



Mit Beteiligung der Europäischen Union aus dem Haushalt der Transeuropäischen Verkehrsnetze finanziertes Vorhaben

Opera finanziata con la partecipazione dell'Unione Europea attraverso il bilancio delle reti di trasporto transeuropee



Ausbau Eisenbahnachse München-Verona

BRENNER BASISTUNNEL

Ausführungsprojekt

Potenziamento Asse Ferroviario Monaco-Verona

GALLERIA DI BASE DEL BRENNERO

Progetto Esecutivo

Sub-Baulos Hauptbauwerke Eisackunterquerung Sublotto di costruzione Opere Principali Sottoattraversamento Isarco

Fachbereich				Settore			
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				Progettazione del tracciato e dell'opera			
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				Spostamento linea storica – Calcolo dei cedimenti di terrapieno della ferrovia			
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Contenuto documento: Calcolo dei cedimenti di terrapieno della
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1 INTRODUZIONE

Il lotto di costruzione "Sottoattraversamento Isarco", costituisce la parte estrema meridionale della Galleria di Base del Brennero prima dell'accesso nella stazione di Fortezza, ed è ubicato ca. 1 km a nord dell'abitato di Fortezza, in località Prà di Sopra, in Provincia di Bolzano.

Il lotto di costruzione comprende essenzialmente le opere civili grezze in sotterraneo e le opere esterne individuate dal programma lavori 2010 e successivi aggiornamenti della Galleria di Base del Brennero.

Le opere progettate costituiscono pertanto un "lotto costruttivo non funzionale" facente parte del progetto complessivo della Galleria di Base del Brennero.

I requisiti di progetto e funzionali delle opere progettate rispondono a quelli del progetto definitivo della Galleria di Base del Brennero che ha ottenuto l'approvazione da parte delle autorità competenti.

Le opere progettate inoltre recepiscono le prescrizioni impartite nel corso dei diversi iter autorizzativi, le ottimizzazioni e la specificazione di standard elaborati nell'ambito della progettazione guida transfrontaliera, nonché i risultati delle campagne geognostiche integrative effettuate negli anni 2010-2011, e successivamente nel 2015 propedeutica alla predisposizione del progetto esecutivo, con particolare riferimento all'aggiornamento del modello idrogeologico.

Le interfacce e gli standard di costruzione definiti consentono l'integrazione delle infrastrutture e delle dotazioni impiantistiche dei diversi lotti di costruzione previsti dal programma lavori della Galleria di base del Brennero, tra i quali è compreso il lotto di costruzione "Sottoattraversamento Isarco".

Il lotto di costruzione "Sottoattraversamento Isarco" è suddiviso a sua volta nei due seguenti sublotti:

- sublotto di costruzione "Opere propedeutiche Sottoattraversamento Isarco", del quale è stato elaborato il progetto esecutivo;

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- subplotto “Opere principali Sottoattraversamento Isarco” oggetto del presente progetto esecutivo.

2 INQUADRAMENTO GENERALE

2.1 IL LOTTO DI COSTRUZIONE “SOTTOATTRAVERSAMENTO ISARCO”

L'ubicazione delle aree interessate dai lavori ed i limiti del lotto di costruzione sono rilevabili negli elaborati progettuali ai quali si rimanda.

Ai fini della localizzazione delle opere, si stabilisce che la progressivazione delle gallerie principali utilizzata nei documenti delle progettazioni è quella generale dell'Opera, riferita per la galleria Est (binario dispari) alla stazione di Innsbruck, mentre la progressivazione delle interconnessioni sono riferite al loro punto di sfocco dei tracciati delle interconnessioni da quelle delle gallerie principali.

2.1.1 Opere del subplotto “Opere propedeutiche Sottoattraversamento Isarco”

Le opere del subplotto “Opere propedeutiche Sottoattraversamento Isarco”, le quali non fanno parte del progetto esecutivo in oggetto, consistono essenzialmente in:

- variante alla S.S.12 del Brennero dal km 490+500 al km 491+500, compreso un nuovo ponte sul Rio Bianco, con spostamento dei sottoservizi interferiti e realizzazione di un accesso all'area di cantiere;
- ponte sull'Isarco;
- sottopasso alla linea ferroviaria del Brennero, al km 200+400;
- viabilità interna di cantiere.

2.1.2 Opere del subplotto “Opere principali Sottoattraversamento Isarco”

Le opere del subplotto “Opere principali Sottoattraversamento Isarco”, che fanno parte del

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progetto esecutivo, consistono essenzialmente in:

Gallerie principali

1° tratto

- Galleria principale est – binario dispari - (tratto in galleria naturale) da pk 54+015.00 (inizio lotto) a pk 54+600.67 di cui:
 - da pk 54+015.00 a pk 54+465.00 in galleria naturale a doppio binario (scavo e rivestimento definitivo);
 - da pk 54+465.00 a pk 54+600.67 in galleria naturale di diramazione a doppio binario (scavo e rivestimento definitivo).
- Galleria principale ovest – binario pari - (tratto in galleria naturale) da pk 54+042.00 (inizio lotto) a pk 54+598.85 di cui:
 - da pk 54+042.00 a pk 54+440.00 in galleria naturale a doppio binario (scavo e rivestimento definitivo);
 - da pk 54+440.00 a pk 54+598.85 in galleria naturale di diramazione a doppio binario (scavo e rivestimento definitivo).

2° tratto (Attraversamento Fiume Isarco)

- Galleria principale est – binario dispari – (tratto galleria naturale), da pk 54+600.67 a pk 54+700.77 (compresi pozzi di accesso alle gallerie) in galleria naturale a singolo binario (scavo e rivestimento definitivo).
- Galleria principale ovest – binario pari – (tratto galleria naturale), da pk 54+598.85 a pk 54+711.07 (compresi pozzi di accesso alle gallerie) in galleria naturale a singolo binario (scavo e rivestimento definitivo).

3° tratto

- Galleria principale est – binario dispari - (tratto in galleria naturale), da pk 54+700.77 a pk 54+968.00 in galleria naturale a singolo binario

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(scavo e rivestimento definitivo).

- Galleria principale ovest - binario pari – (tratto in galleria naturale), da pk 54+711.07 a pk 54+916.00 in galleria naturale a singolo binario (scavo e rivestimento definitivo).

4° tratto

- Galleria principale est – binario dispari - (tratto in galleria artificiale), da pk 54+968.00 a pk 55+060.00 in galleria artificiale a singolo binario (scavo e opera grezza).
- Galleria principale ovest - binario pari – (tratto in galleria artificiale), da pk 54+916.00 a pk 55+018.00 in galleria artificiale a singolo binario (scavo e opera grezza).

5° tratto

- Galleria principale est – binario dispari - (tratto in galleria naturale), da pk 55+060.00 a pk 56+100.00 (fine lotto) di cui:
 - da pk 55+060.00 a pk 55+485.00 in galleria naturale a singolo binario (scavo e rivestimento definitivo);
 - da pk 55+485.00 a pk 56+100.00 in galleria naturale a doppio binario (scavo e rivestimento definitivo).

***Avvertenza:** Lo scavo della galleria termina in roccia; le opere di portale non sono oggetto del lotto.*

- Galleria principale ovest – binario pari - (tratto in galleria naturale), da pk 55+018.00 a pk 56+190.00 (fine lotto) di cui:
 - da pk 55+018.00 a pk 55+549.00 in galleria naturale a singolo binario (scavo e rivestimento definitivo);
 - da pk 55+549.00 a pk 56+190.00 in galleria naturale a doppio binario (scavo e rivestimento definitivo).

***Avvertenza:** Lo scavo della galleria termina in roccia;*

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le opere di portale non sono oggetto del lotto.

Interconnessioni

- Interconnessione est – binario dispari, “tratto di diramazione dalla galleria principale – fine lotto”, da pk 1+971.44 (pk 54+600.67 Galleria principale est – binario dispari) a pk 2+683.62 di cui:
 - da pk 1+971.44 a pk 2+069.97 (compresi pozzi di accesso alle gallerie) in galleria naturale attraversamento Isarco a singolo binario (scavo e rivestimento definitivo);
 - da pk 2+069.97a pk 2+270.00 in galleria artificiale a singolo binario (scavo e opera grezza);
 - da pk 2+270.00 a pk 2+525.00 corpo stradale ferroviario a binario singolo con scavo “a vascone” (scavo e opere civili);
 - da pk 2+525.00 a pk 2+683.62 corpo stradale ferroviario in rilevato/trincea (scavo e opere civili).
- Interconnessione ovest – binario pari, “tratto di diramazione dalla galleria principale – fine lotto”, da pk 1+693.13 (pk 54+598.85 Galleria principale ovest – binario pari) a pk 2+550.00 di cui:
 - da pk 1+693.13 a pk 1+795.86 (compresi pozzi di accesso alle gallerie) in galleria naturale attraversamento Isarco a singolo binario (scavo e rivestimento definitivo);
 - da pk 1+795.86 a pk 2+550.00 in galleria naturale a binario singolo (scavo e rivestimento definitivo).

Avvertenza: Lo scavo della galleria termina in roccia; le opere di portale non sono oggetto del lotto.

Spostamento linea storica FS

- da pk 199+935 ca. a pk 200+900 ca. (binario pari) della linea ferroviaria esistente Verona Brennero, per una lunghezza di m 965 ca. (realizzazione della nuova sede ferroviaria e

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attrezzaggio, messa in esercizio).

Opere minori e accessorie

Sono comprese nel lotto di costruzione le seguenti opere minori:

- pozzi e uscite di emergenza (scavo e rivestimento definitivo);
- cunicoli trasversali di collegamento (scavo e rivestimento definitivo);
- opere complementari in corrispondenza del tratto di linea FS spostata;
- interventi di messa in sicurezza contro la caduta massi sopra la linea storica da ca. km 199+000 a ca. km 200+265;
- interventi di ripristino ambientale e sistemazione finale del fiume Isarco e delle aree interessate dai lavori;
- viabilità di accesso alla zona di soccorso presso il portale interconnessione pari fino alla pk 0+275 ca.

Costituiscono inoltre parte integrante del progetto del subplotto di costruzione, la realizzazione di tutte le opere accessorie e di piccole dimensioni che ricadono nel tratto oggetto dell'intervento, la cui realizzazione risulta necessaria e/o funzionale alla compiuta esecuzione delle opere.

2.2 OPERE DEL SUBLOTTO "OPERE PRINCIPALI SOTTOATTRAVERSAMENTO ISARCO" NON OGGETTO DI PROGETTAZIONE

Le seguenti opere ed impianti sono escluse dalla presente progettazione:

- **Impianti ferroviari** a servizio delle gallerie principali e delle interconnessioni costituiti essenzialmente da:
 - sovrastruttura;

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- interventi per la mitigazione dalle vibrazioni;
 - impianti di trazione elettrica e approvvigionamento energetico;
 - sistemi di telecomunicazione e sorveglianza;
 - sistemi di comando/controllo;
 - impianti meccanici (come definiti nel progetto definitivo 2008);
 - impianto di sorveglianza cantiere e localizzazione delle persone.
- **Opere di portali delle due gallerie principali est ed ovest** (binari dispari e pari) e i tratti iniziali delle medesime gallerie, secondo i limiti di lotto precedentemente definiti.
 - **Opere di portali della galleria d'interconnessione pari** ed il tratto iniziale della medesima galleria, secondo il limite di lotto precedentemente definito.
 - **Opere presso il portale d'interconnessione pari** e la relativa viabilità di accesso dalla pk 0+275 ca. alla pk 0+400 ca. ed al Bacino di ritenuta Holer Graben.
 - Opere riferite all'ambito della **stazione di Fortezza**.

3 CONTENUTO DELLA RELAZIONE

Il presente Documento analizza le deformazioni e assestamenti dei rilevati ferroviari, in relazione alla realizzazione delle nuove opere.

Vengono in particolare analizzate sia la potenziale deformabilità dei nuovi riempimenti, che le deformazioni che conseguono alla realizzazione degli scavi.

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4 NORME E DIRETTIVE

[NTC 2008]		[NTC 2008]	Decreto ministeriale D.M. 14.01.2008 Nuove norme tecniche sulle costruzioni (NTC 2008) e Circolare esplicativa del 2009.
Ergänzend dazu werden betrachtet:		Ad integrazione, vengono considerate:	
[EN 1991-1-1]	Allgemeine Einwirkungen – Wichten, Eigengewichte und Nutzlasten für den Hochbau	[EN 1991-1-1]	Azioni generali – Densità, pesi propri, sovraccarichi per gli edifici
[EN 1991-1-2]	Eurocode 1 - Einwirkungen auf Tragwerke - Teil 1-2: Allgemeine Einwirkungen - Brandeinwirkungen auf Tragwerke	[EN 1991-1-2]	Eurocodice 1 – Azioni sulle strutture – Parte 1-2: Azioni in generale – Azioni sulle strutture esposte al fuoco.
[EN 1991-1-3]	Eurocode 1 - Einwirkungen auf Tragwerke - Teil 1-3: Allgemeine Einwirkungen, Schneelasten	[EN 1991-1-3]	Eurocodice 1 – Azioni sulle costruzioni – Parte 1-3: Azioni generali, carichi della neve
[EN 1991-1-4]	Allgemeine Einwirkungen, Windlasten	[EN 1991-1-4]	Azioni generali, azioni del vento
[EN 1991-1-5]	Eurocode 1 - Einwirkungen auf Tragwerke - Teil 1-5: Allgemeine Einwirkungen- Temperatureinwirkungen	[EN 1991-1-5]	Eurocodice 1 - Azioni sulle costruzioni – Parte 1-5: Azioni generali – Azioni termiche
[EN 1992-1]	Eurocode 2: Bemessung und Konstruktion von Stahlbeton- und Spannbetontragwerken – Grundlagen und Anwendungsregeln für den Hochbau	[EN 1992-1]	Eurocodice 2: Progettazione delle strutture di calcestruzzo – Regole generali e regole per gli edifici
[EN 1992-2]	Eurocode 2: Bemessung und Konstruktion von Stahlbeton- und Spannbetontragwerken - Brückenbau	[EN 1992-2]	Eurocodice 2: Progettazione delle strutture di calcestruzzo - Ponti
[EN 206-1]	EN 206-1: Beton - Teil 1: Festlegung, Herstellung, Verwendung und	[EN 206-1]	Norma UNI EN 206-1: Calcestruzzo – Parte 1: Specifiche, prestazioni,

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	Konformität		produzione e conformità
[EN 1997-1]	Eurocode 7: Entwurf, Berechnung und Bemessung in der Geotechnik - Teil 1: Allgemeine Regeln	[EN 1997-1]	Eurocodice 7: Progettazione geotecnica – Parte 1: regole generali
[ENV 1997-2]	Eurocode 7: Entwurf in der Geotechnik – Teil 2: laborunterstützter Entwurf	[ENV 1997-2]	Eurocodice 7: Progettazione geotecnica – Parte 2: Progettazione assistita da accertamenti di laboratorio
[EN 1998-1]	Eurocode 8: Auslegung von Bauwerken in Erdbebengebieten - Teil 1: Grundlagen, Erdbebeneinwirkungen und Regeln für Hochbauten	[EN 1998-1]	Eurocodice 8: Progetto delle strutture in zona sismica – Parte 1: Regole generali, azione sismica e regole per edifici
[Amtsblatt]	Ordentliches Beiblatt zum Amtsblatt, allgemeine Reihenfolge Nr. 222, 23.9.2005	[Gazzetta Ufficiale]	Supplemento ordinario alla Gazzetta Ufficiale, serie generale n.222, 23-9-2005
[EN 1537]	Ausführung von Arbeiten im Spezialtiefbau - Verpressanker	[EN 1537]	Esecuzione di lavori geotecnici speciali – Tiranti di ancoraggio
[EN 14199]	Ausführung von Arbeiten im Spezialtiefbau – Mikropfähle	[EN 14199]	Esecuzione di lavori geotecnici speciali – Micropali
(intrad) RVS	RVS 09.01.41 österreichische richtlinien und Vorschriften für den Straßenbau) RVS 09.01.41 Statische Baurichtlinie – Offene Bauweise	(intrad) RVS	direttive austriache e prescrizioni per opere stradali (n.d.t RVS 09.01.41 Direttiva costruttiva statica – metodo in artificiale)

Des weiteren ist bei der Bemessung zu berücksichtigen:

Da osservare, inoltre, ai fini del dimensionamento:

- Bemessungsregeln für den BBT, übermittelt per E-Mail von BBT am 07.12.2012
- "life cycle description", übermittelt per E-Mail von BBT am 22.11.2012
- Regole di dimensionamento del BBT, trasmesse via email da BBT il 07.12.2012
- "life cycle description", trasmesso via email da BBT il 22.11.2012
- Istruzione Tecnica RFI TCAR ST AR 01 001

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5 APPROCCIO PROGETTUALE

Gli scavi sono stati progettati sulla base dell'impiego di gettiniezione, al fine di creare un blocco impermeabile di spessore sufficiente a resistere alle importanti pressioni e sottopressioni idrauliche esterne.

Il fatto che gli scavi non comportino alterazioni dei livelli di falda fa sì che le pressioni efficaci del terreno circostante non siano modificate.

A questo scopo, si è scelta la via di sostenere gli scavi con puntoni in acciaio che, oltre alla velocità di installazione e attivazione, evitano i potenziali problemi legati a perforazione e installazione sotto falda.

Fa localmente eccezione la zona di sostegno diretto della linea ferroviaria storica in corrispondenza della galleria binario dispari, dove si è reso necessario l'impiego di ancoraggi attivi associati a una paratia in micropali al fine di limitare i cedimenti della sede ferroviaria. Gli ancoraggi tuttavia sono installati a partire da un livello superiore a quello della linea di falda, per cui la perforazione con comporta potenzialmente effetti sulla falda.

Il Campo prove sulla gettiniezione ha confermato la possibilità di ottenere colonne di diametro maggiore, rispetto a quanto indicato nel Progetto Definitivo. Ciò ha consentito di perfezionare ulteriormente la geometria dei trattamenti e la gestione delle operazioni di scavo. In tal senso, il procedimento di sostegno dello scavo mediante sottomurazione con un muro in calcestruzzo di 80 cm e più ordini di puntoni, è stato modificato con un procedimento che comporta un maggiore spessore di jettinazione, derivante dalla geometria delle singole colonne, bilanciato da un minore spessore della controparete. Questa è realizzata in calcestruzzo spruzzato e fortemente armato, per offrire un più rapido contributo alla resistenza.

La struttura della galleria è quadrata o poligonale, all'esterno, e policentrica, all'interno, con altezza e larghezza totali nell'ordine di 10 m e 9 m, rispettivamente. La struttura sarà impermeabilizzata

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esternamente.

Lo scavo sarà realizzato in sezione aperta, con scarpate divergenti nella parte superiore e a pareti verticali in quella più profonda che accoglierà la struttura.

La parte profonda sarà sostenuta mediante preventivo trattamento colonnare in jet grouting delle pareti e del fondo, in modo da formare uno scafo robusto e impermeabile entro cui poter lavorare.

Le pareti di jet-grouting saranno localmente rinforzate con armatura in micropalo, disposto sia nella colonna interna che in quella più esterna, ove necessario ridurre il numero di puntoni, per particolari esigenze costruttive.

Come parte del sostegno e per conferire regolarità alla superficie finale contro cui verrà posata la impermeabilizzazione e realizzati i getti della galleria, verrà costruita una contro-parete in calcestruzzo spruzzato, in aderenza al jet-grouting. Lo spessore medio di tale controparete sarà proporzionato alla profondità delle irregolarità della gettiniezione.

Lo scavo sarà progressivamente sostenuto da puntoni in acciaio, disposti lungo 3 allineamenti nella parte alta e nella parte intermedia. Le spinte dei puntoni superiori saranno raccolte da una robusta trave di ripartizione in calcestruzzo armato. Quelle dei punti inferiori saranno ripartite da travi in spessore formate con una robusta armatura trasversale e verticale all'interno della parete in calcestruzzo spruzzato, che chiameranno a lavorare anche parte del sottostante terreno trattato.

Una volta completata la struttura verranno realizzati i riempimenti in terra, fino alla superficie originaria. Negli elaborati di progetto sono fornite specifiche indicazioni per la posa e compattazione del terreno sotto i rilevati ferroviari.

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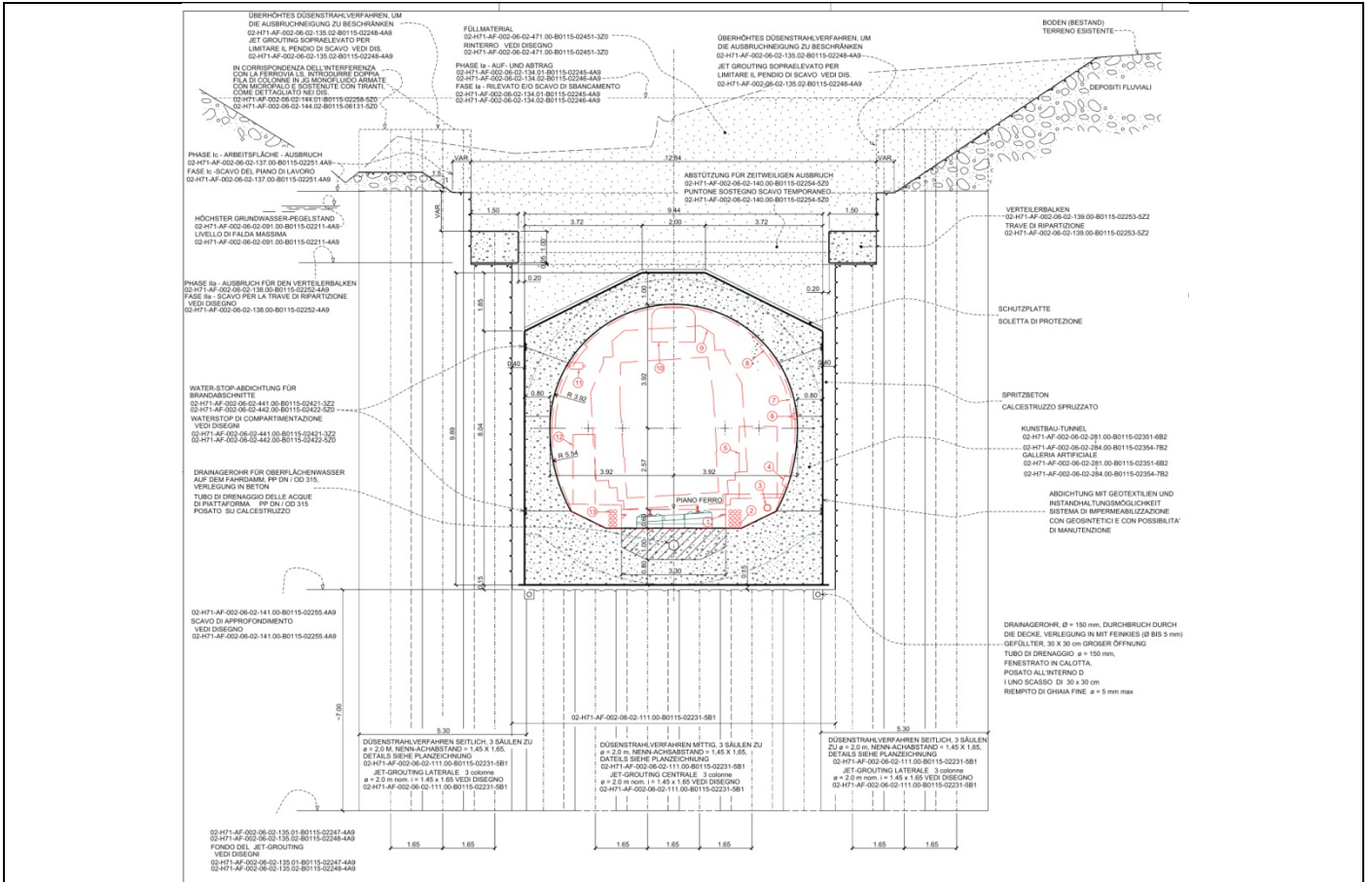


Figura 1: Sezione tipo di scavo della Galleria Binario Dispari.

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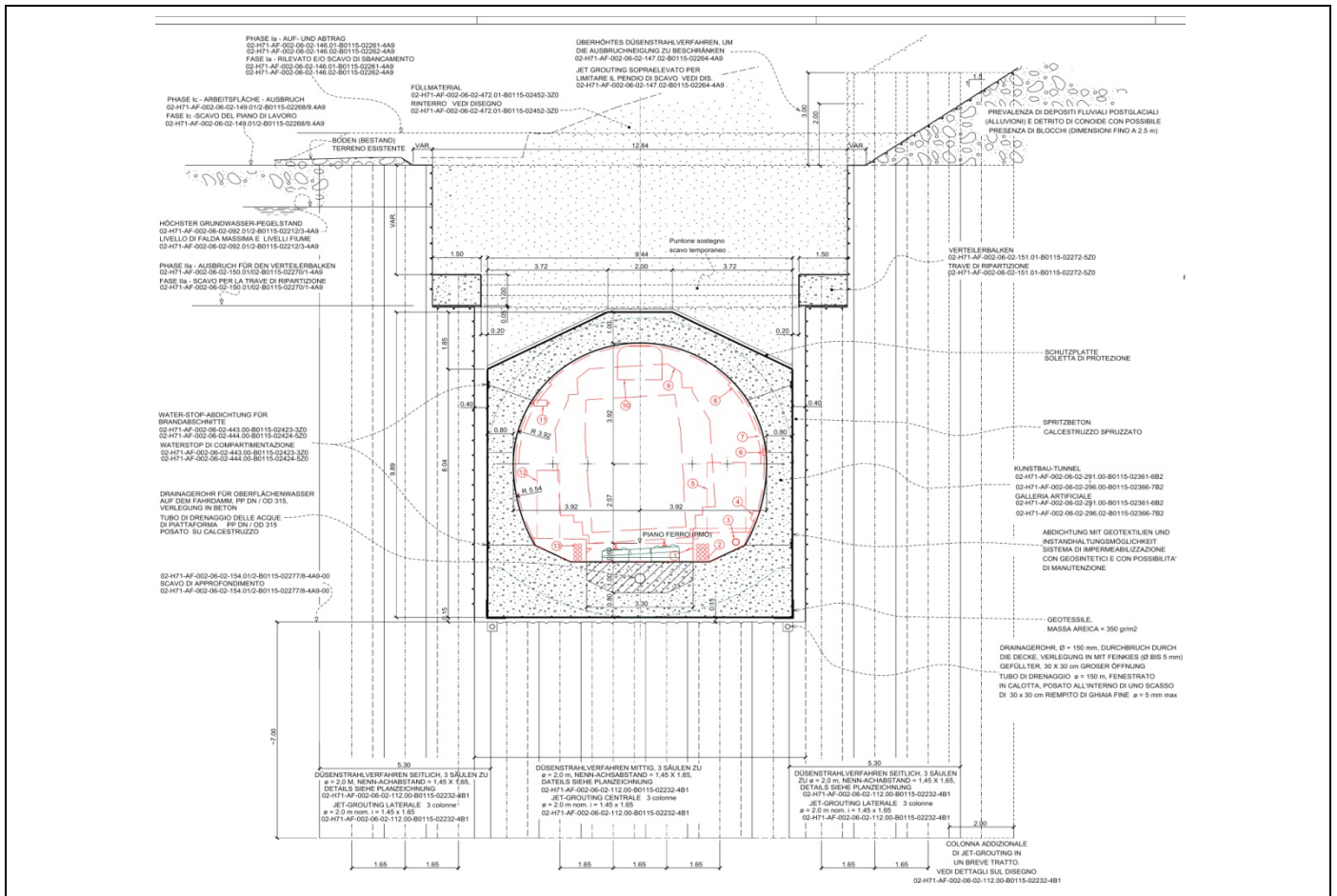


Figura 2: Sezione tipo della Galleria Binario Pari.

5.1 MONITORAGGIO

Durante tutta la costruzione saranno monitorati con regolarità gli spostamenti di alcune mire distribuite lungo il bordo scavo e la ferrovia storica.

Verranno in particolare misurati sia gli spostamenti verticali che quelli orizzontali mediante rilievo topografico ripetuto.

Verranno inoltre monitorati con regolarità i piezometri e pozzi adiacenti la zona di lavoro.

5.2 FASI COSTRUTTIVE

La sequenza di scavo può essere riassunta come segue:

- realizzazione della paratia lungo la ferrovia

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- b) scavo di ribasso e installazione dei tiranti lungo la ferrovia
- c) realizzazione dei piazzali di lavoro per la gettiniezione
- d) gettiniezione e relativa installazione di micropali, ove richiesto
- e) ribasso fino alla quota di imposta della trave di ripartizione
- f) realizzazione della trave di ripartizione
- g) scavo minimo di approfondimento per l'installazione del primo ordine di puntoni
- h) installazione del primo ordine di puntoni
- i) scavo di approfondimento per installazione secondo ordine di puntoni
- j) installazione del secondo ordine di puntoni
- k) scavo di approfondimento per installazione terzo ordine di puntoni
- l) installazione del terzo ordine di puntoni
- m) completamento dello scavo
- n) creazione di un piano di posa in magrone, integrato con un sistema di drenaggio del fondo, per un ottimale controllo delle eventuali acque di filtrazione mentre si procede con i getti
- o) posa della parte profonda della impermeabilizzazione. La membrana andrà risvoltata e sostenuta ai lati, e mantenenuta poco sopra il livello dei getti previsti
- p) getto dei solettoni di fondo della galleria
- q) completamento della galleria. La geomembrana andrà mano mano posata in anticipo sui getti e alla fine risvoltata sopra la galleria
- r) ricoprimento della galleria con terra compattata.
- s) eventuale esecuzione dei rilevati ferroviari, ove previsto.

Non appena raggiunta la profondità di scavo prevista in progetto, sarà realizzato il solettone della galleria in calcestruzzo, in modo da fornire un significativo contributo alla stabilità e mantenere le lunghezze libere degli scavi esposti al minimo.

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Si potrà quindi procedere alla rimozione del puntone intermedio ed al getto del rivestimento definitivo della galleria.

L'ordine superiore di puntoni sarà invece rimosso solo a struttura completata e dopo almeno 28 giorni di maturazione del calcestruzzo.

6 MATERIALI DA COSTRUZIONE E TERRENI DI SCAVO

6.1 ACCIAIO

6.1.1 Acciaio per cemento armato

Acciaio saldabile per cemento armato B450C ai sensi della NTC2008 e della Norma UNI EN 1992-1-1:2005, dotato delle seguenti caratteristiche fisiche:

Peso specifico: $\gamma = 78.5 \text{ kN/m}^3$

Modulo elastico acciaio: $E = 206000 \text{ N/mm}^2$

6.1.2 Acciaio da carpenteria

Acciaio saldabile per carpenteria (profili trafilati a caldo per travi di ripartizione, tubi per puntoni, laminati per piastre e irrigidenti) S355J2 ai sensi della NTC2008 e della Norma UNI EN 1992-1-1:2005, dotato delle seguenti caratteristiche fisiche:

Peso specifico: $\gamma = 78.5 \text{ kN/m}^3$

Modulo elastico acciaio: $E = 206000 \text{ N/mm}^2$

6.1.3 Acciaio per micropali

Acciaio per micropali S355J2 ai sensi della NTC2008 e della Norma UNI EN 1992-1-1:2005, dotato delle seguenti caratteristiche fisiche:

Peso specifico $\gamma = 78.5 \text{ kN/m}^3$

Modulo elastico acciaio: $E = 206000 \text{ N/mm}^2$

6.1.4 Acciaio per tiranti

Acciaio armonico per trefoli ai sensi della NTC2008 e della Norma UNI EN 1992-1-1:2005, dotato delle seguenti caratteristiche fisiche:

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Peso specifico $\gamma = 78.5 \text{ kN/m}^3$

Modulo elastico acciaio: $E = 206000 \text{ N/mm}^2$

6.2 CALCESTRUZZO

6.2.1 Calcestruzzo per trave di ripartizione

Calcestruzzo di classe C25/30 ai sensi della NTC2008 e della Norma UNI EN 1992-1-1:2005:

Peso dell'unità di volume: $\gamma = 25 \text{ kN/m}^3$

Modulo elastico: $E = 31475 \text{ N/mm}^2$

6.2.2 Calcestruzzo spruzzato

Calcestruzzo di classe C25/30 ai sensi della NTC2008 e della Norma UNI EN 1992-1-1:2005:

Peso dell'unità di volume: $\gamma = 25 \text{ kN/m}^3$

Modulo elastico: $E = 31475 \text{ N/mm}^2$

6.3 TERRENI

6.3.1 Profilo del Terreno

Le gallerie artificiali verranno realizzate all'interno del fondovalle dove sono presenti in prevalenza terreni alluvionali costituiti da ghiaie sabbiose.

Il progetto di scavi e riempimenti nonché le relative analisi e verifiche sono stati eseguiti sulla base delle informazioni contenute nella relazione geologica e in quella geotecnica.

02-H71-AF-002-03-01-001-01-B0115-00829-RT3-00:
Relazione geol/idrogeologia

02-H71-AF-002-03-01-002-00-B0115-01011-RT3-00:
Relazione geotecnica

6.3.2 Terreno Naturale

Il terreno è costituito da detriti di versante e da conoidi alluvionali. I range sui parametri fisici e meccanici di tale materiale riportati nella relazione geotecnica sono i seguenti:

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Peso dell'unità di volume: $\gamma = 19-22 \text{ kN/m}^3$

Modulo elastico: $E = 25-80 \text{ MPa}$

Angolo di attrito: $\phi' = 33-39^\circ$

Coesione: $c' = 0-5 \text{ kN/m}^2$

6.3.3 Terreno trattato mediante gettiniezione

Per il terreno trattato mediante gettiniezione si possono considerare i seguenti range di variazione dei parametri fisici:

Peso dell'unità di volume: $\gamma = 21-24 \text{ kN/m}^3$

Modulo elastico: $E = 1000-1500 \text{ MPa}$

Per quanto riguarda i parametri di resistenza, si assimila il terreno trattato ad una roccia con le seguenti caratteristiche meccaniche:

UCS = 5-10 MPa

GSI = 65-80

$m_i = 10-15$

A partire da tali valori, i parametri di resistenza sono stati espressi con un criterio di rottura alla Mohr-Coulomb come segue:

$c = 500 \text{ kPa}$

$\phi = 36^\circ$

6.3.4 Terreno del rilevato della ferrovia esistente

Per il terreno del rilevato ferroviario esistente, si considerano i seguenti range di variazione delle caratteristiche dei materiali:

Peso dell'unità di volume: $\gamma = 19-22 \text{ kN/m}^3$

Modulo elastico: $E = 80-120 \text{ MPa}$

Angolo di attrito: $\phi' = 35^\circ - 45^\circ$

Coesione: $c' = 0-5 \text{ kN/m}^2$

6.3.5 Terreno compattato

Per il terreno compattato si possono considerare i seguenti range di variazione dei parametri fisici:

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Peso dell'unità di volume: $\gamma = 21.0 \text{ kN/m}^3$ (stimato)

Per quanto riguarda i parametri di resistenza, si adottano le seguenti caratteristiche:

$$c = 0 \text{ kPa}$$

$$\phi = 33-38^\circ$$

6.4 PARAMETRI ADOTTATI PER I MATERIALI

6.4.1 Terreno di base - Alluvionali

Alle alluvionali è stato assegnato un criterio di rottura alla Mohr-Coulomb con le seguenti proprietà di resistenza di picco e residue:

$$\Phi_p' = 36^\circ \qquad \Phi_r' = 35^\circ$$

$$C_p' = 2 \text{ kN/m}^2 \qquad C_r' = 0$$

Come peso dell'unità di volume si è assunto:

$$\gamma = 20.5 \text{ kN/m}^3$$

Per quanto riguarda i parametri deformabilità, sono stati assegnati i seguenti valori di modulo elastico e modulo di Poisson.

$$E = 60 \text{ MPa}$$

$$\nu = 0.3$$

Infine si è assunto che il terreno avesse un modulo di ricarico pari al doppio di quello iniziale.

6.4.2 Terreno trattato – Jet Grouting

Al Jet Grouting è stato assegnato un criterio di rottura alla Mohr-Coulomb con i seguenti parametri di resistenza:

$$c = 500 \text{ kPa}$$

$$\phi = 36^\circ$$

Come peso dell'unità di volume si è assunto:

$$\gamma = 21 \text{ kN/m}^3$$

Il comportamento elastico è governato dai seguenti

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moduli di Young e di Poisson.

$$E = 1000 \text{ MPa}$$

$$\nu = 0.3$$

6.4.3 Terreno del rilevato della ferrovia

Alle alluvionali è stato assegnato un criterio di rottura alla Morh-Coulomb con le seguenti proprietà di resistenza di picco e residue:

$$\Phi_p' = 37^\circ$$

$$\Phi_r' = 37^\circ$$

$$C_p' = 0 \text{ kPa}$$

$$C_r' = 0 \text{ kPa}$$

Il peso dell'unità di volume è stato assunto pari a $\gamma = 21 \text{ kN/m}^3$.

Per quanto riguarda i parametri deformabilità, sono stati assegnati i seguenti valori di modulo elastico e modulo di Poisson.

$$E = 100 \text{ MPa}$$

$$\nu = 0.3$$

6.4.4 Terreno compattato

Per il terreno compattato sono stati utilizzati i seguenti valori:

Peso dell'unità di volume: $\gamma = 20.5 \text{ kN/m}^3$ (stimato)

coesione $c = 2 \text{ kPa}$

angolo d'attrito $\phi = 35^\circ$

Modulo $E = 60 \text{ MPa}$

Coefficiente di Poisson $\nu = 0.3$

6.4.5 Calcestruzzo

Al calcestruzzo è stato assegnato un comportamento elastico governato dai seguenti valori di modulo elastico e modulo di Poisson.

$$E = 31200 \text{ MPa}$$

$$\nu = 0.2$$

Come peso dell'unità di volume si è assunto:

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$$\gamma = 25 \text{ kN/m}^3$$

6.4.6 Calcestruzzo spruzzato

Al calcestruzzo è stato assegnato un comportamento elastico governato dai seguenti valori di modulo elastico e modulo di Poisson.

$$E = 31200 \text{ MPa}$$

$$\nu = 0.2$$

Come peso dell'unità di volume si è assunto:

$$\gamma = 25 \text{ kN/m}^3$$

6.4.7 Acciaio

All'acciaio è stato assegnato un comportamento elastico governato dai seguenti valori di modulo elastico e modulo di Poisson.

$$E = 210000 \text{ MPa}$$

$$\nu = 0.2$$

7 ANALISI TENSO-DEFORMAZIONALE DEI RILEVATI IN SEGUITO A SCAVI O COSTRUZIONE

7.1 DESCRIZIONE DEL MODELLO

7.1.1 Analisi condotte

Le analisi deformazionali sono state condotte per stimare gli spostamenti di rilevati esistenti a seguito delle operazioni di scavo e per definire gli assestamenti dei nuovi rilevati, nella fascia in cui sovrappassano le gallerie artificiali.

In entrambi i casi, si è ritenuto necessario modellare l'intera sequenza di scavo e ricostruzione, in modo da ottenere risultati realistici.

7.1.2 Schematizzazioni di calcolo

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Lo stato tenso-deformativo dello scavo, in fase di costruzione, è stato valutato mediante un'analisi FEM bidimensionale, non lineare, per mezzo del software Phase2 di RocScience Inc., nell'ipotesi di stato piano di deformazione.

Il codice di calcolo consente di svolgere analisi accoppiate che considerano la sollecitazione dovuta ai carichi statici e la sollecitazione dovuta alla pressione dell'acqua, in un regime di filtrazione, fornendo i risultati in termini di tensioni efficaci. Inoltre è consentita la modellazione diretta di elementi strutturali monodimensionali (per esempio puntoni e micropali) che risultano efficaci e si adattano agevolmente alla Mesh 2D.

La Mesh di calcolo 2D è formata da elementi quadrati a 8 nodi con funzione di forma quadratica. Questi elementi consentono il calcolo sia del Potenziale Idraulico Totale e quindi il calcolo della piezometrica sia dello stato tensionale e deformativo.

Le condizioni al contorno statiche sono di vincolo con appoggi fissi alla base e appoggi scorrevoli sul lato verticale della Mesh.

Le condizioni al contorno idrauliche sono di tipo Potenziale Totale sul lato verticale della Mesh e di tipo Potenziale incognito di flusso uscente sul fronte di scavo.

L'analisi simula inoltre lo stato tensionale geostatico iniziale del terreno, le fasi di costruzione delle opere di sostegno e le fasi di scavo. In particolare nel caso esaminato sono stati considerati le seguenti fasi:

- 1) Calcolo dello stato tensionale geostatico iniziale del terreno;
- 2) Creazione della paratia di protezione del rilevato ferroviario (solo per lo scavo della Galleria Binario Dispari);
- 3) Sbancamento superficiale e creazione del piano di lavoro ;
- 4) Creazione delle colonne e tappo di fondo tramite trattamento del terreno con jet-grouting dal piano campagna. Installazione dei micropali verticali ed inclinati.
- 5) Approfondimento dello scavo e creazione della

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trave di ripartizione longitudinale;

- 6) Installazione del Primo puntone di contrasto;
- 7) Seconda fase di scavo;
- 8) Installazione del Secondo puntone di contrasto;
- 9) Terza fase di scavo fino a fondo scavo;
- 10) Installazione del Terzo puntone di contrasto;
- 11) Quarta fase di scavo fino a fondo scavo;
- 12) Getto del solettone di fondo della galleria;
- 13) Rimozione del secondo puntone;
- 14) Getto dei piedritti e della calotta della galleria;
- 15) Rimozione del Primo puntone.

7.2 AZIONI CONSIDERATE

7.2.1 Pesì propri dei materiali

Si riportano i pesi dell'unità di volume e i pesi specifici dei materiali considerati nelle analisi.

• Terreno – Alluvionali	20.5 kN/m ³
• Jet-Grouting	21.0 kN/m ³
• Acciaio	78.5 kN/m ³
• Calcestruzzo armato	25.0 kN/m ³
• Acqua	9.81 kN/m ³

7.2.2 Spinte del terreno e dell'acqua di falda

Le spinte del terreno e della falda vengono valutate direttamente dal programma di calcolo in funzione dei dati di input e della geometria del problema inseriti. In particolare per quanto riguarda la quota di falda essa è stata posta a circa 3.0 m di profondità dal piano campagna.

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Il codice di calcolo consente di svolgere analisi accoppiate che considerano la sollecitazione dovuta ai carichi statici e la sollecitazione dovuta alla pressione dell'acqua, in un regime di filtrazione, fornendo i risultati in termini di tensioni efficaci. Inoltre è consentita la modellazione diretta di elementi strutturali monodimensionali (per esempio puntoni e micropali) che risultano efficaci e si adattano agevolmente alla Mesh 2D.

7.2.3 Carichi di superficie

Il traffico dei mezzi di cantiere viene considerato applicando, sulla superficie, un carico di 10 kN/m².

7.2.4 Carico da temperatura

Il carico da distorsione termica è stato considerato nelle verifiche degli elementi di supporto (puntoni). Si possono trovare maggiori dettagli nelle Relazioni di dimensionamento degli scavi delle due Gallerie.

7.2.5 Carico da sisma

Le NTC prevedono che le lavorazioni e opere associate possano essere considerate temporanee, se la loro vita non occupa una durata complessiva superiore ai 2 anni, e che in tali circostanze il carico da sisma non debba essere incluso tra le azioni di dimensionamento.

In questo caso, il Programma Lavori prevede che la costruzione della galleria artificiale Binario Dispari occupi circa 19 mesi, tra giugno 2016 e gennaio 2018, mentre sono previsti circa 15 mesi, tra novembre 2016 e gennaio 2018, per la costruzione della galleria artificiale Binario Pari.

Per tali ragioni, il carico da sisma non viene applicato in considerazione della natura temporanea delle opere analizzate.

7.2.6 Carico da traffico ferroviario

Carico ferroviario è definito per mezzo dei modelli di seguito riportati.

Il primo modello di carico è rappresentativo degli effetti statici prodotti dal traffico normale ed è identificato come Treno di carico LM71 ed è schematizzato nella seguente figura.

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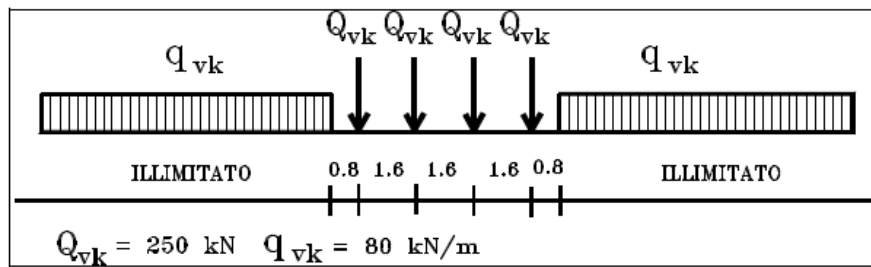


Figura 3: Treno di carico LM71, come da NTC 2008, Fig. 5.2.1.

Il secondo modello è rappresentativo degli effetti statici prodotti dal traffico ferroviario pesante ed è identificato come Treno di carico SW/0 o SW/2 ed è schematizzato nella seguente figura.

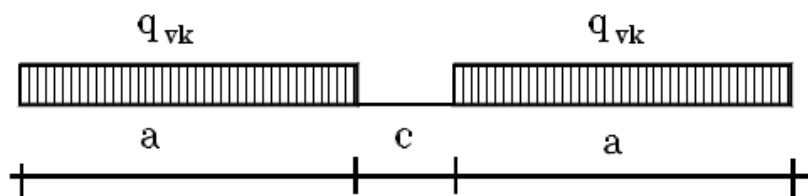


Figura 4: Treno di carico SW, come da NTC 2008, Fig. 5.2.2.

Il Tipo di carico SW/0 o SW/2 è indicato nella seguente figura.

Tipo di Carico	q_{vk} [kN/m]	a [m]	c [m]
SW/0	133	15,0	5,3
SW/2	150	25,0	7,0

Figura 5: caratteristiche Treni di carico SW, come da NTC 2008, Tab. 5.2.1.

Poichè la linea ha due binari si considera la contemporaneità di più treni prendendo come riferimento quanto riportato nella seguente figura.

Fachbereich:
Thema:
Dokumenteninhalt:

Settore: Spostamento linea storica
Tema: Progettazione del tracciato e dell'opera
Contenuto documento: Calcolo dei cedimenti di terrapieno della ferrovia

Numero di binari	Binari Carichi	Traffico normale		Traffico pesante ⁽²⁾
		caso a ⁽¹⁾	caso b ⁽¹⁾	
1	Primo	1,0 (LM 71 ⁺⁺ SW/0 ⁺⁺)	-	1,0 SW/2
2	Primo	1,0 (LM 71 ⁺⁺ SW/0 ⁺⁺)	-	1,0 SW/2
	secondo	1,0 (LM 71 ⁺⁺ SW/0 ⁺⁺)	-	1,0 (LM 71 ⁺⁺ SW/0 ⁺⁺)
≥ 3	Primo	1,0 (LM 71 ⁺⁺ SW/0 ⁺⁺)	0,75 (LM 71 ⁺⁺ SW/0 ⁺⁺)	1,0 SW/2
	secondo	1,0 (LM 71 ⁺⁺ SW/0 ⁺⁺)	0,75 (LM 71 ⁺⁺ SW/0 ⁺⁺)	1,0 (LM 71 ⁺⁺ SW/0 ⁺⁺)
	Altri	-	0,75 (LM 71 ⁺⁺ SW/0 ⁺⁺)	-

⁽¹⁾ LM71 ⁺⁺ SW/0 significa considerare il più sfavorevole fra i treni LM 71, SW/0

⁽²⁾ Salvo i casi in cui sia esplicitamente escluso

Figura 6: Carichi mobili in funzione del numero di binari presenti, come da NTC 2008, Tab. 5.2.III.

Per il primo binario si seleziona un carico distribuito da traffico pesante SW/2 che vale 150 kN/m.

Per il secondo binario si seleziona un carico da traffico pesante che deve essere il più sfavorevole tra il treno di carico LM 71 e il treno di carico SW/0.

Il treno di carico LM 71 per metro di profondità è stimato essere pari ad un valore medio di 118 kN/m.

Il treno di carico SW/0 è pari a 133 kN/m.

Per il secondo binario si seleziona quindi un carico da traffico pesante SW/0 di 133 kN/m.

Si nota che nel modello il carico del treno è stato applicato su un elemento di ripartizione con la rigidità del calcestruzzo, che simula la presenza delle traversine.

7.3 COMBINAZIONI DI CALCOLO

Il calcolo tenso-deformazionale è eseguito senza amplificazione dei carichi né riduzione delle resistenze.

In conformità con la circolare ministeriale 2009 al paragrafo C 6.2.3.3.

7.4 CARATTERISTICHE DEI MATERIALI E DEGLI ELEMENTI STRUTTURALI

7.4.1 Calcestruzzo

Le caratteristiche sono presentate al Punto 6.4.5.

7.4.2 Calcestruzzo spruzzato

Fachbereich:
Thema:
Dokumenteninhalt:

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Le caratteristiche sono presentate al Punto 6.4.5.

7.4.3 Terreno

Le caratteristiche sono presentate al Punto 6.4.1.

7.4.4 Jet - grouting

Le caratteristiche sono presentate al Punto 6.4.2.

7.4.5 Terreno del Rilevato ferroviario esistente

Le caratteristiche sono presentate al Punto 6.4.3.

7.4.6 Terreno Compattato

Le caratteristiche sono presentate al Punto 6.4.4.

7.4.7 Micropali paratia in Jet grouting (Binario Dispari pk 54+980)

La paratia in jet grouting a protezione del rilevato ferroviario in prossimità dell'estremità Nord della Galleria sarà armata con tubi in acciaio con le seguenti caratteristiche:

- Diametro esterno $D=168.3$ mm;
- Spessore $s=10$ mm;
- Interasse pali $l= 0.75$ m.

Il singolo tubo è stato modellato come elemento lineare tenendo presente che in condizioni di stato piano della Mesh 2D il calcolo è riferito ad un metro di profondità. I dati di input sono i seguenti:

Area Utile per metro di profondità: 0.00663 m²

Poisson $\nu = 0.2$

Modulo elastico: $E = 210000$ MPa

Momento d' Inerzia per metro di profondità:

$i = 2.08E-005$ m⁴

Peso dell'unità di volume: $\gamma = 78.5$ kN/m³

7.4.8 Micropali per paratia berlinese (Binario Dispari pk 54+997)

La paratia berlinese a protezione del rilevato ferroviario nel tratto più distante dallo scavo sarà costituita da una doppia fila di micropali e avrà le seguenti caratteristiche:

Fachbereich:
Thema:
Dokumenteninhalt:

Settore: Spostamento linea storica
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- Diametro perforazione $D=270$ mm;
- Diametro esterno tubo d'acciaio $D=168.3$ mm
- Spessore tubo d'acciaio $s=10$ mm;
- Interasse longitudinale pali $l= 0.45$ m.
- Interasse trasversale pali $l= 0.45$ m

Nel modello di calcolo è stato inserito un elemento monodimensionale al quale sono state assegnate le caratteristiche geometriche del tubo d'acciaio e della miscela di calcestruzzo presente al suo interno moltiplicate per 2 (per considerare la doppia fila). Naturalmente è stato necessario eseguire un'operazione di omogeneizzazione:

Area Utile per metro di profondità: 0.4081 m^2

Poisson $\nu = 0.2$

Modulo elastico: $E = 30000$ MPa

Momento d' Inerzia per metro di profondità:

$i = 0.00115 \text{ m}^4$

7.4.9 Micropali di ancoraggio della paratia(Binario Dispari)

La paratia a protezione del rilevato ferroviario sarà sostenuta un sistema di ancoraggi in micropali

Essi sono modellati come elementi monodimensionali elastici dotati delle seguenti caratteristiche:

Diametro equivalente : $D= 168.3$ mm

Modulo elastico: $E = 210000$ MPa

Interasse: $i = 1.50$ m (modello alla pk 54+980)

Interasse: $i = 2.25$ m (modello alla pk 54+997)

7.4.10 Micropali per jet grouting (Binario Pari)

Il trattamento di jet grouting a protezione dello scavo per la Galleria binario Pari sarà armato con tubi in acciaio con le seguenti caratteristiche:

- Diametro esterno $D=168.3$ mm;
- Spessore $s=10$ mm;

Fachbereich:
Thema:
Dokumenteninhalt:

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– Interasse pali $l = 1.45$ m.

Il singolo tubo è stato modellato come elemento lineare tenendo presente che in condizioni di stato piano della Mesh 2D il calcolo è riferito ad un metro di profondità. I dati di input sono i seguenti:

Area Utile per metro di profondità: 0.00342 m^2

Poisson $\nu = 0.2$

Modulo elastico: $E = 210000 \text{ MPa}$

Momento d'inerzia per metro di profondità:

$i = 1.78E-005 \text{ m}^4$

Peso dell'unità di volume: $\gamma = 78.5 \text{ kN/m}^3$

7.4.11 Puntoni

Il Primo puntone (ordine superiore) è un profilo tubolare circolare con le seguenti caratteristiche:

Diametro esterno $D = 406.4 \text{ mm}$

Spessore $s = 12.5 \text{ mm}$

Interasse $l =$ circa 4 m

Lunghezza $L =$ circa 10m

Il singolo puntone è stato modellato come elemento monodimensionale. Tenendo presente che, in condizioni di stato piano della Mesh 2D, il calcolo è riferito ad un metro di profondità si sono assegnate le seguenti caratteristiche:

Area Utile per metro di profondità: $A = 0.003865 \text{ m}^2$

Poisson $\nu = 0.2$

Modulo elastico: $E = 210000 \text{ MPa}$

Momento d'inerzia per metro di profondità: $i = 7.51E-005 \text{ m}^4$

Peso dell'unità di volume: $\gamma = 78.5 \text{ kN/m}^3$

Il Secondo e Terzo puntone (ordine inferiore) sono stati modellati come un profilo tubolare circolare con le seguenti caratteristiche:

Diametro esterno $D = 355.6 \text{ mm}$

Spessore $s = 12 \text{ mm}$

Interasse $l =$ circa 4 m

Lunghezza $L =$ circa 10m

Fachbereich:
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Il singolo puntone è stato modellato come elemento monodimensionale. Tenendo presente che in condizioni di stato piano della Mesh 2D il calcolo è riferito ad un metro di profondità si sono assegnate le seguenti caratteristiche:

Area Utile per metro di profondità: $A = 0.003237\text{m}^2$

Poisson $\nu = 0.2$

Modulo elastico: $E = 210000\text{ MPa}$

Momento d' Inerzia per metro di profondità: $i = 4.781\text{E}-005\text{ m}^4$

Peso dell'unità di volume: $\gamma = 78.5\text{ kN/m}^3$

8 DEFORMAZIONI DOVUTE AGLI SCAVI

8.1 ANALISI CONDOTTE

Il calcolo deformatore è stato svolto all'interno dell'analisi agli elementi finiti descritti nei Capitoli precedenti.

I risultati relativi allo stato tensionale sugli elementi strutturali e sul terreno, agli spostamenti e l'output completo del programma per ciascuna fase di costruzione sono riportati in allegato alla presente relazione.

I risultati sintetici delle analisi sono riportati nel seguito per accompagnare la descrizione.

8.2 GALLERIA BINARIO DISPARI

8.2.1 Schematizzazione di calcolo

La distanza dello scavo dalla ferrovia esistente non è costante, ma diminuisce procedendo verso Nord, diventando minima, in prossimità della testa dello scavo. In questa zona, la testata dello scavo, che in pratica costituisce un setto trasversale di irrigimento, offre un notevole contributo alla resistenza e realizza condizioni di tridimensionalità.

Per meglio analizzare la mappa di deformazioni del rilevato ferroviario esistente, sono state analizzati gli

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spostamenti in 4 sezioni poste a distanze variabili da 10 a 17 m, lungo l'asse di scavo, ossia le sezioni poste alle progressive pk 54+968, 54+980, 54+997 e 55+007. Ciò consente di definire una mappa di spostamenti lungo i rilevati. I valori ottenuti tendono a essere superiori rispetto a quelli reali, in quanto in metodo sfrutta sezioni bi-dimensionali. Le stime ottenute sono pertanto conservative.

Sono stati considerate 3 diverse combinazioni di carico, ossia rilevato non caricato dal treno, carico del treno aggiunto a fine scavo, e carico del treno mantenuto mentre lo scavo e la costruzione procedono. Come ulteriore controllo e calibrazione dei risultati, si è stimato l'assestamento prodotto dal carico del treno sul rilevato senza scavo.

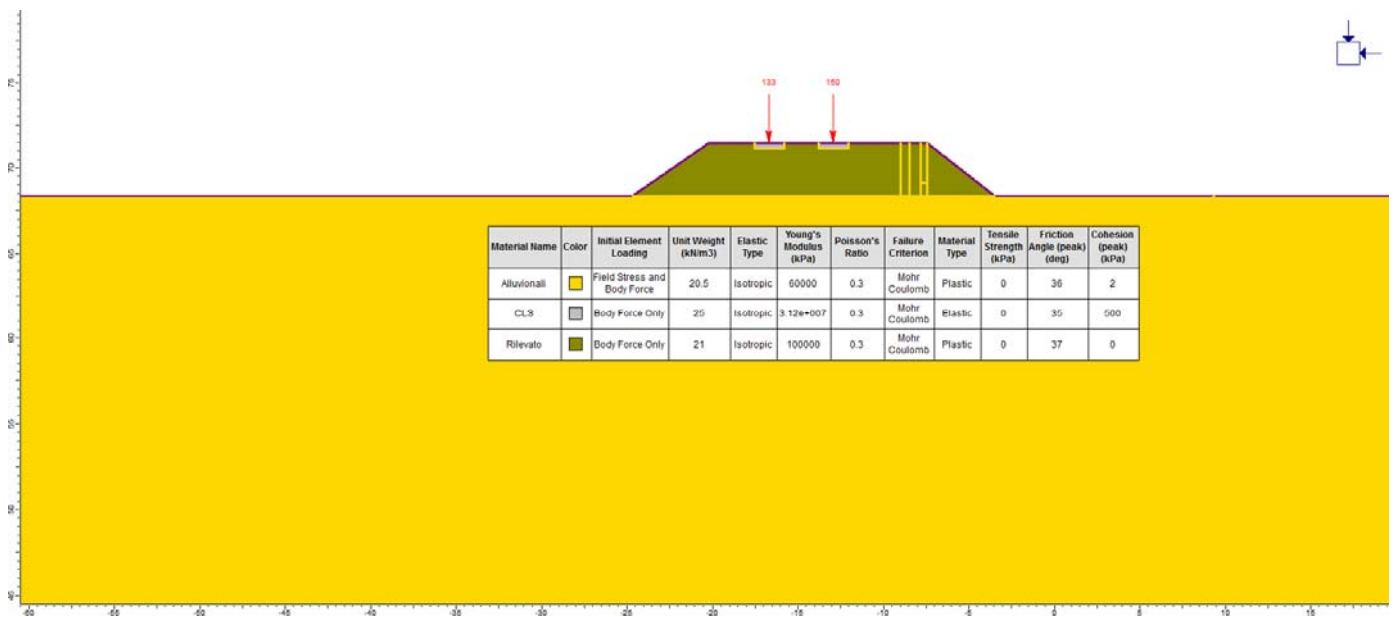


Figura 7: Galleria Binario Dispari. Vista modello elementi finiti – pk 54+968

Fachbereich:
 Thema:
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 Tema: Progettazione del tracciato e dell'opera
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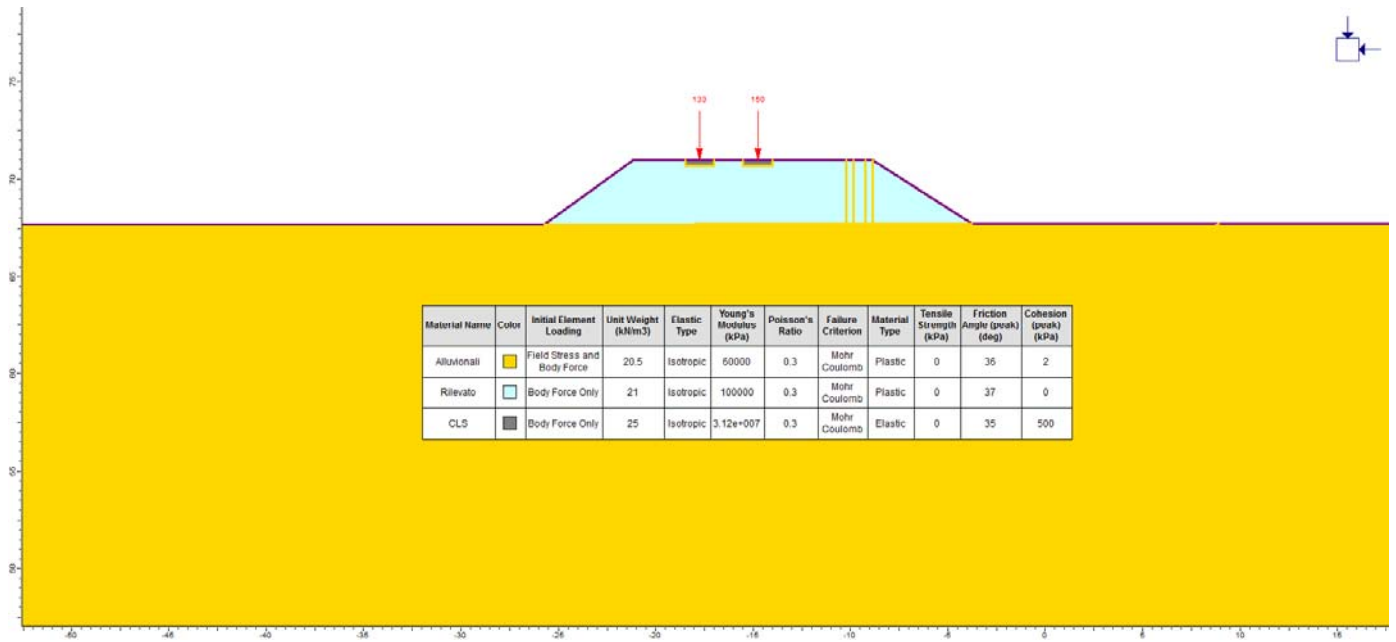


Figura 8: Galleria Binario Dispari. Vista modello elementi finiti – pk 54+980

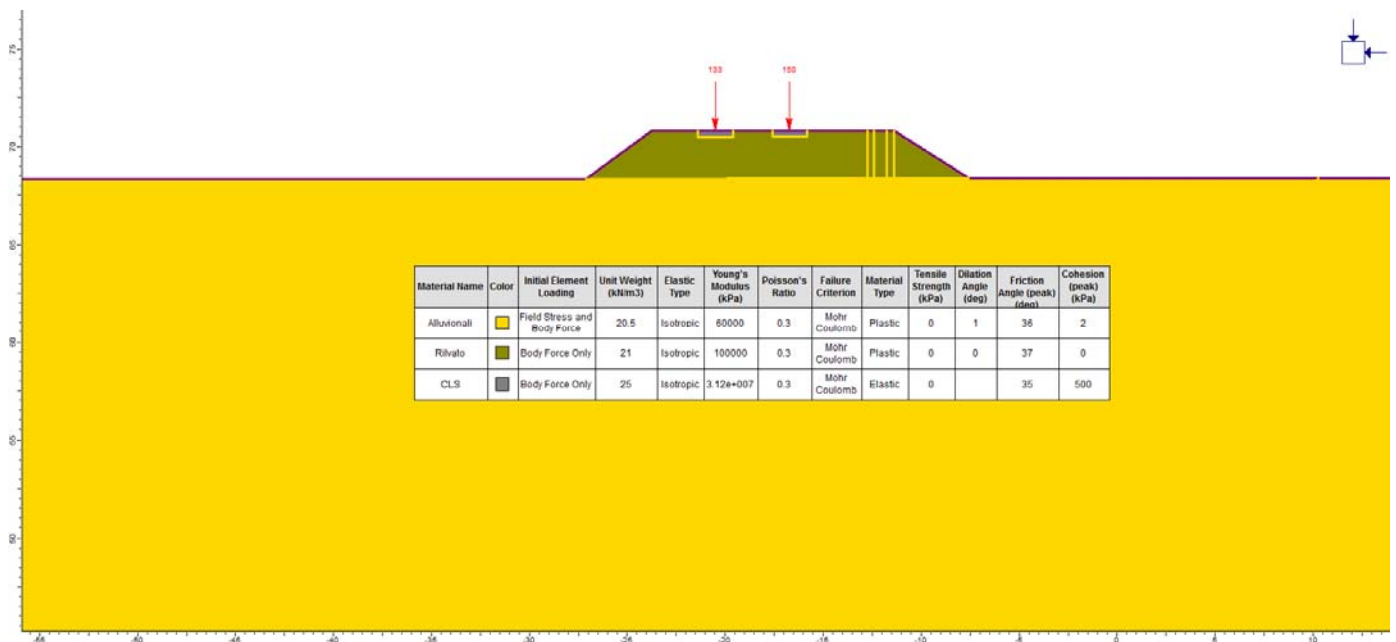


Figura 9: Galleria Binario Dispari. Vista modello elementi finiti – pk 54+997

Fachbereich:
Thema:
Dokumenteninhalt:

Settore: Spostamento linea storica
Tema: Progettazione del tracciato e dell'opera
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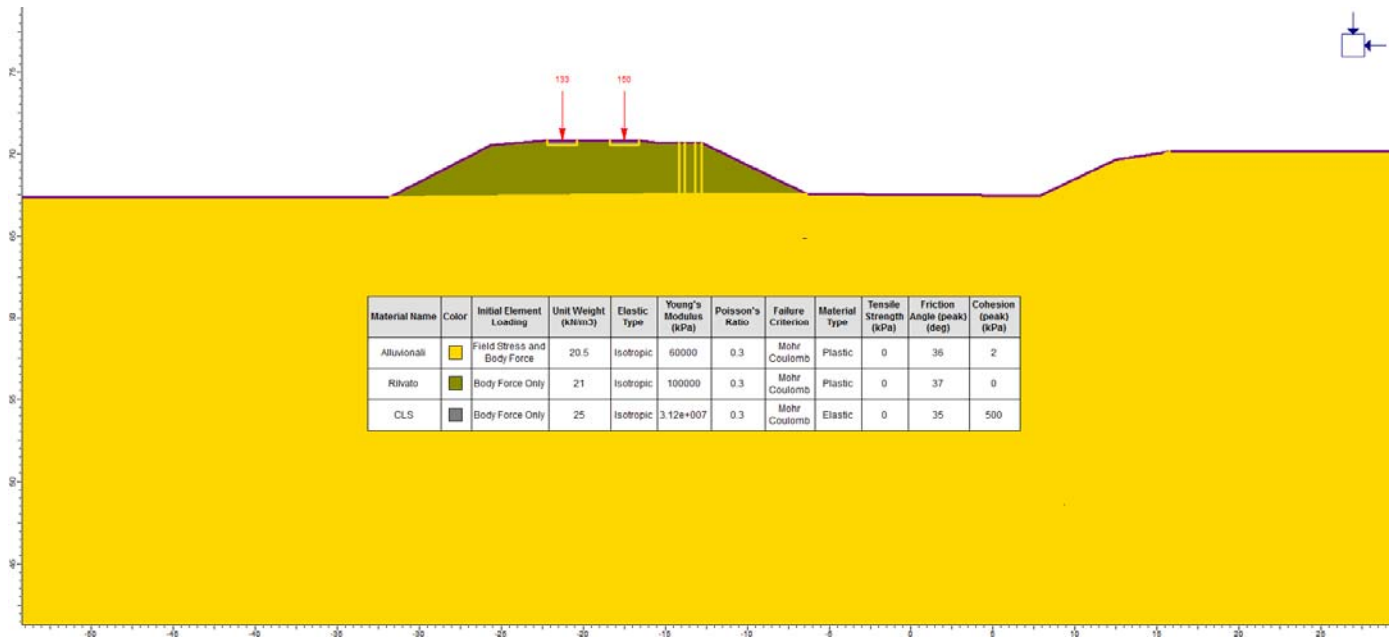


Figura 10: Galleria Binario Dispari. Vista modello elementi finiti – pk 55+007

8.2.2 Deformazioni in fase di costruzione

Per tutte le sezioni analizzate, va sottolineato che, durante le fasi di scavo, le zone plasticizzate sono limitate alle scarpate dello scavo del piano di lavoro e a una fascia immediatamente a tergo del blocco di terreno trattato. Raggiunto il fondo scavo le plasticizzazioni interessano anche una parte limitata alla base della parete di jetgrouting. In ogni caso non è compromessa la stabilità dell'opera, come dimostra il calcolo SRF (vedi relazione di calcolo della Galleria Binario Dispari).

Anche le componenti orizzontale e verticale degli spostamenti sono limitate: ovvero dell'ordine di pochi millimetri. Si osservano spostamenti orizzontali massimi nell'ordine di 15 mm, mentre quelli verticali sono compresi tra 15 e 20 mm, in concomitanza della rimozione dei puntoni sulla parete sottostante il rilevato ferroviario. Questa concentrazione è compatibile con il fatto che qui lo spessore di gettiniezione è leggermente inferiore che altrove.

