Progetto DPC-ReLUIS 2024-2026 WP12
task 12.1 - Costruzioni in acciaio

Linee guida progettuali di carattere pre-normativo per la resistenza a collasso progressivo degli edifici

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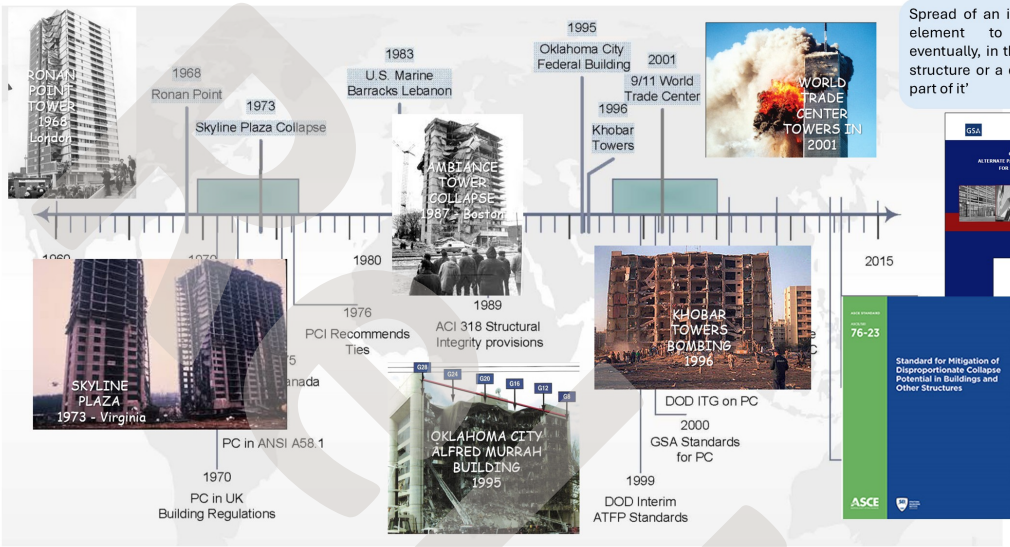
PROGRESSIVE COLLAPSE TIMELINE



Spread of an initial local failure from element to element resulting, eventually, in the collapse of an entire structure or a disproportionately large part of it'

NONLINEAR STATIC PROCEDURE

DYNAMIC INCREASE FACTOR FOR NSP (Ω_N)

In Table 5-4, θ_{pra} is the plastic rotation angle given in the acceptance criteria tables in Chapter 6 for the appropriate structural response level for the particular component or connection; θ_y is the yield rotation. For steel, θ_y is given in ASCE 41. For reinforced concrete, θ_y is determined with the effective stiffness values provided in ASCE 41. Note that for connections, θ_y is the yield rotation angle of the structural component that is being connected (beam, slab, etc.) and θ_{pra} is the plastic rotation of the connection (determined from ASCE 41 and this standard). Columns are omitted from the determination of the DIF.

To determine the DIF for the analysis of the entire structure, choose the smallest ratio of θ_{pra}/θ_y for any primary component, or connection in the model within or touching the area that is loaded with the increased gravity load. In other words, the DIF for every primary connection, beam, girder, wall component, and so forth, that falls within or touches the perimeter marked as A-B-C-D shall be determined and the largest value shall be used for the analysis.

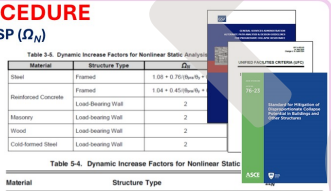


Table 5-4. Dynamic Increase Factors for Nonlinear Static Analysis

Material	Structure Type	Ω_N
Steel	Framed	$1.08 + 0.76/(\theta_{pra}/\theta_y + 0.83)$
Reinforced Concrete	Framed	$1.04 + 0.45/(\theta_{pra}/\theta_y + 0.48)$
	Load-Bearing Wall	2
Masonry	Load-Bearing Wall	2
Wood	Load-Bearing Wall	2
Cold-formed Steel	Load-Bearing Wall	2

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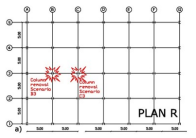
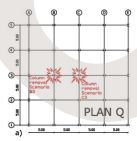
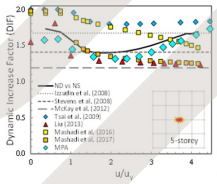
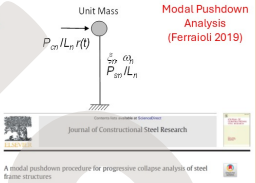
RIGID CONNECTIONS - MOMENT RESISTING FRAMES

