MIDAS SQUARE

MIDAS SQUARE 공학 기술강연

성능기반내풍설계 사례

김대영 | 한빛구조이엔지

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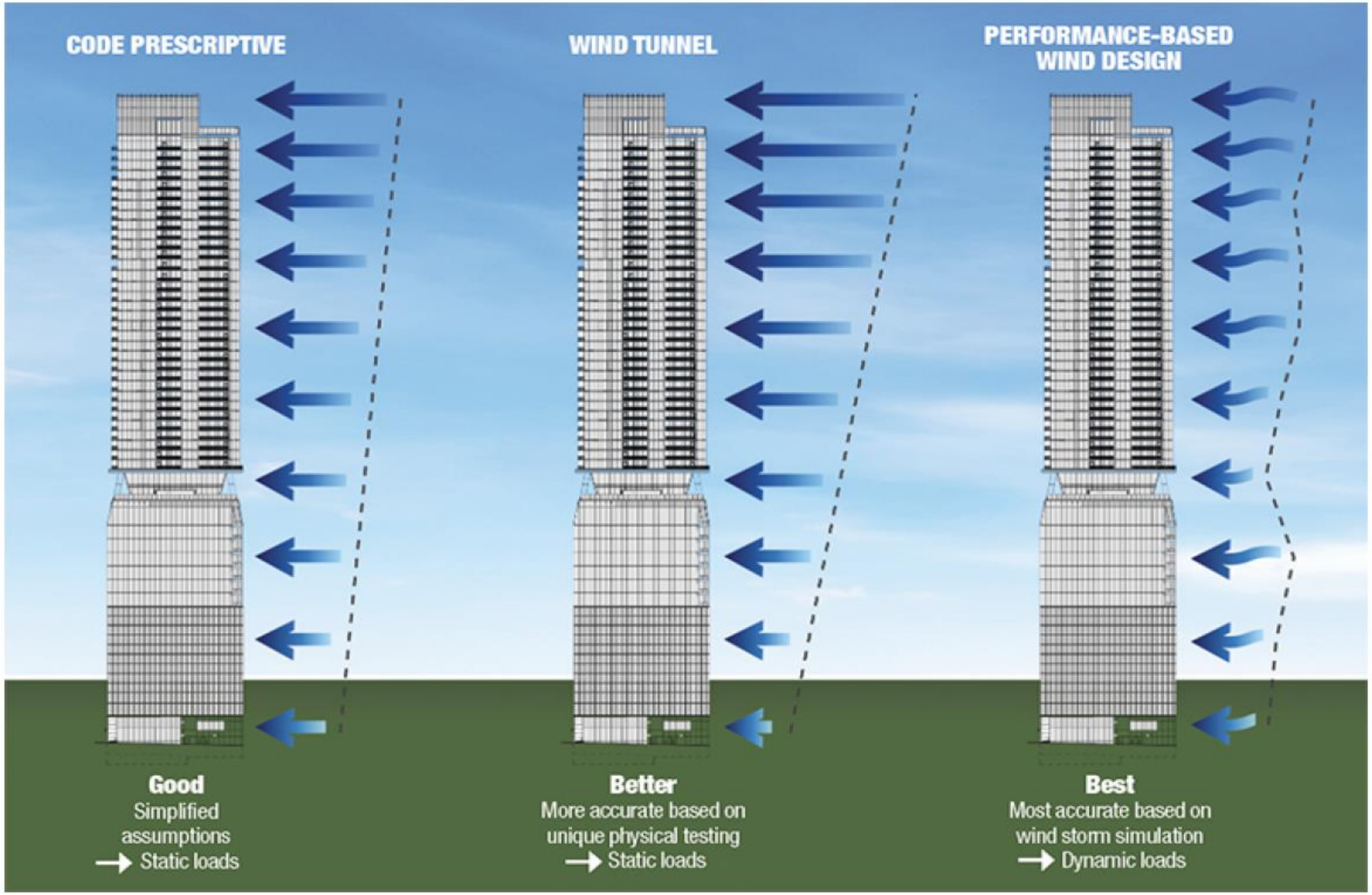
(선형, 비선형 동적해석)

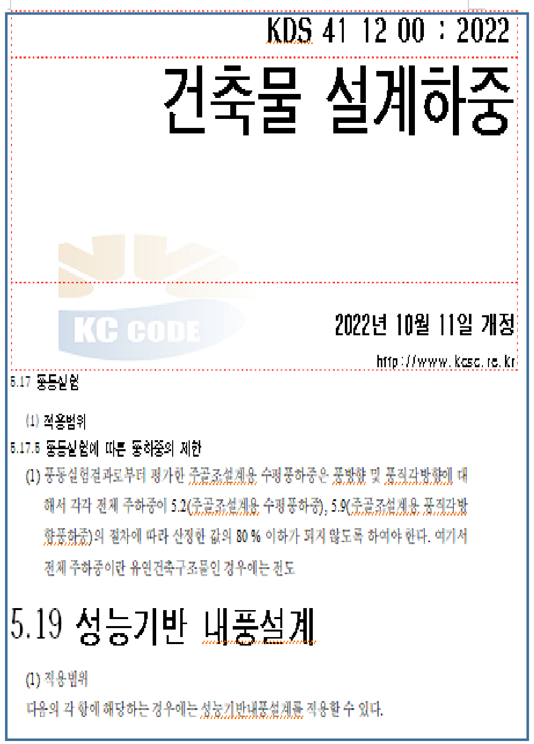


출처 : Engineering News-Record 6 2022

성능기반 내풍 설계 개요

Performance-Based Wind Design - Code

적용범위, 성능목표, 해석방법, 허용기준 및 평가방법



KDS 41 12 00 : 2022

건축물 설계하중

KC CODE

2022년 10월 11일 개정

http://www.kcsc.re.kr

5.17 풍동실험

(1) 적용범위

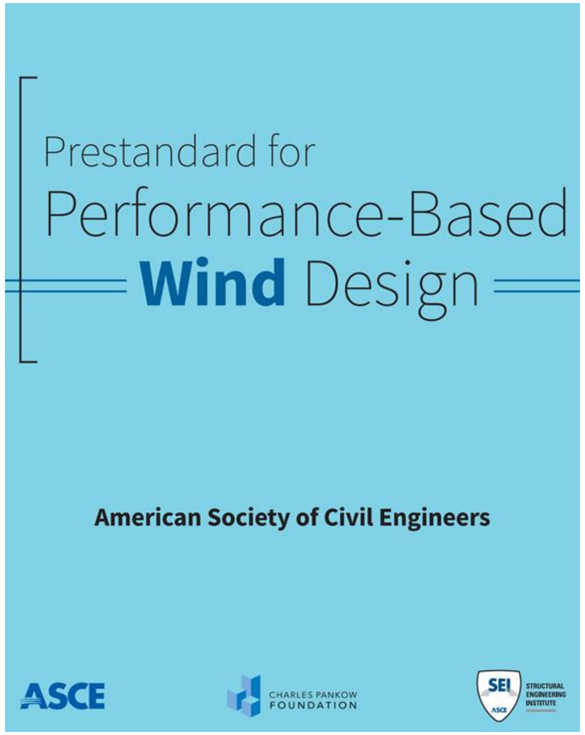
5.17.5 풍동실험에 따른 풍하중의 제한

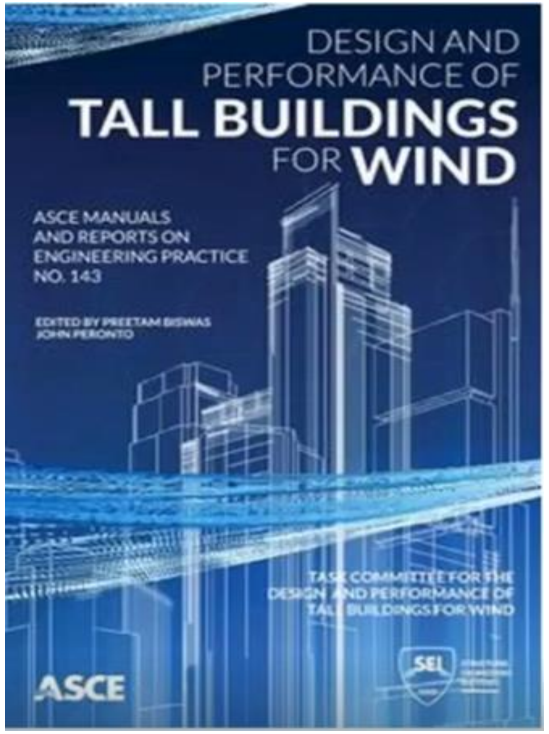
(1) 풍동실험결과로부터 평가한 주골조설계용 수평풍하중은 풍방향 및 풍직각방향에 대해서 각각 전체 주하중이 5.2(주골조설계용 수평풍하중), 5.9(주골조설계용 풍직각방향풍하중)의 절차에 따라 산정한 값의 80 % 이하가 되지 않도록 하여야 한다. 여기서 전체 주하중이란 유연건축구조물인 경우에는 전도

5.19 성능기반 내풍설계

(1) 적용범위

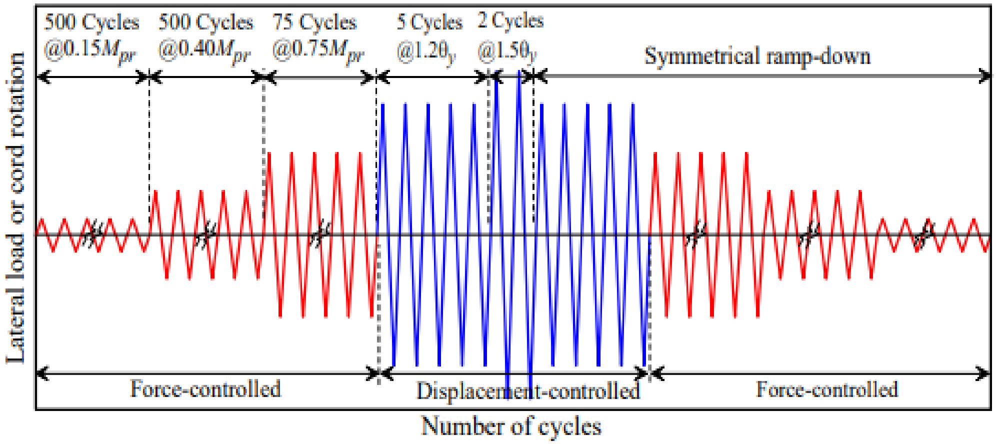
다음의 각 항에 해당하는 경우에는 성능기반내풍설계를 적용할 수 있다.





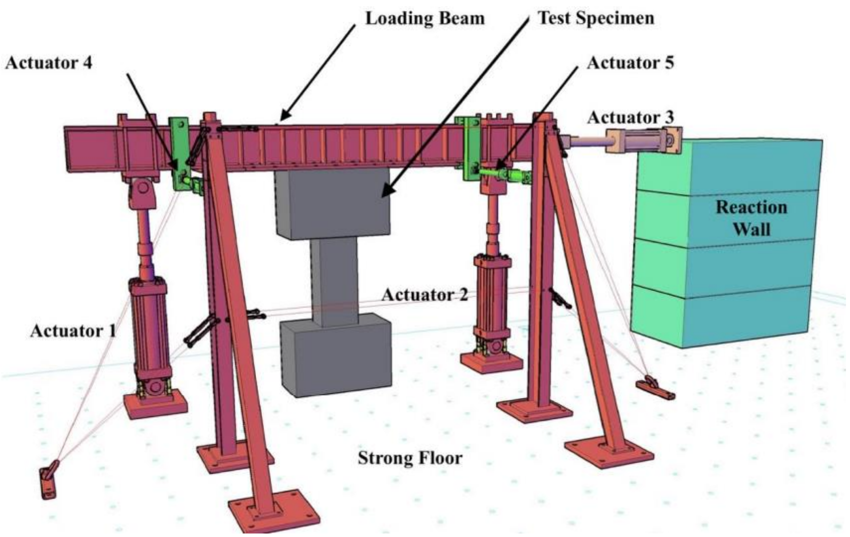
성능기반 내풍 설계 개요

Performance-Based Wind Design – Experimental Study



#0: Wind loading protocol

Alternative wind loading protocol
- #1: More yielding cycles
- #2: Non-zero mean
- #3: Two ramp-up and ramp-downs



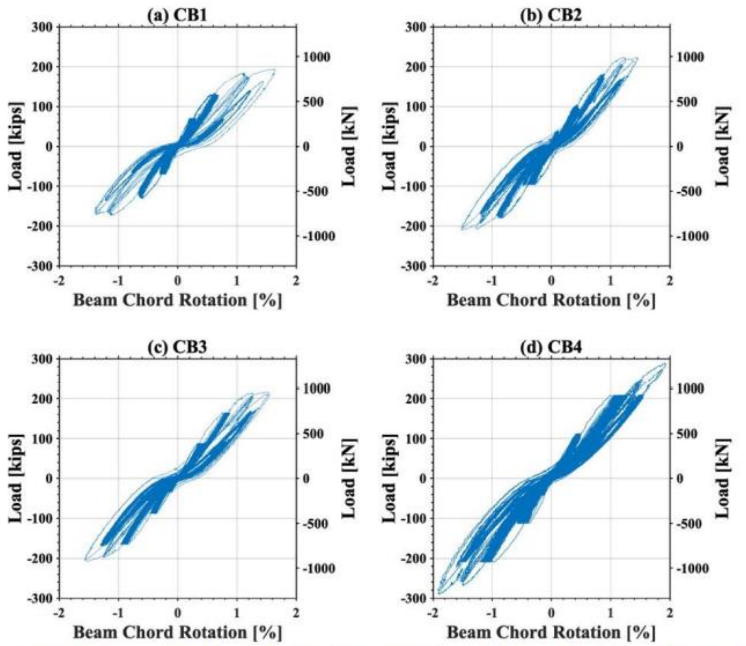
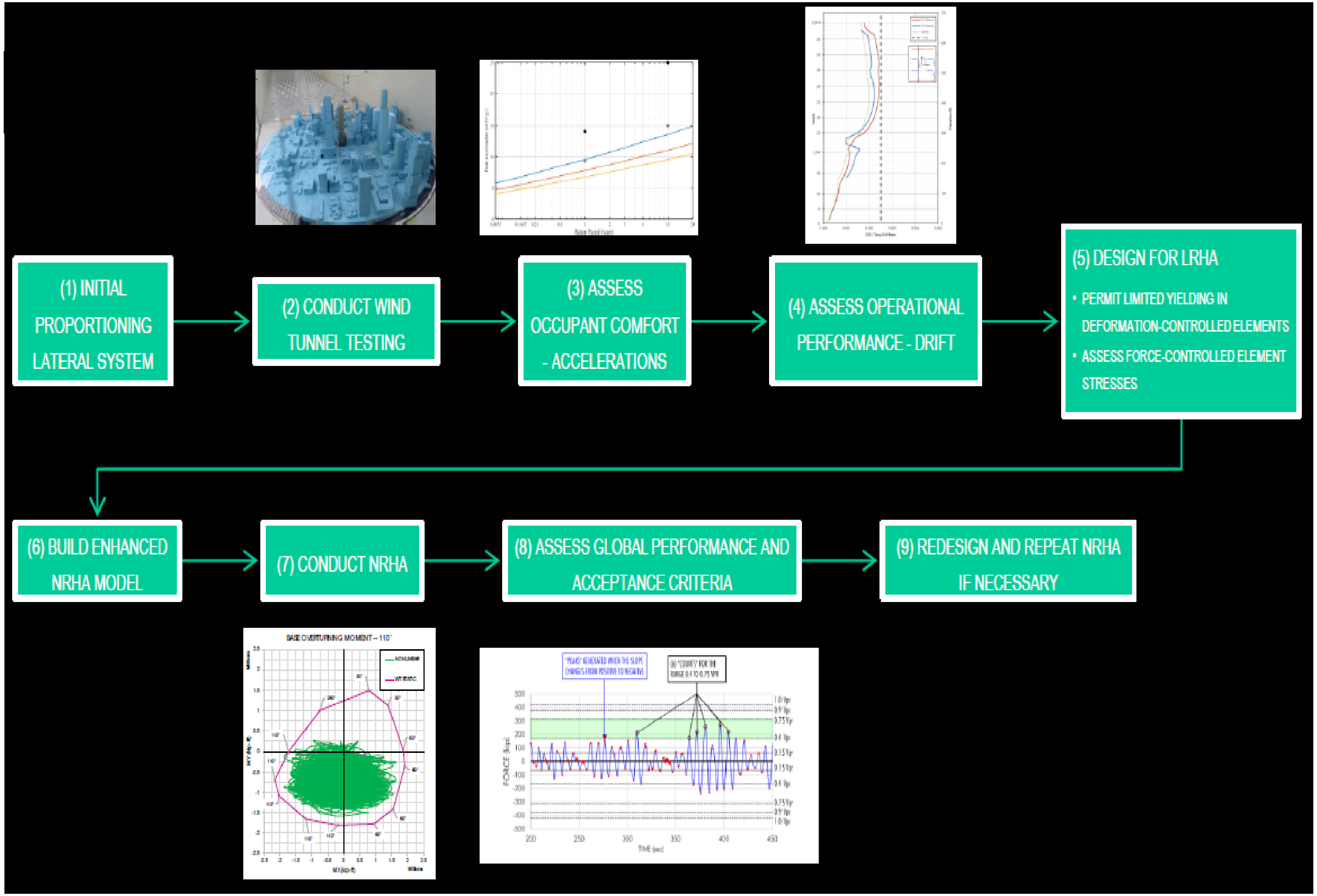


Figure 22. Load versus chord rotation relationships: wind loading protocol.

출처 : coupling beams subjected to wind loading protocols, UCLA

성능기반 내풍 설계 개요

Performance-Based Wind Design - Process



(1) INITIAL PROPORTIONING LATERAL SYSTEM

(2) CONDUCT WIND TUNNEL TESTING

(3) ASSESS OCCUPANT COMFORT - ACCELERATIONS

(4) ASSESS OPERATIONAL PERFORMANCE - DRIFT

(5) DESIGN FOR LRHA
- PERMIT LIMITED YIELDING IN DEFORMATION-CONTROLLED ELEMENTS
- ASSESS FORCE-CONTROLLED ELEMENT STRESSES

(6) BUILD ENHANCED NRHA MODEL

(7) CONDUCT NRHA

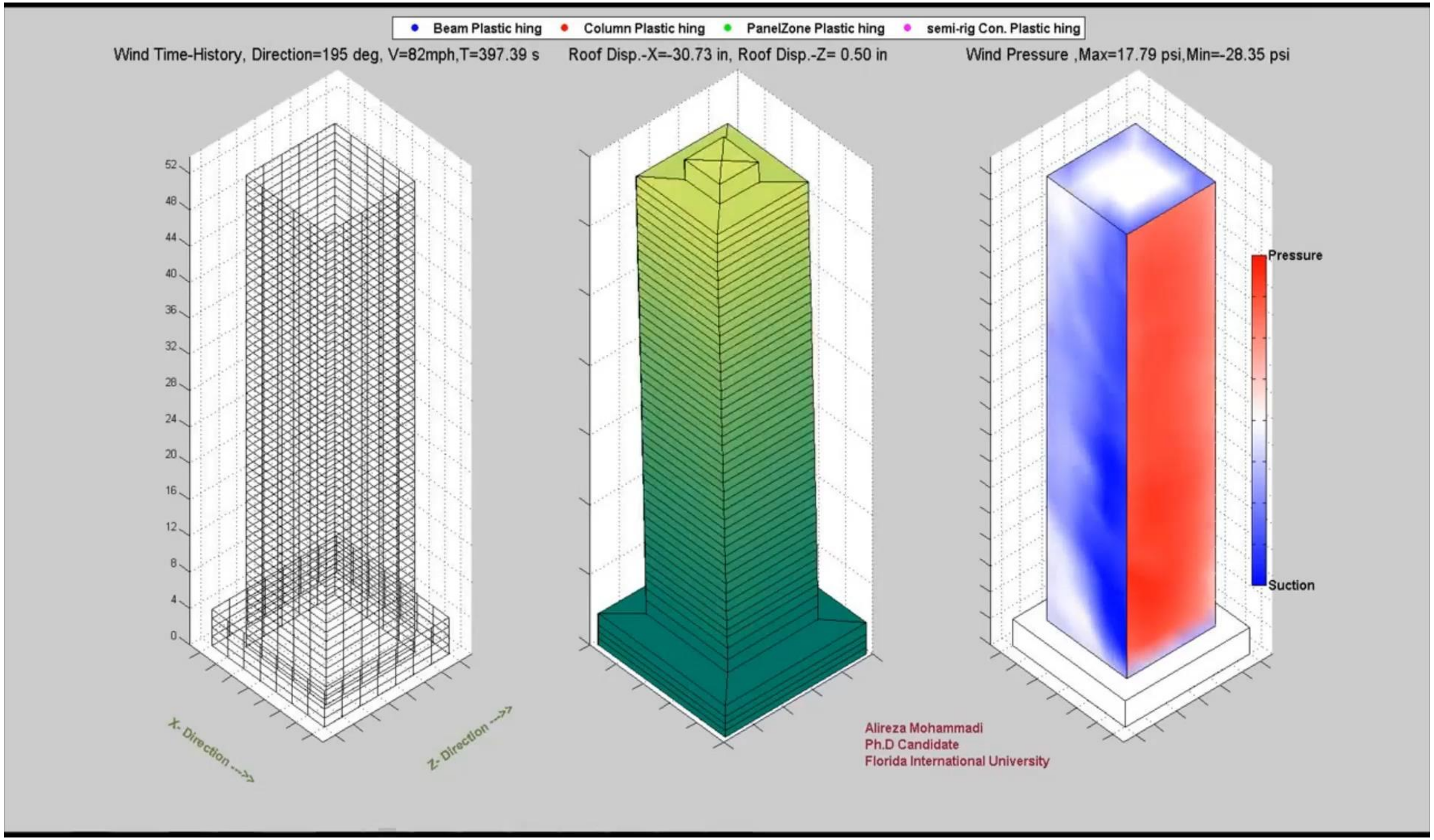
(8) ASSESS GLOBAL PERFORMANCE AND ACCEPTANCE CRITERIA

(9) REDESIGN AND REPEAT NRHA IF NECESSARY

출처 : MAGNUSSON KLEMANCIC ASSOCIATES

성능기반 내풍 설계 개요

Performance-Based Wind Design – Time History Analysis



출처 : Florida International University, Mohammadi

성능기반 내풍설계 적용사례

성능기반 내풍 설계 적용사례

적용 사례 1. Austin Tower

구조 개요

- 높이 58층(205m), 콘크리트 코어+콘크리트 아웃리거의 횡력저항 시스템
- 성능기반내풍설계의 적용효과를 알아보기 위하여 일반설계와 성능기반내풍설계를 병행 수행

Design Review

- 콘크리트 전단벽의 콘크리트 물량 5%(1,380m^3)절감
- 코어월 두께를 당초 955mm에서 760mm로 줄임
- 코어 매립 철골물량을 당초 175ton에서 125ton을 절감하여 50ton만 설치
- 구조물량이 5% 절감되었고 탄소배출량은 6% 절감
- 부가적인 효과로 임대면적이 늘어났음
- 건물의 기초면적이 줄어들어 기초물량 절감에 따른 공기단축
- 합리적인 성능설계 수행 시 단순 구조물량 절감만으로 12% 정도의 탄소배출량 절감이 예상

