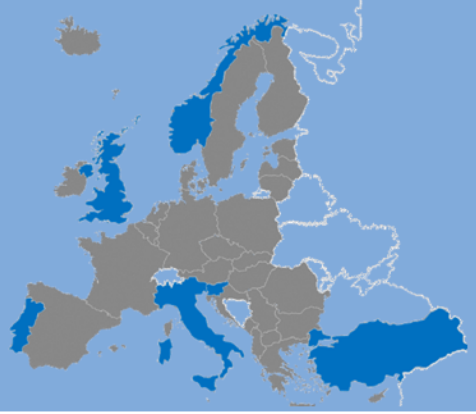
European Commission

Horizon 2020
European Union funding
for Research & Innovation

liquefACT



ASSESSMENT AND MITIGATION OF LIQUEFACTION POTENTIAL ACROSS EUROPE

A holistic approach to protect structures / infrastructures for improved resilience to earthquake-induced liquefaction disasters

RegioneEmilia-Romagna

Il progetto LIQUEFACT
in Emilia-Romagna

MODELLAZIONE FISICA IN CENTRIFUGA DI TECNICHE DI MITIGAZIONE DEL RISCHIO LIQUEFAZIONE SISMO-INDOTTA

Vincenzo Fioravante, *Daniela Giretti*, Sergio Airoldi, Jenni Moglie

WP4. Comparative Analysis of State of the Art Liquefaction Mitigation Measures
T4.2 – Small scale centrifuge modelling

ISMGEO
ISTITUTO SPERIMENTALE MODELLI GEOTECNICI

February 17th 2021

Riproduzione del comportamento dinamico di depositi sabbiosi sottoposti a sisma mediante *PROVE DINAMICHE in CENTRIFUGA GEOTECNICA* in presenza e in assenza di

- ✓ *DRENI VERTICALI*
- ✓ *DRENI ORIZZONTALI*
- ✓ *PARZIALE SATURAZIONE INDOTTA*
- ✓ *STRUTTURA IN SUPERFICIE* (telaio a un grado di libertà con fondazioni superficiali)

PROTOTIPO DI RIFERIMENTO = depositi sabbiosi tipici dell'area interessata dalla liquefazione in Emilia Romagna nel 2012

- ✓ *Strato di sabbia di 14 m di spessore*
- ✓ *Piano campagna orizzontale*
- ✓ *Deposito omogeneo o con strato superficiale* ("crosta") di terreno fine a bassa permeabilità

obiettivo delle prove =produrre una banca dati sperimentale da utilizzare per calibrare e validare metodi numerici con i quali eseguire studi parametrici

(1) INNESCO DELLA LIQEFAZIONE

Terreni di prova: (1) Sabbia del Ticino – S1
(2) Sabbia di Pieve di Cento pulita – S2
(3) Sabbia di Pieve di Cento naturale (12% contenuto di fine) – S3

Stratigrafia: (1) Sabbia omogenea – modello M1
(2) Sabbia omogenea + crosta fine in superficie (2 strati) – M2
FALDA A PIANO CAMPAGNA

Sollecitazione sismica: GM 17, 23, 34, 31, 31+

Interazione terreno-struttura: (1) modello omogeneo senza e con struttura (F)

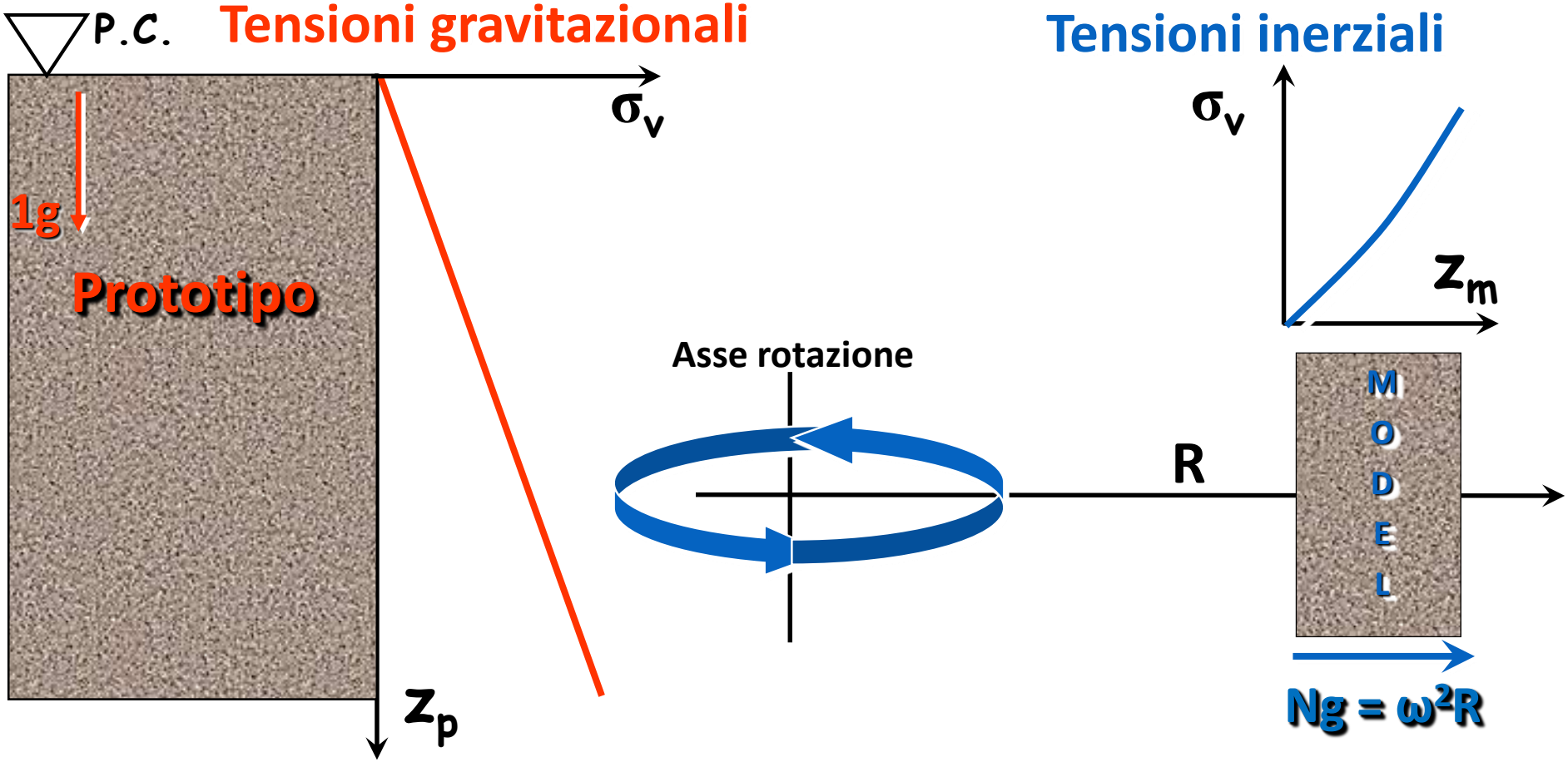
(2) modello 2 strati senza e con struttura (F)

(2 e 3) EFFICCACIA TECNICHE DI MITIGAZIONE

Sabbia S1, Modelli M1 e M2, M1F, M2F, GM31 e GM31+

1. dreni VERTICALI (V)
2. dreni ORIZZONTALI (H)
3. Induced Partial Saturation (IPS)

$$(\sigma_v)_{prot} = \rho g\, z_p = \rho\,(Ng)(z_p/N) \approx \rho N g\, z_m = (\sigma_v)_{mod}$$



MODELLAZIONE IN CENTRIFUGA – LEGGI DI SCALA

	Variable	Scale factor $X^*=X_{prototype}/X_{model}$	Ng model
L	Length	L^*	N
ρ	Soil density	ρ^*	1
ε	Strain	ε^*	1
σ	Stresses (effective and total)	$\sigma^*=x^*\rho^*g^*$	1
G	Stiffness	$G^*=x^*\rho^*g^*/\varepsilon^*$	1
ρ_f	Fluid density	ρ^*	1
p	Fluid pressure	$p^*= x^*\rho^*g^*$	1
u	Soil displacement (continuum)	$u^*=x^*\varepsilon^*$	N
v	Velocity	$v^*=(x^*\varepsilon^*g^*)^{0.5}$	1
ü	Acceleration	g^*	N^{-1}
t	Time (consolidation)	$t^*=\mu^*L^{*2}/G^*$	N^2
t	Time (creep)	t^*	1
t	Time (dynamic)	$t^*=(x^*\varepsilon^*/g^*)^{0.5}$	N
μ	Dynamic viscosity of fluid	$\mu^*=\rho^*(g^*/x^*\varepsilon^*)^{0.5}$	N^{-1}
K_f	Compressibility modulus of soil	$K_f^*=x^*\rho^*g^*/\varepsilon^*$	1

