



Modellazione del comportamento di superfici sportive sintetiche

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Brescia, 14/03/2023

Laboratorio di ingegneria dei polimeri



R. Frassine



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O. Bressan

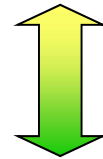


A. Pavan



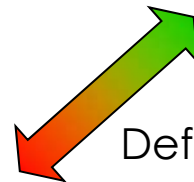
M. Rink

Applicazioni



Sviluppo e standardizzazione di
metodi di prova

Proprietà

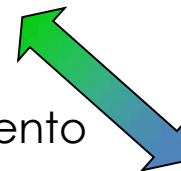


Deformazione, Snervamento
Frattura, Reologia

Microstruttura



Trasformazione



Tecniche sperimentali

MECHANICAL

tension, bending, compression, shear, creep, fatigue, DMA, TMA, impact, wear, friction, hardness

RHEOLOGICAL

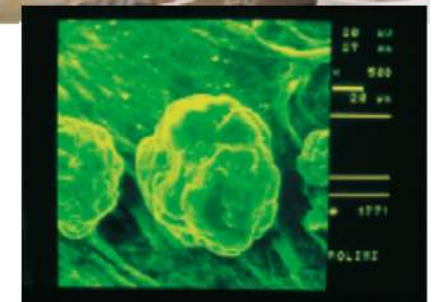
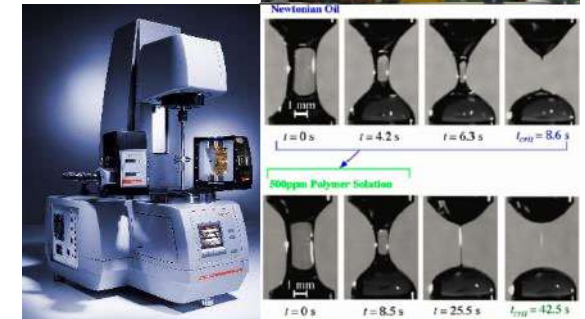
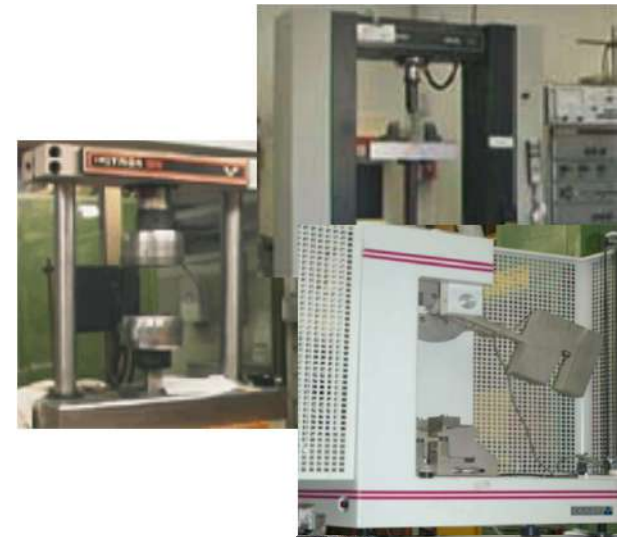
rotational and extensional viscosity, MFI, high pressure dilatometry (PVT)

PHYSICO-CHEMICAL

FT-IR, GPC, chemical resistance, composition, DSC, DTA, accelerated chemical and physical aging

FAILURE ANALYSIS

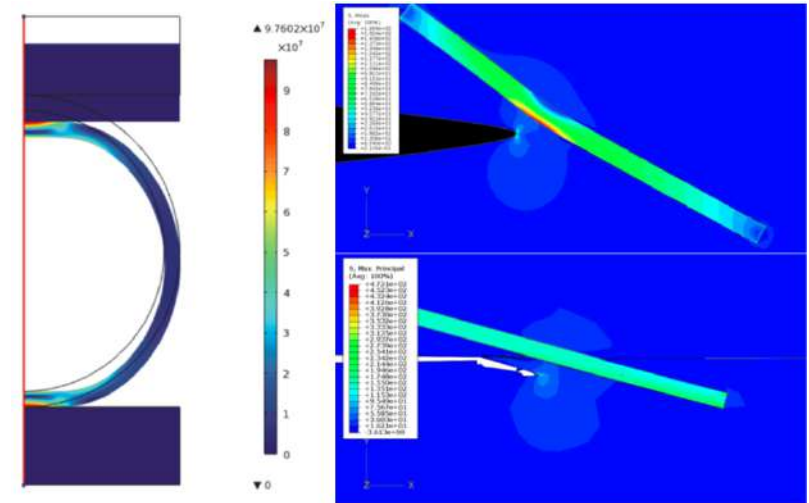
fractography, case histories, fracture mechanics, damage analysis, residual lifetime



Analisi numerica

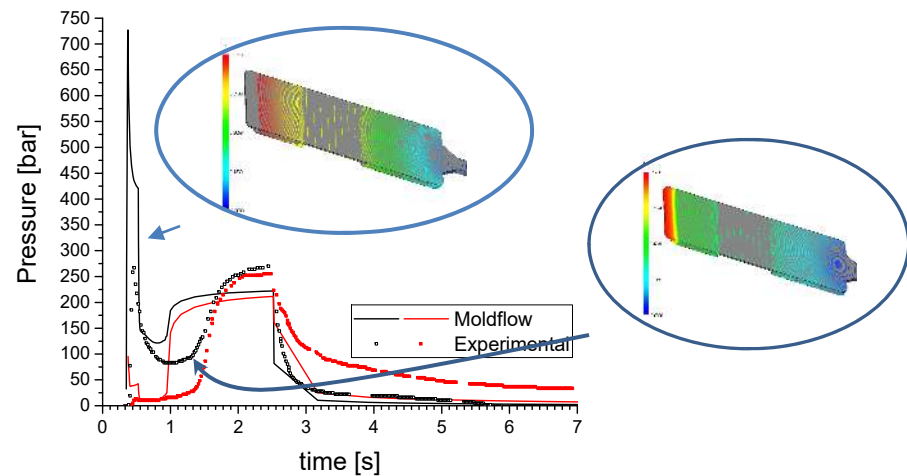
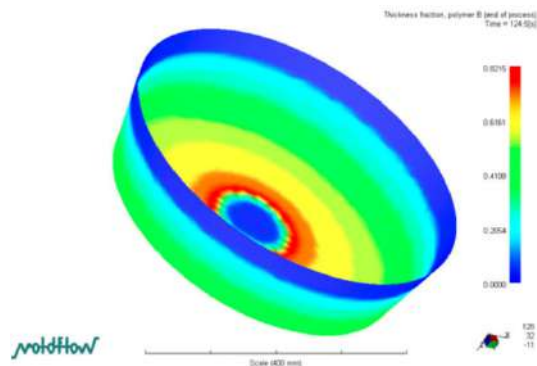
MECHANICAL BEHAVIOUR SIMULATION

Small deformation, yielding and fracture,
quasi-static and dynamic simulations
viscoelastic or elastic, linear or non-linear behaviour



PROCESS SIMULATION

Injection moulding of polymers



Requisiti delle superfici sportive

Le piste devono garantire **sicurezza** e **prestazioni**

- Restituzione energia
- Assorbimento urti
- Estetica
- Attrito



Costruzione delle piste

Due famiglie principali:

Sistemi prefabbricati

Miscela di gomme sintetiche con cariche e additivi minerali, calandrate e reticolate in condizioni controllate, tipicamente con un più strati e una struttura geometrica per ottimizzare il comportamento



Sistemi in-situ

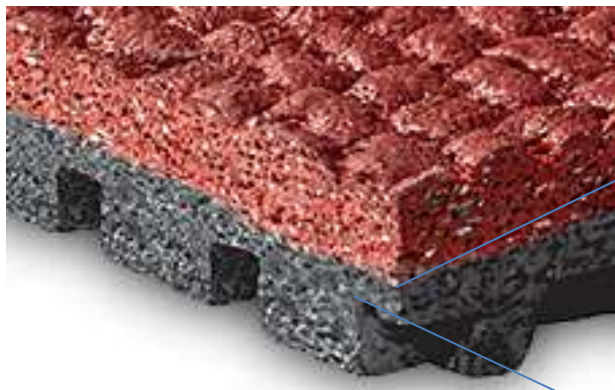
Granuli di gomma inglobati in una resina poliuretetica con un rivestimento spruzzato sulla superficie



Costruzione delle piste

Sistemi prefabbricati

Miscela di gomme sintetiche con cariche e additivi minerali, calandrate e reticolate in condizioni controllate, tipicamente con un più strati e una struttura geometrica per ottimizzare il comportamento



