

MADLab-ER – LEZIONI DAL SISMA 2012

The days of the earthquake. Lessons from the tragedy.
L'esperienza del terremoto dell'Emilia, dopo l'ora più buia

LEZIONE 4 - MODENA - Giovedì 9 Aprile 2026

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Donato Sabia | PoliT0)

Il monitoraggio statico e dinamico

Monitoraggio Statico di Ghirlandina e Duomo di Modena

Monitoraggio statico con tecniche e strumentazione geomatiche

- Livellazione geometrica di precisione

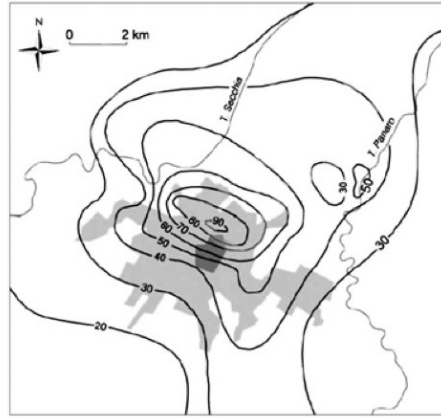
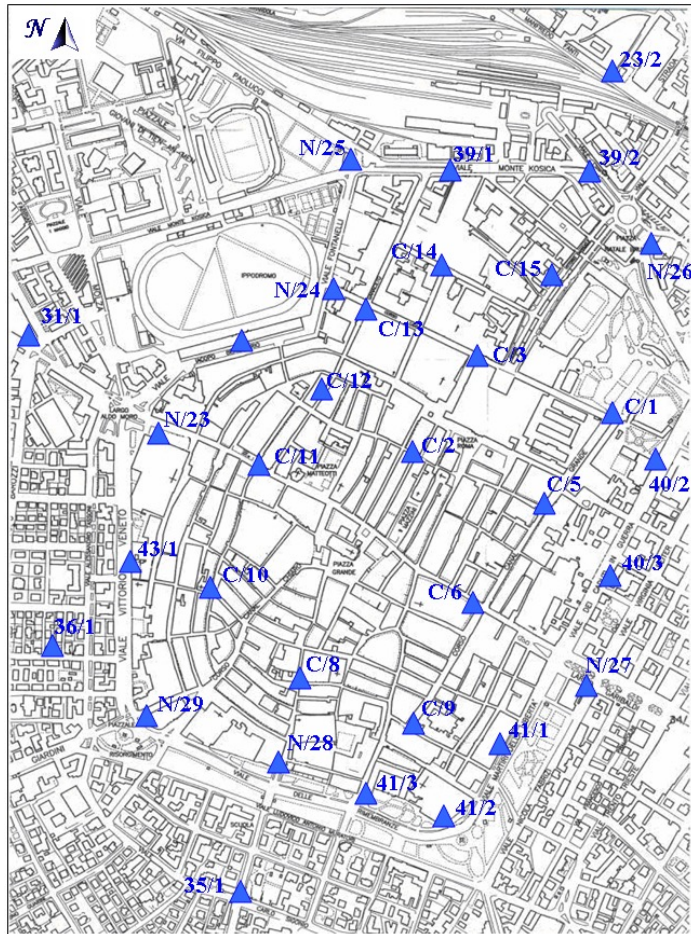
- Coordinatometro (Pendolo)

- Piezometri

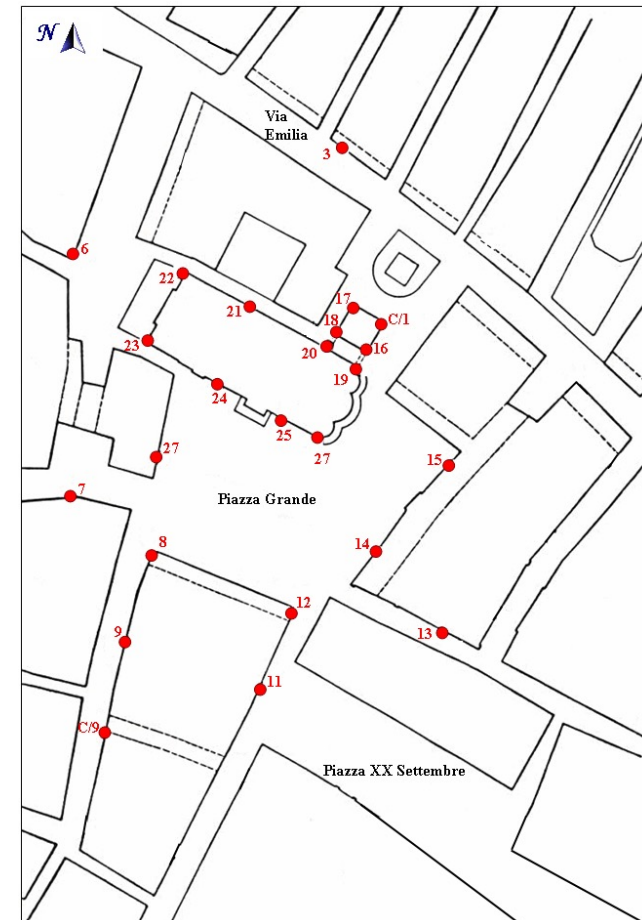
Diagnostica strutturale con laser scanner

