Interdisciplinary Rockfall Workshop

2011–Innsbruck-Igls

POLITECNICO DI MILANO





DYNAMIC BEHAVIOUR OF ROCKFALL SHELTERS

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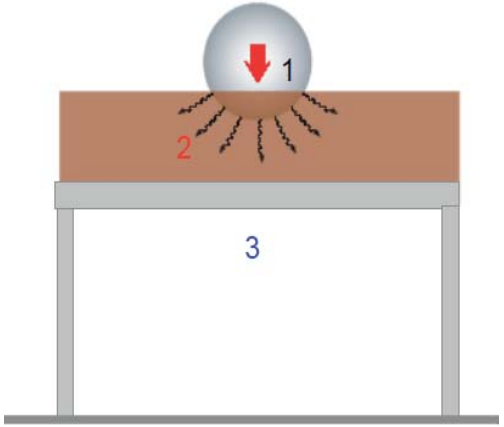
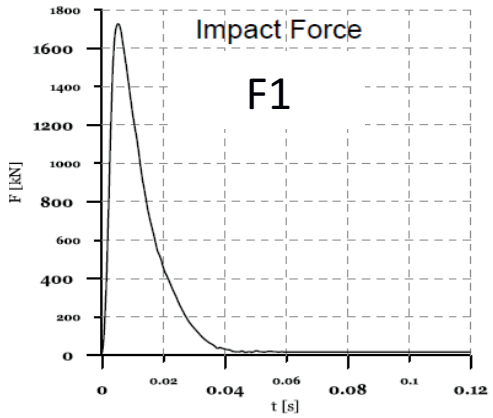
POLITECNICO DI MILANO

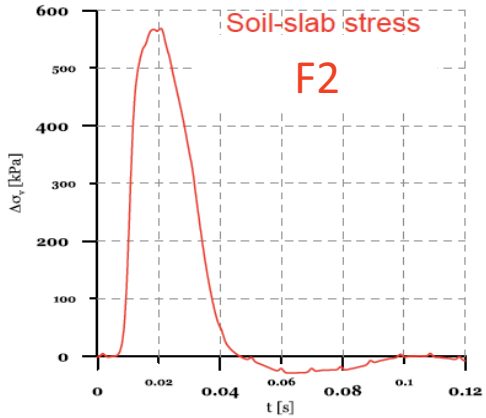
Francesco Tondini

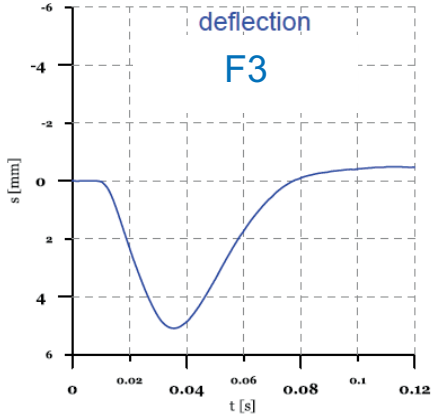
Rockfall shelter typology: artificial tunnels covered by soil layer



Calvetti & di Prisco: An uncoupled approach for the design of rockfall protection shelters
WSL Interdisciplinary Workshop on Rockfall Protection 2008 June 23-25, Morschach, CH







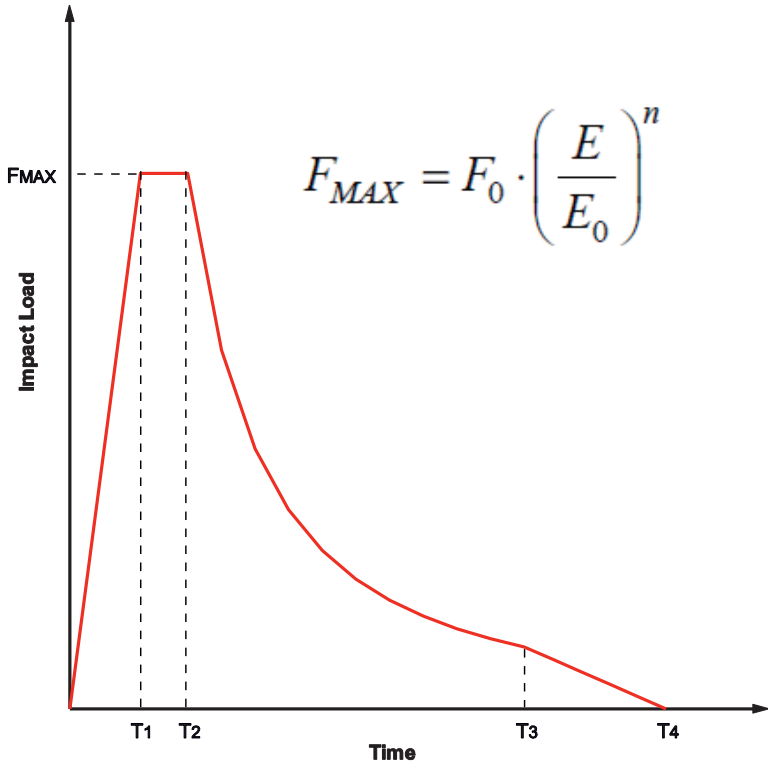
F_1 Impact force ➔ F_2 Actions on the shelter ➔ F_3 Structural actions

Local interaction: boulder-soil surface

Stress propagation

Structural response

Uncoupled design approach, STEP 1: Impact force

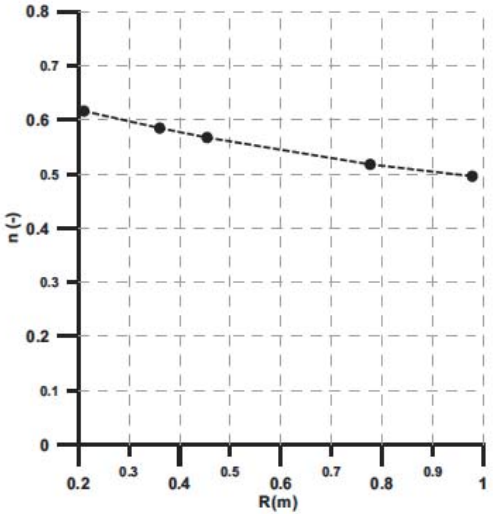


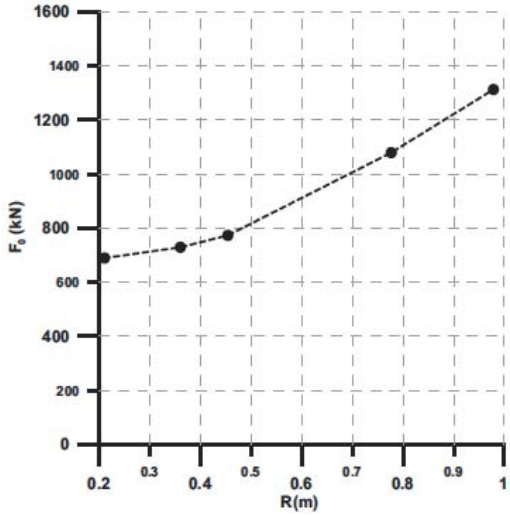
$$F_{MAX} = F_0 \cdot \left(\frac{E}{E_0} \right)^n$$

