CITTA' DI TORINO

DIVISIONE INFRASTRUTTURE MOBILITÀ

Area infrastrutture - Servizio Suolo Parcheggi

PARCHEGGIO PUBBLICO INTERRATO PIAZZA BENGASI

CUP C11I13000010007 - **CIG** 8530185359 - **CPV** 71242000-6 - **C. NUTS** ITC11

PROGETTO ESECUTIVO

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GEOTECNICA

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Regione Piemonte
COMUNE DI TORINO

PARCHEGGIO PUBBLICO INTERRATO
PIAZZA BENGASI

PROGETTO DEFINITIVO

RELAZIONE GEOTECNICA

ORDINE DEGLI INGEGNERI
PROVINCIA DI TORINO
N° 6129 S
Dott. Ing. Mauro Battaglio

Rif.891-21-R1 **Torino,31.03.2022**

INDICE

1. PREMESSA

La relazione riporta le verifiche della stabilità delle berliesi di pali trivellati accostati, che costituiscono le opere di sostegno provvisorie da eseguirsi nell'ambito dei lavori per la realizzazione del parcheggio interrato multipiano nell'area di Piazza Bengasi nel Comune di Torino.

I pali che formano le berlinesi sono del tipo CFA (pali ad elica continua con getto del calcestruzzo dall'interno dell'utensile di perforazione e inserimento successivo della gabbia di armatura). Il diametro dei pali varia in funzione della sezione considerata e della profondità di scavo (60 cm, 80 cm, 100 cm): nel seguito sono prese in considerazione n. 4 sezioni tipo, di cui una avente pali di diametro pari a 60 cm, una pali di diametro pari a 80 cm e le altre due pali da 100 cm.

Quanto analizzato e nel seguito esposto si basa sugli elaborati di progetto redatti dallo studio di progettazione ICIS srl di Torino e sulle indagini del terreno nel seguito richiamate.

L'analisi di ciascuna berlinese si compone di due passaggi: (1) calcolo della lunghezza minima di infissione, in relazione alla geometria dell'opera e alla massima profondità di scavo, date che siano la spinta attiva e passiva che si esercitano sull'opera (2) analisi del comportamento della berlinese applicando i metodi dell'interazione terreno-struttura. In questo secondo casi si determinano le sollecitazioni derivanti dall'andamento delle pressioni sull'opera.

Quanto sopra è condotto nel rispetto della Normativa vigente (DM del 17 gennaio 2018 e successive precisazioni). Trattandosi di opera provvisoria non viene presa in considerazione la presenza del sisma.

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2. INDAGINE GEOLOGICO-GEOTECNICA DI RIFERIMENTO

Essa si basa sulla relazione "Relazione geologico-geotecnica" – *Elaborato n. 4* redatta in data 01-10-2020 a cura della Città di Torino (Divisione infrastrutture e mobilità, Area infrastrutture). In questo documento sono richiamati i risultati delle indagini geologico-geotecniche eseguite nell'ambito del progetto per la realizzazione del prolungamento Sud della Linea 1 – Tratta 4, Lingotto – Bengasi.

Limitatamente alle profondità interessate, che al massimo arrivano a circa 8 metri dal piano della piazza sovrastante, il terreno di fondazione è costituito dai depositi fluvio glaciali e fluviali Rissiani, costituiti da ghiaie, ciottoli e livelli di sabbie in matrice sabbioso limosa. Possono essere presenti livelli limoso-argillosi.

Può essere presente, a profondità variabili da zona a zona, terreno cementato, dovuto alla percolazione di acqua ricca di sali calcarei. Il grado di cementazione varia da strato a strato. Nei casi in cui esso è elevato la formazione assume le caratteristiche di una roccia tenera. Tale caratteristica si limita a spessori dell'ordine di 30÷50 cm. Secondo le informazioni disponibile quest'ultima circostanza dovrebbe potersi escludere, in virtù della limitata profondità.

Il deposito fluvio glaciale sopra descritto è sormontato da uno strato di riporto recente, dovuto agli interventi che si sono succeduti nel corso degli ultimi decenni. I suoi massimi spessori sono dell'ordine di 4÷7 metri.

Sulla base delle misurazioni più recenti, la soggiacenza della falda è collocabile nell'intorno di 220 m lmm. Considerato che il livello della copertura del parcheggio è situato all'incirca alla quota 231 m lmm, la soggiacenza caratteristica è pari a circa 11 metri. Nel rispetto della richiesta del Committente, tale dato viene incrementato di 2 metri, pervenendo così alla soggiaceenza di progetto, nella condizione provvisoria in esame, di 9 metri dallo zero di progetto.

Per la caratterizzazione geotecnica del terreno ci si riferisce anche ai sondaggi denominati SCI2 e SCI7 eseguiti nella zona del parcheggio in progetto in occasione della progettazione esecutica della tratta di metropolitana citata sopra..

La Figura 1 mostra i risultati del sondaggio SCI2, limitatamente alla profondità di circa 20 metri. La Figura 2 mostra quelli relativi al sondaggio SCI7.

Da esse si può osservare che:

- la profondità della superficie piezometrica è pari a circa 12 metri da piano campagna,
- i valori della resistenza penetrometrica dinamica SPT misurata con la prova Standard Penetration Test sono sempre molto elevati, nonostante le profondità relativamente modeste,
- ove presente (SCI12, lo strato di limo sabbioso appare molto addensato/consistente, e quindi di buone caratteristiche meccaniche,
- la natura del terreno è prevalentemente non coesiva.

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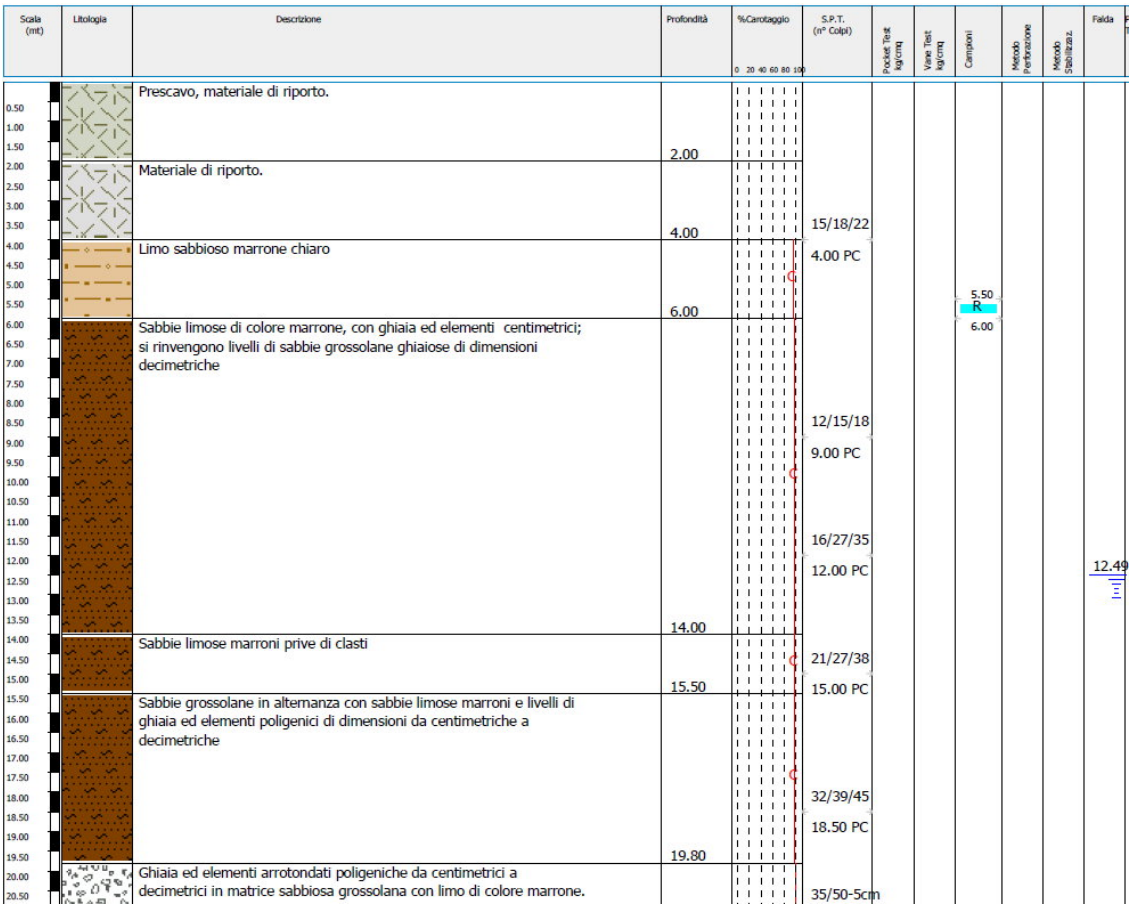

Figura 1 – Sondaggio SCI2

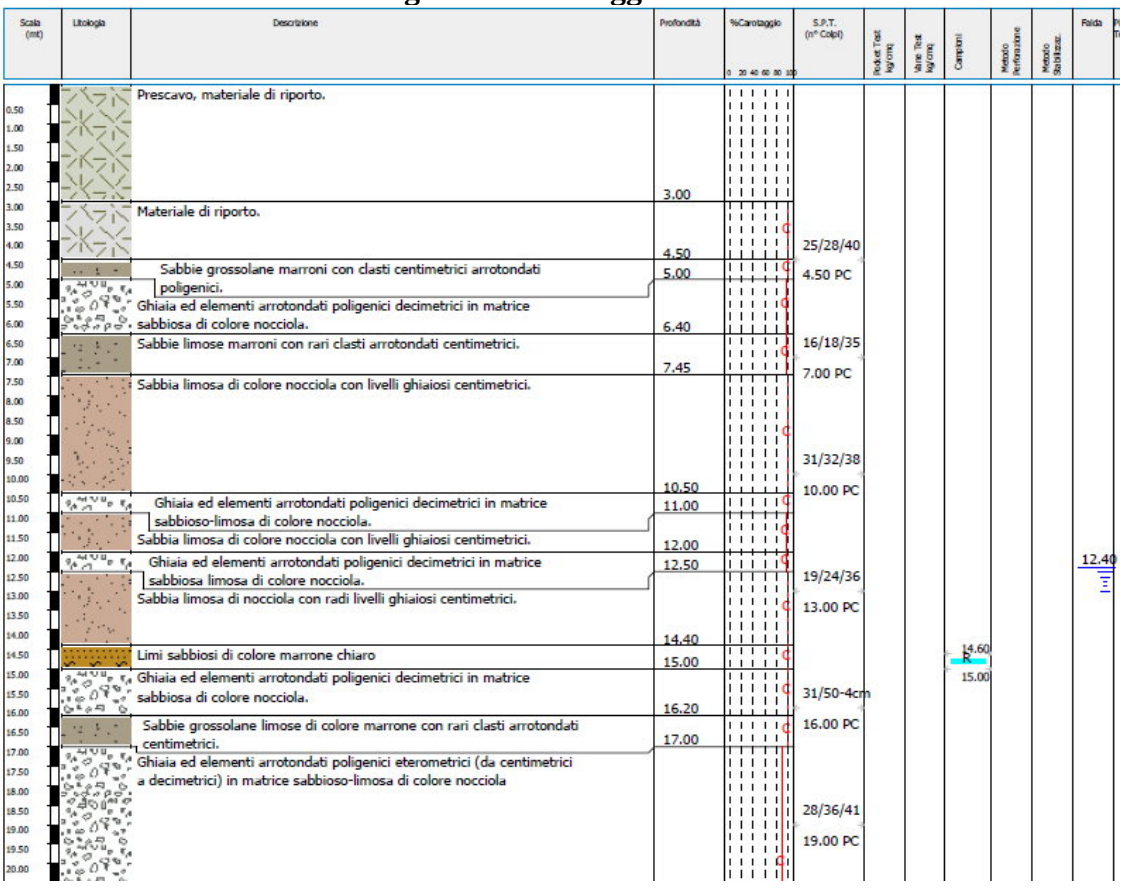

Figura 2 – Sondaggio SCI7

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La caratterizzazione geotecnica del terreno, utilizzata per l'analisi delle opere di sostegno qui esaminate, si avvale dei risultati sopra citati e soprattutto dei risultati e dell'interpretazione delle prove in sito e di laboratorio che sono state eseguite in occasione del progetto del tratto di metropolitana sopra richiamato. In relazione a queste ultime, nella Tabella 1 sono stati riportati i valori di N_{SPT} misurati alle varie profondità nei due fori di sondaggio sopra richiamati.

Tabella 1 – Valori di N_{SPT} alle varie profondità

Sondaggio	4.0	4.5	7.0	9.0	10.0	12.0	13.0	15.0	16.0	18.5	19.0
SCI2	40	-	-	33	-	62	-	65	-	84	-
SCI7	-	68	43	-	70	-	60	-	R	-	77

Come si osserva dalla Tabella 1 i valori di N_{SPT} sono sempre molto elevati a tutte le profondità, sia nel caso del terreno sabbio ghiaioso sia in quello limoso sabbioso. Ciò è dovuto all'elevato grado di addensamento del terreno e del riporto superficiale. Tuttavia la diversa composizone granulometrica contribuisce a differenziare i valori dell'angolo di resistenza al taglio. Inoltre, la variabilità delle caratteristiche del terreno di riporto comporta l'assegnazione, a questo strato, di parametri cautelativi.

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3. CARATTERIZZAZIONE GEOTECNICA E PARAMETRI DI CALCOLO

Sulla base di quanto descritto al capitolo precedente, è possibile dedurre due stratigrafie caratteristiche dell'area in esame: nella prima (Figura 1) è presente da circa 4 a circa 6 metri uno strato di limo sabbioso compatto, sottostante lo strato di riporto di spessore di 4 metri; nella seconda stratigrafia (Figura 2) lo spessore del riporto è pari a 4.5 metri circa e lo strato limoso sabbioso compatto è assente.

Le analisi di stabilità hanno considerato entrambe le situazioni: dai risultati delle analisi la stratigrafia di Figura 1 risulta la più sfavorevole, per cui quanto esposto si limita a tale condizione.

Con riferimento ai risultati delle precedenti indagini, i parametri del terreno (valori caratteristici) sono:

Strato 1 (riporto o sabbia limosa mediamente addensata) – da zero a 3.5 metri
- Peso di volume, γ: 18.5 kN/m^3
- Coesione, c: zero
- Angolo di resistenza al taglio, ϕ': 32°
- Modulo di deformazione E: 25 MPa

Strato 2 (limo sabbioso compatto) – da 3.5 metri a 6.0 metri
- Peso di volume, γ: 18.5 kN/m^3
- Coesione, *c*: 5 kPa
- Angolo di resistenza al taglio, ϕ': 28°
- Modulo di deformazione E: 30 MPa

Strato 3 (sabbia limosa addensata) – da 6.0 metri a 15.5 metri
- Peso di volume, γ: 18.5 kN/m^3
- Coesione, *c*: 0 kPa
- Angolo di resistenza al taglio, ϕ': 32°
- Modulo di deformazione E: 30 MPa

Strato 4 (ghiaia e sabbia poco limosa, molto addensata)- oltre 15.5 metri
- Peso di volume, γ: 20 kN/m^3
- Coesione, c: 0 kPa
- Angolo di resistenza al taglio, ϕ': 38°
- Modulo di deformazione E: 60 MPa

La posizione della superficie piezometrica è posta a 9 metri sotto il piano zero di riferimento, secondo le considerazioni svolte al capitolo 2.

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4. PROGETTO DELLA BERLINESE E VERIFICHE

Il valore dei parametri sopra indicati viene ridotto secondo la normativa vigente già citata in premessa, ed in particolare:

- SLU Geotecnico: collasso per rotazione della struttura di sosstegno – Approccio 1 adotttando la Combinazione 1 (A1 + M1 + R1) e la Combinazione 2 (A2 + M2 + R1), con R1 = 1;
- SLU Geotecnico: instabilità globale – Approccio 1 con la Combinazione 2 (A2 + M2 + R2), con R2 = 1.1,
- SLU strutturale: Approccio 1 Combinazione 1 (A1 + M1 + R1).

