Progetto DPC-ReLUIS 2022-2024

WP 15 – Contributi normativi relativi a Isolamento e Dissipazione

Task 15.2: Applicazione dell'isolamento e/o dissipazione agli edifici e ponti

Sub-Task 15.2.2: Dissipazione di energia

PROTEZIONE CIVILE
Presidenza del Consiglio dei Ministri
Dipartimento della Protezione Civile

The Direct Five-Step Procedure for the seismic design of structures equipped with fluid-viscous dampers

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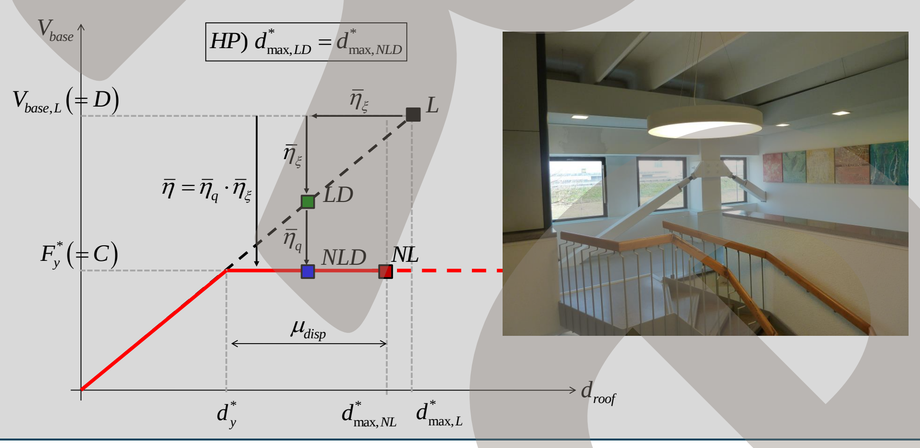
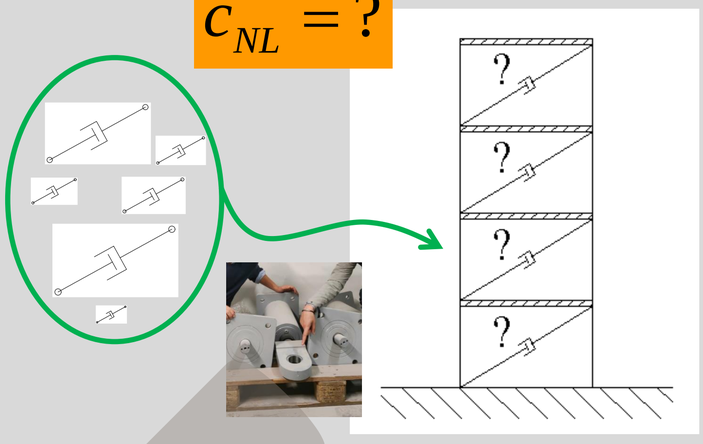
OBJECTIVE: reduction of the seismic base shear demand on the building through the installation of fluid-viscous dampers



DESIGN QUESTION:
How to size the dampers?

$\overline{c_{NL}} = ?$



RESULT:
Proposal of a **5-step procedure** for the design of fluid-viscous dampers to be inserted in new/existing frame structures, accounting for:

- **viscous dissipation** in the damper system, and
- **hysteretic dissipation** in the structural elements ("behaviour factor")

