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Influence of actual plastic hinge placement on the behavior of ductile frames

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Methods of plastic analysis of ductile frames

Engineers have two categories of methods at their disposal for the assessment of collapse analysis of ductile frames: the finite element (FEM) nonlinear step-by-step methods and the limit analysis methods of plasticity.

FE analyses are more general, but can be very time-consuming, while limit analysis methods are focused on the determination of the global safety margins of the structure and are based on the solution of much simpler convex optimization problems.

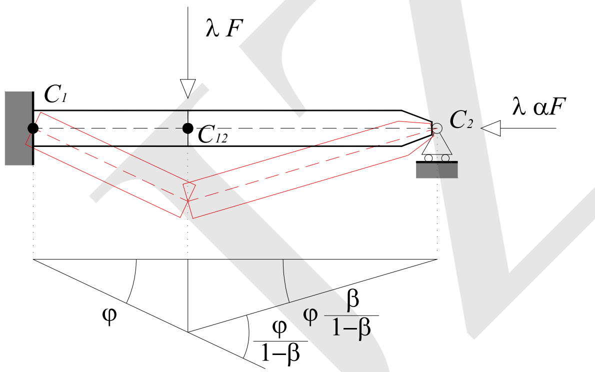
Limit analysis methods are incorporated in many codes and guidelines and can be very effective to analyse the effects of the design parameters of the cross section on the ultimate load and the actual kinematics at collapse in a direct and very effective way.

Drawbacks of some simplifications in limit analysis

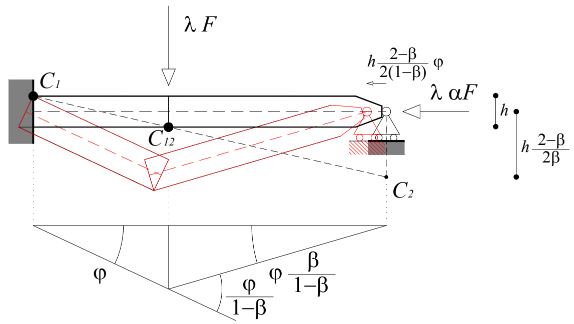
Simplifications at the basis of the limit analysis procedures might be sometimes overlooked and not properly accounted in a much idealised modeling of the structure and as such they require careful attention.

This is the case of the effects of the actual plastic hinges localization through the cross section on the collapse load and kinematics of the structure.

Reference has to be made to the axial force-bending moment interaction, otherwise the safety factors of the frame structure may be significantly affected, also in common loading cases.