CHARTS FOR

n and F_0 as a function of block size

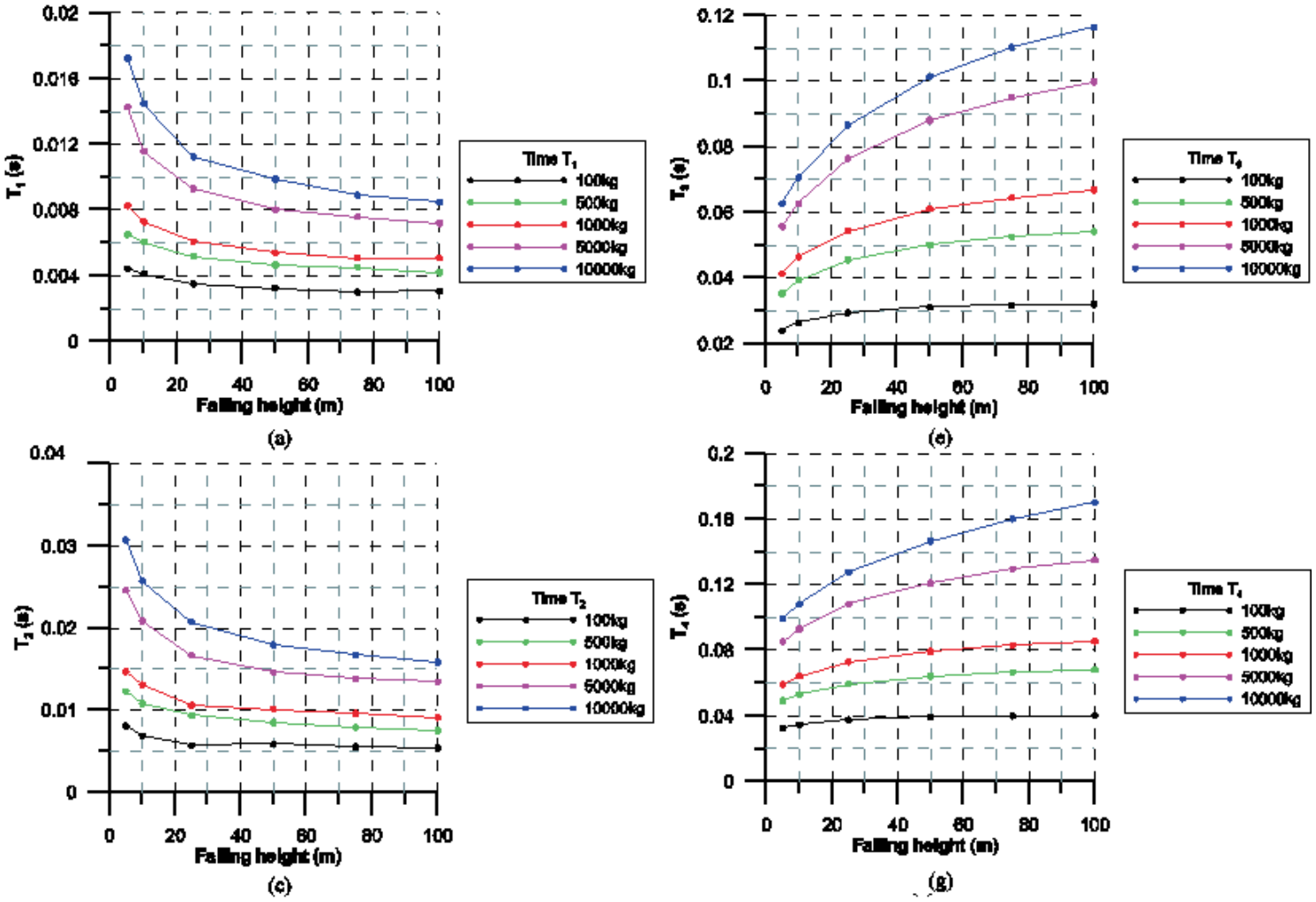
(dense sand-gravel soil layer)



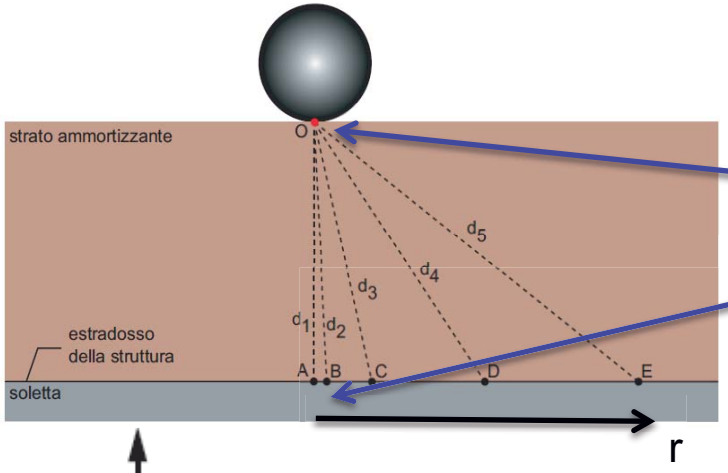


Impact Force: design charts

$T_{1,2,3\&4}$ as a function of falling height and block mass
(dense sand-gravel soil layer)