Subsidenza in area Modena

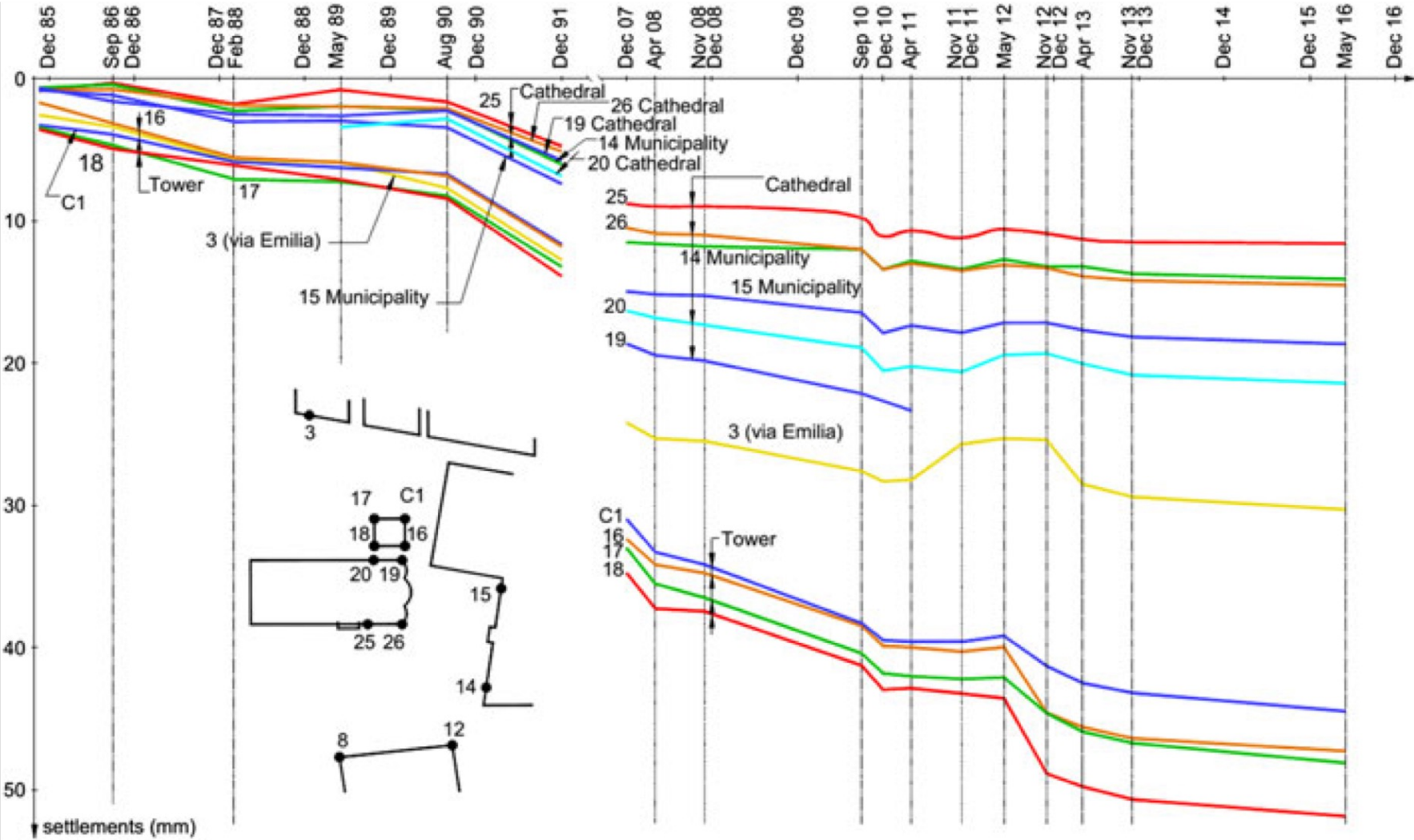
Rete altimetrica per il controllo della subsidenza del centro storico di Modena.



Rete altimetrica per il controllo della subsidenza del centro monumentale di Modena.



Andamento abbassamenti verticali



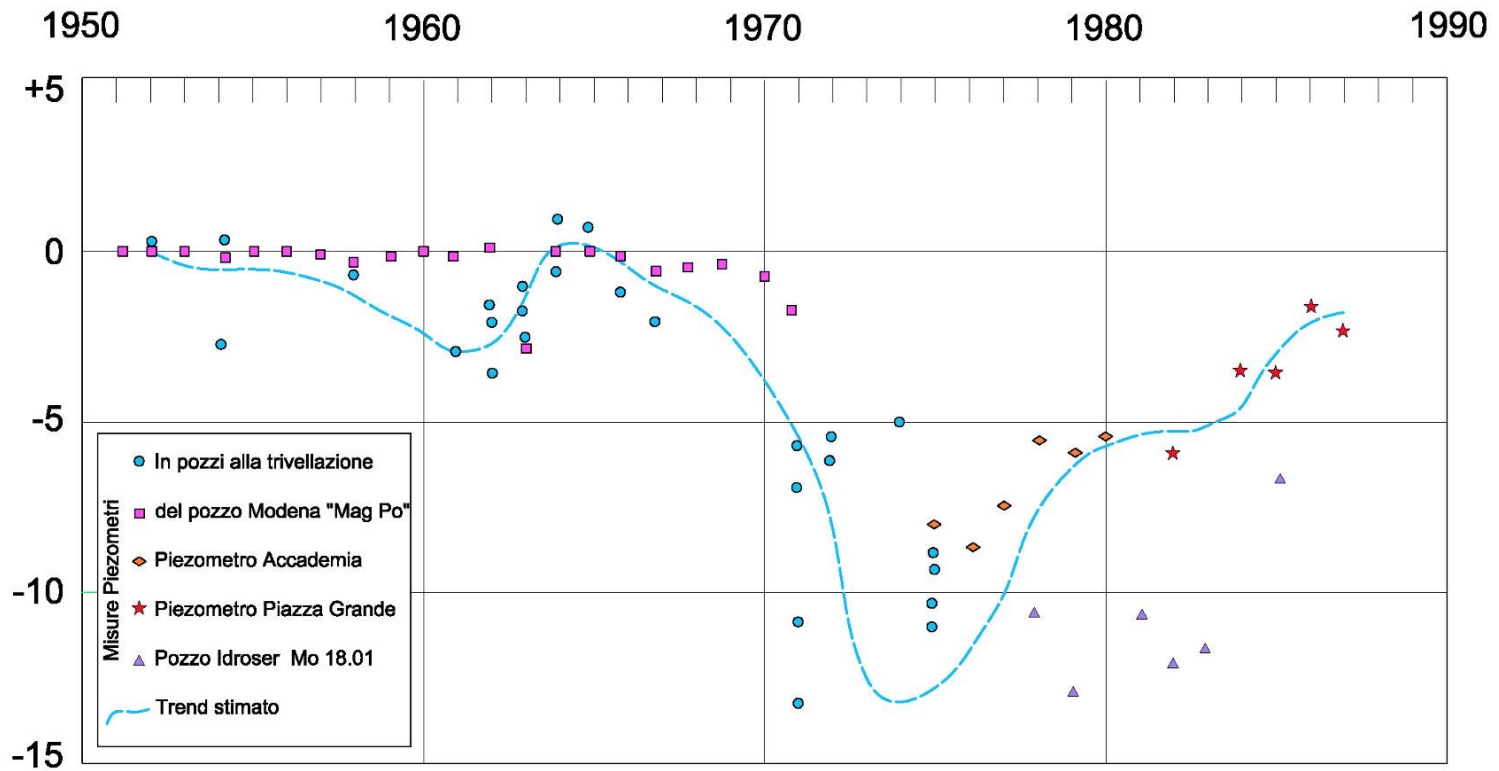
Andamento della depressione piezometrica misurata in pozzi situati nel Comune di Modena relativamente al 1951



Comune di Modena
Settore ambiente



Servizio Risorse e Territorio



Subsidenza effetti locali ed andamenti area



Which integration?