DESIGN PHASE

Design strategy + Performance objective

$\overline{\eta} \rightarrow \overline{\xi}_{visc}$

1

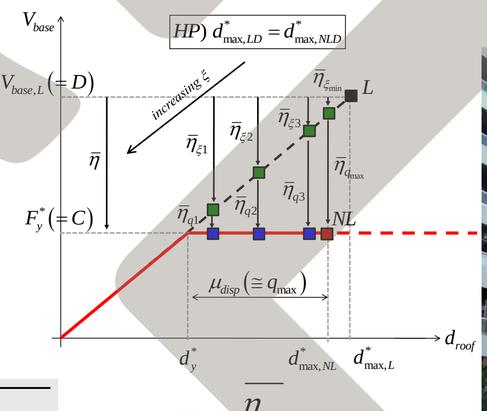
$$\overline{\eta_{tot}} = \overline{\eta}_q \cdot \overline{\eta}_\xi = \frac{1}{q} \cdot \sqrt{\frac{10}{5+\overline{\xi}_{visc}}}$$

$$\overline{\eta_q} = \frac{1}{q}$$

hysteretic dissipation

$$\overline{\eta}_\xi = \sqrt{\frac{10}{5+\xi_{intr}+\overline{\xi}_{visc}}}$$

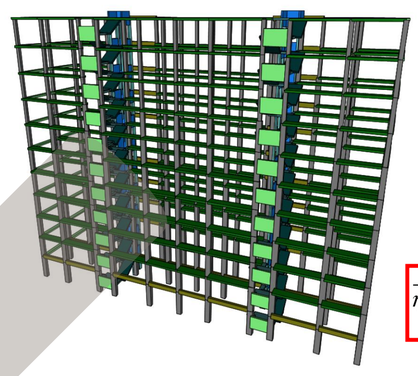
viscous dissipation



$$\overline{\eta}_\xi = \frac{\overline{\eta_{tot}}}{\overline{\eta}_q}$$

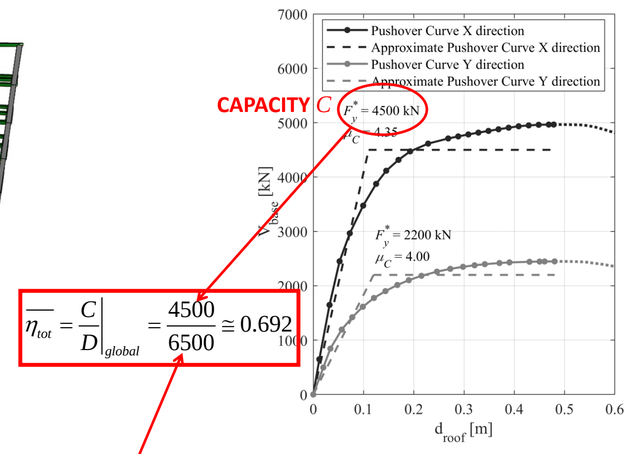
$$\overline{\xi}_{visc} = \frac{10\left(1-\overline{\eta}_\xi^{\,2}\right)}{\overline{\eta}_\xi}$$

existing building



$$V_{base} \cong 0.85\frac{W_{tot}}{g} \cdot S_a(T_1) = 0.85\frac{45050\ \text{kN}}{g} \cdot 0.17g \cong 6500\ \text{kN}$$

DEMAND D



$$\overline{\eta_{tot}} = \left.\frac{C}{D}\right|_{global} = \frac{4500}{6500} \cong 0.692$$

at the global response level of the entire structure in terms of base shear - top displacement curve

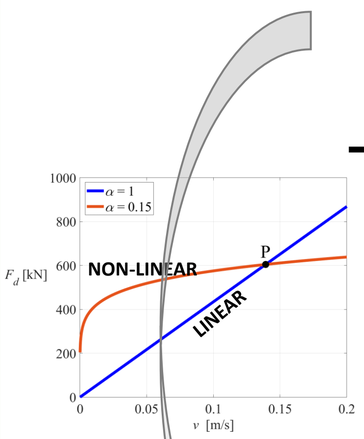
2 Linear behaviour assumption of the dampers

$\overline{\xi}_{visc} \rightarrow \overline{c_L}$

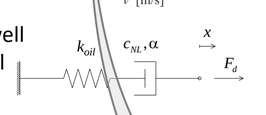
$$\overline{c_L} = \overline{\xi}_{visc} \cdot \omega_1 \cdot m_{tot} \cdot \left(\frac{N+1}{n}\right)$$

