Interazione linea-monumenti – Monitoraggio Tratta T3

FACOLTÀ DI INGEGNERIA
CIVILE E INDUSTRIALE

SAPIENZA
UNIVERSITÀ DI ROMA

Sebastiano Rampello



Mura Aureliane a Porta Metronia

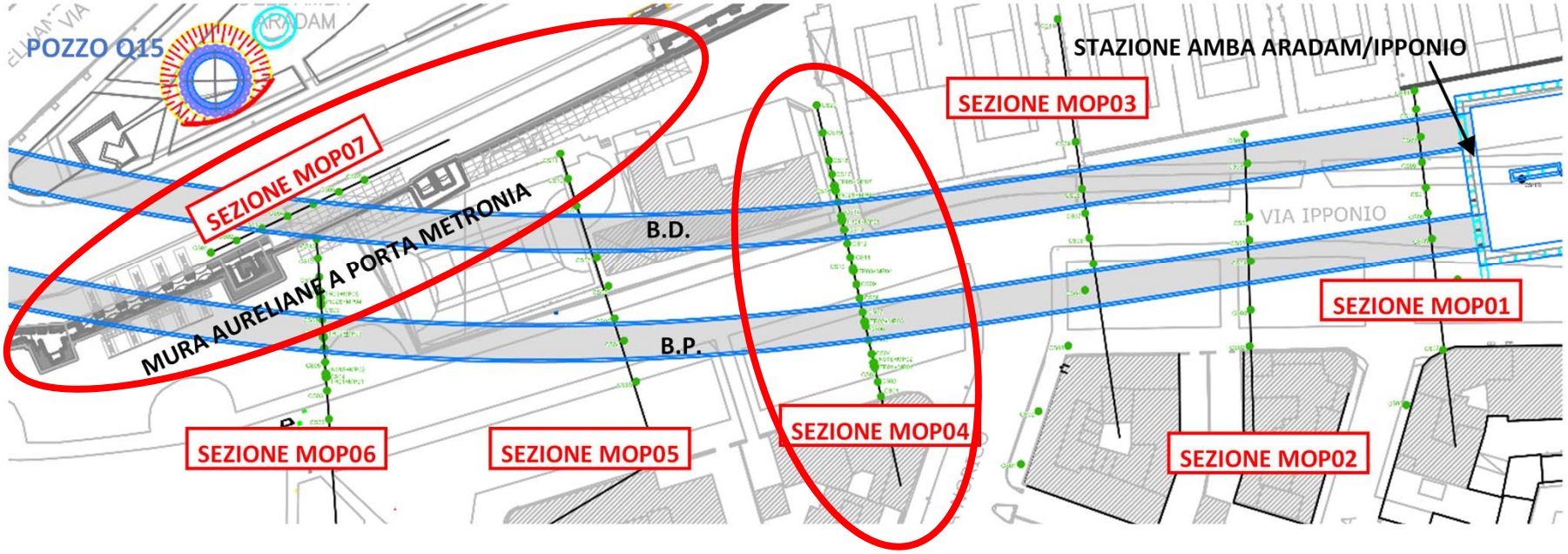








Mura Aureliane a Porta Metronia

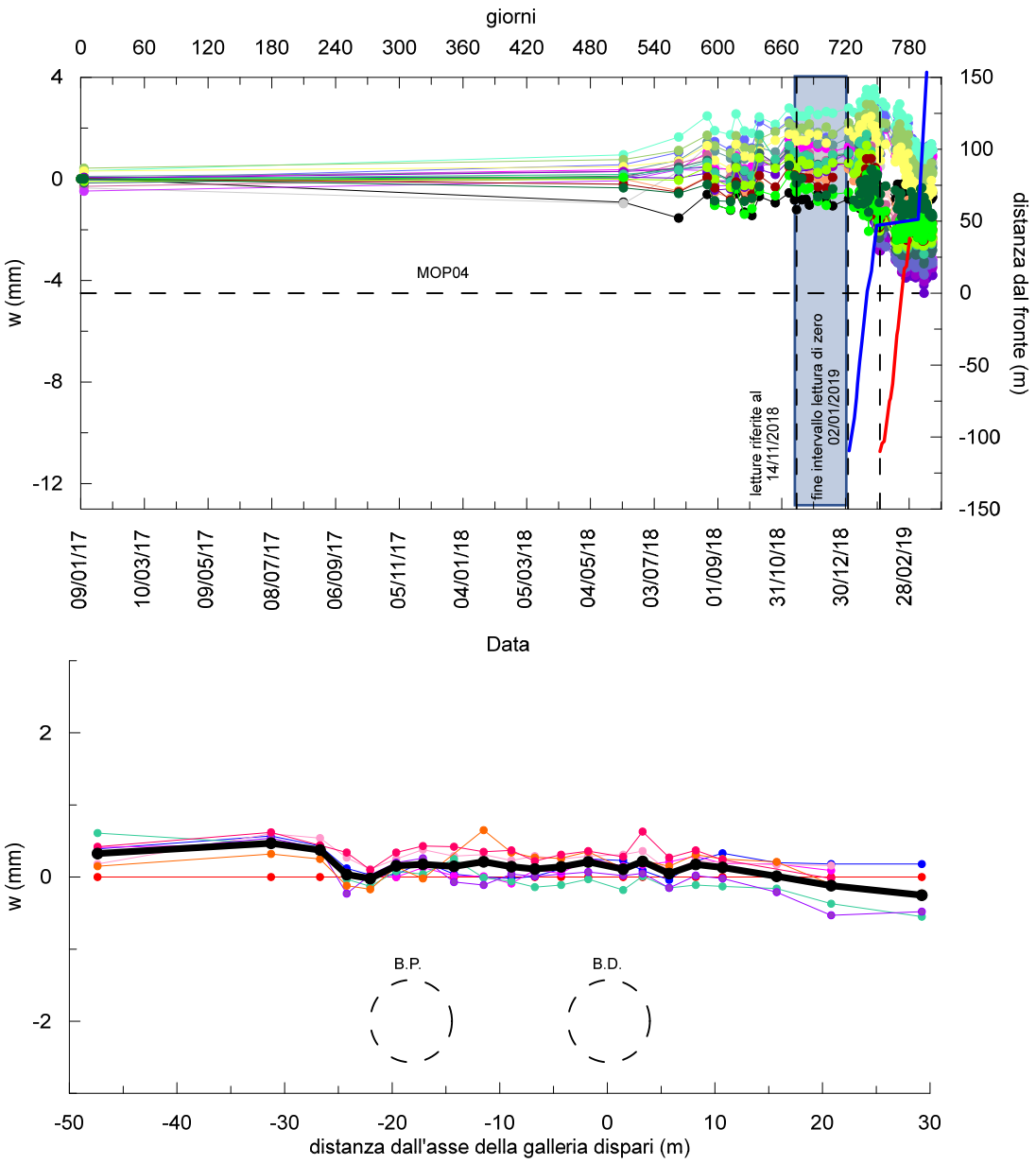


7 sezioni di monitoraggio normali alle gallerie
(capisaldi, inclinometri, Trivec, celle piezometriche)

strumentazione sulle Mura (tazze livellometriche, tiltmetri, staffe livellometriche

profondità gallerie ≈ 27m

sezione MOP04



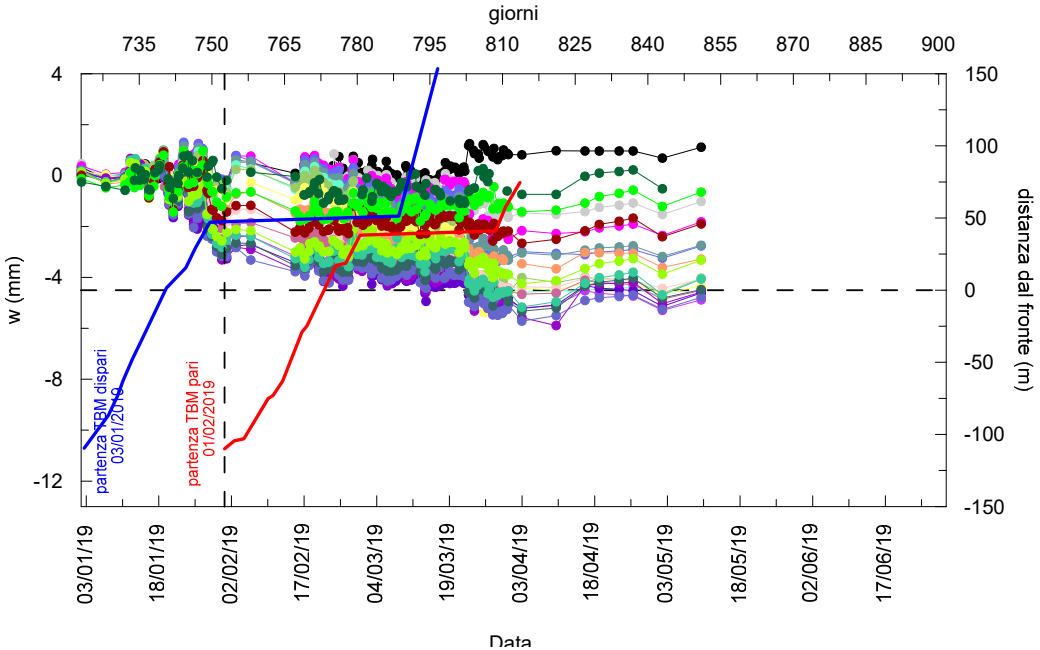
storie temporali caposaldi

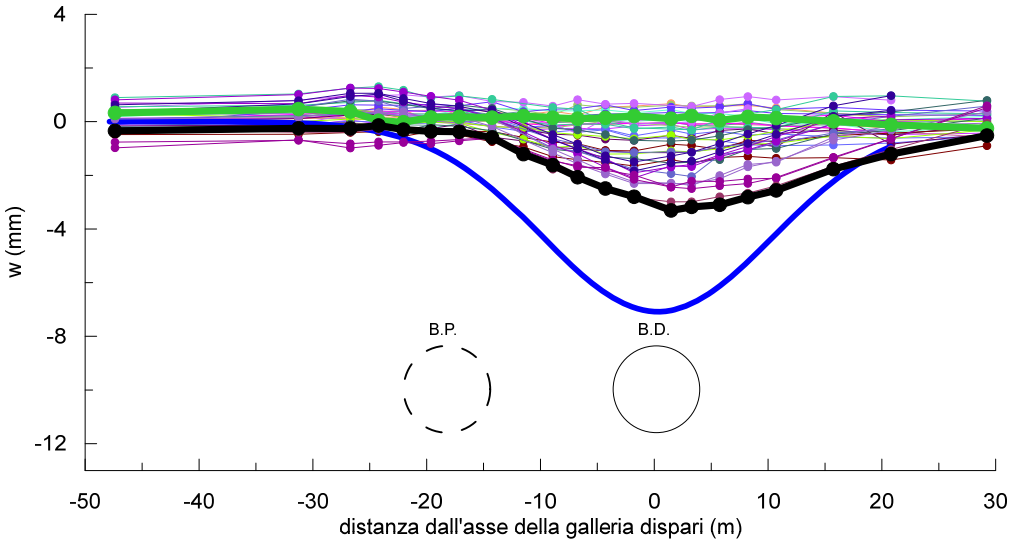
- avanzamento BD
- avanzamento BP

isocrone spostamenti

- periodo di riferimento
- zero di riferimento

sezione MOP04





storie temporali caposaldi depurati della lettura di zero

avanzamento BD

avanzamento BP

isocrone spostamenti

periodo 02-30/01/19

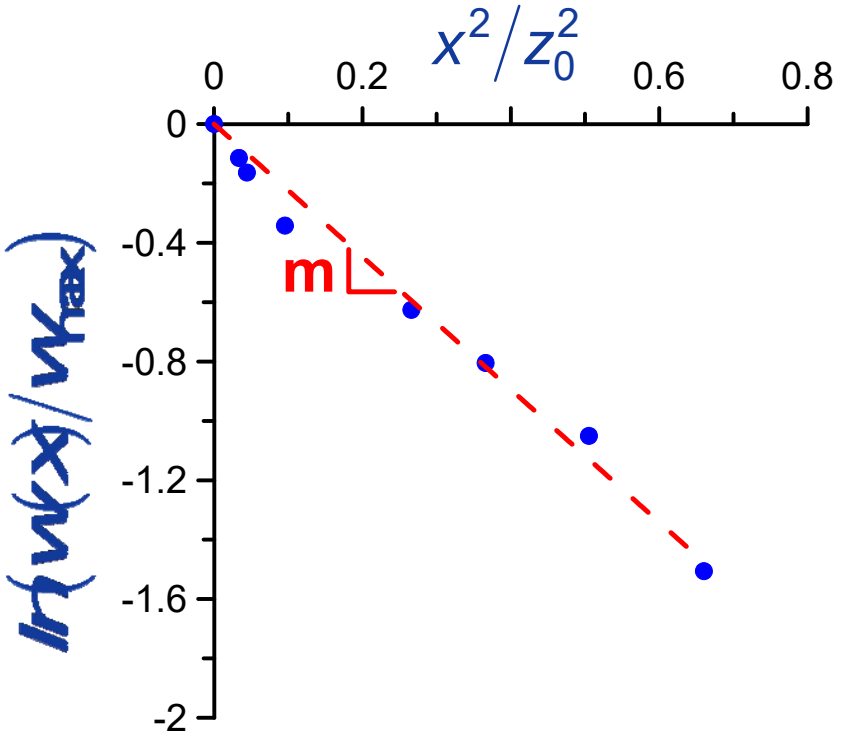
metodi empirici

$$w(x) = w_{max} \cdot e^{\left(-\frac{x^2}{2 \cdot i^2}\right)}$$

$$ln\left(\frac{w(x)}{w_{max}}\right) = -\frac{x^2}{2 \cdot i^2} \cdot \frac{z_0^2}{z_0^2} = -\frac{z_0^2}{2 \cdot i^2} \cdot \frac{x^2}{z_0^2}$$

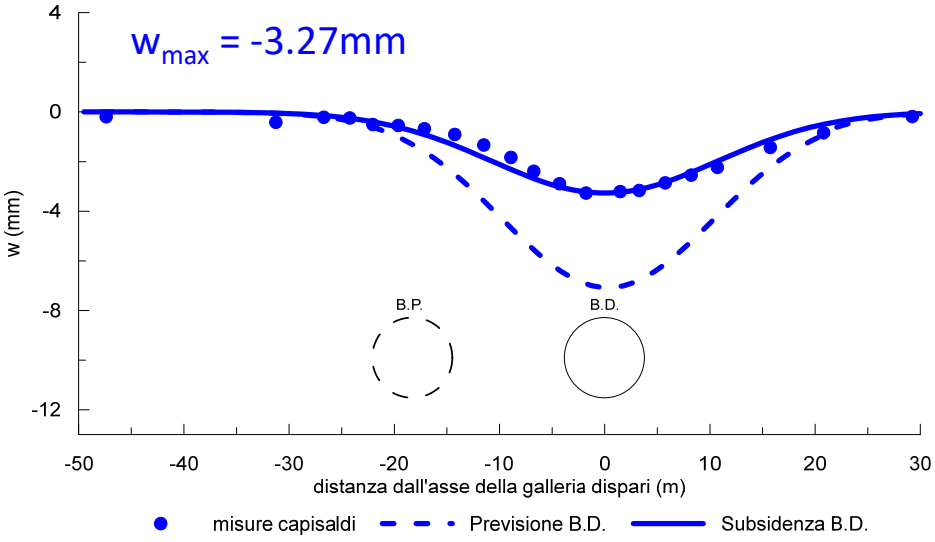
$$m = -\frac{z_0^2}{2 \cdot i^2}$$

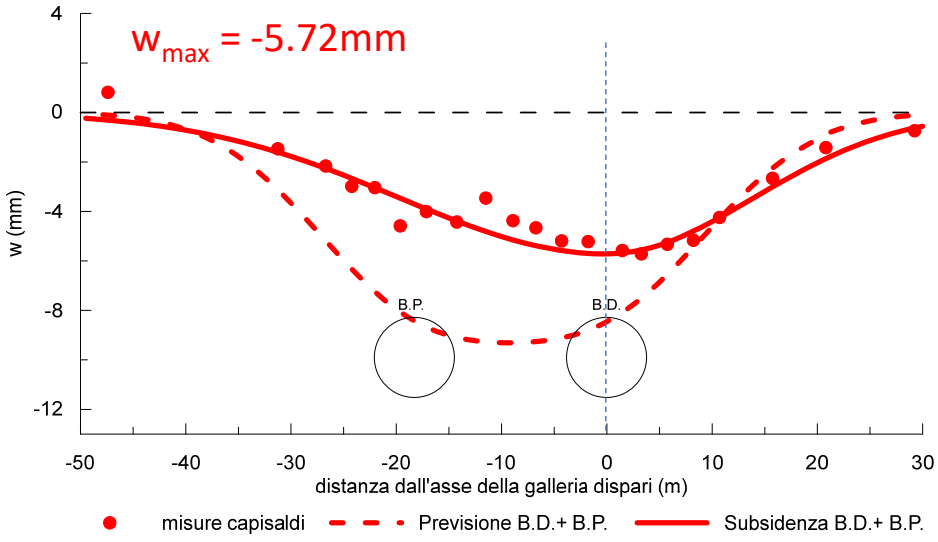
$$ln\left(\frac{w(x)}{w_{max}}\right) = -m \cdot \frac{x^2}{z_0^2}$$



$$i = \sqrt{\left(-\frac{z_0^2}{2 \cdot m}\right)} \quad \Rightarrow \quad i = k \cdot z_0 \quad \Rightarrow \quad V_L = \frac{\Delta V}{V_0} = \frac{\sqrt{2\pi} \cdot i \cdot w_{max}}{V_0}$$

sezione MOP04

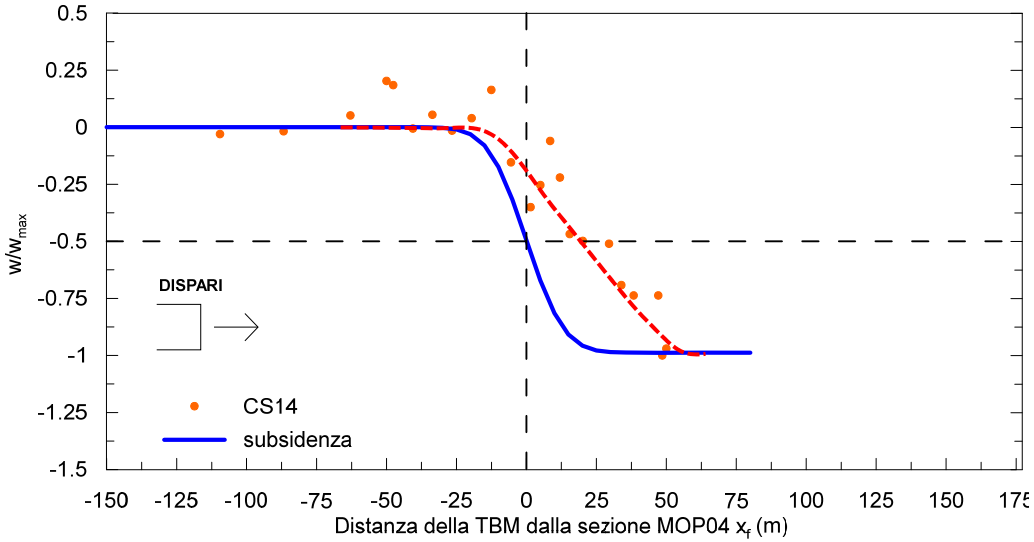




i = 10.7m, k = 0.44, V_L = 0.25%

-y i = 19.6m, k = 0.81, V_L = 0.40%

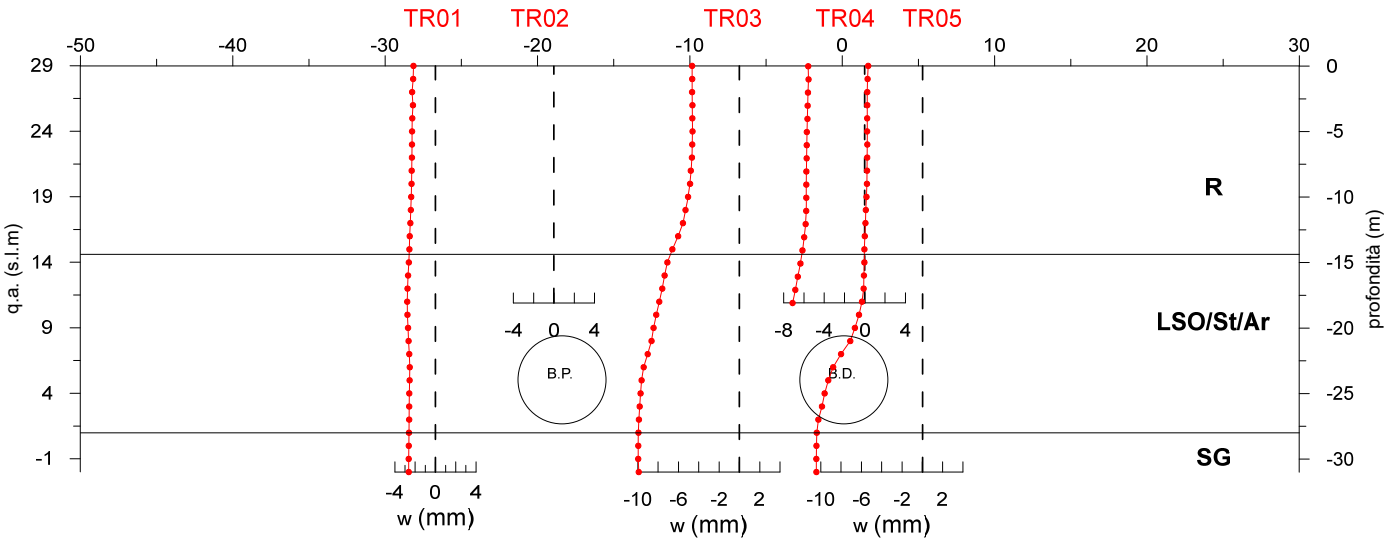
+y i = 13.9m, k = 0.58, V_L = 0.28%



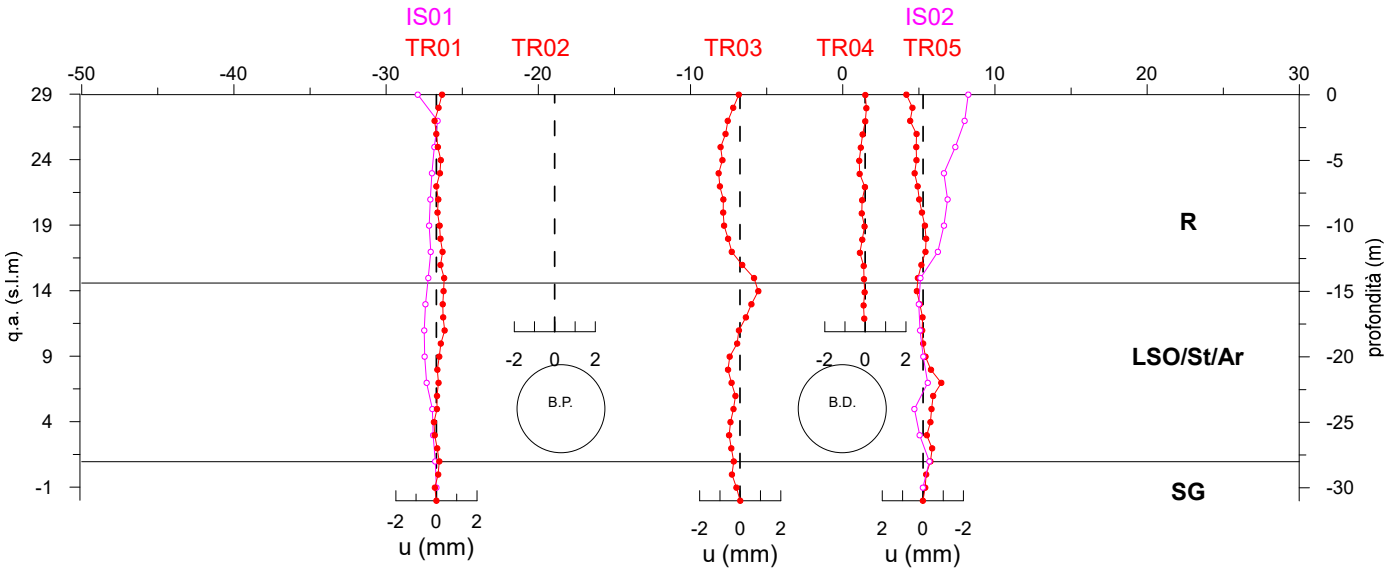
	GALLERIA DISPARI				
	MOP01	**MOP02**	**MOP03**	**MOP04**	**MOP05**
***i* (m)**	9.9	7.2	-	10.7	10.8
V_L%	0.61	0.15	-	0.25	0.13