출처 : ENR June 22, 2022

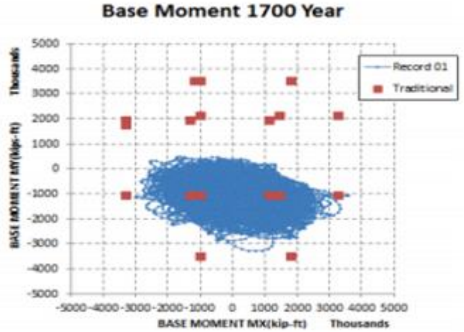
성능기반 내풍 설계 적용사례

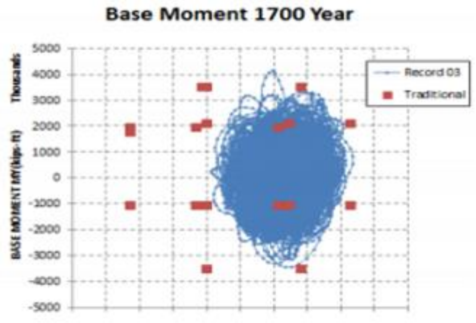
적용 사례 2. Rainer Square Tower

출처 : Wei-Chu Chuang,2019

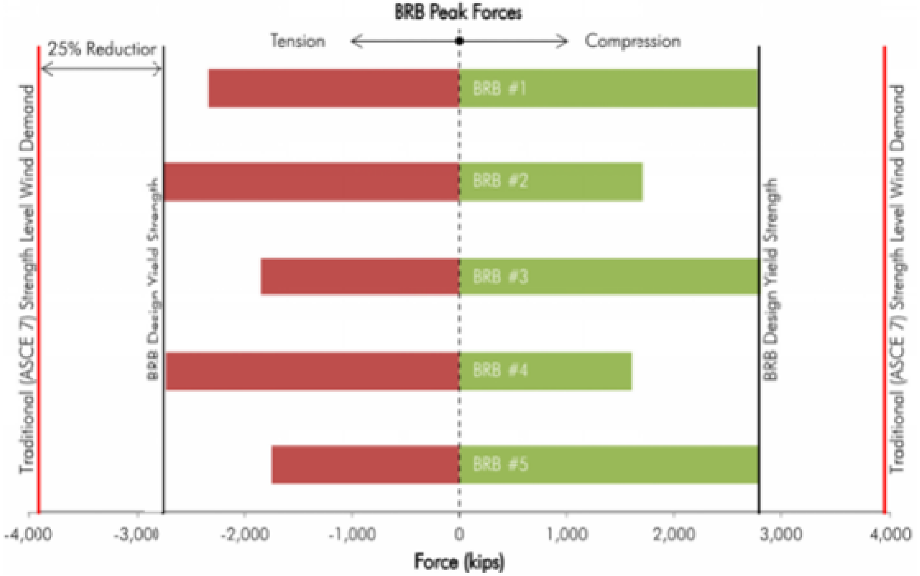
구조 개요

- 높이 58층(258m), 콘크리트 코어+BRB 아웃리거의 횡력저항 시스템





25% Reduction in BRB size at outrigger system

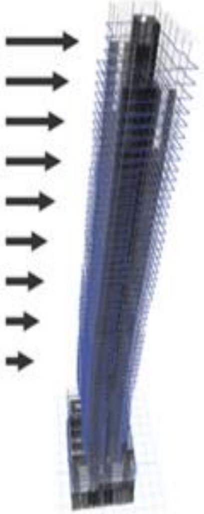


BRB Forces From Nonlinear Analysis

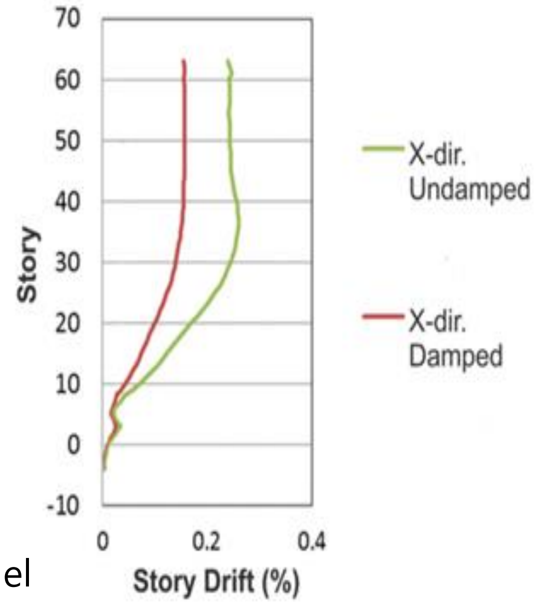
성능기반 내풍 설계 적용사례

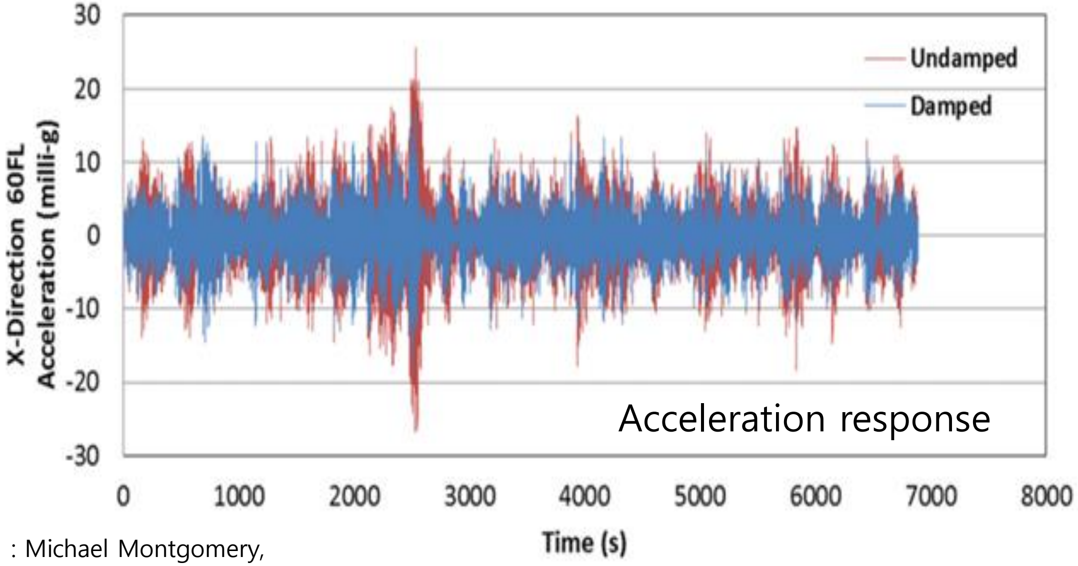
적용 사례 3. Yonge College Condominiums

Wind tunnel model



Structural model



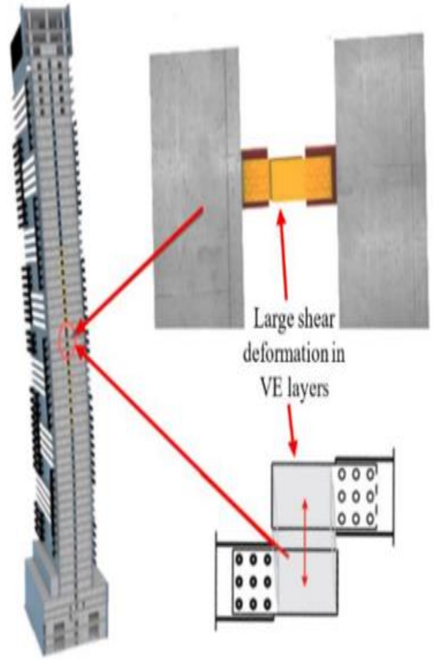


Acceleration response

출처 : Michael Montgomery,
Luis Ardila, Constantin Christopoulos, 2021

구조 개요

- 층수 66층, 형상비 11, RC조
- 0.9%추가 감쇠를 위해 21개 층에 42개의 댐퍼(VCD)설치

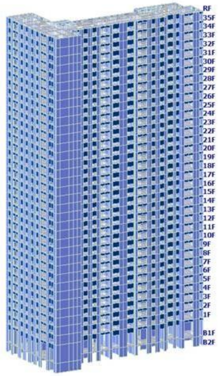


Viscoelastic damper

성능기반 내풍 설계 적용사례

적용 사례 4. 35층 전단벽식 건물.

구조설계 개요



35층 전단벽식 건물

- 건물 높이: 99.4m
- 기본풍속: 38m/s
- 지표면조도구분 B
- 설계기준: Korean Building Code (KBC 2016)
- 풍하중 반응수정계수 1.0과 1.5에 따른 내풍설계 비교
- 풍직각방향과 비틀림 풍하중은 상당히 저감 가능

	R_{WR} = 1.0 (일반 설계)	R_W = 1.5 (비탄성 내풍설계)
풍방향 풍하중	W_{DX} = 8,837 kN W_{DY} = 17,807 kN	W_{DX} = 7,765 kN (-12.1%) W_{DY} = 15,507 kN (-12.9%)
풍직각방향 풍하중	W_{LX} = 11,219 kN W_{LY} = 5,651 kN	W_{LX} = 8,063 kN (-28.1%) W_{LY} = 4,582 kN (-18.9%)
비틀림 풍하중	W_{TX} = 9,404,834 kN-m W_{TY} = 5,001,651 kN-m	W_{TX} = 6,589,429 kN-m (-29.9%) W_{TY} = 3,835,866 kN-m (-23.3%)
벽체 철근량	620 ton	520 ton (-16.1%)

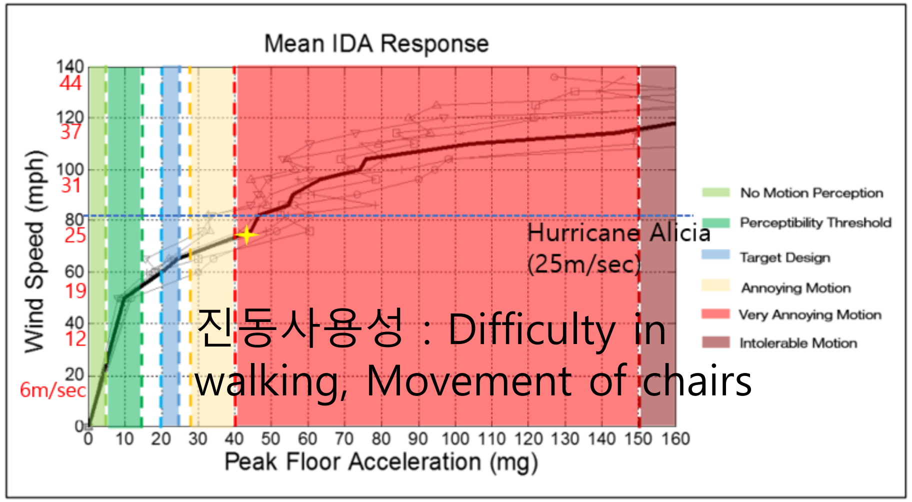
출처 : 건축구조기술세미나 2022,Kang Thomas H.-K.

성능기반 내풍 설계 적용사례

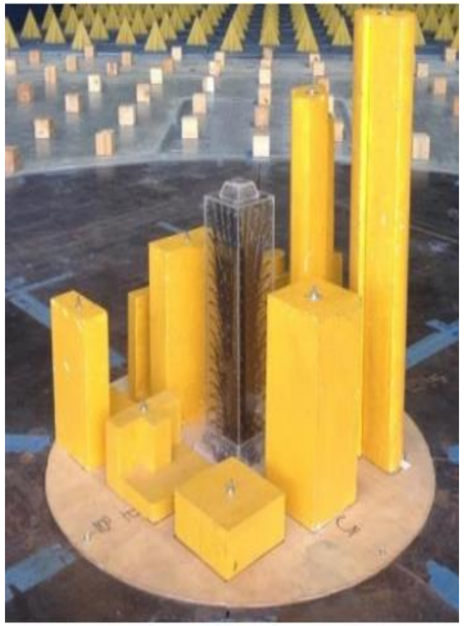
적용 사례 5. 47-Story Building in Houston, Texas

구조 개요

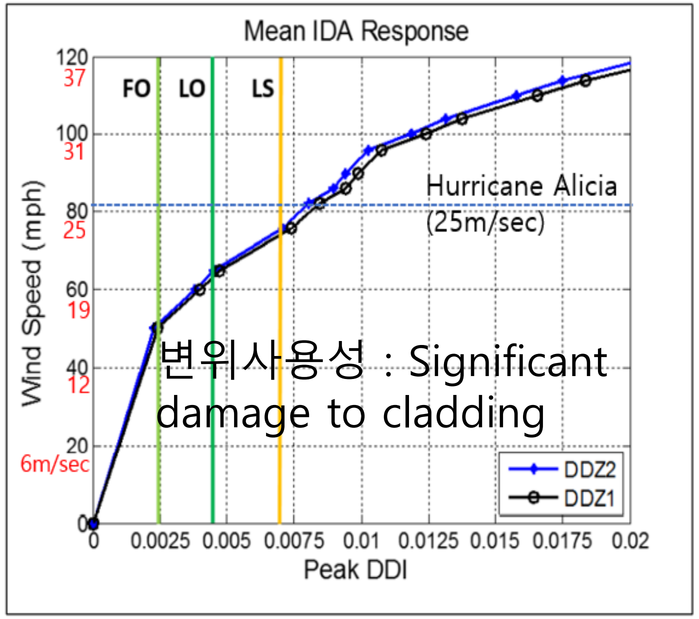
- 지상 47층, 높이 628ft(191m), Houston Texas에 위치
- 1971년 Houston Building Code로 설계 (횡변위 제한 없음)
- Hurricane Alicia(1983년)시의 피해기록과 성능기반내풍설계에 의한 성능평가비교



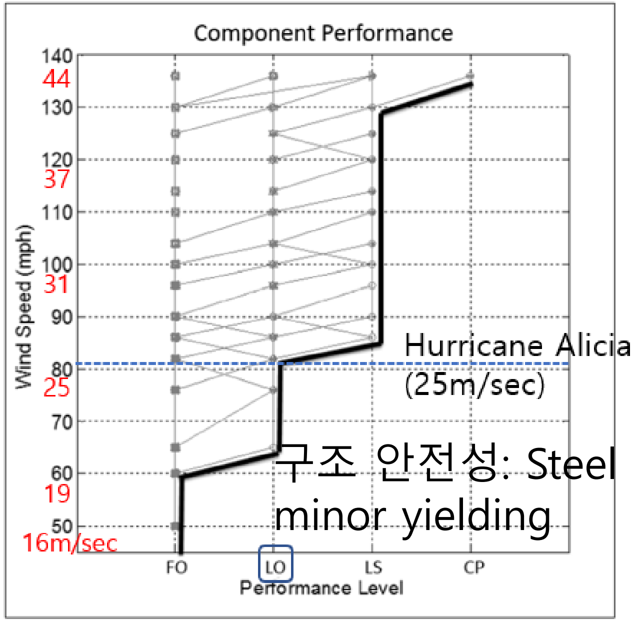
진동사용성 : Difficulty in walking, Movement of chairs



Wind Tunnel Test



변위사용성 : Significant damage to cladding



구조 안전성: Steel minor yielding

출처 : Alireza Mohammadi, 2016

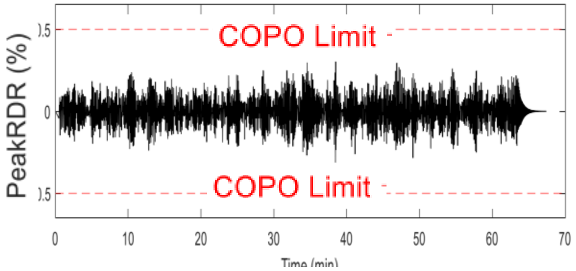
성능기반 내풍 설계 적용사례

적용 사례 6. 40-story office in Toronto

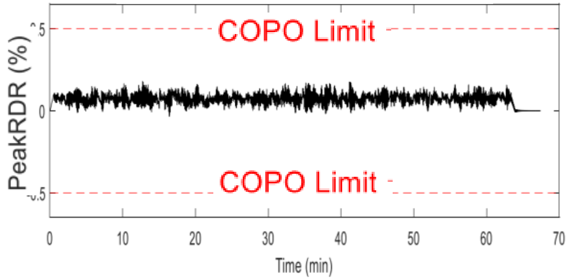
구조 개요

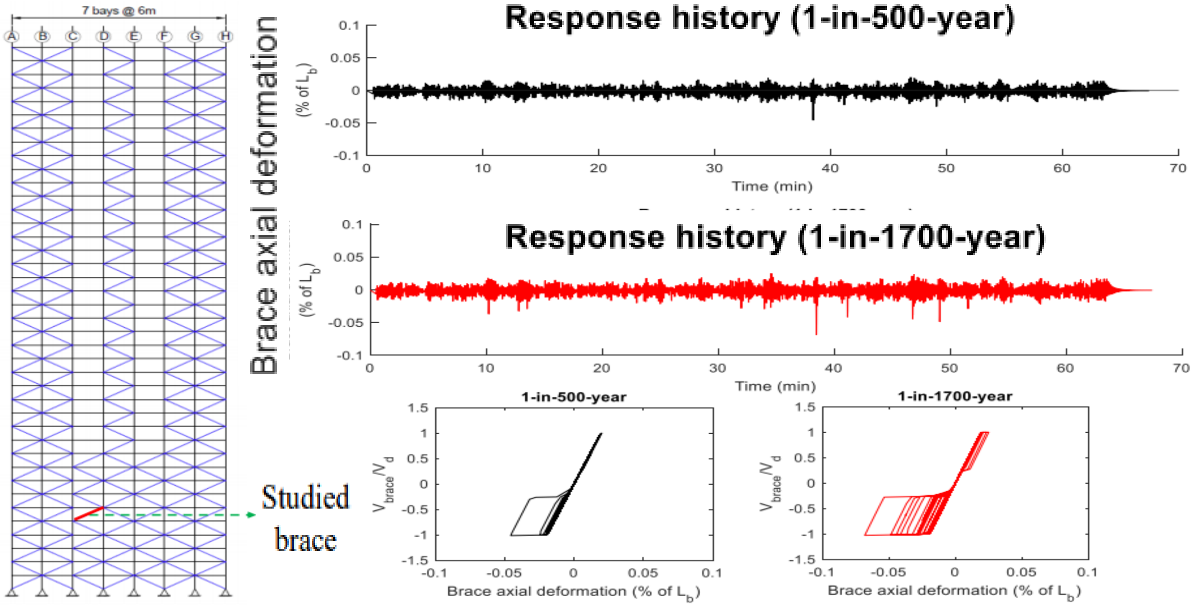
- 지상 40층(136m), S조, Shear-truss braces(LLRS)
- Self-centering system 성능검증
- Brace 최적화 설계

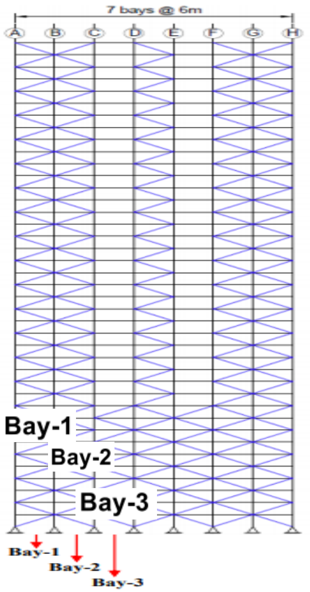
X direction (Across-wind)

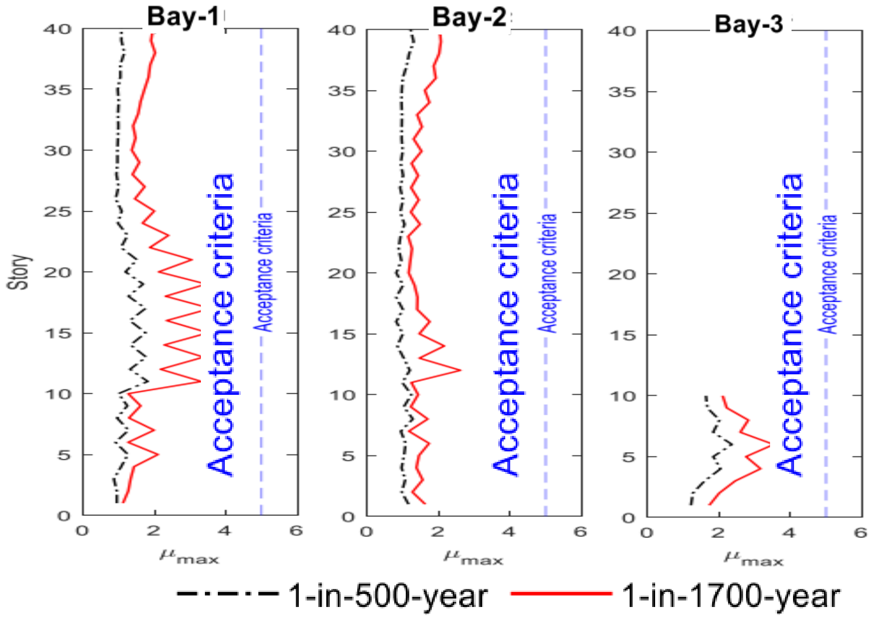


Y direction (Along-wind)









출처 : Matiyas Bezabeh, 2020

성능기반 내풍 설계 적용사례

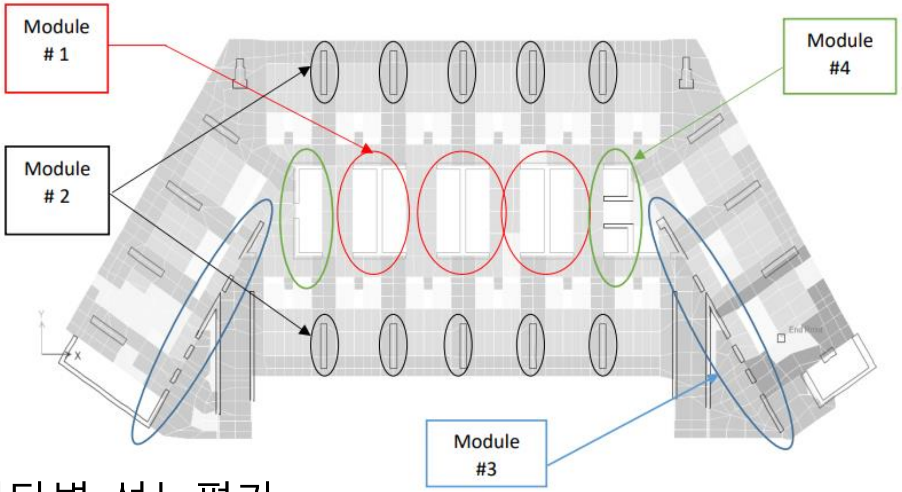
적용 사례 7. Abraj Al Bait Tower in Mecca, Saudi Arabia

구조 개요

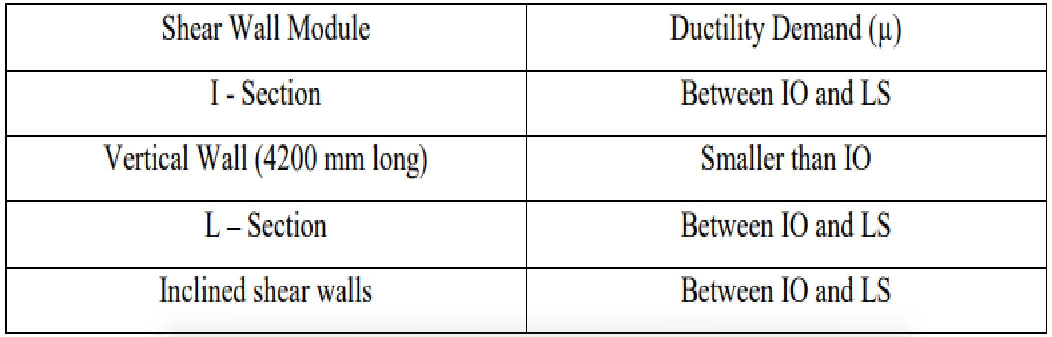
- 지상 65층(232m), 50mx70m평면 콘크리트 전단벽식 구조
- 성능기반내풍설계로 구조물량 절감

Wind Tunnel Test

Design Review: Concrete shear wall cross sections were reduced by 20-25% as a result of applying a load reduction factor to wind resonant component by R_W=2



전단벽 성능평가



Shear Wall Module	Ductility Demand (μ)
I - Section	Between IO and LS
Vertical Wall (4200 mm long)	Smaller than IO
L – Section	Between IO and LS
Inclined shear walls	Between IO and LS

출처 : Fouad Y. Elezaby, 2017

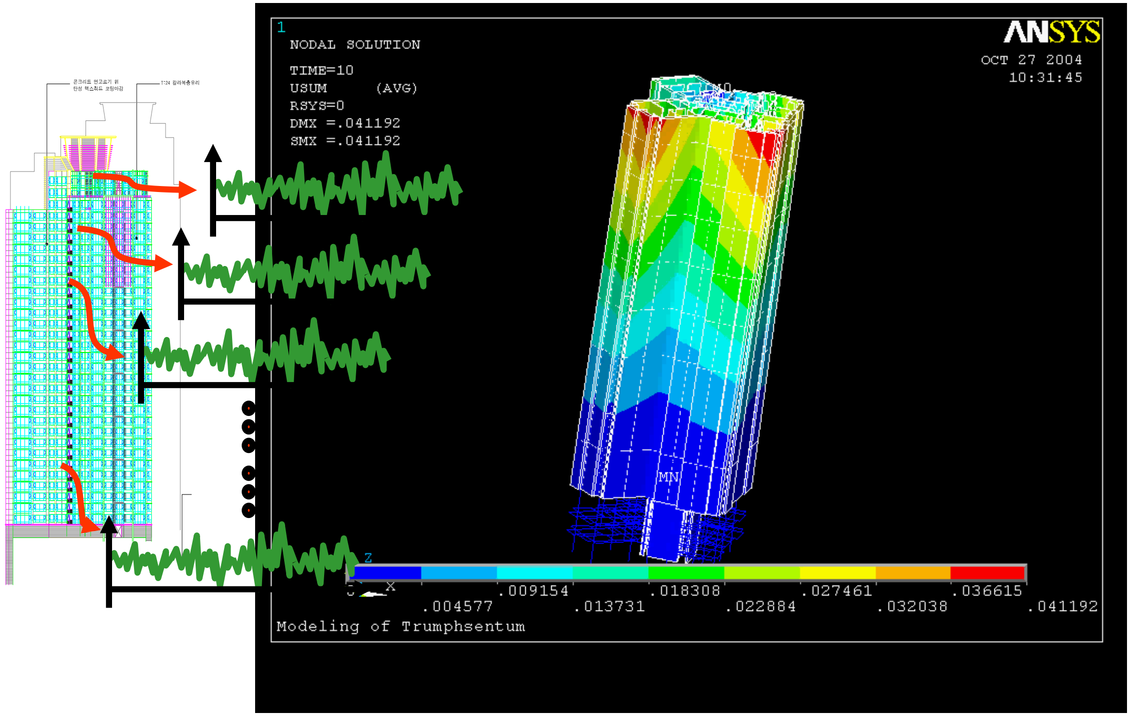
성능기반 내풍 설계 적용사례

적용 사례 8. 트럼프 월드 센텀

구조 개요

- 지상 35층(100.4m),
  50mx70m평면
  콘크리트 전단벽식 구조

- 성능기반내풍설계로
  사용성 합리적 평가



Over-estimation of Acceleration Responses

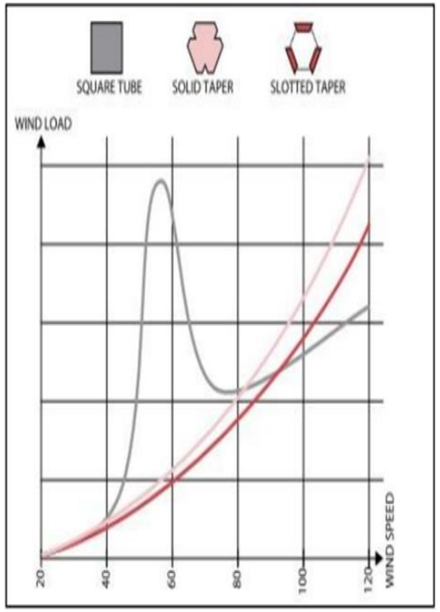
Test model	Peak lateral drift (m)		Acceleration (m/s^2)		
	x direction	y direction	Peak	x component	y component
시간이력해석	0.20	0.27	0.13	0.06	0.12
응답 스펙트럼해석	0.21	0.31(115%)	0.21(162%)	0.13	0.16

성능기반 내풍설계 기술 내용

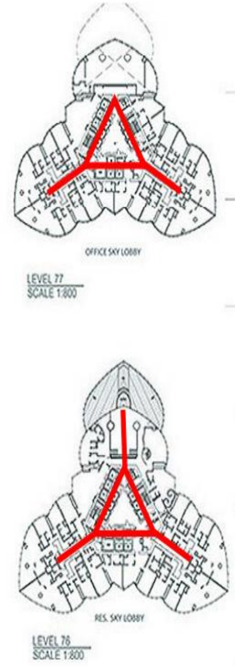
성능기반 내풍 설계 기술내용

Wind Engineering

A.공기역학적 설계

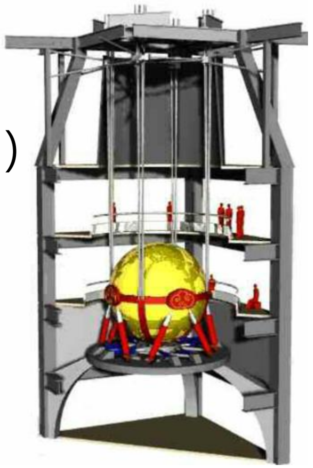


B.횡강성 증대



C.일반화 질량 증대

D.감쇠 증대
(제진장치)

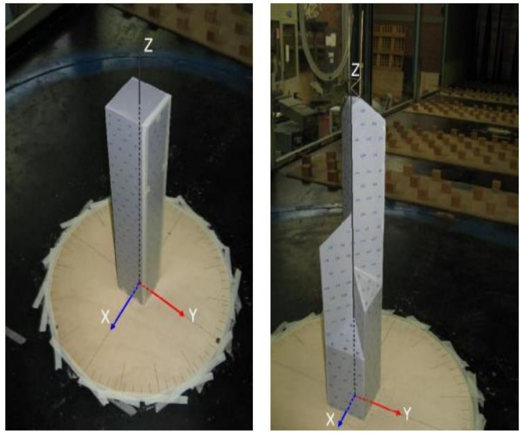


Performance-Based Wind Design

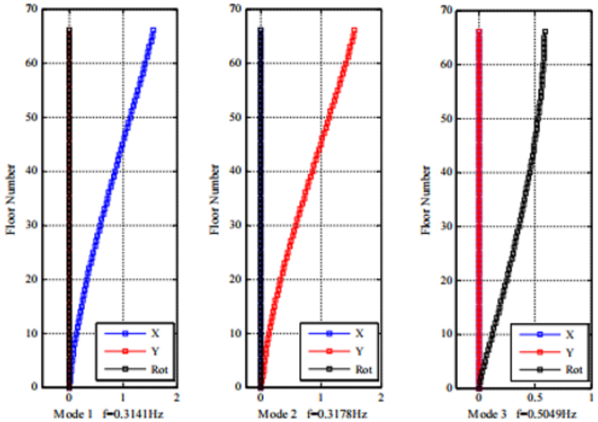
성능기반 내풍 설계 기술내용

Performance-Based Wind Design – Why?