Per quanto riguarda i sovraccarichi, nei casi in cui sono presenti, i fattori amplificativi ad essi applicati sono:

Carichi permanenti svavorevoli: *EQU = 1.1 A1 = 1.3 A2 = 1.0*

Carichi variabili: *EQU = 1.5 A1 = 1.5 A2 = 1.3*

Le sezioni considerate sono rappresentate nelle Figure 3, 4, 5, 6 riprodotte alla fine del testo. Esse sono denominate: Sezione 1-a, Sezione 1-b, Sezione 4, Sezione 5 Sud, secondo la nomenclatura adottata nelle tavole tecniche di progetto. In sintesi queste le caratteristiche geometriche per ciascuna di esse:

Sezione 1-a

Pali accostati di diametro 100 cm e passo in orizzontale i = 110 cm

Massimo scavo: 7.03 metri

Piano terreno a tergo dell'opera: orizzontale

Lunghezza dei pali: L = 15 metri

Sezione 1-b

Pali accostati di diametro 60 cm e passo in orizzontale i = 70 cm

Massimo scavo: 1.80 metri

Piano terreno a tergo dell'opera: inclianto di circa 40 gradi

Lunghezza dei pali: L = 6 metri

Sezione 4

Pali accostati di diametro 100 cm e passo in orizzontale i = 110 cm

Massimo scavo: 7.81 metri

Piano terreno a tergo dell'opera: orizzontale

Lunghezza dei pali: L = 16 metri

Sezione 5 Sud

Pali accostati di diametro 80 cm e passo in orizzontale i = 90 cm

Massimo scavo: 5.53 metri

Piano terreno a tergo dell'opera: orizzontale

Lunghezza dei pali: L = 13 metri

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4.1 Verifica della stabilità delle berlinesi

Questa verifica viene condotta in Combinazione 1 e in Combinazione 2; essa riguarda la possibilità che l'opera ruoti rigidamente a seguito dell'azione esercitata dalla spinta attiva, con la spinta passiva che si oppone a tale rotazione. Con tale verifica viene determinata la minima infissione nel terreno dei pali che costituiscono la berlinese.

Relativamente alla Sezione 4, che presenta la massima profondità di scavo, in Figura 7 viene riportato il risultato del calcolo: per uno scavo di 7.83 metri è richiesta un'infissione di 7.39 metri, che comporta la lunghezza totale dei pali pari a 15.20 metri. La lunghezza adottata è pari a 16 metri.

Per la Sezione 1-a, che presenta uno scavo di 7.03 metri, la lunghezza totale richiesta è pari a 14.09 metri, con un incastro nel terreno di 7.06 metri. La lunghezza adottata è pari a 15 metri.

Per la Sezione 1-b, con scavo di soli 1.80 metri ma con terreno fortemente inclinato a monte, la lunghezza richiesta è pari a 4.24 metri con un incastro di 2.44 metri (in questo caso i pali hanno diametro di 60 cm). La lunghezza di palo adottata è pari a 6 metri.

Infine, per la Sezione 5 Sud, con scavo a 7.03 metri, con pali del diametro di 80 cm, la lunghezza minima richiesta è pari a 11.61 metri, con incastro pari a 6.09 metri. La lunghezza adottata è pari a 13 metri.

In Allegato 1 sono riportati i dettagli del calcolo in esame (figure e tabultato), per il caso della berlinese della sezione 4, considerando sempre la Combinazione 2, che rappresenta sempre il caso più sfavorevole.

4.2 Verifica del comportamento della berlinese

L'analisi del comportamento delle berlinesi, in questo caso comporta la presa in conto della deformabilità dell'opera e quindi la contemporanea variazione dell'entità della spinta del terreno su di essa esercitata, a partire da una situazione di spinta attiva a monte e di spinta passiva a valle. L'interazione tra terreno e opera di sostegno è espressa dal modulo di reazione orizzontale del terreno, che viene determinato a partire dal modulo di deformazione del terreno, strato per strato, e dalla sezione equivalente della berlinese.

Con questo approccio sono calcolati sia lo spostamento orizzontale (teorico) della berlinese sia le sollecitazioni su di esso agenti (momento e taglio). Noto il loro valore è possibile definire l'armatura del palo.

Limitatamente al caso della Sezione 4, le figure 8 e 9 mostrano i risultati ottenuti, per la sola Combinazione 2 che è la più gravosa.

In Allegato 2 sono riportati i dettagli del calcolo in esame (figure e tabulato), per il caso della berlinese della sezione 4, considerando sia la Combinazione 1 sia la Combinazione 2.

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4.3 Verifica della stabilità generale

Questa verifica, che riguarda una possibile rottura che comprende il terreno circostante e la berlinese, viene analizzata con il metodo di Bishop, che considera una ipotetica superficie di rottura di forma circolare. I parametri del terreno sono quelli della Combinazione 2, e quindi ridotti, nel caso dell'angolo di resistenza al taglio, di un fattore pari a 1.25 e di un fattore pari a 1.4 per la componente di coesione. Per la Sezione 4 la superficie di scorrimento che ha un fattore di mobilitazione maggiore (inverso del fattore di sicurezza) è quella mostrata in figura 10 in cui la berlinese è rappresentata dal segmento verticale di colore rosso. Il valore del fattore di mobilitazione vale per la superficie più sfavorevole 40.8 %, cui corrisponde un valore del fattore di sicurezza pari a:

$$F_S = 2.45$$

In Allegato 3 sono riportati i dettagli dall'analisi di stabilità della Sezione 4.

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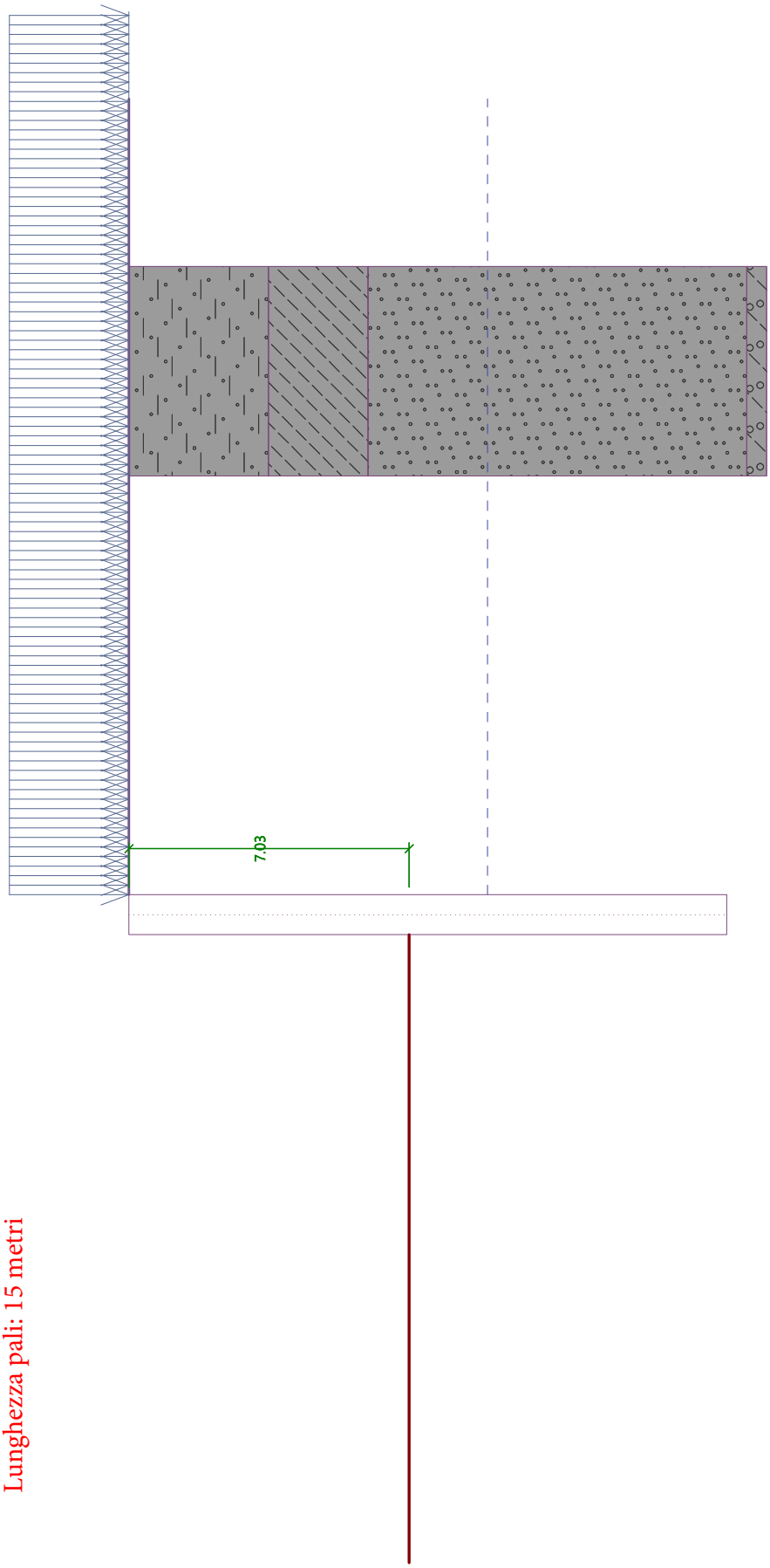
Name : **Stage : 3**



Sezione 1-a Stratigrafia 1
Berlinese di pali CFA diametro 100 cm, passo 110 cm
Massimo scavo: 7.03 metri
Sovraccarico: 5 kPa
Lunghezza pali: 15 metri

Figura 3 - Sezione 1-a: geometria

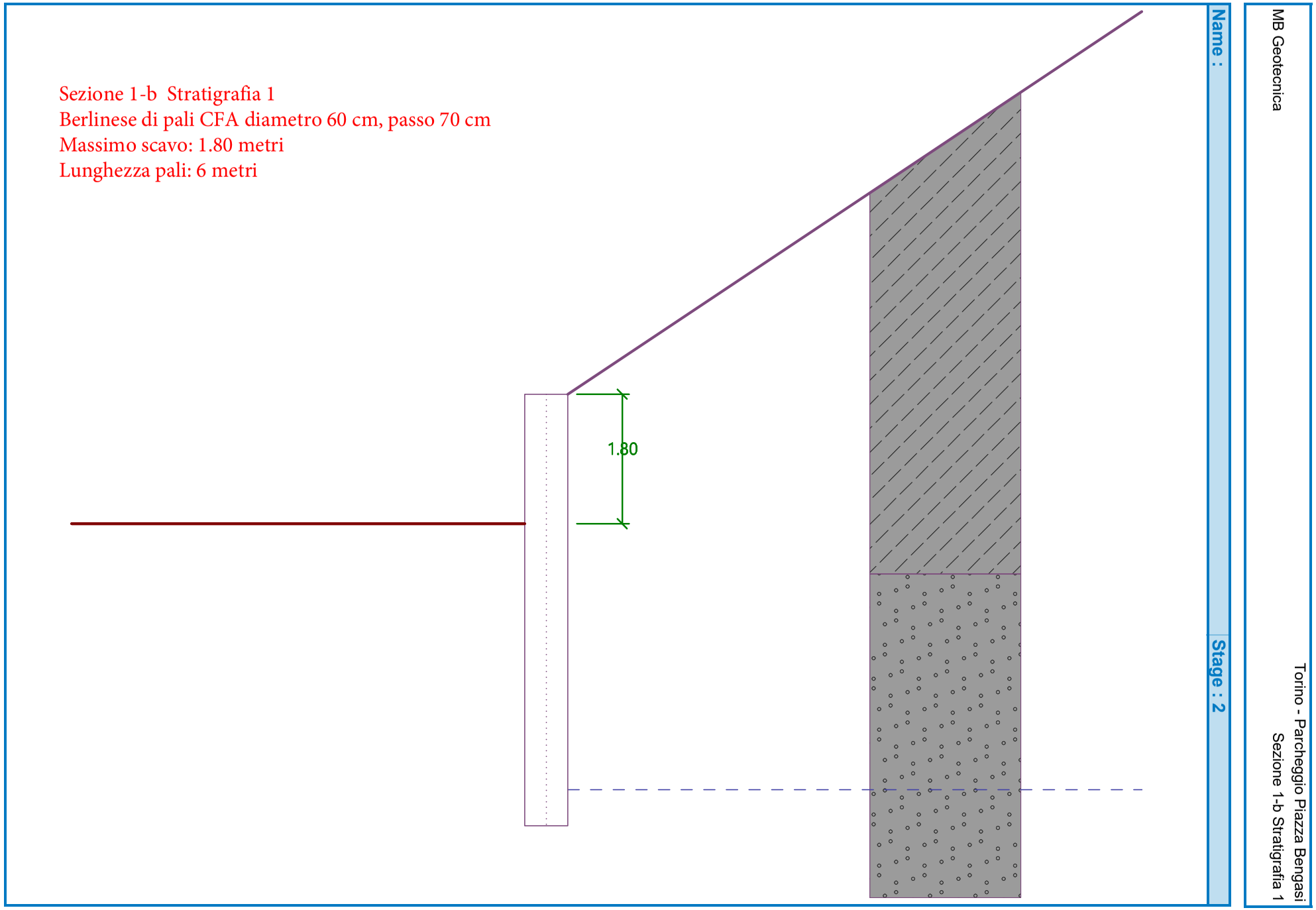
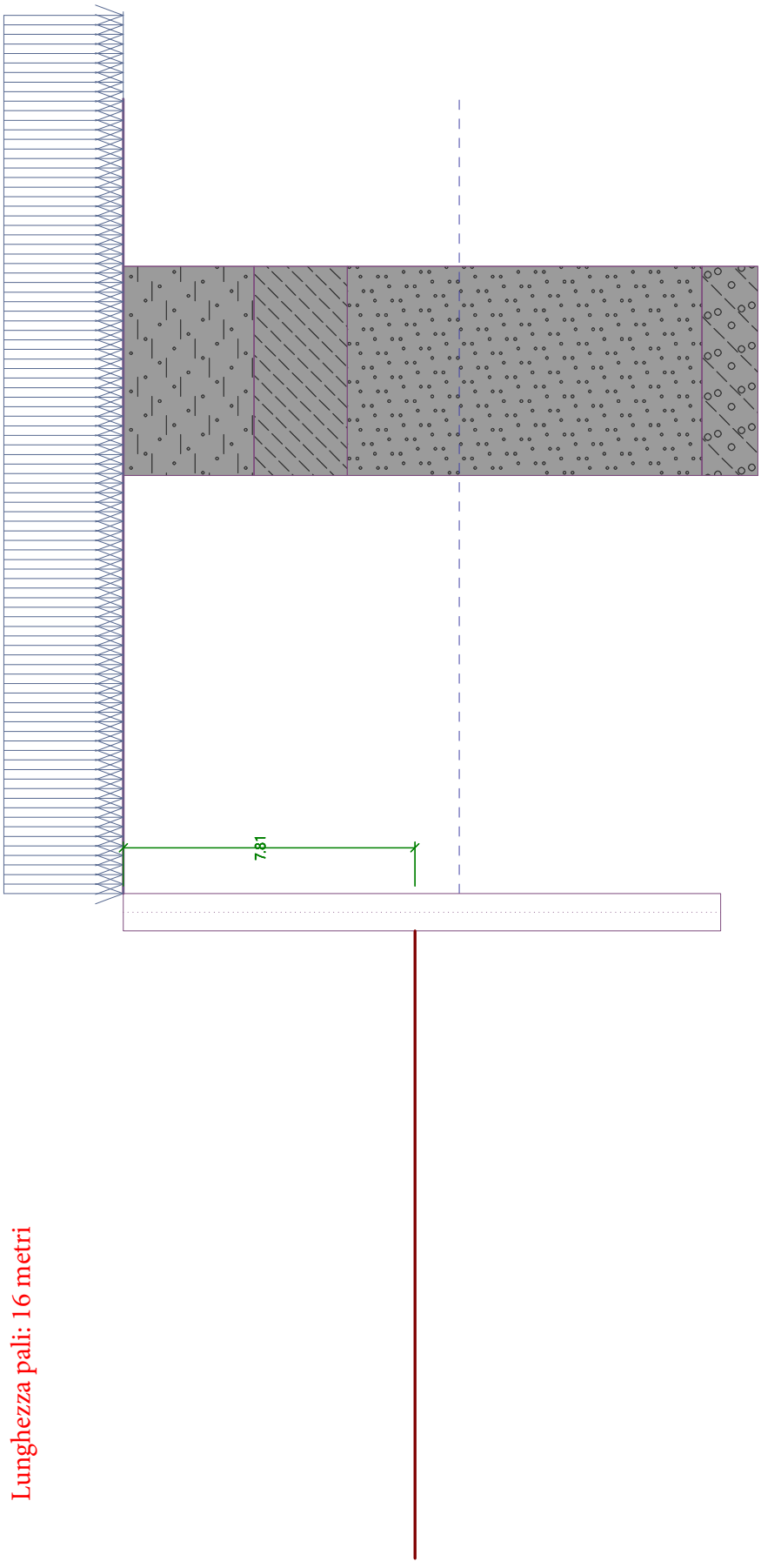