GNSS SURVEY

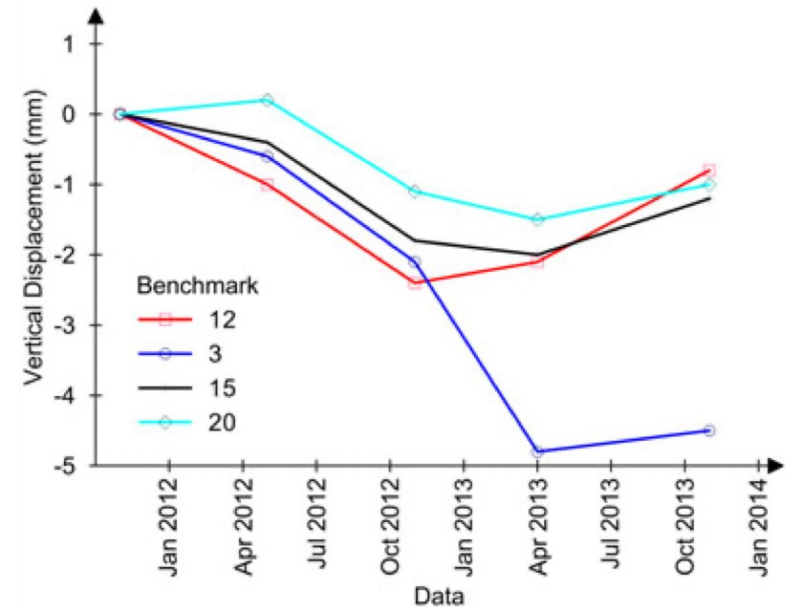
ID	029120	C/1	029140	
Ellipsoidal h [m]	73.0358	72.6792	72.9607	
N [m]	38.74715	38.74715	38.74715	
Geodetic H [m]	1999	34.3266	33.9798	34.2396
	2005	34.3084	33.9574	34.2298
	2011	34.2887	33.9321	34.2136
Displacement [cm]	1999-2005	-1.82	-2.24	-0.98
	2005-2011	-1.970	-2.539	-1.623

EFFECTS DUE TO SUBSIDENCE AND TO THE STRUCTURE ITSELF (MICROSUBS, SUBSTRATE, WEIGHT)

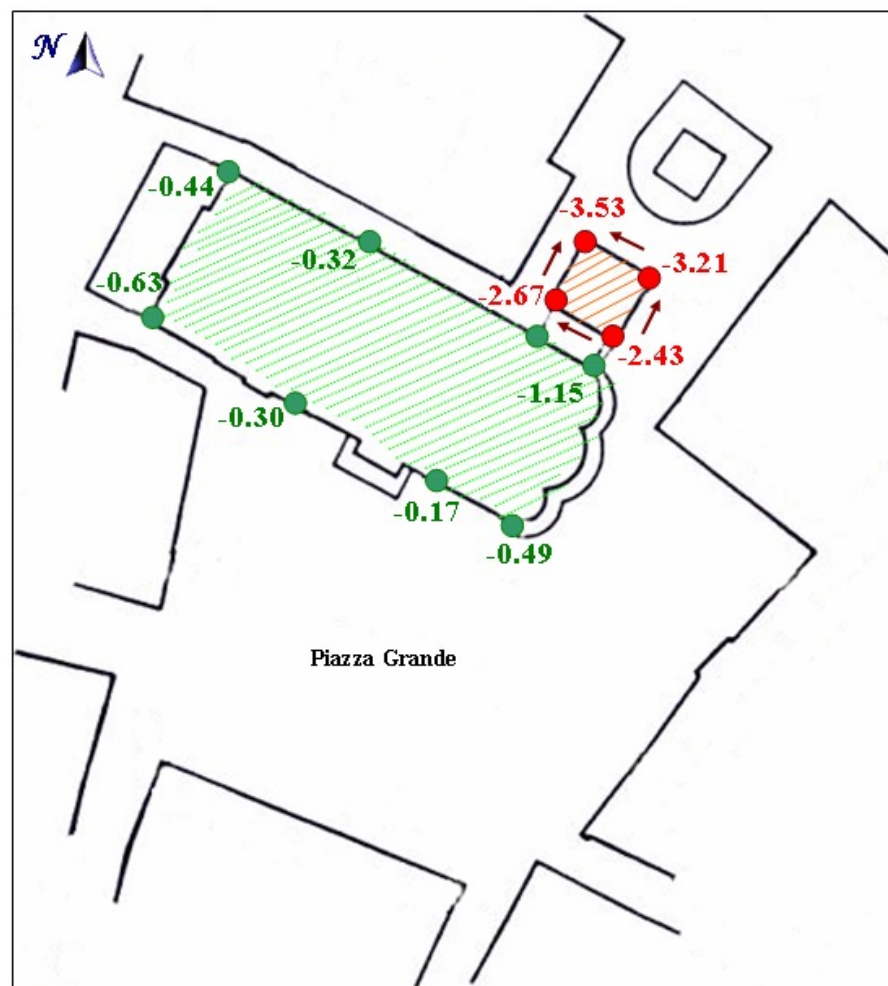
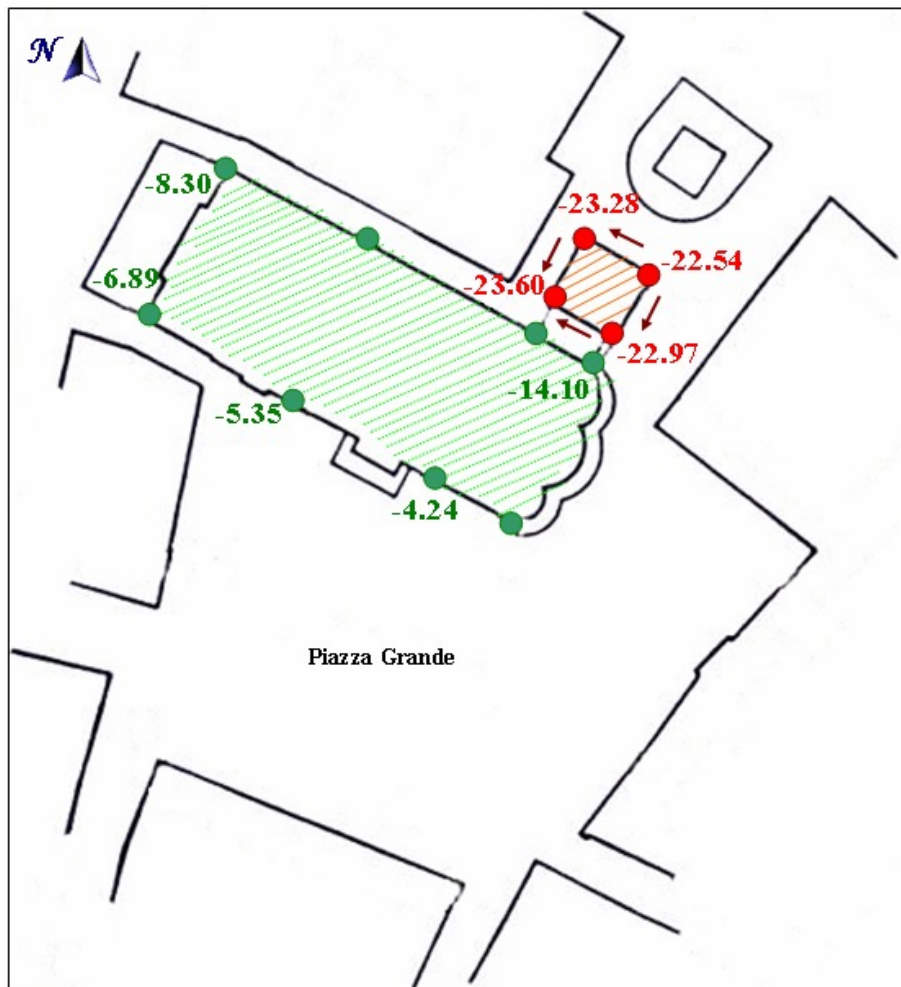
SUBSIDENCE ≈ 1.8 CM