$\alpha = 1$

$k_{oil} = \infty$

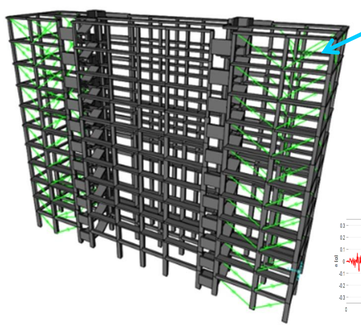


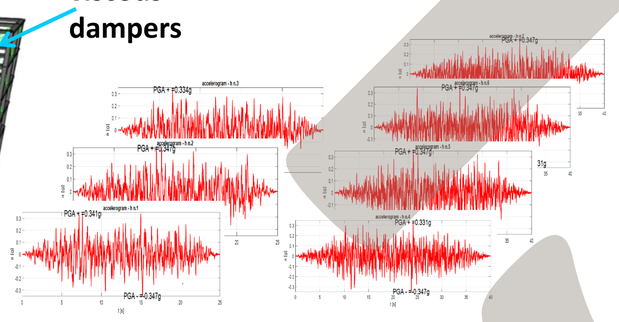
Maxwell model



$$F_d = k_{oil} \cdot x = c_{NL} \cdot v^\alpha$$

3 Seismic response of the structure with linear dampers





maximum damper velocity V_{max} :

- either numerically obtained from FE time-history analyses
- or even analytically estimated:

$$v_{max} = \frac{S_{e,\xi}(T_1)}{\omega_1} \cdot \frac{2}{(N+1)} \cdot \cos\theta$$

4 Non-linear behaviour of the dampers

$\overline{c_L} \rightarrow \begin{Bmatrix} \overline{c_{NL}} \\ \overline{\alpha} \\ \overline{k_{oil}} \end{Bmatrix}$

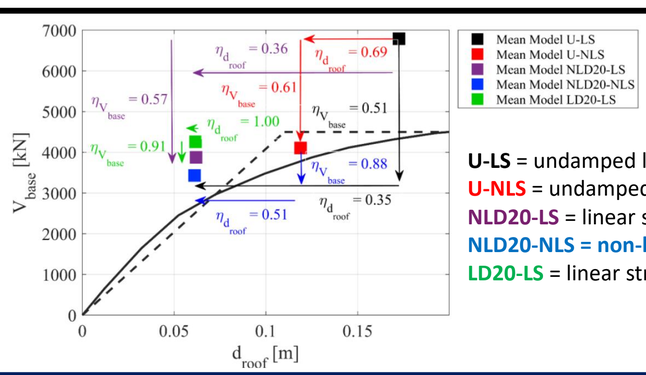
$$\overline{c_{NL}} = \overline{\xi}_{visc} \cdot \frac{2\pi}{T_1} \cdot \frac{W}{g} \cdot \left(\frac{N+1}{n}\right) \cdot \frac{1}{\cos^2\theta} \cdot \left(0.8 \cdot \frac{S_e\left(T_1, \overline{\eta}_\xi\right)}{2\pi/T_1} \cdot \frac{2}{N+1} \cdot \cos\theta\right)^{1-\alpha}$$

$\overline{\alpha} = 0.15$

$$\overline{k_{oil}} \geq 10 \cdot \frac{F_{max}}{x_{max}} \cong 10 \cdot \overline{c_L} \cdot \omega_1$$

VERIFICATION PHASE

5 Seismic response of the structure with non-linear dampers (FE analyses)



U-LS = undamped linear structural model
U-NLS = undamped non-linear structural model
NLD20-LS = linear structural model with non-linear dampers leading to ξ = 20%
NLD20-NLS = non-linear structural model with non-linear dampers leading to ξ = 20%
LD20-LS = linear structural model with linear dampers leading to ξ = 20%

$\overline{c_{NL}}$

SEISMIC RETROFIT achievement