Figura 4 - Sezione 1-b: geometria

Name : **Stage : 3**



Sezione 4 Stratigrafia 1
Berlinese di pali CFA diametro 100 cm, passo 110 cm
Massimo scavo: 7.81 metri
Sovraccarico: 5 kPa
Lunghezza pali: 16 metri

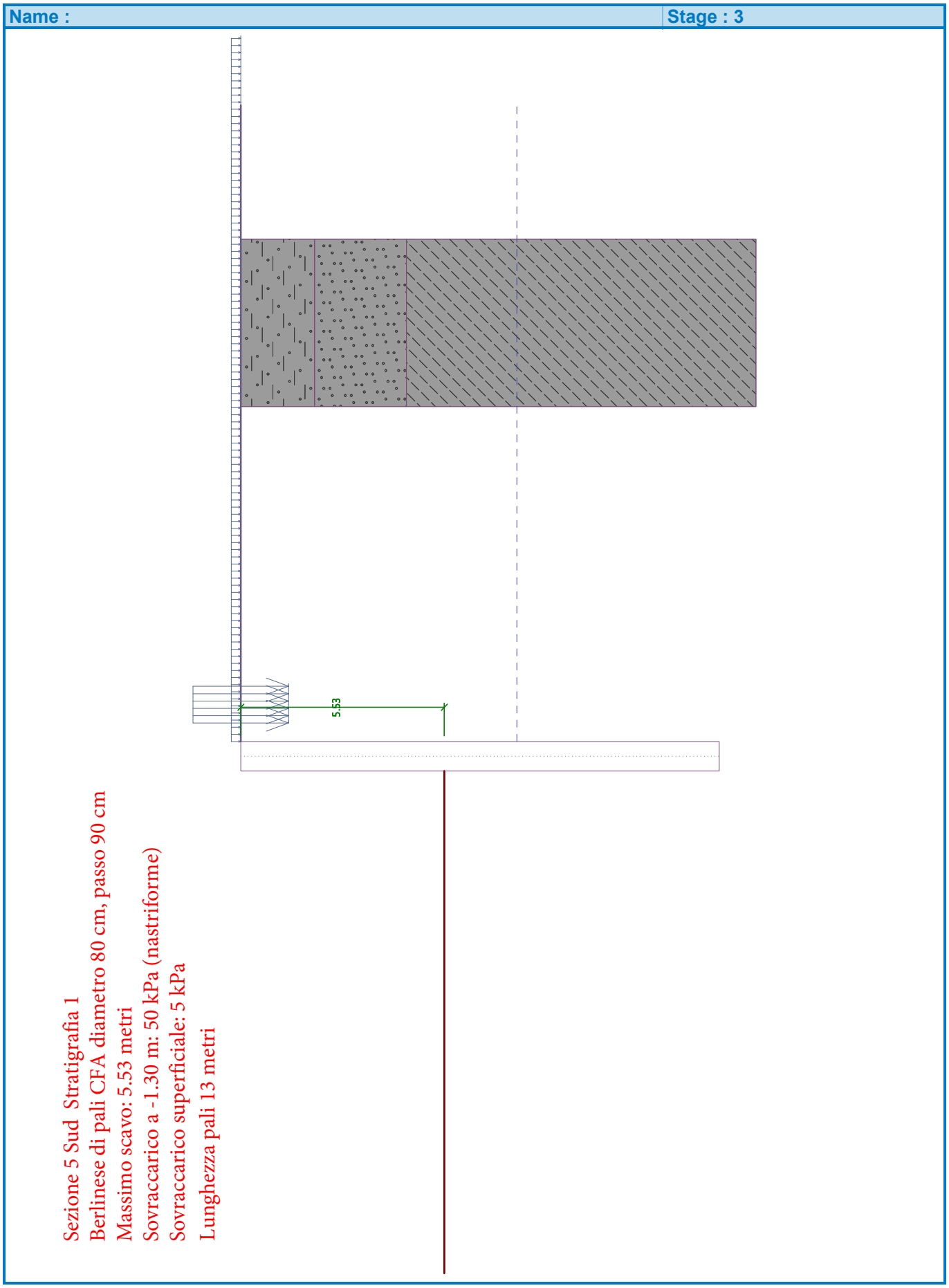


Figura 6 - Sezione 5 Sud: geometria

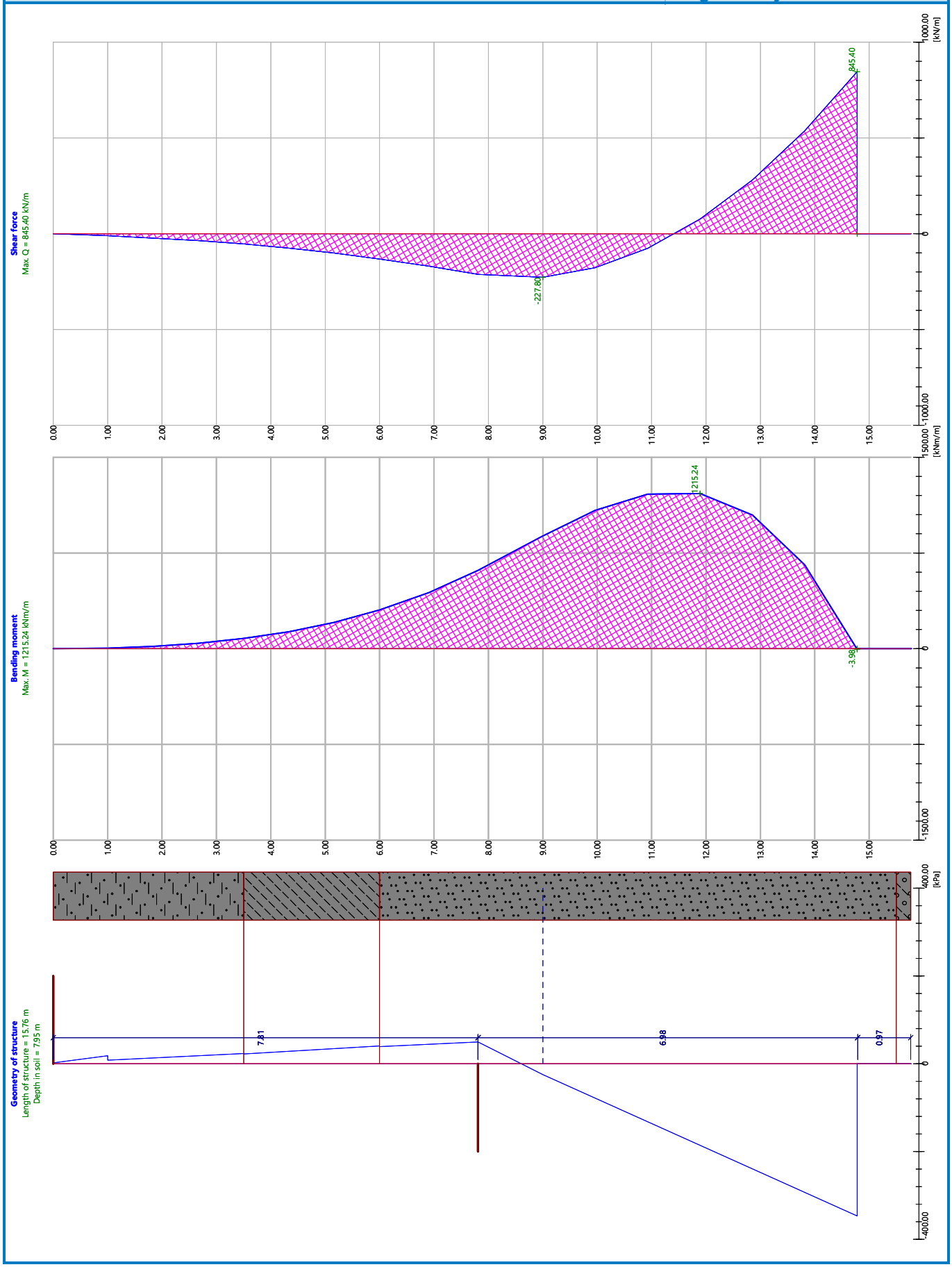


Figura 7 - Sezione 4: infissione minima e incastro

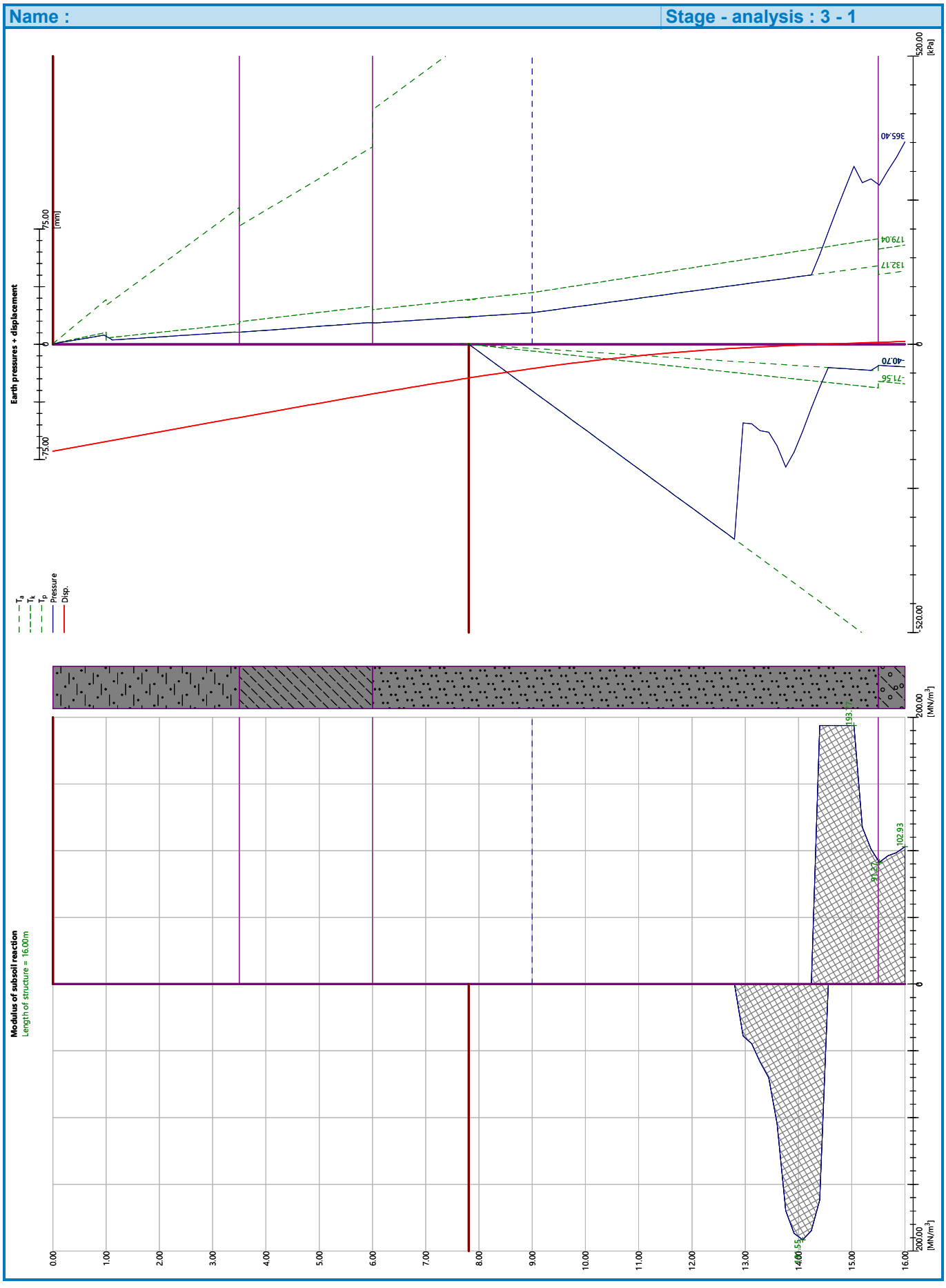


Figura 8 - Analisi del comportamento della berlinese della sezione 4

spostamento momento flettente taglio

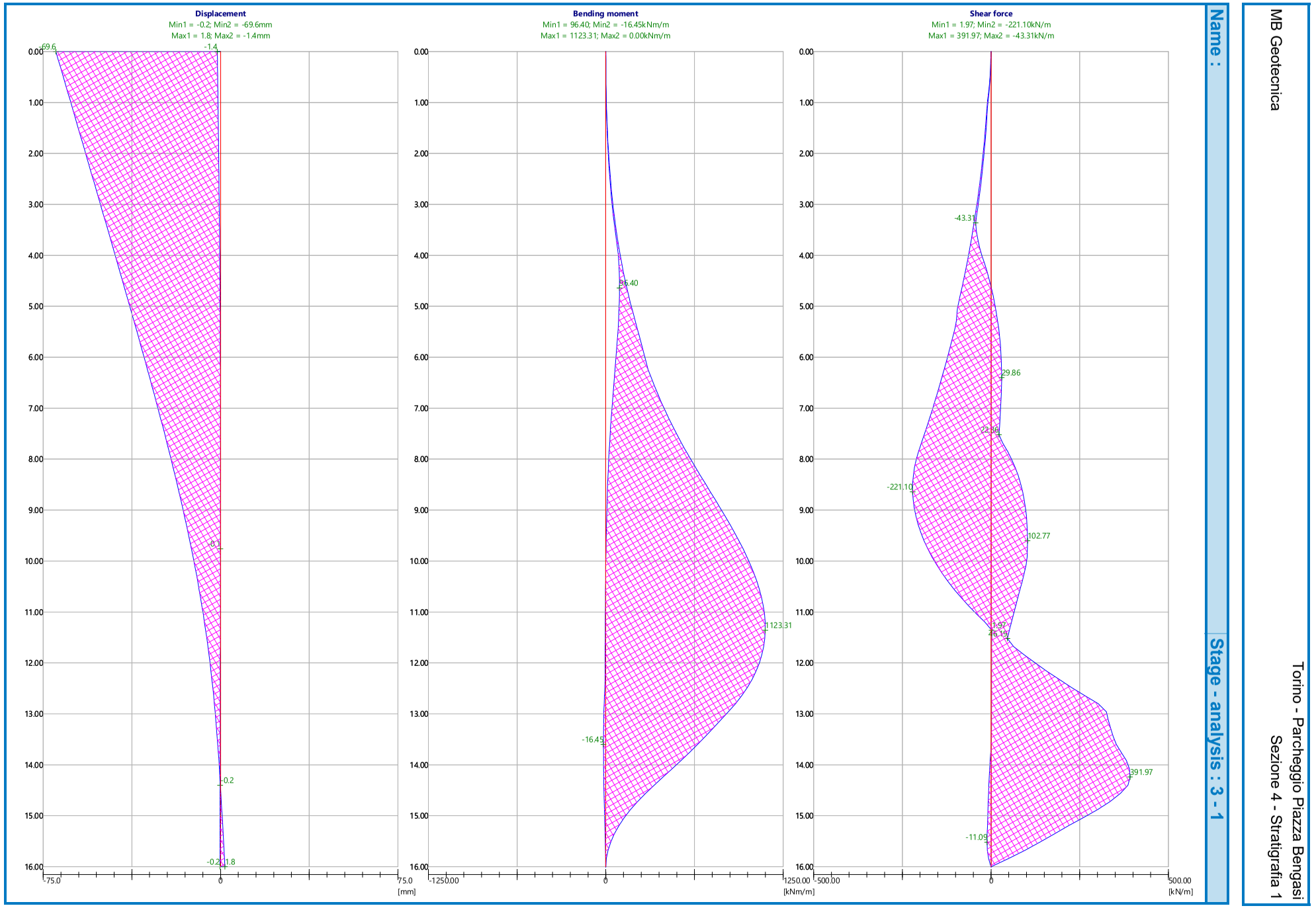
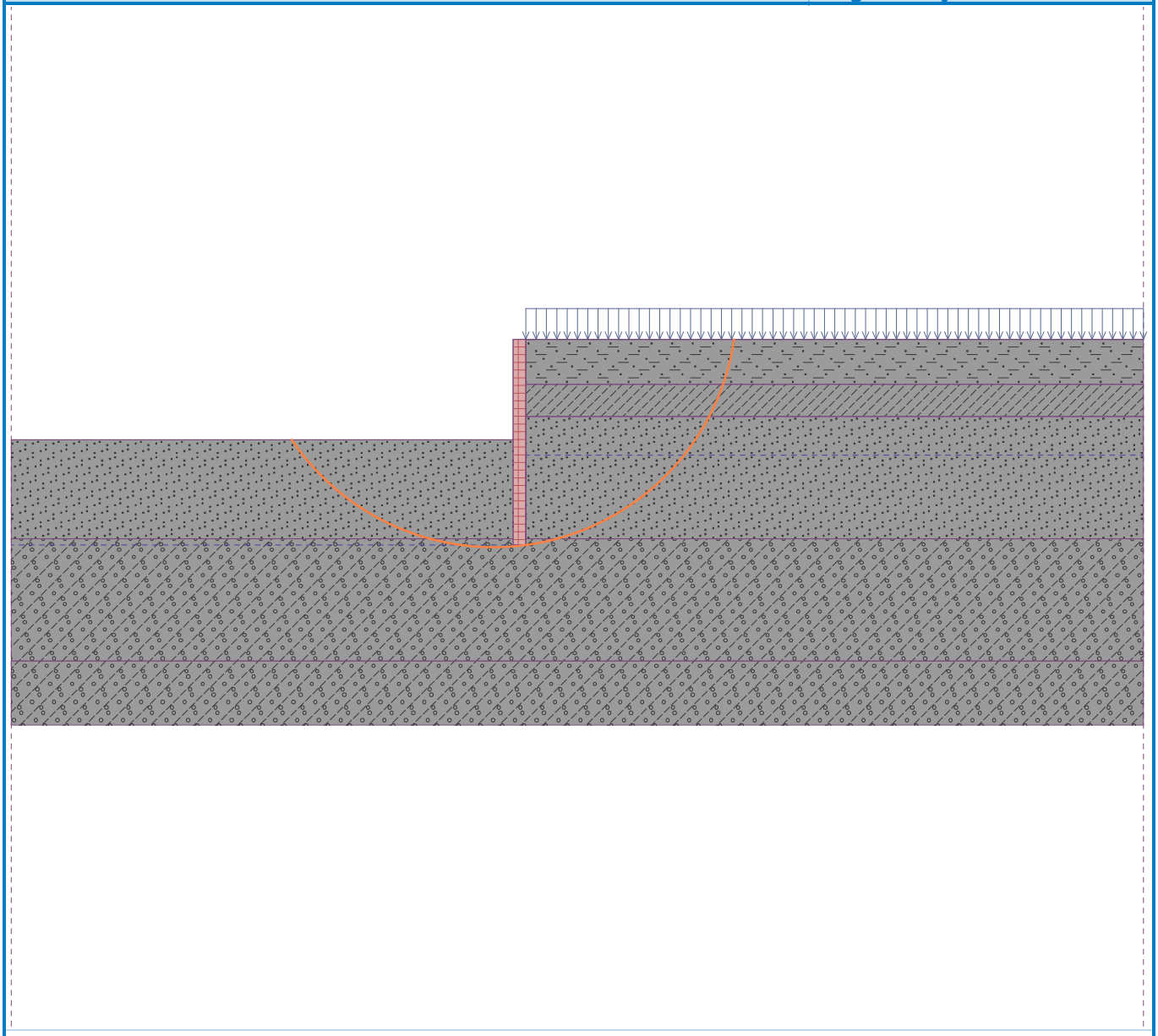