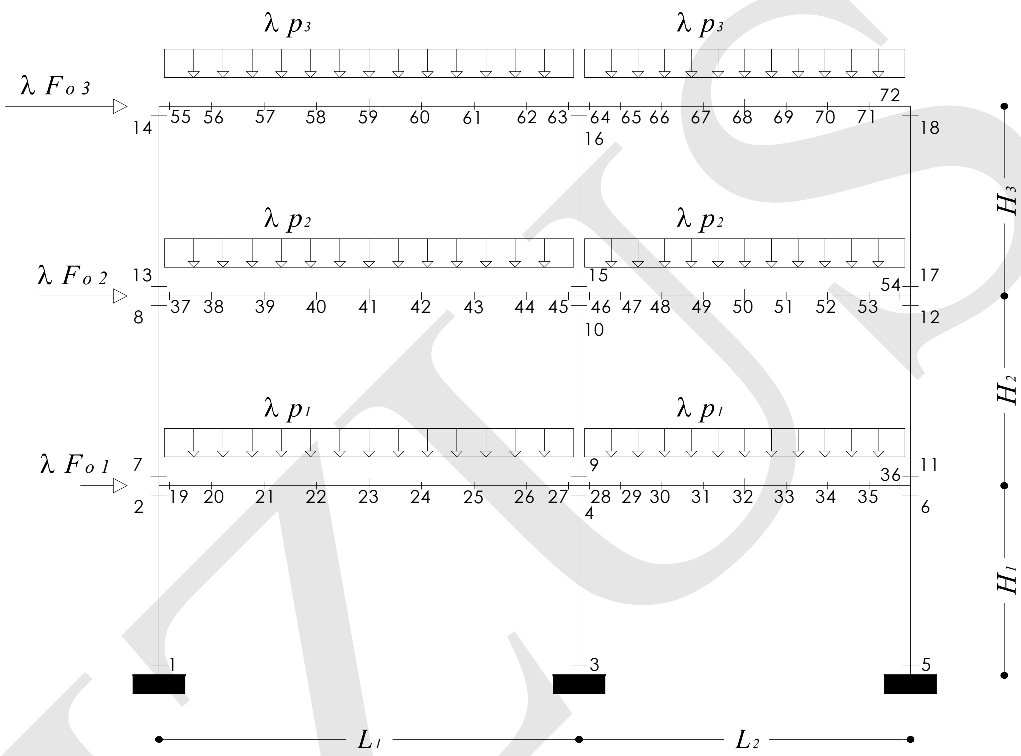


kinematics at collapse for pure bending



kinematics at collapse for bending moment and axial force interaction

Example

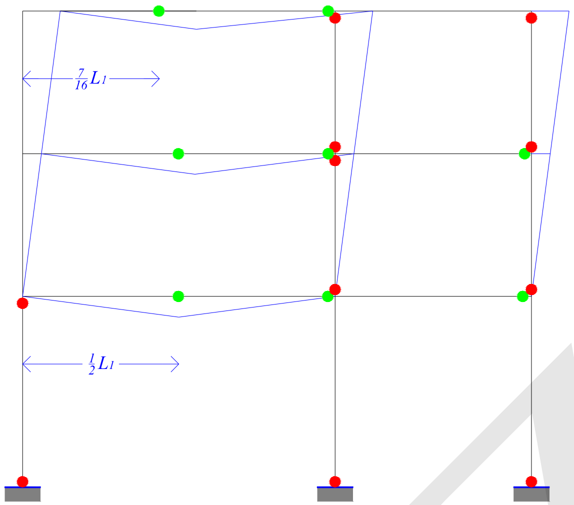


Column	Section type
H_1	*HEB200*
H_2	*HEB180*
H_3	*HEB160*

Yield stress $\sigma_o = 3.55\ 10^5\ kN/m^2$

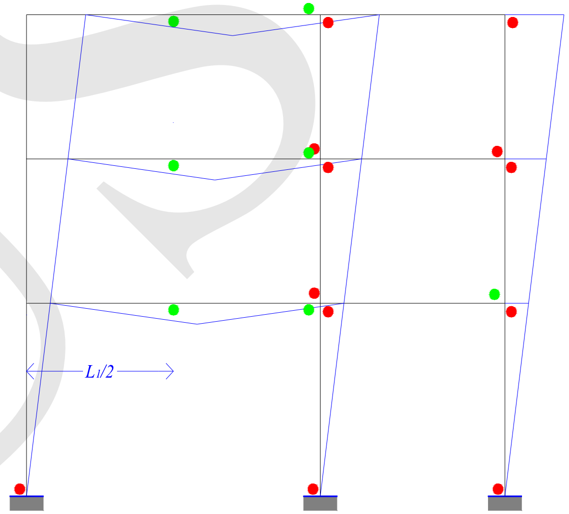
Beam	Section type	Vertical load *(kN/m)*	Horizontal force *(kN)*
1st floor	*HEB220*	$p_1=26.7$	$F_{o1}=21.6$
2nd floor	*HEB180*	$P_2=26.7$	$F_{o2}=30.0$
3rd floor	*HEB160*	$P_3=18.6$	$F_{o3}=43.4$

Example



kinematics at collapse for pure bending

$L_1 = 5$ m
$L_2 = 5$ m
$\lambda_M = 4.66$
$\lambda_{MN} = 3.78$
$\Delta\lambda\% = 19.05$



kinematics at collapse for bending moment and axial force interaction

Red dots show plastic hinges in columns.
Green dots show plastic hinges in beams

Conclusions

The sensitivity of the limit load and of the collapsing modes of the ductile frames to the actual kinematics arising from plastic hinges on account of the axial force-bending moment interaction in presence of combined vertical and horizontal forces is pointed out.

The study clearly shows that great care must be adopted in the design of new structures or in the strengthening of existing ones.

The proposed approach may be relevant to practising engineers dealing with code prescriptions and standardization committees.