	GALLERIA DISPARI + PARI				
	MOP01	**MOP02**	**MOP03**	**MOP04**	**MOP05**
***i* (m)**	14.1	10.2	7	16.8	20
V_L%	0.53	0.14	0.13	0.34	0.67

sezione MOP04

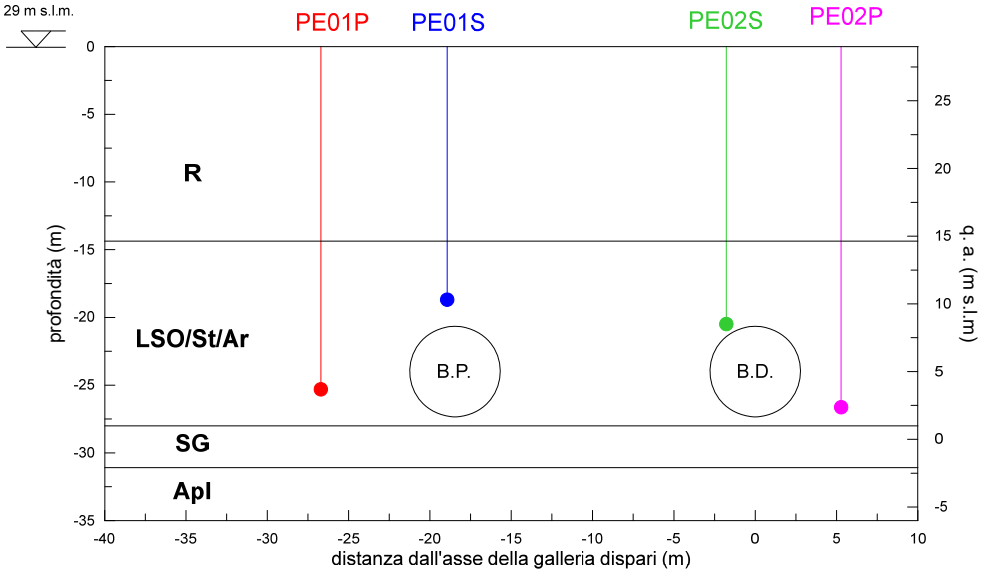


spostamenti verticali

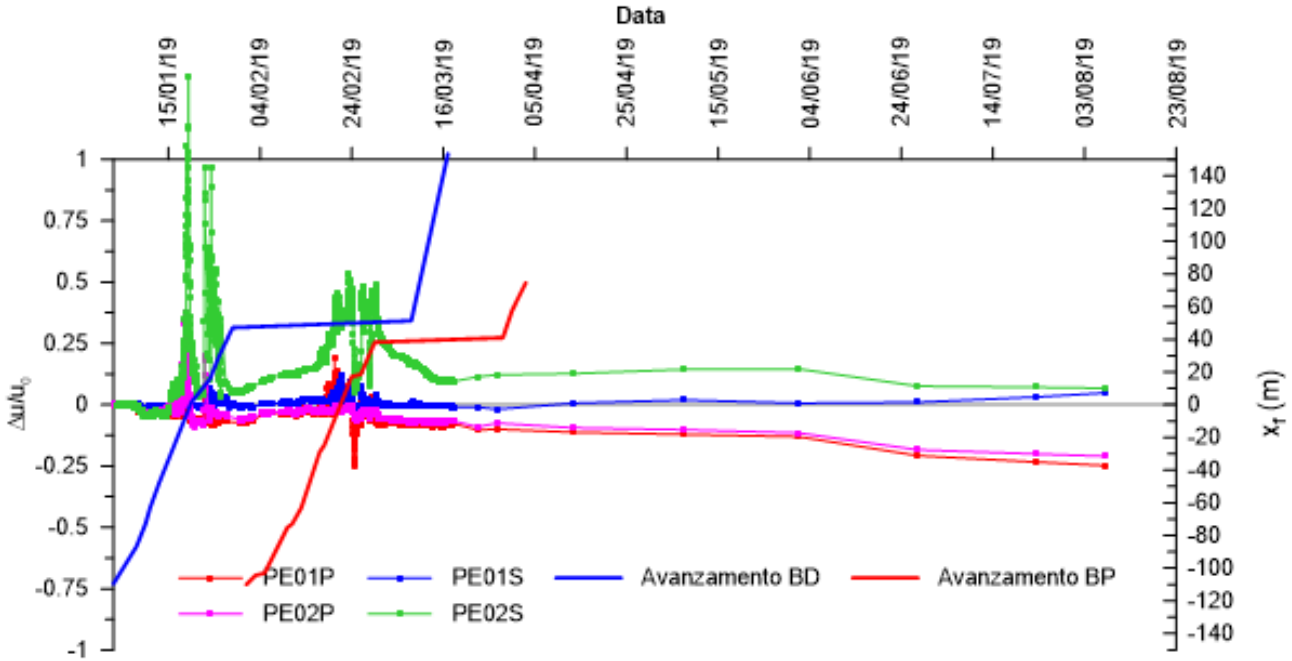


spostamenti orizzontali

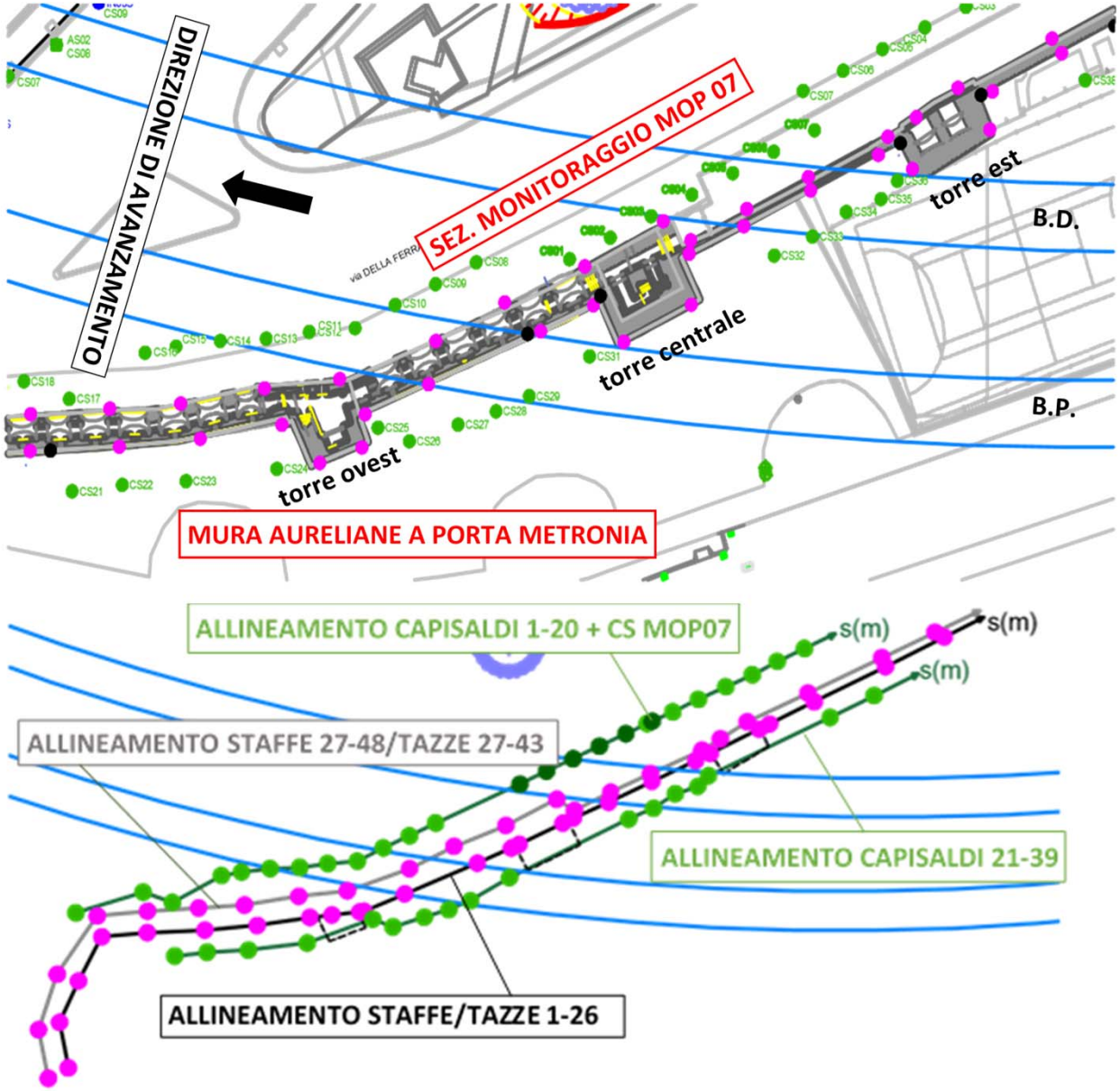
sezione MOP04



celle piezometriche
a corda vibrante



monitoraggio sulle Mura

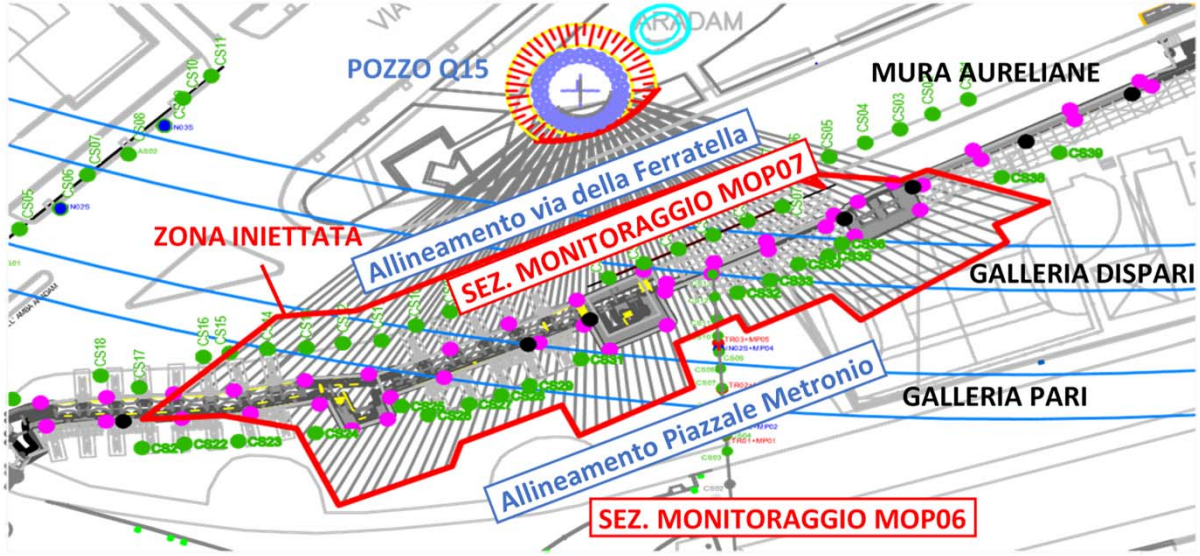


43 tazze livellometriche
48 staffe livellometriche
45 capisaldi

allineamento 1-26:
Piazzale Metronio

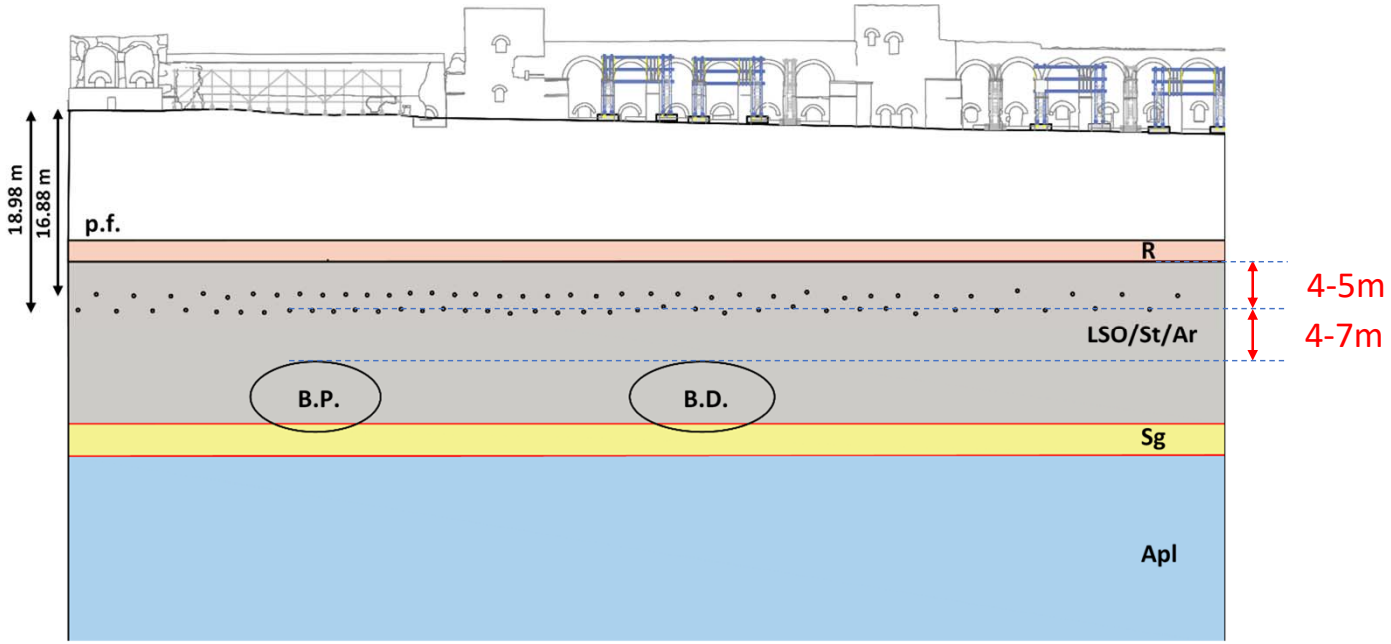
allineamento 27-43
Via della Ferratella

trattamento di compensation grouting



perforazione e installazione
09/07 – 17/10 2018

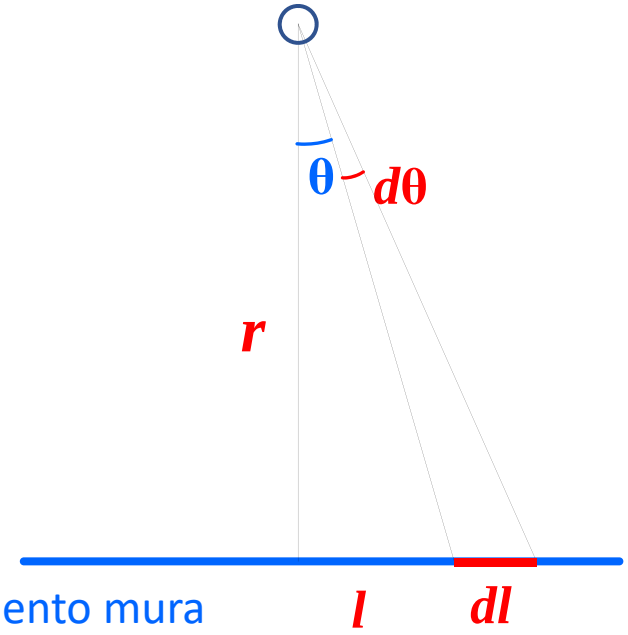
pre-trattamento
17/10/18 – 08/03/19



densità di trattamento

definita in funzione della geometria delle perforazioni

pozzo compensation grouting



a parità di ***dθ***, ***dl*** cresce al crescere di ***l***

$$\text{d.t.} \propto \frac{d\theta}{dl} = \frac{\cos^2\theta}{r} \quad \Rightarrow \quad \cos^2\theta$$

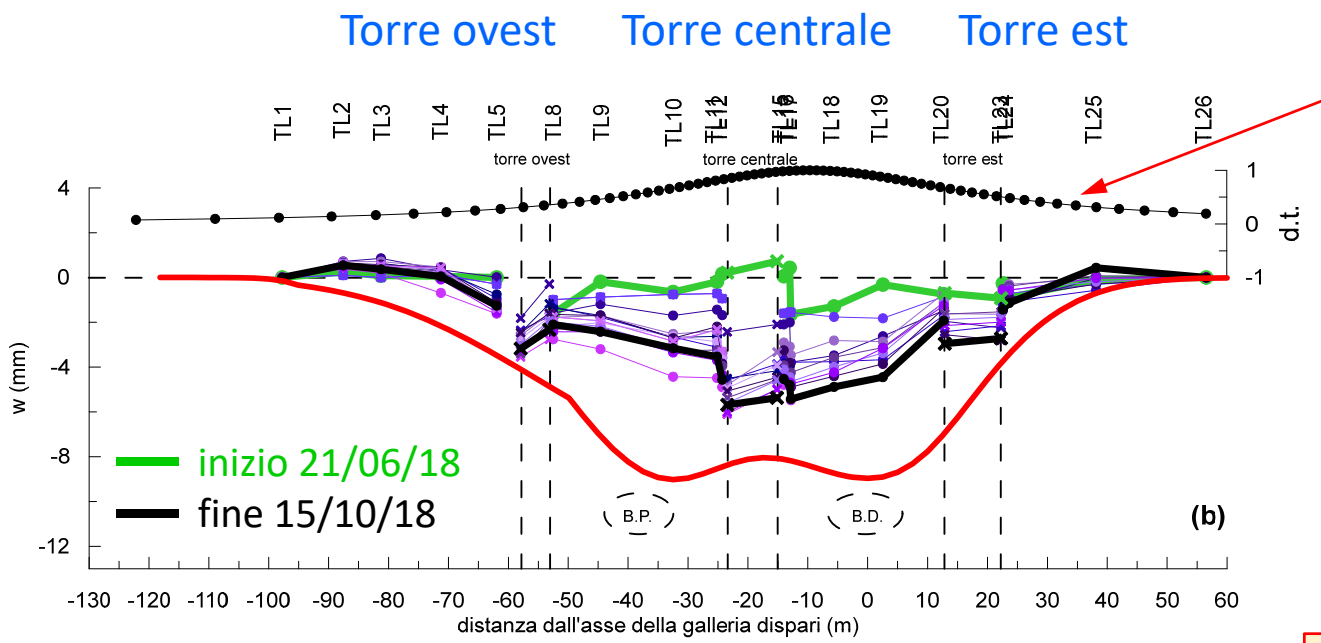
$$l = r \cdot \tan\theta$$

$$\frac{dl}{d\theta} = r\frac{d}{d\theta}\tan\theta = \frac{r}{\cos^2\theta}$$

d.t. decresce al crescere di *l*

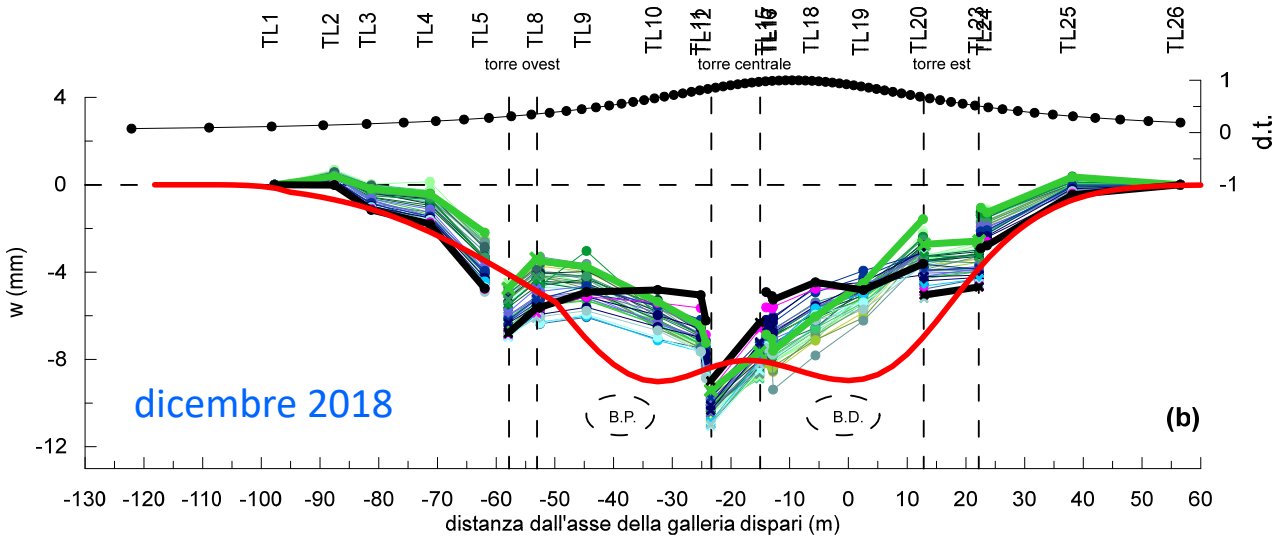
- ***r*** distanza pozzo - allineamento in direzione normale all'allineamento (cost)
- θ apertura angolare delle perforazioni
- ***l*** apertura delle perforazioni lungo l'allineamento

tazze livellometriche sulle Mura – lato p.le Metronio



$\cos^2 \theta$

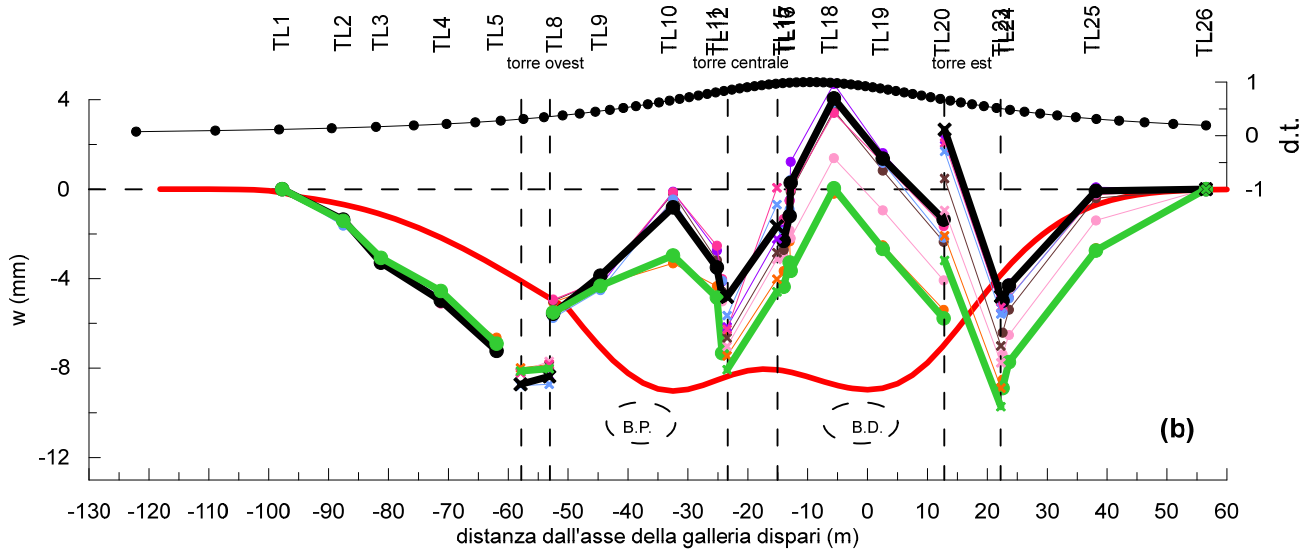
effetto perforazioni e installazione tubi



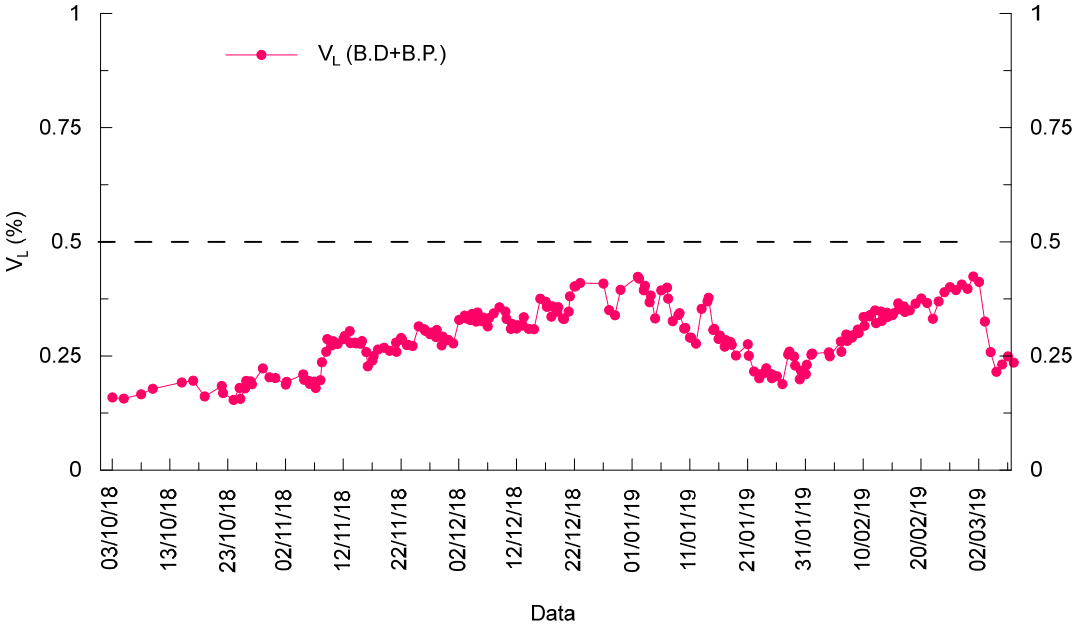
previsioni su p.f. Mura (z= 10 m) per V_L = 0.5%

effetto iniezioni di condizionamento

effetto iniezioni di pre-trattamento



01-08 marzo 2019



allineamento mura non ortogonale alle gallerie

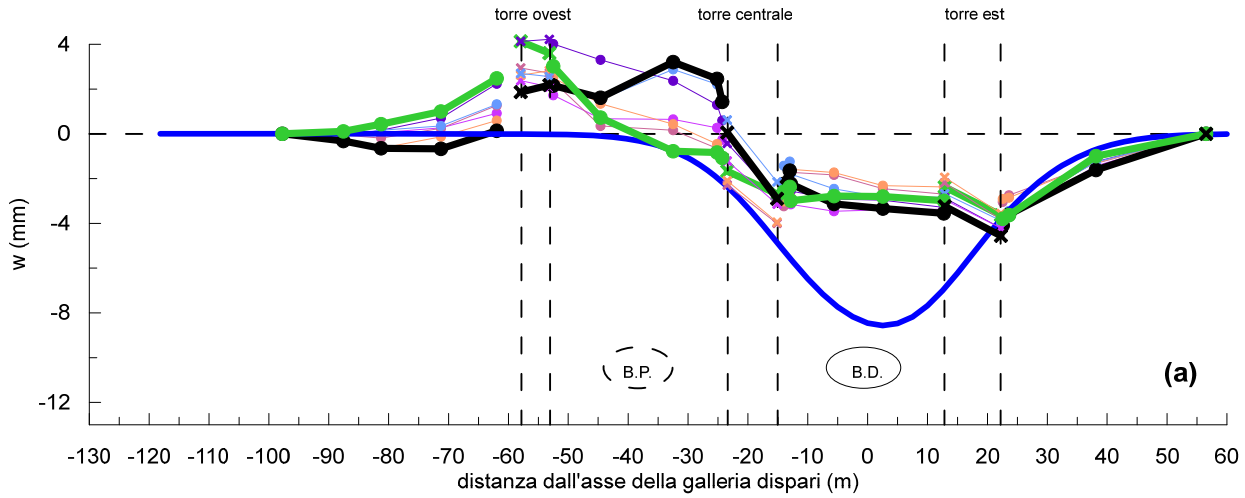
perdita di volume equivalente a quella indotta dal passaggio delle gallerie

$$V_L = \frac{V_{S,TL}}{V_{S,P}} \cdot 0.5\%$$

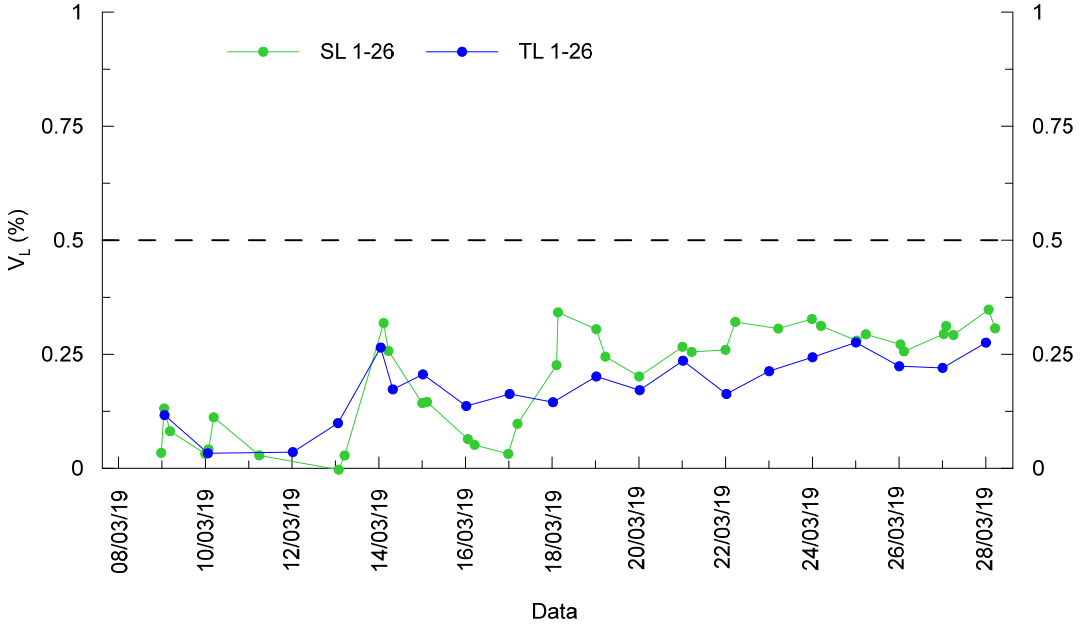
$V_{S,TL}$ volume conca dalle misure su TL