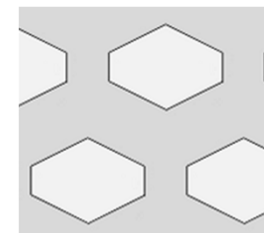
Strato superiore

- Durabilità
- Attrito

Strato inferiore

- Assorbimento urti
- Restituzione energia

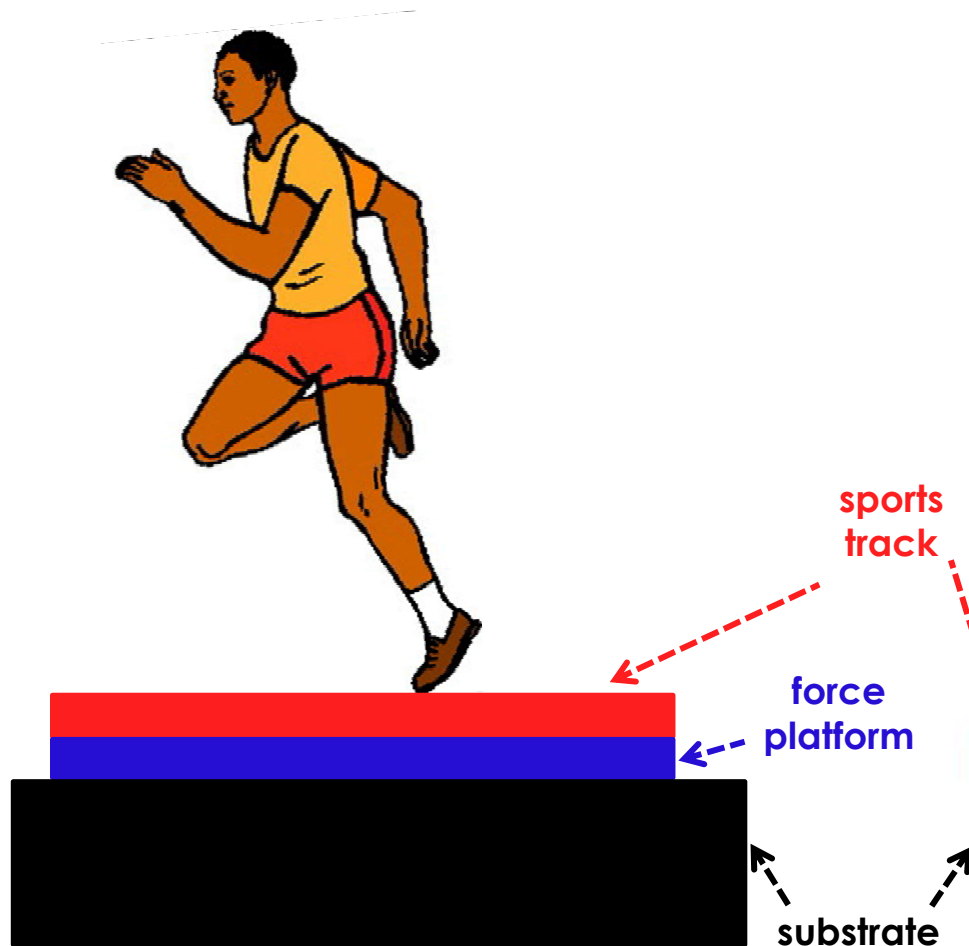
Struttura alveolare



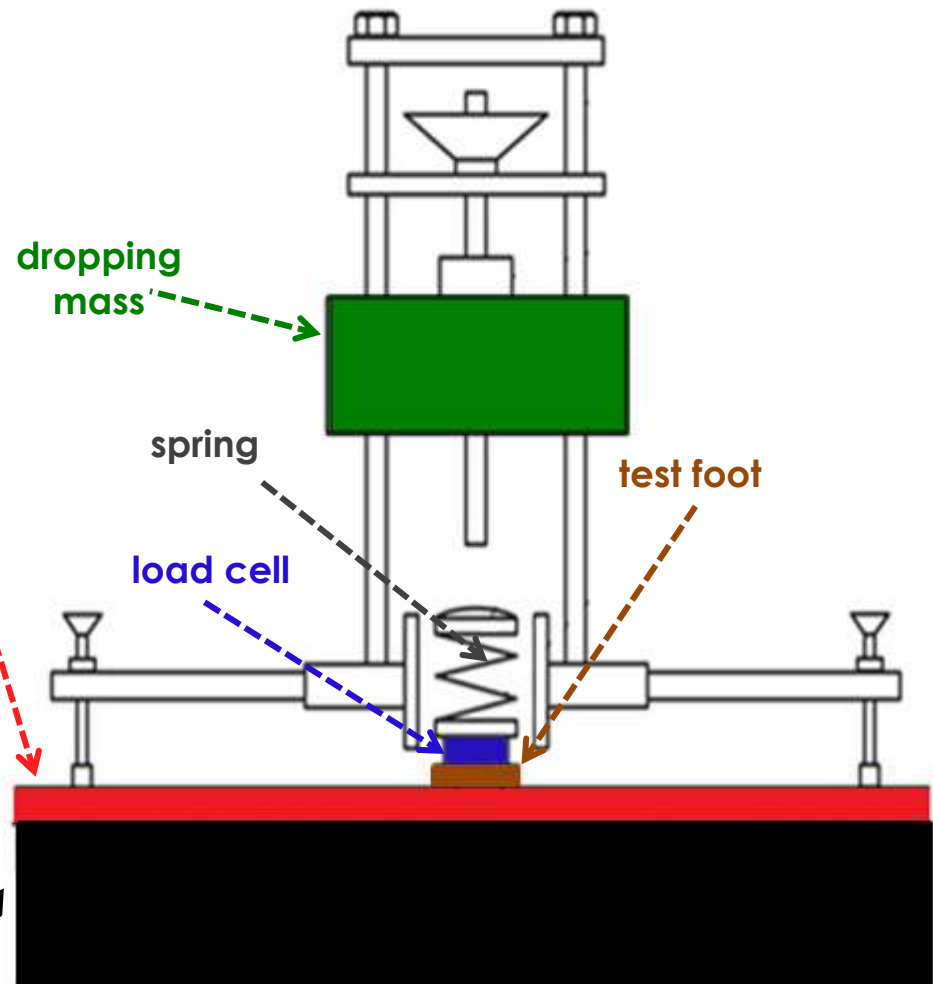
 **MONDO**

Caratterizzazione delle piste

Test su atleta



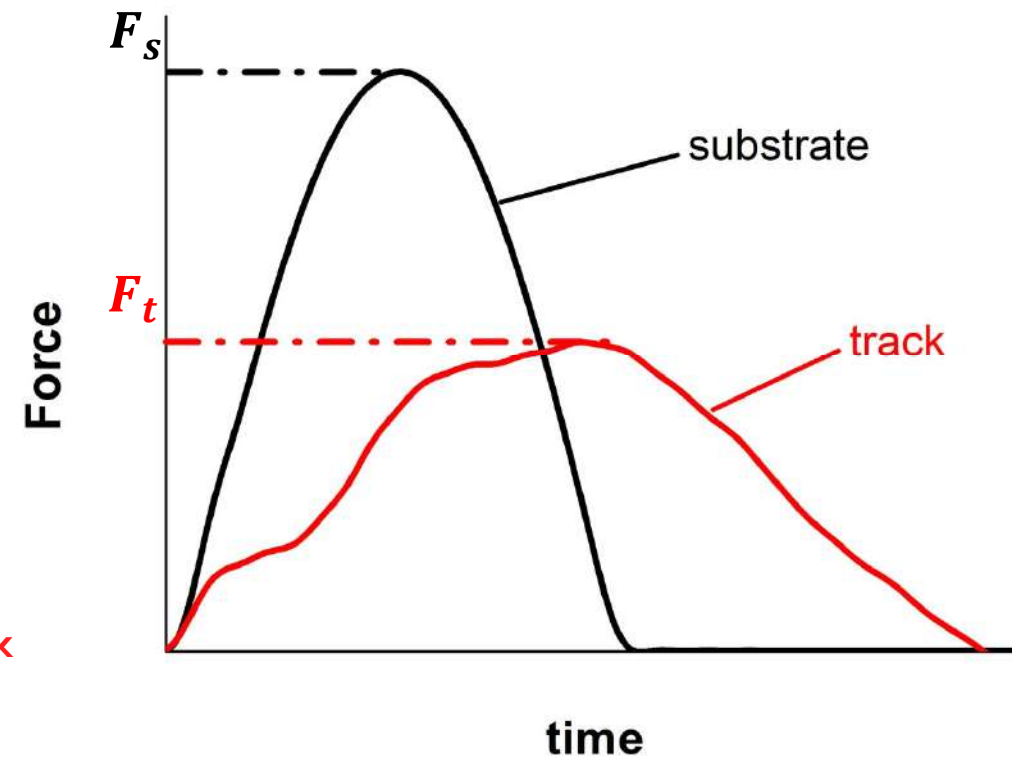
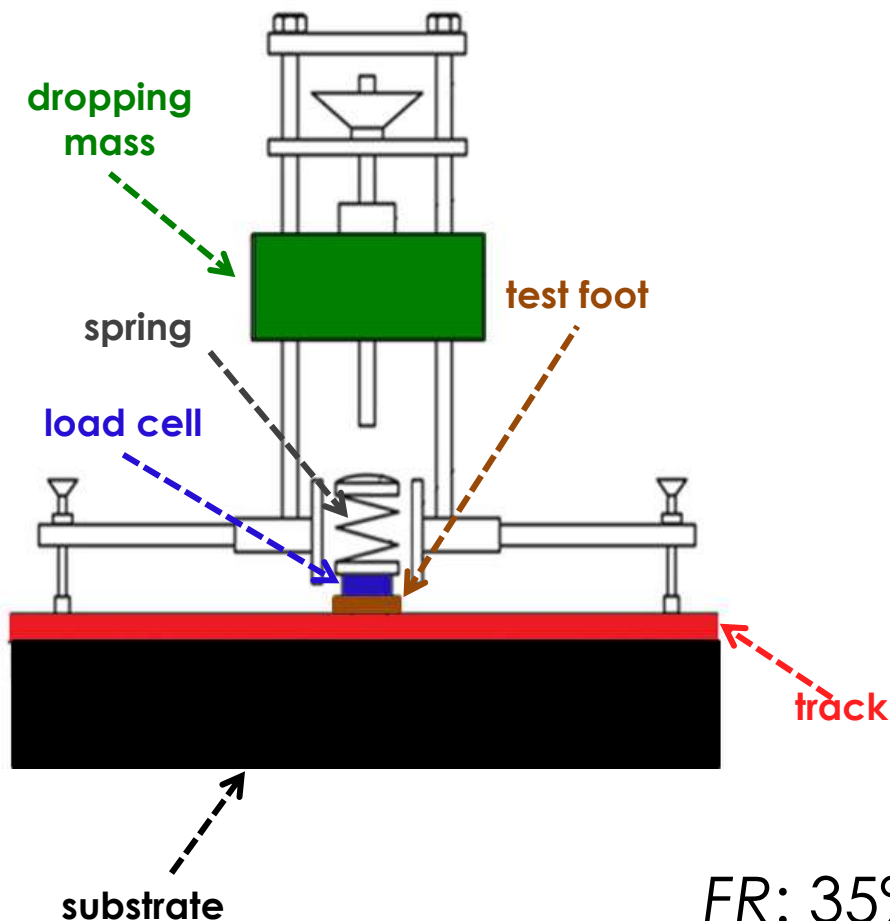
Test su materiali Atleta Artificiale



Omologazione delle piste – *Force Reduction*

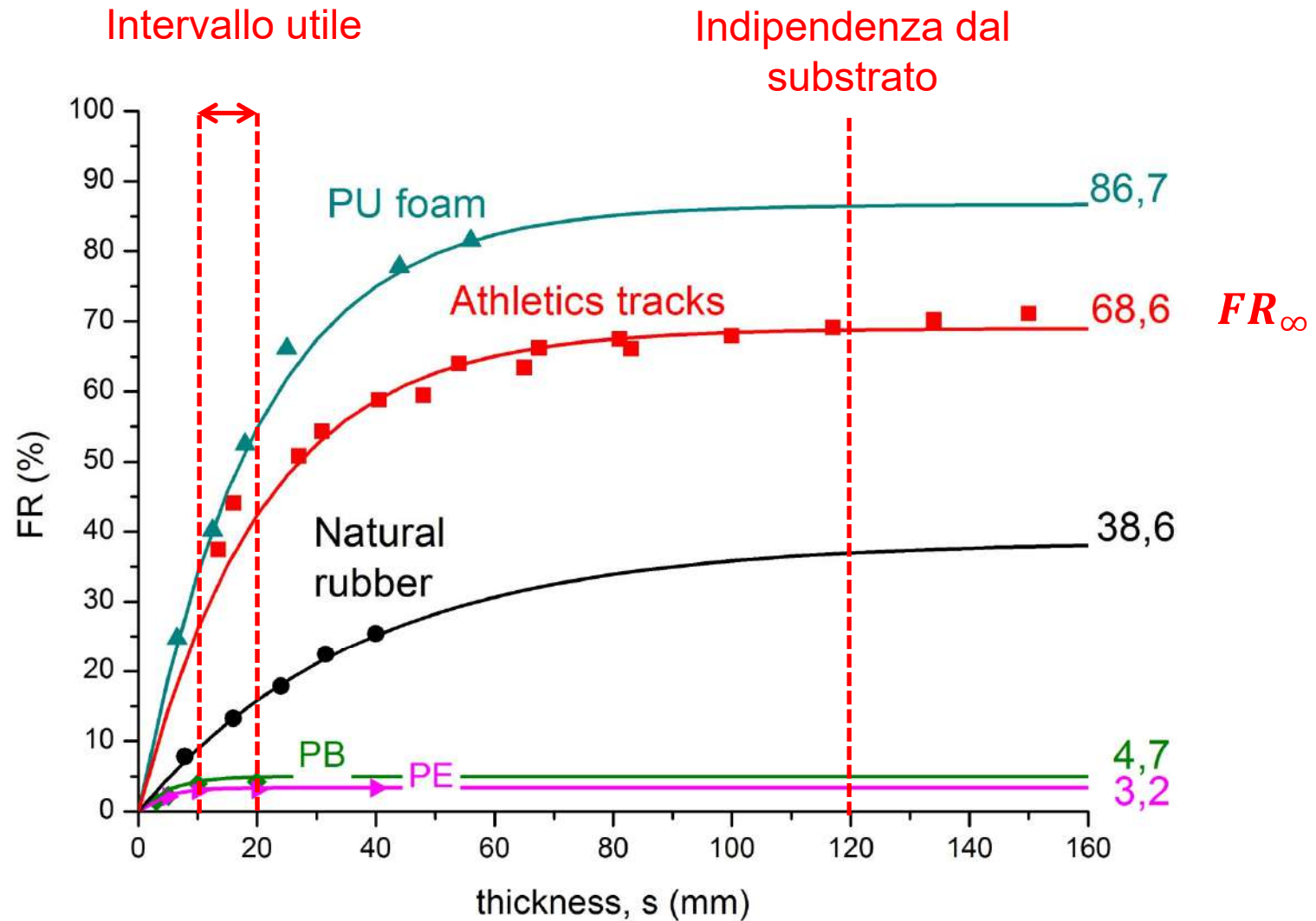
Artificial Athlete

$$FR = \left(1 - \frac{F_t}{F_s}\right) \times 100$$



FR: 35%-50%

Effetto dello spessore

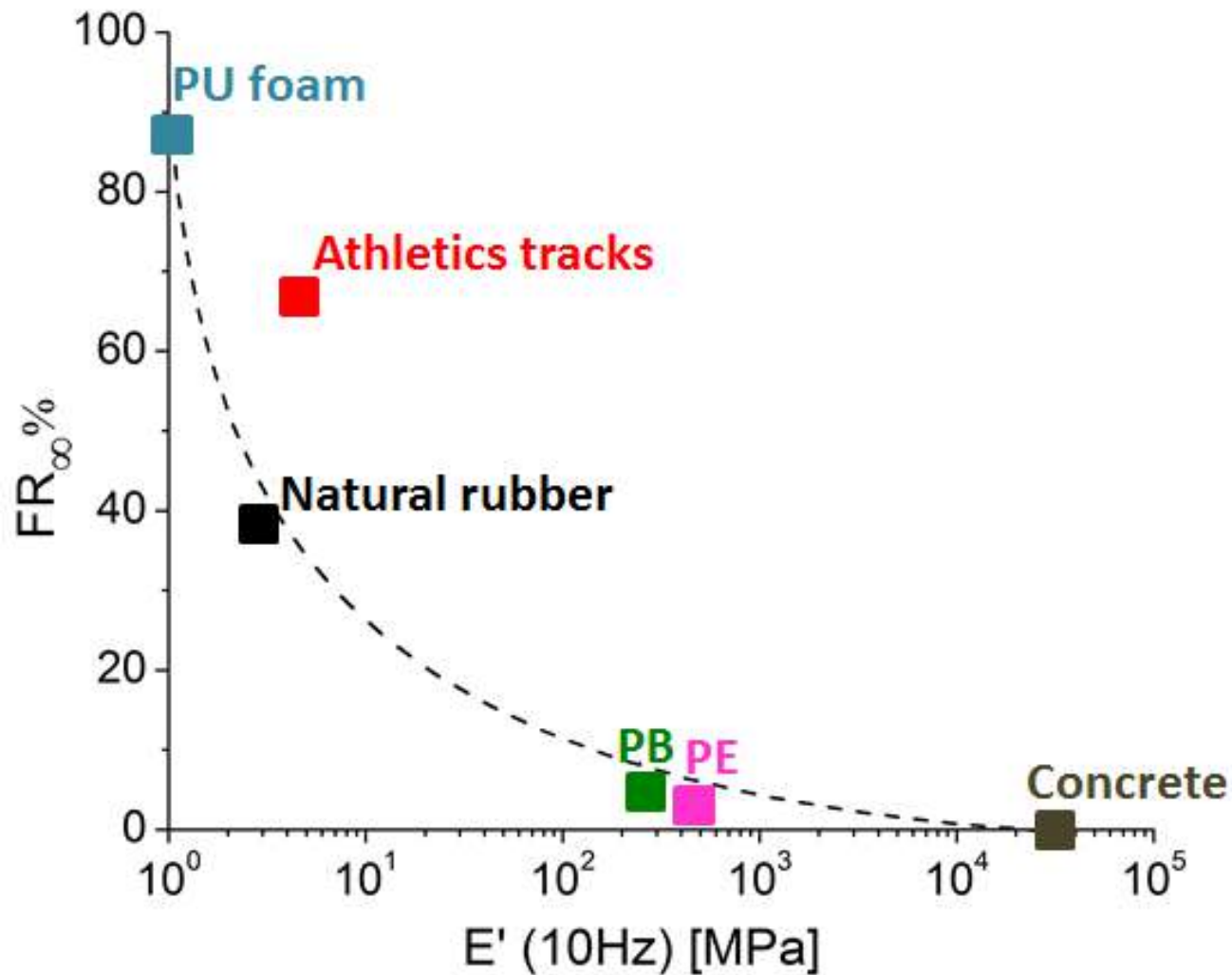


$$FR(s) = FR_{\infty} \left(1 - e^{-\frac{s}{s_0}}\right)$$

Viscoelastic behavior of athletics track surfaces in relation to their force reduction

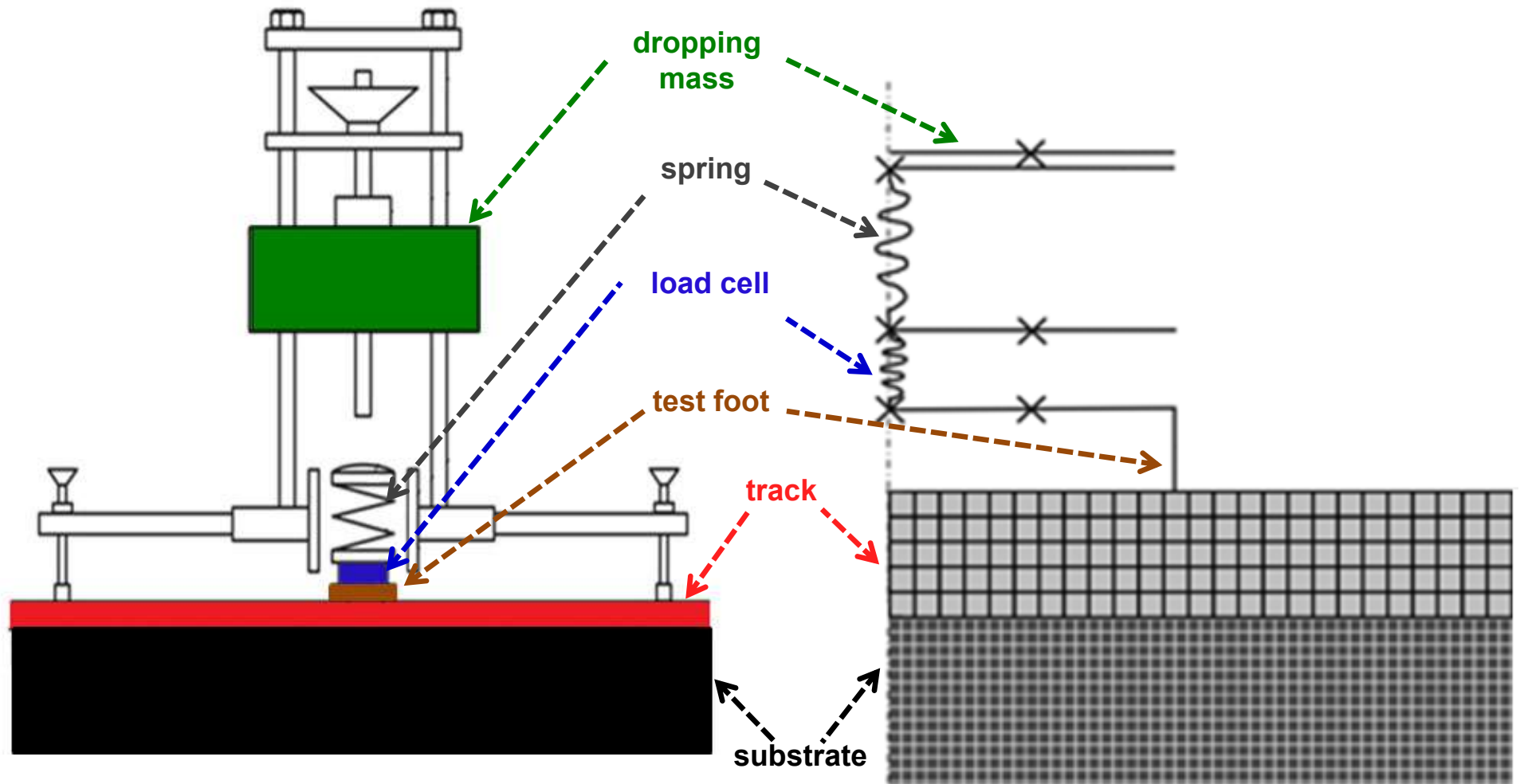
M. Benanti, L. Andena, F. Briatico-Vangosa, A. Pavan; *Polymer Testing* (2013)

Effetto del materiale



↓
Modulo elastico

Modello numerico ad elementi finiti (2D)

