



UNIONE EUROPEA
Fondo Europeo di Sviluppo Regionale



*Mitigazione dei rischi naturali per la sicurezza e la mobilità
nelle aree montane del Mezzogiorno*

Università degli studi della Basilicata

Modelli di gestione delle strutture ed infrastrutture viarie finalizzati alla mitigazione del rischio sismico OR3-OR6

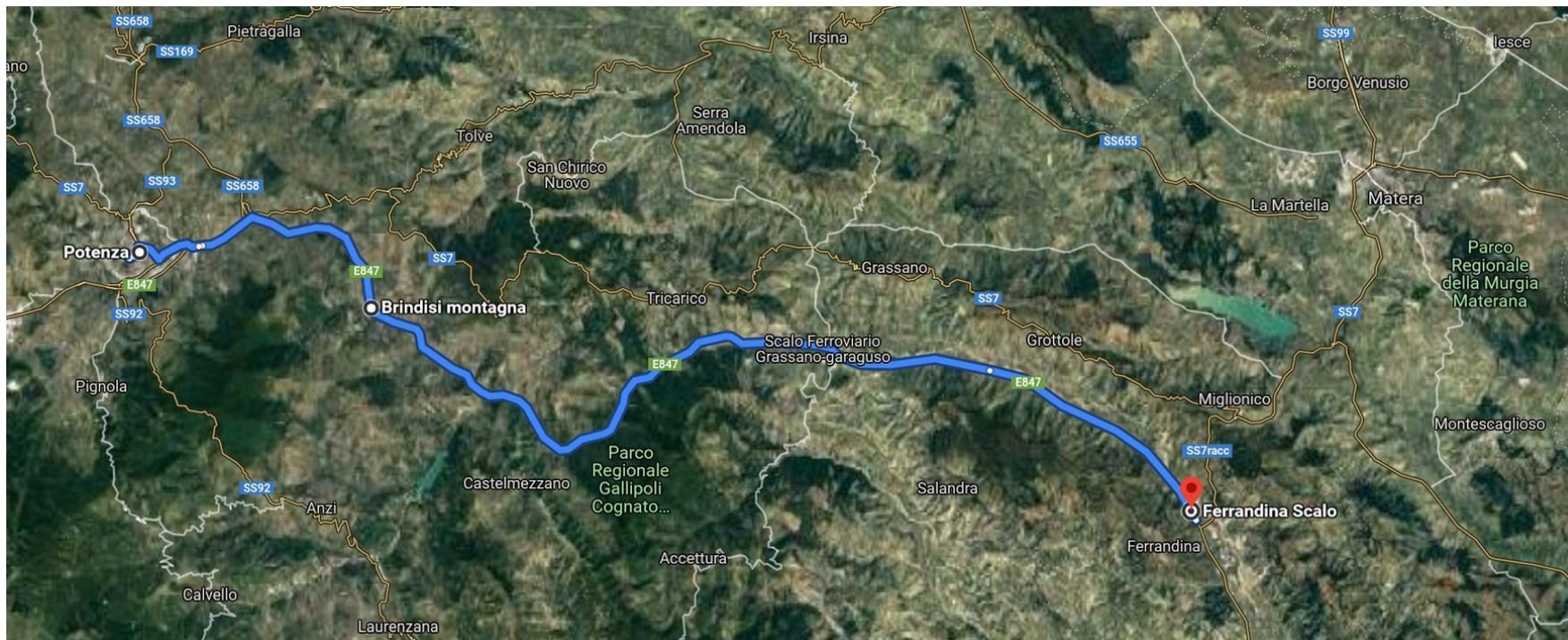
Marco VONA (OR3)

Donatello CARDONE (OR6)

Benedetto MANGANELLI

Paolo HARABAGLIA

27 Febbraio 2024



SS 407 “Basentana”

POTENZA - METAPONTO

	Viadotto	Coordinate GPS
1	Tiera di vaglio +	40°39'22.86"N, 15°52'28.81"E
2	Difesa II +	40°39'15.78"N, 15°53'17.49"E
3	Difesa I +	40°39'14.71"N, 15°53'23.83"E
4	Basento +	40°39'3.07"N, 15°53'46.01"E
5	PO_SS407_6072	40°39'6.41"N, 15°53'35.74"E
6	PO_SS407_6476	40°38'57.12"N, 15°55'51.25"E
7	PO_SS407_6957	40°38'53.10"N, 15°56'7.37"E
8	Grancia I +	40°37'49.51"N, 15°57'0.33"E
9	Grancia II +	40°37'25.38"N, 15°57'2.05"E
10	Brindisi I +	40°36'50.64"N, 15°57'10.60"E
11	Brindisi II +	40°36'41.48"N, 15°57'15.20"E
12	Giaconte +	40°36'38.74"N, 15°57'23.94"E
13	Gianni +	40°36'18.95"N, 15°58'22.38"E
14	Mecca +	40°36'17.53"N, 15°58'41.99"E
15	Coronati +	40°35'55.68"N, 15°59'3.68"E
16	Brutto +	40°35'40.01"N, 15°59'9.05"E
17	Pietra +	40°35'24.89"N, 15°59'42.60"E
18	Adamo +	40°34'57.17"N, 16° 0'31.79"E
19	Trivigno +	40°34'51.89"N, 16° 0'50.77"E
20	Sodo +	40°34'36.22"N, 16° 1'0.65"E
21	Albano +	40°34'28.46"N, 16° 1'14.07"E
22	Freddo +	40°34'19.37"N, 16° 1'32.64"E
23	Moliano +	40°34'17.38"N, 16° 2'9.17"E
24	Monticello +	40°34'14.69"N, 16° 2'23.47"E
25	Calcesi +	40°33'25.75"N, 16° 3'28.56"E
26	Arena +	40°33'15.35"N, 16° 3'36.95"E
27	Della vecchia +	40°33'3.92"N, 16° 3'46.50"E
28	Balzano +	40°32'41.95"N, 16° 4'28.04"E
29	Gallipoli +	40°32'52.37"N, 16° 4'59.67"E
30	Scannacapre +	40°33'1.30"N, 16° 5'25.10"E
31	Vallone +	40°33'6.12"N, 16° 5'49.39"E
32	Ruderi +	40°33'58.50"N, 16° 6'46.59"E
33	Mandria II +	40°34'2.33"N, 16° 6'49.09"E
34	Chiaromonte +	40°34'36.52"N, 16° 7'8.26"E
35	Fattore +	40°34'42.73"N, 16° 7'15.02"E
36	Valicante +	40°34'52.89"N, 16° 7'57.99"E
37	Cognato +	40°35'8.15"N, 16° 8'15.96"E
38	Turato +	40°35'10.73"N, 16° 8'23.64"E
39	Calciano I +	40°35'32.20"N, 16° 9'20.79"E
40	Tricarico I +	40°35'52.46"N, 16° 10'2.31"E
41	Tricarico II +	40°35'55.05"N, 16° 10'20.36"E
42	Tricarico III +	40°35'59.57"N, 16° 10'41.43"E
43	Calciano II +	40°35'58.53"N, 16° 10'56.26"E
44	Calciano III +	40°35'48.26"N, 16° 13'1.61"E
45	Garuguso +	40°35'39.66"N, 16° 14'38.39"E
46	Auletta +	40°35'34.67"N, 16° 14'48.99"E
47	Vallone Scamarce	40°35'9.21"N, 16° 16'48.57"E
48	Salandra	40°34'57.99"N, 16° 21'2.36"E
49	Concone	40°31'40.55"N, 16° 27'49.20"E

PONTI E VIADOTTI DELLA RETE VIARIA

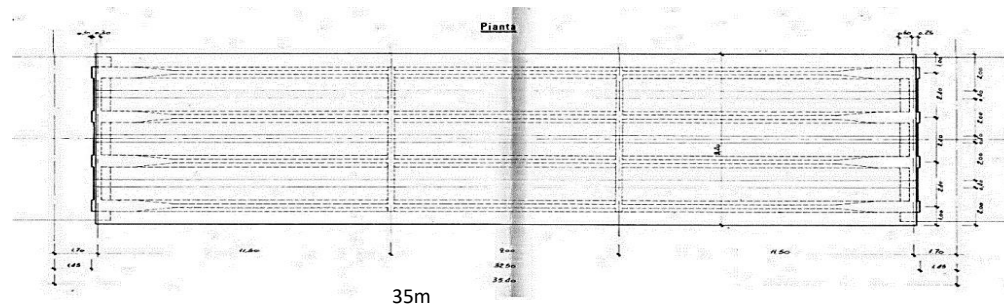
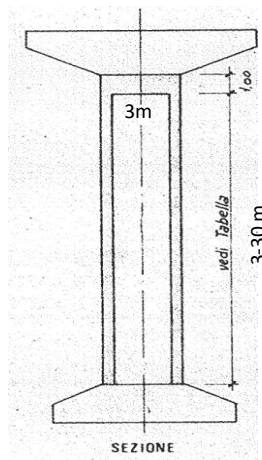
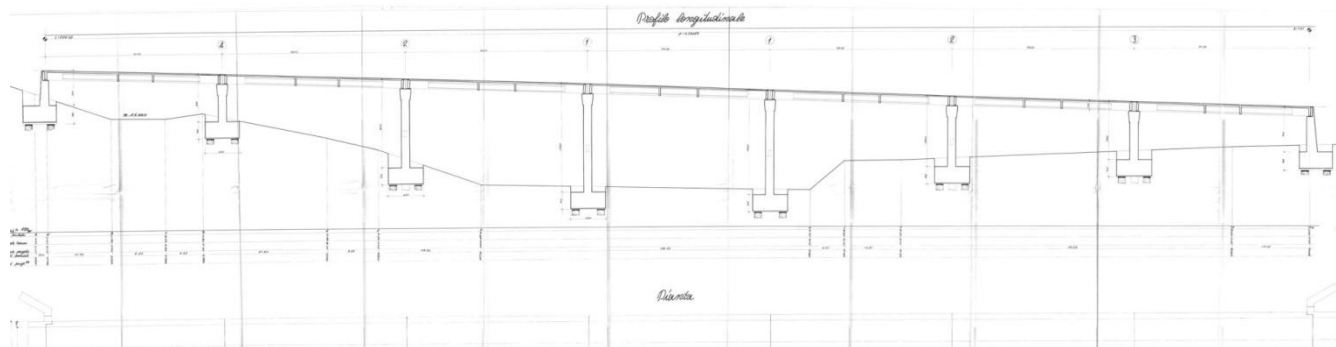