$V_{S,P}$ volume conca calcolato, per V_L=0.5%, lungo allineamento mura

effetto galleria dispari



23-28 marzo 2019



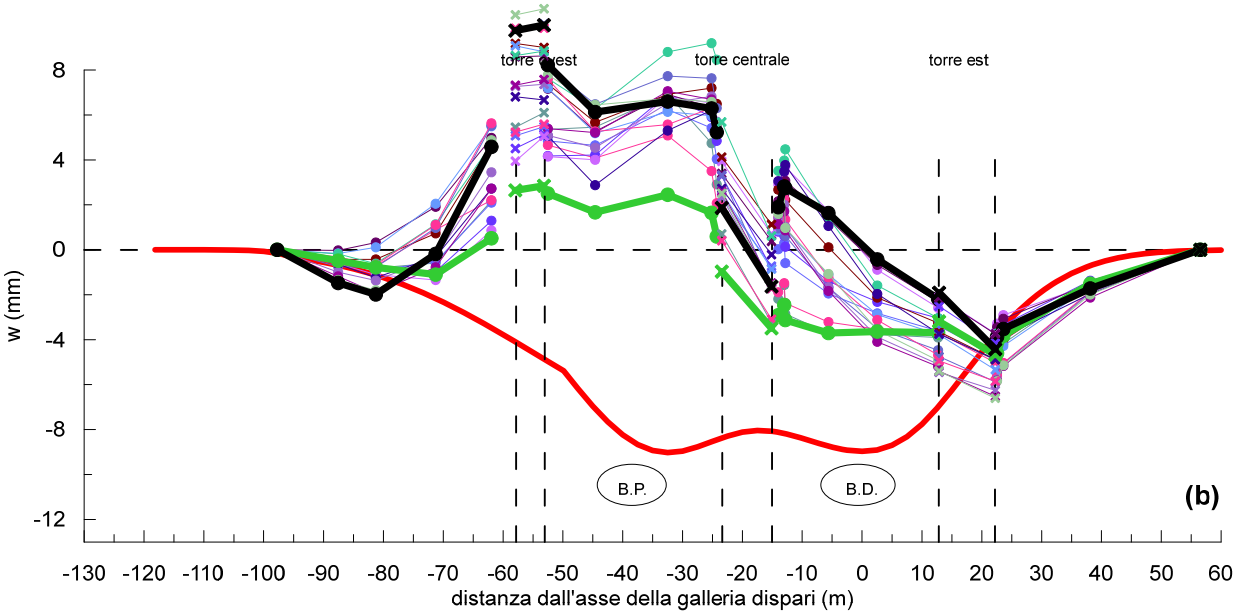
allineamento mura non ortogonale alle gallerie: perdita di volume equivalente

$$V_L = \frac{V_{S,TL}}{V_{S,P}} \cdot 0.5\%$$

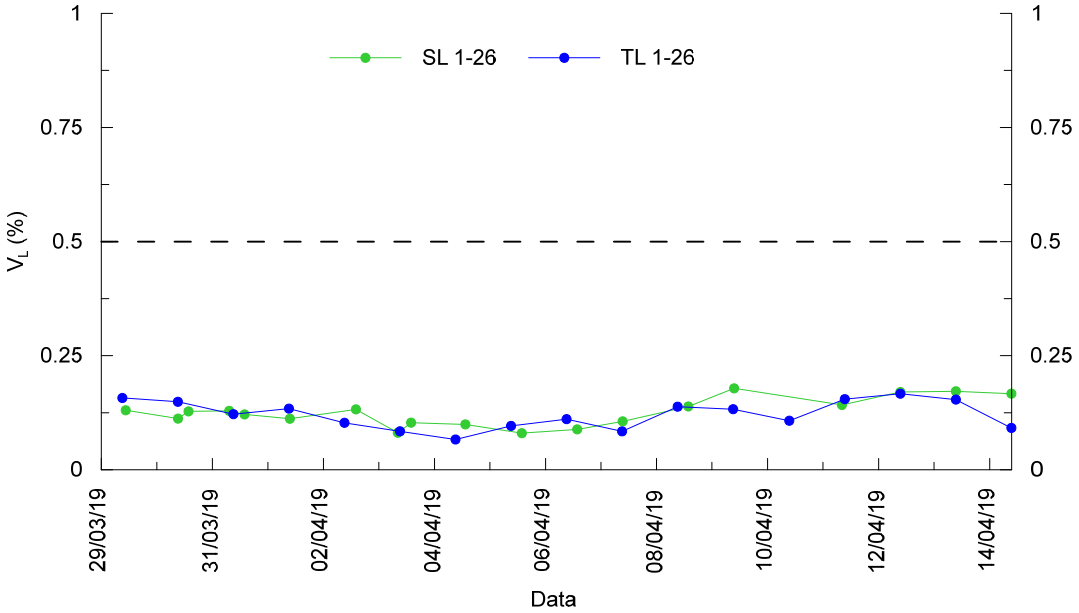
$V_{S,TL}$ volume conca dalle misure su TL

$V_{S,P}$ volume conca calcolato, per V_L=0.5%, lungo allineamento mura

effetto galleria dispari + pari



29/03 – 14/04 2019



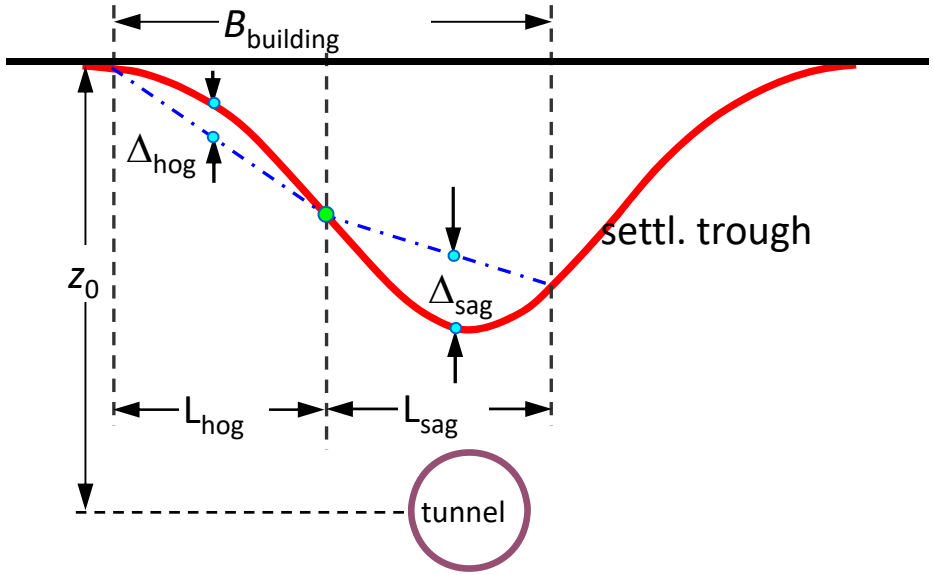
allineamento mura non ortogonale alle gallerie: perdita di volume equivalente

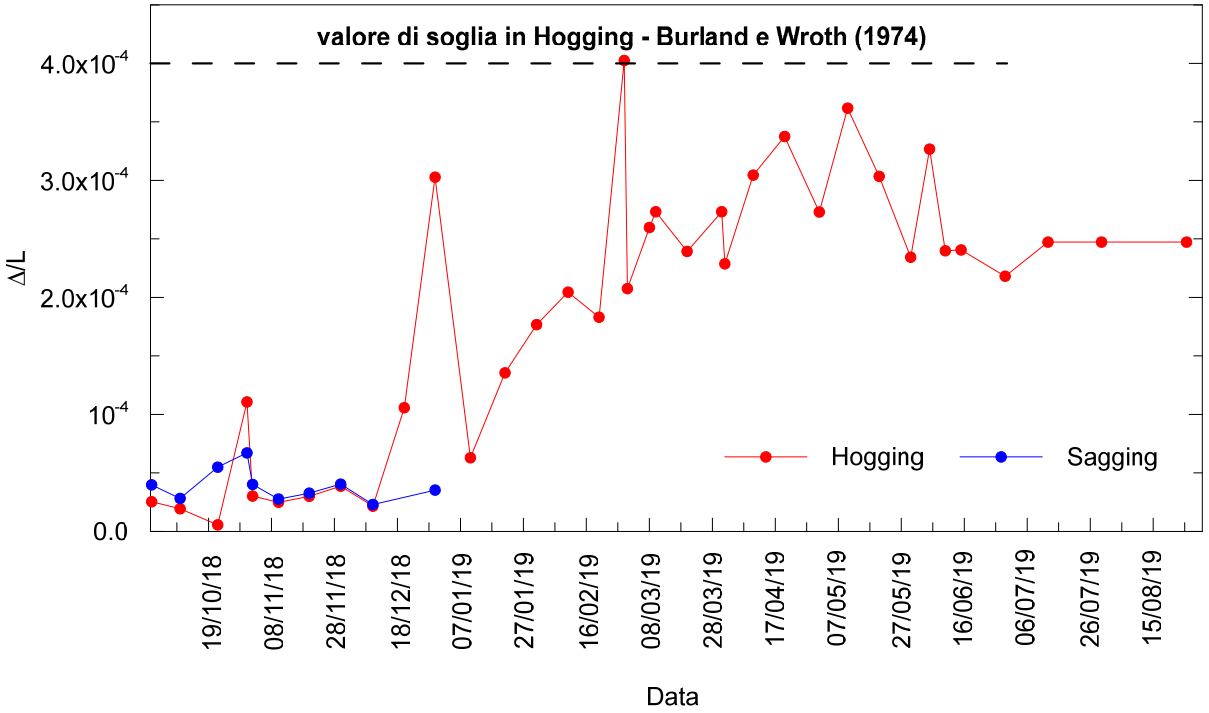
$$V_L = \frac{V_{S,TL}}{V_{S,P}} \cdot 0.5\%$$

$V_{S,TL}$ volume conca dalle misure su TL

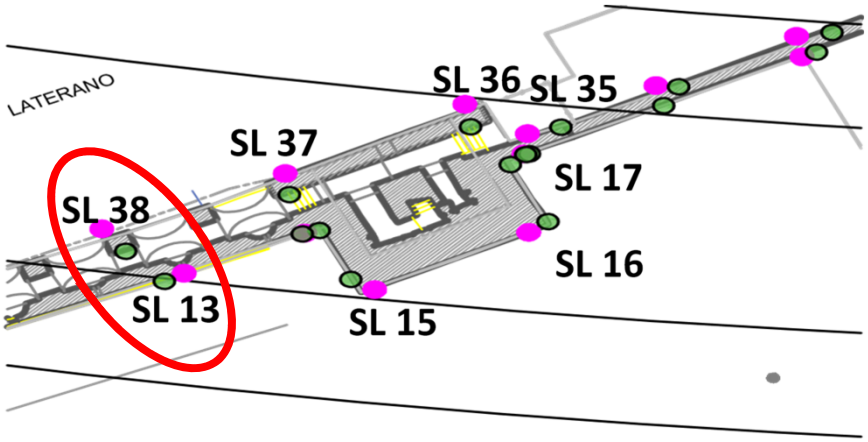
$V_{S,P}$ volume conca calcolato, per V_L=0.5%, lungo allineamento mura

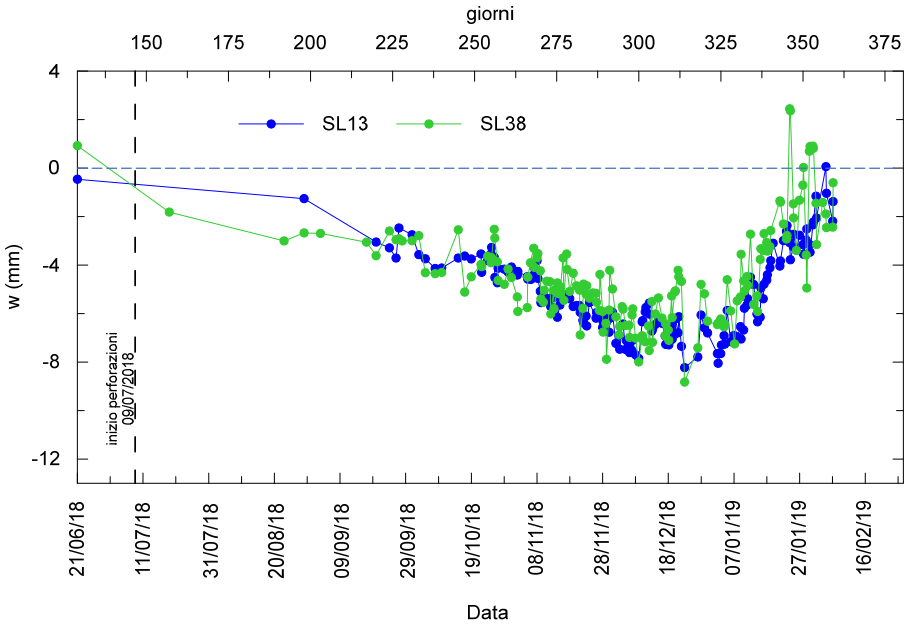
inflessione relativa massima sulle Mura

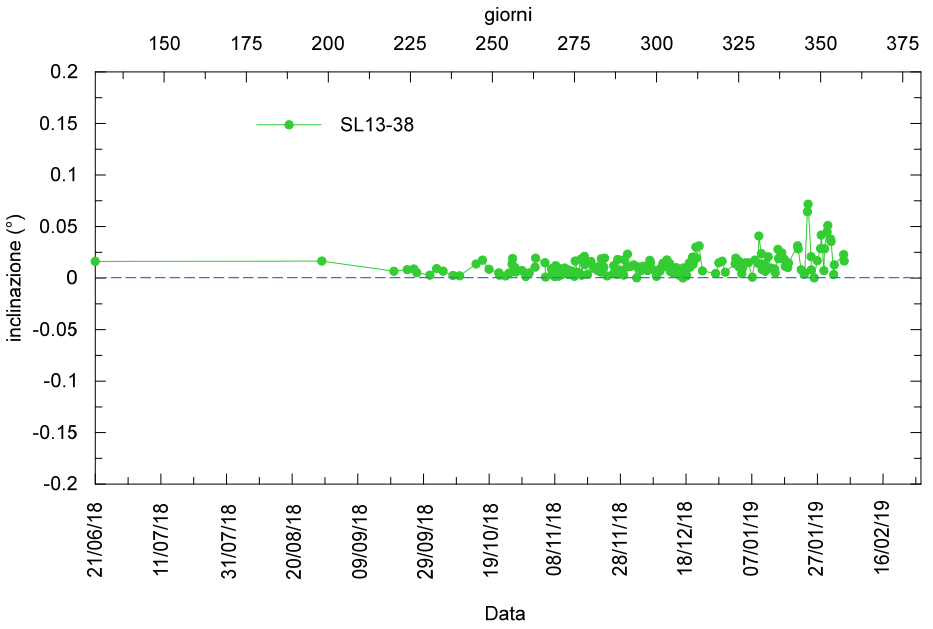




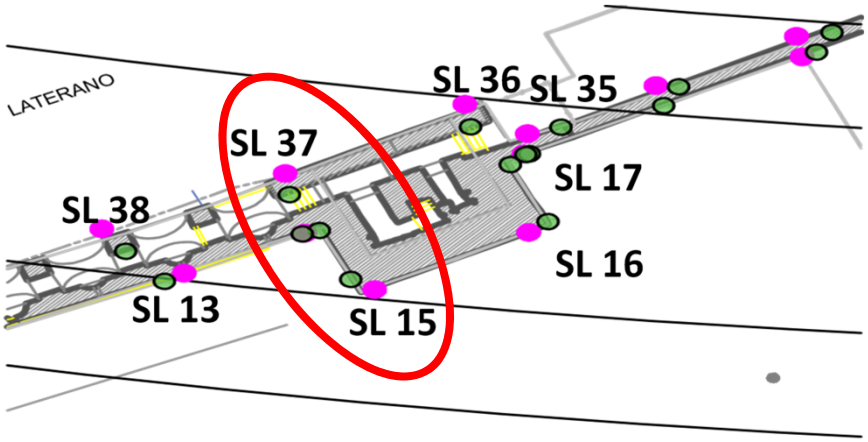
inclinazione fuori piano delle Mura

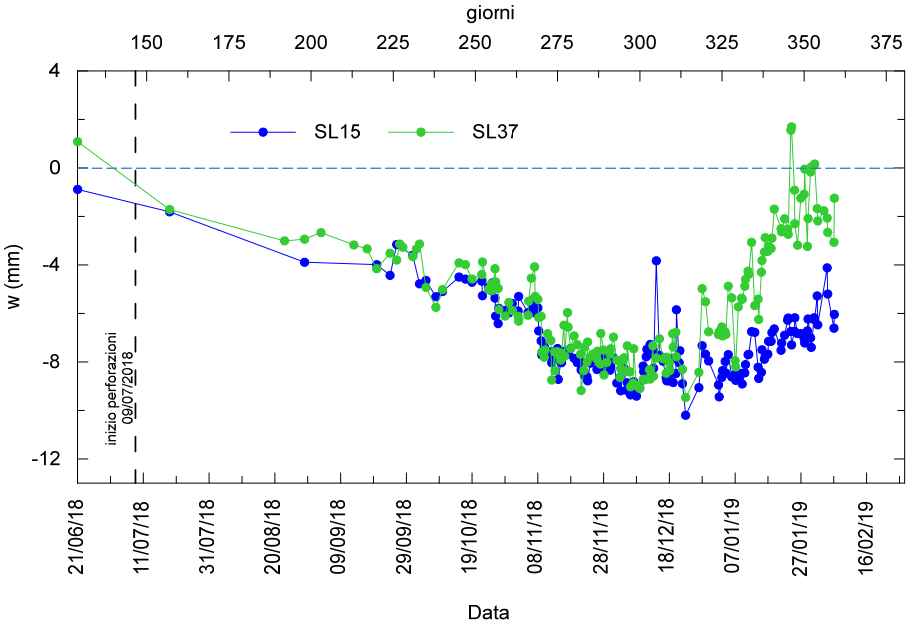


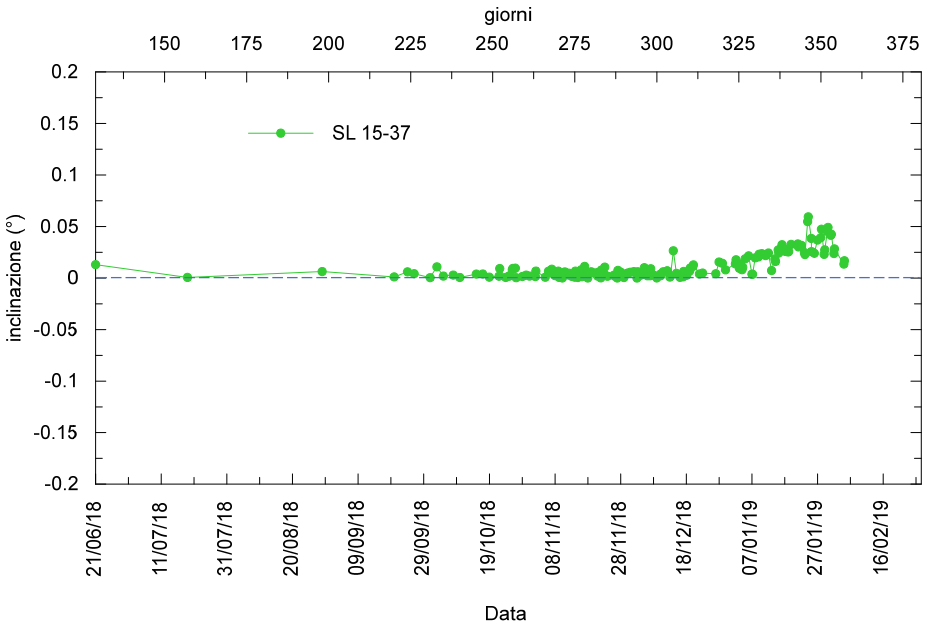




inclinazione fuori piano delle Mura







Santo Stefano Rotondo

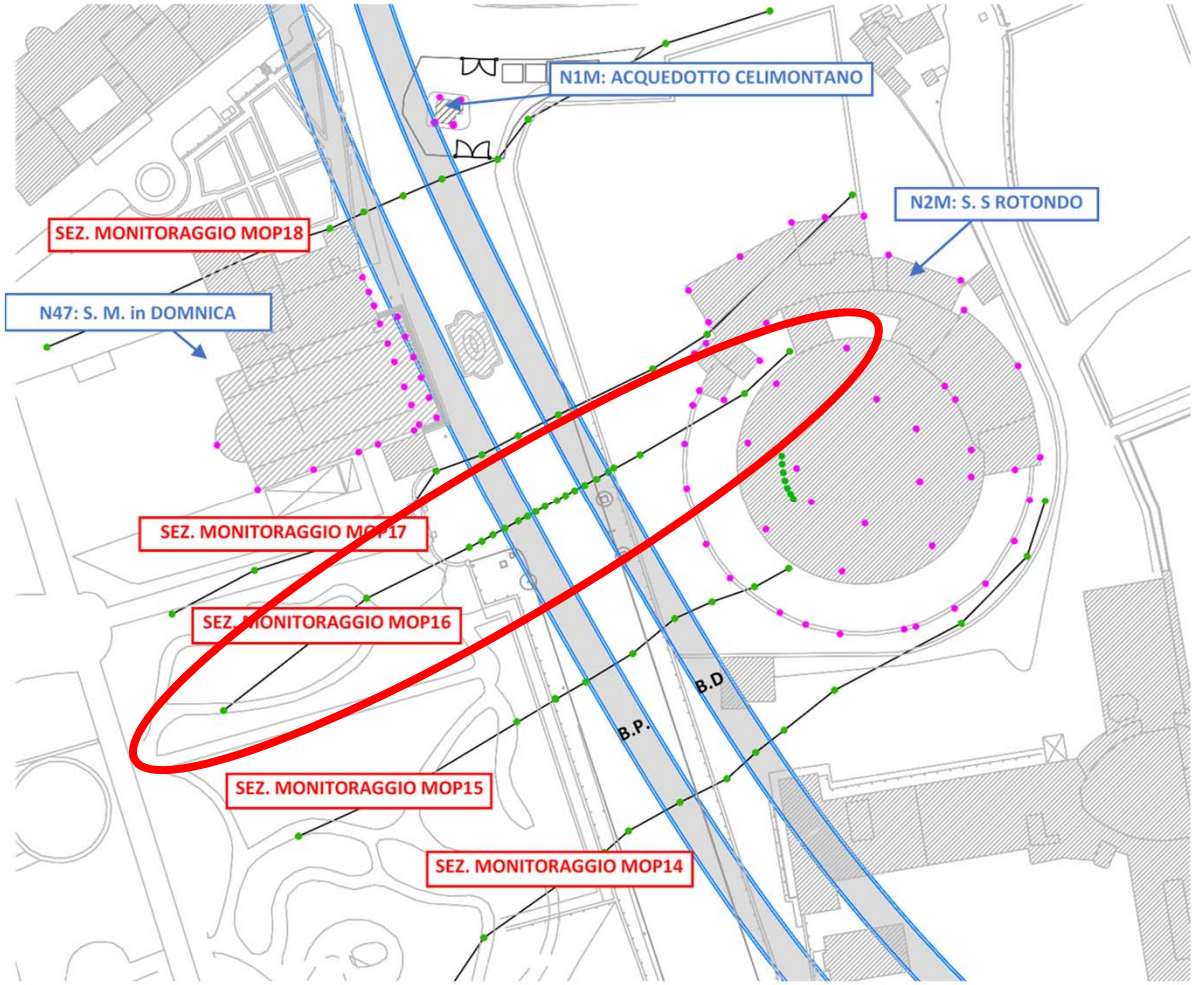








Santo Stefano Rotondo

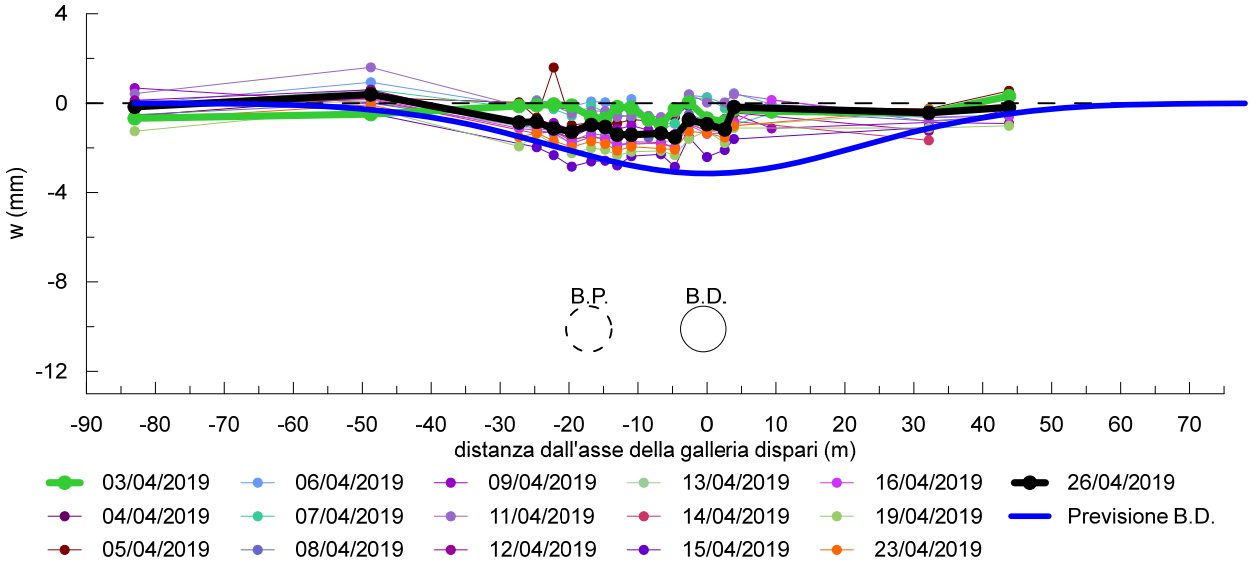


z gallerie ≈ 55m

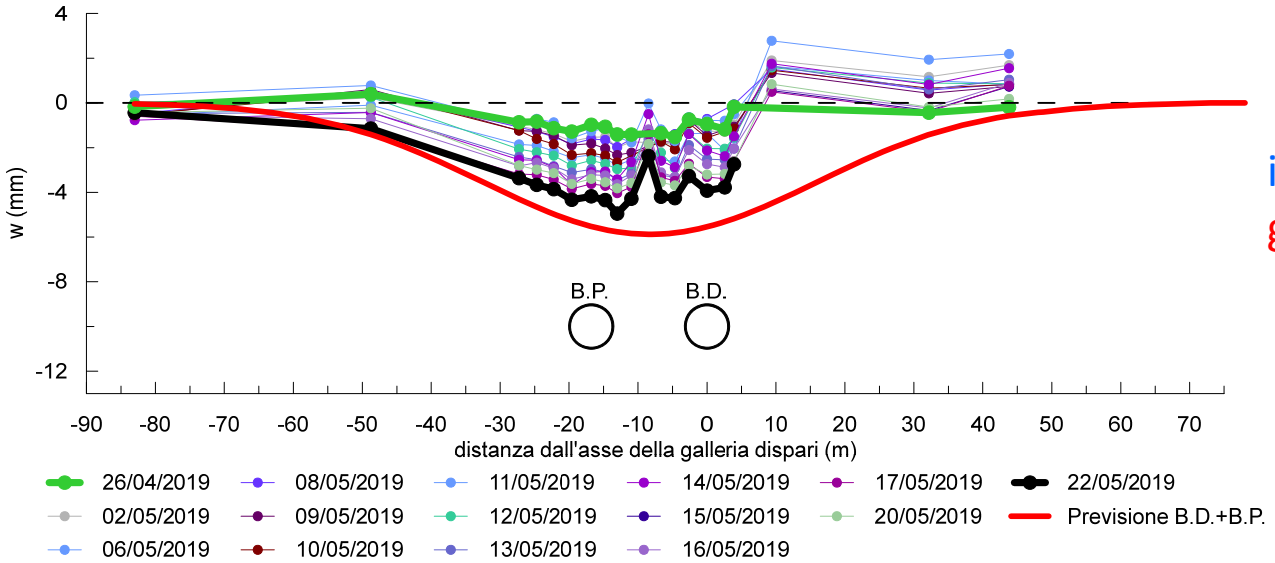
5 sezioni di monitoraggio normali alle gallerie
(capisaldi, inclinometri, Trivec, celle piezometriche)