LA CENTRIFUGA SISMICA ITALIANA

CARATTERISTICHE CENTRIFUGA

VELOCITA' LIMITE.....600 g
PAYLOAD.....4 kN
CAPACITA'.....240 g-ton
RAGGIO BRACCIO.....3 m

ASSE ROTAZIONE

BRACCIO SIMMETRICO ROTANTE

CONTRAPPESO

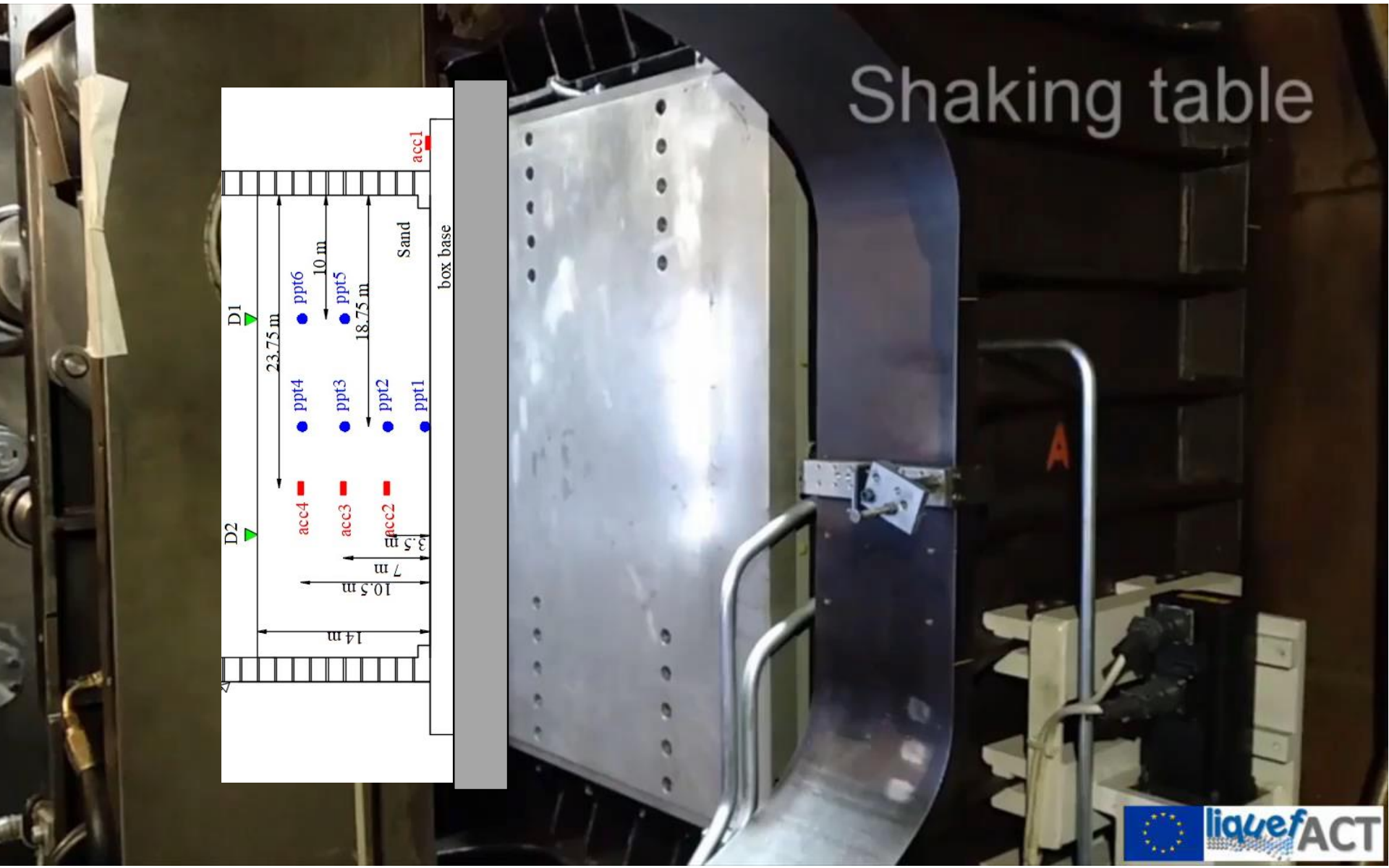
MODELLO

CARATTERISTICHE DEL MODELLO

RAGGIO NOMINALE.....2 m
DIMENSIONI MAX....1x0.8x0.5 m

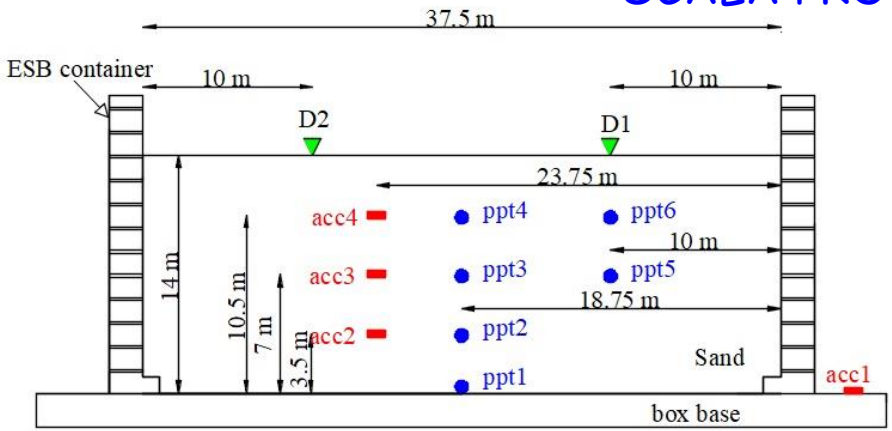
Video sull'utilizzo della centrifuga nell'ambito del progetto liquefact

https://www.youtube.com/channel/UCQ2wa0eluwdkGSppjCvVCyQ

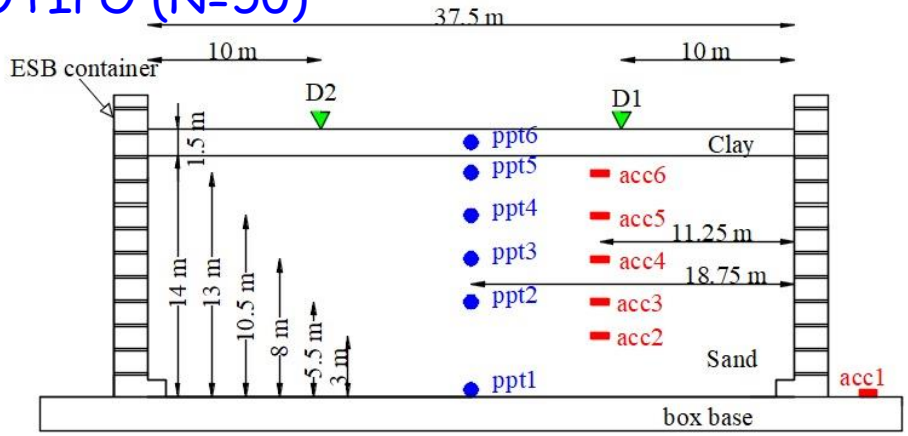

Shaking table
acc1
box base
Sand
D1
D2
ppt6
ppt5
ppt4
ppt3
ppt2
ppt1
10 m
18.75 m
23.75 m
acc4
acc3
acc2
3.5 m
7 m
10.5 m
14 m

SERIE 1 e 2 – LE PROVE DISCUSSE

M1_S1_GM31

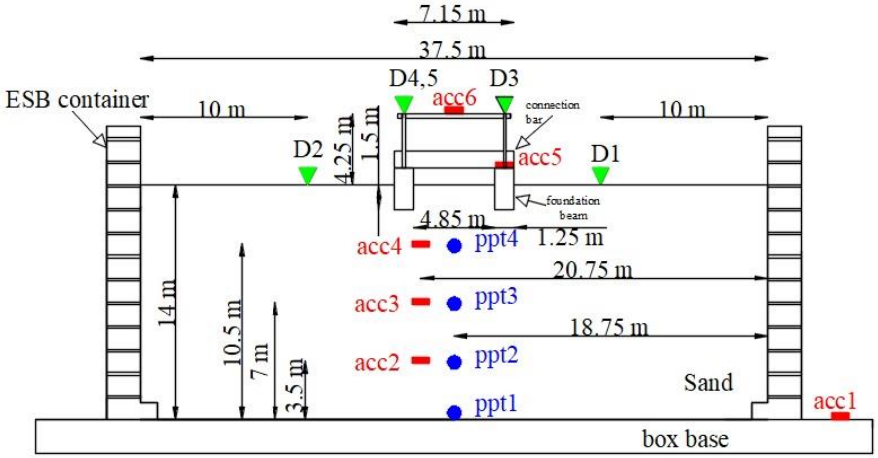


M2_S1_GM31

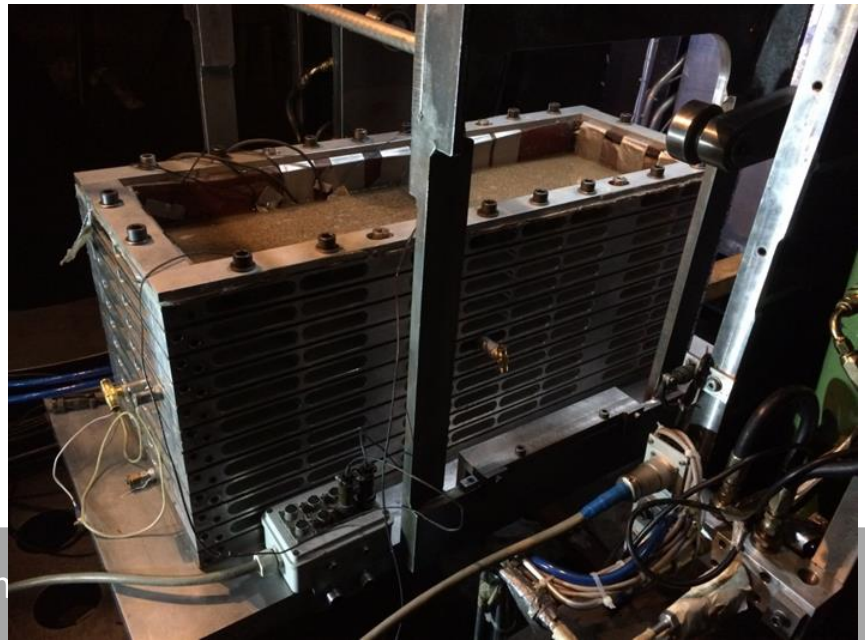


SCALA PROTOTIPO (N=50)