METAPONTO-POTENZA

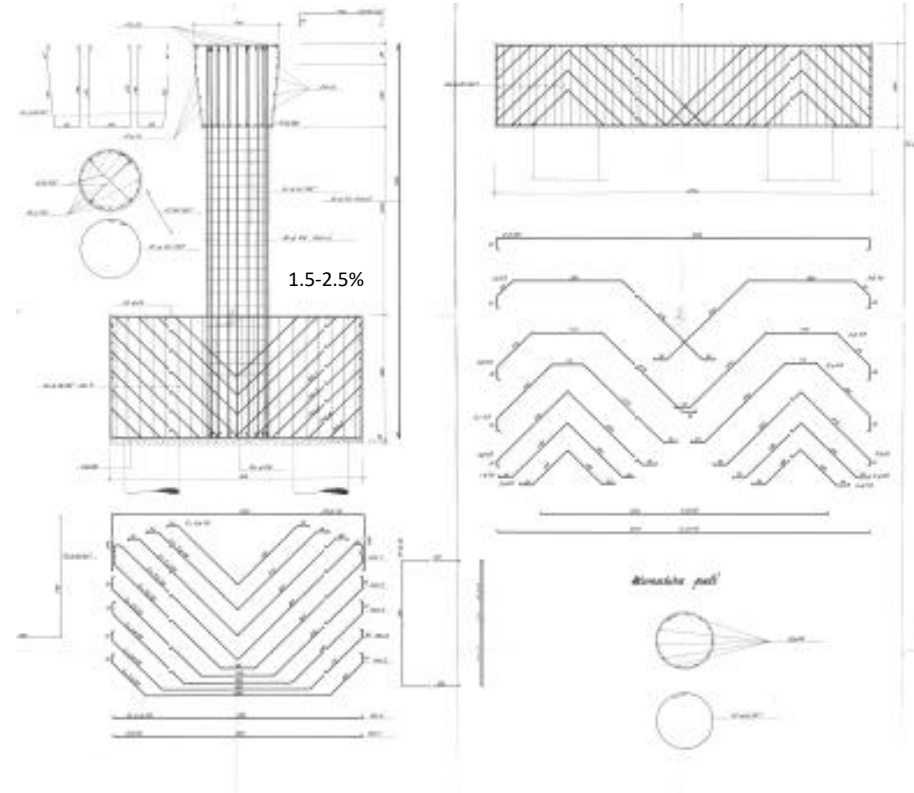
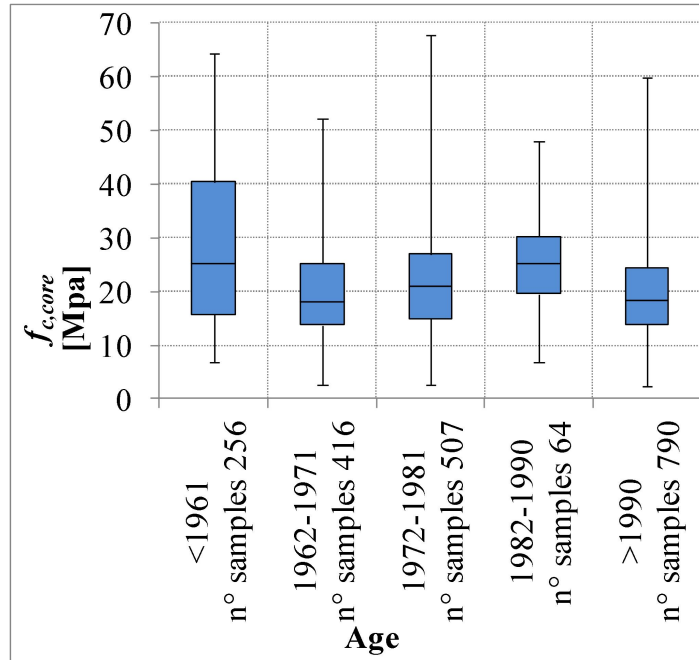
	Viadotto	Coordinate GPS
50	PO_SS407<_6476	40°38'57.12"N, 15°55'51.25"E
51	PO_SS407<_6957	40°38'52.78"N, 15°56'8.97"E
52	Grancia I --	40°37'47.72"N, 15°57'0.49"E
53	Grancia II --	40°37'25.14"N, 15°57'2.63"E
54	Brindisi I -	40°36'49.74"N, 15°57'11.02"E
55	Brindisi II --	40°36'41.01"N, 15°57'17.15"E
56	Giaconte --	40°36'32.24"N, 15°57'47.23"E
57	Gianni --	40°36'20.29"N, 15°58'32.02"E
58	Mecca --	40°36'16.20"N, 15°58'46.97"E
59	Coronati --	40°35'45.94"N, 15°59'4.74"E
60	Brutto --	40°35'39.84"N, 15°59'10.69"E
61	Pietra --	40°35'20.94"N, 15°59'51.36"E
62	Adamo --	40°34'56.79"N, 16° 0'35.76"E
63	Trivigno --	40°34'50.13"N, 16° 0'54.22"E
64	Ferrovia --	40°34'40.82"N, 16° 0'59.05"E
65	Sodo --	40°34'31.60"N, 16° 1'8.60"E
66	Albano --	40°34'28.55"N, 16° 1'14.10"E
67	Freddo --	40°34'16.82"N, 16° 1'42.45"E
68	Moliano --	40°34'16.31"N, 16° 2'20.24"E
69	Monticello --	40°34'11.09"N, 16° 2'39.26"E
70	Costa --	40°33'39.48"N, 16° 3'18.00"E
71	Calcesi --	40°33'22.28"N, 16° 3'31.83"E
72	Della vecchia --	40°32'58.36"N, 16° 3'54.88"E
73	Balzano --	40°32'46.26"N, 16° 4'46.56"E
74	Gallipoli --	40°33'3.51"N, 16° 5'34.88"E
75	Vallone --	40°33'10.00"N, 16° 5'56.94"E
76	Cipressi --	40°33'11.77"N, 16° 6'6.55"E
77	Carvotto II --	40°33'14.45"N, 16° 6'13.13"E
78	Carvotto I --	40°33'17.79"N, 16° 6'16.71"E
79	Ruderi --	40°34'1.08"N, 16° 6'47.59"E
80	Mandria II --	40°34'17.94"N, 16° 6'50.22"E
81	Mandria I --	40°34'34.81"N, 16° 7'6.42"E
82	Chiaromonte --	40°34'41.13"N, 16° 7'11.66"E
83	Fattore --	40°34'43.94"N, 16° 7'16.84"E
84	Valicante --	40°35'6.20"N, 16° 8'10.40"E
85	Cognato --	40°35'9.83"N, 16° 8'19.92"E
86	Turato --	40°35'22.69"N, 16° 8'50.25"E
87	Calciano I --	40°35'48.16"N, 16° 9'39.44"E
88	Tricarico I --	40°35'53.32"N, 16° 10'6.26"E
89	Calciano II --	40°35'50.21"N, 16° 11'10.78"E

Caratteristiche geometriche

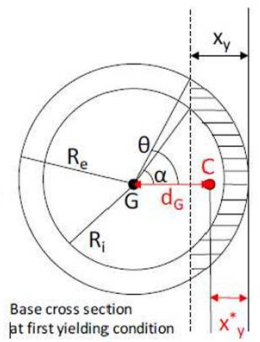
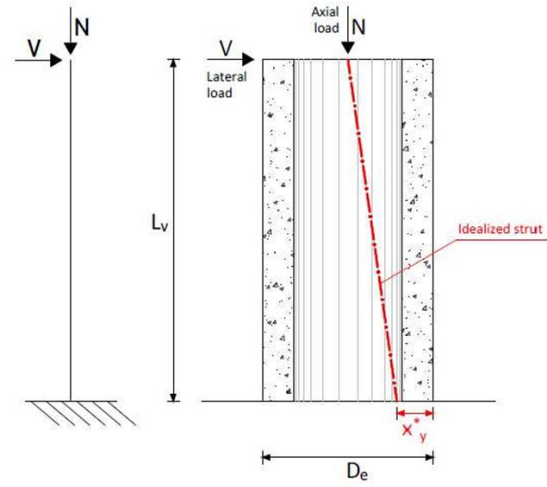
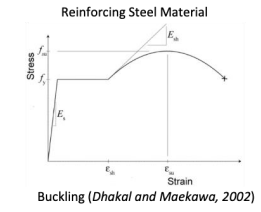
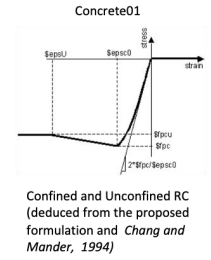
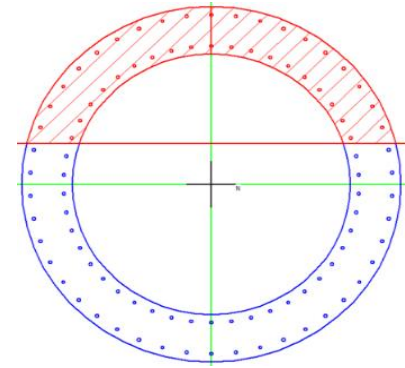
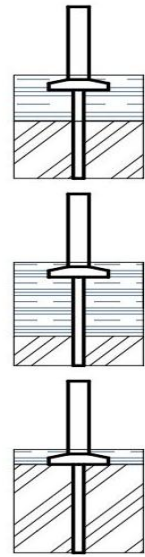
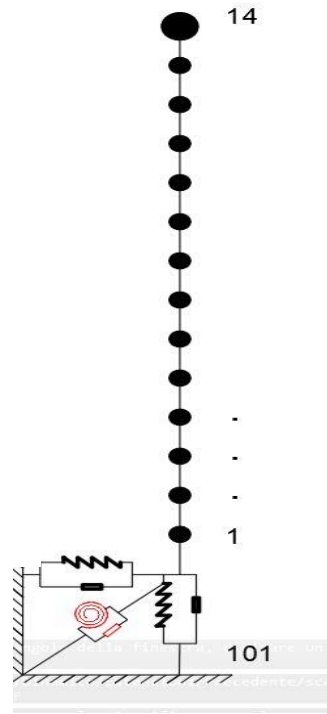
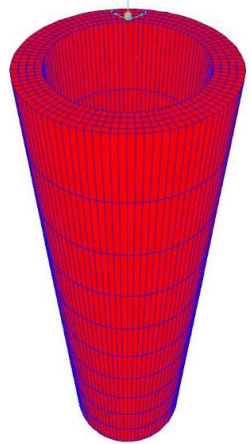
Viadotto	H media	H min	Hmax
Chiaromonte	21,1	19,2	23,0
Cognato	14,8	10,7	18,9
Valicante	21,9	2,8	28,7
Turato	14,8	2,0	23,9
Scannacapre	4,8	1,0	9,2
Trivigno	5,6	4,9	6,3
Arena	7,9	7,7	8,1
Calcesi	6,0	5,6	6,5
Della vecchia	6,1	4,2	8,7
Freddo	9,9	5,7	11,9
Monticello	7,7	2,1	11,0
Sodo	7,1	5,1	11,0
Balzano	13,5	8,7	15,0
Gallipoli	12,4	11,6	13,4
Mandria II	11,8	6,3	17,2
Vallone	5,8	4,6	6,9



Caratteristiche strutturali



Modelli numerici (Single pier model approach)

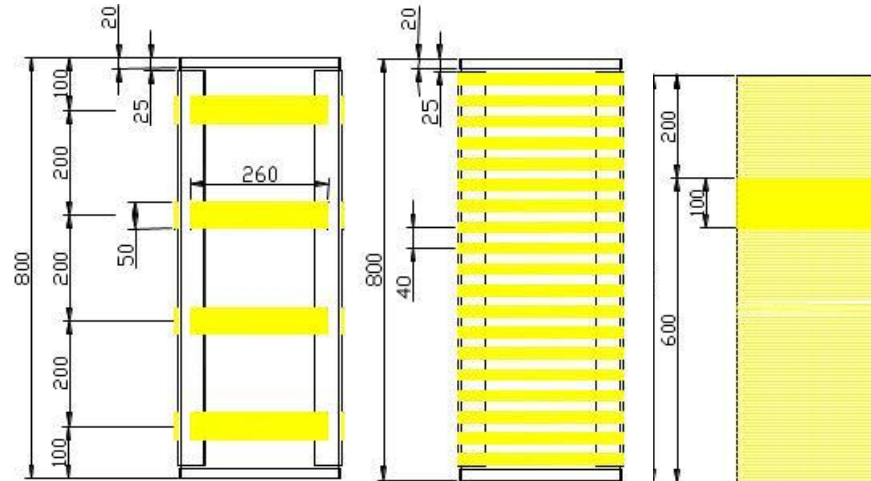


Esito verifiche:

- *Adeguate resistenza flessionale*
- *Scarsa resistenza a taglio (pile basse)*
- *Scarsa duttilità (pile alte)*



INCAMICIATURA IN ACCIAIO
INCAMICIATURA CON C.A.M.
INCAMICIATURA FRP
INCAMICIATURA IN C.A.