Figura 9 - Sezione 4: spostamento, momento e taglio della berlinese

Name :	Stage - analysis : 1 - 1



The slip surface after optimization.

Slope stability verification (Bishop)
Combination 1
Sum of active forces : F_a = 1295.38 kN/m
Sum of passive forces : F_p = 3830.34 kN/m

Sliding moment : M_a = 23265.08 kNm/m
Resisting moment : M_p = 68792.98 kNm/m
Utilization : 33.8 %

Slope stability ACCEPTABLE
Combination 2
Sum of active forces : F_a = 1339.52 kN/m
Sum of passive forces : F_p = 3279.70 kN/m

Sliding moment : M_a = 25330.39 kNm/m
Resisting moment : M_p = 62019.06 kNm/m
Utilization : 40.8 %

Slope stability ACCEPTABLE
Optimized slip surface for : Combination 2

Figura 10 - Sezione 4: stabilità generale

ALLEGATO 1

Sezione 4 – Calcolo dell’infissione minima per la stabilità della berlinese

Sheeting structure design

Input data

Project

Task : Torino - Parcheggio Piazza Bengasi
Part : Sezione 4 - Lato rampa
Description : Berlinese palo diametro 100 cm passo dei pali 1.1 m
Customer : ICIS srl - Torino
Author : MB Geotecnica
Date : 24/03/2022
Project ID : 891-21
Project number : 891-21-Sezione 4 D=1 m Stratigr 1

Settings

(input for current task)

Materials and standards

Concrete structures : EN 1992-1-1 (EC2)
Coefficients EN 1992-1-1 : standard
Steel structures : EN 1993-1-1 (EC3)
Partial factor on bearing capacity of steel cross section : γ_{M0} = 1.00
Timber structures : EN 1995-1-1 (EC5)
Partial factor for timber property : γ_M = 1.30
Modif. factor of load duration and moisture content : k_{mod} = 0.50
Coeff. of effective width for shear stress : k_{cr} = 0.67

Pressure analysis

Verification methodology : according to EN 1997
Active earth pressure calculation : Coulomb
Passive earth pressure calculation : Caquot-Kerisel
Earthquake analysis : Mononobe-Okabe
Design approach : 1 - reduction of actions and soil parameters

Partial factors on actions (A)

Transient design situation

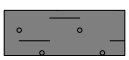
		Combination 1				Combination 2			
		Unfavourable		Favourable		Unfavourable		Favourable	
Permanent actions :	γ_G =	1.30	[–]	1.00	[–]	1.00	[–]	1.00	[–]
Variable actions :	γ_Q =	1.50	[–]	0.00	[–]	1.30	[–]	0.00	[–]
Water load :	γ_w =	1.35	[–]			1.00	[–]		

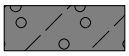
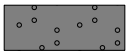
Partial factors for soil parameters (M)

Transient design situation

		Combination 1		Combination 2	
Partial factor on internal friction :	γ_ϕ =	1.00	[–]	1.25	[–]
Partial factor on effective cohesion :	γ_c =	1.00	[–]	1.25	[–]
Partial factor on undrained shear strength :	γ_{cu} =	1.00	[–]	1.40	[–]
Partial factor on Poisson's ratio :	γ_v =	1.00	[–]	1.00	[–]

Basic soil parameters

No.	Name	Pattern	φ_{ef} [°]	c_{ef} [kPa]	γ [kN/m³]	γ_{su} [kN/m³]	δ [°]
1	Strato 1 di riporto		32.00	0.00	18.00	8.50	16.00

No.	Name	Pattern	φ_{ef} [°]	c_{ef} [kPa]	γ [kN/m³]	γ_{su} [kN/m³]	δ [°]
2	Strato 2 limo sabbioso compatto		28.00	5.00	18.50	8.50	14.00
3	Strato 4 sabbia e ghiaia addensata		38.00	0.00	20.00	10.00	19.00
4	Strato 3 Sabbia limosa addensata		32.00	0.00	18.00	8.50	16.00

Soil parameters

Strato 1 di riporto

Unit weight : γ = 18.00 kN/m³
Stress-state : effective
Angle of internal friction : φ_{ef} = 32.00 °
Cohesion of soil : c_{ef} = 0.00 kPa
Angle of friction struc.-soil : δ = 16.00 °
Soil : cohesionless
Saturated unit weight : γ_{sat} = 18.50 kN/m³

Strato 2 limo sabbioso compatto

Unit weight : γ = 18.50 kN/m³
Stress-state : effective
Angle of internal friction : φ_{ef} = 28.00 °
Cohesion of soil : c_{ef} = 5.00 kPa
Angle of friction struc.-soil : δ = 14.00 °
Soil : cohesionless
Saturated unit weight : γ_{sat} = 18.50 kN/m³

Strato 4 sabbia e ghiaia addensata

Unit weight : γ = 20.00 kN/m³
Stress-state : effective
Angle of internal friction : φ_{ef} = 38.00 °
Cohesion of soil : c_{ef} = 0.00 kPa
Angle of friction struc.-soil : δ = 19.00 °
Soil : cohesionless
Saturated unit weight : γ_{sat} = 20.00 kN/m³

Strato 3 Sabbia limosa addensata

Unit weight : γ = 18.00 kN/m³
Stress-state : effective
Angle of internal friction : φ_{ef} = 32.00 °
Cohesion of soil : c_{ef} = 0.00 kPa
Angle of friction struc.-soil : δ = 16.00 °
Soil : cohesionless
Saturated unit weight : γ_{sat} = 18.50 kN/m³

Material of structure

Analysis of concrete structures carried out according to the standard EN 1992-1-1 (EC2).

Concrete: C 25/30

Cylinder compressive strength f_{ck} = 25.00 MPa
Tensile strength f_{ctm} = 2.60 MPa

Longitudinal steel: B500B

Yield strength f_{yk} = 500.00 MPa

Geological profile and assigned soils

No.	Thickness of layer t [m]	Depth z [m]	Assigned soil	Pattern
1	3.50	0.00 .. 3.50	Strato 1 di riporto	
2	2.50	3.50 .. 6.00	Strato 2 limo sabbioso compatto	
3	9.50	6.00 .. 15.50	Strato 3 Sabbia limosa addensata	
4	9.50	15.50 .. 25.00	Strato 4 sabbia e ghiaia addensata	
5	-	25.00 .. ∞	Strato 4 sabbia e ghiaia addensata	

Geometry of structure

Soil in front of wall is excavated to a depth of 7.81 m.

Cross-section

Cross-section name : Pile curtain d = 1.00 m; a = 1.10 m
Material of pile : concrete
Computed coefficient of pressure reduction below the ditch = 1.00
Area of cross-section A = 7.14E-01 m^2/m
Moment of inertia I = 4.46E-02 m^4/m
Elastic modulus E = 31000.00 MPa
Shear modulus G = 12917.00 MPa

Pressure acting on structure

Type of pressure : active
Minimum pressure is considered as $\sigma_{a,min} = 0.20\sigma_z$
Type of redistribution : no redistribution

Terrain profile

Terrain behind the structure is flat.

Water influence

GWT behind the structure lies at a depth of 9.00 m
The evolution of tensile cracks is considered in the analyses. Depth of cracks is 1.00 m.

Input surface surcharges

No.	Surcharge new	Surcharge change	Action	Mag.1 [kN/m²]	Mag.2 [kN/m²]	Ord.x x [m]	Length l [m]	Depth z [m]
1	Yes		variable	5.00				on terrain

No.	Name
1	Carico 1

Settings of the stage of construction

Design situation : transient

Verification No. 1

Design of non-anchored wall

Combination No. 2
Coeff. of reduction of passive pressure = 1.00
Max. value of shear force = 845.40 kN/m
Max. value of moment = 1215.24 kNm/m
Required depth of structure in soil = 7.95 m
Overall length of structure = 15.76 m

Distribution of pressure and internal forces along the structure

Depth [m]	Act.Press. [kPa]	Pass.Press. [kPa]	Total Pressure [kPa]	Shear Force [kN/m]	Moment [kNm/m]
0.00	2.19	0.00	2.19	0.00	0.00
1.00	18.24	0.00	18.24	-10.21	3.77
1.00	8.24	0.00	8.24	-10.21	3.77
1.83	13.28	0.00	13.28	-23.35	18.04
2.67	18.33	0.00	18.33	-36.52	42.69
3.50	23.37	0.00	23.37	-53.89	80.06
3.50	22.41	0.00	22.41	-53.89	80.06
4.33	28.40	0.00	28.40	-75.06	133.44
5.17	34.39	0.00	34.39	-101.22	206.55
6.00	40.38	0.00	40.38	-132.38	303.54
6.00	38.92	0.00	38.92	-132.38	303.54
6.90	44.40	0.00	44.40	-170.08	440.03
7.81	49.88	0.00	49.88	-212.74	612.88
9.00	57.08	-81.65	-24.57	-227.80	883.79
9.96	69.46	-147.74	-78.28	-178.26	1083.51
10.93	81.85	-213.83	-131.98	-77.00	1210.61
11.89	94.24	-279.92	-185.69	76.00	1215.24
12.85	106.62	-346.01	-239.39	280.74	1047.58
13.82	119.01	-412.11	-293.10	537.20	657.78
14.78	131.39	-478.20	-346.80	845.40	-3.98

ALLEGATO 2

Sezione 4 – Analisi del comportamento della berlinese

Sheeting structure verification

Input data

Project

Task : Torino - Parcheggio Piazza Bengasi
Part : Sezione 4 - Stratigrafia 1
Description : Berlinese di pali D = 100 cm e interasse i = 1.10 m
Customer : ICIS srl
Author : MB Geotecnica
Date : 18/01/2022
Project ID : 891-21
Project number : 891-21-Sez. 4 Stratigr. 1

Settings

(input for current task)

Materials and standards

Concrete structures : EN 1992-1-1 (EC2)
Coefficients EN 1992-1-1 : standard
Steel structures : EN 1993-1-1 (EC3)
Partial factor on bearing capacity of steel cross section : γ_{M0} = 1.00
Timber structures : EN 1995-1-1 (EC5)
Partial factor for timber property : γ_M = 1.30
Modif. factor of load duration and moisture content : k_{mod} = 0.50
Coeff. of effective width for shear stress : k_{cr} = 0.67

Pressure analysis

Verification methodology : according to EN 1997
Active earth pressure calculation : Coulomb
Passive earth pressure calculation : Caquot-Kerisel
Analysis method : dependent pressures
Earthquake analysis : Mononobe-Okabe
Modulus of subsoil reaction : standard
Consider reduction of the modulus of subsoil reaction for a braced sheeting
Design approach : 1 - reduction of actions and soil parameters

Partial factors on actions (A)
Transient design situation

		Combination 1				Combination 2			
		Unfavourable		Favourable		Unfavourable		Favourable	
Permanent actions :	γ_G =	1.30	[–]	1.00	[–]	1.00	[–]	1.00	[–]
Variable actions :	γ_Q =	1.50	[–]	0.00	[–]	1.30	[–]	0.00	[–]
Water load :	γ_w =	1.35	[–]			1.00	[–]		

Partial factors for soil parameters (M)
Transient design situation

		Combination 1		Combination 2	
Partial factor on internal friction :	γ_ϕ =	1.00	[–]	1.25	[–]
Partial factor on effective cohesion :	γ_c =	1.00	[–]	1.25	[–]
Partial factor on undrained shear strength :	γ_{cu} =	1.00	[–]	1.40	[–]
Partial factor on Poisson's ratio :	γ_v =	1.00	[–]	1.00	[–]

Anchors

Verification methodology : Limit states (LSD)

Reduction coefficients			
Reduction. coeff of steel strength :	γ_s =	1.35	[–]
Reduction coefficient of pull out resistance (soil) :	γ_e =	1.35	[–]
Reduction coefficient of pull out resistance (grouting) :	γ_c =	1.35	[–]

Geometry of structure

Structure length = 16.00 m

Cross-section name : Pile curtain d = 1.00 m; a = 1.10 m
Material of pile : concrete
Computed coefficient of pressure reduction below the ditch = 1.00
Area of cross-section A = 7.14E-01 m^2/m
Moment of inertia I = 4.46E-02 m^4/m
Elastic modulus E = 31000.00 MPa
Shear modulus G = 12917.00 MPa

Material of structure

Analysis of concrete structures carried out according to the standard EN 1992-1-1 (EC2).

Concrete: C 25/30
Cylinder compressive strength f_{ck} = 25.00 MPa
Tensile strength f_{ctm} = 2.60 MPa
Elasticity modulus E_{cm} = 31000.00 MPa
Shear modulus G = 12917.00 MPa

Longitudinal steel: B500B
Yield strength f_{yk} = 500.00 MPa

Transverse steel: B500B
Yield strength f_{yk} = 500.00 MPa

Modulus of reaction

Modulus of subsoil reaction computed from deformation characteristics of soils.

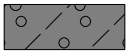
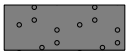
Basic soil parameters

No.	Name	Pattern	φ_{ef} [°]	c_{ef} [kPa]	γ [kN/m³]	γ_{su} [kN/m³]	δ [°]
1	Strato 1 Riporto		32.00	0.00	18.50	9.00	16.00
2	Strato 2 Limo sabbioso compatto		28.00	5.00	18.50	8.50	14.00
3	Strato 4 sabbia ghiaiosa addensata		38.00	0.00	20.00	10.00	19.00
4	Strato 3 Sabbia limosa		32.00	0.00	18.50	9.00	16.00

All soils are considered as cohesionless for at rest pressure analysis.