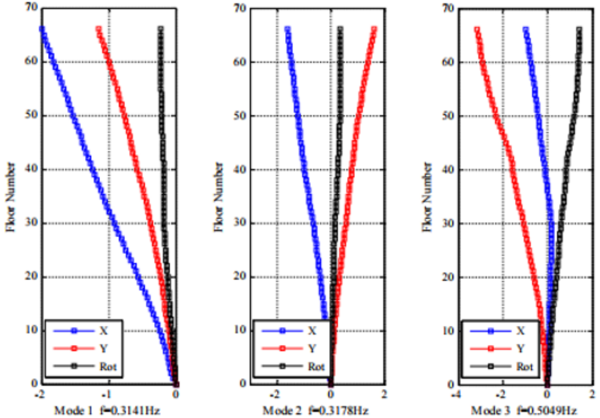
연성진동 (Coupled Vibration) 영향



정형 및 비정형 건물

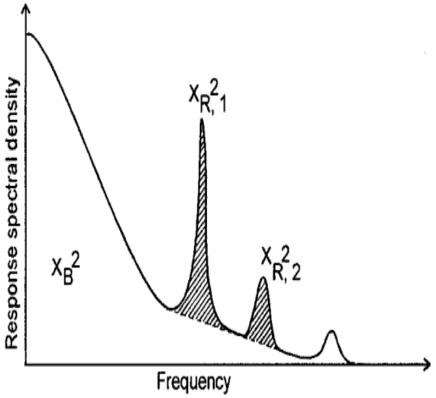


정형건물의 모드형상

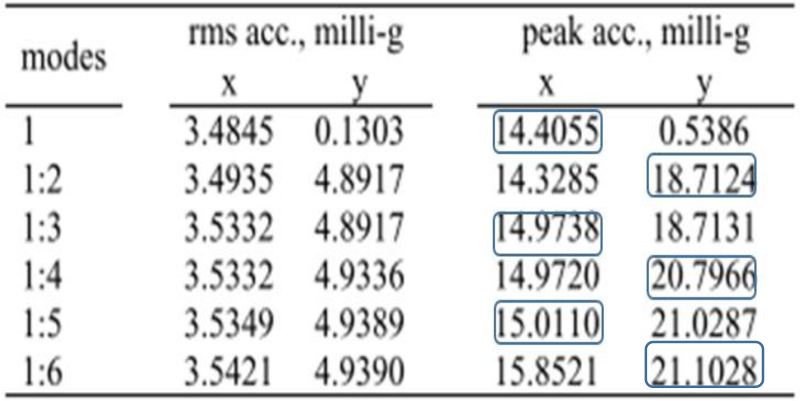


비정형건물의 모드형상

고차모드 영향



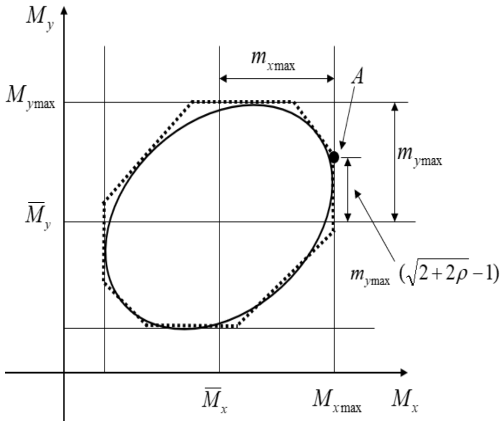
(고차모드 고려시 x, y방향 각각 10.6%, 12.8% 증가)



modes	rms acc., milli-g		peak acc., milli-g	
	x	y	x	y
1	3.4845	0.1303	14.4055	0.5386
1:2	3.4935	4.8917	14.3285	18.7124
1:3	3.5332	4.8917	14.9738	18.7131
1:4	3.5332	4.9336	14.9720	20.7966
1:5	3.5349	4.9389	15.0110	21.0287
1:6	3.5421	4.9390	15.8521	21.1028

고려된 모드수에 따른 가속도 응답

응답의 상관 영향

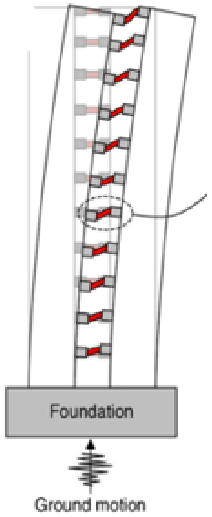


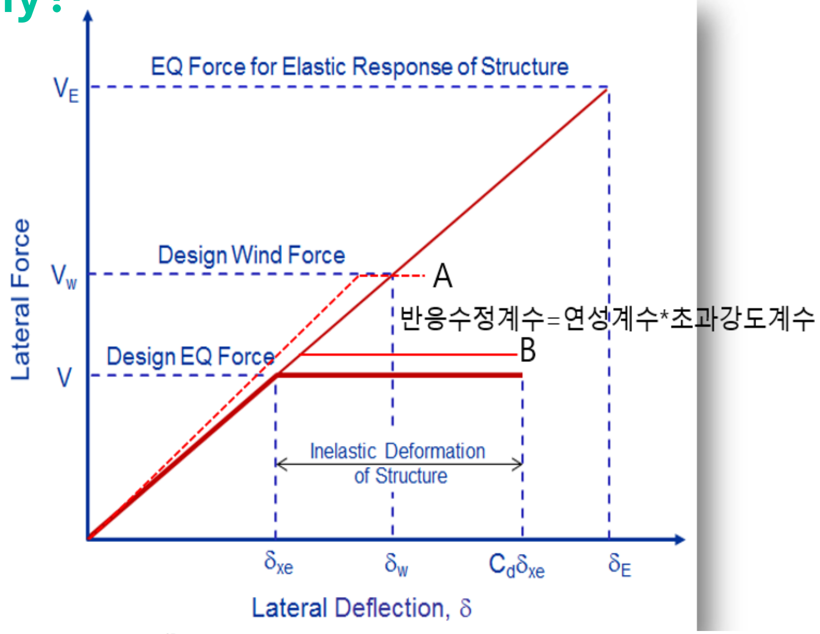
출처: INFLUENCE OF HIGHER MODES ON THE DYNAMIC RESPONSE OF IRREGULAR AND REGULAR TALL BUILDINGS

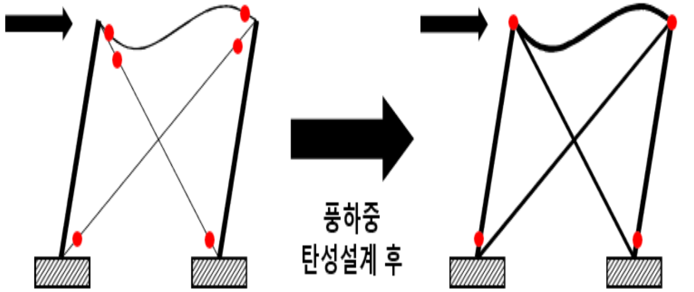
성능기반 내풍 설계 기술내용

Performance-Based Wind Design – Why?

Structural Fuse Element

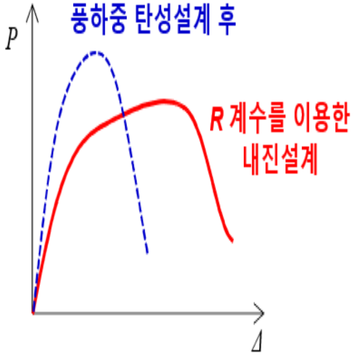






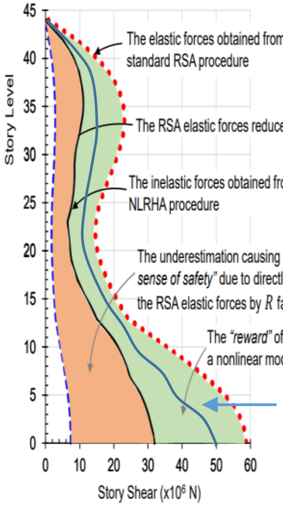
설계 지진하중이 지배적인 경우
(보와 가새의 항복)

풍하중이 지배적인 경우
(수직부재 및 접합부 항복·파괴)



구조물의 연성능력

출처 : 건축구조기술세미나 2022,Kang Thomas H.-K.

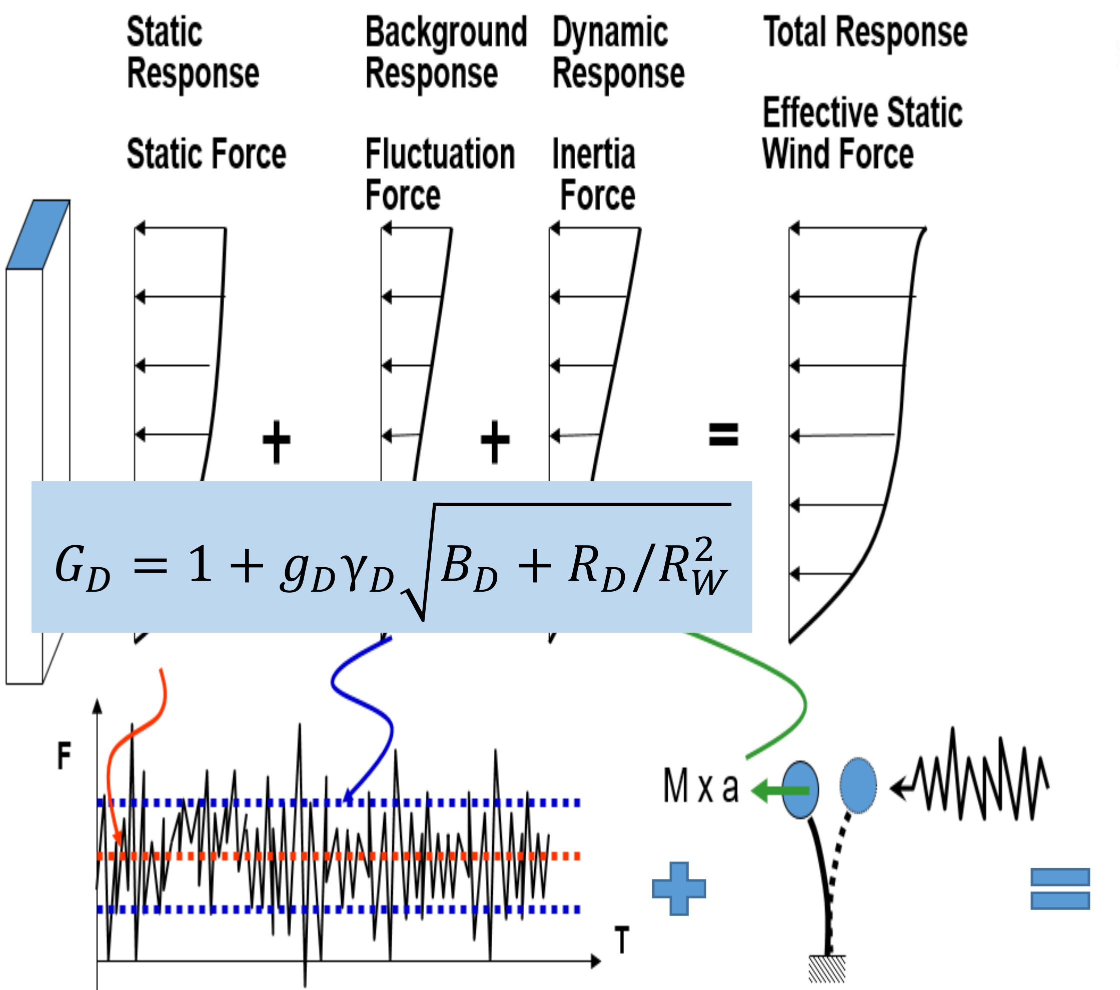


High strength demand by elastic wind design

출처 : AIT Solutions

성능기반 내풍 설계 기술내용

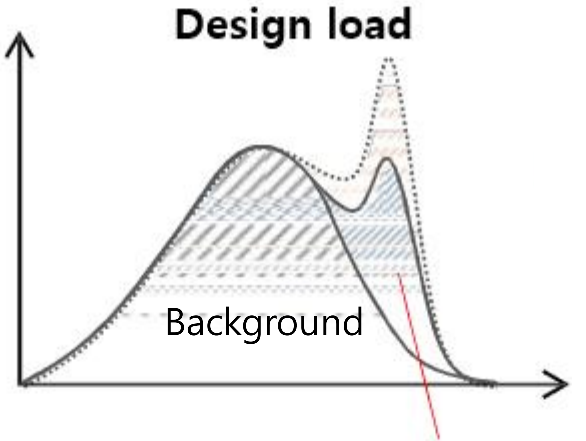
Structural Design Wind Load(반응수정계수)



$$G_D = 1 + g_D \gamma_D \sqrt{B_D + R_D / R_W^2}$$

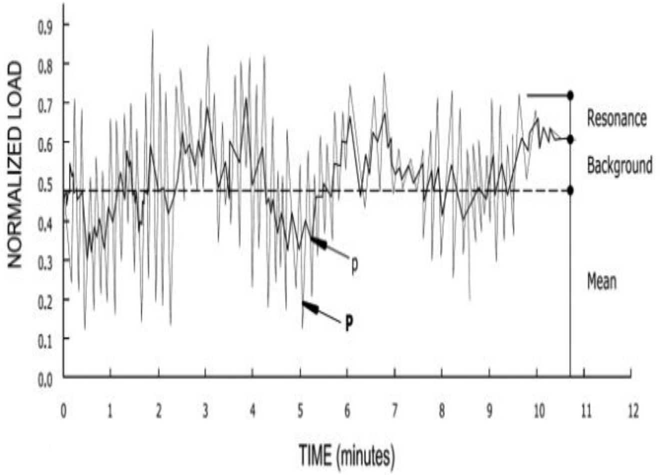
Mean and background wind forces (wind properties)

Inertia forces induced by vibration (structural properties)



Reduced Resonant with R_W

출처 : Kang Thomas H.-K., 2022



성능기반 내풍 설계 기술내용

Modeling and Analysis (Effective Stiffness)

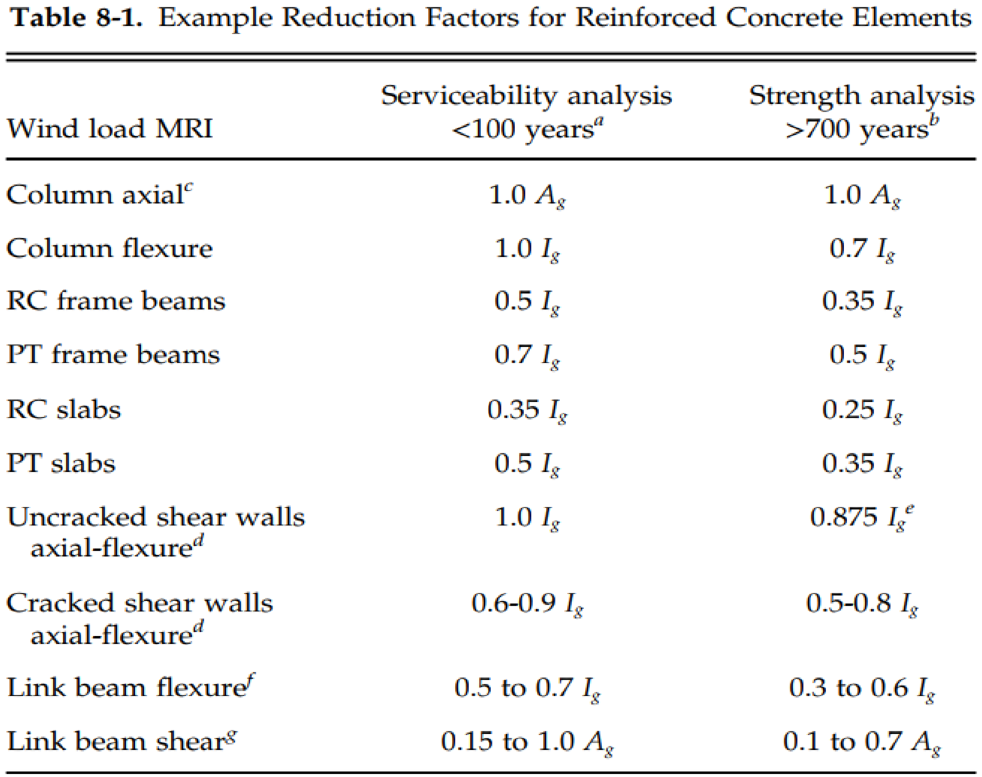
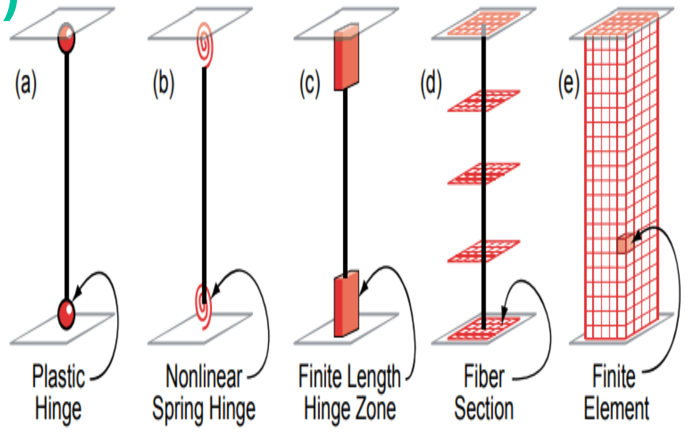


Table 8-1. Example Reduction Factors for Reinforced Concrete Elements

Wind load MRI	Serviceability analysis <100 years[a]	Strength analysis >700 years[b]
Column axial[c]	$1.0\ A_g$	$1.0\ A_g$
Column flexure	$1.0\ I_g$	$0.7\ I_g$
RC frame beams	$0.5\ I_g$	$0.35\ I_g$
PT frame beams	$0.7\ I_g$	$0.5\ I_g$
RC slabs	$0.35\ I_g$	$0.25\ I_g$
PT slabs	$0.5\ I_g$	$0.35\ I_g$
Uncracked shear walls axial-flexure[d]	$1.0\ I_g$	$0.875\ I_g$[e]
Cracked shear walls axial-flexure[d]	0.6-0.9 I_g	0.5-0.8 I_g
Link beam flexure[f]	0.5 to 0.7 I_g	0.3 to 0.6 I_g
Link beam shear[g]	0.15 to 1.0 A_g	0.1 to 0.7 A_g



Range of structural model types (NIST, 2010).

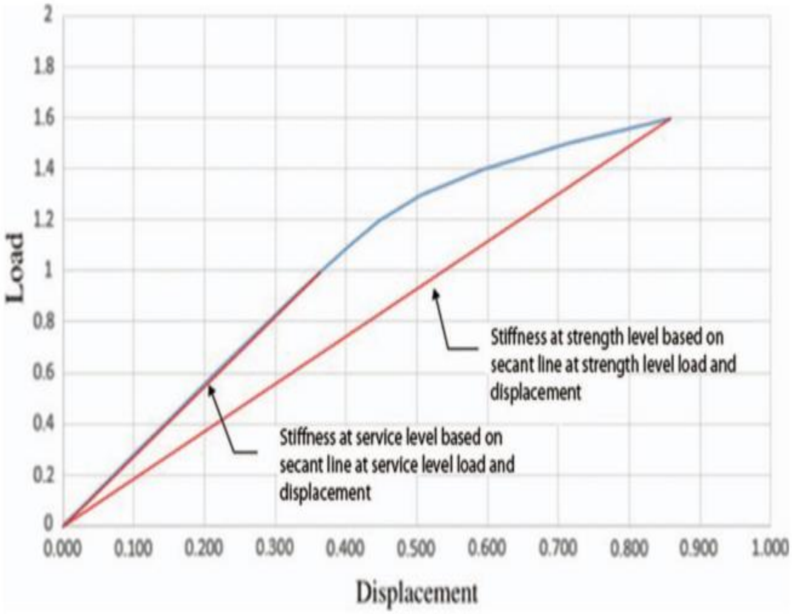
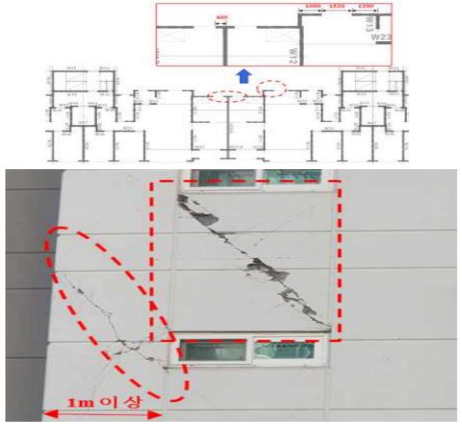


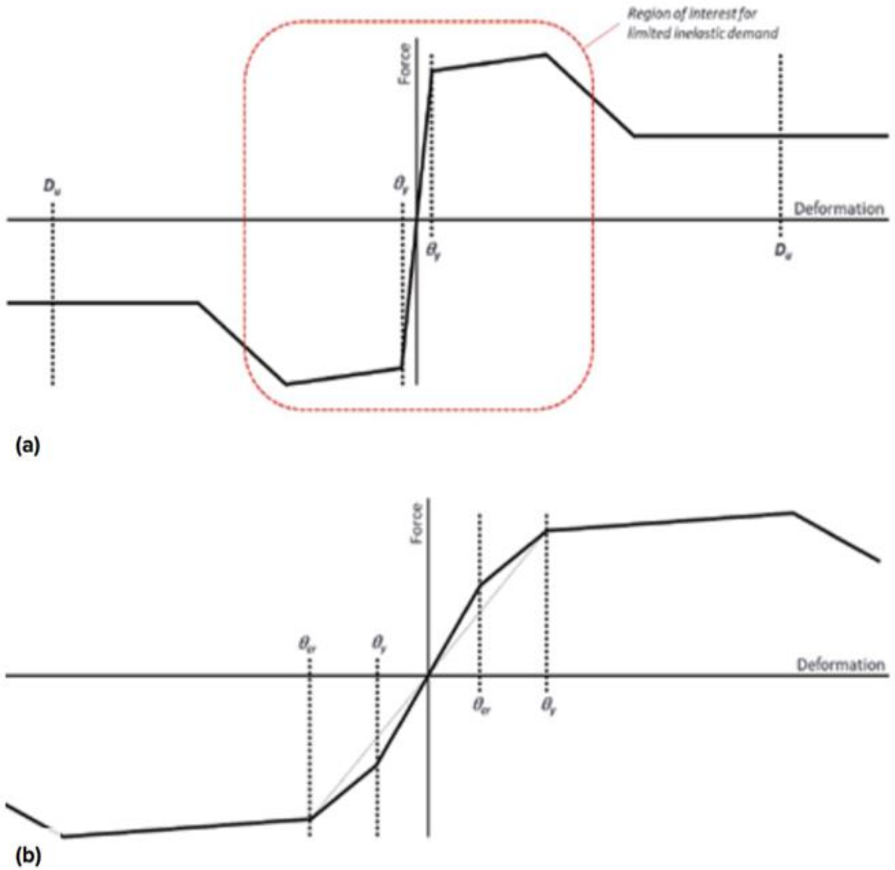
Figure 8-2. Secant stiffness approximation.