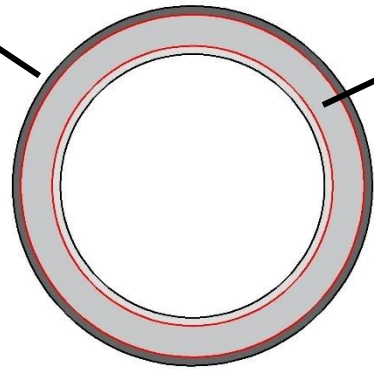
Ricostruzione volumetrica con UHPFRC

Legame costitutivo UHPFRC

Legame costitutivo cls confinato:

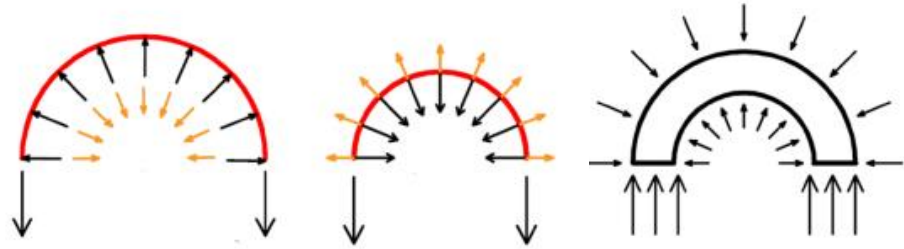
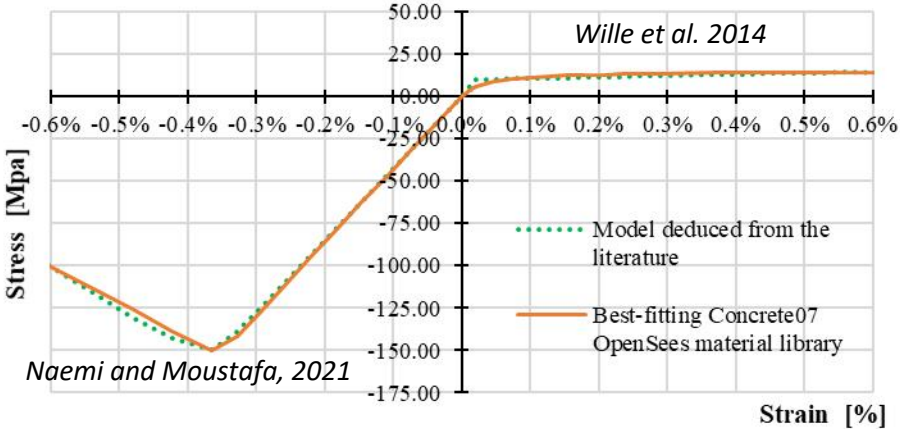
$$f'_{co, v_f=0} \approx 140 \text{ Mpa}$$

$$v_f = 2\%$$



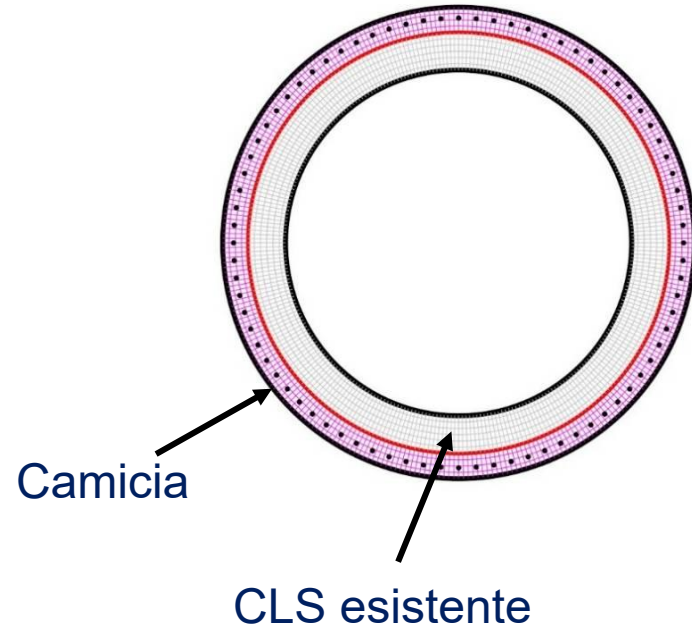
$$f_{lr} = 2 \cdot \left[\frac{\alpha_{h,o} \cdot f_{yh,o} \cdot A_{sh,o} \cdot \frac{s_{h,o}}{s_{h,i}} \cdot \alpha_{h,i} \cdot f_{yh,i} \cdot A_{sh,i} + \frac{s_{h,o}}{s_i} \cdot \alpha_t \cdot f_{yt} \cdot A_{st} \cdot \sum \sin\theta + \alpha_{cc} \cdot \sigma_{cc} \cdot s_{h,o} \cdot \frac{(D_e - d_{h,o})}{2}}{s_{h,o} \cdot (d_{h,o} + d_{h,i})} \right]$$

$$f_{lc} = 2 \cdot \left[\frac{\alpha_{h,o} \cdot f_{yh,o} \cdot A_{sh,o} + \frac{s_{h,o}}{s_{h,i}} \cdot \alpha_{h,i} \cdot f_{yh,i} \cdot A_{sh,i} + \alpha_{cc} \cdot \sigma_{cc} \cdot s_{h,o} \cdot \frac{(D_e - d_{h,o})}{2}}{s_{h,o} \cdot (d_{h,o} - d_{h,i})} \right]$$

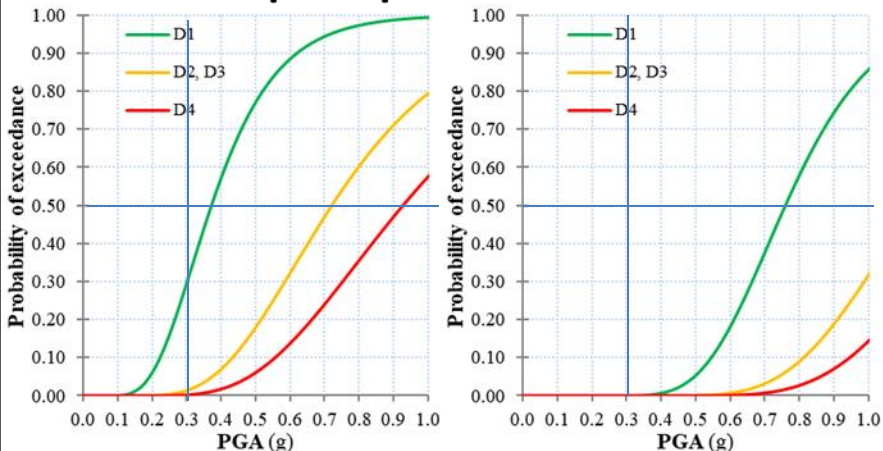


Incamiciatura in c.a.

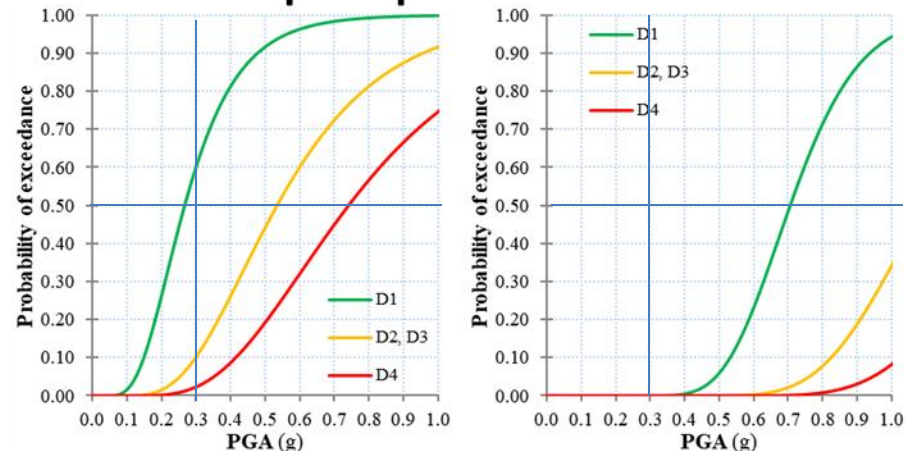
- Camicia 16 cm di Cls C80/95
- Armature B450C:
70 Φ 28 in direzione longitudinale
 Φ 10/120" in direzione trasversale



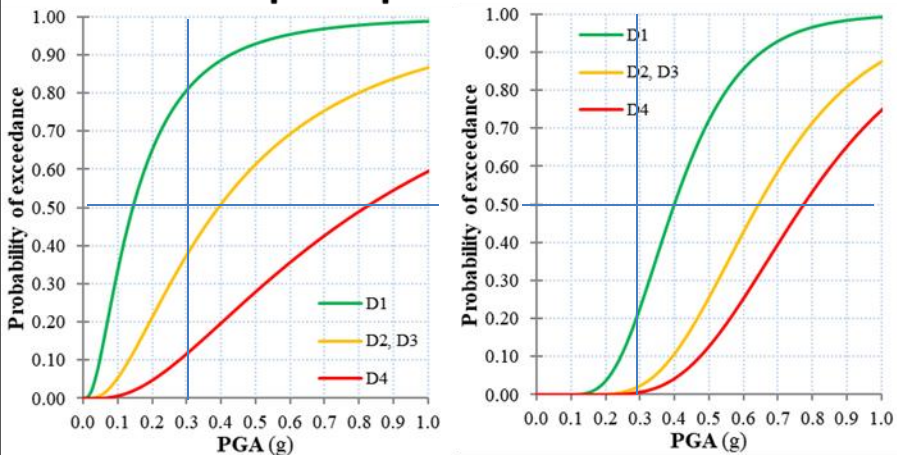
P1 pre e post intervento



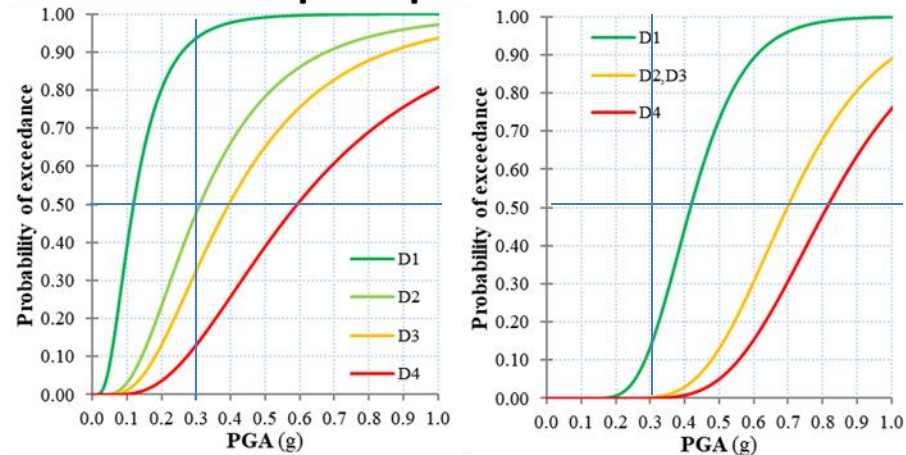
P2 pre e post intervento

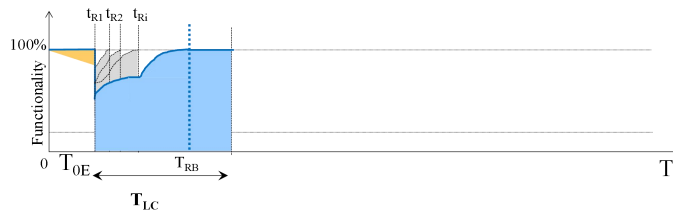
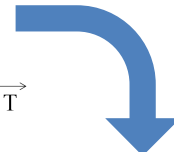
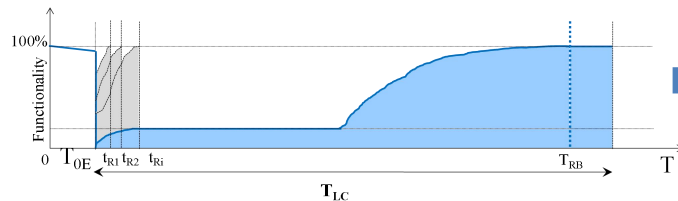
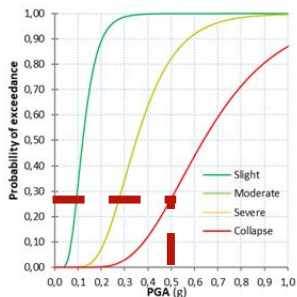
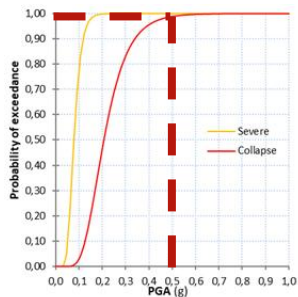