Parameters of soils to compute modulus of subsoil reaction (iterate)

No.	Name	Pattern	v [–]	E_{oed} [MPa]	E_{def} [MPa]	m [–]
1	Strato 1 Riporto		0.30	-	25.00	0.30
2	Strato 2 Limo sabbioso compatto		0.30	-	30.00	0.30

No.	Name	Pattern	v [–]	E_{oed} [MPa]	E_{def} [MPa]	m [–]
3	Strato 4 sabbia ghiaiosa addensata		0.30	-	60.00	0.20
4	Strato 3 Sabbia limosa		0.30	-	30.00	0.30

Soil parameters

Strato 1 Riporto

Unit weight :	γ	=	18.50 kN/m³
Stress-state :	effective		
Angle of internal friction :	φ_{ef}	=	32.00 °
Cohesion of soil :	c_{ef}	=	0.00 kPa
Angle of friction struc.-soil :	δ	=	16.00 °
Soil :	cohesionless		
Deformation modulus :	E_{def}	=	25.00 MPa
Poisson's ratio :	v	=	0.30
Coeff. of structural strength :	m	=	0.30
Saturated unit weight :	γ_{sat}	=	19.00 kN/m³

Strato 2 Limo sabbioso compatto

Unit weight :	γ	=	18.50 kN/m³
Stress-state :	effective		
Angle of internal friction :	φ_{ef}	=	28.00 °
Cohesion of soil :	c_{ef}	=	5.00 kPa
Angle of friction struc.-soil :	δ	=	14.00 °
Soil :	cohesionless		
Deformation modulus :	E_{def}	=	30.00 MPa
Poisson's ratio :	v	=	0.30
Coeff. of structural strength :	m	=	0.30
Saturated unit weight :	γ_{sat}	=	18.50 kN/m³

Strato 4 sabbia ghiaiosa addensata

Unit weight :	γ	=	20.00 kN/m³
Stress-state :	effective		
Angle of internal friction :	φ_{ef}	=	38.00 °
Cohesion of soil :	c_{ef}	=	0.00 kPa
Angle of friction struc.-soil :	δ	=	19.00 °
Soil :	cohesionless		
Deformation modulus :	E_{def}	=	60.00 MPa
Poisson's ratio :	v	=	0.30
Coeff. of structural strength :	m	=	0.20
Saturated unit weight :	γ_{sat}	=	20.00 kN/m³

Strato 3 Sabbia limosa

Unit weight :	γ	=	18.50 kN/m³
Stress-state :	effective		
Angle of internal friction :	φ_{ef}	=	32.00 °
Cohesion of soil :	c_{ef}	=	0.00 kPa
Angle of friction struc.-soil :	δ	=	16.00 °
Soil :	cohesionless		
Deformation modulus :	E_{def}	=	30.00 MPa
Poisson's ratio :	v	=	0.30
Coeff. of structural strength :	m	=	0.30
Saturated unit weight :	γ_{sat}	=	19.00 kN/m³

Geological profile and assigned soils

No.	Thickness of layer t [m]	Depth z [m]	Assigned soil	Pattern
1	3.50	0.00 .. 3.50	Strato 1 Riporto	
2	2.50	3.50 .. 6.00	Strato 2 Limo sabbioso compatto	
3	9.50	6.00 .. 15.50	Strato 3 Sabbia limosa	
4	9.50	15.50 .. 25.00	Strato 4 sabbia ghiaiosa addensata	
5	-	25.00 .. ∞	Strato 4 sabbia ghiaiosa addensata	

Excavation

Soil in front of wall is excavated to a depth of 3.00 m.

Terrain profile

Terrain behind the structure is flat.

Water influence

GWT behind the structure lies at a depth of 9.00 m
The evolution of tensile cracks is considered in the analyses. Depth of cracks is 1.00 m.

Input surface surcharges

No.	Surcharge		Action	Mag.1 [kN/m²]	Mag.2 [kN/m²]	Ord.x x [m]	Length l [m]	Depth z [m]
	new	change						
1	Yes		variable	5.00				on terrain

No.	Name
1	Fase 1

Global settings

Number of FEs to discretize wall = 100
Analysis of depending pressures : reduce according to comb.1
Minimum pressure is considered as $\sigma_{a,min} = 0.10\sigma_z$

Settings of the stage of construction

Design situation : transient

Analysis results (Stage of construction 1)

Distribution of pressures acting on the structure (in front and behind the wall)

Depth [m]	Ta,p [kPa]	Tk,p [kPa]	Tp,p [kPa]	Ta,z [kPa]	Tk,z [kPa]	Tp,z [kPa]
0.00	0.00	0.00	0.00	2.01	2.35	2.35
1.00	0.00	0.00	0.00	21.94	21.94	111.58
1.00	0.00	0.00	0.00	8.44	11.05	101.59
3.00	0.00	0.00	0.00	21.30	28.44	304.73
3.00	-0.00	-0.00	-0.01	21.30	28.44	304.74
3.50	-3.22	-4.35	-50.79	24.51	32.79	355.51
3.50	0.00	-4.91	-58.75	22.36	37.00	290.50
3.88	0.00	-8.60	-87.81	25.22	40.70	319.56
6.00	-16.18	-29.44	-251.88	41.40	61.54	483.63
6.00	-19.29	-26.09	-304.73	40.59	54.53	609.45
9.00	-38.58	-52.18	-609.45	59.88	80.62	914.18

Depth [m]	Ta,p [kPa]	Tk,p [kPa]	Tp,p [kPa]	Ta,z [kPa]	Tk,z [kPa]	Tp,z [kPa]
15.50	-80.38	-108.71	-1269.69	167.96	173.12	1300.38
15.50	-61.73	-88.88	-2005.85	149.35	153.40	2016.64
16.00	-64.40	-92.72	-2092.59	157.44	160.32	2065.01

Distributions of the modulus of subsoil reaction and internal forces on the structure

Depth [m]	kh,p [MN/m³]	kh,z [MN/m³]	Displacement [mm]	Pressure [kPa]	Shear Force [kN/m]	Moment [kNm/m]
0.00	0.00	0.00	-1.33	2.35	-0.00	0.00
0.80	0.00	0.00	-1.11	17.95	-8.01	2.36
1.60	0.00	0.00	-0.89	12.29	-18.72	13.58
2.40	0.00	0.00	-0.68	17.44	-30.62	33.04
3.20	0.00	0.00	-0.48	2.27	-44.59	63.53
4.00	197.40	0.00	-0.32	-45.48	-16.78	90.83
4.80	198.29	0.00	-0.19	-22.65	9.92	92.35
5.60	199.18	0.00	-0.11	-7.91	21.63	78.94
6.40	200.07	0.00	-0.06	2.31	23.45	60.30
7.04	200.79	0.00	-0.04	4.41	21.13	45.97
7.20	200.96	0.00	-0.04	4.49	20.42	42.64
8.00	201.86	0.00	-0.04	2.74	17.31	27.65
8.80	202.75	202.75	-0.05	8.92	10.57	15.99
9.60	203.64	203.64	-0.07	4.05	5.54	9.78
10.40	204.53	0.00	-0.09	-0.12	5.04	5.83
11.20	205.43	0.00	-0.12	0.55	4.84	1.83
12.00	206.32	0.00	-0.15	1.00	4.22	-1.82
12.80	207.21	0.00	-0.18	1.56	3.21	-4.83
13.60	208.10	0.00	-0.20	2.51	1.62	-6.82
14.40	208.99	0.00	-0.22	4.04	-0.96	-7.17
15.20	209.89	0.00	-0.24	6.20	-5.02	-4.90
16.00	403.71	0.00	-0.26	-39.49	0.00	0.00

Maximum shear force = 44.59 kN/m
Maximum moment = 94.23 kNm/m
Maximum displacement = 1.3 mm

Input data (Stage of construction 2)

Geological profile and assigned soils

No.	Thickness of layer t [m]	Depth z [m]	Assigned soil	Pattern
1	3.50	0.00 .. 3.50	Strato 1 Riporto	
2	2.50	3.50 .. 6.00	Strato 2 Limo sabbioso compatto	
3	9.50	6.00 .. 15.50	Strato 3 Sabbia limosa	
4	9.50	15.50 .. 25.00	Strato 4 sabbia ghiaiosa addensata	
5	-	25.00 .. ∞	Strato 4 sabbia ghiaiosa addensata	

Excavation

Soil in front of wall is excavated to a depth of 5.00 m.

Terrain profile

Terrain behind the structure is flat.

Water influence

GWT behind the structure lies at a depth of 9.00 m
The evolution of tensile cracks is considered in the analyses. Depth of cracks is 1.00 m.

Input surface surcharges

No.	Surcharge		Action	Mag.1	Mag.2	Ord.x	Length	Depth
	new	change		[kN/m²]	[kN/m²]	x [m]	l [m]	z [m]
1	No	No	variable	5.00				on terrain

No.	Name
1	Fase 1

Settings of the stage of construction

Design situation : transient

Analysis results (Stage of construction 2)

Distribution of pressures acting on the structure (in front and behind the wall)

Depth [m]	Ta,p [kPa]	Tk,p [kPa]	Tp,p [kPa]	Ta,z [kPa]	Tk,z [kPa]	Tp,z [kPa]
0.00	0.00	0.00	0.00	2.01	2.35	2.35
1.00	0.00	0.00	0.00	21.94	21.94	111.58
1.00	0.00	0.00	0.00	8.44	11.05	101.59
3.50	0.00	0.00	0.00	24.51	32.79	355.51
3.50	0.00	0.00	0.00	22.36	37.00	290.50
5.00	0.00	0.00	0.00	33.78	51.73	406.38
5.00	0.00	-0.00	-20.14	33.78	51.73	406.39
5.88	0.00	-8.60	-87.81	40.46	60.33	474.06
6.00	-0.94	-9.81	-97.38	41.40	61.54	483.63
6.00	-6.43	-8.70	-101.58	40.59	54.53	609.45
9.00	-25.72	-34.79	-406.30	59.88	80.62	914.18
15.50	-67.52	-91.31	-1066.54	167.96	173.12	1300.38
15.50	-51.85	-74.66	-1684.91	149.35	153.40	2016.64
16.00	-54.52	-78.50	-1771.65	157.44	160.32	2065.01

Distributions of the modulus of subsoil reaction and internal forces on the structure

Depth [m]	kh,p [MN/m³]	kh,z [MN/m³]	Displacement [mm]	Pressure [kPa]	Shear Force [kN/m]	Moment [kNm/m]
0.00	0.00	0.00	-7.46	2.35	0.00	-0.00
0.80	0.00	0.00	-6.57	17.95	-8.01	2.36
1.60	0.00	0.00	-5.70	12.29	-18.72	13.58
2.40	0.00	0.00	-4.82	17.44	-30.62	33.04
3.20	0.00	0.00	-3.97	22.58	-46.63	63.67
4.00	0.00	0.00	-3.14	26.17	-65.69	108.43
4.80	0.00	0.00	-2.36	32.26	-89.07	170.01
5.60	0.00	0.00	-1.67	-28.13	-91.33	245.83
6.40	109.58	0.00	-1.08	-86.99	-42.92	302.86
7.04	145.00	0.00	-0.71	-73.55	6.92	313.90
7.20	162.54	0.00	-0.64	-73.82	18.75	311.82
8.00	201.86	0.00	-0.33	-39.37	68.32	274.84

Depth [m]	kh,p [MN/m³]	kh,z [MN/m³]	Displacement [mm]	Pressure [kPa]	Shear Force [kN/m]	Moment [kNm/m]
8.80	202.75	0.00	-0.16	-5.97	84.97	211.75
9.60	203.64	0.00	-0.08	14.14	81.19	144.18
10.40	204.53	0.00	-0.07	22.85	65.69	84.96
11.20	205.43	0.00	-0.09	23.46	46.79	39.93
12.00	206.32	0.00	-0.14	20.11	29.21	9.71
12.80	207.21	0.00	-0.19	15.65	14.90	-7.70
13.60	208.10	0.00	-0.24	11.73	4.01	-15.06
14.40	208.99	0.00	-0.28	9.10	-4.23	-14.85
15.20	209.89	0.00	-0.32	7.76	-10.90	-8.73
16.00	403.71	0.00	-0.35	-61.60	0.00	0.00

Maximum shear force = 96.81 kN/m
Maximum moment = 314.08 kNm/m
Maximum displacement = 7.5 mm

Input data (Stage of construction 3)

Geological profile and assigned soils

No.	Thickness of layer t [m]	Depth z [m]	Assigned soil	Pattern
1	3.50	0.00 .. 3.50	Strato 1 Riporto	
2	2.50	3.50 .. 6.00	Strato 2 Limo sabbioso compatto	
3	9.50	6.00 .. 15.50	Strato 3 Sabbia limosa	
4	9.50	15.50 .. 25.00	Strato 4 sabbia ghiaiosa addensata	
5	-	25.00 .. ∞	Strato 4 sabbia ghiaiosa addensata	

Excavation

Soil in front of wall is excavated to a depth of 7.81 m.

Terrain profile

Terrain behind the structure is flat.

Water influence

GWT behind the structure lies at a depth of 9.00 m
The evolution of tensile cracks is considered in the analyses. Depth of cracks is 1.00 m.

Input surface surcharges

No.	Surcharge new	Surcharge change	Action	Mag.1 [kN/m²]	Mag.2 [kN/m²]	Ord.x x [m]	Length l [m]	Depth z [m]
1	No	Yes	variable	2.00				on terrain

No.	Name
1	Fase 3

Settings of the stage of construction

Design situation : transient

Analysis results (Stage of construction 3)

Distribution of pressures acting on the structure (in front and behind the wall)

Depth [m]	Ta,p [kPa]	Tk,p [kPa]	Tp,p [kPa]	Ta,z [kPa]	Tk,z [kPa]	Tp,z [kPa]
0.00	0.00	0.00	0.00	0.80	0.94	0.94
1.00	0.00	0.00	0.00	20.73	20.73	111.58
1.00	0.00	0.00	0.00	7.23	9.64	101.59
3.50	0.00	0.00	0.00	23.31	31.38	355.51
3.50	0.00	0.00	0.00	20.93	35.41	290.50
6.00	0.00	0.00	0.00	39.98	59.95	483.63
6.00	0.00	0.00	0.00	39.38	53.12	609.45
7.81	0.00	0.00	0.00	51.02	68.86	793.30
7.81	-0.00	-0.00	-0.01	51.02	68.86	793.31
9.00	-7.65	-10.35	-120.87	58.68	79.21	914.18
15.50	-49.45	-66.88	-781.12	166.76	171.71	1300.38
15.50	-37.98	-54.68	-1234.00	148.43	152.24	2016.64
16.00	-40.65	-58.52	-1320.74	156.51	159.17	2065.01

Distributions of the modulus of subsoil reaction and internal forces on the structure

Depth [m]	kh,p [MN/m³]	kh,z [MN/m³]	Displacement [mm]	Pressure [kPa]	Shear Force [kN/m]	Moment [kNm/m]
0.00	0.00	0.00	-63.45	0.95	0.00	0.00
0.80	0.00	0.00	-58.81	16.75	-7.03	1.97
1.60	0.00	0.00	-54.18	11.09	-16.78	12.01
2.40	0.00	0.00	-49.54	16.24	-27.71	29.54
3.20	0.00	0.00	-44.93	21.38	-42.76	57.45
4.00	0.00	0.00	-40.33	24.74	-60.74	98.70
4.80	0.00	0.00	-35.79	30.84	-82.97	155.86
5.60	0.00	0.00	-31.32	36.93	-110.08	232.76
6.40	0.00	0.00	-26.96	41.96	-141.72	333.23
7.04	0.00	0.00	-23.57	46.07	-169.89	432.80
7.20	0.00	0.00	-22.75	47.10	-177.35	460.58
8.00	0.00	0.00	-18.75	32.95	-215.25	617.96
8.80	0.00	0.00	-15.05	-43.17	-211.16	792.59
9.60	0.00	0.00	-11.71	-113.17	-148.04	939.96
10.40	0.00	0.00	-8.80	-181.13	-30.32	1014.93
11.20	22.47	0.00	-6.35	-77.99	106.66	977.45
12.00	26.35	0.00	-4.36	-43.39	153.83	871.38
12.80	55.37	0.00	-2.77	-74.78	204.23	730.45
13.60	102.44	0.00	-1.51	-70.84	261.30	543.80
14.40	187.10	0.00	-0.51	-2.22	307.17	312.57
15.20	0.00	193.78	0.36	226.52	214.43	90.65
16.00	0.00	146.42	1.17	333.63	0.00	0.00

Distributions of the modulus of subsoil reaction and internal forces on the structure - in detail