N.	Author	Description
1	Izzuddin (2008)	Analytical DIF based on energy balance
2	McKay *et al.* (2012) - LS	Empirical DIF based on Life Safety ductility
3	McKay *et al.* (2012) - CP	Empirical DIF based on Collapse Prevention ductility
4	Stevens *et al.* (2008)	Empirical DIF depending on ductility
5	Tsai *et al.* (2009)	Analytical DIF depending on ductility and post-elastic stiffness ratio
6	Liu (2013)	Empirical DIF based on residual capacity of model
7	Mashadi *et al.* (2016)	Empirical DIF depending on ductility and damping ratio
8	Mashadi *et al.* (2017a)	Empirical DIF depending on ductility post-elastic stiffness ratio









DIF FORMULATIONS BASED ON MDOF MODEL

CAPACITY-BASED DIF

Stevens et al. (2008) $\mathrm{DIF} = 1.44m^{-0.12}$

where m is the plastic hinge rotation divided by yield rotation of the component in the area which is loaded with the amplified gravity load.

McKay et al. (2012) $\mathrm{DIF} = 1.08 + \dfrac{0.76}{\theta_{pra}/\theta_y + 0.83}$

θ_{pra} is the prescribed maximum acceptable plastic hinge rotation angle; θ_y is the yield rotation angle.

DEMAND-BASED DIF

Liu (2013) $\mathrm{DIF} = 0.84 + \dfrac{1.23}{2.95\max\left(M_d/M_p\right) - 0.28}$

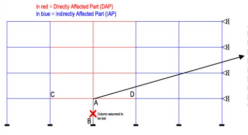
$(M_d/M_p) \geq 0.5$

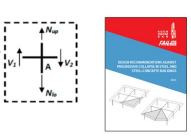
Mashhadi et al. (2016) $\mathrm{DIF} = (2 - 2.54\xi) - \dfrac{(0.9 - 1.81\xi)\theta_p/\theta_y}{(0.84 - 2.15\xi) + \theta_p/\theta_y}$

Mashhadi et al. (2017) $\mathrm{DIF} = (1.1 + 2\eta) + \dfrac{0.56 - \eta}{0.65 + \theta_p/\theta_y}$

Ferraioli (2019) MODAL PUSHDOWN

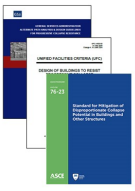
Considering the response being dominated by a single deformation mode





Ductility Limit

DEMAND-BASED DIF



Chopra (1995)

$$\mathrm{DIF} = 1 + \frac{\sin\left(\pi t_r/T_n\right)}{\pi t_r/T_n}$$

DIF=2

T_n is the structural natural period in the force direction force and t_r is the rise time of the step force function. Since the column is removed suddenly, t_r/T_n tends to zero and DIF is approximated to two.

$$\mathrm{DIF} = 1.08 + \frac{0.76}{\theta_{pra}/\theta_y + 0.83}$$

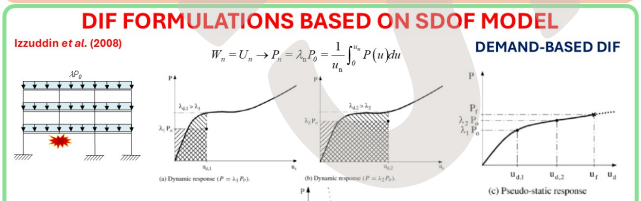
CAPACITY-BASED DIF

DIF FORMULATIONS BASED ON SDOF MODEL

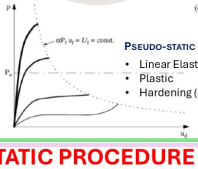
Izzuddin *et al.* (2008)

$$W_n = U_n \rightarrow P_n = \lambda_0 P_0 = \frac{1}{u_n}\int_0^{u_n} P(u)du$$

DEMAND-BASED DIF



Energy balance method:
With the assumption of a SDOF mode, the maximum dynamic response is reached when the kinetic energy is reduced back to zero or, in other words, work done by **the gravity loads (W_n)** becomes identical to the **internal energy absorbed by the structure (U_n)**. This gives rise to the concept of a pseudo-static response.

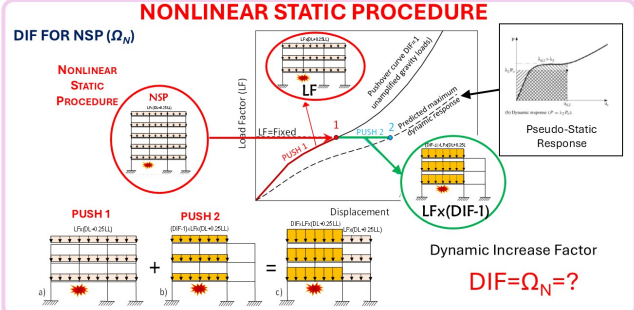


PSEUDO-STATIC RESPONSES

- Linear Elastic
- Plastic
- Hardening (catenary effect)

NONLINEAR STATIC PROCEDURE

DIF FOR NSP (Ω_N)



Convegno ReLUIS - Napoli, 13-14 ottobre 2025