P3 pre e post intervento



P3b pre e post intervento



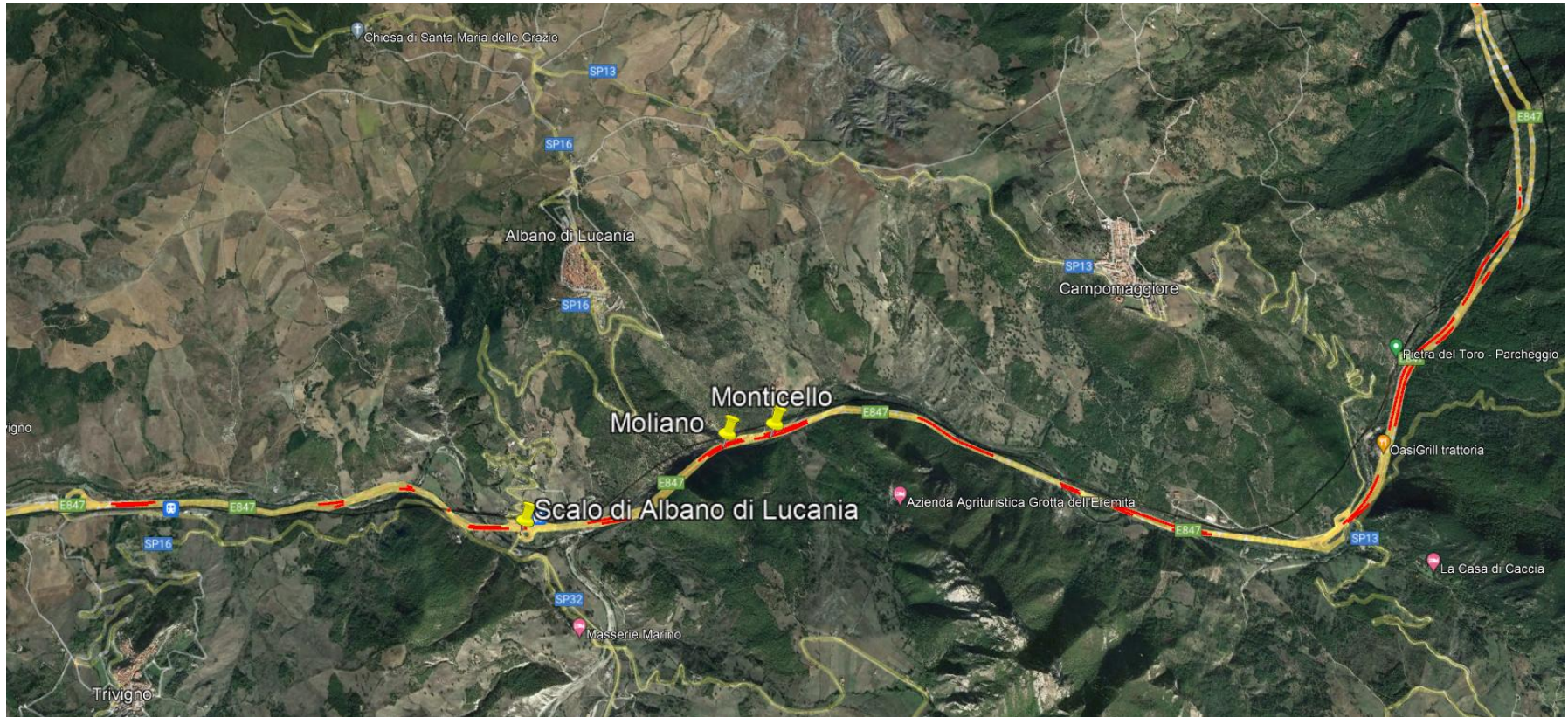


$$R_{\text{index}}(I) = \sum_{\text{area}=1}^n \left\{ W_{\text{area}} \cdot \left(1 - \sum_{\text{type}=1}^m \frac{E[T_{RB} | C_{r,r} | I]}{T_{LC}} E[C_{r,r} | d_{l,type} | I] P[d_l = d_{l,type} | I] \right) \right\}$$

Casi studio selezionati

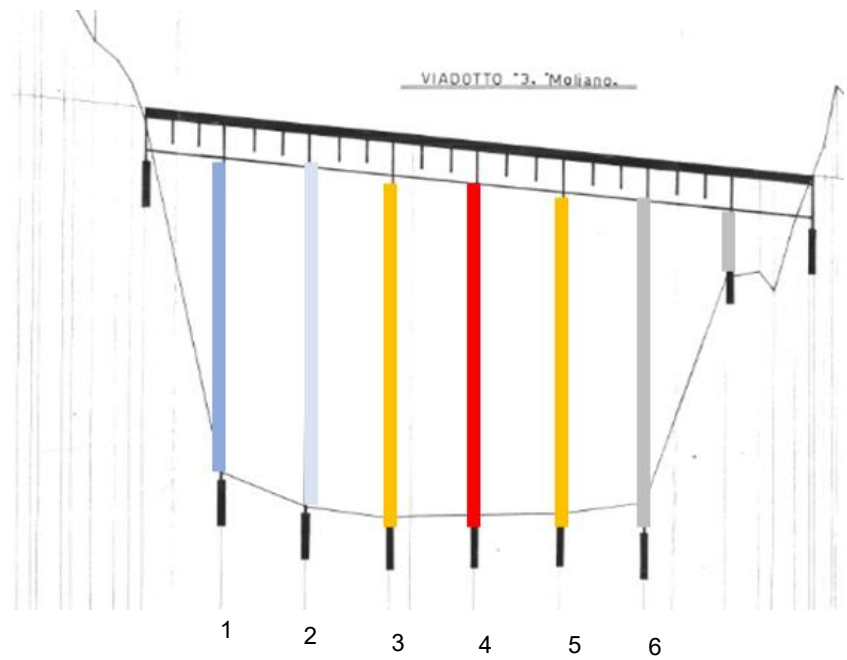


Casi studio selezionati



Casi studio selezionati

MOLIANO +		
Lunghezza	281	m
campate	8	
l camp max	35.15	m
interferenza	fiume	
zona sismica	2	
Altitudine media	446	m
Layout	MEDIUM	
Orografia	V	
Hmin	0.4	m
Hmax	12.43	m
Hmedia	7.04	m



Livello di difettosità viadotto
ALTO
MEDIO-ALTO
MEDIO
MEDIO-BASSO
BASSO
NO DEGRADO CORROSIVO

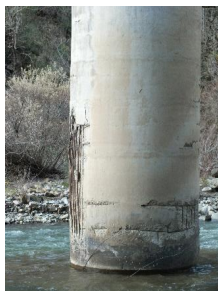
Stato di fatto al 31.12.2021

Stato di degrado delle pile del viadotto Moliano

PILA 3



PILA 4

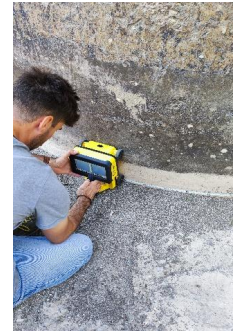


PILA 5



Rilievo del degrado

- Misure dirette in sito
- Rilievi con **Sistema Aeromobile a Pilotaggio Remoto (SAPR)**
- Indagini Termografiche
- Rilievi con GEORADAR



Identificazione degrado (SAPR)

- Georeferenziazione infrastruttura



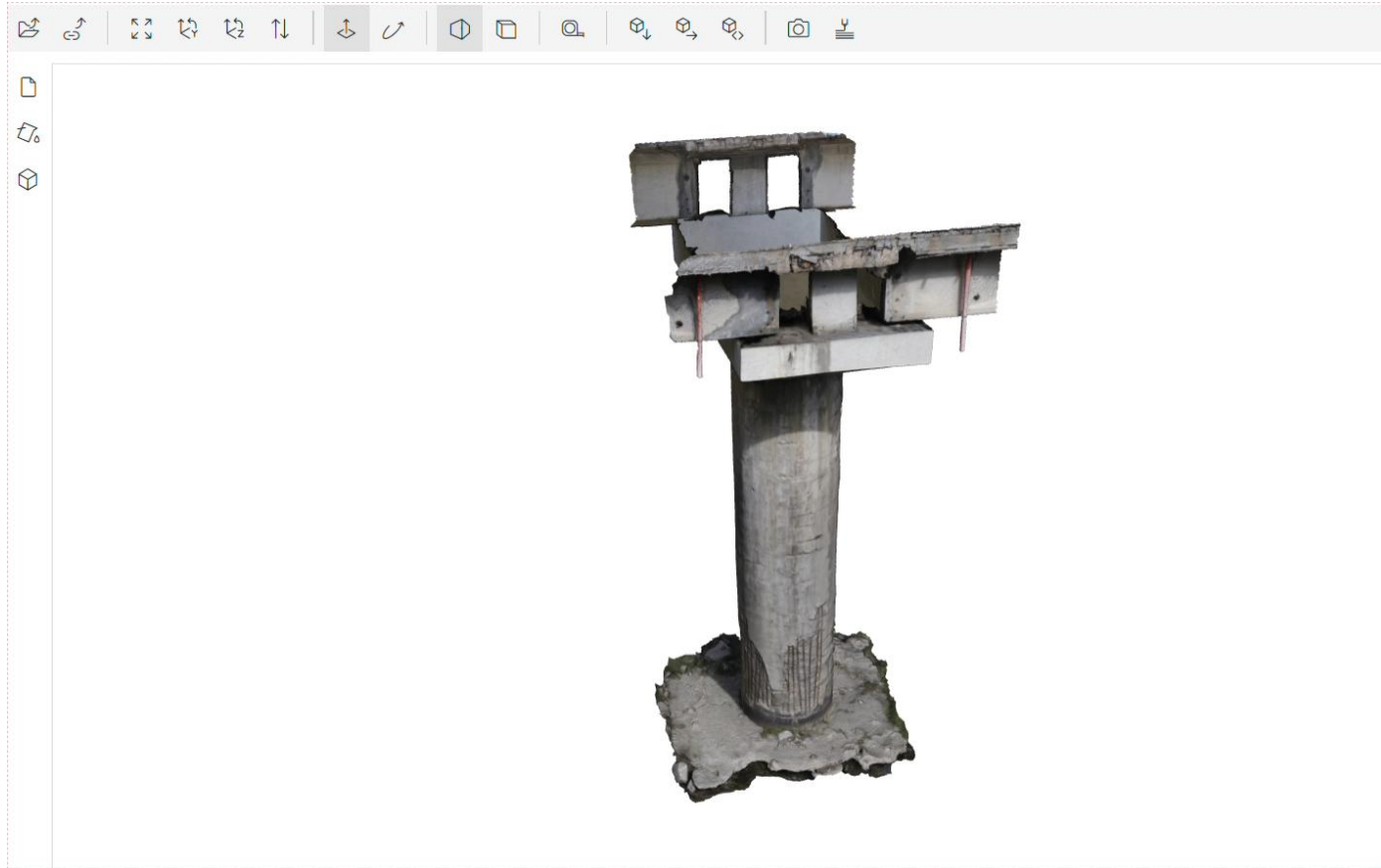
- Ortofoto infrastruttura (in CAD)



- Generazione modelli 3D singole pile



Identificazione degrado (SAPR)



Identificazione degrado (indagini termografiche)

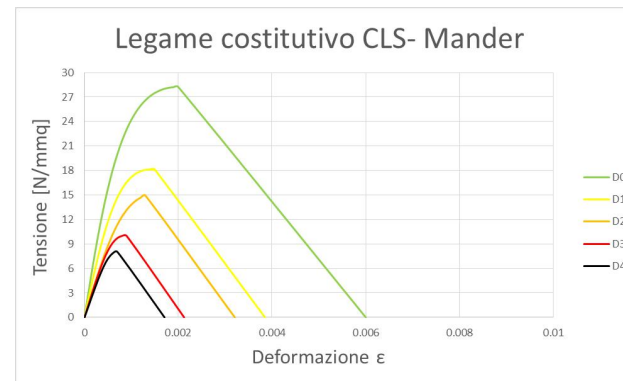
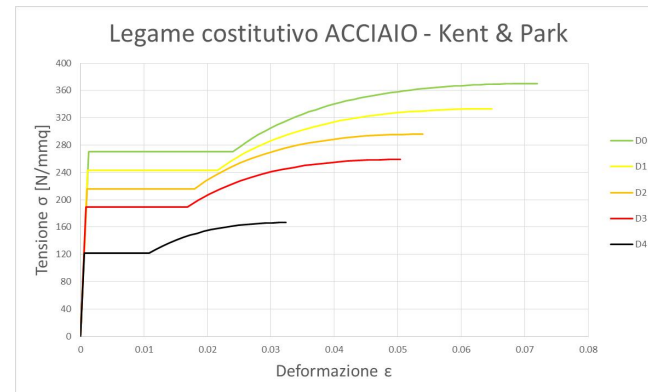


- Individuazione zone copriferro distaccato
- Individuazione zone copriferro fortemente ammalorato

Modellazione degrado



Scenario	Livello di degrado			
	w_cr	Psi_L	Psi_T	W_cr_nucleo
D0	0	0	0	0
D1	1	0.05	0.05	0
D2	3	0.15	0.15	1
D3	espulso	0.2	0.2	3
D4	espulso	0.3	0.3	espulso