E' interessante notare che allo scavo si accompagna un leggero sollevamento della superficie, che nel punto di maggiore espansione (asse scavo) raggiunge 20-25 mm. Localmente, sulla testa degli elementi rigidi (jet-grouting, ecc.) si osservano spostamenti verticali fino a

Fachbereich:

Thema:

Dokumenteninhalt:

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circa 20 mm. La fascia interessata da tali spostamenti si estende per circa 30 m su ciascuno dei lati dello scavo.

In corrispondenza del rilevato ferroviario esistente, tale sollevamento è in parte attenuato dagli assestamenti che conseguono all'espansione verso lo scavo. In pratica, gli spostamenti verticali si mantengono nell'ordine di millimetri (vedi paragrafo successivo).

Gli spostamenti di sollevamento vengono sostanzialmente riassorbiti una volta ricoperta la galleria e completati i rilevati.

Fachbereich:
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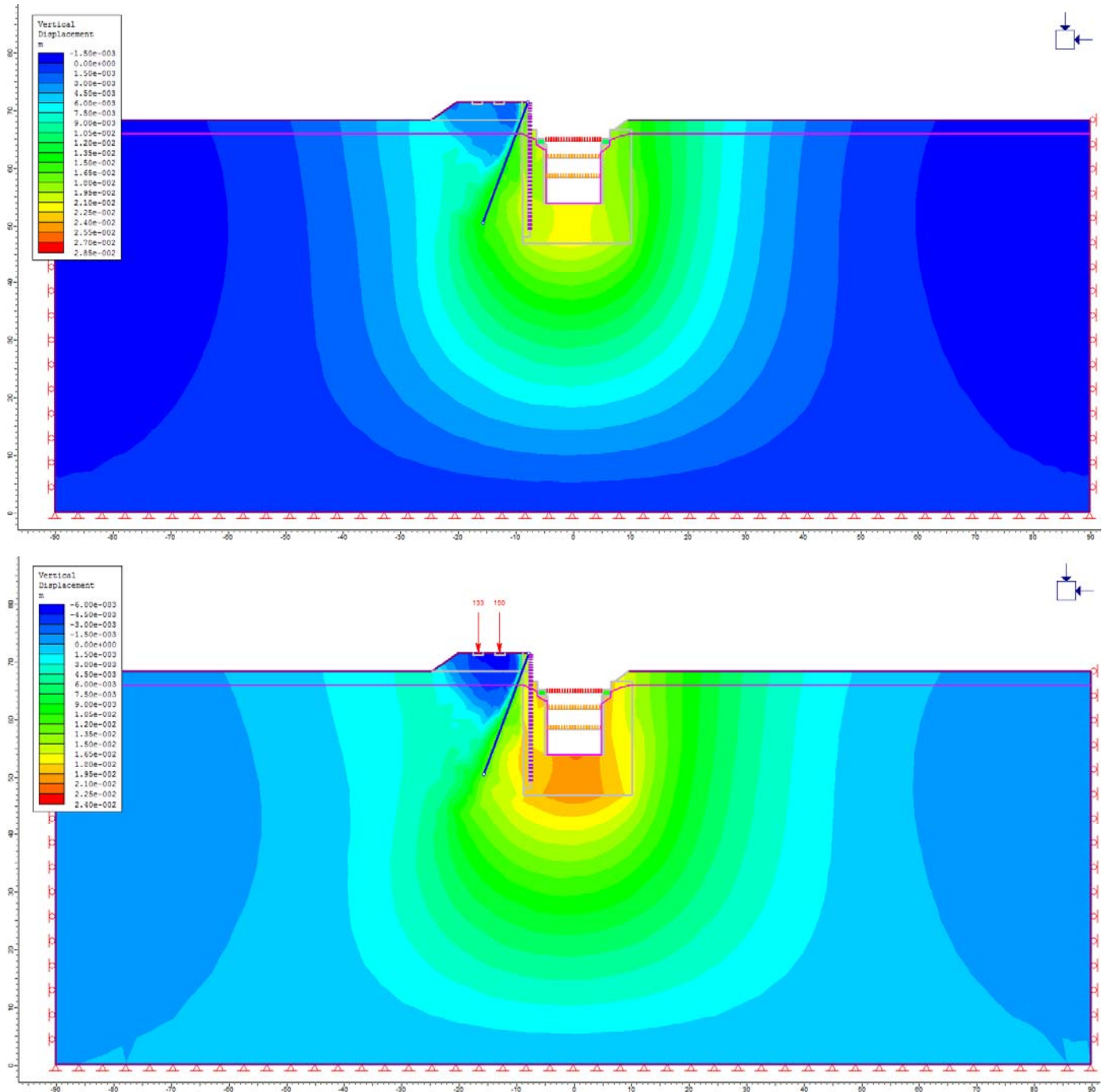


Figura 11: Galleria di Base binario Dispari. Cedimenti nella fase di fondo scavo - pk 54+968

Fachbereich:
Thema:
Dokumenteninhalt:

Settore: Spostamento linea storica
Tema: Progettazione del tracciato e dell'opera
Contenuto documento: Calcolo dei cedimenti di terrapieno della
ferrovia

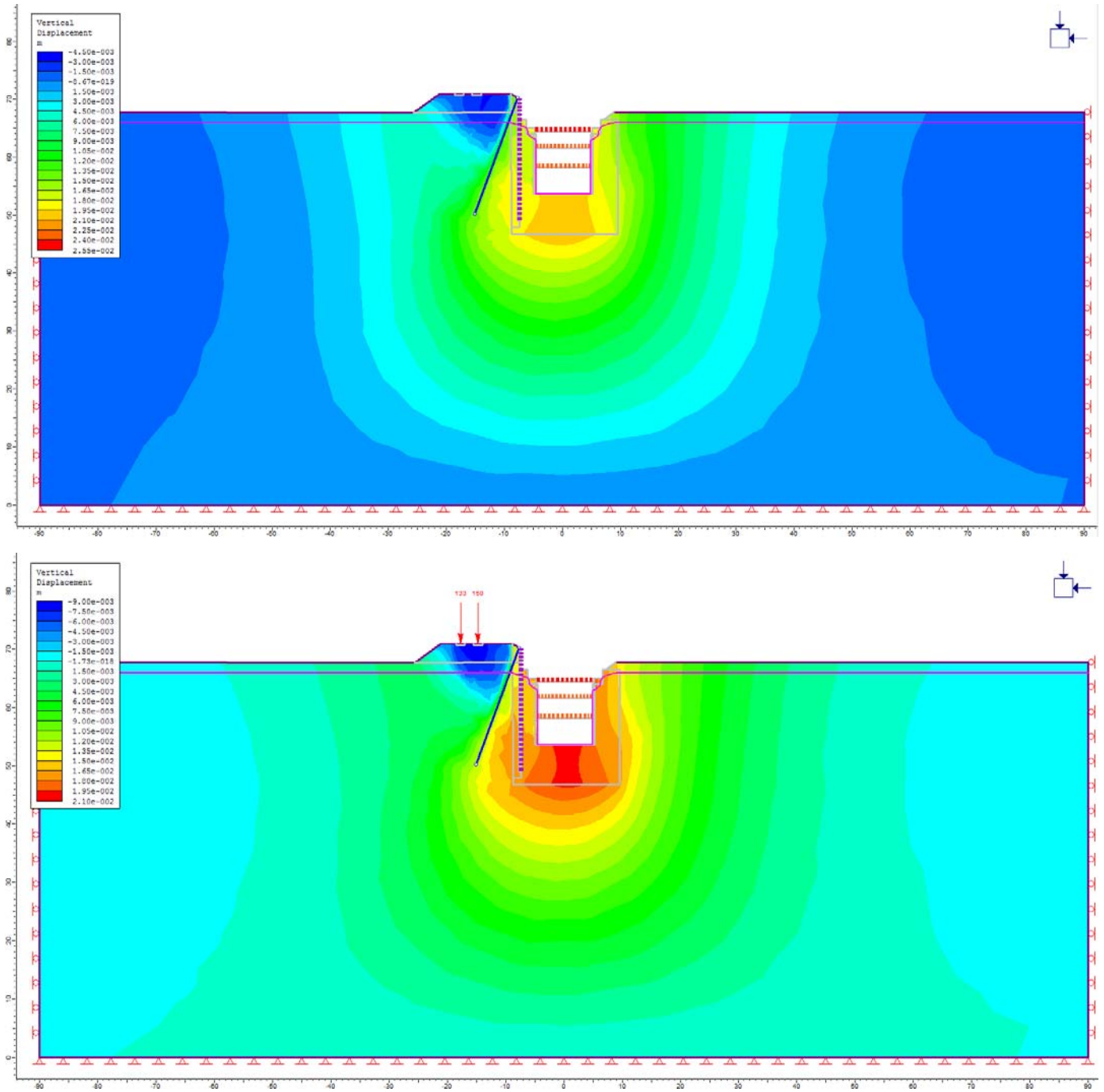


Figura 12: Galleria di Base binario Dispari.Cedimenti nella fase di fondo scavo - pk 54+980

Fachbereich:
Thema:
Dokumenteninhalt:

Settore: Spostamento linea storica
Tema: Progettazione del tracciato e dell'opera
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ferrovia

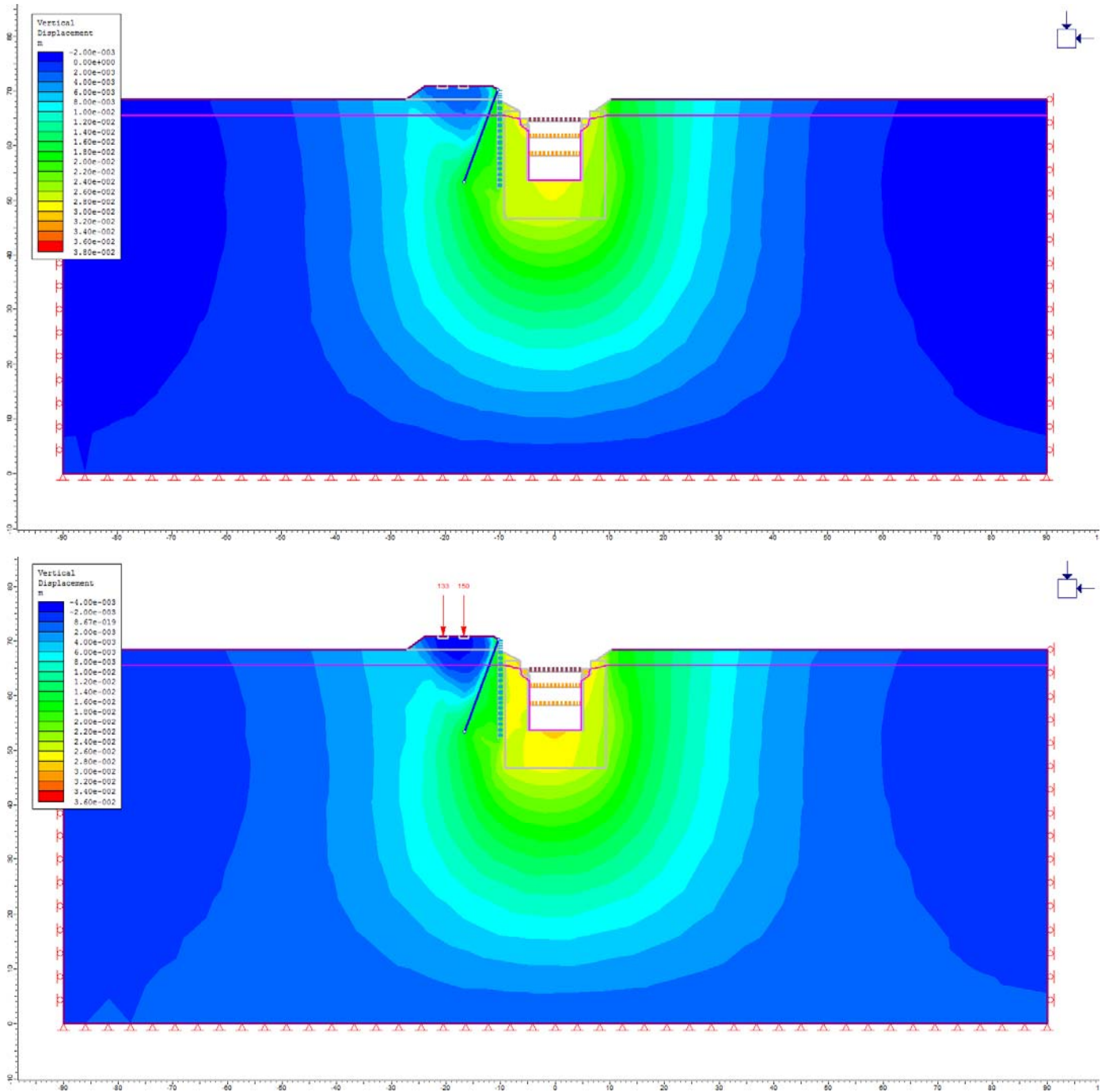


Figura 13: Galleria di Base binario Dispari. Cedimenti nella fase di fondo scavo - pk 54+997

Fachbereich:
Thema:
Dokumenteninhalt:

Settore: Spostamento linea storica
Tema: Progettazione del tracciato e dell'opera
Contenuto documento: Calcolo dei cedimenti di terrapieno della
ferrovia

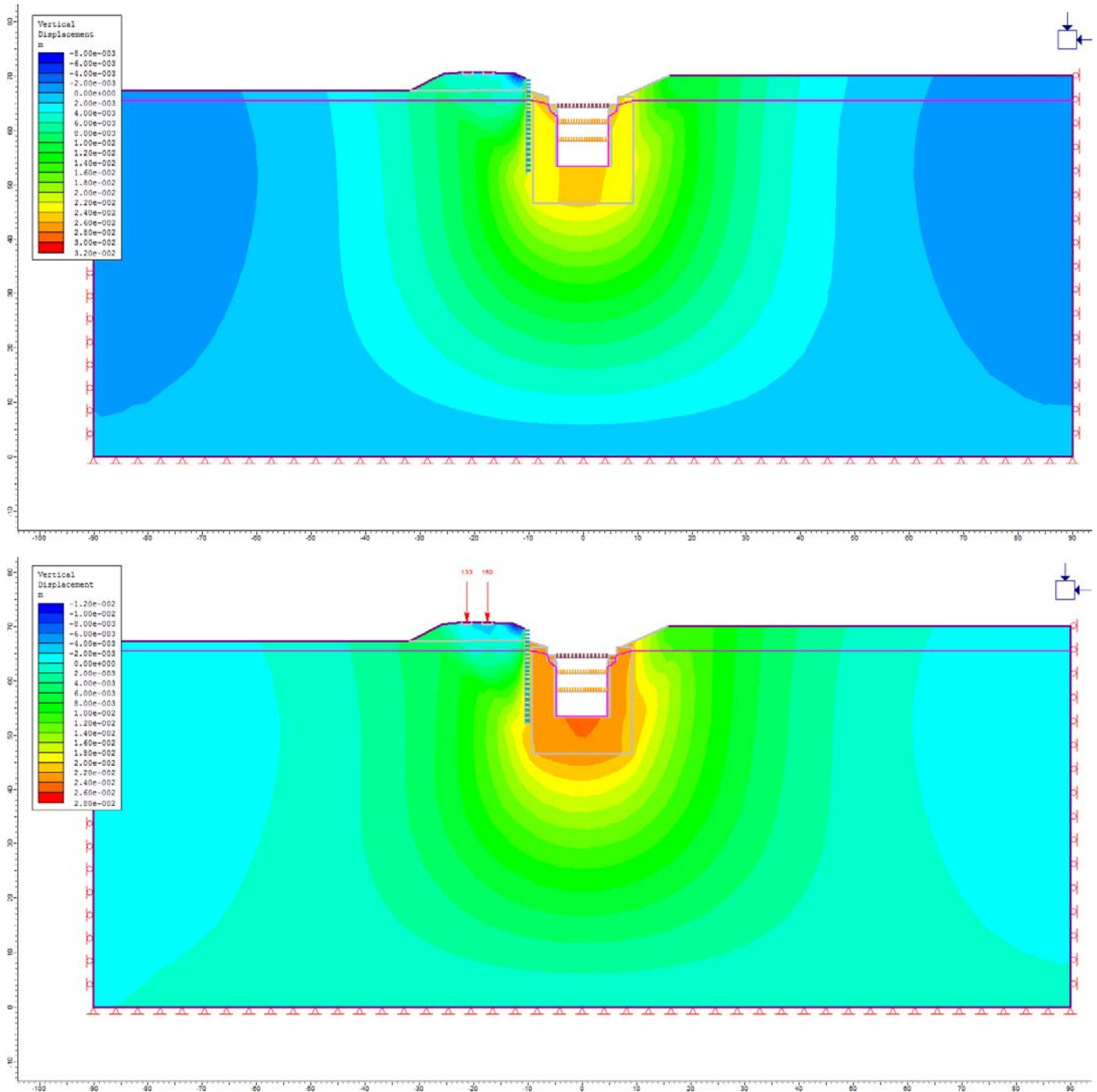


Figura 14: Galleria di Base binario Dispari.Cedimenti nella fase di fondo scavo - pk 55+007

8.2.3 Deformazioni del rilevato ferroviario esistente

Nella situazione indisturbata (senza scavo e senza jet-grouting) gli spostamenti sotto i binari, al passaggio del

Fachbereich:
Thema:
Dokumenteninhalt:

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Contenuto documento: Calcolo dei cedimenti di terrapieno della ferrovia

treno sono nell'ordine di 6-7 mm.

I risultati disponibili di assestamento nelle varie sezioni lungo la linea sono presentati sinteticamente nelle tabelle di Figura 15 e Figura 16 e nella Figura 11, Figura 12, Figura 13 e Figura 14.

Per le sezioni analizzate in fase di scavo e con lo scavo alla sua profondità massima, si registrano spostamenti massimi sotto i binari nell'ordine di $-2 \div +9$ mm (sollevamento), con rilevato scarico, $-9 \div +4$ mm, con rilevato caricato una volta completato lo scavo, e $-13 \div +2$ mm, con scavo eseguito in presenza di carico equivalente al treno. L'assestamento verticale compensa il sollevamento prodotto dallo scarico tensionale attorno a 12 m dalla testata dello scavo (Sez 3).

Gli spostamenti dovuti al carico del treno (differenza tra rilevato scarico e carico) sono variabili da 4.7 a 11.4 mm. I corrispondenti spostamenti differenziali lungo la stesa di carico sono nell'ordine di 1-4 mm.

Osservando gli spostamenti differenziali lungo stazioni adiacenti di un singolo binario, si osservano distorsioni massime nell'ordine di 0.19 ‰ ($< 4\text{mm}/3\text{m}$), quando tutti i punti risultino sottoposti alla stessa stesa di carico.

Quando si osservi la distorsione massima che si manifesta alla fine di una stesa di carico con la sezione scarica adiacente, le distorsioni massime diventano nell'ordine di 1.34‰ ($< 4.29\text{ mm}/3\text{m}$). In questo caso tuttavia, non è stata considerata la ripartizione dei carichi dovuta alla presenza dell'armamento e dello strato di sottofondazione e quindi tali distorsioni sono verosimilmente superiori rispetto a quelle attese a livello binario.

Le distorsioni longitudinali sono contenute.

Osservando i dati di spostamento tra binari contigui, si nota che il differenziale massimo in asse ai binari è di 2.5 mm, su una distanza di 3.8 m. Assunto che ciò corrisponda a una rotazione rigida di entrambi i binari, si può stimare una distorsione trasversale nell'ordine di 0.66 ‰.

Anche le distorsioni laterali appaiono contenute.

Fachbereich:

Thema:

Dokumenteninhalt:

Settore: Spostamento linea storica

Tema: Progettazione del tracciato e dell'opera

Contenuto documento: Calcolo dei cedimenti di terrapieno della ferrovia

A)

pk	L(m)	statici	assoluti treno a fine scavo	scavo con treno	netto treno a fine scavo	cedimento differenziale	distorsione	netto scavo con treno	cedimento differenziale	distorsione	
54+	889	7.2	2.5	0.2	-4.7		‰	-7.0		‰	
54+	968	79	3.4	-4.8	-5.6	-8.2	-3.5	-0.0441	-9.0	-2.0	-0.0256
54+	980	12	-1.2	-7.8	-12.6	-6.7	1.5	0.1279	-11.4	-2.4	-0.2009
54+	997	17	3.4	-3.6	-5.2	-7.0	-0.3	-0.0174	-8.6	2.8	0.1669
54+	1007	10	4.7	-2.1	-3.7	-6.8	0.1	0.0128	-8.4	0.2	0.0211

B)

pk	L(m)	treno a fine scavo pk crescente			treno a fine scavo pk decrescente			
		dist	‰	dist	‰			
54+	889	79	0.00087	0.0000	0.0110			
54+	968	12	0.00361	0.0003	0.3007	0.01203	0.0002	0.1523
54+	980	17	0.01124	0.0007	0.6611	0.01124	0.0009	0.9366
54+	997	10	0.00825	0.0008	0.8253	0.00237	0.0001	0.1394
54+	1007					0.00552	0.0006	0.5523

B)

pk	L(m)	scavo con treno pk crescente			scavo con treno pk decrescente			
		dist	‰	dist	‰			
54+	889	79	0.00317	0.0000	0.0401			
54+	968	12	0.00517	0.0004	0.4310	0.01359	0.0002	0.1720
54+	980	17	0.01602	0.0009	0.9424	0.01602	0.0013	1.3351
54+	997	10	0.00990	0.0010	0.9903	0.00402	0.0002	0.2365
54+	1007					0.00709	0.0007	0.7090

A) distorsioni con tutti i punti sottoposti alla stessa stesa di carico; B) distorsioni nel punto di fine stesa di carico

Figura 15: Galleria di Base binario Dispari. Assestamenti del binario di Sinistra nella fase di fondo scavo

Fachbereich:

Settore: Spostamento linea storica

Thema:

Tema: Progettazione del tracciato e dell'opera

Dokumenteninhalt:

Contenuto documento: Calcolo dei cedimenti di terrapieno della ferrovia

A)

pk	L(m)	statici	assoluti treno a fine scavo	scavo con treno	netto treno a fine scavo	cedimento differenziale	distorsione	netto scavo con treno	cedimento differenziale	distorsione	
54+	889	8.8	3.9	1.1	-4.9		‰	-7.7		‰	
54+	968	79	2.6	-5.9	-6.4	-8.5	-3.6	-0.0456	-9.0	-1.3	-0.0167
54+	980	12	-2.6	-8.9	-12.5	-6.2	2.3	0.1887	-9.9	-0.9	-0.0714
54+	997	17	3.4	-3.4	-5.8	-6.8	-0.6	-0.0333	-9.1	0.7	0.0440
54+	1007	10	3.7	-3.7	-7.1	-7.5	-0.7	-0.0665	-10.9	-1.7	-0.1707

B)

pk	L(m)	treno a fine scavo pk crescente			treno a fine scavo pk decrescente			
		dist	‰	dist	‰			
54+	889	79	-0.00129	0.0000	-0.0163			
54+	968	12	0.00323	0.0003	0.2693	0.01467	0.0002	0.1857
54+	980	17	0.01225	0.0007	0.7206	0.01149	0.0010	0.9574
54+	997	10	0.00717	0.0007	0.7167	0.00077	0.0000	0.0454
54+	1007					0.00709	0.0007	0.7085

B)

pk	L(m)	scavo con treno pk crescente			scavo con treno pk decrescente			
		dist	‰	dist	‰			
54+	889	79	0.00154	0.0000	0.0194			
54+	968	12	0.00485	0.0004	0.4046	0.01629	0.0002	0.2063
54+	980	17	0.01591	0.0009	0.9361	0.01515	0.0013	1.2627
54+	997	10	0.00952	0.0010	0.9517	0.00312	0.0002	0.1836
54+	1007					0.01048	0.0010	1.0478

A) distorsioni con tutti i punti sottoposti alla stessa stesa di carico; B) distorsioni nel punto di fine stesa di carico

Figura 16: Galleria di Base binario Dispari. Assestamenti del binario di destra(il più vicino alla paratia e allo scavo) nella fase di fondo scavo

Fachbereich:
 Thema:
 Dokumenteninhalt:

Settore: Spostamento linea storica
 Tema: Progettazione del tracciato e dell'opera
 Contenuto documento: Calcolo dei cedimenti di terrapieno della ferrovia

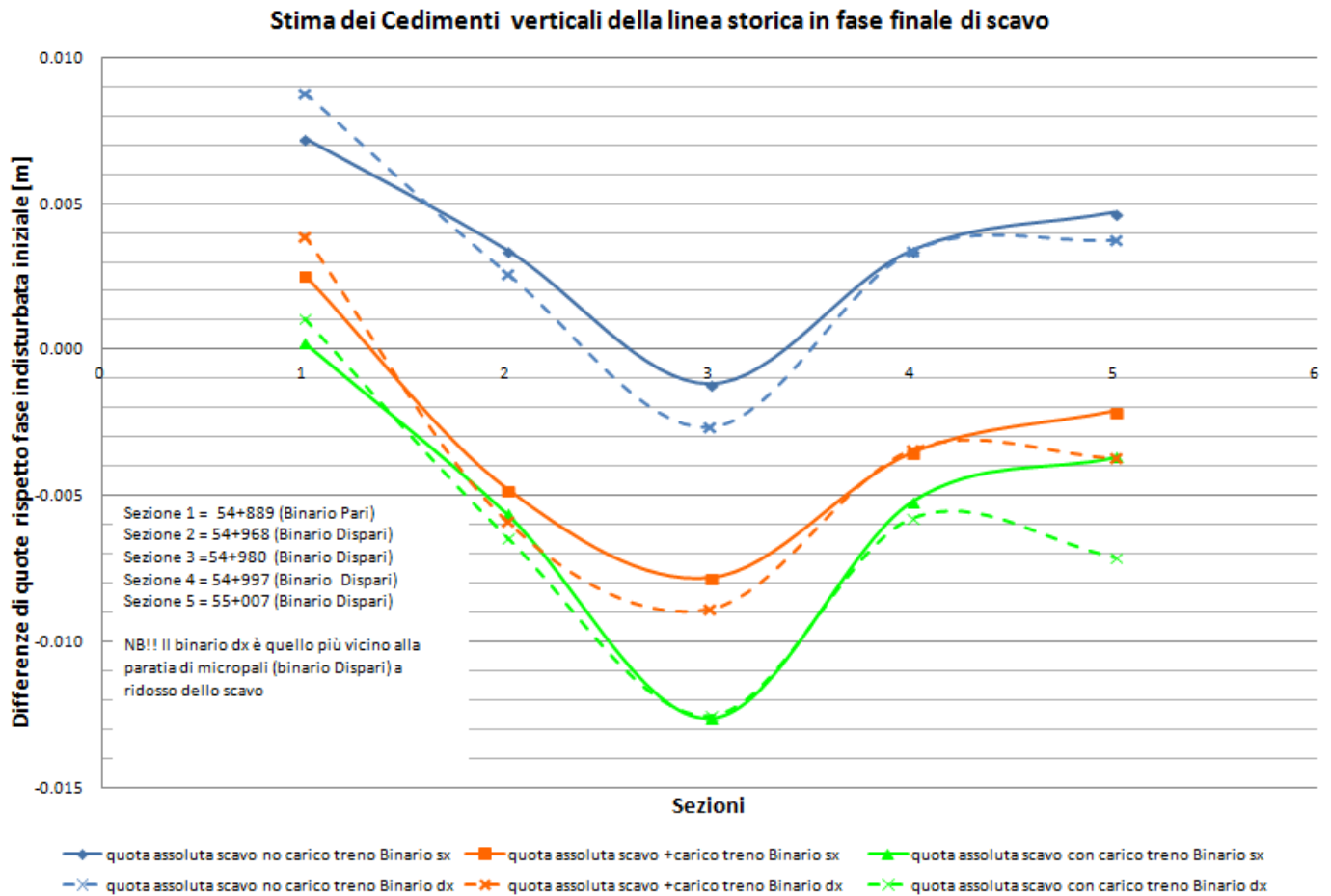


Figura 17: Galleria di Base binario Dispari. Assestamenti della testa rilevato dovuti allo scavo per la galleria e sotto un carico equivalente al passaggio del treno nelle 4 sezioni analizzate.

8.3 GALLERIA BINARIO PARI

8.3.1 Schematizzazioni di calcolo

In questo caso è stata analizzata una sola sezione alla progressiva km 54+889, la cui geometria è presentata in Figura 18. Sono stati considerate 3 diverse combinazioni di carico, ossia rilevato non caricato dal treno, carico del treno aggiunto a fine scavo, e carico del treno mantenuto mentre lo scavo e la costruzione procedono. Come ulteriore controllo e calibrazione dei risultati, si è stimato l'assestamento prodotto dal carico del treno sul rilevato senza scavo.

Fachbereich:
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Settore: Spostamento linea storica
Tema: Progettazione del tracciato e dell'opera
Contenuto documento: Calcolo dei cedimenti di terrapieno della ferrovia

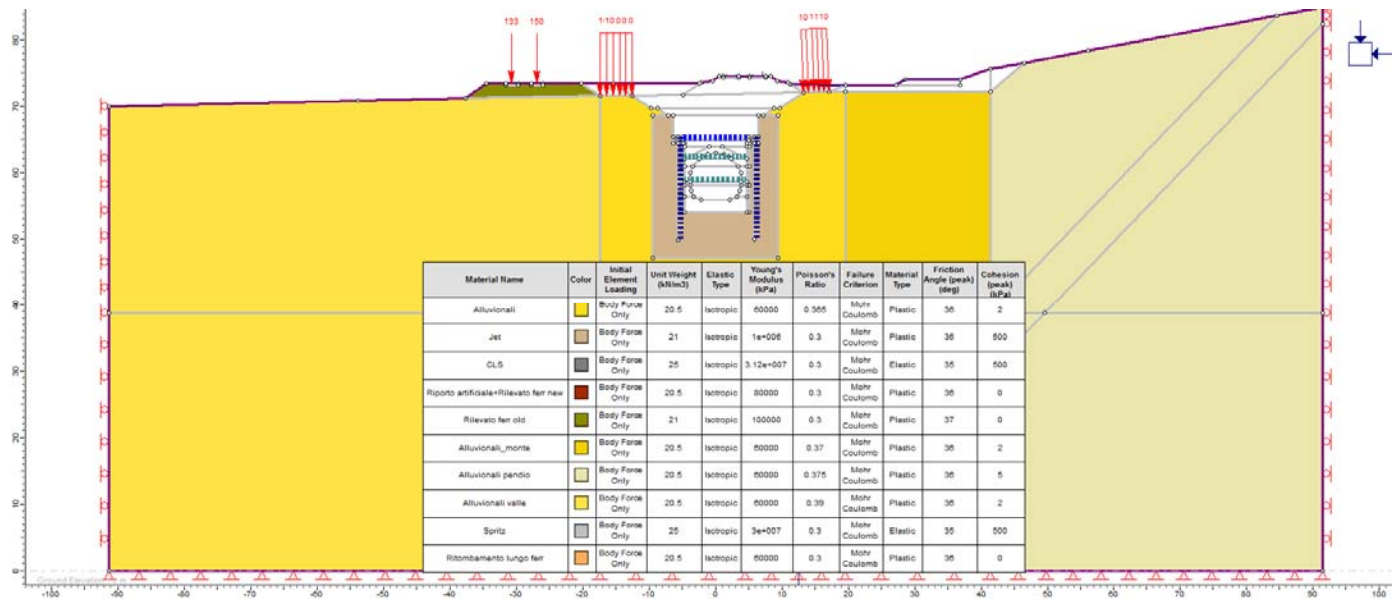


Figura 18: Galleria binario Pari. Vista modello elementi finiti – pk 54+889

8.3.2 Deformazioni in fase di costruzione

Per la sezione analizzata, le componenti orizzontale e verticale degli spostamenti sono in genere limitate: ovvero dell'ordine di pochi millimetri. Solo in concomitanza della rimozione dei puntoni in zone localizzate del modello, si osservano spostamenti massimi nell'ordine di 22 mm, in senso verticale, e 14 mm, in orizzontale, lungo la parete di scavo. Gli spostamenti ottenuti sono pari al $14/18000 = 1/1285$ e quindi ammissibili. Inoltre tali spostamenti non hanno influenza diretta su altre opere.

8.3.3 Deformazioni del rilevato ferroviario

Nella situazione indisturbata (senza scavo e senza jet-grouting) gli spostamenti al passaggio del treno sono nell'ordine di 4-5 mm, sotto i binari.

I risultati disponibili di assestamento di questa sezione sono presentati sinteticamente nelle tabelle di Figura 15 e Figura 16, assieme a quelli delle altre sezioni lungo la linea.

Si può osservare che gli spostamenti associati alle varie condizioni di carico di questa sezione sono in genere inferiori a quelli delle altre sezioni e modesti in valore assoluto (pochi millimetri). In genere, vista la distanza dagli scavi, il sollevamento provocato dallo

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Dokumenteninhalt:

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ferrovia

scarico tensionale è in genere prevalente.

Nel complesso valgono le considerazioni presentate e discusse al paragrafo precedente per gli assestamenti indotti dalla galleria binario dispari, essendo le sezioni di linea vicine tra loro. Gli spostamenti del rilevato ferroviario dovuti allo scavo della galleria pari appaiono quindi compatibili con l'esercizio della ferrovia.

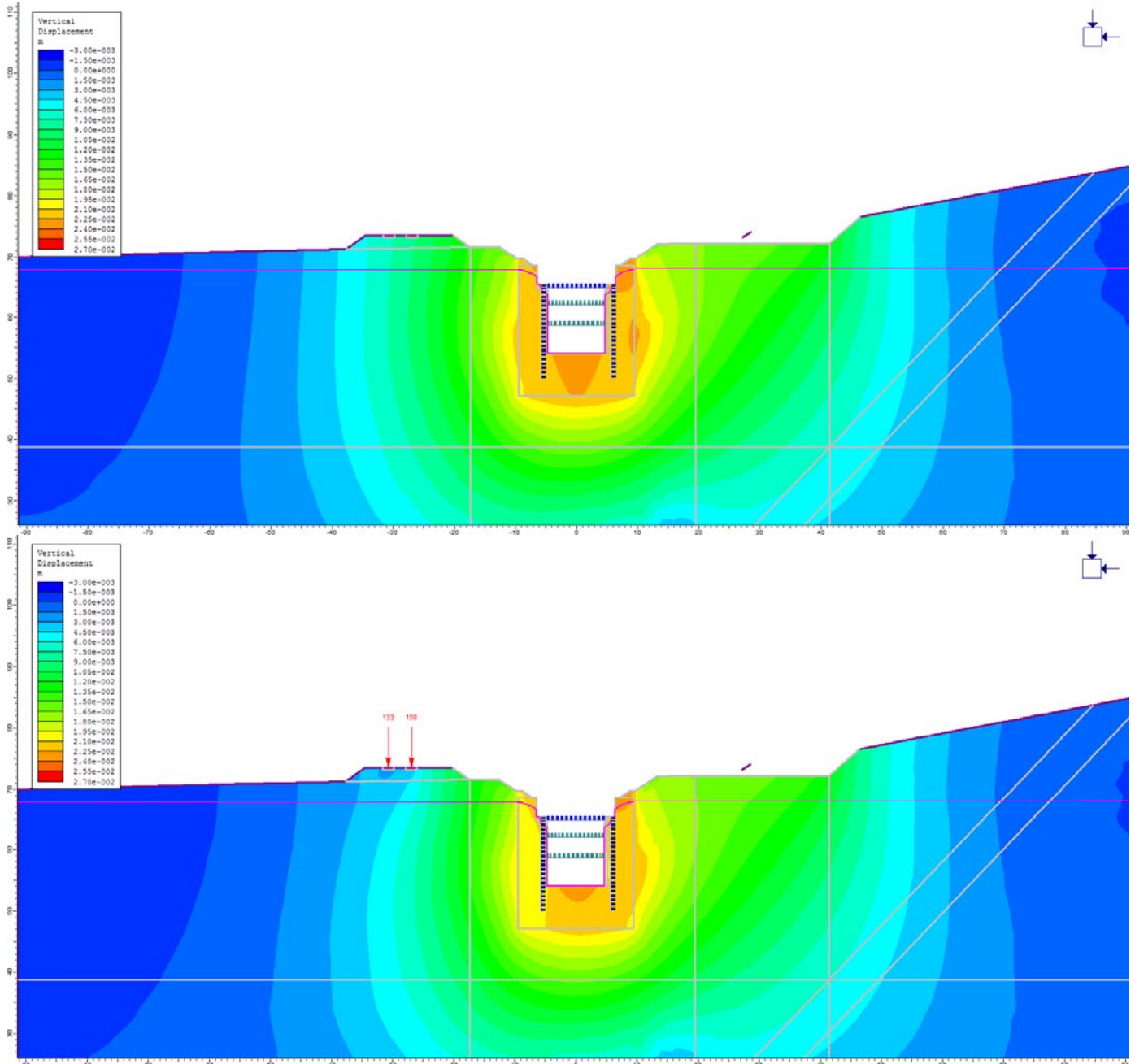


Figura 19: Galleria di Base binario Pari. Progressiva pk_54+889. Spostamenti verticali dY. Fase finale di scavo.

Fachbereich:
Thema:
Dokumenteninhalt:

Settore: Spostamento linea storica
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Contenuto documento: Calcolo dei cedimenti di terrapieno della ferrovia

9 DEFORMAZIONI DOVUTE ALLA COSTRUZIONE DEI NUOVI RILEVATI

9.1 CARATTERISTICHE DEI RIEMPIMENTI

I riempimenti di terreno sono realizzati con il materiale disponibile in sito e ricavato dagli scavi stessi, che consiste principalmente in ghiaie con sabbia e fine in quantità subordinata.

I riempimenti sotto ai rilevati potranno essere realizzati in strati di 60 cm sciolti, con contenuto d'acqua all'ottimo modificato e con 6 passate di rullo con carico lineare specifico da 35 kg/cm.

9.2 ASSESTAMENTI STIMABILI CON METODI SEMPLIFICATI

Si assume che il carico da traffico ferroviario pari a 180 kPa (treno di carico SW/2) sia applicato su una larghezza di 3.0 m, ed una profondità di 70 cm sotto il piano del ferro e che il rilevato sia spesso 3.5 m (spessore medio).

$$b_0 = 3.0 \text{ m}$$

$$b_1 = 3.0 + 2 \cdot 3.5 \cdot \tan(30^\circ) = 7.04 \text{ m}$$

$$q_{vk} = 180 \cdot 3 / 7.04 = 76 \text{ kPa}$$

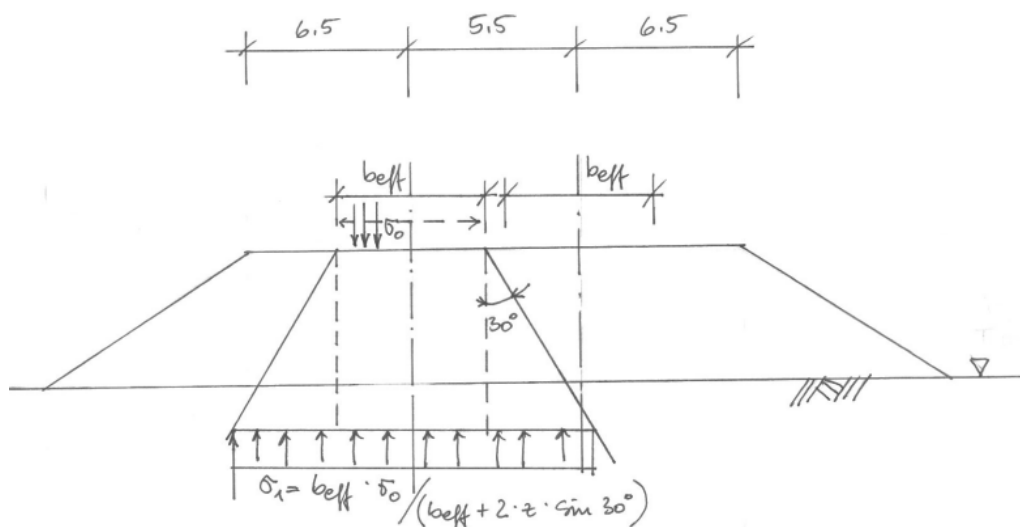


Figura 20: Propagazione del carico per carichi da traffico nel rilevato

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Il modulo di reazione per un'impronta di carico di 7 m puo essere stimato a partire da quello su piastra di 0.6 m con la relazione di Terzaghi $w/w_p = (2B/1+B)^2$, dove B = diametro di carico in piedi. Essendo:

$$\text{piastra 60 cm } w/w_i = (2 \cdot 2 / (1 + 2))^2 = 1.78$$

$$\text{impronta 7 m } w/w_i = (2 \cdot 23 / (1 + 23))^2 = 3.67$$

Il rapporto di assestamento tra le due impronte risulta:

$$w_7/w_{0.6} = 3.67/1.78 = 2$$

Il modulo di reazione a 7 m di profondità è dunque nell'ordine di $k = 100/2 = 50 \text{ kPa/mm}$.

L'assestamento elastico sotto i carichi di esercizio stimabile sulla base dei dati oggi disponibili è dunque nell'ordine di $w = 76 / 50 = 1 - 2 \text{ mm}$.

Per una stima dell'assestamento del rilevato, si può assumere una pressione media all'interno del rilevato pari a $p_{\text{medio}} = 180 / (3+7)/2 = 36 \text{ kPa}$. La deformazione media è pari a $\text{eps} = 36/60000 = 0.06\%$, da cui si può stimare un assestamento di $0.06/100 \cdot 3500 = 2.1 \text{ mm}$.

Complessivamente, l'assestamento stimabile con metodi semplificati sotto al binario risulta nell'ordine di $d_{\text{tot}} = 2+2 = 4 \text{ mm}$.

9.3 ASSESTAMENTI STIMABILI CON L'ANALISI FEM

9.3.1 Modellazione condotta

Una stima degli assestamenti dei rilevati ferroviari che passano sopra le gallerie artificiali è stata eseguita con il Programma agli Elementi Finiti Phase2, di Rocscience. Il programma consente di simulare l'intero percorso tensionale di scavo e costruzione fino alla realizzazione del rilevato e tiene conto quindi dell'effettivo stato tensionale presente in fondazione.

Sono stati analizzati due modelli diversi, sopra la galleria binario Dispari e Pari rispettivamente. La geometria di analisi è riportata nella Figura 18.

Gli assestamenti stimati con l'analisi agli elementi finiti, per i rilevati di nuova costruzione sopra le gallerie artificiali sono riassunti nella Figura 17 e Figura 19, mentre l'output completo è contenuto nell'Allegato B.

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Dokumenteninhalt:

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Tema: Progettazione del tracciato e dell'opera
Contenuto documento: Calcolo dei cedimenti di terrapieno della ferrovia

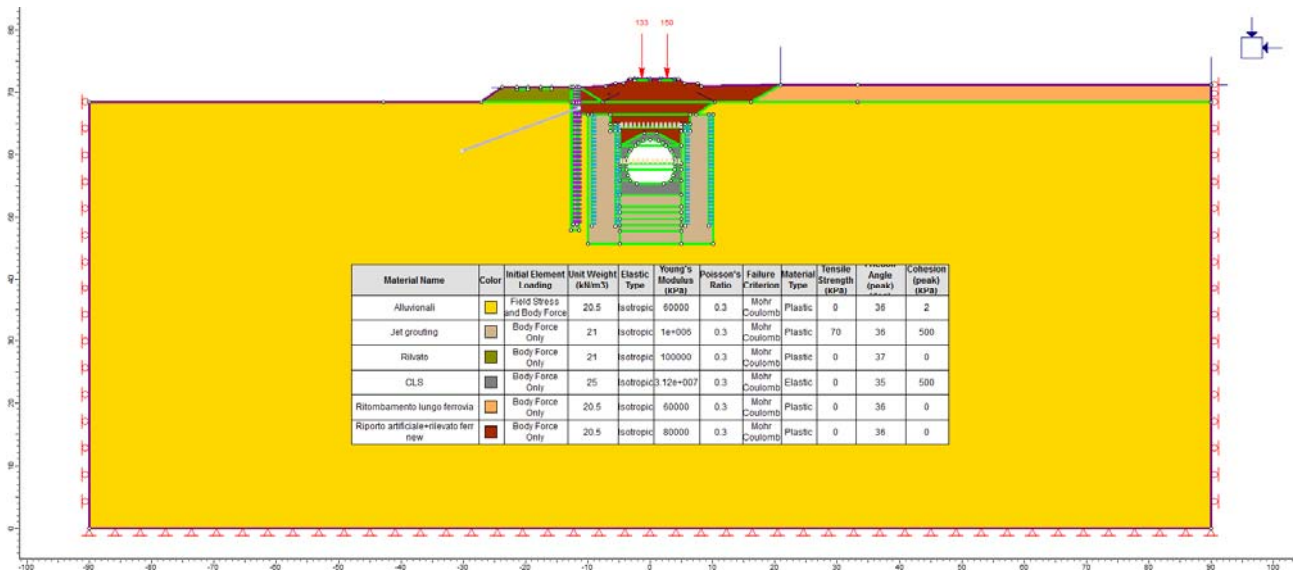


Figura 21: Galleria Binario Dispari. Assestamento del rilevato della Linea Storica spostata, sezione pk 0+325. Geometria di calcolo

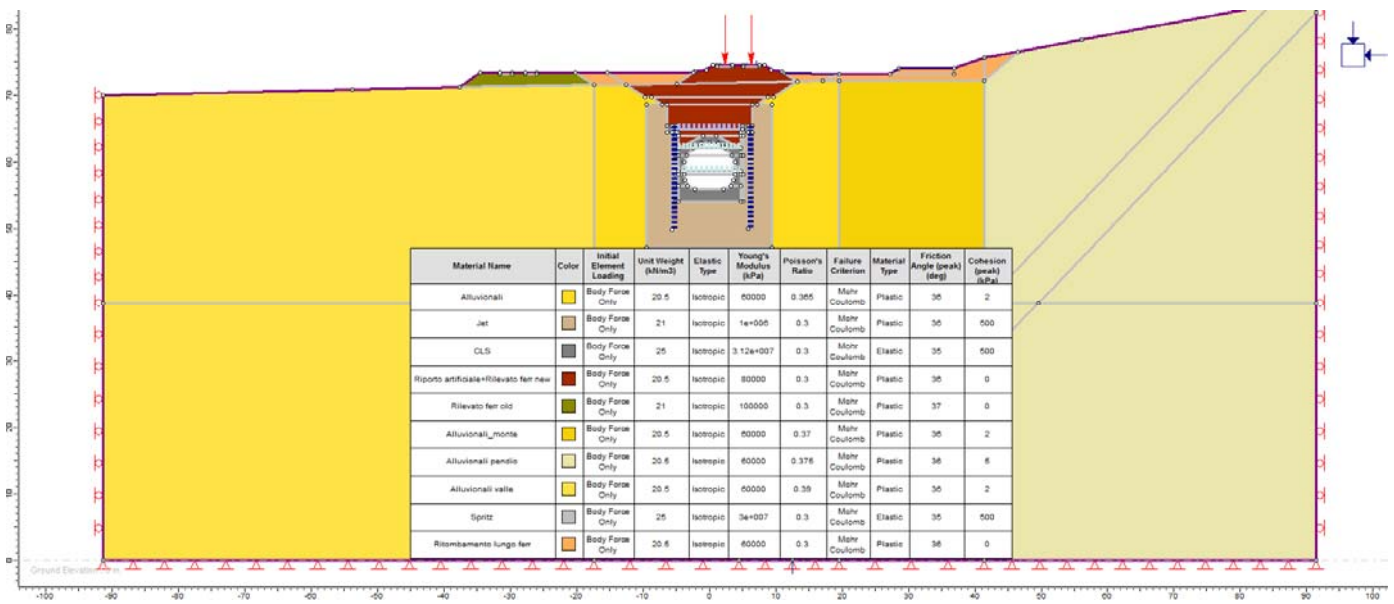


Figura 22: Galleria Binario Pari. Assestamento del rilevato della Linea Storica spostata, sezione pk 0+425. Geometria di calcolo

Fachbereich:

Thema:

Dokumenteninhalt:

Settore: Spostamento linea storica

Tema: Progettazione del tracciato e dell'opera

Contenuto documento: Calcolo dei cedimenti di terrapieno della ferrovia

9.3.2 Risultati

Gli assestamenti stimati con l'analisi agli elementi finiti, per i rilevati di nuova costruzione sopra le gallerie artificiali (Figura 23 e Figura 24) sono stati ottenuti per le configurazioni rilevato scarico e rilevato caricato dal treno su entrambi i binari, per massimizzare l'effetto. In entrambi i casi è stata simulata l'intera costruzione, per cui il valore finale di assestamento ne include gli effetti.

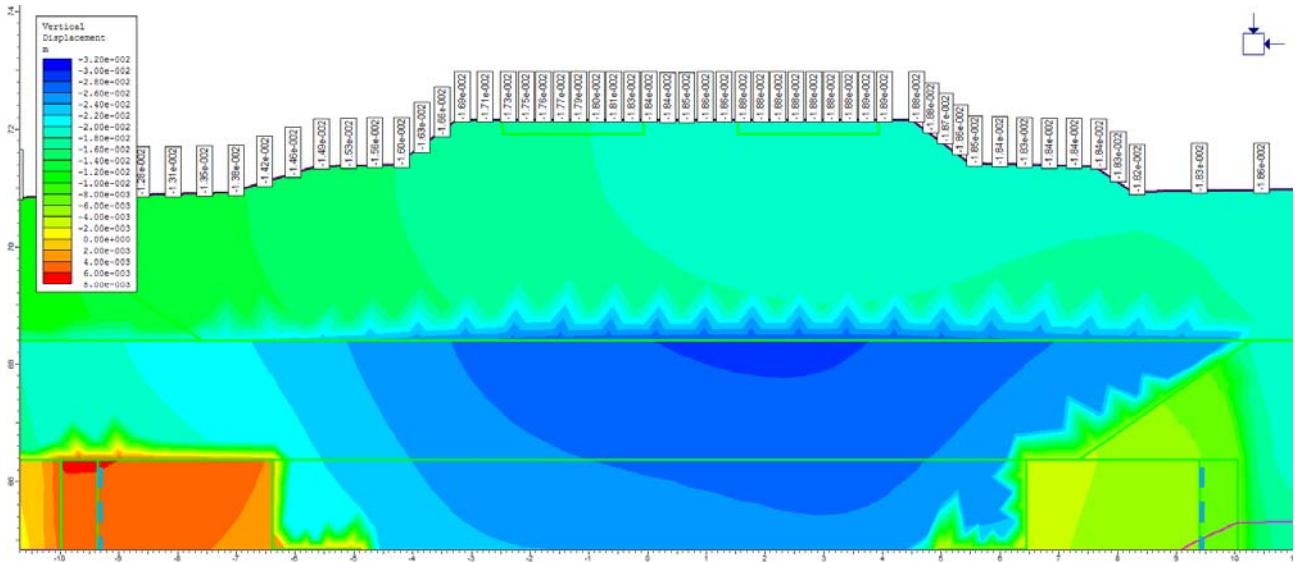
Gli assestamenti così ottenuti senza il carico del treno sono nell'ordine di 19 mm, per il Binario Dispari, e 13 mm, per quello pari. Con il carico del treno, tali valori diventano 23 e 18 mm, rispettivamente.

Chiaramente la parte di assestamento dovuto alla costruzione è irrilevante rispetto all'esercizio, in quanto interamente scontato prima della posa dell'armamento.

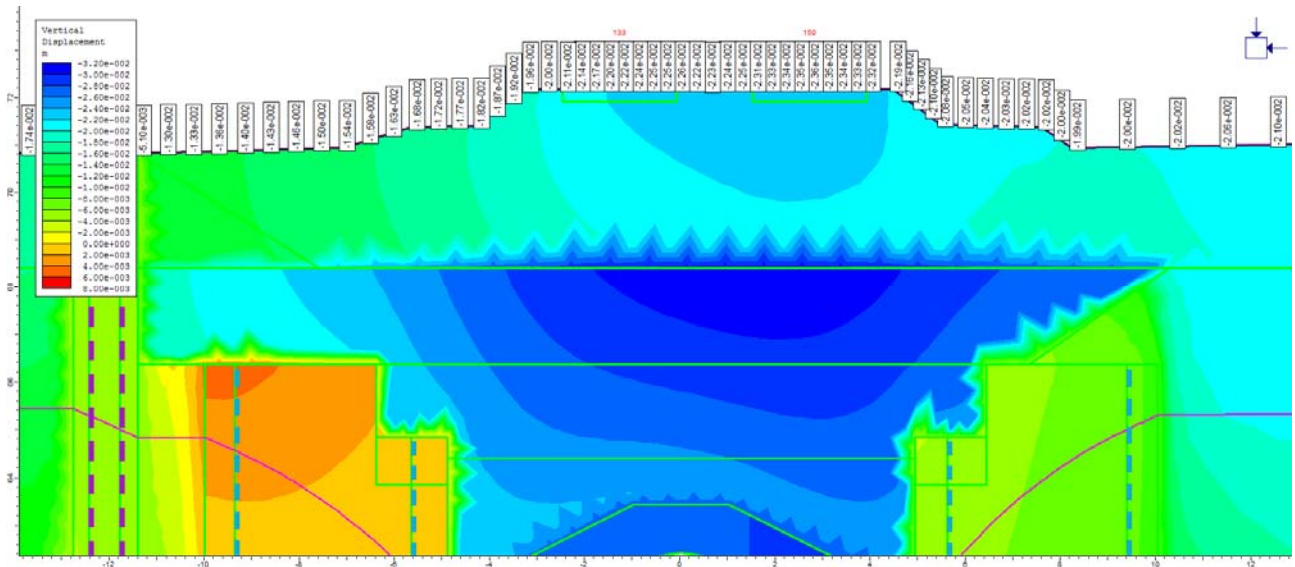
Per differenza si ottiene che lo spostamento verticale alla base dei binari dovuto al carico del treno è stimabile nell'ordine di 4-5 mm.

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a)

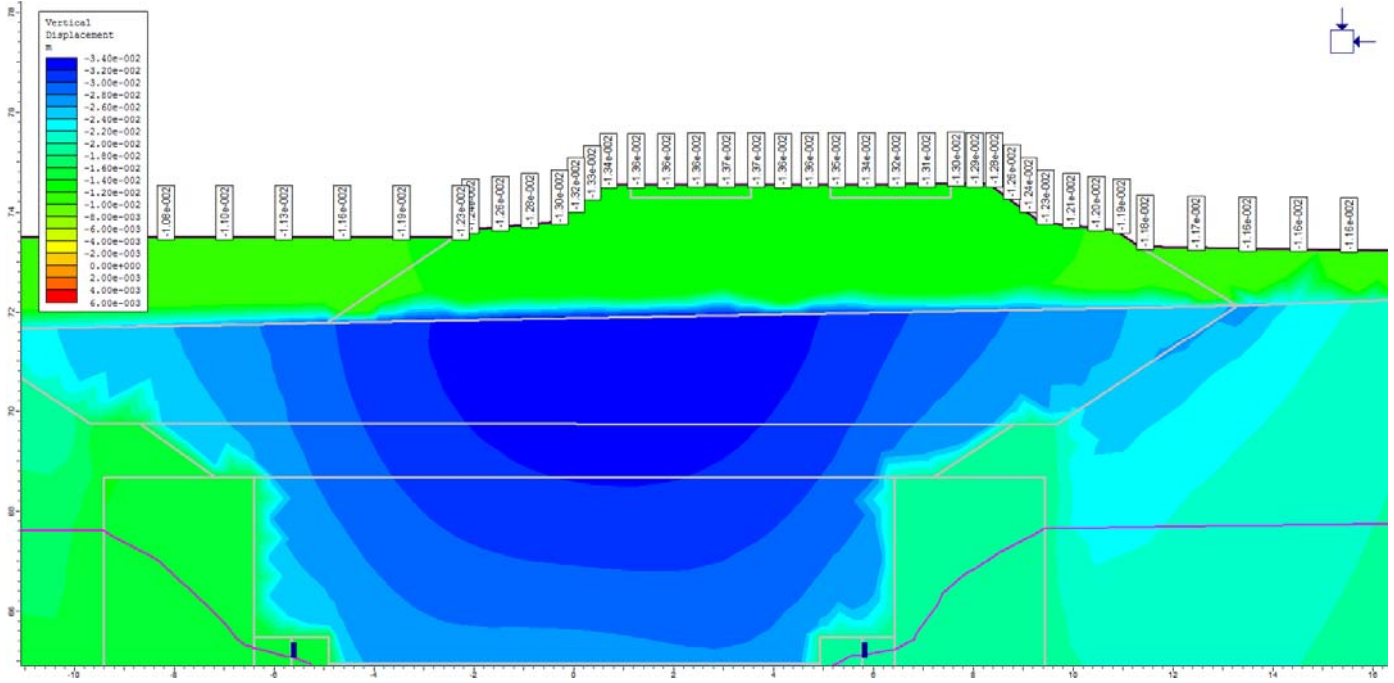


b)

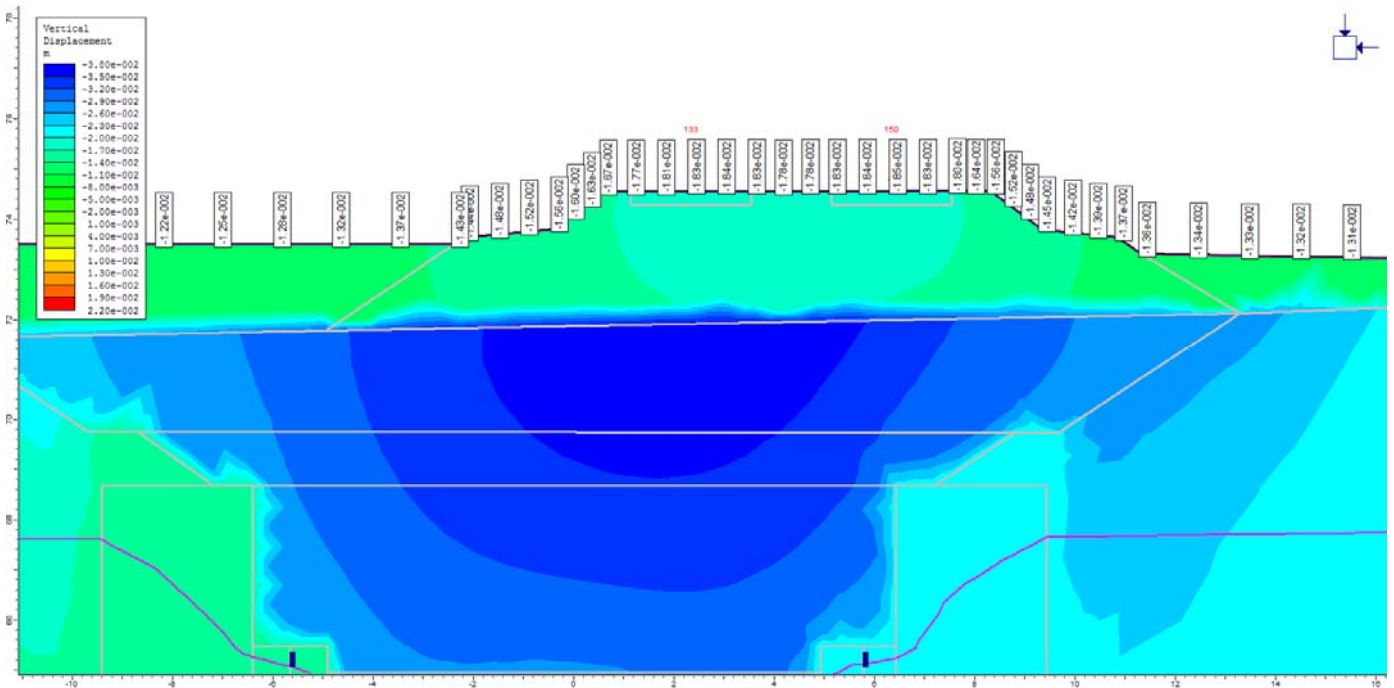
Figura 23: Galleria Binario Dispari. Assestamento del rilevato della Linea Storica spostata, sezione pk 0+325. a) Solo rilevato; b) rilevato e carico del treno

Fachbereich:
 Thema:
 Dokumenteninhalt:

Settore: Spostamento linea storica
 Tema: Progettazione del tracciato e dell'opera
 Contenuto documento: Calcolo dei cedimenti di terrapieno della ferrovia



a)



b)

Figura 24: Galleria Binario Pari. Assestamento del rilevato della Linea Storica spostata, sezione pk 0+425. a) Solo rilevato; b) rilevato e carico del treno

Fachbereich:
Thema:
Dokumenteninhalt:

Settore: Spostamento linea storica
Tema: Progettazione del tracciato e dell'opera
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10 ELENCHI

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Fachbereich:
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ANLAGE A	ALLEGATO A
	<p>Analisi tenso-deformativa dello scavo per la valutazione dei cedimenti della linea ferroviaria Storica nei pressi della Galleria di Base binario Dispari alle progressive pk 54+968, pk 54+980, pk 54+997, pk 55+007 e alla progressiva pk 54+889 per il binario Pari</p>

OGGETTO E SCOPO

In seguito, sono riassunti i risultati delle analisi FEM non lineari eseguite per verificare i cedimenti della linea ferroviaria storica che corre nei pressi degli scavi per la realizzazione delle Gallerie artificiali di Base del Brennero, binario dispari e binario pari .

Il calcolo è stato eseguito con il software Phase2 con l'ipotesi di stato piano 2D ed è rappresentativo delle sezioni critiche alle progressive pk_54+968, pk_54+980, pk_54+997, pk_55+007 della Galleria di Base binario Dispari e pk_54+889 per la Galleria di Base binario Pari.

Il modello consente di accoppiare la sollecitazione dovuta a carichi statici, con la sollecitazione dovuta alla pressione dell'acqua in un regime di filtrazione ed ottenere i risultati in termini di Tensioni efficaci. L'analisi inoltre comprende le varie fasi di costruzione dell'opera di sostegno dello scavo ed in particolare: la creazione delle colonne di Jet-grouting e del tappo di fondo dal piano campagna, l'inserimento di micropali laterali allo scavo e tiranti, una prima fase di scavo, l'installazione del Primo puntone di contrasto, un secondo approfondimento dello scavo, installazione del Secondo puntone, un terzo approfondimento fino a fondo scavo e la rimozione dei puntoni una volta gettata la galleria.

L'output del programma ed i risultati in termini di spostamenti orizzontali e verticali, sono di seguito riportati.

