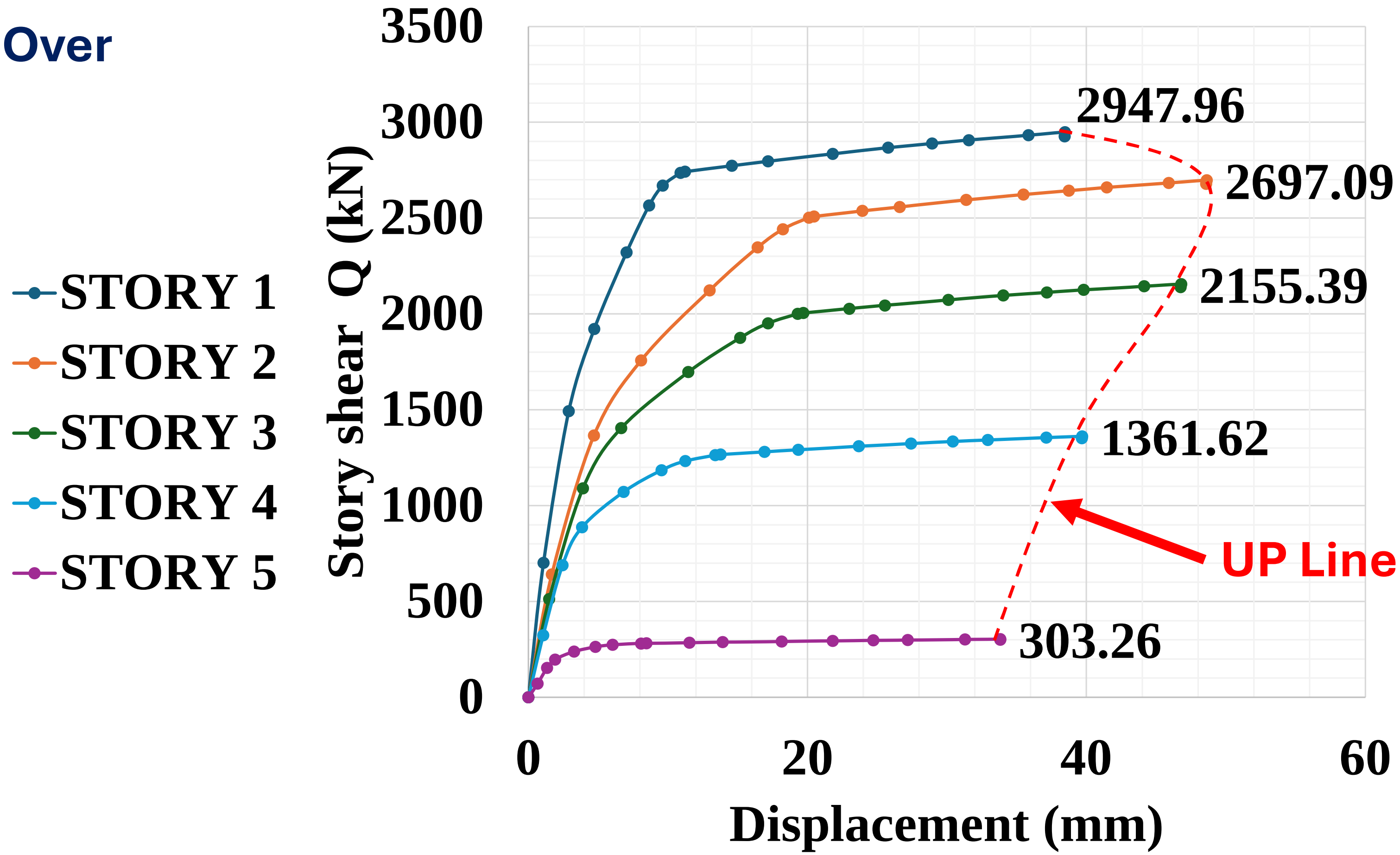


1. **NTDS**
2. **ASCE 41-13**
3. **METODOLOGÍA JAPONESA**
4. **EXPERIMENTOS PROYECTO HOKYO**

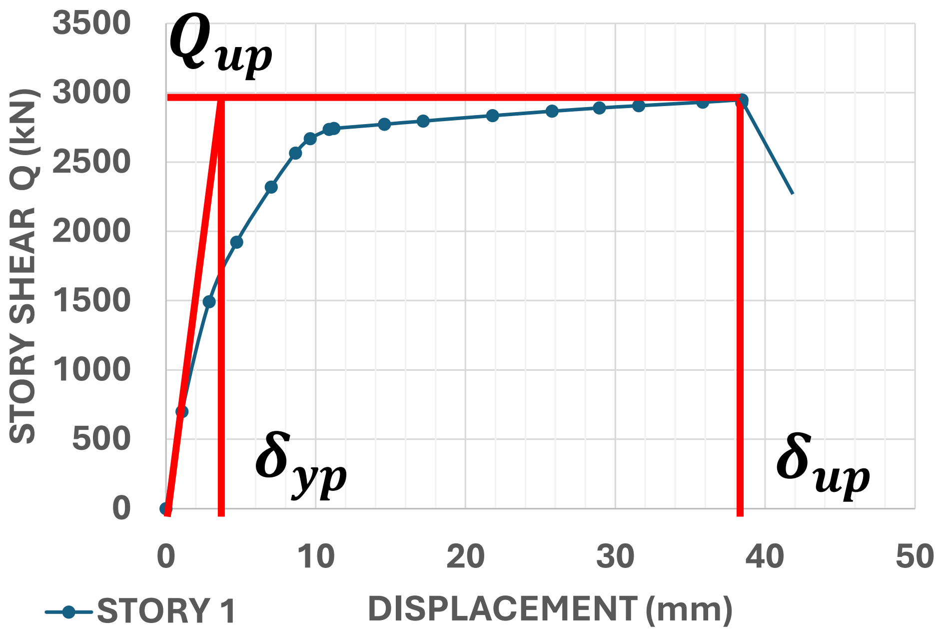
EVALUACION SISMICA DETALLADA

Resultados Push Over





EVALUACION SISMICA DETALLADA



$$E_o = \emptyset \times C \times F$$

$$F = \frac{\delta_{up}}{\delta_{yp}} \qquad C = \frac{Q_{up}}{\sum W_i}$$

$$\emptyset = \frac{n+1}{n+i}$$

$$I_s = E_o \times S_D \times T$$

STORY	C	F	∅	Eo	T	SD	Is	Iso	Conclusion
5	0.41	**2.00**	0.60	0.49	0.90	1.00	**0.44**	1.44	**REFORZAR**
4	0.43	**2.00**	0.67	0.57	0.90	1.00	**0.52**	1.44	**REFORZAR**
3	0.39	**2.00**	0.75	0.58	0.90	1.00	**0.52**	1.44	**REFORZAR**
2	0.33	**2.00**	0.86	0.57	0.90	1.00	**0.51**	1.44	**REFORZAR**
1	0.28	**2.00**	1.00	0.57	0.90	1.00	**0.51**	1.44	**REFORZAR**

Plan de Reforzamiento

EVALUACION SISMICA DETALLADA

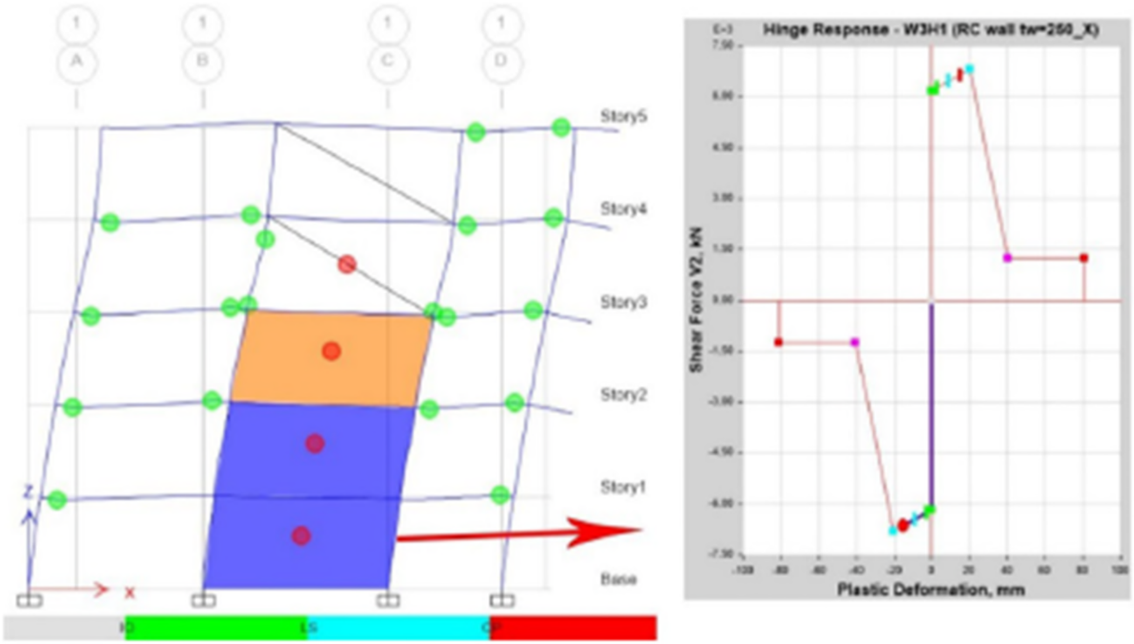
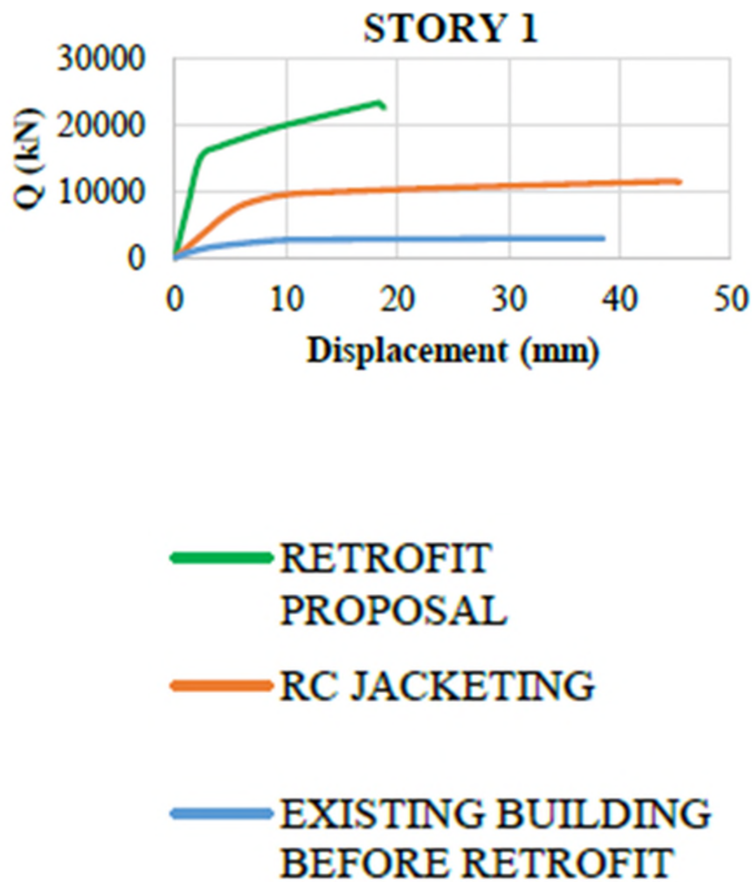


Figure 52. Hinge response RC wall t=250 mm story 1, axis 1.



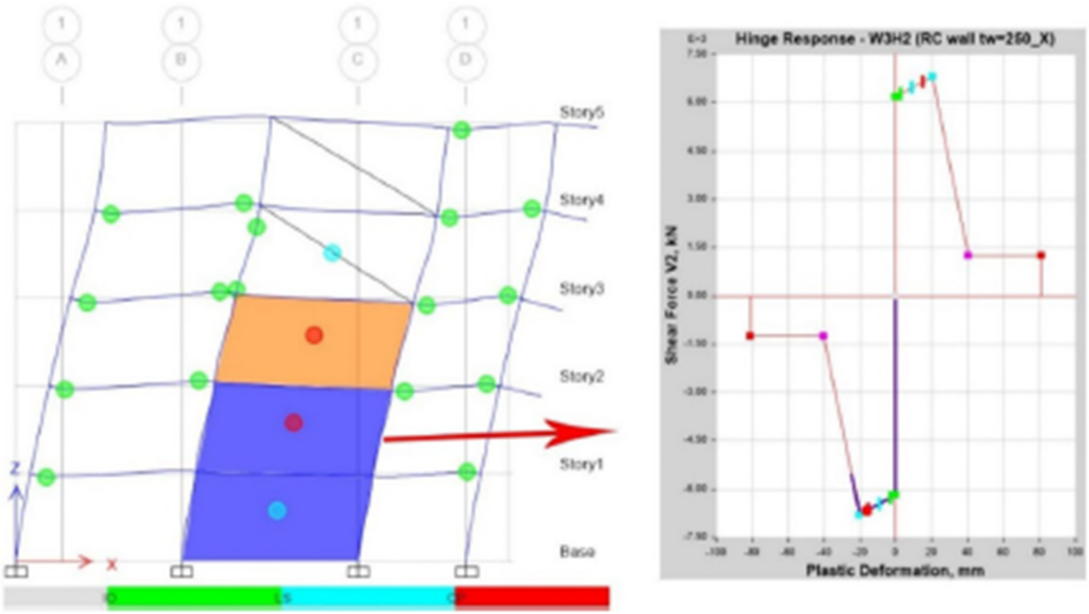
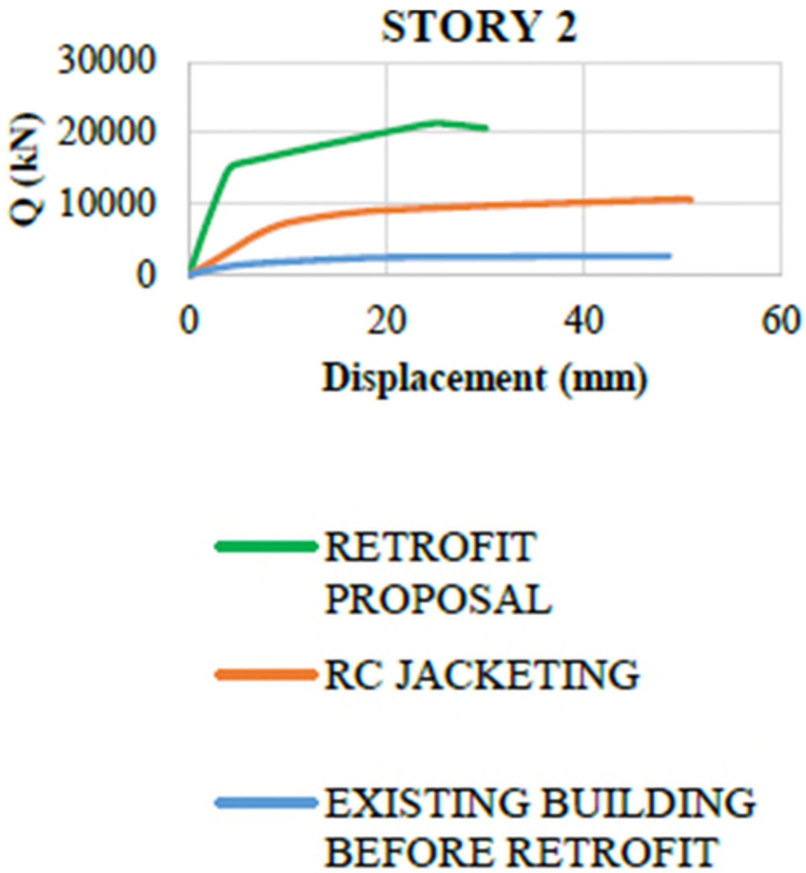