strumentazione sulla Chiesa (staffe livellometriche)

sezione di monitoraggio MOP16

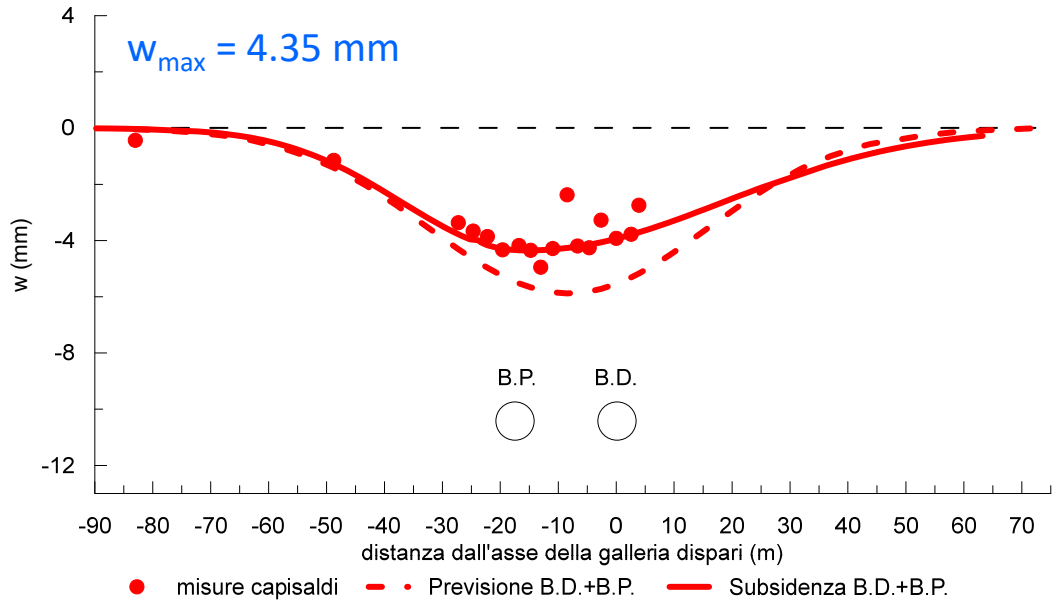


isocrone cedimenti
galleria dispari



isocrone cedimenti
galleria dispari + pari

sezione di monitoraggio MOP16

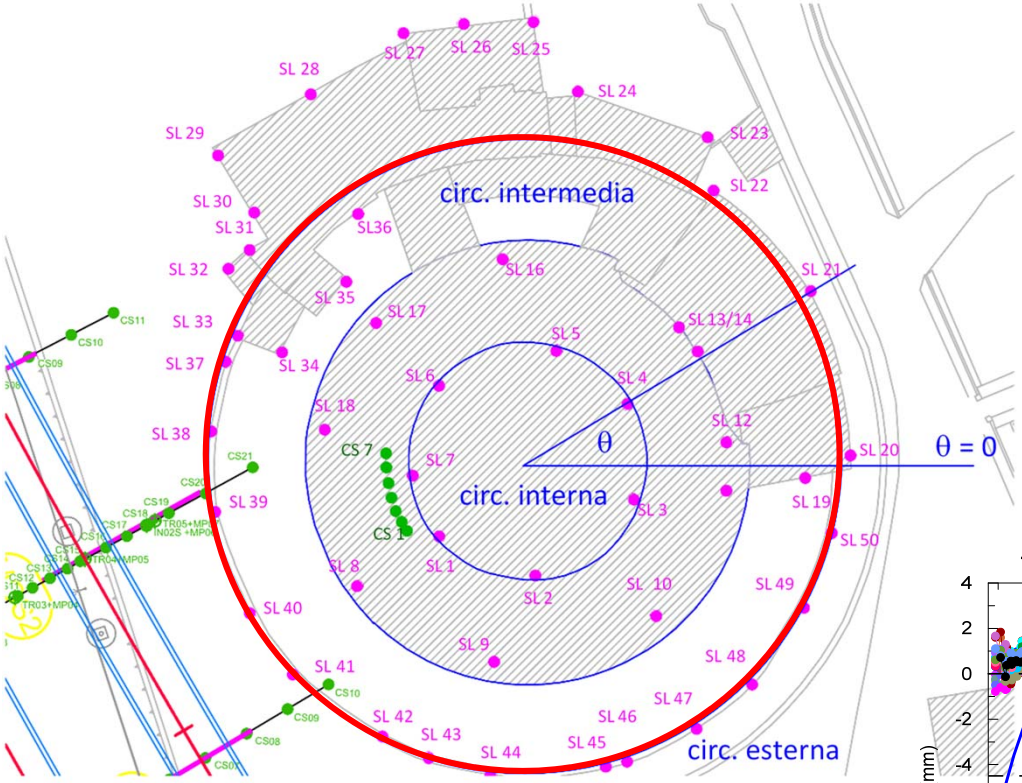


-y i = 20.8m, k = 0.38, V_L = 0.30%

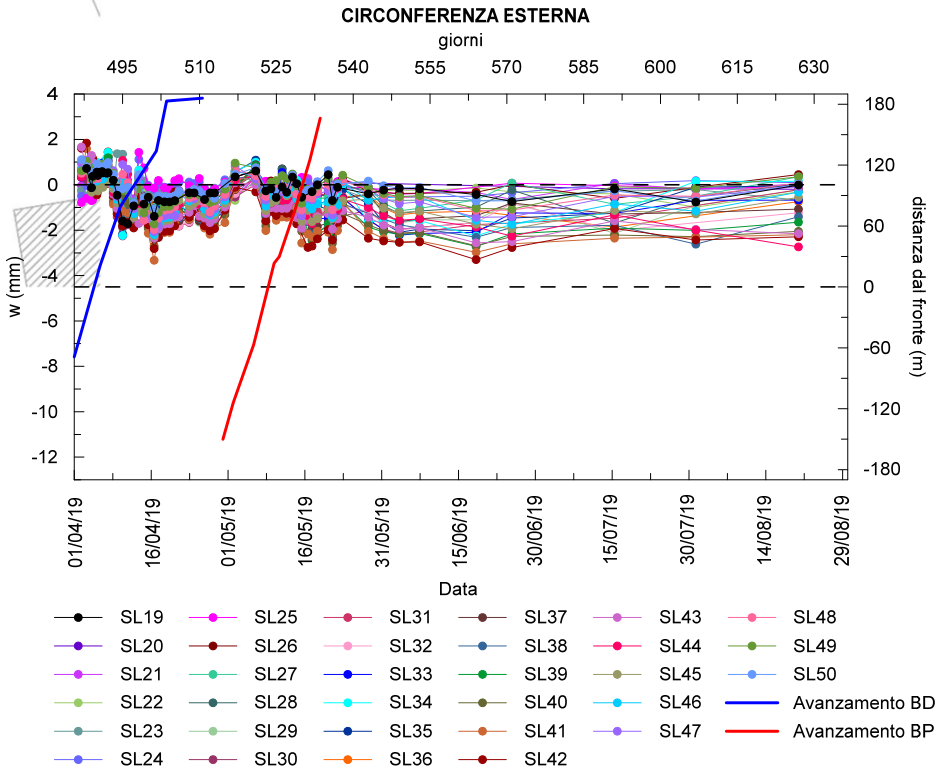
+y i = 33.2m, k = 0.61, V_L = 0.5%

	GALLERIA DISPARI				
	MOP14	**MOP15**	**MOP16**	**MOP17**	**MOP18**
V_L%	0.2	0.4	0.1	0.2	0.5
w_{max} (mm)	-1.6	-3	-1.5	-1.3	-2.04
	GALLERIA DISPARI + PARI				
	MOP14	**MOP15**	**MOP16**	**MOP17**	**MOP18**
V_L%	0.4	0.36	0.4	0.3	0.5
w_{max} (mm)	-4.2	-3.8	-4.4	-4.1	-4.8

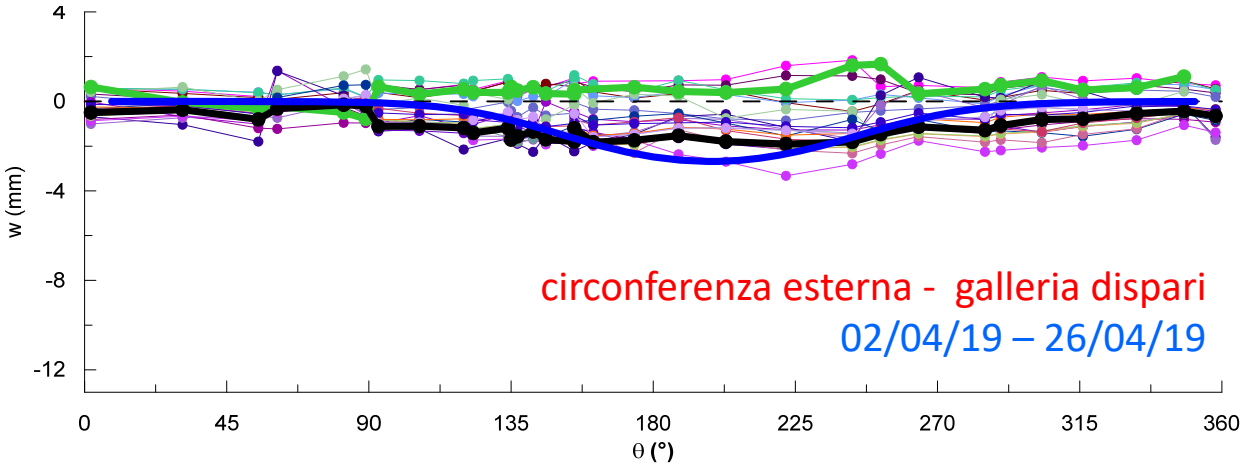
Santo Stefano Rotondo – monitoraggio



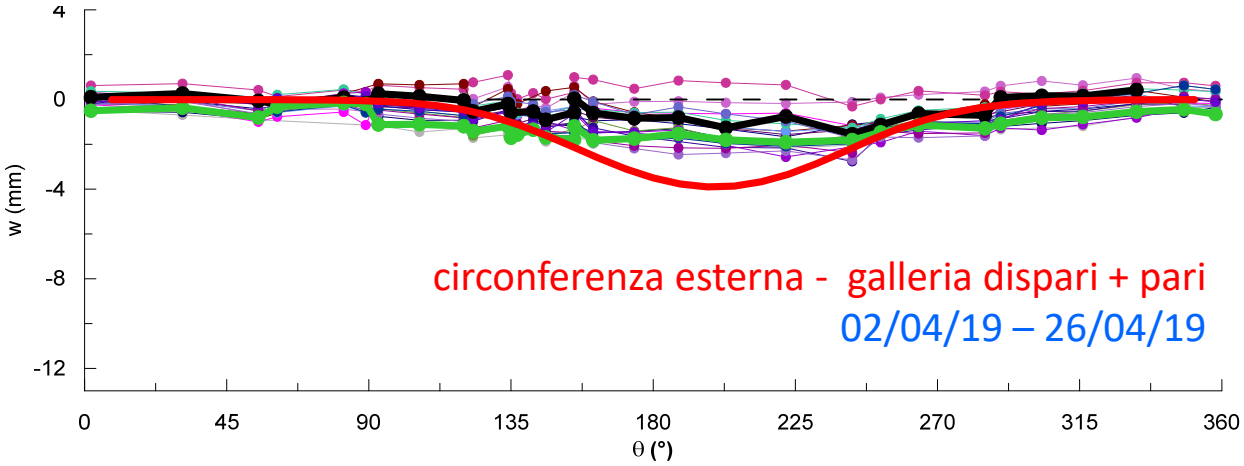
circonferenza esterna



Santo Stefano Rotondo – monitoraggio



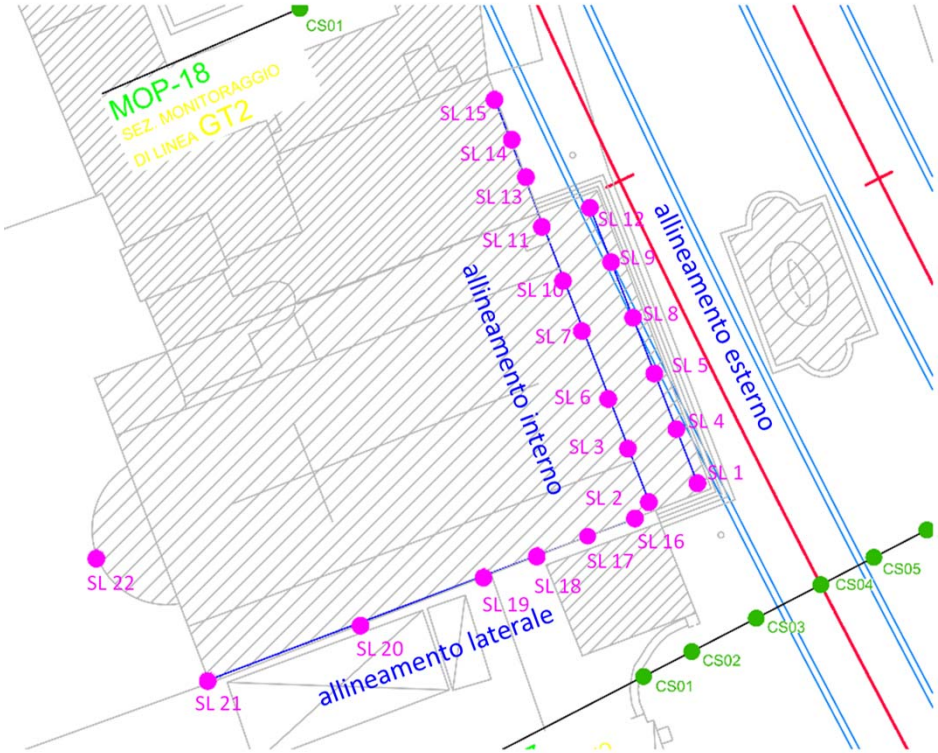
	w_{medio} mm
previsioni	-1.11
misure	-0.40

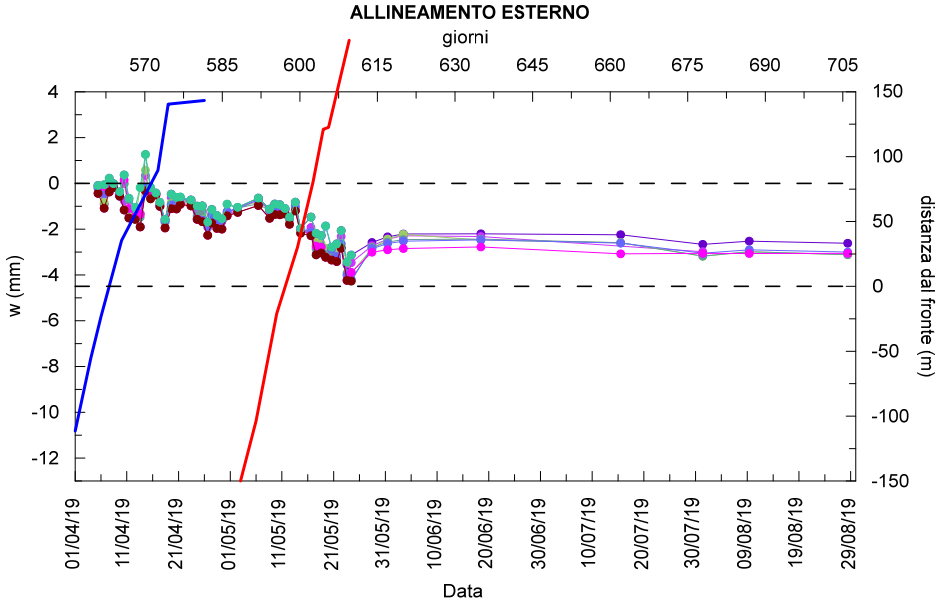


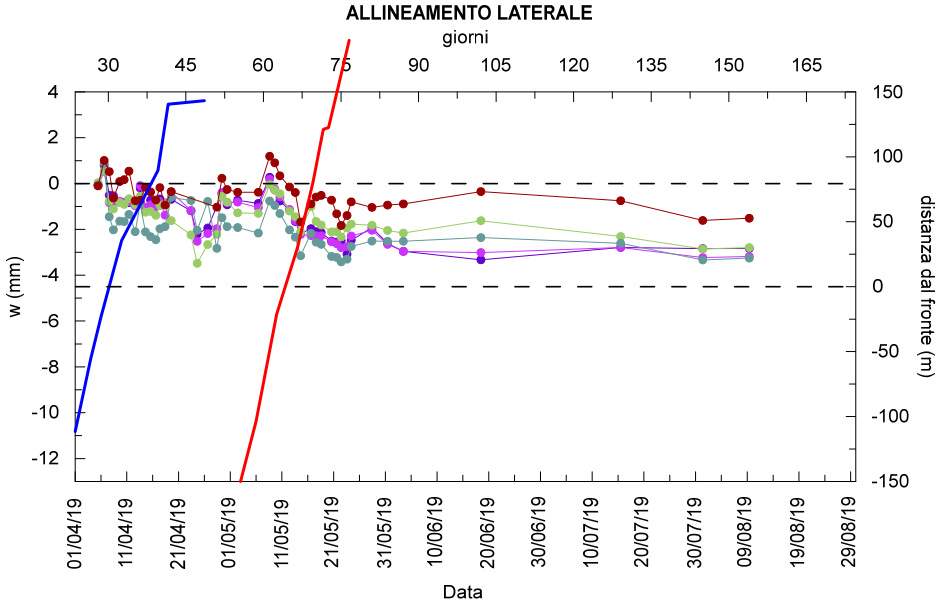
	w_{medio} mm
previsioni	-1.11
misure	-0.78

previsioni su piano fondazione Chiesa (z= 3,35 m)

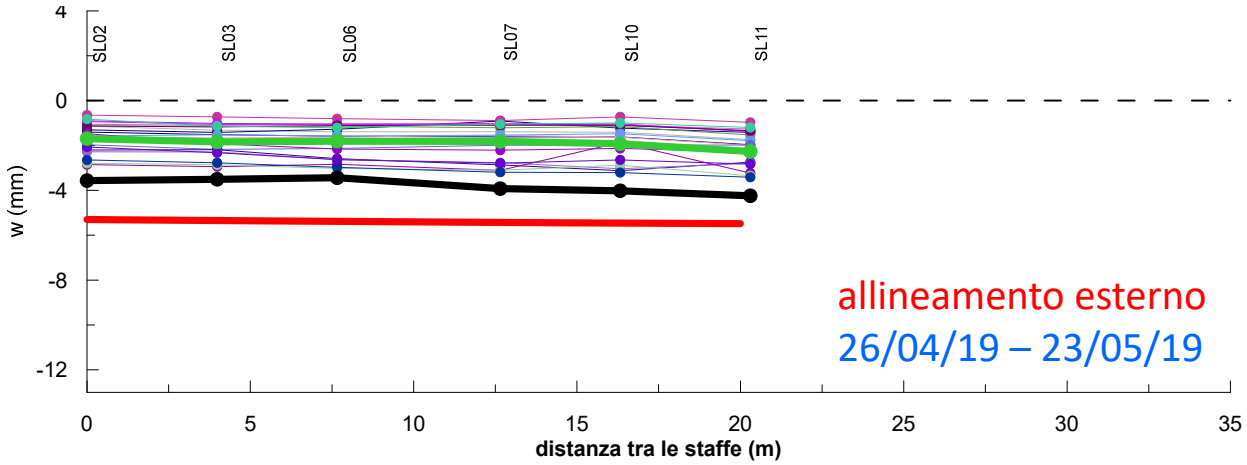
Santa Maria in Domnica – monitoraggio



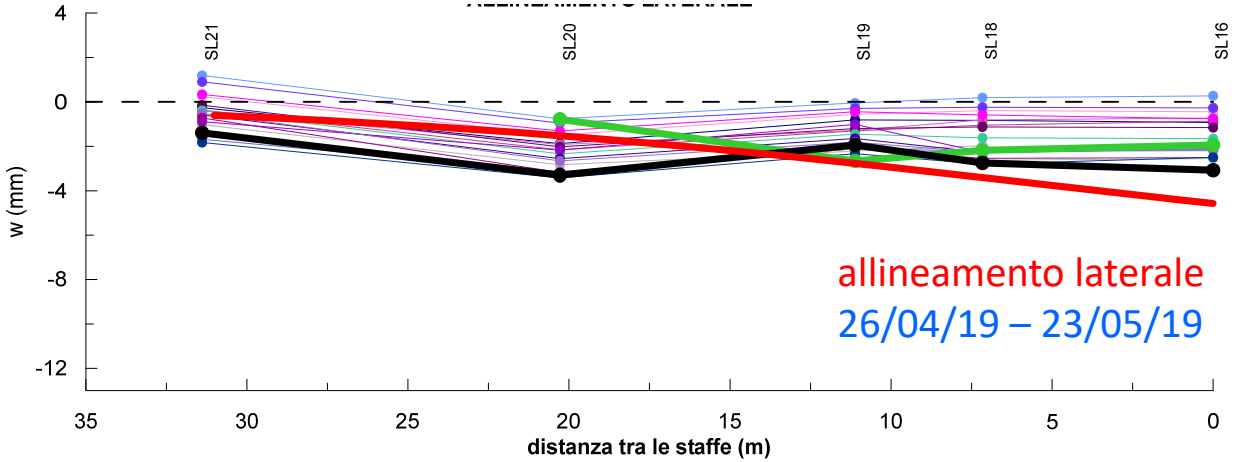




Santa Maria in Domnica – monitoraggio



	w_{medio} mm
previsioni	-5.32
misure	-3.75



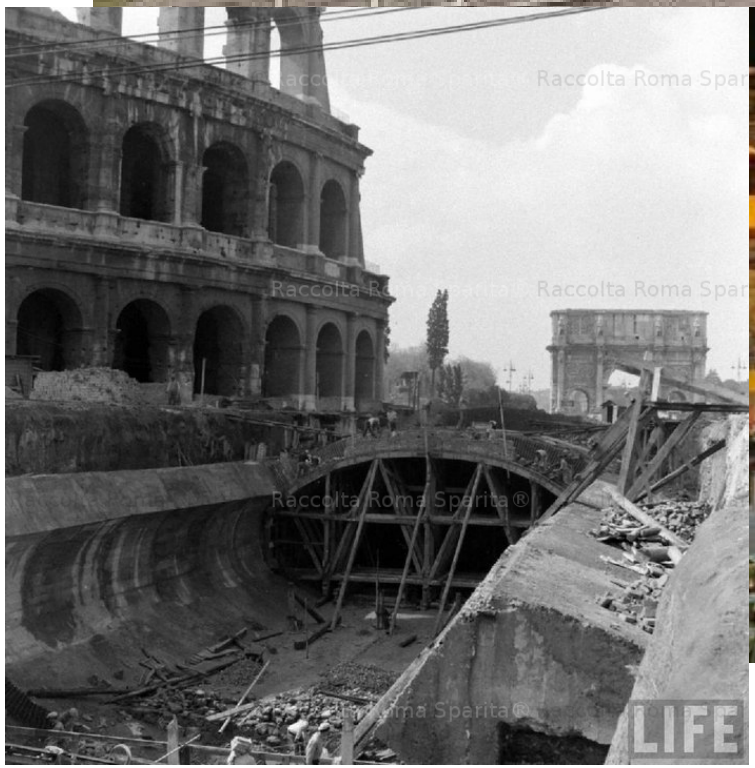
	w_{medio} mm	w_{max} mm
previsioni	-2.26	-4.6
misure	-2.56	-3.3

previsioni piano fondazione Chiesa (z= 5 m)