OUTPUTS DI CALCOLO E RISULTATI ANALISI TENSO-DEFORMATIVA SEZIONE PK_54+968 BINARIO DISPARI

Phase2 Analysis Information

Project Settings

- Document Name: Sez 54+968_M-C_solo linea.fez
- Project Title: Phase2 - Finite Element Analysis of Excavations in Rock
- Number of Stages: 3
- Analysis Type: Plane Strain
- Solver Type: Gaussian Elimination
- Units: Metric, stress as kPa

Stress Analysis

- Maximum Number of Iterations: 2000
- Tolerance: 0.001
- Number of Load Steps: Automatic
- Convergence Type: Absolute Energy
- Tensile Failure: Reduces Shear Strength
- Joint tension reduces joint stiffness by a factor of 0.01

Groundwater

- Method: Finite Element Analysis
- Pore Fluid Unit Weight: 9.81 kN/m³
- Maximum Number of Iterations: 500
- Tolerance: 1e-006

Field Stress

- Field stress: gravity
- Using actual ground surface
- Effective stress ratio (horizontal/vertical in-plane): 1
- Effective stress ratio (horizontal/vertical out-of-plane): 1
- Locked-in horizontal stress (in-plane): 0
- Locked-in horizontal stress (out-of-plane): 0

Mesh

- Mesh type: graded
- Element type: 8 noded quadrilaterals
- Number of elements on Geostatico: 2241
- Number of nodes on Geostatico: 6824
- Number of elements on Paratia: 2241
- Number of nodes on Paratia: 6824
- Number of elements on CARICO TRENO: 2241
- Number of nodes on CARICO TRENO: 6824

Mesh Quality

- All elements are of good quality

Poor quality elements defined as:

- Side length ratio (maximum / minimum) > 30.00
- Minimum interior angle < 2.0 degrees
- Maximum interior angle > 175.0 degrees

Reset Displacements

- Displacements reset after: Geostatico
- Displacements reset after: Paratia

Material Properties

Material: Alluvionali

Initial element loading	field stress & body force
Unit weight	20.5 kN/m ³
Elastic type	isotropic
Young's modulus	60000 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	36 degrees
Peak cohesion	2 kPa
Material type	Plastic
Dilation Angle	1 degrees
Residual Friction Angle	35 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Properties changed in Paratia

- Unit weight: Young's modulus: 120000 kPa (factor = 2) Field Stress Gravity Ground surface elevation 0 m Unit weight of overburden 27 kN/m³ Effective stress ratio (horizontal/vertical in-plane) 0.413 Effective stress ratio (horizontal/vertical out-of-plane) 0.413 Locked-in horizontal stress (in-plane) 0 Locked-in horizontal stress (out-of-plane) 0

Material: Rilevato

Initial element loading	body force only
Unit weight	21 kN/m ³
Elastic type	isotropic
Young's modulus	100000 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	37 degrees
Peak cohesion	0 kPa
Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	37 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1

K Angle	0 degrees
---------	-----------

Field Stress Gravity Ground surface elevation 0 m Unit weight of overburden 27 kN/m3 Effective stress ratio (horizontal/vertical in-plane) 1 Effective stress ratio (horizontal/vertical out-of-plane) 1 Locked-in horizontal stress (in-plane) 0 Locked-in horizontal stress (out-of-plane) 0

Material: CLS

Initial element loading	body force only
Unit weight	25 kN/m3
Elastic type	isotropic
Young's modulus	3.12e+007 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	35 degrees
Peak cohesion	500 kPa
Material type	Elastic
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	1e-012 m/s
K2/K1	1
K Angle	0 degrees

Excavation Areas

Original Un-deformed Areas

- External Boundary Area: 12326.797 m2
- External Boundary Perimeter: 498.398 m

Geostatico

- External Boundary Area: 12326.797 m2 (0 m2 change from original area)
- External Boundary Perimeter: 498.398 m (0 m change from original perimeter)

Paratia

- Values not available until this stage is viewed in a window

CARICO TRENO

- External Boundary Area: 12326.659 m2 (-0.13792 m2 change from original area)
- External Boundary Perimeter: 498.396 m (-0.00137692 m change from original perimeter)

Displacements

- Displacement data is not available for Geostatico until total displacement is viewed in a window

- Displacement data is not available for Paratia until total displacement is viewed in a window
- Displacement data is not available for CARICO TRENO until total displacement is viewed in a window

Yielded Elements

Yielded Mesh Elements

- Number of yielded mesh elements on Geostatico: 424
- Number of yielded mesh elements is not available for Paratia until the stage is viewed in a window
- Number of yielded mesh elements on CARICO TRENO: 437

Yielded Bolt Elements

- Number of yielded bolt elements on Geostatico: 0
- Number of yielded bolt elements on Paratia: 0
- Number of yielded bolt elements on CARICO TRENO: 0

List of All Coordinates

External boundary

X	Y
-90.179	0.169958
89.821	0.169958
89.821	68.361
23.07	68.361
9.353	68.361
-3.503	68.359
-7.51802	71.454
-7.88949	71.454
-9	71.454
-12.065	71.454
-13.8	71.454
-15.806	71.454
-17.563	71.454
-20.213	71.454
-24.708	68.361
-37.366	68.361
-90.179	68.361

Material boundary

X	Y
-24.708	68.361
-9	68.361
-7.88949	68.359
-7.51802	68.359
-3.503	68.359

Material boundary

X	Y
-9	68.361
-8.87831	48.1476
-8.87831	47.0198
10.02	47.0198
10.02	66.6906
7.05641	66.6906
6.41999	66.6906
6.41999	65.1696
6.41999	64.1695
5.12055	64.1696
4.91999	64.1696
4.72282	64.1696
4.72282	63.7598
4.72282	61.81
4.72282	60.4249
4.72282	58.3565
4.72282	57.9302
4.72282	56.2092
4.72282	53.8696
-4.71957	53.8699
-4.71957	56.2092
-4.71957	57.9302
-4.71957	58.3565
-4.71957	60.4249
-4.71957	61.81
-4.71957	63.7598
-4.71957	64.17
-4.92	64.17
-5.12008	64.17
-6.42	64.17
-6.42	65.17
-6.42	66.69
-7.51802	66.6897
-7.51802	48.1476
-8.87831	48.1476

Material boundary

X	Y
-6.42	65.17
-4.92	65.17

-4.92	64.6661
-4.92	64.17

Material boundary

X	Y
6.41999	65.1696
4.91999	65.1696
4.91999	64.6661
4.91999	64.1696

Material boundary

X	Y
-7.88949	68.359
-7.88949	49.1474

Material boundary

X	Y
-4.71957	61.81
-1.00001	63.7598
0.999994	63.7598
4.72282	61.81

Material boundary

X	Y
-4.92	64.6661
4.91999	64.6661

Material boundary

X	Y
-4.71957	58.3565
-3.84483	58.3565
3.84482	58.3565
4.72282	58.3565

Material boundary

X	Y
-2.15001	55.6698
2.14999	55.6698

3.25563	56.2092
3.62135	57.0454
3.84482	57.9302
3.84482	58.3565
3.84482	59.7828
3.52711	60.4249
3.17134	61.1439
2.43157	61.81
1.95999	62.2346
1.21134	62.5679
-5.74383e-006	62.7598
-1.21135	62.5679
-1.96001	62.2346
-2.43158	61.81
-3.17135	61.1439
-3.52712	60.4249
-3.84483	59.7828
-3.84483	58.3565
-3.84483	57.9302
-3.62136	57.0454
-3.25565	56.2092
-2.15001	55.6698

Material boundary

X	Y
7.05641	66.6906
9.353	68.361

Material boundary

X	Y
-3.84483	57.9302
-4.71957	57.9302

Material boundary

X	Y
-3.84483	57.9302
3.84482	57.9302
4.72282	57.9302

Material boundary

X	Y
---	---

-12.065	71.454
-12.065	71.1675
-13.8	71.1675
-13.8	71.454

Material boundary

X	Y
-15.806	71.454
-15.806	71.168
-17.563	71.168
-17.563	71.454

Material boundary

X	Y
-4.71957	61.81
-2.43158	61.81
2.43157	61.81
4.72282	61.81

Material boundary

X	Y
-3.25565	56.2092
-4.71957	56.2092

Material boundary

X	Y
3.25563	56.2092
4.72282	56.2092

Material boundary

X	Y
-6.42	66.69
6.41999	66.6906

Material boundary

X	Y
-1.00001	63.7598
-4.71957	63.7598

Material boundary

X	Y
0.999994	63.7598
4.72282	63.7598

Material boundary

X	Y
-5.12008	64.17
-5.12008	60.4249
-5.12008	57.9302
-5.12008	53.8699

Material boundary

X	Y
-4.71957	53.8699
-5.12008	53.8699

Material boundary

X	Y
5.12055	64.1696
5.12055	60.4249
5.12055	57.9302
5.12055	53.8696

Material boundary

X	Y
4.72282	53.8696
5.12055	53.8696

Material boundary

X	Y
-4.71957	60.4249
-3.52712	60.4249
3.52711	60.4249
4.72282	60.4249

Material boundary

X	Y
---	---

-4.71957	60.4249
-5.12008	60.4249

Material boundary

X	Y
4.72282	60.4249
5.12055	60.4249

Material boundary

X	Y
-4.71957	57.9302
-5.12008	57.9302

Material boundary

X	Y
4.72282	57.9302
5.12055	57.9302

Material boundary

X	Y
-7.51802	66.6897
-7.51802	68.359
-7.51802	71.454

Material boundary

X	Y
-7.88949	68.359
-7.88949	71.454

Material boundary

X	Y
-9	68.361
-9	71.454

Phase2 Analysis Information

Project Settings

- Document Name: Sez 54+968_M-C_fondo scavo + carico.fez
- Project Title: Phase2 - Finite Element Analysis of Excavations in Rock
- Number of Stages: 17
- Analysis Type: Plane Strain
- Solver Type: Gaussian Elimination
- Units: Metric, stress as kPa

Stress Analysis

- Maximum Number of Iterations: 2000
- Tolerance: 0.001
- Number of Load Steps: Automatic
- Convergence Type: Absolute Energy
- Tensile Failure: Reduces Shear Strength
- Joint tension reduces joint stiffness by a factor of 0.01

Groundwater

- Method: Finite Element Analysis
- Pore Fluid Unit Weight: 9.81 kN/m³
- Maximum Number of Iterations: 500
- Tolerance: 1e-006

Field Stress

- Field stress: gravity
- Using actual ground surface
- Effective stress ratio (horizontal/vertical in-plane): 1
- Effective stress ratio (horizontal/vertical out-of-plane): 1
- Locked-in horizontal stress (in-plane): 0
- Locked-in horizontal stress (out-of-plane): 0

Mesh

- Mesh type: graded
- Element type: 8 noded quadrilaterals
- Number of elements on Geostatico: 2192
- Number of nodes on Geostatico: 6675
- Number of elements on Paratia: 2192
- Number of nodes on Paratia: 6675
- Number of elements on Piano lavoro: 2101
- Number of nodes on Piano lavoro: 6416
- Number of elements on Jet: 2101
- Number of nodes on Jet: 6416
- Number of elements on I ribasso: 1938
- Number of nodes on I ribasso: 5959
- Number of elements on I puntone: 1967
- Number of nodes on I puntone: 6046
- Number of elements on II ribasso: 1774
- Number of nodes on II ribasso: 5515
- Number of elements on II puntone: 1774
- Number of nodes on II puntone: 5515

- Number of elements on III ribasso: 1672
- Number of nodes on III ribasso: 5223
- Number of elements on III puntone: 1672
- Number of nodes on III puntone: 5223
- Number of elements on Fondo scavo: 1521
- Number of nodes on Fondo scavo: 4792
- Number of elements on CARICO TRENO: 1521
- Number of nodes on CARICO TRENO: 4792
- Number of elements on Solettone: 1593
- Number of nodes on Solettone: 4996
- Number of elements on Rimozione puntone: 1593
- Number of nodes on Rimozione puntone: 4996
- Number of elements on Getto calotta: 1722
- Number of nodes on Getto calotta: 5390
- Number of elements on Rimozione puntone: 1722
- Number of nodes on Rimozione puntone: 5390
- Number of elements on Ritombamento: 1968
- Number of nodes on Ritombamento: 6072

Mesh Quality

- All elements are of good quality

Poor quality elements defined as:

- Side length ratio (maximum / minimum) > 30.00
- Minimum interior angle < 2.0 degrees
- Maximum interior angle > 175.0 degrees

Reset Displacements

- Displacements reset after: Geostatico
- Displacements reset after: Paratia

Material Properties

Material: Alluvionali

Initial element loading	field stress & body force
Unit weight	20.5 kN/m ³
Elastic type	isotropic
Young's modulus	60000 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	36 degrees
Peak cohesion	2 kPa
Material type	Plastic
Dilation Angle	1 degrees
Residual Friction Angle	35 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa

Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Properties changed in Paratia

- Unit weight:

Properties changed in Piano lavoro

- Unit weight: Young's modulus: 120000 kPa (factor = 2) Field Stress Gravity Ground surface elevation 0 m Unit weight of overburden 27 kN/m3 Effective stress ratio (horizontal/vertical in-plane) 0.413 Effective stress ratio (horizontal/vertical out-of-plane) 0.413 Locked-in horizontal stress (in-plane) 0 Locked-in horizontal stress (out-of-plane) 0

Material: Jet grouting

Initial element loading	body force only
Unit weight	21 kN/m3
Elastic type	isotropic
Young's modulus	1e+006 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	75 kPa
Peak friction angle	36 degrees
Peak cohesion	500 kPa
Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	36 degrees
Residual Cohesion	500 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	1e-008 m/s
K2/K1	1
K Angle	0 degrees

Material: Rilevato

Initial element loading	body force only
Unit weight	21 kN/m3
Elastic type	isotropic
Young's modulus	100000 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	37 degrees
Peak cohesion	0 kPa
Material type	Plastic

Dilation Angle	0 degrees
Residual Friction Angle	37 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Field Stress Gravity Ground surface elevation 0 m Unit weight of overburden 27 kN/m³ Effective stress ratio (horizontal/vertical in-plane) 1
Effective stress ratio (horizontal/vertical out-of-plane) 1 Locked-in horizontal stress (in-plane) 0 Locked-in horizontal stress (out-of-plane) 0

Material: CLS

Initial element loading	body force only
Unit weight	25 kN/m ³
Elastic type	isotropic
Young's modulus	3.12e+007 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	35 degrees
Peak cohesion	500 kPa
Material type	Elastic
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	1e-012 m/s
K2/K1	1
K Angle	0 degrees

Material: Spritz

Initial element loading	field stress & body force
Unit weight	24 kN/m ³
Elastic type	isotropic
Young's modulus	3e+007 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	35 degrees
Peak cohesion	10.5 kPa
Material type	Elastic
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	1e-008 m/s
K2/K1	1
K Angle	0 degrees

Properties changed in Rimozione puntone

- Unit weight: Ks: 1e-010 m/s (factor = 0.01)K Angle: 0 degrees (factor = 0)

Excavation Areas

Original Un-deformed Areas

- External Boundary Area: 12326.797 m²
- External Boundary Perimeter: 498.398 m

Geostatico

- External Boundary Area: 12326.797 m² (0 m² change from original area)
- External Boundary Perimeter: 498.398 m (0 m change from original perimeter)

Paratia

- Values not available until this stage is viewed in a window

Piano lavoro

- Values not available until this stage is viewed in a window

Jet

- Values not available until this stage is viewed in a window

I ribasso

- Values not available until this stage is viewed in a window

I puntone

- Values not available until this stage is viewed in a window

II ribasso

- Values not available until this stage is viewed in a window

II puntone

- Values not available until this stage is viewed in a window

III ribasso

- Values not available until this stage is viewed in a window

III puntone

- Values not available until this stage is viewed in a window

Fondo scavo

- Values not available until this stage is viewed in a window

CARICO TRENO

- Values not available until this stage is viewed in a window

Solettone

- Values not available until this stage is viewed in a window

Rimozione puntone

- Values not available until this stage is viewed in a window

Getto calotta

- Values not available until this stage is viewed in a window

Rimozione puntone

- Values not available until this stage is viewed in a window

Ritombamento

- Values not available until this stage is viewed in a window

Liner Properties

Liner: Micropalo_F168_sp10/0.75m

Liner Type	Standard Beam
Formulation	Timoshenko
Area	0.0066275 m ²
Moment of Inertia	2.08e-005 m ⁴

Elastic Properties

Young's modulus	2.1e+008 kPa
Poisson's ratio	0.2

Liner: Tubo_F406.4_sp12.5/4m

Liner Type	Standard Beam
Formulation	Timoshenko
Area	0.0038651 m ²

Moment of Inertia	7.5038e-005 m4
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Elastic Properties

Young's modulus	2.1e+008 kPa
Poisson's ratio	0.2
Liner Unit Weight	78.5 kN/m3

Liner: Liner 8

Liner Type	Standard Beam
Formulation	Timoshenko
Thickness	0.1 m

Elastic Properties

Young's modulus	3e+007 kPa
Poisson's ratio	0.2

Bolt Properties

Bolt name	Tirante
Bolt Type	Fully bonded bolt
Diameter	168.3 mm
Young's modulus	2.1e+008 kPa
Tensile capacity	1600 kN
Residual Tensile capacity	0.01 kN
Pre-tensioning	0 kN
Out-of-plane spacing	1.5 m

Displacements

- Displacement data is not available for Geostatico until total displacement is viewed in a window
- Displacement data is not available for Paratia until total displacement is viewed in a window
- Displacement data is not available for Piano lavoro until total displacement is viewed in a window
- Displacement data is not available for Jet until total displacement is viewed in a window
- Displacement data is not available for I ribasso until total displacement is viewed in a window
- Displacement data is not available for I puntone until total displacement is viewed in a window
- Displacement data is not available for II ribasso until total displacement is viewed in a window
- Displacement data is not available for II puntone until total displacement is viewed in a window
- Displacement data is not available for III ribasso until total displacement is viewed in a window
- Displacement data is not available for III puntone until total displacement is viewed in a window
- Displacement data is not available for Fondo scavo until total displacement is viewed in a window
- Displacement data is not available for CARICO TRENO until total displacement is viewed in a window
- Displacement data is not available for Solettone until total displacement is viewed in a window
- Displacement data is not available for Rimozione puntone until total displacement is viewed in a window
- Displacement data is not available for Getto calotta until total displacement is viewed in a window
- Displacement data is not available for Rimozione puntone until total displacement is viewed in a window
- Displacement data is not available for Ritombamento until total displacement is viewed in a window

Yielded Elements

Yielded Mesh Elements

- Number of yielded mesh elements on Geostatico: 434
- Number of yielded mesh elements is not available for Paratia until the stage is viewed in a window
- Number of yielded mesh elements is not available for Piano lavoro until the stage is viewed in a window
- Number of yielded mesh elements is not available for Jet until the stage is viewed in a window
- Number of yielded mesh elements is not available for I ribasso until the stage is viewed in a window
- Number of yielded mesh elements is not available for I puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for II ribasso until the stage is viewed in a window
- Number of yielded mesh elements is not available for II puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for III ribasso until the stage is viewed in a window
- Number of yielded mesh elements is not available for III puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for Fondo scavo until the stage is viewed in a window
- Number of yielded mesh elements is not available for CARICO TRENO until the stage is viewed in a window
- Number of yielded mesh elements is not available for Solettone until the stage is viewed in a window
- Number of yielded mesh elements is not available for Rimozione puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for Getto calotta until the stage is viewed in a window
- Number of yielded mesh elements is not available for Rimozione puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for Ritombamento until the stage is viewed in a window

Yielded Bolt Elements

- Number of yielded bolt elements on Geostatico: 0
- Number of yielded bolt elements on Paratia: 0
- Number of yielded bolt elements on Piano lavoro: 0
- Number of yielded bolt elements on Jet: 0
- Number of yielded bolt elements on I ribasso: 0
- Number of yielded bolt elements on I puntone: 0
- Number of yielded bolt elements on II ribasso: 0
- Number of yielded bolt elements on II puntone: 0
- Number of yielded bolt elements on III ribasso: 0
- Number of yielded bolt elements on III puntone: 0
- Number of yielded bolt elements on Fondo scavo: 0
- Number of yielded bolt elements on CARICO TRENO: 0
- Number of yielded bolt elements on Solettone: 0
- Number of yielded bolt elements on Rimozione puntone: 0
- Number of yielded bolt elements on Getto calotta: 0
- Number of yielded bolt elements on Rimozione puntone: 0
- Number of yielded bolt elements on Ritombamento: 0

Yielded Liner Elements

- Number of yielded liner elements on Geostatico: 0
- Number of yielded liner elements on Paratia: 0
- Number of yielded liner elements on Piano lavoro: 0
- Number of yielded liner elements on Jet: 0
- Number of yielded liner elements on I ribasso: 0
- Number of yielded liner elements on I puntone: 0
- Number of yielded liner elements on II ribasso: 0
- Number of yielded liner elements on II puntone: 0
- Number of yielded liner elements on III ribasso: 0
- Number of yielded liner elements on III puntone: 0
- Number of yielded liner elements on Fondo scavo: 0
- Number of yielded liner elements on CARICO TRENO: 0
- Number of yielded liner elements on Solettone: 0
- Number of yielded liner elements on Rimozione puntone: 0
- Number of yielded liner elements on Getto calotta: 0
- Number of yielded liner elements on Rimozione puntone: 0
- Number of yielded liner elements on Ritombamento: 0

List of All Coordinates

External boundary

X	Y
-90.179	0.169958
89.821	0.169958
89.821	68.361
23.07	68.361
9.353	68.361
-3.503	68.359
-7.51802	71.454
-7.88949	71.454
-9	71.454
-12.065	71.454
-13.8	71.454
-15.806	71.454
-17.563	71.454
-20.213	71.454
-24.708	68.361
-37.366	68.361
-90.179	68.361

Material boundary

X	Y
-24.708	68.361
-9	68.361
-7.88949	68.359
-7.51802	68.359
-3.503	68.359

Material boundary

X	Y
-9	68.361
-8.87831	48.1476
-8.87831	47.0198
10.02	47.0198
10.02	66.6906
7.05641	66.6906
6.41999	66.6906
6.41999	65.1696
6.41999	64.1695
5.12055	64.1696
4.91999	64.1696
4.72282	64.1696
4.72282	63.7598
4.72282	61.81

4.72282	60.4249
4.72282	58.3565
4.72282	57.9302
4.72282	56.2092
4.72282	53.8696
-4.71957	53.8699
-4.71957	56.2092
-4.71957	57.9302
-4.71957	58.3565
-4.71957	60.4249
-4.71957	61.81
-4.71957	63.7598
-4.71957	64.17
-4.92	64.17
-5.12008	64.17
-6.42	64.17
-6.42	65.17
-6.42	66.69
-7.51802	66.6897
-7.51802	48.1476
-8.87831	48.1476

Material boundary

X	Y
-6.42	65.17
-4.92	65.17
-4.92	64.6661
-4.92	64.17

Material boundary

X	Y
6.41999	65.1696
4.91999	65.1696
4.91999	64.6661
4.91999	64.1696

Material boundary

X	Y
-7.88949	68.359
-7.88949	49.1474

Material boundary

X	Y
-4.71957	61.81

-1.00001	63.7598
0.999994	63.7598
4.72282	61.81

Material boundary

X	Y
-4.92	64.6661
4.91999	64.6661

Material boundary

X	Y
-4.71957	58.3565
-3.84483	58.3565
3.84482	58.3565
4.72282	58.3565

Material boundary

X	Y
-2.15001	55.6698
2.14999	55.6698
3.25563	56.2092
3.62135	57.0454
3.84482	57.9302
3.84482	58.3565
3.84482	59.7828
3.52711	60.4249
3.17134	61.1439
2.43157	61.81
1.95999	62.2346
1.21134	62.5679
-5.74383e-006	62.7598
-1.21135	62.5679
-1.96001	62.2346
-2.43158	61.81
-3.17135	61.1439
-3.52712	60.4249
-3.84483	59.7828
-3.84483	58.3565
-3.84483	57.9302
-3.62136	57.0454
-3.25565	56.2092
-2.15001	55.6698

Material boundary

X	Y
7.05641	66.6906
9.353	68.361

Material boundary

X	Y
-3.84483	57.9302
-4.71957	57.9302

Material boundary

X	Y
-3.84483	57.9302
3.84482	57.9302
4.72282	57.9302

Material boundary

X	Y
-12.065	71.454
-12.065	71.1675
-13.8	71.1675
-13.8	71.454

Material boundary

X	Y
-15.806	71.454
-15.806	71.168
-17.563	71.168
-17.563	71.454

Material boundary

X	Y
-4.71957	61.81
-2.43158	61.81
2.43157	61.81
4.72282	61.81

Material boundary

X	Y
-3.25565	56.2092
-4.71957	56.2092

Material boundary

X	Y
3.25563	56.2092
4.72282	56.2092

Material boundary

X	Y
-6.42	66.69
6.41999	66.6906

Material boundary

X	Y
-1.00001	63.7598
-4.71957	63.7598

Material boundary

X	Y
0.999994	63.7598
4.72282	63.7598

Material boundary

X	Y
-5.12008	64.17
-5.12008	60.4249
-5.12008	57.9302
-5.12008	53.8699

Material boundary

X	Y
-4.71957	53.8699
-5.12008	53.8699

Material boundary

X	Y
5.12055	64.1696
5.12055	60.4249
5.12055	57.9302
5.12055	53.8696

Material boundary

X	Y
4.72282	53.8696
5.12055	53.8696

Material boundary

X	Y
-4.71957	60.4249
-3.52712	60.4249
3.52711	60.4249
4.72282	60.4249

Material boundary

X	Y
-4.71957	60.4249
-5.12008	60.4249

Material boundary

X	Y
4.72282	60.4249
5.12055	60.4249

Material boundary

X	Y
-4.71957	57.9302
-5.12008	57.9302

Material boundary

X	Y
4.72282	57.9302
5.12055	57.9302

Material boundary

X	Y
-7.51802	66.6897
-7.51802	68.359
-7.51802	71.454

Material boundary

X	Y
-7.88949	68.359

-7.88949	71.454
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Material boundary

X	Y
-9	68.361
-9	71.454

Phase2 Analysis Information

Project Settings

- Document Name: Sez 54+968_M-C_fondo scavo con carico.fez
- Project Title: Phase2 - Finite Element Analysis of Excavations in Rock
- Number of Stages: 16
- Analysis Type: Plane Strain
- Solver Type: Gaussian Elimination
- Units: Metric, stress as kPa

Stress Analysis

- Maximum Number of Iterations: 2000
- Tolerance: 0.001
- Number of Load Steps: Automatic
- Convergence Type: Absolute Energy
- Tensile Failure: Reduces Shear Strength
- Joint tension reduces joint stiffness by a factor of 0.01

Groundwater

- Method: Finite Element Analysis
- Pore Fluid Unit Weight: 9.81 kN/m³
- Maximum Number of Iterations: 500
- Tolerance: 1e-006

Field Stress

- Field stress: gravity
- Using actual ground surface
- Effective stress ratio (horizontal/vertical in-plane): 1
- Effective stress ratio (horizontal/vertical out-of-plane): 1
- Locked-in horizontal stress (in-plane): 0
- Locked-in horizontal stress (out-of-plane): 0

Mesh

- Mesh type: graded
- Element type: 8 noded quadrilaterals
- Number of elements on Geostatico: 2192
- Number of nodes on Geostatico: 6675
- Number of elements on Paratia: 2192
- Number of nodes on Paratia: 6675
- Number of elements on Piano lavoro: 2101
- Number of nodes on Piano lavoro: 6416
- Number of elements on Jet: 2101
- Number of nodes on Jet: 6416
- Number of elements on I ribasso: 1938
- Number of nodes on I ribasso: 5959
- Number of elements on I puntone: 1967
- Number of nodes on I puntone: 6046
- Number of elements on II ribasso: 1774
- Number of nodes on II ribasso: 5515

- Number of elements on II puntone: 1774
- Number of nodes on II puntone: 5515
- Number of elements on III ribasso: 1672
- Number of nodes on III ribasso: 5223
- Number of elements on III puntone: 1672
- Number of nodes on III puntone: 5223
- Number of elements on Fondo scavo: 1521
- Number of nodes on Fondo scavo: 4792
- Number of elements on Solettone: 1593
- Number of nodes on Solettone: 4996
- Number of elements on Rimozione puntone: 1593
- Number of nodes on Rimozione puntone: 4996
- Number of elements on Getto calotta: 1722
- Number of nodes on Getto calotta: 5390
- Number of elements on Rimozione puntone: 1722
- Number of nodes on Rimozione puntone: 5390
- Number of elements on Ritombamento: 1968
- Number of nodes on Ritombamento: 6072

Mesh Quality

- All elements are of good quality

Poor quality elements defined as:

- Side length ratio (maximum / minimum) > 30.00
- Minimum interior angle < 2.0 degrees
- Maximum interior angle > 175.0 degrees

Reset Displacements

- Displacements reset after: Geostatico
- Displacements reset after: Paratia

Material Properties

Material: Alluvionali

Initial element loading	field stress & body force
Unit weight	20.5 kN/m3
Elastic type	isotropic
Young's modulus	60000 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	36 degrees
Peak cohesion	2 kPa
Material type	Plastic
Dilation Angle	1 degrees
Residual Friction Angle	35 degrees
Residual Cohesion	0 kPa

Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Properties changed in Paratia

- Unit weight:

Properties changed in Piano lavoro

- Unit weight: Young's modulus: 120000 kPa (factor = 2) Field Stress Gravity Ground surface elevation 0 m Unit weight of overburden 27 kN/m³ Effective stress ratio (horizontal/vertical in-plane) 0.413 Effective stress ratio (horizontal/vertical out-of-plane) 0.413 Locked-in horizontal stress (in-plane) 0 Locked-in horizontal stress (out-of-plane) 0

Material: Jet grouting

Initial element loading	body force only
Unit weight	21 kN/m ³
Elastic type	isotropic
Young's modulus	1e+006 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	75 kPa
Peak friction angle	36 degrees
Peak cohesion	500 kPa
Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	36 degrees
Residual Cohesion	500 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	1e-008 m/s
K2/K1	1
K Angle	0 degrees

Material: Rilevato

Initial element loading	body force only
Unit weight	21 kN/m ³
Elastic type	isotropic
Young's modulus	100000 kPa
Poisson's ratio	0.3

Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	37 degrees
Peak cohesion	0 kPa
Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	37 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Field Stress Gravity Ground surface elevation 0 m Unit weight of overburden 27 kN/m³ Effective stress ratio (horizontal/vertical in-plane) 1 Effective stress ratio (horizontal/vertical out-of-plane) 1 Locked-in horizontal stress (in-plane) 0 Locked-in horizontal stress (out-of-plane) 0

Material: CLS

Initial element loading	body force only
Unit weight	25 kN/m ³
Elastic type	isotropic
Young's modulus	3.12e+007 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	35 degrees
Peak cohesion	500 kPa
Material type	Elastic
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	1e-012 m/s
K2/K1	1
K Angle	0 degrees

Material: Spritz

Initial element loading	field stress & body force
Unit weight	24 kN/m ³
Elastic type	isotropic
Young's modulus	3e+007 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa

Peak friction angle	35 degrees
Peak cohesion	10.5 kPa
Material type	Elastic
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	1e-008 m/s
K2/K1	1
K Angle	0 degrees

Properties changed in Rimozione puntone

- Unit weight: Ks: 1e-010 m/s (factor = 0.01)K Angle: 0 degrees (factor = 0)

Excavation Areas

Original Un-deformed Areas

- External Boundary Area: 12326.797 m2
- External Boundary Perimeter: 498.398 m

Geostatico

- External Boundary Area: 12326.797 m2 (0 m2 change from original area)
- External Boundary Perimeter: 498.398 m (0 m change from original perimeter)

Paratia

- Values not available until this stage is viewed in a window

Piano lavoro

- Values not available until this stage is viewed in a window

Jet

- Values not available until this stage is viewed in a window

I ribasso

- Values not available until this stage is viewed in a window

I puntone

- Values not available until this stage is viewed in a window

II ribasso

- Values not available until this stage is viewed in a window

II puntone

- Values not available until this stage is viewed in a window

III ribasso

- Values not available until this stage is viewed in a window

III puntone

- Values not available until this stage is viewed in a window

Fondo scavo

- Values not available until this stage is viewed in a window

Solettone

- Values not available until this stage is viewed in a window

Rimozione puntone

- Values not available until this stage is viewed in a window

Getto calotta

- Values not available until this stage is viewed in a window

Rimozione puntone

- Values not available until this stage is viewed in a window

Ritombamento

- Values not available until this stage is viewed in a window

Liner Properties

Liner: Micropalo_F168_sp10/0.75m

Liner Type	Standard Beam
Formulation	Timoshenko
Area	0.0066275 m ²
Moment of Inertia	2.08e-005 m ⁴

Elastic Properties

Young's modulus	2.1e+008 kPa
Poisson's ratio	0.2

Liner: Tubo_F406.4_sp12.5/4m

Liner Type	Standard Beam
Formulation	Timoshenko
Area	0.0038651 m ²
Moment of Inertia	7.5038e-005 m ⁴

Elastic Properties

Young's modulus	2.1e+008 kPa
Poisson's ratio	0.2
Liner Unit Weight	78.5 kN/m ³

Liner: Liner 8

Liner Type	Standard Beam
Formulation	Timoshenko
Thickness	0.1 m

Elastic Properties

Young's modulus	3e+007 kPa
Poisson's ratio	0.2

Bolt Properties

Bolt name	Tirante
Bolt Type	Fully bonded bolt
Diameter	168.3 mm
Young's modulus	2.1e+008 kPa
Tensile capacity	1600 kN
Residual Tensile capacity	0.01 kN
Pre-tensioning	0 kN
Out-of-plane spacing	1.5 m

Displacements

- Displacement data is not available for Geostatico until total displacement is viewed in a window
- Displacement data is not available for Paratia until total displacement is viewed in a window
- Displacement data is not available for Piano lavoro until total displacement is viewed in a window
- Displacement data is not available for Jet until total displacement is viewed in a window

- Displacement data is not available for I ribasso until total displacement is viewed in a window
- Displacement data is not available for I puntone until total displacement is viewed in a window
- Displacement data is not available for II ribasso until total displacement is viewed in a window
- Displacement data is not available for II puntone until total displacement is viewed in a window
- Displacement data is not available for III ribasso until total displacement is viewed in a window
- Displacement data is not available for III puntone until total displacement is viewed in a window
- Displacement data is not available for Fondo scavo until total displacement is viewed in a window
- Displacement data is not available for Solettone until total displacement is viewed in a window
- Displacement data is not available for Rimozione puntone until total displacement is viewed in a window
- Displacement data is not available for Getto calotta until total displacement is viewed in a window
- Displacement data is not available for Rimozione puntone until total displacement is viewed in a window
- Displacement data is not available for Ritombamento until total displacement is viewed in a window

Yielded Elements

Yielded Mesh Elements

- Number of yielded mesh elements on Geostatico: 434
- Number of yielded mesh elements is not available for Paratia until the stage is viewed in a window
- Number of yielded mesh elements is not available for Piano lavoro until the stage is viewed in a window
- Number of yielded mesh elements is not available for Jet until the stage is viewed in a window
- Number of yielded mesh elements is not available for I ribasso until the stage is viewed in a window
- Number of yielded mesh elements is not available for I puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for II ribasso until the stage is viewed in a window
- Number of yielded mesh elements is not available for II puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for III ribasso until the stage is viewed in a window
- Number of yielded mesh elements is not available for III puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for Fondo scavo until the stage is viewed in a window
- Number of yielded mesh elements is not available for Solettone until the stage is viewed in a window
- Number of yielded mesh elements is not available for Rimozione puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for Getto calotta until the stage is viewed in a window
- Number of yielded mesh elements is not available for Rimozione puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for Ritombamento until the stage is viewed in a window

Yielded Bolt Elements

- Number of yielded bolt elements on Geostatico: 0
- Number of yielded bolt elements on Paratia: 0
- Number of yielded bolt elements on Piano lavoro: 0
- Number of yielded bolt elements on Jet: 0
- Number of yielded bolt elements on I ribasso: 0
- Number of yielded bolt elements on I puntone: 0
- Number of yielded bolt elements on II ribasso: 0
- Number of yielded bolt elements on II puntone: 0
- Number of yielded bolt elements on III ribasso: 0
- Number of yielded bolt elements on III puntone: 0
- Number of yielded bolt elements on Fondo scavo: 0
- Number of yielded bolt elements on Solettone: 0
- Number of yielded bolt elements on Rimozione puntone: 0
- Number of yielded bolt elements on Getto calotta: 0
- Number of yielded bolt elements on Rimozione puntone: 0
- Number of yielded bolt elements on Ritombamento: 0

Yielded Liner Elements

- Number of yielded liner elements on Geostatico: 0
- Number of yielded liner elements on Paratia: 0

- Number of yielded liner elements on Piano lavoro: 0
- Number of yielded liner elements on Jet: 0
- Number of yielded liner elements on I ribasso: 0
- Number of yielded liner elements on I puntone: 0
- Number of yielded liner elements on II ribasso: 0
- Number of yielded liner elements on II puntone: 0
- Number of yielded liner elements on III ribasso: 0
- Number of yielded liner elements on III puntone: 0
- Number of yielded liner elements on Fondo scavo: 0
- Number of yielded liner elements on Solettone: 0
- Number of yielded liner elements on Rimozione puntone: 0
- Number of yielded liner elements on Getto calotta: 0
- Number of yielded liner elements on Rimozione puntone: 0
- Number of yielded liner elements on Ritombamento: 0

List of All Coordinates

External boundary

X	Y
-90.179	0.169958
89.821	0.169958
89.821	68.361
23.07	68.361
9.353	68.361
-3.503	68.359
-7.51802	71.454
-7.88949	71.454
-9	71.454
-12.065	71.454
-13.8	71.454
-15.806	71.454
-17.563	71.454
-20.213	71.454
-24.708	68.361
-37.366	68.361
-90.179	68.361

Material boundary

X	Y
-24.708	68.361
-9	68.361
-7.88949	68.359
-7.51802	68.359
-3.503	68.359

Material boundary

X	Y
-9	68.361
-8.87831	48.1476
-8.87831	47.0198
10.02	47.0198
10.02	66.6906
7.05641	66.6906
6.41999	66.6906
6.41999	65.1696
6.41999	64.1695
5.12055	64.1696
4.91999	64.1696
4.72282	64.1696
4.72282	63.7598
4.72282	61.81
4.72282	60.4249
4.72282	58.3565
4.72282	57.9302
4.72282	56.2092
4.72282	53.8696
-4.71957	53.8699
-4.71957	56.2092
-4.71957	57.9302
-4.71957	58.3565
-4.71957	60.4249
-4.71957	61.81
-4.71957	63.7598
-4.71957	64.17
-4.92	64.17
-5.12008	64.17
-6.42	64.17
-6.42	65.17
-6.42	66.69
-7.51802	66.6897
-7.51802	48.1476
-8.87831	48.1476

Material boundary

X	Y
-6.42	65.17
-4.92	65.17
-4.92	64.6661
-4.92	64.17

Material boundary

X	Y
6.41999	65.1696
4.91999	65.1696
4.91999	64.6661
4.91999	64.1696

Material boundary

X	Y
-7.88949	68.359
-7.88949	49.1474

Material boundary

X	Y
-4.71957	61.81
-1.00001	63.7598
0.999994	63.7598
4.72282	61.81

Material boundary

X	Y
-4.92	64.6661
4.91999	64.6661

Material boundary

X	Y
-4.71957	58.3565
-3.84483	58.3565
3.84482	58.3565
4.72282	58.3565

Material boundary

X	Y
-2.15001	55.6698
2.14999	55.6698
3.25563	56.2092
3.62135	57.0454
3.84482	57.9302
3.84482	58.3565

3.84482	59.7828
3.52711	60.4249
3.17134	61.1439
2.43157	61.81
1.95999	62.2346
1.21134	62.5679
-5.74383e-006	62.7598
-1.21135	62.5679
-1.96001	62.2346
-2.43158	61.81
-3.17135	61.1439
-3.52712	60.4249
-3.84483	59.7828
-3.84483	58.3565
-3.84483	57.9302
-3.62136	57.0454
-3.25565	56.2092
-2.15001	55.6698

Material boundary

X	Y
7.05641	66.6906
9.353	68.361

Material boundary

X	Y
-3.84483	57.9302
-4.71957	57.9302

Material boundary

X	Y
-3.84483	57.9302
3.84482	57.9302
4.72282	57.9302

Material boundary

X	Y
-12.065	71.454
-12.065	71.1675
-13.8	71.1675
-13.8	71.454

Material boundary

X	Y
-15.806	71.454
-15.806	71.168
-17.563	71.168
-17.563	71.454

Material boundary

X	Y
-4.71957	61.81
-2.43158	61.81
2.43157	61.81
4.72282	61.81

Material boundary

X	Y
-3.25565	56.2092
-4.71957	56.2092

Material boundary

X	Y
3.25563	56.2092
4.72282	56.2092

Material boundary

X	Y
-6.42	66.69
6.41999	66.6906

Material boundary

X	Y
-1.00001	63.7598
-4.71957	63.7598

Material boundary

X	Y
---	---

0.999994	63.7598
4.72282	63.7598

Material boundary

X	Y
-5.12008	64.17
-5.12008	60.4249
-5.12008	57.9302
-5.12008	53.8699

Material boundary

X	Y
-4.71957	53.8699
-5.12008	53.8699

Material boundary

X	Y
5.12055	64.1696
5.12055	60.4249
5.12055	57.9302
5.12055	53.8696

Material boundary

X	Y
4.72282	53.8696
5.12055	53.8696

Material boundary

X	Y
-4.71957	60.4249
-3.52712	60.4249
3.52711	60.4249
4.72282	60.4249

Material boundary

X	Y
-4.71957	60.4249
-5.12008	60.4249

Material boundary

X	Y
4.72282	60.4249
5.12055	60.4249

Material boundary

X	Y
-4.71957	57.9302
-5.12008	57.9302

Material boundary

X	Y
4.72282	57.9302
5.12055	57.9302

Material boundary

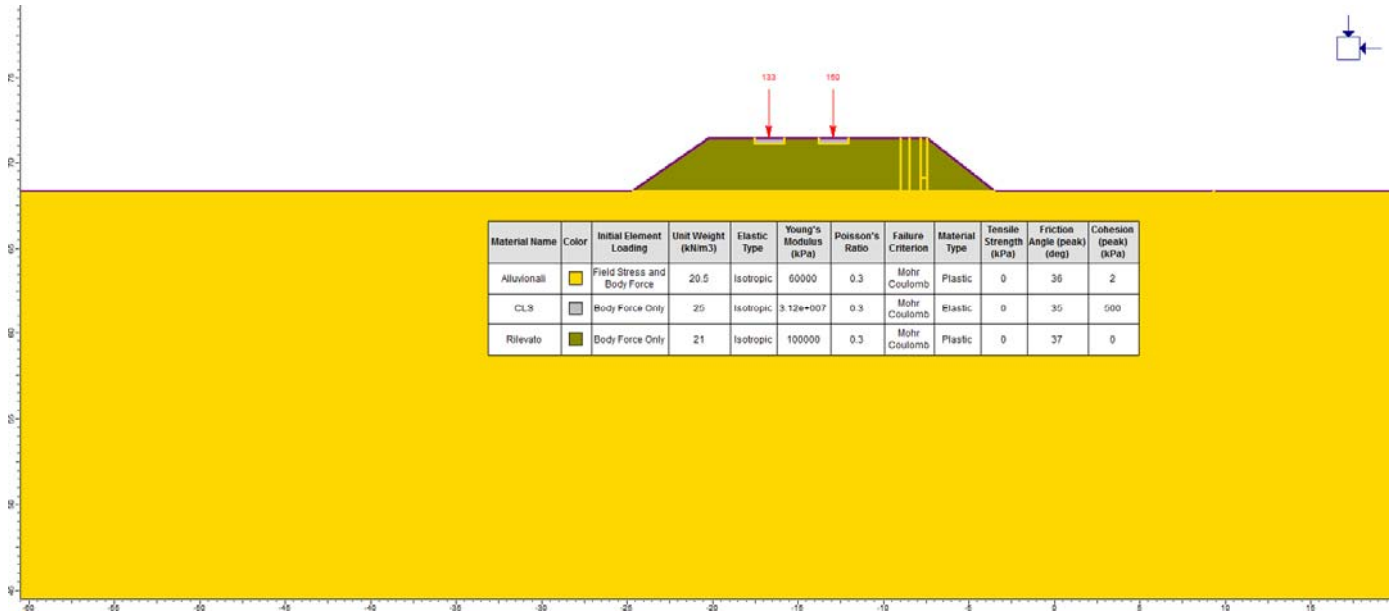
X	Y
-7.51802	66.6897
-7.51802	68.359
-7.51802	71.454

Material boundary

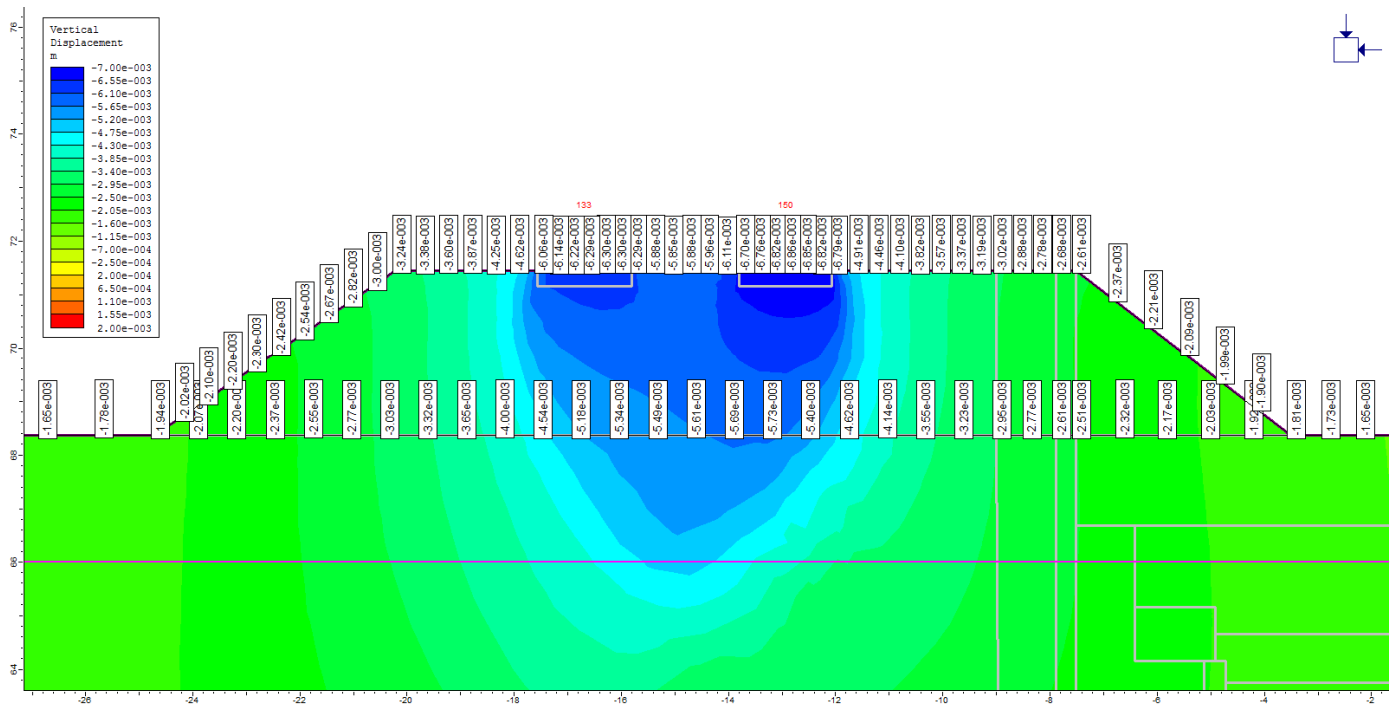
X	Y
-7.88949	68.359
-7.88949	71.454

Material boundary

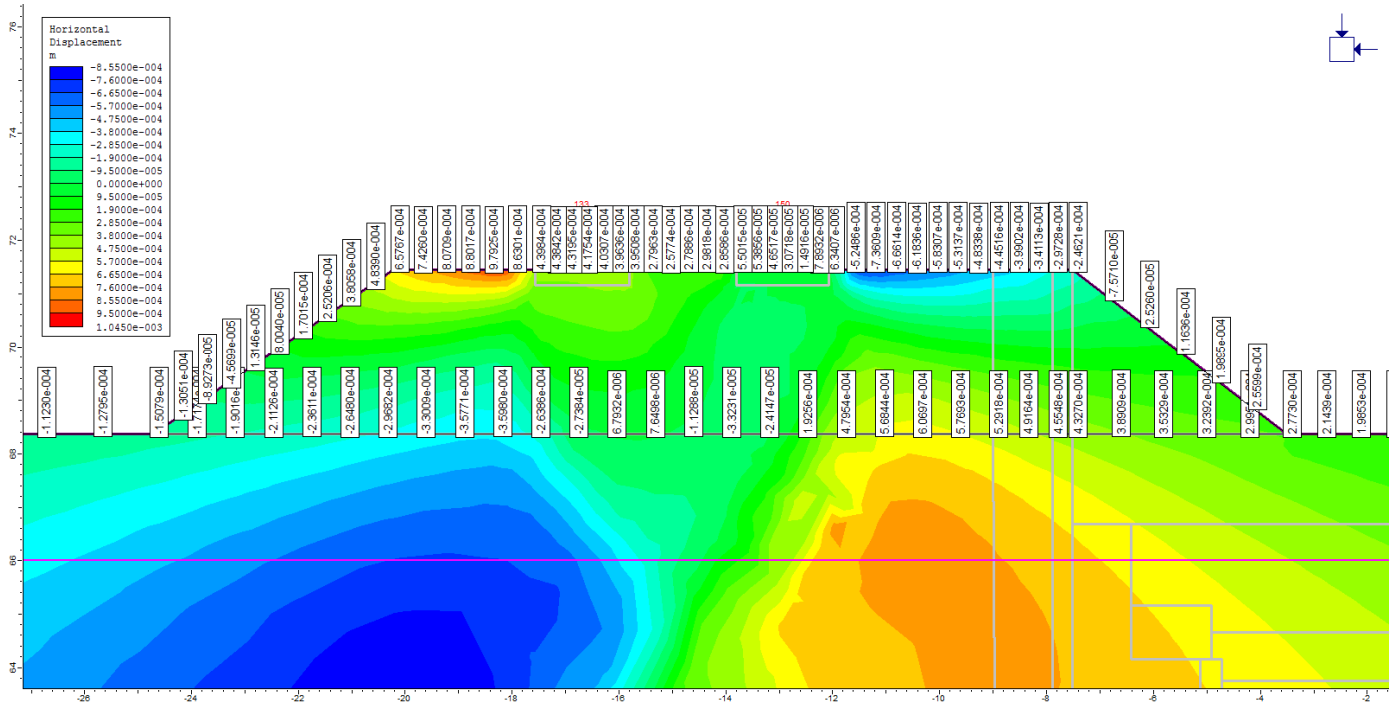
X	Y
-9	68.361
-9	71.454



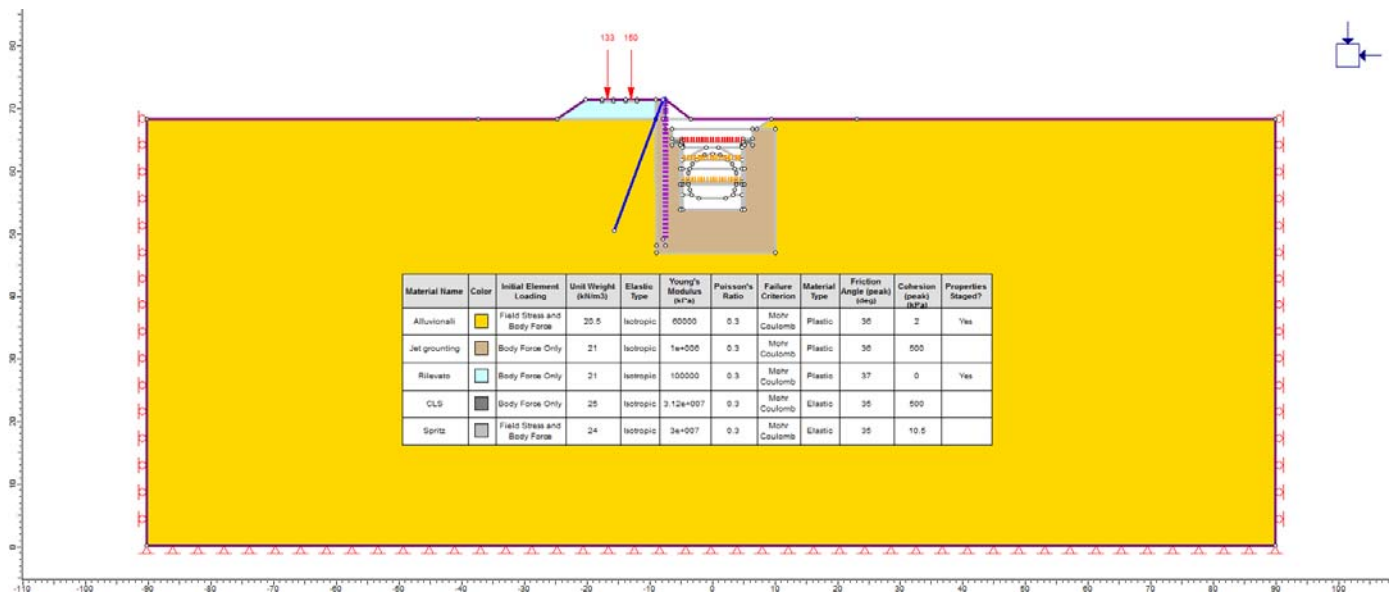
Geometria di calcolo per la Galleria di Base binario Dispari. Progressiva pk_54+968. Carico del treno applicato al rilevato ferroviario prima dello scavo.



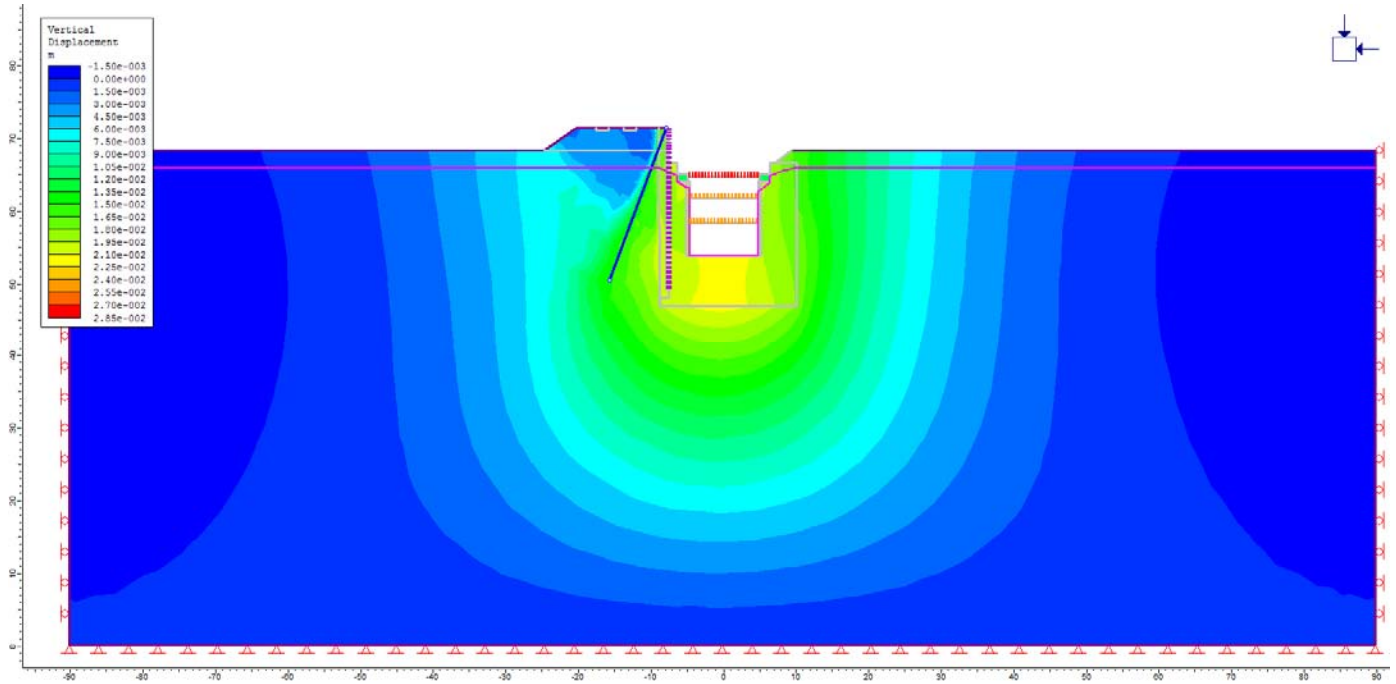
Galleria di Base binario Dispari. Progressiva pk_54+968. Spostamenti verticali dY. Carico del treno applicato al rilevato ferroviario prima dello scavo. Carico non fattorizzato (SLE)



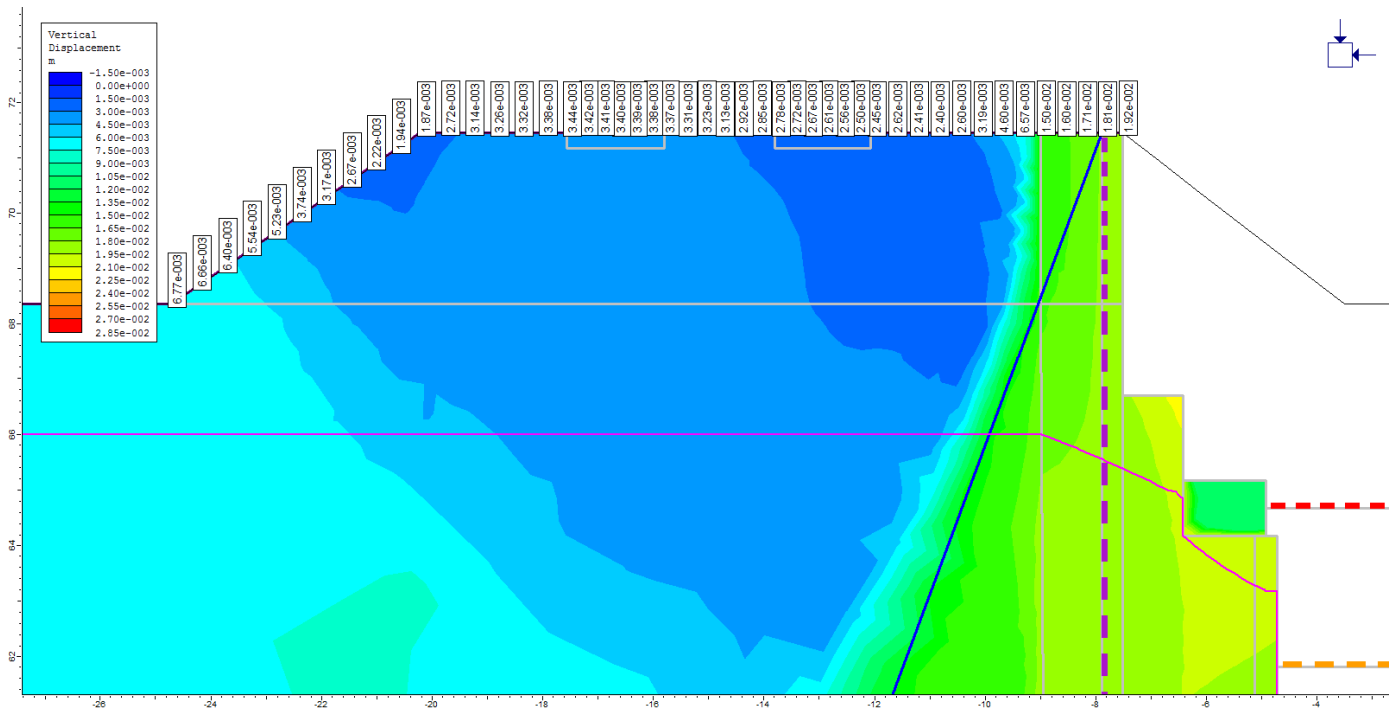
Galleria di Base binario Dispari. Progressiva pk₅₄+968. Spostamenti orizzontali dX. Carico del treno applicato al rilevato ferroviario prima dello scavo. Carico non fattorizzato (SLE)



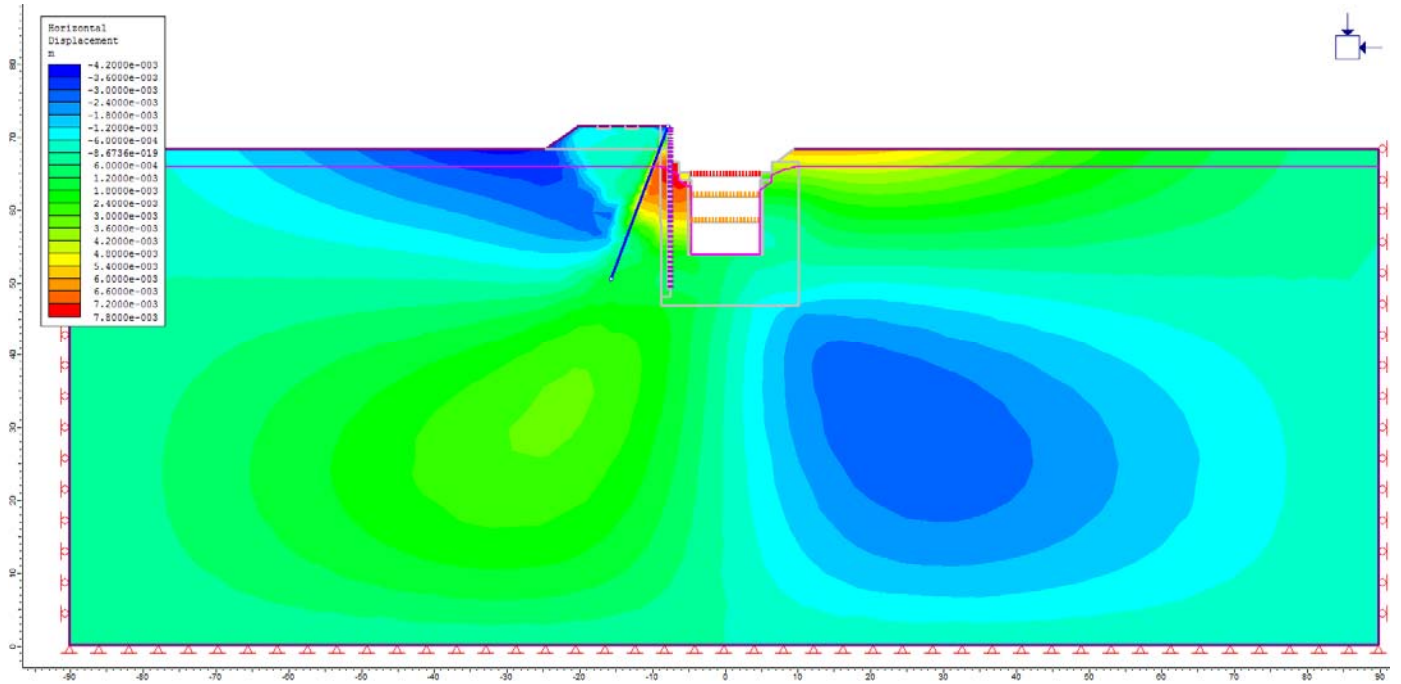
Geometria di calcolo per la Galleria di Base binario Dispari. Progressiva pk₅₄+968. Fase finale di scavo più carico del treno.



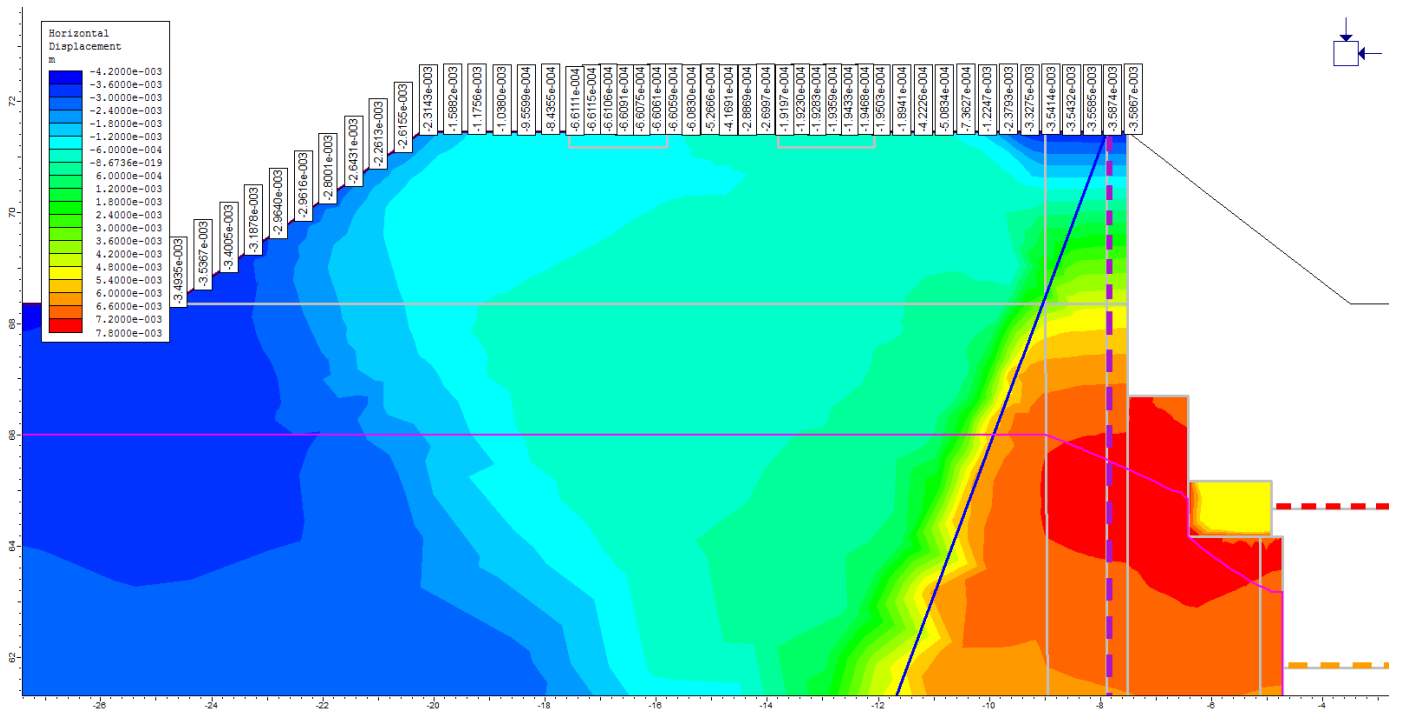
Galleria di Base binario Dispari. Progressiva pk_54+968. Spostamenti verticali dY. Fase finale di scavo. Carico non fattorizzato (SLE)



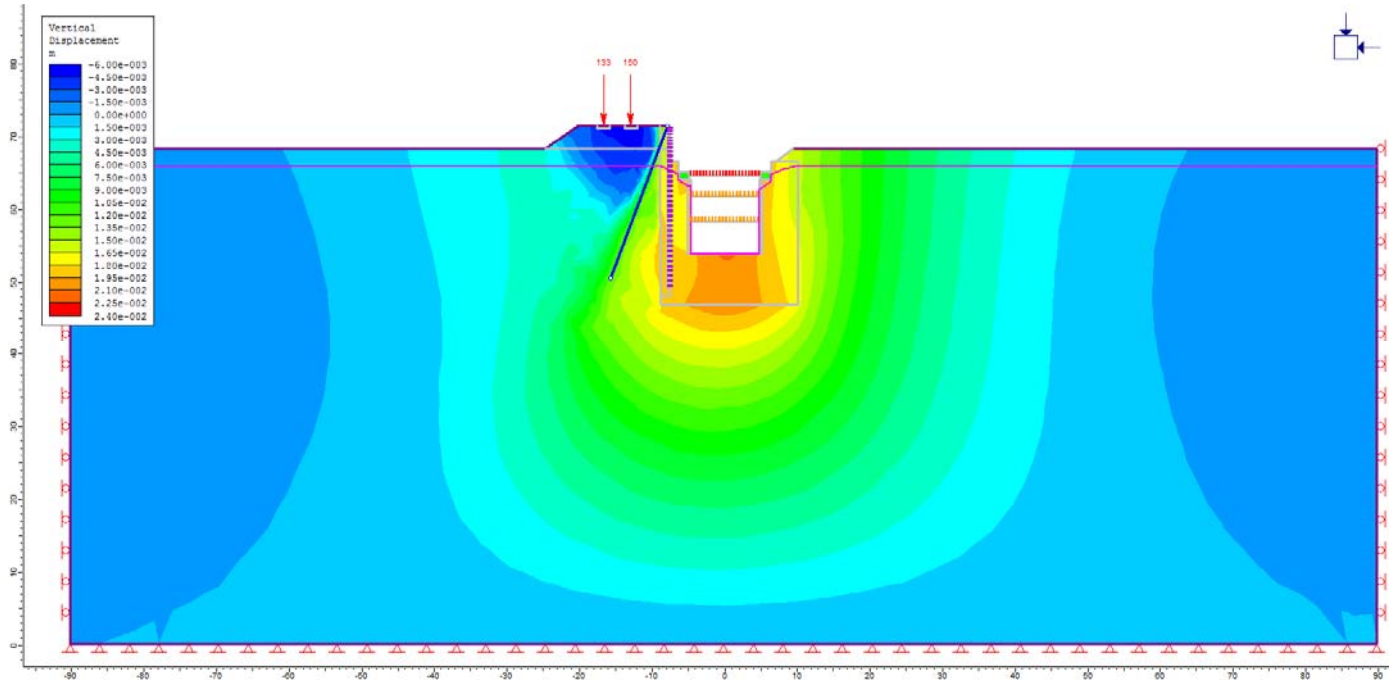
Galleria di Base binario Dispari. Progressiva pk_54+968. Spostamenti verticali dY. Fase finale di scavo. Particolare del rilevato ferroviario. Carico non fattorizzato (SLE)



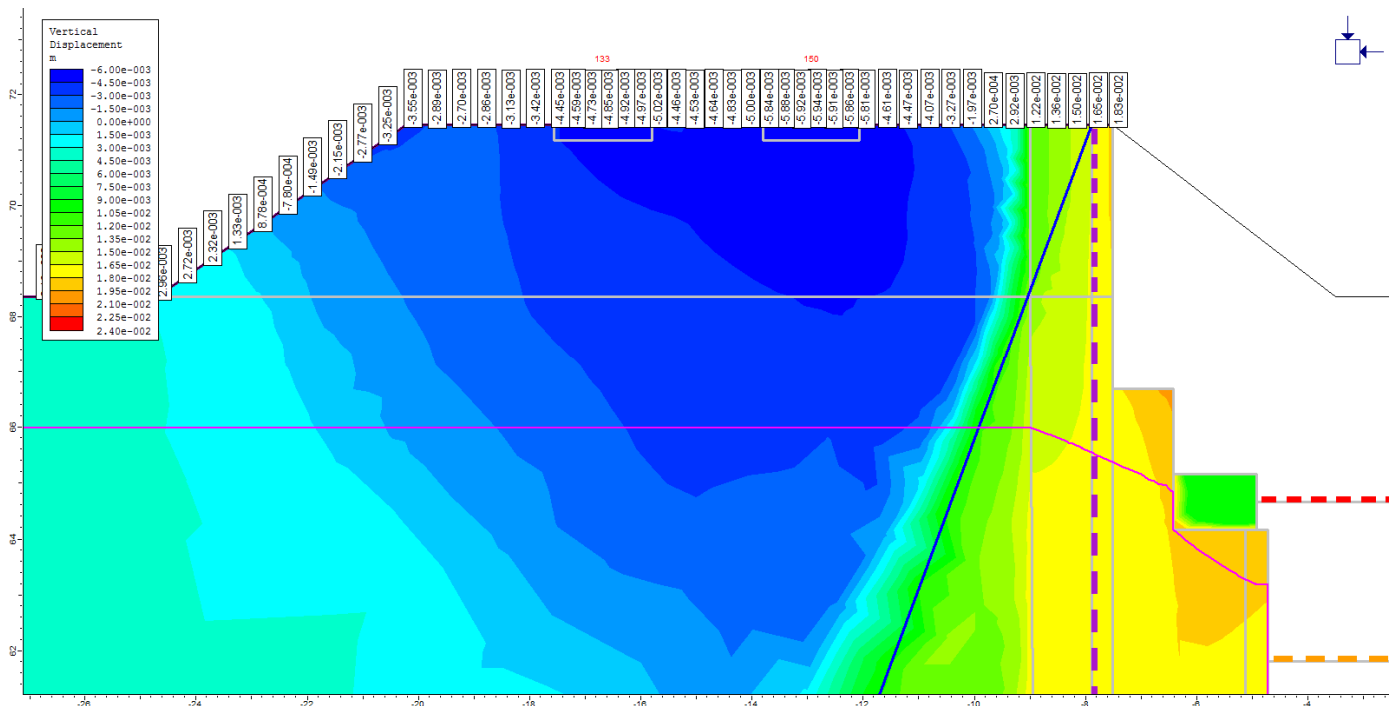
Galleria di Base binario Dispari. Progressiva pk₅₄₊₉₆₈. Spostamenti orizzontali dX. Fase finale di scavo. Carico non fattorizzato (SLE)



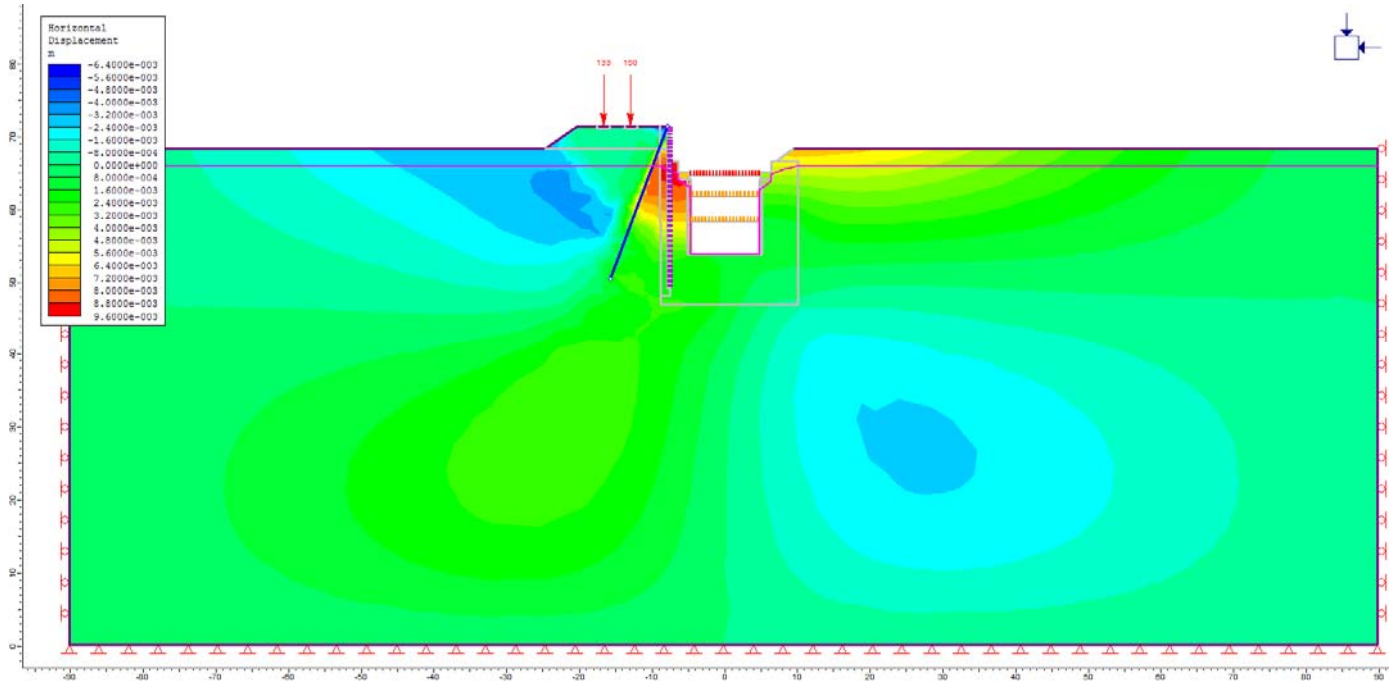
Galleria di Base binario Dispari. Progressiva pk₅₄₊₉₆₈. Spostamenti orizzontali dX. Fase finale di scavo. Particolare del rilevato ferroviario. Carico non fattorizzato (SLE)