M1F_S1_GM31 e GM31+



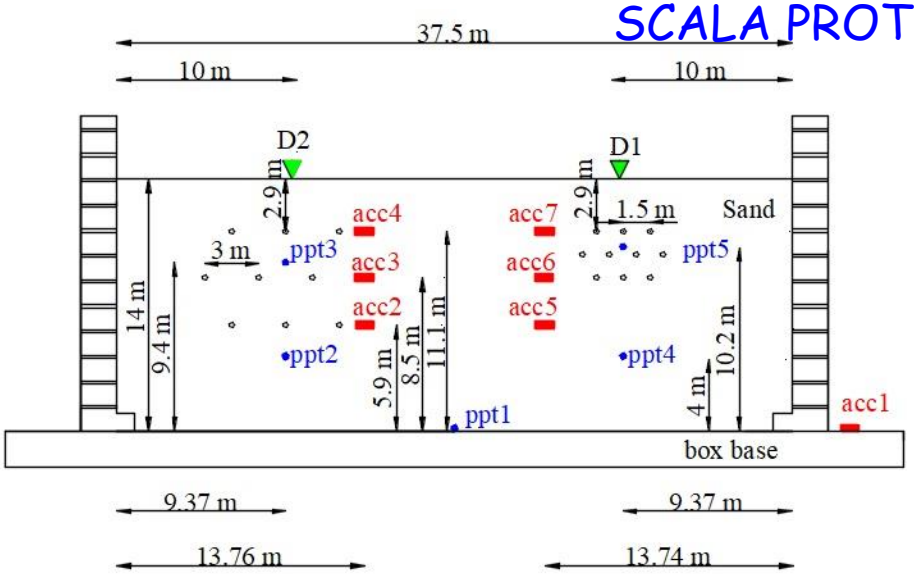
CONTENITORE ESB



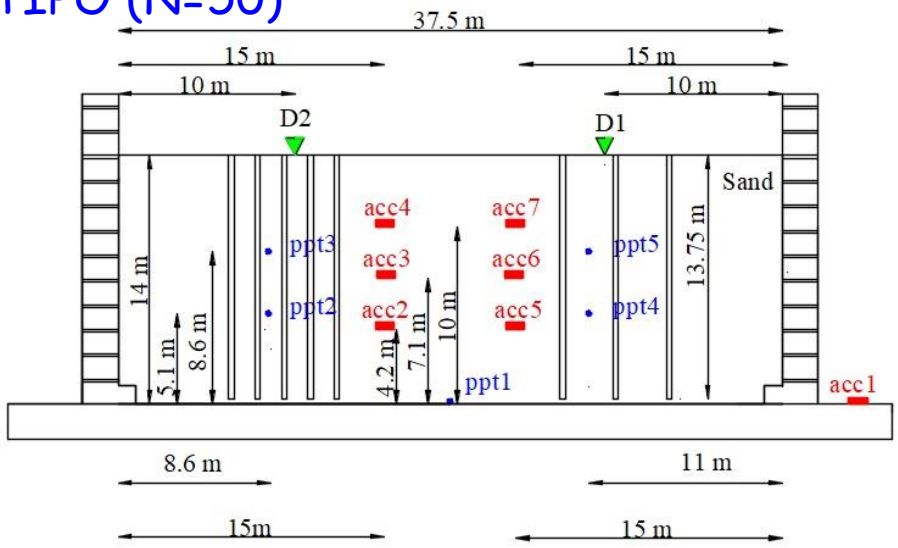
SERIE 1 e 2 – LE PROVE DISCUSSE

M1_S1_HD_GM31

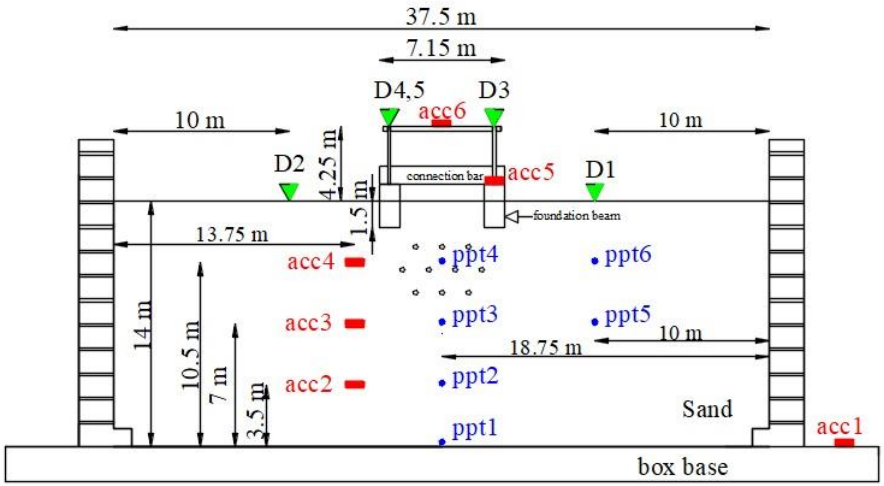
SCALA PROTOTIPO (N=50)