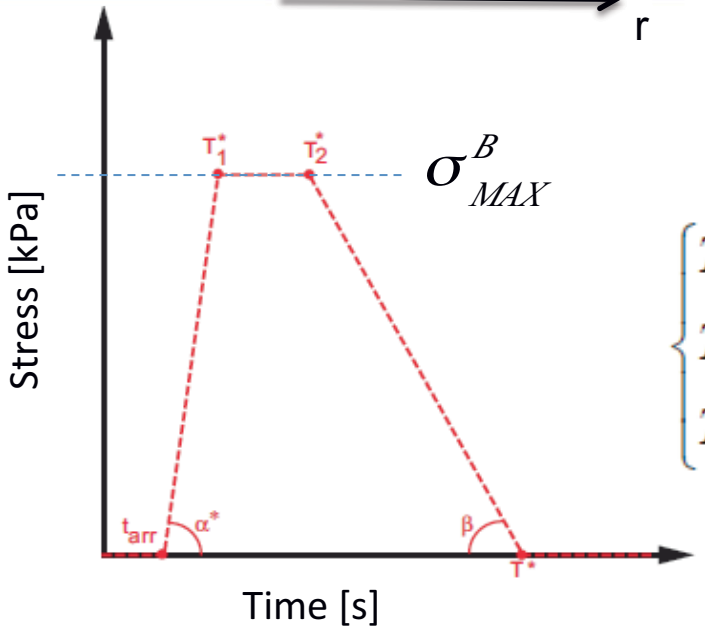


Impact wave propagation - dynamic stress diffusion

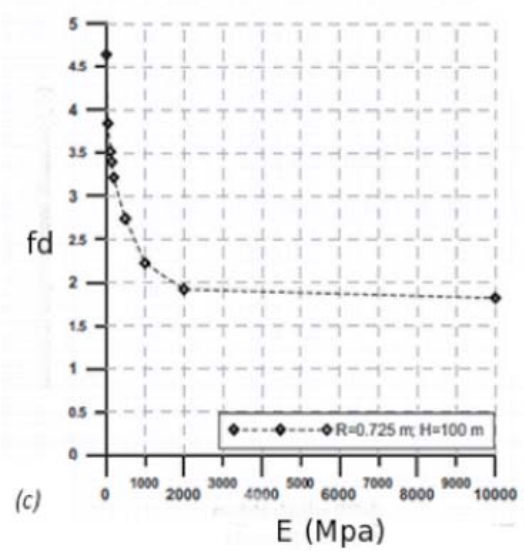


Elastic solution

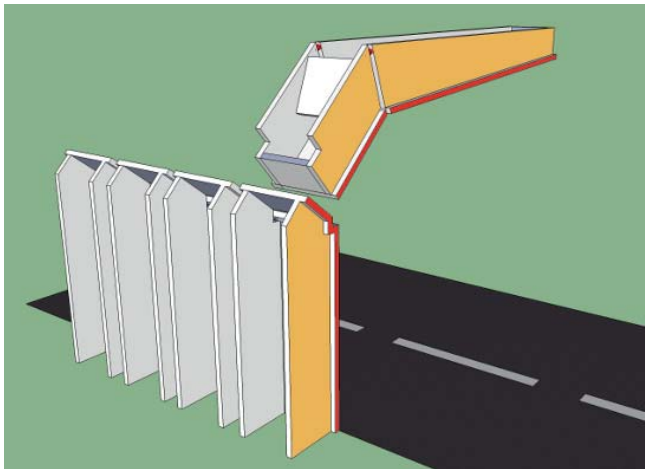
$$\sigma^{B}_{MAX}(r) = \sigma^{S}_{MAX} \cdot f_d \cdot f_g$$

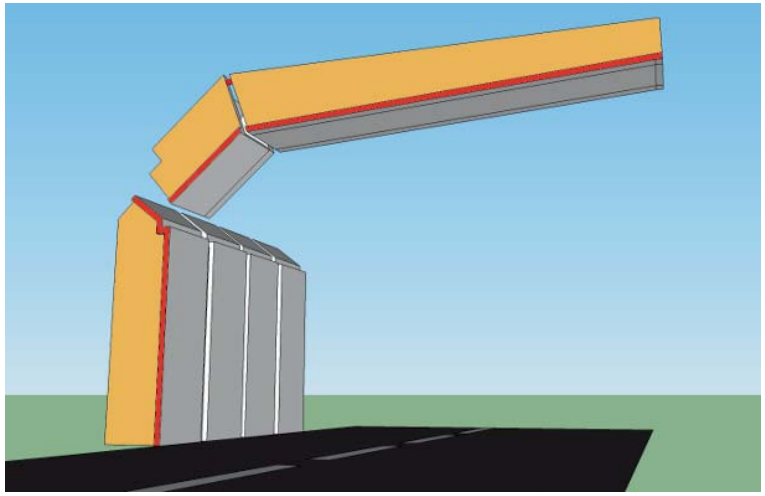


$$\begin{cases} T_1^* = t_{arr} + T_1 \\ T_2^* = 2.2 \cdot T_2 \\ T_4^* = 0.8 \cdot (t_{arr} + T_4) \end{cases}$$