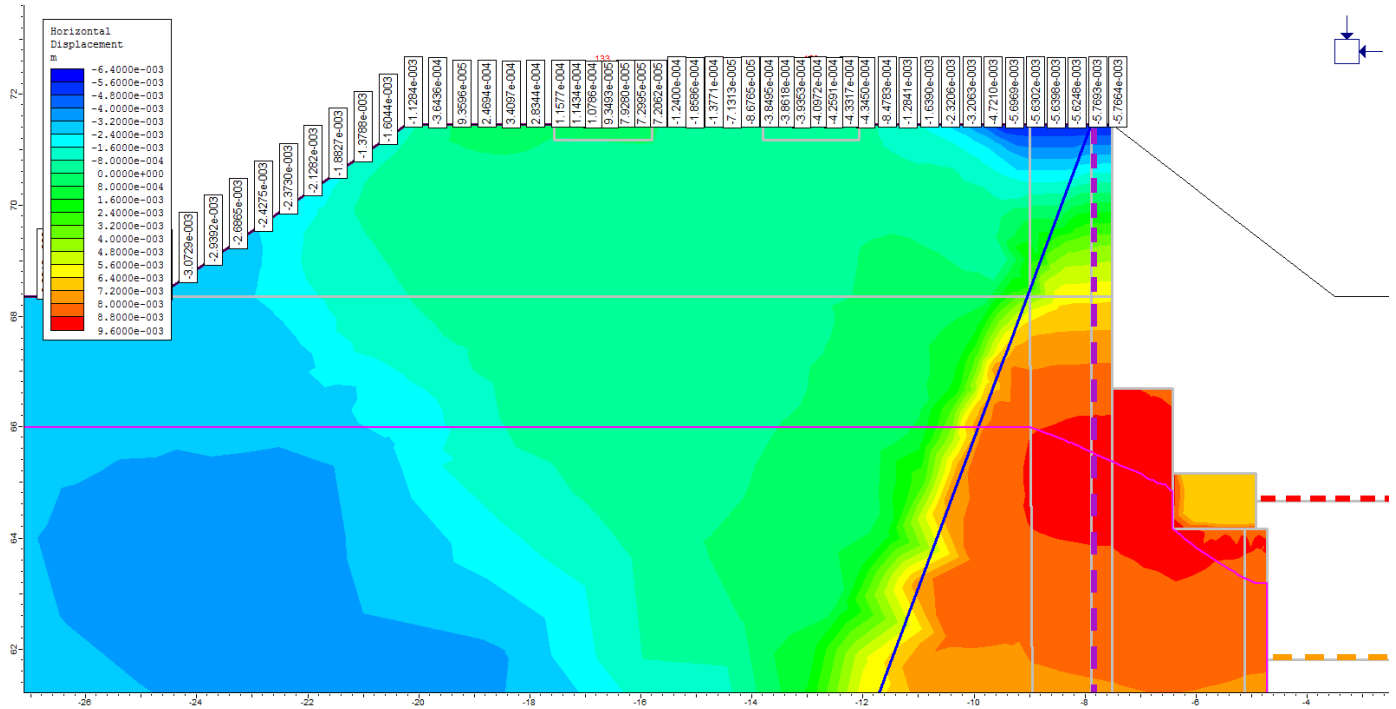
Galleria di Base binario Dispari. Progressiva pk₅₄+968.
 Spostamenti verticali dY. Fase finale di scavo più carico del treno. Carico non fattorizzato (SLE)



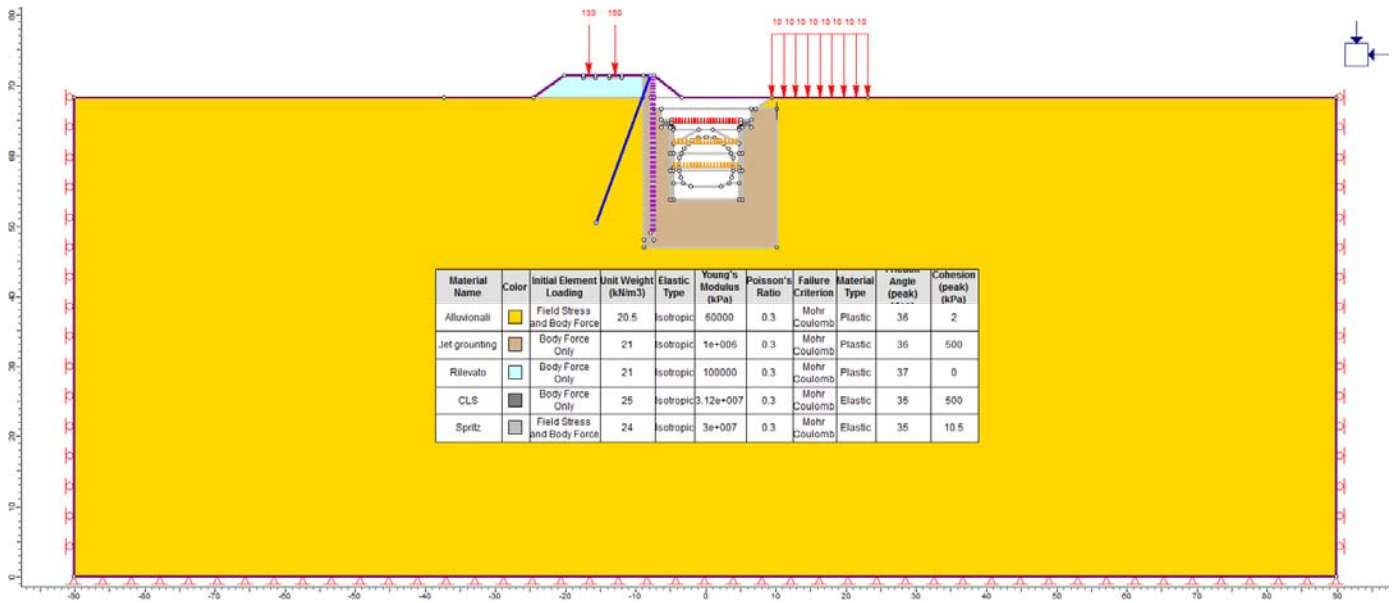
Galleria di Base binario Dispari. Progressiva pk₅₄+968.
 Spostamenti verticali dY. Fase finale di scavo più carico del treno. Particolare del rilevato ferroviario. Carico non fattorizzato (SLE)



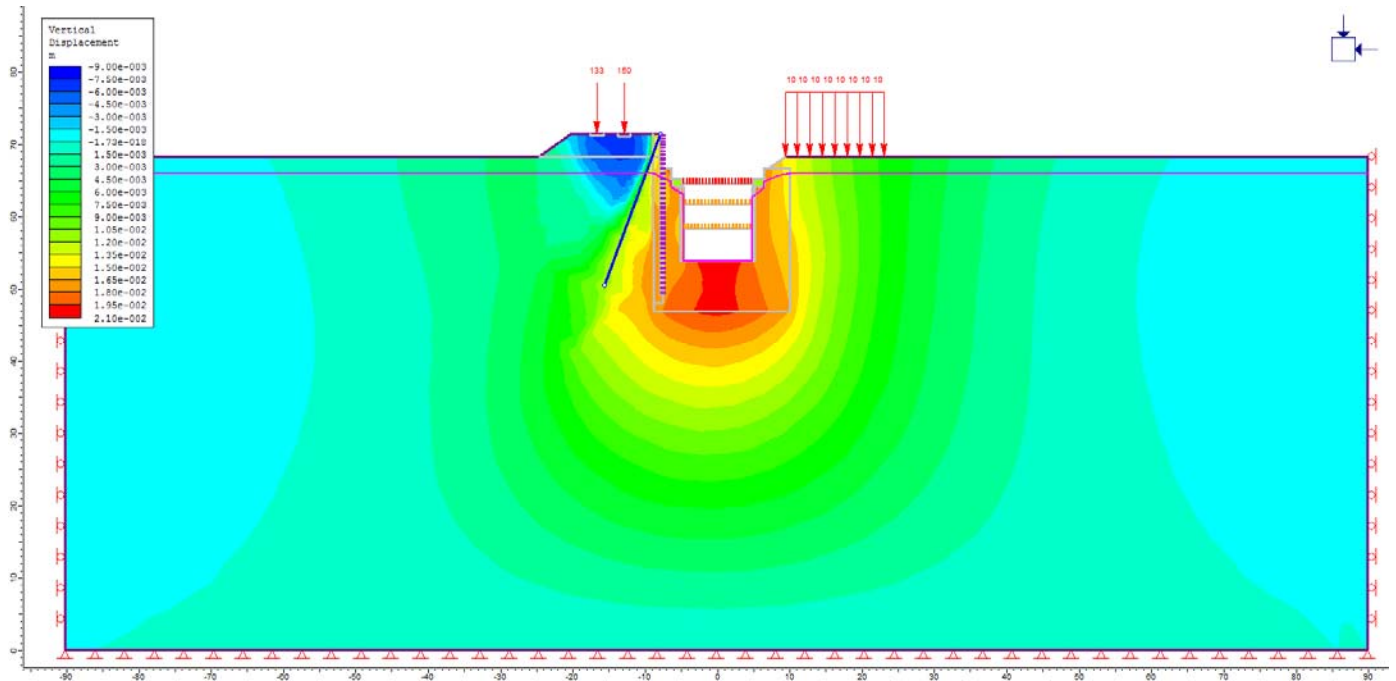
Galleria di Base binario Dispari. Progressiva pk₅₄₊₉₆₈. Spostamenti orizzontali dX. Fase finale di scavo più carico del treno. Carico non fattorizzato (SLE)



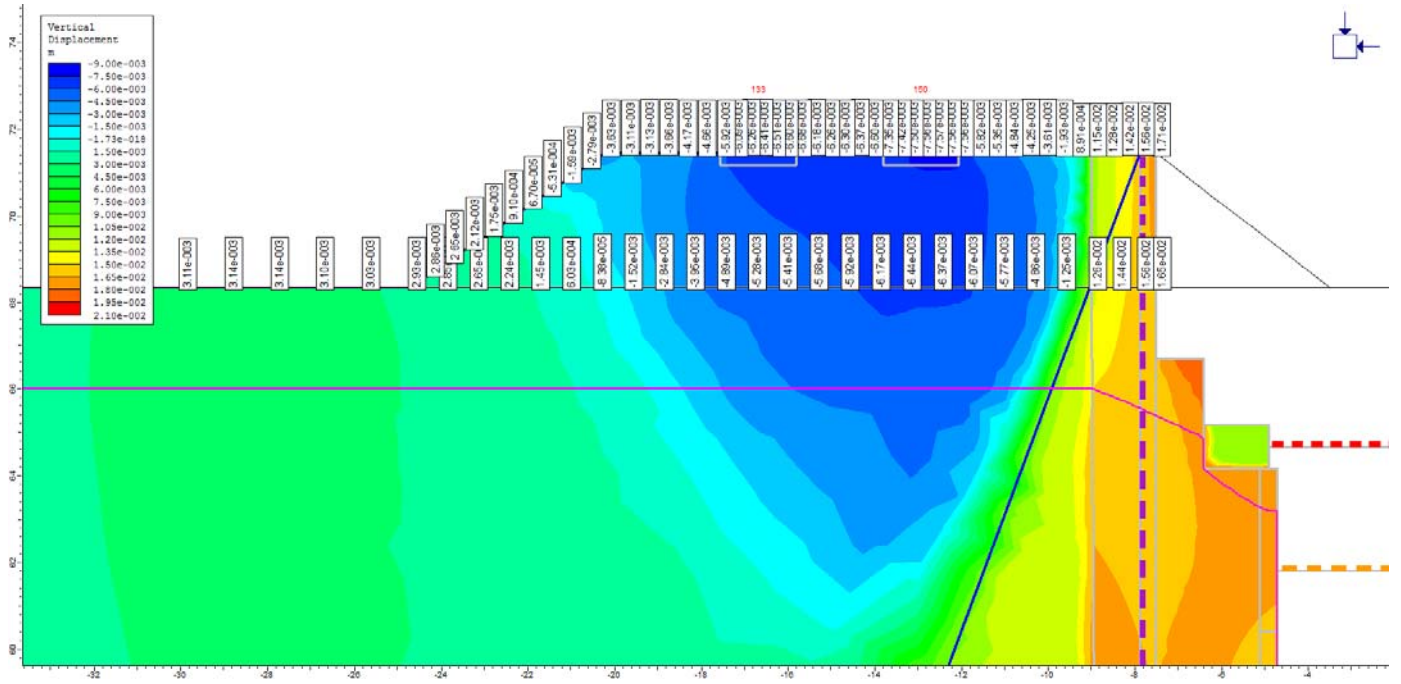
Galleria di Base binario Dispari. Progressiva pk₅₄₊₉₆₈. Spostamenti orizzontali dX. Fase finale di scavo più carico del treno. Particolare del rilevato ferroviario. Carico non fattorizzato (SLE)



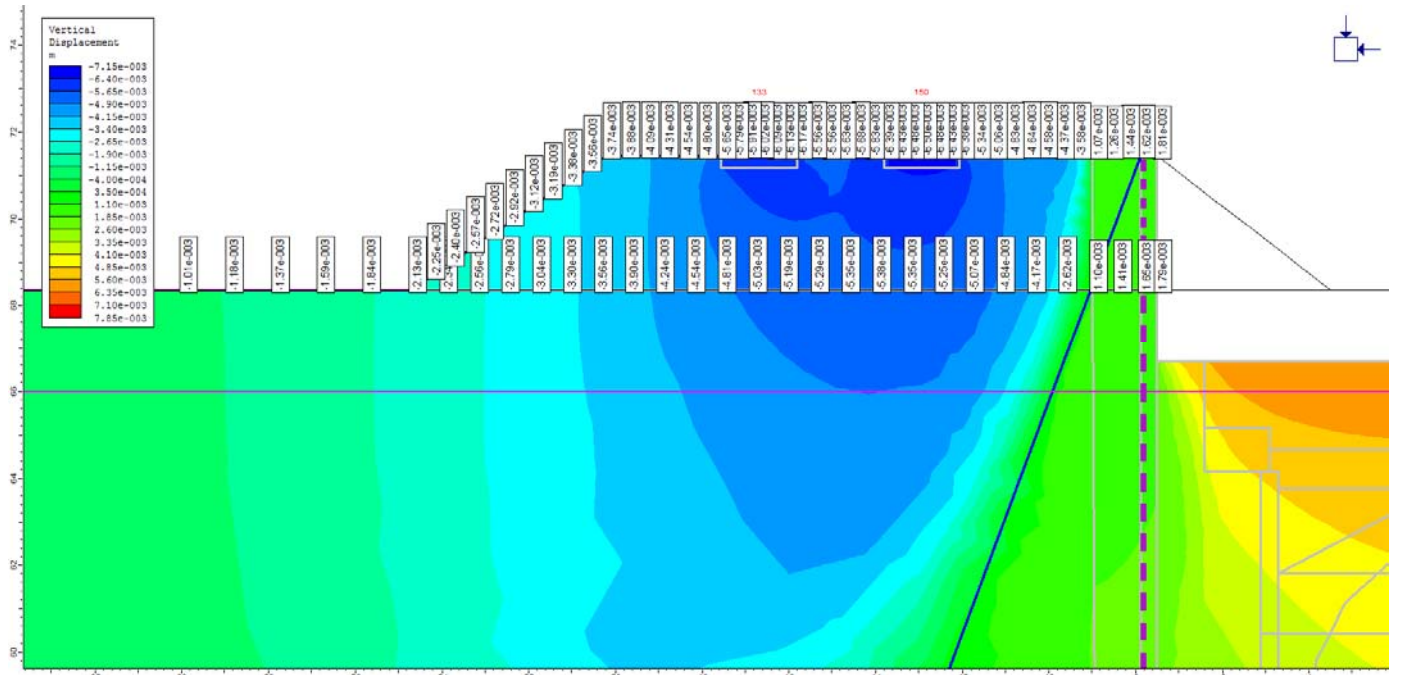
Geometria di calcolo per la Galleria di Base binario Dispari. Progressiva pk_54+968. Fase finale di scavo con carico del treno e carico distribuito durante costruzione.



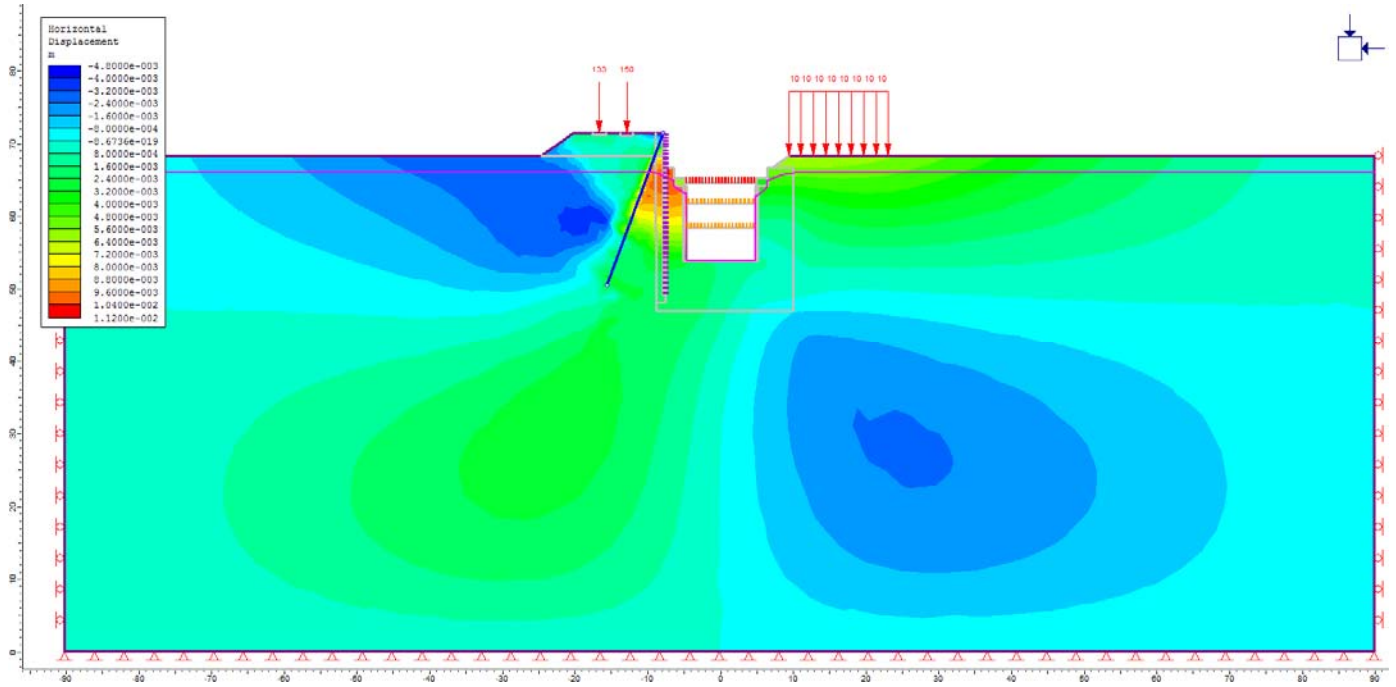
Galleria di Base binario Dispari. Progressiva pk_54+968. Spostamenti verticali dY. Fase finale di scavo, eseguito con carico del treno. Carico non fattorizzato (SLE)



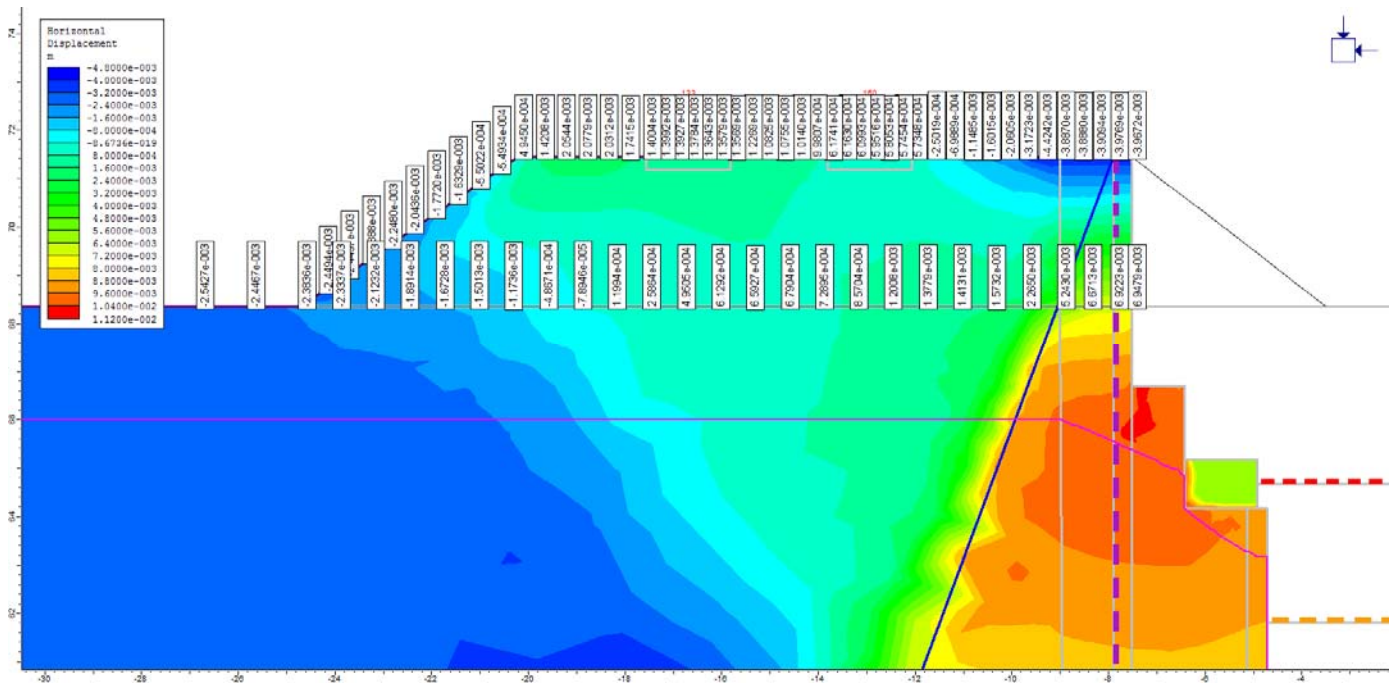
Galleria di Base binario Dispari. Progressiva pk₅₄₊₉₆₈. Spostamenti verticali dY. Fase finale di scavo, eseguito con carico del treno. Particolare del rilevato ferroviario. Carico non fattorizzato (SLE)



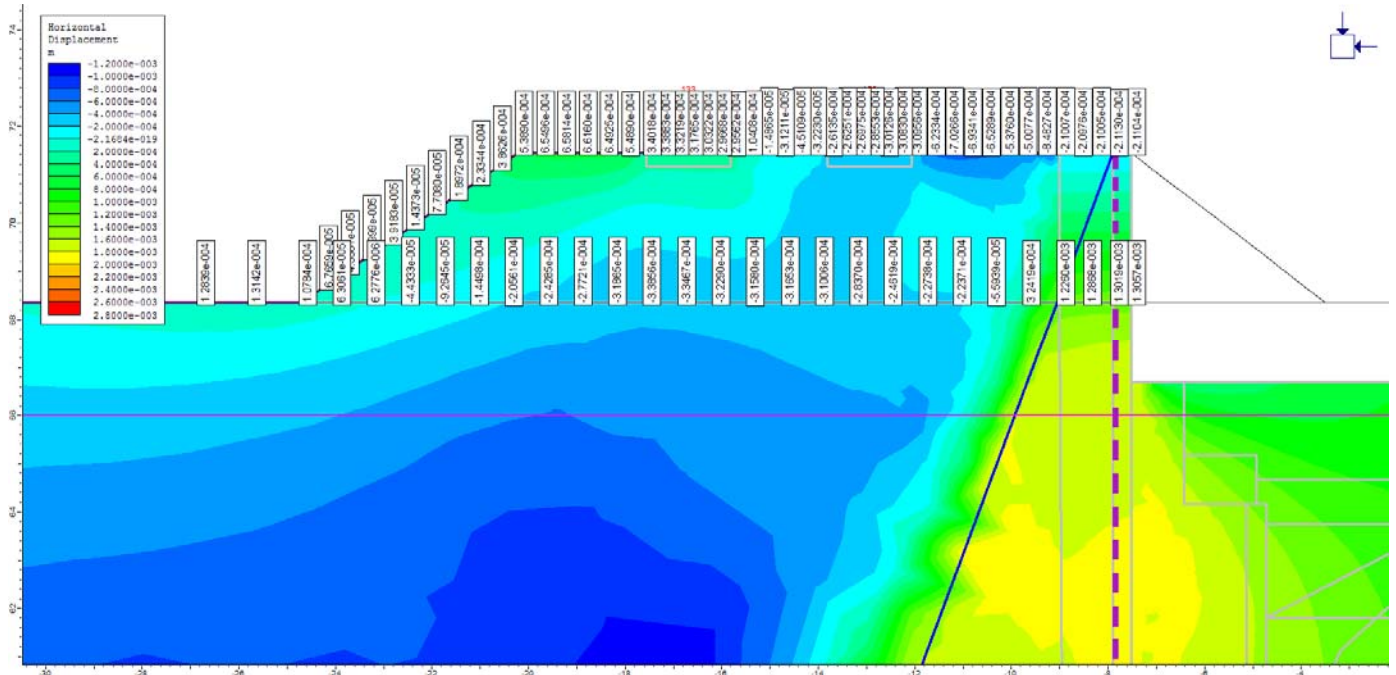
Galleria di Base binario Dispari. Progressiva pk₅₄₊₉₆₈. Spostamenti verticali dY. Fase di scavo fino a raggiungere quota del piano di lavoro del Jet grouting. Particolare del rilevato ferroviario. Carico non fattorizzato (SLE)



Galleria di Base binario Dispari. Progressiva pk₅₄+968. Spostamenti orizzontali dX. Fase finale di scavo, eseguito con carico del treno. Carico non fattorizzato (SLE)



Galleria di Base binario Dispari. Progressiva pk₅₄+968. Spostamenti orizzontali dX. Particolare del rilevato ferroviario. Carico non fattorizzato (SLE)



Galleria di Base binario Dispari. Progressiva pk₅₄₊₉₆₈. Spostamenti verticali dx. Fase di scavo fino a raggiungere quota del piano di lavoro del Jet grouting. Particolare del rilevato ferroviario. Carico non fattorizzato (SLE)

Phase2 Analysis Information

Project Settings

- Document Name: Sez 54+980_M-C_solo linea.fez
- Project Title: Phase2 - Finite Element Analysis of Excavations in Rock
- Number of Stages: 3
- Analysis Type: Plane Strain
- Solver Type: Gaussian Elimination
- Units: Metric, stress as kPa

Stress Analysis

- Maximum Number of Iterations: 2000
- Tolerance: 0.001
- Number of Load Steps: Automatic
- Convergence Type: Absolute Energy
- Tensile Failure: Reduces Shear Strength
- Joint tension reduces joint stiffness by a factor of 0.01

Groundwater

- Method: Finite Element Analysis
- Pore Fluid Unit Weight: 9.81 kN/m³
- Maximum Number of Iterations: 500
- Tolerance: 1e-006

Field Stress

- Field stress: gravity
- Using actual ground surface
- Effective stress ratio (horizontal/vertical in-plane): 1
- Effective stress ratio (horizontal/vertical out-of-plane): 1
- Locked-in horizontal stress (in-plane): 0
- Locked-in horizontal stress (out-of-plane): 0

Mesh

- Mesh type: graded
- Element type: 8 noded quadrilaterals
- Number of elements on Geostatico: 1855
- Number of nodes on Geostatico: 5596
- Number of elements on Paratia: 1855
- Number of nodes on Paratia: 5596
- Number of elements on Carico Treno: 1855
- Number of nodes on Carico Treno: 5596

Mesh Quality

- All elements are of good quality

Poor quality elements defined as:

- Side length ratio (maximum / minimum) > 30.00
- Minimum interior angle < 2.0 degrees
- Maximum interior angle > 175.0 degrees

Reset Displacements

- Displacements reset after: Geostatico
- Displacements reset after: Paratia

Material Properties

Material: Alluvionali

Initial element loading	field stress & body force
Unit weight	20.5 kN/m ³
Elastic type	isotropic
Young's modulus	60000 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	36 degrees
Peak cohesion	2 kPa
Material type	Plastic
Dilation Angle	1 degrees
Residual Friction Angle	35 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Properties changed in Paratia

- Unit weight: Young's modulus: 120000 kPa (factor = 2) Field Stress Gravity Ground surface elevation 0 m Unit weight of overburden 27 kN/m³ Effective stress ratio (horizontal/vertical in-plane) 0.413 Effective stress ratio (horizontal/vertical out-of-plane) 0.413 Locked-in horizontal stress (in-plane) 0 Locked-in horizontal stress (out-of-plane) 0

Material: Rilevato

Initial element loading	body force only
Unit weight	21 kN/m ³
Elastic type	isotropic
Young's modulus	100000 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	37 degrees
Peak cohesion	0 kPa
Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	37 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Field Stress Gravity Ground surface elevation 0 m Unit weight of overburden 27 kN/m³ Effective stress ratio (horizontal/vertical in-plane) 1 Effective stress ratio (horizontal/vertical out-of-plane) 1 Locked-in horizontal stress (in-plane) 0 Locked-in horizontal stress (out-of-plane) 0

Material: CLS

Initial element loading	body force only
Unit weight	25 kN/m ³
Elastic type	isotropic
Young's modulus	3.12e+007 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	35 degrees
Peak cohesion	500 kPa
Material type	Elastic
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	1e-012 m/s
K2/K1	1
K Angle	0 degrees

Excavation Areas

Original Un-deformed Areas

- External Boundary Area: 12249.238 m²

- External Boundary Perimeter: 497.494 m

Geostatico

- External Boundary Area: 12249.238 m² (0 m² change from original area)
- External Boundary Perimeter: 497.494 m (0 m change from original perimeter)

Paratia

- Values not available until this stage is viewed in a window

Carico Treno

- Values not available until this stage is viewed in a window

Displacements

- Displacement data is not available for Geostatico until total displacement is viewed in a window
- Displacement data is not available for Paratia until total displacement is viewed in a window
- Displacement data is not available for Carico Treno until total displacement is viewed in a window

Yielded Elements

Yielded Mesh Elements

- Number of yielded mesh elements on Geostatico: 435
- Number of yielded mesh elements is not available for Paratia until the stage is viewed in a window
- Number of yielded mesh elements is not available for Carico Treno until the stage is viewed in a window

Yielded Bolt Elements

- Number of yielded bolt elements on Geostatico: 0
- Number of yielded bolt elements on Paratia: 0
- Number of yielded bolt elements on Carico Treno: 0

List of All Coordinates

External boundary

X	Y
-90	3.6e-015
90	-3.6e-015
90	67.7518
24.547	67.7518
8.92667	67.7518
-3.77498	67.7518
-7.33906	70.022
-7.71053	70.2586
-8.83906	70.9774

-14.0003	70.9774
-15.505	70.9774
-17.0036	70.9774
-18.502	70.9774
-21.1763	70.9774
-25.7295	67.7112
-90	67.7518

Material boundary

X	Y
-25.7295	67.7112
-8.81939	67.7397
-7.71053	67.7418
-7.33906	67.7425
-3.77498	67.7518

Material boundary

X	Y
-8.81939	67.7397
-8.69935	47.9777
-8.69935	46.8498
9.59935	46.8498
9.59935	66.5208
7.23537	66.5206
6.59895	66.5206
6.59895	64.9996
6.59895	63.9996
5.29951	63.9996
5.09895	63.9996
4.90178	63.9996
4.90178	63.5898
4.90178	61.64
4.90178	60.2549
4.90178	58.1865
4.90178	57.7603
4.90178	56.0393
4.90178	53.6996
-4.54061	53.6999
-4.54061	56.0393
-4.54061	57.7603
-4.54061	58.1865
-4.54061	60.2549
-4.54061	61.64

-4.54061	63.5898
-4.54061	64
-4.74104	64
-4.94112	64
-6.24104	64
-6.24104	65
-6.24104	66.52
-7.33906	66.5197
-7.33906	47.9777
-8.69935	47.9777

Material boundary

X	Y
-6.24104	65
-4.74104	65
-4.74104	64.4961
-4.74104	64

Material boundary

X	Y
6.59895	64.9996
5.09895	64.9996
5.09895	64.4961
5.09895	63.9996

Material boundary

X	Y
-7.71053	67.7418
-7.71053	48.9774

Material boundary

X	Y
-4.54061	61.64
-0.821045	63.5898
1.17895	63.5898
4.90178	61.64

Material boundary

X	Y
-4.74104	64.4961

5.09895	64.4961
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Material boundary

X	Y
-4.54061	58.1865
-3.66587	58.1865
4.02378	58.1865
4.90178	58.1865

Material boundary

X	Y
-1.97105	55.4998
2.32895	55.4998
3.43459	56.0393
3.80031	56.8754
4.02378	57.7603
4.02378	58.1865
4.02378	59.6128
3.70607	60.2549
3.3503	60.9739
2.61053	61.64
2.13895	62.0646
1.3903	62.3979
0.178955	62.5898
-1.03239	62.3979
-1.78105	62.0646
-2.25262	61.64
-2.99239	60.9739
-3.34816	60.2549
-3.66587	59.6128
-3.66587	58.1865
-3.66587	57.7603
-3.4424	56.8754
-3.07669	56.0393
-1.97105	55.4998

Material boundary

X	Y
7.23537	66.5206
8.92667	67.7518

Material boundary

X	Y
-3.66587	57.7603
-4.54061	57.7603

Material boundary

X	Y
-3.66587	57.7603
4.02378	57.7603
4.90178	57.7603

Material boundary

X	Y
-14.0003	70.9774
-14.0003	70.702
-15.505	70.702
-15.505	70.9774

Material boundary

X	Y
-17.0036	70.9774
-17.0036	70.691
-18.502	70.691
-18.502	70.9774

Material boundary

X	Y
-4.54061	61.64
-2.25262	61.64
2.61053	61.64
4.90178	61.64

Material boundary

X	Y
-3.07669	56.0393
-4.54061	56.0393

Material boundary

X	Y
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3.43459	56.0393
4.90178	56.0393

Material boundary

X	Y
-6.24104	66.52
6.59895	66.5206

Material boundary

X	Y
-0.821045	63.5898
-4.54061	63.5898

Material boundary

X	Y
1.17895	63.5898
4.90178	63.5898

Material boundary

X	Y
-4.94112	64
-4.94112	60.2549
-4.94112	57.7603
-4.94112	53.6999

Material boundary

X	Y
-4.54061	53.6999
-4.94112	53.6999

Material boundary

X	Y
5.29951	63.9996
5.29951	60.2549
5.29951	57.7603
5.29951	53.6996

Material boundary

X	Y
4.90178	53.6996
5.29951	53.6996

Material boundary

X	Y
-4.54061	60.2549
-3.34816	60.2549
3.70607	60.2549
4.90178	60.2549

Material boundary

X	Y
-4.54061	60.2549
-4.94112	60.2549

Material boundary

X	Y
4.90178	60.2549
5.29951	60.2549

Material boundary

X	Y
-4.54061	57.7603
-4.94112	57.7603

Material boundary

X	Y
4.90178	57.7603
5.29951	57.7603

Material boundary

X	Y
-7.33906	66.5197
-7.33906	67.7425
-7.33906	70.022

Material boundary

X	Y
-7.71053	67.7418
-7.71053	70.2586

Material boundary

X	Y
-8.81939	67.7397
-8.83906	70.9774

Phase2 Analysis Information

Project Settings

- Document Name: Sez 54+980_M-C_fondo scavo + carico.fez
- Project Title: Phase2 - Finite Element Analysis of Excavations in Rock
- Number of Stages: 17
- Analysis Type: Plane Strain
- Solver Type: Gaussian Elimination
- Units: Metric, stress as kPa

Stress Analysis

- Maximum Number of Iterations: 2000
- Tolerance: 0.001
- Number of Load Steps: Automatic
- Convergence Type: Absolute Energy
- Tensile Failure: Reduces Shear Strength
- Joint tension reduces joint stiffness by a factor of 0.01

Groundwater

- Method: Finite Element Analysis
- Pore Fluid Unit Weight: 9.81 kN/m³
- Maximum Number of Iterations: 500
- Tolerance: 1e-006

Field Stress

- Field stress: gravity
- Using actual ground surface
- Effective stress ratio (horizontal/vertical in-plane): 1
- Effective stress ratio (horizontal/vertical out-of-plane): 1
- Locked-in horizontal stress (in-plane): 0
- Locked-in horizontal stress (out-of-plane): 0

Mesh

- Mesh type: graded
- Element type: 8 noded quadrilaterals
- Number of elements on Geostatico: 1350
- Number of nodes on Geostatico: 3969
- Number of elements on Paratia: 1350
- Number of nodes on Paratia: 3969
- Number of elements on Piano lavoro: 1296
- Number of nodes on Piano lavoro: 3823
- Number of elements on Jet: 1296
- Number of nodes on Jet: 3823
- Number of elements on I ribasso: 1212
- Number of nodes on I ribasso: 3613
- Number of elements on I puntone: 1212
- Number of nodes on I puntone: 3613
- Number of elements on II ribasso: 1116
- Number of nodes on II ribasso: 3367
- Number of elements on II puntone: 1116

- Number of nodes on II puntone: 3367
- Number of elements on III ribasso: 1036
- Number of nodes on III ribasso: 3145
- Number of elements on III puntone: 1036
- Number of nodes on III puntone: 3145
- Number of elements on Fondo scavo: 949
- Number of nodes on Fondo scavo: 2908
- Number of elements on CARICO TRENO: 949
- Number of nodes on CARICO TRENO: 2908
- Number of elements on Solettone: 985
- Number of nodes on Solettone: 3010
- Number of elements on Rimozione puntone: 985
- Number of nodes on Rimozione puntone: 3010
- Number of elements on Getto calotta: 1069
- Number of nodes on Getto calotta: 3257
- Number of elements on Rimozione puntone: 1069
- Number of nodes on Rimozione puntone: 3257
- Number of elements on Ritombamento: 1221
- Number of nodes on Ritombamento: 3647

Mesh Quality

- All elements are of good quality

Poor quality elements defined as:

- Side length ratio (maximum / minimum) > 30.00
- Minimum interior angle < 2.0 degrees
- Maximum interior angle > 175.0 degrees

Reset Displacements

- Displacements reset after: Geostatico
- Displacements reset after: Paratia

Material Properties

Material: Alluvionali

Initial element loading	field stress & body force
Unit weight	20.5 kN/m ³
Elastic type	isotropic
Young's modulus	60000 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	36 degrees
Peak cohesion	2 kPa
Material type	Plastic
Dilation Angle	1 degrees
Residual Friction Angle	35 degrees

Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Properties changed in Paratia

- Unit weight:

Properties changed in Piano lavoro

- Unit weight: Young's modulus: 120000 kPa (factor = 2) Field Stress Gravity Ground surface elevation 0 m Unit weight of overburden 27 kN/m³ Effective stress ratio (horizontal/vertical in-plane) 0.413 Effective stress ratio (horizontal/vertical out-of-plane) 0.413 Locked-in horizontal stress (in-plane) 0 Locked-in horizontal stress (out-of-plane) 0

Material: Jet grouting

Initial element loading	body force only
Unit weight	21 kN/m ³
Elastic type	isotropic
Young's modulus	1e+006 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	75 kPa
Peak friction angle	36 degrees
Peak cohesion	500 kPa
Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	36 degrees
Residual Cohesion	500 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	1e-008 m/s
K2/K1	1
K Angle	0 degrees

Material: Rilevato

Initial element loading	body force only
Unit weight	21 kN/m ³
Elastic type	isotropic
Young's modulus	100000 kPa

Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	37 degrees
Peak cohesion	0 kPa
Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	37 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Field Stress Gravity Ground surface elevation 0 m Unit weight of overburden 27 kN/m³ Effective stress ratio (horizontal/vertical in-plane) 1 Effective stress ratio (horizontal/vertical out-of-plane) 1 Locked-in horizontal stress (in-plane) 0 Locked-in horizontal stress (out-of-plane) 0

Material: CLS

Initial element loading	body force only
Unit weight	25 kN/m ³
Elastic type	isotropic
Young's modulus	3.12e+007 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	35 degrees
Peak cohesion	500 kPa
Material type	Elastic
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	1e-012 m/s
K2/K1	1
K Angle	0 degrees

Material: Spritz

Initial element loading	field stress & body force
Unit weight	24 kN/m ³
Elastic type	isotropic
Young's modulus	3e+007 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb

Tensile strength	0 kPa
Peak friction angle	35 degrees
Peak cohesion	10.5 kPa
Material type	Elastic
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	1e-008 m/s
K2/K1	1
K Angle	0 degrees

Properties changed in Rimozione puntone

- Unit weight: Ks: 1e-010 m/s (factor = 0.01)K Angle: 0 degrees (factor = 0)

Excavation Areas

Original Un-deformed Areas

- External Boundary Area: 12249.238 m²
- External Boundary Perimeter: 497.494 m

Geostatico

- External Boundary Area: 12249.238 m² (0 m² change from original area)
- External Boundary Perimeter: 497.494 m (0 m change from original perimeter)

Paratia

- Values not available until this stage is viewed in a window

Piano lavoro

- Values not available until this stage is viewed in a window

Jet

- Values not available until this stage is viewed in a window

I ribasso

- Values not available until this stage is viewed in a window

I puntone

- Values not available until this stage is viewed in a window

II ribasso

- Values not available until this stage is viewed in a window

II puntone

- Values not available until this stage is viewed in a window

III ribasso

- Values not available until this stage is viewed in a window

III puntone

- Values not available until this stage is viewed in a window

Fondo scavo

- Values not available until this stage is viewed in a window

CARICO TRENO

- Values not available until this stage is viewed in a window

Solettone

- Values not available until this stage is viewed in a window

Rimozione puntone

- Values not available until this stage is viewed in a window

Getto calotta

- Values not available until this stage is viewed in a window

Rimozione puntone

- Values not available until this stage is viewed in a window

Ritombamento

- Values not available until this stage is viewed in a window

Liner Properties

Liner: Micropalo_F168_sp10/0.75m

Liner Type	Standard Beam
Formulation	Timoshenko
Area	0.0066275 m ²
Moment of Inertia	2.08e-005 m ⁴

Elastic Properties

Young's modulus	2.1e+008 kPa
Poisson's ratio	0.2

Liner: Tubo_F406.4_sp12.5/4m

Liner Type	Standard Beam
Formulation	Timoshenko
Area	0.0038651 m ²
Moment of Inertia	7.5038e-005 m ⁴

Elastic Properties

Young's modulus	2.1e+008 kPa
Poisson's ratio	0.2
Liner Unit Weight	78.5 kN/m ³

Liner: Tubo_355.6_sp12/4m

Liner Type	Standard Beam
Formulation	Timoshenko
Area	0.003236 m ²
Moment of Inertia	4.782e-005 m ⁴

Elastic Properties

Young's modulus	2.1e+008 kPa
Poisson's ratio	0.2
Liner Unit Weight	78.5 kN/m ³

Bolt Properties

Bolt name	Tirante
Bolt Type	Fully bonded bolt
Diameter	168.3 mm
Young's modulus	2.1e+008 kPa
Tensile capacity	1600 kN
Residual Tensile capacity	0.01 kN

Pre-tensioning	0 kN
Out-of-plane spacing	1.5 m

Displacements

- Displacement data is not available for Geostatico until total displacement is viewed in a window
- Displacement data is not available for Paratia until total displacement is viewed in a window
- Displacement data is not available for Piano lavoro until total displacement is viewed in a window
- Displacement data is not available for Jet until total displacement is viewed in a window
- Displacement data is not available for I ribasso until total displacement is viewed in a window
- Displacement data is not available for I puntone until total displacement is viewed in a window
- Displacement data is not available for II ribasso until total displacement is viewed in a window
- Displacement data is not available for II puntone until total displacement is viewed in a window
- Displacement data is not available for III ribasso until total displacement is viewed in a window
- Displacement data is not available for III puntone until total displacement is viewed in a window
- Displacement data is not available for Fondo scavo until total displacement is viewed in a window
- Displacement data is not available for CARICO TRENO until total displacement is viewed in a window
- Displacement data is not available for Solettone until total displacement is viewed in a window
- Displacement data is not available for Rimozione puntone until total displacement is viewed in a window
- Displacement data is not available for Getto calotta until total displacement is viewed in a window
- Displacement data is not available for Rimozione puntone until total displacement is viewed in a window
- Displacement data is not available for Ritombamento until total displacement is viewed in a window

Yielded Elements

Yielded Mesh Elements

- Number of yielded mesh elements on Geostatico: 287
- Number of yielded mesh elements is not available for Paratia until the stage is viewed in a window
- Number of yielded mesh elements is not available for Piano lavoro until the stage is viewed in a window
- Number of yielded mesh elements is not available for Jet until the stage is viewed in a window
- Number of yielded mesh elements is not available for I ribasso until the stage is viewed in a window
- Number of yielded mesh elements is not available for I puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for II ribasso until the stage is viewed in a window
- Number of yielded mesh elements is not available for II puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for III ribasso until the stage is viewed in a window
- Number of yielded mesh elements is not available for III puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for Fondo scavo until the stage is viewed in a window
- Number of yielded mesh elements is not available for CARICO TRENO until the stage is viewed in a window
- Number of yielded mesh elements is not available for Solettone until the stage is viewed in a window
- Number of yielded mesh elements is not available for Rimozione puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for Getto calotta until the stage is viewed in a window
- Number of yielded mesh elements is not available for Rimozione puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for Ritombamento until the stage is viewed in a window

Yielded Bolt Elements

- Number of yielded bolt elements on Geostatico: 0
- Number of yielded bolt elements on Paratia: 0
- Number of yielded bolt elements on Piano lavoro: 0
- Number of yielded bolt elements on Jet: 0
- Number of yielded bolt elements on I ribasso: 0
- Number of yielded bolt elements on I puntone: 0
- Number of yielded bolt elements on II ribasso: 0
- Number of yielded bolt elements on II puntone: 0
- Number of yielded bolt elements on III ribasso: 0
- Number of yielded bolt elements on III puntone: 0

- Number of yielded bolt elements on Fondo scavo: 0
- Number of yielded bolt elements on CARICO TRENO: 0
- Number of yielded bolt elements on Solettone: 0
- Number of yielded bolt elements on Rimozione puntone: 0
- Number of yielded bolt elements on Getto calotta: 0
- Number of yielded bolt elements on Rimozione puntone: 0
- Number of yielded bolt elements on Ritombamento: 0

Yielded Liner Elements

- Number of yielded liner elements on Geostatico: 0
- Number of yielded liner elements on Paratia: 0
- Number of yielded liner elements on Piano lavoro: 0
- Number of yielded liner elements on Jet: 0
- Number of yielded liner elements on I ribasso: 0
- Number of yielded liner elements on I puntone: 0
- Number of yielded liner elements on II ribasso: 0
- Number of yielded liner elements on II puntone: 0
- Number of yielded liner elements on III ribasso: 0
- Number of yielded liner elements on III puntone: 0
- Number of yielded liner elements on Fondo scavo: 0
- Number of yielded liner elements on CARICO TRENO: 0
- Number of yielded liner elements on Solettone: 0
- Number of yielded liner elements on Rimozione puntone: 0
- Number of yielded liner elements on Getto calotta: 0
- Number of yielded liner elements on Rimozione puntone: 0
- Number of yielded liner elements on Ritombamento: 0

List of All Coordinates

External boundary

X	Y
-90	3.6e-015
90	-3.6e-015
90	67.7518
24.547	67.7518
8.92667	67.7518
-3.77498	67.7518
-7.33906	70.022
-7.71053	70.2586
-8.83906	70.9774
-14.0003	70.9774
-15.505	70.9774
-17.0036	70.9774
-18.502	70.9774
-21.1763	70.9774
-25.7295	67.7112
-90	67.7518

Material boundary

X	Y
-25.7295	67.7112
-8.81939	67.7397
-7.71053	67.7418
-7.33906	67.7425
-3.77498	67.7518

Material boundary

X	Y
-8.81939	67.7397
-8.69935	47.9777
-8.69935	46.8498
9.59935	46.8498
9.59935	66.5208
7.23537	66.5206
6.59895	66.5206
6.59895	64.9996
6.59895	63.9996
5.29951	63.9996
5.09895	63.9996
4.90178	63.9996
4.90178	63.5898
4.90178	61.64
4.90178	60.2549
4.90178	58.1865
4.90178	57.7603
4.90178	56.0393
4.90178	53.6996
-4.54061	53.6999
-4.54061	56.0393
-4.54061	57.7603
-4.54061	58.1865
-4.54061	60.2549
-4.54061	61.64
-4.54061	63.5898
-4.54061	64
-4.74104	64
-4.94112	64
-6.24104	64
-6.24104	65
-6.24104	66.52
-7.33906	66.5197
-7.33906	47.9777
-8.69935	47.9777

Material boundary

X	Y
-6.24104	65
-4.74104	65
-4.74104	64.4961
-4.74104	64

Material boundary

X	Y
6.59895	64.9996
5.09895	64.9996
5.09895	64.4961
5.09895	63.9996

Material boundary

X	Y
-7.71053	67.7418
-7.71053	48.9774

Material boundary

X	Y
-4.54061	61.64
-0.821045	63.5898
1.17895	63.5898
4.90178	61.64

Material boundary

X	Y
-4.74104	64.4961
5.09895	64.4961

Material boundary

X	Y
-4.54061	58.1865
-3.66587	58.1865
4.02378	58.1865
4.90178	58.1865

Material boundary

X	Y
-1.97105	55.4998
2.32895	55.4998
3.43459	56.0393
3.80031	56.8754
4.02378	57.7603
4.02378	58.1865
4.02378	59.6128
3.70607	60.2549
3.3503	60.9739
2.61053	61.64
2.13895	62.0646
1.3903	62.3979
0.178955	62.5898
-1.03239	62.3979
-1.78105	62.0646
-2.25262	61.64
-2.99239	60.9739
-3.34816	60.2549
-3.66587	59.6128
-3.66587	58.1865
-3.66587	57.7603
-3.4424	56.8754
-3.07669	56.0393
-1.97105	55.4998

Material boundary

X	Y
7.23537	66.5206
8.92667	67.7518

Material boundary

X	Y
-3.66587	57.7603
-4.54061	57.7603

Material boundary

X	Y
-3.66587	57.7603
4.02378	57.7603
4.90178	57.7603

Material boundary

X	Y
-14.0003	70.9774
-14.0003	70.702
-15.505	70.702
-15.505	70.9774

Material boundary

X	Y
-17.0036	70.9774
-17.0036	70.691
-18.502	70.691
-18.502	70.9774

Material boundary

X	Y
-4.54061	61.64
-2.25262	61.64
2.61053	61.64
4.90178	61.64

Material boundary

X	Y
-3.07669	56.0393
-4.54061	56.0393

Material boundary

X	Y
3.43459	56.0393
4.90178	56.0393

Material boundary

X	Y
-6.24104	66.52
6.59895	66.5206

Material boundary

X	Y
---	---

-0.821045	63.5898
-4.54061	63.5898

Material boundary

X	Y
1.17895	63.5898
4.90178	63.5898

Material boundary

X	Y
-4.94112	64
-4.94112	60.2549
-4.94112	57.7603
-4.94112	53.6999

Material boundary

X	Y
-4.54061	53.6999
-4.94112	53.6999

Material boundary

X	Y
5.29951	63.9996
5.29951	60.2549
5.29951	57.7603
5.29951	53.6996

Material boundary

X	Y
4.90178	53.6996
5.29951	53.6996

Material boundary

X	Y
-4.54061	60.2549
-3.34816	60.2549
3.70607	60.2549
4.90178	60.2549

Material boundary

X	Y
-4.54061	60.2549
-4.94112	60.2549

Material boundary

X	Y
4.90178	60.2549
5.29951	60.2549

Material boundary

X	Y
-4.54061	57.7603
-4.94112	57.7603

Material boundary

X	Y
4.90178	57.7603
5.29951	57.7603

Material boundary

X	Y
-7.33906	66.5197
-7.33906	67.7425
-7.33906	70.022

Material boundary

X	Y
-7.71053	67.7418
-7.71053	70.2586

Material boundary

X	Y
-8.81939	67.7397
-8.83906	70.9774

Phase2 Analysis Information

Project Settings

- Document Name: Sez 54+980_M-C_fondo scavo con carico.fez
- Project Title: Phase2 - Finite Element Analysis of Excavations in Rock
- Number of Stages: 16
- Analysis Type: Plane Strain
- Solver Type: Gaussian Elimination
- Units: Metric, stress as kPa

Stress Analysis

- Maximum Number of Iterations: 2000
- Tolerance: 0.001
- Number of Load Steps: Automatic
- Convergence Type: Absolute Energy
- Tensile Failure: Reduces Shear Strength
- Joint tension reduces joint stiffness by a factor of 0.01

Groundwater

- Method: Finite Element Analysis
- Pore Fluid Unit Weight: 9.81 kN/m³
- Maximum Number of Iterations: 500
- Tolerance: 1e-006

Field Stress

- Field stress: gravity
- Using actual ground surface
- Effective stress ratio (horizontal/vertical in-plane): 1
- Effective stress ratio (horizontal/vertical out-of-plane): 1
- Locked-in horizontal stress (in-plane): 0
- Locked-in horizontal stress (out-of-plane): 0

Mesh

- Mesh type: graded
- Element type: 8 noded quadrilaterals
- Number of elements on Geostatico: 1350
- Number of nodes on Geostatico: 3969
- Number of elements on Paratia: 1350
- Number of nodes on Paratia: 3969
- Number of elements on Piano lavoro: 1296
- Number of nodes on Piano lavoro: 3823
- Number of elements on Jet: 1296
- Number of nodes on Jet: 3823
- Number of elements on I ribasso: 1212
- Number of nodes on I ribasso: 3613
- Number of elements on I puntone: 1212
- Number of nodes on I puntone: 3613
- Number of elements on II ribasso: 1116
- Number of nodes on II ribasso: 3367
- Number of elements on II puntone: 1116

- Number of nodes on II puntone: 3367
- Number of elements on III ribasso: 1036
- Number of nodes on III ribasso: 3145
- Number of elements on III puntone: 1036
- Number of nodes on III puntone: 3145
- Number of elements on Fondo scavo: 949
- Number of nodes on Fondo scavo: 2908
- Number of elements on Solettone: 985
- Number of nodes on Solettone: 3010
- Number of elements on Rimozione puntone: 985
- Number of nodes on Rimozione puntone: 3010
- Number of elements on Getto calotta: 1069
- Number of nodes on Getto calotta: 3257
- Number of elements on Rimozione puntone: 1069
- Number of nodes on Rimozione puntone: 3257
- Number of elements on Ritombamento: 1221
- Number of nodes on Ritombamento: 3647

Mesh Quality

- All elements are of good quality

Poor quality elements defined as:

- Side length ratio (maximum / minimum) > 30.00
- Minimum interior angle < 2.0 degrees
- Maximum interior angle > 175.0 degrees

Reset Displacements

- Displacements reset after: Geostatico
- Displacements reset after: Paratia

Material Properties

Material: Alluvionali

Initial element loading	field stress & body force
Unit weight	20.5 kN/m ³
Elastic type	isotropic
Young's modulus	60000 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	36 degrees
Peak cohesion	2 kPa
Material type	Plastic
Dilation Angle	1 degrees
Residual Friction Angle	35 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees

Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Properties changed in Paratia

- Unit weight:

Properties changed in Piano lavoro

- Unit weight: Young's modulus: 120000 kPa (factor = 2) Field Stress Gravity Ground surface elevation 0 m Unit weight of overburden 27 kN/m³ Effective stress ratio (horizontal/vertical in-plane) 0.413 Effective stress ratio (horizontal/vertical out-of-plane) 0.413 Locked-in horizontal stress (in-plane) 0 Locked-in horizontal stress (out-of-plane) 0

Material: Jet grouting

Initial element loading	body force only
Unit weight	21 kN/m ³
Elastic type	isotropic
Young's modulus	1e+006 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	75 kPa
Peak friction angle	36 degrees
Peak cohesion	500 kPa
Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	36 degrees
Residual Cohesion	500 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	1e-008 m/s
K2/K1	1
K Angle	0 degrees

Material: Rilevato

Initial element loading	body force only
Unit weight	21 kN/m ³
Elastic type	isotropic
Young's modulus	100000 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb

Tensile strength	0 kPa
Peak friction angle	37 degrees
Peak cohesion	0 kPa
Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	37 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Field Stress Gravity Ground surface elevation 0 m Unit weight of overburden 27 kN/m³ Effective stress ratio (horizontal/vertical in-plane) 1 Effective stress ratio (horizontal/vertical out-of-plane) 1 Locked-in horizontal stress (in-plane) 0 Locked-in horizontal stress (out-of-plane) 0

Material: CLS

Initial element loading	body force only
Unit weight	25 kN/m ³
Elastic type	isotropic
Young's modulus	3.12e+007 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	35 degrees
Peak cohesion	500 kPa
Material type	Elastic
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	1e-012 m/s
K2/K1	1
K Angle	0 degrees

Material: Spritz

Initial element loading	field stress & body force
Unit weight	24 kN/m ³
Elastic type	isotropic
Young's modulus	3e+007 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	35 degrees

Peak cohesion	10.5 kPa
Material type	Elastic
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	1e-008 m/s
K2/K1	1
K Angle	0 degrees

Properties changed in Rimozione puntone

- Unit weight: Ks: 1e-010 m/s (factor = 0.01)K Angle: 0 degrees (factor = 0)

Excavation Areas

Original Un-deformed Areas

- External Boundary Area: 12249.238 m2
- External Boundary Perimeter: 497.494 m

Geostatico

- External Boundary Area: 12249.238 m2 (0 m2 change from original area)
- External Boundary Perimeter: 497.494 m (0 m change from original perimeter)

Paratia

- Values not available until this stage is viewed in a window

Piano lavoro

- Values not available until this stage is viewed in a window

Jet

- Values not available until this stage is viewed in a window

I ribasso

- Values not available until this stage is viewed in a window

I puntone

- Values not available until this stage is viewed in a window

II ribasso

- Values not available until this stage is viewed in a window

II puntone

- Values not available until this stage is viewed in a window

III ribasso

- Values not available until this stage is viewed in a window

III puntone

- Values not available until this stage is viewed in a window

Fondo scavo

- Values not available until this stage is viewed in a window

Solettone

- Values not available until this stage is viewed in a window

Rimozione puntone

- Values not available until this stage is viewed in a window

Getto calotta

- Values not available until this stage is viewed in a window

Rimozione puntone

- Values not available until this stage is viewed in a window

Ritombamento

- Values not available until this stage is viewed in a window

Liner Properties

Liner: Micropalo_F168_sp10/0.75m

Liner Type	Standard Beam
Formulation	Timoshenko
Area	0.0066275 m ²
Moment of Inertia	2.08e-005 m ⁴

Elastic Properties

Young's modulus	2.1e+008 kPa
Poisson's ratio	0.2

Liner: Tubo_F406.4_sp12.5/4m

Liner Type	Standard Beam
Formulation	Timoshenko
Area	0.0038651 m ²
Moment of Inertia	7.5038e-005 m ⁴

Elastic Properties

Young's modulus	2.1e+008 kPa
Poisson's ratio	0.2
Liner Unit Weight	78.5 kN/m ³

Liner: Tubo_355.6_sp12/4m

Liner Type	Standard Beam
Formulation	Timoshenko
Area	0.003236 m ²
Moment of Inertia	4.782e-005 m ⁴

Elastic Properties

Young's modulus	2.1e+008 kPa
Poisson's ratio	0.2
Liner Unit Weight	78.5 kN/m ³

Bolt Properties

Bolt name	Tirante
Bolt Type	Fully bonded bolt
Diameter	168.3 mm
Young's modulus	2.1e+008 kPa
Tensile capacity	1600 kN
Residual Tensile capacity	0.01 kN
Pre-tensioning	0 kN
Out-of-plane spacing	1.5 m

Displacements

- Displacement data is not available for Geostatico until total displacement is viewed in a window

- Displacement data is not available for Paratia until total displacement is viewed in a window
- Displacement data is not available for Piano lavoro until total displacement is viewed in a window
- Displacement data is not available for Jet until total displacement is viewed in a window
- Displacement data is not available for I ribasso until total displacement is viewed in a window
- Displacement data is not available for I puntone until total displacement is viewed in a window
- Displacement data is not available for II ribasso until total displacement is viewed in a window
- Displacement data is not available for II puntone until total displacement is viewed in a window
- Displacement data is not available for III ribasso until total displacement is viewed in a window
- Displacement data is not available for III puntone until total displacement is viewed in a window
- Displacement data is not available for Fondo scavo until total displacement is viewed in a window
- Displacement data is not available for Solettone until total displacement is viewed in a window
- Displacement data is not available for Rimozione puntone until total displacement is viewed in a window
- Displacement data is not available for Getto calotta until total displacement is viewed in a window
- Displacement data is not available for Rimozione puntone until total displacement is viewed in a window
- Displacement data is not available for Ritombamento until total displacement is viewed in a window

Yielded Elements

Yielded Mesh Elements

- Number of yielded mesh elements on Geostatico: 287
- Number of yielded mesh elements is not available for Paratia until the stage is viewed in a window
- Number of yielded mesh elements is not available for Piano lavoro until the stage is viewed in a window
- Number of yielded mesh elements is not available for Jet until the stage is viewed in a window
- Number of yielded mesh elements is not available for I ribasso until the stage is viewed in a window
- Number of yielded mesh elements is not available for I puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for II ribasso until the stage is viewed in a window
- Number of yielded mesh elements is not available for II puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for III ribasso until the stage is viewed in a window
- Number of yielded mesh elements is not available for III puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for Fondo scavo until the stage is viewed in a window
- Number of yielded mesh elements is not available for Solettone until the stage is viewed in a window
- Number of yielded mesh elements is not available for Rimozione puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for Getto calotta until the stage is viewed in a window
- Number of yielded mesh elements is not available for Rimozione puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for Ritombamento until the stage is viewed in a window

Yielded Bolt Elements

- Number of yielded bolt elements on Geostatico: 0
- Number of yielded bolt elements on Paratia: 0
- Number of yielded bolt elements on Piano lavoro: 0
- Number of yielded bolt elements on Jet: 0
- Number of yielded bolt elements on I ribasso: 0
- Number of yielded bolt elements on I puntone: 0
- Number of yielded bolt elements on II ribasso: 0
- Number of yielded bolt elements on II puntone: 0
- Number of yielded bolt elements on III ribasso: 0
- Number of yielded bolt elements on III puntone: 0
- Number of yielded bolt elements on Fondo scavo: 0
- Number of yielded bolt elements on Solettone: 0
- Number of yielded bolt elements on Rimozione puntone: 0
- Number of yielded bolt elements on Getto calotta: 0
- Number of yielded bolt elements on Rimozione puntone: 0
- Number of yielded bolt elements on Ritombamento: 0

Yielded Liner Elements

- Number of yielded liner elements on Geostatico: 0
- Number of yielded liner elements on Paratia: 0
- Number of yielded liner elements on Piano lavoro: 0
- Number of yielded liner elements on Jet: 0
- Number of yielded liner elements on I ribasso: 0
- Number of yielded liner elements on I puntone: 0
- Number of yielded liner elements on II ribasso: 0
- Number of yielded liner elements on II puntone: 0
- Number of yielded liner elements on III ribasso: 0
- Number of yielded liner elements on III puntone: 0
- Number of yielded liner elements on Fondo scavo: 0
- Number of yielded liner elements on Solettone: 0
- Number of yielded liner elements on Rimozione puntone: 0
- Number of yielded liner elements on Getto calotta: 0
- Number of yielded liner elements on Rimozione puntone: 0
- Number of yielded liner elements on Ritombamento: 0

List of All Coordinates

External boundary

X	Y
-90	3.6e-015
90	-3.6e-015
90	67.7518
24.547	67.7518
8.92667	67.7518
-3.77498	67.7518
-7.33906	70.022
-7.71053	70.2586
-8.83906	70.9774
-14.0003	70.9774
-15.505	70.9774
-17.0036	70.9774
-18.502	70.9774
-21.1763	70.9774
-25.7295	67.7112
-90	67.7518

Material boundary

X	Y
-25.7295	67.7112
-8.81939	67.7397
-7.71053	67.7418
-7.33906	67.7425
-3.77498	67.7518

Material boundary

X	Y
-8.81939	67.7397
-8.69935	47.9777
-8.69935	46.8498
9.59935	46.8498
9.59935	66.5208
7.23537	66.5206
6.59895	66.5206
6.59895	64.9996
6.59895	63.9996
5.29951	63.9996
5.09895	63.9996
4.90178	63.9996
4.90178	63.5898
4.90178	61.64
4.90178	60.2549
4.90178	58.1865
4.90178	57.7603
4.90178	56.0393
4.90178	53.6996
-4.54061	53.6999
-4.54061	56.0393
-4.54061	57.7603
-4.54061	58.1865
-4.54061	60.2549
-4.54061	61.64
-4.54061	63.5898
-4.54061	64
-4.74104	64
-4.94112	64
-6.24104	64
-6.24104	65
-6.24104	66.52
-7.33906	66.5197
-7.33906	47.9777
-8.69935	47.9777

Material boundary

X	Y
-6.24104	65
-4.74104	65
-4.74104	64.4961
-4.74104	64

Material boundary

X	Y
6.59895	64.9996
5.09895	64.9996
5.09895	64.4961
5.09895	63.9996

Material boundary

X	Y
-7.71053	67.7418
-7.71053	48.9774

Material boundary

X	Y
-4.54061	61.64
-0.821045	63.5898
1.17895	63.5898
4.90178	61.64

Material boundary

X	Y
-4.74104	64.4961
5.09895	64.4961

Material boundary

X	Y
-4.54061	58.1865
-3.66587	58.1865
4.02378	58.1865
4.90178	58.1865

Material boundary

X	Y
-1.97105	55.4998
2.32895	55.4998
3.43459	56.0393
3.80031	56.8754
4.02378	57.7603
4.02378	58.1865

4.02378	59.6128
3.70607	60.2549
3.3503	60.9739
2.61053	61.64
2.13895	62.0646
1.3903	62.3979
0.178955	62.5898
-1.03239	62.3979
-1.78105	62.0646
-2.25262	61.64
-2.99239	60.9739
-3.34816	60.2549
-3.66587	59.6128
-3.66587	58.1865
-3.66587	57.7603
-3.4424	56.8754
-3.07669	56.0393
-1.97105	55.4998

Material boundary

X	Y
7.23537	66.5206
8.92667	67.7518

Material boundary

X	Y
-3.66587	57.7603
-4.54061	57.7603

Material boundary

X	Y
-3.66587	57.7603
4.02378	57.7603
4.90178	57.7603

Material boundary

X	Y
-14.0003	70.9774
-14.0003	70.702
-15.505	70.702
-15.505	70.9774

Material boundary

X	Y
-17.0036	70.9774
-17.0036	70.691
-18.502	70.691
-18.502	70.9774

Material boundary

X	Y
-4.54061	61.64
-2.25262	61.64
2.61053	61.64
4.90178	61.64

Material boundary

X	Y
-3.07669	56.0393
-4.54061	56.0393

Material boundary

X	Y
3.43459	56.0393
4.90178	56.0393

Material boundary

X	Y
-6.24104	66.52
6.59895	66.5206

Material boundary

X	Y
-0.821045	63.5898
-4.54061	63.5898

Material boundary

X	Y
---	---

1.17895	63.5898
4.90178	63.5898

Material boundary

X	Y
-4.94112	64
-4.94112	60.2549
-4.94112	57.7603
-4.94112	53.6999

Material boundary

X	Y
-4.54061	53.6999
-4.94112	53.6999

Material boundary

X	Y
5.29951	63.9996
5.29951	60.2549
5.29951	57.7603
5.29951	53.6996

Material boundary

X	Y
4.90178	53.6996
5.29951	53.6996

Material boundary

X	Y
-4.54061	60.2549
-3.34816	60.2549
3.70607	60.2549
4.90178	60.2549

Material boundary

X	Y
-4.54061	60.2549
-4.94112	60.2549

Material boundary

X	Y
4.90178	60.2549
5.29951	60.2549

Material boundary

X	Y
-4.54061	57.7603
-4.94112	57.7603

Material boundary

X	Y
4.90178	57.7603
5.29951	57.7603

Material boundary

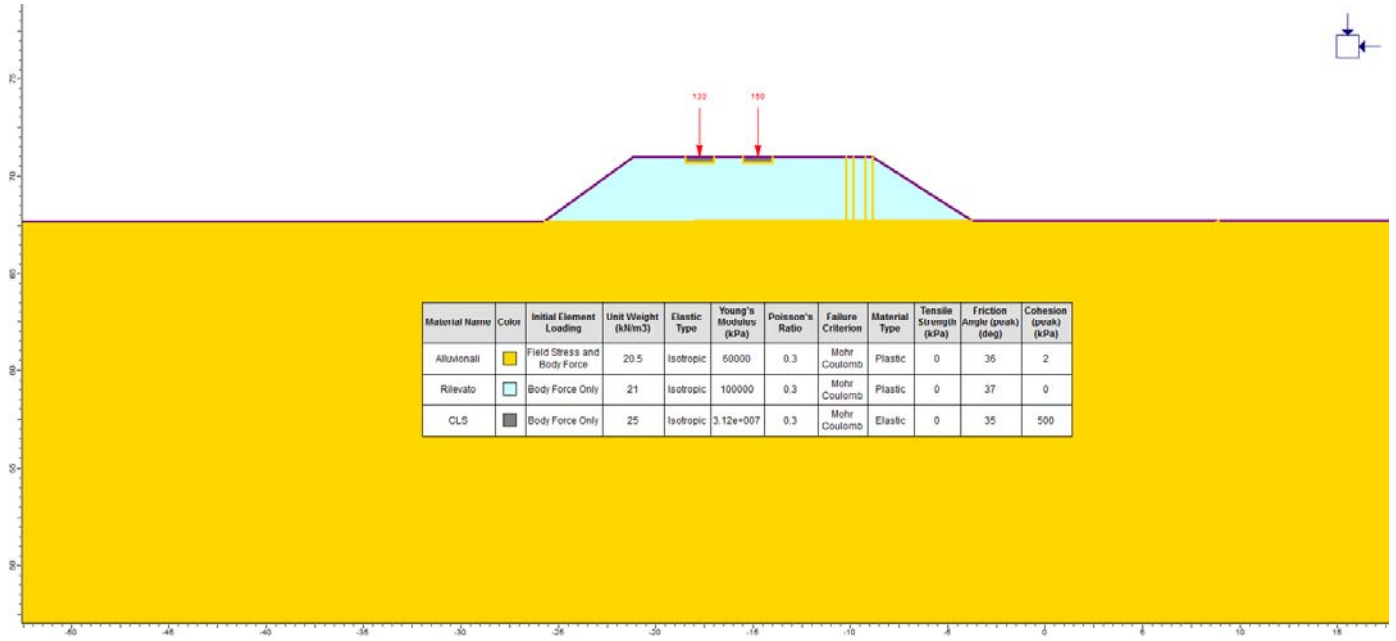
X	Y
-7.33906	66.5197
-7.33906	67.7425
-7.33906	70.022

Material boundary

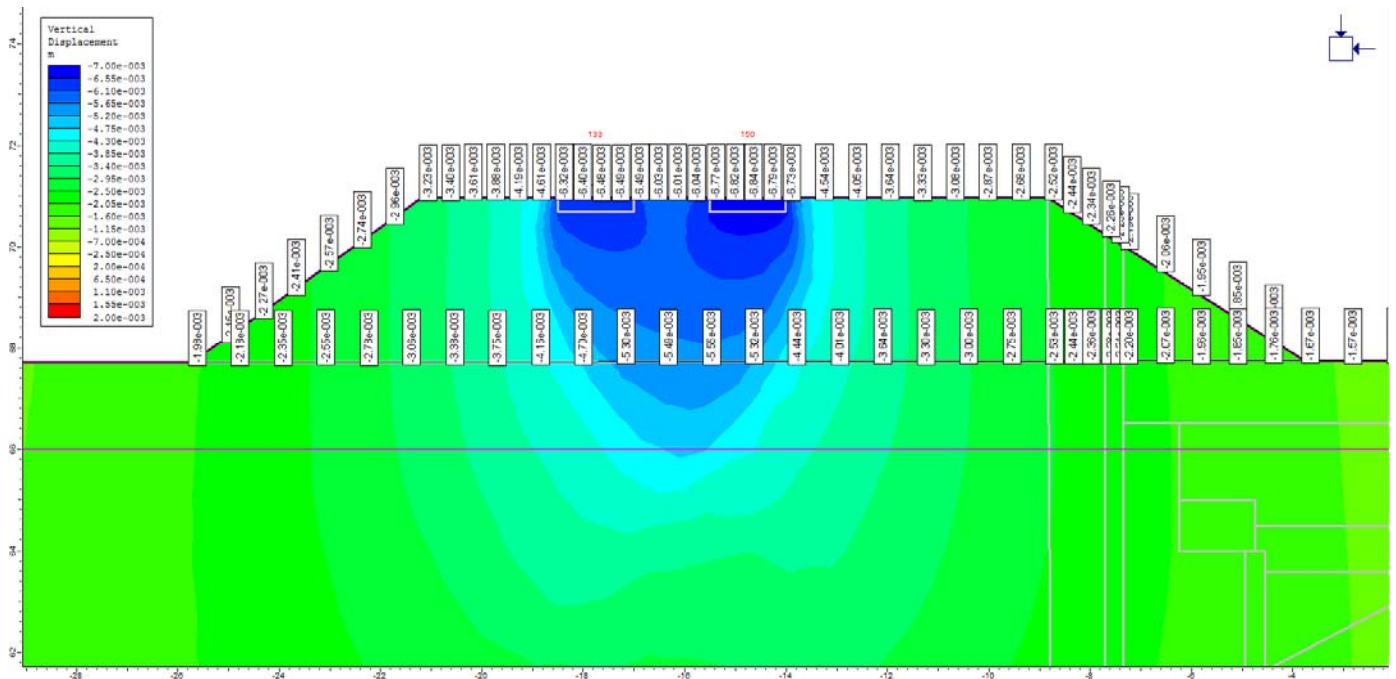
X	Y
-7.71053	67.7418
-7.71053	70.2586

Material boundary

X	Y
-8.81939	67.7397
-8.83906	70.9774

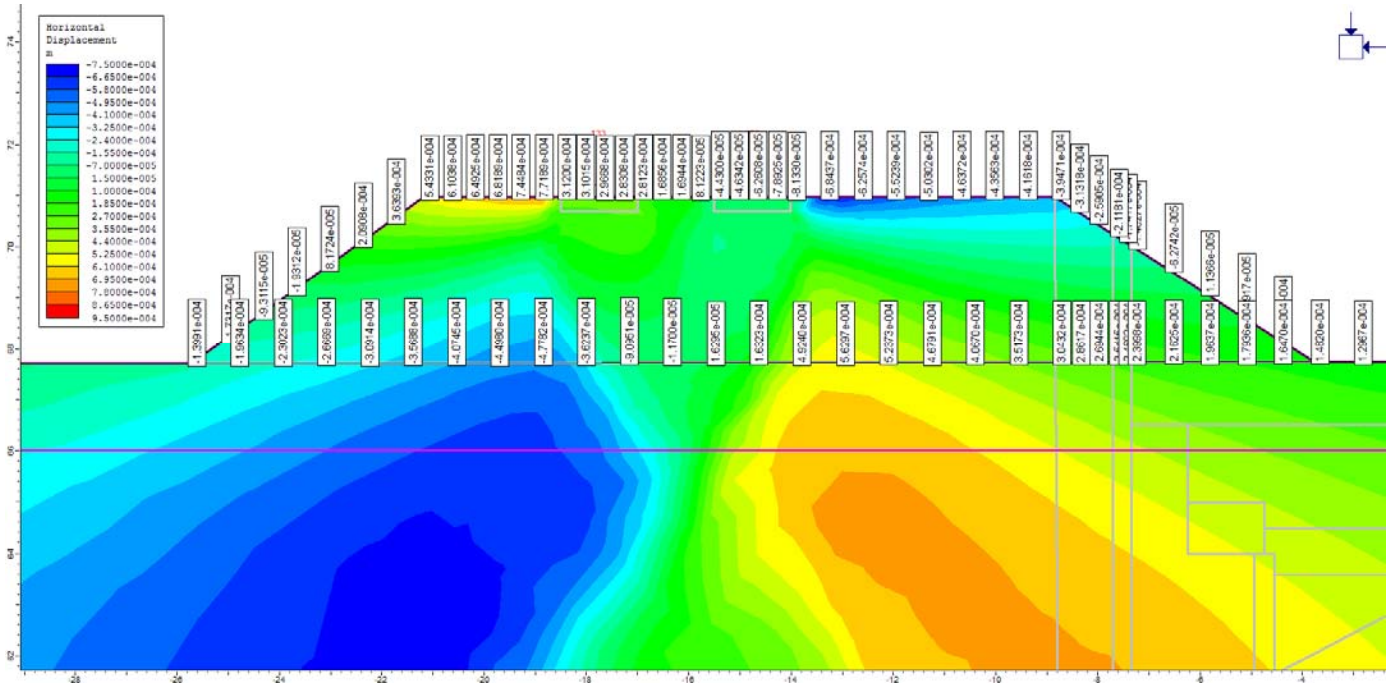


Geometria di calcolo per la Galleria di Base binario Dispari. Progressiva pk_54+980. Carico del treno applicato al rilevato ferroviario prima dello scavo.