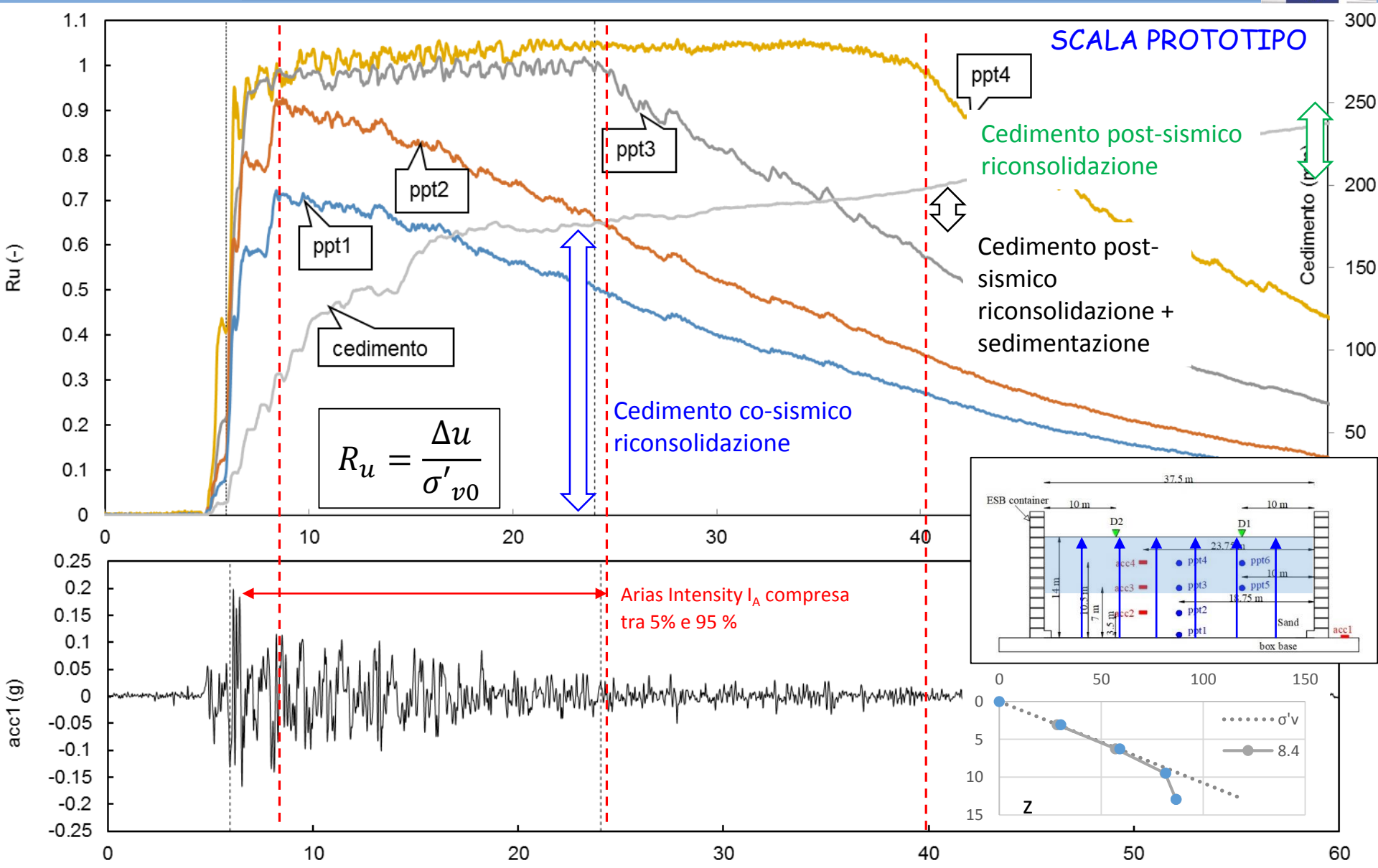
M1_S1_VD_GM31



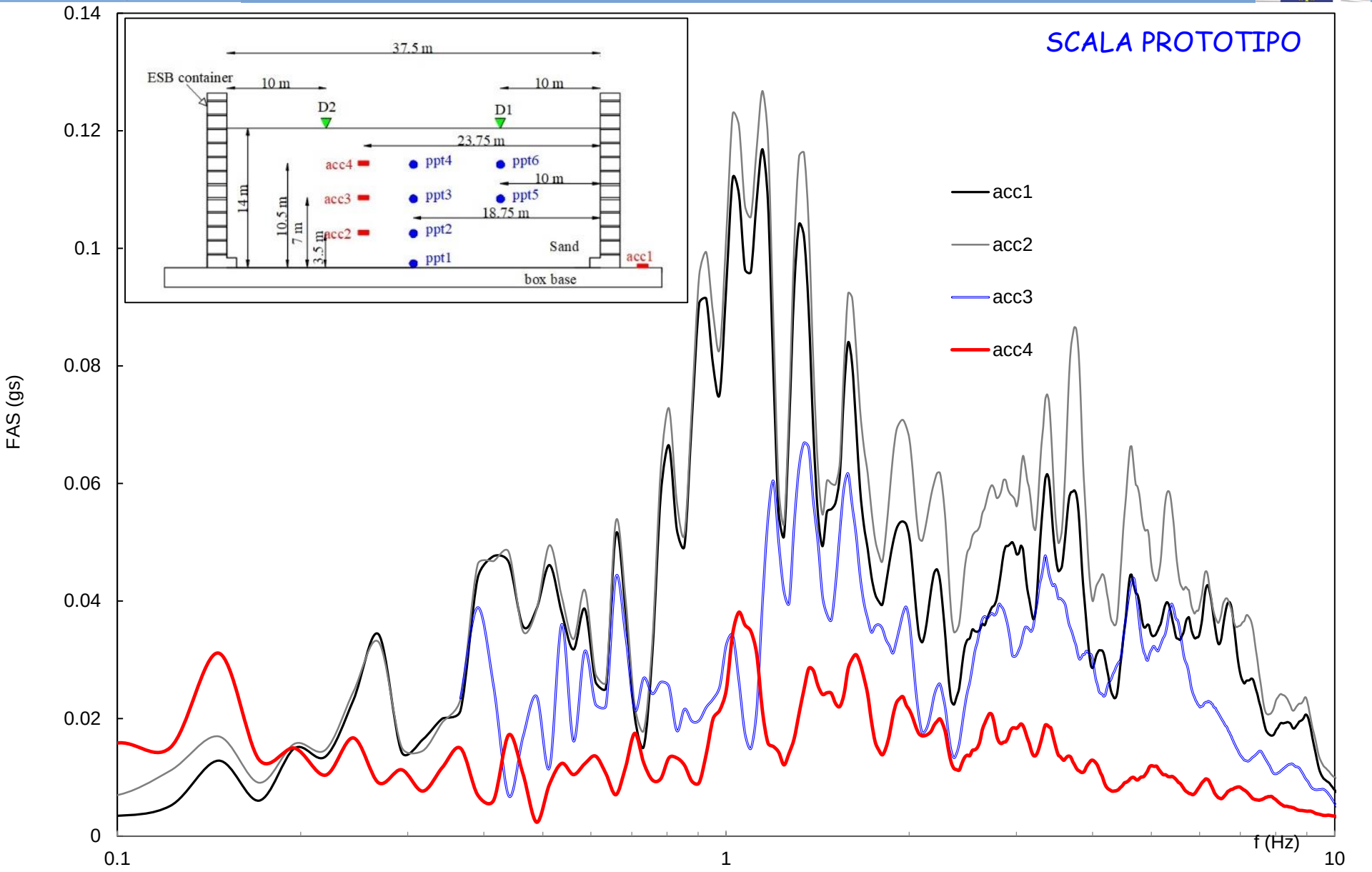
M1F_S1_HD1_GM31+



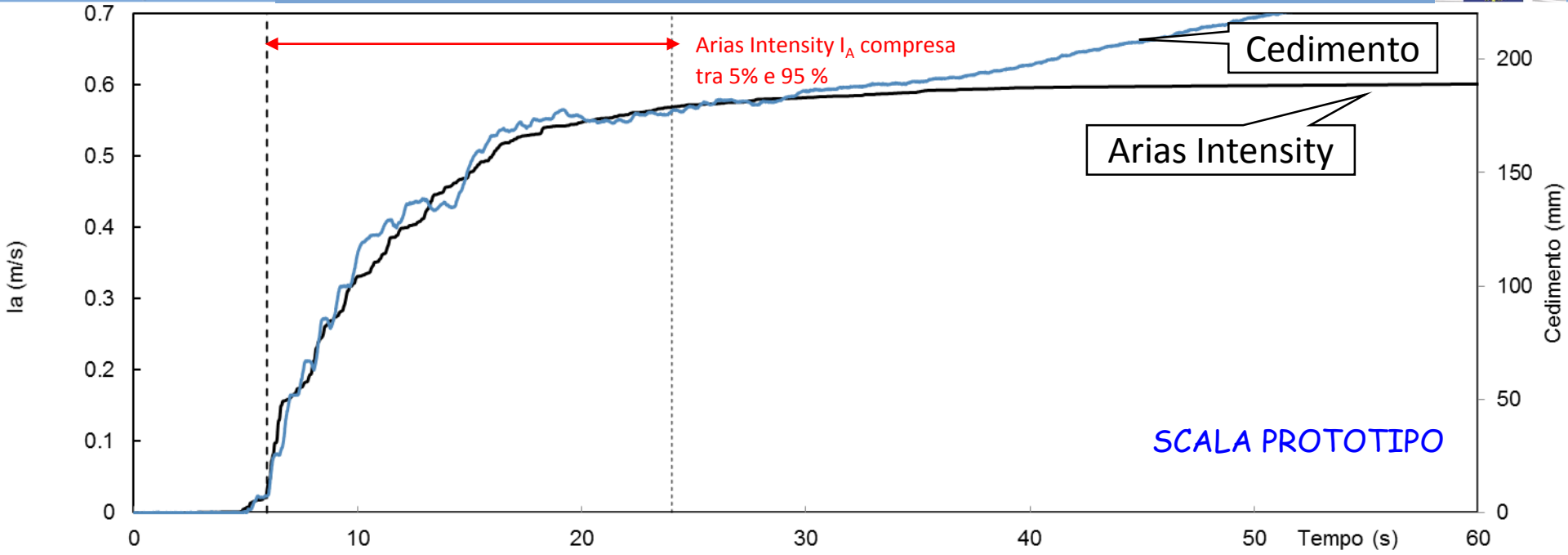
MODELLO DI RIFERIMENTO M1_S1_GM31

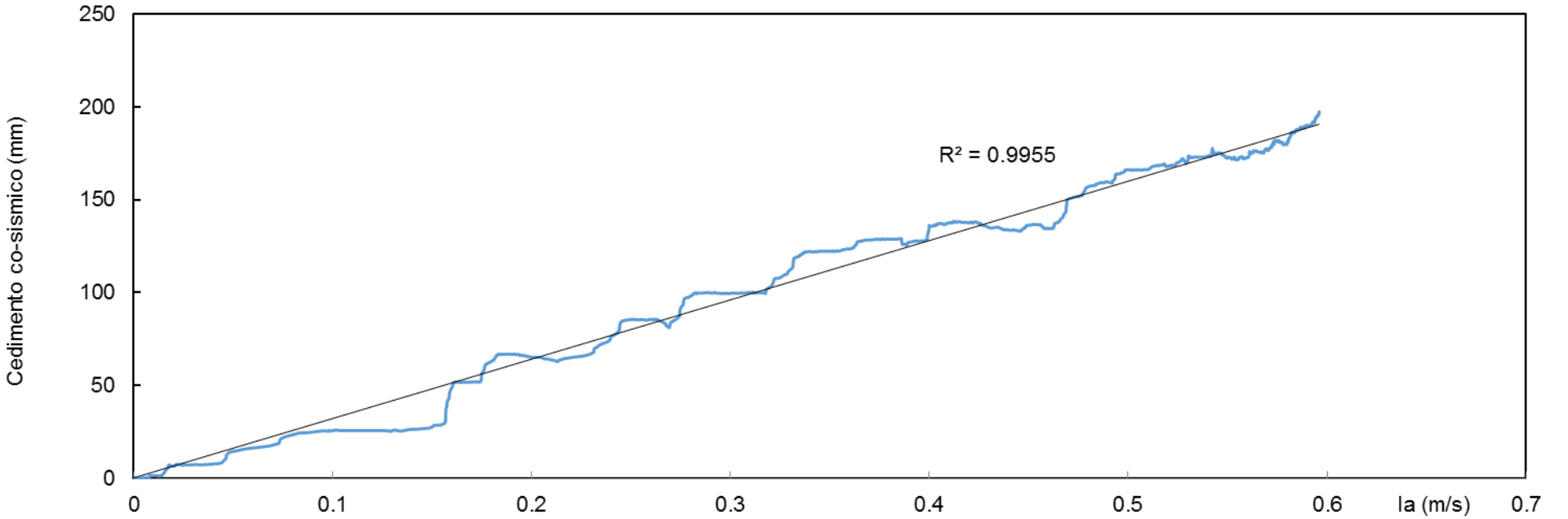


MODELLO DI RIFERIMENTO M1_S1_GM31



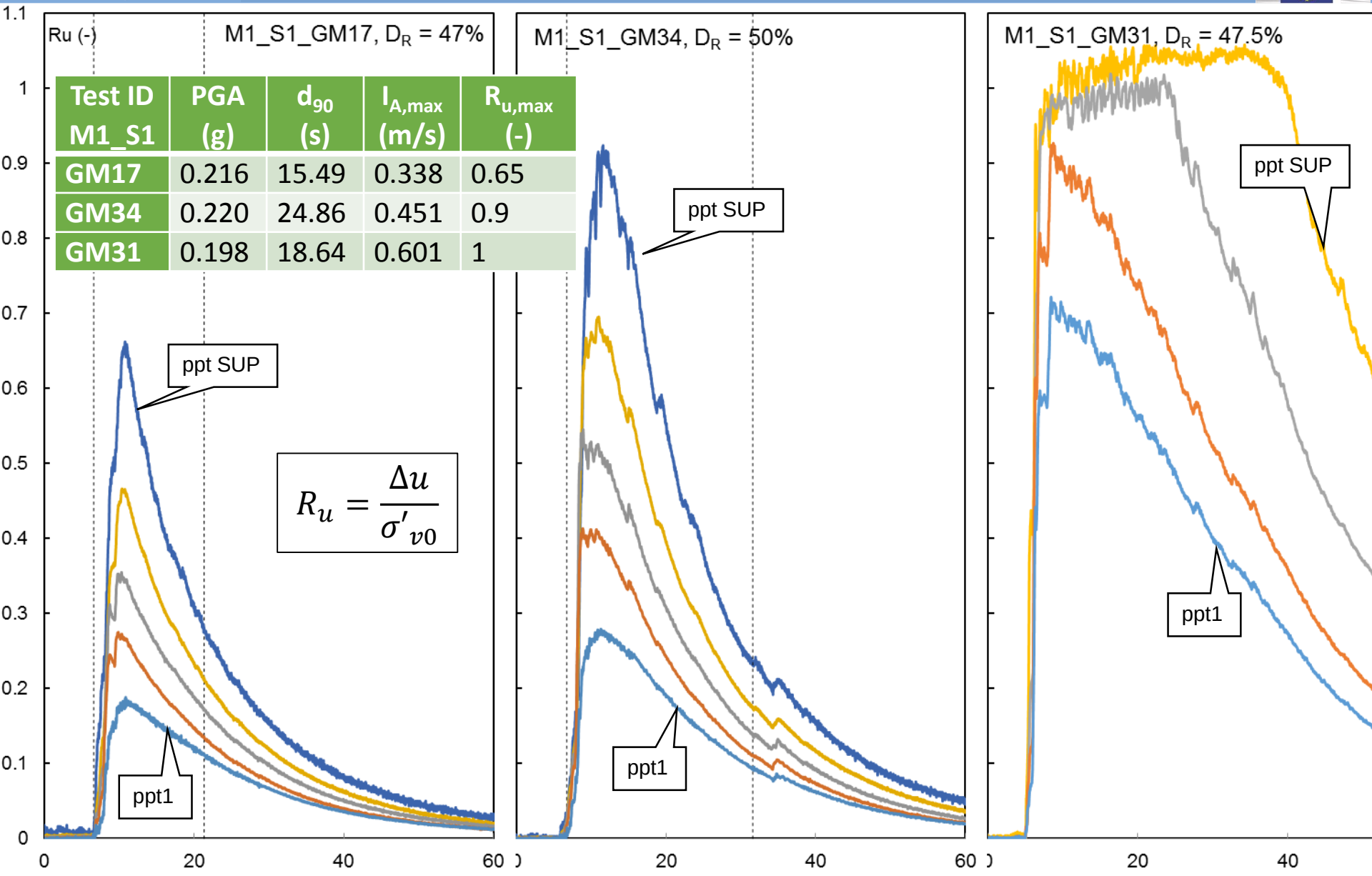
MODELLO DI RIFERIMENTO M1_S1_GM31





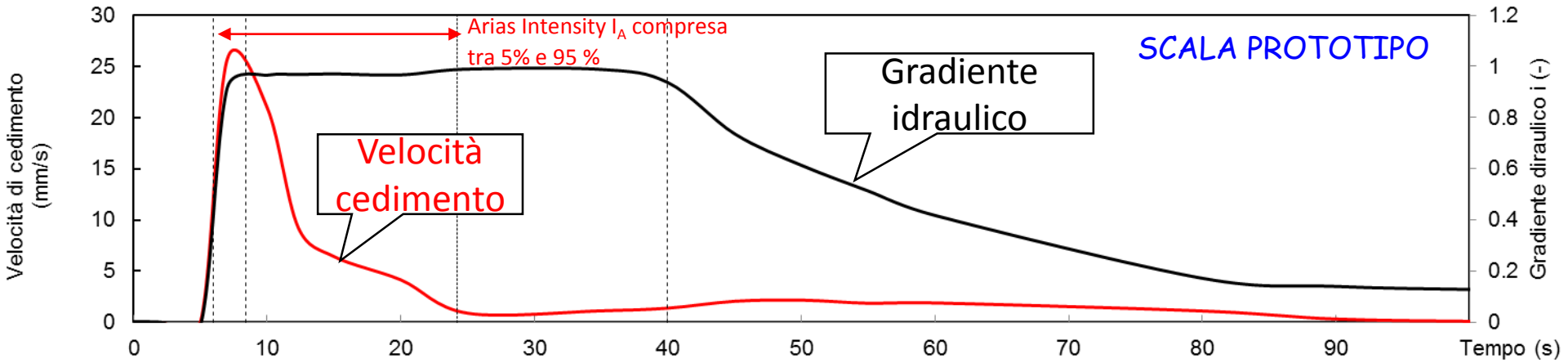
modelli M1_S1

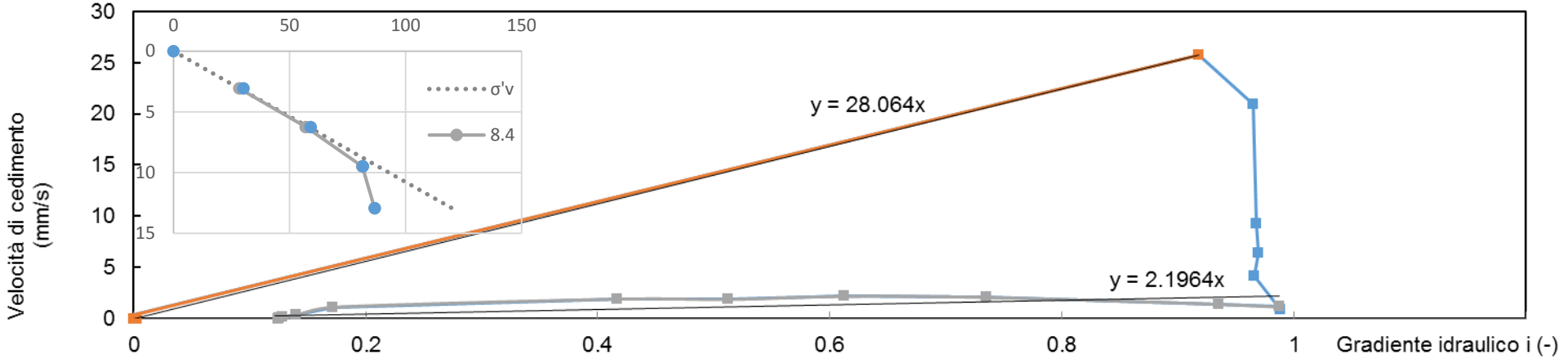
Test ID M1_S1	PGA (g)	d_{90} (s)	$I_{A,max}$ (m/s)	$R_{u,max}$ (-)
GM17	0.216	15.49	0.338	0.65
GM34	0.220	24.86	0.451	0.9
GM31	0.198	18.64	0.601	1