Depth [m]	kh,p [MN/m³]	kh,z [MN/m³]	Displacement [mm]	Pressure [kPa]	Shear Force [kN/m]	Moment [kNm/m]
0.00	0.00	0.00	-63.45	0.95	0.00	0.00
0.16	0.00	0.00	-62.52	3.99	-0.40	0.03
0.32	0.00	0.00	-61.60	7.18	-1.29	0.15

Depth [m]	kh,p [MN/m³]	kh,z [MN/m³]	Displacement [mm]	Pressure [kPa]	Shear Force [kN/m]	Moment [kNm/m]
0.48	0.00	0.00	-60.67	10.37	-2.69	0.46
0.64	0.00	0.00	-59.74	13.56	-4.61	1.04
0.80	0.00	0.00	-58.81	16.75	-7.03	1.97
0.96	0.00	0.00	-57.89	19.94	-9.97	3.32
1.12	0.00	0.00	-56.96	8.00	-12.20	5.12
1.28	0.00	0.00	-56.03	9.03	-13.56	7.18
1.44	0.00	0.00	-55.10	10.06	-15.09	9.47
1.60	0.00	0.00	-54.18	11.09	-16.78	12.01
1.76	0.00	0.00	-53.25	12.12	-18.64	14.85
1.92	0.00	0.00	-52.32	13.15	-20.66	17.99
2.08	0.00	0.00	-51.40	14.18	-22.85	21.47
2.24	0.00	0.00	-50.47	15.21	-25.20	25.31
2.40	0.00	0.00	-49.54	16.24	-27.71	29.54
2.56	0.00	0.00	-48.62	17.26	-30.39	34.19
2.72	0.00	0.00	-47.69	18.29	-33.24	39.27
2.88	0.00	0.00	-46.77	19.32	-36.25	44.83
3.04	0.00	0.00	-45.85	20.35	-39.42	50.88
3.20	0.00	0.00	-44.93	21.38	-42.76	57.45
3.36	0.00	0.00	-44.00	22.41	-46.26	64.57
3.52	0.00	0.00	-43.09	21.09	-49.74	72.26
3.68	0.00	0.00	-42.17	22.31	-53.21	80.49
3.84	0.00	0.00	-41.25	23.52	-56.88	89.30
4.00	0.00	0.00	-40.33	24.74	-60.74	98.70
4.16	0.00	0.00	-39.42	25.96	-64.80	108.74
4.32	0.00	0.00	-38.51	27.18	-69.05	119.45
4.48	0.00	0.00	-37.60	28.40	-73.50	130.85
4.64	0.00	0.00	-36.69	29.62	-78.14	142.98
4.80	0.00	0.00	-35.79	30.84	-82.97	155.86
4.96	0.00	0.00	-34.89	32.05	-88.00	169.54
5.12	0.00	0.00	-33.99	33.27	-93.23	184.03
5.28	0.00	0.00	-33.10	34.49	-98.65	199.38
5.44	0.00	0.00	-32.21	35.71	-104.27	215.61
5.60	0.00	0.00	-31.32	36.93	-110.08	232.76
5.76	0.00	0.00	-30.44	38.15	-116.08	250.85
5.92	0.00	0.00	-29.56	39.37	-122.29	269.92
6.08	0.00	0.00	-28.69	39.90	-128.63	289.99
6.24	0.00	0.00	-27.82	40.93	-135.09	311.08
6.40	0.00	0.00	-26.96	41.96	-141.72	333.23
6.56	0.00	0.00	-26.10	42.99	-148.52	356.44
6.72	0.00	0.00	-25.25	44.01	-155.48	380.76
6.88	0.00	0.00	-24.41	45.04	-162.60	406.21
7.04	0.00	0.00	-23.57	46.07	-169.89	432.80
7.20	0.00	0.00	-22.75	47.10	-177.35	460.58
7.36	0.00	0.00	-21.93	48.13	-184.96	489.56
7.52	0.00	0.00	-21.12	49.16	-192.75	519.78
7.68	0.00	0.00	-20.32	50.19	-200.70	551.25
7.81	0.00	0.00	-19.70	51.00	-207.07	576.94

Depth [m]	kh,p [MN/m³]	kh,z [MN/m³]	Displacement [mm]	Pressure [kPa]	Shear Force [kN/m]	Moment [kNm/m]
7.81	0.00	0.00	-19.66	50.64	-207.48	578.60
7.84	0.00	0.00	-19.53	48.17	-208.76	584.01
7.84	0.00	0.00	-19.53	48.17	-208.76	584.01
8.00	0.00	0.00	-18.75	32.95	-215.25	617.96
8.16	0.00	0.00	-17.99	17.72	-219.30	652.76
8.32	0.00	0.00	-17.23	2.50	-220.92	688.01
8.48	0.00	0.00	-16.49	-12.72	-220.10	723.32
8.64	0.00	0.00	-15.76	-27.95	-216.85	758.31
8.80	0.00	0.00	-15.05	-43.17	-211.16	792.59
8.96	0.00	0.00	-14.35	-58.39	-203.04	825.75
9.12	0.00	0.00	-13.66	-72.39	-192.57	857.43
9.28	0.00	0.00	-12.99	-85.98	-179.90	887.26
9.44	0.00	0.00	-12.34	-99.58	-165.06	914.88
9.60	0.00	0.00	-11.71	-113.17	-148.04	939.96
9.76	0.00	0.00	-11.09	-126.76	-128.84	962.14
9.92	0.00	0.00	-10.49	-140.35	-107.48	981.08
10.08	0.00	0.00	-9.91	-153.94	-83.93	996.42
10.24	0.00	0.00	-9.34	-167.53	-58.21	1007.82
10.40	0.00	0.00	-8.80	-181.13	-30.32	1014.93
10.56	0.00	0.00	-8.27	-194.72	-0.25	1017.40
10.72	0.00	0.00	-7.76	-208.31	31.99	1014.89
10.88	0.00	0.00	-7.28	-221.90	66.41	1007.05
11.04	23.91	0.00	-6.81	-99.01	92.53	993.41
11.20	22.47	0.00	-6.35	-77.99	106.66	977.45
11.36	22.82	0.00	-5.92	-68.97	118.41	959.42
11.52	23.45	0.00	-5.50	-61.59	128.86	939.61
11.68	24.22	0.00	-5.11	-54.84	138.18	918.22
11.84	25.12	0.00	-4.72	-48.53	146.46	895.43
12.00	26.35	0.00	-4.36	-43.39	153.83	871.38
12.16	28.91	0.00	-4.01	-43.23	160.79	846.18
12.32	35.10	0.00	-3.68	-55.29	168.74	819.79
12.48	45.30	0.00	-3.36	-76.40	179.40	791.91
12.64	51.14	0.00	-3.06	-78.95	191.89	762.17
12.80	55.37	0.00	-2.77	-74.78	204.23	730.45
12.96	60.92	0.00	-2.49	-72.28	216.04	696.79
13.12	67.95	0.00	-2.23	-70.86	227.56	661.26
13.28	76.29	0.00	-1.98	-69.23	238.84	623.91
13.44	87.29	0.00	-1.74	-69.00	249.99	584.75
13.60	102.44	0.00	-1.51	-70.84	261.30	543.80
13.76	124.25	0.00	-1.29	-75.56	273.19	500.98
13.92	148.74	0.00	-1.08	-74.46	285.38	456.23
14.08	166.84	0.00	-0.88	-58.83	296.17	409.64
14.24	186.27	0.00	-0.69	-37.59	304.00	361.55
14.40	187.10	0.00	-0.51	-2.22	307.17	312.57
14.56	180.05	0.00	-0.33	34.70	304.51	263.57
14.72	75.64	193.75	-0.15	90.09	295.14	215.39
14.88	0.00	193.76	0.02	153.73	275.19	169.62

Depth [m]	kh,p [MN/m³]	kh,z [MN/m³]	Displacement [mm]	Pressure [kPa]	Shear Force [kN/m]	Moment [kNm/m]
15.04	0.00	193.77	0.19	190.38	247.72	127.71
15.20	0.00	193.78	0.36	226.52	214.43	90.65
15.36	0.00	168.64	0.52	245.57	176.54	59.31
15.52	0.00	146.82	0.68	252.68	136.52	34.23
15.68	0.00	137.47	0.85	269.18	94.70	15.68
15.84	0.00	134.50	1.01	290.82	49.88	4.06
16.00	0.00	146.42	1.17	333.63	0.00	0.00

Maximum shear force = 307.17 kN/m
Maximum moment = 1017.40 kNm/m
Maximum displacement = 63.5 mm

Sheeting structure verification

Input data

Project

Task : Torino - Parcheggio Piazza Bengasi
Part : Sezione 4 - Stratigrafia 1
Description : Berlinese di pali D = 100 cm e interasse i = 1.10 m
Customer : ICIS srl
Author : MB Geotecnica
Date : 18/01/2022
Project ID : 891-21
Project number : 891-21-Sez. 4 Stratigr. 1

Settings

(input for current task)

Materials and standards

Concrete structures : EN 1992-1-1 (EC2)
Coefficients EN 1992-1-1 : standard
Steel structures : EN 1993-1-1 (EC3)
Partial factor on bearing capacity of steel cross section : γ_{M0} = 1.00
Timber structures : EN 1995-1-1 (EC5)
Partial factor for timber property : γ_M = 1.30
Modif. factor of load duration and moisture content : k_{mod} = 0.50
Coeff. of effective width for shear stress : k_{cr} = 0.67

Pressure analysis

Verification methodology : according to EN 1997
Active earth pressure calculation : Coulomb
Passive earth pressure calculation : Caquot-Kerisel
Analysis method : dependent pressures
Earthquake analysis : Mononobe-Okabe
Modulus of subsoil reaction : standard
Consider reduction of the modulus of subsoil reaction for a braced sheeting
Design approach : 1 - reduction of actions and soil parameters

Partial factors on actions (A)
Transient design situation

		Combination 1				Combination 2			
		Unfavourable		Favourable		Unfavourable		Favourable	
Permanent actions :	γ_G =	1.30	[–]	1.00	[–]	1.00	[–]	1.00	[–]
Variable actions :	γ_Q =	1.50	[–]	0.00	[–]	1.30	[–]	0.00	[–]
Water load :	γ_w =	1.35	[–]			1.00	[–]		

Partial factors for soil parameters (M)
Transient design situation

		Combination 1		Combination 2	
Partial factor on internal friction :	γ_ϕ =	1.00	[–]	1.25	[–]
Partial factor on effective cohesion :	γ_c =	1.00	[–]	1.25	[–]
Partial factor on undrained shear strength :	γ_{cu} =	1.00	[–]	1.40	[–]
Partial factor on Poisson's ratio :	γ_v =	1.00	[–]	1.00	[–]

Anchors

Verification methodology : Limit states (LSD)

Reduction coefficients			
Reduction. coeff of steel strength :	γ_s =	1.35	[–]
Reduction coefficient of pull out resistance (soil) :	γ_e =	1.35	[–]
Reduction coefficient of pull out resistance (grouting) :	γ_c =	1.35	[–]

Geometry of structure

Structure length = 16.00 m

Cross-section name : Pile curtain d = 1.00 m; a = 1.10 m
Material of pile : concrete
Computed coefficient of pressure reduction below the ditch = 1.00
Area of cross-section A = 7.14E-01 m^2/m
Moment of inertia I = 4.46E-02 m^4/m
Elastic modulus E = 31000.00 MPa
Shear modulus G = 12917.00 MPa

Material of structure

Analysis of concrete structures carried out according to the standard EN 1992-1-1 (EC2).

Concrete: C 25/30
Cylinder compressive strength f_{ck} = 25.00 MPa
Tensile strength f_{ctm} = 2.60 MPa
Elasticity modulus E_{cm} = 31000.00 MPa
Shear modulus G = 12917.00 MPa

Longitudinal steel: B500B
Yield strength f_{yk} = 500.00 MPa

Transverse steel: B500B
Yield strength f_{yk} = 500.00 MPa

Modulus of reaction

Modulus of subsoil reaction computed from deformation characteristics of soils.

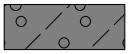
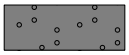
Basic soil parameters

No.	Name	Pattern	φ_{ef} [°]	c_{ef} [kPa]	γ [kN/m³]	γ_{su} [kN/m³]	δ [°]
1	Strato 1 Riporto		32.00	0.00	18.50	9.00	16.00
2	Strato 2 Limo sabbioso compatto		28.00	5.00	18.50	8.50	14.00
3	Strato 4 sabbia ghiaiosa addensata		38.00	0.00	20.00	10.00	19.00
4	Strato 3 Sabbia limosa		32.00	0.00	18.50	9.00	16.00

All soils are considered as cohesionless for at rest pressure analysis.

Parameters of soils to compute modulus of subsoil reaction (iterate)

No.	Name	Pattern	v [–]	E_{oed} [MPa]	E_{def} [MPa]	m [–]
1	Strato 1 Riporto		0.30	-	25.00	0.30
2	Strato 2 Limo sabbioso compatto		0.30	-	30.00	0.30

No.	Name	Pattern	v [–]	E_{oed} [MPa]	E_{def} [MPa]	m [–]
3	Strato 4 sabbia ghiaiosa addensata		0.30	-	60.00	0.20
4	Strato 3 Sabbia limosa		0.30	-	30.00	0.30

Soil parameters

Strato 1 Riporto

Unit weight :	γ	=	18.50 kN/m³
Stress-state :	effective		
Angle of internal friction :	φ_{ef}	=	32.00 °
Cohesion of soil :	c_{ef}	=	0.00 kPa
Angle of friction struc.-soil :	δ	=	16.00 °
Soil :	cohesionless		
Deformation modulus :	E_{def}	=	25.00 MPa
Poisson's ratio :	v	=	0.30
Coeff. of structural strength :	m	=	0.30
Saturated unit weight :	γ_{sat}	=	19.00 kN/m³

Strato 2 Limo sabbioso compatto

Unit weight :	γ	=	18.50 kN/m³
Stress-state :	effective		
Angle of internal friction :	φ_{ef}	=	28.00 °
Cohesion of soil :	c_{ef}	=	5.00 kPa
Angle of friction struc.-soil :	δ	=	14.00 °
Soil :	cohesionless		
Deformation modulus :	E_{def}	=	30.00 MPa
Poisson's ratio :	v	=	0.30
Coeff. of structural strength :	m	=	0.30
Saturated unit weight :	γ_{sat}	=	18.50 kN/m³

Strato 4 sabbia ghiaiosa addensata

Unit weight :	γ	=	20.00 kN/m³
Stress-state :	effective		
Angle of internal friction :	φ_{ef}	=	38.00 °
Cohesion of soil :	c_{ef}	=	0.00 kPa
Angle of friction struc.-soil :	δ	=	19.00 °
Soil :	cohesionless		
Deformation modulus :	E_{def}	=	60.00 MPa
Poisson's ratio :	v	=	0.30
Coeff. of structural strength :	m	=	0.20
Saturated unit weight :	γ_{sat}	=	20.00 kN/m³

Strato 3 Sabbia limosa

Unit weight :	γ	=	18.50 kN/m³
Stress-state :	effective		
Angle of internal friction :	φ_{ef}	=	32.00 °
Cohesion of soil :	c_{ef}	=	0.00 kPa
Angle of friction struc.-soil :	δ	=	16.00 °
Soil :	cohesionless		
Deformation modulus :	E_{def}	=	30.00 MPa
Poisson's ratio :	v	=	0.30
Coeff. of structural strength :	m	=	0.30
Saturated unit weight :	γ_{sat}	=	19.00 kN/m³

Geological profile and assigned soils

No.	Thickness of layer t [m]	Depth z [m]	Assigned soil	Pattern
1	3.50	0.00 .. 3.50	Strato 1 Riporto	
2	2.50	3.50 .. 6.00	Strato 2 Limo sabbioso compatto	
3	9.50	6.00 .. 15.50	Strato 3 Sabbia limosa	
4	9.50	15.50 .. 25.00	Strato 4 sabbia ghiaiosa addensata	
5	-	25.00 .. ∞	Strato 4 sabbia ghiaiosa addensata	

Excavation

Soil in front of wall is excavated to a depth of 3.00 m.

Terrain profile

Terrain behind the structure is flat.

Water influence

GWT behind the structure lies at a depth of 9.00 m
The evolution of tensile cracks is considered in the analyses. Depth of cracks is 1.00 m.