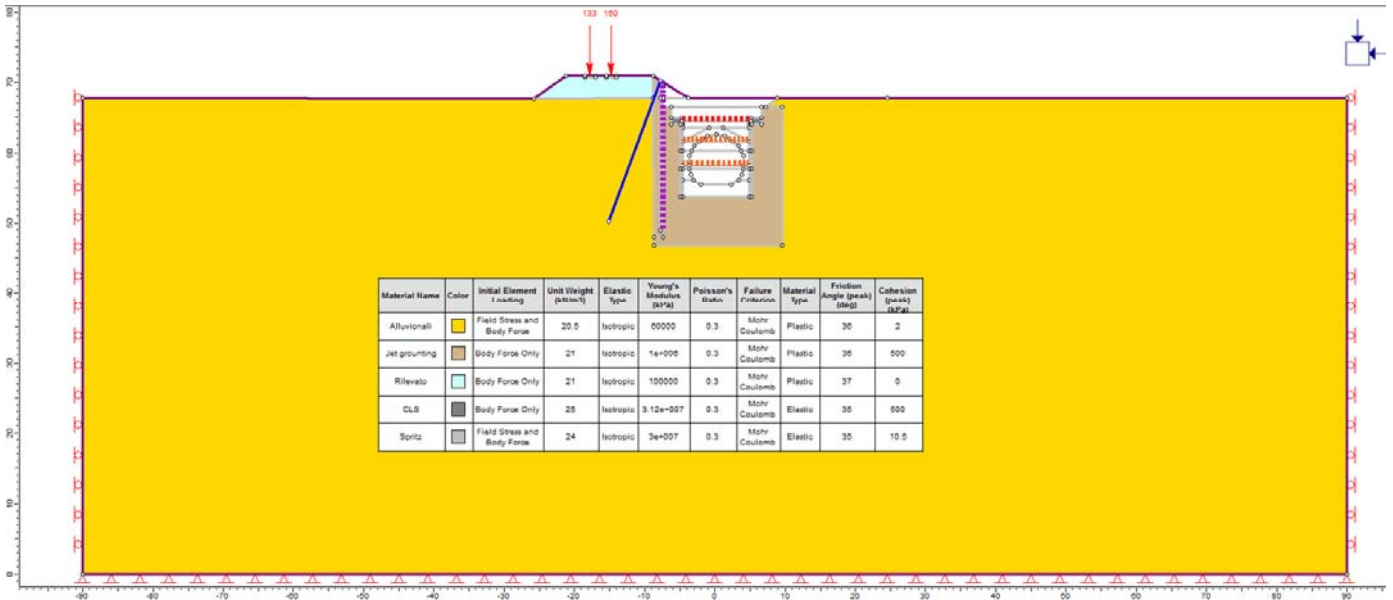


Galleria di Base binario Dispari. Progressiva pk_54+980. Spostamenti verticali dY. Carico del treno applicato al rilevato

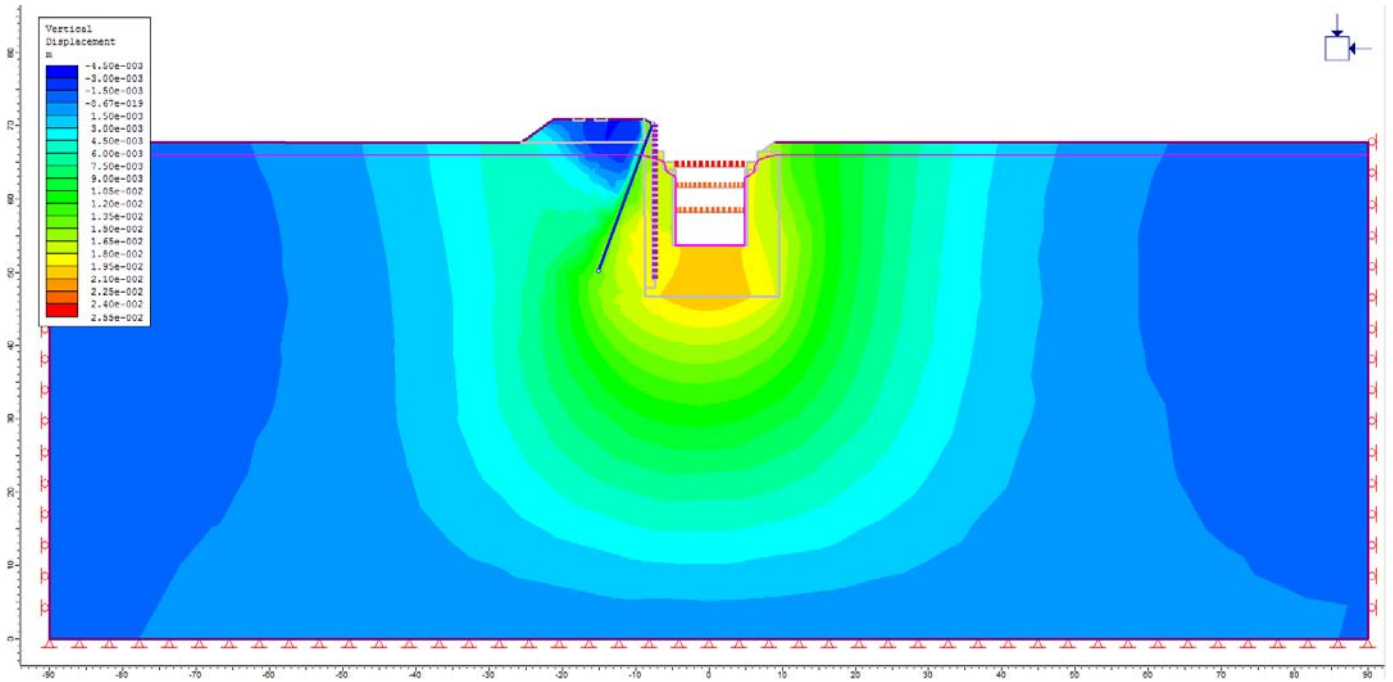
ferroviario prima dello scavo. Carico non fattorizzato (SLE)



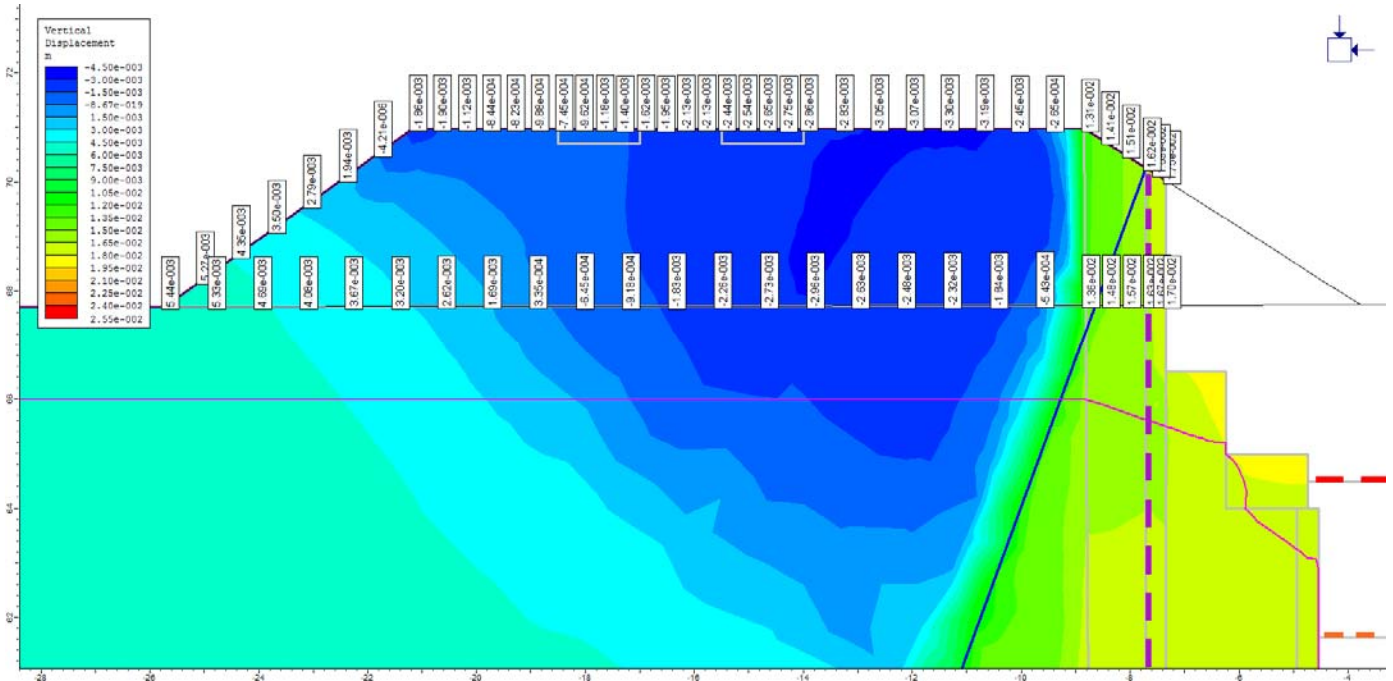
Galleria di Base binario Dispari. Progressiva pk_54+980. Spostamenti orizzontali dX. Carico del treno applicato al rilevato ferroviario prima dello scavo. Carico non fattorizzato (SLE)



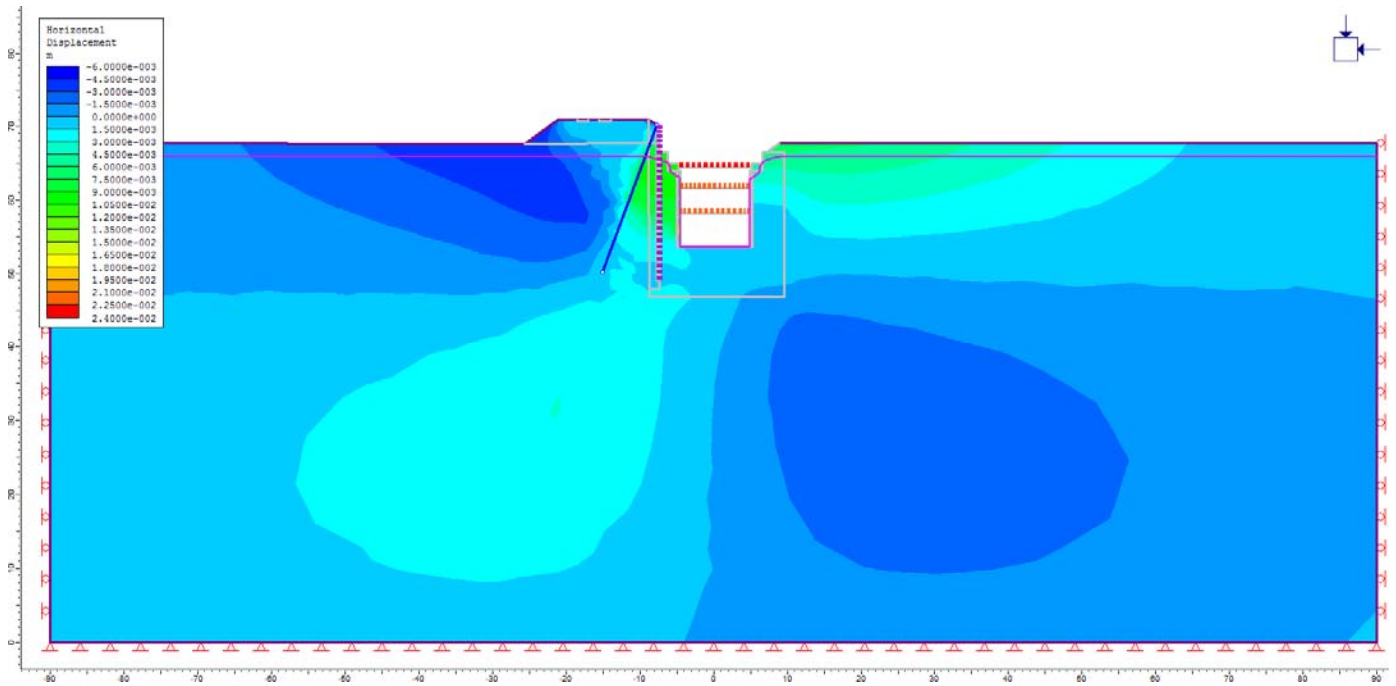
Geometria di calcolo per la Galleria di Base binario Dispari. Progressiva pk_54+980. Fase finale di scavo più carico del treno.



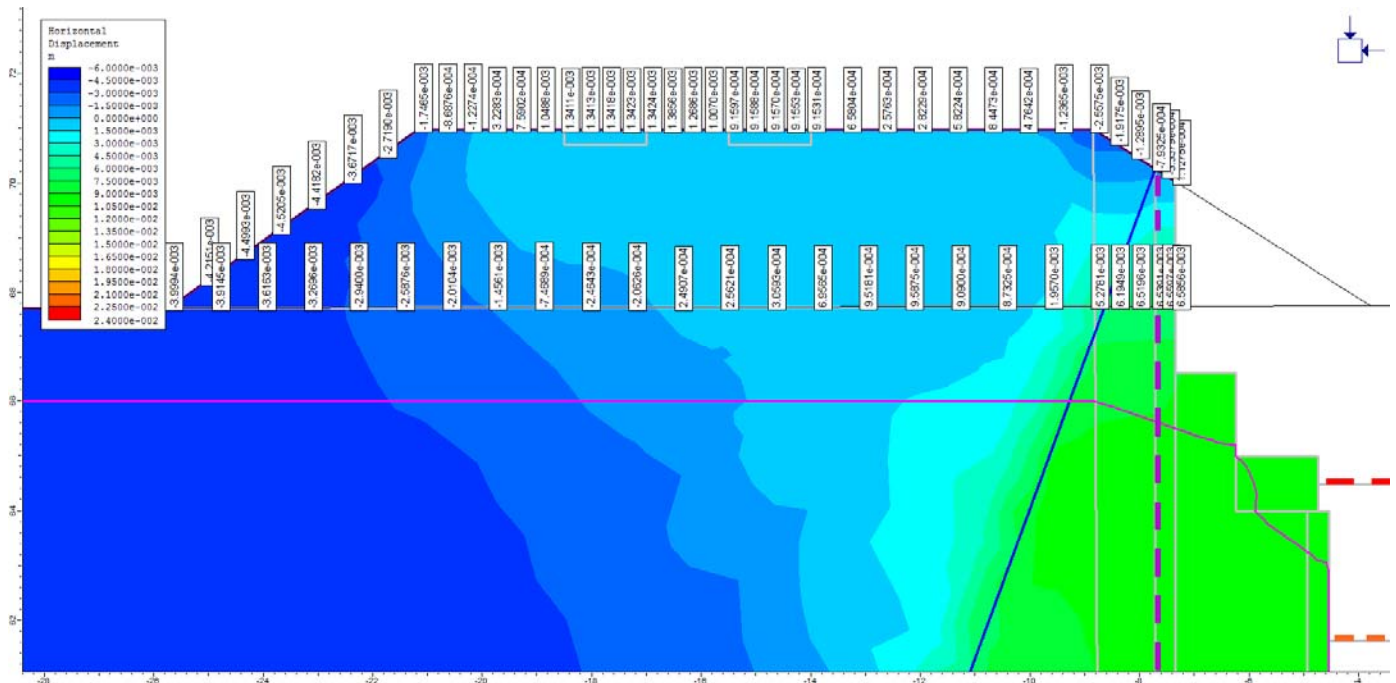
Galleria di Base binario Dispari. Progressiva pk₅₄₊₉₈₀. Spostamenti verticali dY. Fase finale di scavo. Carico non fattorizzato (SLE)



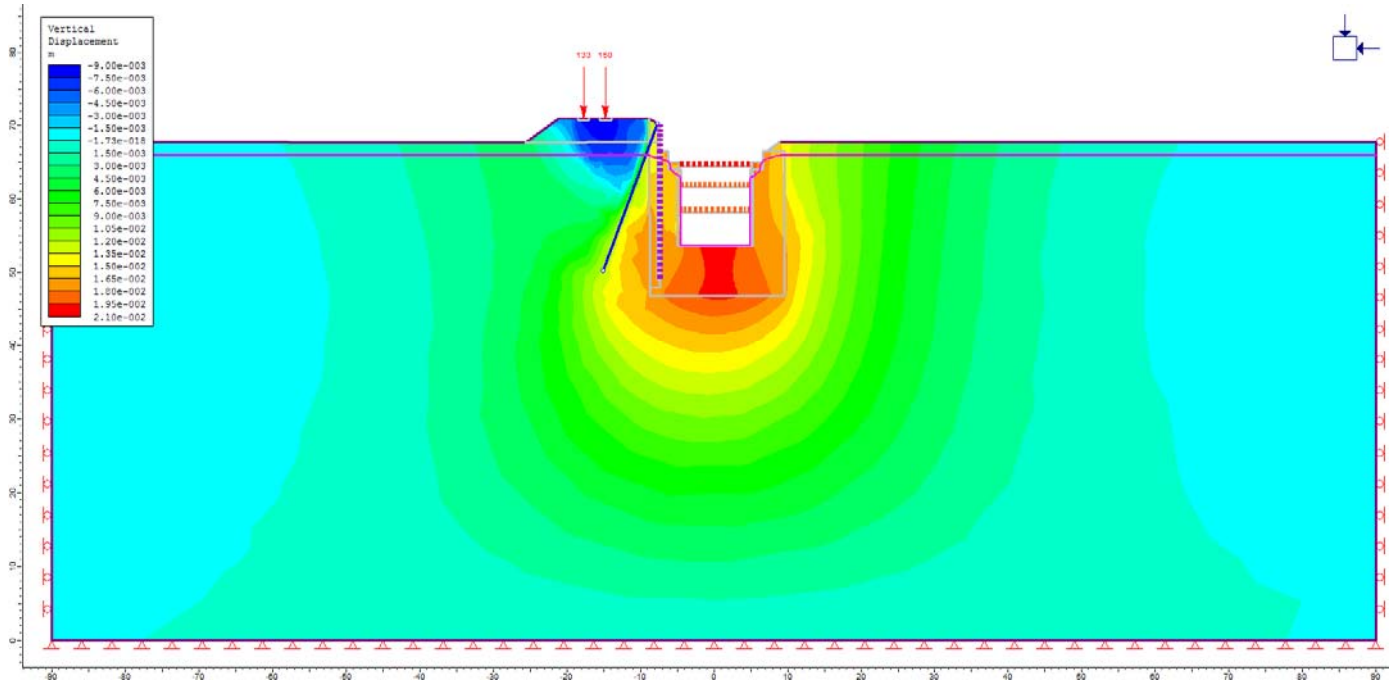
Galleria di Base binario Dispari. Progressiva pk₅₄₊₉₈₀. Spostamenti verticali dY. Fase finale di scavo. Particolare del rilevato ferroviario. Carico non fattorizzato (SLE)



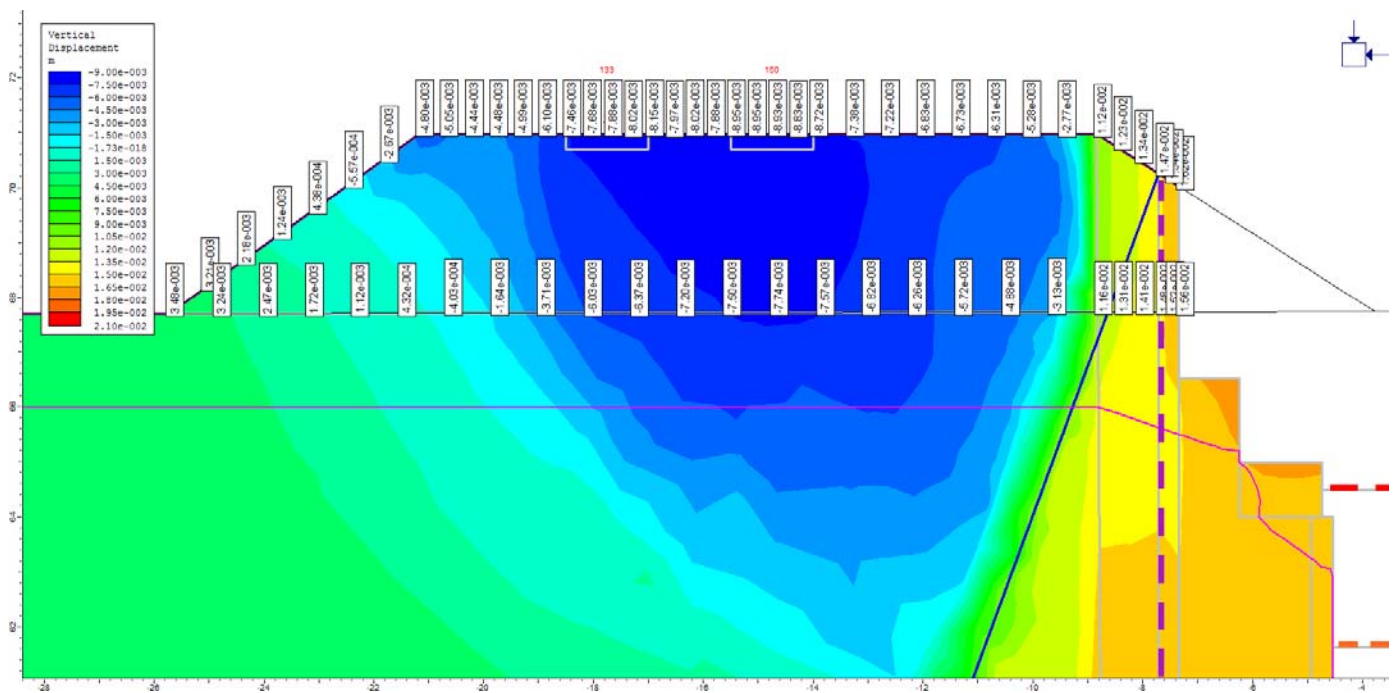
Galleria di Base binario Dispari. Progressiva pk₅₄₊₉₈₀. Spostamenti orizzontali dX. Fase finale di scavo. Carico non fattorizzato (SLE)



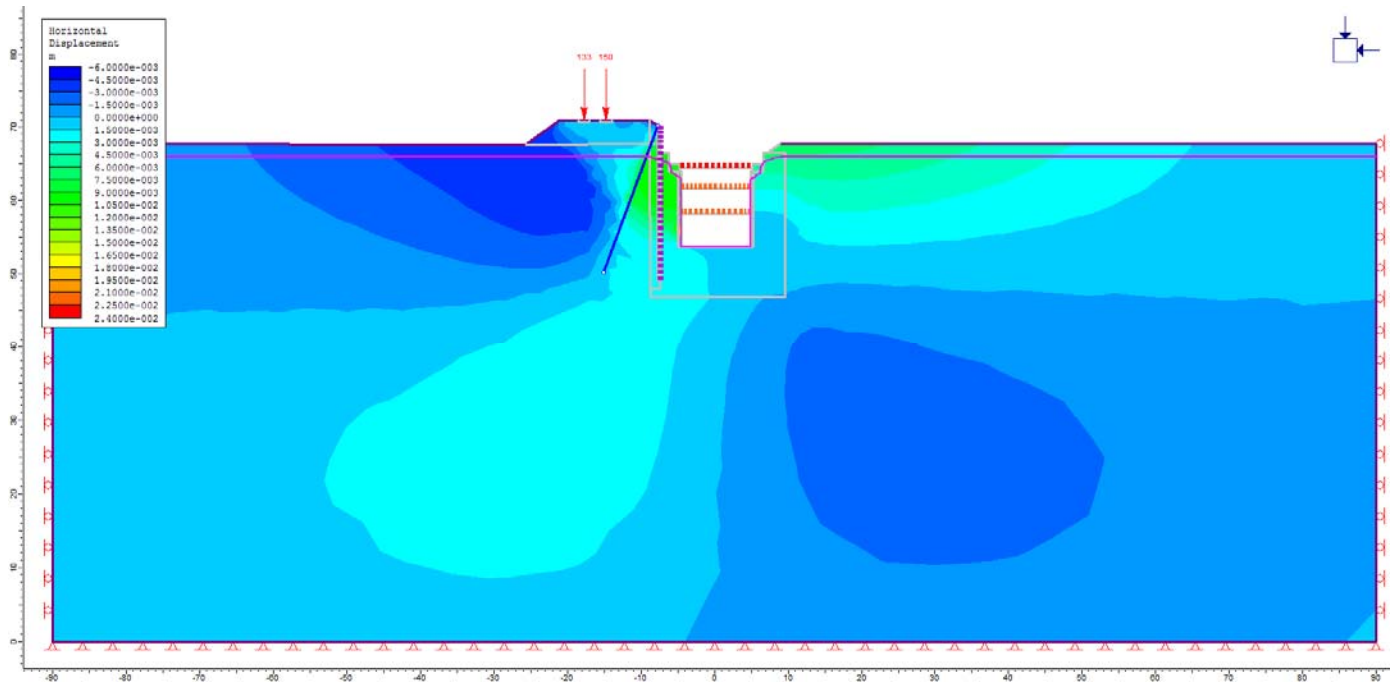
Galleria di Base binario Dispari. Progressiva pk₅₄₊₉₈₀. Spostamenti orizzontali dX. Fase finale di scavo. Particolare del rilevato ferroviario. Carico non fattorizzato (SLE)



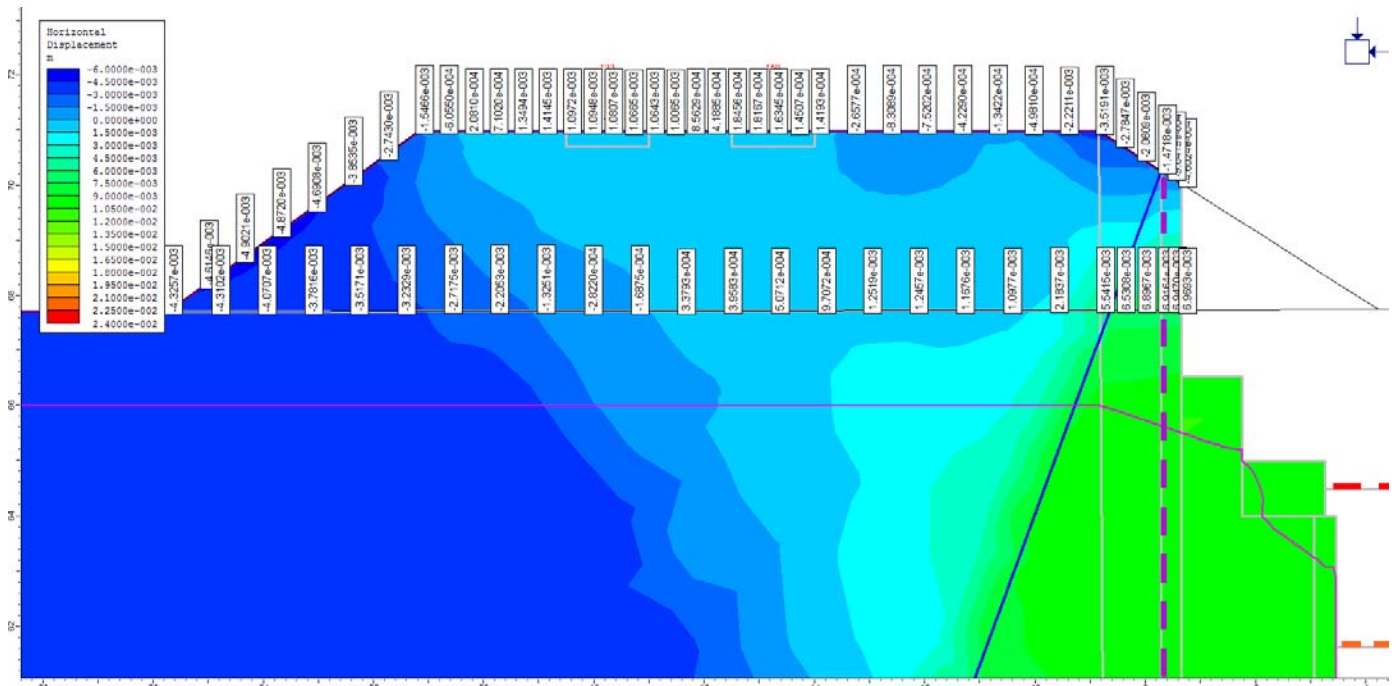
Galleria di Base binario Dispari. Progressiva pk₅₄₊₉₈₀. Spostamenti verticali dY. Fase finale di scavo più carico del treno. Carico non fattorizzato (SLE)



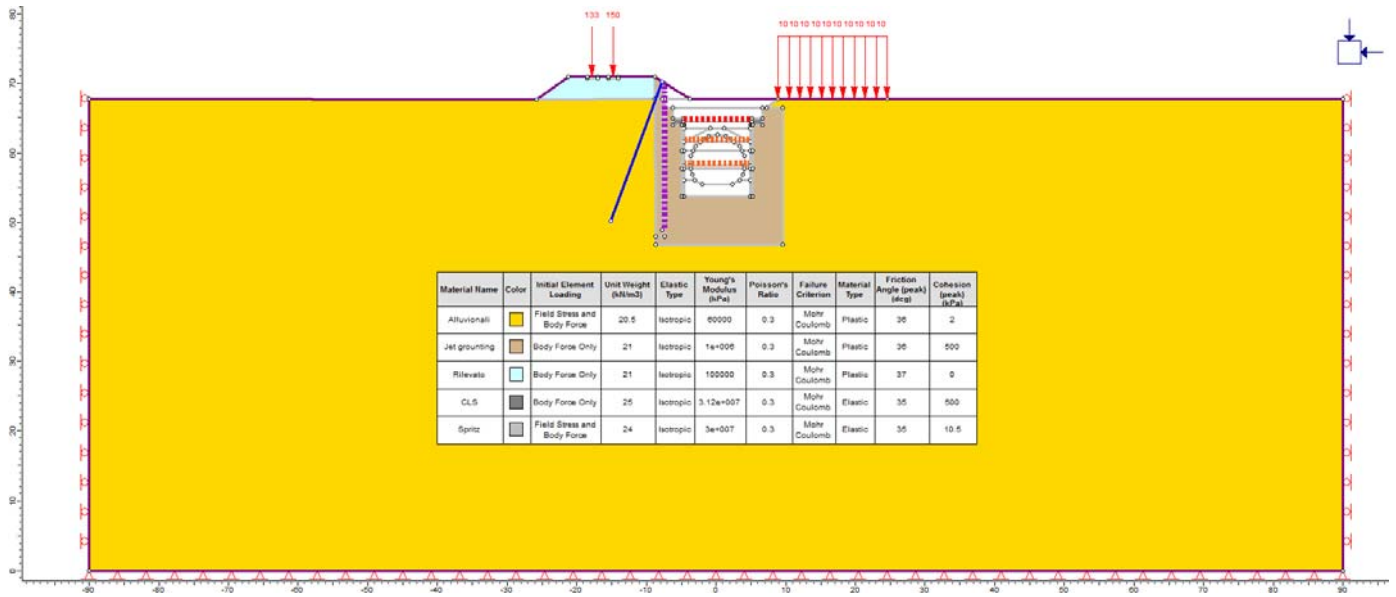
Galleria di Base binario Dispari. Progressiva pk₅₄₊₉₈₀. Spostamenti verticali dY. Fase finale di scavo più carico del treno. Particolare del rilevato ferroviario. Carico non fattorizzato (SLE)



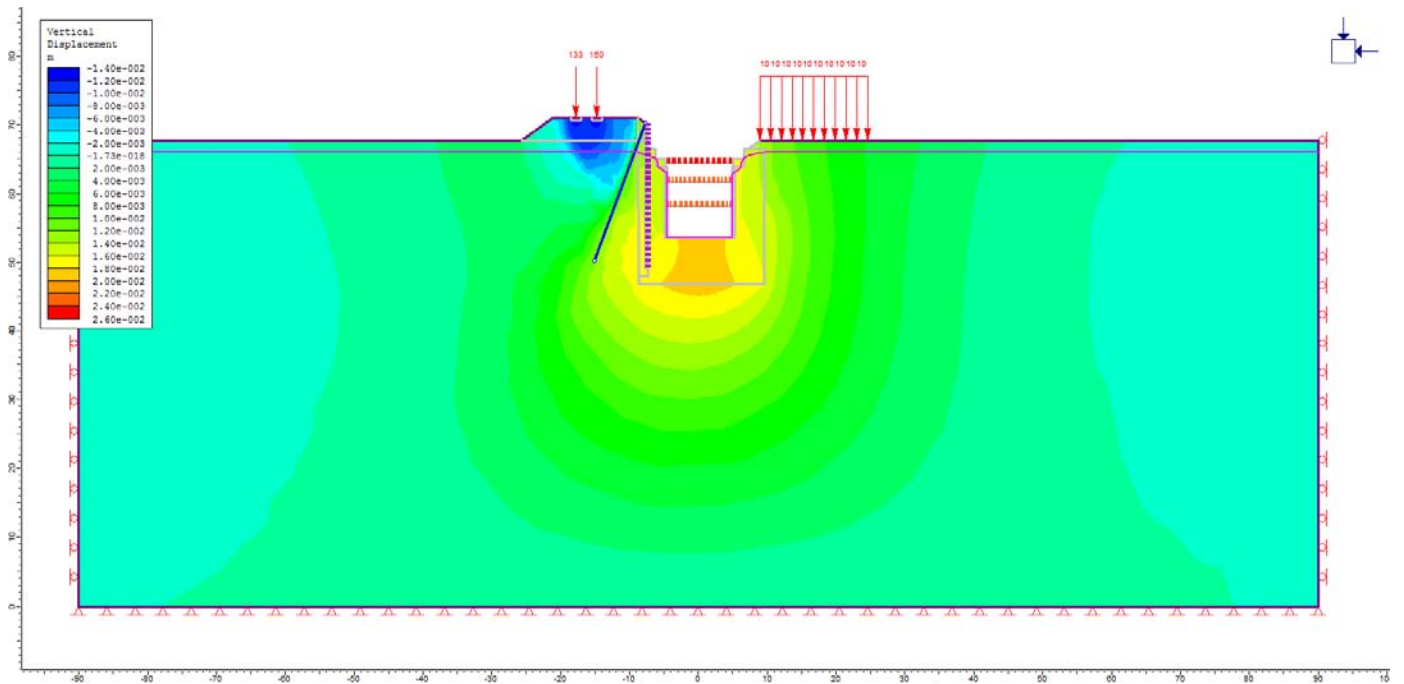
Galleria di Base binario Dispari. Progressiva pk₅₄₊₉₈₀. Spostamenti orizzontali dX. Fase finale di scavo più carico del treno. Carico non fattorizzato (SLE)



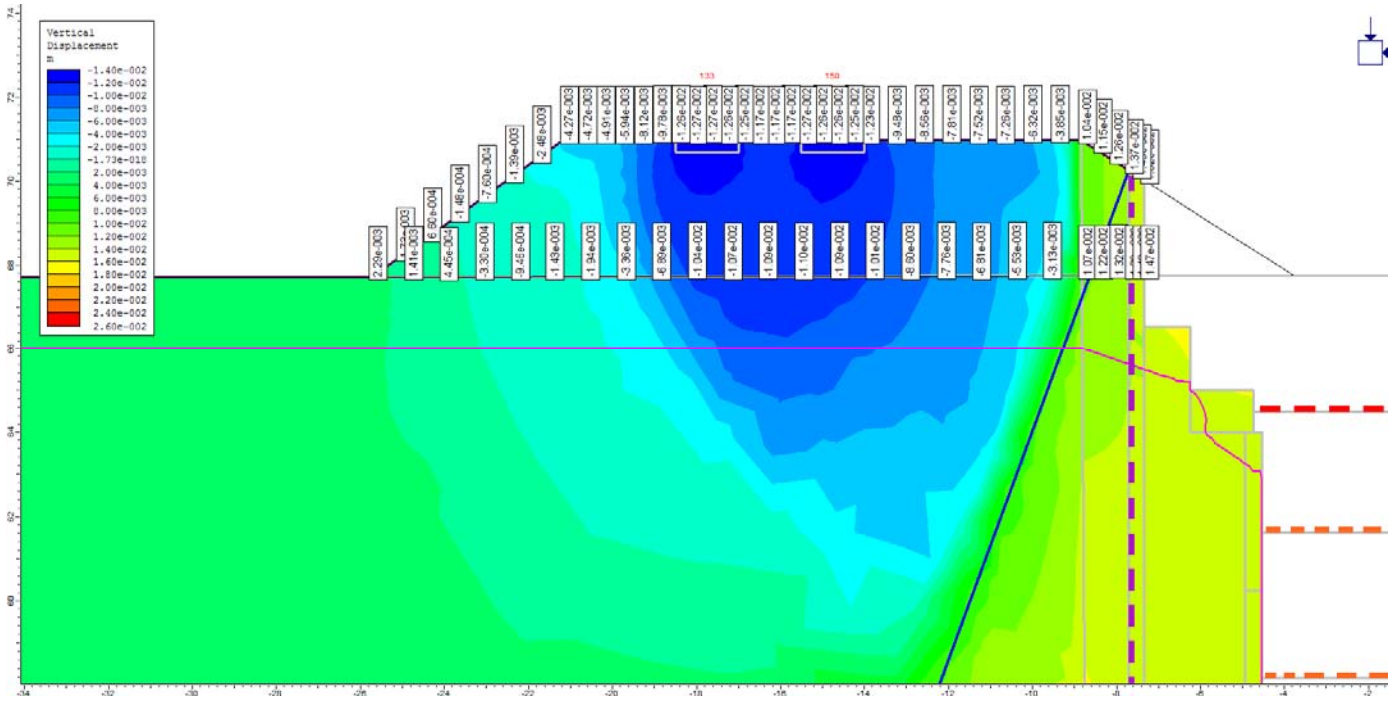
Galleria di Base binario Dispari. Progressiva pk₅₄₊₉₈₀. Spostamenti orizzontali dX. Fase finale di scavo più carico del treno. Particolare del rilevato ferroviario. Carico non fattorizzato (SLE)



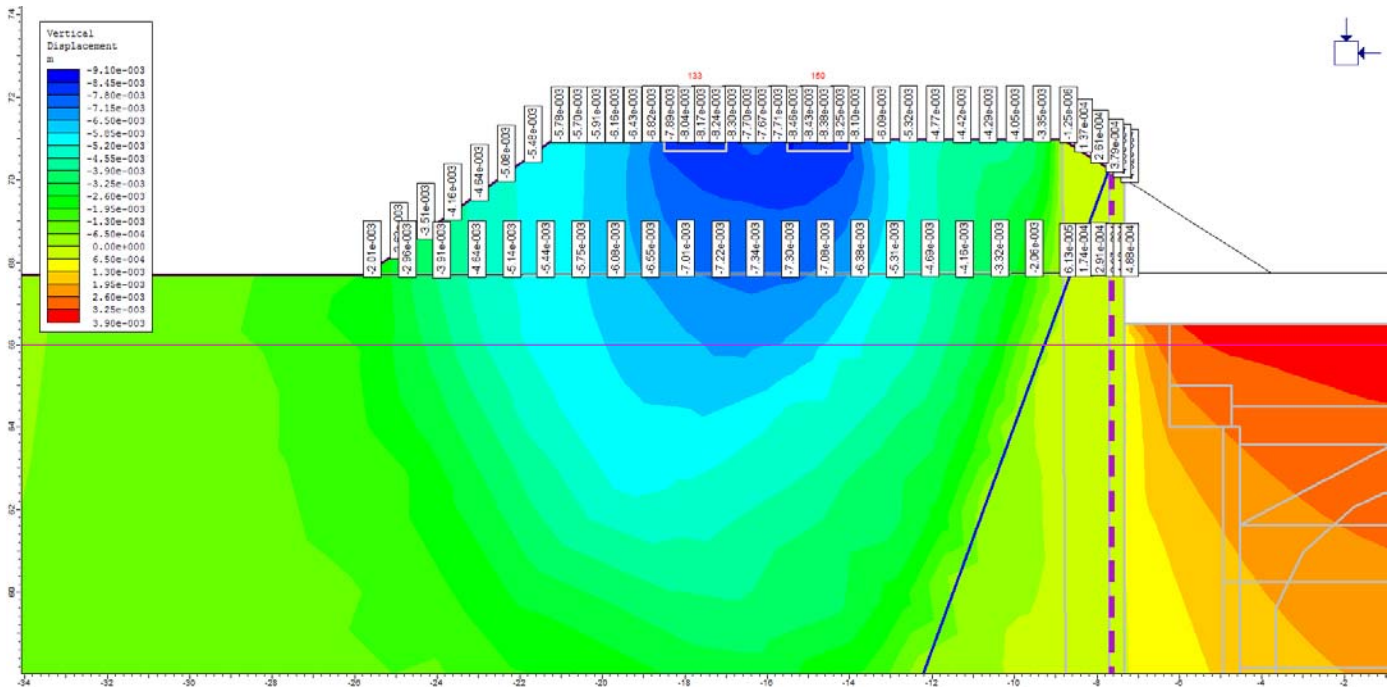
Geometria di calcolo per la Galleria di Base binario Dispari. Progressiva pk_54+980. Fase finale di scavo con carico del treno e carico distribuito durante costruzione.



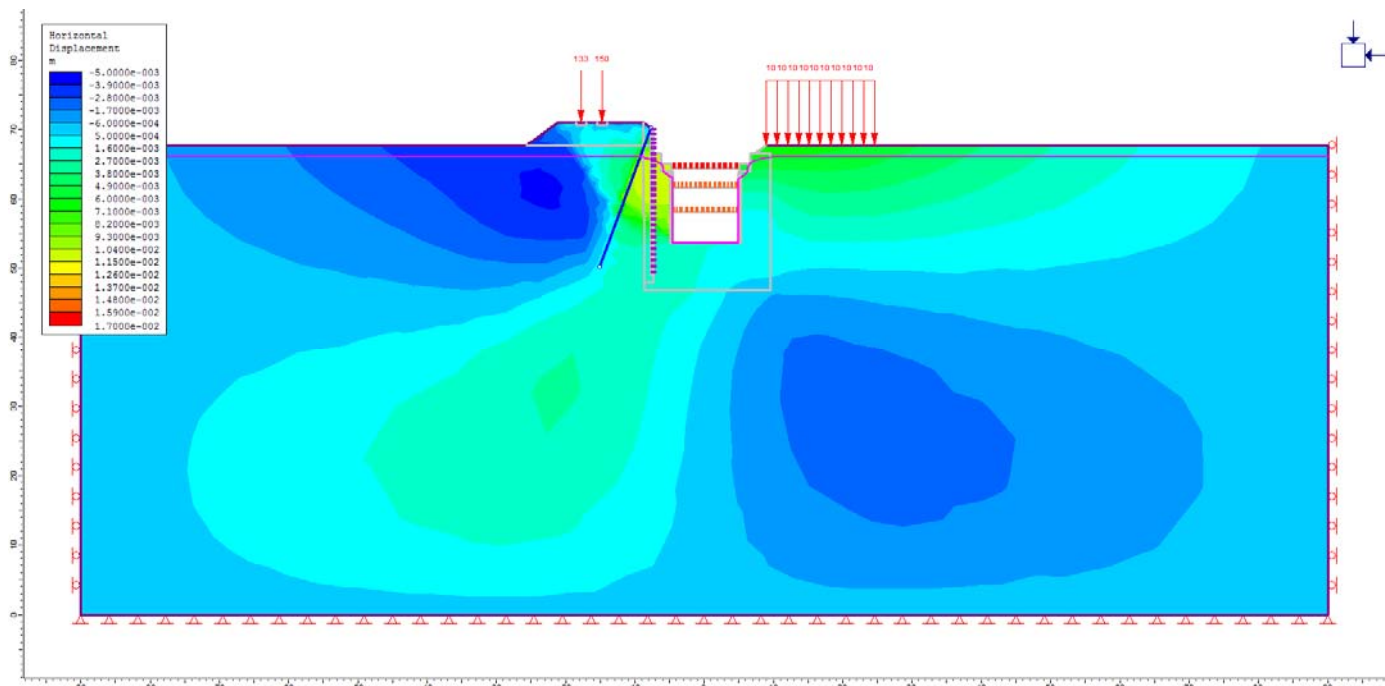
Galleria di Base binario Dispari. Progressiva pk_54+980. Spostamenti verticali dY. Fase finale di scavo, eseguito con carico del treno e carico distribuito durante costruzione. Carico non fattorizzato (SLE)



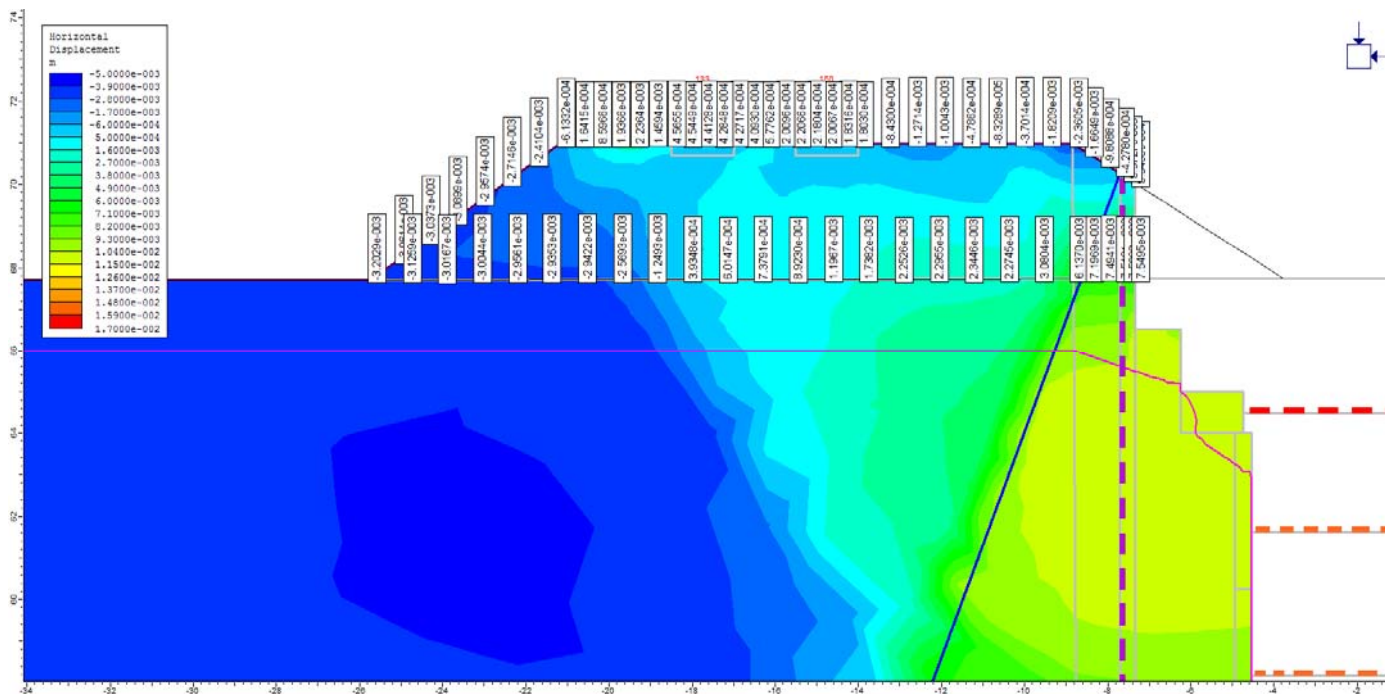
Galleria di Base binario Dispari. Progressiva pk₅₄₊₉₈₀. Spostamenti verticali dY. Fase finale di scavo, eseguito con carico del treno e carico distribuito durante costruzione. Particolare del rilevato ferroviario. Carico non fattorizzato (SLE)



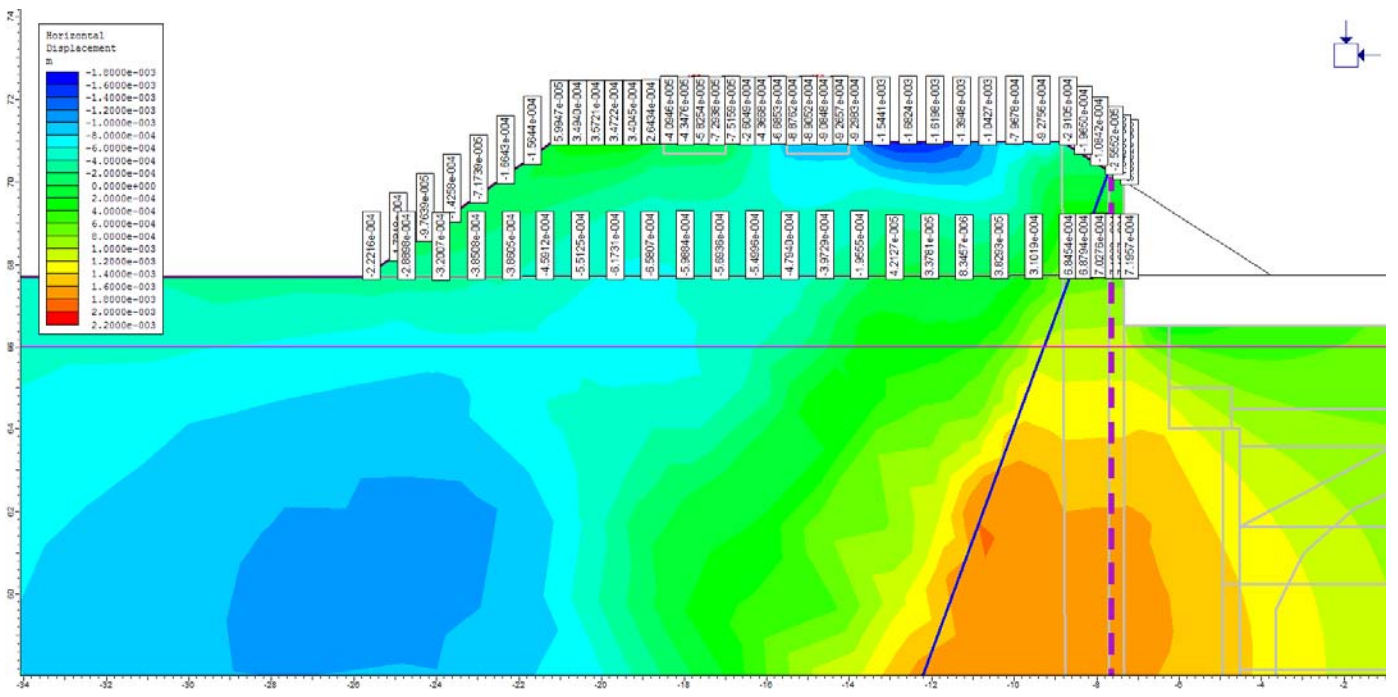
Galleria di Base binario Dispari. Progressiva pk₅₄₊₉₈₀. Spostamenti verticali dY. Fase di scavo fino a raggiungere quota del piano di lavoro del Jet grouting. Particolare del rilevato ferroviario. Carico non fattorizzato (SLE)



Galleria di Base binario Dispari. Progressiva pk₅₄+980. Spostamenti orizzontali dX. Fase finale di scavo, eseguito con carico del treno e carico distribuito durante costruzione. Carico non fattorizzato (SLE)



Galleria di Base binario Dispari. Progressiva pk₅₄+980. Spostamenti orizzontali dX. Fase finale di scavo, eseguito con carico del treno e carico distribuito durante costruzione. Particolare del rilevato ferroviario. Carico non fattorizzato (SLE)



Galleria di Base binario Dispari. Progressiva pk₅₄₊₉₈₀. Spostamenti orizzontali dX. Fase di scavo fino a raggiungere quota del piano di lavoro del Jet grouting. Particolare del rilevato ferroviario. Carico non fattorizzato (SLE)

Phase2 Analysis Information

Project Settings

- Document Name: Sez 54+997_M-C solo linea.fez
- Project Title: Phase2 - Finite Element Analysis of Excavations in Rock
- Number of Stages: 3
- Analysis Type: Plane Strain
- Solver Type: Gaussian Elimination
- Units: Metric, stress as kPa

Stress Analysis

- Maximum Number of Iterations: 9000
- Tolerance: 0.001
- Number of Load Steps: Automatic
- Convergence Type: Absolute Energy
- Tensile Failure: Reduces Shear Strength
- Joint tension reduces joint stiffness by a factor of 0.01

Groundwater

- Method: Finite Element Analysis
- Pore Fluid Unit Weight: 9.81 kN/m³
- Maximum Number of Iterations: 500
- Tolerance: 1e-006

Field Stress

- Field stress: gravity
- Using actual ground surface
- Effective stress ratio (horizontal/vertical in-plane): 1
- Effective stress ratio (horizontal/vertical out-of-plane): 1
- Locked-in horizontal stress (in-plane): 0
- Locked-in horizontal stress (out-of-plane): 0

Mesh

- Mesh type: graded
- Element type: 8 noded quadrilaterals
- Number of elements on Geostatico: 1908
- Number of nodes on Geostatico: 5725
- Number of elements on Paratia: 1908
- Number of nodes on Paratia: 5725
- Number of elements on Carico Treno: 1908
- Number of nodes on Carico Treno: 5725

Mesh Quality

- All elements are of good quality

Poor quality elements defined as:

- Side length ratio (maximum / minimum) > 30.00
- Minimum interior angle < 2.0 degrees
- Maximum interior angle > 175.0 degrees

Reset Displacements

- Displacements reset after: Geostatico
- Displacements reset after: Paratia

Material Properties

Material: Alluvionali

Initial element loading	field stress & body force
Unit weight	20.5 kN/m ³
Elastic type	isotropic
Young's modulus	60000 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	36 degrees
Peak cohesion	2 kPa
Material type	Plastic
Dilation Angle	1 degrees
Residual Friction Angle	35 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Properties changed in Paratia

- Unit weight: Young's modulus: 120000 kPa (factor = 2) Field Stress Gravity Ground surface elevation 0 m Unit weight of overburden 0.027 kN/m³ Effective stress ratio (horizontal/vertical in-plane) 0.413 Effective stress ratio (horizontal/vertical out-of-plane) 0.413 Locked-in horizontal stress (in-plane) 0 Locked-in horizontal stress (out-of-plane) 0

Material: Rilvato

Initial element loading	body force only
Unit weight	21 kN/m ³
Elastic type	isotropic
Young's modulus	100000 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	37 degrees
Peak cohesion	0 kPa
Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	37 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Material: CLS

Initial element loading	body force only
Unit weight	25 kN/m ³
Elastic type	isotropic
Young's modulus	3.12e+007 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	35 degrees
Peak cohesion	500 kPa
Material type	Elastic
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	1e-012 m/s
K2/K1	1
K Angle	0 degrees

Excavation Areas

Original Un-deformed Areas

- External Boundary Area: 12350.370 m²
- External Boundary Perimeter: 498.284 m

Geostatico

- External Boundary Area: 12350.370 m² (0 m² change from original area)
- External Boundary Perimeter: 498.284 m (0 m change from original perimeter)

Paratia

- Values not available until this stage is viewed in a window

Carico Treno

- External Boundary Area: 12350.214 m² (-0.156194 m² change from original area)
- External Boundary Perimeter: 498.282 m (-0.00203309 m change from original perimeter)

Displacements

- Displacement data is not available for Geostatico until total displacement is viewed in a window
- Displacement data is not available for Paratia until total displacement is viewed in a window
- Displacement data is not available for Carico Treno until total displacement is viewed in a window

Yielded Elements

Yielded Mesh Elements

- Number of yielded mesh elements on Geostatico: 225
- Number of yielded mesh elements is not available for Paratia until the stage is viewed in a window
- Number of yielded mesh elements on Carico Treno: 247

Yielded Bolt Elements

- Number of yielded bolt elements on Geostatico: 0
- Number of yielded bolt elements on Paratia: 0
- Number of yielded bolt elements on Carico Treno: 0

List of All Coordinates

External boundary

X	Y
-90	0
90	0
90	68.4018
10.2799	68.4018
-7.58693	68.4018
-10.4458	70.2228
-11.395	70.8274
-15.8378	70.8274
-17.603	70.8274
-19.6031	70.8274

-21.416	70.8274
-23.7323	70.8274
-27.127	68.3922
-90	68.3922

Material boundary

X	Y
-7.58693	68.4018
-10.4458	68.4004
-27.127	68.3922

Material boundary

X	Y
-9.19101	66.3697
-9.19101	46.6998
9.24938	46.6998
9.24938	66.3708
7.33876	66.3707

Material boundary

X	Y
7.33876	66.3707
10.2799	68.4018

Material boundary

X	Y
6.44898	64.8496
6.44898	63.8496
5.14993	63.8496
4.94898	63.8496
4.94898	64.4023
4.94898	64.8496
6.44898	64.8496
6.44898	66.3706

Material boundary

X	Y
-6.39101	64.85
-4.89101	64.85
-4.89101	64.4023

-4.89101	63.85
-5.09501	63.85
-6.39101	63.85
-6.39101	64.85

Material boundary

X	Y
-6.39101	64.85
-6.39101	66.37

Material boundary

X	Y
-4.69294	61.49
-0.971016	63.4398
1.02898	63.4398
4.75091	61.49
4.75091	60.4206
4.75091	58.2092
4.75091	57.6103
4.75091	55.8893
4.75091	53.5496
-4.69294	53.5499
-4.69294	55.8893
-4.69294	57.6103
-4.69294	58.2092
-4.69294	60.4206
-4.69294	61.49

Material boundary

X	Y
-4.89101	64.4023
4.94898	64.4023

Material boundary

X	Y
-2.12102	55.3498
2.17898	55.3498
3.28462	55.8893
3.65034	56.7254
3.87381	57.6103
3.87381	58.2092

3.87381	59.4628
3.39991	60.4206
3.20033	60.8239
2.46056	61.49
1.98898	61.9146
1.24033	62.2479
0.0289837	62.4398
-1.18236	62.2479
-1.93102	61.9146
-2.40259	61.49
-3.14236	60.8239
-3.34194	60.4206
-3.81584	59.4628
-3.81584	58.2092
-3.81584	57.6103
-3.59237	56.7254
-3.22666	55.8893
-2.12102	55.3498

Material boundary

X	Y
-4.69294	61.49
-4.69294	63.4398
-4.69294	63.85
-4.89101	63.85

Material boundary

X	Y
4.75091	61.49
4.75091	63.4398
4.75091	63.8496
4.94898	63.8496

Material boundary

X	Y
-15.8378	70.8274
-15.8378	70.534
-17.603	70.534
-17.603	70.8274

Material boundary

X	Y
-19.6031	70.8274
-19.6031	70.524
-21.416	70.524
-21.416	70.8274

Material boundary

X	Y
6.44898	66.3706
-6.39101	66.37

Material boundary

X	Y
-6.39101	66.37
-9.19101	66.3697

Material boundary

X	Y
6.44898	66.3706
7.33876	66.3707

Material boundary

X	Y
-10.4458	68.4004
-10.4458	60.0062

Material boundary

X	Y
-10.4458	68.4004
-10.4458	70.2228

Material boundary

X	Y
-10.4458	68.4004
-6.39101	66.37

Material boundary

X	Y
-0.971016	63.4398
-4.69294	63.4398

Material boundary

X	Y
1.02898	63.4398
4.75091	63.4398

Material boundary

X	Y
-5.09501	63.85
-5.09501	60.4206
-5.09501	57.6103
-5.09501	53.55

Material boundary

X	Y
-4.69294	53.5499
-4.89101	53.5499
-5.09501	53.55

Material boundary

X	Y
5.14993	63.8496
5.14993	60.4206
5.14993	57.6103
5.14993	53.5496

Material boundary

X	Y
4.75091	53.5496
4.94898	53.5496
5.14993	53.5496

Material boundary

X	Y
-10.4458	60.0062

-10.4458	56.2046
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Material boundary

X	Y
-10.4458	56.2046
-10.4458	52.1785

Material boundary

X	Y
4.75091	60.4206
3.39991	60.4206
-3.34194	60.4206
-4.69294	60.4206

Material boundary

X	Y
3.28462	55.8893
4.75091	55.8893

Material boundary

X	Y
-3.22666	55.8893
-4.69294	55.8893

Material boundary

X	Y
-4.69294	61.49
-2.40259	61.49
2.46056	61.49
4.75091	61.49

Material boundary

X	Y
-4.69294	58.2092
-3.81584	58.2092
3.87381	58.2092
4.75091	58.2092

Material boundary

X	Y
-4.89101	57.6103
-4.69294	57.6103

Material boundary

X	Y
-4.89101	60.4206
-4.69294	60.4206

Material boundary

X	Y
4.94898	57.6103
4.75091	57.6103
3.87381	57.6103
-3.81584	57.6103
-4.69294	57.6103

Material boundary

X	Y
4.75091	60.4206
4.94898	60.4206

Material boundary

X	Y
-4.89101	60.4206
-5.09501	60.4206

Material boundary

X	Y
4.94898	60.4206
5.14993	60.4206

Material boundary

X	Y
-4.89101	57.6103
-5.09501	57.6103

Material boundary

X	Y
4.94898	57.6103
5.14993	57.6103

Phase2 Analysis Information

Project Settings

- Document Name: Sez 54+997_M-C fondo scavo + carico.fez
- Project Title: Phase2 - Finite Element Analysis of Excavations in Rock
- Number of Stages: 17
- Analysis Type: Plane Strain
- Solver Type: Gaussian Elimination
- Units: Metric, stress as kPa