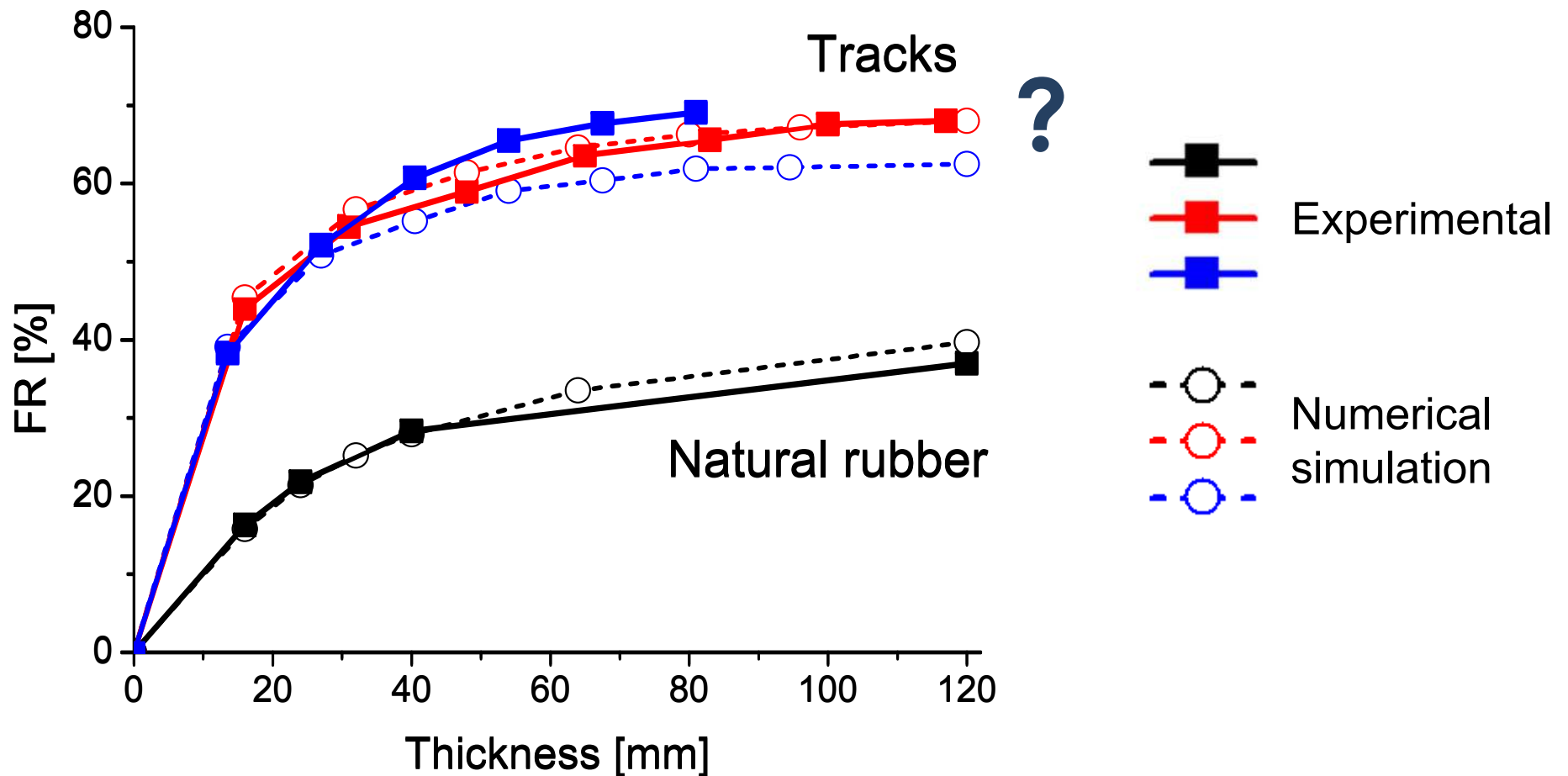


Modeling of shock absorption in athletics track surfaces

L. Andena, F. Briatico-Vangosa, E. Cazzoni, A. Ciancio, S. Mariani, A. Pavan; *Sports Engineering* (2015)

Modello numerico ad elementi finiti (2D)

Il modello 2D assialsimmetrico consente di prevedere FR



Modeling of shock absorption in athletics track surfaces

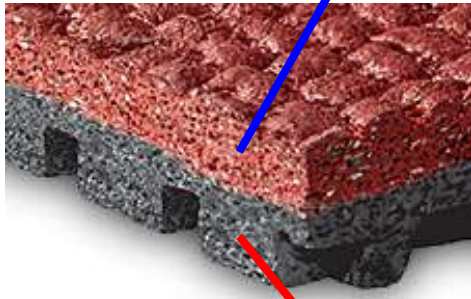
L. Andena, F. Briatico-Vangosa, E. Cazzoni, A. Ciancio, S. Mariani, A. Pavan; *Sports Engineering* (2015)

Geometria

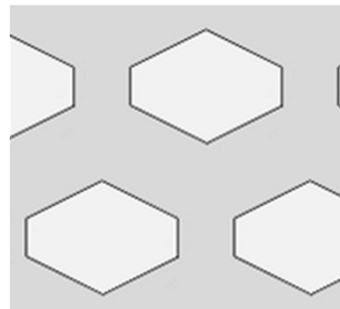
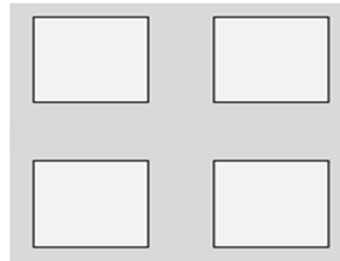
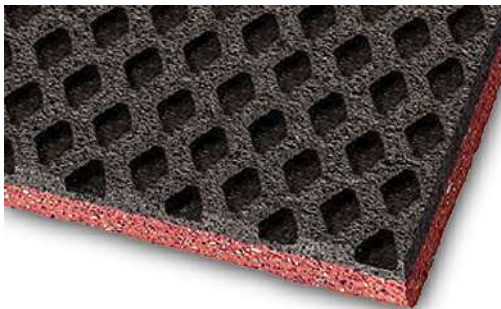
- Spessore
- Multistrato
- Struttura alveolare



Strato superiore

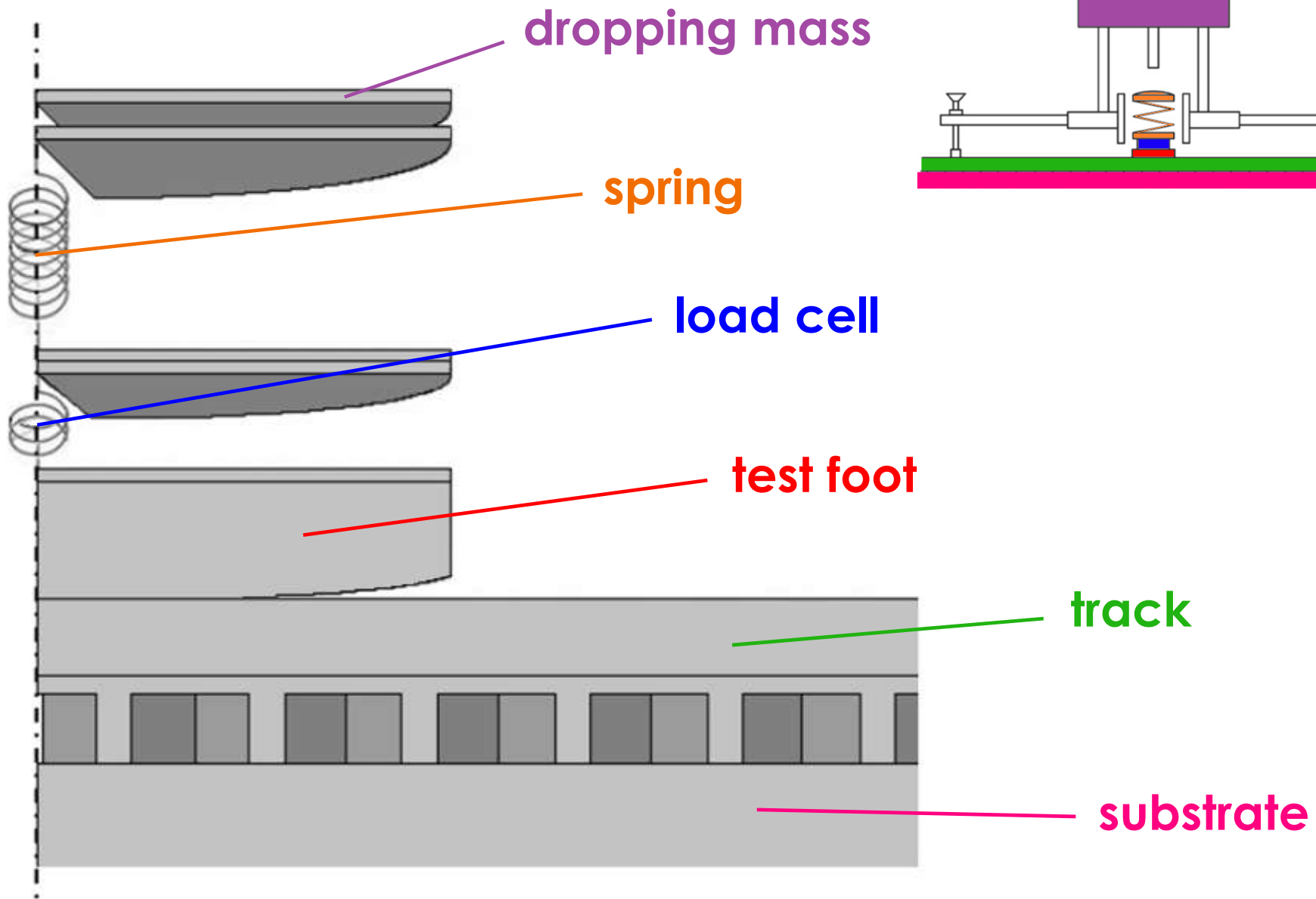


Strato inferiore

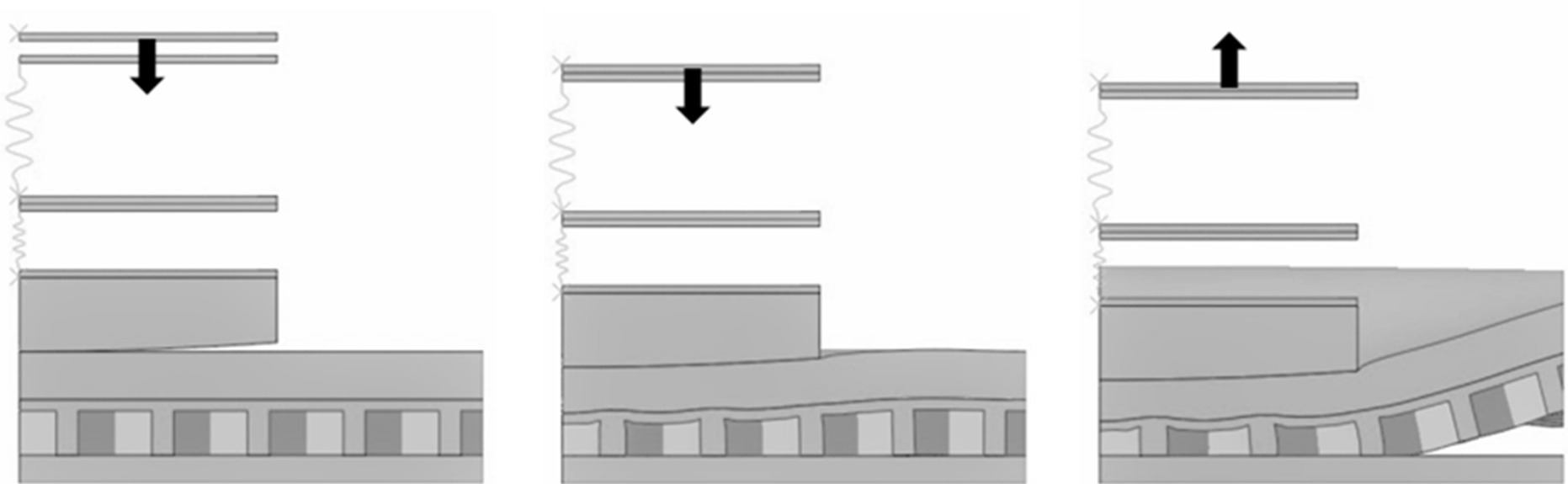


Non
riproducibile
con modello
2D!

modello 3D



modello 3D



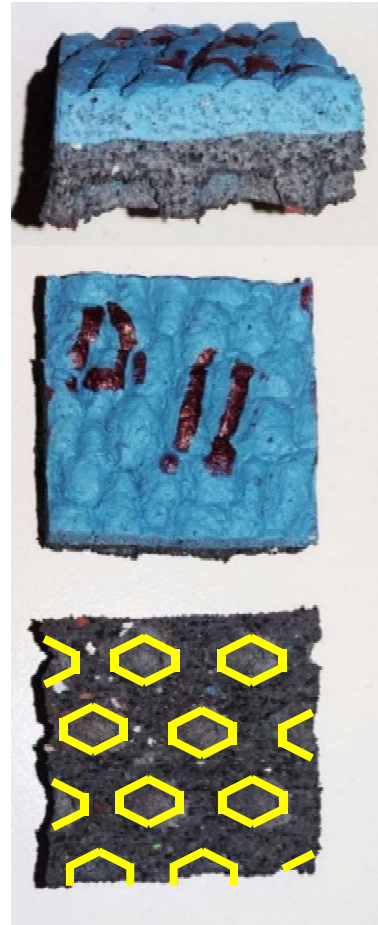
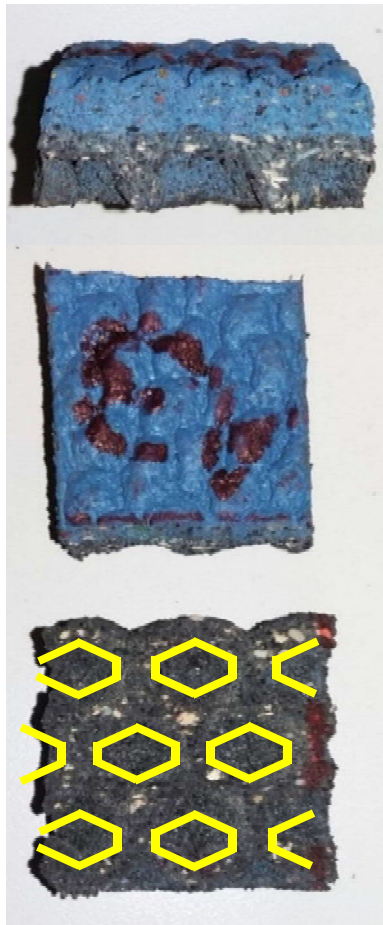
Materiali