Figure 53. Hinge response RC wall t=250 mm story 2, axis 1.



EVALUACION SISMICA DETALLADA

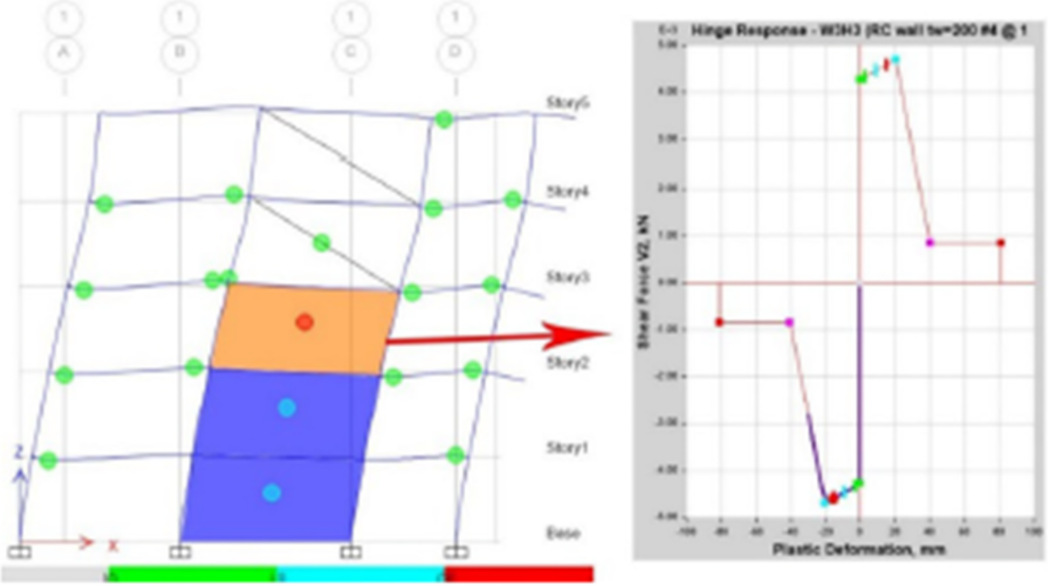
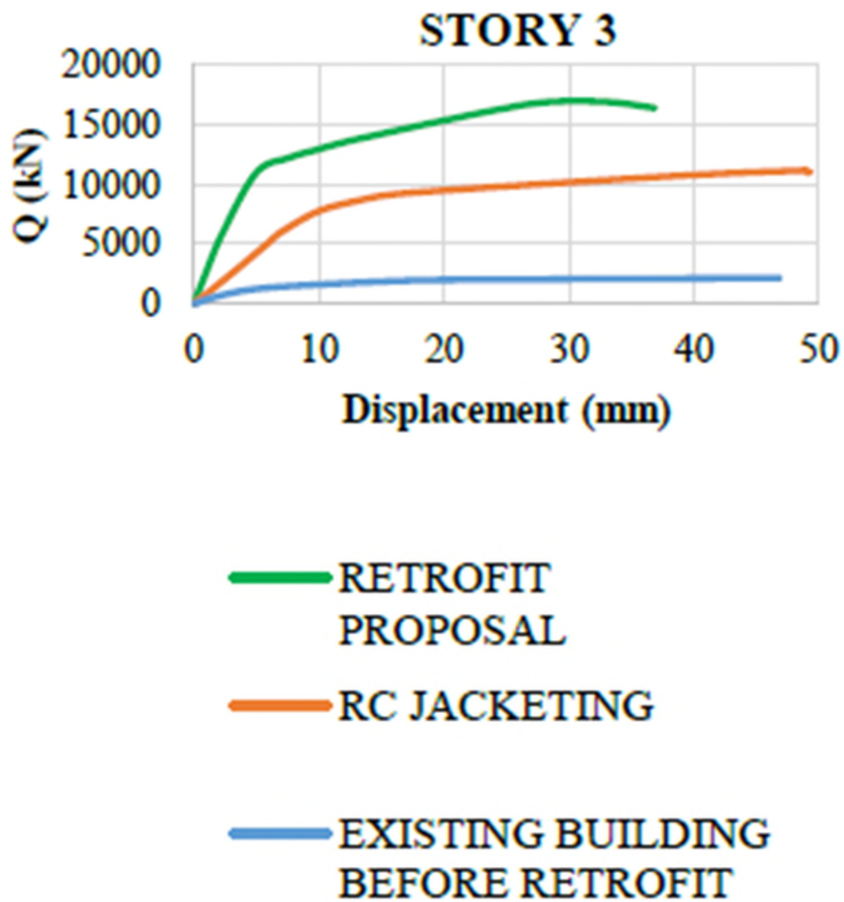
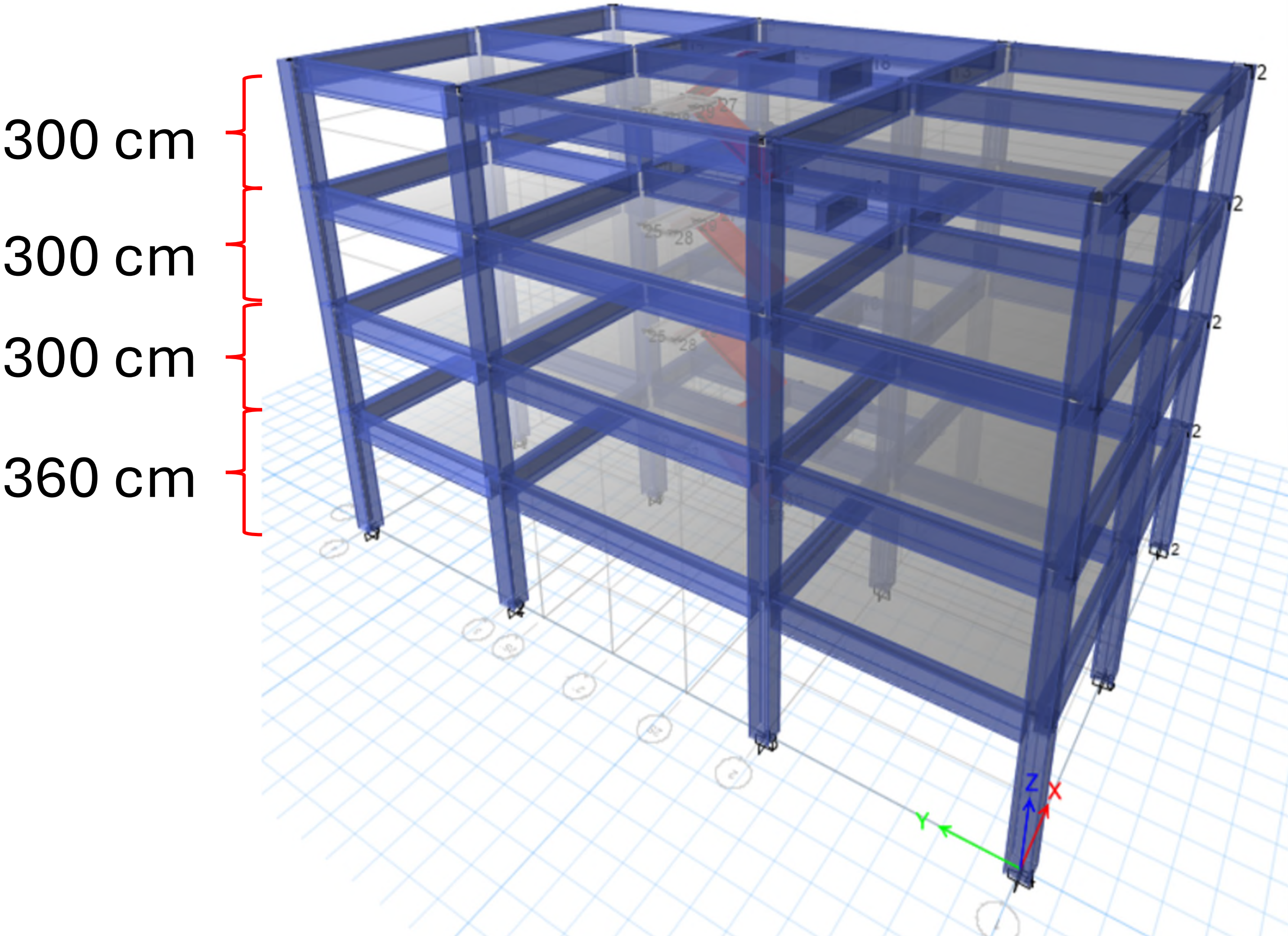
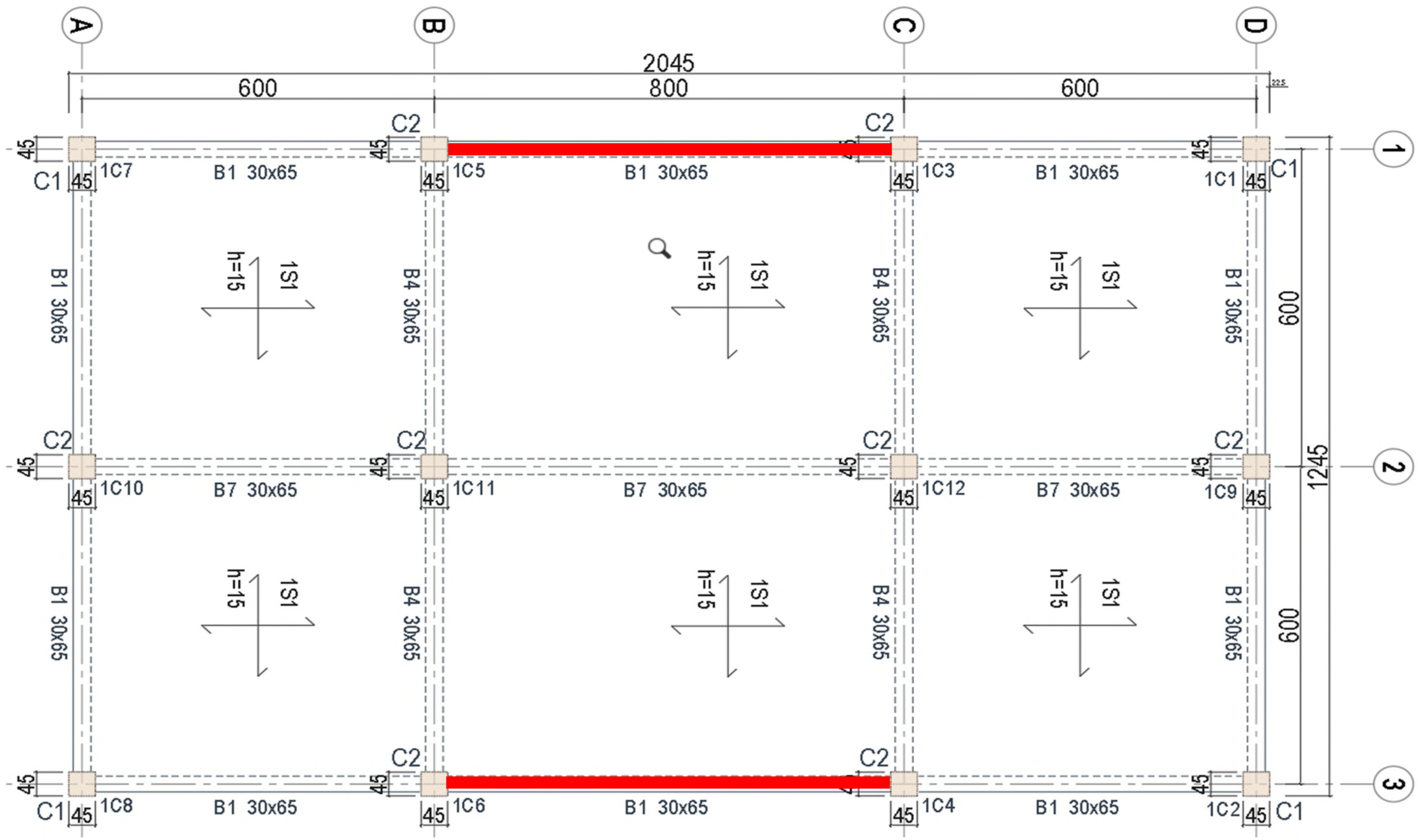


Figure 54. Hinge response RC wall t=200 mm story 3, axis 1.