Colosseo

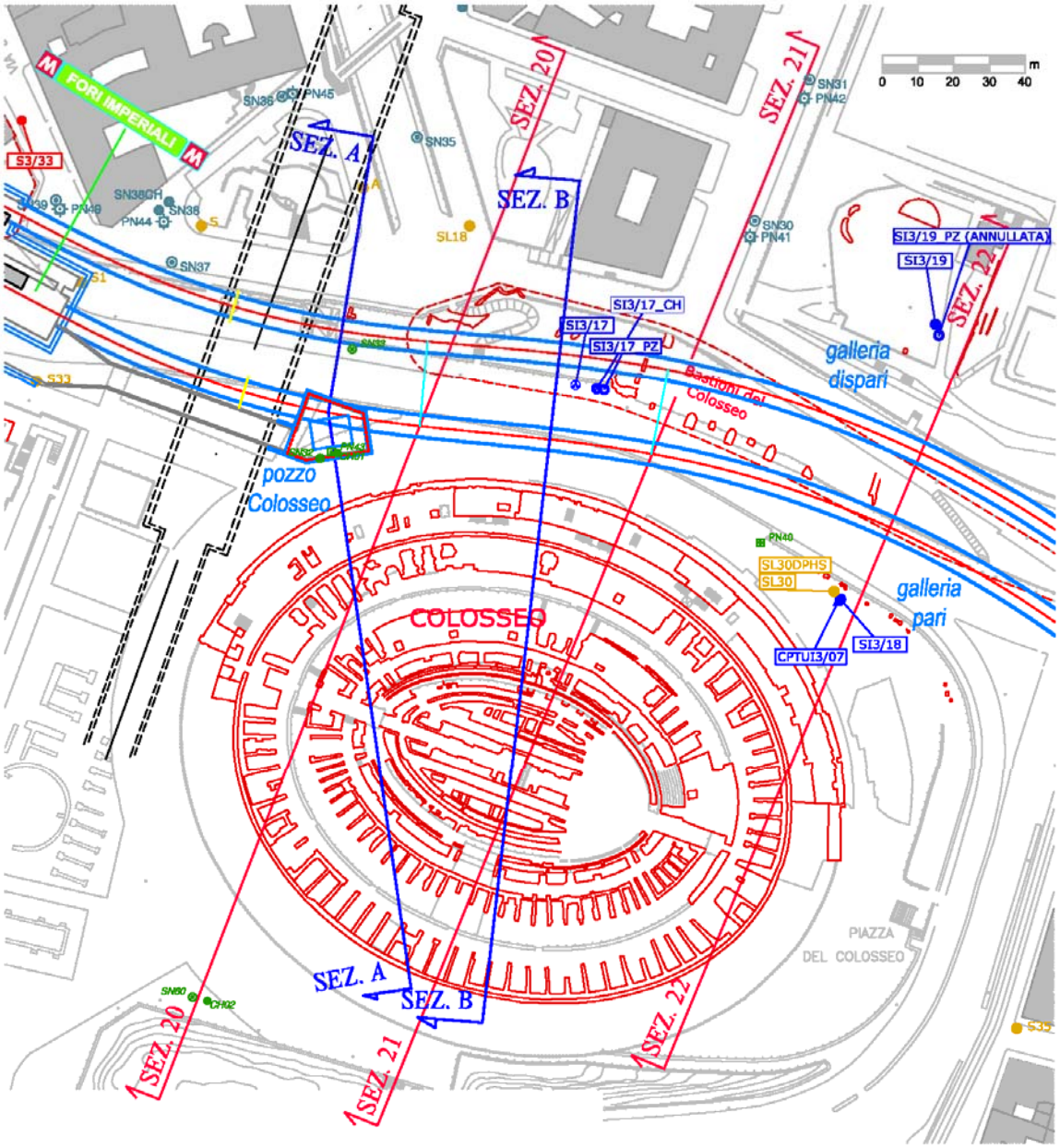




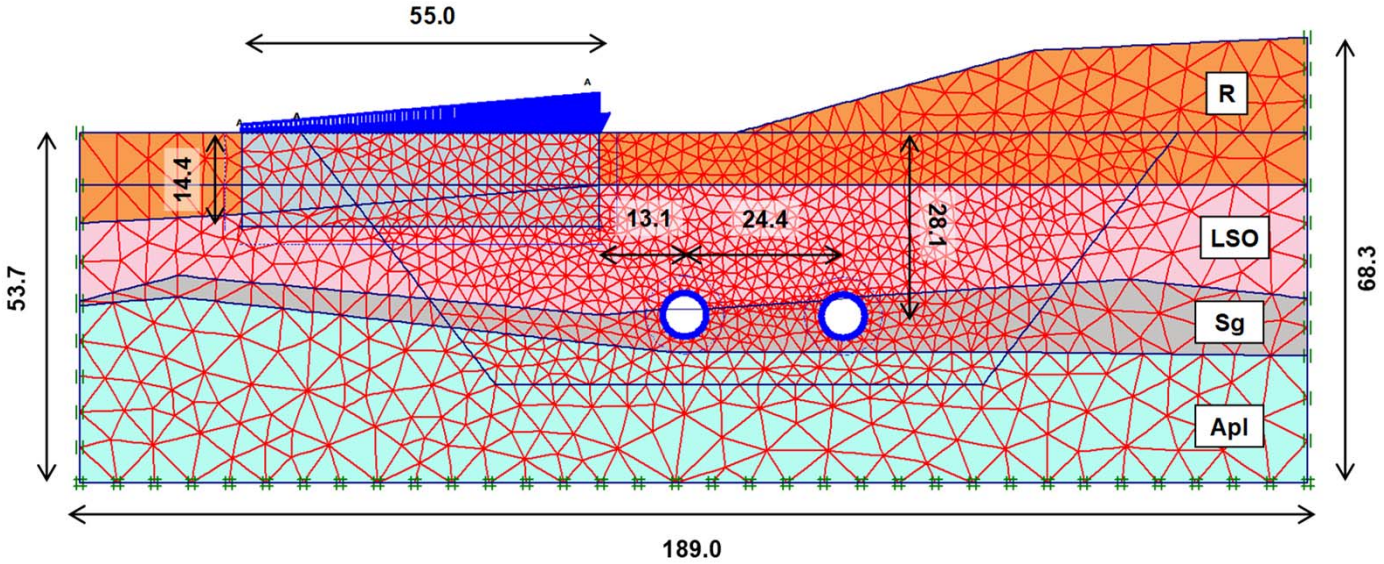


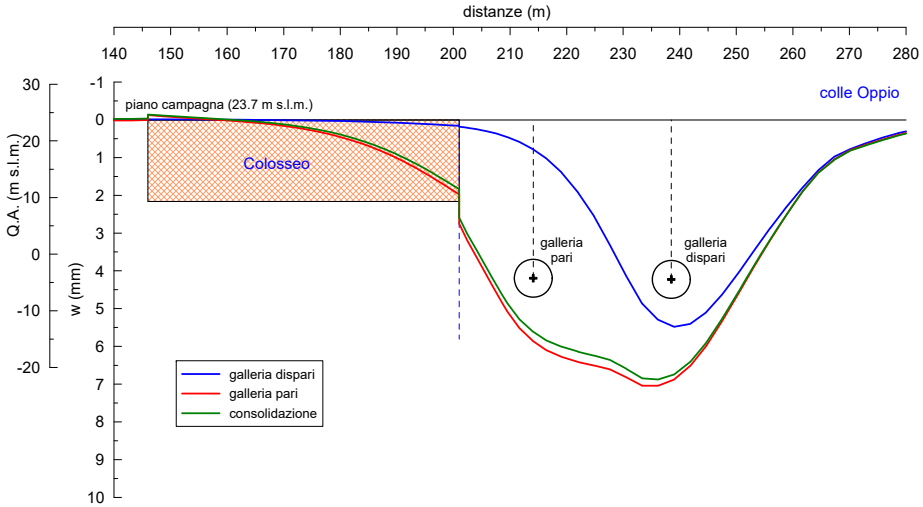


Colosseo – studi di interazione

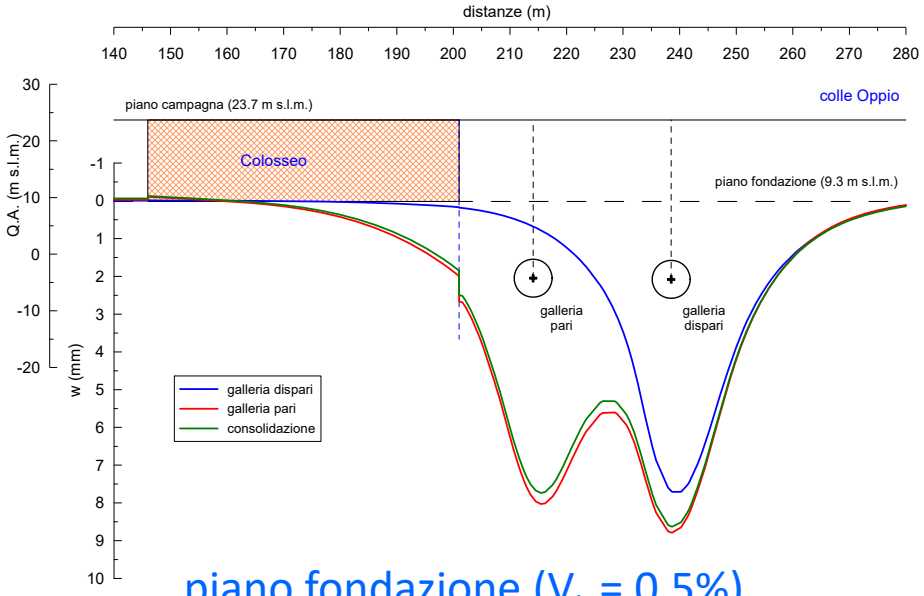


Colosseo – studi di interazione



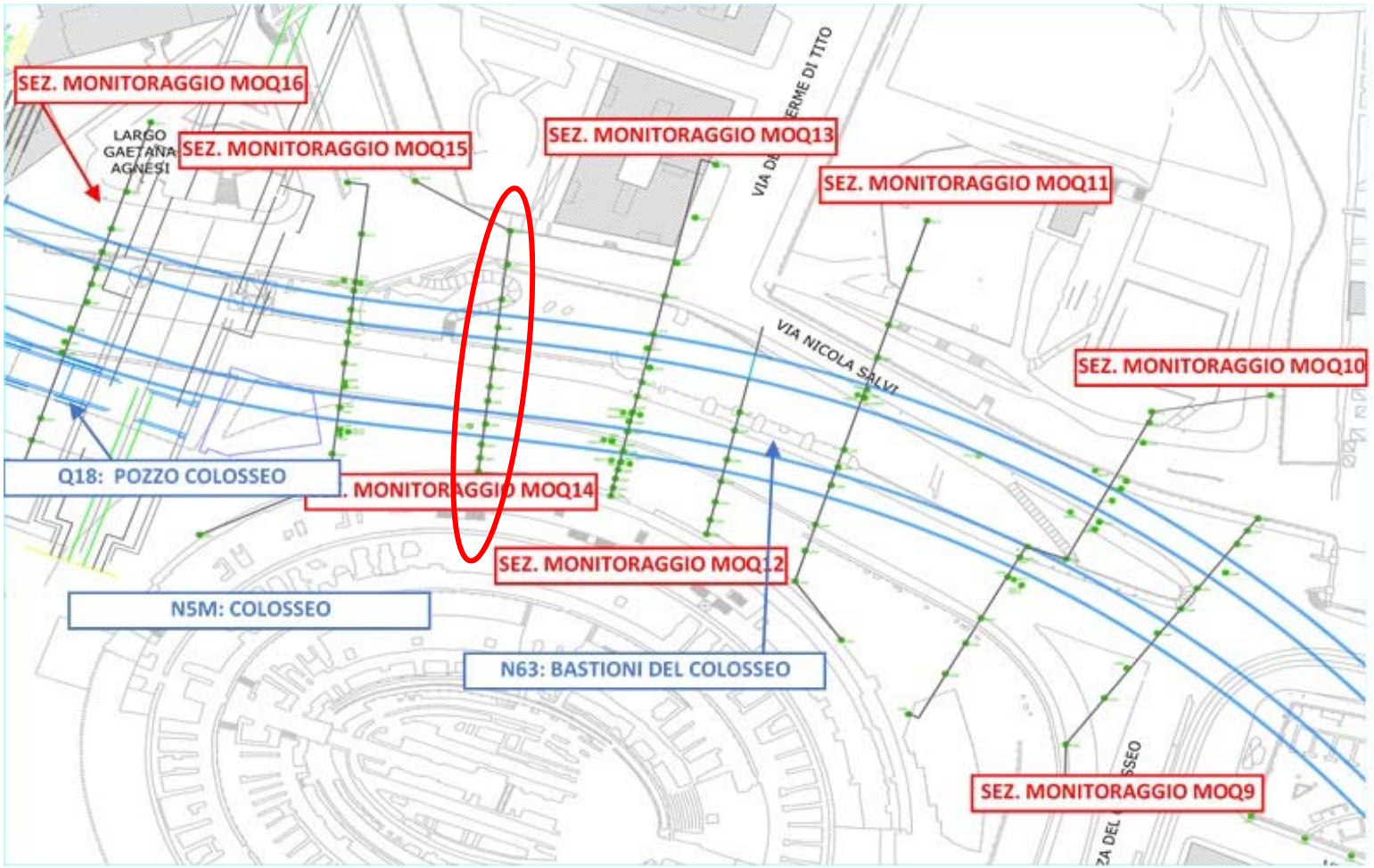


piano campagna (V_L = 0.5%)



piano fondazione (V_L = 0.5%)

Colosseo – monitoraggio – sezione MOQ14

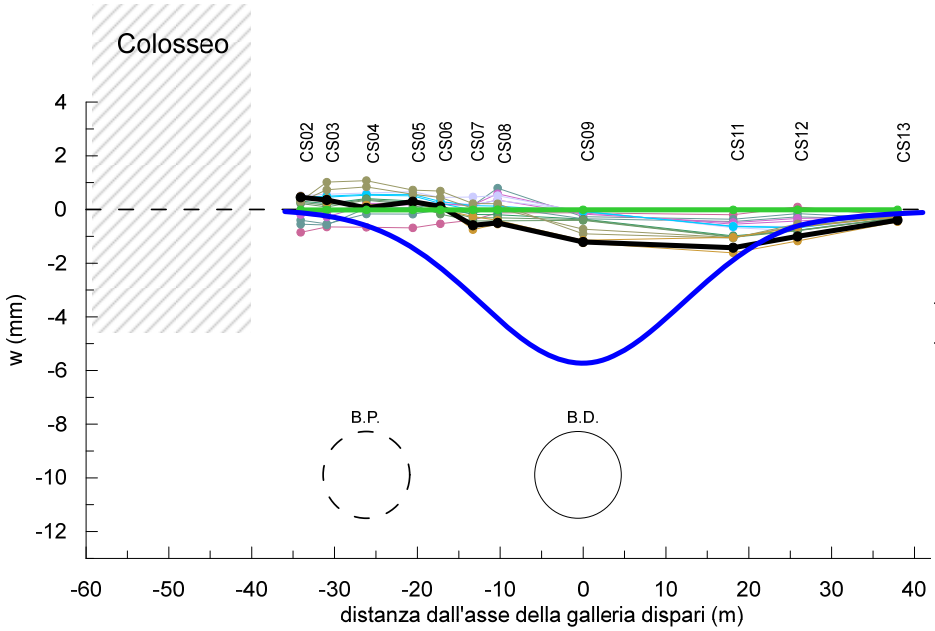


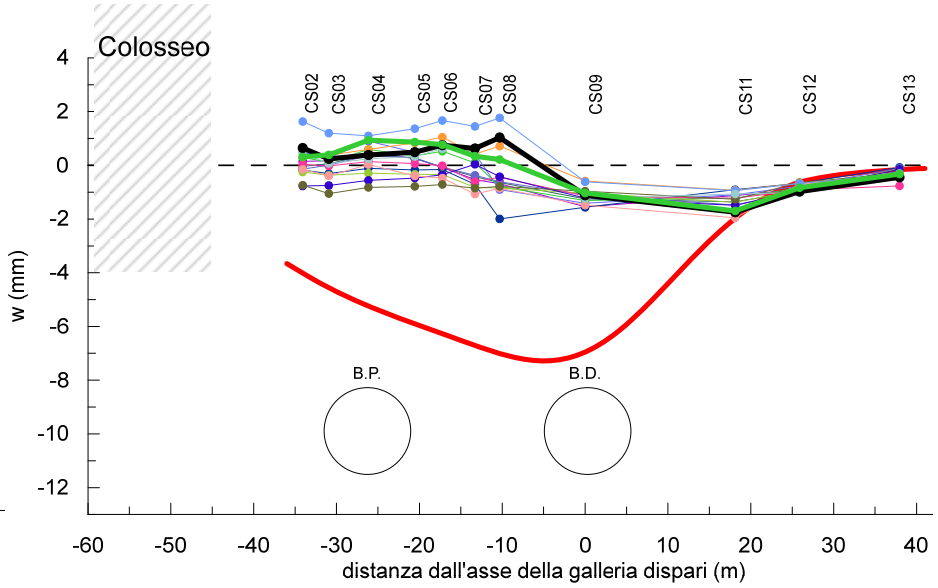
8 sezioni di monitoraggio normali alle gallerie
(capisaldi, inclinometri, Trivec, celle piezometriche)

strumentazione sul Colosseo (staffe livellometriche)

z gallerie ≈ 28 m

Colosseo – monitoraggio – sezione MOQ14





galleria dispari 29/05/19 – 21/06/19

entrambe le gallerie 27/06/19 – 29/07/19

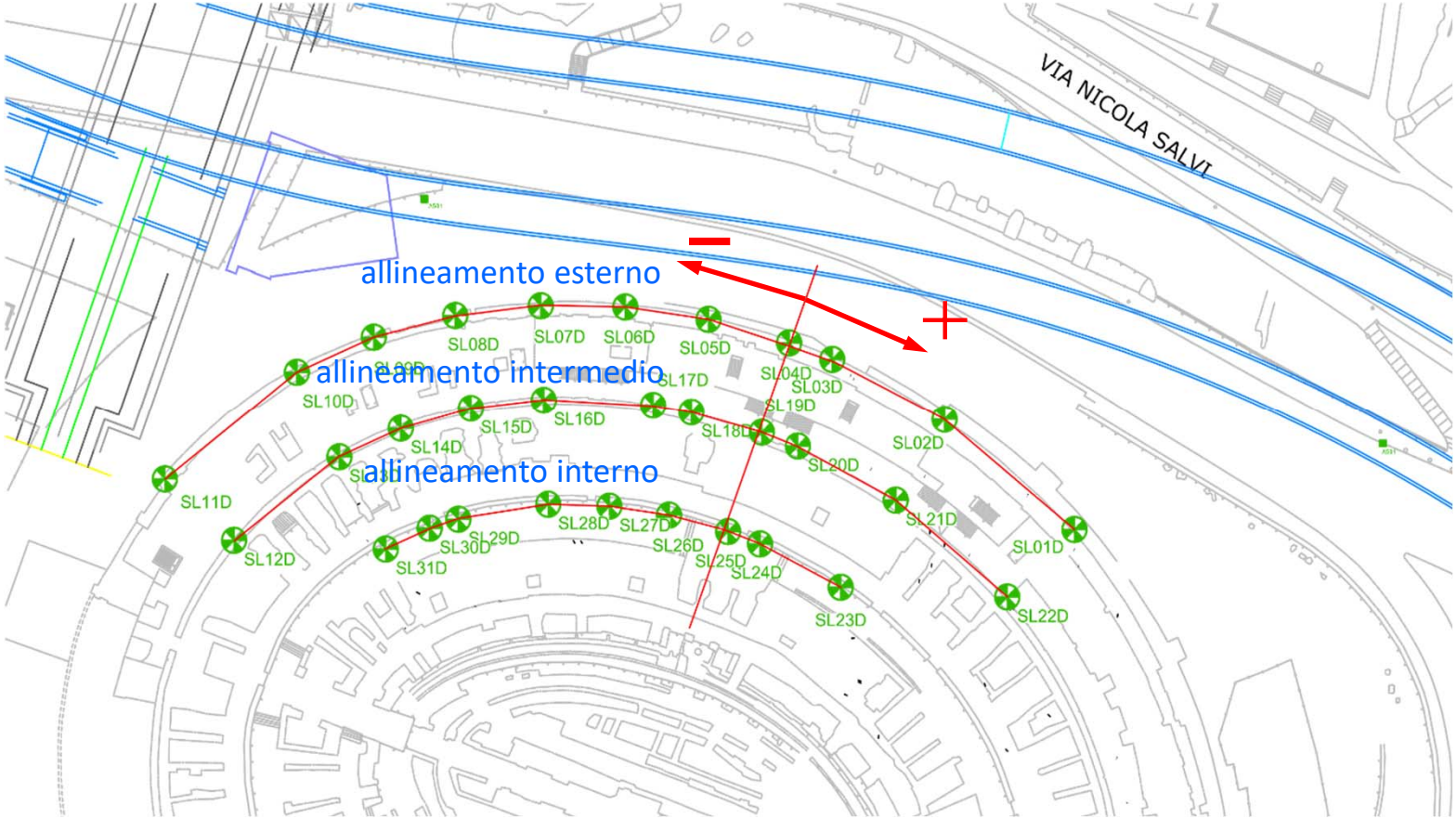
GALLERIA DISPARI

	MOQ9	MOQ10	MOQ11	MOQ12	MOQ13	MOQ14	MOQ15	MOQ16
V_L%	0.1	0.3	0.1	0	0.3	0.2	0.2	0.2
w_{max} (mm)	-2.01	-3.04	-1.61	-0.49	-2.22	1.62	-2.87	-4.67

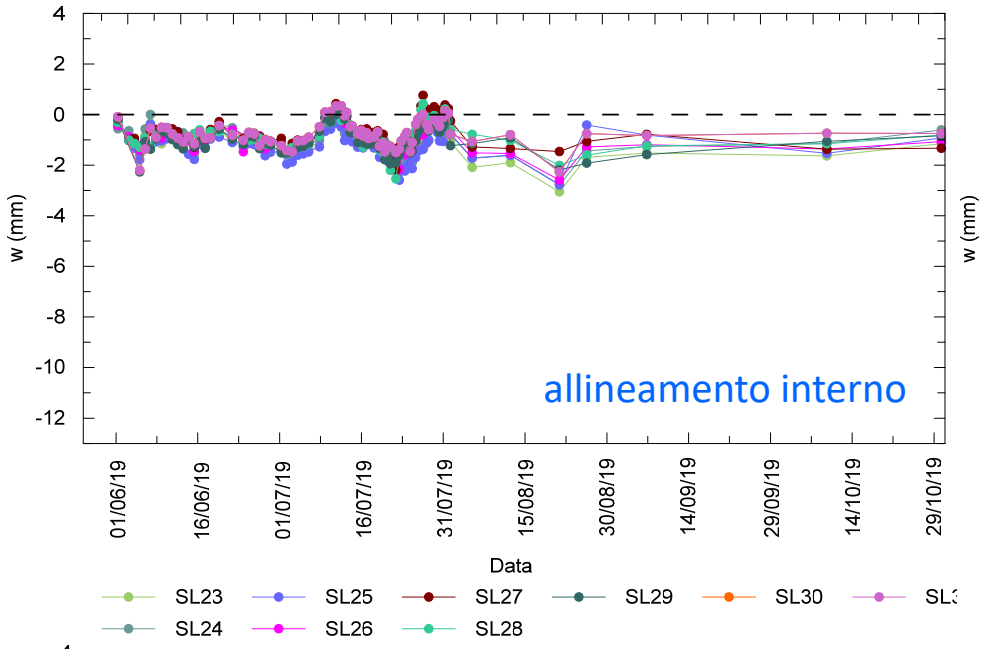
GALLERIA DISPARI + PARI

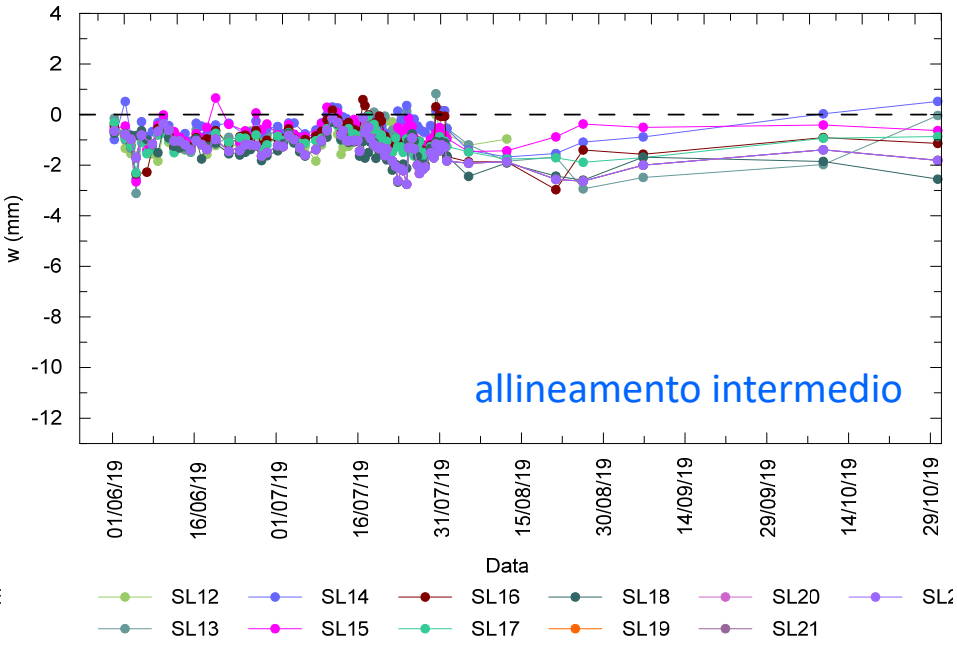
	MOQ9	MOQ10	MOQ11	MOQ12	MOQ13	MOQ14	MOQ15	MOQ16
V_L%	0.04	0.2	0.2	0.1	0.2	0.1	0.1	0.1
w_{max} (mm)	-2.89	-3.16	-3.02	-2.83	-3.36	-2.0	-3.24	-5.17

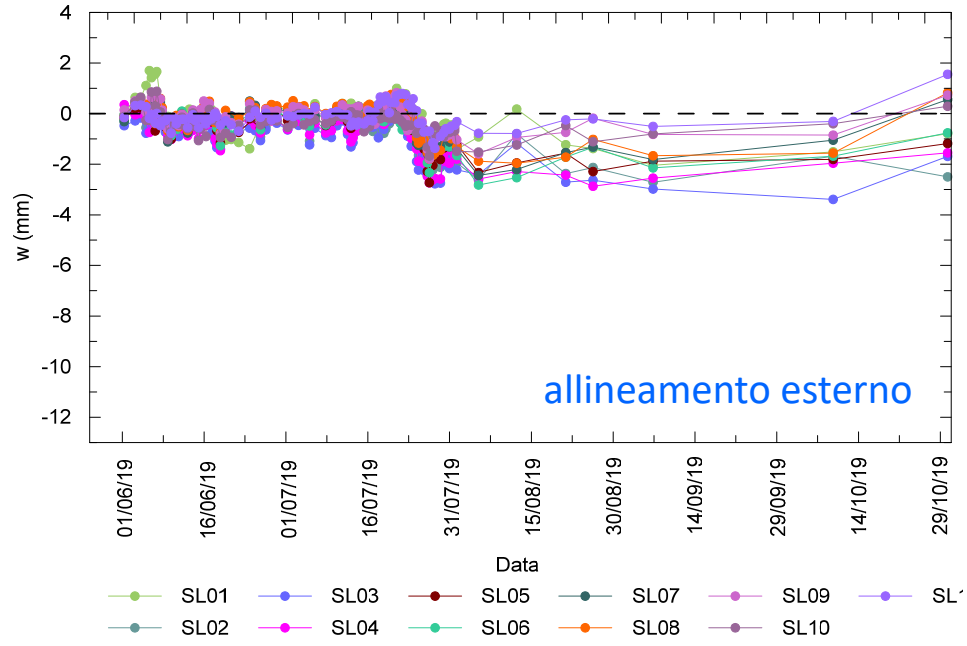
Colosseo – monitoraggio



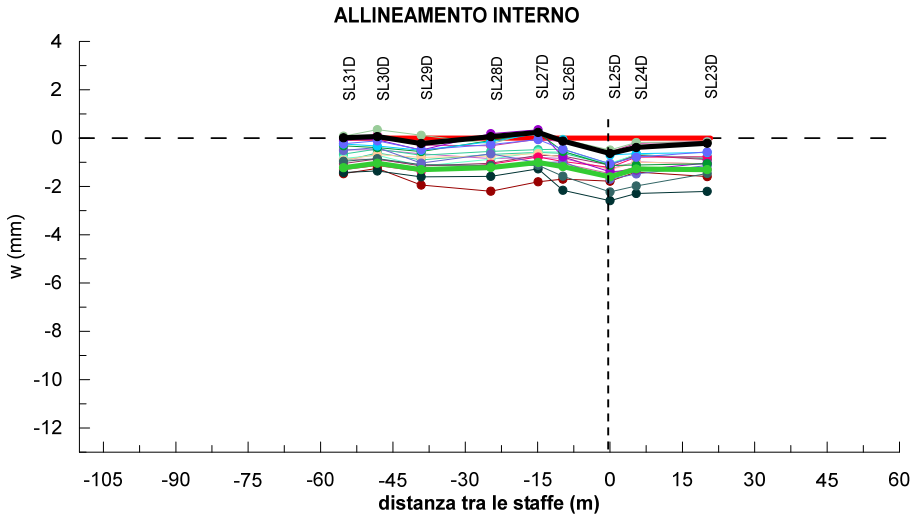
Colosseo – monitoraggio

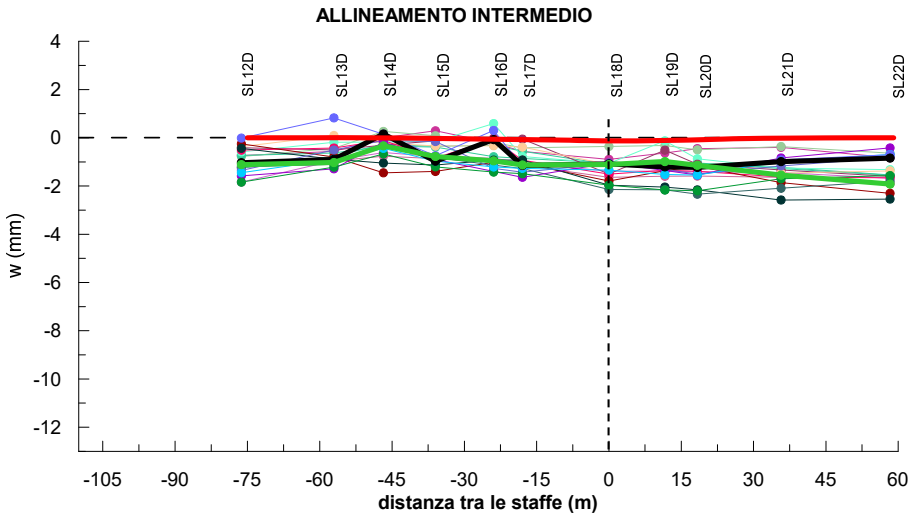


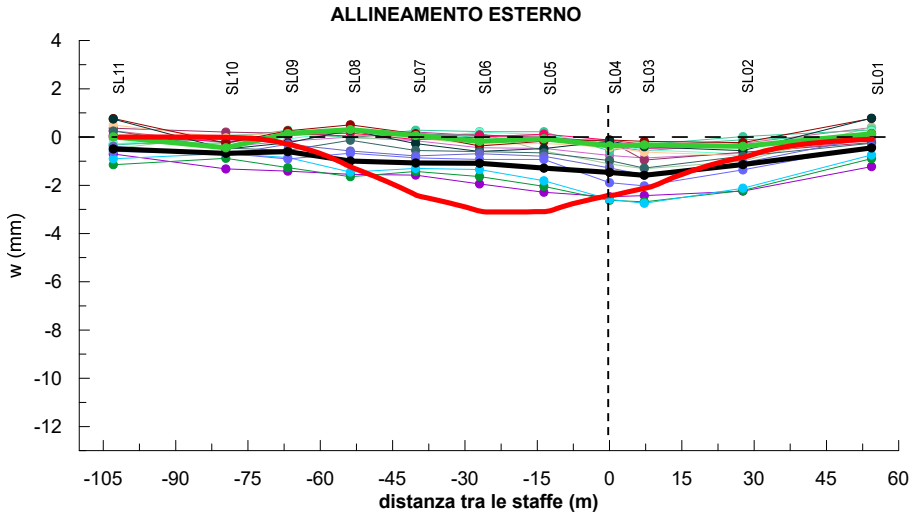




Colosseo – monitoraggio







entrambe le gallerie

isocrone cedimenti
04/07/19 – 31/07/19

previsioni sul piano di fondazione
(z= 14.4 m)

