FABRE – Consorzio di ricerca per la valutazione di ponti viadotti e altre strutture
Ponti, viadotti e gallerie esistenti: ricerca, innovazione e applicazioni
2- 4 Febbraio 2022, Lucca

L'effetto della corrosione per "pitting" sulla risposta forza-spostamento di trefoli in acciaio

Matteo Marra[1], Michele Palermo[1], Stefano Silvestri[1], Tomaso Trombetti[1]
[1]*Università di Bologna*

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

Motivation and objectives

https://espresso.repubblica.it/attualita/2018/09/13/news/ponte-morandi-1.326939/

Research motivation

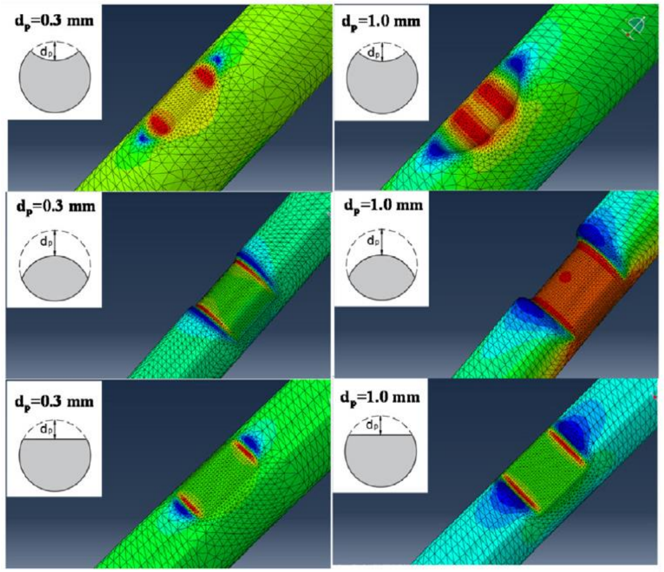
- Most of the Italian existing bridges were built in the 60s-70s
- Prestressed concrete was mainly used for the deck
- Post-tensioned elements with lack of mortar injection may present corrosion problems in the strands
- Corroded strands can lead to high reduction of strength and hence to collapse

Final objective of the work

To provide an estimation of the peak strength force of corroded seven-wire strands subjected to tension force, based on a simplified mechanical model

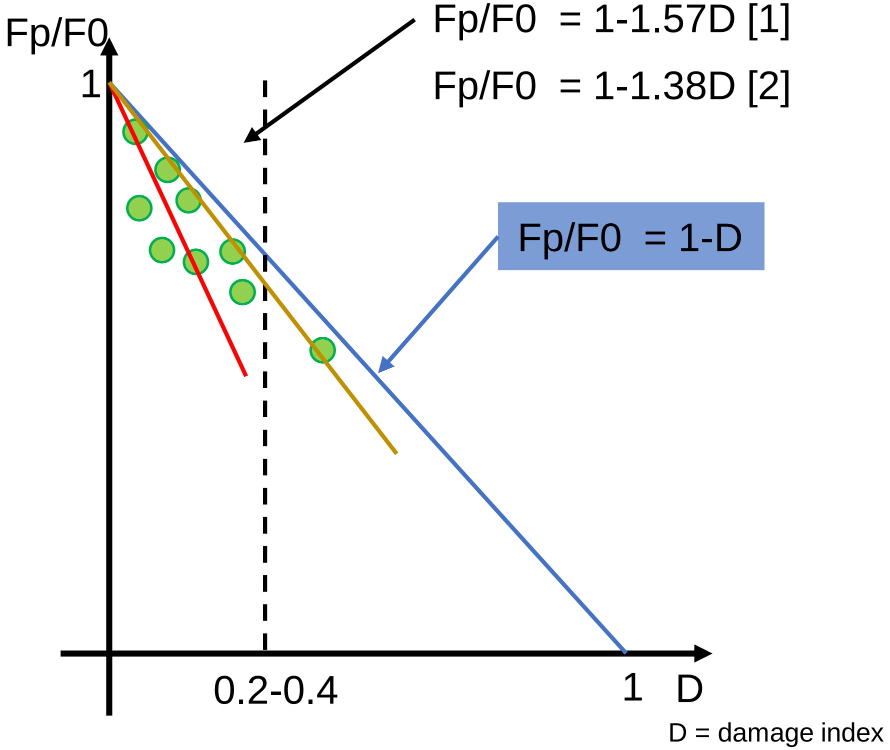
Possible approaches for peak strength reduction evaluation

- Advanced finite element analysis



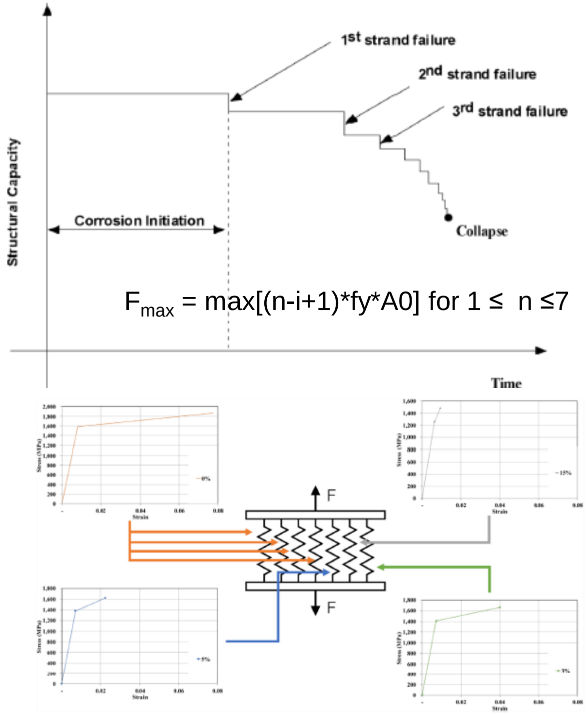
Jeon CH, Bin Lee J, Lon S, Shim CS (2019) Equivalent material model of corroded prestressing
steel strand. J Mater Res Technol 8(2):2450–2460.
https://doi.org/10.1016/j.jmrt.2019.02.010