Stress Analysis

- Maximum Number of Iterations: 9000
- Tolerance: 0.001
- Number of Load Steps: Automatic
- Convergence Type: Absolute Energy
- Tensile Failure: Reduces Shear Strength
- Joint tension reduces joint stiffness by a factor of 0.01

Groundwater

- Method: Finite Element Analysis
- Pore Fluid Unit Weight: 9.81 kN/m³
- Maximum Number of Iterations: 500
- Tolerance: 1e-006

Field Stress

- Field stress: gravity
- Using actual ground surface
- Effective stress ratio (horizontal/vertical in-plane): 1
- Effective stress ratio (horizontal/vertical out-of-plane): 1
- Locked-in horizontal stress (in-plane): 0
- Locked-in horizontal stress (out-of-plane): 0

Mesh

- Mesh type: graded
- Element type: 8 noded quadrilaterals
- Number of elements on Geostatico: 1328
- Number of nodes on Geostatico: 3911
- Number of elements on Paratia: 1328
- Number of nodes on Paratia: 3911
- Number of elements on Piano lavoro: 1256
- Number of nodes on Piano lavoro: 3719
- Number of elements on Jet: 1256
- Number of nodes on Jet: 3719
- Number of elements on I ribasso: 1185
- Number of nodes on I ribasso: 3546
- Number of elements on I puntone: 1185
- Number of nodes on I puntone: 3546
- Number of elements on II ribasso: 1108
- Number of nodes on II ribasso: 3351

- Number of elements on II puntone: 1108
- Number of nodes on II puntone: 3351
- Number of elements on III ribasso: 1028
- Number of nodes on III ribasso: 3129
- Number of elements on III puntone: 1028
- Number of nodes on III puntone: 3129
- Number of elements on Fondo scavo: 943
- Number of nodes on Fondo scavo: 2892
- Number of elements on CARICO TRENO: 943
- Number of nodes on CARICO TRENO: 2892
- Number of elements on Solettone: 977
- Number of nodes on Solettone: 2994
- Number of elements on Rimozione puntone: 977
- Number of nodes on Rimozione puntone: 2994
- Number of elements on Getto calotta: 1052
- Number of nodes on Getto calotta: 3220
- Number of elements on Rimozione puntone: 1052
- Number of nodes on Rimozione puntone: 3220
- Number of elements on Ritombamento: 1207
- Number of nodes on Ritombamento: 3613

Mesh Quality

- All elements are of good quality

Poor quality elements defined as:

- Side length ratio (maximum / minimum) > 30.00
- Minimum interior angle < 2.0 degrees
- Maximum interior angle > 175.0 degrees

Reset Displacements

- Displacements reset after: Geostatico
- Displacements reset after: Paratia

Material Properties

Material: Alluvionali

Initial element loading	field stress & body force
Unit weight	20.5 kN/m ³
Elastic type	isotropic
Young's modulus	60000 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	36 degrees
Peak cohesion	2 kPa
Material type	Plastic
Dilation Angle	1 degrees

Residual Friction Angle	35 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Properties changed in Paratia

- Unit weight:

Properties changed in Jet

- Unit weight: Young's modulus: 120000 kPa (factor = 2) Field Stress Gravity Ground surface elevation 0 m Unit weight of overburden 0.027 kN/m³ Effective stress ratio (horizontal/vertical in-plane) 0.413 Effective stress ratio (horizontal/vertical out-of-plane) 0.413 Locked-in horizontal stress (in-plane) 0 Locked-in horizontal stress (out-of-plane) 0

Material: Jet grouting

Initial element loading	body force only
Unit weight	21 kN/m ³
Elastic type	isotropic
Young's modulus	1e+006 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	75 kPa
Peak friction angle	36 degrees
Peak cohesion	500 kPa
Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	36 degrees
Residual Cohesion	500 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	1e-008 m/s
K2/K1	1
K Angle	0 degrees

Material: Rilvato

Initial element loading	body force only
Unit weight	21 kN/m ³
Elastic type	isotropic

Young's modulus	100000 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	37 degrees
Peak cohesion	0 kPa
Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	37 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Material: CLS

Initial element loading	body force only
Unit weight	25 kN/m ³
Elastic type	isotropic
Young's modulus	3.12e+007 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	35 degrees
Peak cohesion	500 kPa
Material type	Elastic
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	1e-012 m/s
K2/K1	1
K Angle	0 degrees

Material: Ritombamento

Initial element loading	body force only
Unit weight	20.5 kN/m ³
Elastic type	isotropic
Young's modulus	80000 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa

Peak friction angle	36 degrees
Peak cohesion	5 kPa
Material type	Elastic
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Material: Spritz

Initial element loading	body force only
Unit weight	24 kN/m ³
Elastic type	isotropic
Young's modulus	3e+007 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	1 kPa
Peak friction angle	35 degrees
Peak cohesion	500 kPa
Material type	Elastic
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	1e-008 m/s
K2/K1	1
K Angle	0 degrees

Properties changed in Rimozione puntone

- Ks: 1e-010 m/s (factor = 0.01) K Angle: 0 degrees (factor = 0)

Excavation Areas

Original Un-deformed Areas

- External Boundary Area: 12350.370 m²
- External Boundary Perimeter: 498.284 m

Geostatico

- External Boundary Area: 12350.370 m² (0 m² change from original area)
- External Boundary Perimeter: 498.284 m (0 m change from original perimeter)

Paratia

- Values not available until this stage is viewed in a window

Piano lavoro

- Values not available until this stage is viewed in a window

Jet

- Values not available until this stage is viewed in a window

I ribasso

- Values not available until this stage is viewed in a window

I puntone

- Values not available until this stage is viewed in a window

II ribasso

- Values not available until this stage is viewed in a window

II puntone

- Values not available until this stage is viewed in a window

III ribasso

- Values not available until this stage is viewed in a window

III puntone

- Values not available until this stage is viewed in a window

Fondo scavo

- Values not available until this stage is viewed in a window

CARICO TRENO

- Values not available until this stage is viewed in a window

Solettone

- Values not available until this stage is viewed in a window

Rimozione puntone

- Values not available until this stage is viewed in a window

Getto calotta

- Values not available until this stage is viewed in a window

Rimozione puntone

- Values not available until this stage is viewed in a window

Ritombamento

- Values not available until this stage is viewed in a window

Liner Properties

Liner: Tubo_F355_sp12/4m

Liner Type	Standard Beam
Formulation	Timoshenko
Area	0.003236 m ²
Moment of Inertia	4.782e-005 m ⁴

Elastic Properties

Young's modulus	2.1e+008 kPa
Poisson's ratio	0.2
Liner Unit Weight	78.5 kN/m ³

Liner: Tubo_F406_sp12.5/4m

Liner Type	Standard Beam
Formulation	Timoshenko
Area	0.003865 m ²
Moment of Inertia	7.503e-005 m ⁴

Elastic Properties

Young's modulus	2.1e+008 kPa
Poisson's ratio	0.2
Liner Unit Weight	78.5 kN/m ³

Liner: 2Micropali 168.3/0.45m

Liner Type	Standard Beam
Formulation	Timoshenko

Area	0.408 m ²
Moment of Inertia	0.001148 m ⁴

Elastic Properties

Young's modulus	3e+007 kPa
Poisson's ratio	0.2

Bolt Properties

Bolt name	Tirante
Bolt Type	Fully bonded bolt
Diameter	168.3 mm
Young's modulus	2.1e+008 kPa
Tensile capacity	1600 kN
Residual Tensile capacity	0.01 kN
Pre-tensioning	0 kN
Out-of-plane spacing	2.25 m

Displacements

- Displacement data is not available for Geostatico until total displacement is viewed in a window
- Displacement data is not available for Paratia until total displacement is viewed in a window
- Displacement data is not available for Piano lavoro until total displacement is viewed in a window
- Displacement data is not available for Jet until total displacement is viewed in a window
- Displacement data is not available for I ribasso until total displacement is viewed in a window
- Displacement data is not available for I puntone until total displacement is viewed in a window
- Displacement data is not available for II ribasso until total displacement is viewed in a window
- Displacement data is not available for II puntone until total displacement is viewed in a window
- Displacement data is not available for III ribasso until total displacement is viewed in a window
- Displacement data is not available for III puntone until total displacement is viewed in a window
- Displacement data is not available for Fondo scavo until total displacement is viewed in a window
- Displacement data is not available for CARICO TRENO until total displacement is viewed in a window
- Displacement data is not available for Solettone until total displacement is viewed in a window
- Displacement data is not available for Rimozione puntone until total displacement is viewed in a window
- Displacement data is not available for Getto calotta until total displacement is viewed in a window
- Displacement data is not available for Rimozione puntone until total displacement is viewed in a window
- Displacement data is not available for Ritombamento until total displacement is viewed in a window

Yielded Elements

Yielded Mesh Elements

- Number of yielded mesh elements on Geostatico: 162
- Number of yielded mesh elements is not available for Paratia until the stage is viewed in a window
- Number of yielded mesh elements is not available for Piano lavoro until the stage is viewed in a window
- Number of yielded mesh elements is not available for Jet until the stage is viewed in a window
- Number of yielded mesh elements is not available for I ribasso until the stage is viewed in a window
- Number of yielded mesh elements is not available for I puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for II ribasso until the stage is viewed in a window
- Number of yielded mesh elements is not available for II puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for III ribasso until the stage is viewed in a window

- Number of yielded mesh elements is not available for III puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for Fondo scavo until the stage is viewed in a window
- Number of yielded mesh elements is not available for CARICO TRENO until the stage is viewed in a window
- Number of yielded mesh elements is not available for Solettone until the stage is viewed in a window
- Number of yielded mesh elements is not available for Rimozione puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for Getto calotta until the stage is viewed in a window
- Number of yielded mesh elements is not available for Rimozione puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for Ritombamento until the stage is viewed in a window

Yielded Bolt Elements

- Number of yielded bolt elements on Geostatico: 0
- Number of yielded bolt elements on Paratia: 0
- Number of yielded bolt elements on Piano lavoro: 0
- Number of yielded bolt elements on Jet: 0
- Number of yielded bolt elements on I ribasso: 0
- Number of yielded bolt elements on I puntone: 0
- Number of yielded bolt elements on II ribasso: 0
- Number of yielded bolt elements on II puntone: 0
- Number of yielded bolt elements on III ribasso: 0
- Number of yielded bolt elements on III puntone: 0
- Number of yielded bolt elements on Fondo scavo: 0
- Number of yielded bolt elements on CARICO TRENO: 0
- Number of yielded bolt elements on Solettone: 0
- Number of yielded bolt elements on Rimozione puntone: 0
- Number of yielded bolt elements on Getto calotta: 0
- Number of yielded bolt elements on Rimozione puntone: 0
- Number of yielded bolt elements on Ritombamento: 0

Yielded Liner Elements

- Number of yielded liner elements on Geostatico: 0
- Number of yielded liner elements on Paratia: 0
- Number of yielded liner elements on Piano lavoro: 0
- Number of yielded liner elements on Jet: 0
- Number of yielded liner elements on I ribasso: 0
- Number of yielded liner elements on I puntone: 0
- Number of yielded liner elements on II ribasso: 0
- Number of yielded liner elements on II puntone: 0
- Number of yielded liner elements on III ribasso: 0
- Number of yielded liner elements on III puntone: 0
- Number of yielded liner elements on Fondo scavo: 0
- Number of yielded liner elements on CARICO TRENO: 0
- Number of yielded liner elements on Solettone: 0
- Number of yielded liner elements on Rimozione puntone: 0
- Number of yielded liner elements on Getto calotta: 0
- Number of yielded liner elements on Rimozione puntone: 0
- Number of yielded liner elements on Ritombamento: 0

List of All Coordinates

External boundary

X	Y
-90	0

90	0
90	68.4018
10.2799	68.4018
-7.58693	68.4018
-10.4458	70.2228
-11.395	70.8274
-15.8378	70.8274
-17.603	70.8274
-19.6031	70.8274
-21.416	70.8274
-23.7323	70.8274
-27.127	68.3922
-90	68.3922

Material boundary

X	Y
-7.58693	68.4018
-10.4458	68.4004
-27.127	68.3922

Material boundary

X	Y
-9.19101	66.3697
-9.19101	46.6998
9.24938	46.6998
9.24938	66.3708
7.33876	66.3707

Material boundary

X	Y
7.33876	66.3707
10.2799	68.4018

Material boundary

X	Y
6.44898	64.8496
6.44898	63.8496
5.14993	63.8496
4.94898	63.8496
4.94898	64.4023
4.94898	64.8496

6.44898	64.8496
6.44898	66.3706

Material boundary

X	Y
-6.39101	64.85
-4.89101	64.85
-4.89101	64.4023
-4.89101	63.85
-5.09501	63.85
-6.39101	63.85
-6.39101	64.85

Material boundary

X	Y
-6.39101	64.85
-6.39101	66.37

Material boundary

X	Y
-4.69294	61.49
-0.971016	63.4398
1.02898	63.4398
4.75091	61.49
4.75091	60.4206
4.75091	58.2092
4.75091	57.6103
4.75091	55.8893
4.75091	53.5496
-4.69294	53.5499
-4.69294	55.8893
-4.69294	57.6103
-4.69294	58.2092
-4.69294	60.4206
-4.69294	61.49

Material boundary

X	Y
-4.89101	64.4023
4.94898	64.4023

Material boundary

X	Y
-2.12102	55.3498
2.17898	55.3498
3.28462	55.8893
3.65034	56.7254
3.87381	57.6103
3.87381	58.2092
3.87381	59.4628
3.39991	60.4206
3.20033	60.8239
2.46056	61.49
1.98898	61.9146
1.24033	62.2479
0.0289837	62.4398
-1.18236	62.2479
-1.93102	61.9146
-2.40259	61.49
-3.14236	60.8239
-3.34194	60.4206
-3.81584	59.4628
-3.81584	58.2092
-3.81584	57.6103
-3.59237	56.7254
-3.22666	55.8893
-2.12102	55.3498

Material boundary

X	Y
-4.69294	61.49
-4.69294	63.4398
-4.69294	63.85
-4.89101	63.85

Material boundary

X	Y
4.75091	61.49
4.75091	63.4398
4.75091	63.8496
4.94898	63.8496

Material boundary

X	Y
-15.8378	70.8274
-15.8378	70.534
-17.603	70.534
-17.603	70.8274

Material boundary

X	Y
-19.6031	70.8274
-19.6031	70.524
-21.416	70.524
-21.416	70.8274

Material boundary

X	Y
6.44898	66.3706
-6.39101	66.37

Material boundary

X	Y
-6.39101	66.37
-9.19101	66.3697

Material boundary

X	Y
6.44898	66.3706
7.33876	66.3707

Material boundary

X	Y
-10.4458	68.4004
-10.4458	60.0062

Material boundary

X	Y
-10.4458	68.4004
-10.4458	70.2228

Material boundary

X	Y
-10.4458	68.4004
-6.39101	66.37

Material boundary

X	Y
-0.971016	63.4398
-4.69294	63.4398

Material boundary

X	Y
1.02898	63.4398
4.75091	63.4398

Material boundary

X	Y
-5.09501	63.85
-5.09501	60.4206
-5.09501	57.6103
-5.09501	53.55

Material boundary

X	Y
-4.69294	53.5499
-4.89101	53.5499
-5.09501	53.55

Material boundary

X	Y
5.14993	63.8496
5.14993	60.4206
5.14993	57.6103
5.14993	53.5496

Material boundary

X	Y
4.75091	53.5496

4.94898	53.5496
5.14993	53.5496

Material boundary

X	Y
-10.4458	60.0062
-10.4458	56.2046

Material boundary

X	Y
-10.4458	56.2046
-10.4458	52.1785

Material boundary

X	Y
4.75091	60.4206
3.39991	60.4206
-3.34194	60.4206
-4.69294	60.4206

Material boundary

X	Y
3.28462	55.8893
4.75091	55.8893

Material boundary

X	Y
-3.22666	55.8893
-4.69294	55.8893

Material boundary

X	Y
-4.69294	61.49
-2.40259	61.49
2.46056	61.49
4.75091	61.49

Material boundary

X	Y
-4.69294	58.2092
-3.81584	58.2092
3.87381	58.2092
4.75091	58.2092

Material boundary

X	Y
-4.89101	57.6103
-4.69294	57.6103

Material boundary

X	Y
-4.89101	60.4206
-4.69294	60.4206

Material boundary

X	Y
4.94898	57.6103
4.75091	57.6103
3.87381	57.6103
-3.81584	57.6103
-4.69294	57.6103

Material boundary

X	Y
4.75091	60.4206
4.94898	60.4206

Material boundary

X	Y
-4.89101	60.4206
-5.09501	60.4206

Material boundary

X	Y
4.94898	60.4206
5.14993	60.4206

Material boundary

X	Y
-4.89101	57.6103
-5.09501	57.6103

Material boundary

X	Y
4.94898	57.6103
5.14993	57.6103

Phase2 Analysis Information

Project Settings

- Document Name: Sez 54+997_M-C fondo scavo con carico.fez
- Project Title: Phase2 - Finite Element Analysis of Excavations in Rock
- Number of Stages: 16
- Analysis Type: Plane Strain
- Solver Type: Gaussian Elimination
- Units: Metric, stress as kPa

Stress Analysis

- Maximum Number of Iterations: 9000
- Tolerance: 0.001
- Number of Load Steps: Automatic
- Convergence Type: Absolute Energy
- Tensile Failure: Reduces Shear Strength
- Joint tension reduces joint stiffness by a factor of 0.01

Groundwater

- Method: Finite Element Analysis
- Pore Fluid Unit Weight: 9.81 kN/m³
- Maximum Number of Iterations: 500
- Tolerance: 1e-006

Field Stress

- Field stress: gravity
- Using actual ground surface
- Effective stress ratio (horizontal/vertical in-plane): 1
- Effective stress ratio (horizontal/vertical out-of-plane): 1
- Locked-in horizontal stress (in-plane): 0
- Locked-in horizontal stress (out-of-plane): 0

Mesh

- Mesh type: graded
- Element type: 8 noded quadrilaterals
- Number of elements on Geostatico: 1328
- Number of nodes on Geostatico: 3911
- Number of elements on Paratia: 1328
- Number of nodes on Paratia: 3911
- Number of elements on Piano lavoro: 1256
- Number of nodes on Piano lavoro: 3719
- Number of elements on Jet: 1256
- Number of nodes on Jet: 3719
- Number of elements on I ribasso: 1185
- Number of nodes on I ribasso: 3546
- Number of elements on I puntone: 1185
- Number of nodes on I puntone: 3546
- Number of elements on II ribasso: 1108
- Number of nodes on II ribasso: 3351

- Number of elements on II puntone: 1108
- Number of nodes on II puntone: 3351
- Number of elements on III ribasso: 1028
- Number of nodes on III ribasso: 3129
- Number of elements on III puntone: 1028
- Number of nodes on III puntone: 3129
- Number of elements on Fondo scavo: 943
- Number of nodes on Fondo scavo: 2892
- Number of elements on Solettone: 977
- Number of nodes on Solettone: 2994
- Number of elements on Rimozione puntone: 977
- Number of nodes on Rimozione puntone: 2994
- Number of elements on Getto calotta: 1052
- Number of nodes on Getto calotta: 3220
- Number of elements on Rimozione puntone: 1052
- Number of nodes on Rimozione puntone: 3220
- Number of elements on Ritombamento: 1207
- Number of nodes on Ritombamento: 3613

Mesh Quality

- All elements are of good quality

Poor quality elements defined as:

- Side length ratio (maximum / minimum) > 30.00
- Minimum interior angle < 2.0 degrees
- Maximum interior angle > 175.0 degrees

Reset Displacements

- Displacements reset after: Geostatico
- Displacements reset after: Paratia

Material Properties

Material: Alluvionali

Initial element loading	field stress & body force
Unit weight	20.5 kN/m ³
Elastic type	isotropic
Young's modulus	60000 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	1 kPa
Peak friction angle	36 degrees
Peak cohesion	2 kPa
Material type	Plastic
Dilation Angle	1 degrees
Residual Friction Angle	35 degrees
Residual Cohesion	0 kPa

Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Properties changed in Paratia

- Unit weight:

Properties changed in Jet

- Unit weight: Young's modulus: 120000 kPa (factor = 2) Field Stress Gravity Ground surface elevation 0 m Unit weight of overburden 0.027 kN/m³ Effective stress ratio (horizontal/vertical in-plane) 0.413 Effective stress ratio (horizontal/vertical out-of-plane) 0.413 Locked-in horizontal stress (in-plane) 0 Locked-in horizontal stress (out-of-plane) 0

Material: Jet grouting

Initial element loading	body force only
Unit weight	21 kN/m ³
Elastic type	isotropic
Young's modulus	1e+006 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	75 kPa
Peak friction angle	36 degrees
Peak cohesion	500 kPa
Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	36 degrees
Residual Cohesion	500 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	1e-008 m/s
K2/K1	1
K Angle	0 degrees

Material: Rilvato

Initial element loading	body force only
Unit weight	21 kN/m ³
Elastic type	isotropic
Young's modulus	100000 kPa
Poisson's ratio	0.3

Failure criterion	Mohr-Coulomb
Tensile strength	1 kPa
Peak friction angle	37 degrees
Peak cohesion	0 kPa
Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	37 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Material: CLS

Initial element loading	body force only
Unit weight	25 kN/m3
Elastic type	isotropic
Young's modulus	3.12e+007 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	35 degrees
Peak cohesion	500 kPa
Material type	Elastic
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	1e-012 m/s
K2/K1	1
K Angle	0 degrees

Material: Ritombamento

Initial element loading	body force only
Unit weight	20.5 kN/m3
Elastic type	isotropic
Young's modulus	80000 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	36 degrees
Peak cohesion	5 kPa

Material type	Elastic
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Material: Spritz

Initial element loading	body force only
Unit weight	24 kN/m ³
Elastic type	isotropic
Young's modulus	3e+007 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	1 kPa
Peak friction angle	35 degrees
Peak cohesion	500 kPa
Material type	Elastic
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	1e-008 m/s
K2/K1	1
K Angle	0 degrees

Properties changed in Rimozione puntone

- Ks: 1e-010 m/s (factor = 0.01)K Angle: 0 degrees (factor = 0)

Excavation Areas

Original Un-deformed Areas

- External Boundary Area: 12350.370 m²
- External Boundary Perimeter: 498.284 m

Geostatico

- External Boundary Area: 12350.370 m² (0 m² change from original area)
- External Boundary Perimeter: 498.284 m (0 m change from original perimeter)

Paratia

- Values not available until this stage is viewed in a window

Piano lavoro

- Values not available until this stage is viewed in a window

Jet

- Values not available until this stage is viewed in a window

I ribasso

- Values not available until this stage is viewed in a window

I puntone

- Values not available until this stage is viewed in a window

II ribasso

- Values not available until this stage is viewed in a window

II puntone

- Values not available until this stage is viewed in a window

III ribasso

- Values not available until this stage is viewed in a window

III puntone

- Values not available until this stage is viewed in a window

Fondo scavo

- Values not available until this stage is viewed in a window

Solettone

- Values not available until this stage is viewed in a window

Rimozione puntone

- Values not available until this stage is viewed in a window

Getto calotta

- Values not available until this stage is viewed in a window

Rimozione puntone

- Values not available until this stage is viewed in a window

Ritombamento

- Values not available until this stage is viewed in a window

Liner Properties

Liner: Tubo_F355_sp12/4m

Liner Type	Standard Beam
Formulation	Timoshenko
Area	0.003236 m ²
Moment of Inertia	4.782e-005 m ⁴

Elastic Properties

Young's modulus	2.1e+008 kPa
Poisson's ratio	0.2
Liner Unit Weight	78.5 kN/m ³

Liner: Tubo_F406_sp12.5/4m

Liner Type	Standard Beam
Formulation	Timoshenko
Area	0.003865 m ²
Moment of Inertia	7.503e-005 m ⁴

Elastic Properties

Young's modulus	2.1e+008 kPa
Poisson's ratio	0.2
Liner Unit Weight	78.5 kN/m ³

Liner: 2Micropali 168.3/0.45m

Liner Type	Standard Beam
Formulation	Timoshenko
Area	0.408 m ²
Moment of Inertia	0.001148 m ⁴

Elastic Properties

Young's modulus	3e+007 kPa
Poisson's ratio	0.2

Bolt Properties

Bolt name	Tirante
Bolt Type	Fully bonded bolt
Diameter	168.3 mm
Young's modulus	2.1e+008 kPa
Tensile capacity	1600 kN
Residual Tensile capacity	0.01 kN
Pre-tensioning	0 kN
Out-of-plane spacing	2.25 m

Displacements

- Displacement data is not available for Geostatico until total displacement is viewed in a window
- Displacement data is not available for Paratia until total displacement is viewed in a window
- Displacement data is not available for Piano lavoro until total displacement is viewed in a window
- Displacement data is not available for Jet until total displacement is viewed in a window
- Displacement data is not available for I ribasso until total displacement is viewed in a window
- Displacement data is not available for I puntone until total displacement is viewed in a window
- Displacement data is not available for II ribasso until total displacement is viewed in a window
- Displacement data is not available for II puntone until total displacement is viewed in a window
- Displacement data is not available for III ribasso until total displacement is viewed in a window
- Displacement data is not available for III puntone until total displacement is viewed in a window
- Displacement data is not available for Fondo scavo until total displacement is viewed in a window
- Displacement data is not available for Solettone until total displacement is viewed in a window
- Displacement data is not available for Rimozione puntone until total displacement is viewed in a window
- Displacement data is not available for Getto calotta until total displacement is viewed in a window
- Displacement data is not available for Rimozione puntone until total displacement is viewed in a window
- Displacement data is not available for Ritombamento until total displacement is viewed in a window

Yielded Elements

Yielded Mesh Elements

- Number of yielded mesh elements on Geostatico: 161
- Number of yielded mesh elements is not available for Paratia until the stage is viewed in a window
- Number of yielded mesh elements is not available for Piano lavoro until the stage is viewed in a window
- Number of yielded mesh elements is not available for Jet until the stage is viewed in a window
- Number of yielded mesh elements is not available for I ribasso until the stage is viewed in a window
- Number of yielded mesh elements is not available for I puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for II ribasso until the stage is viewed in a window
- Number of yielded mesh elements is not available for II puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for III ribasso until the stage is viewed in a window
- Number of yielded mesh elements is not available for III puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for Fondo scavo until the stage is viewed in a window
- Number of yielded mesh elements is not available for Solettone until the stage is viewed in a window
- Number of yielded mesh elements is not available for Rimozione puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for Getto calotta until the stage is viewed in a window
- Number of yielded mesh elements is not available for Rimozione puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for Ritombamento until the stage is viewed in a window

Yielded Bolt Elements

- Number of yielded bolt elements on Geostatico: 0
- Number of yielded bolt elements on Paratia: 0
- Number of yielded bolt elements on Piano lavoro: 0
- Number of yielded bolt elements on Jet: 0
- Number of yielded bolt elements on I ribasso: 0
- Number of yielded bolt elements on I puntone: 0
- Number of yielded bolt elements on II ribasso: 0
- Number of yielded bolt elements on II puntone: 0
- Number of yielded bolt elements on III ribasso: 0
- Number of yielded bolt elements on III puntone: 0
- Number of yielded bolt elements on Fondo scavo: 0
- Number of yielded bolt elements on Solettone: 0
- Number of yielded bolt elements on Rimozione puntone: 0
- Number of yielded bolt elements on Getto calotta: 0
- Number of yielded bolt elements on Rimozione puntone: 0
- Number of yielded bolt elements on Ritombamento: 0

Yielded Liner Elements

- Number of yielded liner elements on Geostatico: 0
- Number of yielded liner elements on Paratia: 0
- Number of yielded liner elements on Piano lavoro: 0
- Number of yielded liner elements on Jet: 0
- Number of yielded liner elements on I ribasso: 0
- Number of yielded liner elements on I puntone: 0
- Number of yielded liner elements on II ribasso: 0
- Number of yielded liner elements on II puntone: 0
- Number of yielded liner elements on III ribasso: 0
- Number of yielded liner elements on III puntone: 0
- Number of yielded liner elements on Fondo scavo: 0
- Number of yielded liner elements on Solettone: 0
- Number of yielded liner elements on Rimozione puntone: 0
- Number of yielded liner elements on Getto calotta: 0
- Number of yielded liner elements on Rimozione puntone: 0
- Number of yielded liner elements on Ritombamento: 0

List of All Coordinates

External boundary

X	Y
-90	0
90	0
90	68.4018
10.2799	68.4018
-7.58693	68.4018
-10.4458	70.2228
-11.395	70.8274
-15.8378	70.8274
-17.603	70.8274
-19.6031	70.8274

-21.416	70.8274
-23.7323	70.8274
-27.127	68.3922
-90	68.3922

Material boundary

X	Y
-7.58693	68.4018
-10.4458	68.4004
-27.127	68.3922

Material boundary

X	Y
-9.19101	66.3697
-9.19101	46.6998
9.24938	46.6998
9.24938	66.3708
7.33876	66.3707

Material boundary

X	Y
7.33876	66.3707
10.2799	68.4018

Material boundary

X	Y
6.44898	64.8496
6.44898	63.8496
5.14993	63.8496
4.94898	63.8496
4.94898	64.4023
4.94898	64.8496
6.44898	64.8496
6.44898	66.3706

Material boundary

X	Y
-6.39101	64.85
-4.89101	64.85
-4.89101	64.4023

-4.89101	63.85
-5.09501	63.85
-6.39101	63.85
-6.39101	64.85

Material boundary

X	Y
-6.39101	64.85
-6.39101	66.37

Material boundary

X	Y
-4.69294	61.49
-0.971016	63.4398
1.02898	63.4398
4.75091	61.49
4.75091	60.4206
4.75091	58.2092
4.75091	57.6103
4.75091	55.8893
4.75091	53.5496
-4.69294	53.5499
-4.69294	55.8893
-4.69294	57.6103
-4.69294	58.2092
-4.69294	60.4206
-4.69294	61.49

Material boundary

X	Y
-4.89101	64.4023
4.94898	64.4023

Material boundary

X	Y
-2.12102	55.3498
2.17898	55.3498
3.28462	55.8893
3.65034	56.7254
3.87381	57.6103
3.87381	58.2092

3.87381	59.4628
3.39991	60.4206
3.20033	60.8239
2.46056	61.49
1.98898	61.9146
1.24033	62.2479
0.0289837	62.4398
-1.18236	62.2479
-1.93102	61.9146
-2.40259	61.49
-3.14236	60.8239
-3.34194	60.4206
-3.81584	59.4628
-3.81584	58.2092
-3.81584	57.6103
-3.59237	56.7254
-3.22666	55.8893
-2.12102	55.3498

Material boundary

X	Y
-4.69294	61.49
-4.69294	63.4398
-4.69294	63.85
-4.89101	63.85

Material boundary

X	Y
4.75091	61.49
4.75091	63.4398
4.75091	63.8496
4.94898	63.8496

Material boundary

X	Y
-15.8378	70.8274
-15.8378	70.534
-17.603	70.534
-17.603	70.8274

Material boundary

X	Y
-19.6031	70.8274
-19.6031	70.524
-21.416	70.524
-21.416	70.8274

Material boundary

X	Y
6.44898	66.3706
-6.39101	66.37

Material boundary

X	Y
-6.39101	66.37
-9.19101	66.3697

Material boundary

X	Y
6.44898	66.3706
7.33876	66.3707

Material boundary

X	Y
-10.4458	68.4004
-10.4458	60.0062

Material boundary

X	Y
-10.4458	68.4004
-10.4458	70.2228

Material boundary

X	Y
-10.4458	68.4004
-6.39101	66.37

Material boundary

X	Y
-0.971016	63.4398
-4.69294	63.4398

Material boundary

X	Y
1.02898	63.4398
4.75091	63.4398

Material boundary

X	Y
-5.09501	63.85
-5.09501	60.4206
-5.09501	57.6103
-5.09501	53.55

Material boundary

X	Y
-4.69294	53.5499
-4.89101	53.5499
-5.09501	53.55

Material boundary

X	Y
5.14993	63.8496
5.14993	60.4206
5.14993	57.6103
5.14993	53.5496

Material boundary

X	Y
4.75091	53.5496
4.94898	53.5496
5.14993	53.5496

Material boundary

X	Y
-10.4458	60.0062

-10.4458	56.2046
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Material boundary

X	Y
-10.4458	56.2046
-10.4458	52.1785

Material boundary

X	Y
4.75091	60.4206
3.39991	60.4206
-3.34194	60.4206
-4.69294	60.4206

Material boundary

X	Y
3.28462	55.8893
4.75091	55.8893

Material boundary

X	Y
-3.22666	55.8893
-4.69294	55.8893

Material boundary

X	Y
-4.69294	61.49
-2.40259	61.49
2.46056	61.49
4.75091	61.49

Material boundary

X	Y
-4.69294	58.2092
-3.81584	58.2092
3.87381	58.2092
4.75091	58.2092

Material boundary

X	Y
---	---

-4.89101	57.6103
-4.69294	57.6103

Material boundary

X	Y
-4.89101	60.4206
-4.69294	60.4206

Material boundary

X	Y
4.94898	57.6103
4.75091	57.6103
3.87381	57.6103
-3.81584	57.6103
-4.69294	57.6103

Material boundary

X	Y
4.75091	60.4206
4.94898	60.4206

Material boundary

X	Y
-4.89101	60.4206
-5.09501	60.4206

Material boundary

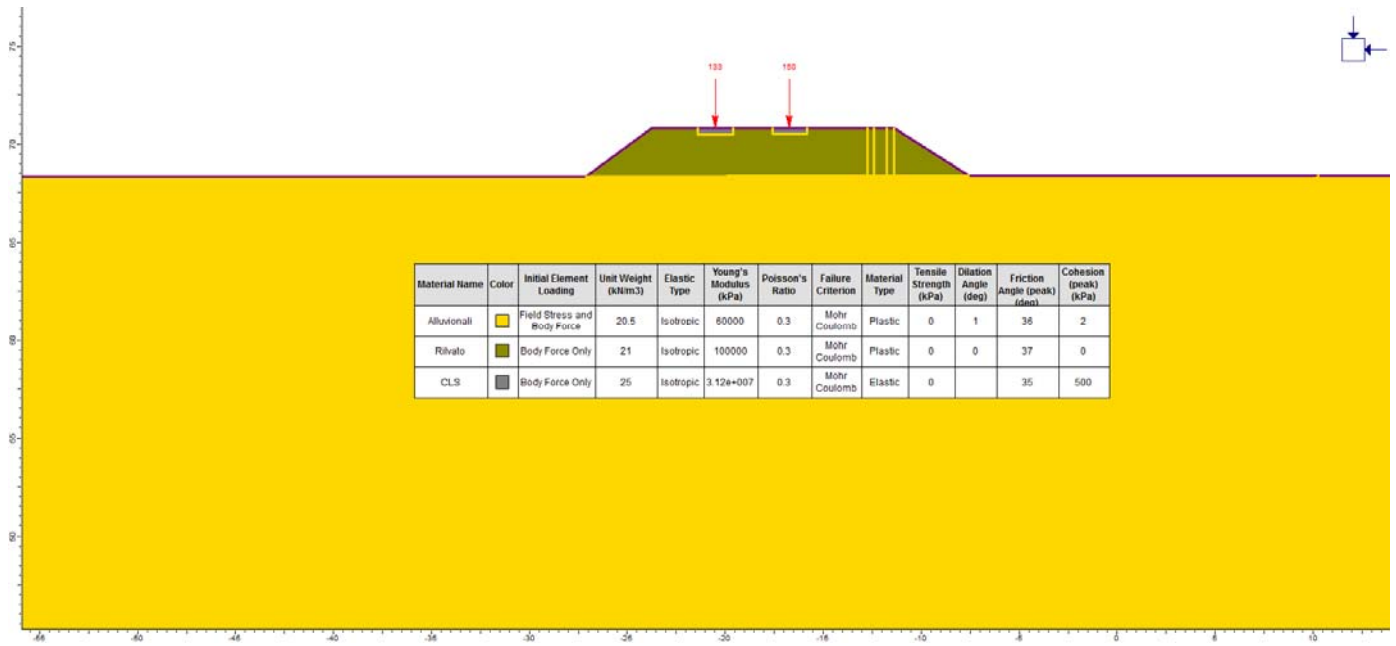
X	Y
4.94898	60.4206
5.14993	60.4206

Material boundary

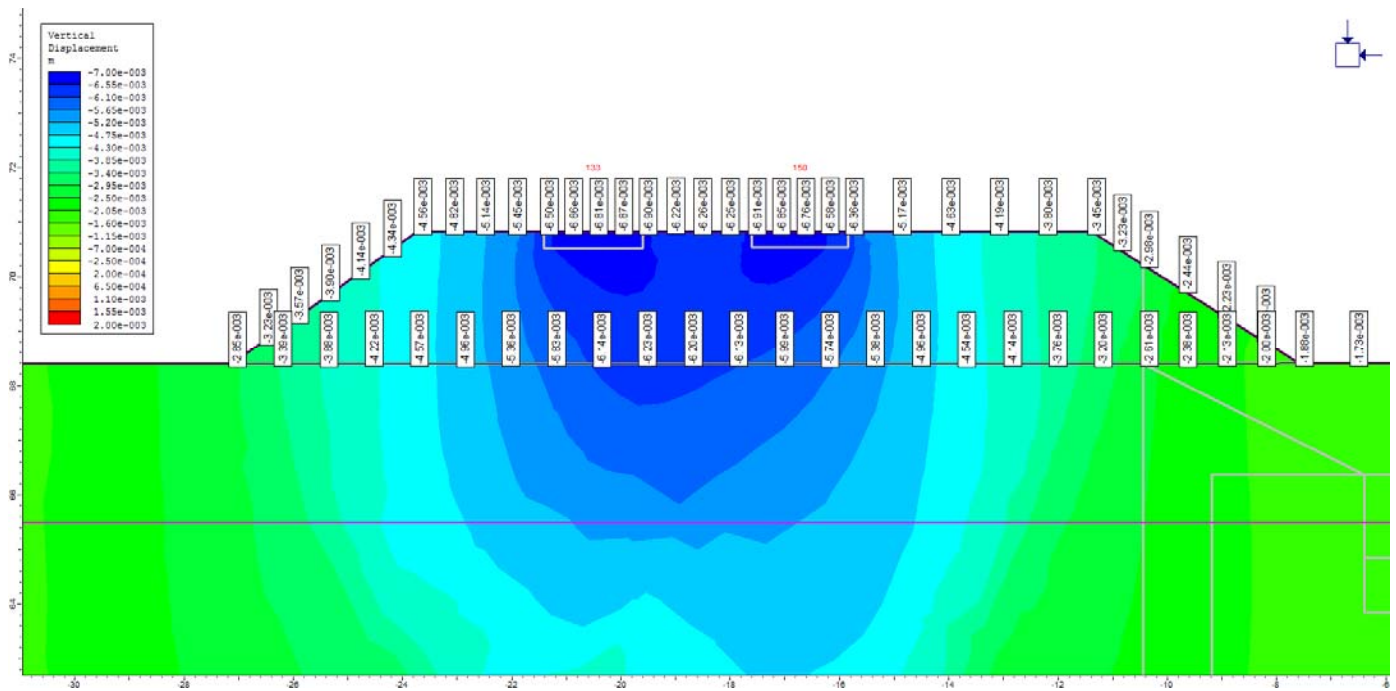
X	Y
-4.89101	57.6103
-5.09501	57.6103

Material boundary

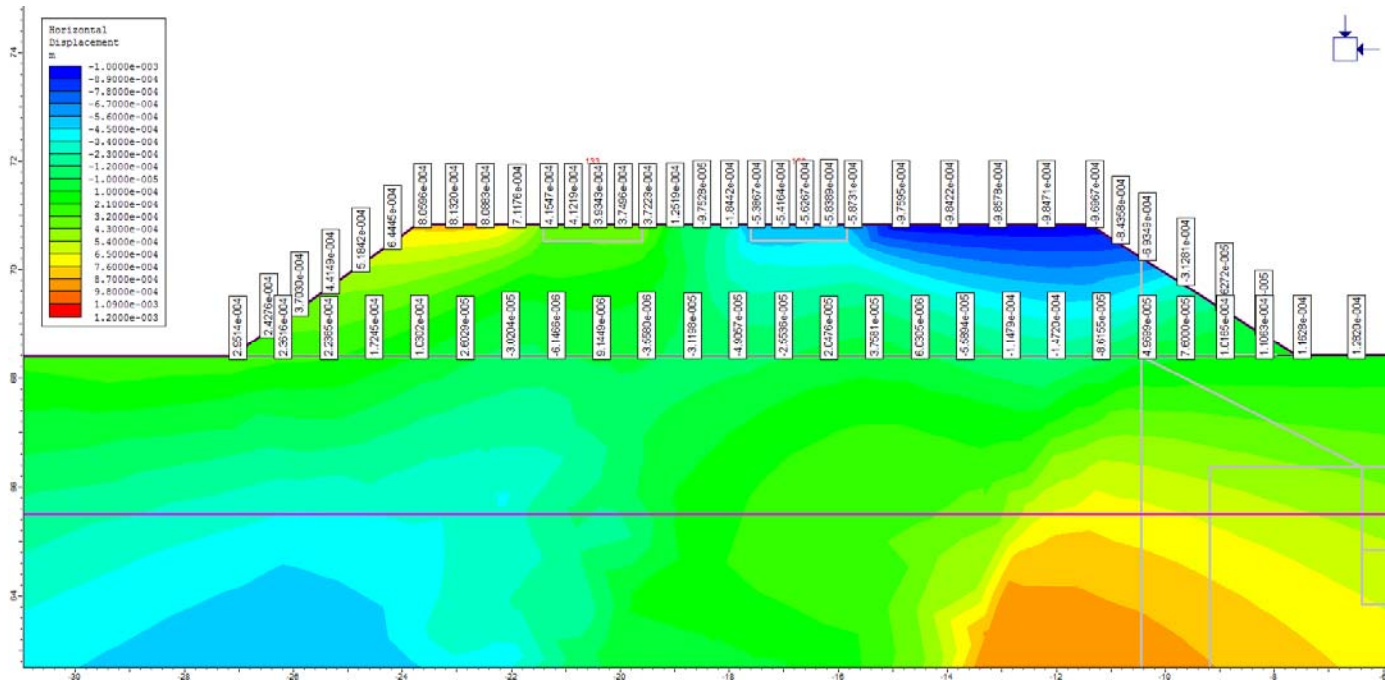
X	Y
4.94898	57.6103
5.14993	57.6103



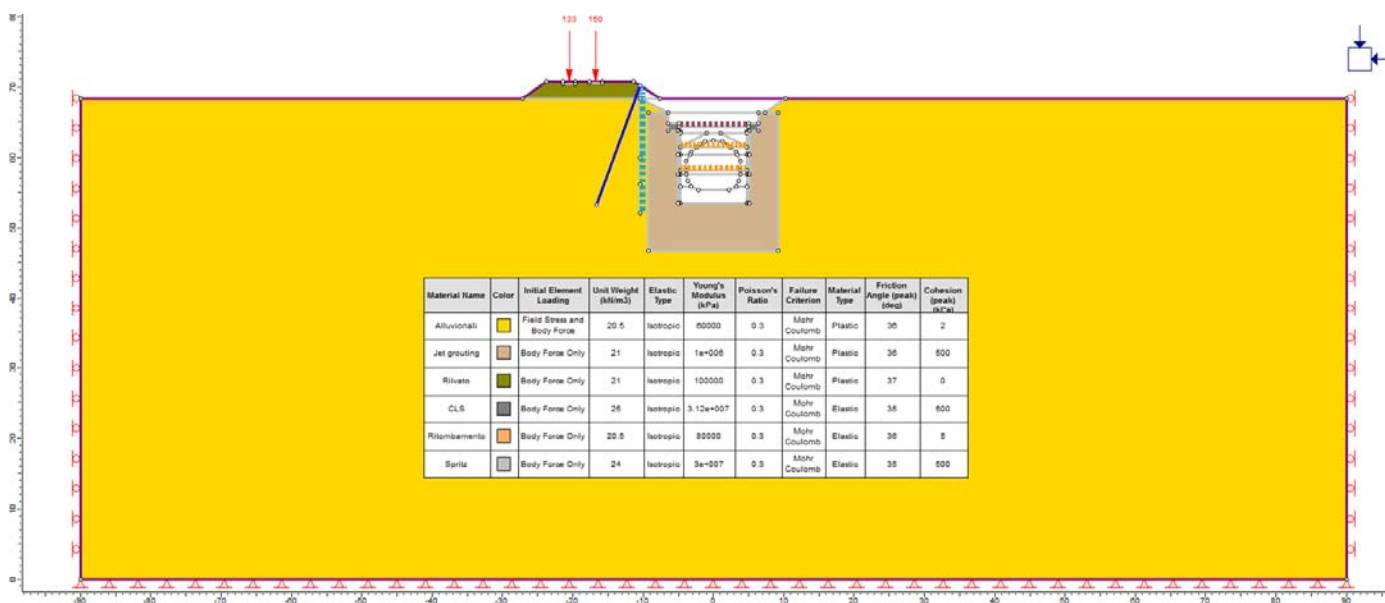
Geometria di calcolo per la Galleria di Base binario Dispari. Progressiva pk_54+997. Carico del treno applicato al rilevato ferroviario prima dello scavo.



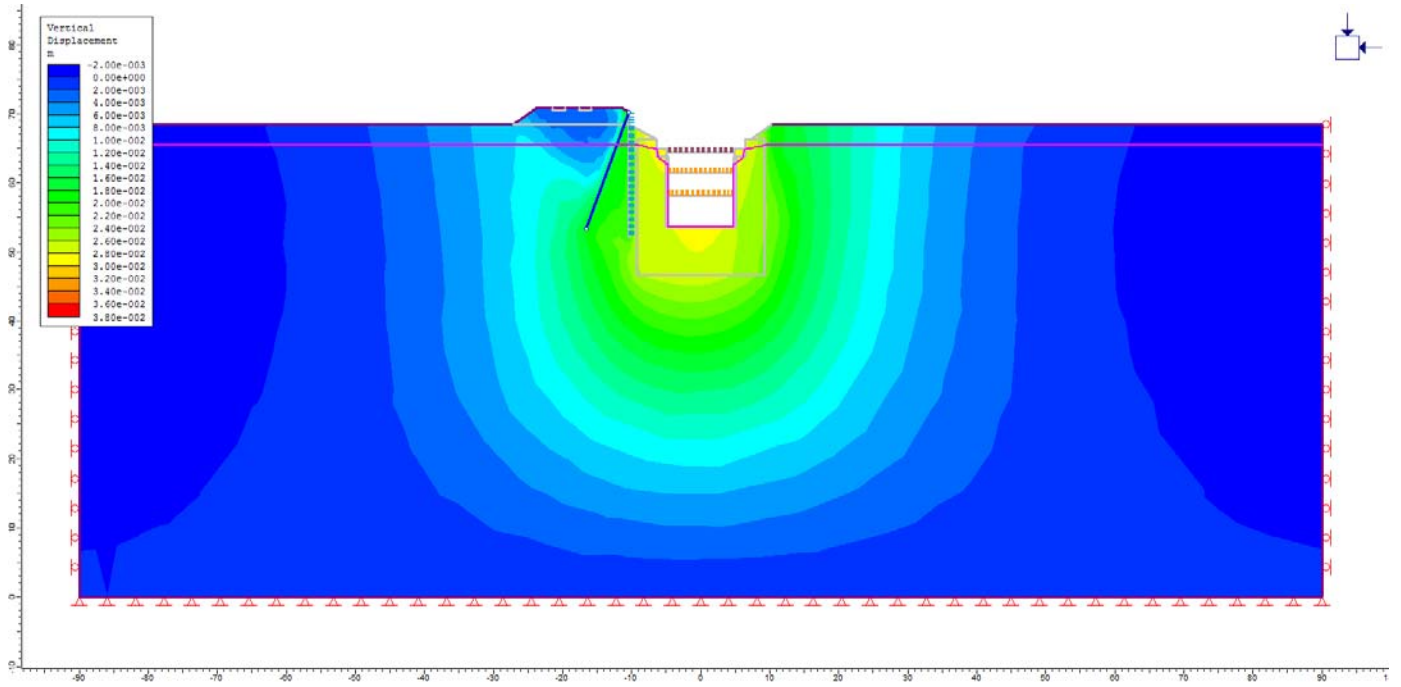
Galleria di Base binario Dispari. Progressiva pk_54+997. Spostamenti verticali dY. Carico del treno applicato al rilevato ferroviario prima dello scavo. Carico non fattorizzato (SLE)



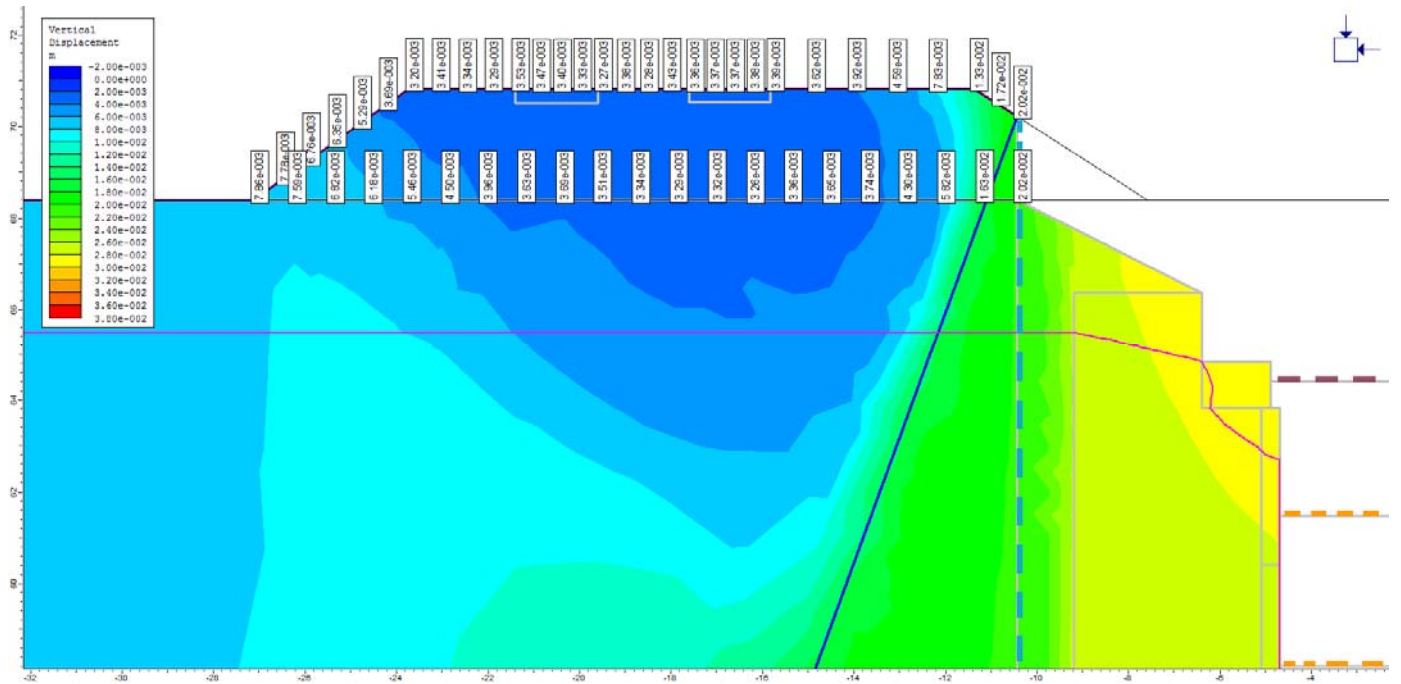
Galleria di Base binario Dispari. Progressiva pk₅₄₊₉₉₇. Spostamenti orizzontale dX. Carico del treno applicato al rilevato ferroviario prima dello scavo. Carico non fattorizzato (SLE)



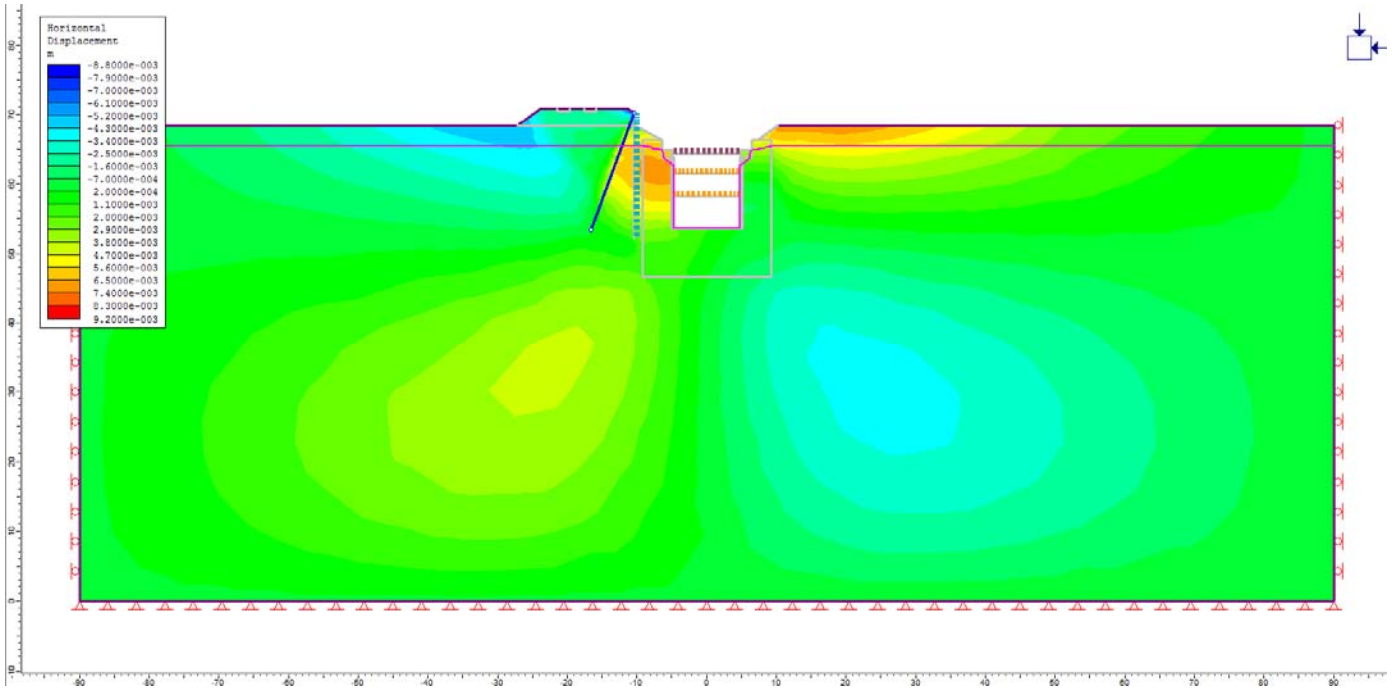
Geometria di calcolo per la Galleria di Base binario Dispari. Progressiva pk₅₄₊₉₉₇. Fase finale di scavo più carico del treno.



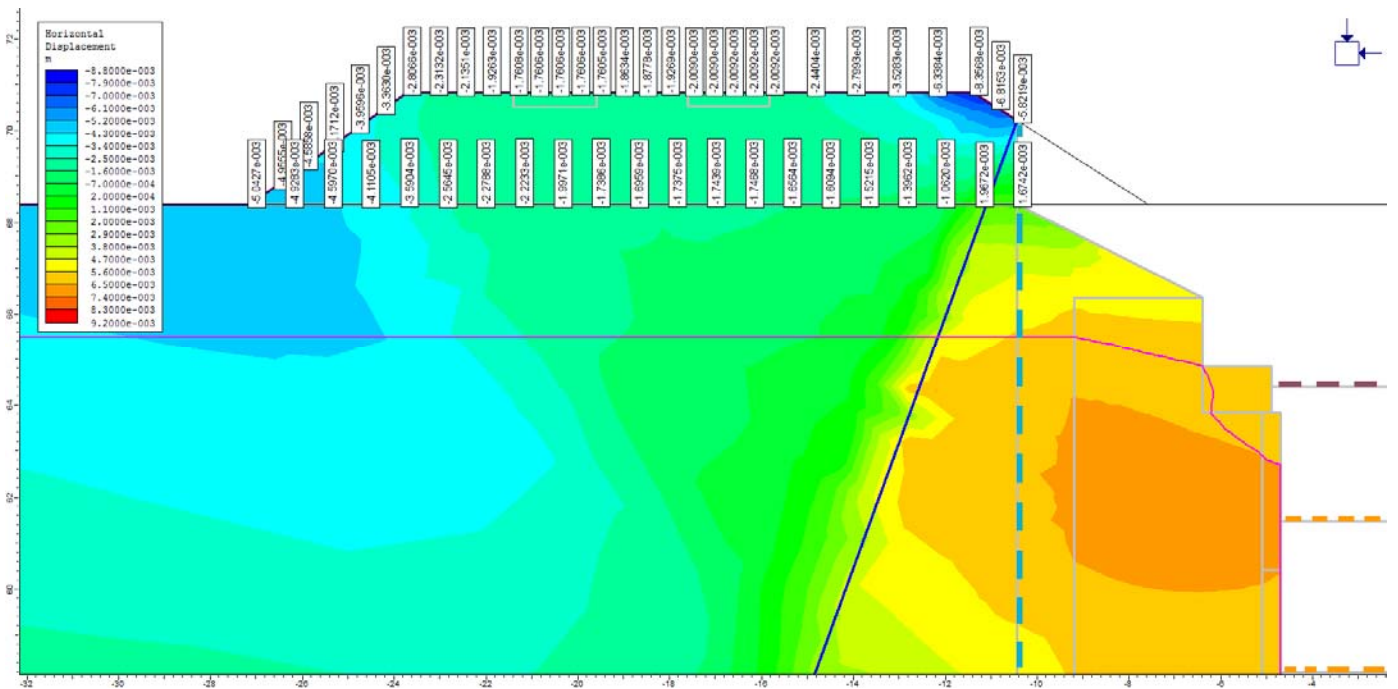
Galleria di Base binario Dispari. Progressiva pk_54+997. Spostamenti verticali dY. Fase finale di scavo. Carico non fattorizzato (SLE)



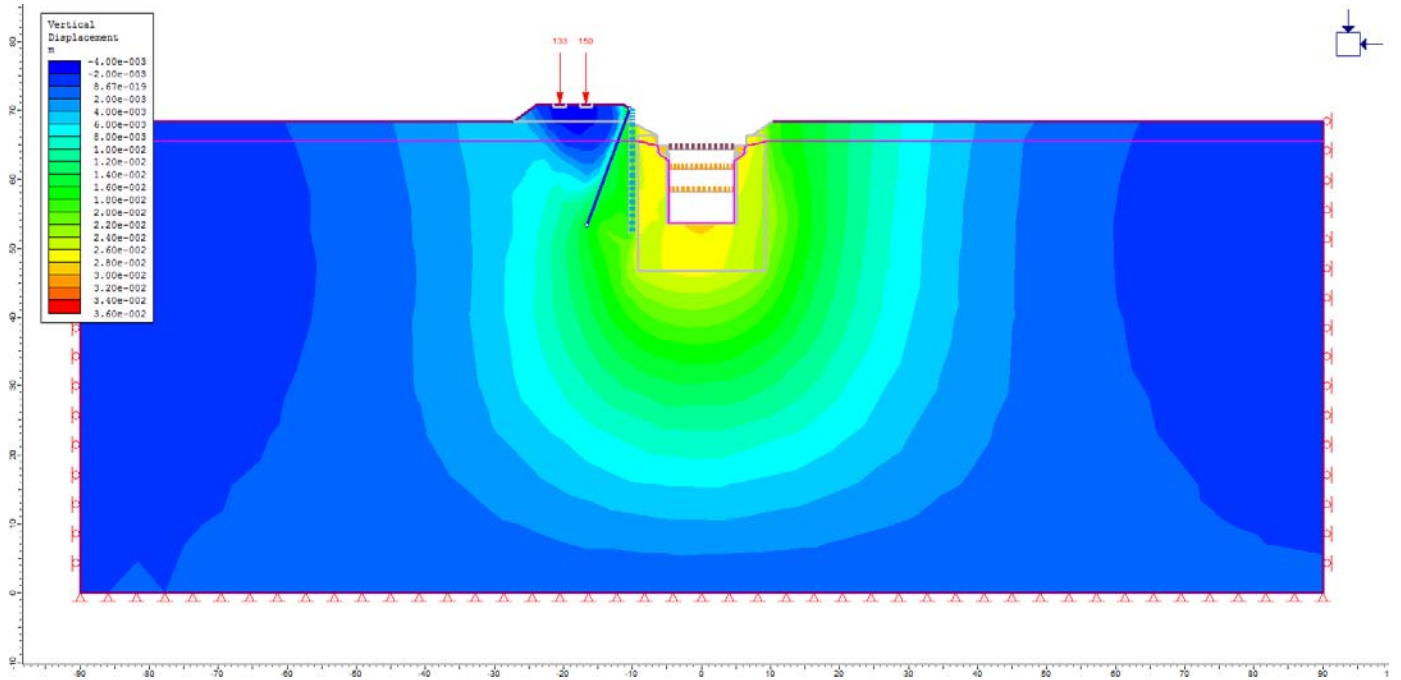
Galleria di Base binario Dispari. Progressiva pk_54+997. Spostamenti verticali dY. Fase finale di scavo. Particolare del rilevato ferroviario. Carico non fattorizzato (SLE)



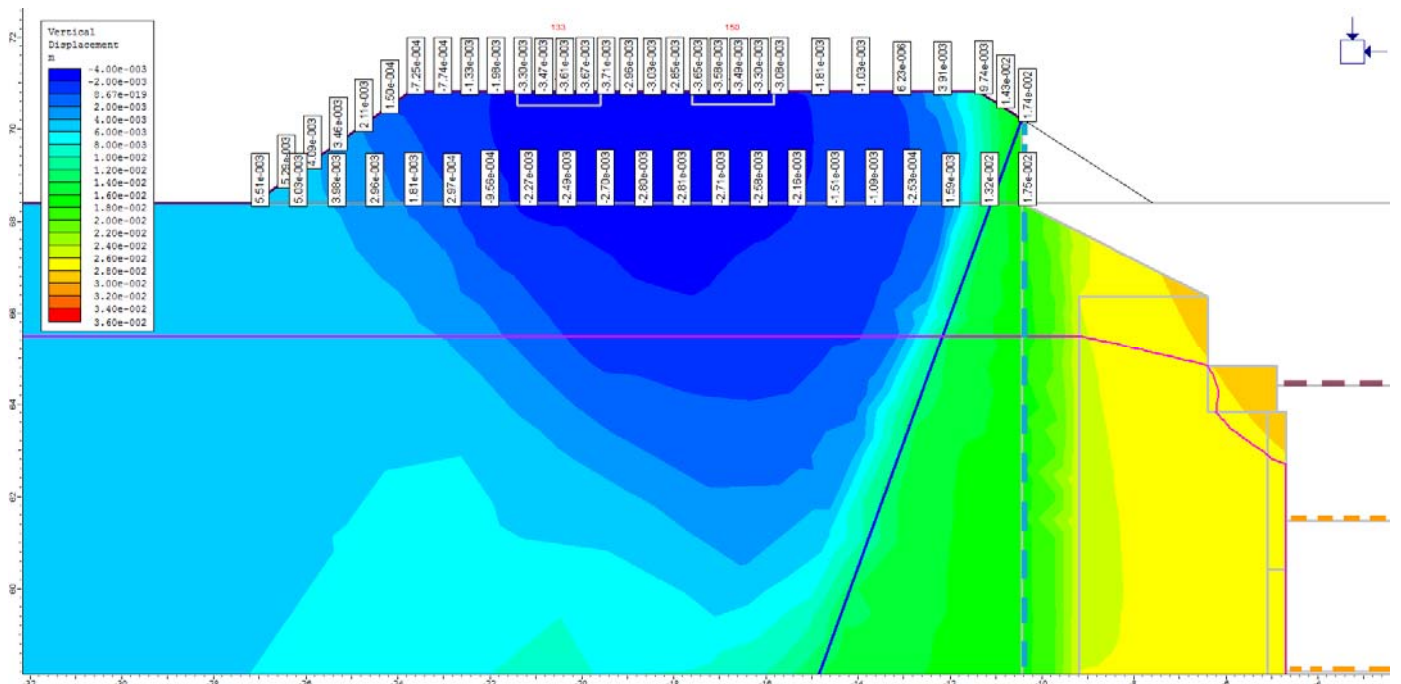
Galleria di Base binario Dispari. Progressiva pk₅₄₊₉₉₇. Spostamenti orizzontali dX. Fase finale di scavo. Carico non fattorizzato (SLE)



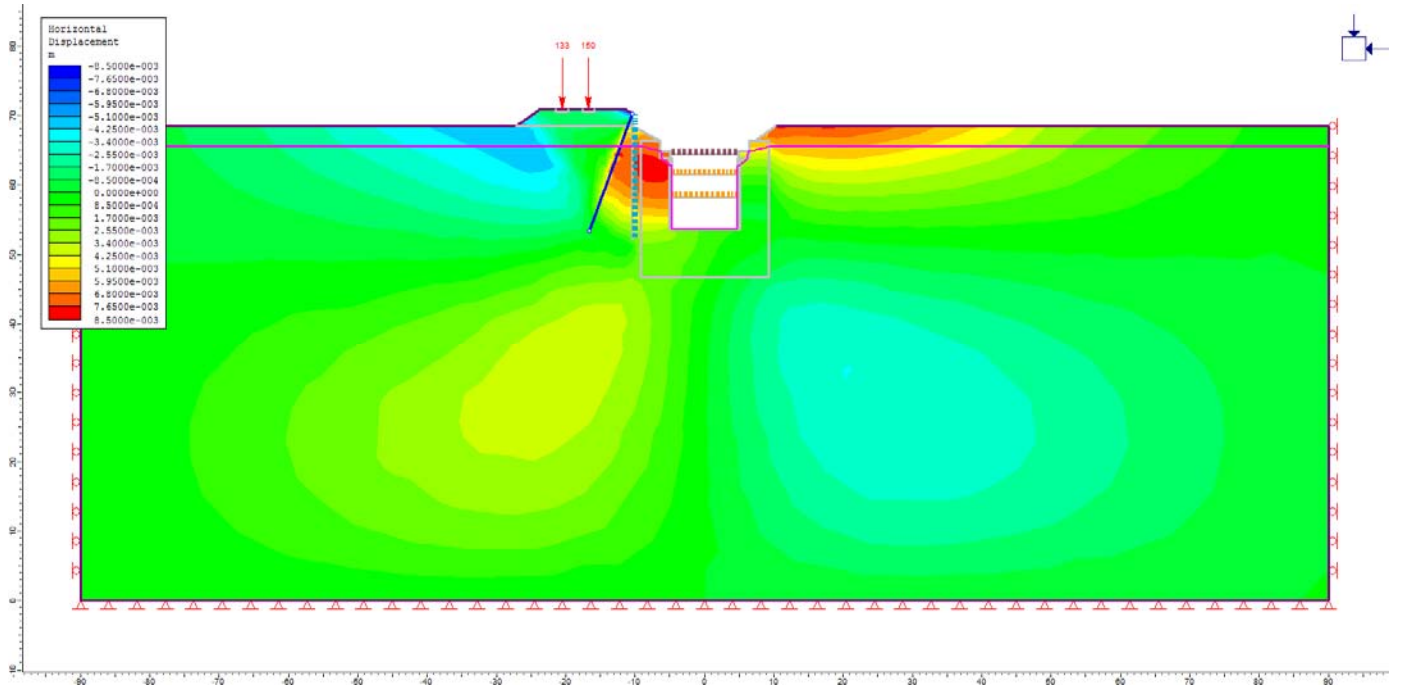
Galleria di Base binario Dispari. Progressiva pk₅₄₊₉₉₇. Spostamenti orizzontali dX. Fase finale di scavo. Particolare del rilevato ferroviario. Carico non fattorizzato (SLE)