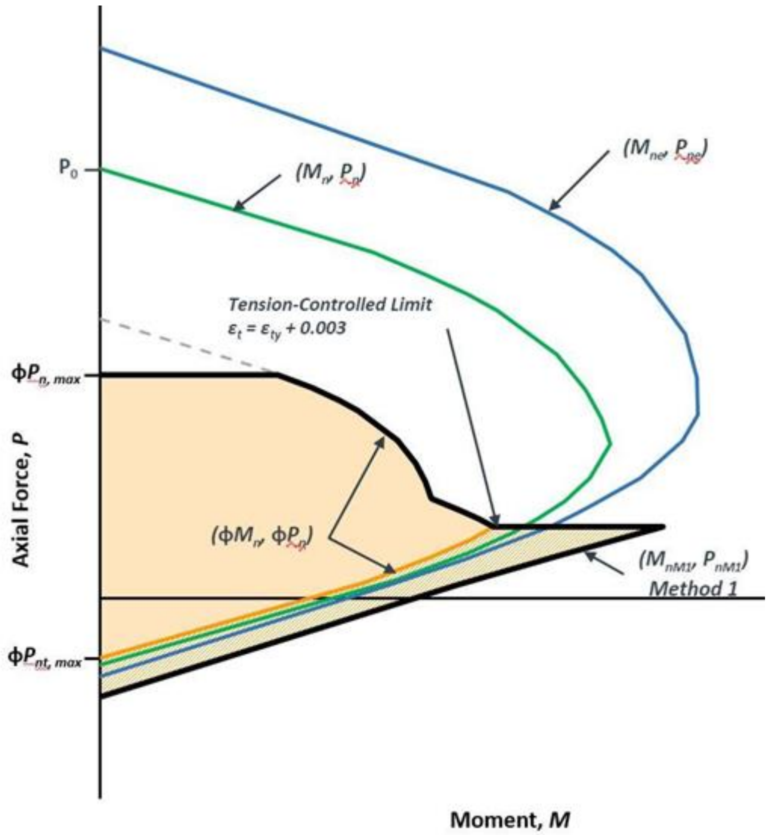
출처 : Design and Performance of TALL BUILDINGS FOR WIND

성능기반 내풍 설계 기술내용

Modeling and Analysis (Backbone curves and P-M curve)



Generalized force-deformation backbone curves for :
(a) Large inelastic deformation(seismic),
(b) Limited inelastic deformation demand (wind)

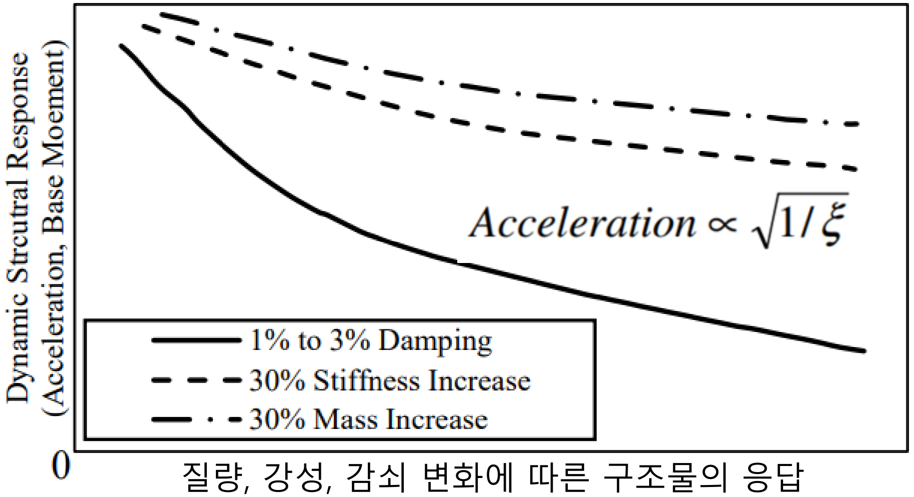


Combined axial load and moment curve

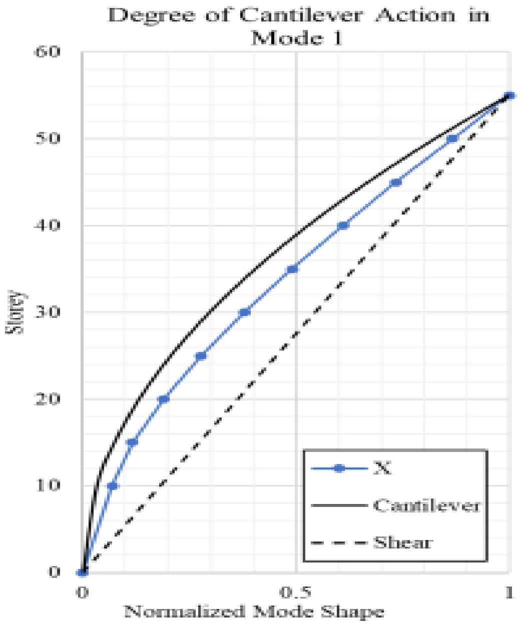
출처 : Concrete International December 2022

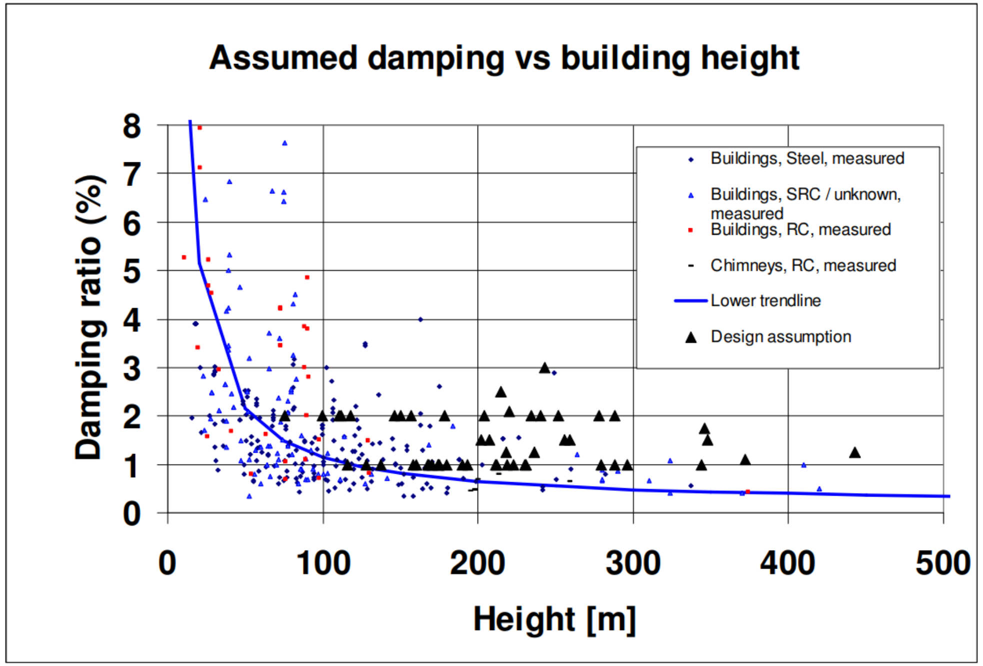
성능기반 내풍 설계 기술내용

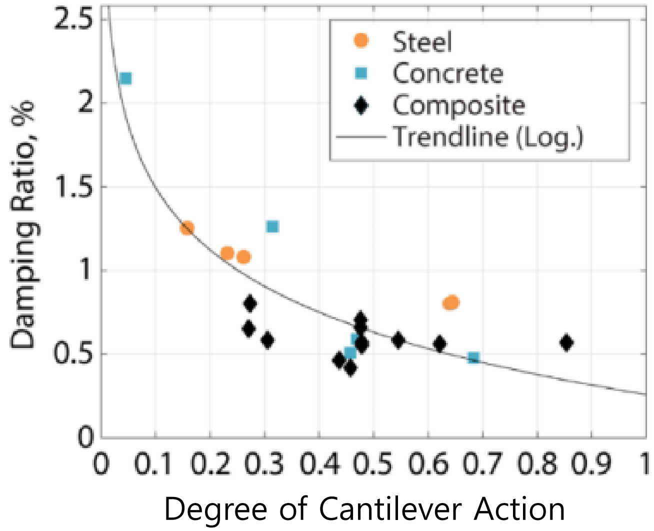
Modeling and Analysis (Damping)



질량, 강성, 감쇠 변화에 따른 구조물의 응답
(가속도, 밑면 전도모멘트)의 저감효과
참조 : Irwin, Kilpatrick, Robinson, & Frisque, 2008)



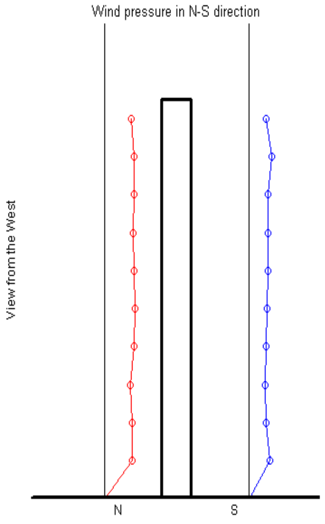




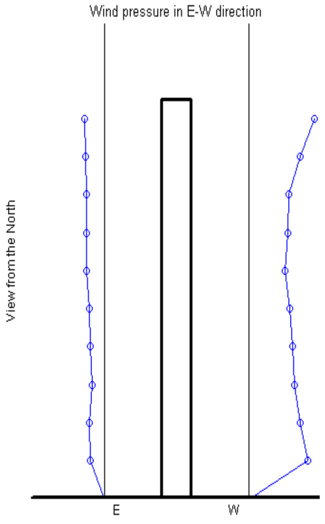
참조 : Bartolini & Kijewski-Correa, 2017

성능기반 내풍 설계 기술내용

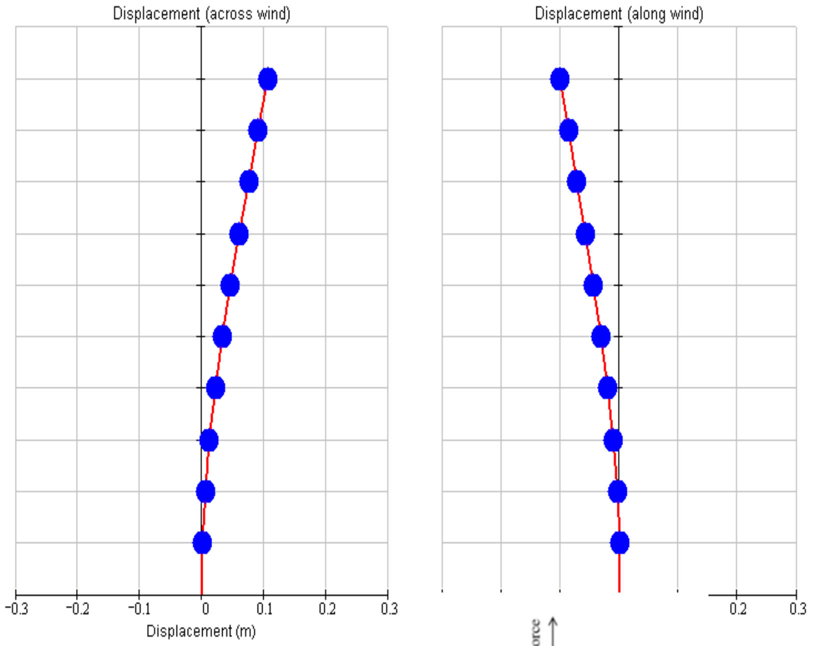
Low-cycle Fatigue and Damage accumulation



Along wind

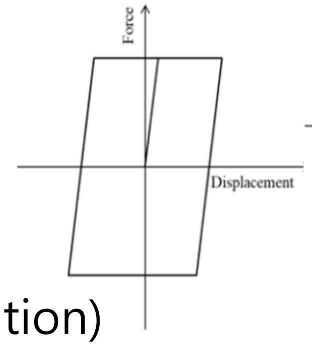


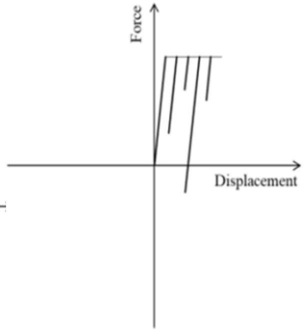
Across wind



Low-cycle Fatigue

Ratchetting Effect
(Damage accumulation)





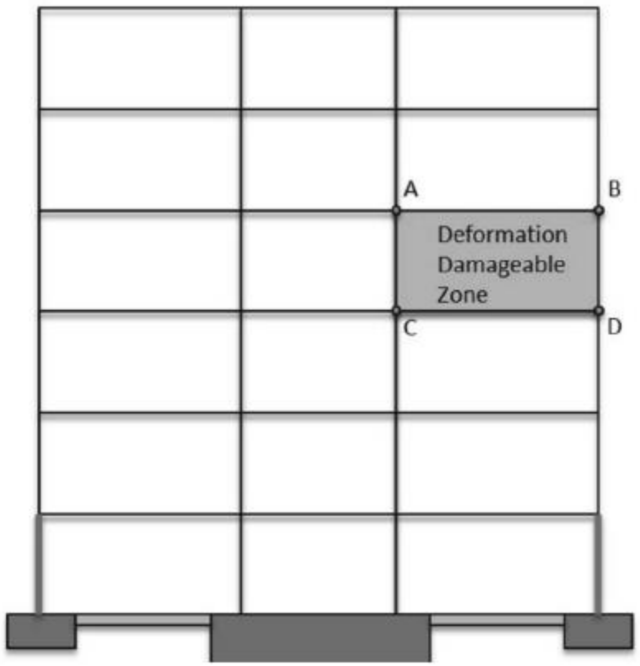
풍직각방향
(across wind)

풍방향
(along wind)

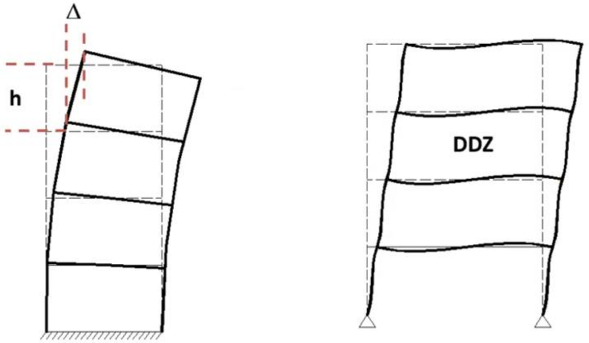
성능기반 내풍 설계 기술내용

Deformation Damage Index

$$DDI = 0.5\left[\frac{X_A - X_C}{H} + \frac{X_B - X_D}{H} + \frac{Y_D - Y_C}{L} + \frac{Y_B - Y_A}{L}\right]$$

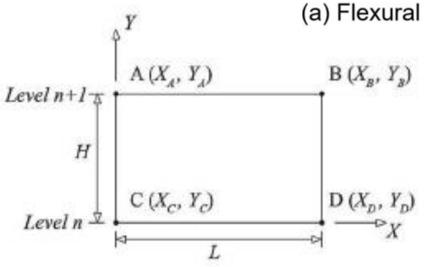


Types of Building deformation



(a) Flexural (Axial) Deformations

(b) Shear (Racking) Deformations



- in-plane shear strain
- filter out rigid body rotation

A single peak drift limit at the Operational performance objective may not be suitable or telling for all types of projects. Furthermore, peak drift does not guarantee adequate performance of the envelope system.

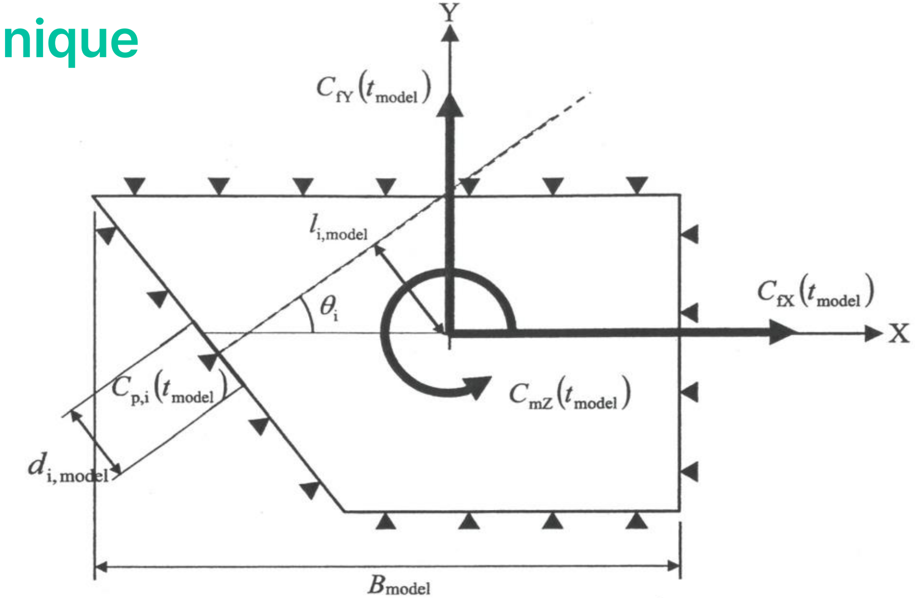
출처 : ATC Design Guide 3

성능기반 내풍 설계 기술내용

Wind Pressure Integration technique

Pressure test model tested at the BLWT

출처 : RWDI



외압측정점과 층풍력계수의 관계

$$C_{fX}(t_{model}) = \sum_i C_{p,i}(t_{model}) \bullet d_{i,model} \cos\theta_i / B_{model}$$

$$C_{fY}(t_{model}) = \sum_i C_{p,i}(t_{model}) \bullet d_{i,model} \sin\theta_i / B_{model}$$

$$C_{mZ}(t_{model}) = \sum_i C_{p,i}(t_{model}) \bullet d_{i,model} \bullet l_i / B_{model}^2$$

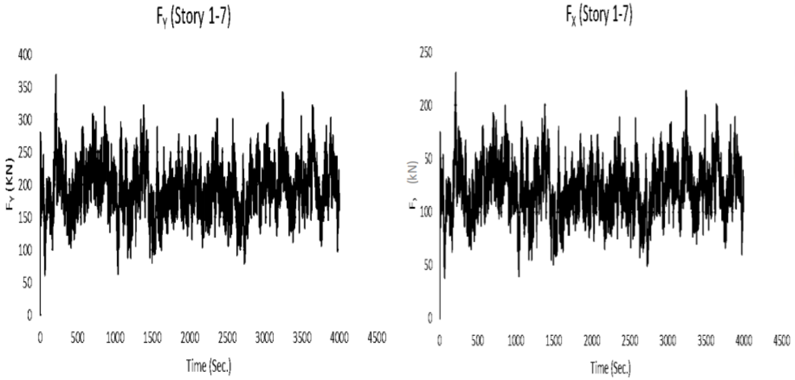
$$f_X(t) = q_H \bullet C_{fX}(t_{model}) \bullet B\Delta h$$

$$f_Y(t) = q_H \bullet C_{fY}(t_{model}) \bullet B\Delta h$$

$$m_Z(t) = q_H \bullet C_{mZ}(t_{model}) \bullet B^2\Delta h$$

$$(t = t_{model} \bullet \frac{B}{B_{model}} \bullet \frac{V_{H,model}}{V_H})$$

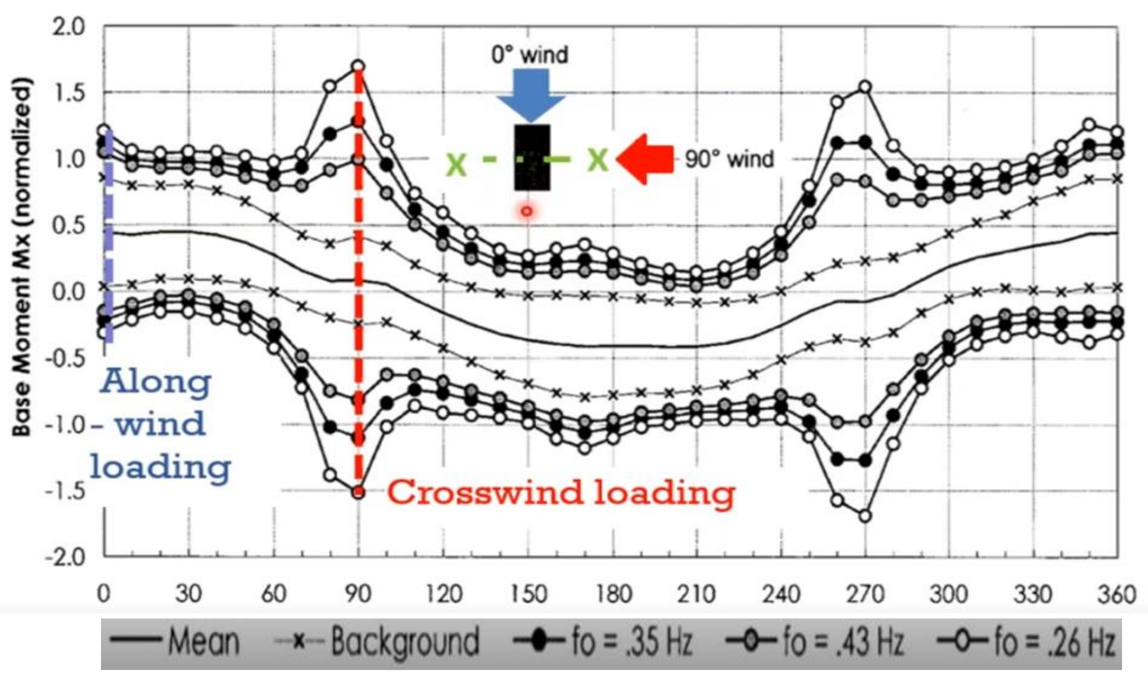
출처 : Guidebook of Recommendations for Loads on Buildings 2

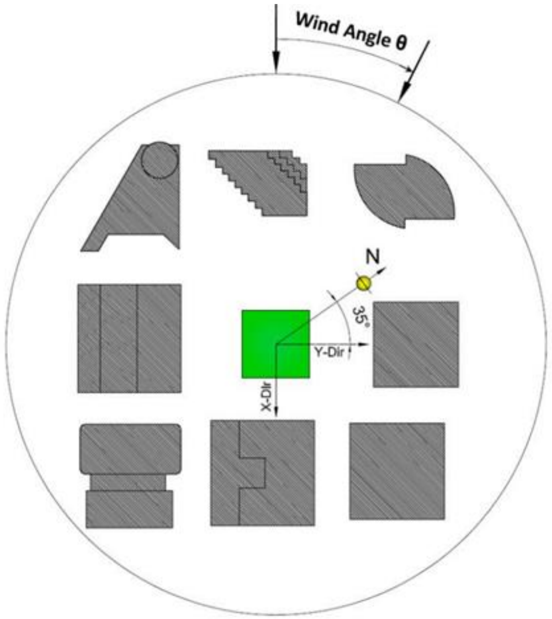


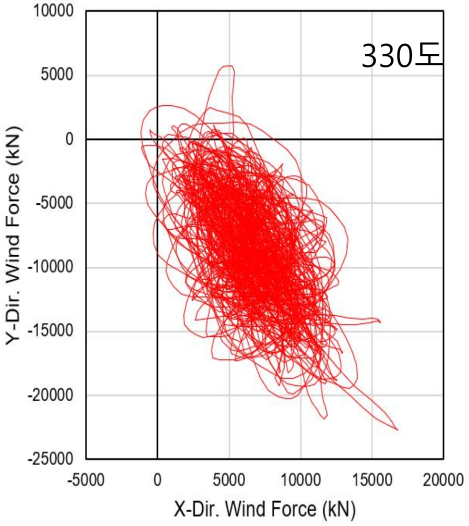
Story forces for stories

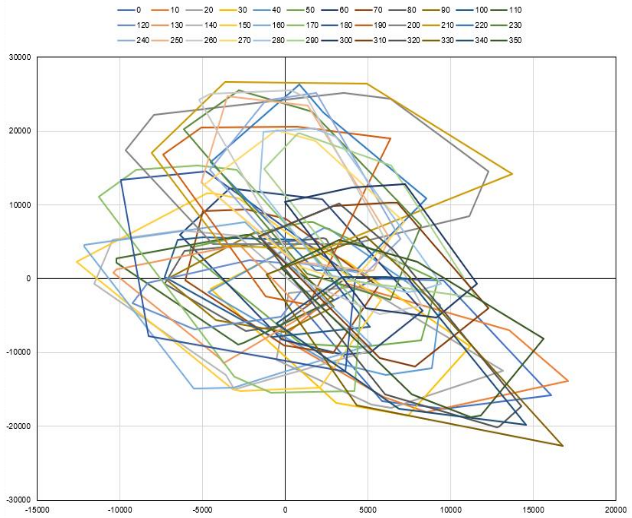
성능기반 내풍 설계 기술내용

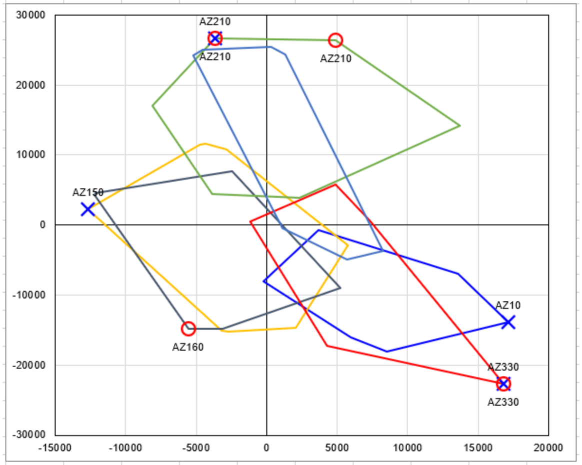
Critical Wind Direction











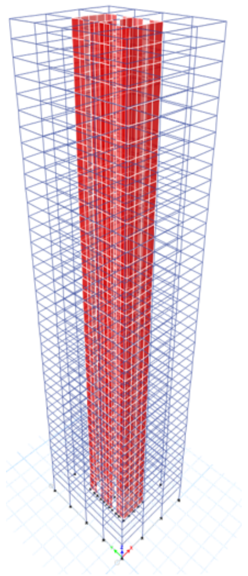
성능기반 내풍설계 사례(정형·단독 건물)