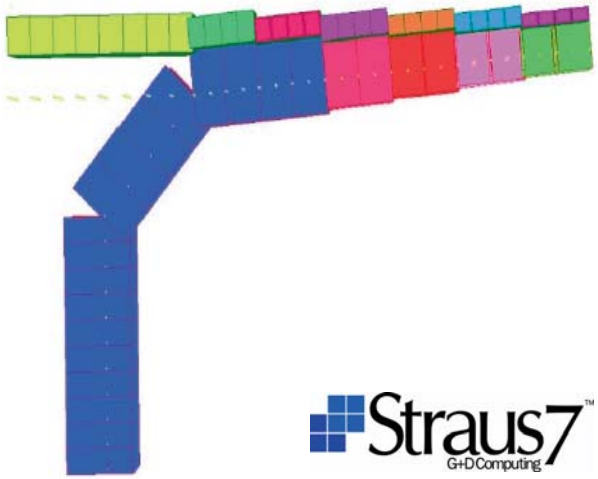


Reference structure: cantilever shelter covered by soil cushion

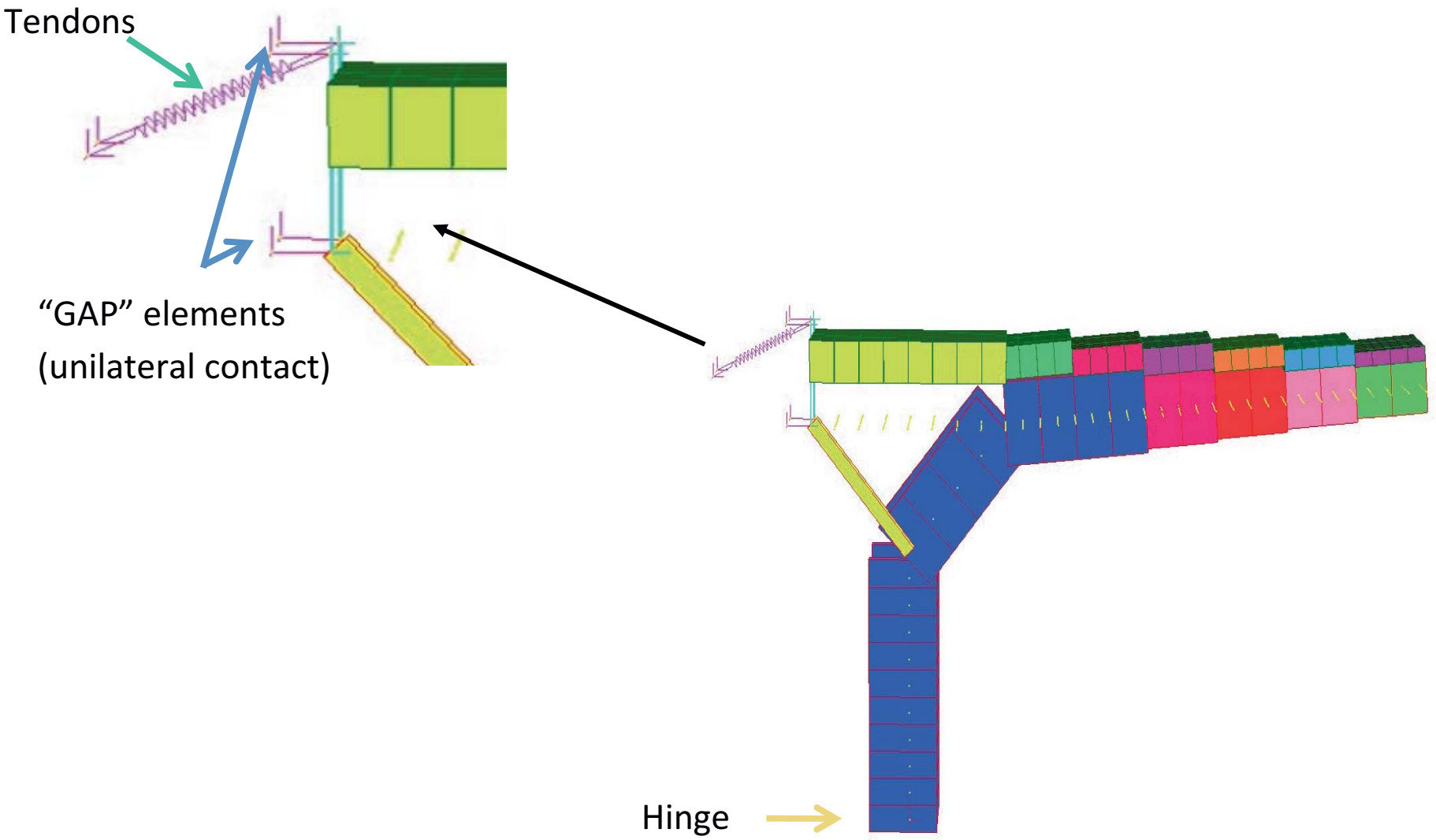




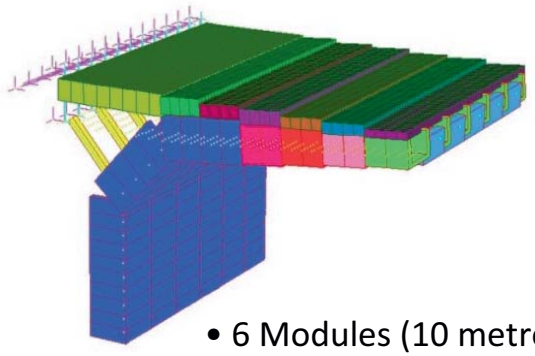
BETON COSTRUZIONI



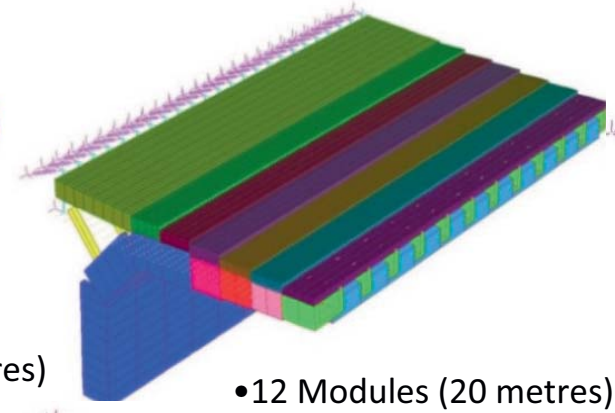
FEM model of 1 module



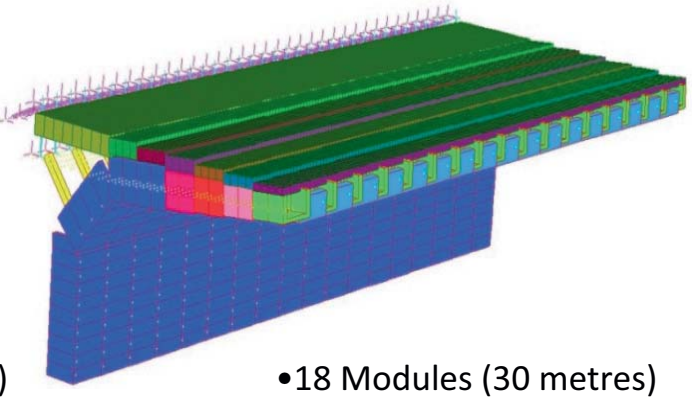
FEM model of assembled structure



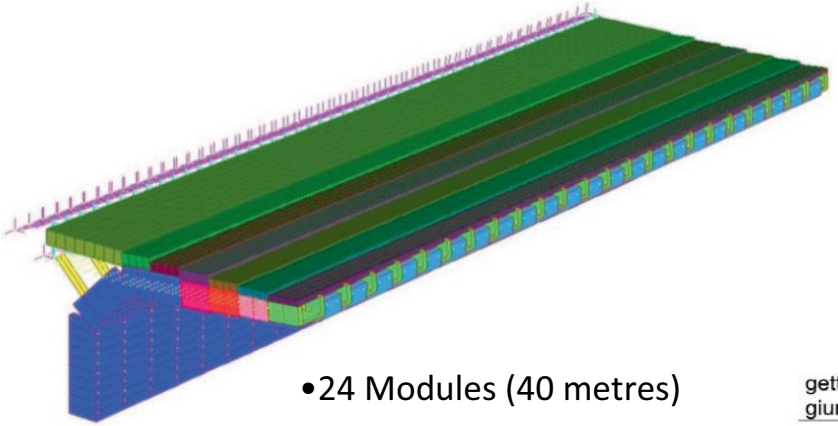
• 6 Modules (10 metres)



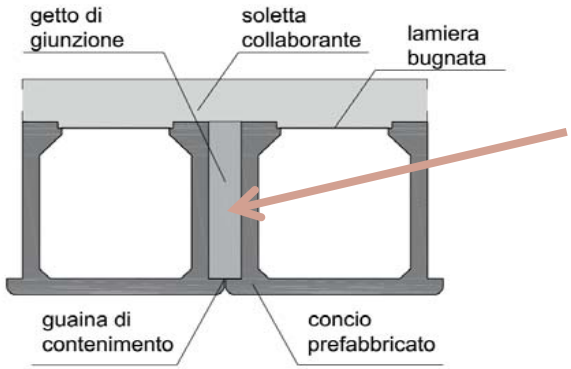
•12 Modules (20 metres)



•18 Modules (30 metres)



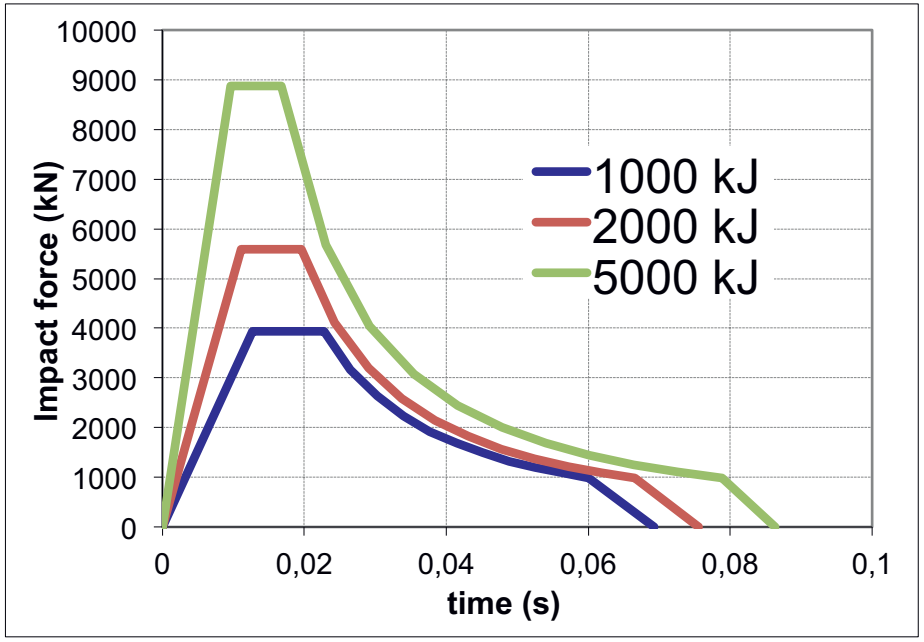
•24 Modules (40 metres)