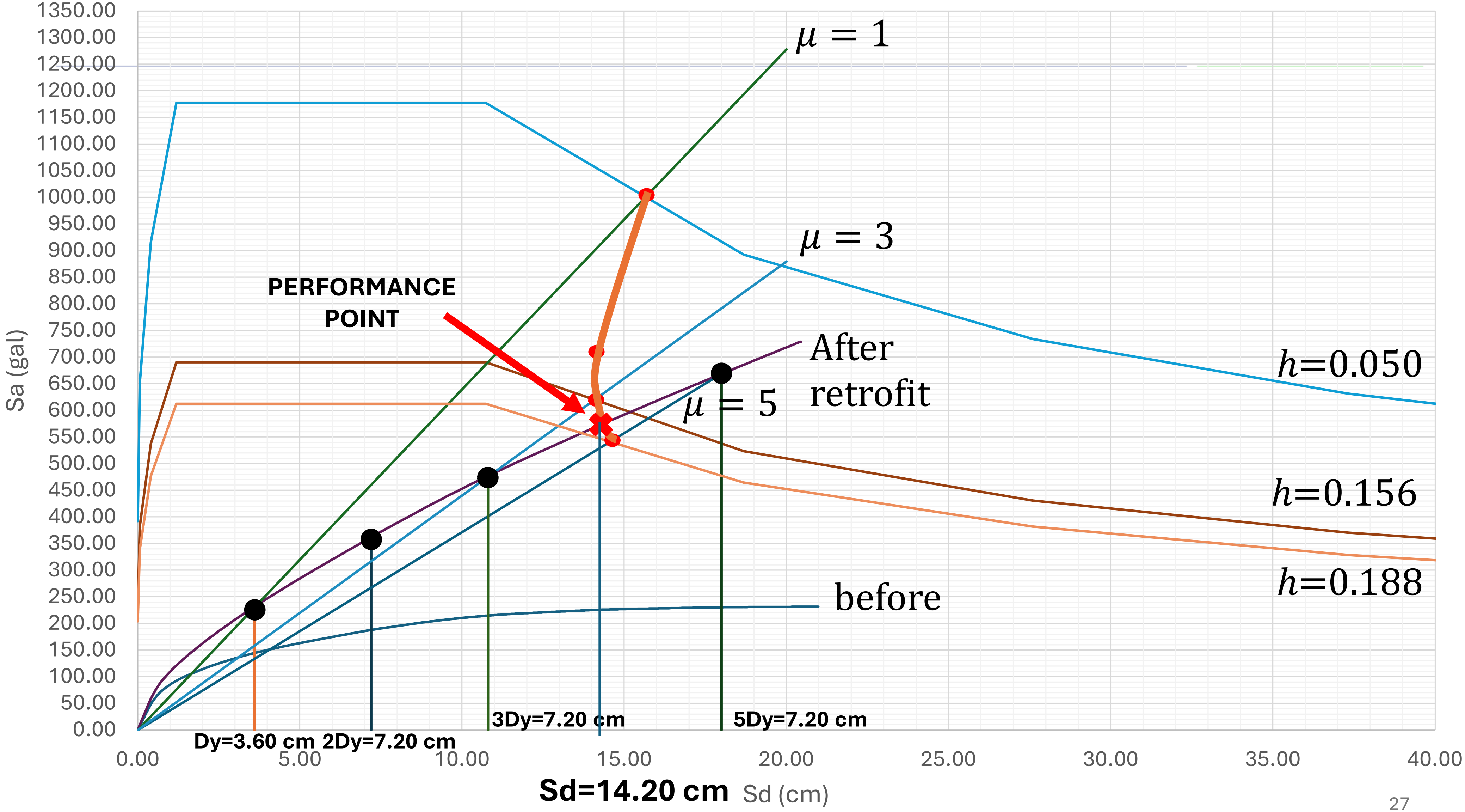
BASADO EN EL DESEMPEÑO SISMICO

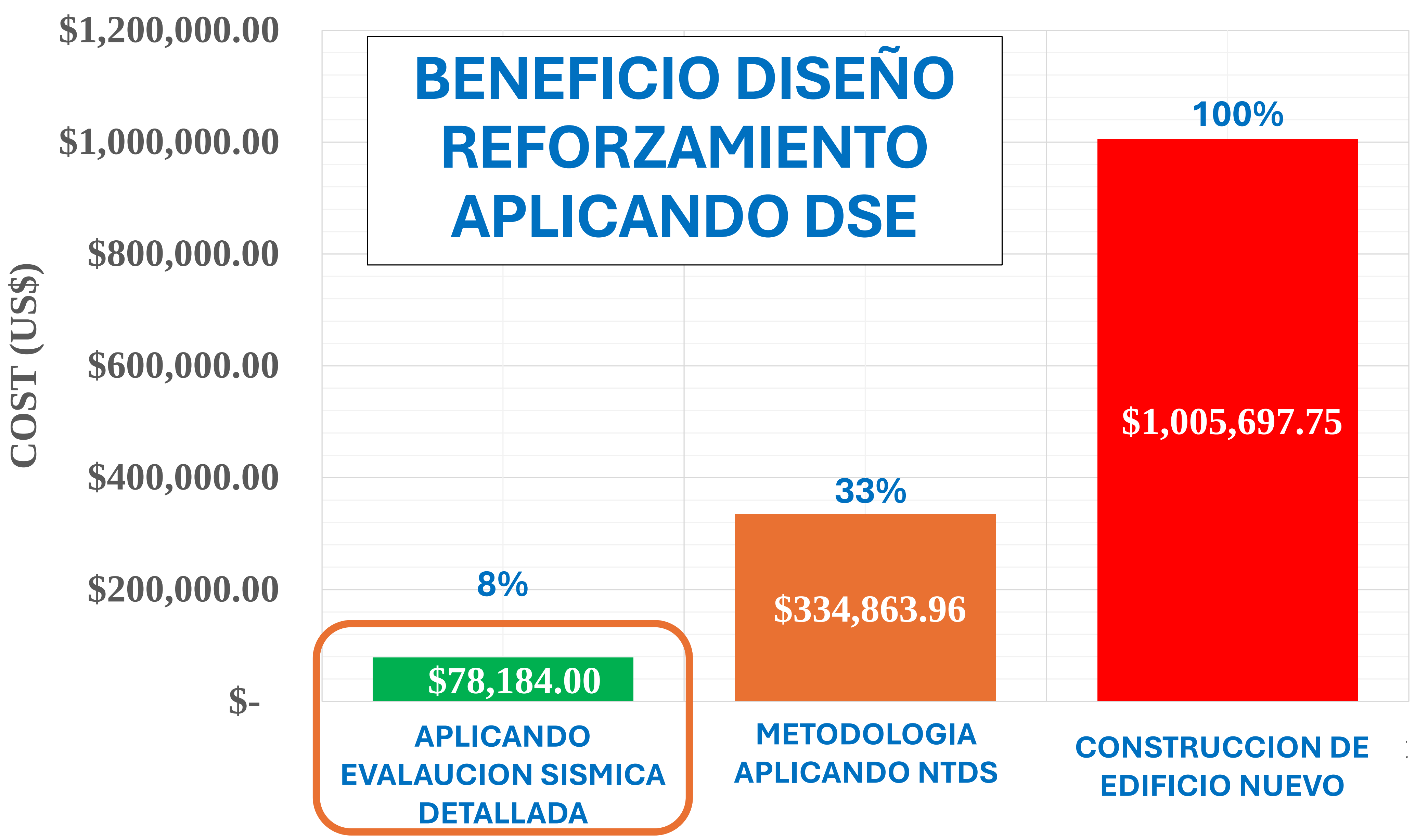




STOREY: 1 () - LEVEL: +3.60m - SCALE: 1/50

BASADO EN EL DESEMPEÑO SISMICO




BENEFICIO DISEÑO
REFORZAMIENTO
APLICANDO DSE
COST (US$)
$1,200,000.00
$1,000,000.00
$800,000.00
$600,000.00
$400,000.00
$200,000.00
$-
8%
$78,184.00
33%
$334,863.96
100%
$1,005,697.75
APLICANDO EVALAUCION SISMICA DETALLADA
METODOLOGIA APLICANDO NTDS
CONSTRUCCION DE EDIFICIO NUEVO

GRACIAS

COAMSS OPAMSS

1. Demanda Sísmica NTDS

Items	Información/datos
Ubicación	**San Salvador**, El Salvador
Uso propuesto	**Edificio de oficinas**
Sistema estructural	Marcos de concreto reforzado
Numero de niveles	**5 niveles**
Factor de Importancia	1.2 (tabla 4 NTDS)
Perfil de suelo	S3 (tabla 2 NTDS)
Fc	27 Mpa (N/mm2)
Fy	280 Mpa (N/mm2)
Total peso sísmico	10,381.35 kN
Altura total	**15.15 m**
Periodo fundamental	**0.56 s**

Espectro de Respuesta

$$T_m < \frac{T_o}{3} \qquad C_{sm} = \frac{IA}{R}\left[1 + \frac{3(C_o - 1)T_m}{T_o}\right]$$

$$\frac{T_o}{3} \leq T_m \leq T_o \qquad C_{sm} = \frac{IAC_o}{R}$$

$$T_o < T_m \leq 4.0\ s \qquad C_{sm} = \frac{IAC_o}{R}\left(\frac{T_o}{T_m}\right)^{2/3}$$