Mondotrack 1

Mondotrack 2

Mondotrack 3

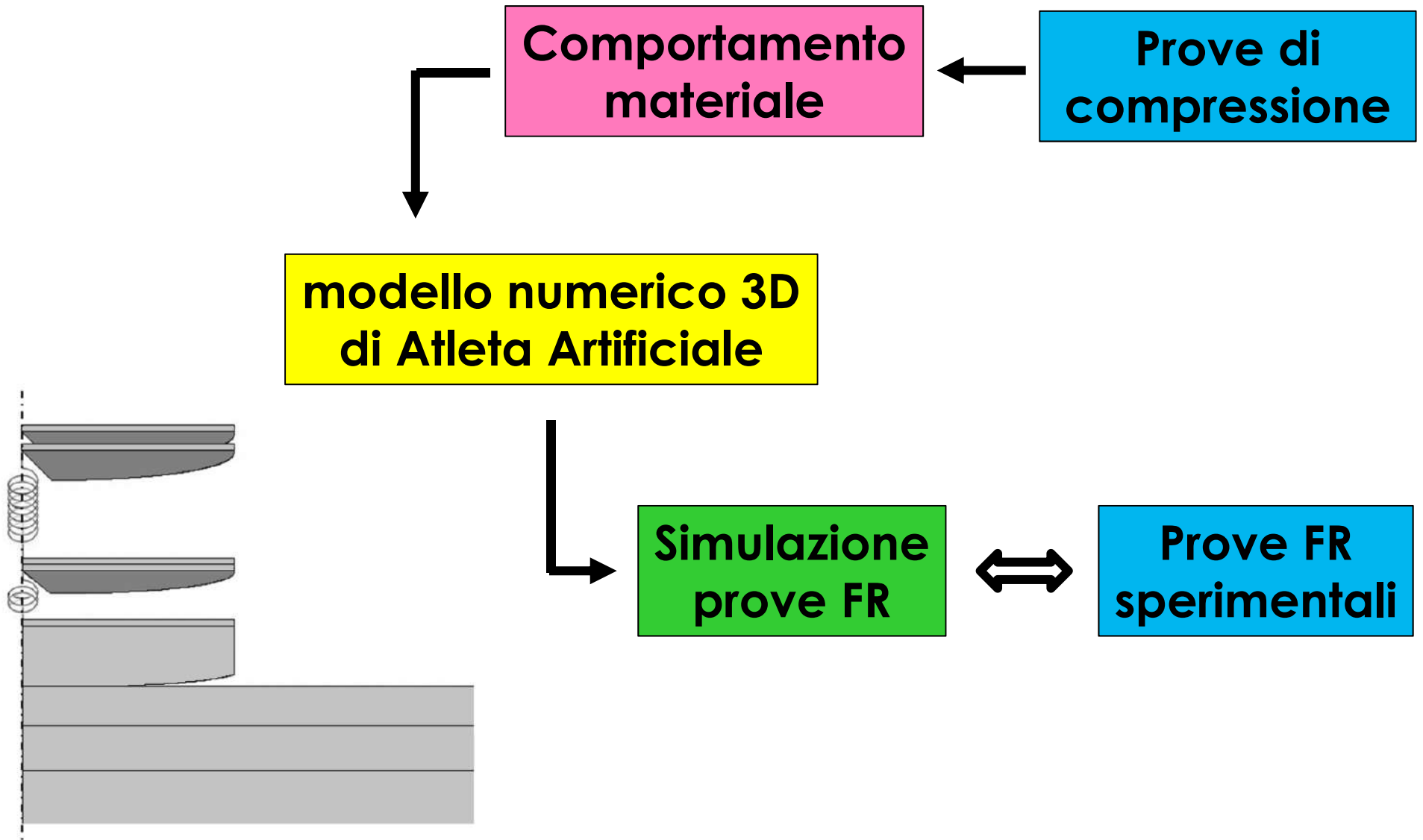


→ Completa

→ Superiore

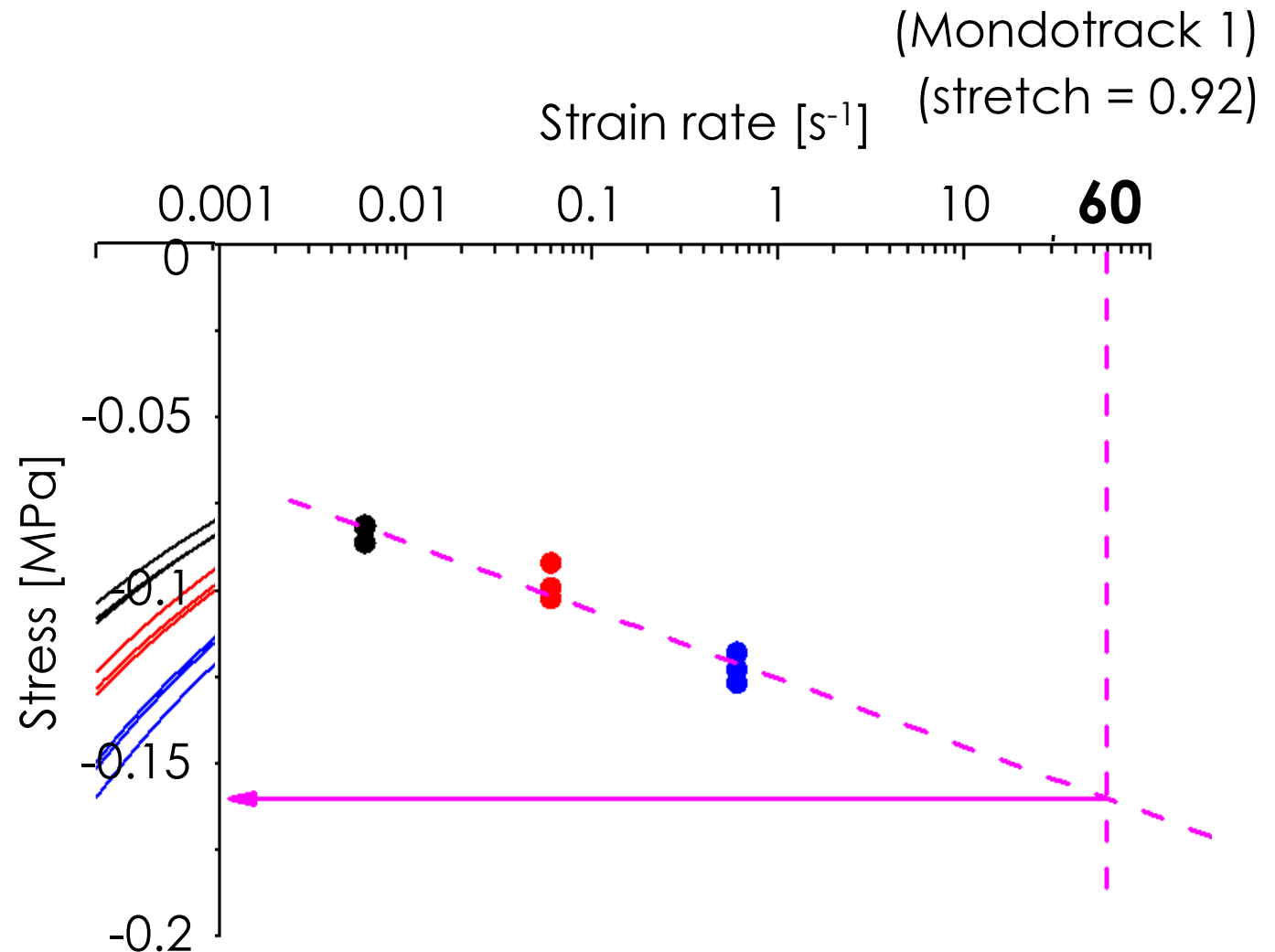
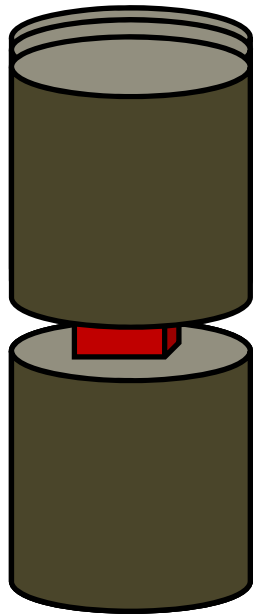
→ Inferiore

Modello 3D omogeneizzato



Caratterizzazione dei materiali

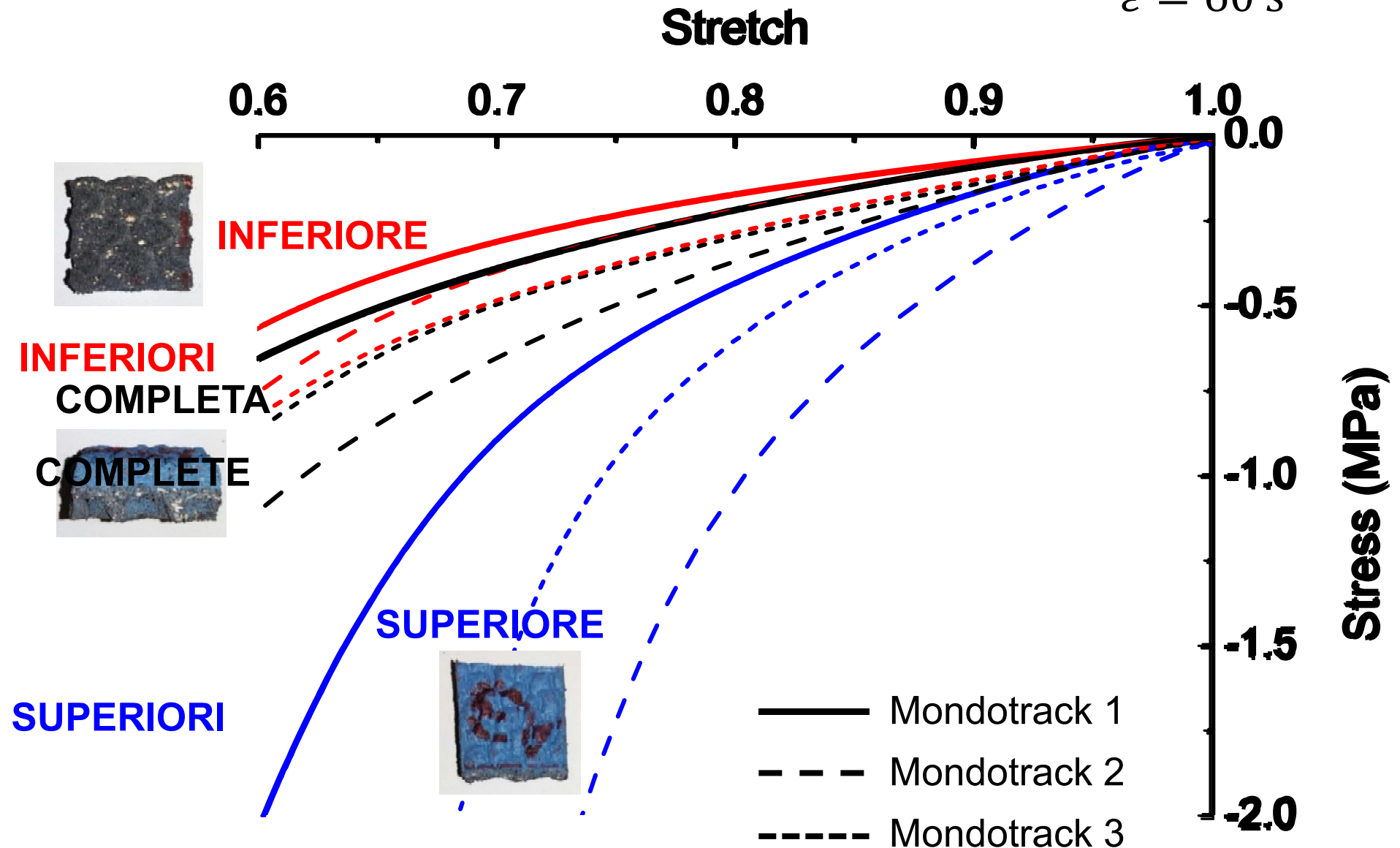
1. Prove di compressione a velocità diverse (0.006 , 0.06 e 0.6 s^{-1})
2. Estrapolazione dei dati a 60 s^{-1}



Caratterizzazione dei materiali

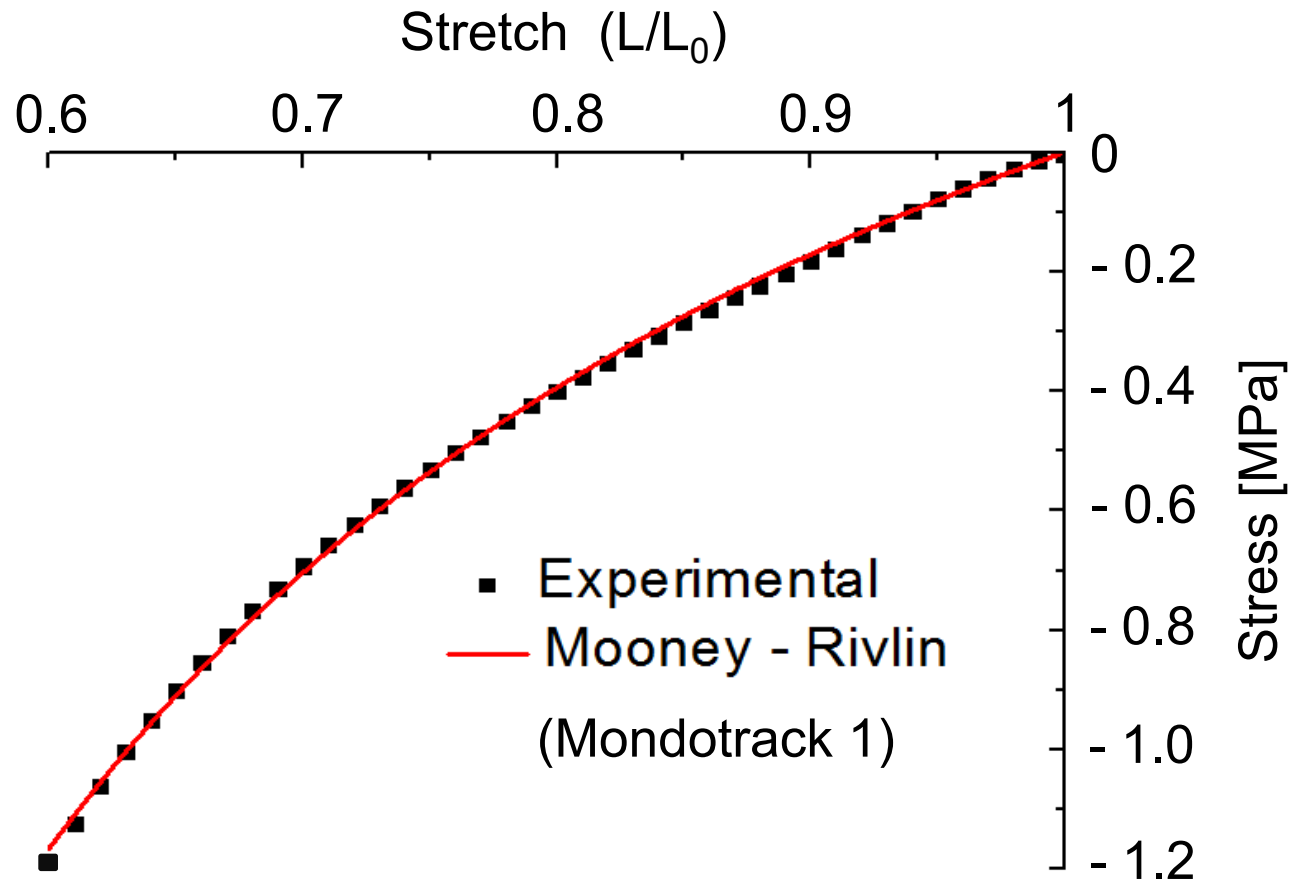
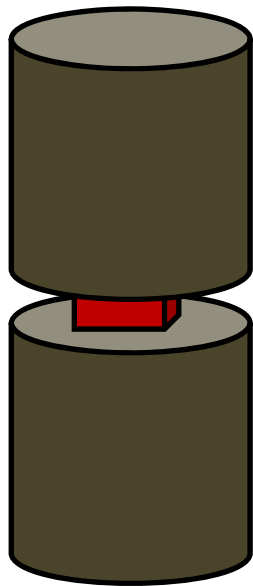
(Mondotrack 1)

$$\dot{\varepsilon} = 60 \text{ s}^{-1}$$



Caratterizzazione dei materiali

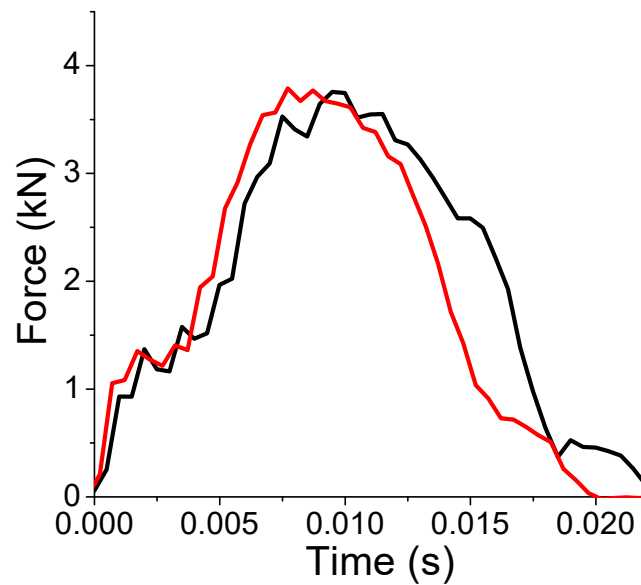
1. Prove di compressione a velocità diverse (0.006 , 0.06 e 0.6 s^{-1})
2. Estrapolazione dei dati a 60 s^{-1}
3. Interpolazione con modelli iperelastici
(Mooney – Rivlin, Ogden...)



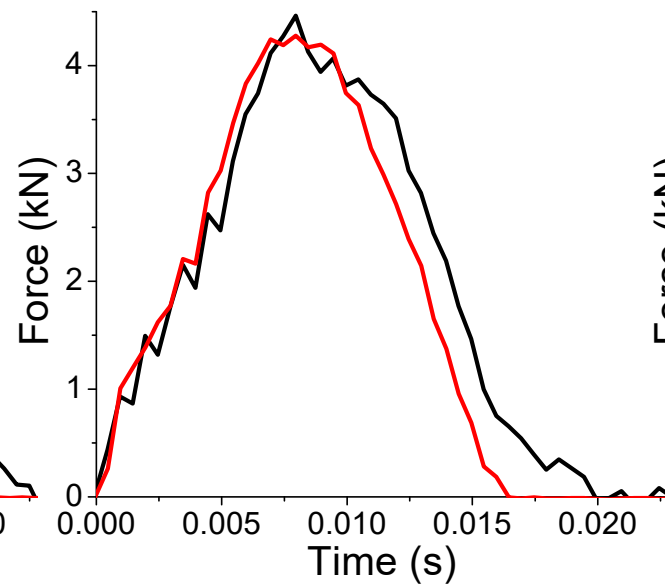
Prove con AA

— sperimentale
— modello numerico

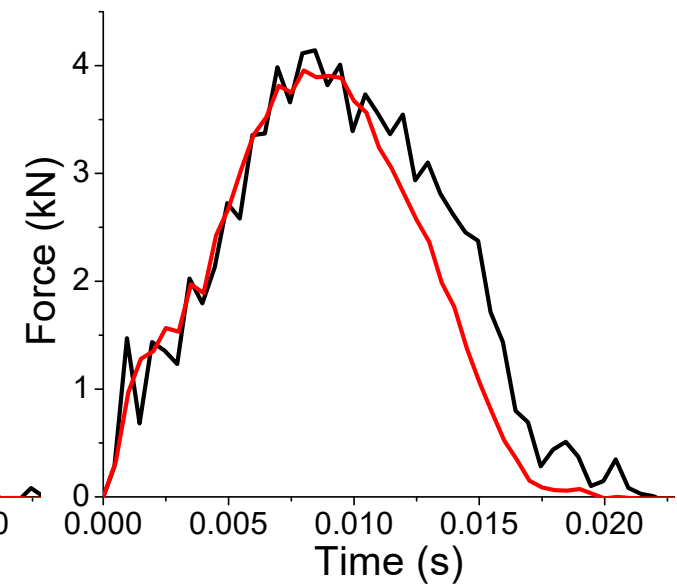
Mondotrack 1



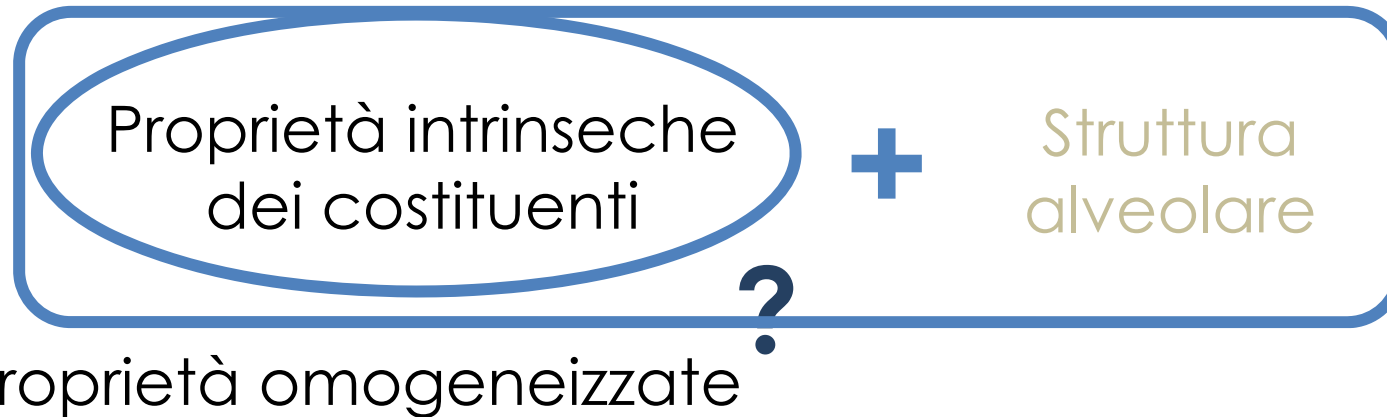
Mondotrack 2



Mondotrack 3



Modellazione della struttura

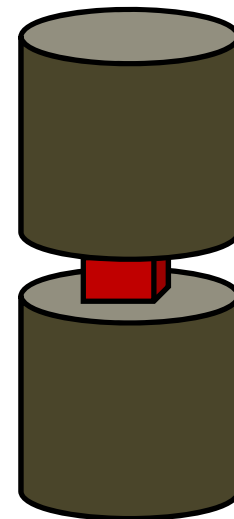
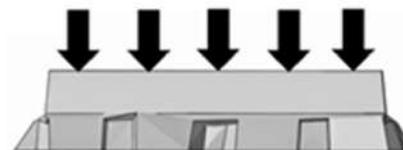
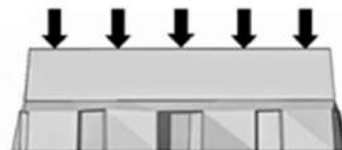