- Experimental campaign with statistical approach



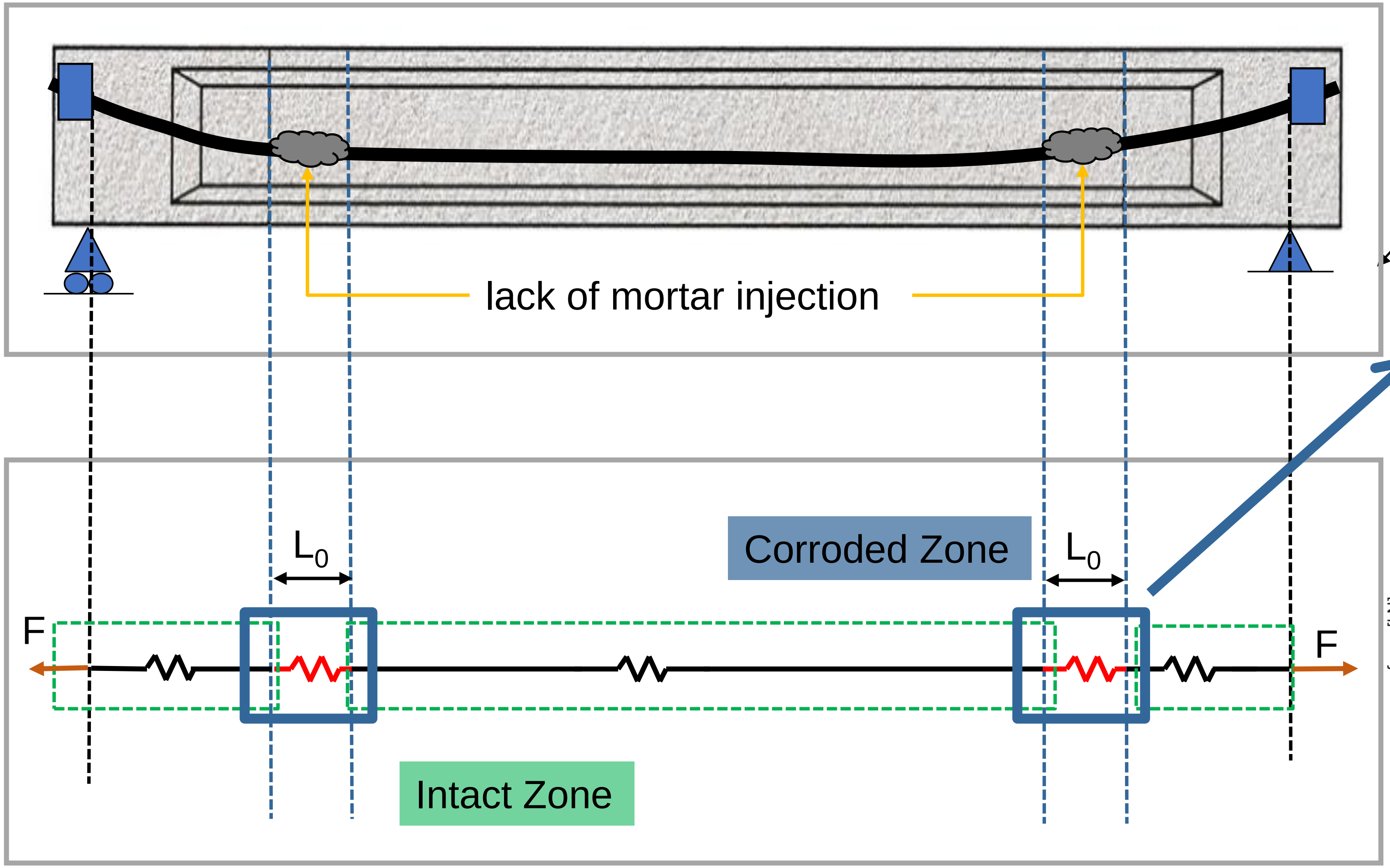
[1] Chi-Ho Jeon, Cuong Duy Nguyen and Chang-Su Shim. Assessment of Mechanical Properties of Corroded Prestressing Strands.
[2] Chiho JEON 1, Jaebin LEE 1, Changsu SHIM. Mechanical behaviour of corroded prestressing steel strand.

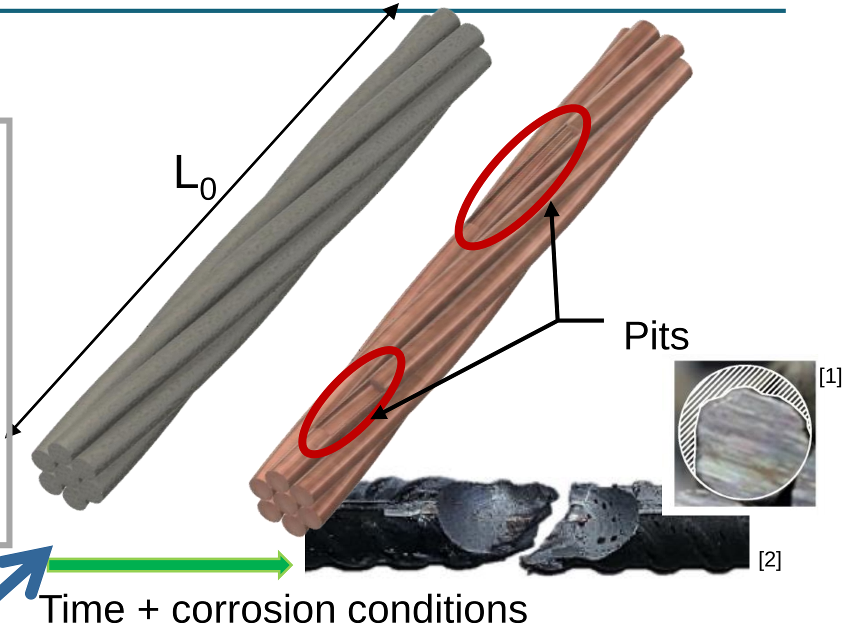
- Simplified models:
  - Darmawan-Stewart [1]
  - Equivalent material model [2]