EFFECTS DUE TO THE STRUCTURE ITSELF: 2.5 - 1.8 = 0.7 CM

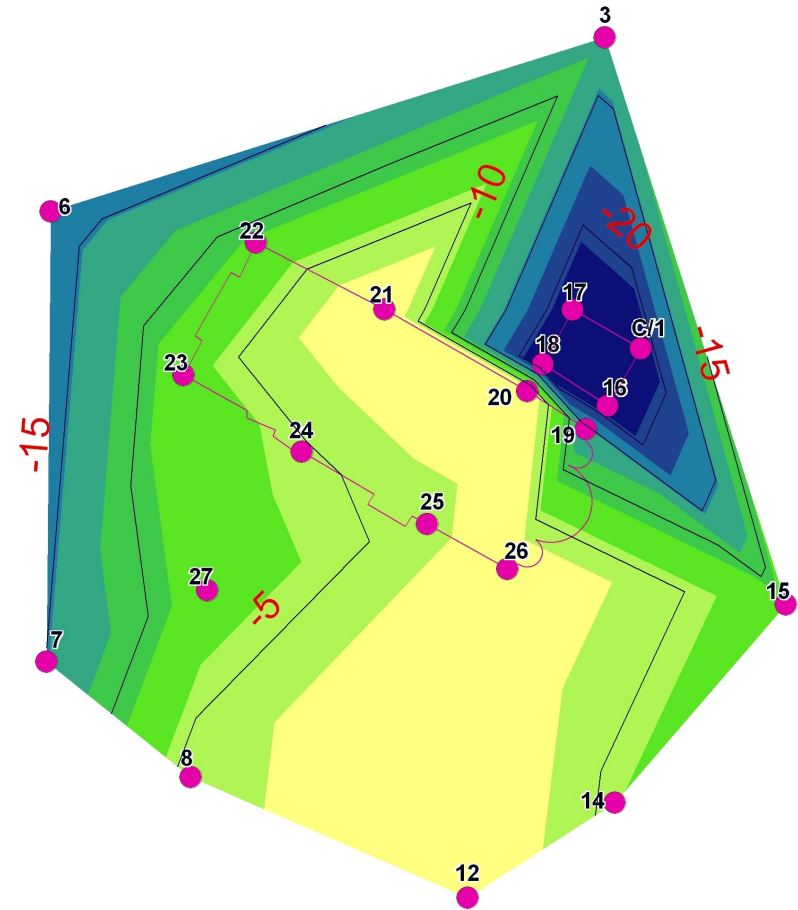
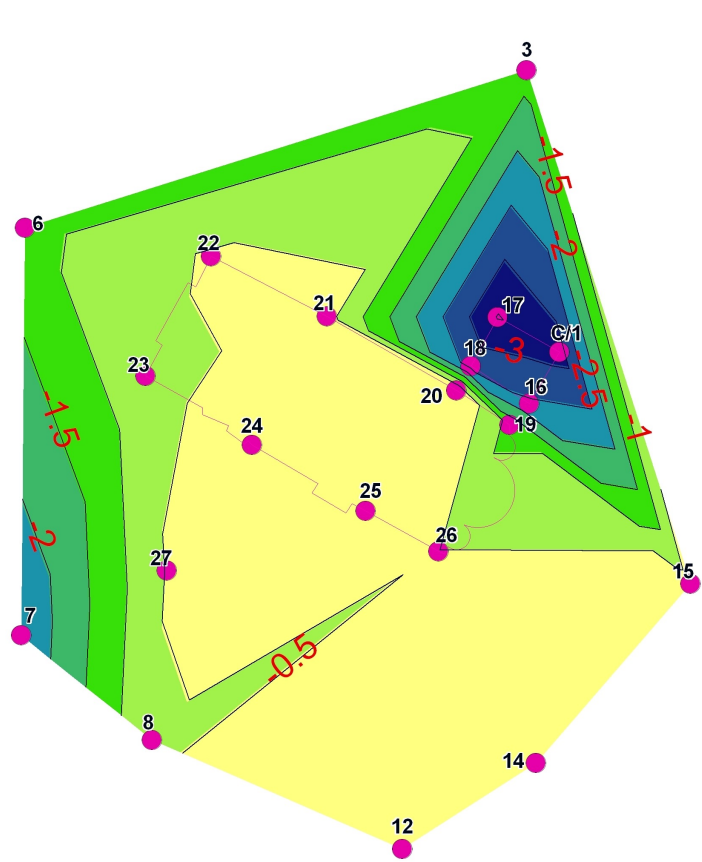
structures monitoring



i differenziali nel periodo Novembre/2008-Dicembre/1991 (sinistra) e Novembre/2008-Dicembre/2007 (de



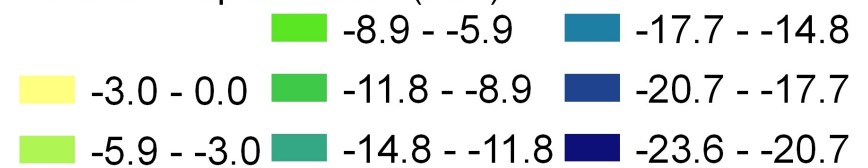
Curve di livello degli abbassamenti relativi rispettivamente al Novembre/2008-Dicembre 1991 (sinistra) e Novembre/2008-Dicembre/2007(destra). Valori in mm.



Vertical Displacement (mm)



Vertical Displacement (mm)



Il Pendolo

Pendolo dritto a filo per il controllo dell'inclinazione della Torre, dotato di telecoordinometro intermedio supplementare.