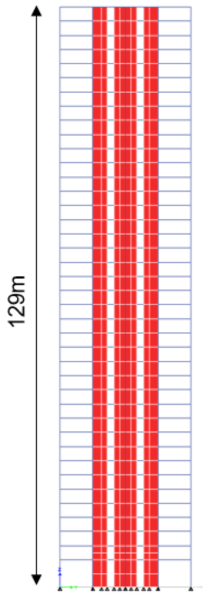
성능기반 내풍 설계 사례 (정형·단독 건물)

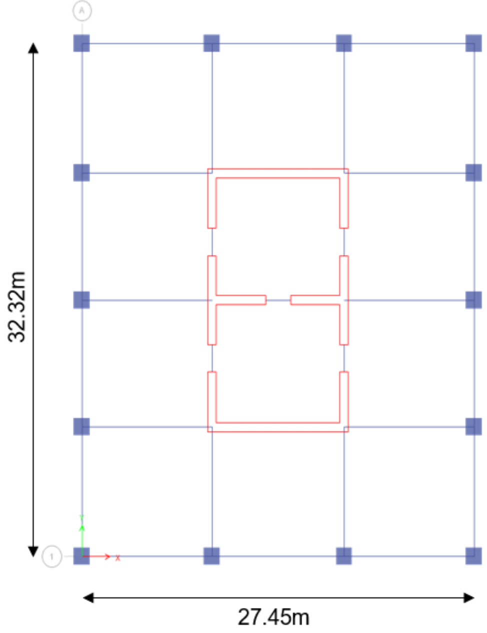
구조설계 개요

항목	구조개요
규모	지상 40층(H=129m, B=32.32m, D=27.45m)
형상비	1 : 4~4.7
구조시스템	중간모멘트골조를 가진 이중골조 시스템 (철근콘크리트 보통전단벽) (R=5.5, Ω=2.5, Cd=4.5)
적용기준	건축구조기준 (KDS 41 00:2022, 국토교통부)
풍하중 변수	기본풍속 V0 = 42m/s(500년 재현주기, 부산) 지표면조도구분 C 지형계수, Kzt = 1.0 풍향계수, KD = 1.0 중요도, Iw = 1.0
지진하중 변수	유효지반가속도 S = 0.176 지반분류 S4 (토층평균전단파속도 < 360m/s)

	Rw=1.0	Rw=2.0
벽체	THK800	THK600
연결보	800x800	600x800
보	1000x800	700x800
기둥	1200x1200	1100x1100
유효중량	668558kN	580648kN
고유주기(X)	3.12 sec	3.36 sec
고유주기(Y)	2.66 sec	2.86 sec

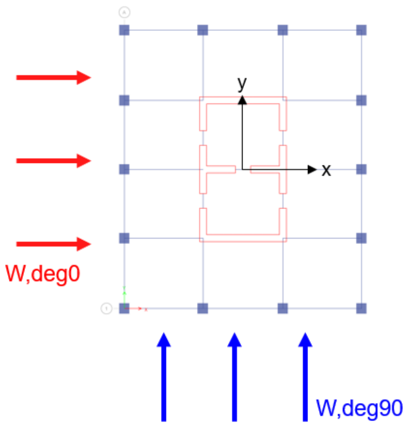


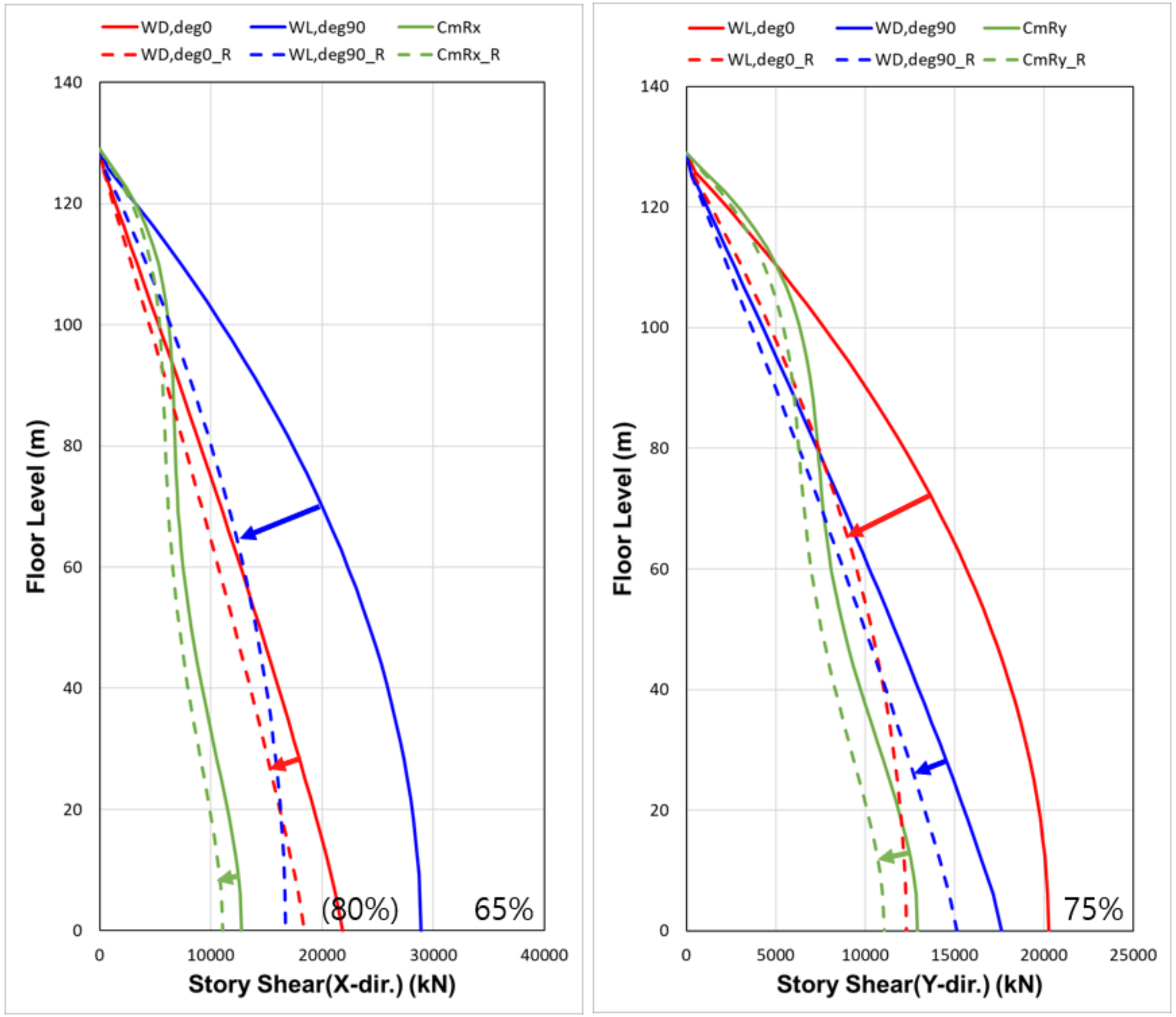




성능기반 내풍 설계 사례 (정형·단독 건물)

Wind load($R_W = 1.0,\ 2.0$) vs Seismic load





설계는 0도,90도 풍하중, 지진하중에 대해 설계(풍방향 하중 지배)

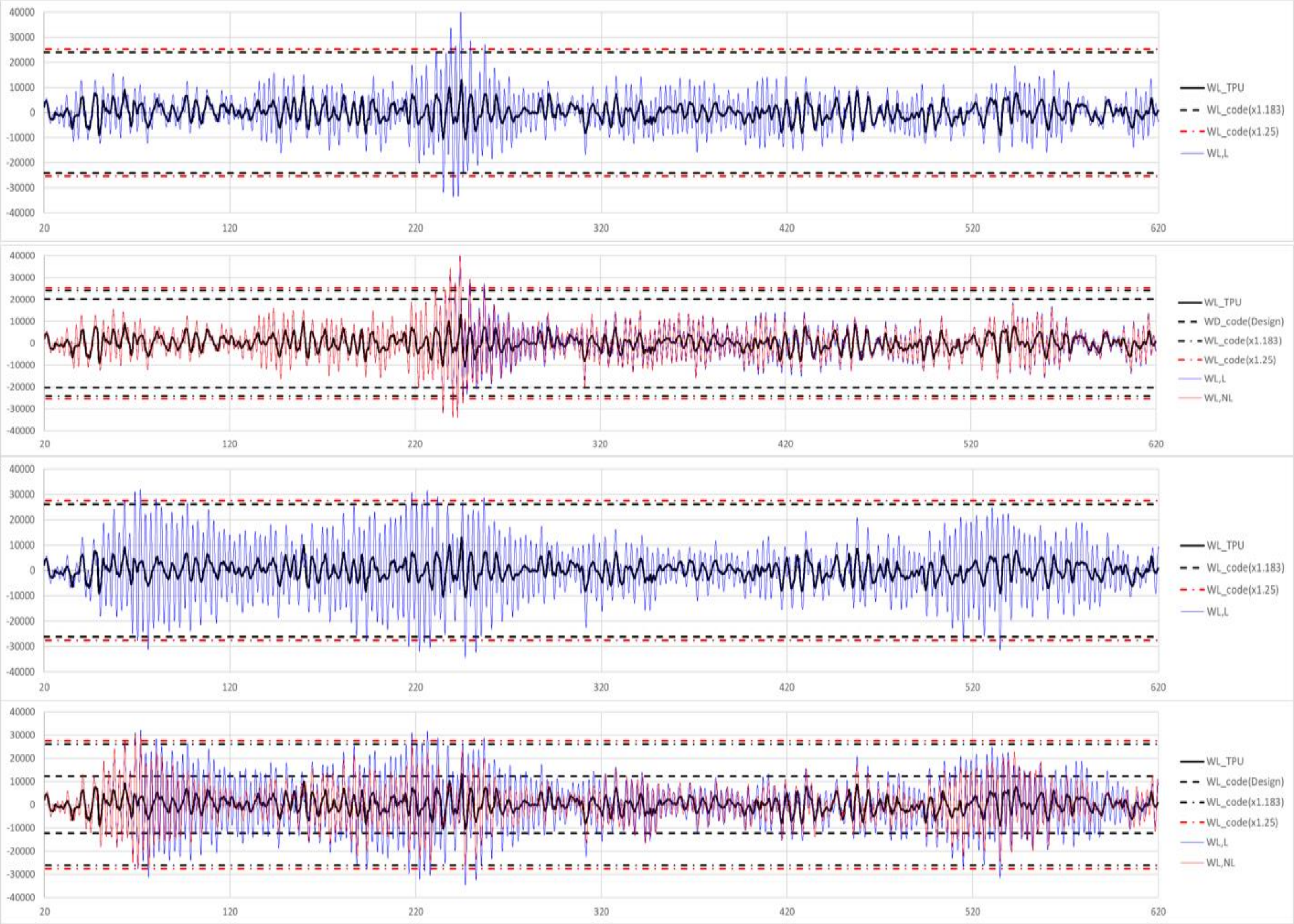
성능기반 내풍 설계 사례 (정형·단독 건물)

Wind load reduction

R=1

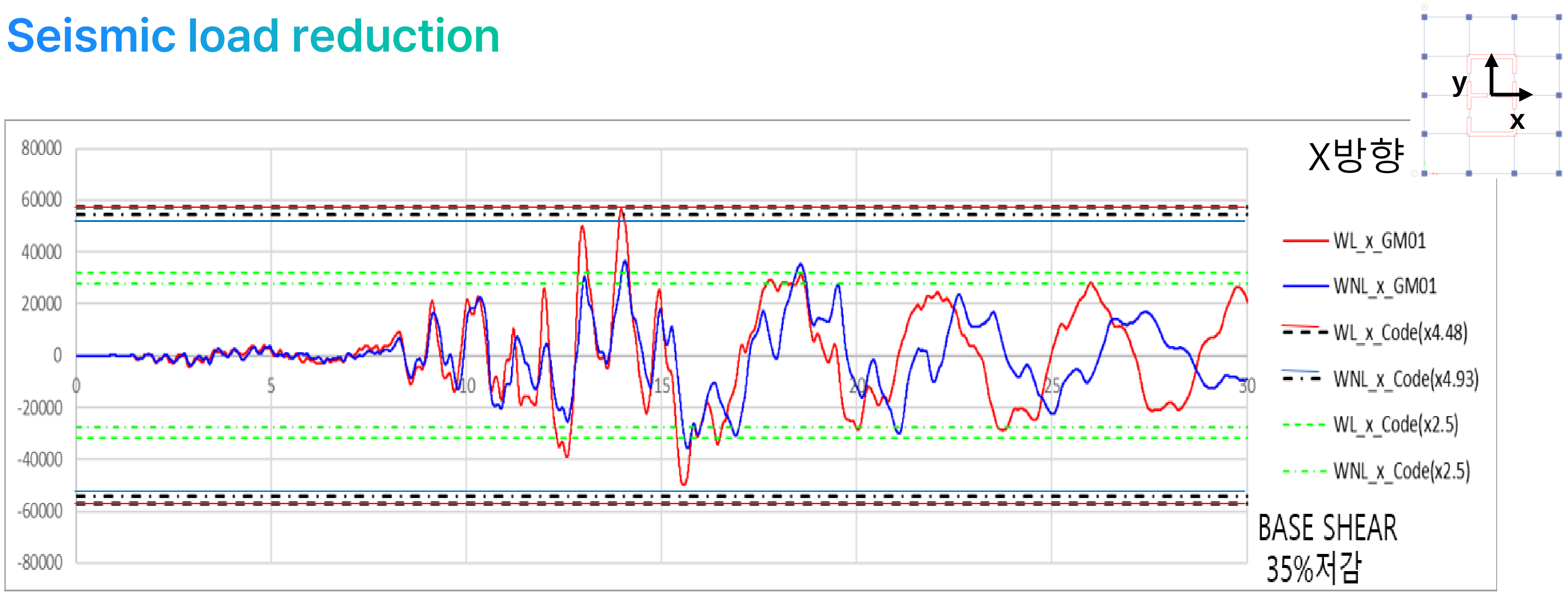
BASE SHEAR 26%저감

R=2



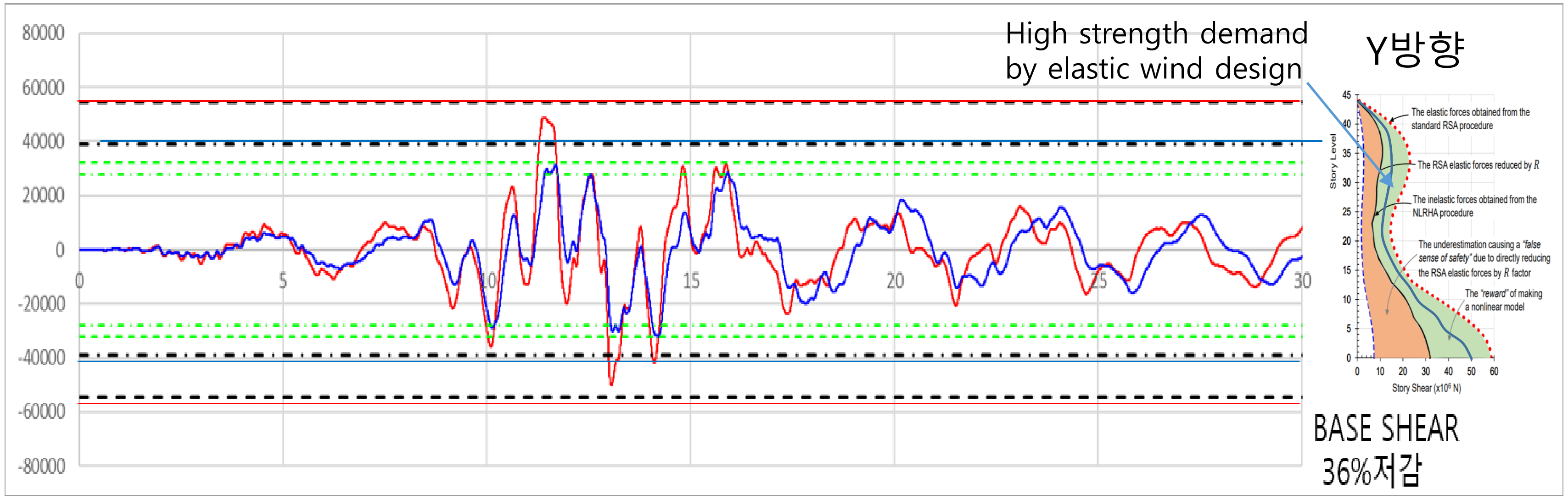
성능기반 내풍 설계 사례 (정형·단독 건물)

Seismic load reduction



X방향

BASE SHEAR 35%저감



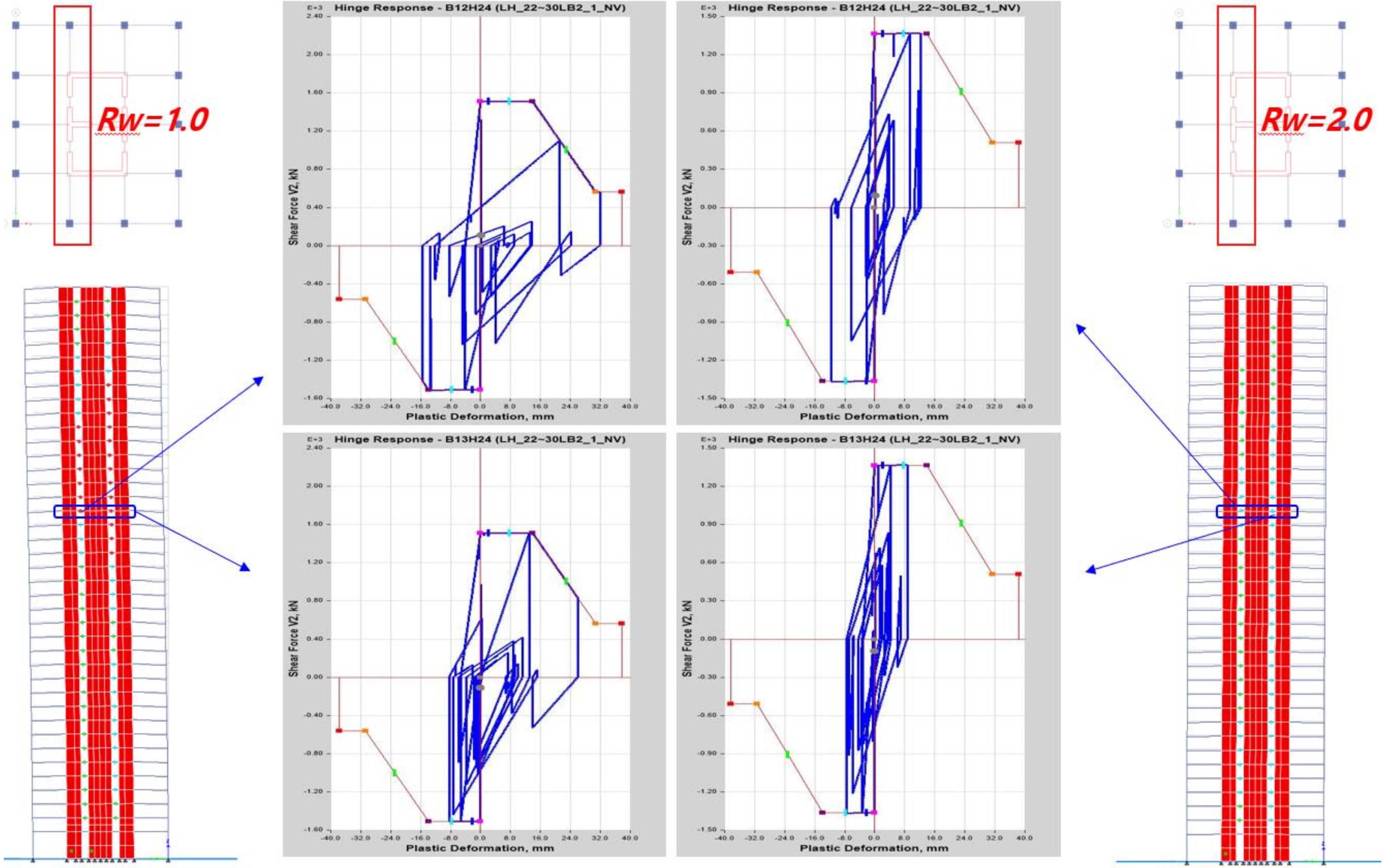
High strength demand by elastic wind design

Y방향

BASE SHEAR 36%저감

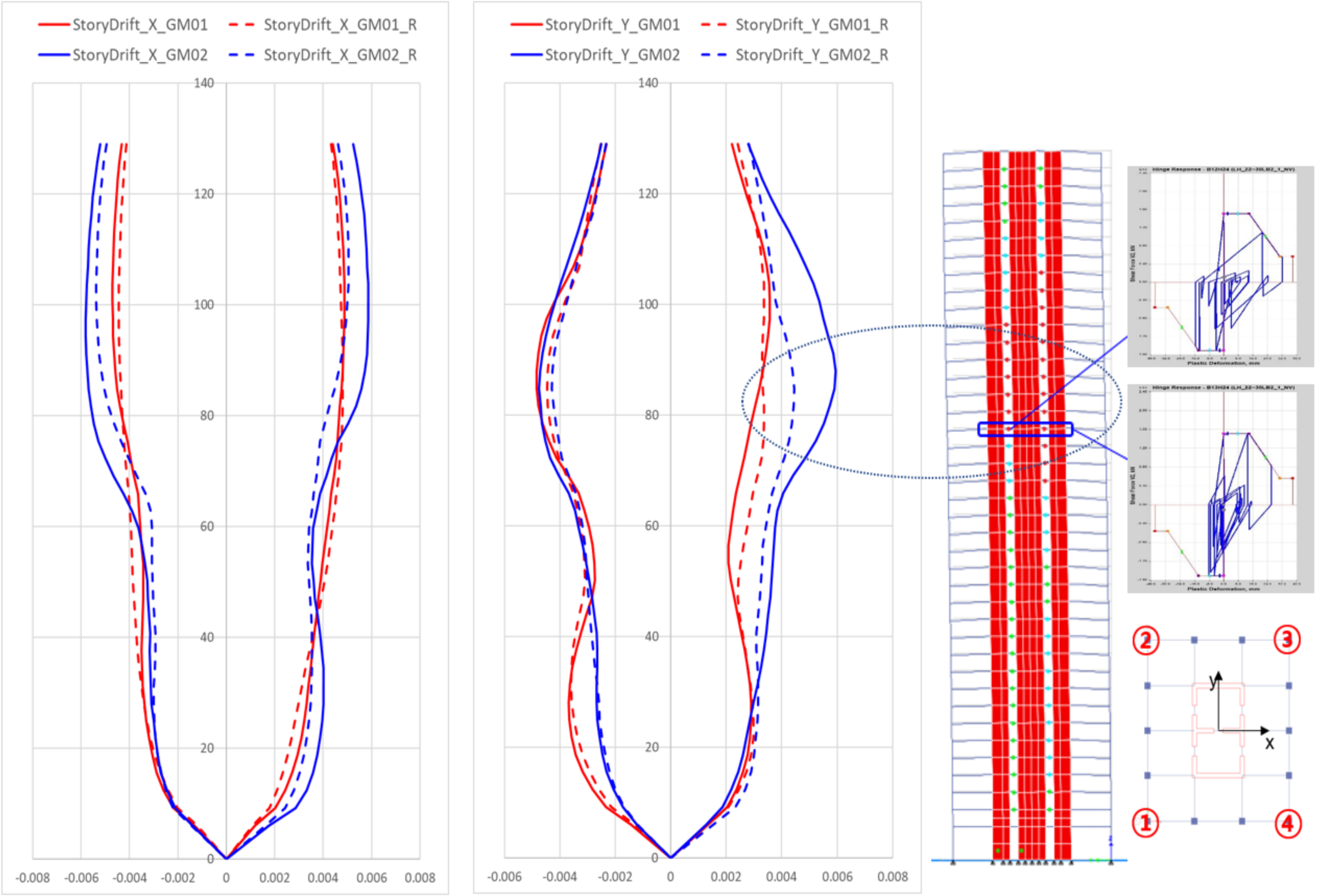
성능기반 내풍 설계 사례 (정형·단독 건물)

Coupling beam plastic deformation



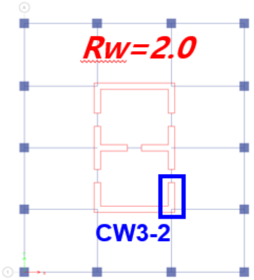
성능기반 내풍 설계 사례 (정형·단독 건물)