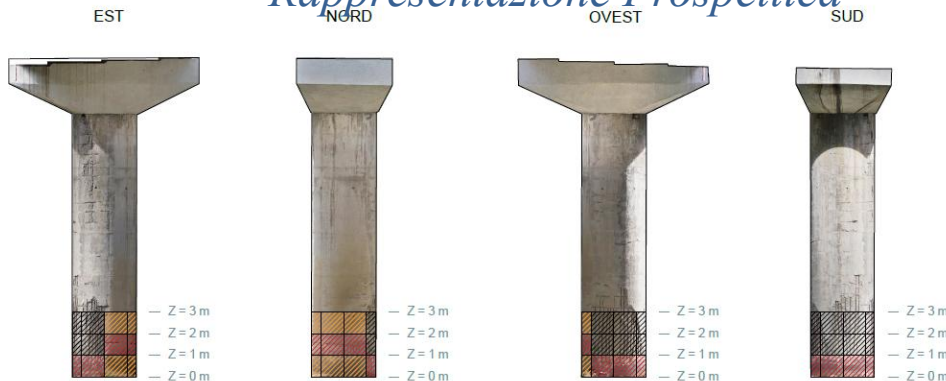


Modellazione degrado

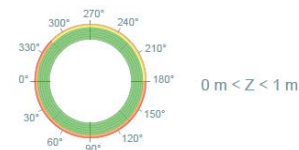
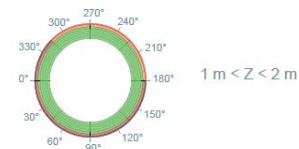
Rappresentazione Prospettica

Scenario	Livello di degrado
D0	nullo
D1	basso
D2	medio
D3	alto
D4	molto alto

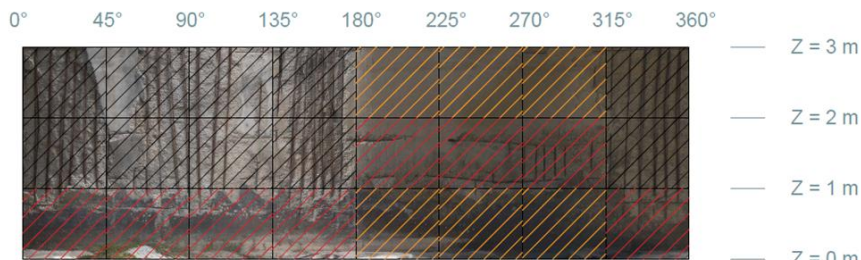
PILA 4



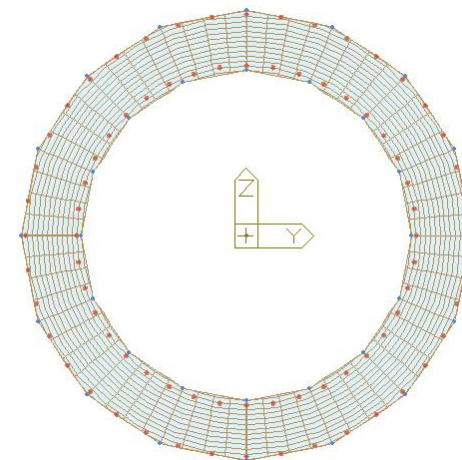
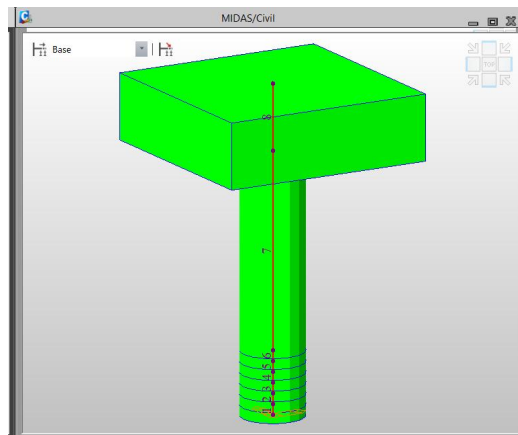
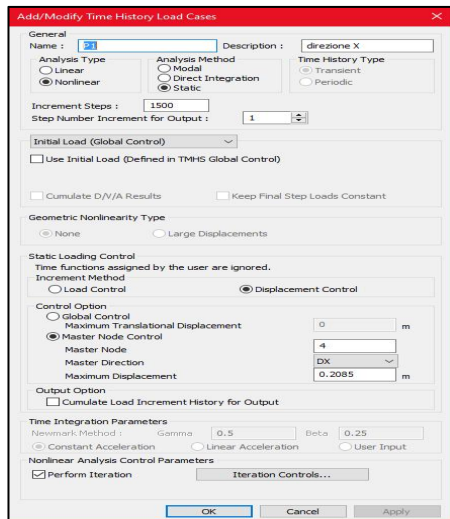
Rappresentazione in sezione



Rappresentazione Superficie Laterale

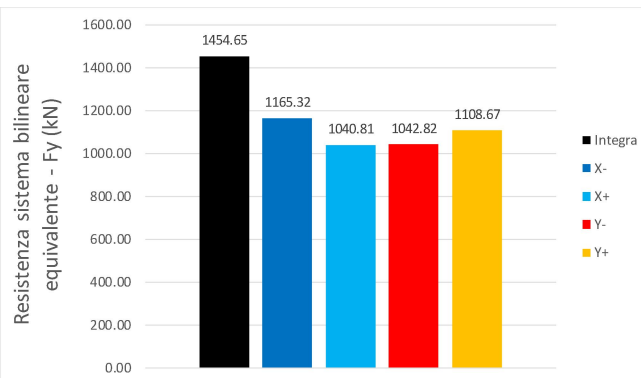
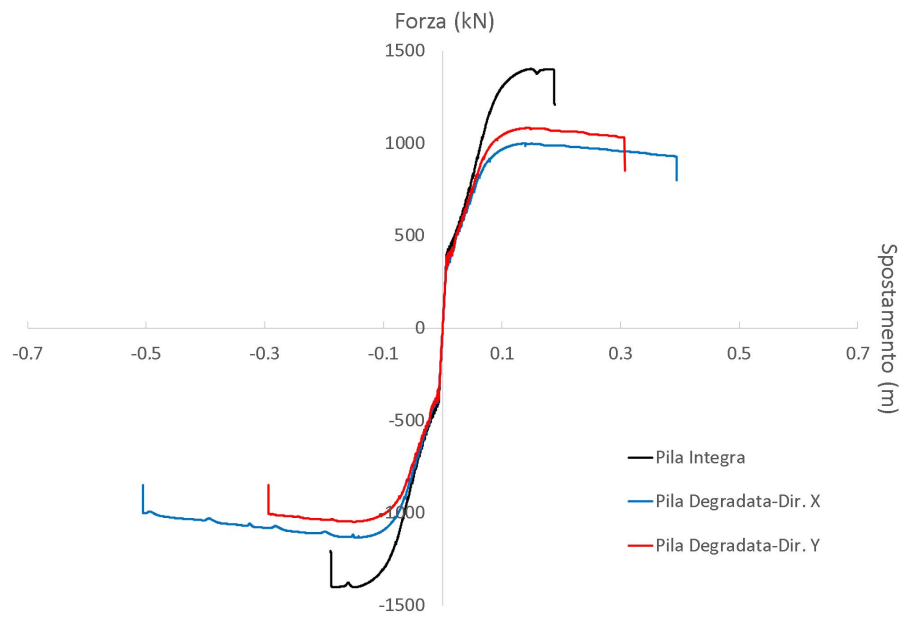


Analisi sismica (pushover)

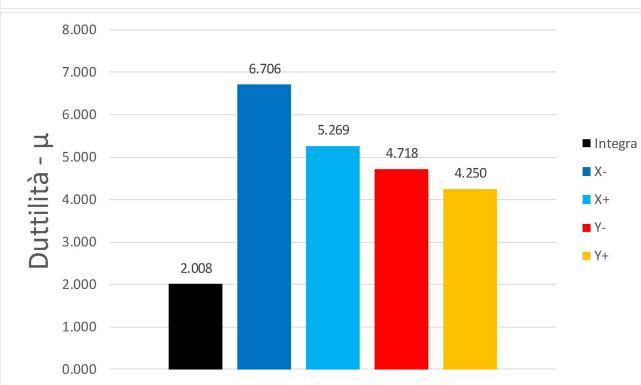


Analisi sismica (pushover)

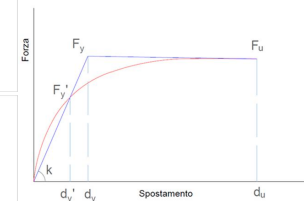
PILA 4 -Confronto Curve Forza-Spostamento



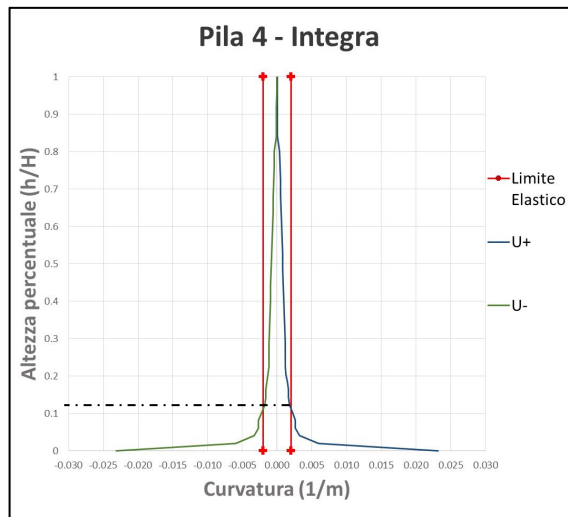
$$\Delta F_{y(d-i)} = -28,3\%$$



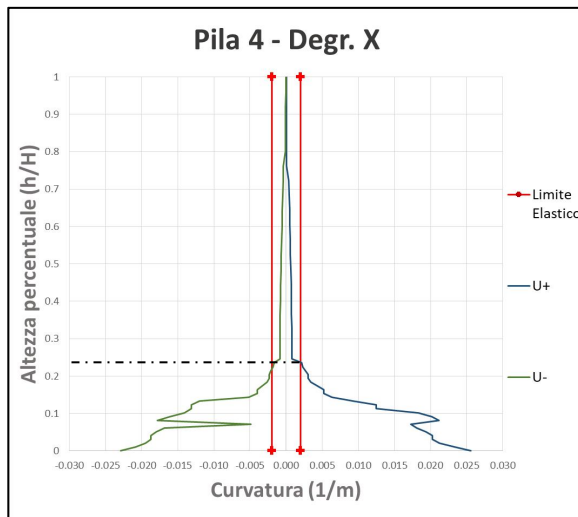
$$\Delta \mu_{(d-i)} = +104\%$$



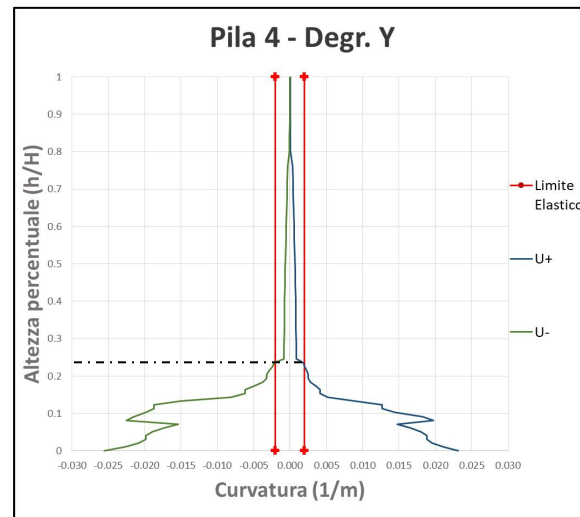
Analisi sismica (pushover)