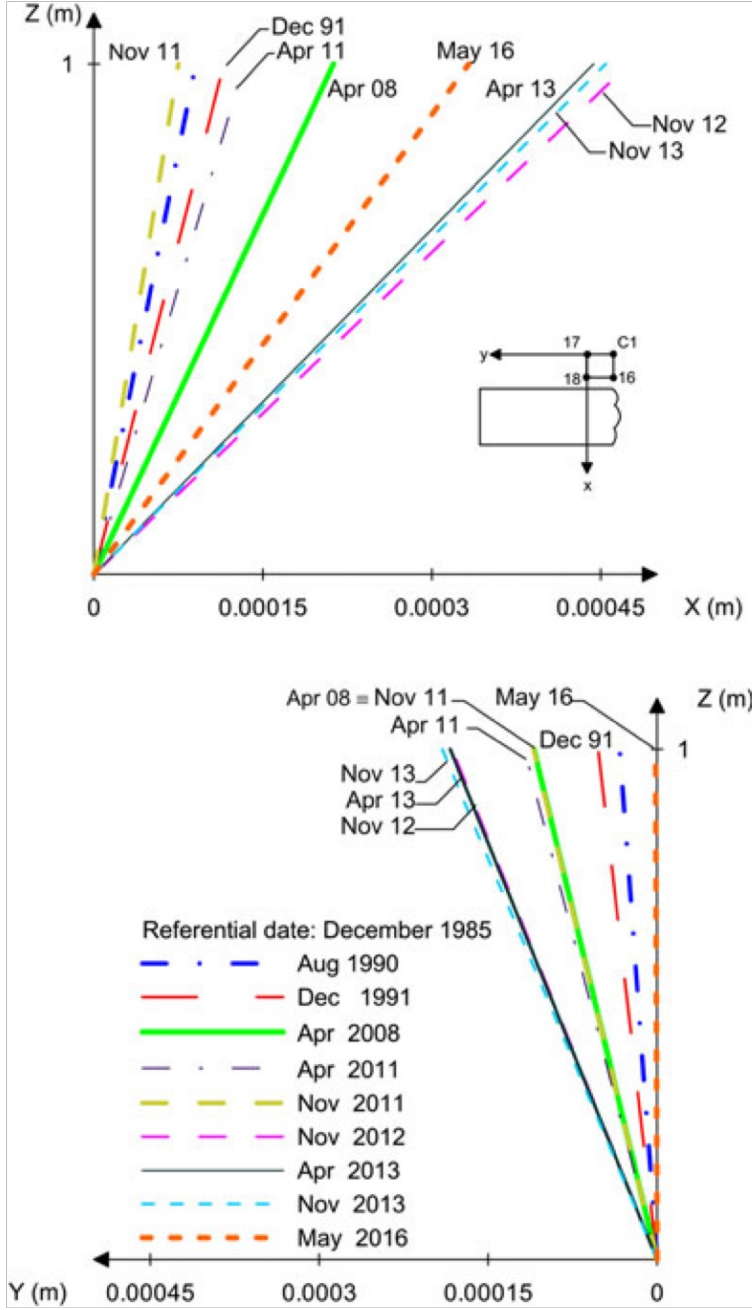
Analisi Pendolo



Due to: scaffold for restoration



Time evolution of the Tower tilt obtained by high-precision leveling over the period 1984–2016

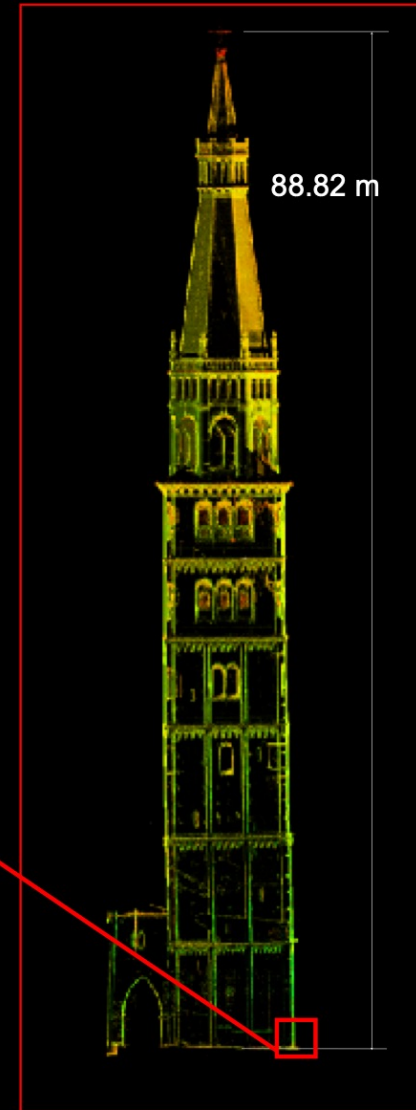
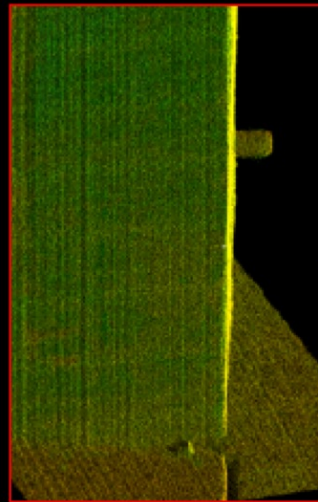


Laser Scanner for structure diagnostic

Torre Ghirlandina: esempi di analisi

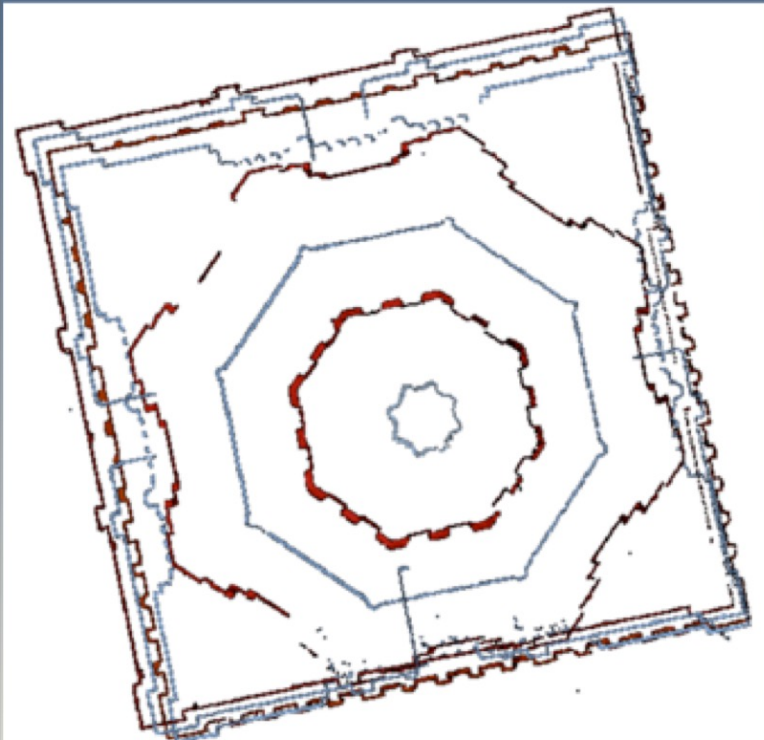
Determinazione dell'altezza della Torre della Ghirlandina attraverso rilievo laser scanner

Caposaldo di livellazione rilevato dal modello laser scanner che permette la determinazione della quota assoluta.