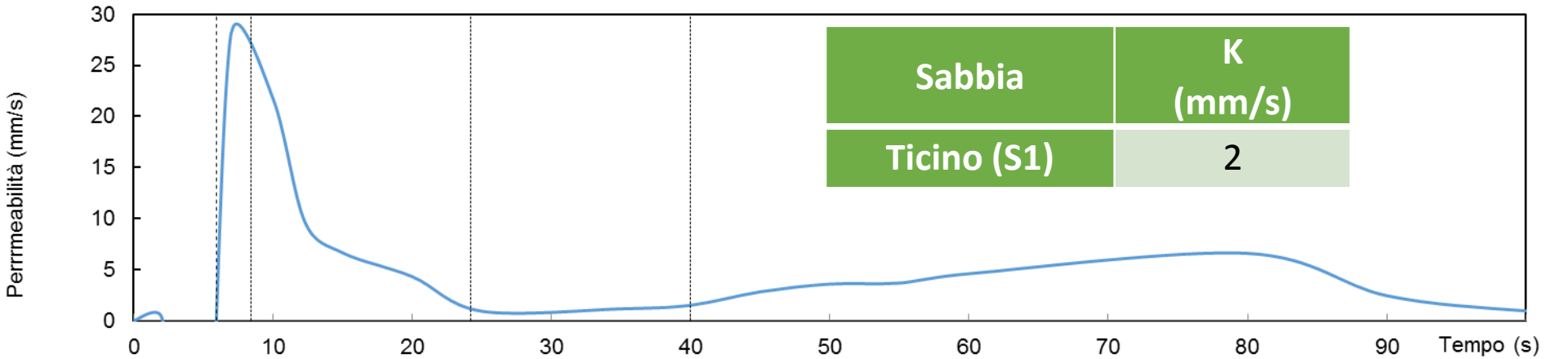


SCALA PROTOTIPO

MODELLO DI RIFERIMENTO M1_S1_GM31



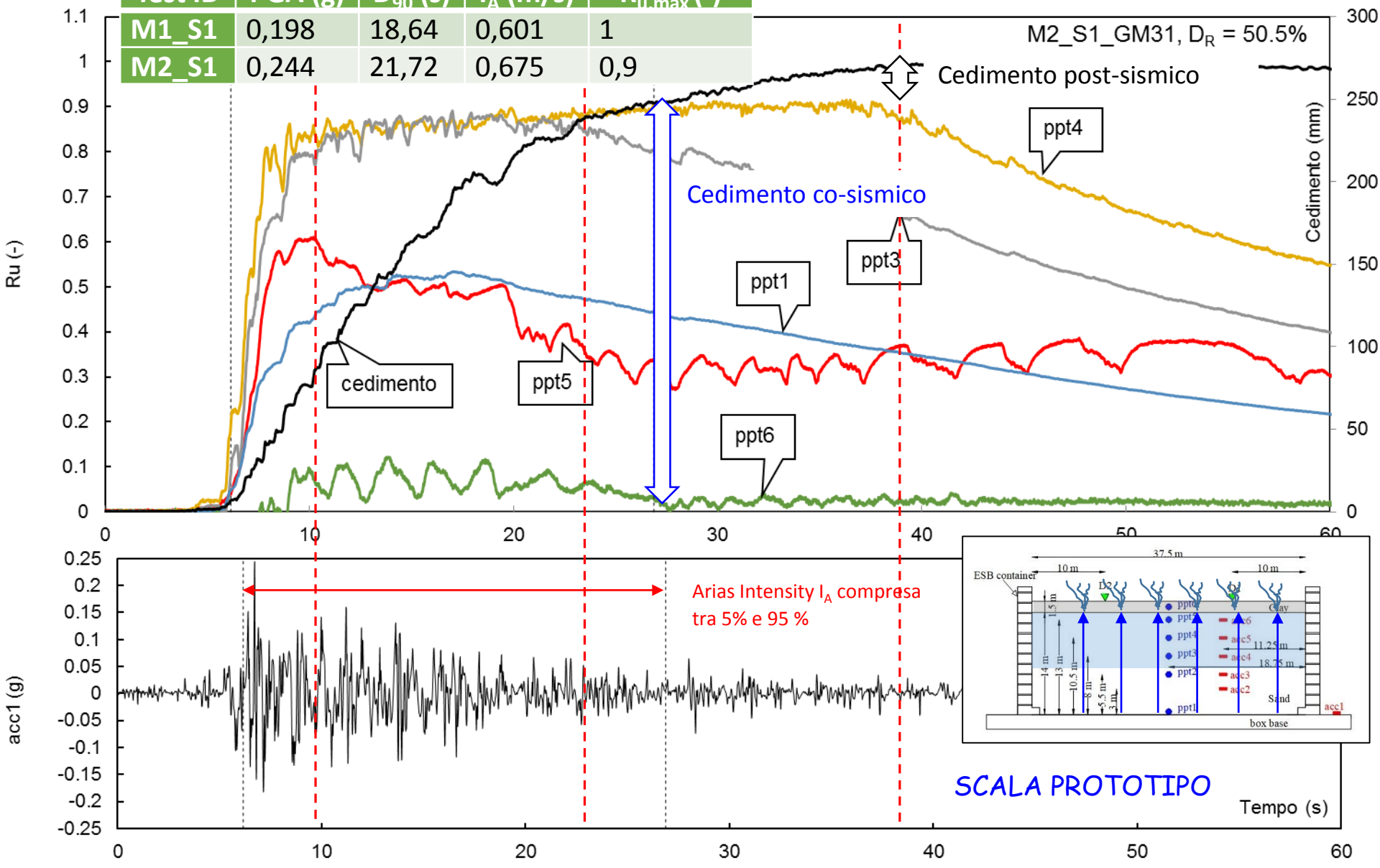




Sabbia	K (mm/s)
Ticino (S1)	2

PRESENZA DI UNA CROSTA SUPERFICIALE M2_S1_GM31

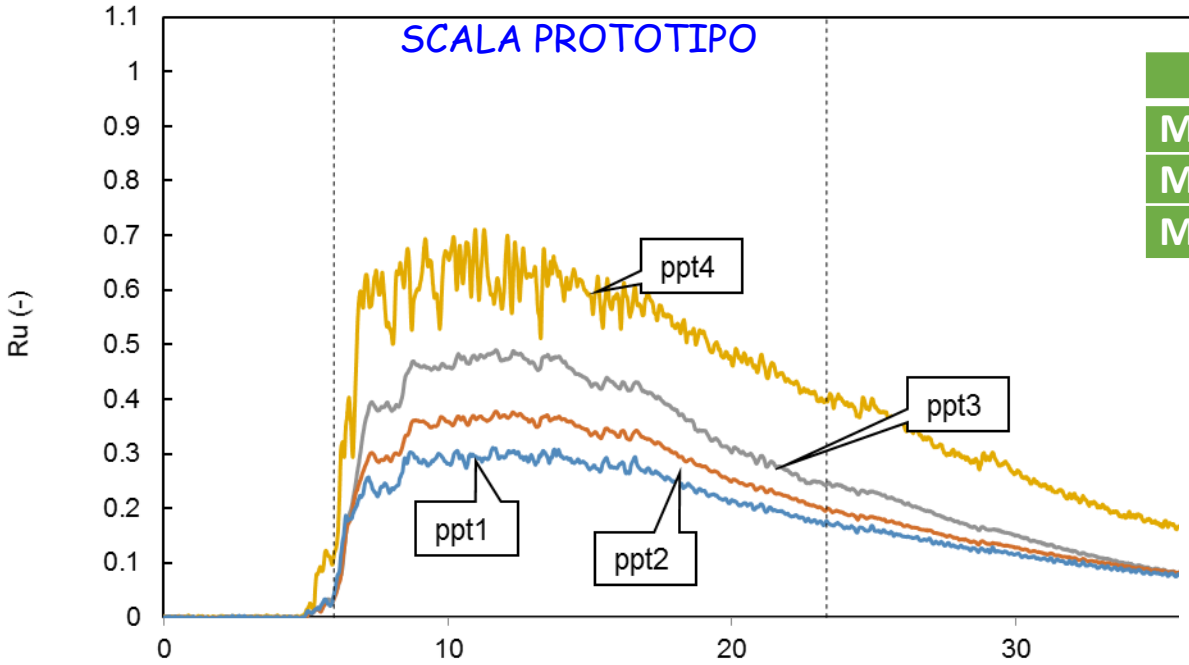
Test ID	PGA (g)	D_{90} (s)	I_A (m/s)	$R_{u,max}$ (-)
M1_S1	0,198	18,64	0,601	1
M2_S1	0,244	21,72	0,675	0,9



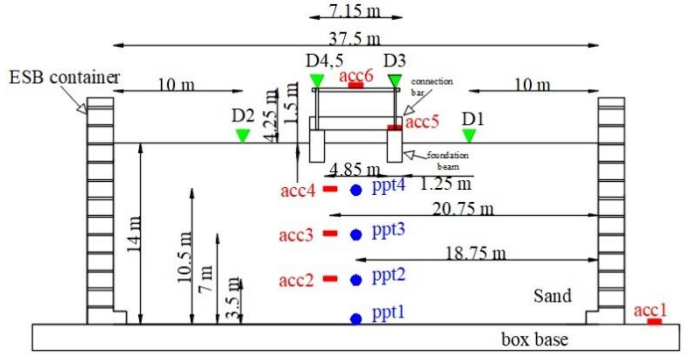
PRESENZA DI UNA CROSTA SUPERFICIALE M2_S1_GM31