Basilica di Massenzio

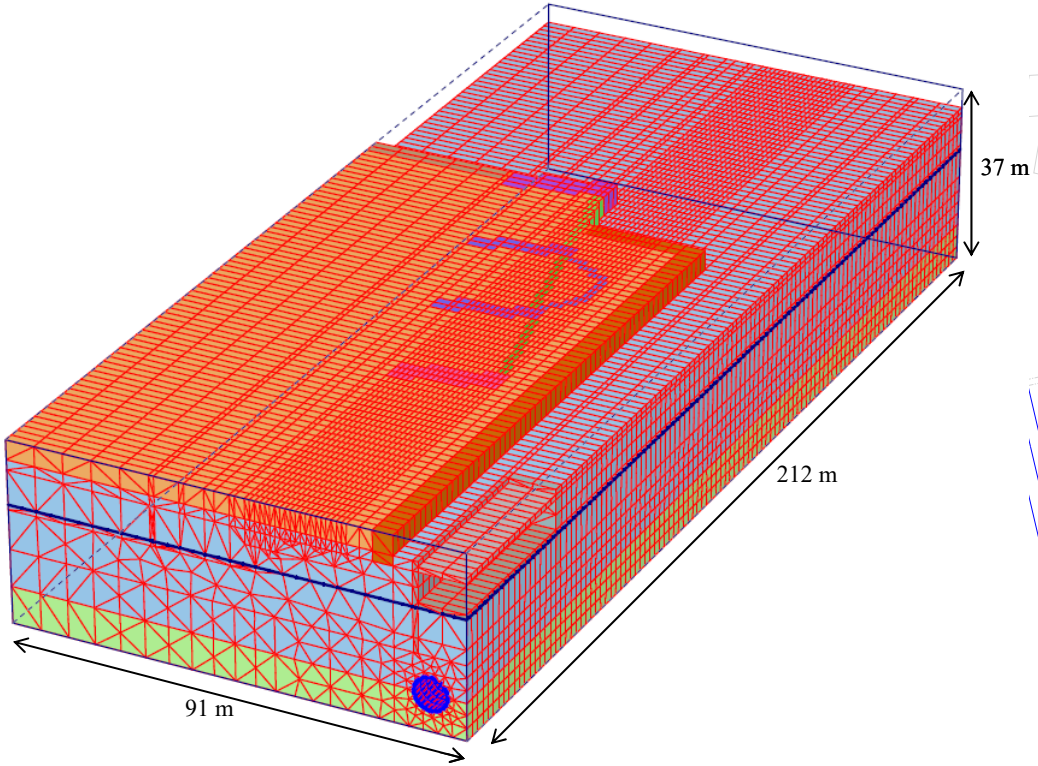


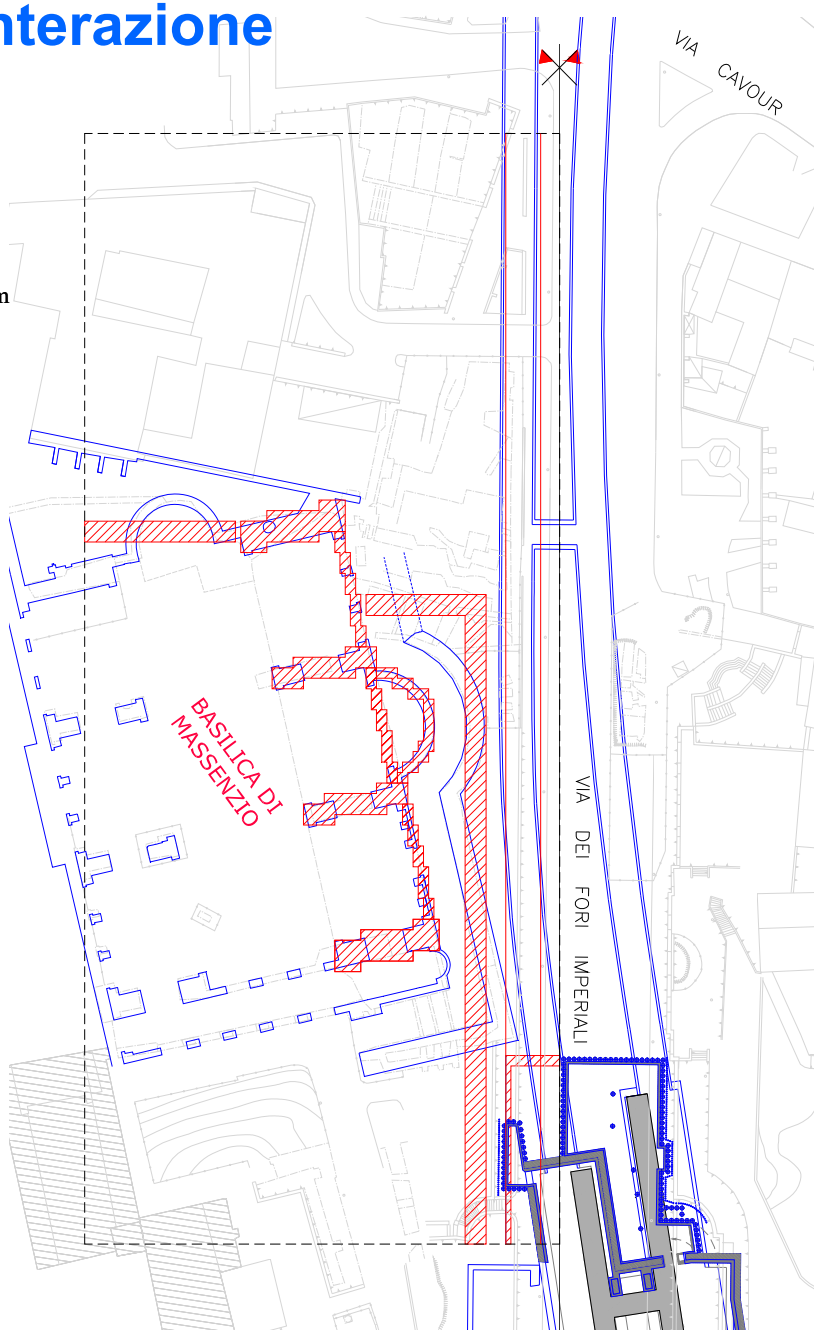






Basilica di Massenzio – studi di interazione

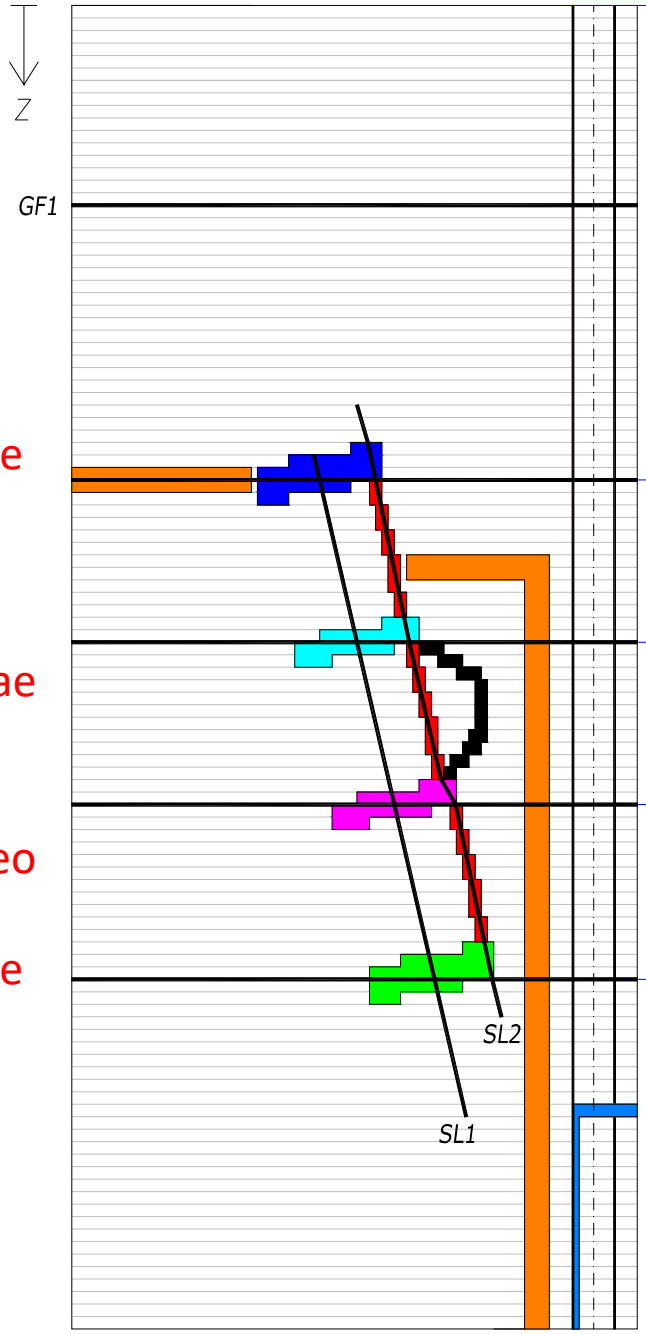




- quota calpestio Basilica 27m s.l.m.
- quota via dei Fori Imperiali 23m s.l.m.
- profondità gallerie ≈ 25m da via dei Fori Imperiali
- interasse gallerie 19,7 – 13,9 m
- distanza minima da pilone Colosseo 16m
- distanza massima da pilone Carinae 34m

Basilica di Massenzio

studi di interazione



avanz. **5** (212/212)
galleria passata

sezione pilone
Carinae

avanz. **4** (136/212)

sezione pilone
centrale Carinae

avanz. **3** (110/212)

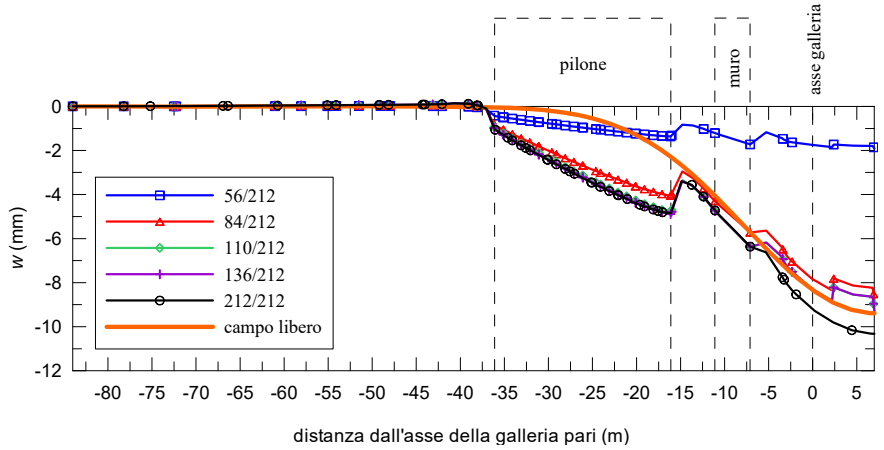
sezione pilone
centrale Colosseo

avanz. **2** (84/212)

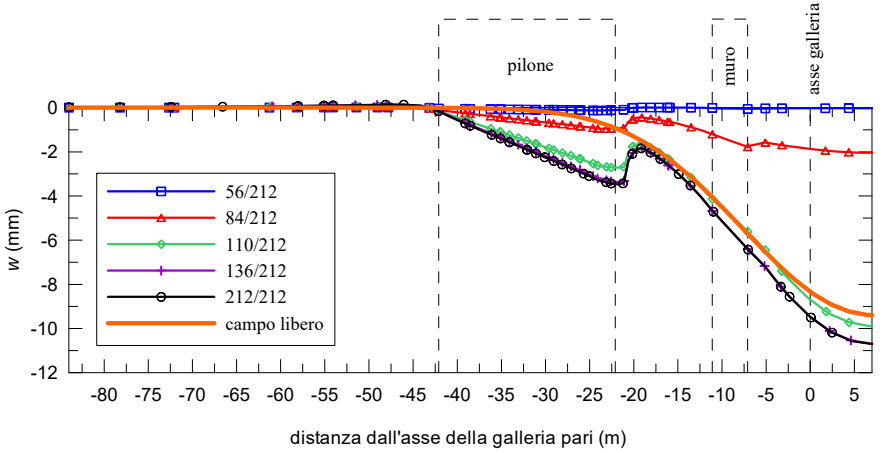
sezione pilone
Colosseo

avanz. **1** (56/212)

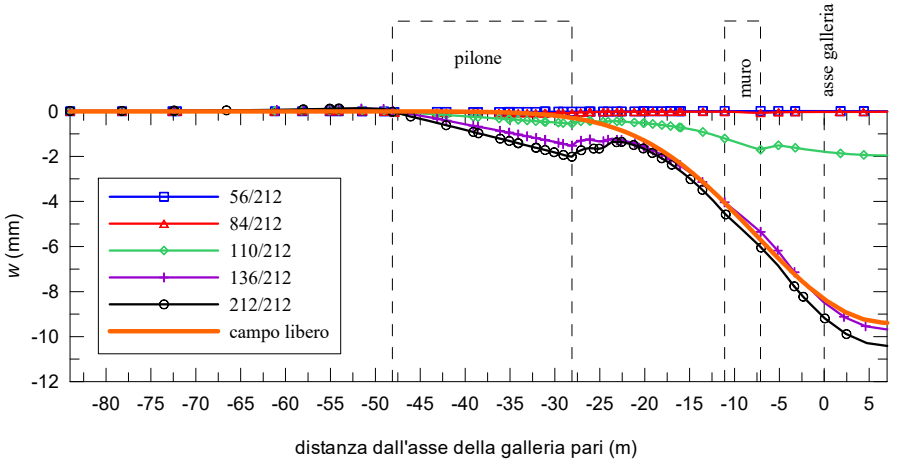
Basilica di Massenzio – studi di interazione



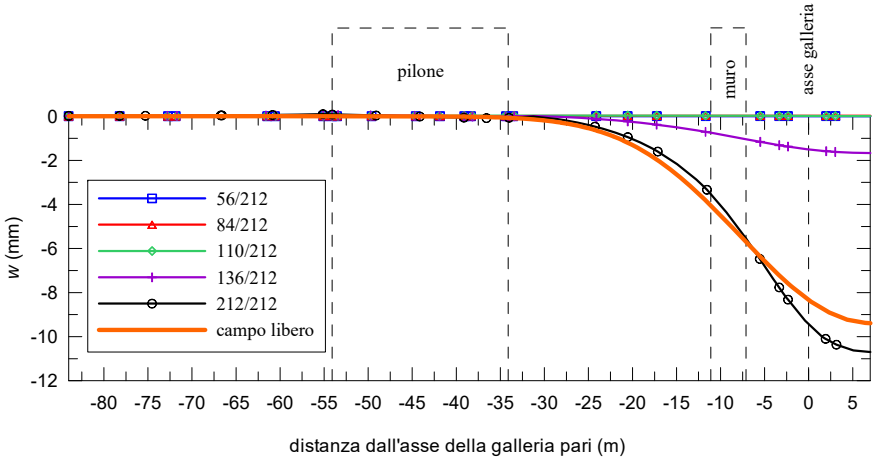
pilone Colosseo (23m s.l.m. – z = 4m)



pilone centrale Colosseo (21 m s.l.m. – z = 6m)

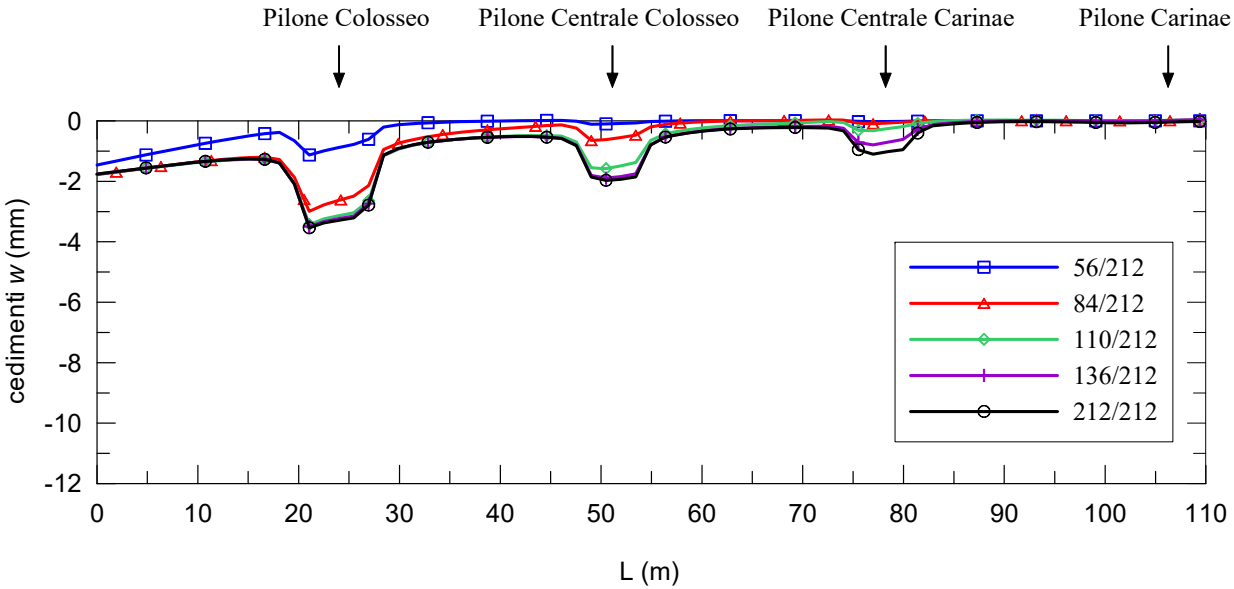


pilone centrale Carinae (21m s.l.m. z = 6m)

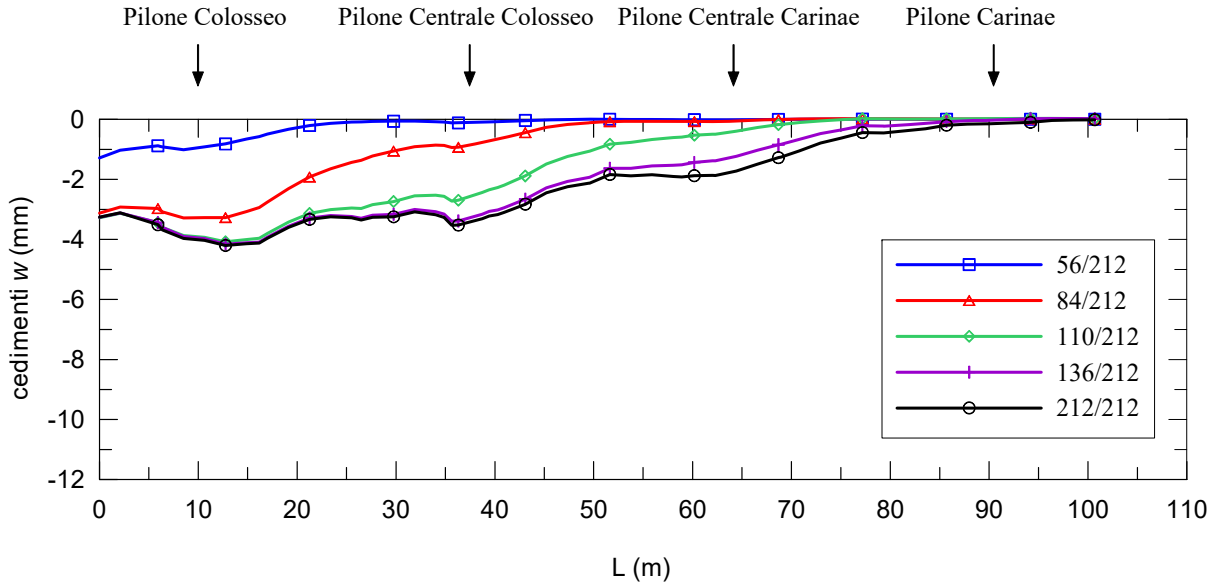


pilone Carinae (z = 13m s.l.m. – z = 13m)

Basilica di Massenzio – studi di interazione

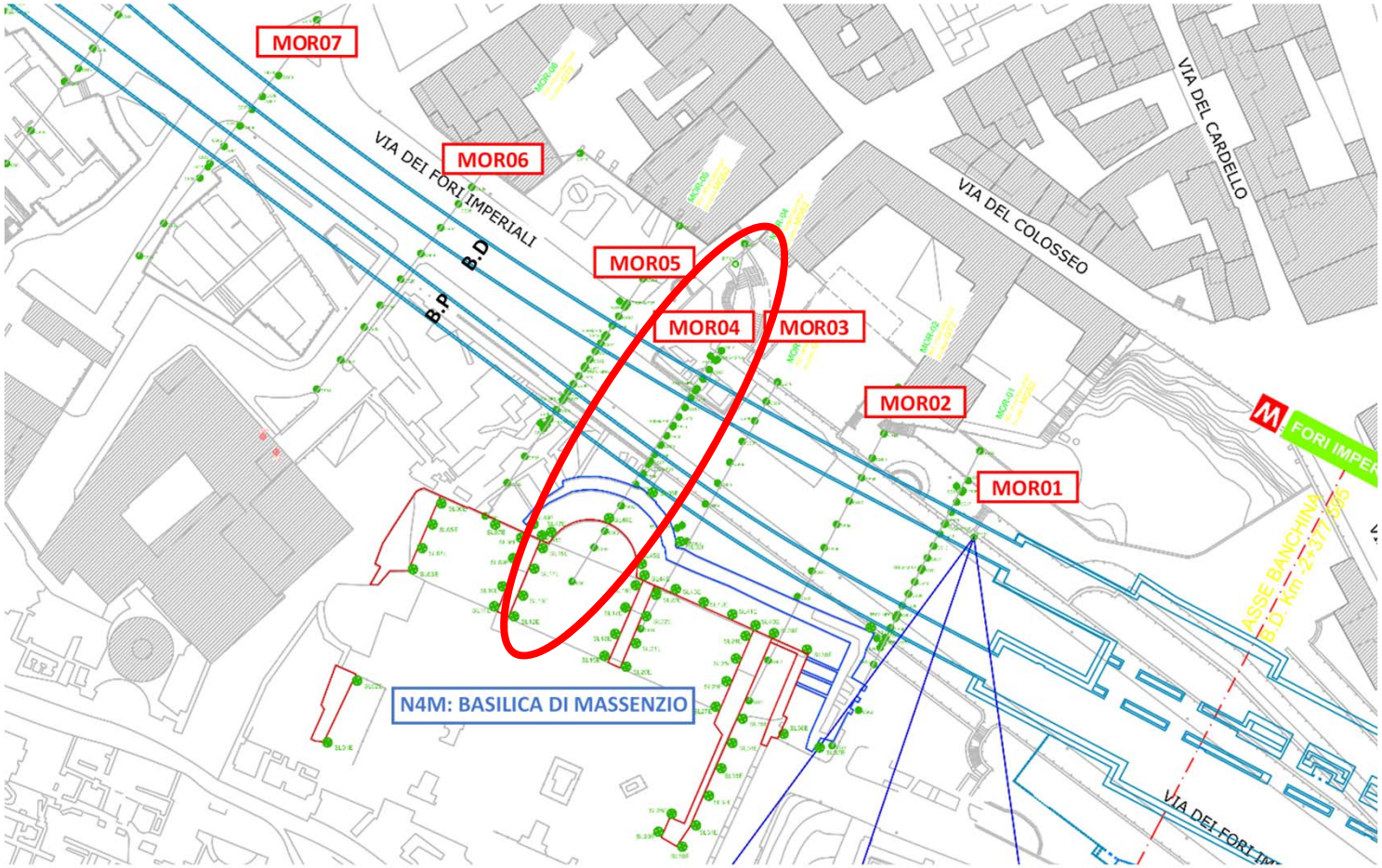


allineamento SL1
piloni
(prof. media z = 4 m)



allineamento SL2
parete trifore
(prof. media z = 6 m)