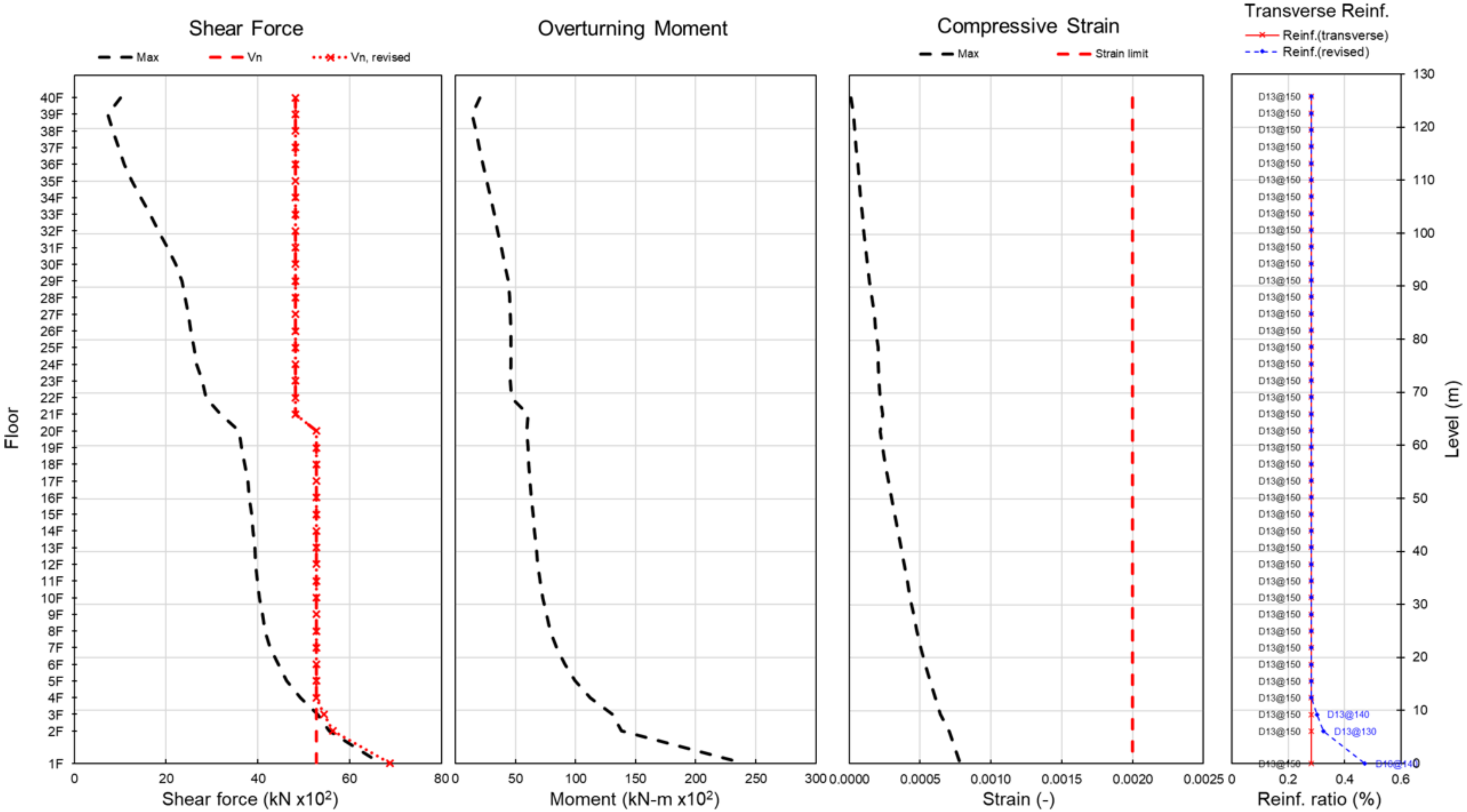
Story Drift



성능기반 내풍 설계 사례 (정형·단독 건물)

Member Design





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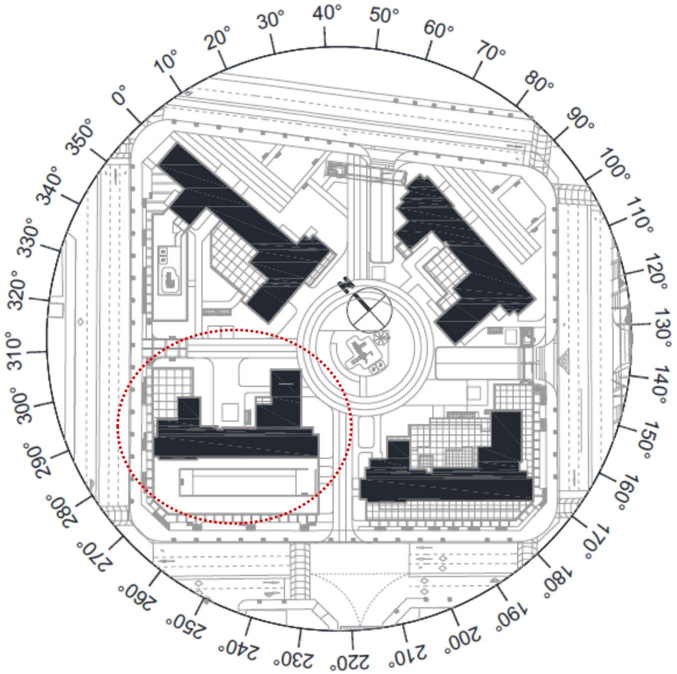
성능기반 내풍설계 (비정형· 군집 건물)

성능기반 내풍 설계 (비정형·군집 건물)

Wind load vs Seismic load

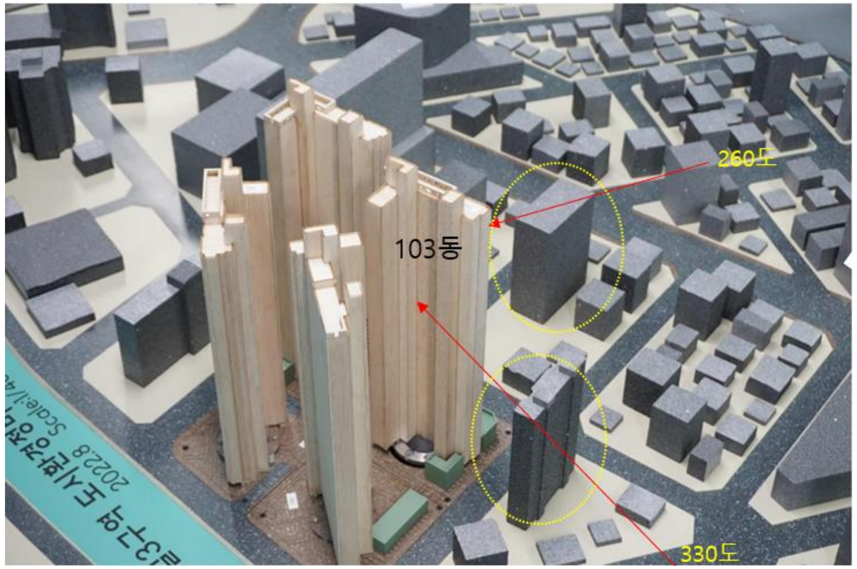


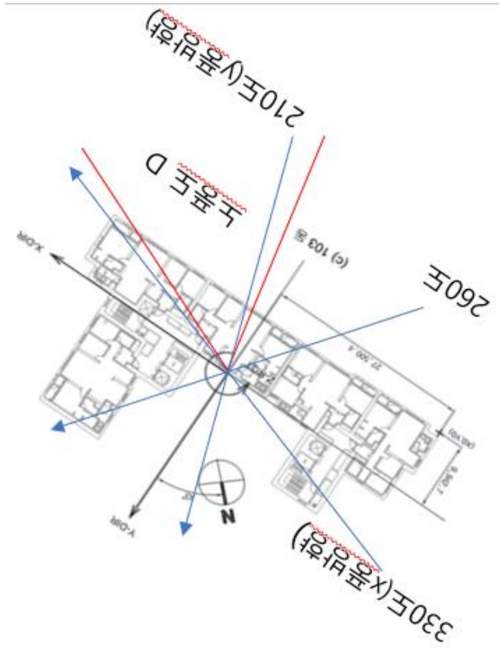
Building	Direction		Max. Base Shear [kN]	Azimuth(°)	풍하중 지진하중
101동	X-Dir.	+	6,309.23	60	
		-	-8,752.64 (14,444)	330	(78 %)
	Y-Dir.	+	29,847.06 (14,518)	60	(267 %)
		-	-24,309.42	330	
102동	X-Dir.	+	22,985.11 (13,455)	200	(221 %)
		-	-19,276.34	10	
	Y-Dir.	+	23,248.67 (13,450)	80	(225 %)
		-	-20,357.92	10	
103동	X-Dir.	+	25,901.46 (13,698)	330	(246 %)
		-	-18,828.79	260	
	Y-Dir.	+	31,431.97 (13,723)	260	(298 %)
		-	-28,717.27	330	
104동	X-Dir.	+	20,445.17 (18,305)	210	(146 %)
		-	-20,433.95	140	
	Y-Dir.	+	31,581.05 (17,656)	210	(233 %)
		-	-23,576.06	140	

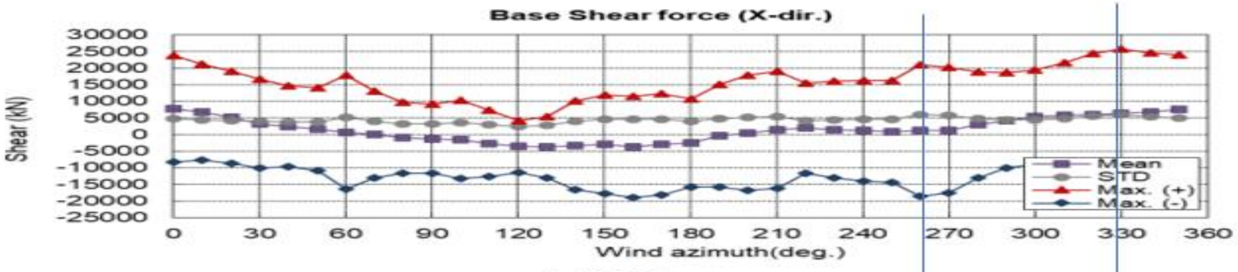
\# 풍하중에 하중조합계수 1.3 적용

성능기반 내풍 설계 (비정형· 군집 건물)

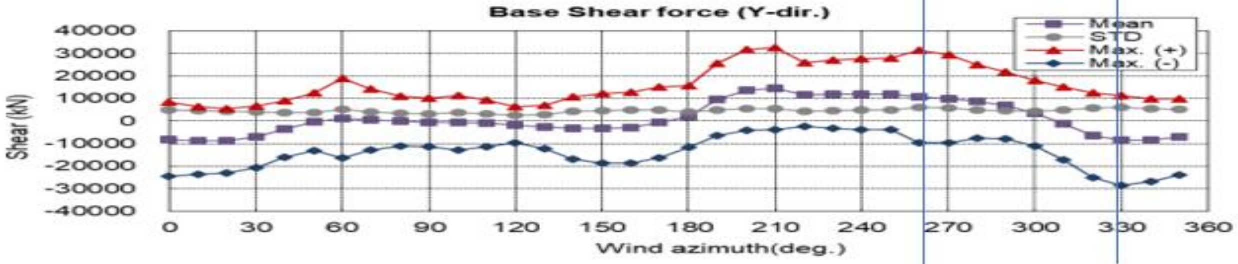
Critical Wind Direction







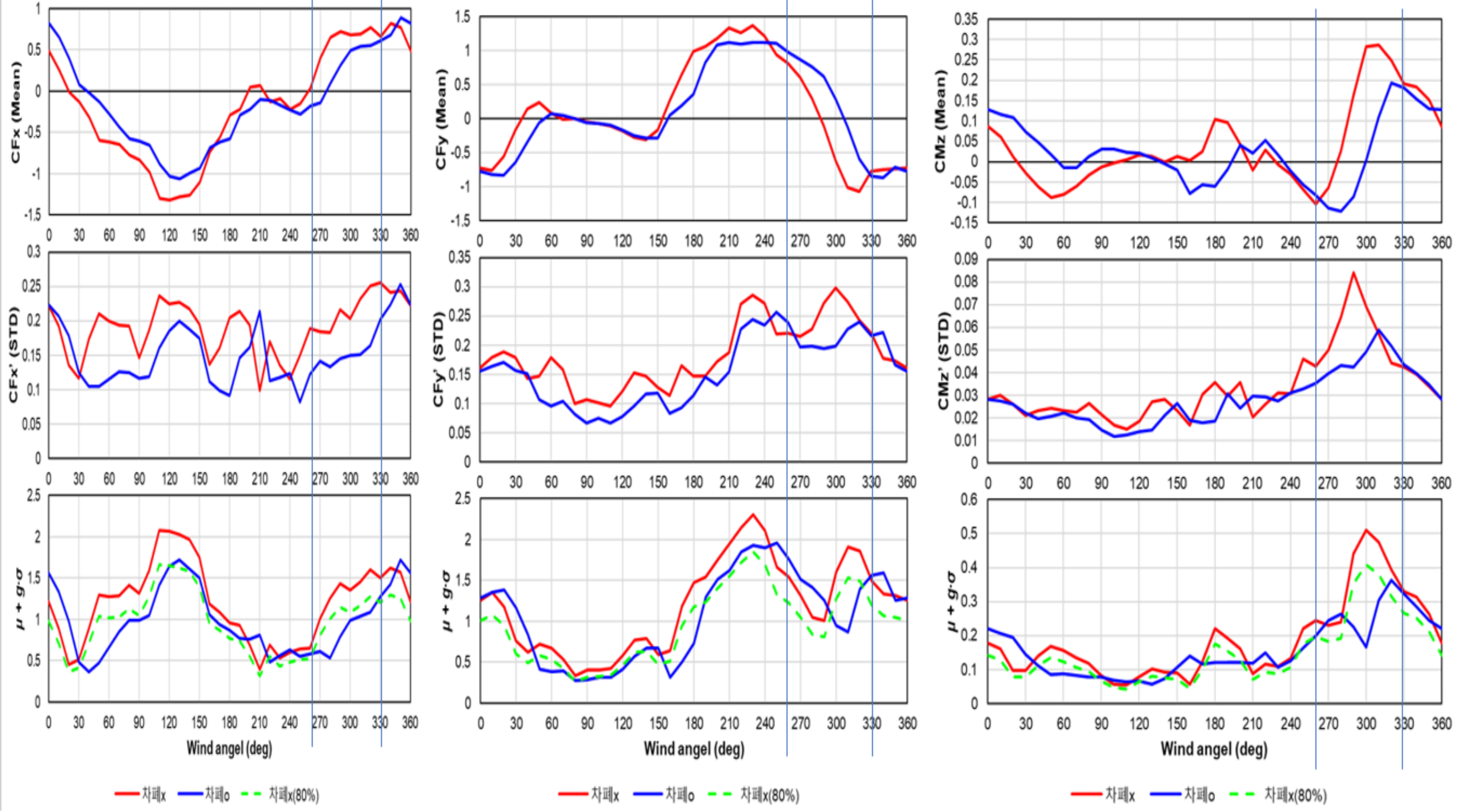
(a) X-Dir.



(b) Y-Dir.

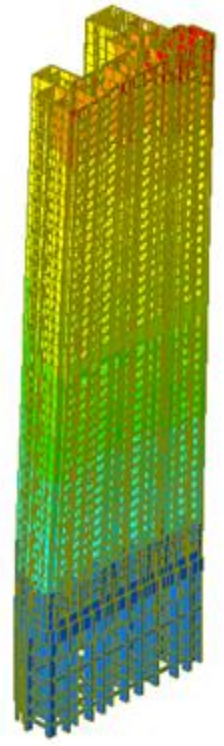
성능기반 내풍 설계 (비정형· 군집 건물)

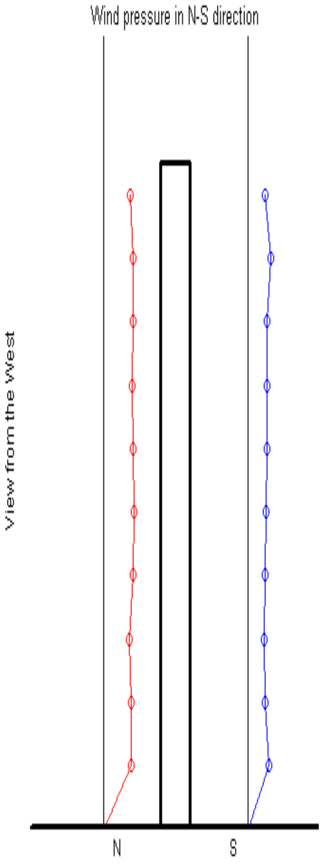
Shielding Effects of Surrounding Buildings

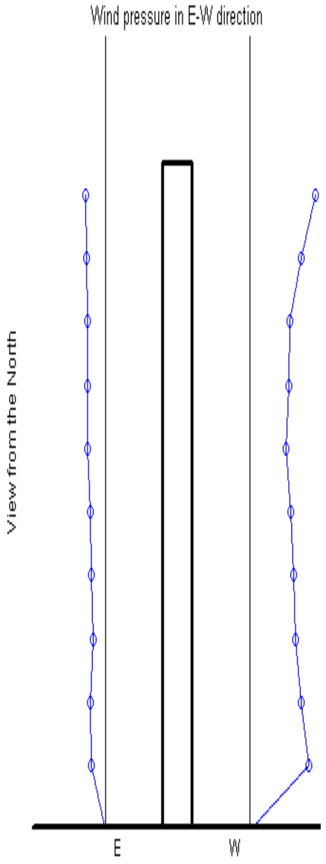


성능기반 내풍 설계 (비정형· 군집 건물)

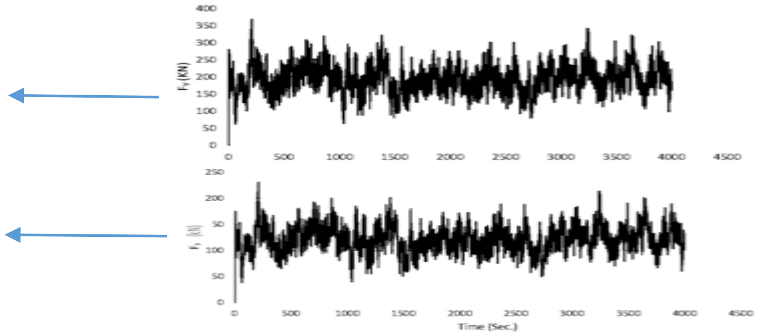
Calculation of Story Wind Force (Wind Pressure Integration)

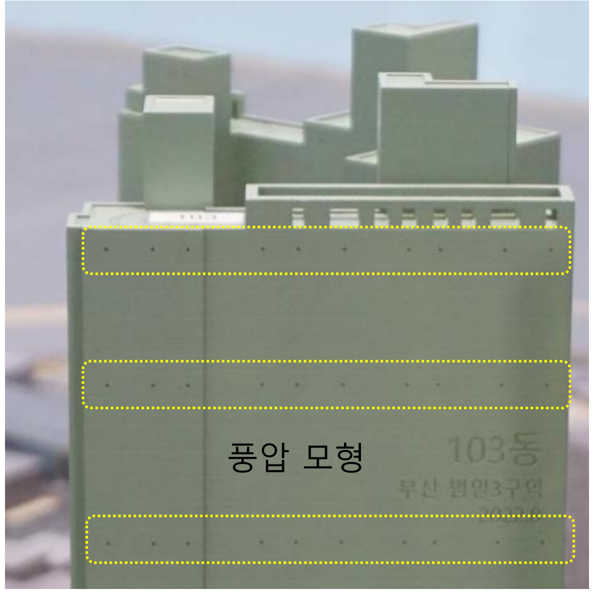






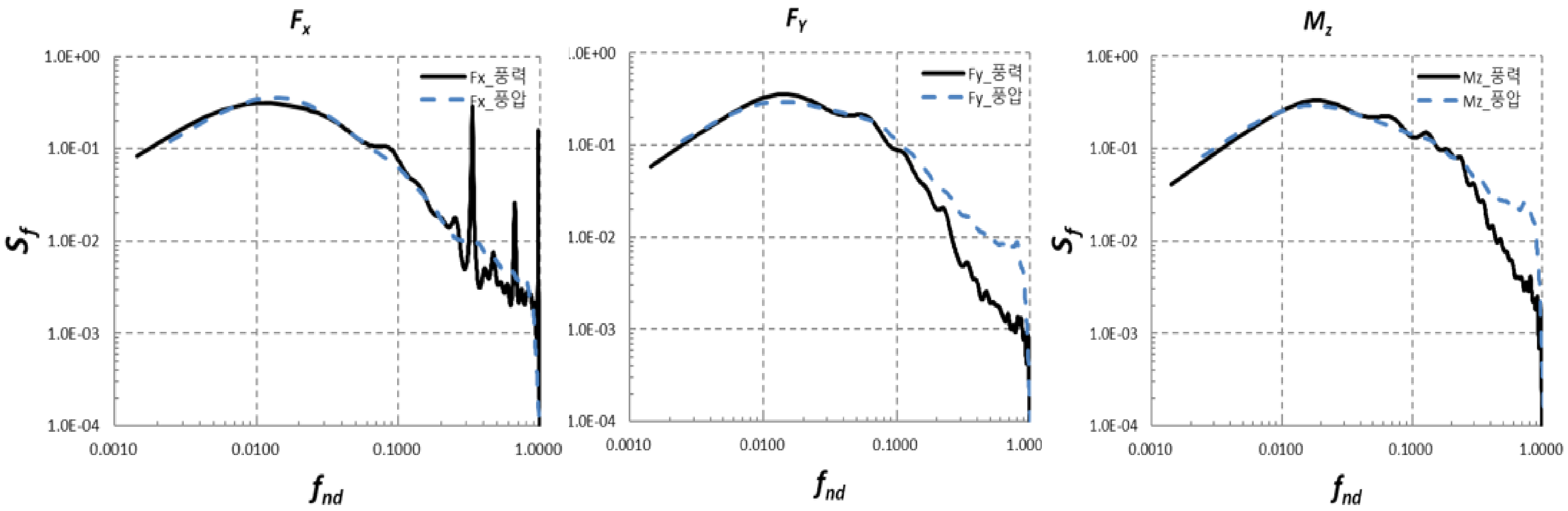
Time-history story wind force



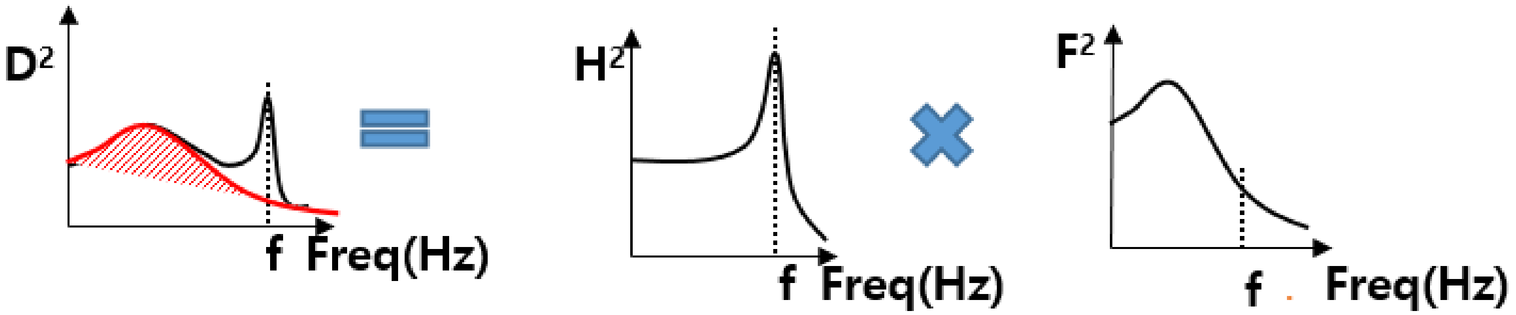

풍압 모형

성능기반 내풍 설계 (비정형·군집 건물)

풍력, 풍압실험의 스펙트럼해석 비교



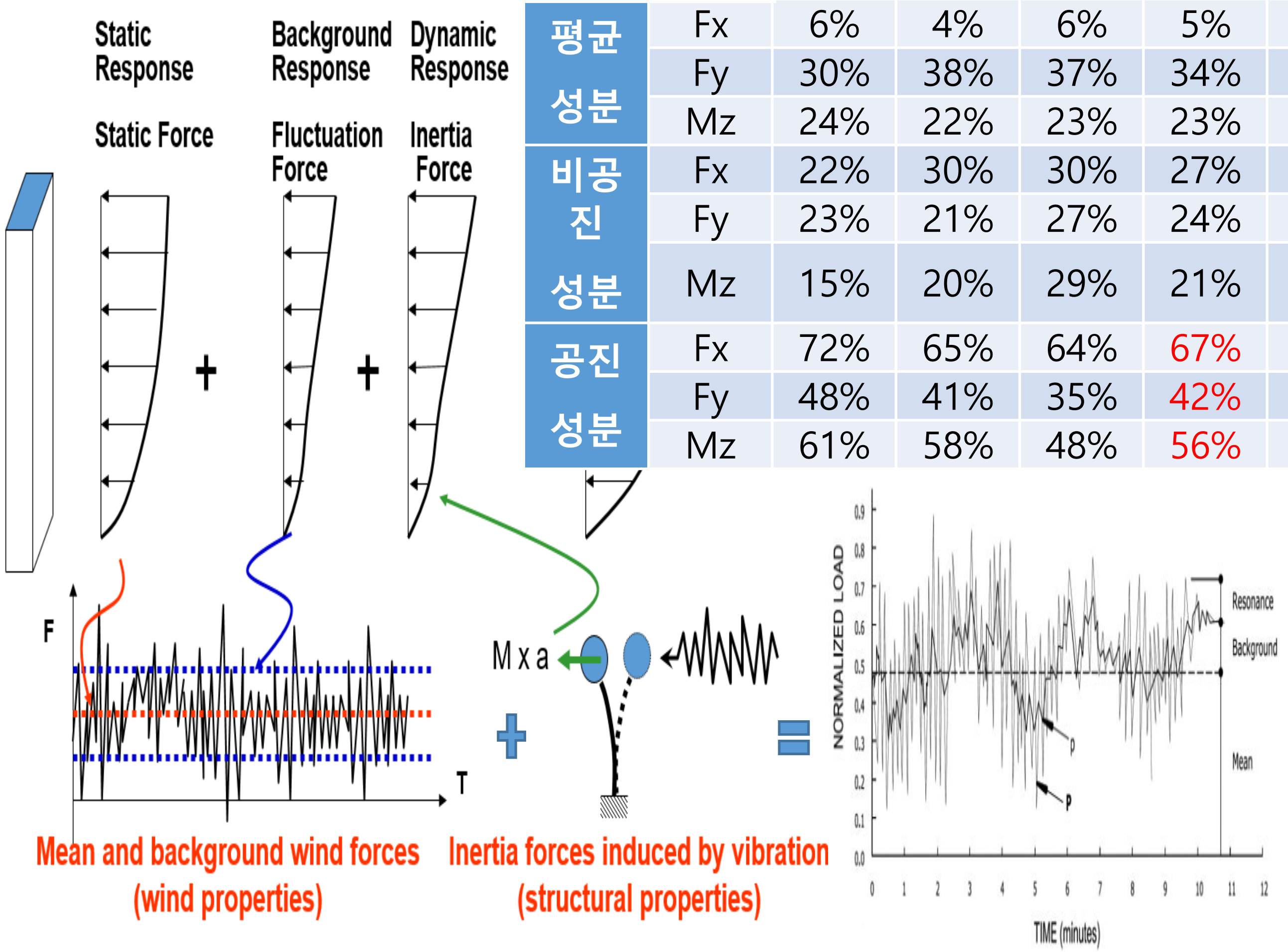
$$S_x(n) = (1/k)^2 . \left|H(n)\right|^2 .S_F(n)$$