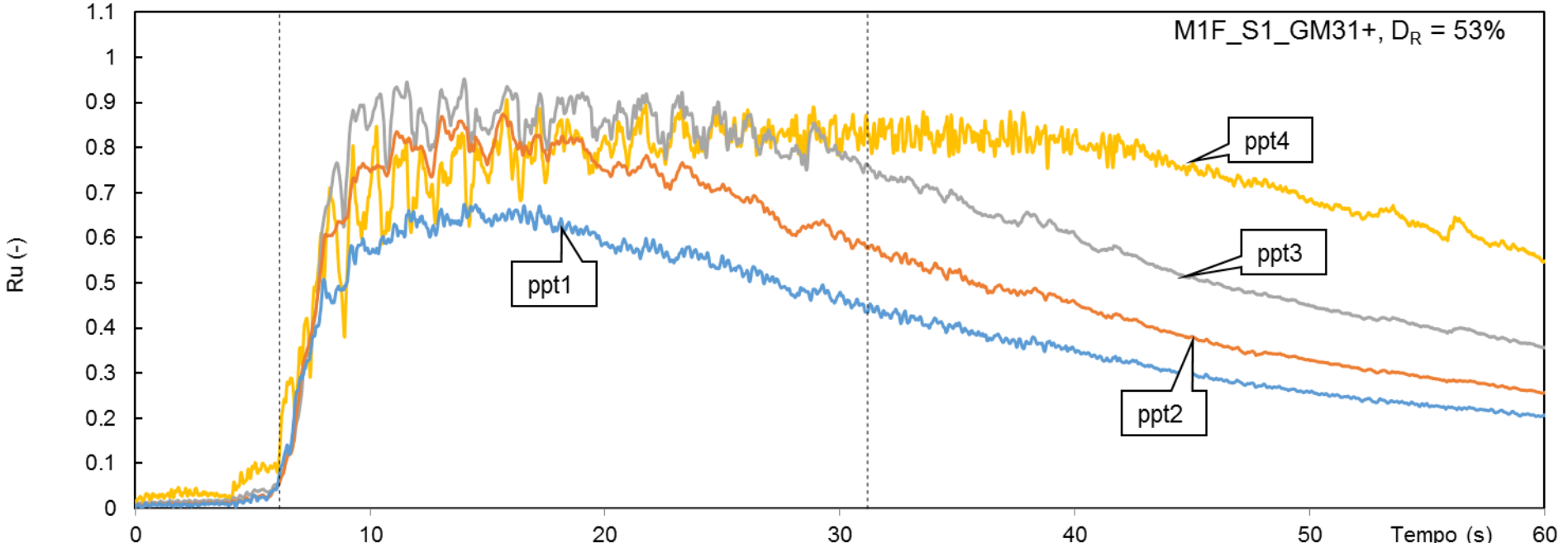
PRESENZA DI UNA CROSTA SUPERFICIALE

PRESENZA DI UNA STRUTTURA M1F_S1_GM31&31+

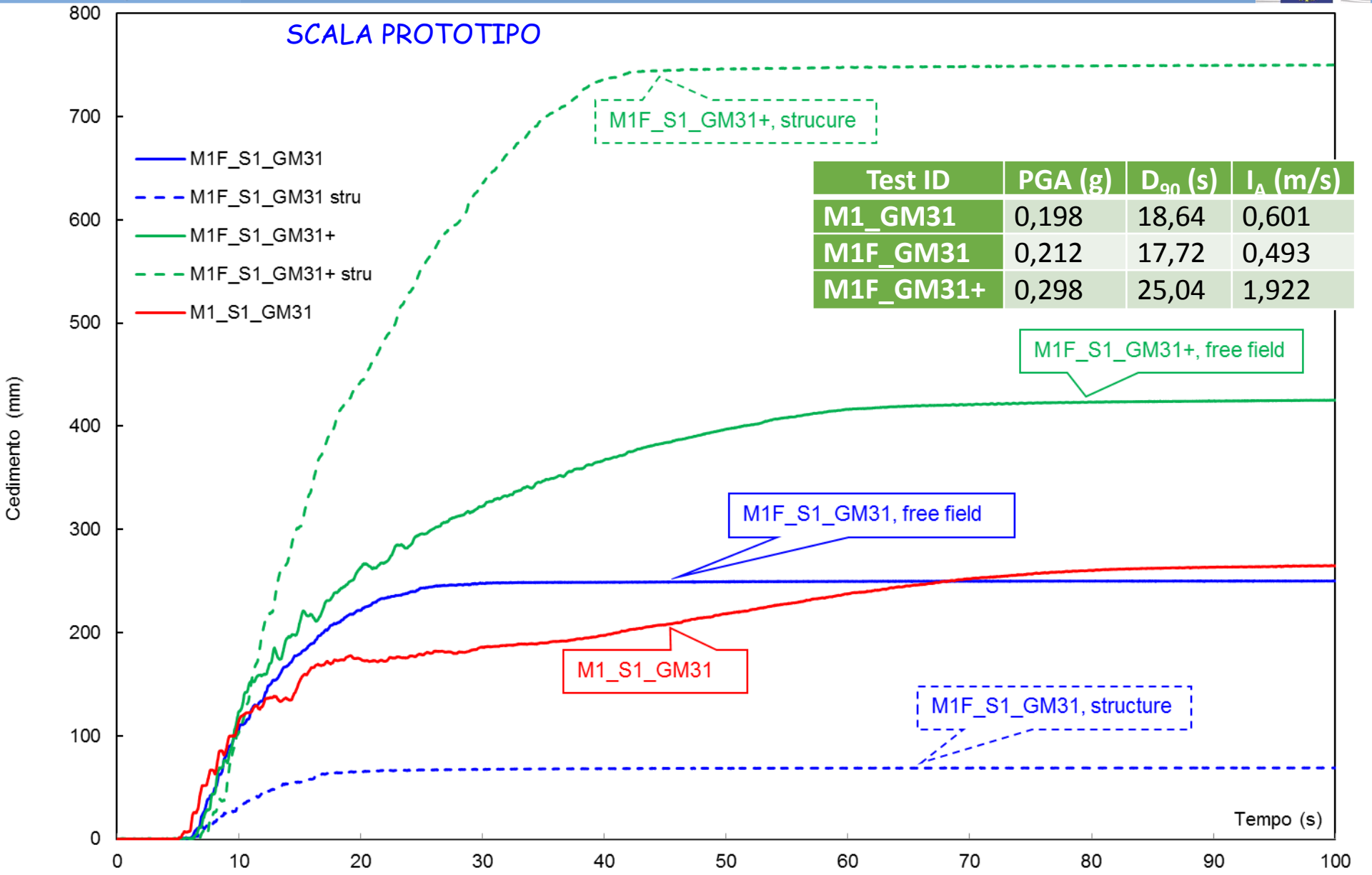


Test ID	PGA (g)	D_{90} (s)	I_A (m/s)
M1_GM31	0,198	18,64	0,601
M1F_GM31	0,212	17,72	0,493
M1F_GM31+	0,298	25,04	1,922