Basilica di Massenzio – monitoraggio

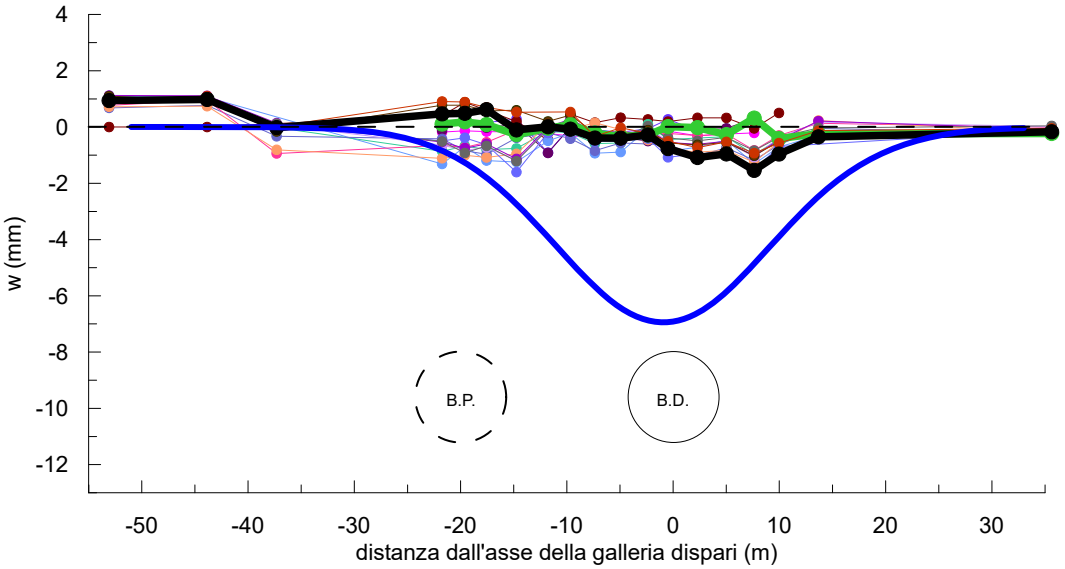


6 sezioni di monitoraggio normali alle gallerie
(capisaldi, inclinometri, Trivec, celle piezometriche)

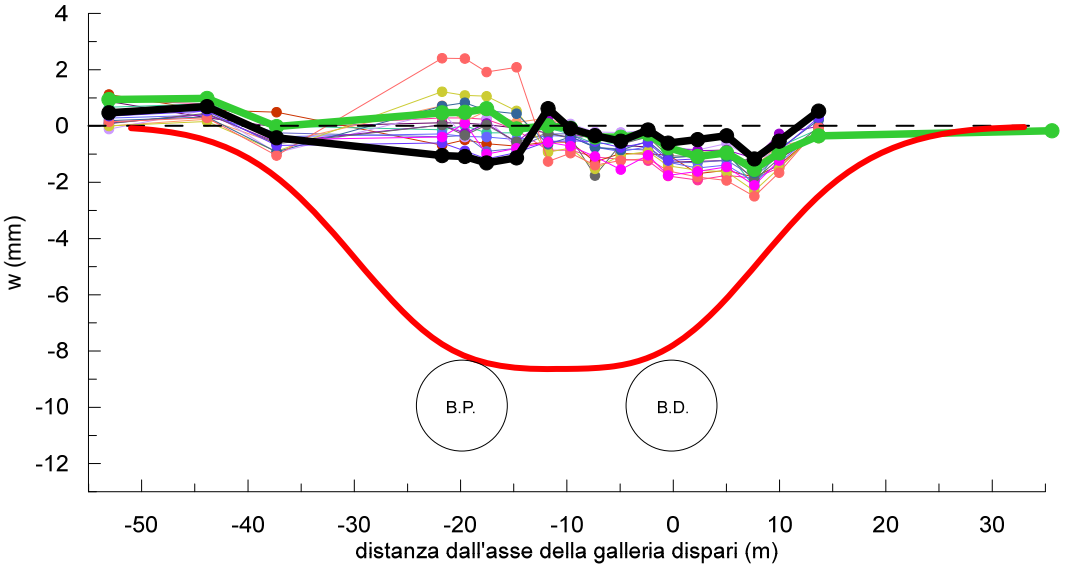
strumentazione sulla Basilica (staffe livellometriche)

z gallerie ≈ 25 m

Basilica di Massenzio – monitoraggio

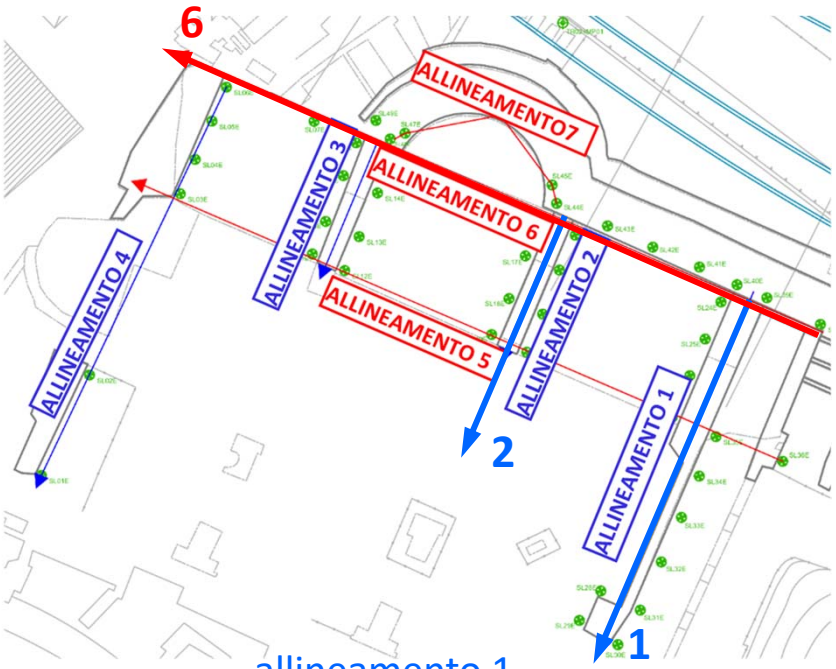


sezione **MOR04**
galleria dispari
09/9 – 01/10 2019

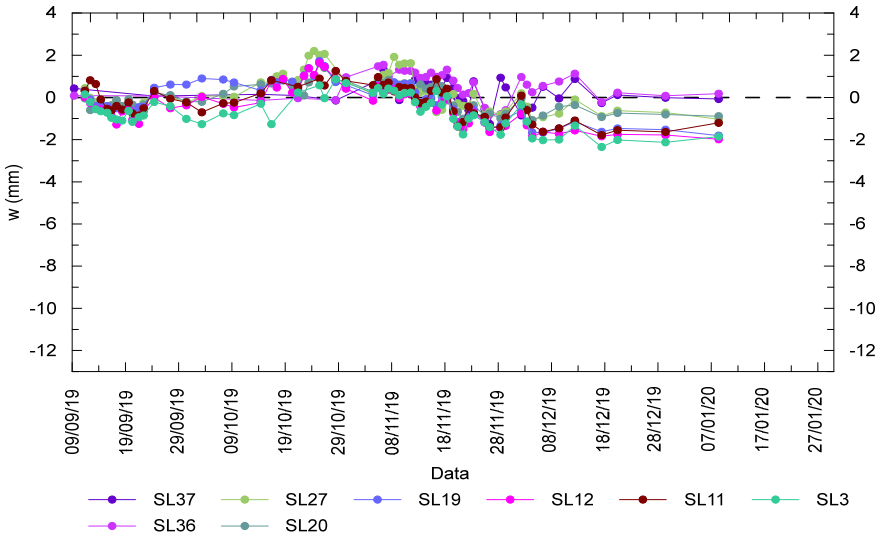


sezione **MOR04**
entrambe le gallerie
01/10 – 18/11 2019

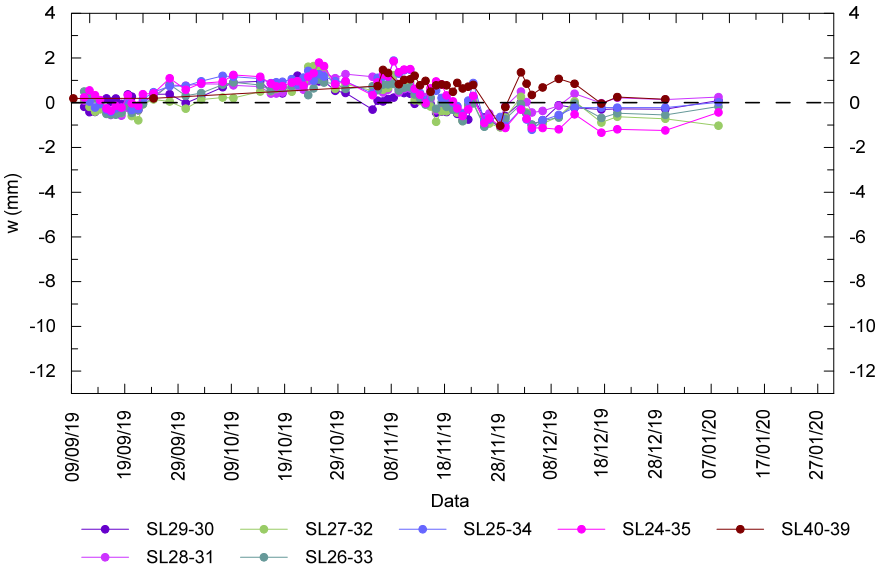
Basilica di Massenzio – monitoraggio struttura