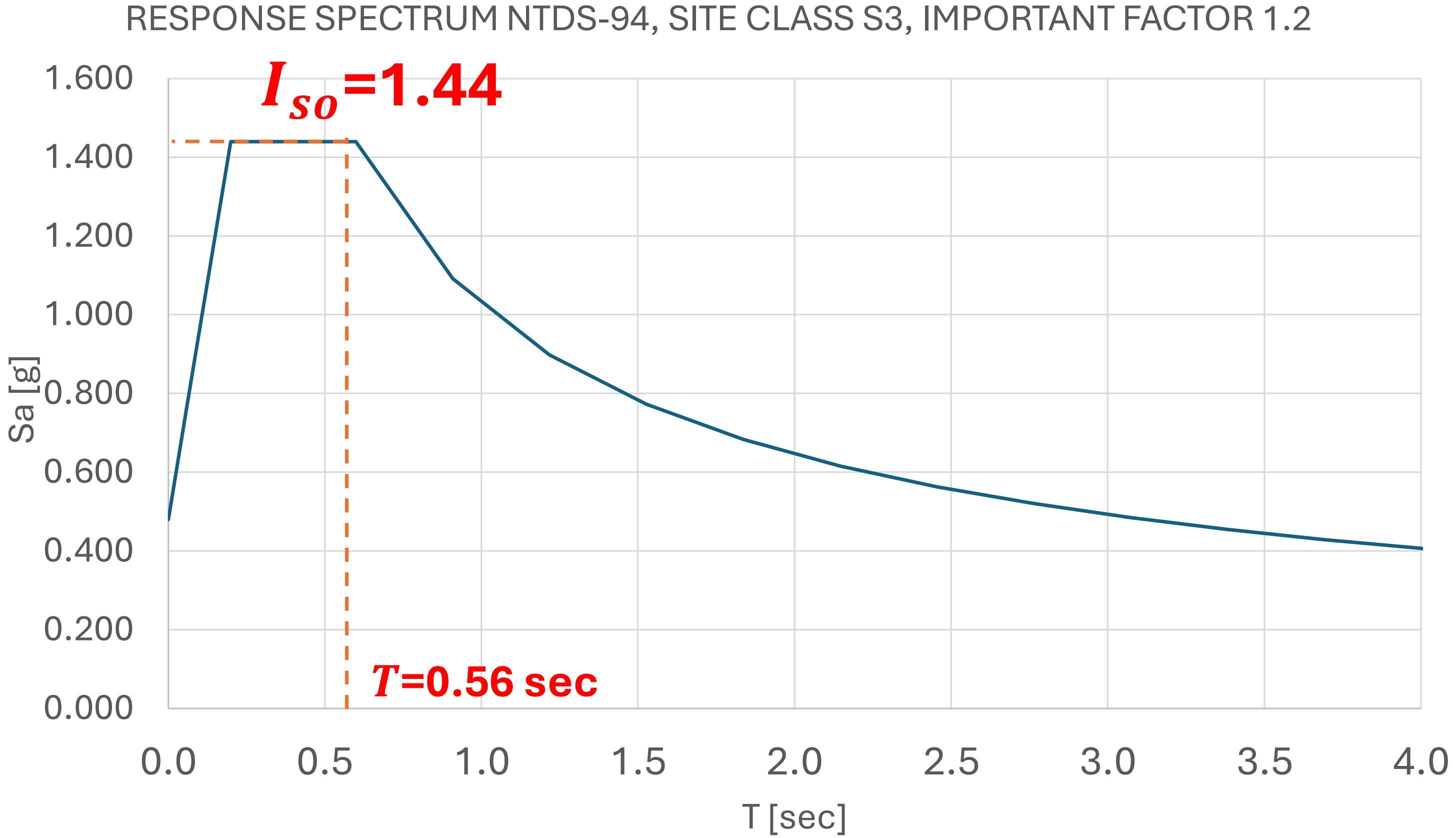
CAPITULO 5 NTDS

Factor A de zonificación sísmica

Zona	Factor A
1	0.4
2	0.3

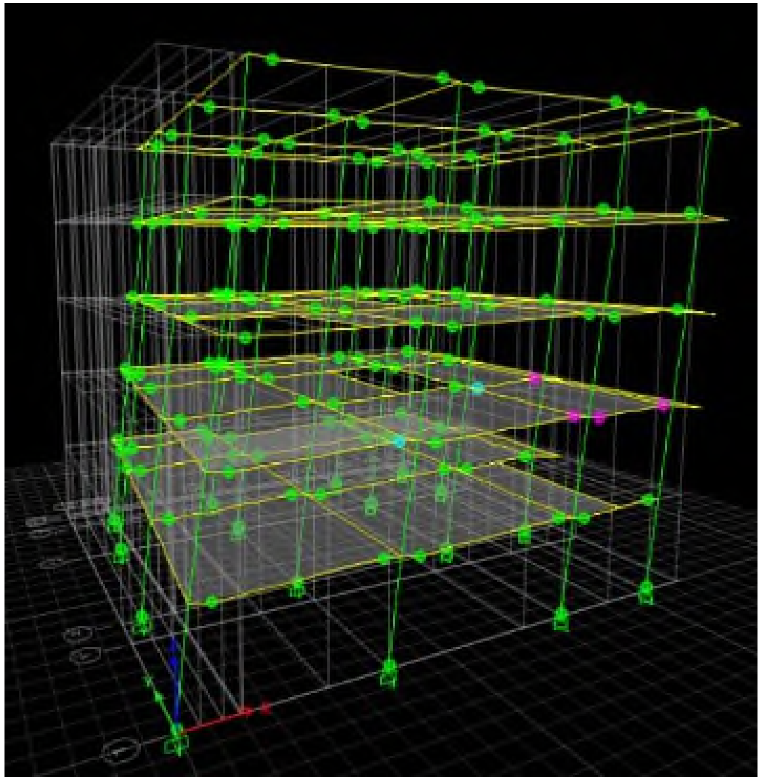
Índice Sísmico Objetivo

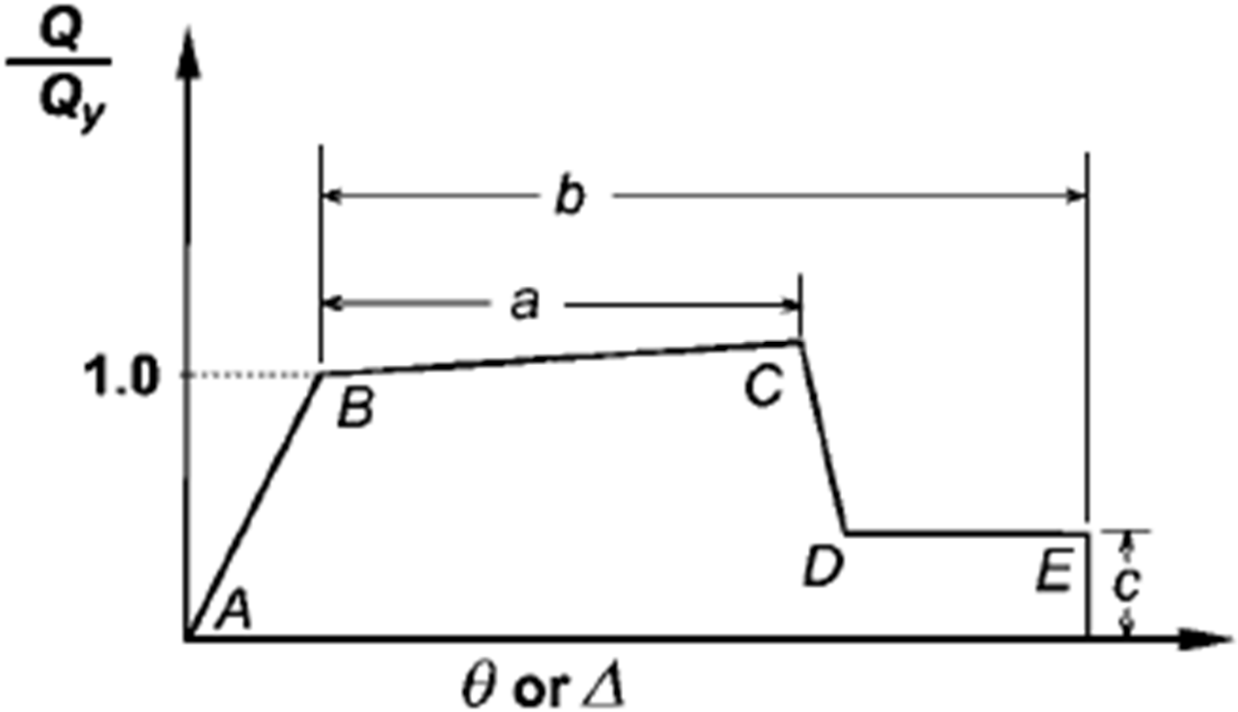
$$T = C_t . h_n^{3/4} \Rightarrow T = 0.073 \times 15.15^{3/4} = 0.56\ sec$$

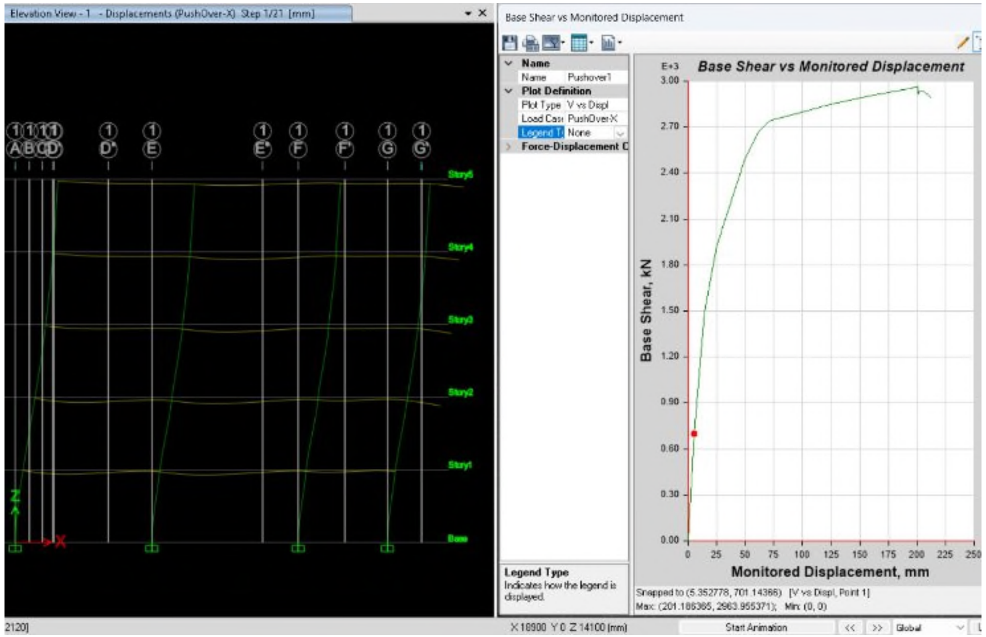


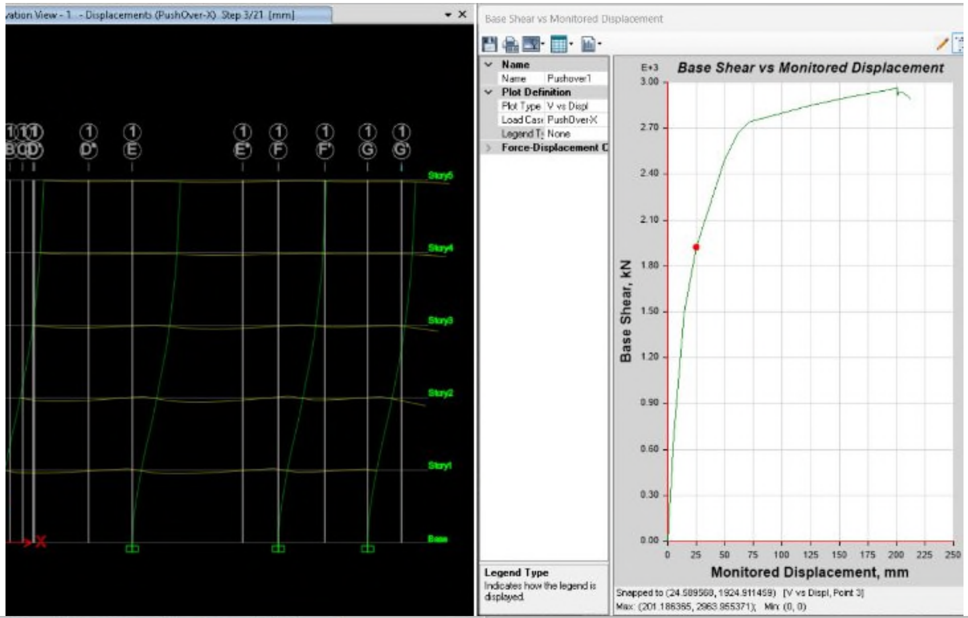
$T = C_t \cdot h_n^{3/4}$	Altura Total (m)	15.15
	Ct	0.073
	T (seg)	0.56

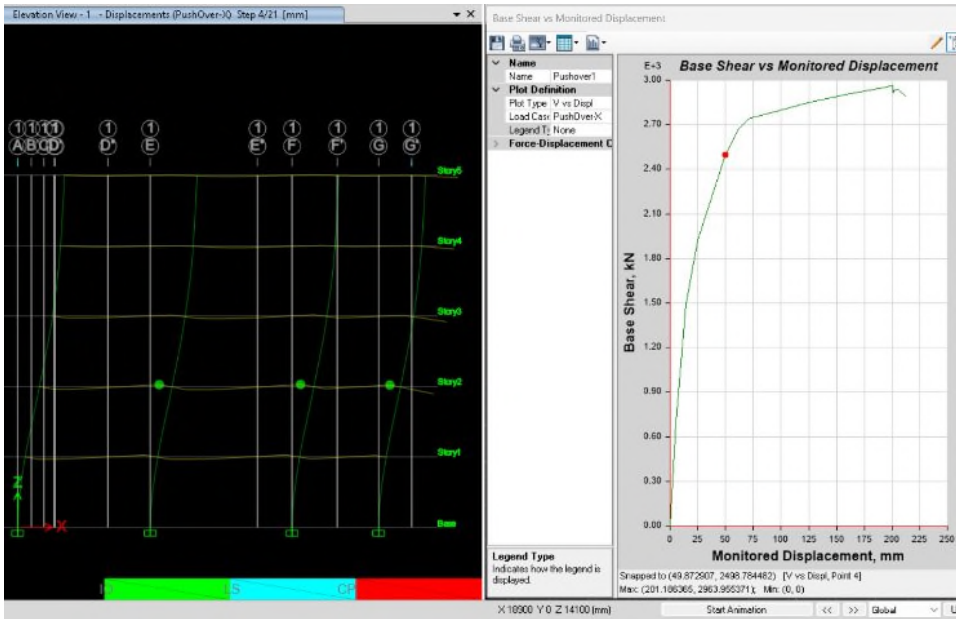
2. ASCE 41-13 (Parámetros de Modelamiento de Rotulas)






Elevation View - 1 - Displacements (PushOver-X) Step 1/21 [mm]
Base Shear vs Monitored Displacement
Name
Plot Definition
Force-Displacement
Legend Type
Indicates how the legend is displayed.
Base Shear vs Monitored Displacement
Base Shear, kN
Monitored Displacement, mm
Start Animation


Displacements (PushOver-X) Step 3/21 [mm]
Base Shear vs Monitored Displacement
Legend Type
Indicates how the legend is displayed.
Base Shear vs Monitored Displacement
Base Shear, kN
Monitored Displacement, mm


Elevation View - 1 - Displacements (PushOver-X) Step 4/21 [mm]
Base Shear vs Monitored Displacement
Legend Type
Indicates how the legend is displayed.
Base Shear vs Monitored Displacement
Base Shear, kN
Monitored Displacement, mm
Start Animation