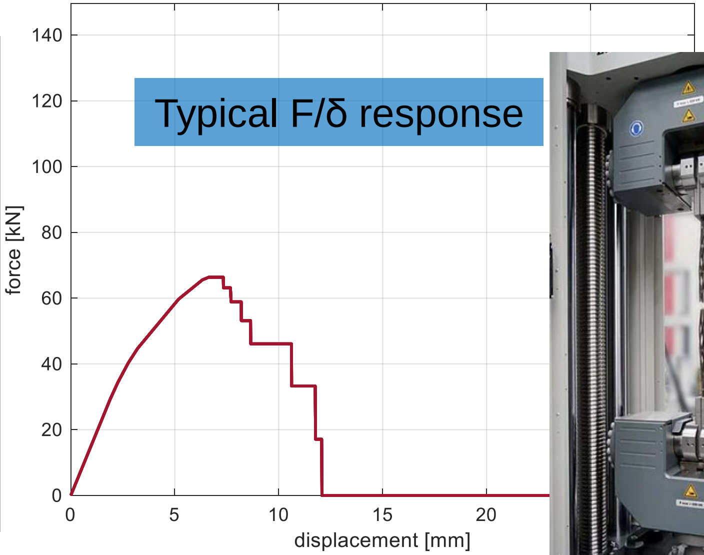


[1] M.Sigit Darmawan, Mark G. Stewart. Spatial time-dependent reliability analysis of corroding pretensioned prestressed concrete bridge girders
[2] Jeon CH, Bin Lee J, Lon S, Shim CS (2019) Equivalent material model of corroded prestressing
steel strand. J Mater Res Technol 8(2):2450–2460.
https://doi.org/10.1016/j.jmrt.2019.02.010

Problem formulation







[3]

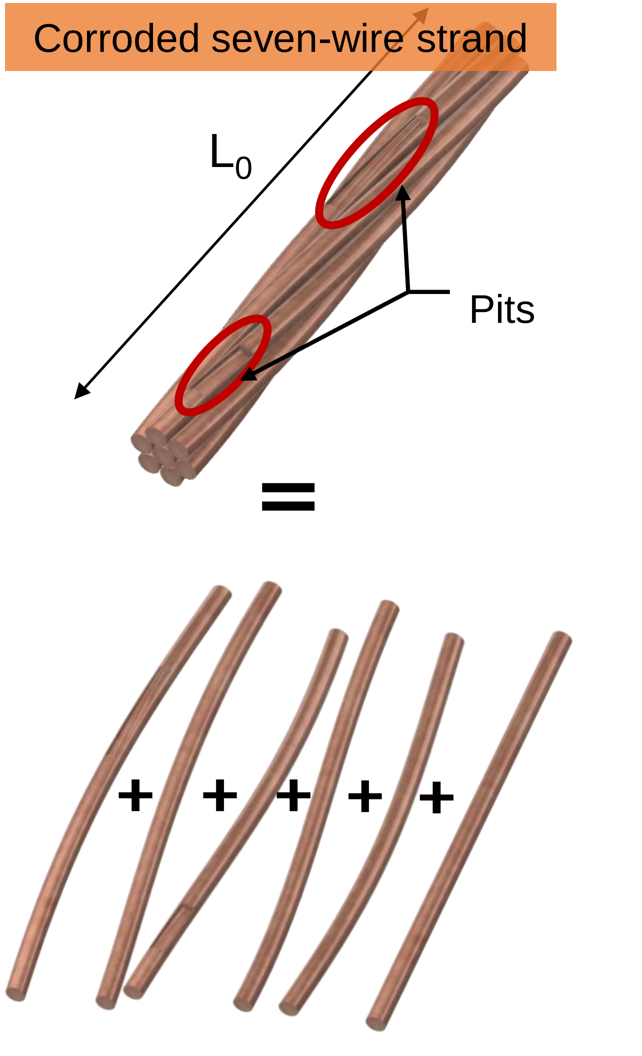
[1] Jeon CH, Bin Lee J, Lon S, Shim CS (2019) Equivalent material model of corroded prestressing steel strand. J Mater Res Technol 8(2):2450–2460. https://doi.org/10.1016/j.jmrt.2019.02.010

[2] Structural response of reinforcing bars affected by pitting corrosion: experimental evaluation. Finozzi, A. Saetta a, H. Budelmann

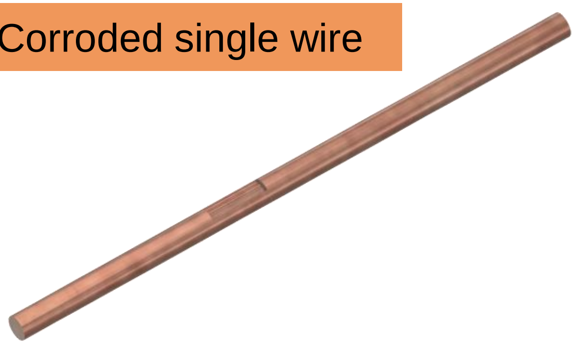
[3] https://www.zwickroell.com/it/settori-industriali/metalli/prodotti-lunghi/trefoli-in-acciaio-iso-15630-3-astm-a416-astm-a1061/