$$h_{CP} = 0,12 \cdot H$$



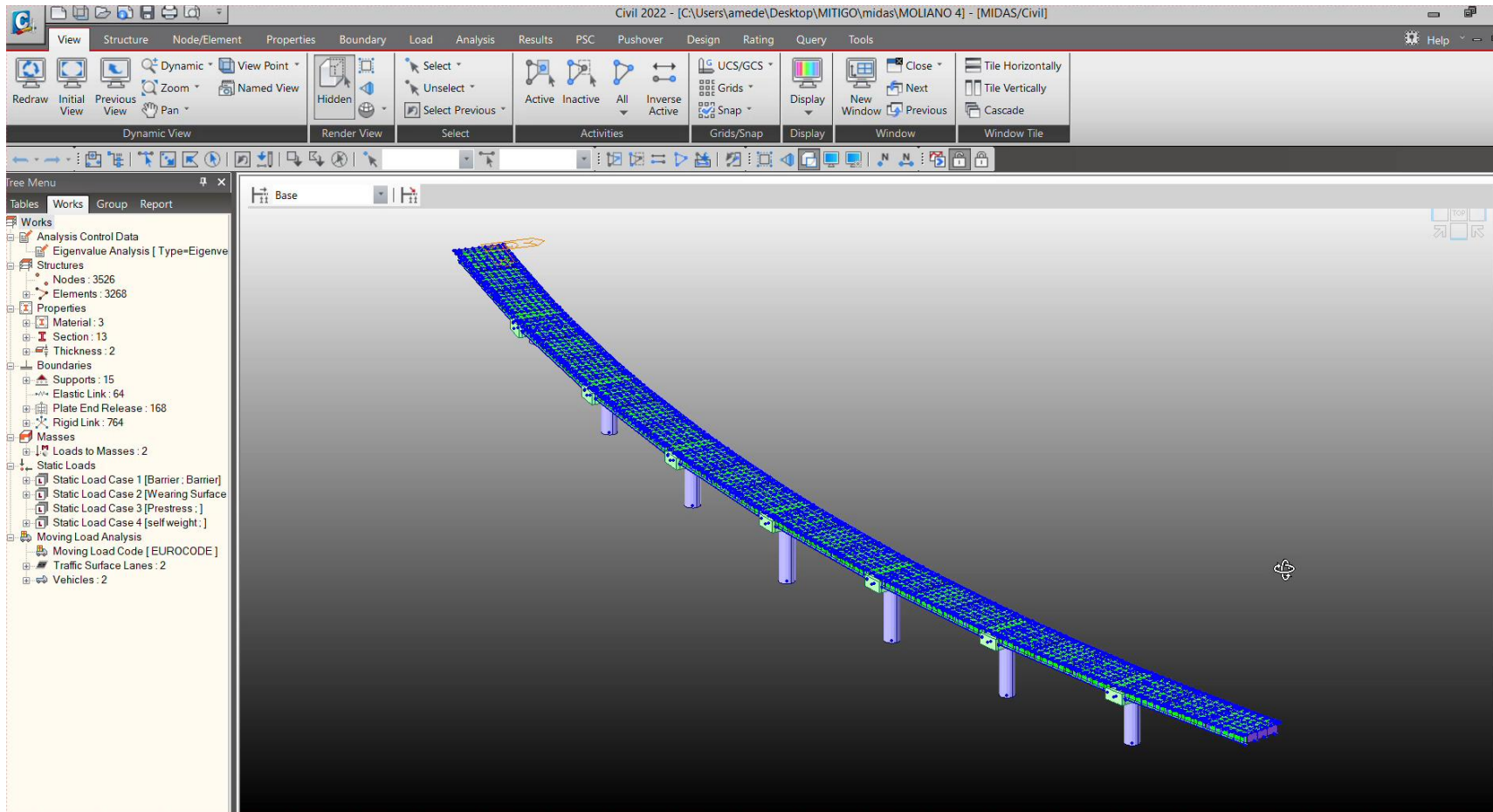
$$h_{CP} = 0,23 \cdot H$$



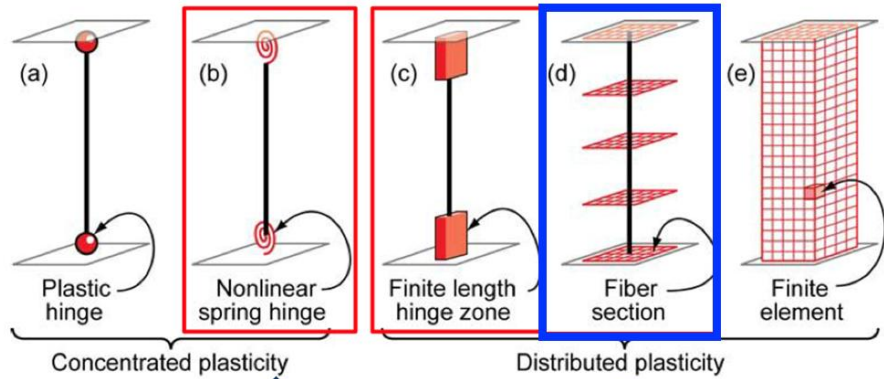
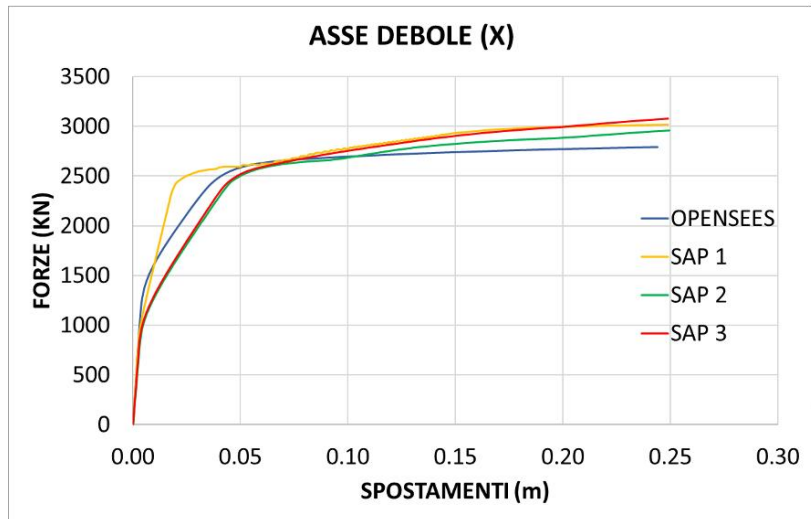
$$h_{CP} = 0,24 \cdot H$$

h_{CP} = lunghezza della cerniera plastica
 χ = curvatura
 ϕ_{pl} = rotazione plastica
 μ = duttilità

$$L_{CP}(D) > L_{CP}(I) \xrightarrow{\phi_{pl} = \chi_{med} \cdot L_{CP}} \phi_{pl}(D) > \phi_{pl}(I) \xrightarrow{\mu = \phi_{pl} \cdot (H - L_{CP})} \mu(D) > \mu(I)$$



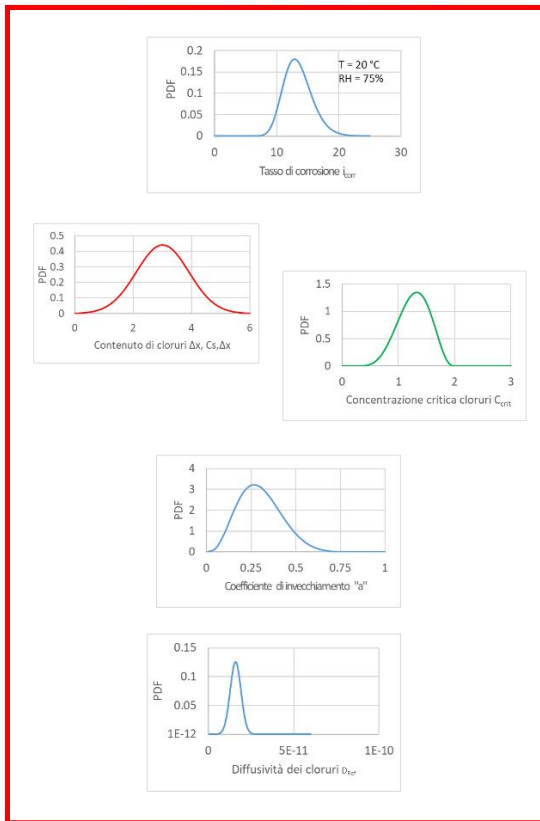
- Ampliamento analisi numeriche
- Interazione con il sistema di gestione della rete mediante GIS
- Calcolo indice di rischio (basato su FC)
- Ottimizzazione uso risorse mediante prioritizzazione interventi
- Sviluppo modello di gestione e programmazione interventi (non necessariamente riferito alla SS407)



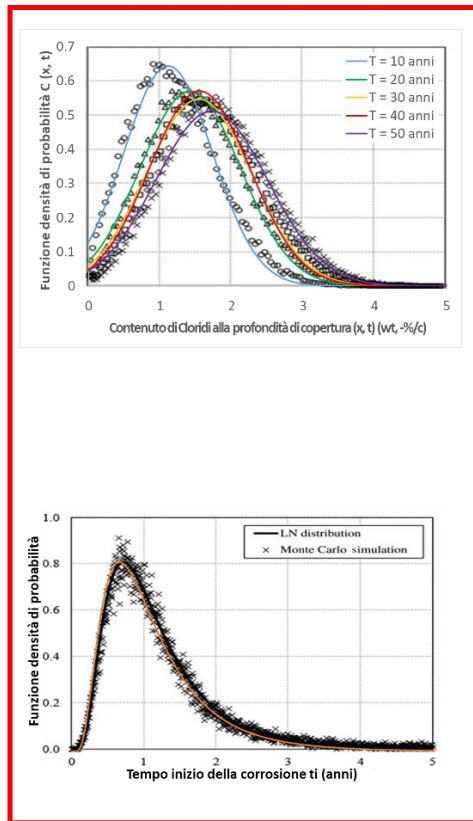
SAP 2000

OpenSees

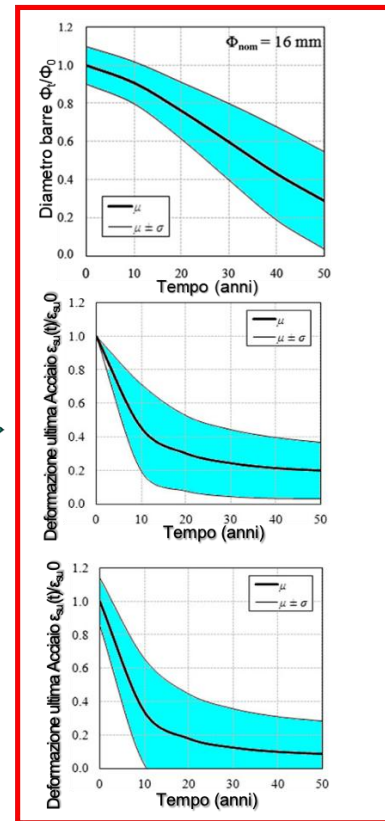
VARIABILI ALEATORIE



METODO MONTECARLO



OUTPUT





*Mitigazione dei rischi naturali per la sicurezza e la mobilità
nelle aree montane del Mezzogiorno*

Università degli studi della Basilicata

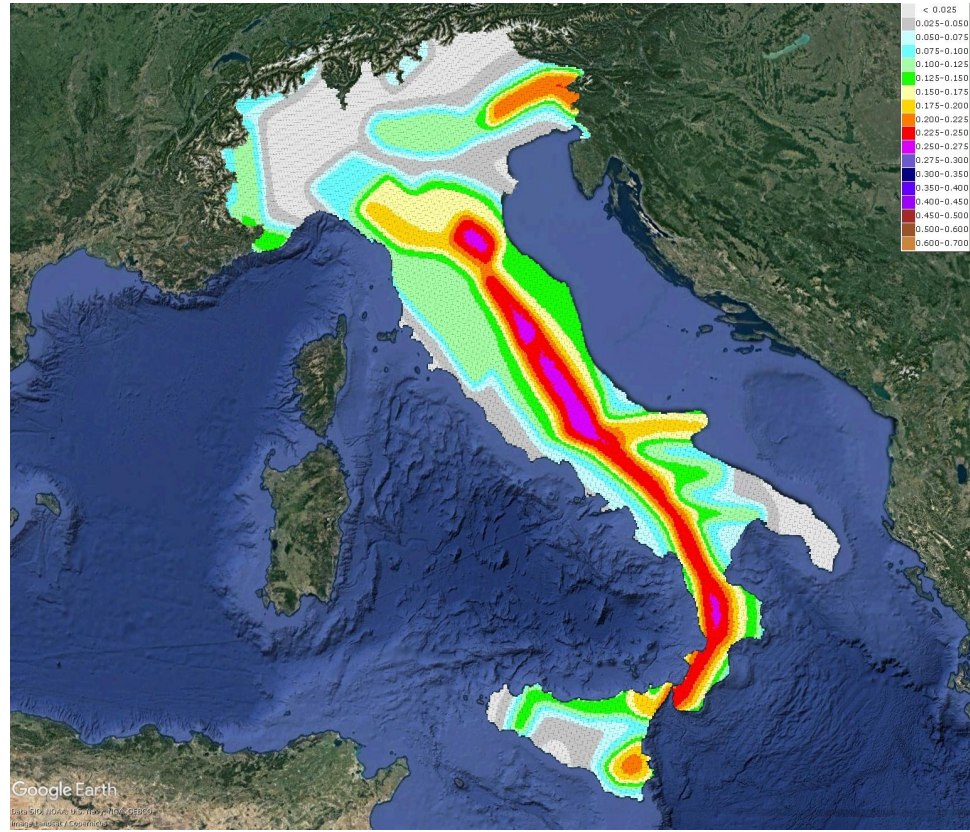
**Modelli di gestione delle strutture ed infrastrutture viarie finalizzati
alla mitigazione del rischio sismico**