~~1. Misura sperimentale diretta~~

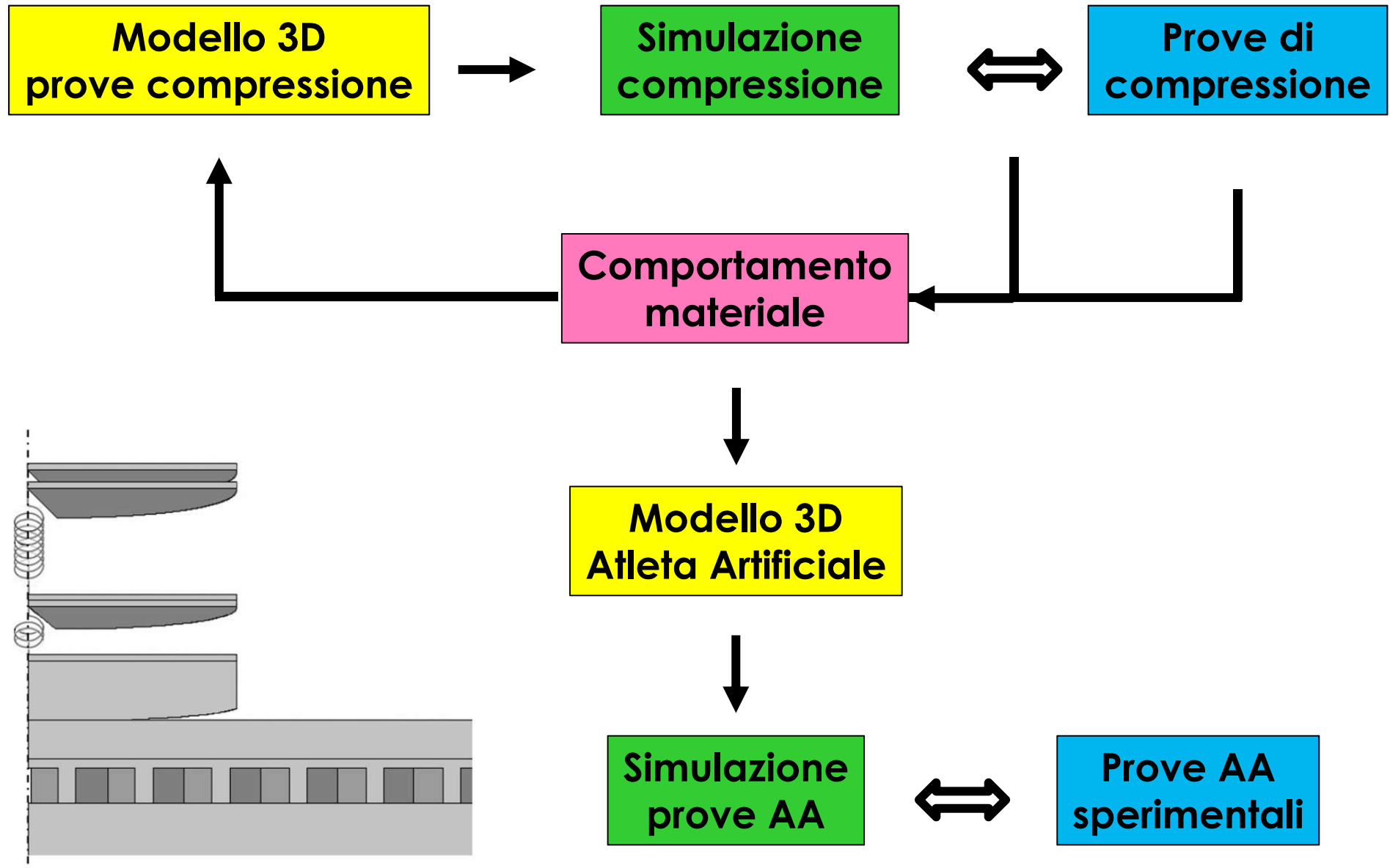


Impossibile
ricavare dei
campioni

2. Identificazione parametrica
(attraverso modello numerico)



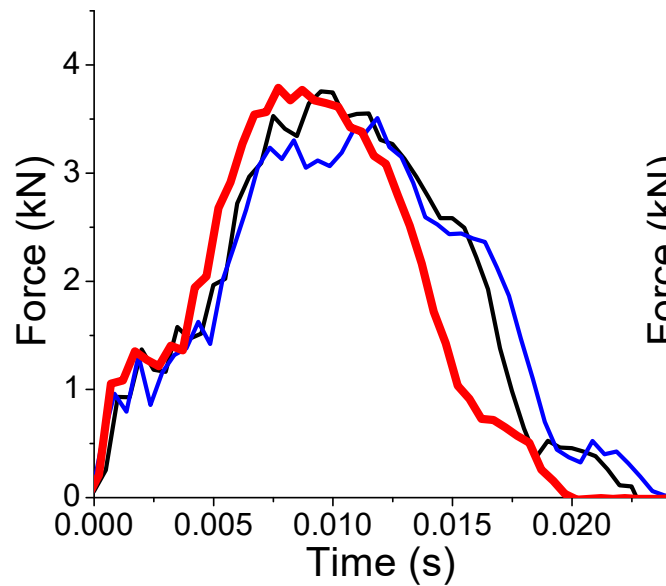
Modello 3D con struttura



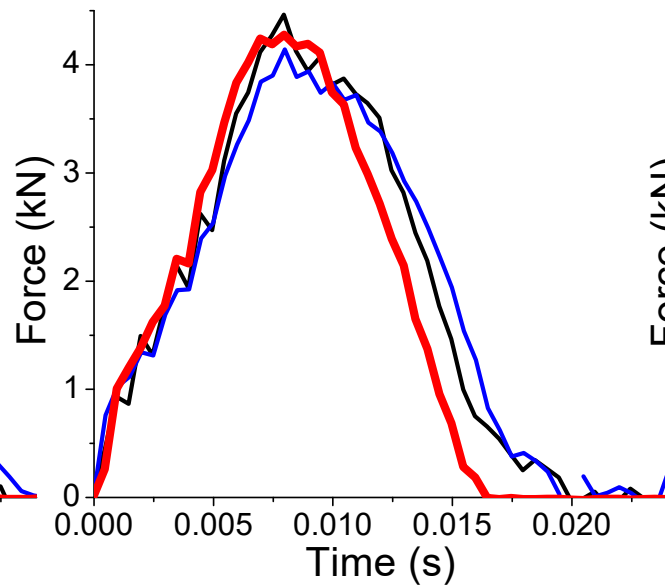
Prove con AA

- sperimentale
- modello numerico (omogeneizzato)
- modello numerico (con struttura)

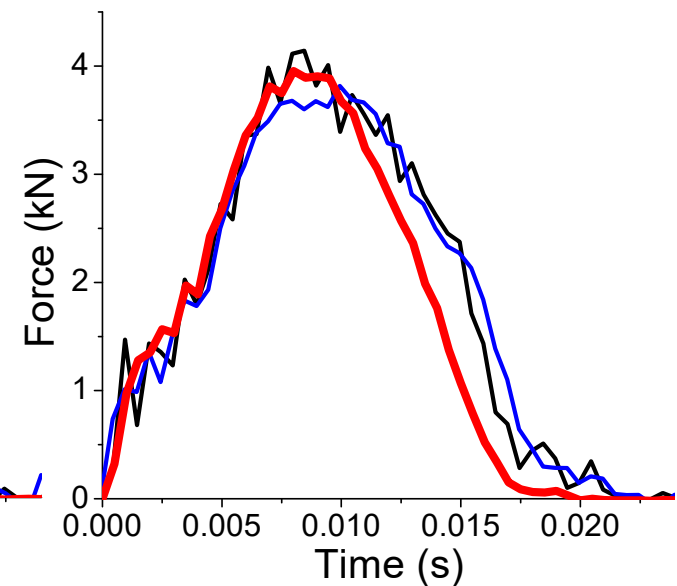
Mondotrack 1



Mondotrack 2



Mondotrack 3



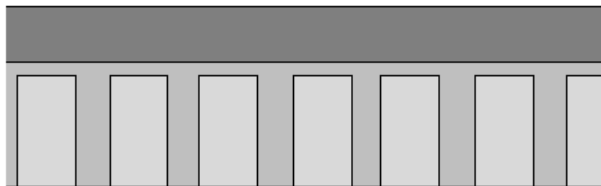
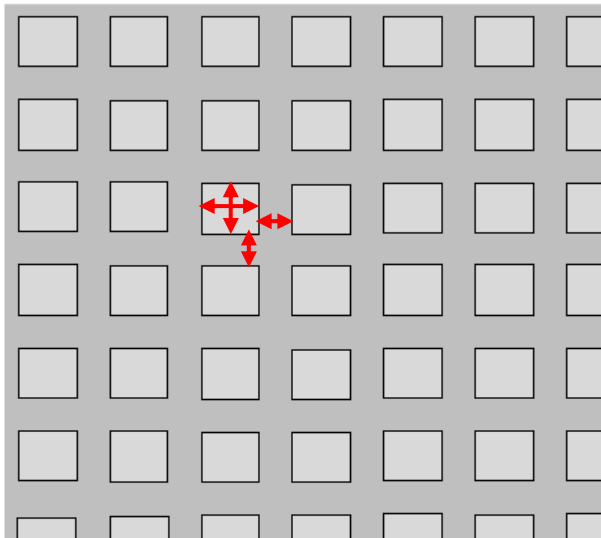
Modelling the cushioning properties of athletic tracks

L. Andena, S. Aleo, F. Briatico-Vangosa, S. Mariani, S. Tagliabue, A. Pavan; *Sports Engineering* (2018)

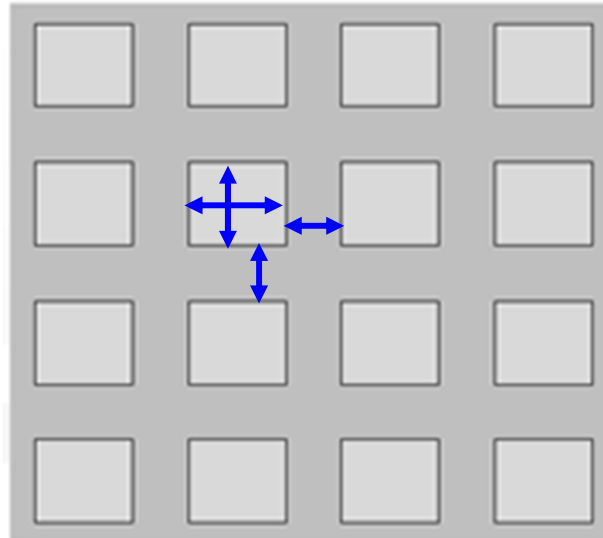
Modifica della struttura

1. Dimensione delle celle (nel piano) $\longrightarrow L' = L$ $\left\{ \begin{array}{l} - 40 \% \\ - 20 \% \\ + 20 \% \\ + 40 \% \\ + 80 \% \end{array} \right.$

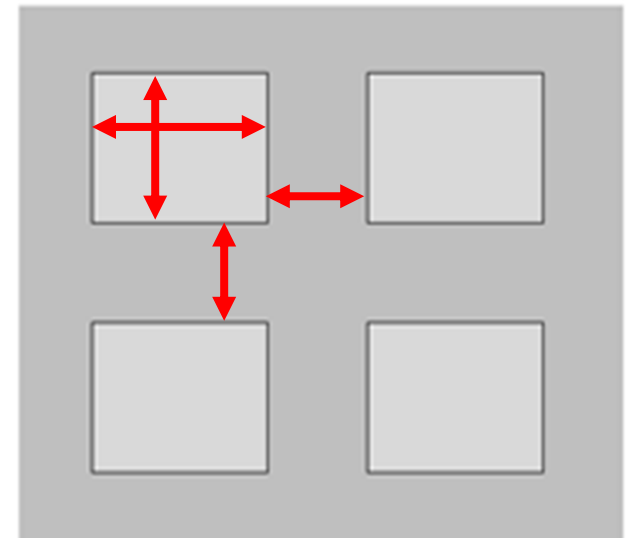
- 40 %



as is



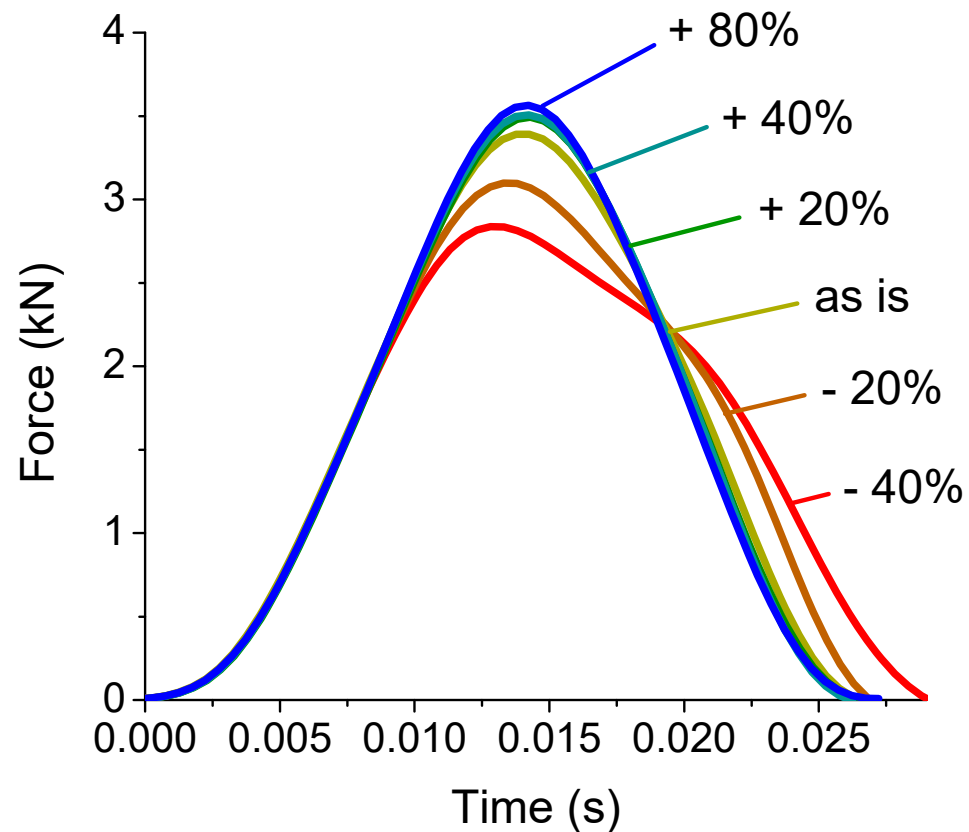
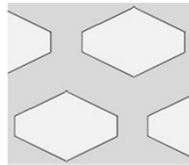
+ 80 %