Modelling approach

Corroded seven-wire strand

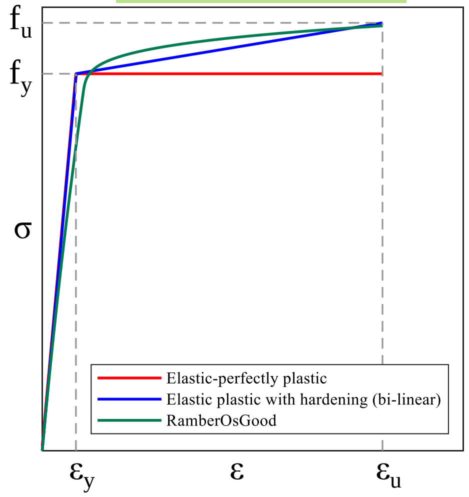


Corroded single wire



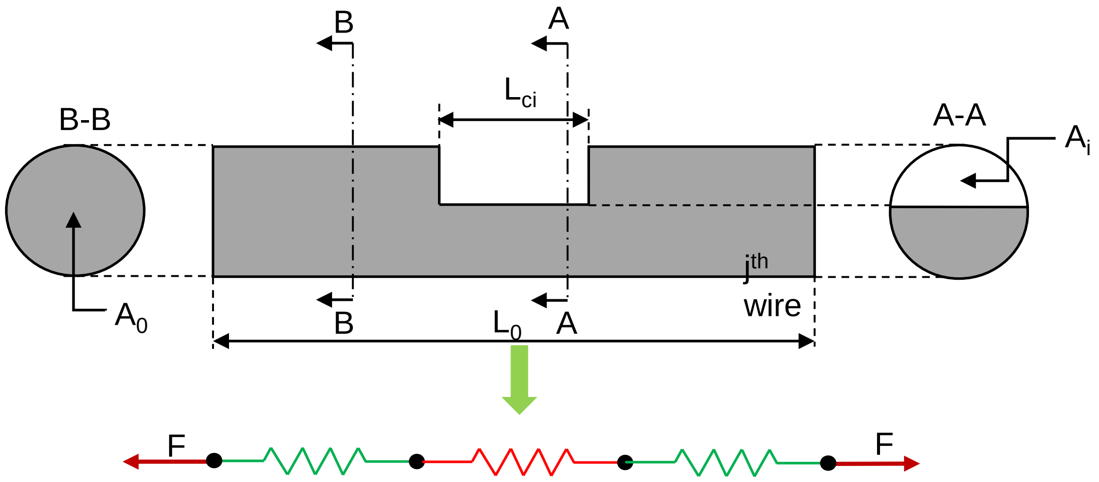
1. Wires are subjected only to tension force
2. Wires are straight (the contribution due to lay angle is neglected)

Steel material



- Material ductility: $\mu_{\varepsilon} = \varepsilon_u / \varepsilon_y$
- Hardening coefficient: r

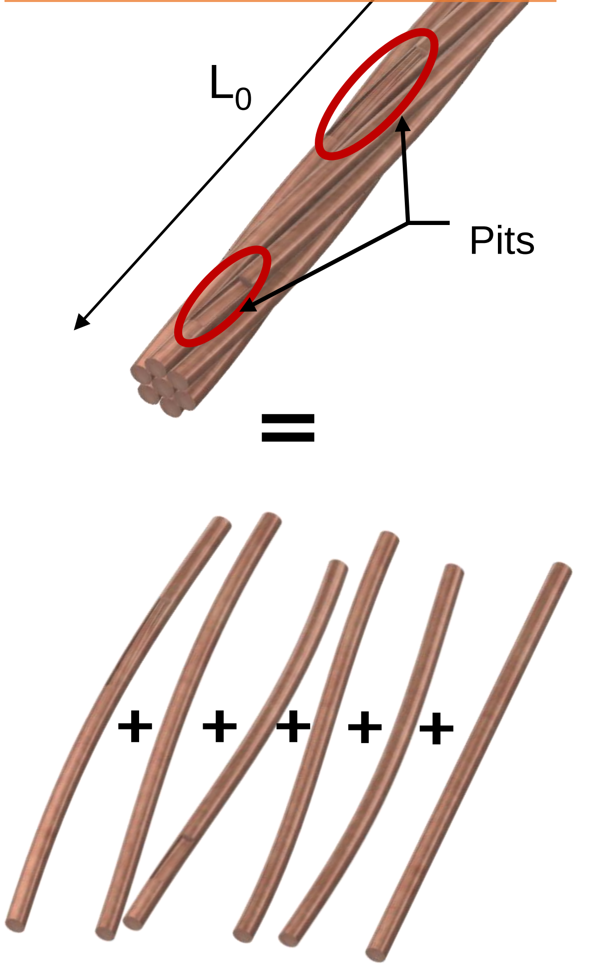
Corrosion geometry



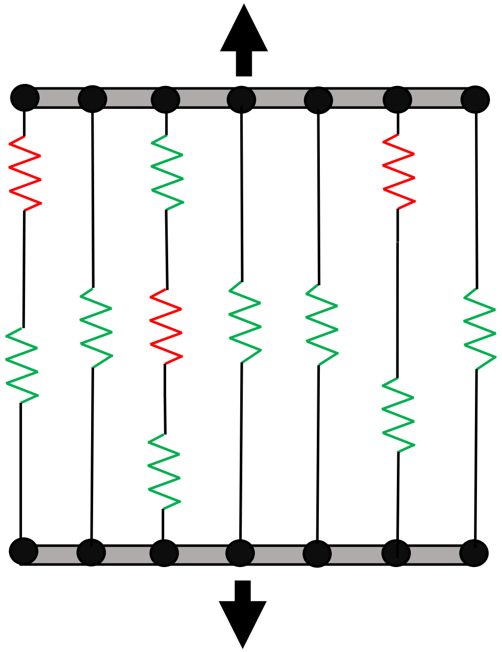
- adimensional reduction of cross-section area: $\rho_i = A_i / A_0$
- adimensional corrosion extension : $\lambda_i = L_{ci} / L_0$