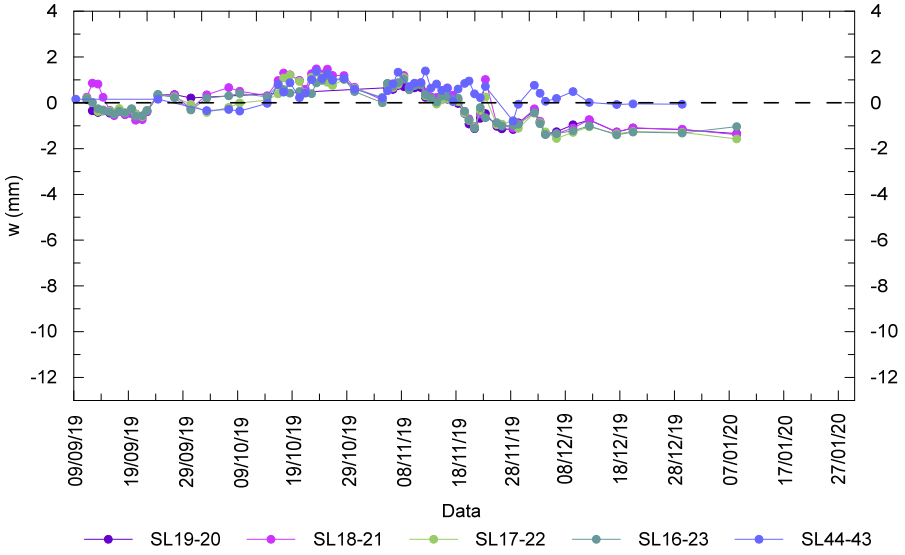
allineamento 6



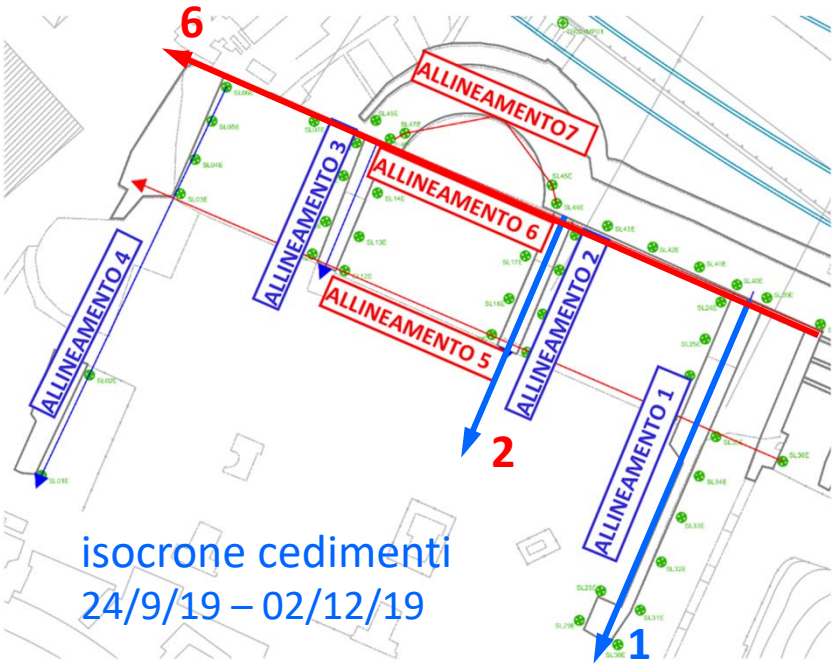
allineamento 1

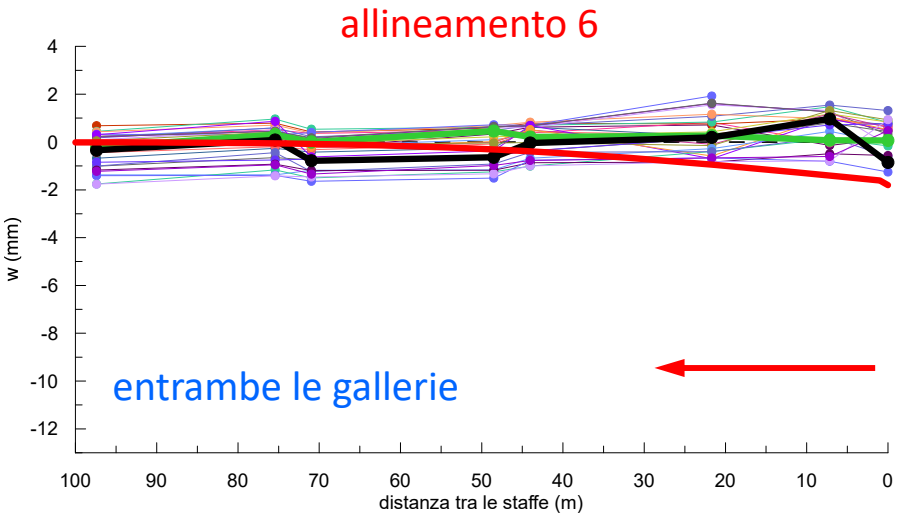


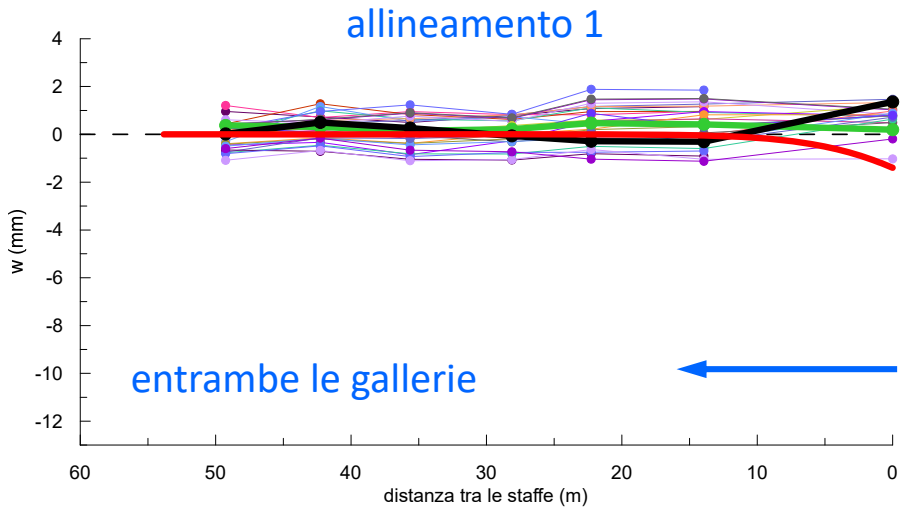
allineamento 2

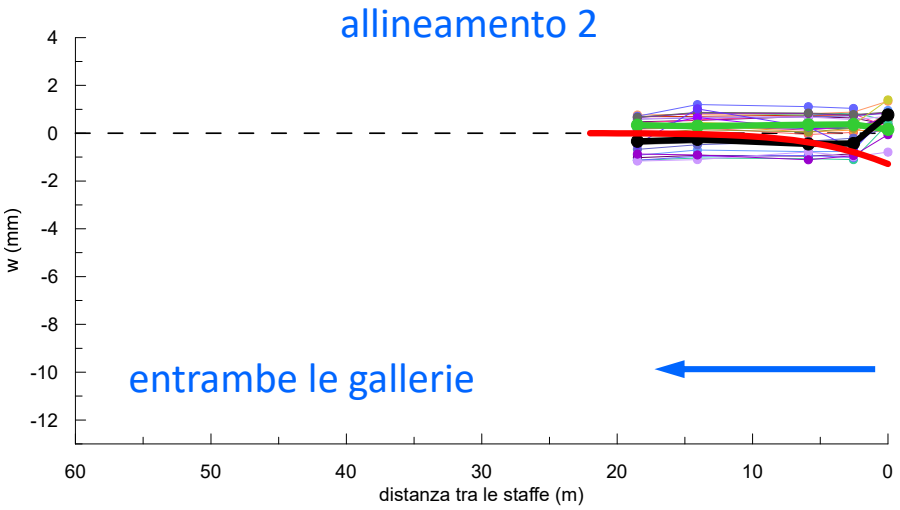


Basilica di Massenzio – monitoraggio struttura









Interazione linea-monumenti – Monitoraggio Tratta T3

FACOLTÀ DI INGEGNERIA
CIVILE E INDUSTRIALE

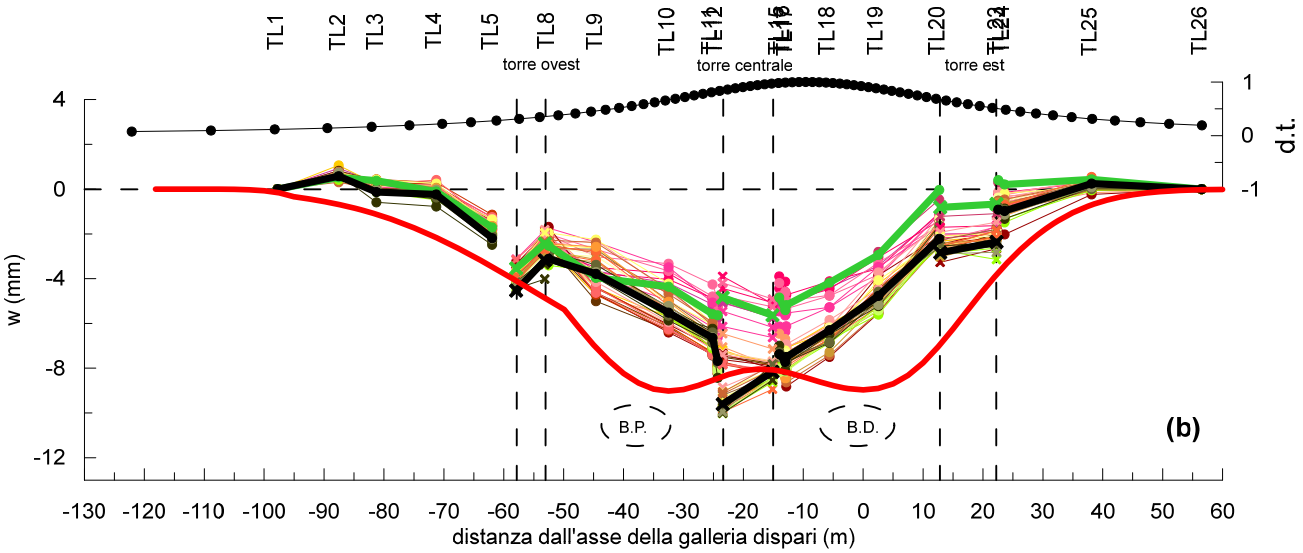
SAPIENZA
UNIVERSITÀ DI ROMA

Sebastiano Rampello



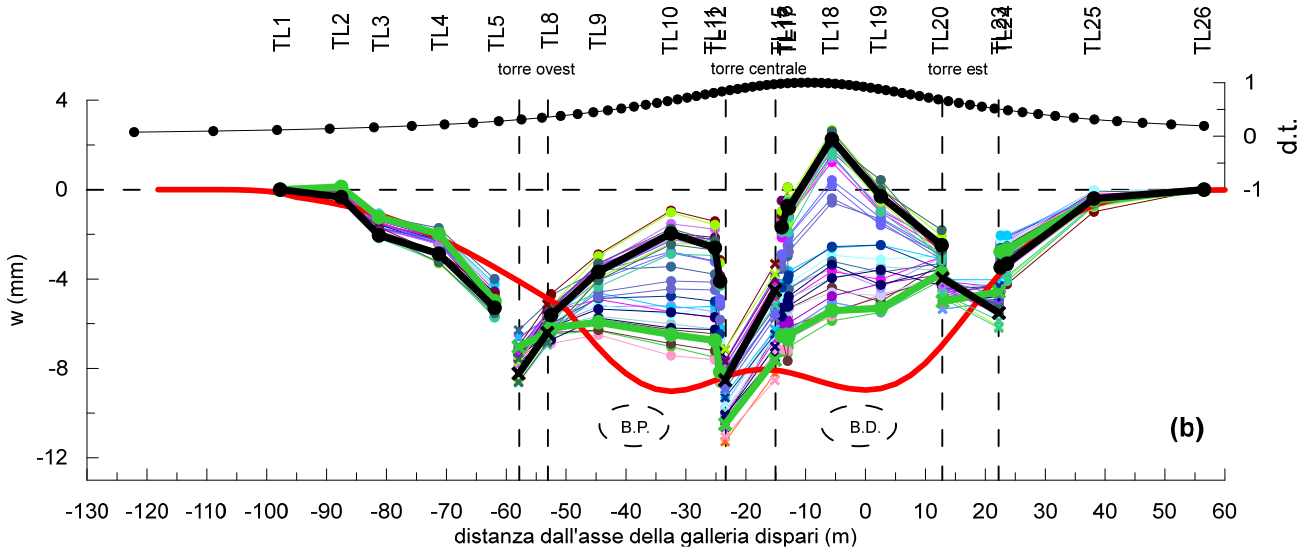
spare slides Metronia

effetto iniezioni di pre-trattamento

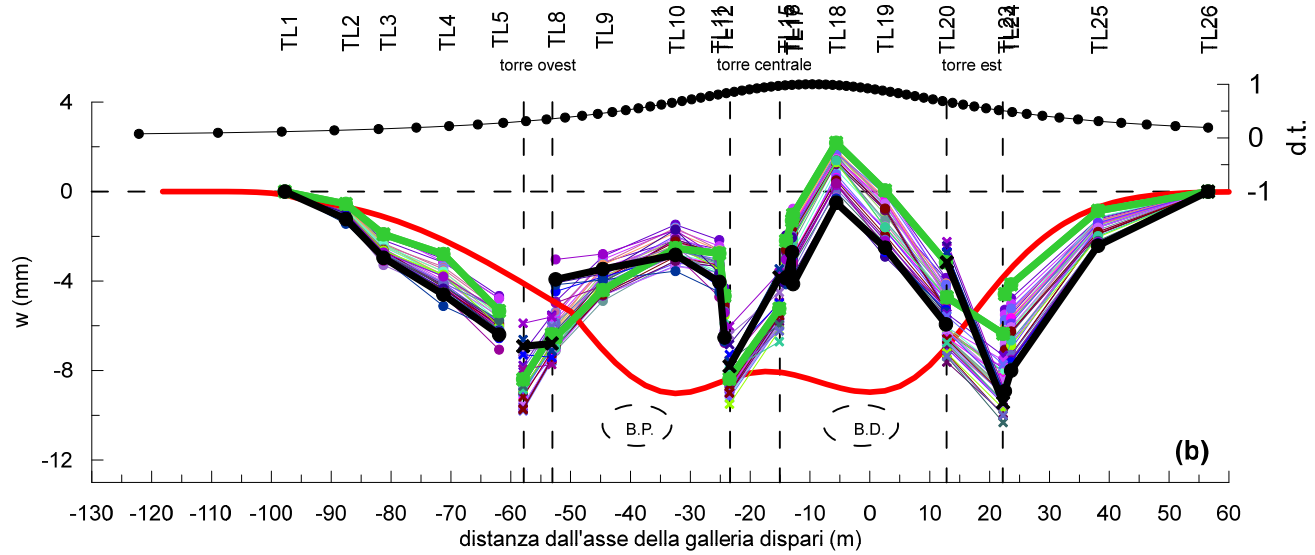


novembre 2018

effetto iniezioni di pre-trattamento

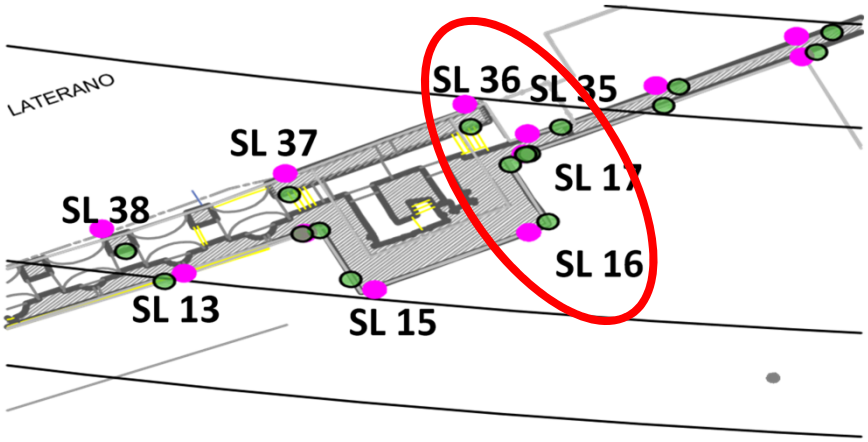


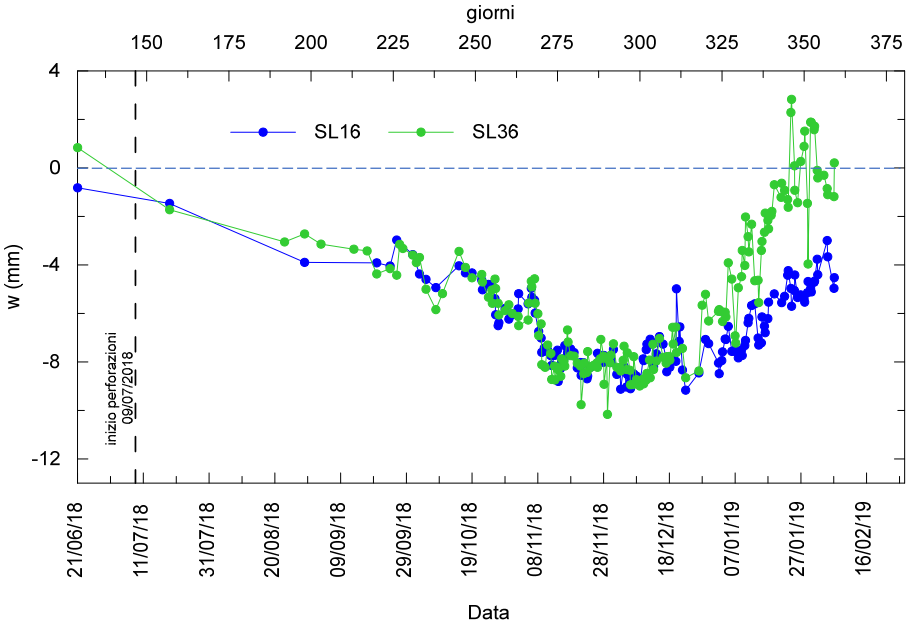
gennaio 2019

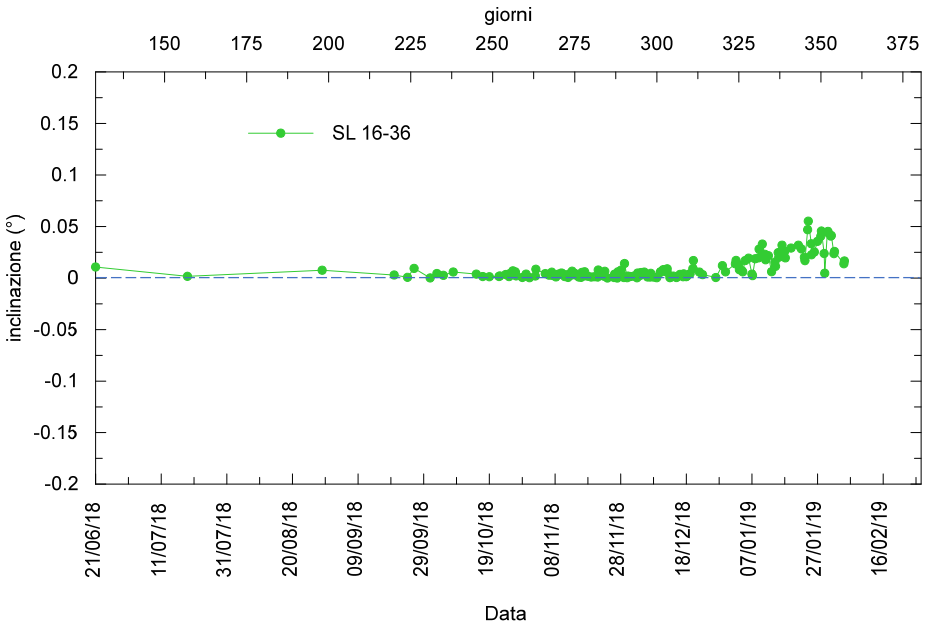


febbraio 2019

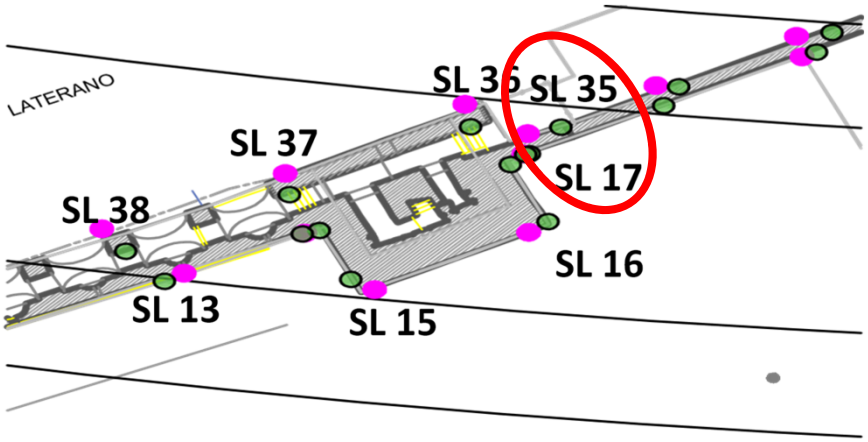
inclinazione fuori piano delle Mura

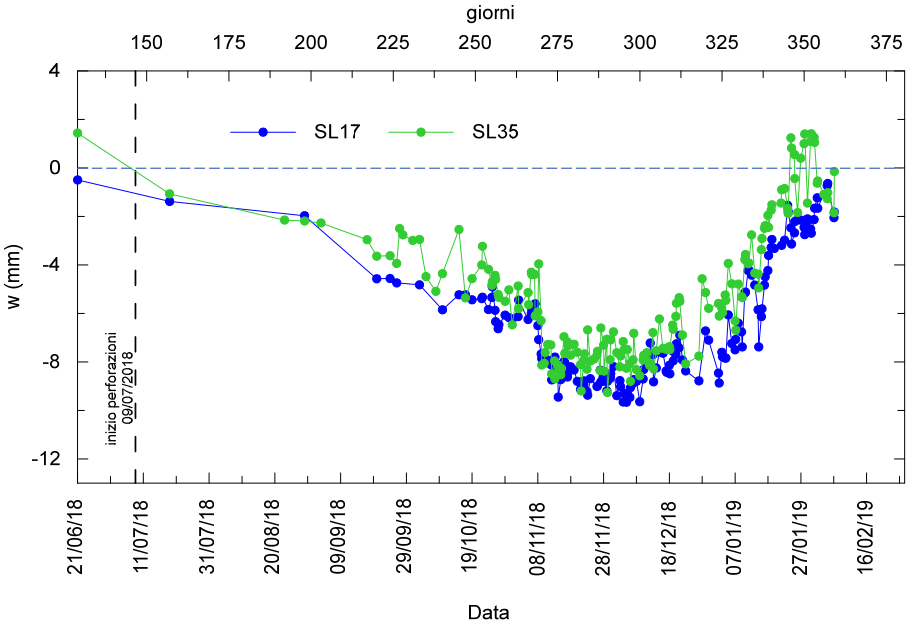


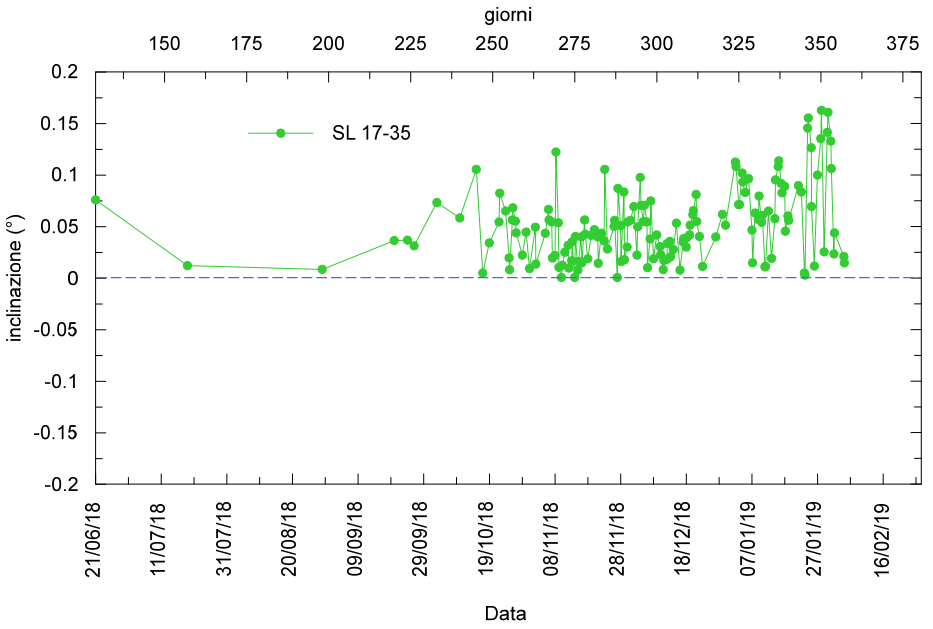




inclinazione fuori piano delle Mura

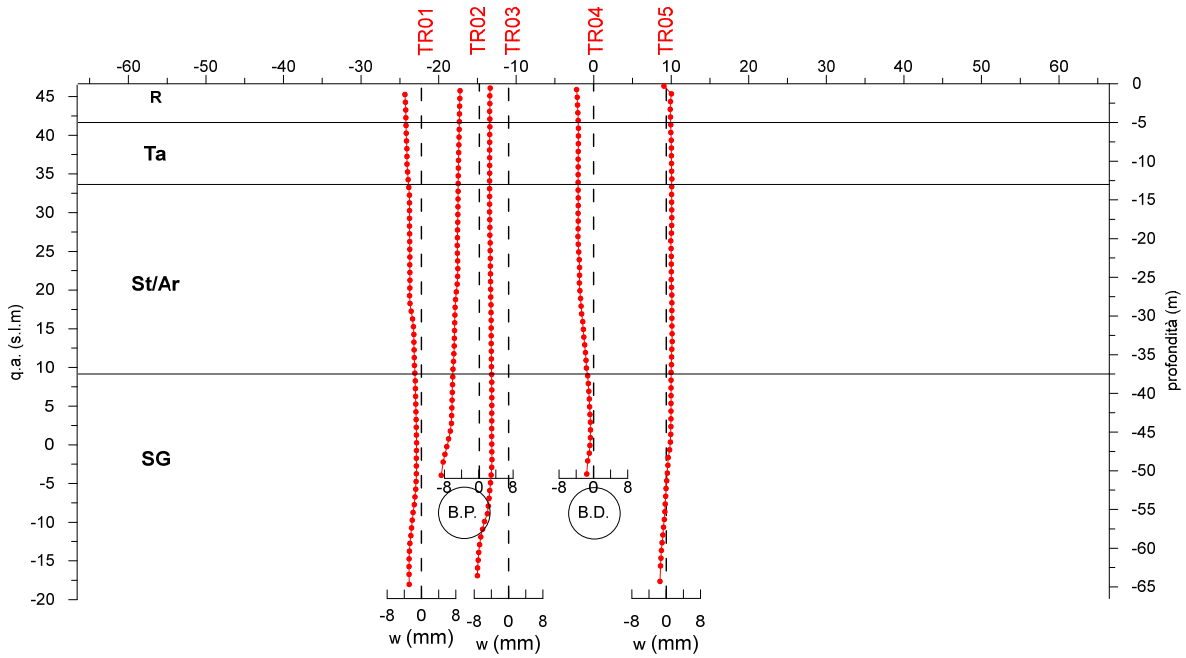




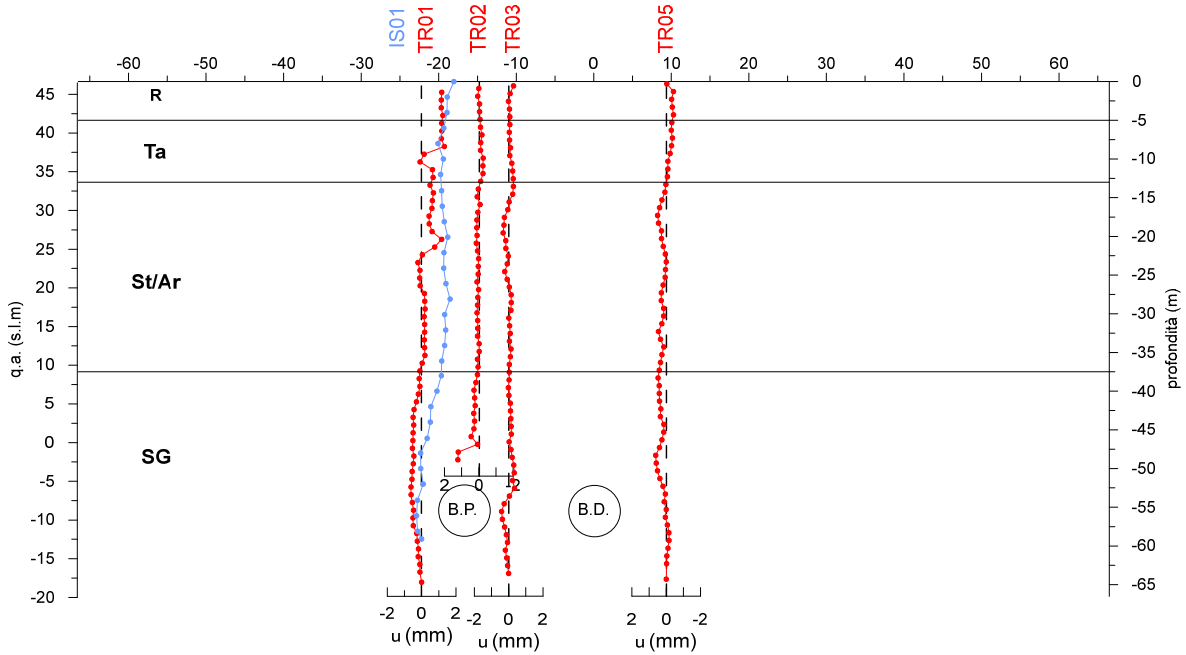


spare slides Santo Stefano Rotondo

sezione MOP16

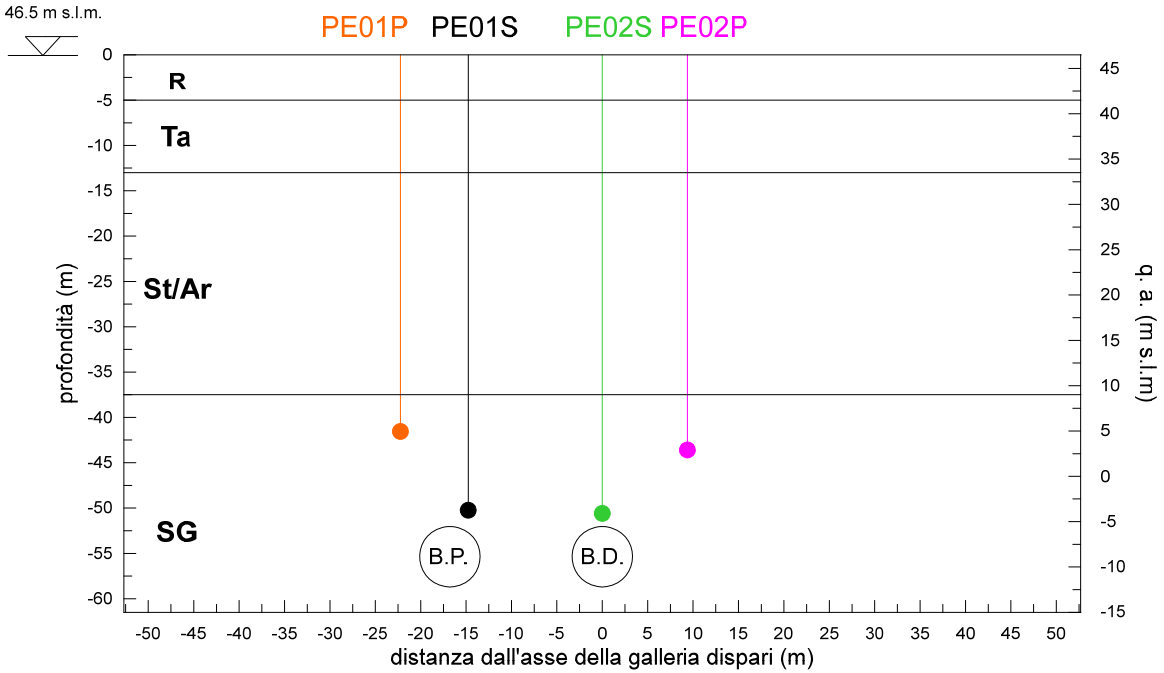


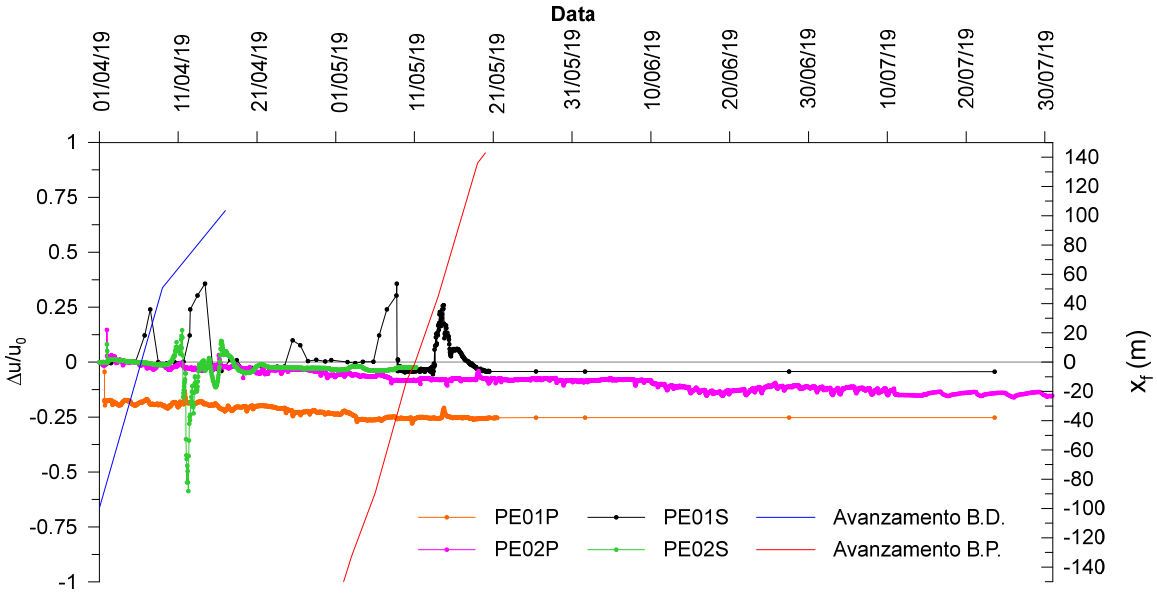
profili spostamenti verticali entrambe le gallerie



profili spostamenti orizzontali entrambe le gallerie

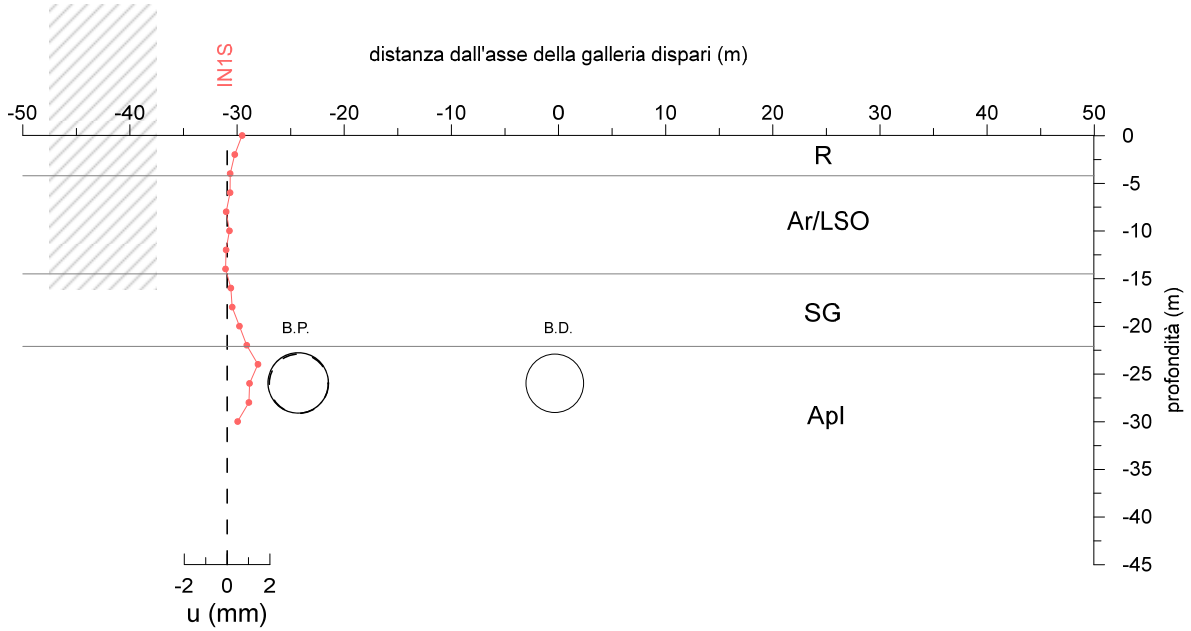
sezione MOP16





spare slides Colosseo

Colosseo – monitoraggio



spostamenti orizzontali
a gallerie passate

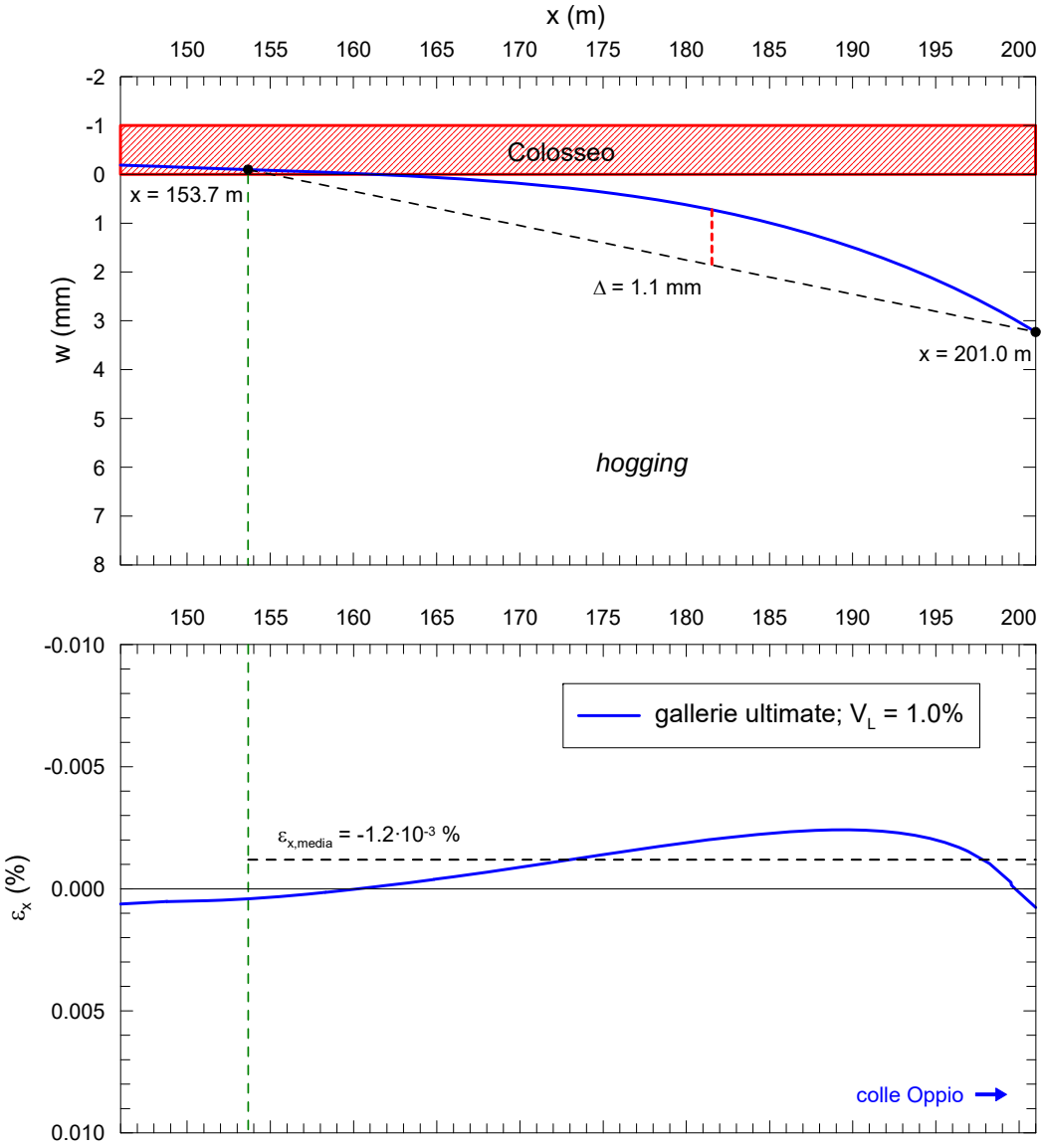
GALLERIA DISPARI

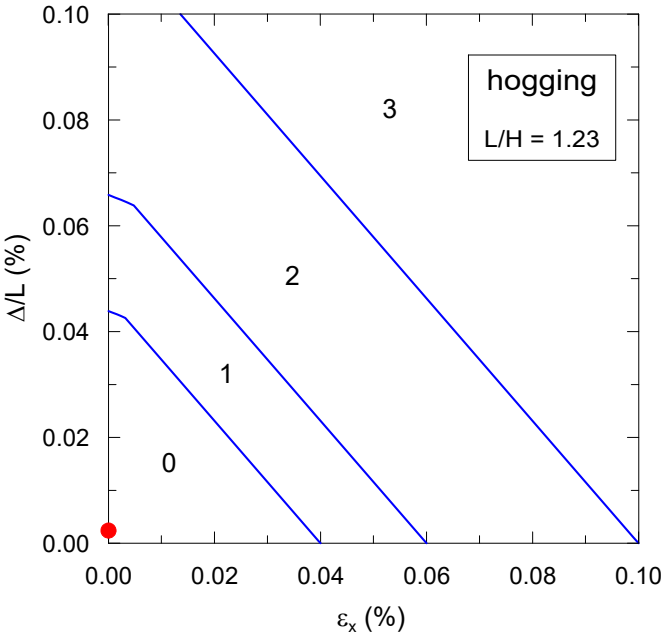
	MOQ9	MOQ10	MOQ11	MOQ12	MOQ13	MOQ14	MOQ15	MOQ16
V_L%	0.1	0.3	0.1	0	0.3	0.2	0.2	0.2
w_{max} (mm)	-2.01	-3.04	-1.61	-0.49	-2.22	1.62	-2.87	-4.67

GALLERIA DISPARI + PARI

	MOQ9	MOQ10	MOQ11	MOQ12	MOQ13	MOQ14	MOQ15	MOQ16
V_L%	0.04	0.2	0.2	0.1	0.2	0.1	0.1	0.1
w_{max} (mm)	-2.89	-3.16	-3.02	-2.83	-3.36	-2.0	-3.24	-5.17

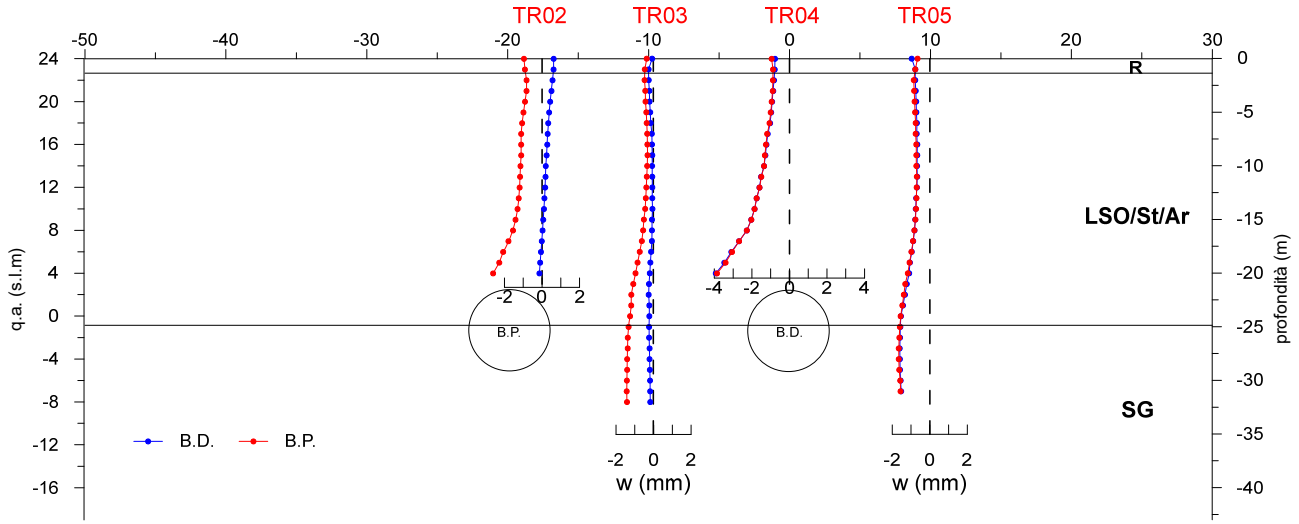
Colosseo – studi di interazione





spare slides Massenzio

Basilica di Massenzio – monitoraggio



sezione **MOR04**

- spostamenti verticali
- pressioni interstiziali