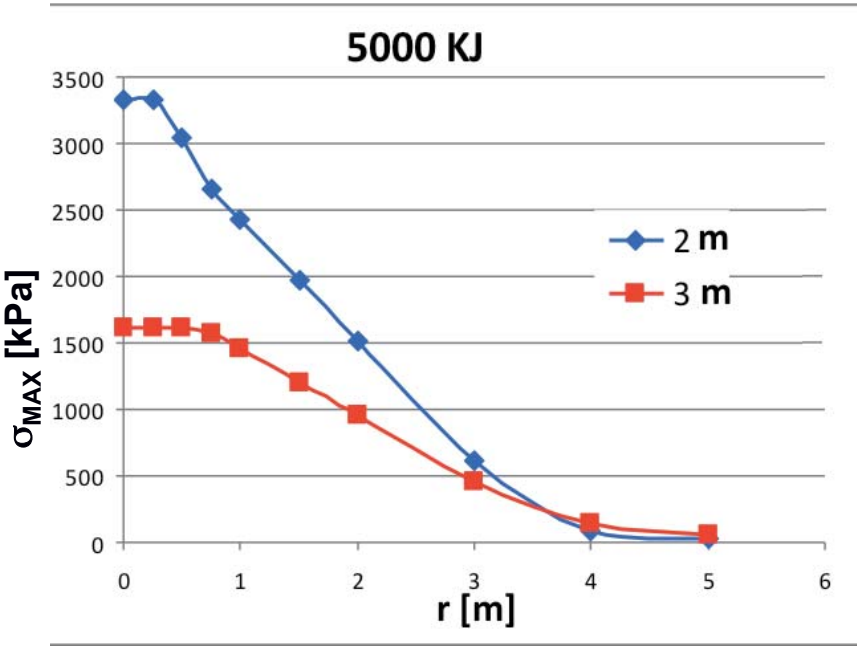


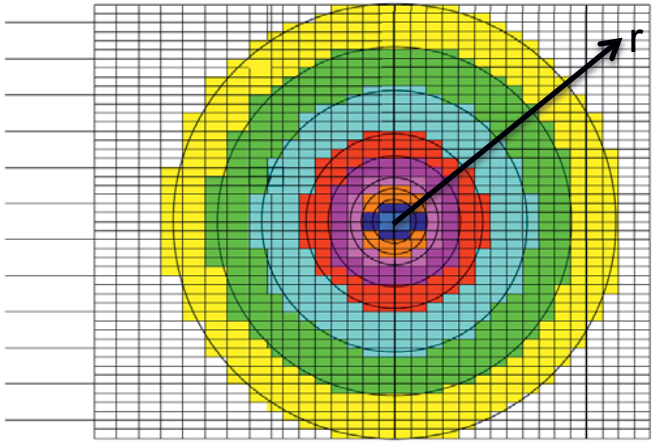
"GAP" Elements

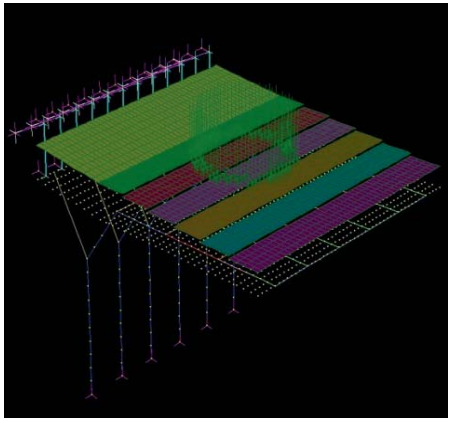
Reference impacts: Block mass: 7.8 tons

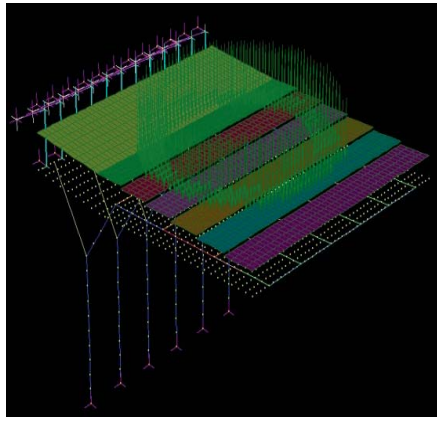
Soil thickness 2-3 m (dense sand-gravel); Impact Energy : E= 1000-2000-5000 kJ (H = 13-26-65 m)