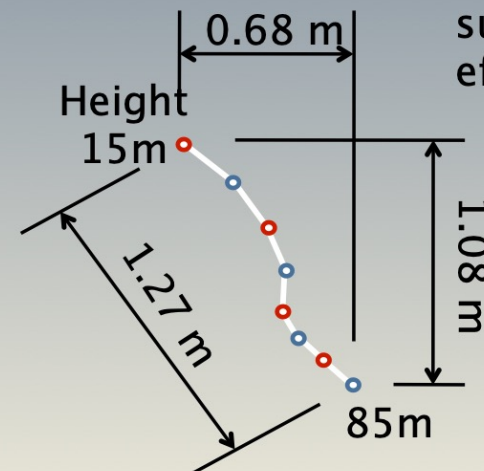
Variations of axis inclination Torre Ghirlandina

Horizontal sections



Horizontal projection of barycenters of section made every 10 m from 15 m height to the top

Axis inclination is due to intervention made during the construction (vertical correction) at about 40 m height and to subsidence effects.



The reconstruction resolution of the barycentric axis could be increased through the definition of an increasing number of horizontal slices.

Proiezione sul piano orizzontale
della posizione dei baricentri
delle sezioni:
da quota 15m alla sommità.



Quota: 15m

1.27 m

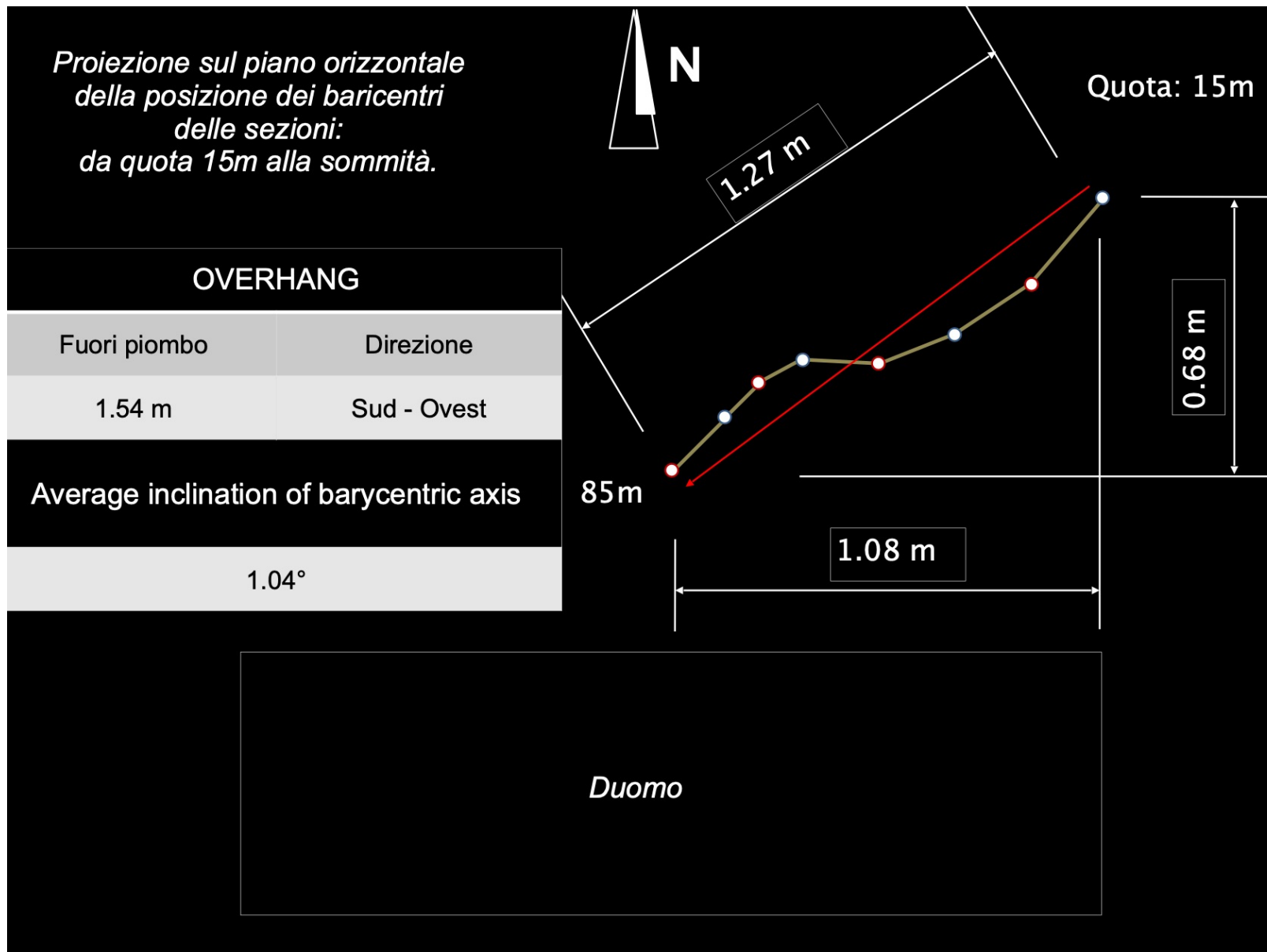
OVERHANG	
Fuori piombo	Direzione
1.54 m	Sud - Ovest
Average inclination of barycentric axis	
1.04°	