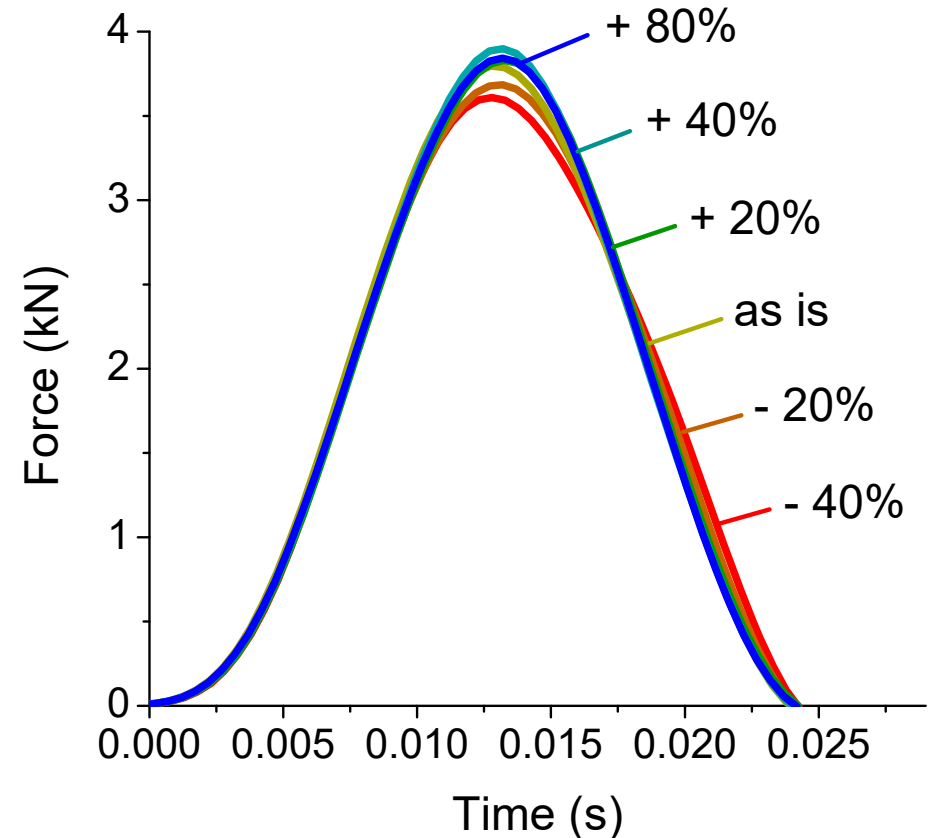
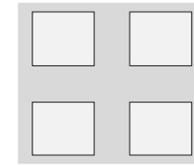
Modifica della struttura

1. Dimensione delle celle (nel piano)

Mondotrack 1



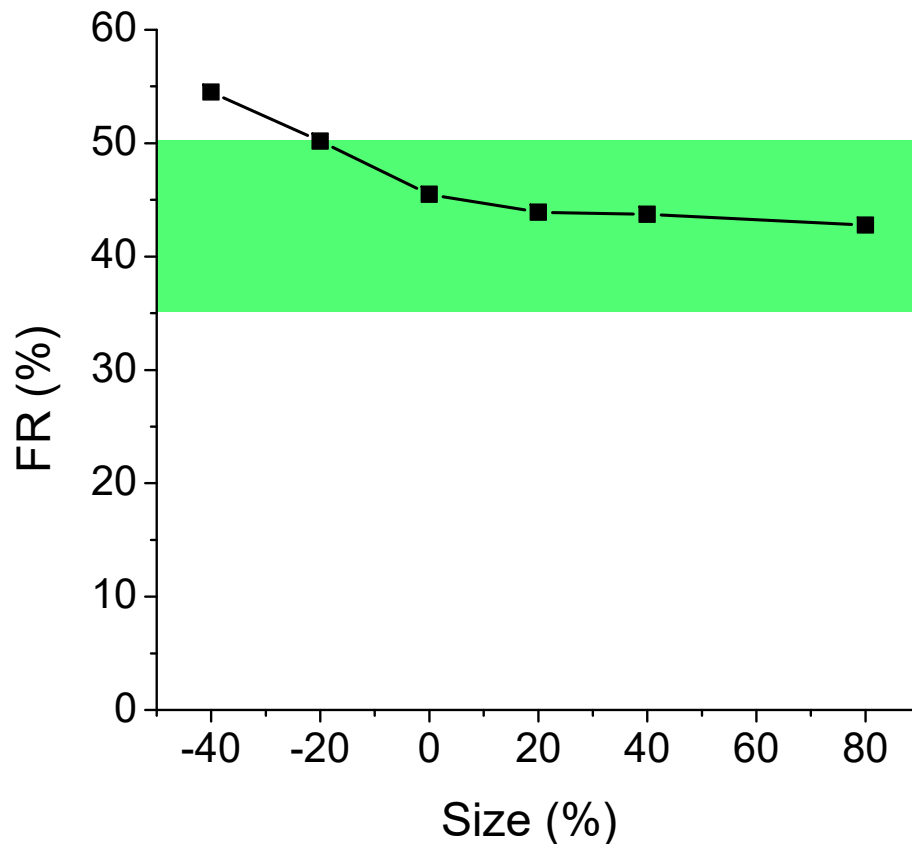
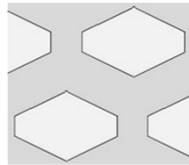
Mondotrack 3



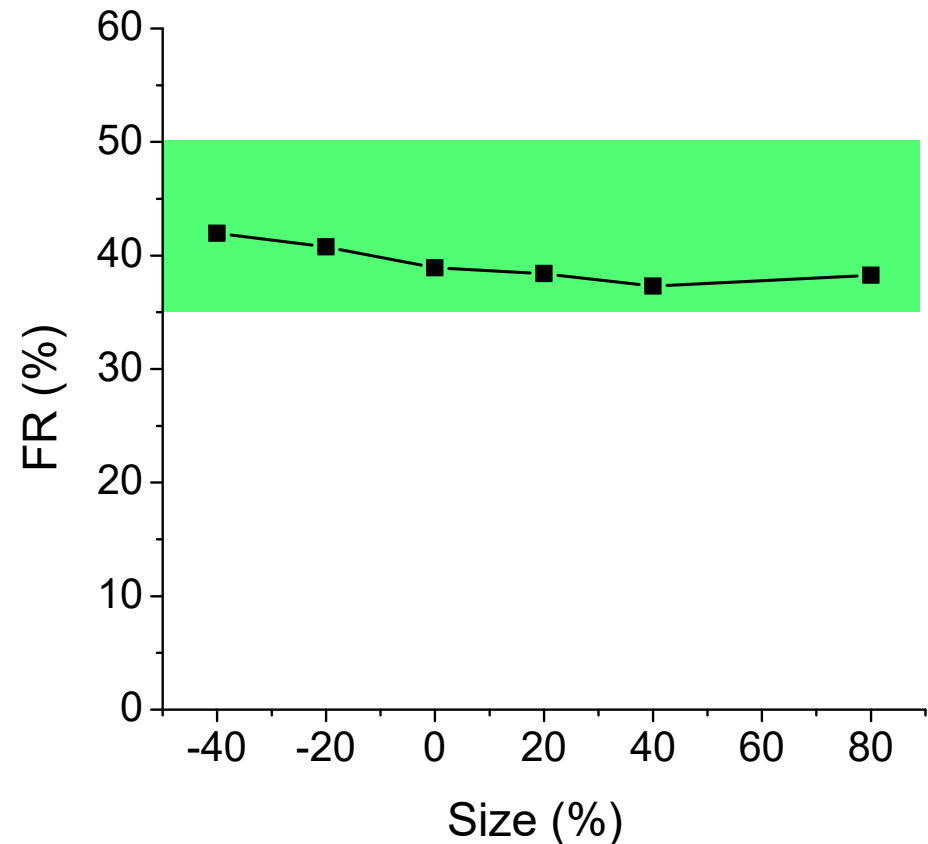
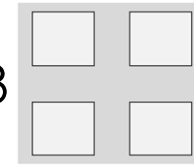
Modifica della struttura

1. Dimensione delle celle (nel piano)

Mondotrack 1

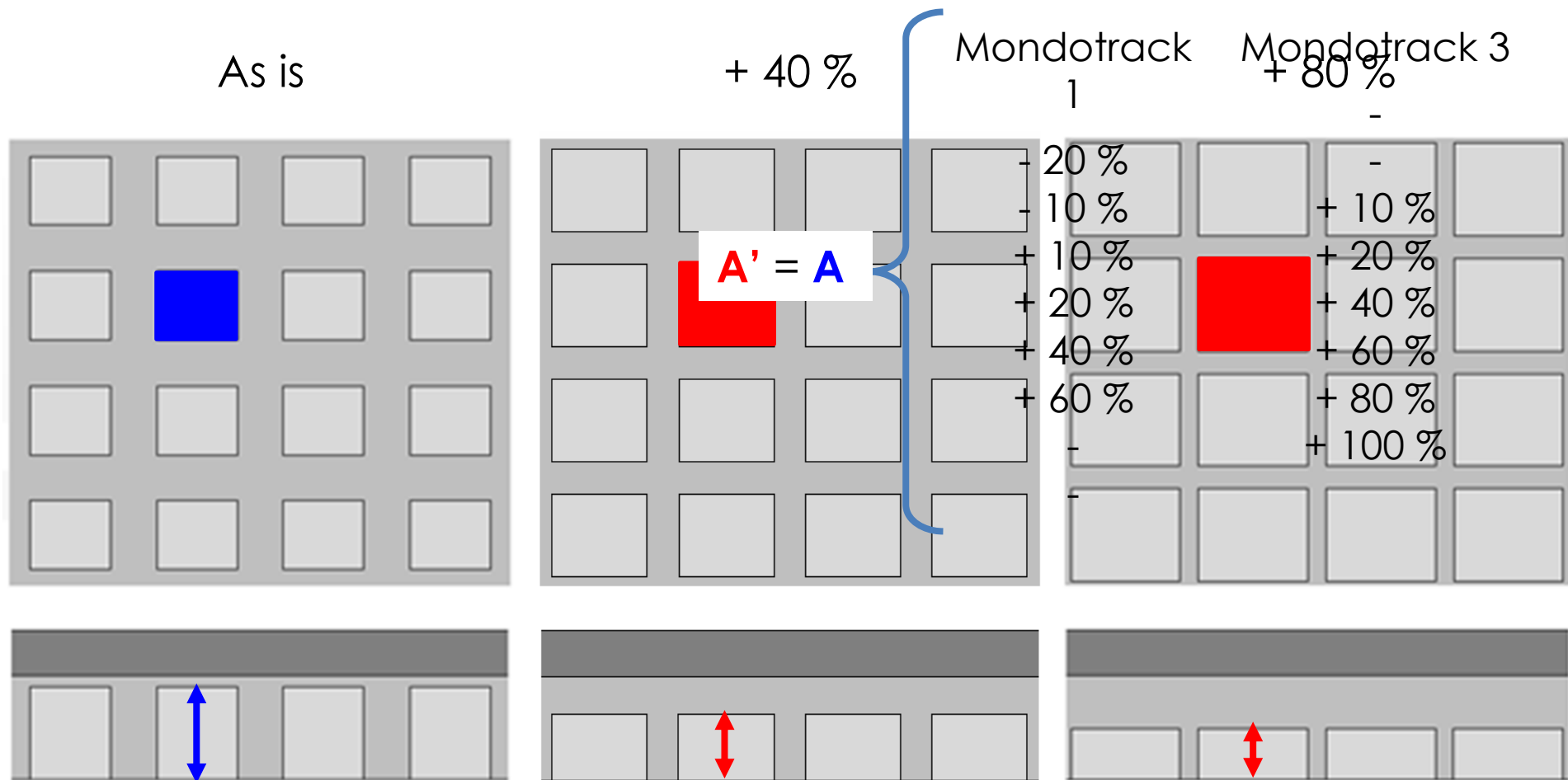


Mondotrack 3



Modifica della struttura

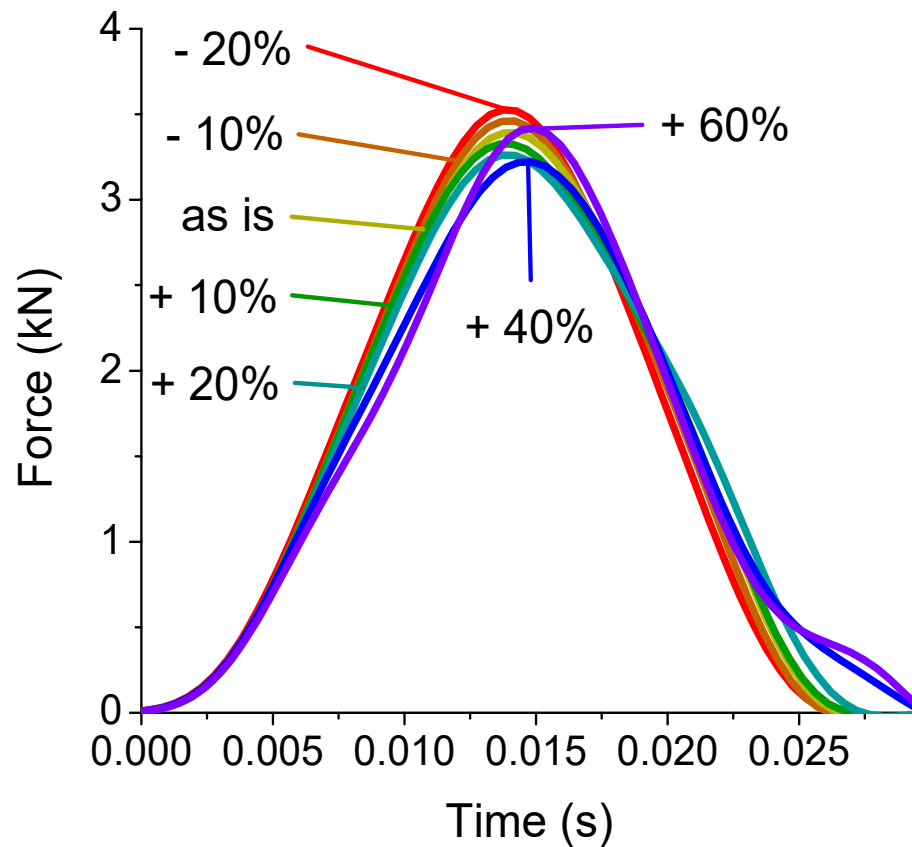
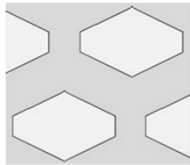
2. Profondità dei vuoti $\rightarrow d' \cdot A' = d \cdot A = \text{Vol}_{\text{voids}} = \text{cost}$



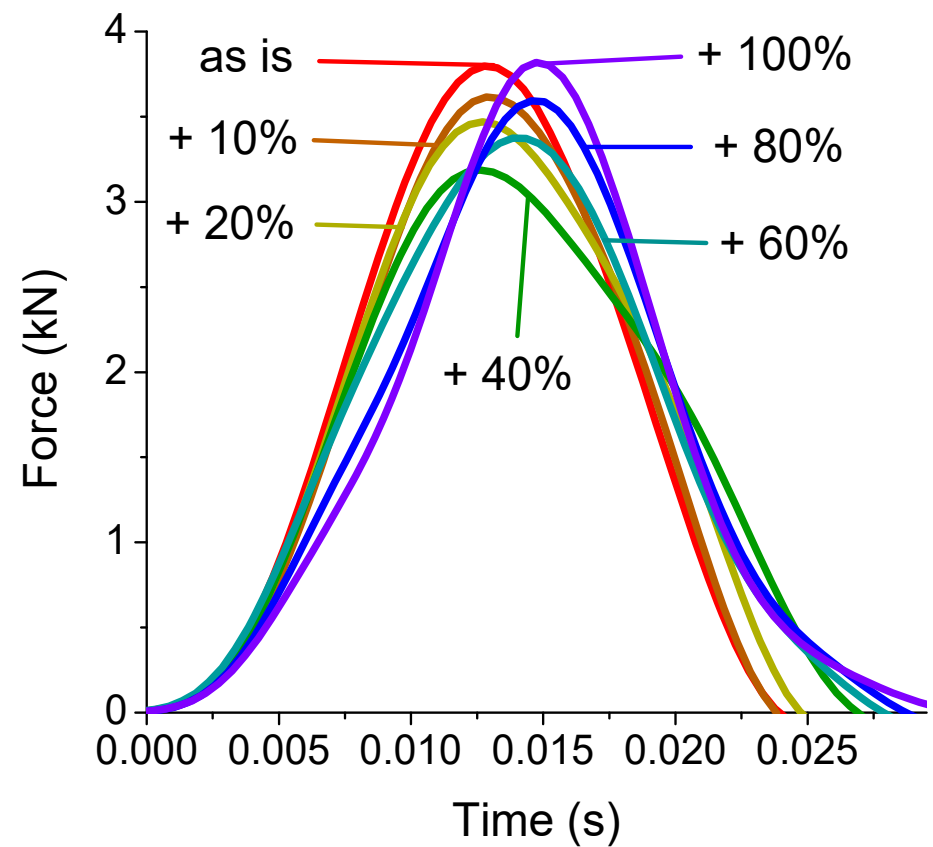
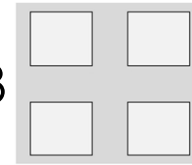
Modifica della struttura