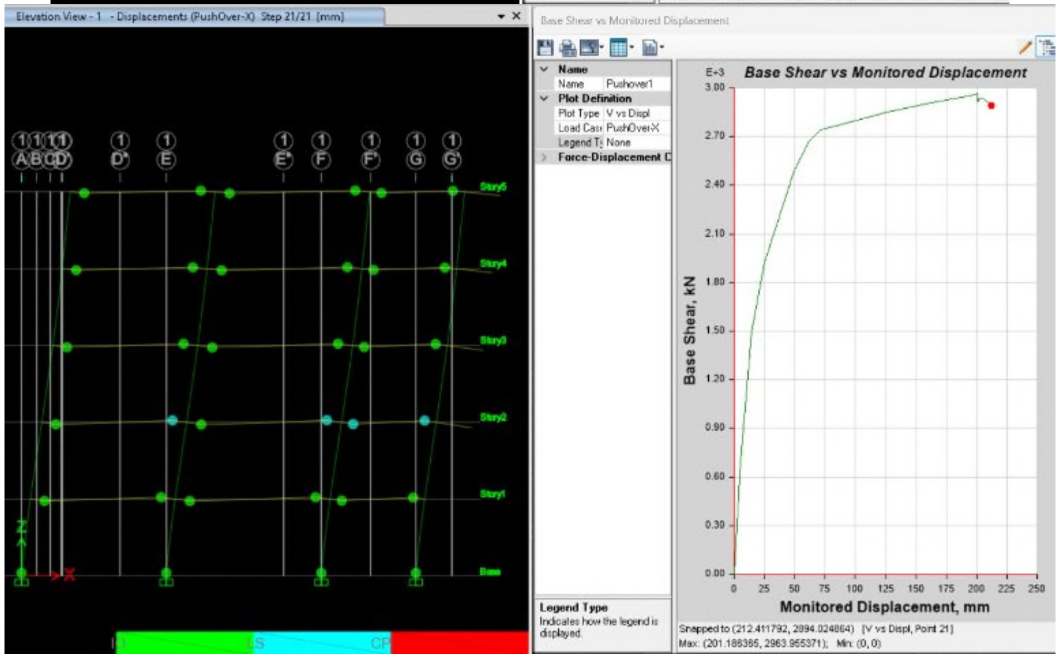
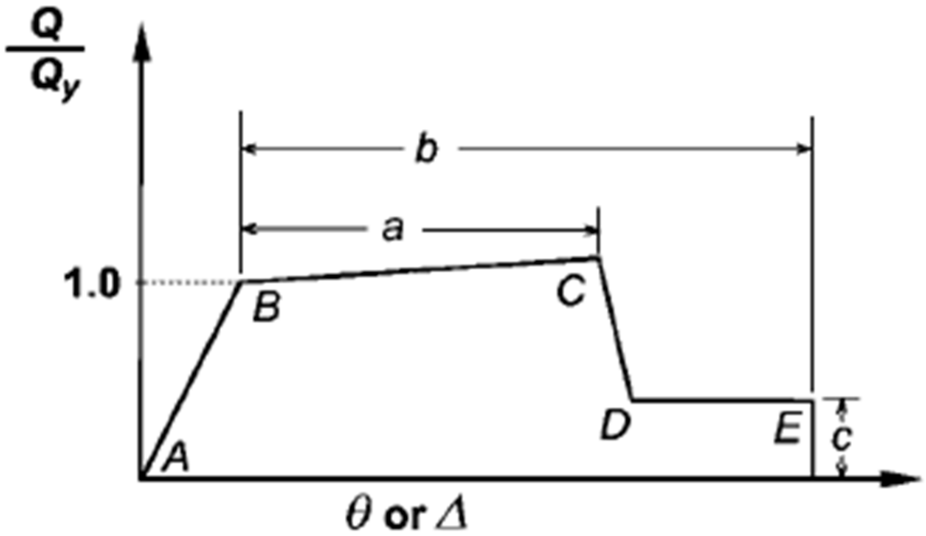
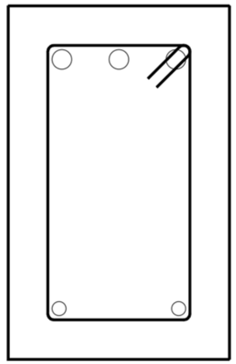

Elevation View - 1 - Displacements (PushOver-X) Step 21/21 [mm]
Base Shear vs Monitored Displacement
Legend Type
Indicates how the legend is displayed.
Base Shear vs Monitored Displacement
Base Shear, kN
Monitored Displacement, mm

Table 10-7. Modeling Parameters and Numerical Acceptance Criteria for Nonlinear Proced

Conditions			Modeling Parameters[a] Plastic Rotations Angle (radians) a	b	Residual Strength Ratio c
Condition i. Beams controlled by flexure[b]					
$\frac{\rho-\rho'}{\rho_{bal}}$	Transverse reinforcement[c]	$\frac{V}{b_w d\sqrt{f'_c}}$ [d]			
≤0.0	C	≤3 (0.25)	0.025	0.05	0.2
≤0.0	C	≥6 (0.5)	0.02	0.04	0.2
≥0.5	C	≤3 (0.25)	0.02	0.03	0.2
≥0.5	C	≥6 (0.5)	0.015	0.02	0.2
≤0.0	NC	≤3 (0.25)	0.02	0.03	0.2
≤0.0	NC	≥6 (0.5)	0.01	0.015	0.2
≥0.5	NC	≤3 (0.25)	0.01	0.015	0.2
≥0.5	NC	≥6 (0.5)	0.005	0.01	0.2
Condition ii. Beams controlled by shear[b]					
Stirrup spacing ≤ $d/2$			0.0030	0.02	0.2
Stirrup spacing > $d/2$			0.0030	0.01	0.2
Condition iii. Beams controlled by inadequate development or splicing along the span[b]					
Stirrup spacing ≤ $d/2$			0.0030	0.02	0.0
Stirrup spacing > $d/2$			0.0030	0.01	0.0
Condition iv. Beams controlled by inadequate embedment into beam–column joint[b]					
			0.015	0.03	0.2

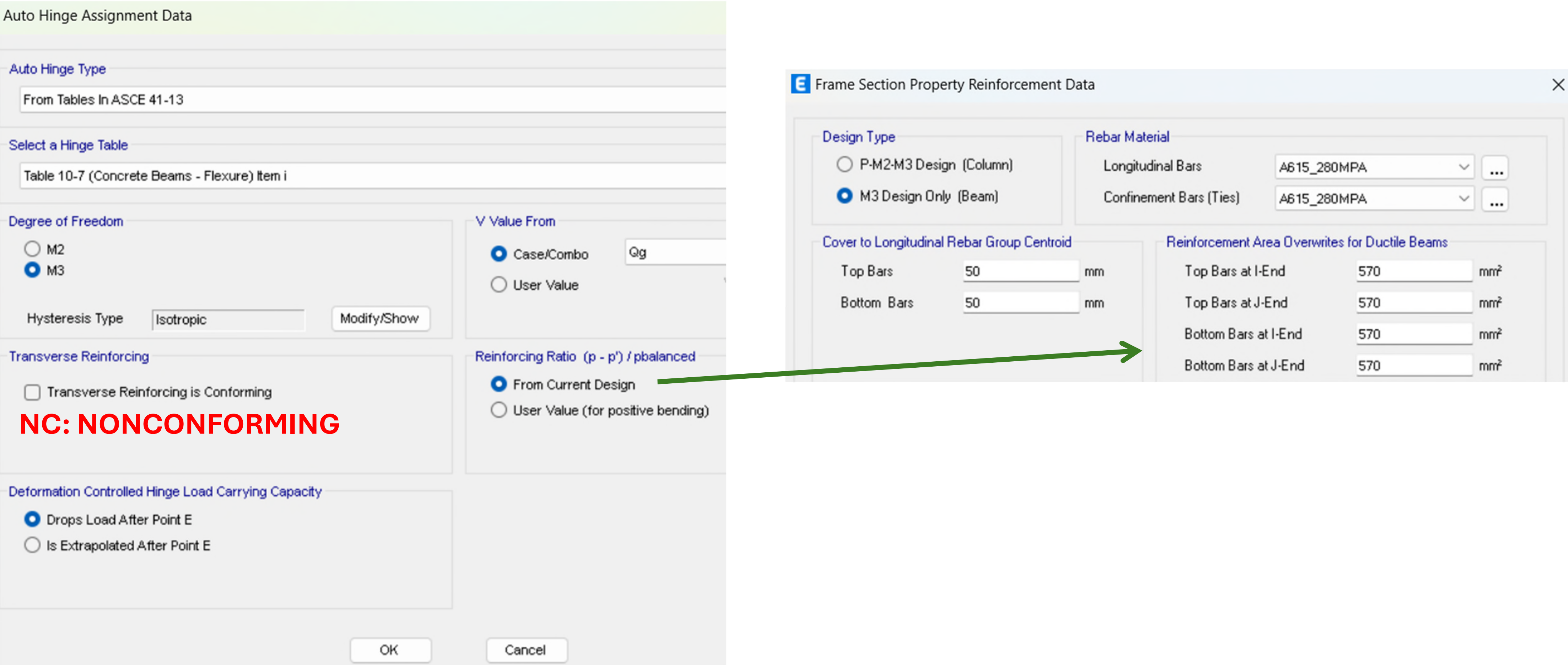


$$\frac{\rho - \rho'}{\rho_{bal}} \qquad \frac{V}{b_w d\sqrt{f'_c}}$$



$$S \leq \frac{d}{3} \quad \textbf{Y} \quad V_s > \frac{3}{4}V$$

Vigas

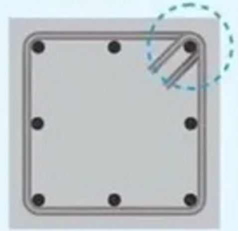

Auto Hinge Assignment Data
Auto Hinge Type
From Tables In ASCE 41-13
Select a Hinge Table
Table 10-7 (Concrete Beams - Flexure) Item i
Degree of Freedom
M2
M3
Hysteresis Type
Isotropic
Modify/Show
V Value From
Case/Combo
Qg
User Value
Transverse Reinforcing
Transverse Reinforcing is Conforming
NC: NONCONFORMING
Reinforcing Ratio (p - p') / pbalanced
From Current Design
User Value (for positive bending)
Deformation Controlled Hinge Load Carrying Capacity
Drops Load After Point E
Is Extrapolated After Point E
OK
Cancel
Frame Section Property Reinforcement Data
Design Type
P-M2-M3 Design (Column)
M3 Design Only (Beam)
Rebar Material
Longitudinal Bars
A615_280MPA
Confinement Bars (Ties)
A615_280MPA
Cover to Longitudinal Rebar Group Centroid
Top Bars
50
mm
Bottom Bars
50
mm
Reinforcement Area Overwrites for Ductile Beams
Top Bars at I-End
570
mm²
Top Bars at J-End
570
mm²
Bottom Bars at I-End
570
mm²
Bottom Bars at J-End
570
mm²

Columnas

Table 10-8. Modeling Parameters and Numerical Acceptance Criteria for Nonlinear Procedures—Re

Conditions			Modeling Parameters[a] Plastic Rotations Angle (radians) a	b	Residual Strength Ratio c
Condition i.[b]					
$\frac{P}{A_g f'_c}$ [c]	$\rho = \frac{A_v}{b_w s}$				
≤0.1	≥0.006		0.035	0.060	0.2
≥0.6	≥0.006		0.010	0.010	0.0
≤0.1	=0.002		0.027	0.034	0.2
≥0.6	=0.002		0.005	0.005	0.0
Condition ii.[b]					
$\frac{P}{A_g f'_c}$ [c]	$\rho = \frac{A_v}{b_w s}$	$\frac{V}{b_w d\sqrt{f'_c}}$ [d]			
≤0.1	≥0.006	≤3 (0.25)	0.032	0.060	0.2
≤0.1	≥0.006	≥6 (0.5)	0.025	0.060	0.2
≥0.6	≥0.006	≤3 (0.25)	0.010	0.010	0.0
≥0.6	≥0.006	≥6 (0.5)	0.008	0.008	0.0
≤0.1	≤0.0005	≤3 (0.25)	0.012	0.012	0.2
≤0.1	≤0.0005	≥6 (0.5)	0.006	0.006	0.2
≥0.6	≤0.0005	≤3 (0.25)	0.004	0.004	0.0
≥0.6	≤0.0005	≥6 (0.5)	0.0	0.0	0.0
Condition iii.[b]					
$\frac{P}{A_g f'_c}$ [c]	$\rho = \frac{A_v}{b_w s}$				
≤0.1	≥0.006		0.0	0.060	0.0
≥0.6	≥0.006		0.0	0.008	0.0
≤0.1	≤0.0005		0.0	0.006	0.0
≥0.6	≤0.0005		0.0	0.0	0.0

Gancho 135°



Gancho 90°

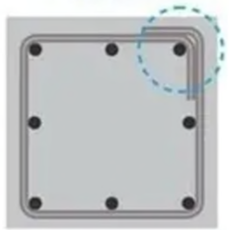


Table 10-11. Transverse Reinforcement Details: Condition to Be Used for Columns in Table 10-8

Shear Capacity Ratio	ACI 318 Conforming Seismic Details with 135-Degree Hooks	Closed Hoops with 90-Degree Hooks	Other (Including Lap-Spliced Transverse Reinforcement)
$V_p/V_o \leq 0.6$	i[a]	ii	ii
$1.0 \geq V_p/V_o > 0.6$	ii	ii	iii
$V_p/V_o > 1.0$	iii	iii	iii

[a]To qualify for condition i, a column should have $A_v/b_w s \geq 0.002$ and $s/d \leq 0.5$ within flexural plastic hinge region. Otherwise, the column is assigned to condition ii.