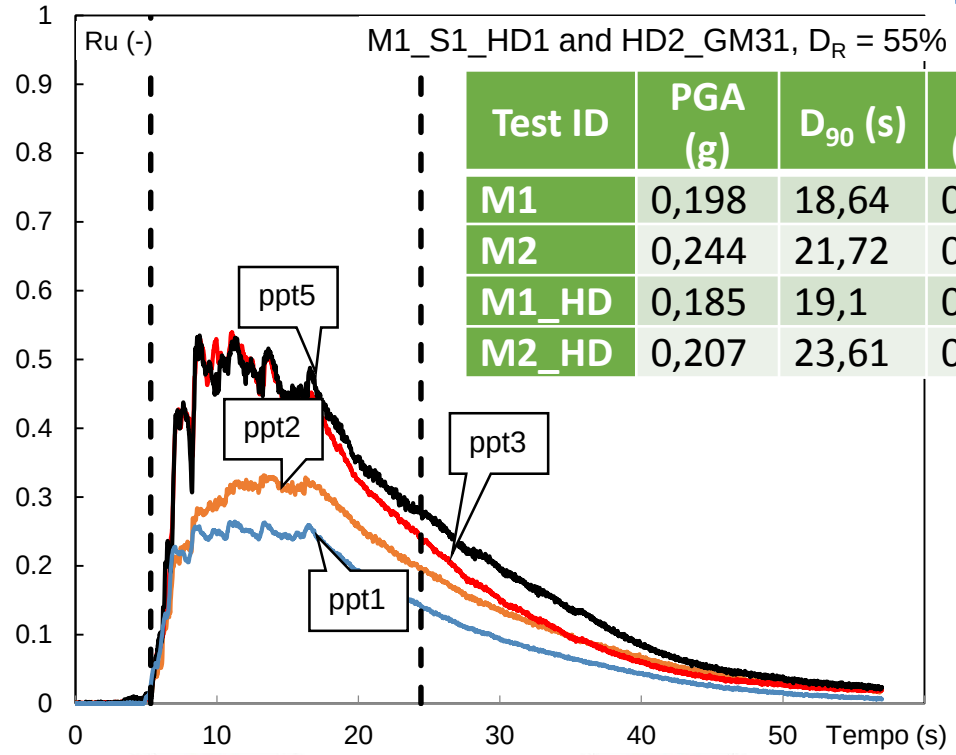


PRESENZA DI UNA STRUTTURA M1F_S1_GM31&31+

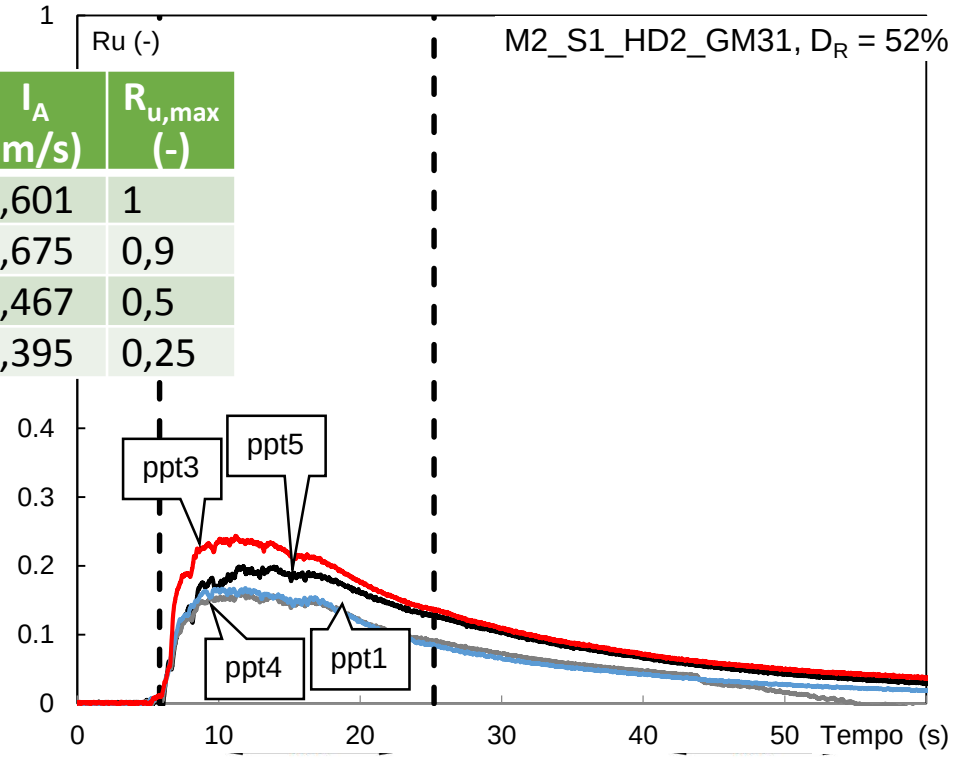


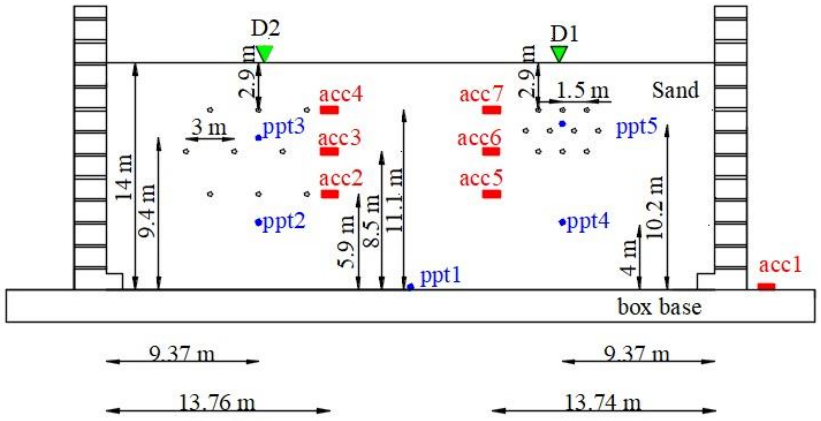
Test ID	PGA (g)	D_{90} (s)	I_A (m/s)
M1_GM31	0,198	18,64	0,601
M1F_GM31	0,212	17,72	0,493
M1F_GM31+	0,298	25,04	1,922

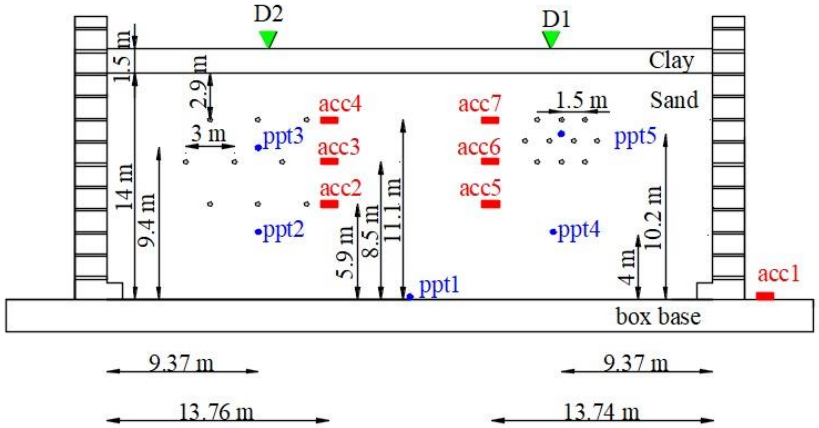
EFFETTO DEI DRENI ORIZZONTALI

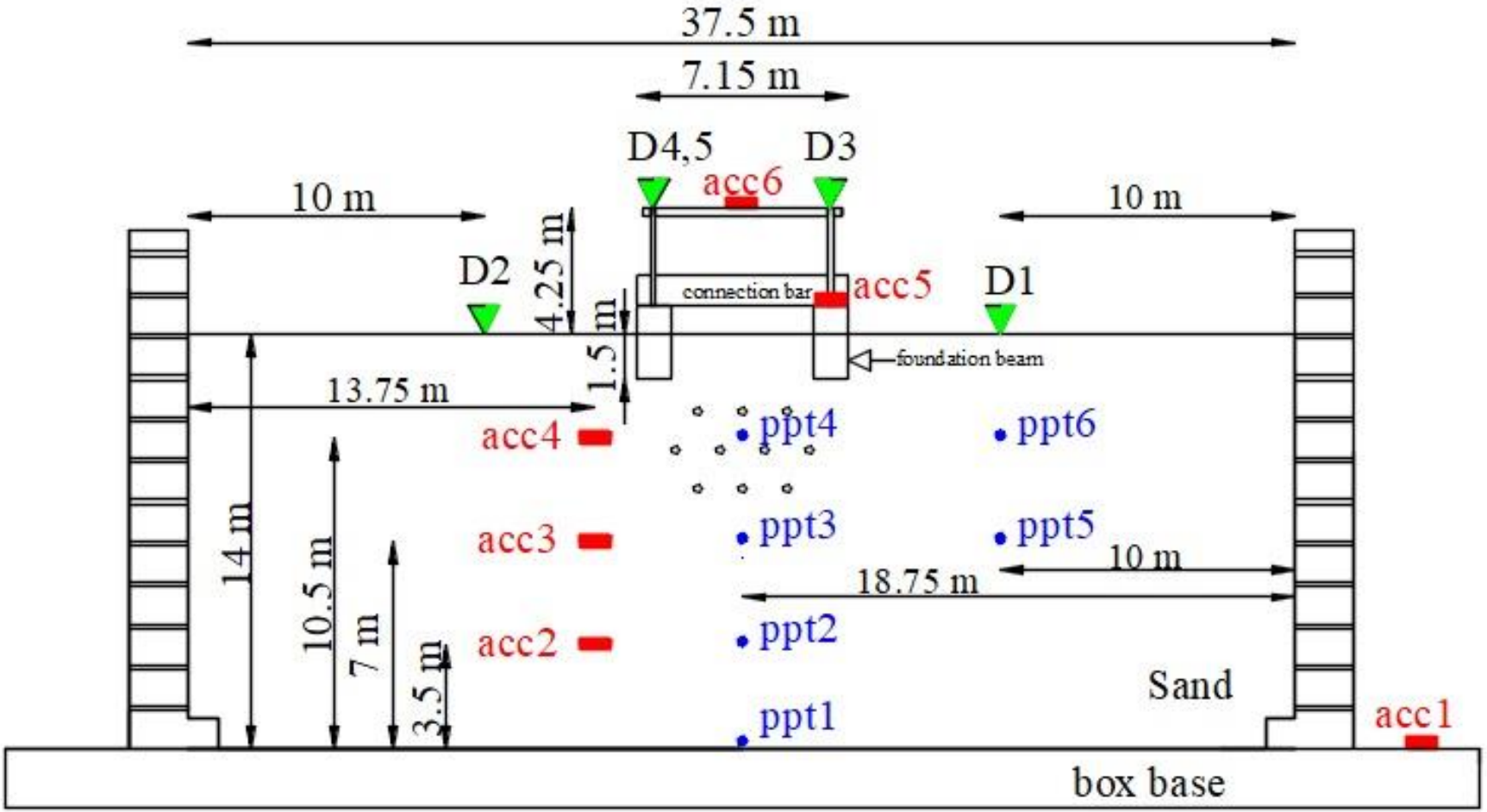


Test ID	PGA (g)	D_{90} (s)	I_A (m/s)	$R_{u,max}$ (-)
M1	0,198	18,64	0,601	1
M2	0,244	21,72	0,675	0,9
M1_HD	0,185	19,1	0,467	0,5
M2_HD	0,207	23,61	0,395	0,25