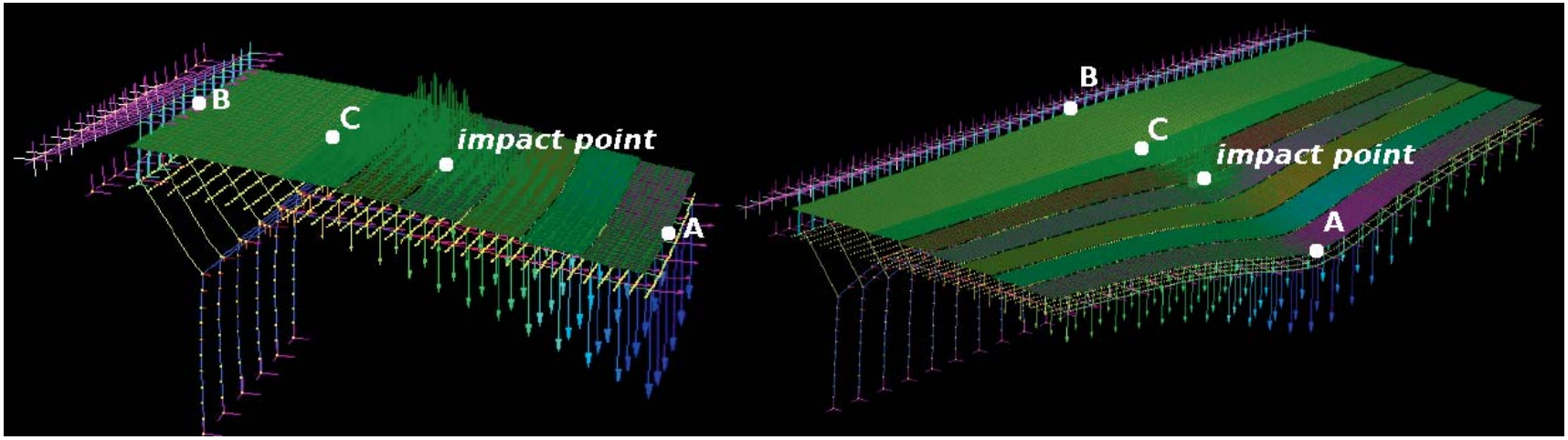


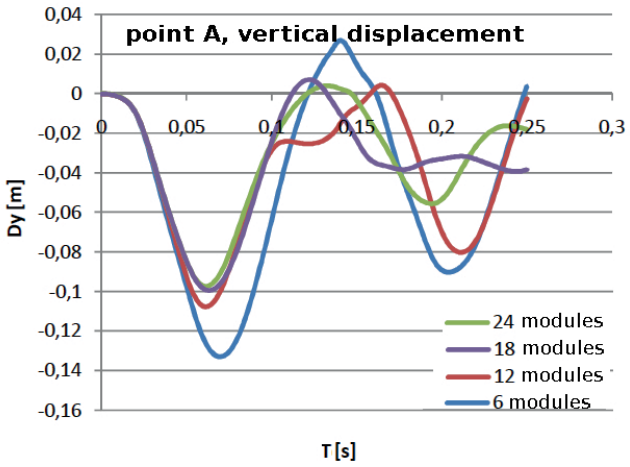


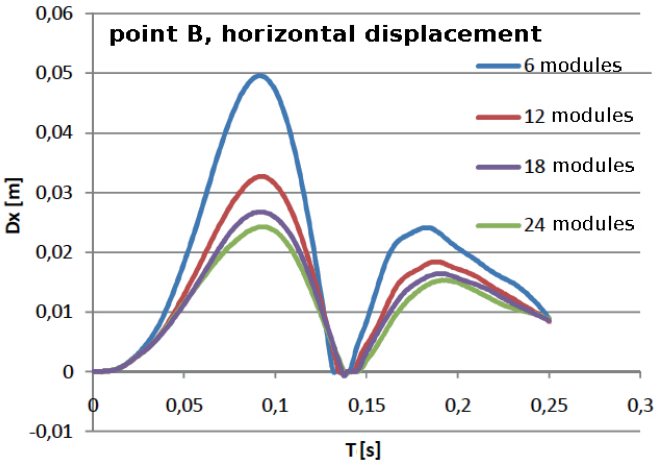
Structural response as a function number of modules

6 modules

24 modules



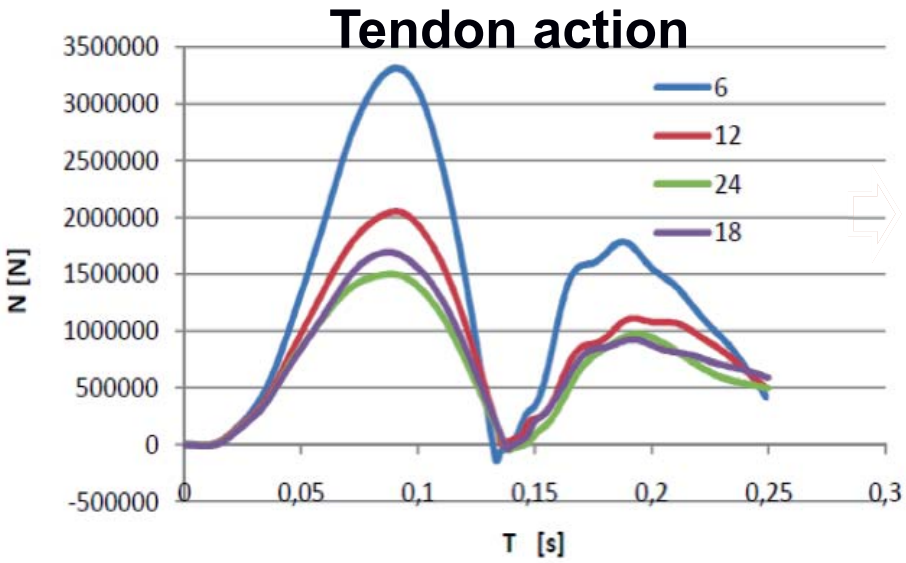




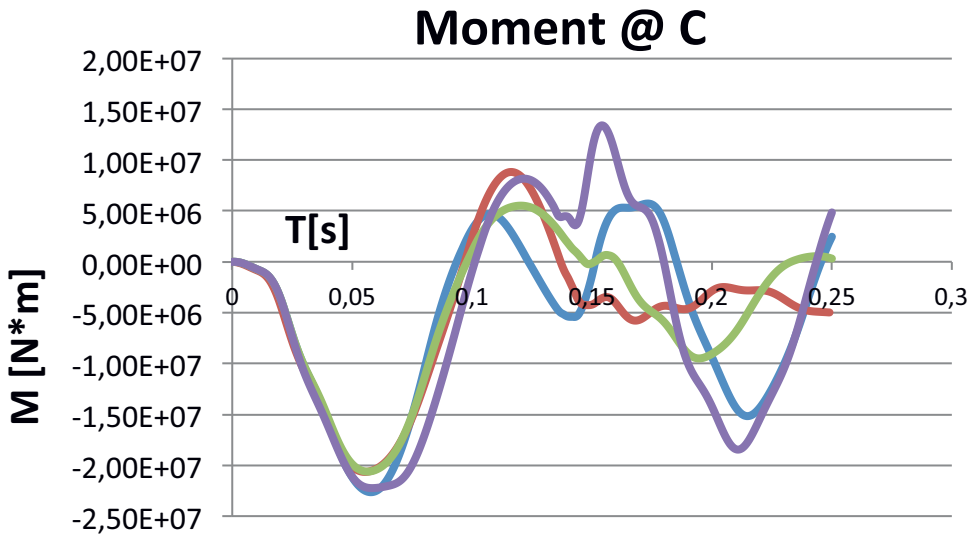
Comparison 18 – 24 modules

E	1000 kJ	2000 kJ	5000 kJ
U_Y	-1,8 %	-1,9 %	-0,06 %
U_X	-6,1 %	-7,7 %	-10,5 %

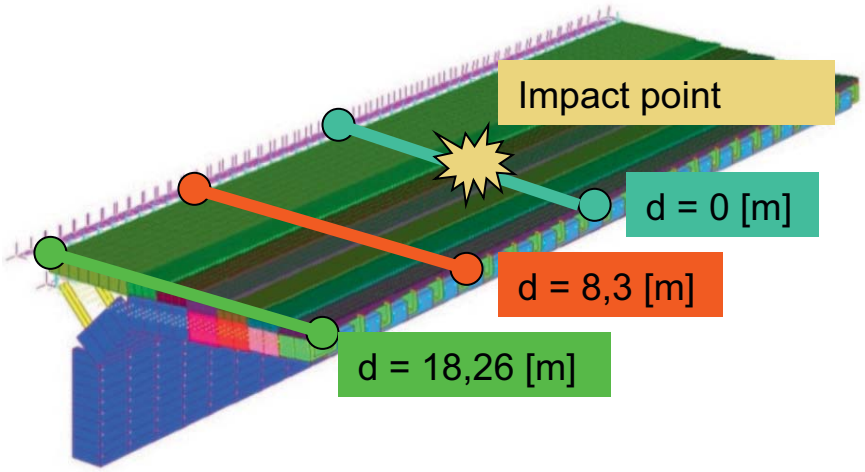
Structural response as a function number of modules