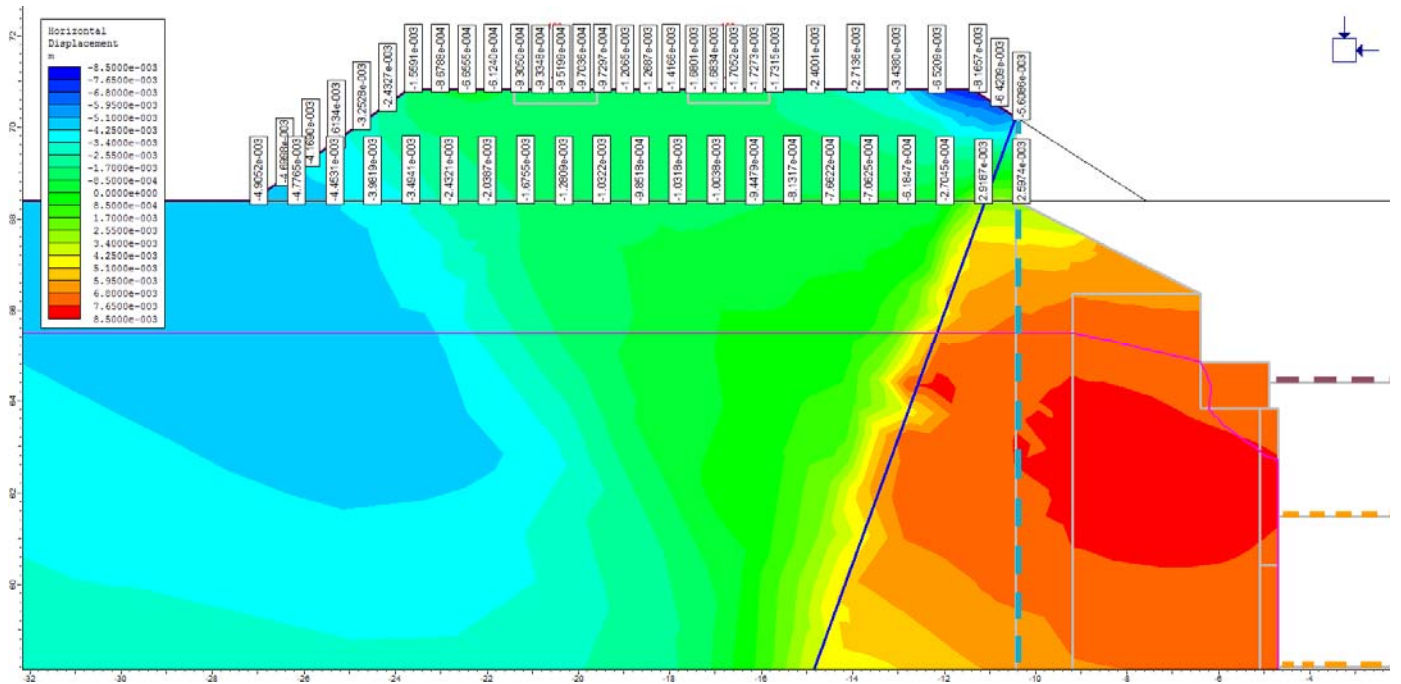
Galleria di Base binario Dispari. Progressiva pk₅₄₊₉₉₇.
 Spostamenti verticali dY. Fase finale di scavo più carico del treno. Carico non fattorizzato (SLE)



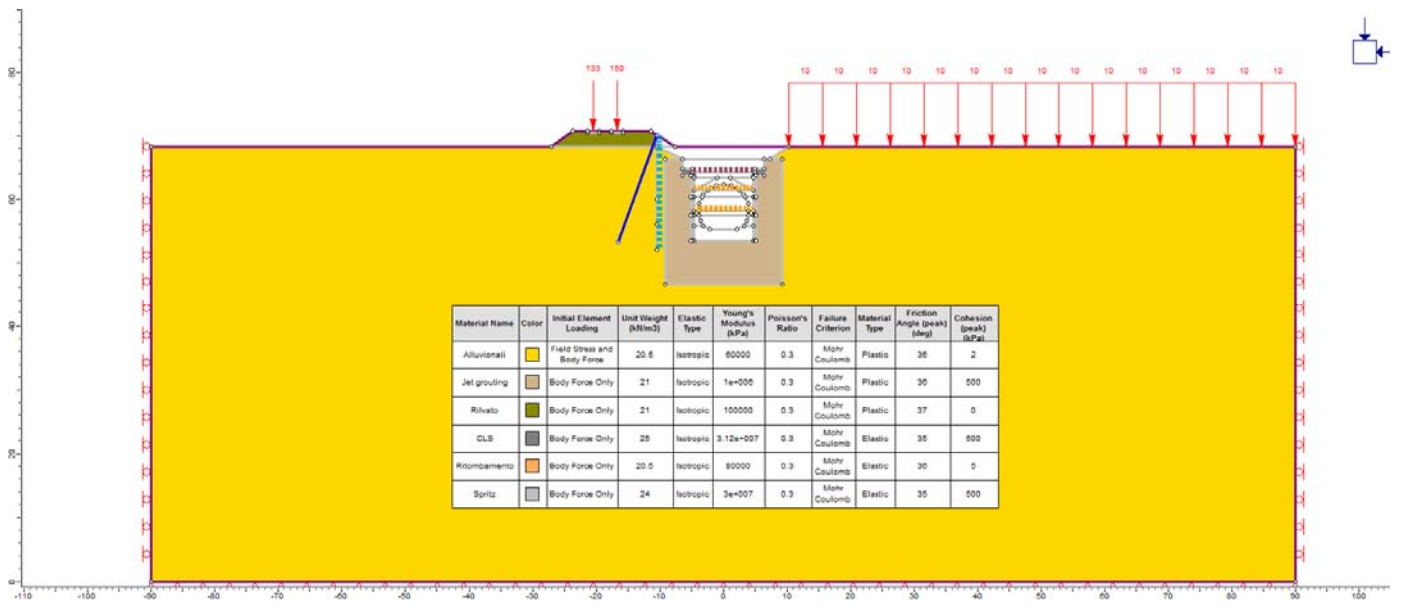
Galleria di Base binario Dispari. Progressiva pk₅₄₊₉₉₇.
 Spostamenti verticali dY. Fase finale di scavo più carico del treno. Particolare del rilevato ferroviario. Carico non fattorizzato (SLE)



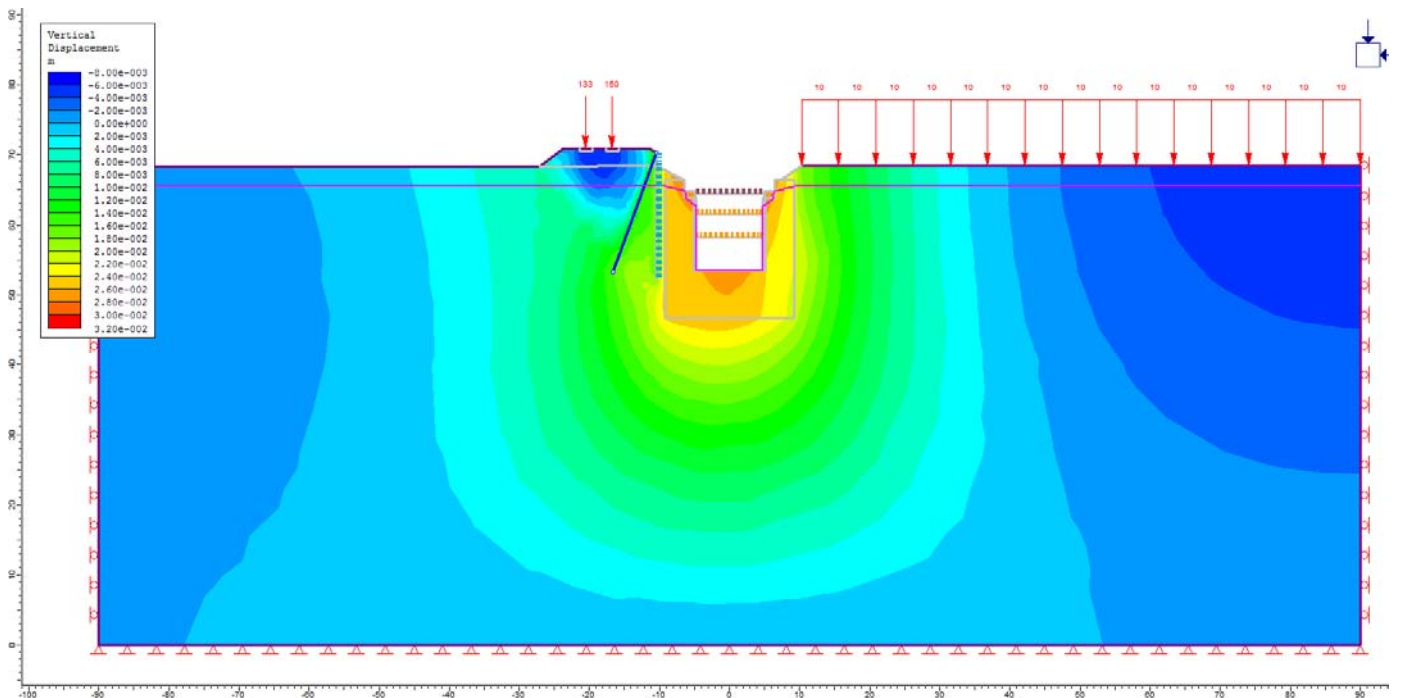
Galleria di Base binario Dispari. Progressiva pk₅₄+997. Spostamenti orizzontali dX. Fase finale di scavo più carico del treno. Carico non fattorizzato (SLE)



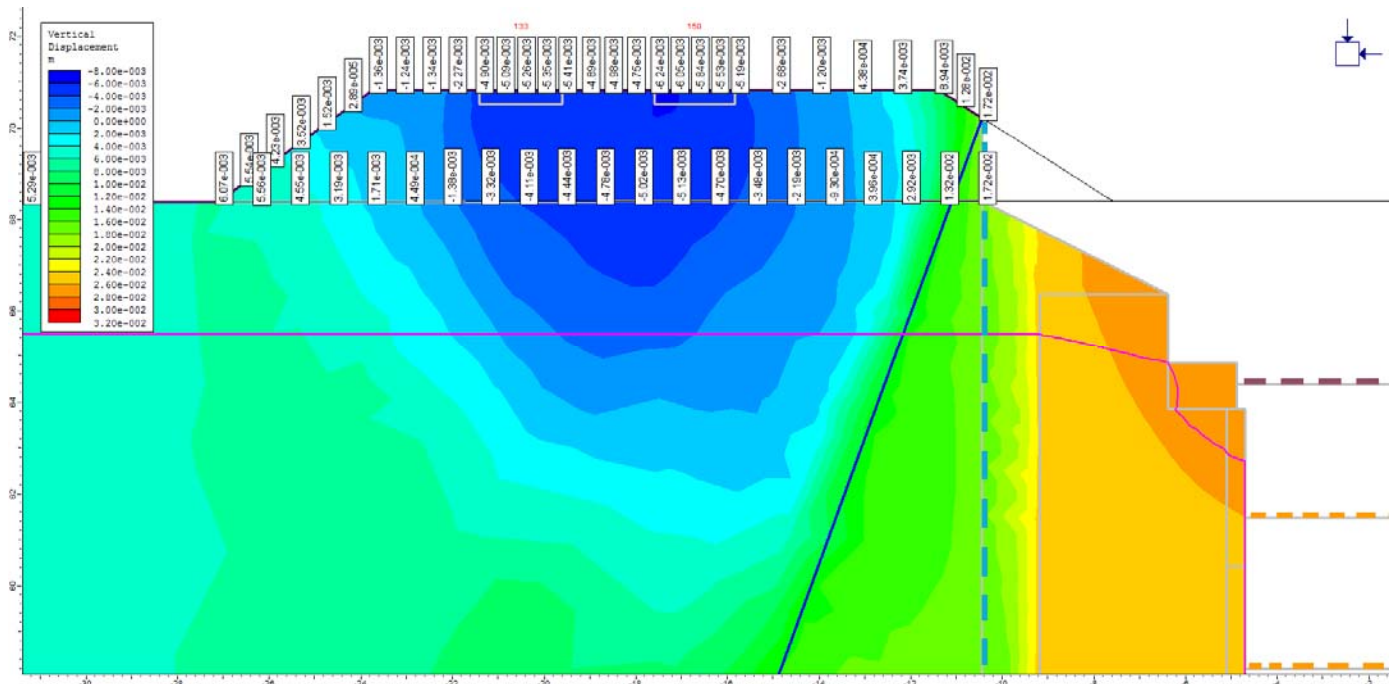
Galleria di Base binario Dispari. Progressiva pk₅₄+997. Spostamenti orizzontali dX. Fase finale di scavo più carico del treno. Particolare del rilevato ferroviario. Carico non fattorizzato (SLE)



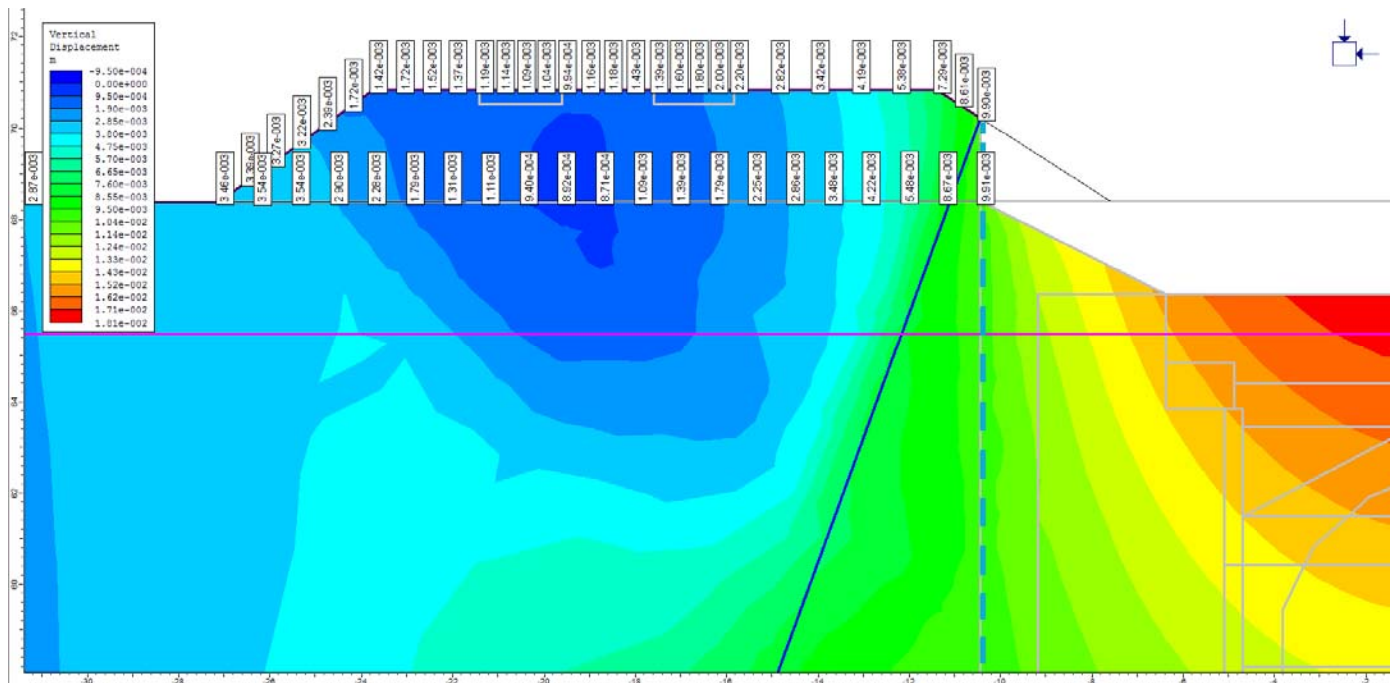
Geometria di calcolo per la Galleria di Base binario Dispari. Progressiva pk_54+997. Fase finale di scavo con carico del treno e carico distribuito durante costruzione.



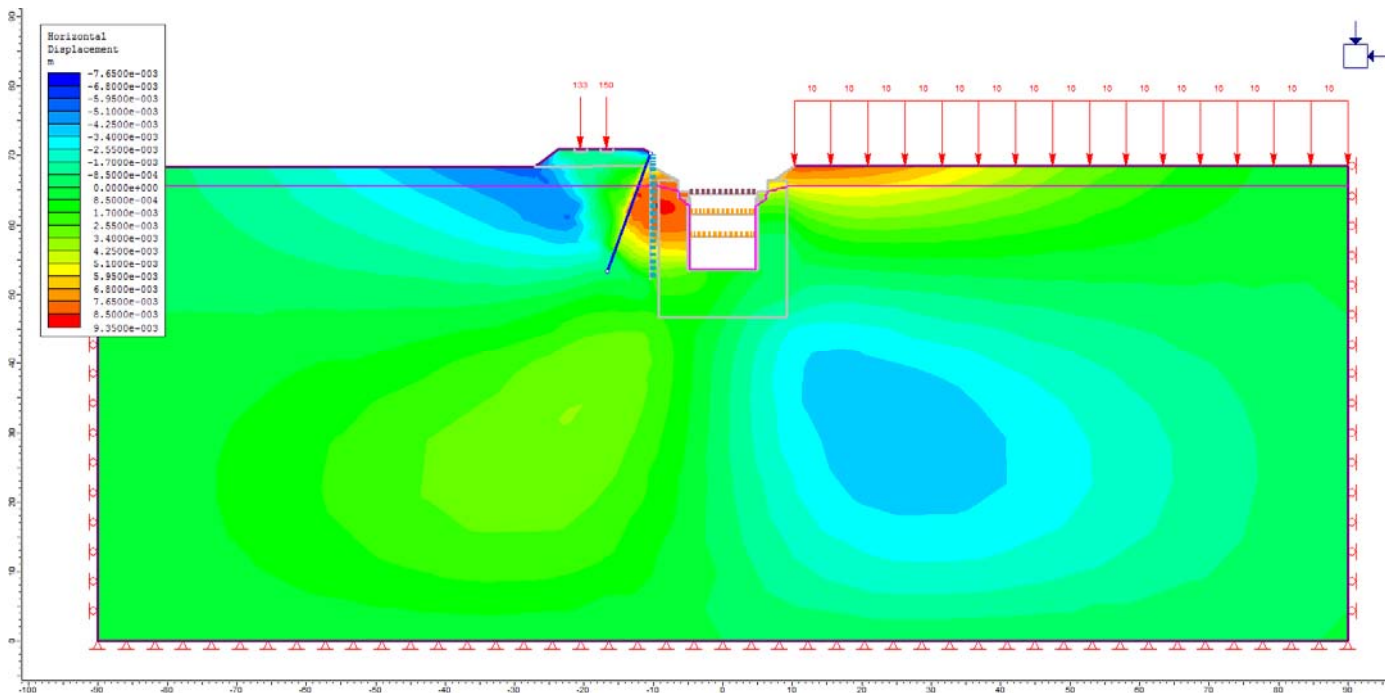
Galleria di Base binario Dispari. Progressiva pk_54+997. Spostamenti verticali dY. Fase finale di scavo, eseguito con carico del treno e carico distribuito durante costruzione. Carico non fattorizzato (SLE)



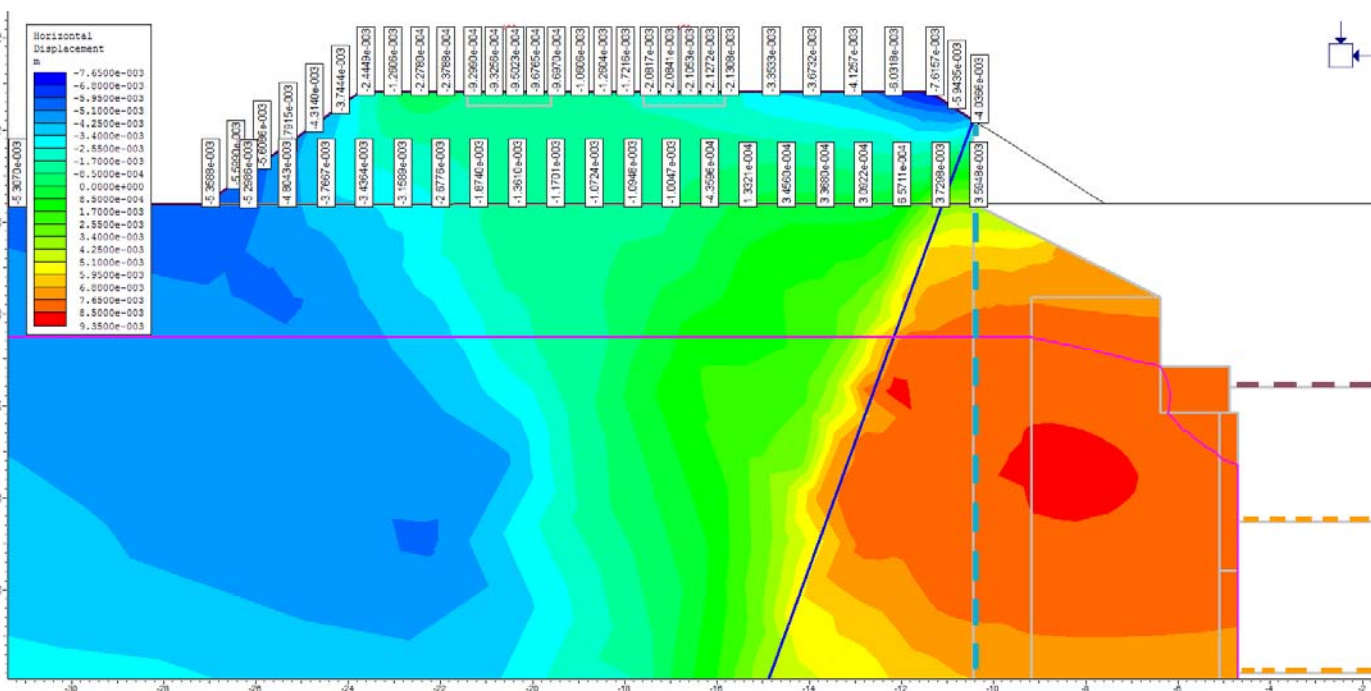
Galleria di Base binario Dispari. Progressiva pk_54+997. Spostamenti verticali dY. Fase finale di scavo, eseguito con carico del treno e carico distribuito durante costruzione. Particolare del rilevato ferroviario. Carico non fattorizzato (SLE)



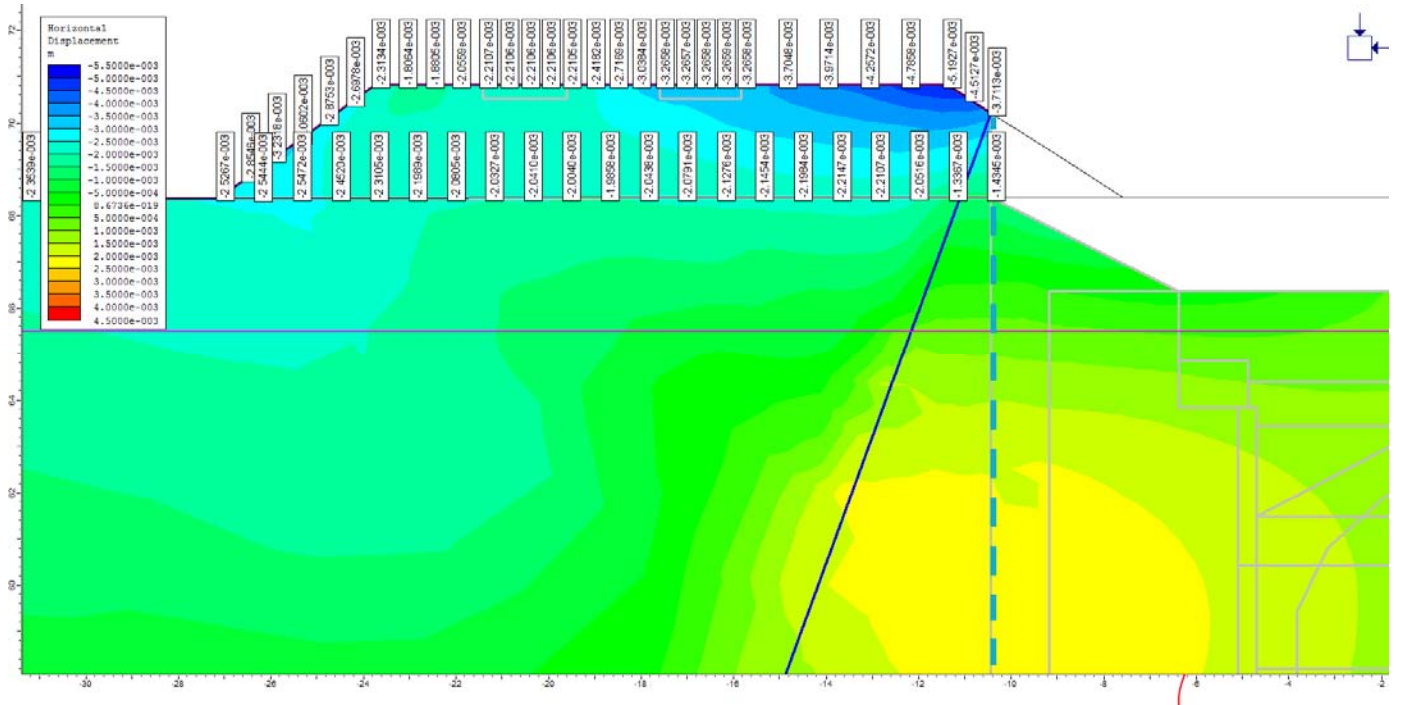
Galleria di Base binario Dispari. Progressiva pk_54+997. Spostamenti verticali dY. Fase di scavo fino a raggiungere quota del piano di lavoro del Jet grouting. Particolare del rilevato ferroviario. Carico non fattorizzato (SLE)



Galleria di Base binario Dispari. Progressiva pk₅₄+997. Spostamenti orizzontali dX. Fase finale di scavo, eseguito con carico del treno e carico distribuito durante costruzione. Carico non fattorizzato (SLE)



Galleria di Base binario Dispari. Progressiva pk₅₄+997. Spostamenti orizzontali dX. Fase finale di scavo, eseguito con carico del treno e carico distribuito durante costruzione. Particolare del rilevato ferroviario. Carico non fattorizzato (SLE)



Galleria di Base binario Dispari. Progressiva pk₅₄₊₉₉₇. Spostamenti orizzontali dX. Fase di scavo fino a raggiungere quota del piano di lavoro del Jet grouting. Particolare del rilevato ferroviario. Carico non fattorizzato (SLE)

Phase2 Analysis Information

Project Settings

- Document Name: Sez 55+007_M-C solo linea.fez
- Project Title: Phase2 - Finite Element Analysis of Excavations in Rock
- Number of Stages: 3
- Analysis Type: Plane Strain
- Solver Type: Gaussian Elimination
- Units: Metric, stress as kPa

Stress Analysis

- Maximum Number of Iterations: 9000
- Tolerance: 0.001
- Number of Load Steps: Automatic
- Convergence Type: Absolute Energy
- Tensile Failure: Reduces Shear Strength
- Joint tension reduces joint stiffness by a factor of 0.01

Groundwater

- Method: Finite Element Analysis
- Pore Fluid Unit Weight: 9.81 kN/m³
- Maximum Number of Iterations: 500
- Tolerance: 1e-006

Field Stress

- Field stress: gravity
- Using actual ground surface
- Effective stress ratio (horizontal/vertical in-plane): 1
- Effective stress ratio (horizontal/vertical out-of-plane): 1
- Locked-in horizontal stress (in-plane): 0
- Locked-in horizontal stress (out-of-plane): 0

Mesh

- Mesh type: graded
- Element type: 8 noded quadrilaterals
- Number of elements on Geostatico: 2209
- Number of nodes on Geostatico: 6704
- Number of elements on Paratia: 2209
- Number of nodes on Paratia: 6704
- Number of elements on Carico treno: 2209
- Number of nodes on Carico treno: 6704

Mesh Quality

- All elements are of good quality

Poor quality elements defined as:

- Side length ratio (maximum / minimum) > 30.00
- Minimum interior angle < 2.0 degrees
- Maximum interior angle > 175.0 degrees

Reset Displacements

- Displacements reset after: Geostatico
- Displacements reset after: Paratia

Material Properties

Material: Alluvionali

Initial element loading	field stress & body force
Unit weight	20.5 kN/m ³
Elastic type	isotropic
Young's modulus	60000 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	36 degrees
Peak cohesion	2 kPa
Material type	Plastic
Dilation Angle	1 degrees
Residual Friction Angle	35 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Properties changed in Paratia

- Unit weight: Young's modulus: 120000 kPa (factor = 2) Field Stress Gravity Ground surface elevation 0 m Unit weight of overburden 0.027 kN/m³ Effective stress ratio (horizontal/vertical in-plane) 0.413 Effective stress ratio (horizontal/vertical out-of-plane) 0.413 Locked-in horizontal stress (in-plane) 0 Locked-in horizontal stress (out-of-plane) 0

Material: Rilvato

Initial element loading	body force only
Unit weight	21 kN/m ³
Elastic type	isotropic
Young's modulus	100000 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	37 degrees
Peak cohesion	0 kPa
Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	37 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Material: CLS

Initial element loading	body force only
Unit weight	25 kN/m ³
Elastic type	isotropic
Young's modulus	3.12e+007 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	35 degrees
Peak cohesion	500 kPa
Material type	Elastic
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	1e-012 m/s
K2/K1	1
K Angle	0 degrees

Excavation Areas

Original Un-deformed Areas

- External Boundary Area: 12427.592 m²
- External Boundary Perimeter: 499.753 m

Geostatico

- External Boundary Area: 12427.592 m2 (0 m2 change from original area)
- External Boundary Perimeter: 499.753 m (0 m change from original perimeter)

Paratia

- Values not available until this stage is viewed in a window

Carico treno

- Values not available until this stage is viewed in a window

Displacements

- Displacement data is not available for Geostatico until total displacement is viewed in a window
- Displacement data is not available for Paratia until total displacement is viewed in a window
- Displacement data is not available for Carico treno until total displacement is viewed in a window

Yielded Elements

Yielded Mesh Elements

- Number of yielded mesh elements on Geostatico: 240
- Number of yielded mesh elements is not available for Paratia until the stage is viewed in a window
- Number of yielded mesh elements is not available for Carico treno until the stage is viewed in a window

Yielded Bolt Elements

- Number of yielded bolt elements on Geostatico: 0
- Number of yielded bolt elements on Paratia: 0
- Number of yielded bolt elements on Carico treno: 0

List of All Coordinates

External boundary

X	Y
-90.025	-0.0990423
89.975	-0.0990423
89.975	70.147
31.5255	70.147
15.761	70.147
12.459	69.633
7.864	67.42
-6.367	67.529
-10.4708	69.5569
-12.77	70.693

-15.463	70.691
-16.59	70.827
-18.355	70.827
-20.355	70.827
-22.168	70.827
-25.614	70.511
-31.8	67.332
-46.4304	67.332
-90.025	67.332

Material boundary

X	Y
-6.367	67.529
-10.4708	67.529
-31.8	67.332

Material boundary

X	Y
-9.216	66.221
-9.216	46.6008
9.22439	46.6008
9.22439	66.221
7.282	66.221

Material boundary

X	Y
7.282	66.221
15.761	70.147

Material boundary

X	Y
6.42399	64.7506
6.42399	63.7505
5.12494	63.7506
4.92399	63.7506
4.92399	64.3033
4.92399	64.7506
6.42399	64.7506
6.42399	66.221

Material boundary

X	Y
-6.416	64.751
-4.916	64.751
-4.916	64.3033
-4.916	63.751
-5.12	63.751
-6.416	63.751
-6.416	64.751

Material boundary

X	Y
-6.416	64.751
-6.416	66.221

Material boundary

X	Y
-4.71792	61.391
-0.996006	63.3408
1.00399	63.3408
4.72592	61.391
4.72592	60.3215
4.72592	58.1102
4.72592	57.5112
4.72592	55.7902
4.72592	53.4506
-4.71792	53.4509
-4.71792	55.7902
-4.71792	57.5112
-4.71792	58.1102
-4.71792	60.3215
-4.71792	61.391

Material boundary

X	Y
-4.916	64.3033
4.92399	64.3033

Material boundary

X	Y
---	---

-2.14601	55.2508
2.15399	55.2508
3.25963	55.7902
3.62535	56.6264
3.84882	57.5112
3.84882	58.1102
3.84882	59.3638
3.37492	60.3215
3.17534	60.7249
2.43557	61.391
1.96399	61.8156
1.21534	62.1489
0.00399426	62.3408
-1.20735	62.1489
-1.95601	61.8156
-2.42758	61.391
-3.16735	60.7249
-3.36693	60.3215
-3.84083	59.3638
-3.84083	58.1102
-3.84083	57.5112
-3.61736	56.6264
-3.25165	55.7902
-2.14601	55.2508

Material boundary

X	Y
-4.71792	61.391
-4.71792	63.3408
-4.71792	63.751
-4.916	63.751

Material boundary

X	Y
4.72592	61.391
4.72592	63.3408
4.72592	63.7506
4.92399	63.7506

Material boundary

X	Y
-16.59	70.827

-16.59	70.435
-18.355	70.435
-18.355	70.827

Material boundary

X	Y
-20.355	70.827
-20.355	70.425
-22.168	70.425
-22.168	70.827

Material boundary

X	Y
6.42399	66.221
-6.416	66.221

Material boundary

X	Y
-6.416	66.221
-9.216	66.221

Material boundary

X	Y
6.42399	66.221
7.282	66.221

Material boundary

X	Y
-10.4708	67.529
-10.4708	59.9072

Material boundary

X	Y
-10.4708	67.529
-10.4708	69.5569

Material boundary

X	Y
-10.4708	67.529
-6.416	66.221

Material boundary

X	Y
-0.996006	63.3408
-4.71792	63.3408

Material boundary

X	Y
1.00399	63.3408
4.72592	63.3408

Material boundary

X	Y
-5.12	63.751
-5.12	60.3215
-5.12	57.5112
-5.12	53.4509

Material boundary

X	Y
-4.71792	53.4509
-4.916	53.4509
-5.12	53.4509

Material boundary

X	Y
5.12494	63.7506
5.12494	60.3215
5.12494	57.5112
5.12494	53.4506

Material boundary

X	Y
4.72592	53.4506
4.92399	53.4506

5.12494	53.4506
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Material boundary

X	Y
-10.4708	59.9072
-10.4708	56.1056

Material boundary

X	Y
-10.4708	56.1056
-10.4708	52.0795

Material boundary

X	Y
4.72592	60.3215
3.37492	60.3215
-3.36693	60.3215
-4.71792	60.3215

Material boundary

X	Y
3.25963	55.7902
4.72592	55.7902

Material boundary

X	Y
-3.25165	55.7902
-4.71792	55.7902

Material boundary

X	Y
-4.71792	61.391
-2.42758	61.391
2.43557	61.391
4.72592	61.391

Material boundary

X	Y
-4.71792	58.1102
-3.84083	58.1102
3.84882	58.1102
4.72592	58.1102

Material boundary

X	Y
-4.916	57.5112
-4.71792	57.5112

Material boundary

X	Y
-4.916	60.3215
-4.71792	60.3215

Material boundary

X	Y
4.92399	57.5112
4.72592	57.5112
3.84882	57.5112
-3.84083	57.5112
-4.71792	57.5112

Material boundary

X	Y
4.72592	60.3215
4.92399	60.3215

Material boundary

X	Y
-4.916	60.3215
-5.12	60.3215

Material boundary

X	Y
4.92399	60.3215
5.12494	60.3215

Material boundary

X	Y
-4.916	57.5112
-5.12	57.5112

Material boundary

X	Y
4.92399	57.5112
5.12494	57.5112

Phase2 Analysis Information

Project Settings

- Document Name: Sez 55+007_M-C fondo scavo + carico.fez
- Project Title: Phase2 - Finite Element Analysis of Excavations in Rock
- Number of Stages: 17
- Analysis Type: Plane Strain
- Solver Type: Gaussian Elimination
- Units: Metric, stress as kPa

Stress Analysis

- Maximum Number of Iterations: 9000
- Tolerance: 0.001
- Number of Load Steps: Automatic
- Convergence Type: Absolute Energy
- Tensile Failure: Reduces Shear Strength
- Joint tension reduces joint stiffness by a factor of 0.01

Groundwater

- Method: Finite Element Analysis
- Pore Fluid Unit Weight: 9.81 kN/m³
- Maximum Number of Iterations: 500
- Tolerance: 1e-006

Field Stress

- Field stress: gravity
- Using actual ground surface
- Effective stress ratio (horizontal/vertical in-plane): 1
- Effective stress ratio (horizontal/vertical out-of-plane): 1
- Locked-in horizontal stress (in-plane): 0
- Locked-in horizontal stress (out-of-plane): 0

Mesh

- Mesh type: graded
- Element type: 8 noded quadrilaterals
- Number of elements on Geostatico: 1908
- Number of nodes on Geostatico: 5799
- Number of elements on Paratia: 1908
- Number of nodes on Paratia: 5799
- Number of elements on Piano lavoro: 1830
- Number of nodes on Piano lavoro: 5587
- Number of elements on Jet: 1830
- Number of nodes on Jet: 5587
- Number of elements on I ribasso: 1727
- Number of nodes on I ribasso: 5306
- Number of elements on I puntone: 1727
- Number of nodes on I puntone: 5306
- Number of elements on II ribasso: 1555
- Number of nodes on II ribasso: 4830

- Number of elements on II puntone: 1555
- Number of nodes on II puntone: 4830
- Number of elements on III ribasso: 1406
- Number of nodes on III ribasso: 4405
- Number of elements on III puntone: 1406
- Number of nodes on III puntone: 4405
- Number of elements on Fondo scavo: 1202
- Number of nodes on Fondo scavo: 3817
- Number of elements on CARICO TRENO: 1202
- Number of nodes on CARICO TRENO: 3817
- Number of elements on Solettone: 1307
- Number of nodes on Solettone: 4120
- Number of elements on Rimozione puntone: 1307
- Number of nodes on Rimozione puntone: 4120
- Number of elements on Getto calotta: 1458
- Number of nodes on Getto calotta: 4580
- Number of elements on Rimozione puntone: 1458
- Number of nodes on Rimozione puntone: 4580
- Number of elements on Ritombamento: 1604
- Number of nodes on Ritombamento: 4968

Mesh Quality

- All elements are of good quality

Poor quality elements defined as:

- Side length ratio (maximum / minimum) > 30.00
- Minimum interior angle < 2.0 degrees
- Maximum interior angle > 175.0 degrees

Reset Displacements

- Displacements reset after: Geostatico
- Displacements reset after: Paratia

Material Properties

Material: Alluvionali

Initial element loading	field stress & body force
Unit weight	20.5 kN/m ³
Elastic type	isotropic
Young's modulus	60000 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	36 degrees
Peak cohesion	2 kPa
Material type	Plastic
Dilation Angle	1 degrees

Residual Friction Angle	35 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Properties changed in Paratia

- Unit weight:

Properties changed in Jet

- Unit weight: Young's modulus: 120000 kPa (factor = 2) Field Stress Gravity Ground surface elevation 0 m Unit weight of overburden 0.027 kN/m³ Effective stress ratio (horizontal/vertical in-plane) 0.413 Effective stress ratio (horizontal/vertical out-of-plane) 0.413 Locked-in horizontal stress (in-plane) 0 Locked-in horizontal stress (out-of-plane) 0

Material: Jet grouting

Initial element loading	body force only
Unit weight	21 kN/m ³
Elastic type	isotropic
Young's modulus	1e+006 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	75 kPa
Peak friction angle	36 degrees
Peak cohesion	500 kPa
Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	36 degrees
Residual Cohesion	500 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	1e-008 m/s
K2/K1	1
K Angle	0 degrees

Material: Rilvato

Initial element loading	body force only
Unit weight	21 kN/m ³
Elastic type	isotropic

Young's modulus	100000 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	37 degrees
Peak cohesion	0 kPa
Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	37 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Material: CLS

Initial element loading	body force only
Unit weight	25 kN/m ³
Elastic type	isotropic
Young's modulus	3.12e+007 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	35 degrees
Peak cohesion	500 kPa
Material type	Elastic
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	1e-012 m/s
K2/K1	1
K Angle	0 degrees

Material: Ritombamento

Initial element loading	body force only
Unit weight	20.5 kN/m ³
Elastic type	isotropic
Young's modulus	80000 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa

Peak friction angle	36 degrees
Peak cohesion	5 kPa
Material type	Elastic
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Material: Spritz

Initial element loading	body force only
Unit weight	24 kN/m ³
Elastic type	isotropic
Young's modulus	3e+007 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	1 kPa
Peak friction angle	35 degrees
Peak cohesion	500 kPa
Material type	Elastic
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	1e-008 m/s
K2/K1	1
K Angle	0 degrees

Properties changed in Rimozione puntone

- Ks: 1e-010 m/s (factor = 0.01) K Angle: 0 degrees (factor = 0)

Excavation Areas

Original Un-deformed Areas

- External Boundary Area: 12427.592 m²
- External Boundary Perimeter: 499.753 m

Geostatico

- External Boundary Area: 12427.592 m² (0 m² change from original area)
- External Boundary Perimeter: 499.753 m (0 m change from original perimeter)

Paratia

- Values not available until this stage is viewed in a window

Piano lavoro

- Values not available until this stage is viewed in a window

Jet

- Values not available until this stage is viewed in a window

I ribasso

- Values not available until this stage is viewed in a window

I puntone

- Values not available until this stage is viewed in a window

II ribasso

- Values not available until this stage is viewed in a window

II puntone

- Values not available until this stage is viewed in a window

III ribasso

- Values not available until this stage is viewed in a window

III puntone

- Values not available until this stage is viewed in a window

Fondo scavo

- Values not available until this stage is viewed in a window

CARICO TRENO

- Values not available until this stage is viewed in a window

Solettone

- Values not available until this stage is viewed in a window

Rimozione puntone

- Values not available until this stage is viewed in a window

Getto calotta

- Values not available until this stage is viewed in a window

Rimozione puntone

- Values not available until this stage is viewed in a window

Ritombamento

- Values not available until this stage is viewed in a window

Liner Properties

Liner: Tubo_F355_sp12/4m

Liner Type	Standard Beam
Formulation	Timoshenko
Area	0.003236 m ²
Moment of Inertia	4.782e-005 m ⁴

Elastic Properties

Young's modulus	2.1e+008 kPa
Poisson's ratio	0.2
Liner Unit Weight	78.5 kN/m ³

Liner: Tubo_F406_sp12.5/4m

Liner Type	Standard Beam
Formulation	Timoshenko
Area	0.003865 m ²
Moment of Inertia	7.503e-005 m ⁴

Elastic Properties

Young's modulus	2.1e+008 kPa
Poisson's ratio	0.2
Liner Unit Weight	78.5 kN/m ³

Liner: 1Micropali 168.3/0.45m

Liner Type	Standard Beam
Formulation	Timoshenko

Area	0.204 m ²
Moment of Inertia	0.000574 m ⁴

Elastic Properties

Young's modulus	3e+007 kPa
Poisson's ratio	0.2

Displacements

- Displacement data is not available for Geostatico until total displacement is viewed in a window
- Displacement data is not available for Paratia until total displacement is viewed in a window
- Displacement data is not available for Piano lavoro until total displacement is viewed in a window
- Displacement data is not available for Jet until total displacement is viewed in a window
- Displacement data is not available for I ribasso until total displacement is viewed in a window
- Displacement data is not available for I puntone until total displacement is viewed in a window
- Displacement data is not available for II ribasso until total displacement is viewed in a window
- Displacement data is not available for II puntone until total displacement is viewed in a window
- Displacement data is not available for III ribasso until total displacement is viewed in a window
- Displacement data is not available for III puntone until total displacement is viewed in a window
- Displacement data is not available for Fondo scavo until total displacement is viewed in a window
- Displacement data is not available for CARICO TRENO until total displacement is viewed in a window
- Displacement data is not available for Solettone until total displacement is viewed in a window
- Displacement data is not available for Rimozione puntone until total displacement is viewed in a window
- Displacement data is not available for Getto calotta until total displacement is viewed in a window
- Displacement data is not available for Rimozione puntone until total displacement is viewed in a window
- Displacement data is not available for Ritombamento until total displacement is viewed in a window

Yielded Elements

Yielded Mesh Elements

- Number of yielded mesh elements on Geostatico: 185
- Number of yielded mesh elements is not available for Paratia until the stage is viewed in a window
- Number of yielded mesh elements is not available for Piano lavoro until the stage is viewed in a window
- Number of yielded mesh elements is not available for Jet until the stage is viewed in a window
- Number of yielded mesh elements is not available for I ribasso until the stage is viewed in a window
- Number of yielded mesh elements is not available for I puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for II ribasso until the stage is viewed in a window
- Number of yielded mesh elements is not available for II puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for III ribasso until the stage is viewed in a window
- Number of yielded mesh elements is not available for III puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for Fondo scavo until the stage is viewed in a window
- Number of yielded mesh elements is not available for CARICO TRENO until the stage is viewed in a window
- Number of yielded mesh elements is not available for Solettone until the stage is viewed in a window
- Number of yielded mesh elements is not available for Rimozione puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for Getto calotta until the stage is viewed in a window
- Number of yielded mesh elements is not available for Rimozione puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for Ritombamento until the stage is viewed in a window

Yielded Bolt Elements

- Number of yielded bolt elements on Geostatico: 0
- Number of yielded bolt elements on Paratia: 0
- Number of yielded bolt elements on Piano lavoro: 0

- Number of yielded bolt elements on Jet: 0
- Number of yielded bolt elements on I ribasso: 0
- Number of yielded bolt elements on I puntone: 0
- Number of yielded bolt elements on II ribasso: 0
- Number of yielded bolt elements on II puntone: 0
- Number of yielded bolt elements on III ribasso: 0
- Number of yielded bolt elements on III puntone: 0
- Number of yielded bolt elements on Fondo scavo: 0
- Number of yielded bolt elements on CARICO TRENO: 0
- Number of yielded bolt elements on Solettone: 0
- Number of yielded bolt elements on Rimozione puntone: 0
- Number of yielded bolt elements on Getto calotta: 0
- Number of yielded bolt elements on Rimozione puntone: 0
- Number of yielded bolt elements on Ritombamento: 0

Yielded Liner Elements

- Number of yielded liner elements on Geostatico: 0
- Number of yielded liner elements on Paratia: 0
- Number of yielded liner elements on Piano lavoro: 0
- Number of yielded liner elements on Jet: 0
- Number of yielded liner elements on I ribasso: 0
- Number of yielded liner elements on I puntone: 0
- Number of yielded liner elements on II ribasso: 0
- Number of yielded liner elements on II puntone: 0
- Number of yielded liner elements on III ribasso: 0
- Number of yielded liner elements on III puntone: 0
- Number of yielded liner elements on Fondo scavo: 0
- Number of yielded liner elements on CARICO TRENO: 0
- Number of yielded liner elements on Solettone: 0
- Number of yielded liner elements on Rimozione puntone: 0
- Number of yielded liner elements on Getto calotta: 0
- Number of yielded liner elements on Rimozione puntone: 0
- Number of yielded liner elements on Ritombamento: 0

List of All Coordinates

External boundary

X	Y
-90.025	-0.0990423
89.975	-0.0990423
89.975	70.147
31.5255	70.147
15.761	70.147
12.459	69.633
7.864	67.42
-6.367	67.529
-10.4708	69.5569
-12.77	70.693
-15.463	70.691
-16.59	70.827
-18.355	70.827

-20.355	70.827
-22.168	70.827
-25.614	70.511
-31.8	67.332
-46.4304	67.332
-90.025	67.332

Material boundary

X	Y
-6.367	67.529
-10.4708	67.529
-31.8	67.332

Material boundary

X	Y
-9.216	66.221
-9.216	46.6008
9.22439	46.6008
9.22439	66.221
7.282	66.221

Material boundary

X	Y
7.282	66.221
15.761	70.147

Material boundary

X	Y
6.42399	64.7506
6.42399	63.7505
5.12494	63.7506
4.92399	63.7506
4.92399	64.3033
4.92399	64.7506
6.42399	64.7506
6.42399	66.221

Material boundary

X	Y
-6.416	64.751

-4.916	64.751
-4.916	64.3033
-4.916	63.751
-5.12	63.751
-6.416	63.751
-6.416	64.751

Material boundary

X	Y
-6.416	64.751
-6.416	66.221

Material boundary

X	Y
-4.71792	61.391
-0.996006	63.3408
1.00399	63.3408
4.72592	61.391
4.72592	60.3215
4.72592	58.1102
4.72592	57.5112
4.72592	55.7902
4.72592	53.4506
-4.71792	53.4509
-4.71792	55.7902
-4.71792	57.5112
-4.71792	58.1102
-4.71792	60.3215
-4.71792	61.391

Material boundary

X	Y
-4.916	64.3033
4.92399	64.3033

Material boundary

X	Y
-2.14601	55.2508
2.15399	55.2508
3.25963	55.7902
3.62535	56.6264

3.84882	57.5112
3.84882	58.1102
3.84882	59.3638
3.37492	60.3215
3.17534	60.7249
2.43557	61.391
1.96399	61.8156
1.21534	62.1489
0.00399426	62.3408
-1.20735	62.1489
-1.95601	61.8156
-2.42758	61.391
-3.16735	60.7249
-3.36693	60.3215
-3.84083	59.3638
-3.84083	58.1102
-3.84083	57.5112
-3.61736	56.6264
-3.25165	55.7902
-2.14601	55.2508

Material boundary

X	Y
-4.71792	61.391
-4.71792	63.3408
-4.71792	63.751
-4.916	63.751

Material boundary

X	Y
4.72592	61.391
4.72592	63.3408
4.72592	63.7506
4.92399	63.7506

Material boundary

X	Y
-16.59	70.827
-16.59	70.435
-18.355	70.435
-18.355	70.827

Material boundary

X	Y
-20.355	70.827
-20.355	70.425
-22.168	70.425
-22.168	70.827

Material boundary

X	Y
6.42399	66.221
-6.416	66.221

Material boundary

X	Y
-6.416	66.221
-9.216	66.221

Material boundary

X	Y
6.42399	66.221
7.282	66.221

Material boundary

X	Y
-10.4708	67.529
-10.4708	59.9072

Material boundary

X	Y
-10.4708	67.529
-10.4708	69.5569

Material boundary

X	Y
-10.4708	67.529
-6.416	66.221

Material boundary

X	Y
-0.996006	63.3408
-4.71792	63.3408

Material boundary

X	Y
1.00399	63.3408
4.72592	63.3408

Material boundary

X	Y
-5.12	63.751
-5.12	60.3215
-5.12	57.5112
-5.12	53.4509

Material boundary

X	Y
-4.71792	53.4509
-4.916	53.4509
-5.12	53.4509

Material boundary

X	Y
5.12494	63.7506
5.12494	60.3215
5.12494	57.5112
5.12494	53.4506

Material boundary

X	Y
4.72592	53.4506
4.92399	53.4506
5.12494	53.4506

Material boundary

X	Y
-10.4708	59.9072

-10.4708	56.1056
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Material boundary

X	Y
-10.4708	56.1056
-10.4708	52.0795

Material boundary

X	Y
4.72592	60.3215
3.37492	60.3215
-3.36693	60.3215
-4.71792	60.3215

Material boundary

X	Y
3.25963	55.7902
4.72592	55.7902

Material boundary

X	Y
-3.25165	55.7902
-4.71792	55.7902

Material boundary

X	Y
-4.71792	61.391
-2.42758	61.391
2.43557	61.391
4.72592	61.391

Material boundary

X	Y
-4.71792	58.1102
-3.84083	58.1102
3.84882	58.1102
4.72592	58.1102

Material boundary

X	Y
-4.916	57.5112
-4.71792	57.5112

Material boundary

X	Y
-4.916	60.3215
-4.71792	60.3215

Material boundary

X	Y
4.92399	57.5112
4.72592	57.5112
3.84882	57.5112
-3.84083	57.5112
-4.71792	57.5112

Material boundary

X	Y
4.72592	60.3215
4.92399	60.3215

Material boundary

X	Y
-4.916	60.3215
-5.12	60.3215

Material boundary

X	Y
4.92399	60.3215
5.12494	60.3215

Material boundary

X	Y
-4.916	57.5112
-5.12	57.5112

Material boundary

X	Y
4.92399	57.5112
5.12494	57.5112

Phase2 Analysis Information

Project Settings

- Document Name: Sez 55+007_M-C fondo scavo con carico.fez
- Project Title: Phase2 - Finite Element Analysis of Excavations in Rock
- Number of Stages: 16
- Analysis Type: Plane Strain
- Solver Type: Gaussian Elimination
- Units: Metric, stress as kPa

Stress Analysis

- Maximum Number of Iterations: 9000
- Tolerance: 0.001
- Number of Load Steps: Automatic
- Convergence Type: Absolute Energy
- Tensile Failure: Reduces Shear Strength
- Joint tension reduces joint stiffness by a factor of 0.01

Groundwater

- Method: Finite Element Analysis
- Pore Fluid Unit Weight: 9.81 kN/m³
- Maximum Number of Iterations: 500
- Tolerance: 1e-006

Field Stress

- Field stress: gravity
- Using actual ground surface
- Effective stress ratio (horizontal/vertical in-plane): 1
- Effective stress ratio (horizontal/vertical out-of-plane): 1
- Locked-in horizontal stress (in-plane): 0
- Locked-in horizontal stress (out-of-plane): 0

Mesh

- Mesh type: graded
- Element type: 8 noded quadrilaterals
- Number of elements on Geostatico: 1908
- Number of nodes on Geostatico: 5799
- Number of elements on Paratia: 1908
- Number of nodes on Paratia: 5799
- Number of elements on Piano lavoro: 1830
- Number of nodes on Piano lavoro: 5587
- Number of elements on Jet: 1830
- Number of nodes on Jet: 5587
- Number of elements on I ribasso: 1727
- Number of nodes on I ribasso: 5306
- Number of elements on I puntone: 1727
- Number of nodes on I puntone: 5306
- Number of elements on II ribasso: 1555
- Number of nodes on II ribasso: 4830
- Number of elements on II puntone: 1555

- Number of nodes on II puntone: 4830
- Number of elements on III ribasso: 1406
- Number of nodes on III ribasso: 4405
- Number of elements on III puntone: 1406
- Number of nodes on III puntone: 4405
- Number of elements on Fondo scavo: 1202
- Number of nodes on Fondo scavo: 3817
- Number of elements on Solettone: 1307
- Number of nodes on Solettone: 4120
- Number of elements on Rimozione puntone: 1307
- Number of nodes on Rimozione puntone: 4120
- Number of elements on Getto calotta: 1458
- Number of nodes on Getto calotta: 4580
- Number of elements on Rimozione puntone: 1458
- Number of nodes on Rimozione puntone: 4580
- Number of elements on Ritombamento: 1604
- Number of nodes on Ritombamento: 4968

Mesh Quality

- All elements are of good quality

Poor quality elements defined as:

- Side length ratio (maximum / minimum) > 30.00
- Minimum interior angle < 2.0 degrees
- Maximum interior angle > 175.0 degrees

Reset Displacements

- Displacements reset after: Geostatico
- Displacements reset after: Paratia

Material Properties

Material: Alluvionali

Initial element loading	field stress & body force
Unit weight	20.5 kN/m ³
Elastic type	isotropic
Young's modulus	60000 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	36 degrees
Peak cohesion	2 kPa
Material type	Plastic
Dilation Angle	1 degrees
Residual Friction Angle	35 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees

Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Properties changed in Paratia

- Unit weight:

Properties changed in Jet

- Unit weight: Young's modulus: 120000 kPa (factor = 2) Field Stress Gravity Ground surface elevation 0 m Unit weight of overburden 0.027 kN/m³ Effective stress ratio (horizontal/vertical in-plane) 0.413 Effective stress ratio (horizontal/vertical out-of-plane) 0.413 Locked-in horizontal stress (in-plane) 0 Locked-in horizontal stress (out-of-plane) 0

Material: Jet grouting

Initial element loading	body force only
Unit weight	21 kN/m ³
Elastic type	isotropic
Young's modulus	1e+006 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	75 kPa
Peak friction angle	36 degrees
Peak cohesion	500 kPa
Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	36 degrees
Residual Cohesion	500 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	1e-008 m/s
K2/K1	1
K Angle	0 degrees

Material: Rilvato

Initial element loading	body force only
Unit weight	21 kN/m ³
Elastic type	isotropic
Young's modulus	100000 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb

Tensile strength	0 kPa
Peak friction angle	37 degrees
Peak cohesion	0 kPa
Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	37 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Material: CLS

Initial element loading	body force only
Unit weight	25 kN/m ³
Elastic type	isotropic
Young's modulus	3.12e+007 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	35 degrees
Peak cohesion	500 kPa
Material type	Elastic
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	1e-012 m/s
K2/K1	1
K Angle	0 degrees

Material: Ritombamento

Initial element loading	body force only
Unit weight	20.5 kN/m ³
Elastic type	isotropic
Young's modulus	80000 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	36 degrees
Peak cohesion	5 kPa
Material type	Elastic

Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Material: Spritz

Initial element loading	body force only
Unit weight	24 kN/m3
Elastic type	isotropic
Young's modulus	3e+007 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	1 kPa
Peak friction angle	35 degrees
Peak cohesion	500 kPa
Material type	Elastic
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	1e-008 m/s
K2/K1	1
K Angle	0 degrees

Properties changed in Rimozione puntone

- Ks: 1e-010 m/s (factor = 0.01)K Angle: 0 degrees (factor = 0)

Excavation Areas

Original Un-deformed Areas

- External Boundary Area: 12427.592 m2
- External Boundary Perimeter: 499.753 m

Geostatico

- External Boundary Area: 12427.592 m2 (0 m2 change from original area)
- External Boundary Perimeter: 499.753 m (0 m change from original perimeter)

Paratia

- Values not available until this stage is viewed in a window

Piano lavoro

- Values not available until this stage is viewed in a window

Jet

- Values not available until this stage is viewed in a window

I ribasso

- Values not available until this stage is viewed in a window

I puntone

- Values not available until this stage is viewed in a window

II ribasso

- Values not available until this stage is viewed in a window

II puntone

- Values not available until this stage is viewed in a window

III ribasso

- Values not available until this stage is viewed in a window

III puntone

- Values not available until this stage is viewed in a window

Fondo scavo

- Values not available until this stage is viewed in a window

Solettone

- Values not available until this stage is viewed in a window

Rimozione puntone

- Values not available until this stage is viewed in a window

Getto calotta

- Values not available until this stage is viewed in a window

Rimozione puntone

- Values not available until this stage is viewed in a window

Ritombamento

- Values not available until this stage is viewed in a window

Liner Properties

Liner: Tubo_F355_sp12/4m

Liner Type	Standard Beam
Formulation	Timoshenko
Area	0.003236 m ²
Moment of Inertia	4.782e-005 m ⁴

Elastic Properties

Young's modulus	2.1e+008 kPa
Poisson's ratio	0.2
Liner Unit Weight	78.5 kN/m ³

Liner: Tubo_F406_sp12.5/4m

Liner Type	Standard Beam
Formulation	Timoshenko
Area	0.003865 m ²
Moment of Inertia	7.503e-005 m ⁴

Elastic Properties

Young's modulus	2.1e+008 kPa
Poisson's ratio	0.2
Liner Unit Weight	78.5 kN/m ³

Liner: 1Micropali 168.3/0.45m

Liner Type	Standard Beam
Formulation	Timoshenko
Area	0.204 m ²
Moment of Inertia	0.000574 m ⁴

Elastic Properties

Young's modulus	3e+007 kPa
Poisson's ratio	0.2

Displacements

- Displacement data is not available for Geostatico until total displacement is viewed in a window
- Displacement data is not available for Paratia until total displacement is viewed in a window
- Displacement data is not available for Piano lavoro until total displacement is viewed in a window
- Displacement data is not available for Jet until total displacement is viewed in a window
- Displacement data is not available for I ribasso until total displacement is viewed in a window
- Displacement data is not available for I puntone until total displacement is viewed in a window
- Displacement data is not available for II ribasso until total displacement is viewed in a window
- Displacement data is not available for II puntone until total displacement is viewed in a window
- Displacement data is not available for III ribasso until total displacement is viewed in a window
- Displacement data is not available for III puntone until total displacement is viewed in a window
- Displacement data is not available for Fondo scavo until total displacement is viewed in a window
- Displacement data is not available for Solettone until total displacement is viewed in a window
- Displacement data is not available for Rimozione puntone until total displacement is viewed in a window
- Displacement data is not available for Getto calotta until total displacement is viewed in a window
- Displacement data is not available for Rimozione puntone until total displacement is viewed in a window
- Displacement data is not available for Ritombamento until total displacement is viewed in a window

Yielded Elements

Yielded Mesh Elements

- Number of yielded mesh elements on Geostatico: 185
- Number of yielded mesh elements is not available for Paratia until the stage is viewed in a window
- Number of yielded mesh elements is not available for Piano lavoro until the stage is viewed in a window
- Number of yielded mesh elements is not available for Jet until the stage is viewed in a window
- Number of yielded mesh elements is not available for I ribasso until the stage is viewed in a window
- Number of yielded mesh elements is not available for I puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for II ribasso until the stage is viewed in a window
- Number of yielded mesh elements is not available for II puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for III ribasso until the stage is viewed in a window
- Number of yielded mesh elements is not available for III puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for Fondo scavo until the stage is viewed in a window
- Number of yielded mesh elements is not available for Solettone until the stage is viewed in a window
- Number of yielded mesh elements is not available for Rimozione puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for Getto calotta until the stage is viewed in a window
- Number of yielded mesh elements is not available for Rimozione puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for Ritombamento until the stage is viewed in a window

Yielded Bolt Elements

- Number of yielded bolt elements on Geostatico: 0
- Number of yielded bolt elements on Paratia: 0
- Number of yielded bolt elements on Piano lavoro: 0
- Number of yielded bolt elements on Jet: 0
- Number of yielded bolt elements on I ribasso: 0
- Number of yielded bolt elements on I puntone: 0
- Number of yielded bolt elements on II ribasso: 0
- Number of yielded bolt elements on II puntone: 0
- Number of yielded bolt elements on III ribasso: 0
- Number of yielded bolt elements on III puntone: 0
- Number of yielded bolt elements on Fondo scavo: 0
- Number of yielded bolt elements on Solettone: 0

- Number of yielded bolt elements on Rimozione puntone: 0
- Number of yielded bolt elements on Getto calotta: 0
- Number of yielded bolt elements on Rimozione puntone: 0
- Number of yielded bolt elements on Ritombamento: 0

Yielded Liner Elements

- Number of yielded liner elements on Geostatico: 0
- Number of yielded liner elements on Paratia: 0
- Number of yielded liner elements on Piano lavoro: 0
- Number of yielded liner elements on Jet: 0
- Number of yielded liner elements on I ribasso: 0
- Number of yielded liner elements on I puntone: 0
- Number of yielded liner elements on II ribasso: 0
- Number of yielded liner elements on II puntone: 0
- Number of yielded liner elements on III ribasso: 0
- Number of yielded liner elements on III puntone: 0
- Number of yielded liner elements on Fondo scavo: 0
- Number of yielded liner elements on Solettone: 0
- Number of yielded liner elements on Rimozione puntone: 0
- Number of yielded liner elements on Getto calotta: 0
- Number of yielded liner elements on Rimozione puntone: 0
- Number of yielded liner elements on Ritombamento: 0

List of All Coordinates

External boundary

X	Y
-90.025	-0.0990423
89.975	-0.0990423
89.975	70.147
31.5255	70.147
15.761	70.147
12.459	69.633
7.864	67.42
-6.367	67.529
-10.4708	69.5569
-12.77	70.693
-15.463	70.691
-16.59	70.827
-18.355	70.827
-20.355	70.827
-22.168	70.827
-25.614	70.511
-31.8	67.332
-46.4304	67.332
-90.025	67.332

Material boundary

X	Y
-6.367	67.529
-10.4708	67.529
-31.8	67.332

Material boundary

X	Y
-9.216	66.221
-9.216	46.6008
9.22439	46.6008
9.22439	66.221
7.282	66.221

Material boundary

X	Y
7.282	66.221
15.761	70.147

Material boundary

X	Y
6.42399	64.7506
6.42399	63.7505
5.12494	63.7506
4.92399	63.7506
4.92399	64.3033
4.92399	64.7506
6.42399	64.7506
6.42399	66.221

Material boundary

X	Y
-6.416	64.751
-4.916	64.751
-4.916	64.3033
-4.916	63.751
-5.12	63.751
-6.416	63.751
-6.416	64.751

Material boundary

X	Y
-6.416	64.751
-6.416	66.221

Material boundary

X	Y
-4.71792	61.391
-0.996006	63.3408
1.00399	63.3408
4.72592	61.391
4.72592	60.3215
4.72592	58.1102
4.72592	57.5112
4.72592	55.7902
4.72592	53.4506
-4.71792	53.4509
-4.71792	55.7902
-4.71792	57.5112
-4.71792	58.1102
-4.71792	60.3215
-4.71792	61.391

Material boundary

X	Y
-4.916	64.3033
4.92399	64.3033

Material boundary

X	Y
-2.14601	55.2508
2.15399	55.2508
3.25963	55.7902
3.62535	56.6264
3.84882	57.5112
3.84882	58.1102
3.84882	59.3638
3.37492	60.3215
3.17534	60.7249
2.43557	61.391
1.96399	61.8156
1.21534	62.1489
0.00399426	62.3408

-1.20735	62.1489
-1.95601	61.8156
-2.42758	61.391
-3.16735	60.7249
-3.36693	60.3215
-3.84083	59.3638
-3.84083	58.1102
-3.84083	57.5112
-3.61736	56.6264
-3.25165	55.7902
-2.14601	55.2508

Material boundary

X	Y
-4.71792	61.391
-4.71792	63.3408
-4.71792	63.751
-4.916	63.751

Material boundary

X	Y
4.72592	61.391
4.72592	63.3408
4.72592	63.7506
4.92399	63.7506

Material boundary

X	Y
-16.59	70.827
-16.59	70.435
-18.355	70.435
-18.355	70.827

Material boundary

X	Y
-20.355	70.827
-20.355	70.425
-22.168	70.425
-22.168	70.827

Material boundary

X	Y
6.42399	66.221
-6.416	66.221

Material boundary

X	Y
-6.416	66.221
-9.216	66.221

Material boundary

X	Y
6.42399	66.221
7.282	66.221

Material boundary

X	Y
-10.4708	67.529
-10.4708	59.9072

Material boundary

X	Y
-10.4708	67.529
-10.4708	69.5569

Material boundary

X	Y
-10.4708	67.529
-6.416	66.221

Material boundary

X	Y
-0.996006	63.3408
-4.71792	63.3408

Material boundary

X	Y
---	---

1.00399	63.3408
4.72592	63.3408

Material boundary

X	Y
-5.12	63.751
-5.12	60.3215
-5.12	57.5112
-5.12	53.4509

Material boundary

X	Y
-4.71792	53.4509
-4.916	53.4509
-5.12	53.4509

Material boundary

X	Y
5.12494	63.7506
5.12494	60.3215
5.12494	57.5112
5.12494	53.4506

Material boundary

X	Y
4.72592	53.4506
4.92399	53.4506
5.12494	53.4506

Material boundary

X	Y
-10.4708	59.9072
-10.4708	56.1056

Material boundary

X	Y
-10.4708	56.1056
-10.4708	52.0795

Material boundary

X	Y
4.72592	60.3215
3.37492	60.3215
-3.36693	60.3215
-4.71792	60.3215

Material boundary

X	Y
3.25963	55.7902
4.72592	55.7902

Material boundary

X	Y
-3.25165	55.7902
-4.71792	55.7902

Material boundary

X	Y
-4.71792	61.391
-2.42758	61.391
2.43557	61.391
4.72592	61.391

Material boundary

X	Y
-4.71792	58.1102
-3.84083	58.1102
3.84882	58.1102
4.72592	58.1102

Material boundary

X	Y
-4.916	57.5112
-4.71792	57.5112

Material boundary

X	Y
---	---

-4.916	60.3215
-4.71792	60.3215

Material boundary

X	Y
4.92399	57.5112
4.72592	57.5112
3.84882	57.5112
-3.84083	57.5112
-4.71792	57.5112

Material boundary

X	Y
4.72592	60.3215
4.92399	60.3215

Material boundary

X	Y
-4.916	60.3215
-5.12	60.3215

Material boundary

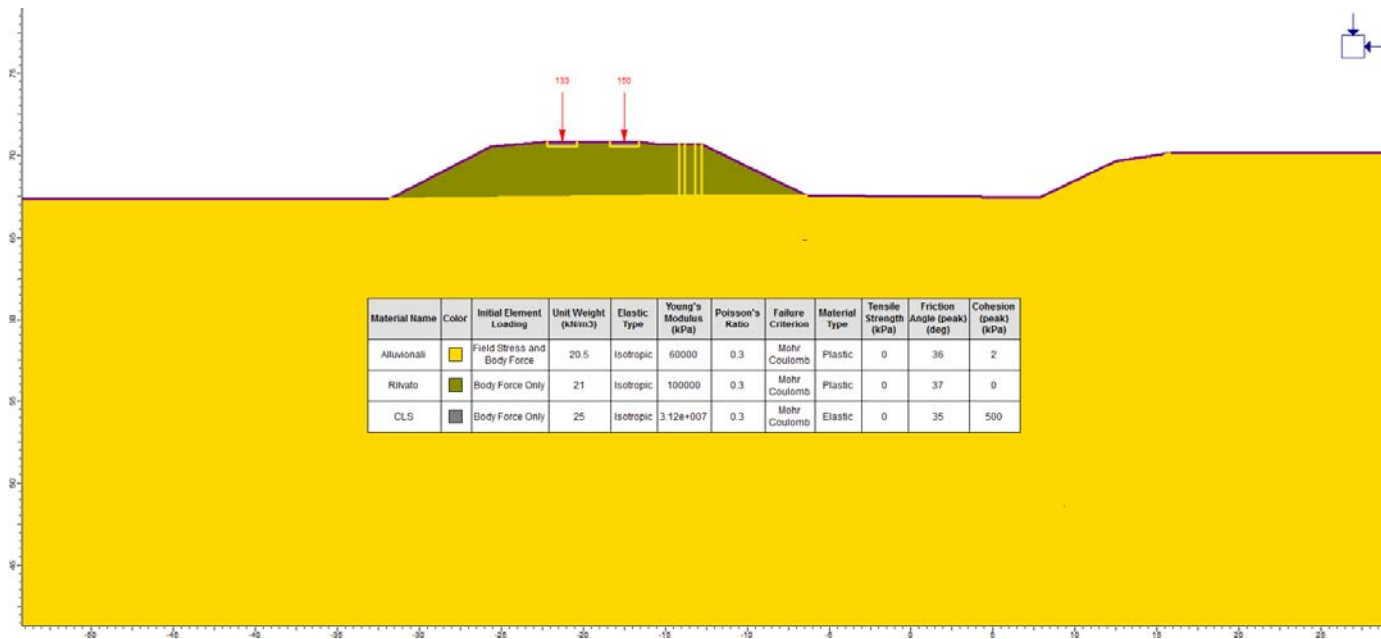
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5.12494	60.3215