Vo = Resistencia a cortante de la columna Ecuación (10-3)

$$V_n = kV_o = k\left[\frac{A_v f_y d}{s} + \lambda\left(\frac{0.5\sqrt{f'_c}}{M/Vd}\sqrt{1+\frac{N_u}{0.5\sqrt{f'_c}A_g}}\right)0.8A_g\right] \quad (10\text{-}3)$$

(MPa units)

Vp = Fuerza cortante al desarrollo de Mu.
Capítulo 10

Columnas

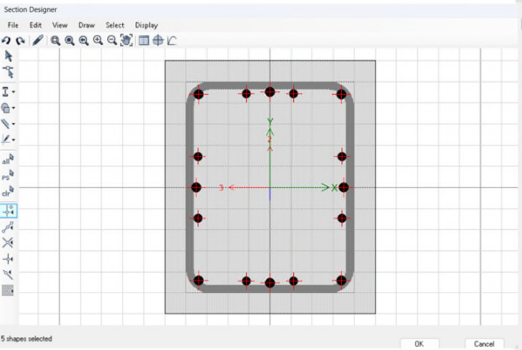
Shear Failure

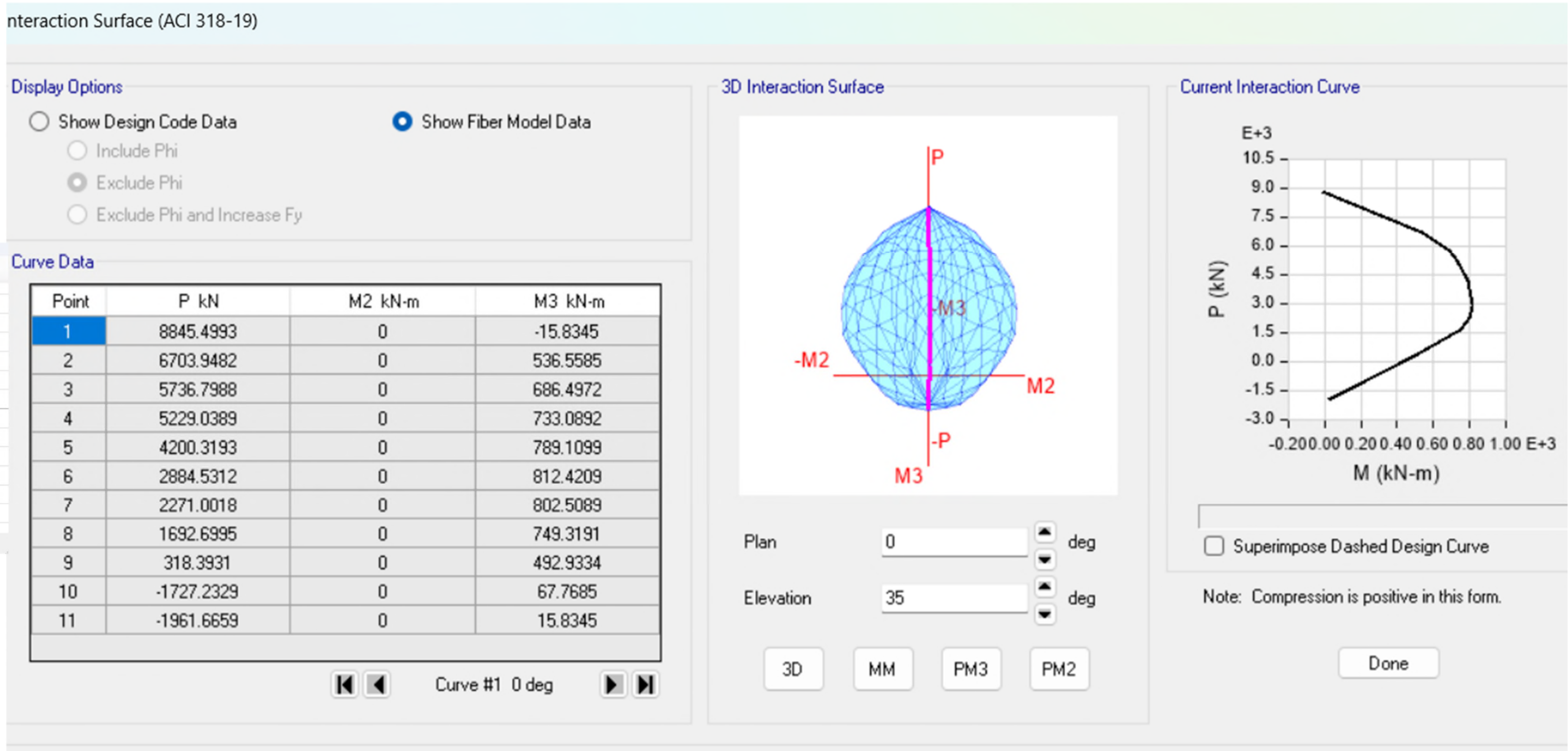
Columnas con espaciamiento muy grande entre estribos
Source: Stelios Antoniou

Source: Seismic Evaluation and Seismic Rehabilitation by A. Nakamura

Columnas

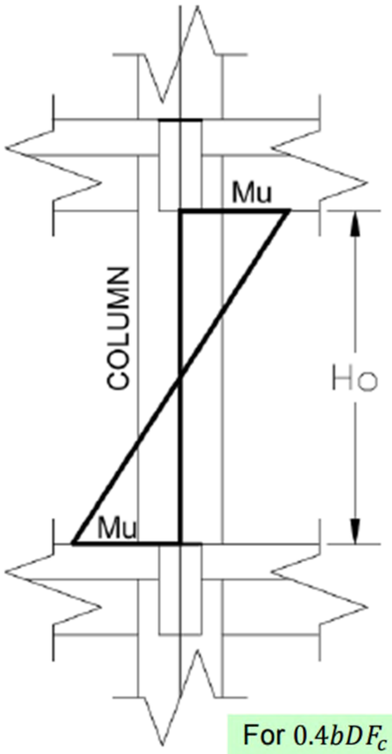
ASCE 41-13





Point	P kN	M2 kN-m	M3 kN-m
1	8845.4993	0	-15.8345
2	6703.9482	0	536.5585
3	5736.7988	0	686.4972
4	5229.0389	0	733.0892
5	4200.3193	0	789.1099
6	2884.5312	0	812.4209
7	2271.0018	0	802.5089
8	1692.6995	0	749.3191
9	318.3931	0	492.9334
10	-1727.2329	0	67.7685
11	-1961.6659	0	15.8345

Columnas



$$Vp = \frac{2 \times M_u}{Ho}$$

For $0.4bDF_c < N \leq N_{max}$

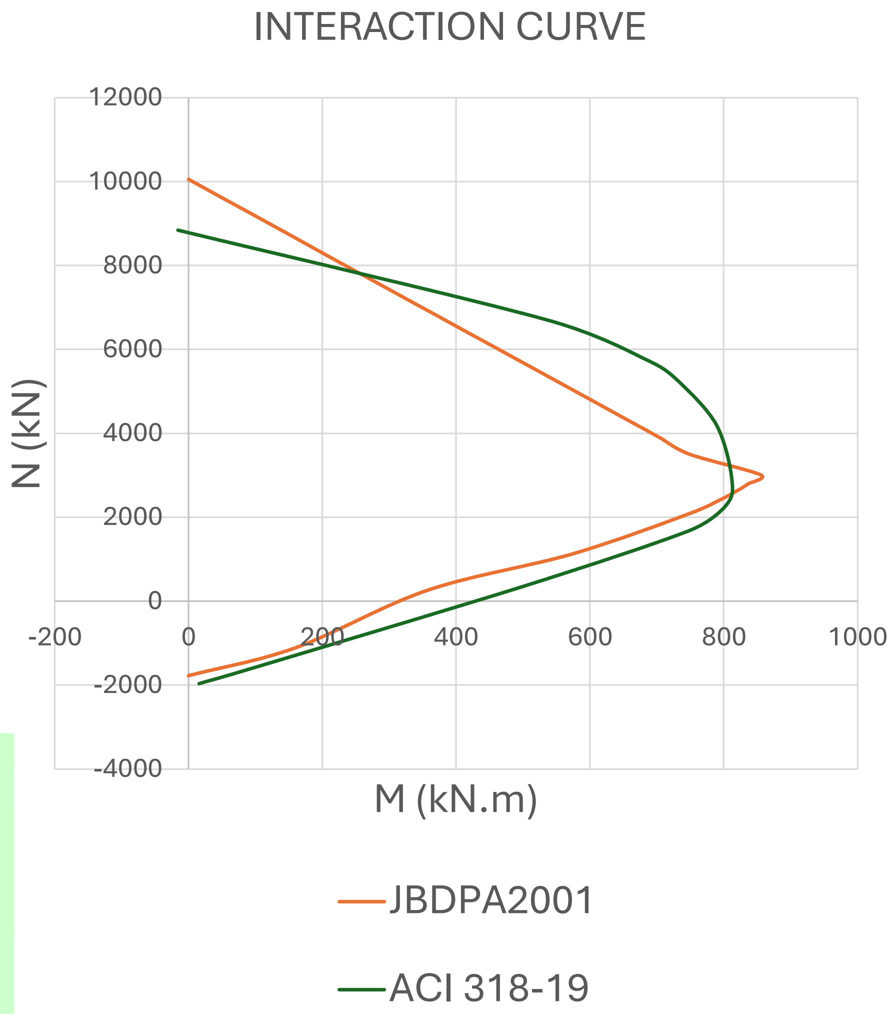
$$M_u = (0.8a_t\sigma_y D + 0.12bD^2F_c)\left(\frac{N_{max} - N}{N_{max} - 0.4bDF_c}\right) \quad (N \cdot mm)$$

For $0 \leq N \leq 0.4bDF_c$

$$M_u = 0.8a_t\sigma_y D + 0.5ND\left(1 - \frac{N}{bDF_c}\right) \quad (N \cdot mm)$$

For $N_{min} \leq N < 0$

$$M_u = 0.8a_t\sigma_y D + 0.4ND \quad (N \cdot mm) \qquad A1.1 - 1$$



1. CONDICION i

$$V_p/V_0 \leq 0.6$$

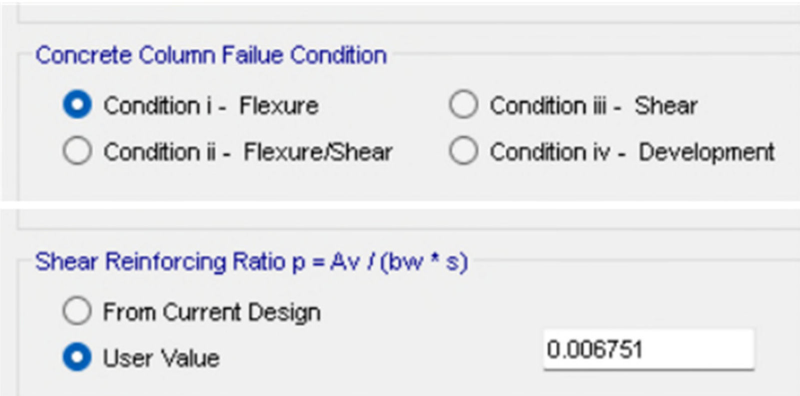
$$Av/b_w s \geq 0.002 \qquad s/d \leq 0.5$$

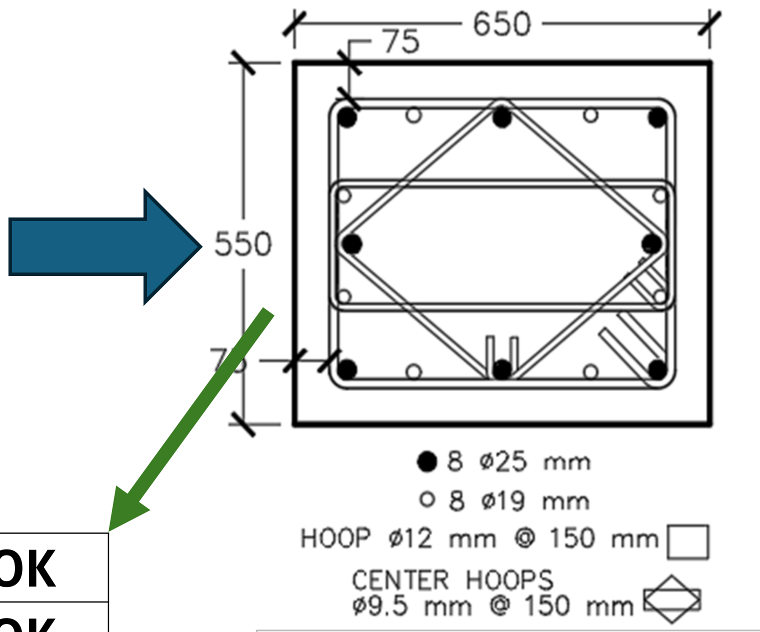
2. CONDICION ii

$$1.0 \geq V_p/V_0 > 0.6$$

3. CONDICION iii

$$V_p/V_0 > 1.0$$





Av/bw*s	0.0067	**OK**
s/d	0.28	**OK**

X-DIRECTION

	LOCATION (AXES)	**N (KN)**	**Mu (kN.m)**	**Vp (kN)**	**Vo (kN)**	**Vp/Vo**
STORY 1	A-2	628.04	455.15	382.48	869.89	0.44

T Índice de Tiempo

Check	Descripcion	Valor de T (marcar el grado relevante)
Deflexión	Se observa la inclinación de la edificación incluso sin observación de asentamiento	0.7
	Suelo de relleno de vertedero (ripio u otros)	0.9
	Se observan deflexiones en vigas y columnas	0.9
	Ninguna de las anteriores	1.0
Grietas en elementos estructurales	Se observan filtraciones de agua con oxido	0.8
	Se observan a simple vista grietas inclinadas en columnas	0.9
	Se observan innumerables grietas en paredes	0.9
	Se observan filtraciones de agua sin oxido	0.9
	Ninguna de las anteriores	1.0

Check	Descripción	Valor de T (marcar el grado relevante)
Exposición a incendios	Vestigio o rastro de incendio	0.7
	Exposición pero sin rastro evidente	0.8
	Ninguna de las anteriores	1.0
Condiciones de acabados	Se observan desprendimientos significantes de acabado externo debido al envejecimientos	0.9
	Se observan desprendimientos significantes de acabado interno debido al envejecimientos	0.9
	Ninguna de las anteriores	1.0

S_D = INDICE DE IRREGULARIDAD

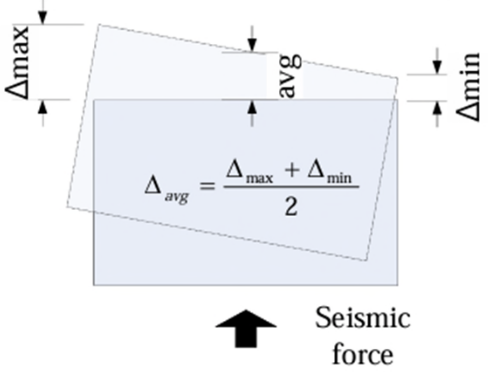
$$S_D = G_T \cdot G_S$$

Donde:

G_T: Grado de Irregularidad Torsional – Tabla 4.4-1

G_S: Grado de Irregularidad de Rigidez –Tabla 4.4-2

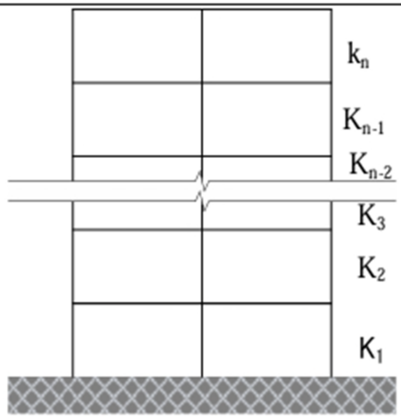
Tabla 4.4-1 Caso de Aplicación de Criterio de Irregularidad Torsional