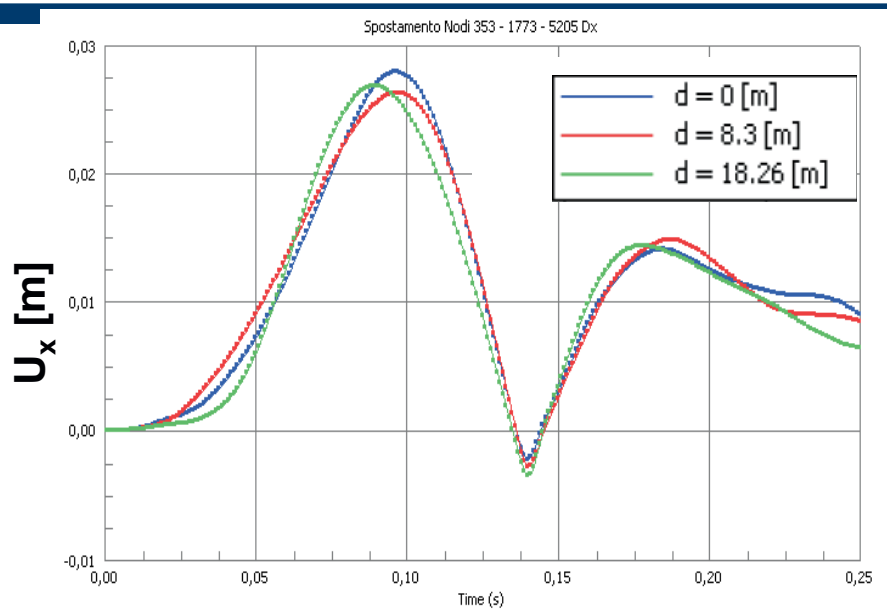


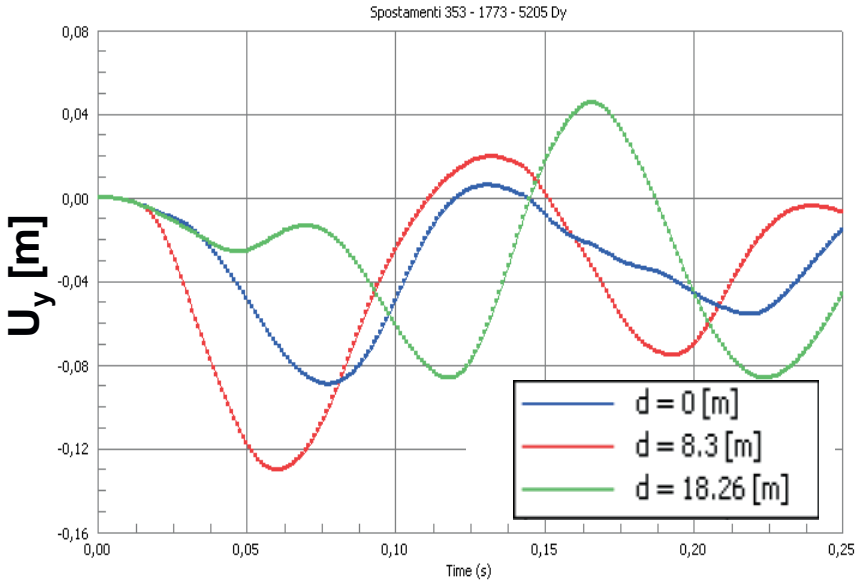
Comparison	1000 kJ	2000 kJ	5000 kJ
6-24 modules	-38,43 %	-45,58 %	-54,71 %
18-24 modules	-6,42 %	-8,44 %	-11,48 %