85m

1.08 m

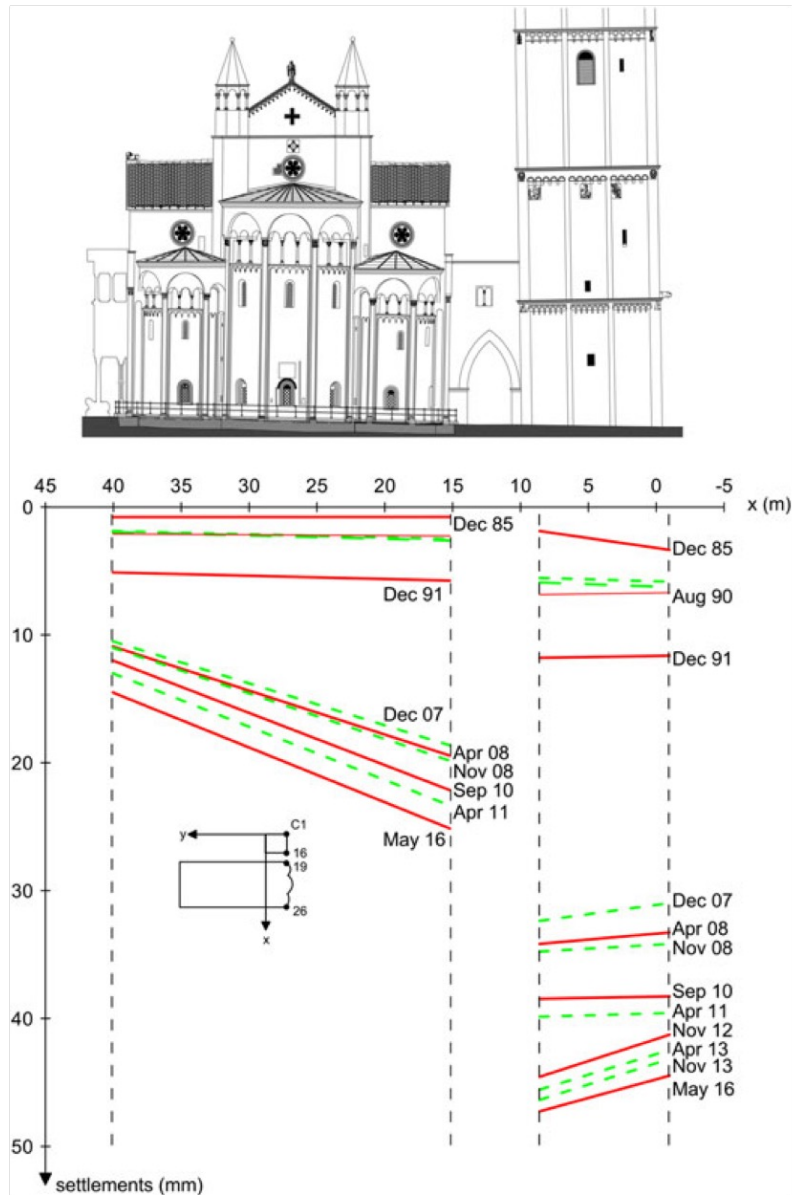
0.68 m

Duomo



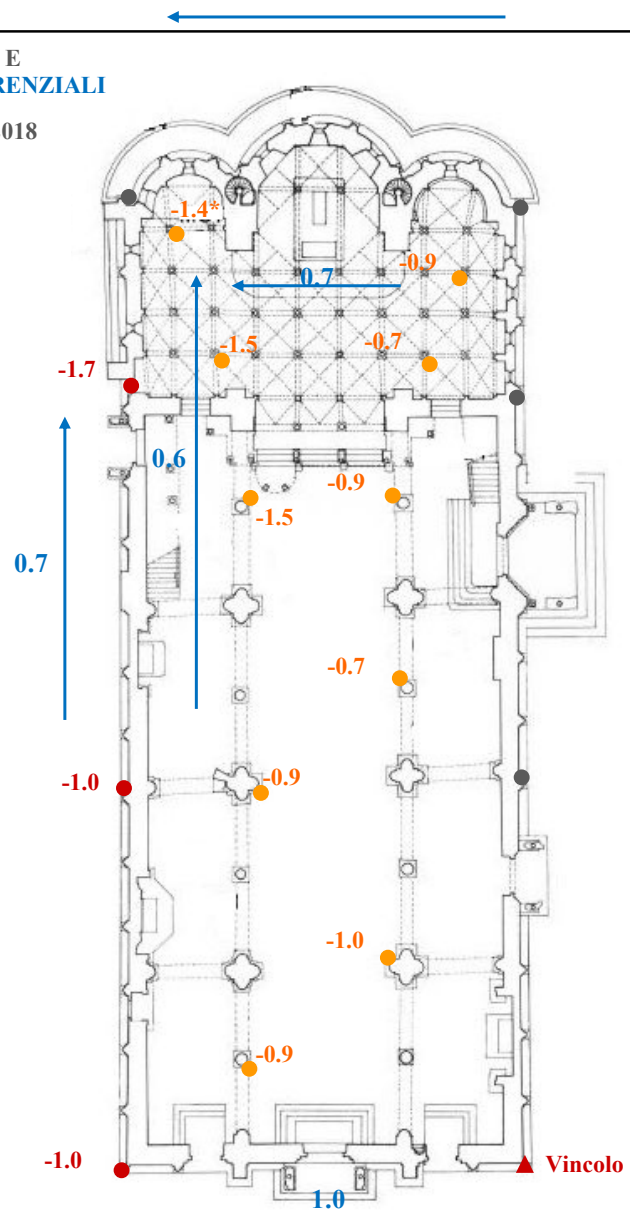
Duomo di Modena

Tendenza 1984-2016



**ABBASSAMENTI E
EFFETTI DIFFERENZIALI**

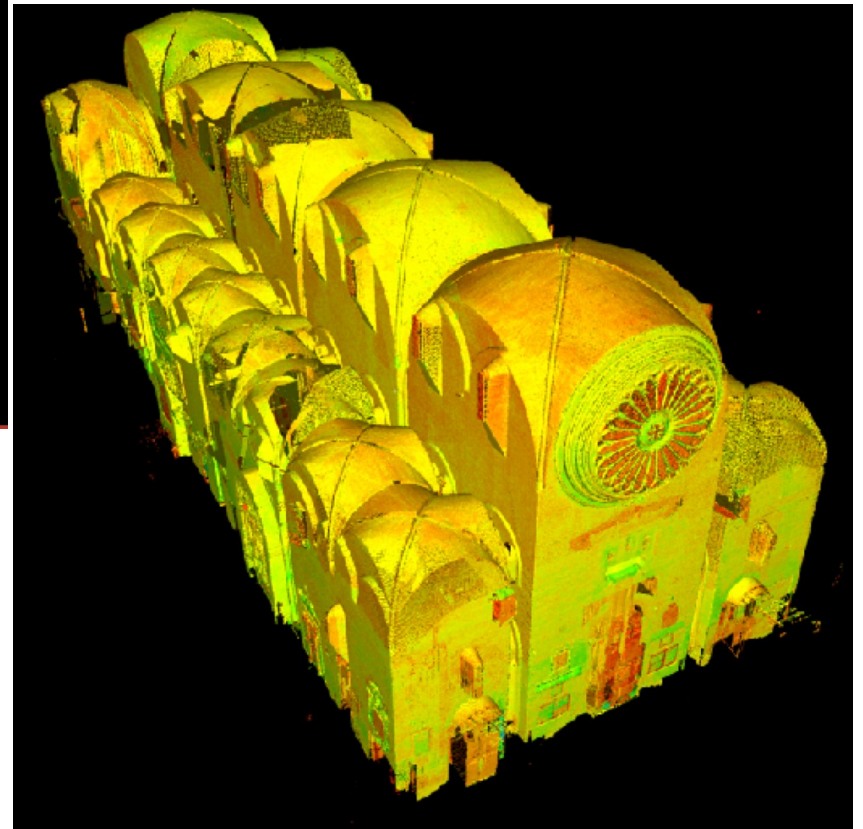
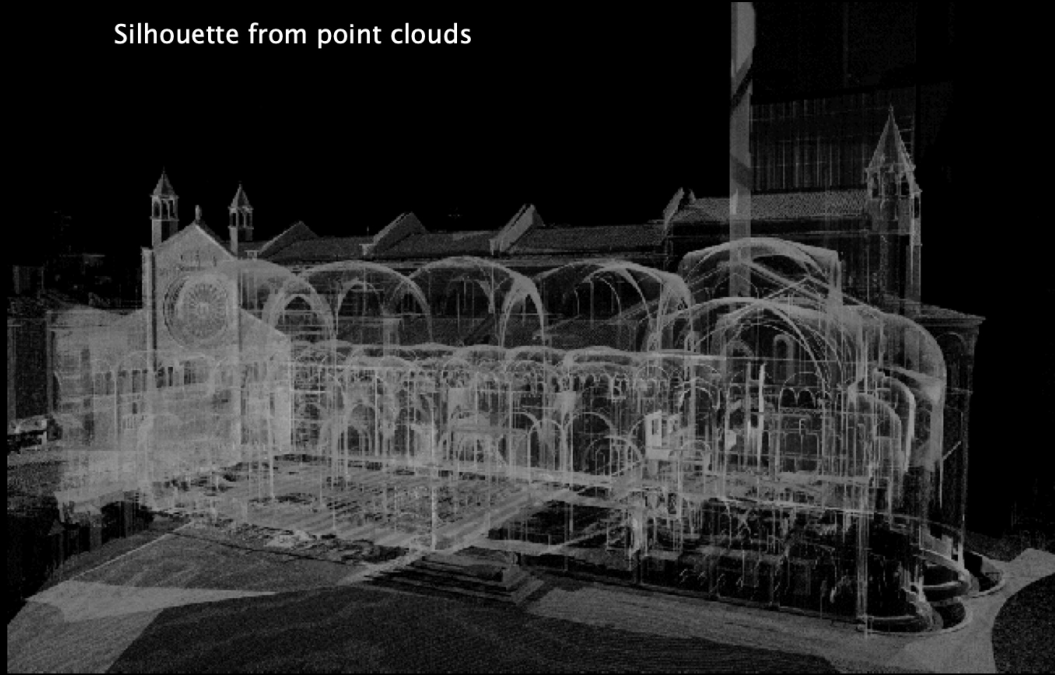
PERIODO: 2012-2018