	$\frac{\Delta max}{\Delta avg}$	G_T
Excentricidad (Irregularidad en planta)	<1.2	1.0
	Entre 1.2 y 1.4	0.9
	>1.4	0.8

Story	Deriva X	Deriva X	Deriva promedio	Δmax/Δavg
	MAX	MIN		
Story5	0.000824	0.000662	0.000743	1.11
Story4	0.001224	0.001184	0.001204	1.02
Story3	0.00181	0.001716	0.001763	1.03
Story2	0.002094	0.001971	0.002033	1.03
Story1	0.001402	0.001348	0.001375	1.02

S_D = INDICE DE IRREGULARIDAD



$k_i < 0.7\, k_{i+1}$

$or\ k_i < 0.8\left(\frac{k_{i+1} + k_{i+2} + k_{i+3}}{3}\right)$

$\frac{k_i}{k_{i+1}}$	G_S
$\left(\frac{3 \cdot k_i}{k_{i+1} + k_{i+2} + k_{i+3}}\right)$	

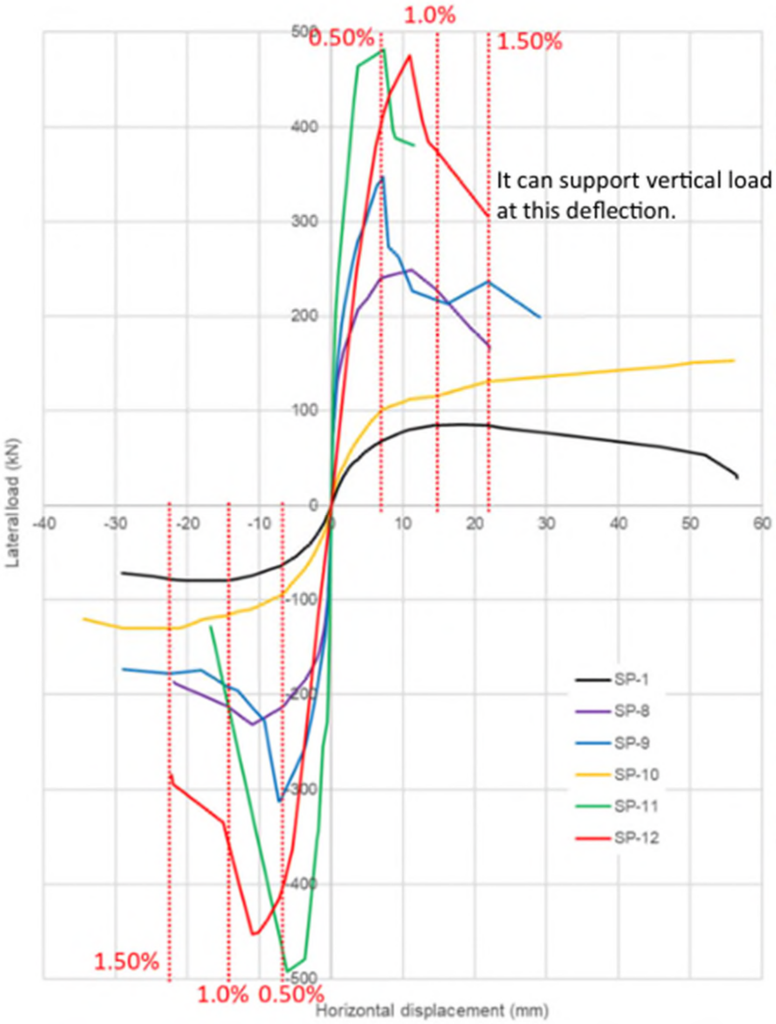
> 0.7 o > 0.8	1.0
Entre 0.6 y 0.7 o Entre 0.7 y 0.8	0.9
0.6> or 0.7>	0.8

Story	**Rigidez X**	**ki/ki+1**	**3*ki/(ki+1+ki+2+ki+3)**
	kN/mm		
Story5	130.35468	-	-
Story4	361.38573	2.77	-
Story3	390.60154	1.08	-
Story2	423.97532	1.09	1.44
Story1	685.20049	1.62	1.75

	Story	GT	GS
X-DIRECTION	todos	1	1

$$S_D = 1.0$$

4. Experimentos Proyecto HOKYO




No.11 RC wall (with opening)

No. 12: Steel framed brace

No. 9: Ferrocement lamination of existing concrete block wall

No.8: Reinforced concrete block wall

No.10: Column jacketing

F=1.27

R=1/150=0.0067

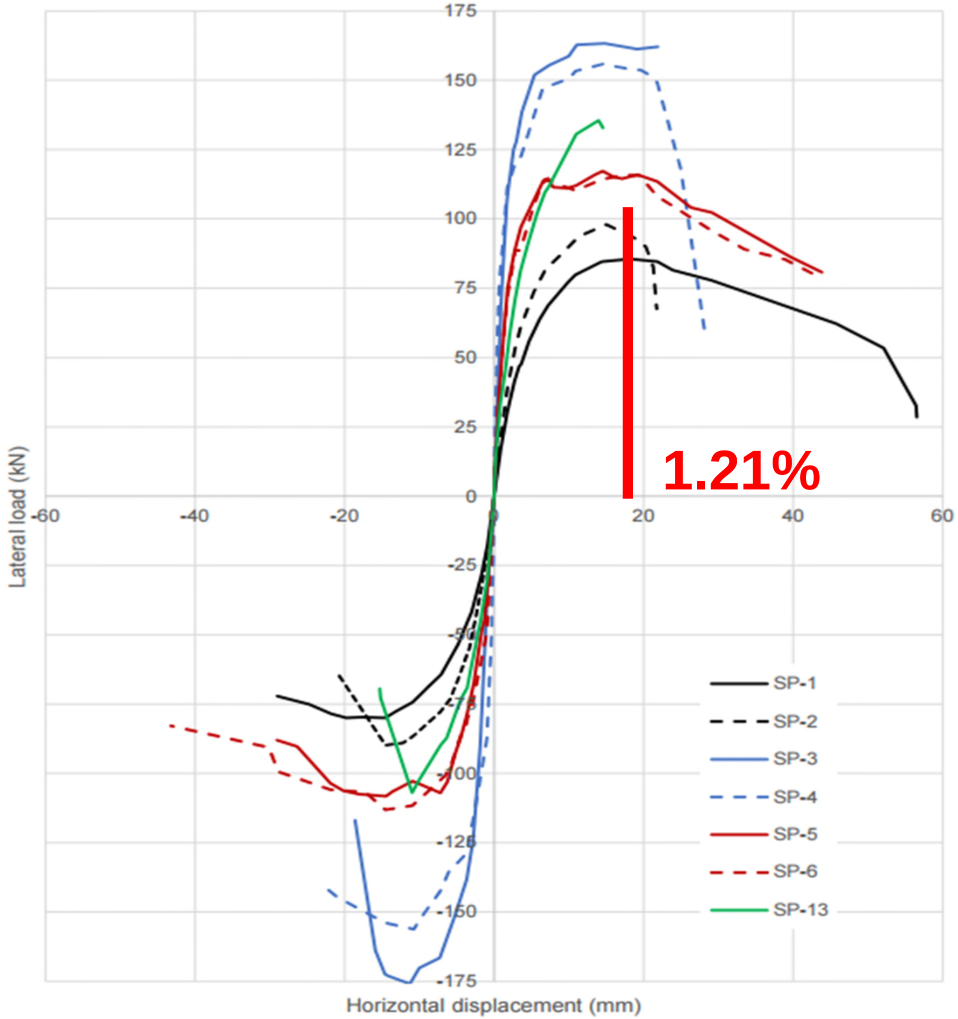
Plan de Reforzamiento

PLANTA BAJA NIV +1.60 | PLANTA DEL SEGUNDO PISO | PLANTA DEL SEPTIMO PISO

Dificultad para encontrar una ubicación adecuada para un nuevo muro, una ubicación valida en un nivel bloquea la funcionalidad de los otros niveles

Source: Stelios Antoniou

Experimentos Proyecto HOKYO



F=2.0

R=1/82=0.0121

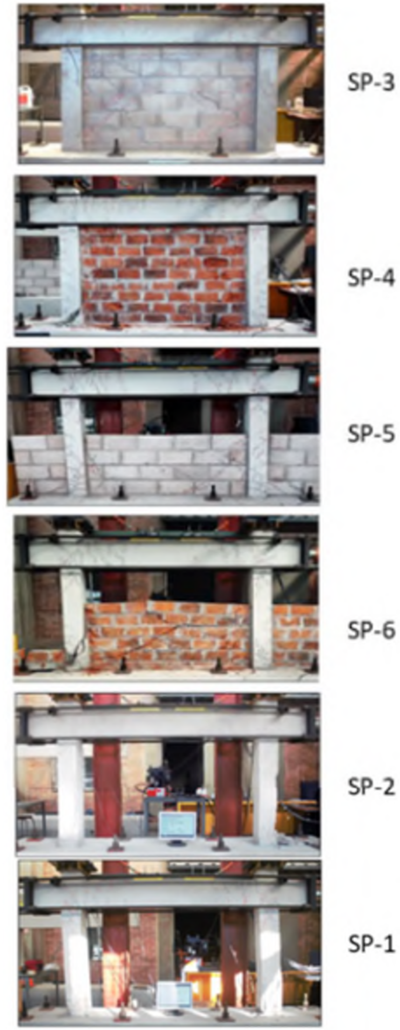
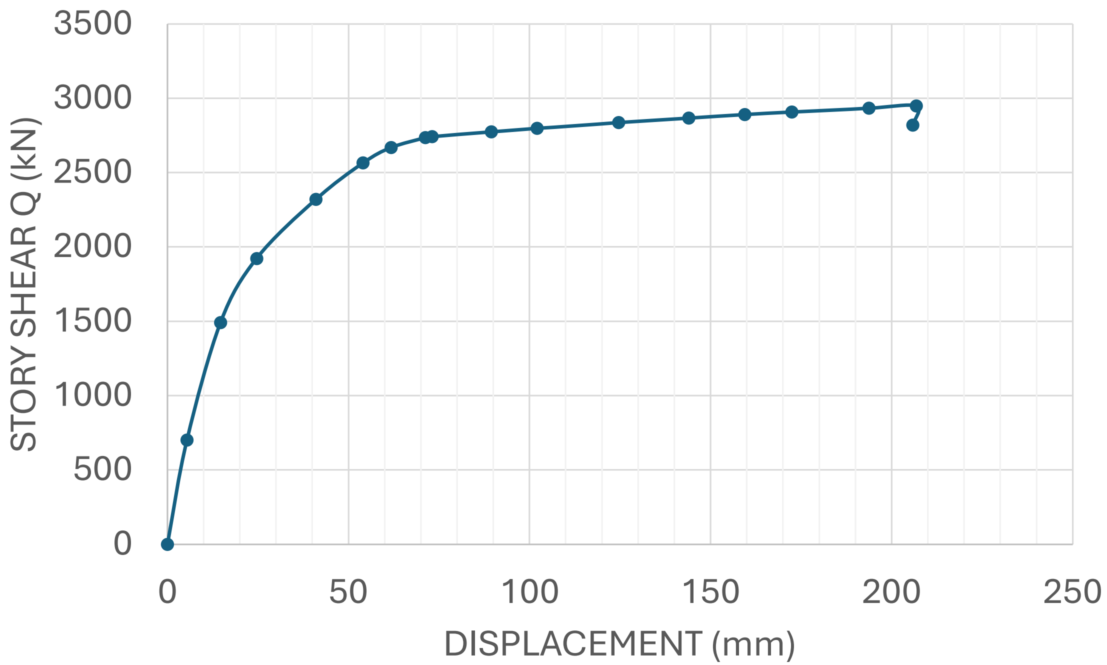
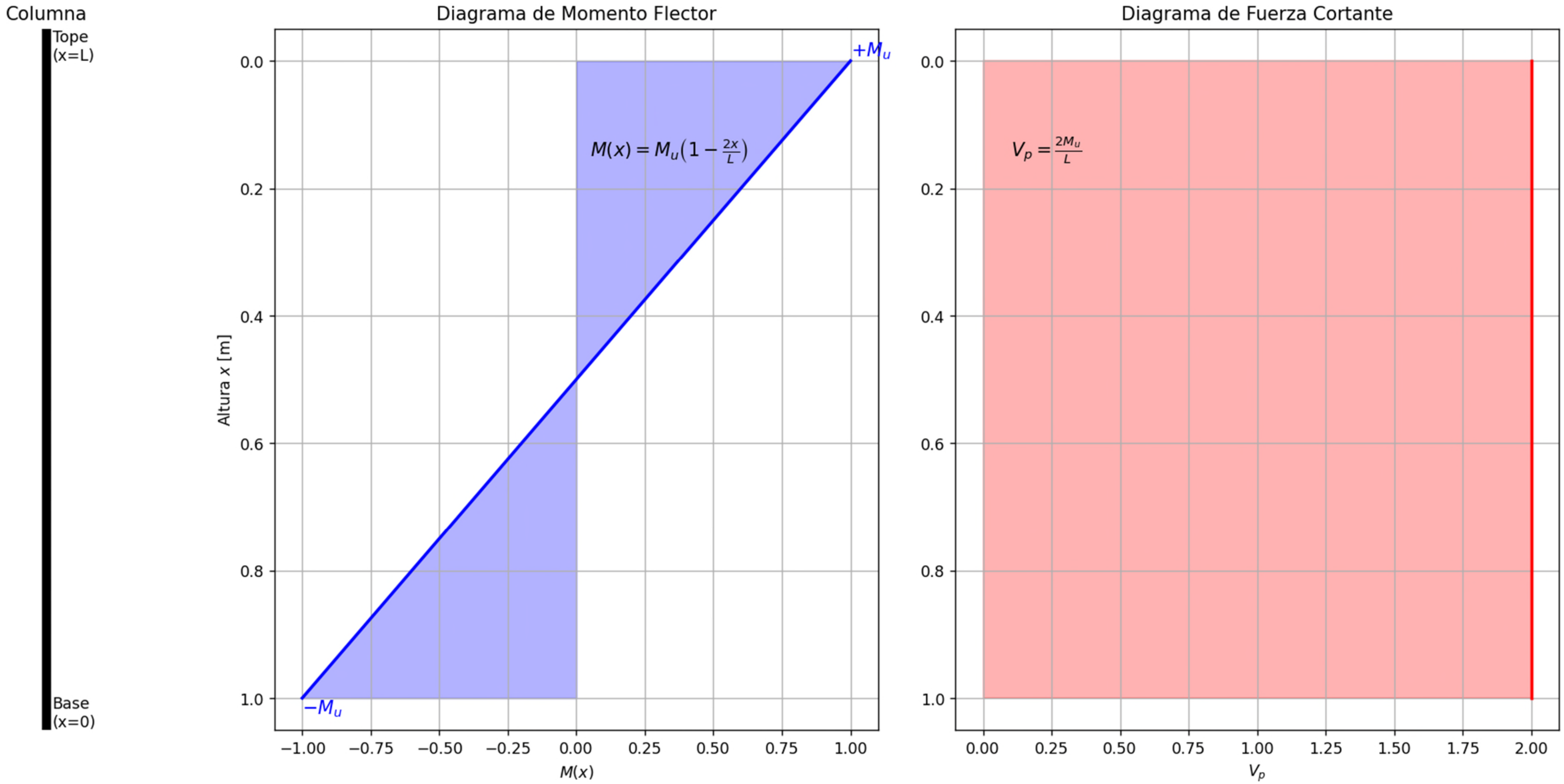