Obiettivo di Ricerca 3

Obiettivo di Ricerca 6

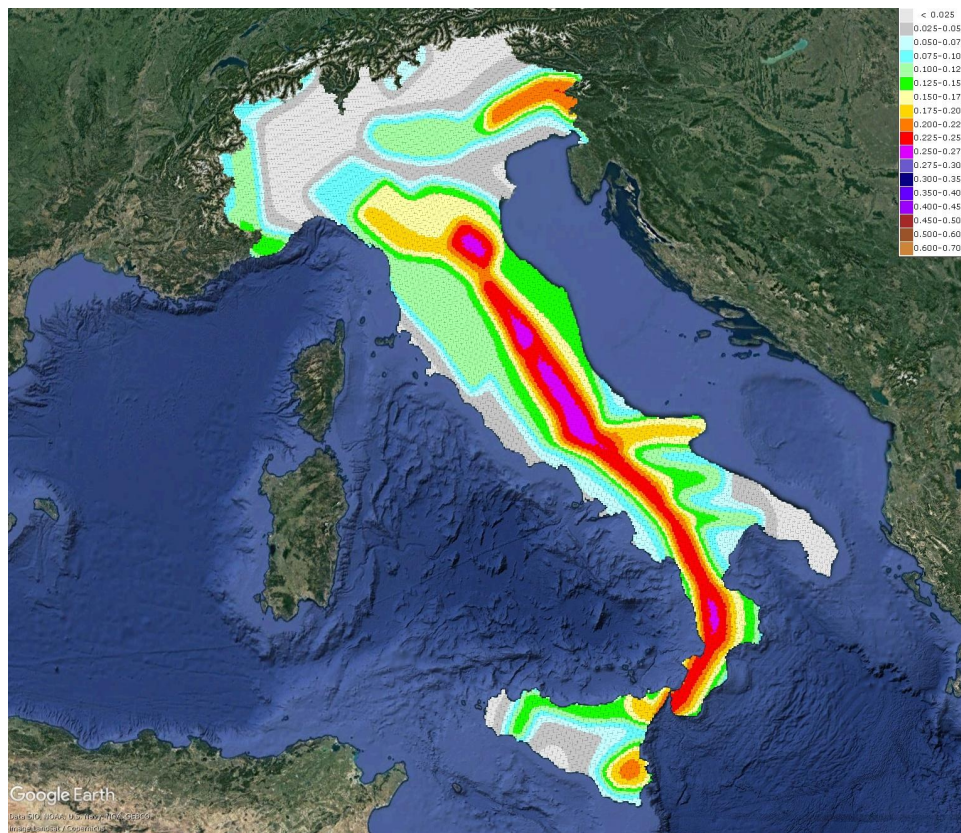
- Marco VONA (OR3)*
- Donatello CARDONE (OR6)*
- Benedetto MANGANELLI*
- Paolo HARABAGLIA*

27 Febbraio 2024



La pericolosità si calcola classicamente con il metodo PSHA ma

p.e. 10% in 50 anni



... questo è

MSCA

MultiSynthetic
Catalog
Approach

10^5 cataloghi sintetici

Attenuazione da Bindi et al. 2011

Parametrizzazione come MPS04

p.e. 10% in 50 anni

MSCA vs. PSHA

Computazionalmente molto più pesante

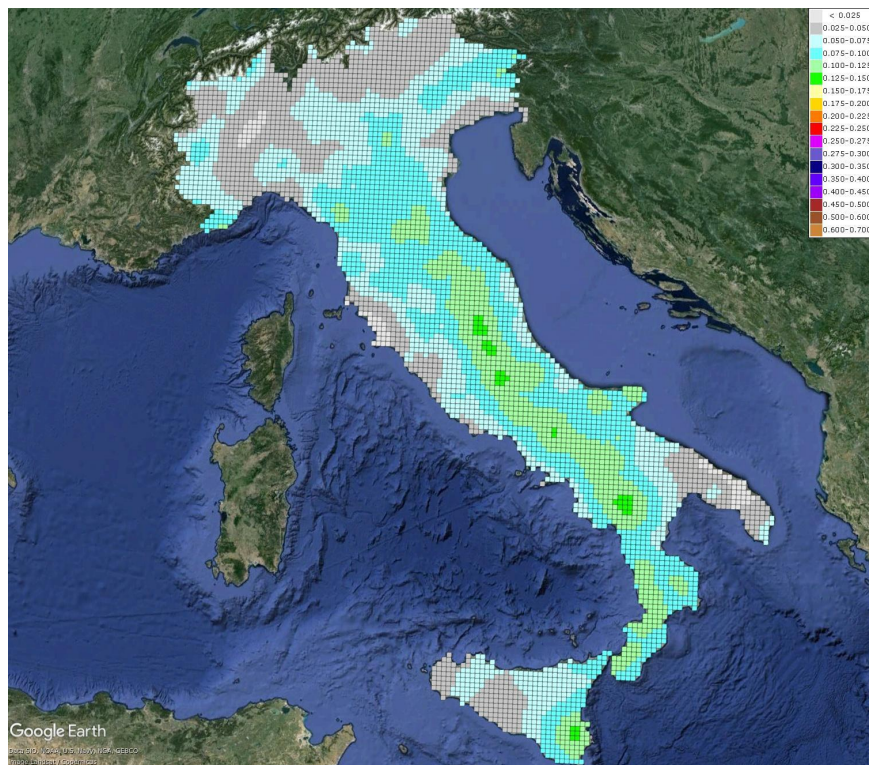
Naturalmente estendibile a:

Danno
Rischio
Resilienza

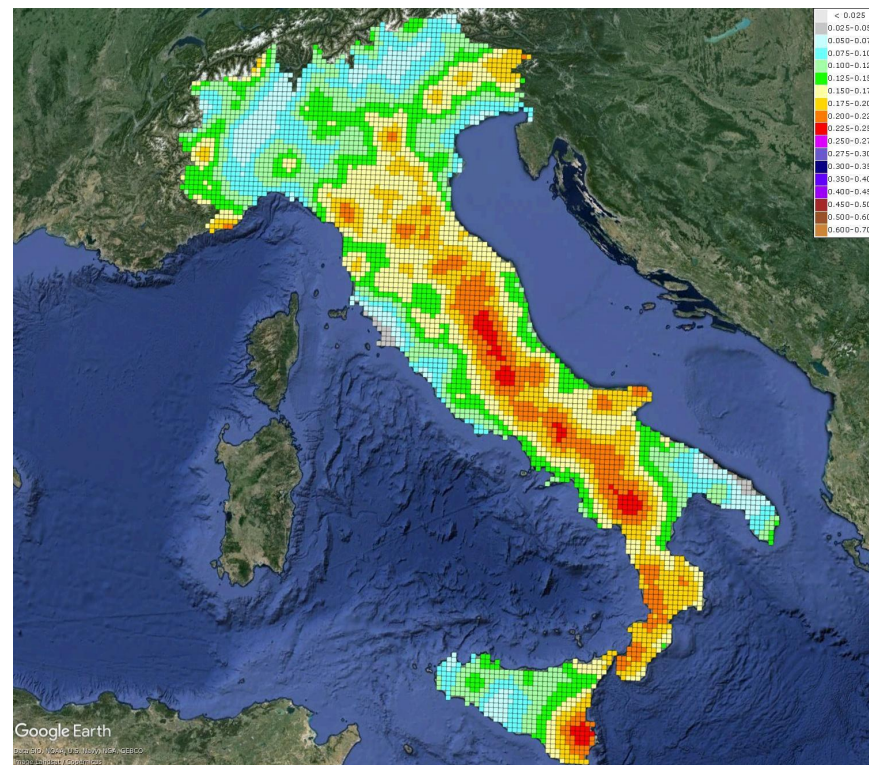
Consente di calcolare la
PROBABILITÀ di scenario

Non limitato alla classica parametrizzazione in termini di zone o di sorgenti sismogenetiche

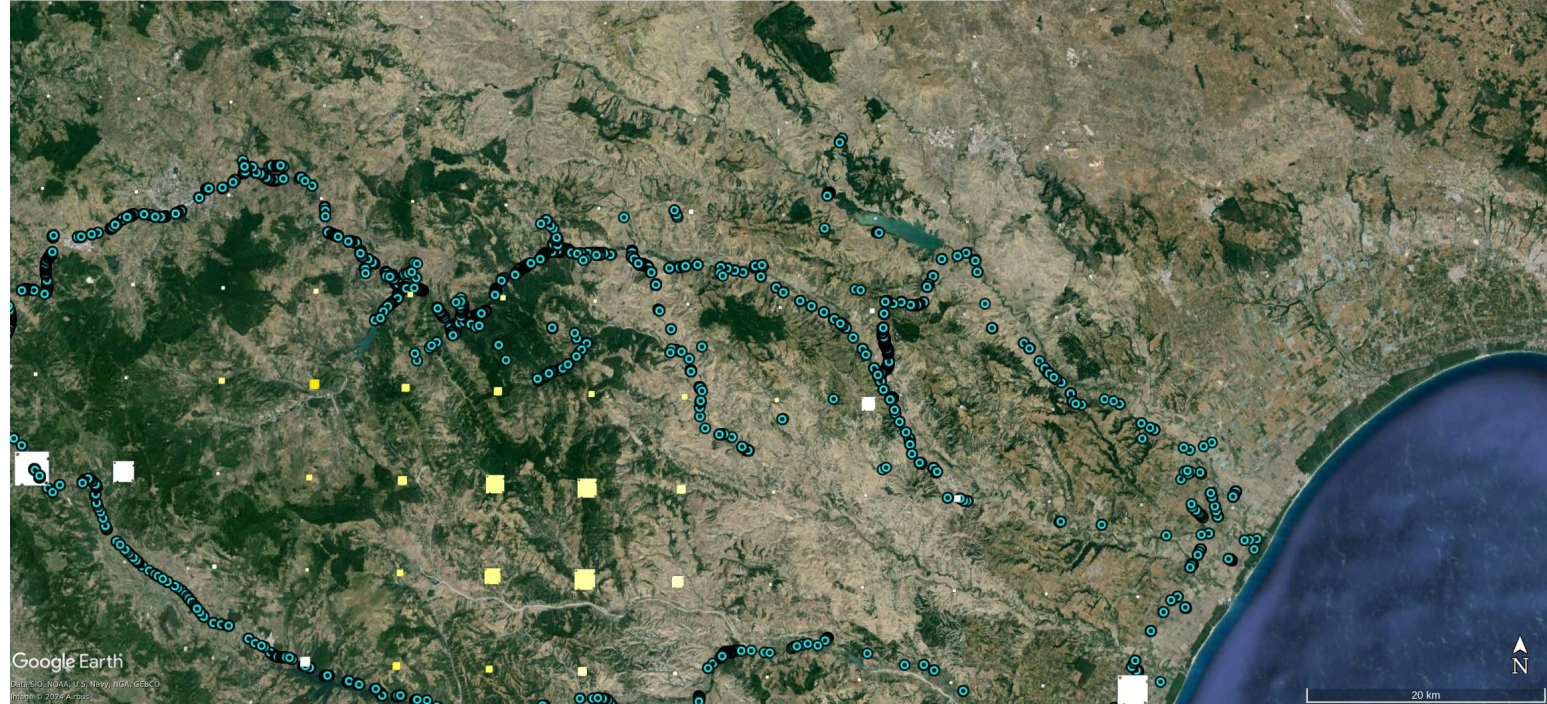
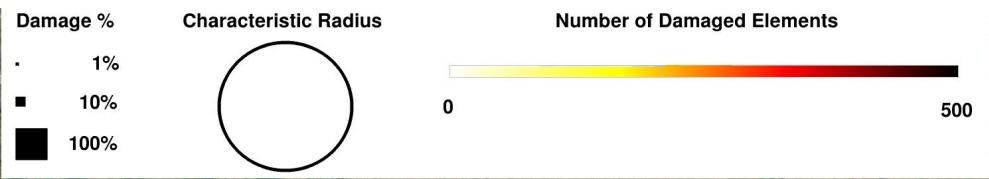
NON POISSONIANA