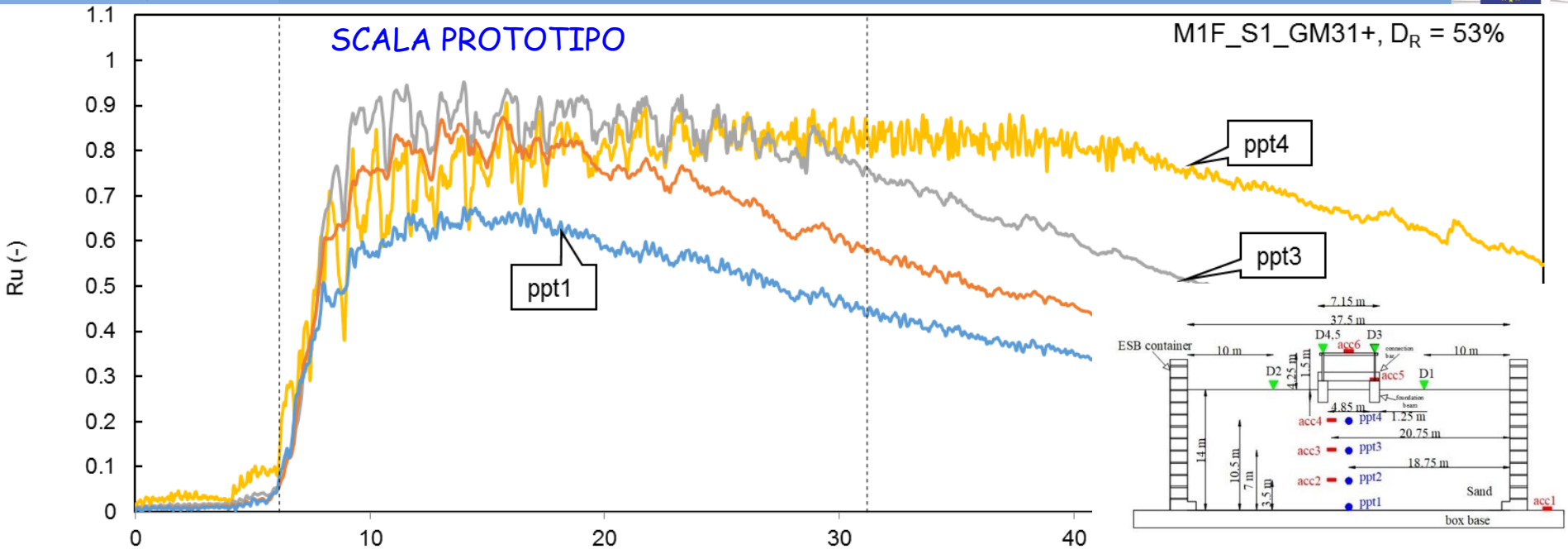


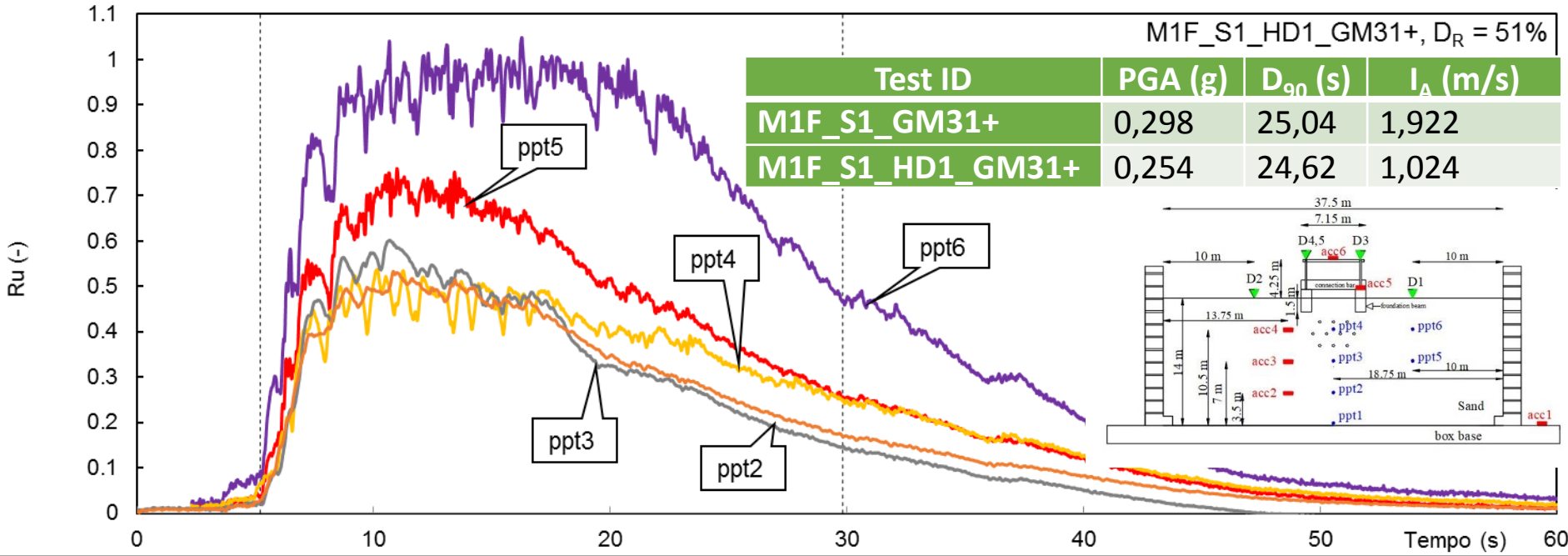





37.5 m
7.15 m
D4,5
D3
acc6
10 m
10 m
D2
4.25 m
connection bar
acc5
D1
1.5 m
foundation beam
13.75 m
acc4
ppt4
ppt6
14 m
10.5 m
7 m
3.5 m
acc3
ppt3
ppt5
10 m
18.75 m
acc2
ppt2
Sand
ppt1
acc1
box base

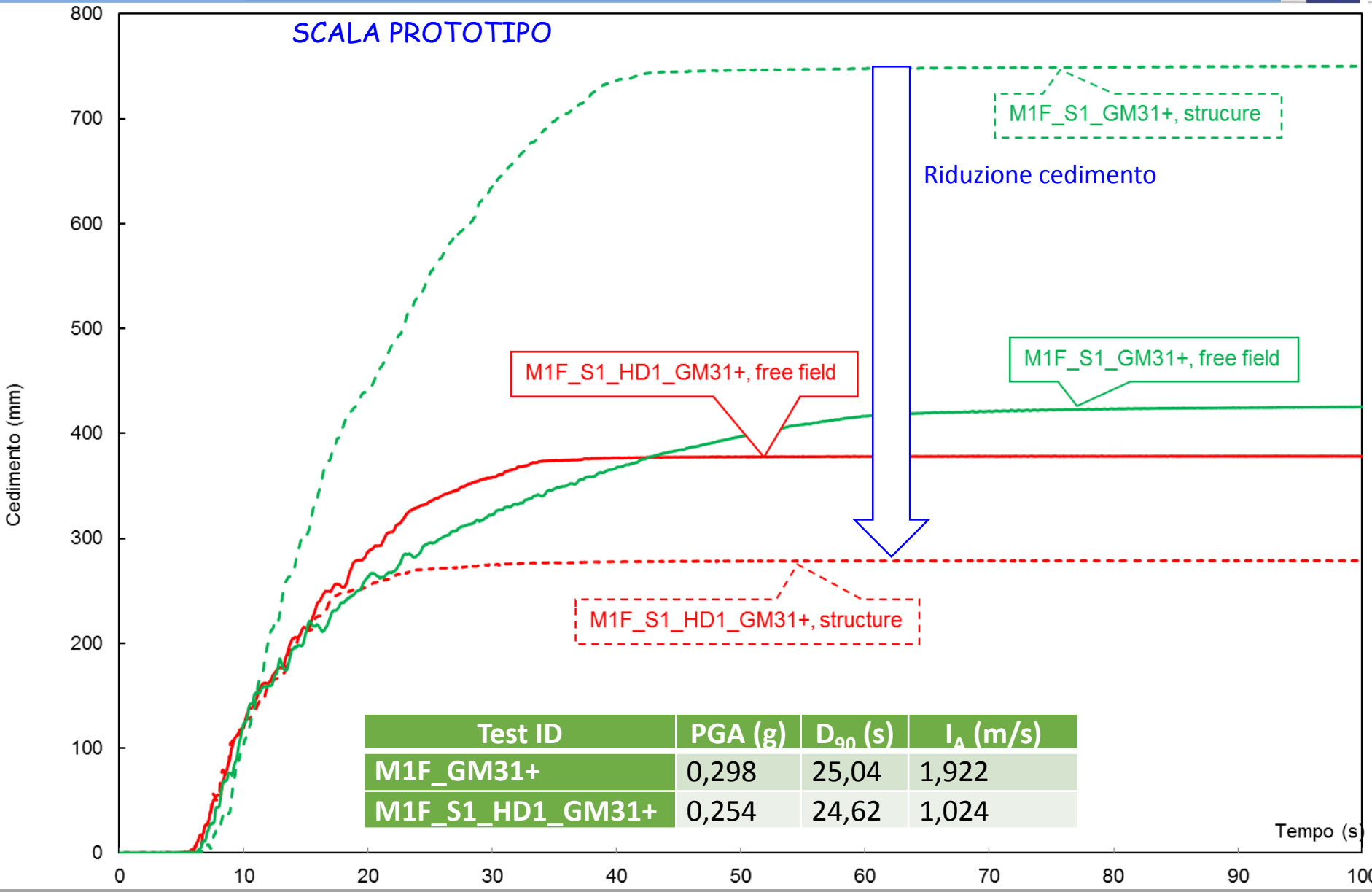
DRENI ORIZZONTALI i = 5D SOTTO LA STRUTTURA



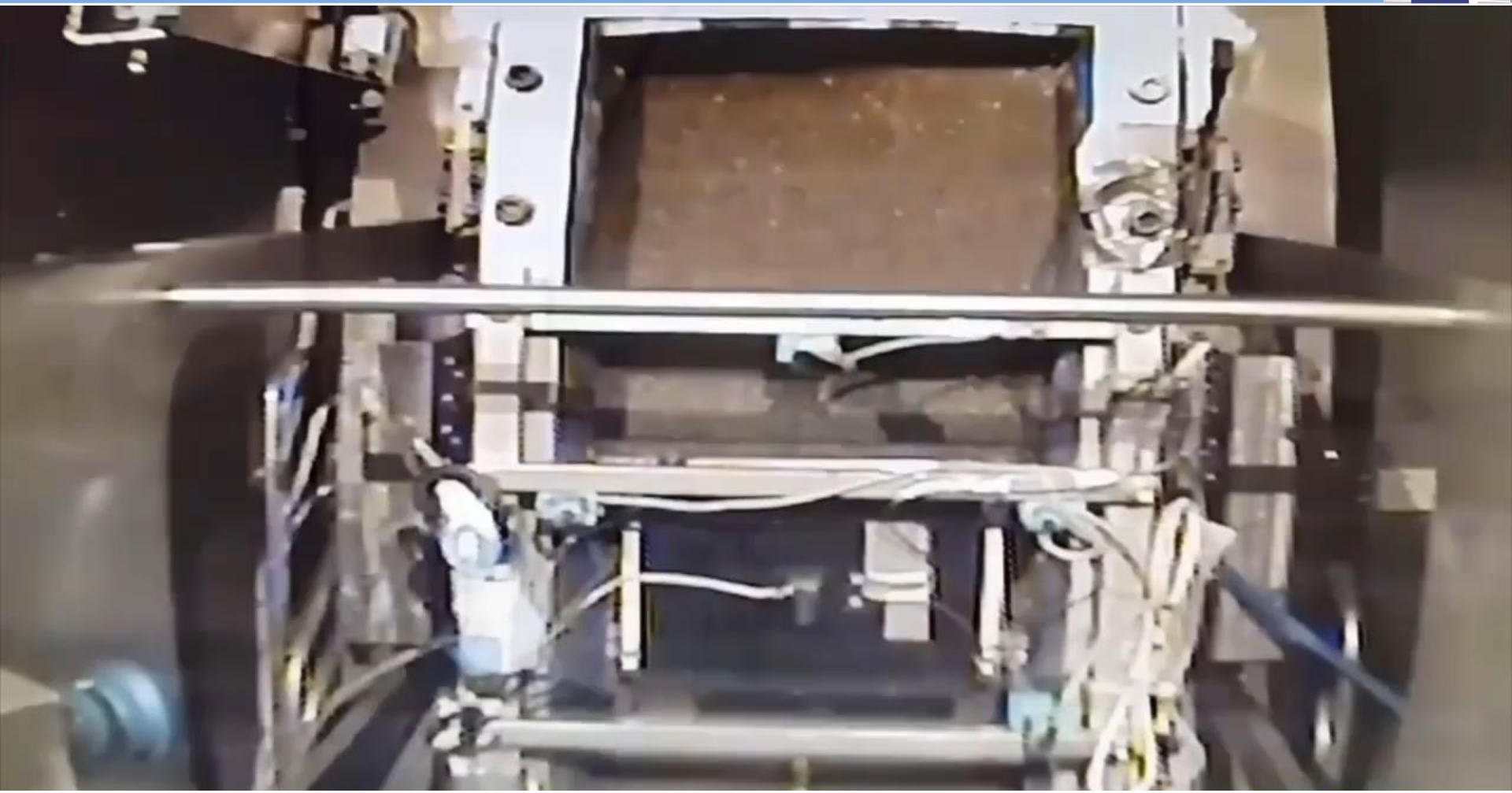


Test ID	PGA (g)	D_{90} (s)	I_A (m/s)
M1F_S1_GM31+	0,298	25,04	1,922
M1F_S1_HD1_GM31+	0,254	24,62	1,024

DRENI ORIZZONTALI i = 5D SOTTO LA STRUTTURA



Test ID	PGA (g)	D_{90} (s)	I_A (m/s)
M1F_GM31+	0,298	25,04	1,922
M1F_S1_HD1_GM31+	0,254	24,62	1,024



GRAZIE PER L'ATTENZIONE