Figure 5.28 Difficulties in finding an appropriate location of a new shear wall: a valid location in one floor blocks the operation of other floors. *Source:* Stelios Antoniou.

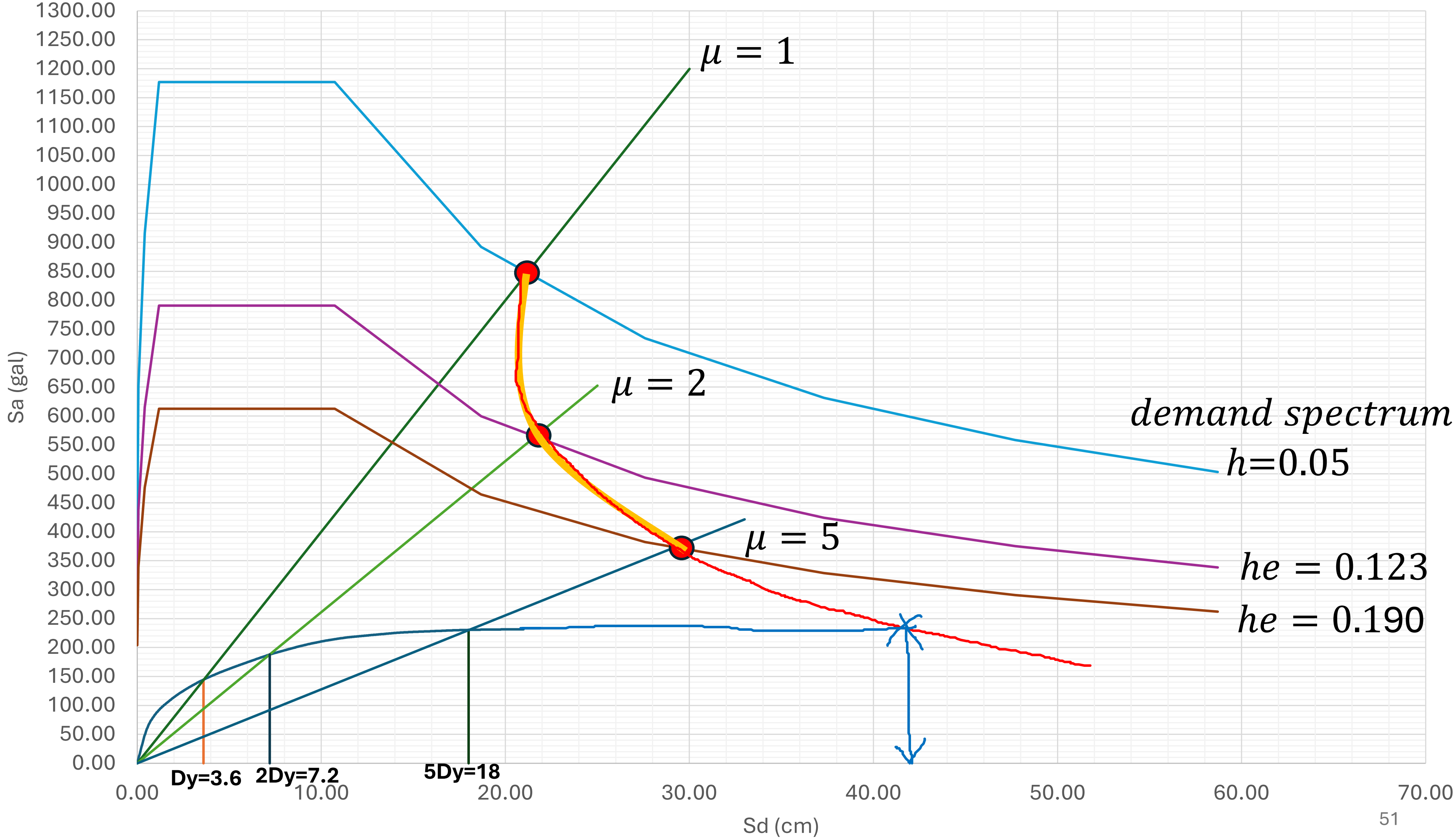


1. **CONDICION i:** Falla por flexion
2. **CONDICION ii:** Falla por flexion cortante
3. **CONDICION iii:** Falla por cortante

1. **NTDS (DEMANDA SISMICA)**
2. **ASCE 41-13 (PARAMETROS DE MODELAMIENTO ROTULAS)**
3. **METODOLOGÍA JAPONESA**
4. **EXPERIMENTOS PROYECTO HOKYO**



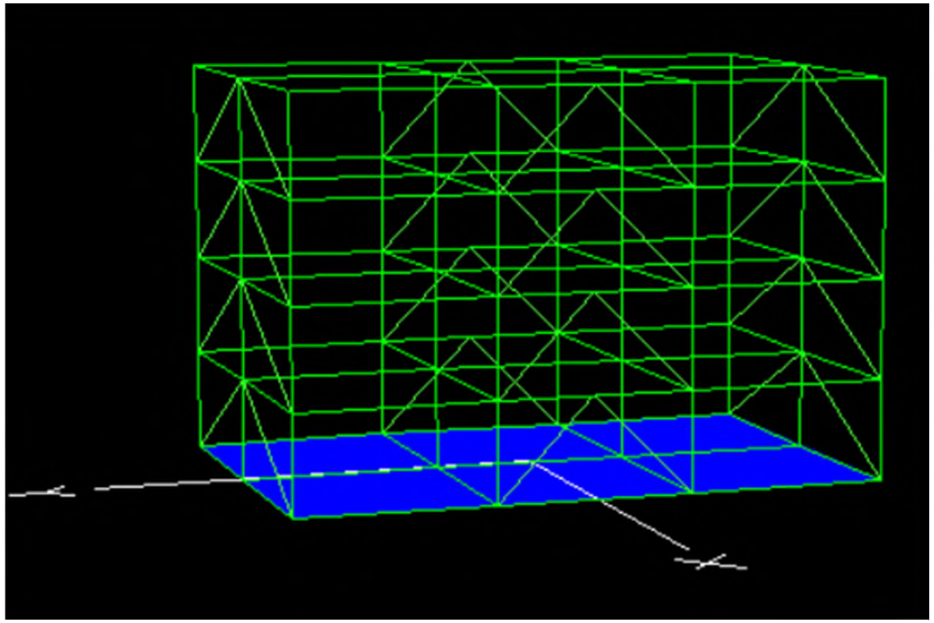
Columna
Tope
(x=L)
Base
(x=0)
Diagrama de Momento Flector
$+M_u$
$M(x) = M_u\left(1 - \frac{2x}{L}\right)$
$-M_u$
Altura x [m]
0.0
0.2
0.4
0.6
0.8
1.0
−1.00
−0.75
−0.50
−0.25
0.00
0.25
0.50
0.75
1.00
$M(x)$
Diagrama de Fuerza Cortante
$V_p = \frac{2M_u}{L}$
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
V_p



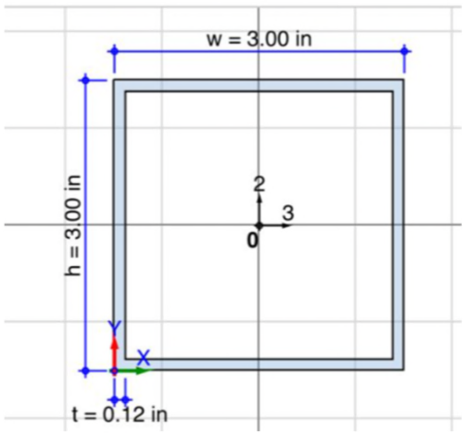
$\mu = 1$
$\mu = 2$
$\mu = 5$
$demand\ spectrum$
h=0.05
$he = 0.123$
$he = 0.190$
Sa (gal)
Sd (cm)
Dy=3.6
2Dy=7.2
5Dy=18
1300.00
1250.00
1200.00
1150.00
1100.00
1050.00
1000.00
950.00
900.00
850.00
800.00
750.00
700.00
650.00
600.00
550.00
500.00
450.00
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00

SEISMIC RETROFITTING

DIRECTION	SECTION	Height (mm)	L (mm)	Length of Buckling (mm)	Aspect Ratio (λ)	i (mm)	A (mm2)
X	75X75X3	3600	4000	5381.45	126.75	29.72	838
Y	50X50X3	3600	6000	6997.14	253.78	19.30	541



HSS3X3X1/8



📊 Resumen comparativo:

Característica	Piso débil (Weak Story)	Piso blando (Soft Story)
Qué mide	**Resistencia lateral**	**Rigidez lateral**
En qué se basa	Capacidad de resistir fuerza	Capacidad de oponerse a la deformación
Causa típica	Menos elementos estructurales resistentes	Columnas altas o grandes aberturas
Efecto	Colapso por sobreesfuerzo	Grandes desplazamientos, pandeo o colapso
Ejemplo común	Columnas delgadas o menos muros	Planta baja con estacionamiento abierto ("edificio pilotis")

💡 En resumen:

- **Piso débil** → falla por **falta de resistencia.**
- **Piso blando** → falla por **excesiva flexibilidad.**

Y en muchos casos reales (como en edificios con planta baja abierta), **un piso puede ser blando y débil al mismo tiempo**, lo que lo hace especialmente peligroso en un sismo.

Table 12.3-2. Vertical Structural Irregularities.

Type	Description	Reference Section*	Seismic Design Category Application
1a.	**Stiffness–Soft Story Irregularity** is defined to exist where there is a story in which the lateral stiffness is less than 70% of that in the story above or, where there are at least three stories above, less than 80% of the average stiffness of the three stories above.	-	-
1b.	**Stiffness–Extreme Soft Story Irregularity** is defined to exist where there is a story in which the lateral stiffness is less than 60% of that in the story above or, where there are at least three stories above, less than 70% of the average stiffness of the three stories above.	12.3.3.1	E, F
2.	**Vertical Geometric Irregularity** is defined to exist where the horizontal dimension of the seismic force-resisting system in any story is more than 130% of that in an adjacent story.	-	-
3.	**In-Plane Discontinuity in Vertical Lateral Force-Resisting Element Irregularity** is defined to exist where there is an in-plane offset of a vertical seismic force-resisting element resulting in overturning demands on supporting structural elements.	12.3.3.4 12.3.3.5	B, C, D, E, F D, E, F
4a.	**Discontinuity in Lateral Strength–Weak Story Irregularity** is defined to exist where the story lateral strength is less than that in the story above. The story lateral strength is the total lateral strength of all seismic force-resisting system elements resisting the story shear for the direction under consideration.	12.3.3.1	E, F
4b.	**Discontinuity in Lateral Strength–Extreme Weak Story Irregularity** is defined to exist where the story lateral strength is less than 65% of that in the story above. The story lateral strength is the total lateral strength of all seismic force-resisting system elements resisting the story shear for the direction under consideration.	12.3.3.1 12.3.3.2 12.3.3.3	E, F D B, C

* See Section 12.8.1.3 for requirement for any structure with an irregularity listed in this table.

3.3.7. Factor de Modificación por nivel.

La modificación del índice E_o (Índice sísmico básico de la estructura) se aplica considerando la distribución vertical de la aceleración horizontal, así mismo el índice sísmico de la estructura, I_s, se puede comparar con el índice de demanda sísmica, I_{so}, en cada nivel con el mismo valor.

$$\frac{n+1}{n+i} = \text{Factor de modificación de cortante de entrepiso}$$

a) Aceleración horizontal α_i(cm/s^2) o carga sísmica

$$F_i = mi \cdot \alpha_i = W_i/(G \cdot \alpha_i)$$

b) Cortante de entrepiso,

$$Q_i = V_i = \Sigma F_i(kN)$$

c) Coeficiente de cortante de entrepiso,

$$C_i = Q_i/\Sigma W_i = V_i/\Sigma W_i$$

d) C_i Modificado

$$C_i = \frac{n+1}{n+i} \cdot C_i$$