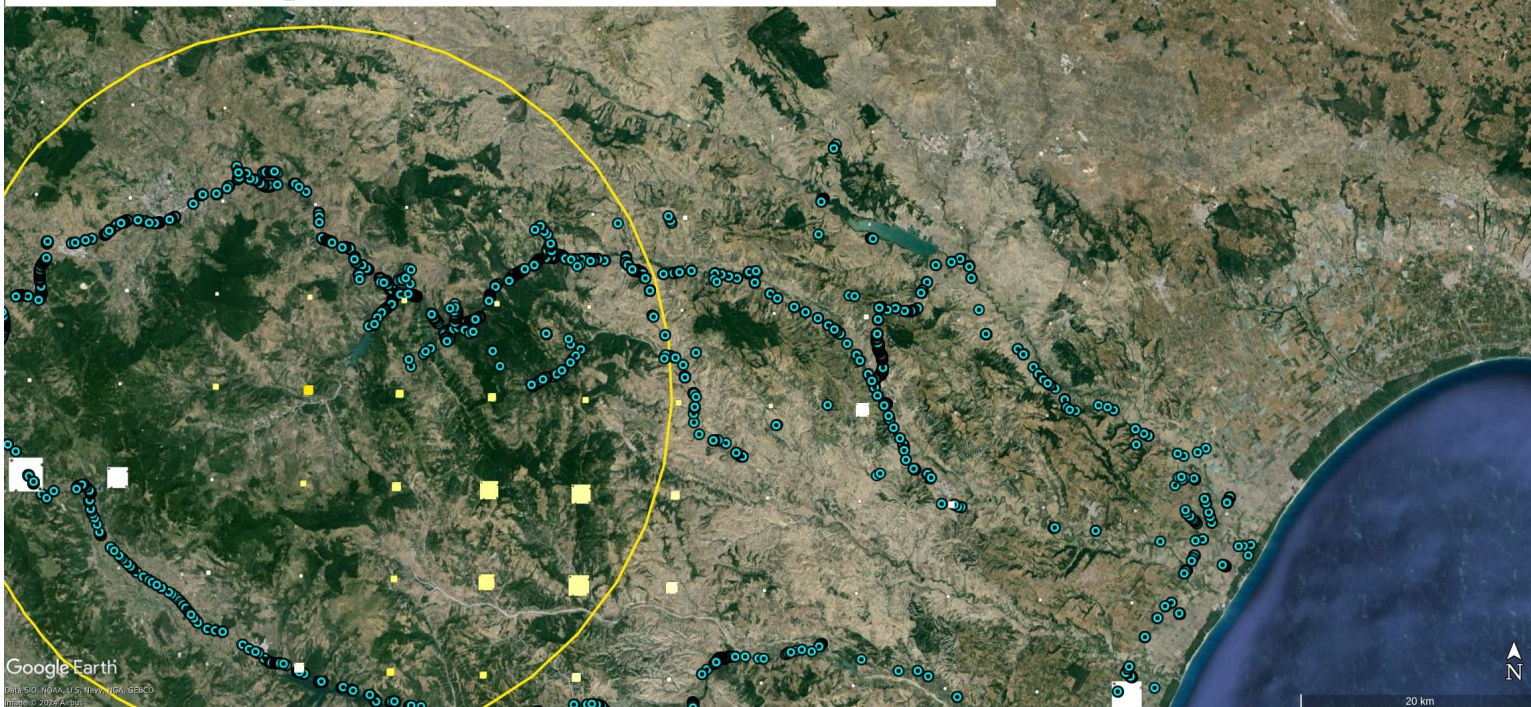
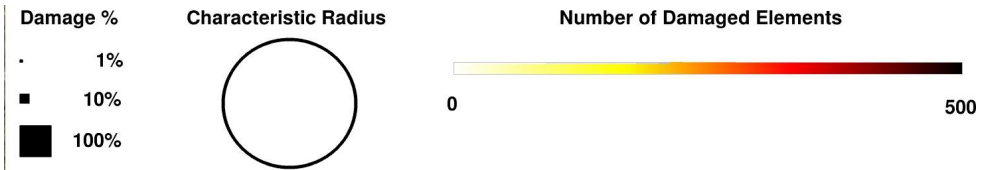
p.e. 10% in 15 anni



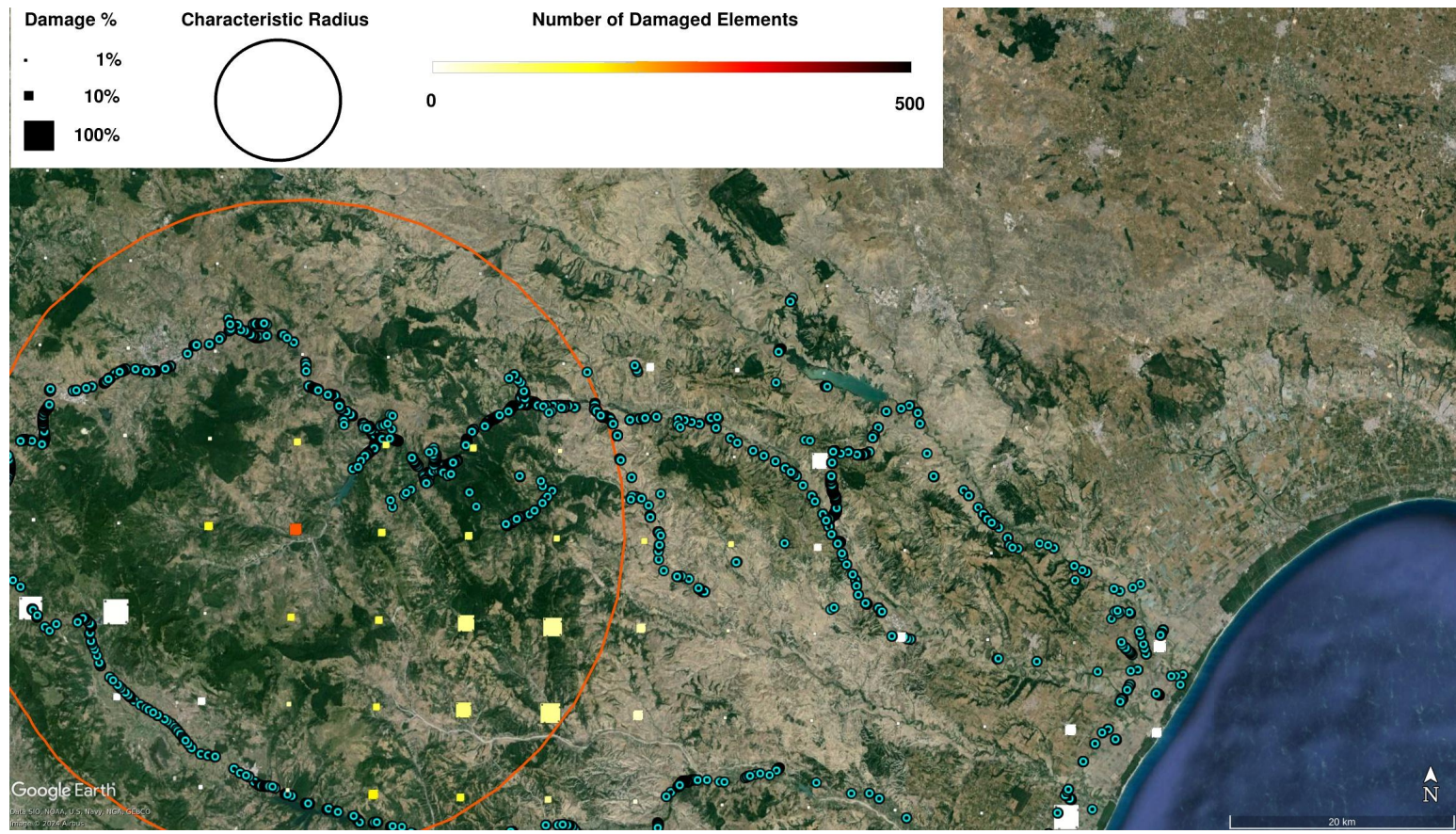
p.e. 2% in 15 anni



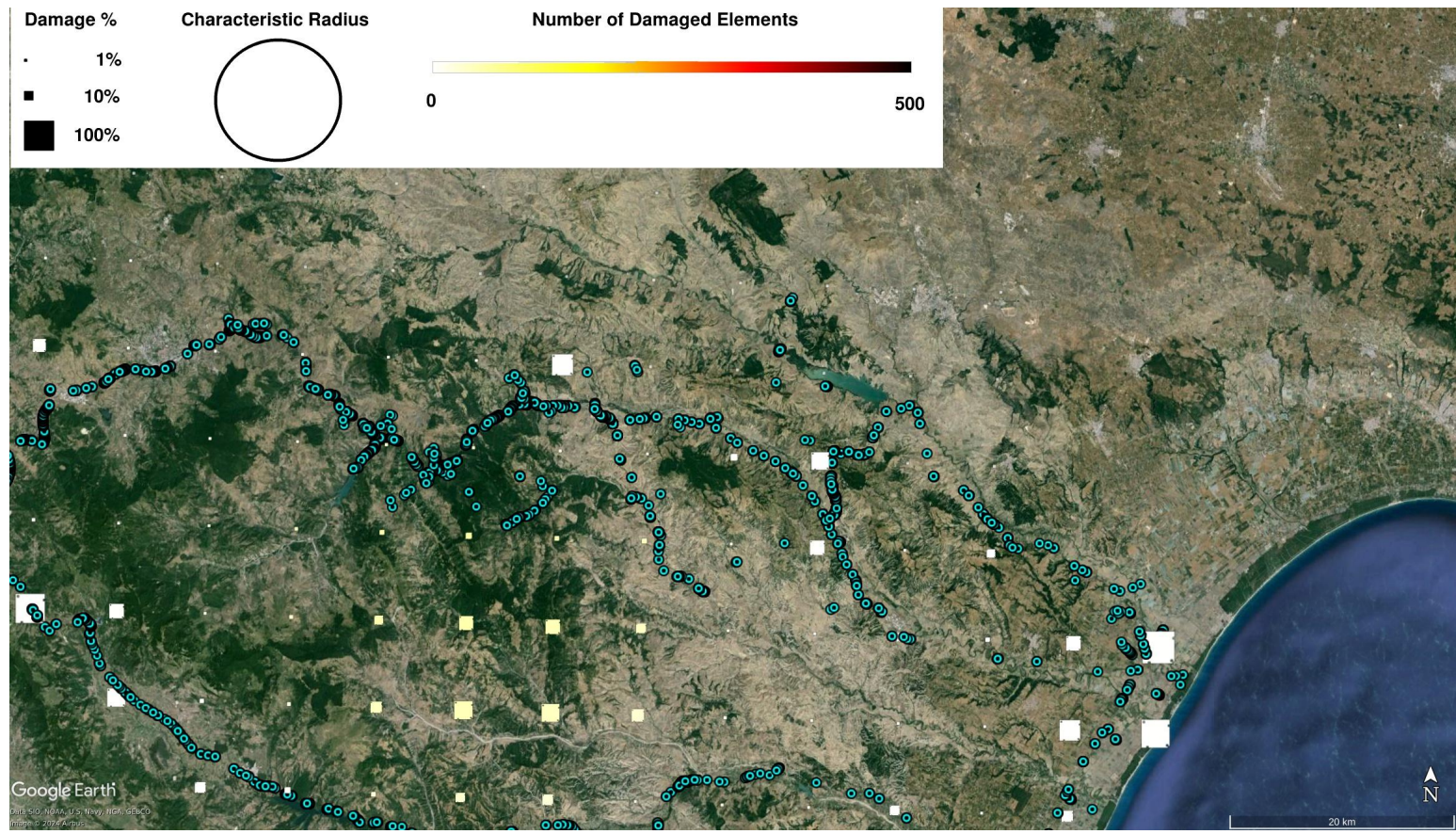
p.e. 10% in 200 anni



p.e. 10% in 200 anni



p.e. 5% in 200 anni



p.e. 10% in 15 anni

- Nuovo modello di attenuazione
- Integrazione del danneggiamento cumulato
- **Miglioramento dell'approccio non-poissoniano**
- Inserimento di un modulo per la gestione degli itinerari
-