Modelling approach

Corroded seven-wire strand



Model for corroded seven-wire strand

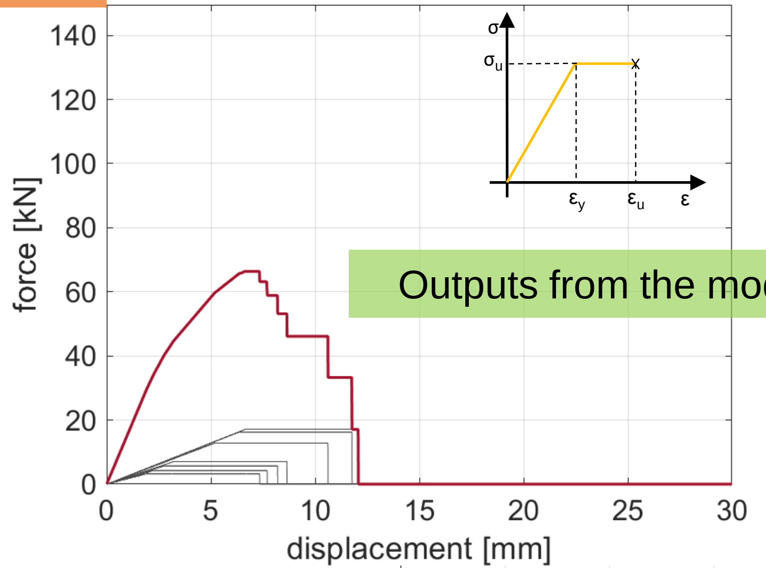


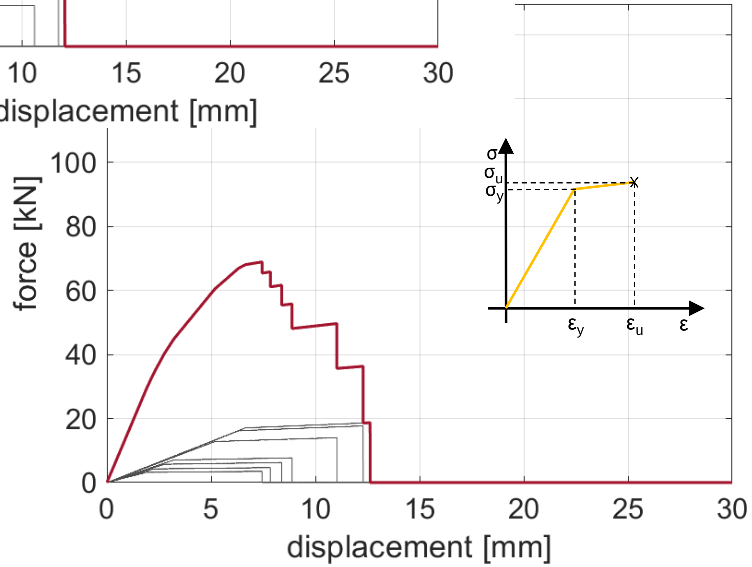
$K_{\text{not-corroded wire portion}}$

$K_{\text{corroded wire portion}}$

- Parallel system of seven wires

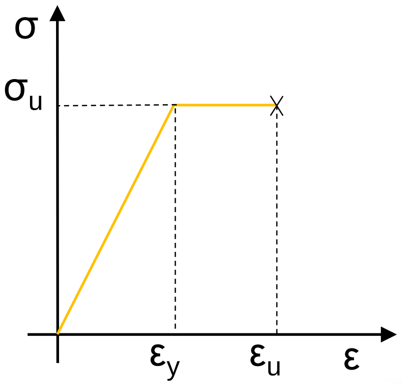
Outputs from the model for λ = 0.1





Corroded single wire behaviour: analytical evaluation

- Assumption of **elastic-perfectly plastic** steel material



- Closed analytical formulations

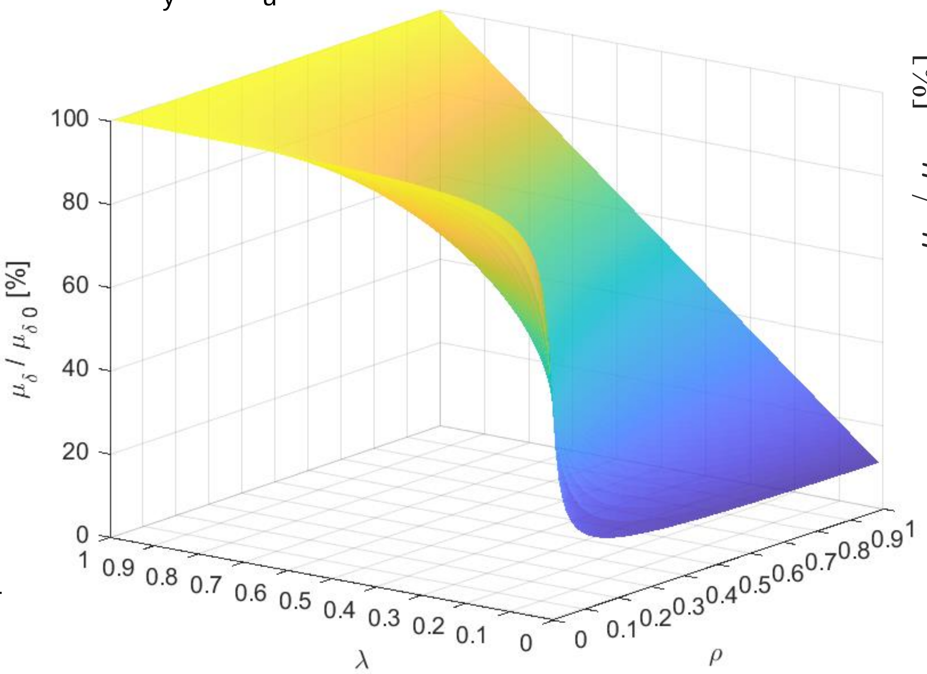
$$K = \frac{EA_0}{L_0}\left[\frac{1}{1+\lambda\left(\frac{1}{\rho}-1\right)}\right]$$