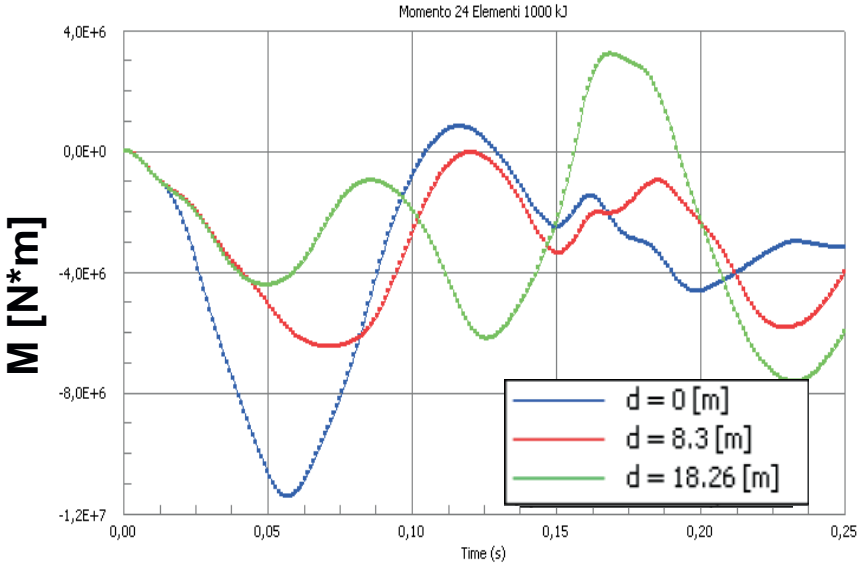


Structural response as a function of distance from impact point

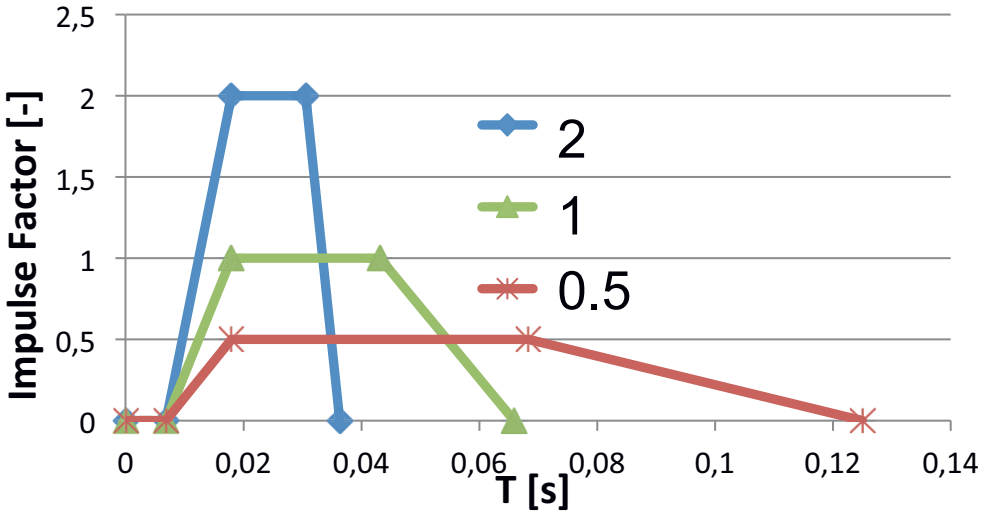


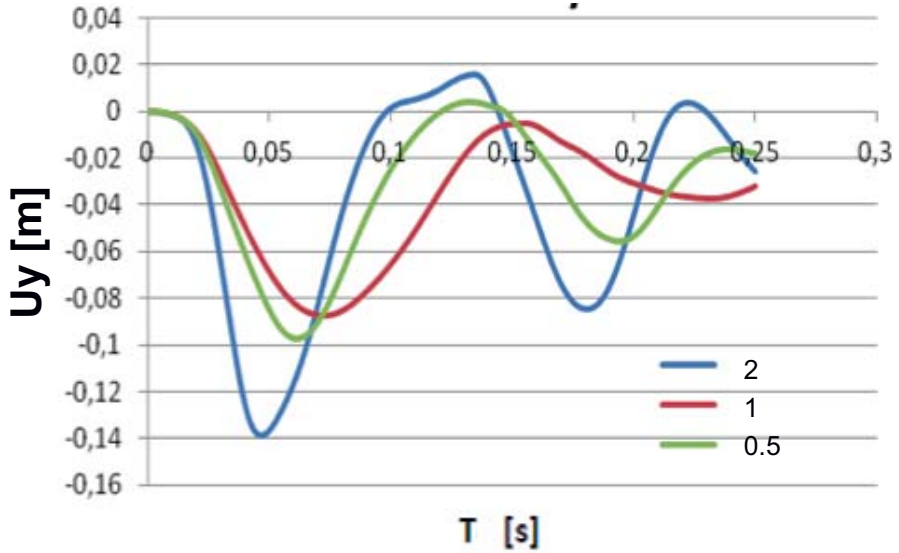


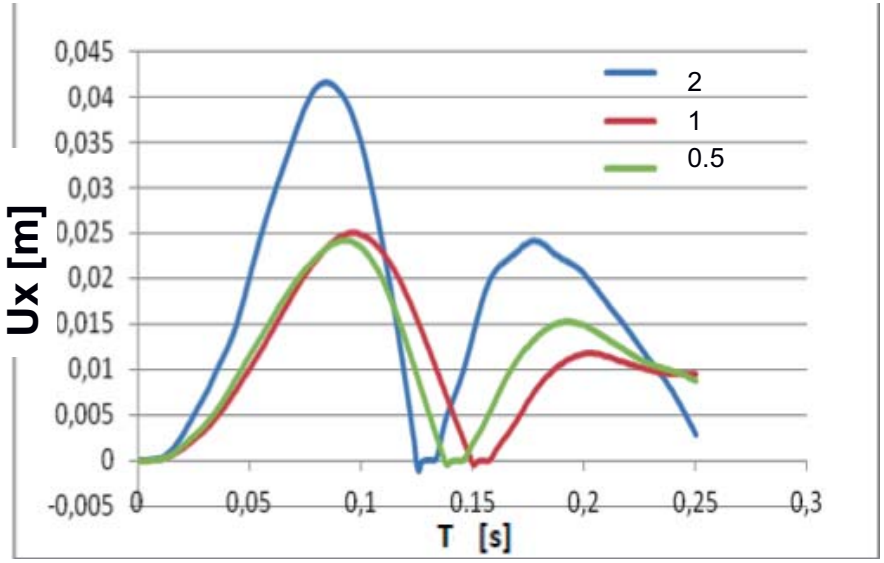




Structural response as a function of impulse shape

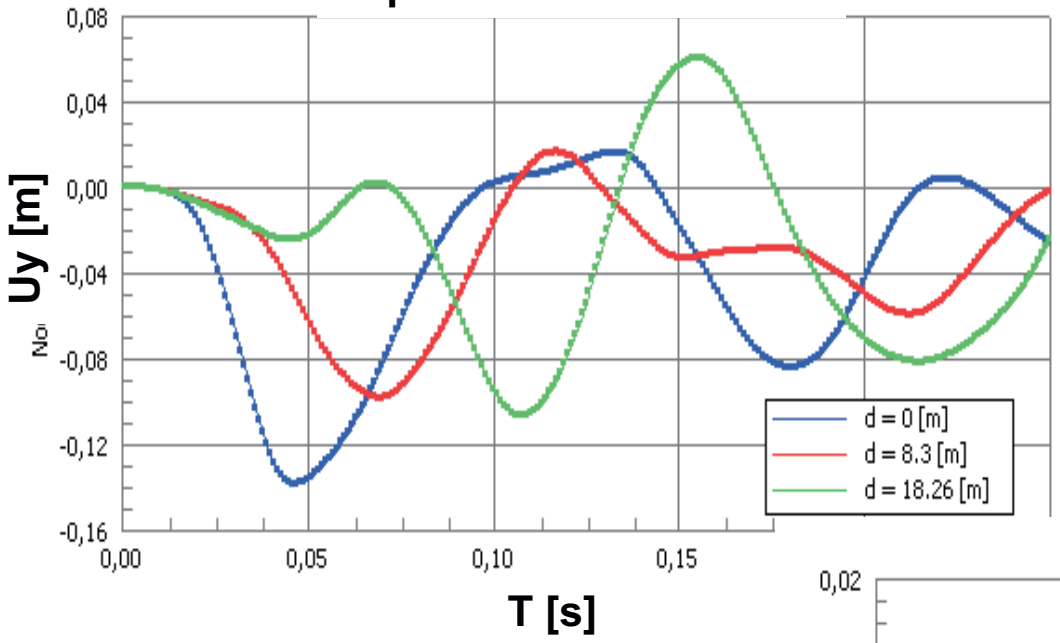






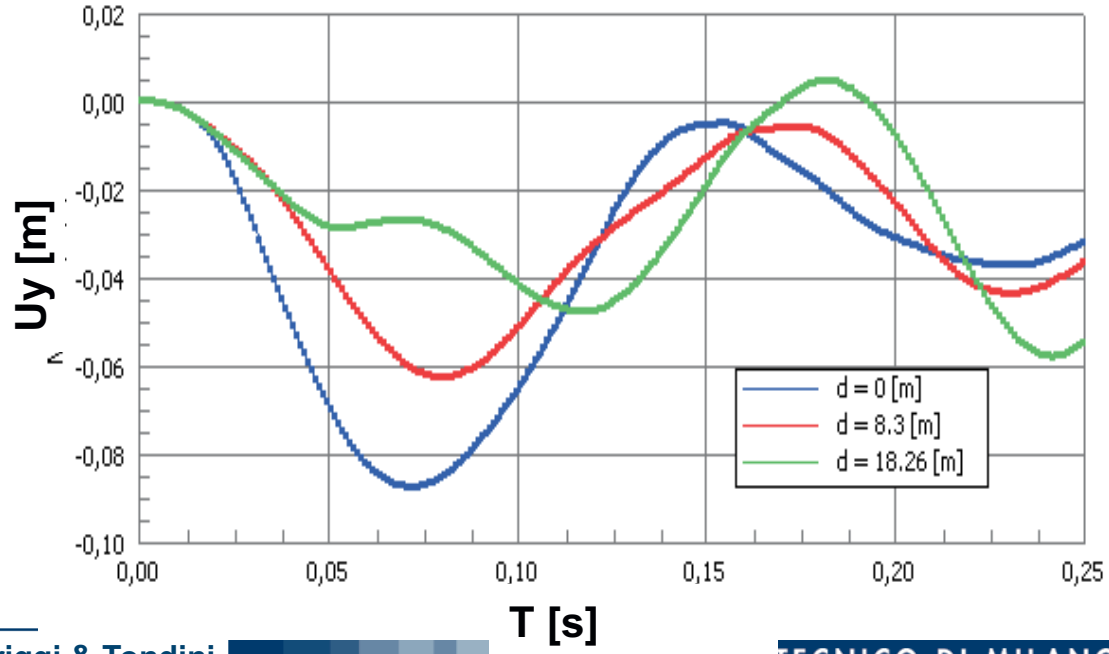
Structural response as a function of distance from impact point

Impulse factor 2.0



Vertical displacements @ A

Impulse factor 0.5



Structural response: dynamic amplification factors

$$R_d = \frac{u_0}{u_{st}}$$

Max. displacement under impulse load

Static displacement under peak of impulsive force