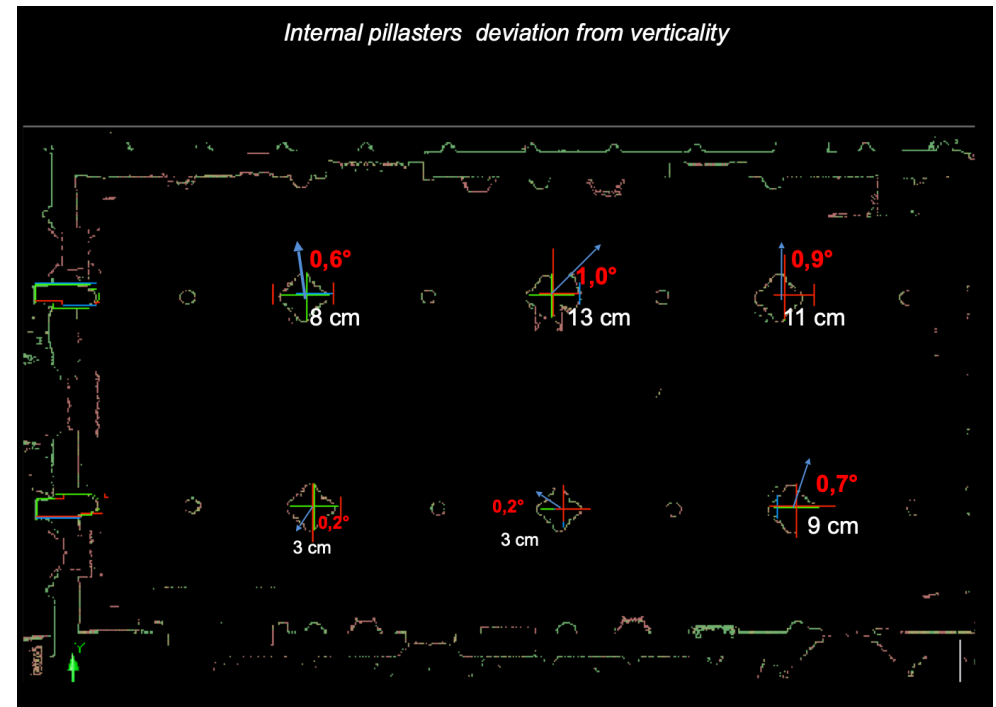
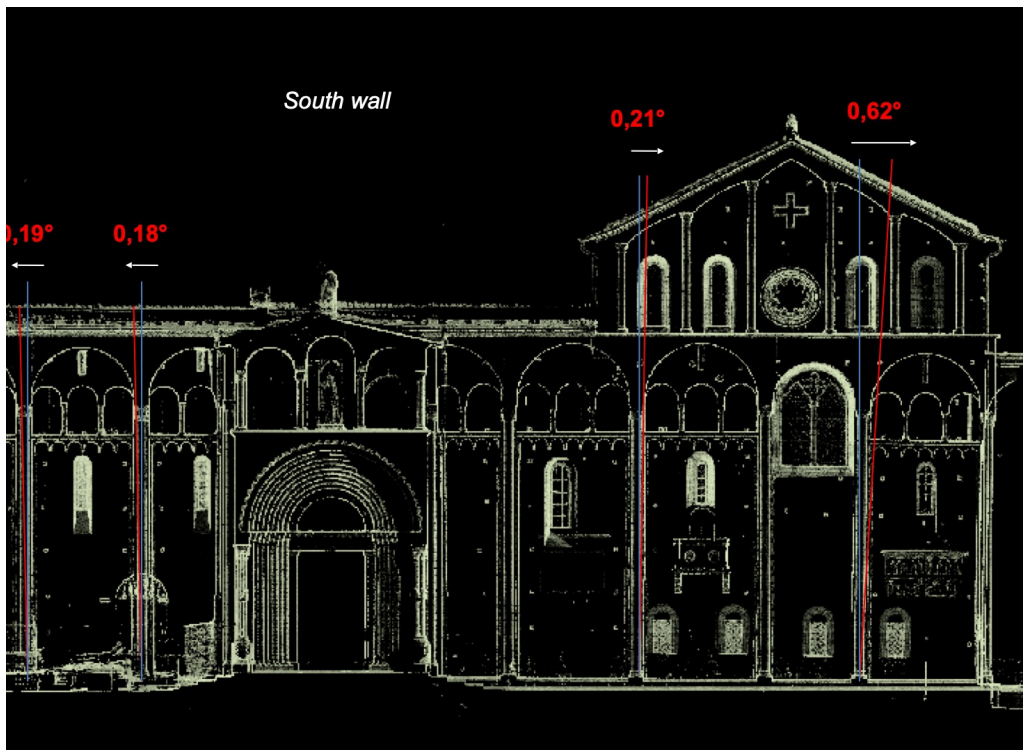


Laser Scanner for structure diagnostic

Modena Cathedral

Silhouette from point clouds





Grazie dell'attenzione