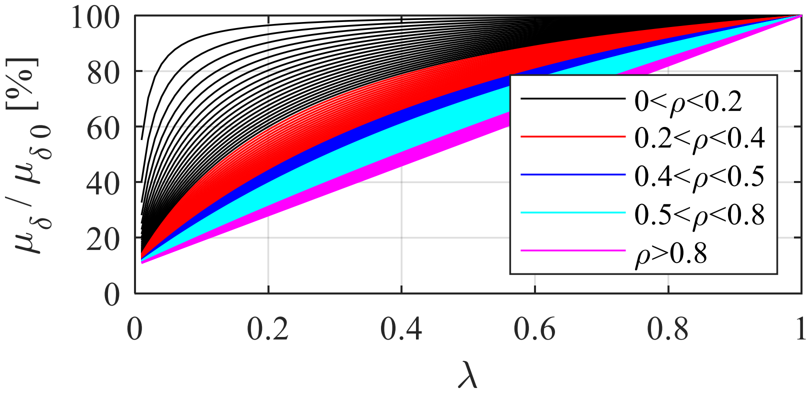
$$F_y = \rho \cdot f_y A_0$$

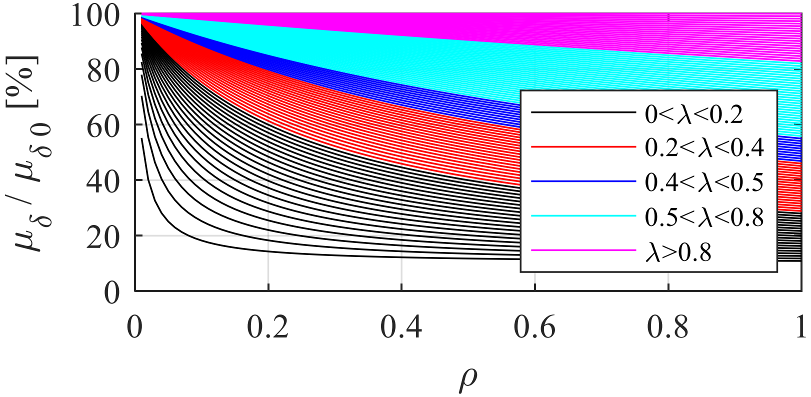
$$\delta_y = \rho \cdot \frac{f_y A_0}{K}$$

$$\delta_u = \delta_y + \left(\varepsilon_u - \varepsilon_y\right)\cdot \lambda \cdot L_0$$

$$\mu_\delta = \frac{\delta_u}{\delta_y} = 1 + \frac{\varepsilon_u - \varepsilon_y}{\varepsilon_y}\cdot \frac{\lambda}{\rho\left[1+\lambda\left(\frac{1}{\rho}-1\right)\right]}$$







- ρ effect: force reduction
- λ effect: ductility reduction
- Ductility reduction highly non linear for small (ρ, λ) values

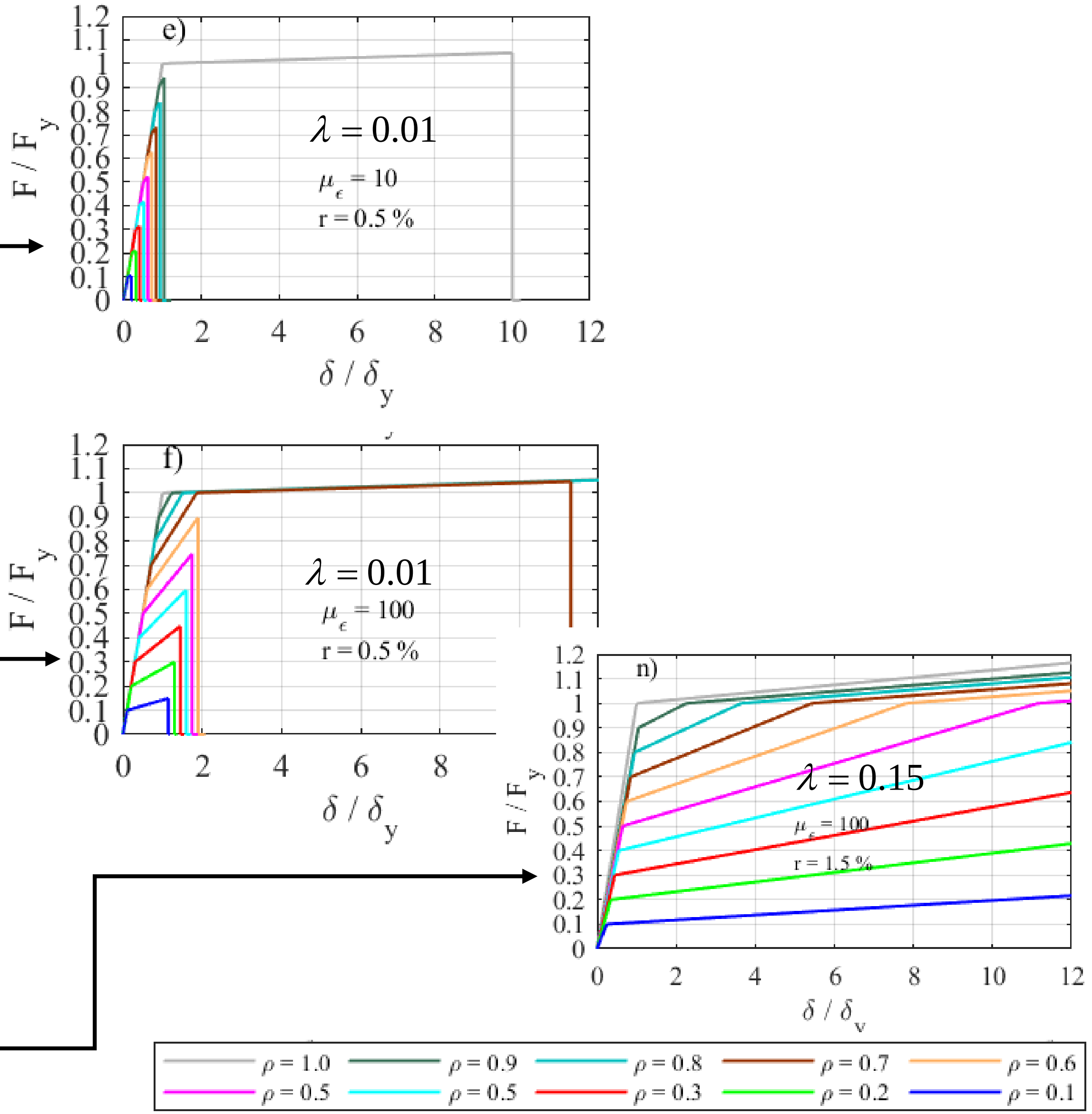
Corroded single wire behaviour: parametric study