2. Profondità dei vuoti

Mondotrack 1



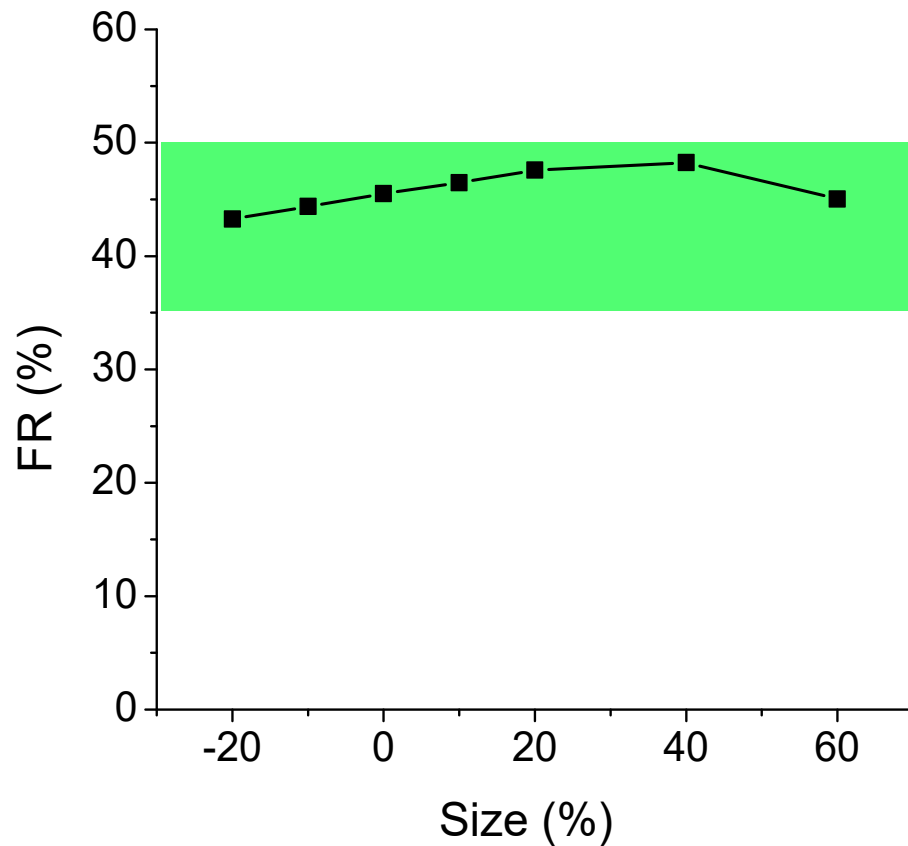
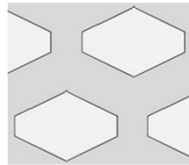
Mondotrack 3



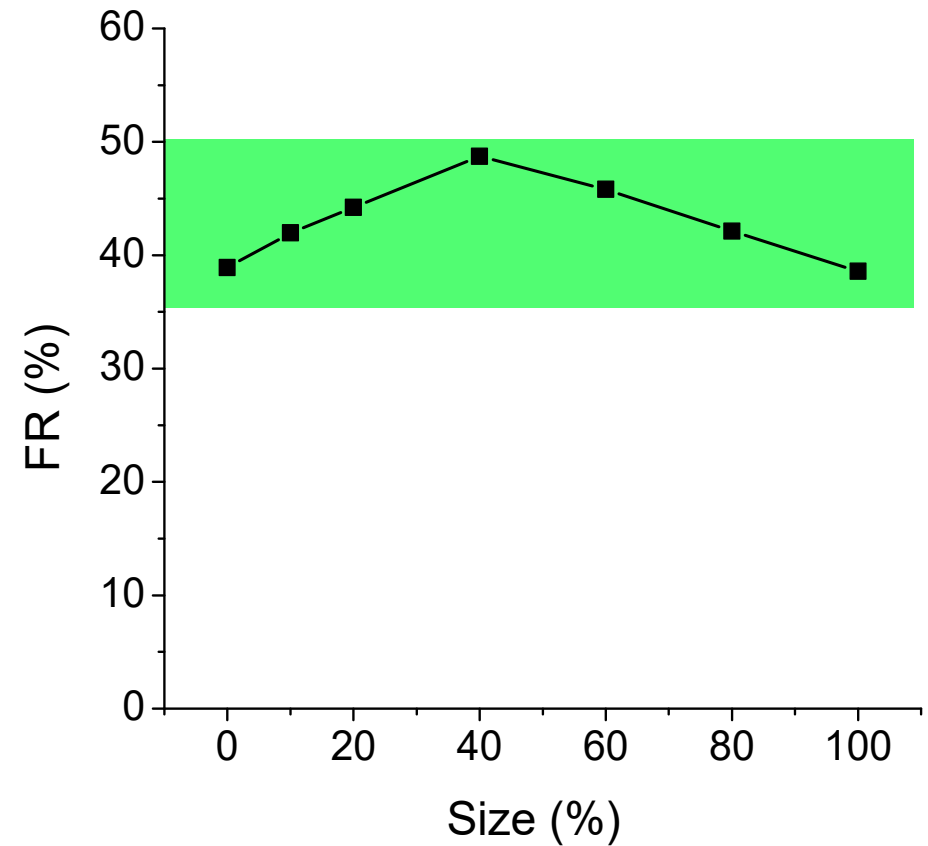
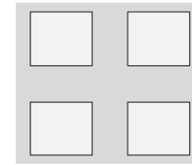
Modifica della struttura

2. Profondità dei vuoti

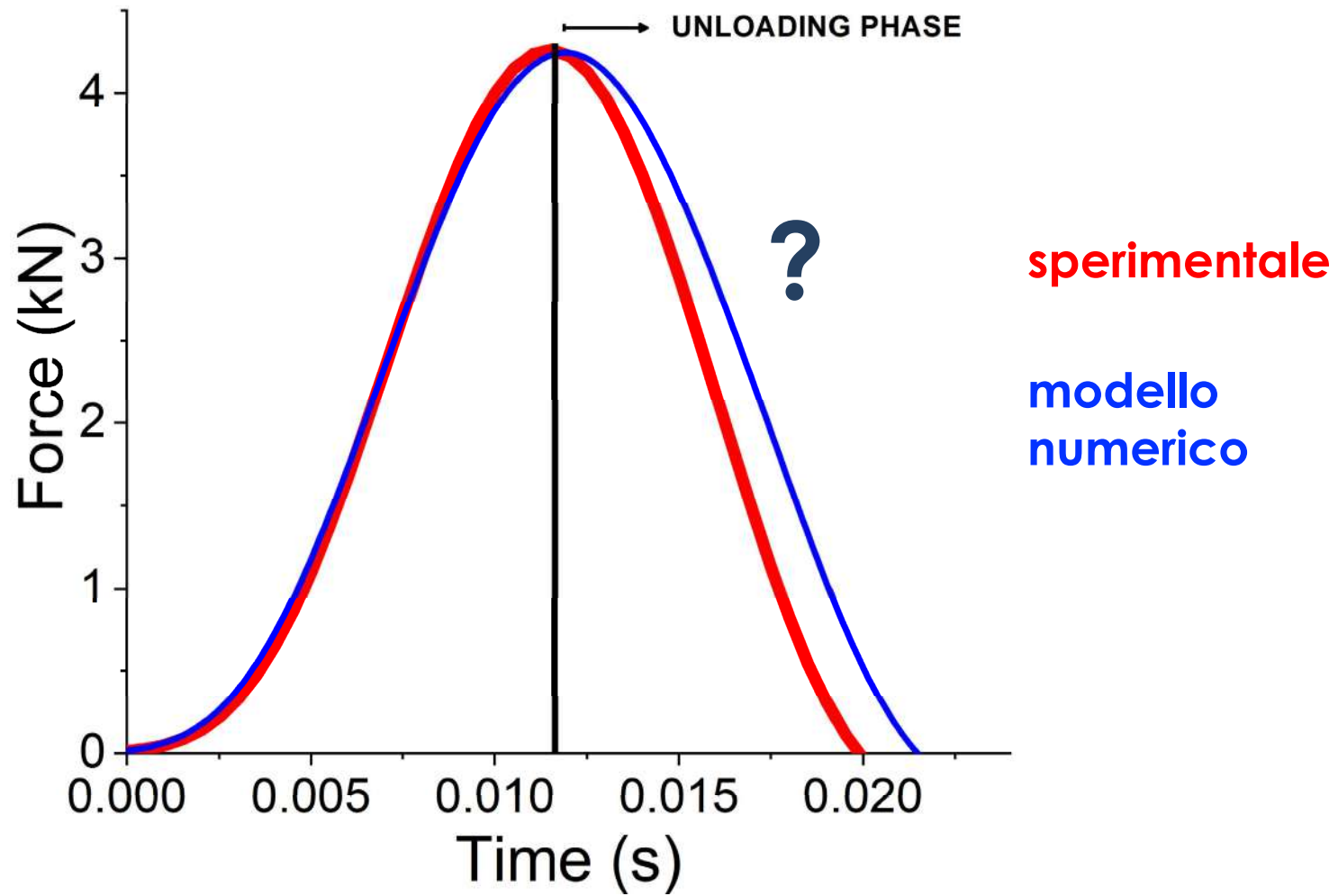
Mondotrack 1



Mondotrack 3



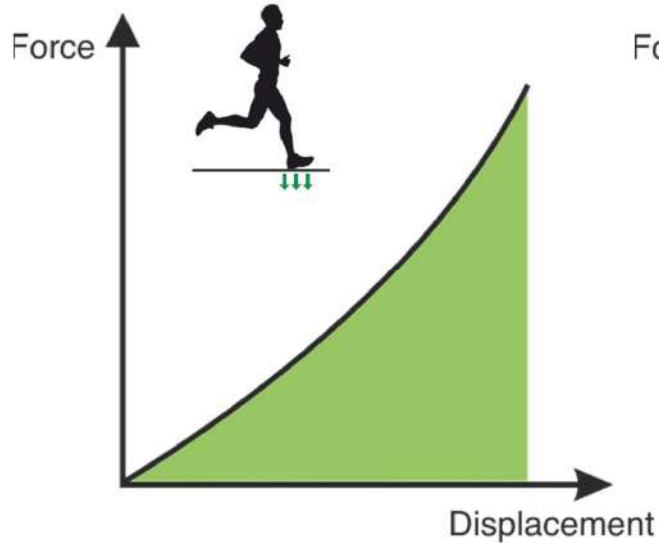
Restituzione di energia



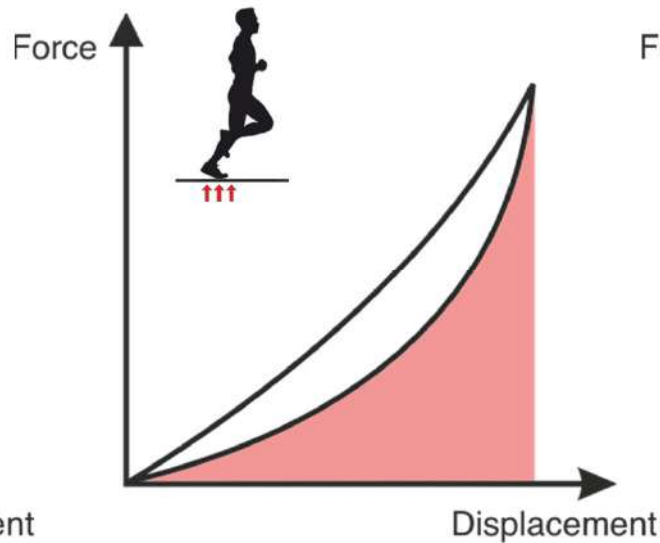
Restituzione di energia

Sviluppo di un modello numerico **visco-iperelastico**

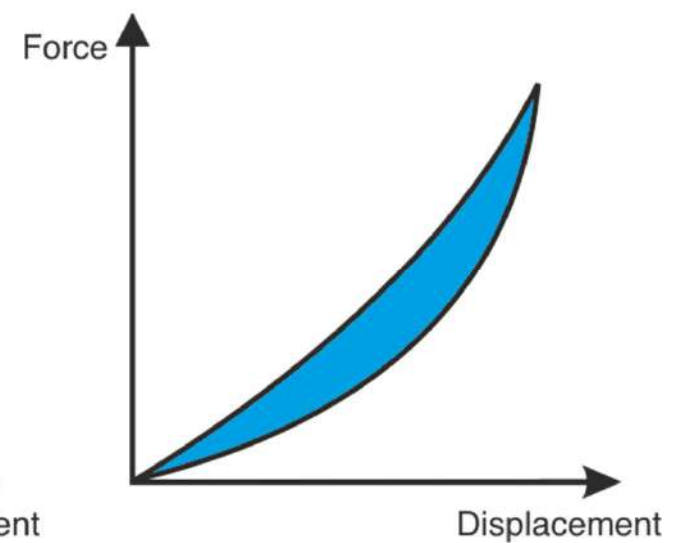
Energy input



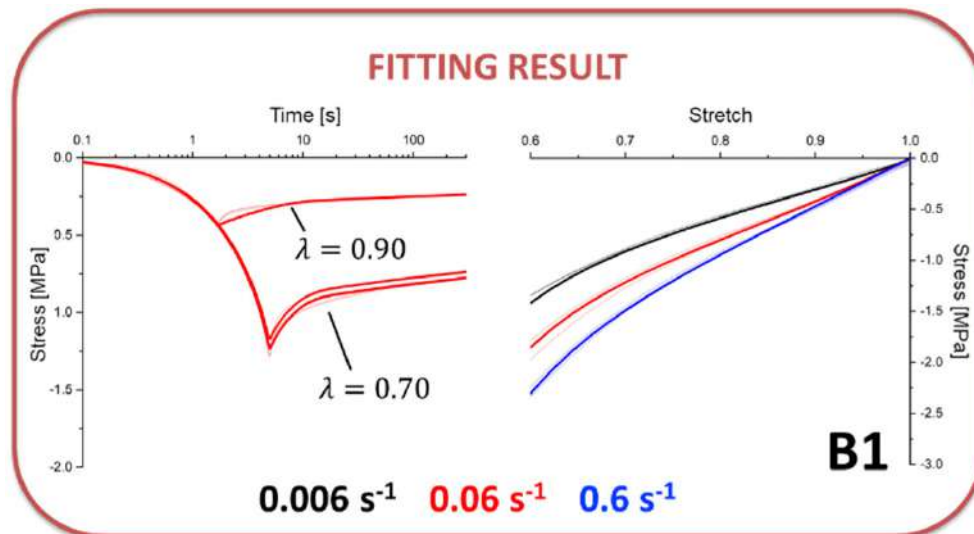
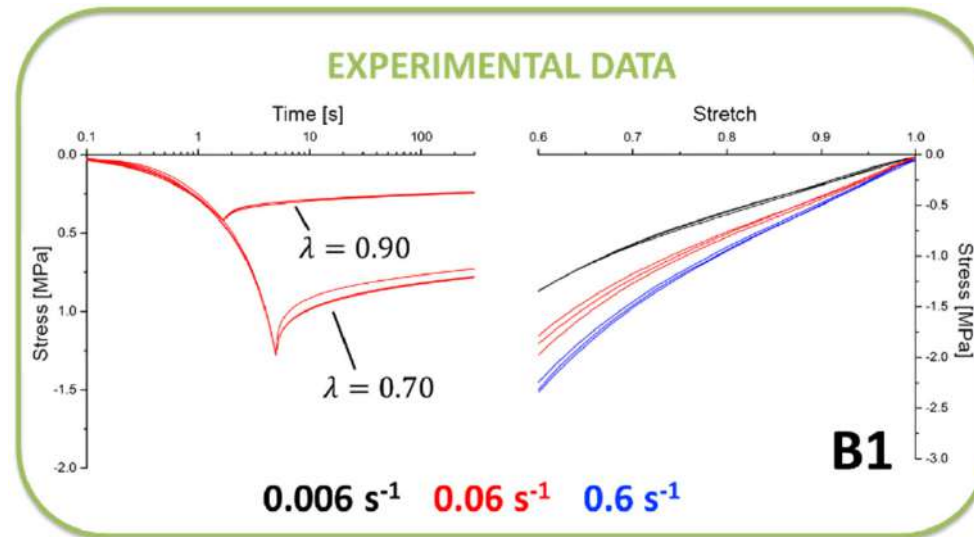
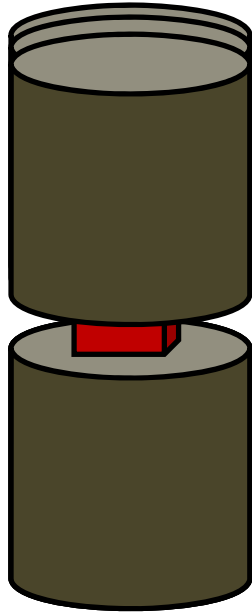
Energy returned