성능기반 내풍 설계 (비정형· 군집 건물)

공진 풍하중 산정

구분		260°				330°			
		1	2	3	Mean	1	2	3	Mean
평균 성분	Fx	6%	4%	6%	5%	25%	23%	26%	25%
	Fy	30%	38%	37%	34%	34%	24%	34%	30%
	Mz	24%	22%	23%	23%	33%	37%	34%	35%
비공진 성분	Fx	22%	30%	30%	27%	35%	36%	40%	37%
	Fy	23%	21%	27%	24%	26%	29%	7%	21%
	Mz	15%	20%	29%	21%	19%	12%	16%	16%
공진 성분	Fx	72%	65%	64%	67%	41%	41%	33%	38%
	Fy	48%	41%	35%	42%	40%	47%	59%	48%
	Mz	61%	58%	48%	56%	48%	52%	50%	50%

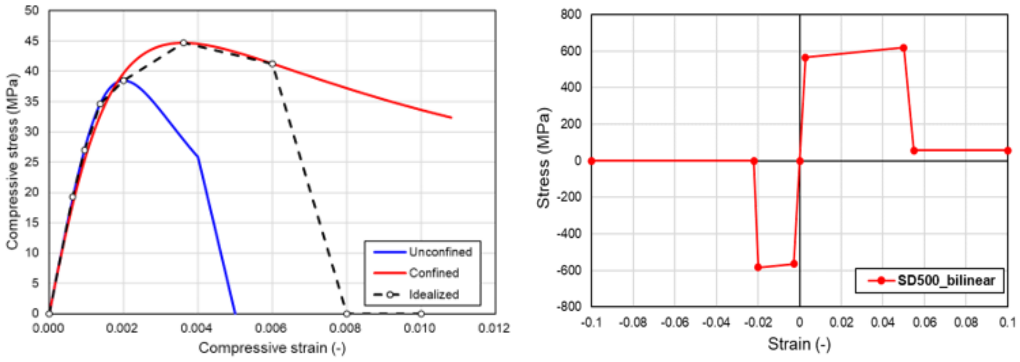


성능기반 내풍 설계 (비정형· 군집 건물)

탄성 재설계 및 비탄성 모델링

조합 풍하중 : 공진 풍하중에 R_W=2를 적용

Load Case	Base Shears [kN]		Base Overturning Moments [MN-m]			Wind Azimuth (°)
	X-Dir.	Y-Dir.	X-Dir.	Y-Dir.	Z-Rot.	
1	25,901	-28,717	2,735	-3,016	113	330
2	-18,829	31,432	-2,106	3,272	-72	260
3	21,082	31,432	2,309	3,272	-72	260
4	25,901	-28,717	2,735	-3,016	113	330
5	14,198	-14,577	1,449	-1,488	174	320
6	9,874	15,586	1,032	1,553	-133	280
7	24,891	-27,120	2,616	-2,842	97	340
8	-19,098	-18,802	-2,011	-2,013	-54	160
9	19,215	32,903	2,088	3,264	86	210
10	24,891	-27,120	2,616	-2,842	97	340
11	15,097	-17,317	1,540	-1,746	169	330
12	9,427	18,305	1,017	1,827	-120	270



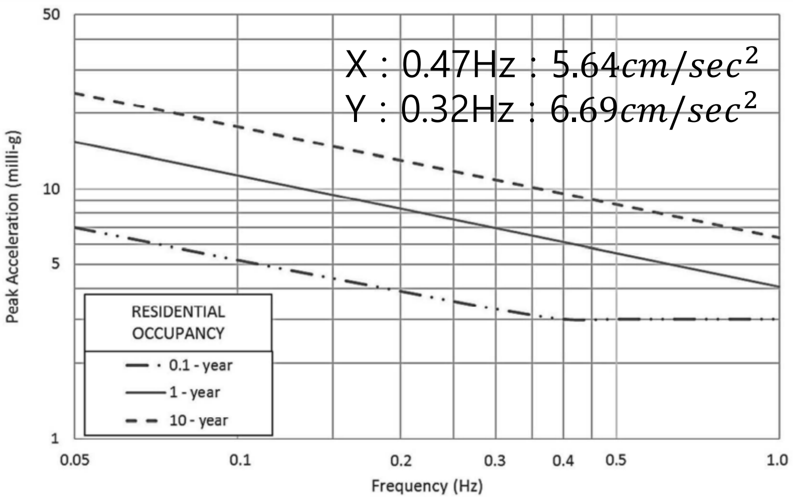
비탄성 재료모델

풍하중 저감 전후의 수직 및 수평 철근비 비교(CW1)

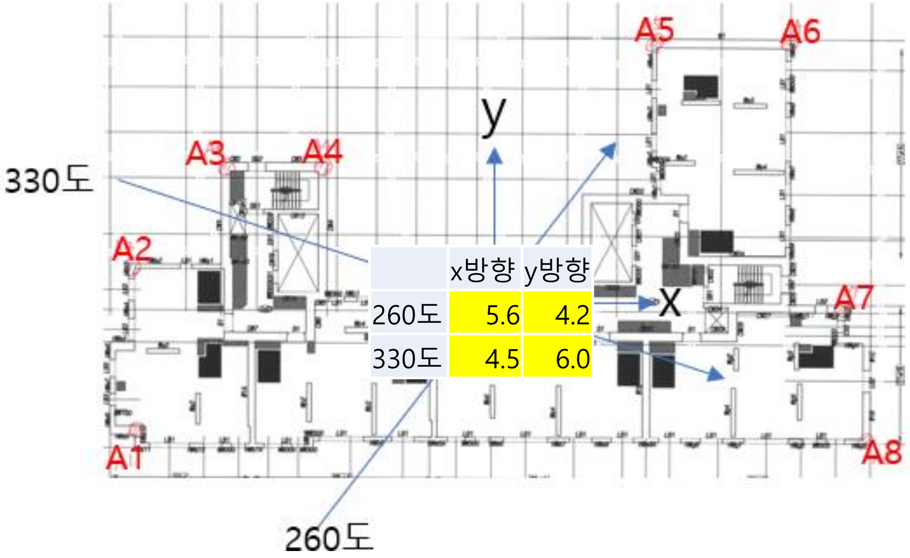
층	수직근 철근비		수평근 철근비		층	수직근 철근비		수평근 철근비	
	변경전	변경후	변경전	변경후		변경전	변경후	변경전	변경후
49F	0.16%	0.12%	0.17%	0.17%	22F	0.28%	0.26%	0.22%	0.22%
48F	0.16%	0.12%	0.22%	0.17%	21F	0.42%	0.26%	0.22%	0.22%
47F	0.16%	0.12%	0.22%	0.17%	20F	0.42%	0.26%	0.22%	0.22%
46F	0.16%	0.12%	0.22%	0.17%	19F	0.42%	0.26%	0.22%	0.22%
45F	0.16%	0.12%	0.22%	0.17%	18F	0.42%	0.26%	0.22%	0.22%
44F	0.16%	0.12%	0.22%	0.17%	17F	0.42%	0.26%	0.22%	0.22%
43F	0.16%	0.12%	0.22%	0.17%	16F	0.66%	0.26%	0.22%	0.22%
42F	0.16%	0.12%	0.22%	0.17%	15F	0.66%	0.27%	0.22%	0.22%
41F	0.16%	0.12%	0.22%	0.17%	14F	0.66%	0.32%	0.22%	0.22%
40F	0.16%	0.12%	0.22%	0.17%	13F	0.66%	0.44%	0.22%	0.22%
39F	0.16%	0.12%	0.22%	0.17%	12F	0.96%	0.44%	0.22%	0.22%
38F	0.16%	0.12%	0.22%	0.17%	11F	0.96%	0.48%	0.22%	0.22%
37F	0.16%	0.12%	0.22%	0.17%	10F	0.96%	0.64%	0.22%	0.22%
36F	0.16%	0.12%	0.22%	0.17%	9F	1.29%	0.66%	0.22%	0.22%
35F	0.16%	0.12%	0.22%	0.17%	8F	1.29%	0.66%	0.22%	0.22%
34F	0.16%	0.12%	0.22%	0.17%	7F	1.29%	0.66%	0.22%	0.22%
33F	0.16%	0.12%	0.22%	0.17%	6F	1.29%	0.66%	0.22%	0.22%
32F	0.16%	0.12%	0.22%	0.17%	5F	1.29%	0.86%	0.30%	0.22%
31F	0.16%	0.12%	0.22%	0.17%	4F	1.69%	0.96%	0.30%	0.22%
30F	0.16%	0.12%	0.22%	0.17%	3F	1.69%	1.29%	0.30%	0.22%
29F	0.16%	0.12%	0.22%	0.17%	PIT	1.69%	1.29%	0.38%	0.22%
28F	0.16%	0.12%	0.22%	0.17%	2F	1.69%	1.29%	0.38%	0.28%
27F	0.16%	0.12%	0.22%	0.17%	1F	1.69%	1.29%	0.38%	0.22%
26F	0.16%	0.12%	0.22%	0.17%	B1F	1.69%	1.29%	0.38%	0.22%
25F	0.28%	0.12%	0.22%	0.17%	B2F	1.69%	1.29%	0.38%	0.22%
24F	0.28%	0.12%	0.22%	0.17%	B3F	1.69%	1.29%	0.22%	0.17%
23F	0.28%	0.26%	0.22%	0.22%	B4F	1.69%	1.29%	0.22%	0.17%

성능기반 내풍 설계 (비정형· 군집 건물)

사용성 평가(수평진동)



X : 0.47Hz : $5.64 cm/sec^2$
Y : 0.32Hz : $6.69 cm/sec^2$

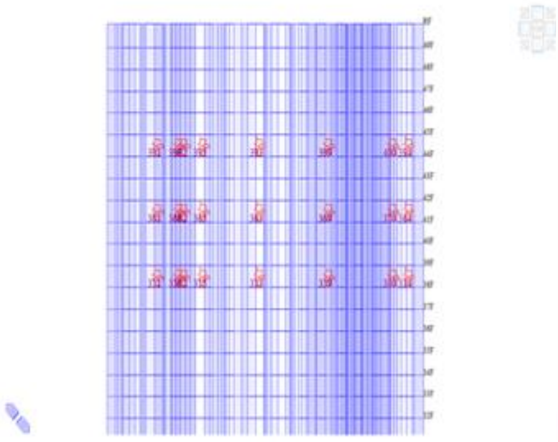


	x방향	y방향
260도	5.6	4.2
330도	4.5	6.0

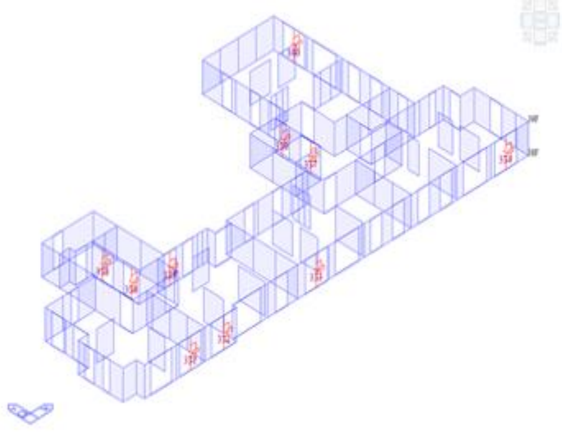
구분		최대 수평진동가속도(X-dir.) [cm/sec^2]				최대 수평진동가속도(Y-dir.) [cm/sec^2]			
		1	2	3	Mean	1	2	3	Mean
260°	A1	8.9	5.9	6.3	6.8	6.7	6.5	6.6	6.4
	A2	7.8	4.6	5.7	5.8	6.8	6.5	6.7	6.5
	A3	7.6	4.6	6.0	5.7	5.8	5.6	5.7	5.6
	A4	7.6	4.6	6.0	5.7	4.8	4.7	4.7	4.7
	A5	7.4	5.3	6.5	6.2	4.7	4.5	4.7	4.5
	A6	7.4	5.3	6.5	6.2	5.2	5.4	6.0	5.3
	A7	7.9	4.6	5.8	6.0	5.5	5.8	6.6	5.7
	A8	9.0	6.0	6.4	6.9	5.7	6.0	6.8	6.0
330°	A1	4.3	4.6	4.3	4.4	7.3	6.7	6.2	6.7
	A2	4.0	4.0	3.9	3.8	7.3	6.8	6.2	6.7
	A3	5.0	4.7	4.8	4.8	7.1	5.7	5.7	6.1
	A4	5.0	4.7	4.8	4.8	6.9	5.3	5.2	5.8
	A5	6.9	5.9	6.4	6.3	7.8	5.8	6.6	6.7
	A6	6.9	5.9	6.4	6.3	10.1	7.4	9.0	8.8
	A7	4.0	3.8	3.7	3.9	11.1	8.1	10.1	9.7
	A8	4.3	4.6	4.4	4.4	11.5	8.4	10.6	10.1

성능기반 내풍 설계 (비정형·군집 건물)

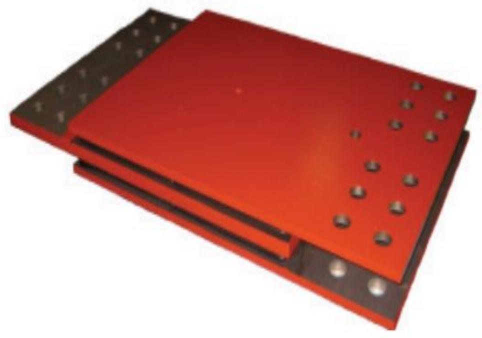
점탄성댐퍼(Viscoelastic Damper) 적용 건물해석



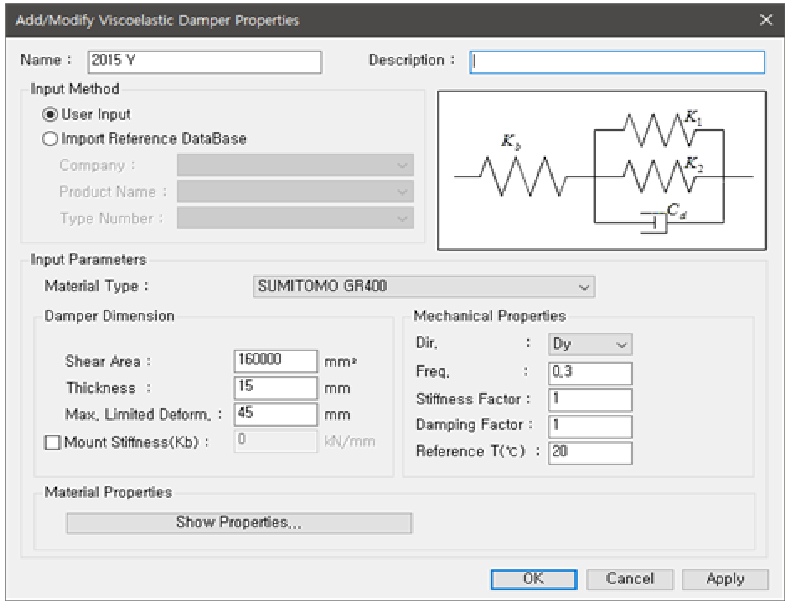
38F,41F,44F



38F View



Viscoelastic Damper



Add/Modify Viscoelastic Damper Properties

Name : 2015 Y

Description :

Input Method

● User Input

○ Import Reference DataBase

Company :

Product Name :

Type Number :

Input Parameters

Material Type : SUMITOMO GR400

Damper Dimension

Shear Area : 160000 mm²

Thickness : 15 mm

Max. Limited Deform. : 45 mm

☐ Mount Stiffness(Kb) : 0 kN/mm

Mechanical Properties

Dir. : Dy

Freq. : 0.3

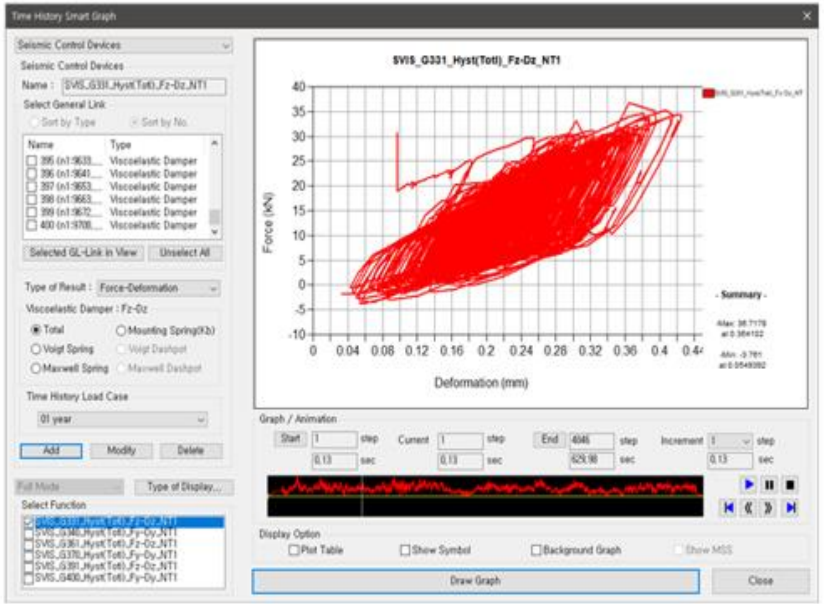
Stiffness Factor : 1

Damping Factor : 1

Reference T(℃) : 20

Material Properties

38F



Time History Smart Graph

Seismic Control Devices

Seismic Control Devices

Name : SVIS_G331_Hyst(Totl)_Fz-Dz_NT1

Select General Link

○ Sort by Type ● Sort by No.

Name	Type
☐ 395 (n1:9633...	Viscoelastic Damper
☐ 396 (n1:9641...	Viscoelastic Damper
☐ 397 (n1:9653...	Viscoelastic Damper
☐ 398 (n1:9663...	Viscoelastic Damper
☐ 399 (n1:9672...	Viscoelastic Damper
☐ 400 (n1:9708...	Viscoelastic Damper

Type of Result : Force-Deformation

Viscoelastic Damper : Fz-Dz

● Total ○ Mounting Spring(Kb)

○ Voigt Spring ○ Voigt Dashpot

○ Maxwell Spring ○ Maxwell Dashpot

Time History Load Case

01 year

Full Mode

Select Function

☑ SVIS_G331_Hyst(Totl)_Fz-Dz_NT1
☐ SVIS_G340_Hyst(Totl)_Fy-Dy_NT1
☐ SVIS_G361_Hyst(Totl)_Fz-Dz_NT1
☐ SVIS_G370_Hyst(Totl)_Fy-Dy_NT1
☐ SVIS_G391_Hyst(Totl)_Fz-Dz_NT1
☐ SVIS_G400_Hyst(Totl)_Fy-Dy_NT1

Graph / Animation

Start 1 step 0.13 sec

Current 1 step 0.13 sec

End 4846 step 629.98 sec

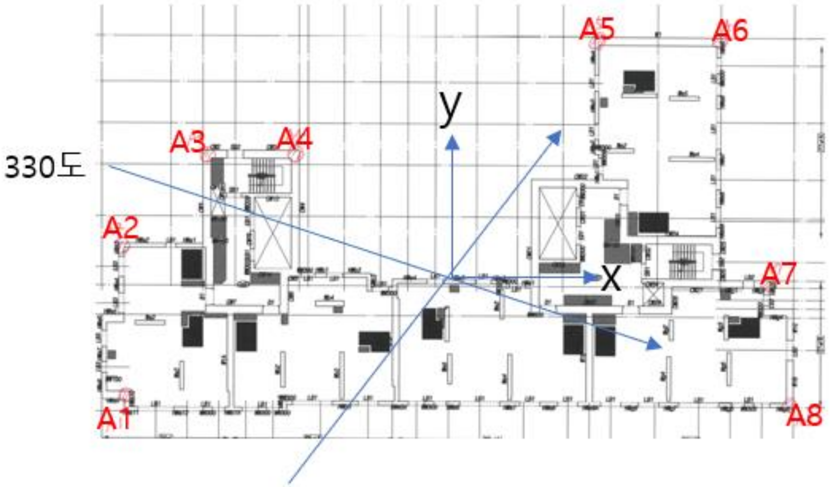
Increment 1 step 0.13 sec

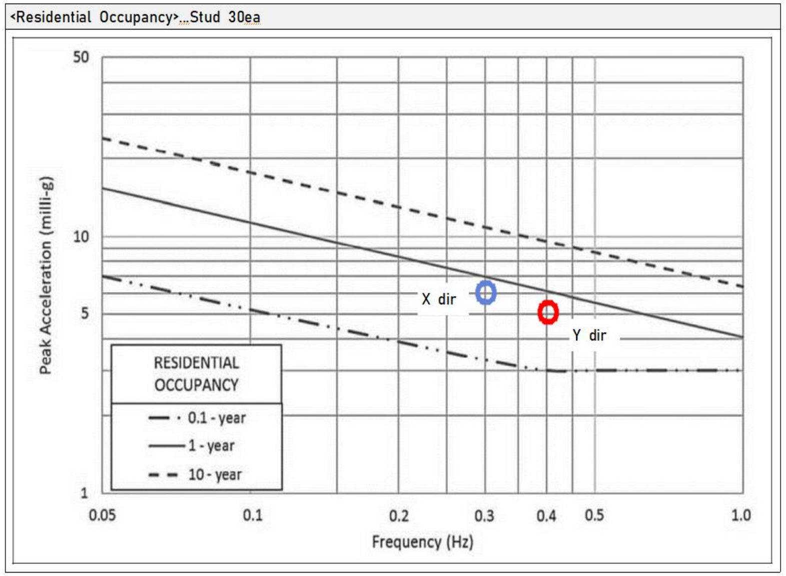
Display Option

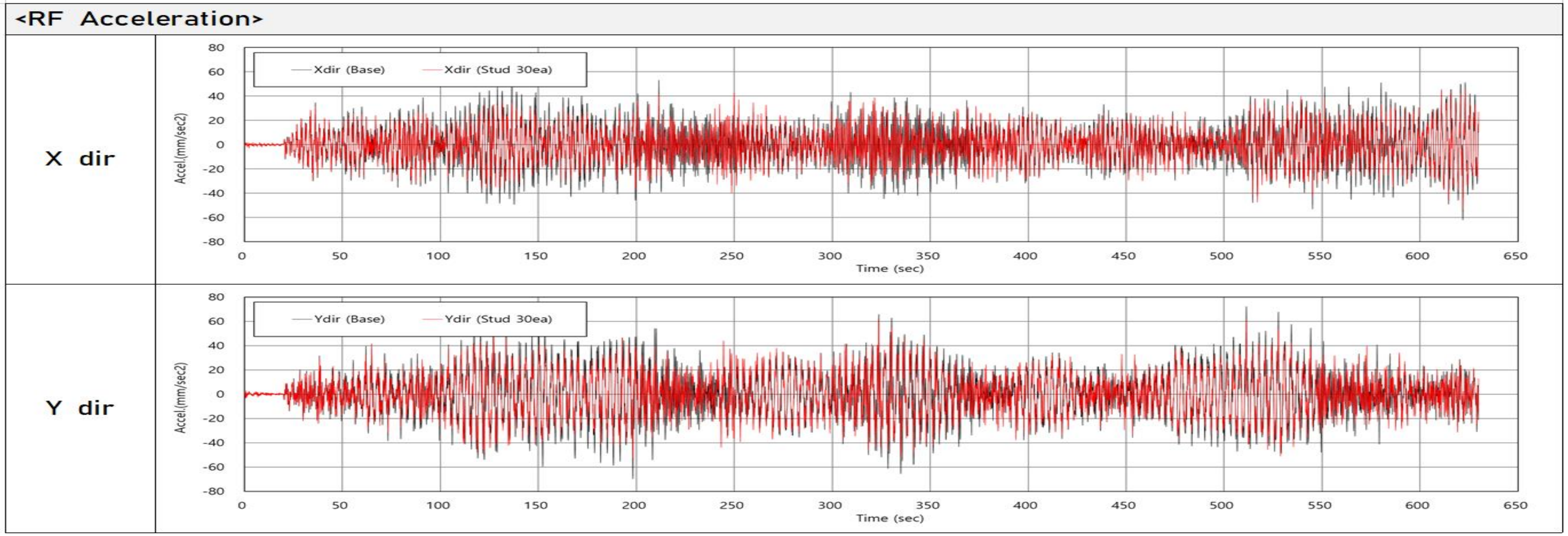
☐ Plot Table ☐ Show Symbol ☐ Background Graph ☐ Show MSS

성능기반 내풍 설계 (비정형· 군집 건물)

점탄성댐퍼 적용 건물 진동사용성 평가



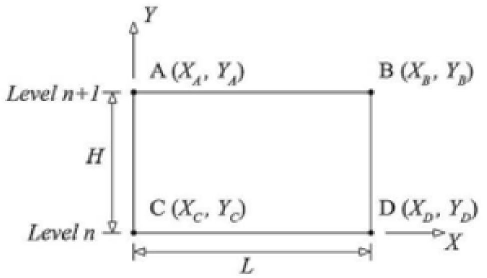


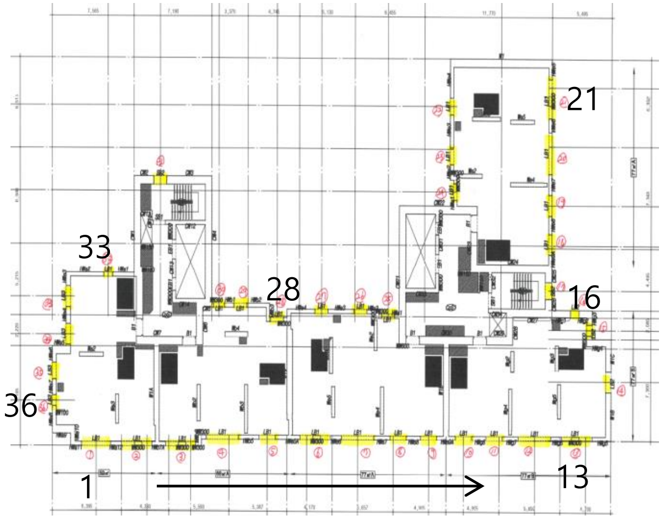


성능기반 내풍 설계 (비정형· 군집 건물)