Input surface surcharges

No.	Surcharge		Action	Mag.1 [kN/m²]	Mag.2 [kN/m²]	Ord.x x [m]	Length l [m]	Depth z [m]
	new	change						
1	Yes		variable	5.00				on terrain

No.	Name
1	Fase 1

Global settings

Number of FEs to discretize wall = 100
Analysis of depending pressures : reduce according to comb.2
Minimum pressure is considered as $\sigma_{a,min} = 0.10\sigma_z$

Settings of the stage of construction

Design situation : transient

Analysis results (Stage of construction 1)

Distribution of pressures acting on the structure (in front and behind the wall)

Depth [m]	Ta,p [kPa]	Tk,p [kPa]	Tp,p [kPa]	Ta,z [kPa]	Tk,z [kPa]	Tp,z [kPa]
0.00	0.00	0.00	0.00	2.19	2.76	2.76
1.00	0.00	0.00	0.00	18.41	22.99	80.52
1.00	0.00	0.00	0.00	8.41	12.99	70.52
3.00	0.00	0.00	0.00	20.85	33.45	211.55
3.00	-0.00	-0.00	-0.01	20.85	33.45	211.56
3.50	-3.11	-5.11	-35.26	23.96	38.56	246.81
3.50	0.00	-5.63	-42.42	23.09	42.45	213.49
3.64	0.00	-7.21	-50.40	24.10	44.03	221.48
6.00	-16.97	-33.78	-184.98	41.06	70.59	356.06
6.00	-18.66	-30.68	-211.55	39.51	64.13	423.11
9.00	-37.32	-61.37	-423.11	58.17	94.82	634.66

Depth [m]	Ta,p [kPa]	Tk,p [kPa]	Tp,p [kPa]	Ta,z [kPa]	Tk,z [kPa]	Tp,z [kPa]
15.50	-77.76	-127.85	-881.47	142.84	192.16	922.65
15.50	-61.81	-108.68	-1270.30	126.88	173.10	1300.97
16.00	-64.49	-113.38	-1325.23	133.22	180.45	1333.44

Distributions of the modulus of subsoil reaction and internal forces on the structure

Depth [m]	kh,p [MN/m³]	kh,z [MN/m³]	Displacement [mm]	Pressure [kPa]	Shear Force [kN/m]	Moment [kNm/m]
0.00	0.00	0.00	-1.36	2.76	-0.00	-0.00
0.80	0.00	0.00	-1.14	15.16	-6.99	2.12
1.60	0.00	0.00	-0.93	12.14	-16.88	11.99
2.40	0.00	0.00	-0.71	17.12	-28.58	29.91
3.20	0.00	0.00	-0.52	7.99	-42.85	58.69
4.00	0.00	0.00	-0.35	-44.24	-26.00	89.09
4.80	198.29	0.00	-0.22	-30.36	6.09	95.83
5.60	199.18	199.18	-0.13	-14.62	24.35	82.83
6.40	200.07	200.07	-0.08	0.91	29.86	60.49
7.04	200.79	200.79	-0.06	7.93	26.72	42.15
7.20	200.96	200.96	-0.06	8.83	25.37	37.98
8.00	201.86	201.86	-0.06	9.71	17.60	20.74
8.80	202.75	202.75	-0.07	6.63	10.89	9.51
9.60	203.64	203.64	-0.08	4.52	6.62	2.60
10.40	204.53	204.53	-0.09	2.77	3.70	-1.44
11.20	205.43	205.43	-0.10	1.19	2.14	-3.70
12.00	206.32	206.32	-0.12	0.24	1.62	-5.16
12.80	207.21	207.21	-0.12	0.21	1.51	-6.41
13.60	208.10	208.10	-0.13	1.34	0.98	-7.47
14.40	208.99	208.99	-0.13	3.85	-1.00	-7.60
15.20	209.89	209.89	-0.13	7.74	-5.55	-5.19
16.00	403.71	0.00	-0.13	-31.95	-0.00	0.00

Maximum shear force = 43.31 kN/m
Maximum moment = 96.40 kNm/m
Maximum displacement = 1.4 mm

Input data (Stage of construction 2)

Geological profile and assigned soils

No.	Thickness of layer t [m]	Depth z [m]	Assigned soil	Pattern
1	3.50	0.00 .. 3.50	Strato 1 Riporto	
2	2.50	3.50 .. 6.00	Strato 2 Limo sabbioso compatto	
3	9.50	6.00 .. 15.50	Strato 3 Sabbia limosa	
4	9.50	15.50 .. 25.00	Strato 4 sabbia ghiaiosa addensata	
5	-	25.00 .. ∞	Strato 4 sabbia ghiaiosa addensata	

Excavation

Soil in front of wall is excavated to a depth of 5.00 m.

Terrain profile

Terrain behind the structure is flat.

Water influence

GWT behind the structure lies at a depth of 9.00 m
The evolution of tensile cracks is considered in the analyses. Depth of cracks is 1.00 m.

Input surface surcharges

No.	Surcharge		Action	Mag.1	Mag.2	Ord.x	Length	Depth
	new	change		[kN/m²]	[kN/m²]	x [m]	l [m]	z [m]
1	No	No	variable	5.00				on terrain

No.	Name
1	Fase 1

Settings of the stage of construction

Design situation : transient

Analysis results (Stage of construction 2)

Distribution of pressures acting on the structure (in front and behind the wall)

Depth [m]	Ta,p [kPa]	Tk,p [kPa]	Tp,p [kPa]	Ta,z [kPa]	Tk,z [kPa]	Tp,z [kPa]
0.00	0.00	0.00	0.00	2.19	2.76	2.76
1.00	0.00	0.00	0.00	18.41	22.99	80.52
1.00	0.00	0.00	0.00	8.41	12.99	70.52
3.50	0.00	0.00	0.00	23.96	38.56	246.81
3.50	0.00	0.00	0.00	23.09	42.45	213.49
5.00	0.00	0.00	0.00	33.87	59.34	299.03
5.00	0.00	-0.00	-13.91	33.88	59.34	299.04
5.64	0.00	-7.21	-50.40	38.48	66.54	335.53
6.00	-2.59	-11.26	-70.93	41.06	70.59	356.06
6.00	-6.22	-10.23	-70.52	39.51	64.13	423.11
9.00	-24.88	-40.91	-282.07	58.17	94.82	634.66
15.50	-65.32	-107.39	-740.43	142.84	192.16	922.65
15.50	-51.92	-91.29	-1067.05	126.88	173.10	1300.97
16.00	-54.60	-95.99	-1121.99	133.22	180.45	1333.44

Distributions of the modulus of subsoil reaction and internal forces on the structure

Depth [m]	kh,p [MN/m³]	kh,z [MN/m³]	Displacement [mm]	Pressure [kPa]	Shear Force [kN/m]	Moment [kNm/m]
0.00	0.00	0.00	-8.44	2.76	0.00	0.00
0.80	0.00	0.00	-7.48	15.16	-6.99	2.12
1.60	0.00	0.00	-6.52	12.14	-16.88	11.99
2.40	0.00	0.00	-5.56	17.12	-28.58	29.91
3.20	0.00	0.00	-4.62	22.09	-44.27	58.78
4.00	0.00	0.00	-3.71	26.68	-63.57	101.68
4.80	0.00	0.00	-2.84	32.44	-87.21	161.69
5.60	0.00	0.00	-2.05	-9.93	-96.86	237.90
6.40	0.00	0.00	-1.37	-56.73	-71.30	307.69
7.04	125.58	0.00	-0.93	-91.12	-21.87	338.50
7.20	132.52	0.00	-0.83	-85.67	-7.71	340.84
8.00	201.86	0.00	-0.45	-68.92	57.87	320.05

Depth [m]	kh,p [MN/m³]	kh,z [MN/m³]	Displacement [mm]	Pressure [kPa]	Shear Force [kN/m]	Moment [kNm/m]
8.80	202.75	0.00	-0.21	-24.92	93.64	257.11
9.60	203.64	0.00	-0.10	-0.27	102.77	177.22
10.40	204.53	204.53	-0.06	36.89	87.78	98.30
11.20	205.43	205.43	-0.07	36.69	57.51	40.20
12.00	206.32	206.32	-0.10	28.46	31.18	5.17
12.80	207.21	207.21	-0.13	18.82	12.32	-11.72
13.60	208.10	208.10	-0.16	11.08	0.54	-16.45
14.40	208.99	208.99	-0.18	6.25	-6.20	-13.94
15.20	209.89	209.89	-0.19	3.94	-10.14	-7.28
16.00	403.71	0.00	-0.20	-43.34	-0.00	-0.00

Maximum shear force = 102.77 kN/m
Maximum moment = 340.96 kNm/m
Maximum displacement = 8.4 mm

Input data (Stage of construction 3)

Geological profile and assigned soils

No.	Thickness of layer t [m]	Depth z [m]	Assigned soil	Pattern
1	3.50	0.00 .. 3.50	Strato 1 Riporto	
2	2.50	3.50 .. 6.00	Strato 2 Limo sabbioso compatto	
3	9.50	6.00 .. 15.50	Strato 3 Sabbia limosa	
4	9.50	15.50 .. 25.00	Strato 4 sabbia ghiaiosa addensata	
5	-	25.00 .. ∞	Strato 4 sabbia ghiaiosa addensata	

Excavation

Soil in front of wall is excavated to a depth of 7.81 m.

Terrain profile

Terrain behind the structure is flat.

Water influence

GWT behind the structure lies at a depth of 9.00 m
The evolution of tensile cracks is considered in the analyses. Depth of cracks is 1.00 m.

Input surface surcharges

No.	Surcharge new	Surcharge change	Action	Mag.1 [kN/m²]	Mag.2 [kN/m²]	Ord.x x [m]	Length l [m]	Depth z [m]
1	No	Yes	variable	2.00				on terrain

No.	Name
1	Fase 3

Settings of the stage of construction

Design situation : transient

Analysis results (Stage of construction 3)

Distribution of pressures acting on the structure (in front and behind the wall)

Depth [m]	Ta,p [kPa]	Tk,p [kPa]	Tp,p [kPa]	Ta,z [kPa]	Tk,z [kPa]	Tp,z [kPa]
0.00	0.00	0.00	0.00	0.87	1.11	1.11
1.00	0.00	0.00	0.00	17.09	21.33	80.52
1.00	0.00	0.00	0.00	7.10	11.33	70.52
3.50	0.00	0.00	0.00	22.65	36.90	246.81
3.50	0.00	0.00	0.00	21.57	40.62	213.49
6.00	0.00	0.00	0.00	39.55	68.77	356.06
6.00	0.00	0.00	0.00	38.20	62.47	423.11
7.81	0.00	0.00	0.00	49.46	80.99	550.74
7.81	-0.00	-0.00	-0.01	49.46	80.99	550.75
9.00	-7.40	-12.17	-83.92	56.86	93.16	634.66
15.50	-47.84	-78.65	-542.28	141.53	190.50	922.65
15.50	-38.03	-66.86	-781.49	125.84	171.69	1300.97
16.00	-40.70	-71.56	-836.42	132.17	179.04	1333.44

Distributions of the modulus of subsoil reaction and internal forces on the structure

Depth [m]	kh,p [MN/m³]	kh,z [MN/m³]	Displacement [mm]	Pressure [kPa]	Shear Force [kN/m]	Moment [kNm/m]
0.00	0.00	0.00	-69.61	0.87	-0.00	-0.00
0.80	0.00	0.00	-64.59	13.85	-5.89	1.66
1.60	0.00	0.00	-59.56	10.83	-14.74	10.24
2.40	0.00	0.00	-54.54	15.80	-25.39	26.03
3.20	0.00	0.00	-49.53	20.78	-40.02	51.92
4.00	0.00	0.00	-44.55	25.17	-58.16	90.98
4.80	0.00	0.00	-39.61	30.92	-80.60	146.17
5.60	0.00	0.00	-34.73	36.67	-107.63	221.16
6.40	0.00	0.00	-29.96	40.69	-138.65	319.49
7.04	0.00	0.00	-26.25	44.67	-165.96	416.83
7.20	0.00	0.00	-25.34	45.66	-173.19	443.96
8.00	0.00	0.00	-20.93	37.24	-210.44	597.57
8.80	0.00	0.00	-16.79	-14.20	-219.66	772.36
9.60	0.00	0.00	-13.01	-61.55	-188.96	938.30
10.40	0.00	0.00	-9.67	-107.54	-121.33	1064.87
11.20	0.00	0.00	-6.81	-153.54	-16.89	1122.62
12.00	0.00	0.00	-4.47	-199.53	124.33	1082.09
12.80	0.00	0.00	-2.62	-245.52	302.35	913.87
13.60	104.71	0.00	-1.19	-66.79	353.13	646.47
14.40	161.82	193.74	-0.06	84.28	385.83	341.79
15.20	0.00	117.48	0.91	245.76	217.36	91.17
16.00	0.00	102.93	1.83	324.70	0.00	-0.00

Distributions of the modulus of subsoil reaction and internal forces on the structure - in detail

Depth [m]	kh,p [MN/m³]	kh,z [MN/m³]	Displacement [mm]	Pressure [kPa]	Shear Force [kN/m]	Moment [kNm/m]
0.00	0.00	0.00	-69.61	0.87	-0.00	-0.00
0.16	0.00	0.00	-68.61	3.47	-0.35	0.02
0.32	0.00	0.00	-67.60	6.06	-1.11	0.13

Depth [m]	kh,p [MN/m³]	kh,z [MN/m³]	Displacement [mm]	Pressure [kPa]	Shear Force [kN/m]	Moment [kNm/m]
0.48	0.00	0.00	-66.60	8.66	-2.29	0.40
0.64	0.00	0.00	-65.59	11.26	-3.88	0.89
0.80	0.00	0.00	-64.59	13.85	-5.89	1.66
0.96	0.00	0.00	-63.58	16.45	-8.31	2.79
1.12	0.00	0.00	-62.57	7.84	-10.26	4.30
1.28	0.00	0.00	-61.57	8.84	-11.59	6.04
1.44	0.00	0.00	-60.56	9.83	-13.08	8.02
1.60	0.00	0.00	-59.56	10.83	-14.74	10.24
1.76	0.00	0.00	-58.55	11.82	-16.55	12.74
1.92	0.00	0.00	-57.55	12.82	-18.52	15.54
2.08	0.00	0.00	-56.55	13.81	-20.65	18.68
2.24	0.00	0.00	-55.54	14.81	-22.94	22.16
2.40	0.00	0.00	-54.54	15.80	-25.39	26.03
2.56	0.00	0.00	-53.54	16.80	-28.00	30.29
2.72	0.00	0.00	-52.53	17.79	-30.77	34.99
2.88	0.00	0.00	-51.53	18.79	-33.69	40.15
3.04	0.00	0.00	-50.53	19.78	-36.78	45.78
3.20	0.00	0.00	-49.53	20.78	-40.02	51.92
3.36	0.00	0.00	-48.53	21.78	-43.43	58.60
3.52	0.00	0.00	-47.53	21.72	-46.91	65.83
3.68	0.00	0.00	-46.54	22.87	-50.47	73.61
3.84	0.00	0.00	-45.54	24.02	-54.22	81.99
4.00	0.00	0.00	-44.55	25.17	-58.16	90.98
4.16	0.00	0.00	-43.55	26.32	-62.28	100.61
4.32	0.00	0.00	-42.56	27.47	-66.58	110.91
4.48	0.00	0.00	-41.58	28.62	-71.07	121.92
4.64	0.00	0.00	-40.59	29.77	-75.74	133.67
4.80	0.00	0.00	-39.61	30.92	-80.60	146.17
4.96	0.00	0.00	-38.63	32.07	-85.63	159.47
5.12	0.00	0.00	-37.65	33.22	-90.86	173.58
5.28	0.00	0.00	-36.67	34.37	-96.27	188.55
5.44	0.00	0.00	-35.70	35.52	-101.86	204.40
5.60	0.00	0.00	-34.73	36.67	-107.63	221.16
5.76	0.00	0.00	-33.77	37.82	-113.59	238.85
5.92	0.00	0.00	-32.81	38.97	-119.74	257.51
6.08	0.00	0.00	-31.86	38.70	-125.95	277.17
6.24	0.00	0.00	-30.91	39.69	-132.22	297.82
6.40	0.00	0.00	-29.96	40.69	-138.65	319.49
6.56	0.00	0.00	-29.03	41.68	-145.24	342.20
6.72	0.00	0.00	-28.10	42.68	-151.99	365.97
6.88	0.00	0.00	-27.17	43.67	-158.90	390.84
7.04	0.00	0.00	-26.25	44.67	-165.96	416.83
7.20	0.00	0.00	-25.34	45.66	-173.19	443.96
7.36	0.00	0.00	-24.44	46.66	-180.58	472.26
7.52	0.00	0.00	-23.55	47.65	-188.12	501.75
7.68	0.00	0.00	-22.67	48.65	-195.83	532.47
7.81	0.00	0.00	-21.98	49.43	-202.00	557.53