Energy lost



Modello visco-iperelastico



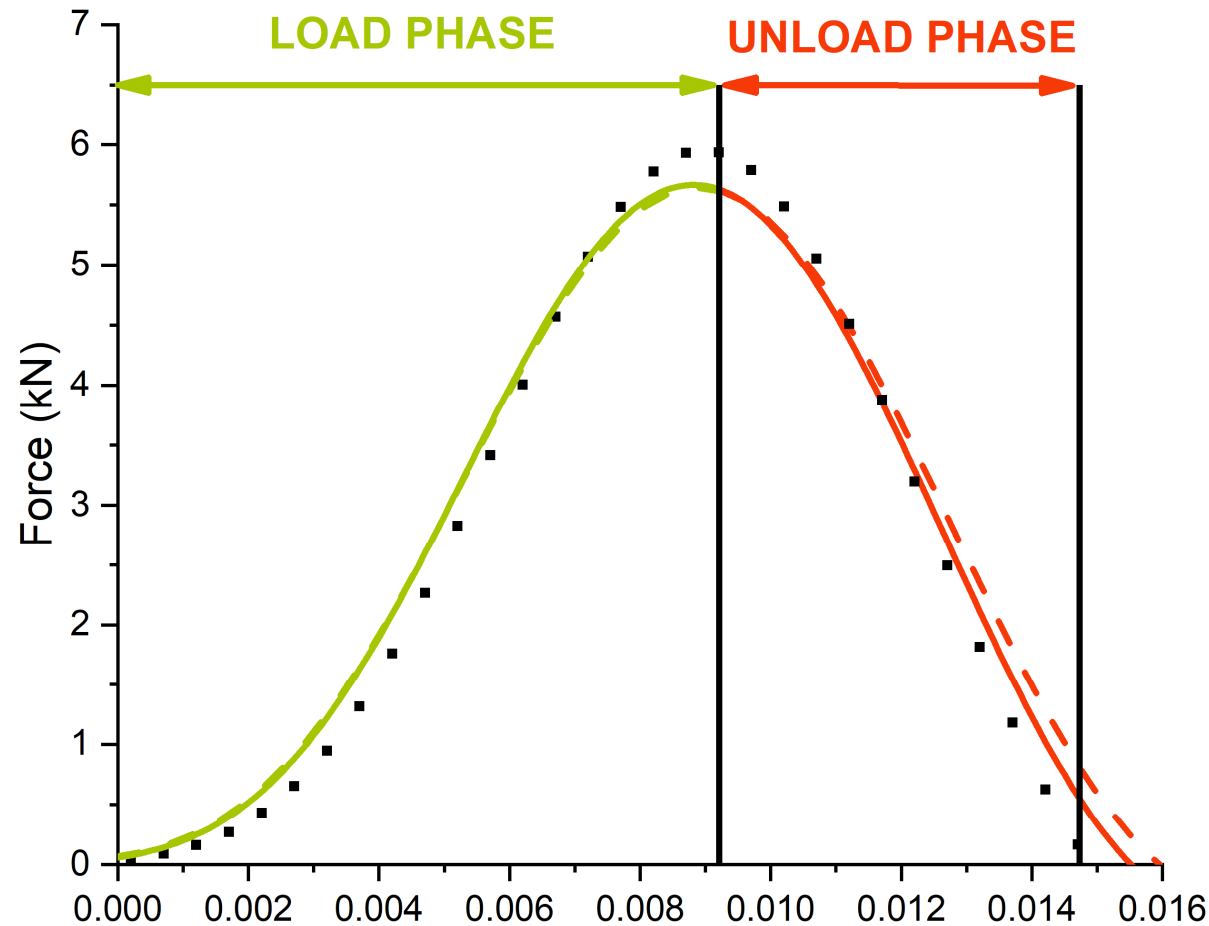
$$\sigma(t) = g_{\infty} \sigma_0(t) + \sum_{i=1}^N h_i(t)$$

Hyperelastic constants	Prony series constants
μ_i, α_i	g_1, g_2, g_3, g_4
ψ, λ_m, a	$\tau_1, \tau_2, \tau_3, \tau_4$

A visco-hyperelastic numerical model for the dynamic behaviour of rubbers

L. Andena, F. Cotta Ramusino, S. Tagliabue, S. Zaffari; ECCMR2022

Modello visco-iperelastico

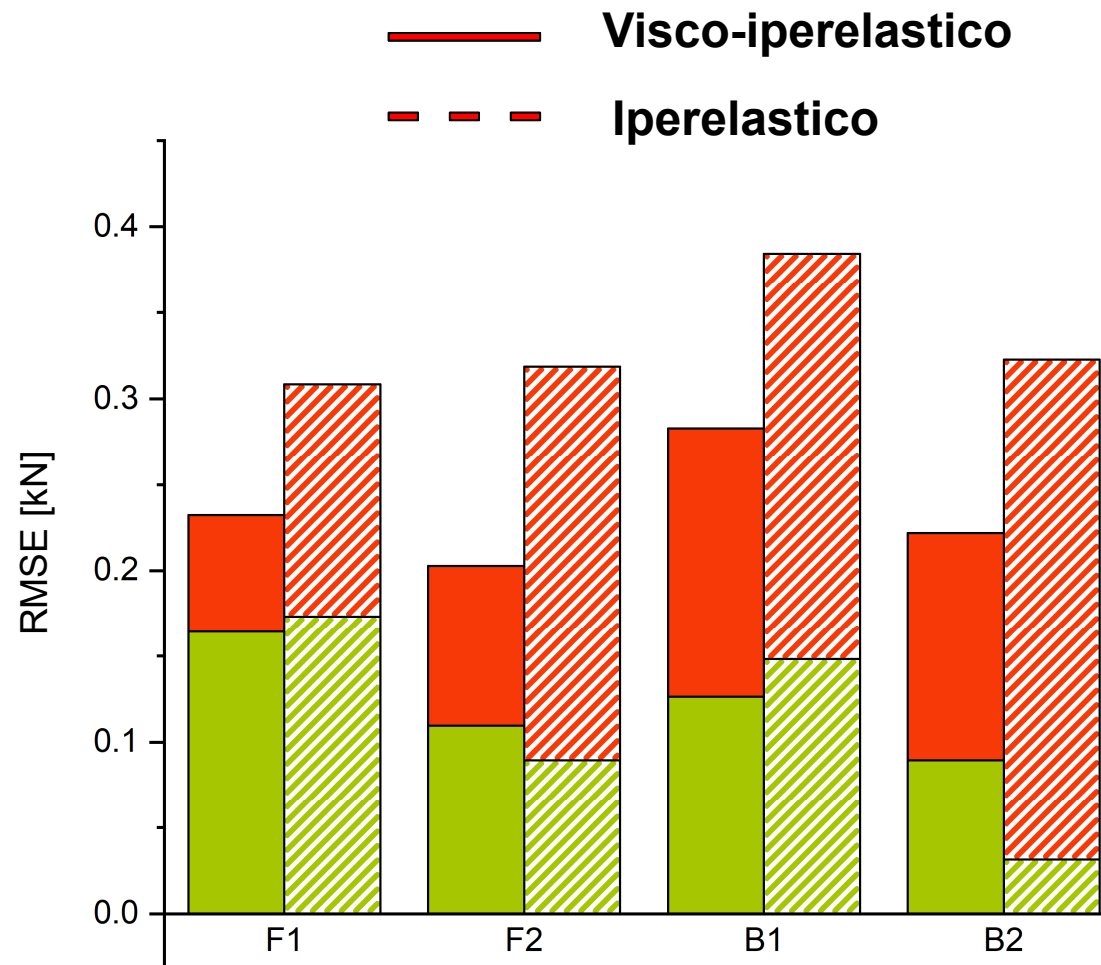


- Sperimentale

— Visco-iperelastico

— Iperelastico

Modello visco-iperelastico



Conclusioni

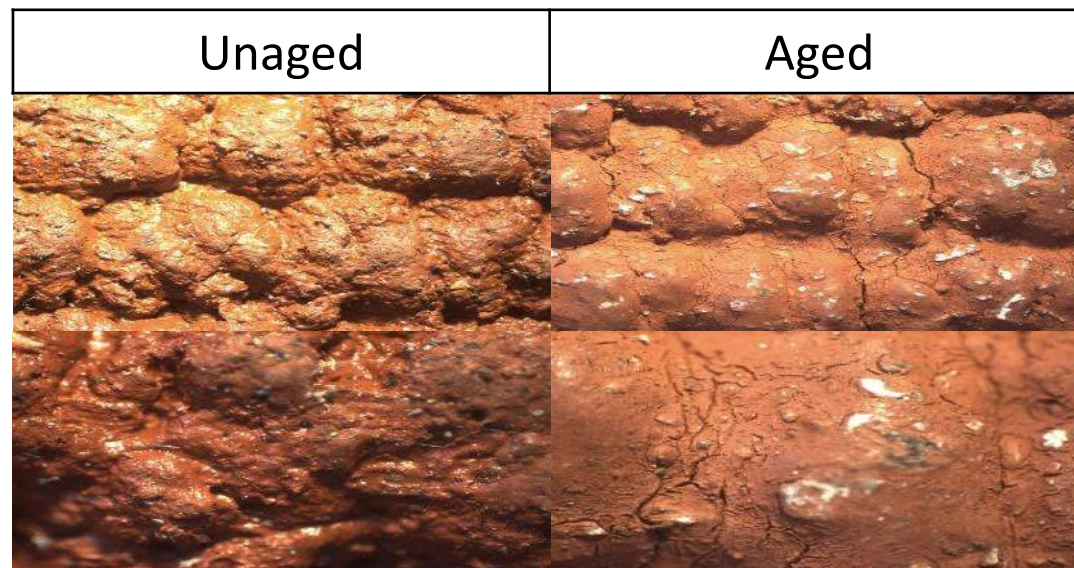
- Effetto del materiale e della geometria
- Modello numerico per la previsione del comportamento
- Possibile sperimentazione virtuale

Sviluppi futuri

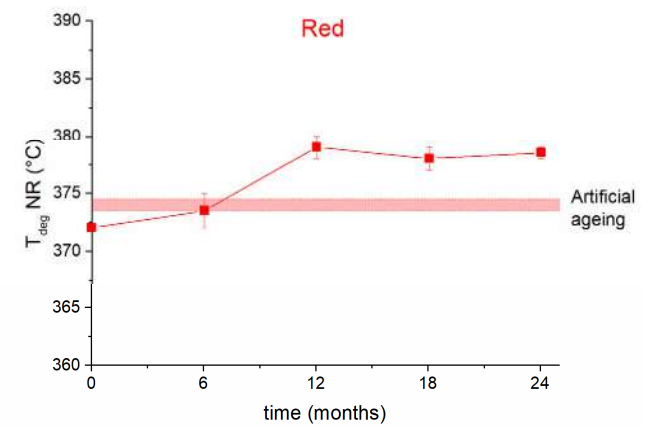
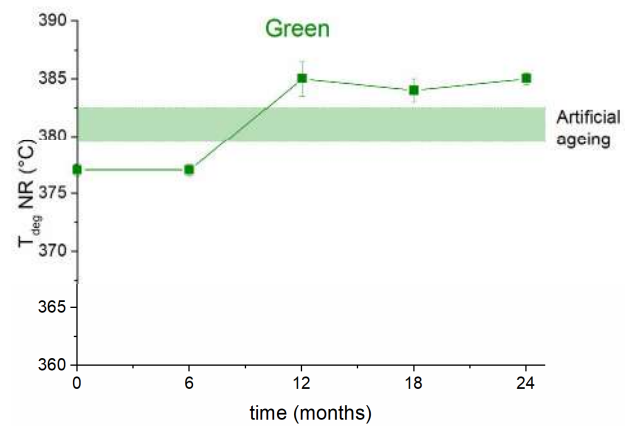
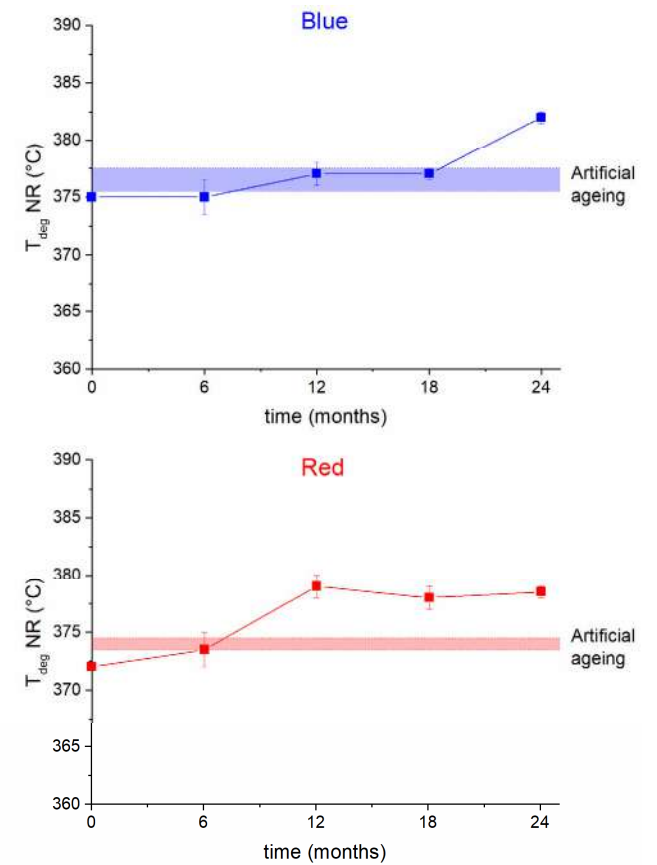
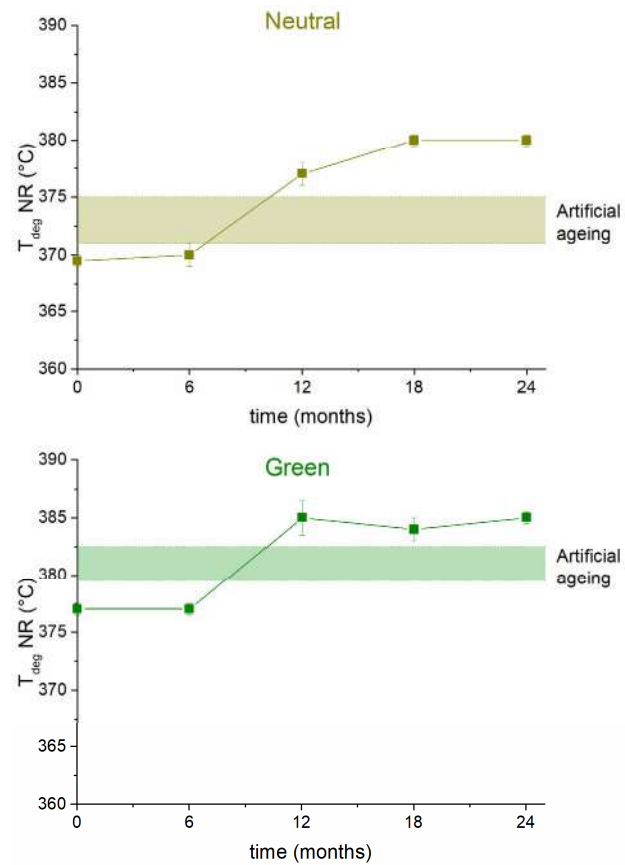
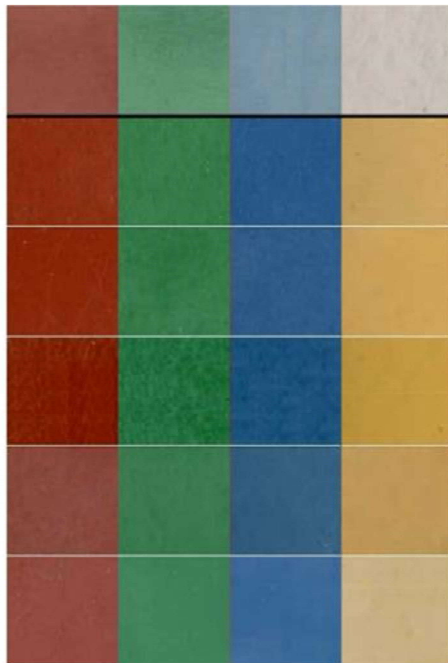
- Ottimizzazione geometrie
- Miglioramento prestazioni
- Attrito
- Integrazione con scarpa/atleta



Ageing of athletics tracks



Ageing of athletics tracks



Ageing of athletics tracks