변위사용성 평가(Deformation Damage Index)

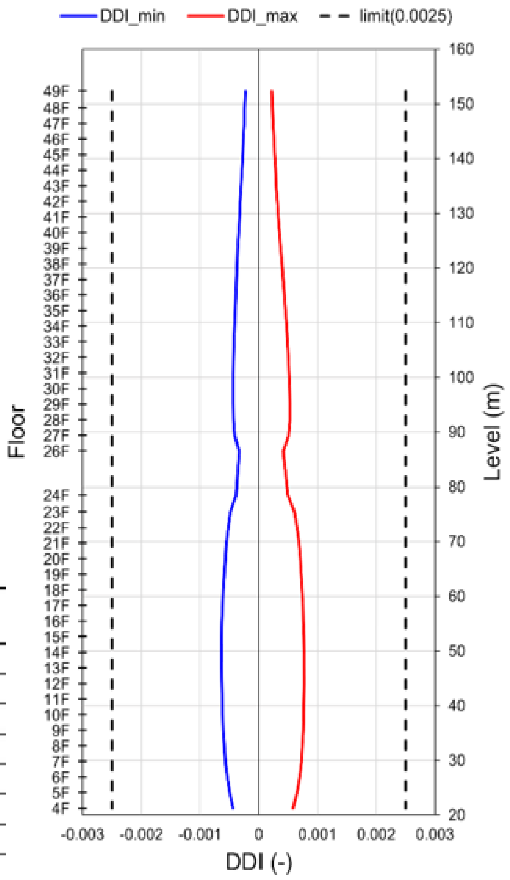
$$DDI = 0.5\left[\frac{X_A - X_C}{H} + \frac{X_B - X_D}{H} + \frac{Y_D - Y_C}{L} + \frac{Y_B - Y_A}{L}\right]$$



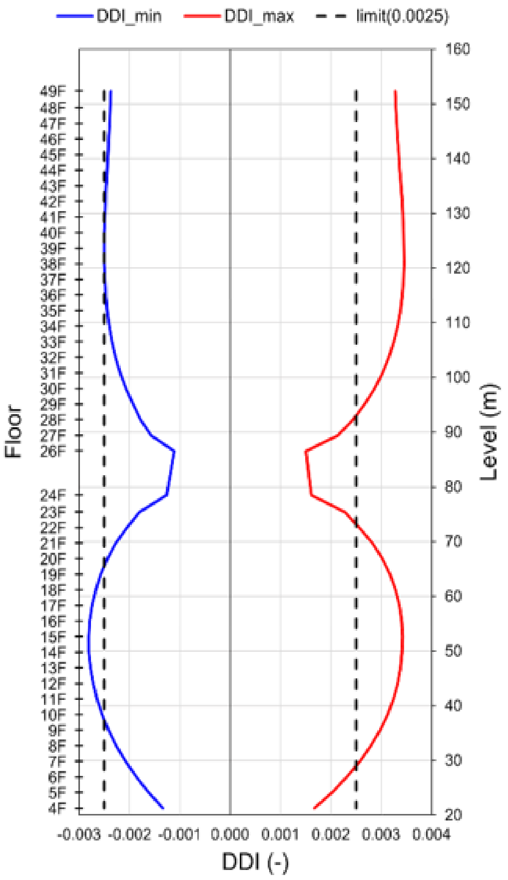


변형손상지수 허용값 (ATC Design Guide 3)

Building Element		Suggested DDI Limit
Exterior Cladding	Brick veneer w/ metal studs	0.0025
	Brick veneer w/ unreinforced masonry	0.0025
	Plaster or stucco	0.0025
	Architectural precast	0.0025
	Stone clad precast	0.0025
	Architectural metal panel	0.0100
	Curtain wall or window wall	0.0025
Interior Partitions	Gypsum drywall, plaster	0.0025
	Concrete masonry, unreinforced	0.0015
	Tile or hollow clay brick	0.0005
Elevators	Drywall enclosure	0.0025



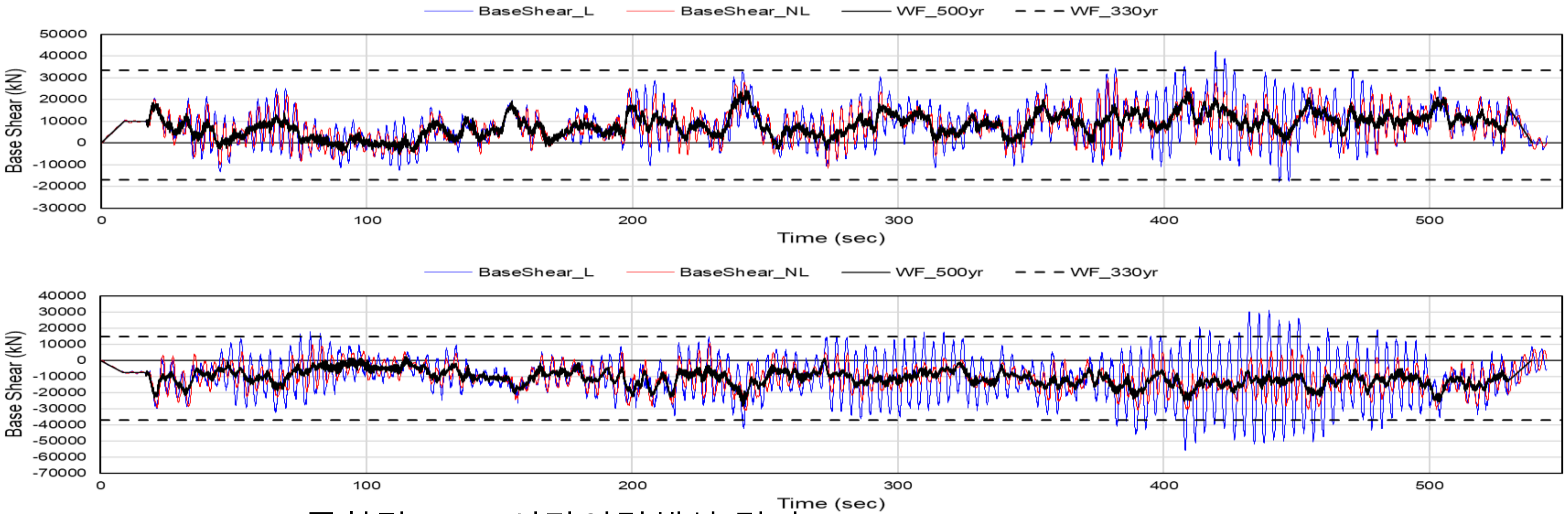
(a) DDI1



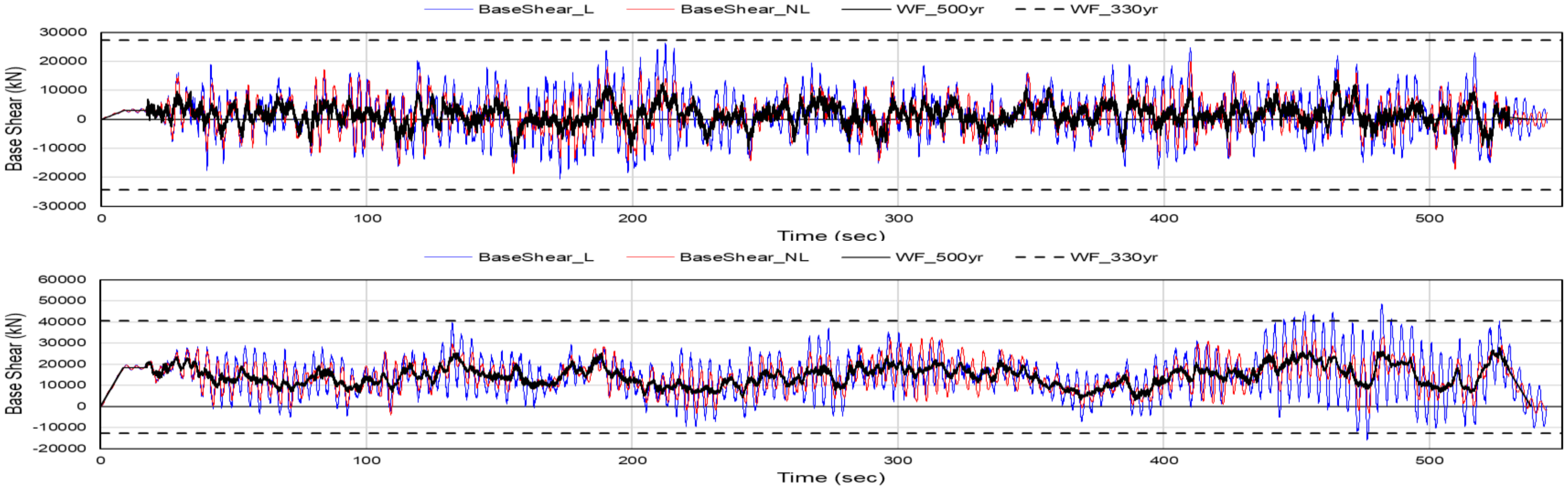
(b) DDI28

성능기반 내풍 설계 (비정형·군집 건물)

풍하중 저감



풍향각 330° 시간이력해석 결과 (x : 80%, y : 81%)



풍향각 260° 시간이력해석 결과 (x : 85%, y : 73%)

성능기반 내풍 설계 (비정형· 군집 건물)

구조안전성 평가

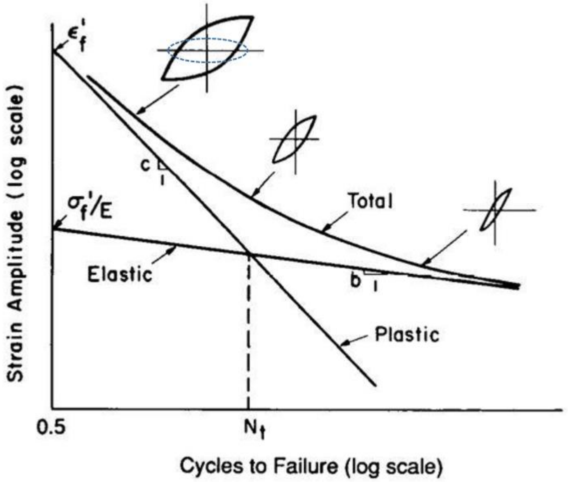
평가항목	허용기준	평 가
최대 횡변위비	H/200~H/300, H는 건물높이	H/263~H/854
DDI	0.02 이하 (외장재 탈락, 낙하 없음)	0.01 이하
잔류변위비	H/1000 이하, H는 건물높이	H/4174~H/7580
잔류층간변위비	h/1000 이하, h는 층고	최대 h/2222
힘지배부재	$max(F_{w1}, F_{w2}, F_{w3}) \le \emptyset F_n$	일부 전단보강
변형지배부재	부재 소성회전각 DC수준 이하	일부 연결보 연성보강
LCF	SN선도를 통해 최대 허용 반복변형률 확인 및 검토	2% 연결보 허용값 초과

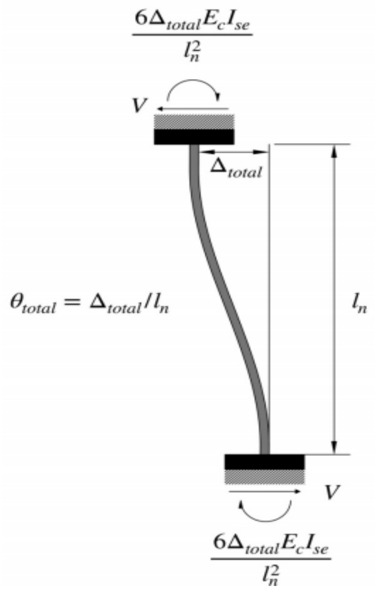
* DC수준 : Damage Control Level (IO와 LS의 중간)

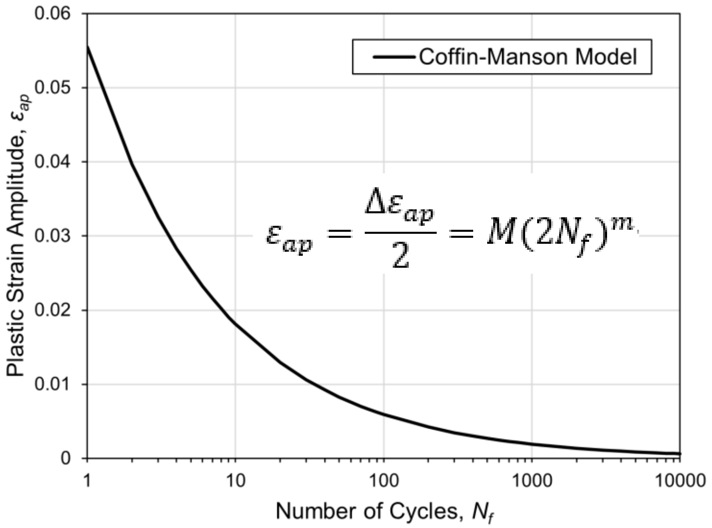
출처 : Structural performance levels based on ASCE-41-17

성능기반 내풍 설계 (비정형· 군집 건물)

저주파 피로(LCF) 평가





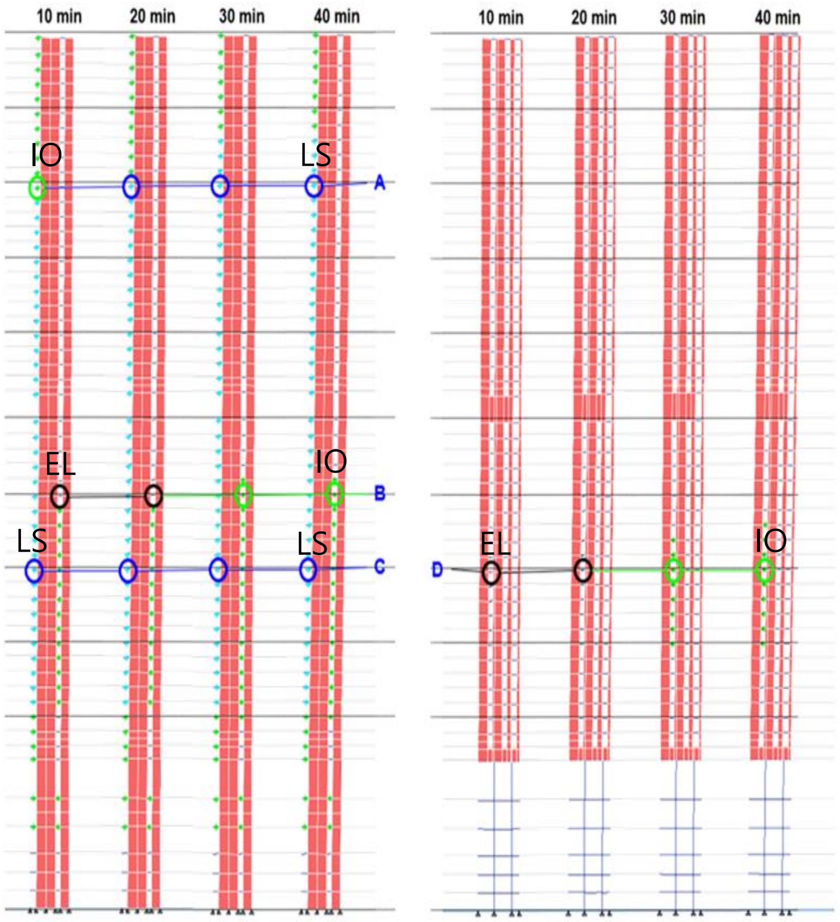


철근의 SN선도(Coffin-Manson Model)

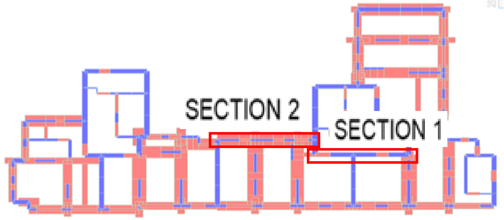
Member	ID	h	L	Δθp	Δεp	10min	20min	30min	40min	50min	60min
		[mm]	[mm]	[rad]	[-]	0.0089	0.0063	0.0052	0.0045	0.0041	0.0037
(21~RF)B1	1	600	1250	0.0079	0.0057	OK	OK	NG	NG	NG	NG
(26F)BG1	2	2720	2700	0.0032	0.0048	OK	OK	OK	NG	NG	NG
(25F)SB2	1	970	1200	0.0035	0.0043	OK	OK	OK	OK	NG	NG
(14~20F)B1	1	600	1250	0.0083	0.0060	OK	OK	NG	NG	NG	NG
(6~13F)B1	1	600	1250	0.0080	0.0058	OK	OK	NG	NG	NG	NG
(6~13F)LB2A	1	1750	800	0.0021	0.0070	OK	NG	NG	NG	NG	NG
(4~5F)LB2A	1	1750	800	0.0022	0.0072	OK	NG	NG	NG	NG	NG

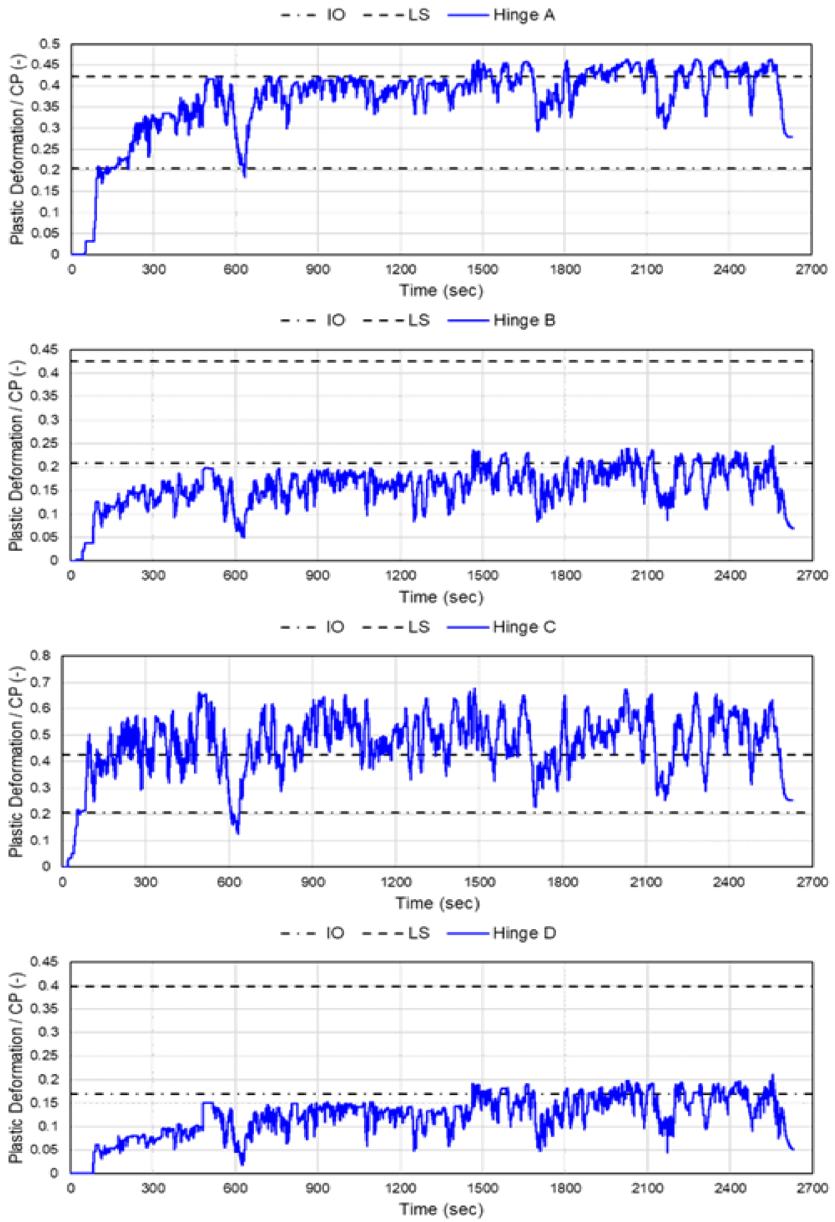
성능기반 내풍 설계 (비정형·군집 건물)

누적손상효과(Damage accumulation) 평가



(a) SECTION 1 (b) SECTION 2

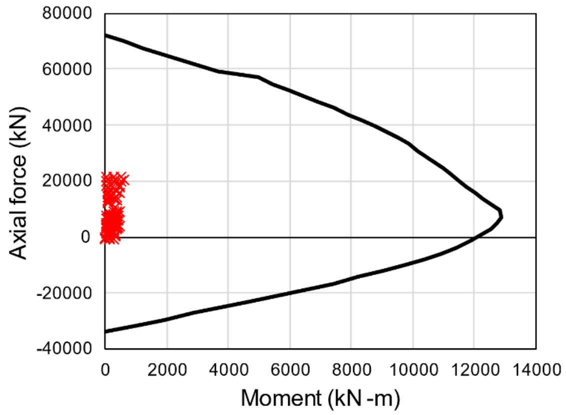




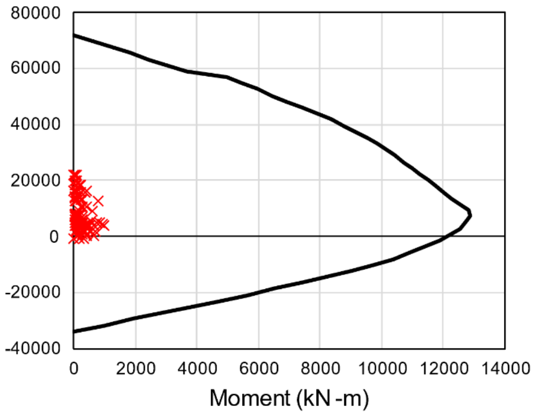
성능기반 내풍 설계 (비정형·군집 건물)

전이기둥 평가

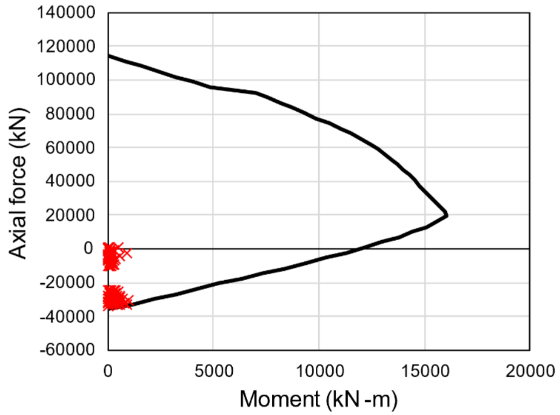
P-M2 Interaction(TC2)



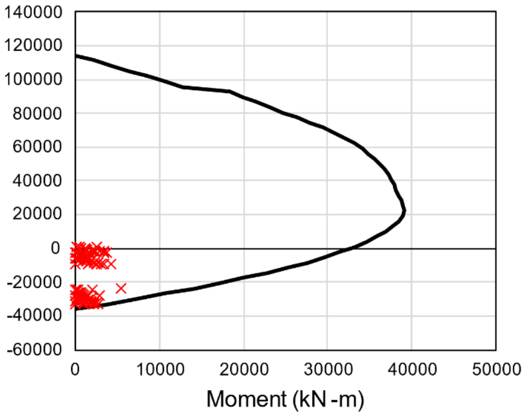
P-M3 Interaction(TC2)



P-M2 Interaction(TC3)



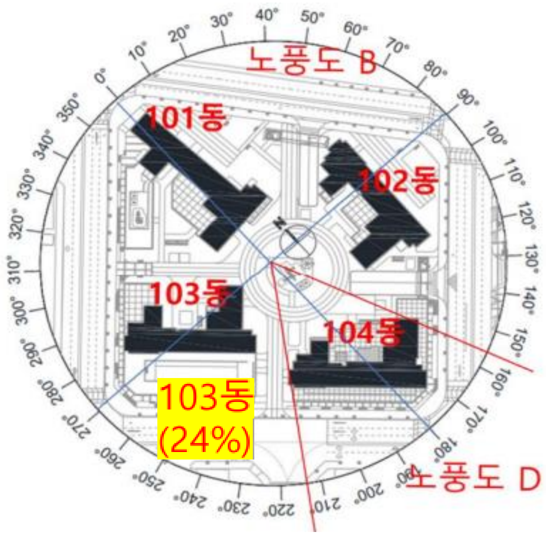
P-M3 Interaction(TC3)



성능기반 내풍 설계 (비정형· 군집 건물)

구조물량 절감

103동		탄성설계[A] (ton)	성능설계[B] (ton)	증감량[A-B=C] (ton)	Ratio[C/A] (%)
수직 철근	D10	131.5	162.8	-31.2	**-24%**
	D13	202.9	184.7	18.1	**9%**
	D16	148.9	122.6	26.3	**18%**
	D19	137.4	74.7	62.8	**46%**
	D22	138.3	64.4	73.9	**53%**
	D25	139.1	33.1	106.0	**76%**
	D29	43.4	-	43.4	**100%**
수평 철근	D10	357.3	360.6	-3.4	**-1%**
	D13	34.0	5.5	28.5	**84%**
Total		**1332.6**	**1008.3**	**324.3**	**24%**



제한적인 비탄성을 허용하는 성능기반내풍설계를 통해 사용성 및 구조안전성의 허용기준을 만족시키는 조건에서 철근물량을 324.3 ton(24%) 절감

결 언

결 언

Paradigm Shift(PBWD) in Tall Building Wind Design Cuts Material, Cost and Carbon (ENR June 22, 2022)

– 풍하중에 대한 고층건물의 성능을 가장 정확하고 직접적인 방법으로 평가

– 내풍설계가 구조물의 내진성능에 미치는 악영향을 최소화

– 바람과 지진에 대한 구조물의 안전성을 높이면서 가장 경제적인 구조물 설계

– 건물의 모든 성능을 향상시키면서 동시에 구조적 신뢰성을 높임

– 건물의 복구기반설계(Resilience-based design)로 나아갈 수 있는 방안

- High-rise PBWD will be the norm the world over in 10 years.