Depth [m]	kh,p [MN/m³]	kh,z [MN/m³]	Displacement [mm]	Pressure [kPa]	Shear Force [kN/m]	Moment [kNm/m]
7.81	0.00	0.00	-21.93	49.20	-202.40	559.15
7.84	0.00	0.00	-21.79	47.53	-203.66	564.43
8.00	0.00	0.00	-20.93	37.24	-210.44	597.57
8.16	0.00	0.00	-20.08	26.95	-215.57	631.68
8.32	0.00	0.00	-19.24	16.67	-219.06	666.47
8.48	0.00	0.00	-18.41	6.38	-220.91	701.69
8.64	0.00	0.00	-17.59	-3.91	-221.10	737.07
8.80	0.00	0.00	-16.79	-14.20	-219.66	772.36
8.96	0.00	0.00	-16.01	-24.48	-216.56	807.27
9.12	0.00	0.00	-15.23	-33.95	-211.89	841.57
9.28	0.00	0.00	-14.48	-43.15	-205.72	875.00
9.44	0.00	0.00	-13.74	-52.35	-198.08	907.32
9.60	0.00	0.00	-13.01	-61.55	-188.96	938.30
9.76	0.00	0.00	-12.31	-70.75	-178.38	967.71
9.92	0.00	0.00	-11.62	-79.95	-166.32	995.31
10.08	0.00	0.00	-10.95	-89.15	-152.80	1020.86
10.24	0.00	0.00	-10.30	-98.35	-137.80	1044.12
10.40	0.00	0.00	-9.67	-107.54	-121.33	1064.87
10.56	0.00	0.00	-9.05	-116.74	-103.38	1082.87
10.72	0.00	0.00	-8.46	-125.94	-83.97	1097.88
10.88	0.00	0.00	-7.89	-135.14	-63.08	1109.66
11.04	0.00	0.00	-7.34	-144.34	-40.72	1117.99
11.20	0.00	0.00	-6.81	-153.54	-16.89	1122.62
11.36	0.00	0.00	-6.30	-162.74	8.41	1123.31
11.52	0.00	0.00	-5.81	-171.93	35.18	1119.85
11.68	0.00	0.00	-5.34	-181.13	63.43	1111.98
11.84	0.00	0.00	-4.89	-190.33	93.14	1099.47
12.00	0.00	0.00	-4.47	-199.53	124.33	1082.09
12.16	0.00	0.00	-4.06	-208.73	156.99	1059.61
12.32	0.00	0.00	-3.67	-217.93	191.13	1031.78
12.48	0.00	0.00	-3.30	-227.13	226.73	998.37
12.64	0.00	0.00	-2.95	-236.32	263.81	959.15
12.80	0.00	0.00	-2.62	-245.52	302.35	913.87
12.96	38.78	0.00	-2.31	-33.71	325.18	862.69
13.12	44.65	0.00	-2.01	-33.09	330.58	810.20
13.28	58.44	0.00	-1.72	-43.23	336.83	756.78
13.44	70.04	0.00	-1.45	-44.01	343.92	702.28
13.60	104.71	0.00	-1.19	-66.79	353.13	646.47
13.76	169.80	0.00	-0.95	-102.76	367.31	588.76
13.92	186.84	0.00	-0.71	-73.53	381.54	528.76
14.08	191.55	0.00	-0.49	-33.62	390.13	466.94
14.24	184.78	0.00	-0.27	9.65	391.97	404.28
14.40	161.82	193.74	-0.06	84.28	385.83	341.79
14.56	0.00	193.75	0.14	161.00	364.90	281.52
14.72	0.00	193.75	0.34	200.18	335.99	225.37
14.88	0.00	193.76	0.53	238.56	300.89	174.33
15.04	0.00	193.77	0.72	276.32	259.69	129.40

Depth [m]	kh,p [MN/m³]	kh,z [MN/m³]	Displacement [mm]	Pressure [kPa]	Shear Force [kN/m]	Moment [kNm/m]
15.20	0.00	117.48	0.91	245.76	217.36	91.17
15.36	0.00	101.36	1.09	251.46	177.46	59.54
15.52	0.00	91.27	1.28	249.19	137.33	34.34
15.68	0.00	96.22	1.46	274.60	95.46	15.68
15.84	0.00	98.51	1.64	297.30	49.73	4.02
16.00	0.00	102.93	1.83	324.70	0.00	-0.00

Maximum shear force = 391.97 kN/m
Maximum moment = 1123.31 kNm/m
Maximum displacement = 69.6 mm

ALLEGATO 3

Sezione 4 – Analisi della stabilità generale

Slope stability analysis

Input data

Project

Settings

(input for current task)

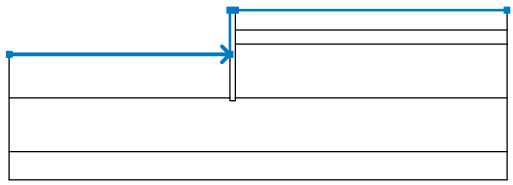
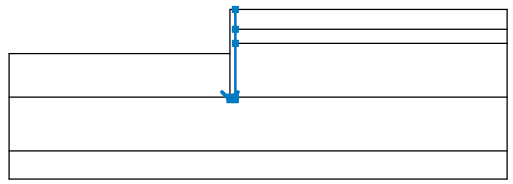
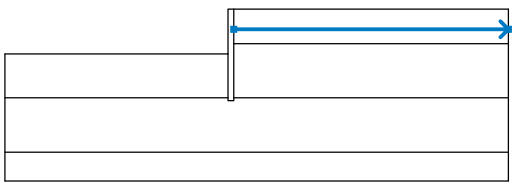
Stability analysis

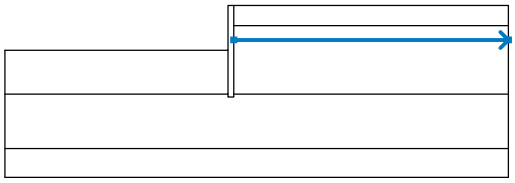
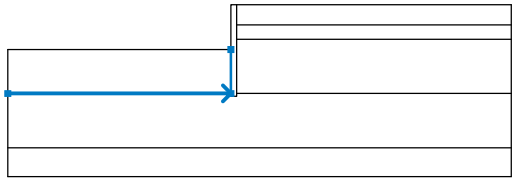
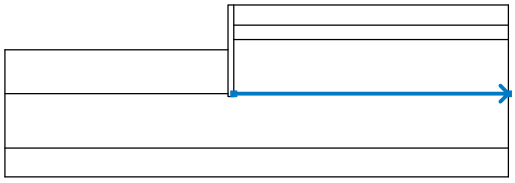
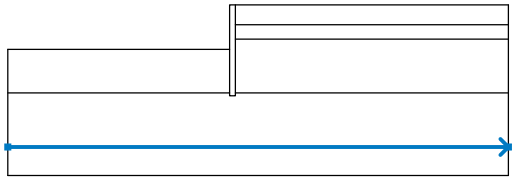
Verification methodology : according to EN 1997
Earthquake analysis : Standard
Design approach : 1 - reduction of actions and soil parameters

Partial factors on actions (A)								
Transient design situation								
		Combination 1				Combination 2			
		Unfavourable		Favourable		Unfavourable		Favourable	
Permanent actions :	γ_G =	1.10	[–]	1.00	[–]	1.10	[–]	1.00	[–]
Variable actions :	γ_Q =	1.50	[–]	0.00	[–]	1.50	[–]	0.00	[–]
Water load :	γ_w =	1.35	[–]			1.00	[–]		

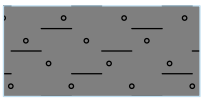
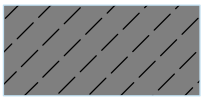
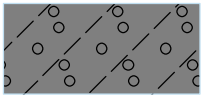
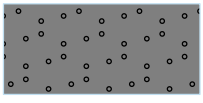
Partial factors for soil parameters (M)					
Transient design situation					
		Combination 1		Combination 2	
Partial factor on internal friction :	γ_ϕ =	1.00	[–]	1.25	[–]
Partial factor on effective cohesion :	γ_c =	1.00	[–]	1.40	[–]
Partial factor on undrained shear strength :	γ_{cu} =	1.00	[–]	1.40	[–]

Interface

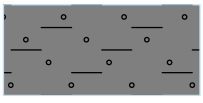
No.	Interface location	Coordinates of interface points [m]					
		x	z	x	z	x	z
1		-40.00	-7.81	-1.00	-7.81	-1.00	0.00
		0.00	0.00	48.00	0.00		
2		-1.00	-15.50	-1.00	-16.00	0.00	-16.00
		0.00	-15.50	0.00	-6.00	0.00	-3.50
		0.00	0.00				
3		0.00	-3.50	48.00	-3.50		

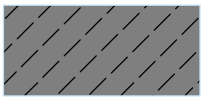
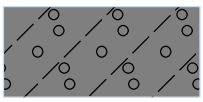
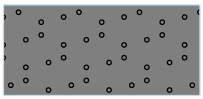
No.	Interface location	Coordinates of interface points [m]					
		x	z	x	z	x	z
4		0.00	-6.00	48.00	-6.00		
5		-40.00	-15.50	-1.00	-15.50	-1.00	-7.81
6		0.00	-15.50	48.00	-15.50		
7		-40.00	-25.00	48.00	-25.00		

Soil parameters - effective stress state

No.	Name	Pattern	φ_{ef} [°]	c_{ef} [kPa]	γ [kN/m³]
1	Strato 1 Riporto		32.00	0.00	18.50
2	Strato 2 Limo sabbioso compatto		28.00	5.00	18.50
3	Strato 4 sabbia ghiaiosa addensata		38.00	0.00	20.00
4	Strato 3 Sabbia limosa		32.00	0.00	18.50

Soil parameters - uplift

No.	Name	Pattern	γ_{sat} [kN/m³]	γ_s [kN/m³]	n [–]
1	Strato 1 Riporto		19.00		

No.	Name	Pattern	γ_{sat} [kN/m³]	γ_s [kN/m³]	n [–]
2	Strato 2 Limo sabbioso compatto		18.50		
3	Strato 4 sabbia ghiaiosa addensata		20.00		
4	Strato 3 Sabbia limosa		19.00		

Soil parameters

Strato 1 Riporto

Unit weight : $\gamma = 18.50$ kN/m³
Stress-state : effective
Angle of internal friction : $\varphi_{ef} = 32.00$ °
Cohesion of soil : $c_{ef} = 0.00$ kPa
Saturated unit weight : $\gamma_{sat} = 19.00$ kN/m³

Strato 2 Limo sabbioso compatto

Unit weight : $\gamma = 18.50$ kN/m³
Stress-state : effective
Angle of internal friction : $\varphi_{ef} = 28.00$ °
Cohesion of soil : $c_{ef} = 5.00$ kPa
Saturated unit weight : $\gamma_{sat} = 18.50$ kN/m³

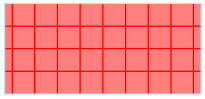
Strato 4 sabbia ghiaiosa addensata

Unit weight : $\gamma = 20.00$ kN/m³
Stress-state : effective
Angle of internal friction : $\varphi_{ef} = 38.00$ °
Cohesion of soil : $c_{ef} = 0.00$ kPa
Saturated unit weight : $\gamma_{sat} = 20.00$ kN/m³

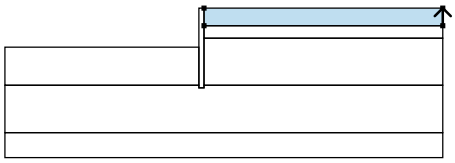
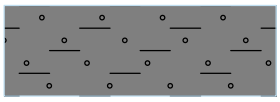
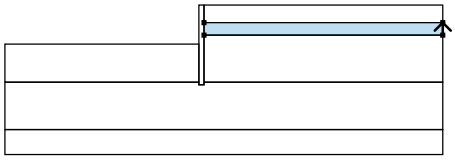
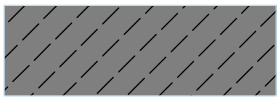
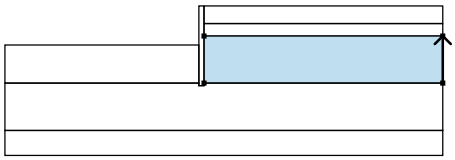
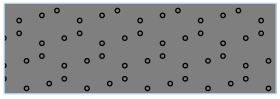
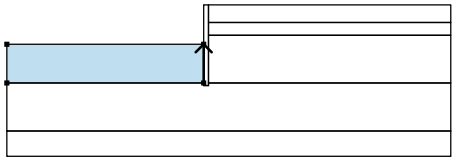
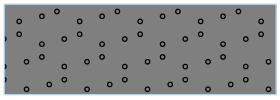
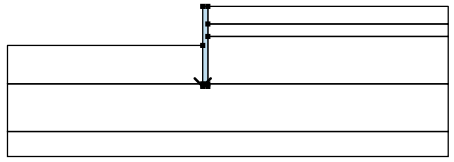
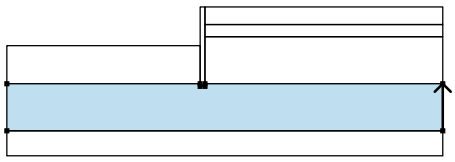
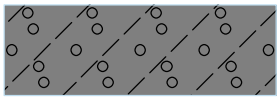
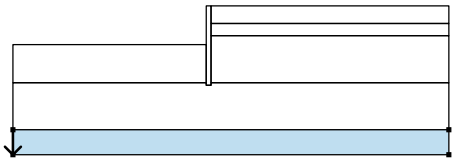
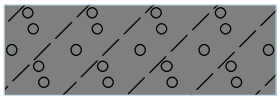
Strato 3 Sabbia limosa

Unit weight : $\gamma = 18.50$ kN/m³
Stress-state : effective
Angle of internal friction : $\varphi_{ef} = 32.00$ °
Cohesion of soil : $c_{ef} = 0.00$ kPa
Saturated unit weight : $\gamma_{sat} = 19.00$ kN/m³

Rigid Bodies

No.	Name	Sample	γ [kN/m³]
1	Material of structure		23.00

Assigning and surfaces

No.	Surface position	Coordinates of surface points [m] x	z	x	z	Assigned soil
1		48.00	-3.50	48.00	0.00	Strato 1 Riporto
		0.00	0.00	0.00	-3.50	
2		48.00	-6.00	48.00	-3.50	Strato 2 Limo sabbioso compatto
		0.00	-3.50	0.00	-6.00	
3		48.00	-15.50	48.00	-6.00	Strato 3 Sabbia limosa
		0.00	-6.00	0.00	-15.50	
4		-1.00	-15.50	-1.00	-7.81	Strato 3 Sabbia limosa
		-40.00	-7.81	-40.00	-15.50	
5		-1.00	-15.50	-1.00	-16.00	Material of structure
		0.00	-16.00	0.00	-15.50	
		0.00	-6.00	0.00	-3.50	
		0.00	0.00	-1.00	0.00	
		-1.00	-7.81			
6		48.00	-25.00	48.00	-15.50	Strato 4 sabbia ghiaiosa addensata
		0.00	-15.50	0.00	-16.00	
		-1.00	-16.00	-1.00	-15.50	
		-40.00	-15.50	-40.00	-25.00	
7		-40.00	-25.00	-40.00	-30.00	Strato 4 sabbia ghiaiosa addensata
		48.00	-30.00	48.00	-25.00	

Surcharge

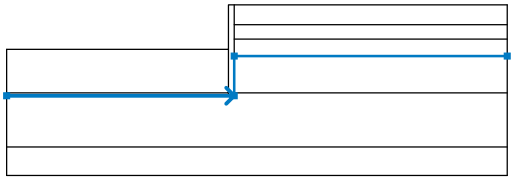
No.	Type	Type of action	Location z [m]	Origin x [m]	Length l [m]	Width b [m]	Slope α [°]	Magnitude q, q_1, f, F, x	Magnitude q_2, z	Magnitude unit
1	strip	variable	on terrain	x = 0.00	l = 48.00		0.00	2.00		kN/m²

Surcharges

No.	Name
1	Fase 3

Water

Water type : GWT

No.	GWT location	Coordinates of GWT points [m]					
		x	z	x	z	x	z
1		-40.00	-16.00	0.00	-16.00	0.00	-9.00
		48.00	-9.00				

Tensile crack

Tensile crack not input.

Earthquake

Earthquake not included.

Settings of the stage of construction

Design situation : transient