Analysis conducted:

- Parametric study of corroded wires varying geometrical parameters of the corrosion (ρ, λ) and the material constitutive parameters *r* and μ_ε

Main results:

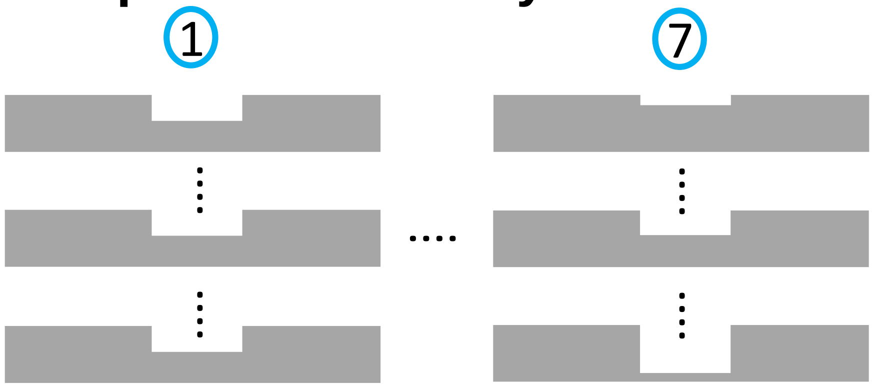
- ρ effect: force reduction
- λ effect: ductility reduction
- Low values of *r* and low values of μ_ε provide:
  - a negligible increase of maximum force
  - no redistribution of stresses between the corroded part and not-corroded ones
- Low values of *r* and high values of μ_ε provide:
  - an increase of maximum force and ultimate displacement
  - redistribution of stresses between the corroded part and not-corroded ones
- Higher values of λ and μ_ε can lead to a redistribution that occurs also for any value of ρ.



Corroded seven-wire strand behaviour: parametric study

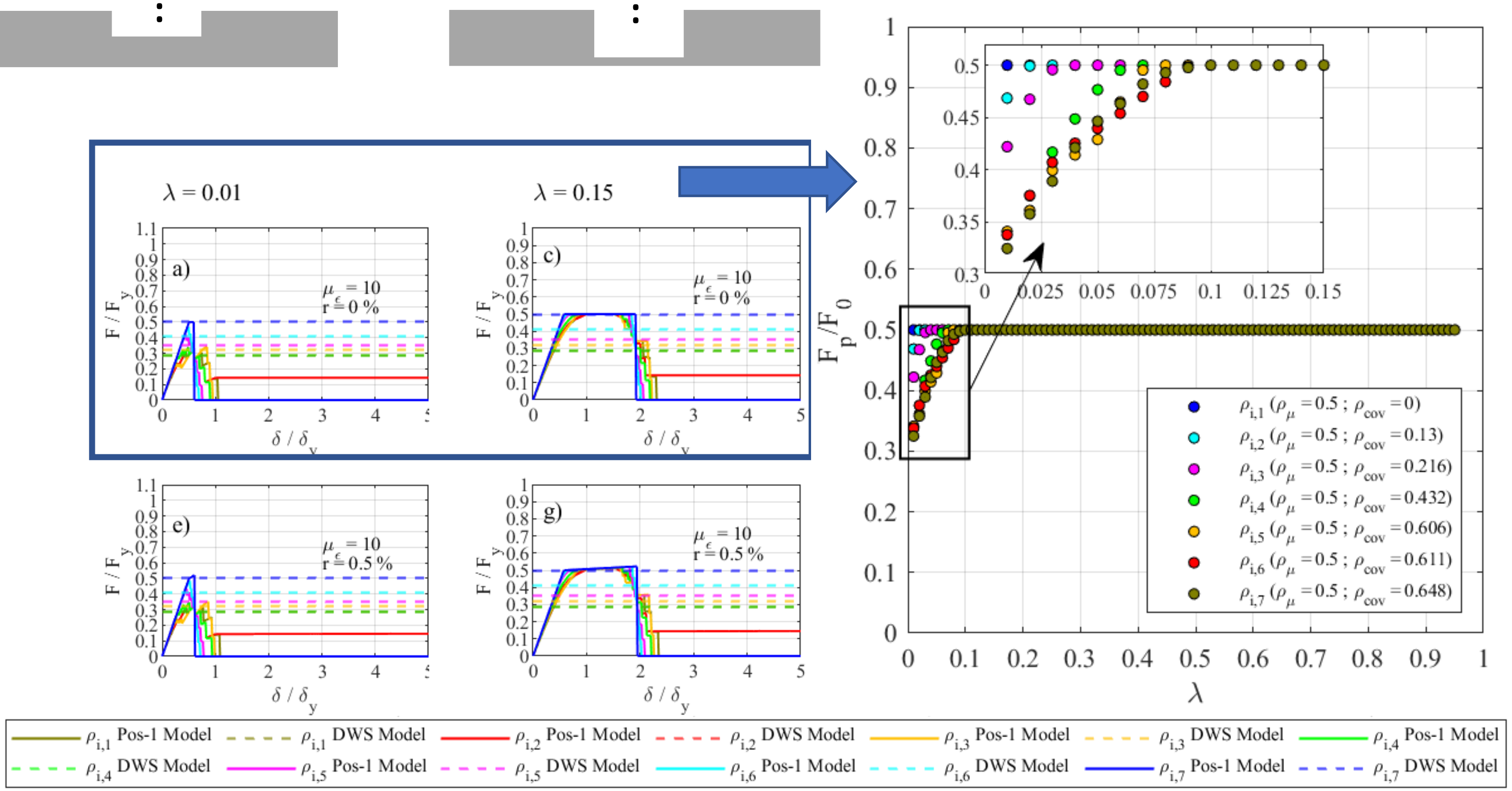
Analysis conducted:

- Parametric study based on seven scenarios, characterized by different variability of the corrosion in the wires $\rho_{cov,}$ and varying geometrical parameters of corrosion (ρ, λ) and material constitutive parameters (*r*, μ_ε)



Main results:

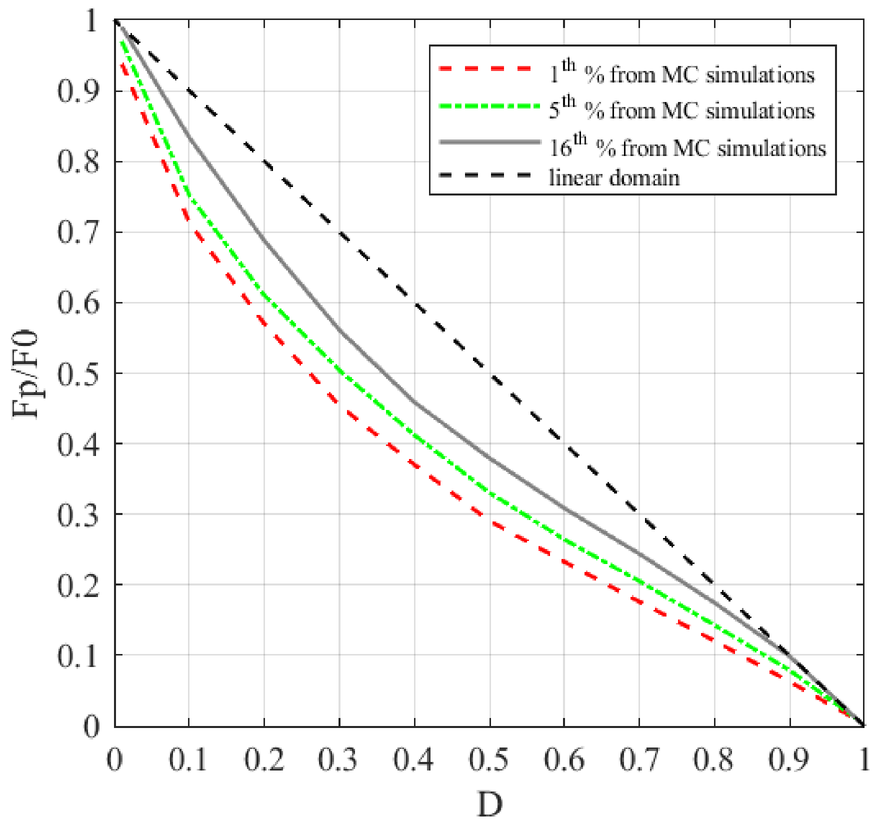
- Strands behaviour governed by the couple (ρ, λ)
- Effects of the steel material parameters result to be negligible
- Elastic-perfectly plastic and bi-linear steel materials are comparable
- Variability in the corrosion of the wires strand provide different force reductions
- Darmawan-Stewart estimation provides reasonable lower bound values for the peak strength



Corroded seven-wire strand behaviour: parametric study

Ongoing studies

- MonteCarlo simulations are currently under development to assess the effect of corrosion variability on the peak strength of the corroded strands.
- The first results leads to the identification of an updated peak strength domain (w.r.t. the ones proposed so far in literature).



Main remarks and future studies

- The mechanical model here introduced is able to describe the force-displacement response of corroded strands.
- Key parameters governing the behaviour of corroded strands are the geometrical parameters of the corrosion (ρ,λ) and the material constitutive parameters (μ_ε , r).
- The peak strength reduction is highly affected (in addition to average corrosion level D) by the variability of the corrosion in the wires $\rho_{cov.}$
- The detailed evaluation of the effect of this variability is the objective of future studies.
- The peak strength reduction domain might be incorporated into future code-like formulas.

Grazie per l'attenzione!

matteo.marra6@unibo.it