Material boundary

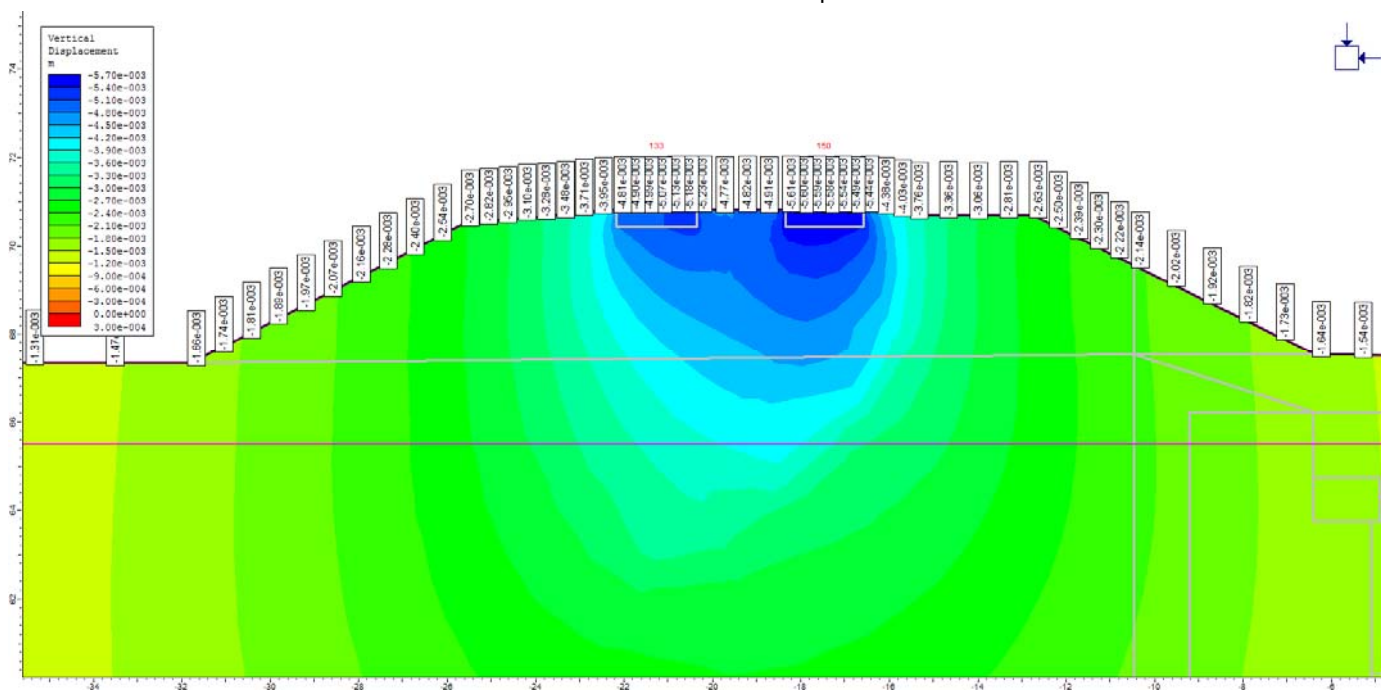
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-5.12	57.5112

Material boundary

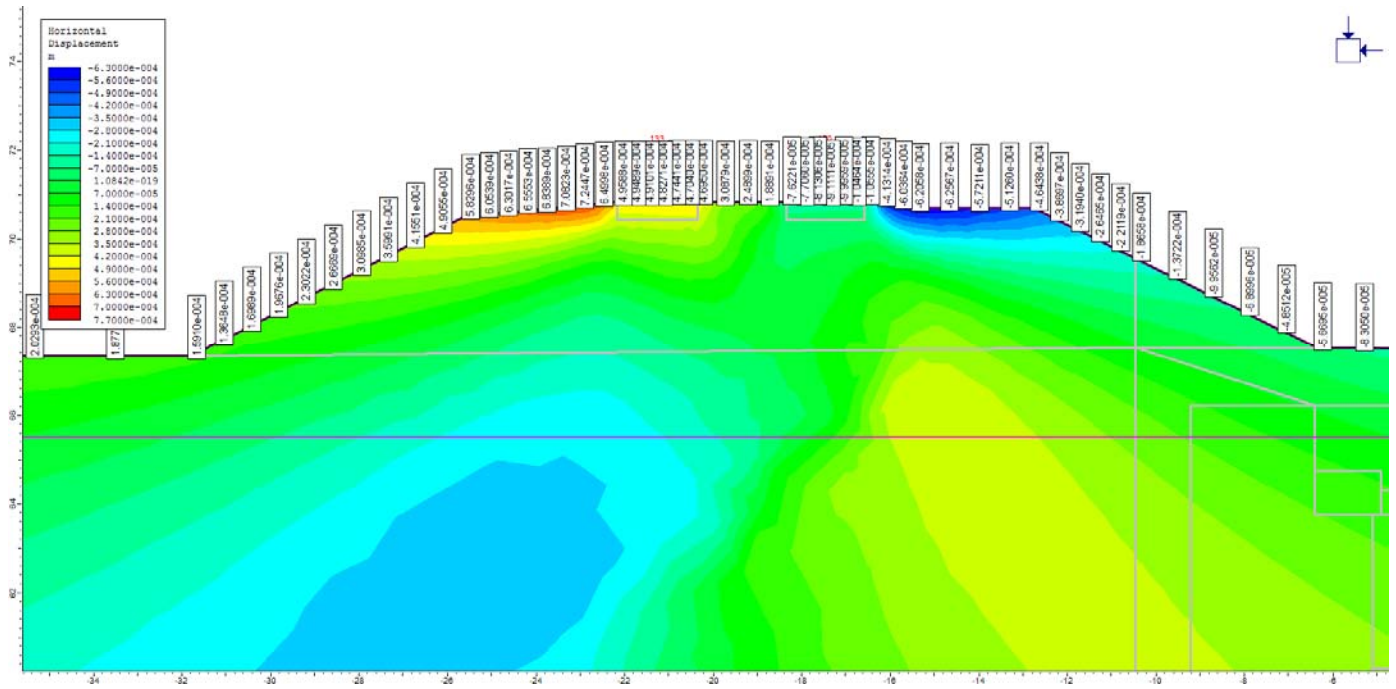
X	Y
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5.12494	57.5112



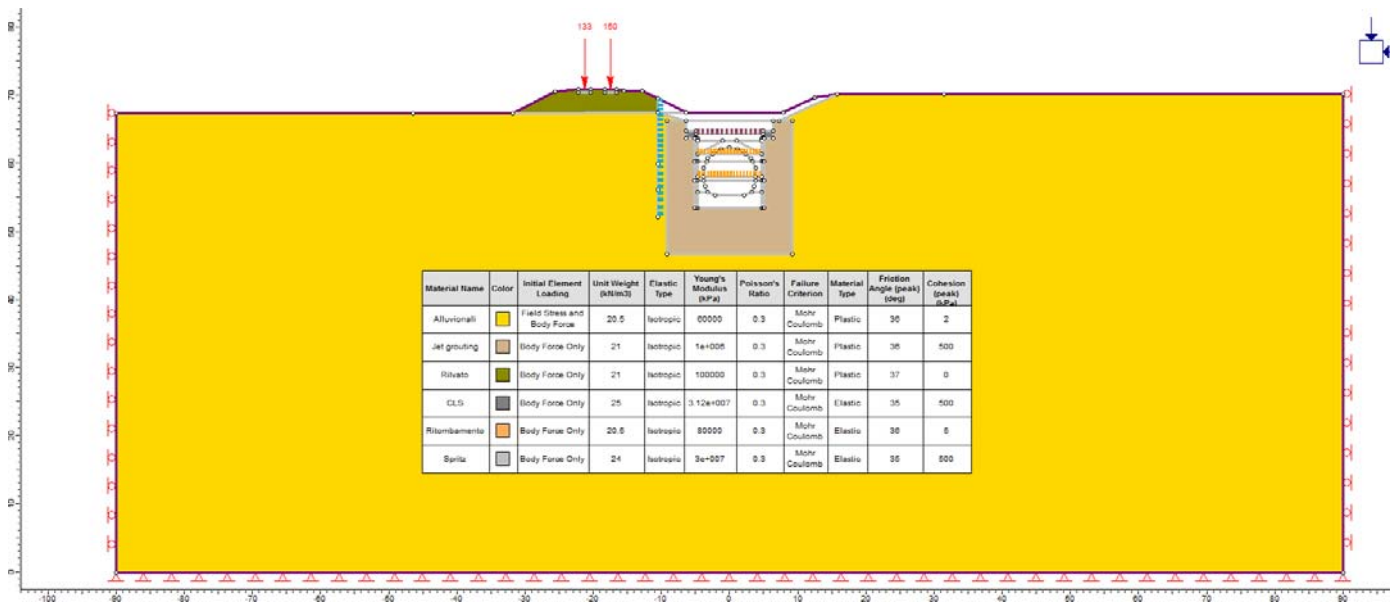
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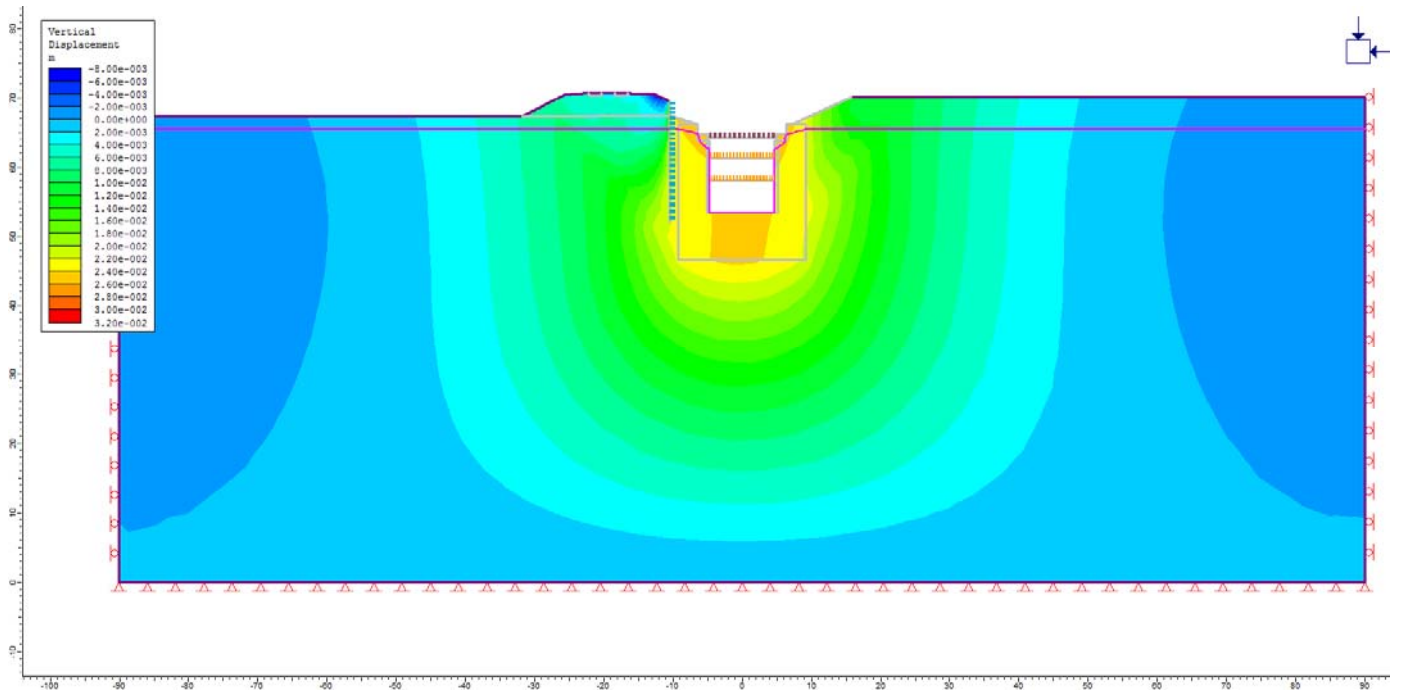
Galleria di Base binario Dispari. Progressiva pk_55+007. Spostamenti verticali dY. Carico del treno applicato al rilevato ferroviario prima dello scavo. Carico non fattorizzato (SLE)



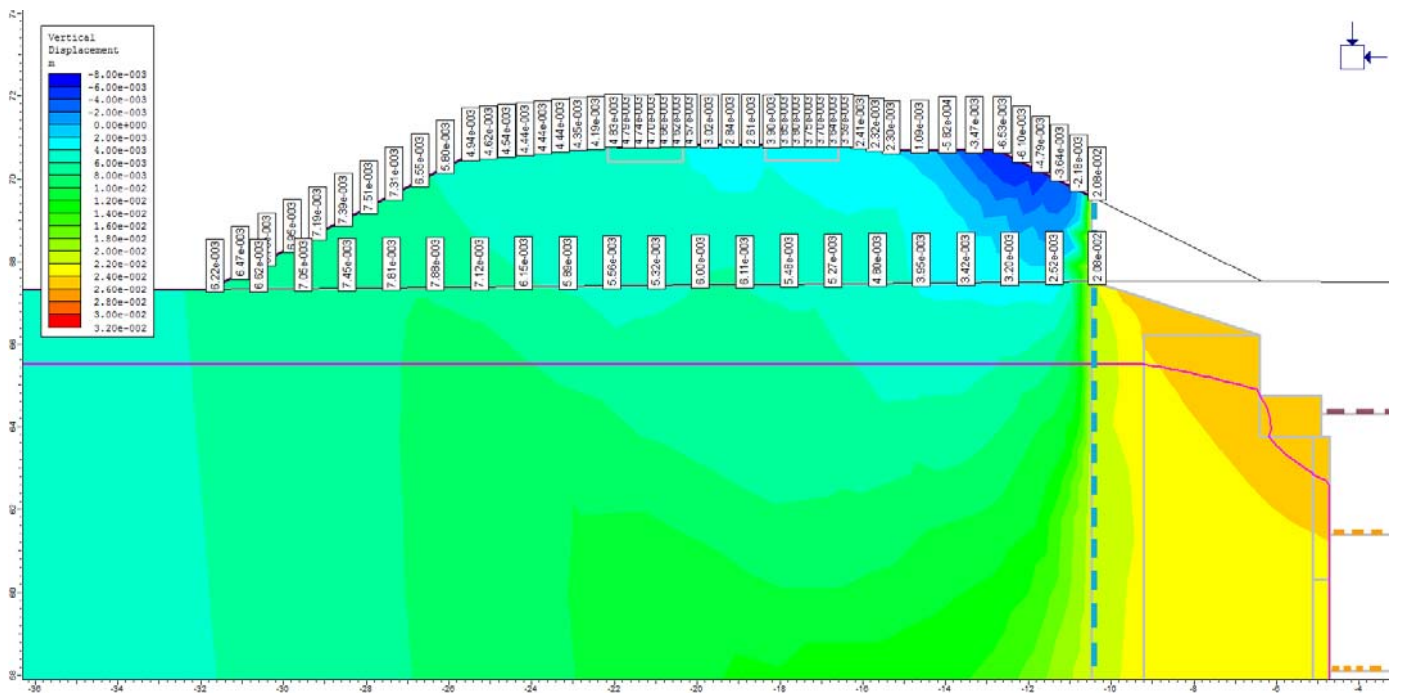
Galleria di Base binario Dispari. Progressiva pk₅₅+007. Spostamenti verticali dX. Carico del treno applicato al rilevato ferroviario prima dello scavo. Carico non fattorizzato (SLE)



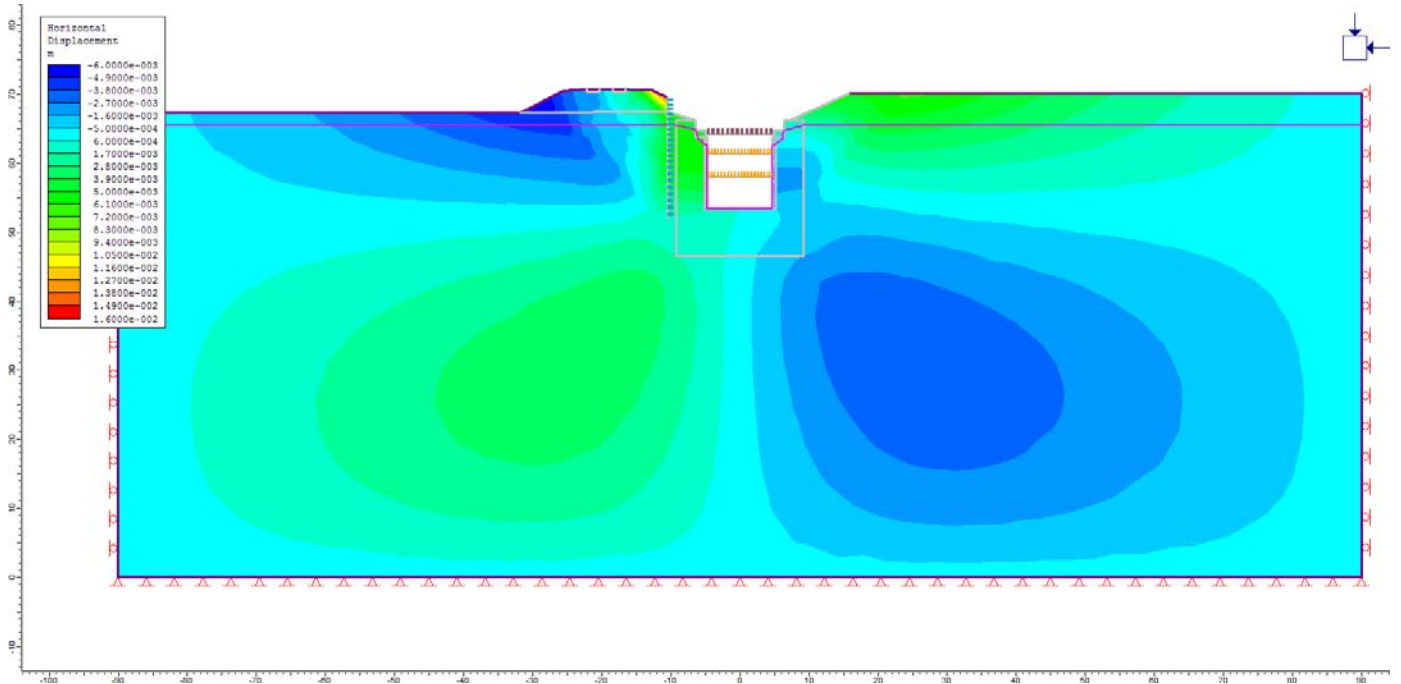
Geometria di calcolo per la Galleria di Base binario Dispari. Progressiva pk₅₅+007. Fase finale di scavo più carico del treno.



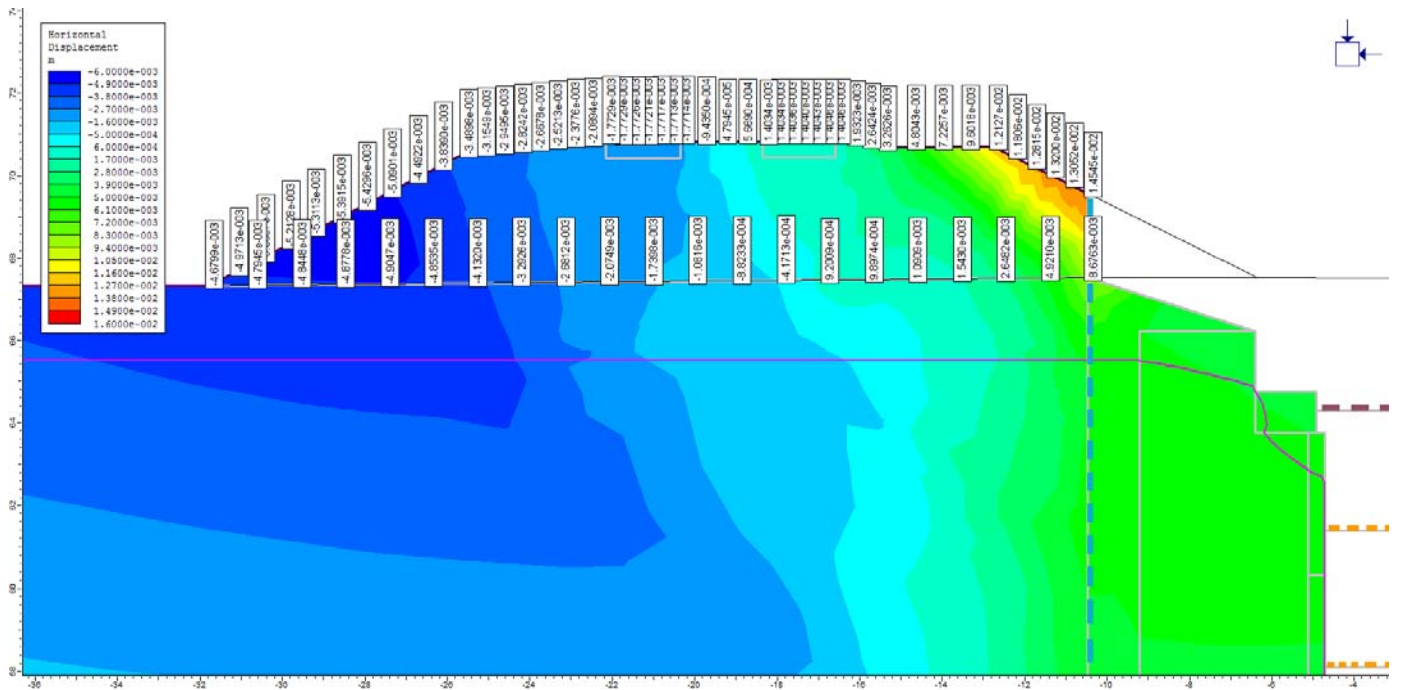
Galleria di Base binario Dispari. Progressiva pk_55+007. Spostamenti verticali dY. Fase finale di scavo. Carico non fattorizzato (SLE)



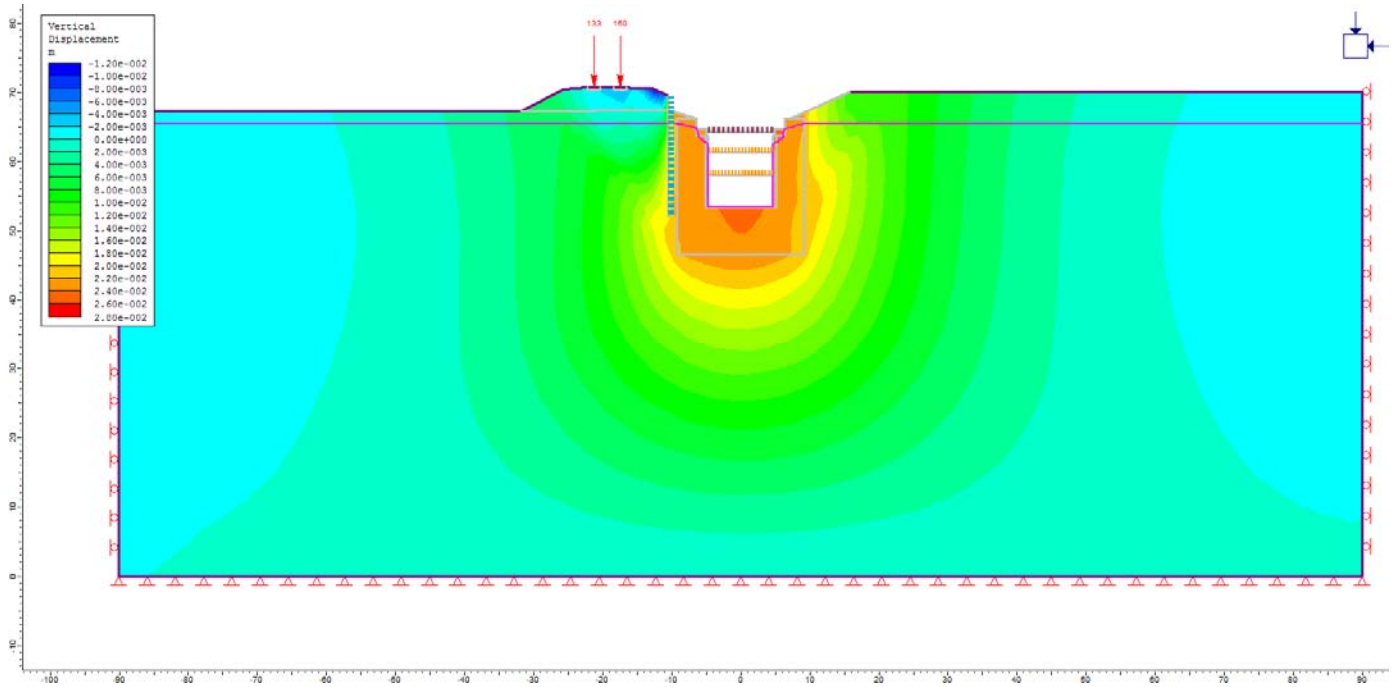
Galleria di Base binario Dispari. Progressiva pk_55+007. Spostamenti verticali dY. Fase finale di scavo. Particolare del rilevato ferroviario. Carico non fattorizzato (SLE)



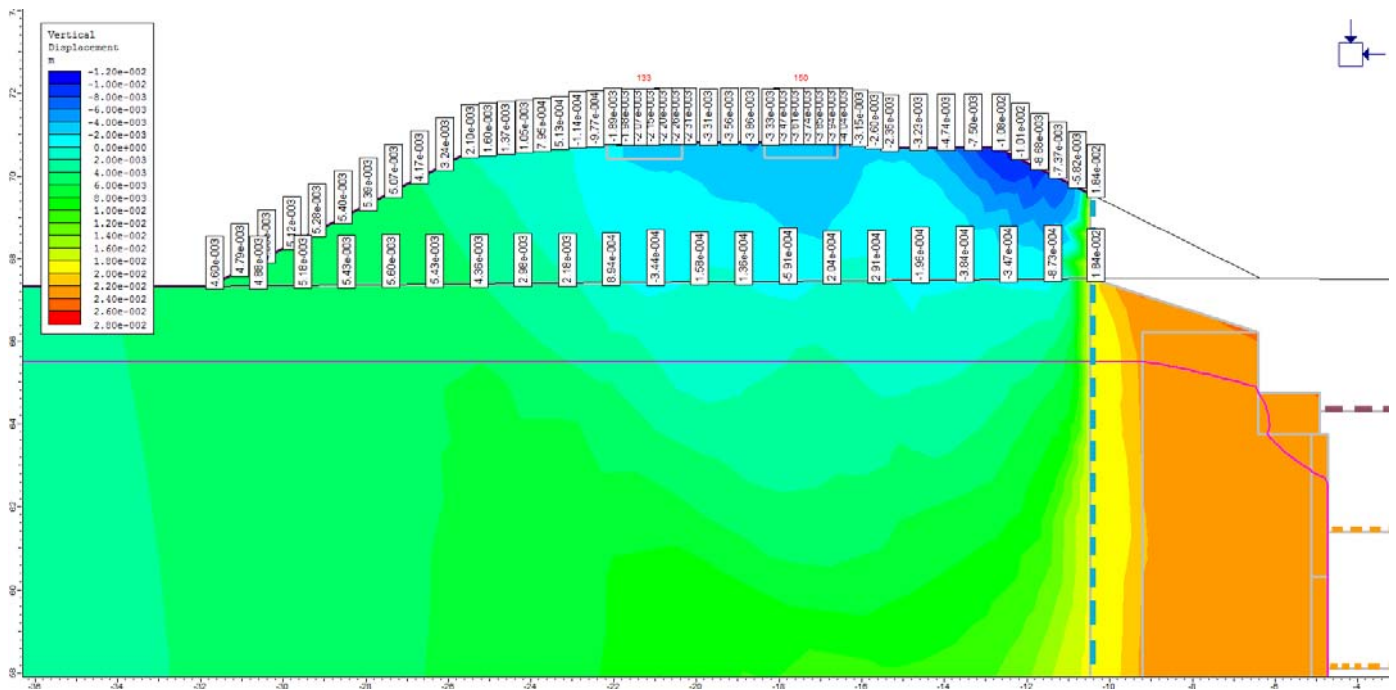
Galleria di Base binario Dispari. Progressiva pk_55+007. Spostamenti orizzontali dX. Fase finale di scavo. Carico non fattorizzato (SLE)



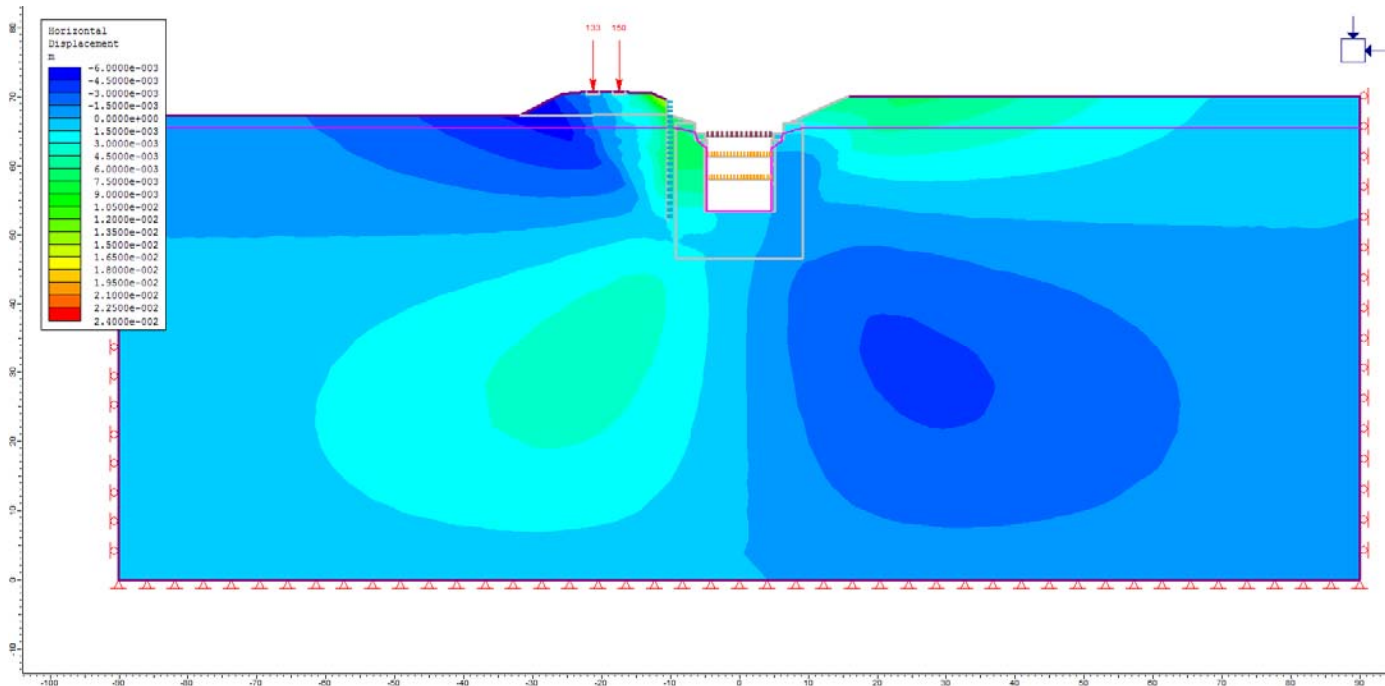
Galleria di Base binario Dispari. Progressiva pk_55+007. Spostamenti orizzontali dX. Fase finale di scavo. Particolare del rilevato ferroviario. Carico non fattorizzato (SLE)



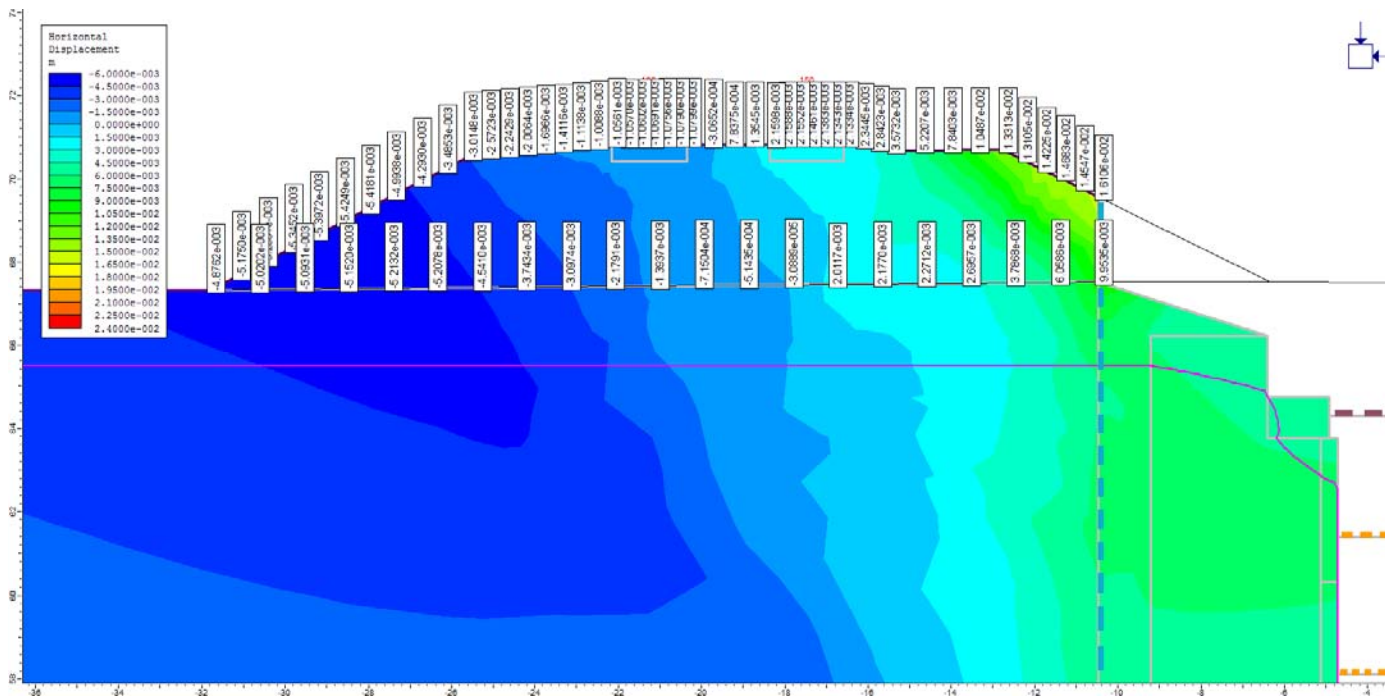
Galleria di Base binario Dispari. Progressiva pk_55+007. Spostamenti verticali dY. Fase finale di scavo più carico del treno. Carico non fattorizzato (SLE)



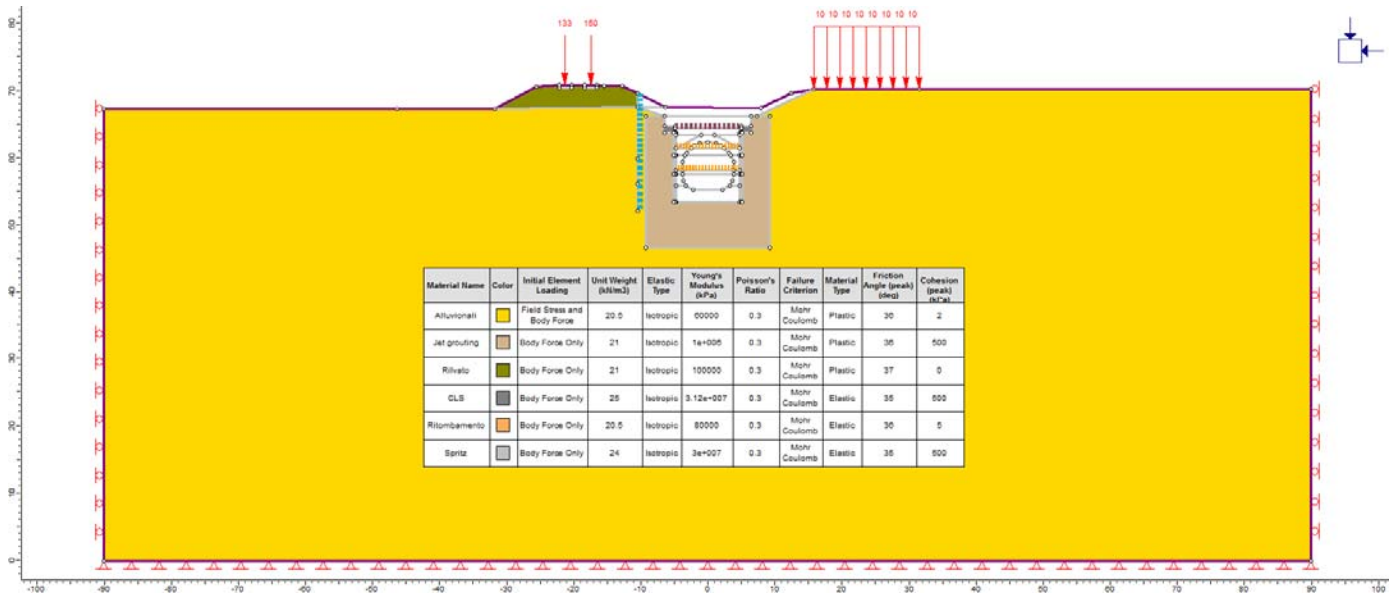
Galleria di Base binario Dispari. Progressiva pk_55+007. Spostamenti verticali dY. Fase finale di scavo più carico del treno. Particolare del rilevato ferroviario. Carico non fattorizzato (SLE)



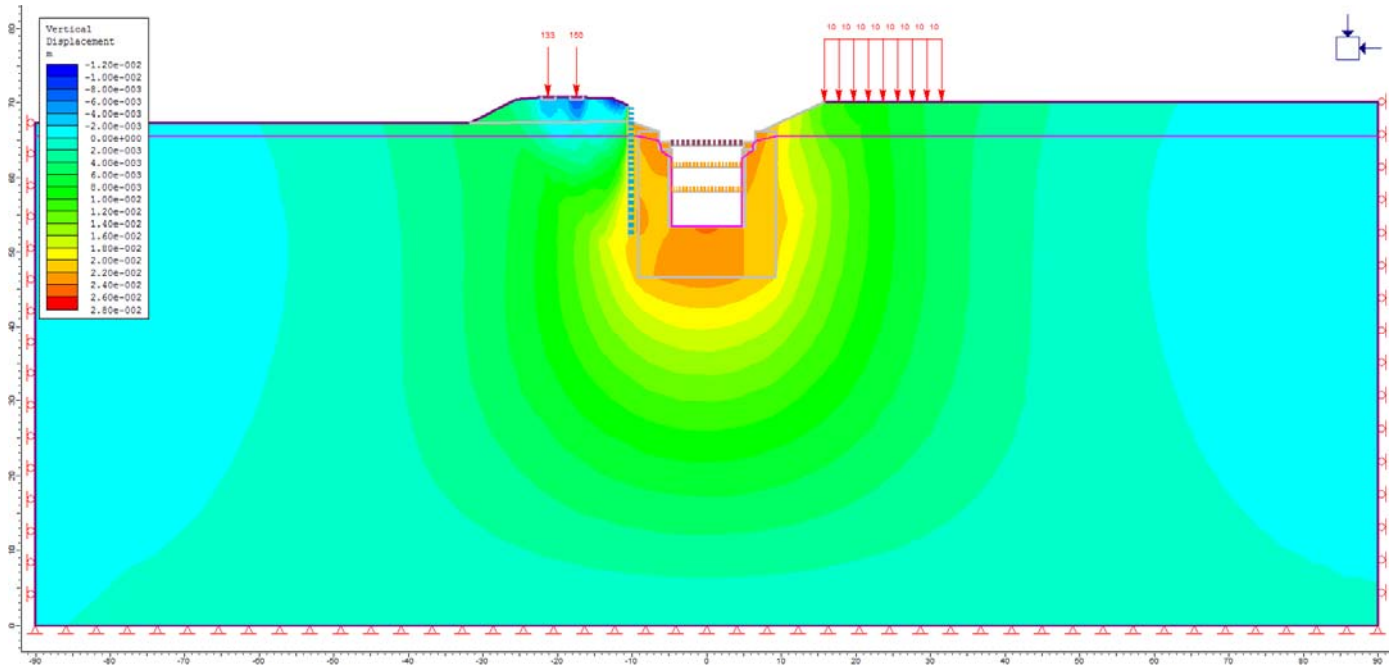
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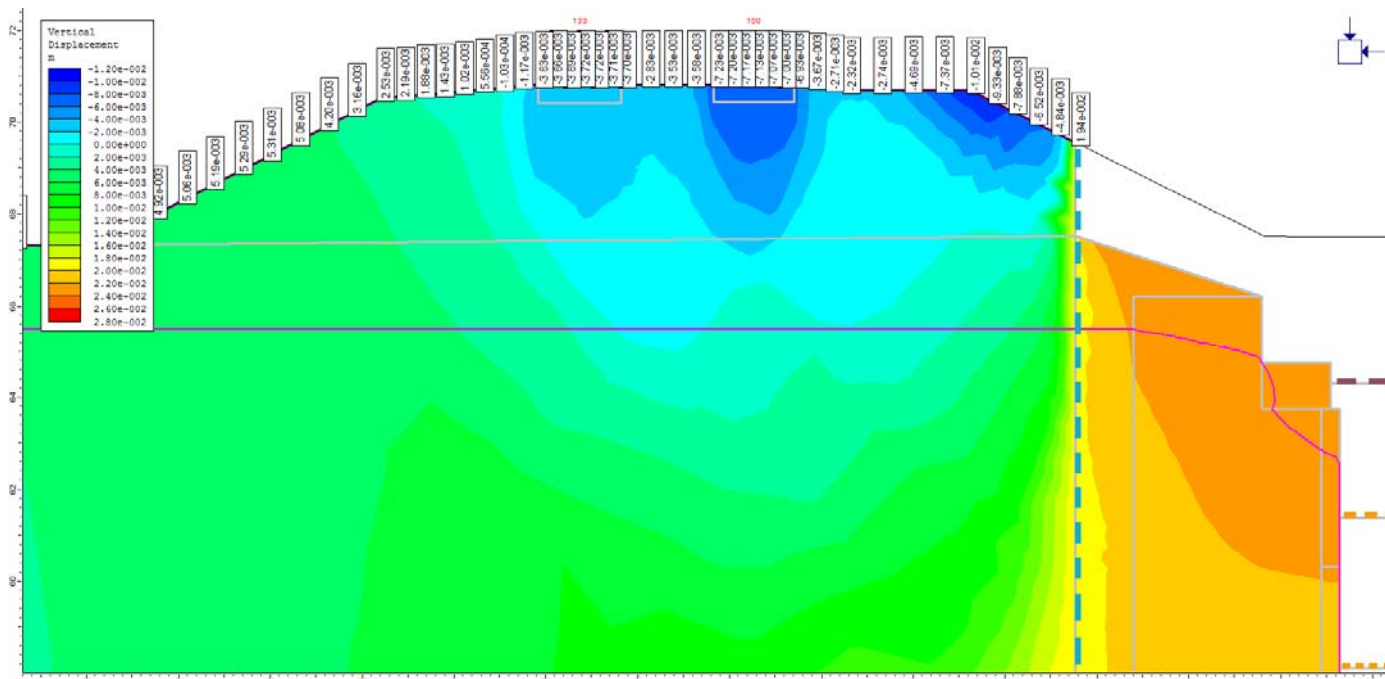
Galleria di Base binario Dispari. Progressiva pk_55+007. Spostamenti orizzontali dX. Fase finale di scavo più carico del treno. Particolare del rilevato ferroviario. Carico non fattorizzato (SLE)



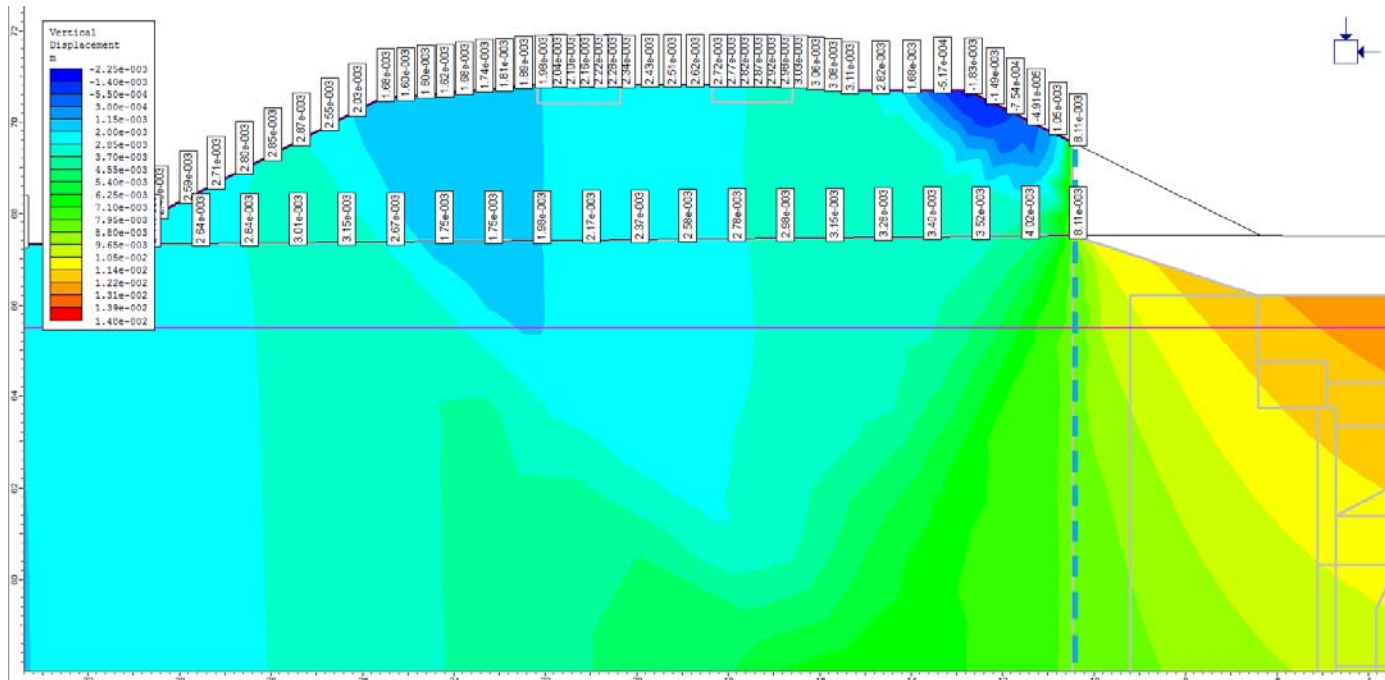
Geometria di calcolo per la Galleria di Base binario Dispari. Progressiva pk_55+007. Fase finale di scavo con carico del treno e carico distribuito durante costruzione.



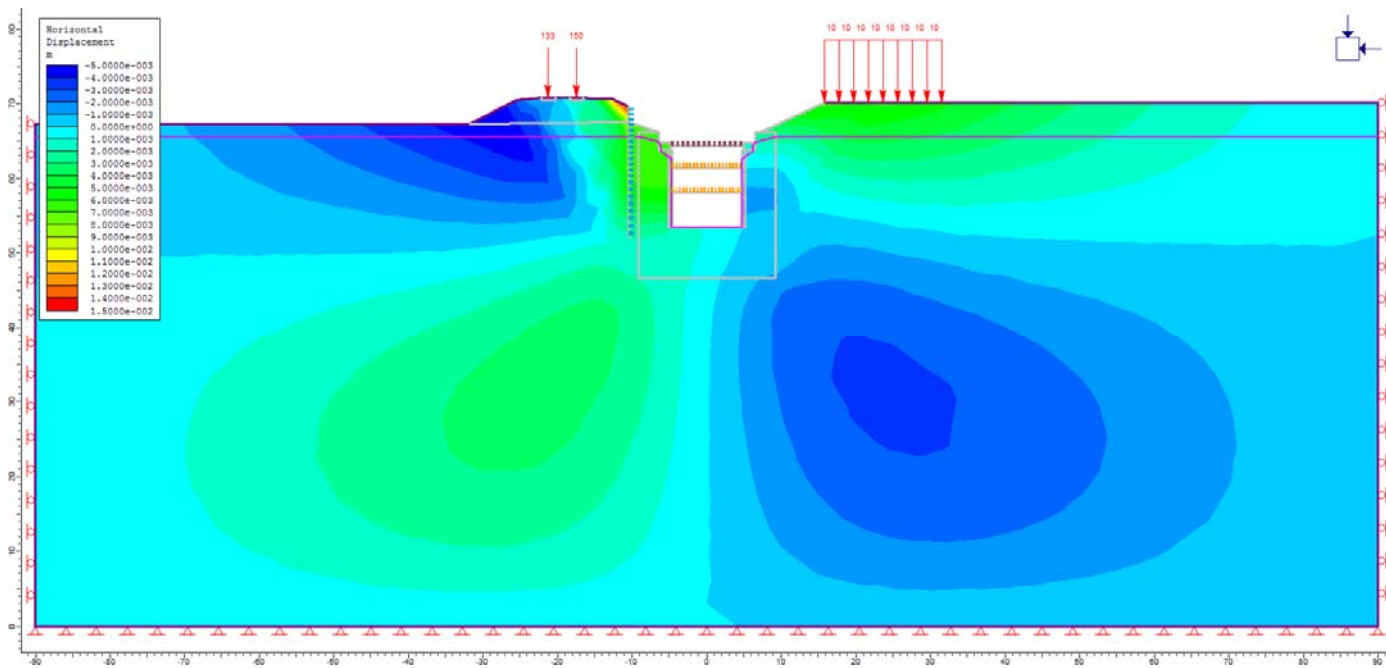
Galleria di Base binario Dispari. Progressiva pk_55+007. Spostamenti verticali dY. Fase finale di scavo, eseguito con carico del treno e carico distribuito durante costruzione. Carico non fattorizzato (SLE)



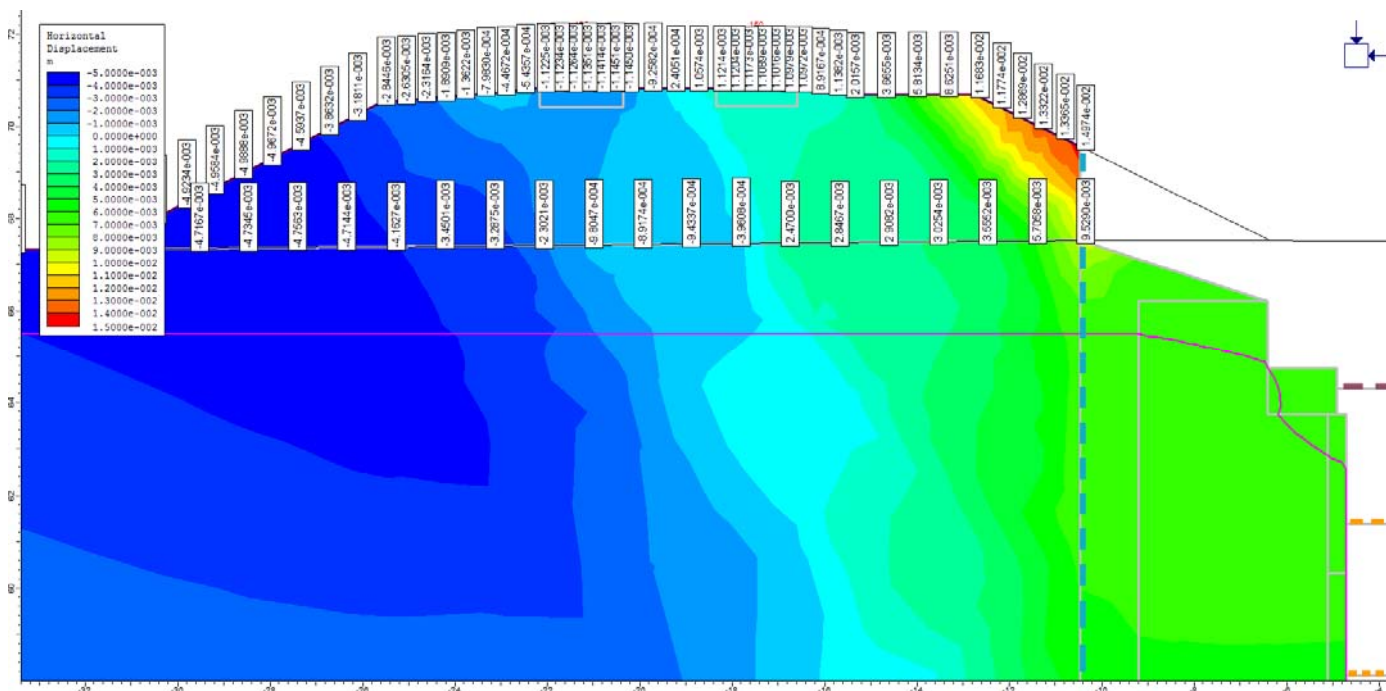
Galleria di Base binario Dispari. Progressiva pk₅₅+007. Spostamenti verticali dY. Fase finale di scavo, eseguito con carico del treno e carico distribuito durante costruzione. Particolare del rilevato ferroviario. Carico non fattorizzato (SLE)



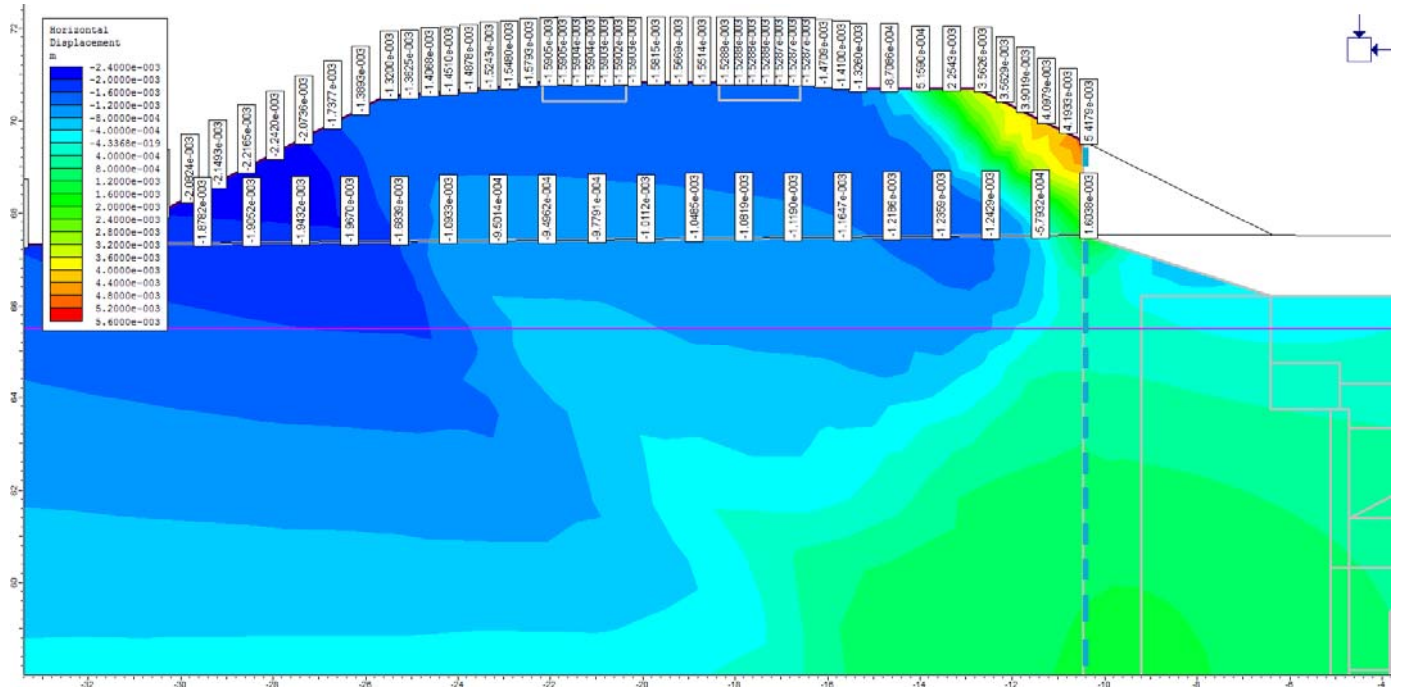
Galleria di Base binario Dispari. Progressiva pk₅₅+007. Spostamenti verticali dY. Fase di scavo fino a raggiungere quota del piano di lavoro del Jet grouting. Particolare del rilevato ferroviario. Carico non fattorizzato (SLE)



Galleria di Base binario Dispari. Progressiva pk_55+007. Spostamenti orizzontali dX. Fase finale di scavo, eseguito con carico del treno e carico distribuito durante costruzione. Carico non fattorizzato (SLE)



Galleria di Base binario Dispari. Progressiva pk_55+007. Spostamenti orizzontali dX. Fase finale di scavo, eseguito con carico del treno e carico distribuito durante costruzione. Particolare del rilevato ferroviario. Carico non fattorizzato (SLE)



Galleria di Base binario Dispari. Progressiva pk_55+007. Spostamenti orizzontali dX. Fase di scavo fino a raggiungere quota del piano di lavoro del Jet grouting. Particolare del rilevato ferroviario. Carico non fattorizzato (SLE)

OUTPUTS DI CALCOLO E RISULTATI ANALISI
TENSO-DEFORMATIVA SEZIONE PK _54+889
BINARIO PARI

Phase2 Analysis Information

Project Settings

- Document Name: Sez 54+889_M_C_solo linea.fez
- Project Title: Tunnel
- Number of Stages: 3
- Analysis Type: Plane Strain
- Solver Type: Gaussian Elimination
- Units: Metric, stress as kPa

Stress Analysis

- Maximum Number of Iterations: 3000
- Tolerance: 0.002
- Number of Load Steps: Automatic
- Convergence Type: Absolute Energy
- Tensile Failure: Reduces Shear Strength

Groundwater

- Method: Finite Element Analysis
- Pore Fluid Unit Weight: 9.81 kN/m³
- Maximum Number of Iterations: 500
- Tolerance: 1e-006

Field Stress

- Field stress: gravity
- Ground surface elevation: 0 m
- Unit weight of overburden: 27 kN/m³
- Total stress ratio (horizontal/vertical in-plane): 1
- Total stress ratio (horizontal/vertical out-of-plane): 1
- Locked-in horizontal stress (in-plane): 0
- Locked-in horizontal stress (out-of-plane): 0

Mesh

- Mesh type: graded
- Element type: 8 noded quadrilaterals
- Number of elements on Geostatico: 1877
- Number of nodes on Geostatico: 5630
- Number of elements on Piano di lavoro: 1877
- Number of nodes on Piano di lavoro: 5630
- Number of elements on CARICO TRENO: 1877
- Number of nodes on CARICO TRENO: 5630

Mesh Quality

- All elements are of good quality

Poor quality elements defined as:

- Side length ratio (maximum / minimum) > 30.00
- Minimum interior angle < 2.0 degrees
- Maximum interior angle > 175.0 degrees

Reset Displacements

- Displacements reset after: Geostatico

Material Properties

Material: Alluvionali

Initial element loading	body force only
Unit weight	20.5 kN/m3
Elastic type	isotropic
Young's modulus	60000 kPa
Poisson's ratio	0.365
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	36 degrees
Peak cohesion	2 kPa
Material type	Plastic
Dilation Angle	1 degrees
Residual Friction Angle	35 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Properties changed in Piano di lavoro

- Young's modulus: 120000 kPa (factor = 2) Poisson's ratio: 0.30003 (factor = 0.822)

Material: CLS

Initial element loading	body force only
Unit weight	25 kN/m3
Elastic type	isotropic
Young's modulus	3.12e+007 kPa
Poisson's ratio	0.3

Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	35 degrees
Peak cohesion	500 kPa
Material type	Elastic
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	1e-012 m/s
K2/K1	1
K Angle	0 degrees

Material: Rilevato ferr old

Initial element loading	body force only
Unit weight	21 kN/m3
Elastic type	isotropic
Young's modulus	100000 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	37 degrees
Peak cohesion	0 kPa
Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	37 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Material: Alluvionali_monte

Initial element loading	body force only
Unit weight	20.5 kN/m3
Elastic type	isotropic
Young's modulus	60000 kPa
Poisson's ratio	0.37
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	36 degrees
Peak cohesion	2 kPa

Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	35 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Properties changed in Piano di lavoro

- Young's modulus: 120000 kPa (factor = 2)Poisson's ratio: 0.30007 (factor = 0.811)

Material: Alluvionali pendio

Initial element loading	body force only
Unit weight	20.5 kN/m3
Elastic type	isotropic
Young's modulus	60000 kPa
Poisson's ratio	0.375
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	36 degrees
Peak cohesion	5 kPa
Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	36 degrees
Residual Cohesion	5 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Properties changed in Piano di lavoro

- Young's modulus: 120000 kPa (factor = 2)Poisson's ratio: 0.3 (factor = 0.8)

Material: Alluvionali valle

Initial element loading	body force only
Unit weight	20.5 kN/m3

Elastic type	isotropic
Young's modulus	60000 kPa
Poisson's ratio	0.39
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	36 degrees
Peak cohesion	2 kPa
Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	35 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Properties changed in Piano di lavoro

- Young's modulus: 120000 kPa (factor = 2)Poisson's ratio: 0.3003 (factor = 0.77)

Excavation Areas

Original Un-deformed Areas

- External Boundary Area: 13642.937 m²
- External Boundary Perimeter: 523.510 m

Geostatico

- External Boundary Area: 13642.937 m² (0 m² change from original area)
- External Boundary Perimeter: 523.510 m (0 m change from original perimeter)

Piano di lavoro

- Values not available until this stage is viewed in a window

CARICO TRENO

- External Boundary Area: 13642.840 m² (-0.0974937 m² change from original area)
- External Boundary Perimeter: 523.510 m (-0.00048904 m change from original perimeter)

Displacements

- Displacement data is not available for Geostatico until total displacement is viewed in a window
- Displacement data is not available for Piano di lavoro until total displacement is viewed in a window
- Displacement data is not available for CARICO TRENO until total displacement is viewed in a window

Yielded Elements

Yielded Mesh Elements

- Number of yielded mesh elements on Geostatico: 155
- Number of yielded mesh elements is not available for Piano di lavoro until the stage is viewed in a window
- Number of yielded mesh elements on CARICO TRENO: 50

Yielded Bolt Elements

- Number of yielded bolt elements on Geostatico: 0
- Number of yielded bolt elements on Piano di lavoro: 0
- Number of yielded bolt elements on CARICO TRENO: 0

List of All Coordinates

External boundary

X	Y
-91.42	0
-17.365	4.59632e-014
4.44157	5.94927e-014
12.443	5.94927e-014
19.4976	6.88338e-014
41.4181	8.26006e-014
91.42	1.137e-013
91.42	38.7809
91.42	82.5506
91.42	85.0339
84.5659	83.7505
56.0805	78.417
46.4332	76.6107
41.4181	75.6717
36.8485	74.1058
28.5227	74.1058
27.222	73.1811
19.4976	73.1811
-20.1913	73.5072
-26.01	73.513
-27.8	73.5148
-29.7979	73.5169
-31.61	73.5187
-34.549	73.5217
-37.6918	71.3098
-53.8224	70.9177
-91.42	70.0037
-91.42	38.7809

Material boundary

X	Y
-37.6918	71.3098
-17.365	71.6502

Material boundary

X	Y
-12.5632	71.6502
-9.69723	69.7519
-8.71149	69.7553
8.80078	69.7457
9.67812	69.7457
13.2747	72.1308

Material boundary

X	Y
-8.71149	69.7553
-7.196	68.6789
-6.4179	68.6789
6.42	68.6789
7.20508	68.6819
8.80078	69.7457

Material boundary

X	Y
-6.4179	68.6789
-6.4179	65.4805
-6.4179	64.4305
-5.65953	64.4305
-5.11838	64.4305
-4.92	64.4305
-4.92	64.9555
-4.92	65.4805
-5.65953	65.4805
-6.4179	65.4805

Material boundary

X	Y
-4.92	64.9555

4.92	64.9555
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Material boundary

X	Y
4.92	65.4805
4.92	64.9555
4.92	64.4305
5.12346	64.4305
5.77317	64.4305
6.42	64.4305
6.42	65.4805
5.77317	65.4805
4.92	65.4805

Material boundary

X	Y
4.92	64.4305
4.72058	64.4305

Material boundary

X	Y
-4.72199	62.0707
-1	64.0205
1	64.0205
4.72058	62.0707

Material boundary

X	Y
1.1e-015	63.0205
-1.21135	62.8286
-1.96	62.4953
-2.43158	62.0707
-3.39482	61.0605
-3.84483	60.0435
-3.84483	58.6994
-3.84483	58.1909
-3.62135	57.3061
-3.25564	56.4699
-2.15	55.9305
2.15	55.9305
3.25564	56.4699

3.62135	57.3061
3.84483	58.1909
3.84483	58.6994
3.84483	60.0435
3.39482	61.0605
2.43158	62.0707
1.96	62.4953
1.21135	62.8286
1.1e-015	63.0205

Material boundary

X	Y
-7.196	68.6789
-9.428	68.6789
-9.428	47.1304
9.428	47.1333
9.428	68.6819
7.20508	68.6819

Material boundary

X	Y
6.42	68.6789
6.42	65.4805

Material boundary

X	Y
-4.72199	62.0707
-2.43158	62.0707
2.43158	62.0707
4.72058	62.0707

Material boundary

X	Y
-4.72199	58.6994
-3.84483	58.6994
3.84483	58.6994
4.72058	58.6994

Material boundary

X	Y
---	---

41.4181	75.6717
41.4181	72.2733
41.4181	38.7809
41.4181	30.2862
41.4181	8.26006e-014

Material boundary

X	Y
19.4976	73.1811
19.4976	72.2733
19.4976	38.7809
19.4976	15.7913
19.4976	7.37376
19.4976	6.88338e-014

Material boundary

X	Y
-20.1913	73.5072
-17.365	71.6502
-17.365	38.7809
-17.365	4.59632e-014

Material boundary

X	Y
-91.42	38.7809
-17.365	38.7809
19.4976	38.7809
41.4181	38.7809
49.5451	38.7809
91.42	38.7809

Material boundary

X	Y
-3.84483	58.1909
3.84483	58.1909

Material boundary

X	Y
-3.84483	58.1909
-4.72199	58.1909

Material boundary

X	Y
3.84483	58.1909
4.72058	58.1909

Material boundary

X	Y
-3.25564	56.4699
-4.72199	56.4699

Material boundary

X	Y
3.25564	56.4699
4.72058	56.4699

Material boundary

X	Y
-26.01	73.513
-26.01	73.208
-27.8	73.208
-27.8	73.5148

Material boundary

X	Y
-29.7979	73.5169
-29.7979	73.209
-31.61	73.209
-31.61	73.5187

Material boundary

X	Y
-12.5632	71.6502
-17.365	71.6502

Material boundary

X	Y
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13.2747	72.1308
17.0946	72.2733
19.4976	73.1811

Material boundary

X	Y
13.2747	72.1308
-4.95631	71.7917
-12.5632	71.6502

Material boundary

X	Y
27.222	73.1811
36.8485	73.1811
36.8485	74.1058

Material boundary

X	Y
19.4976	15.7913
4.44157	5.94927e-014

Material boundary

X	Y
12.443	5.94927e-014
19.4976	7.37376
41.4181	30.2862
49.5451	38.7809
91.42	82.5506

Material boundary

X	Y
19.4976	15.7913
41.4181	38.7809

Material boundary

X	Y
41.4181	38.7809
84.5659	83.7505

Material boundary

X	Y
17.0946	72.2733
19.4976	72.2733
41.4181	72.2733

Material boundary

X	Y
41.4181	72.2733
46.4332	76.6107

Material boundary

X	Y
-3.39482	61.0605
-4.72199	61.0605

Material boundary

X	Y
-3.39482	61.0605
3.39482	61.0605
4.72058	61.0605

Material boundary

X	Y
-5.11838	64.4305
-5.11838	64.0205
-5.11838	61.0605
-5.11838	58.1909
-5.11838	54.1305

Material boundary

X	Y
-4.72199	54.1305
-4.72199	56.4699

Material boundary

X	Y
-4.72199	54.1305

-5.11838	54.1305
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Material boundary

X	Y
-4.72199	56.4699
-4.72199	58.1909

Material boundary

X	Y
-4.72199	58.1909
-4.72199	58.6994

Material boundary

X	Y
-4.72199	58.6994
-4.72199	61.0605

Material boundary

X	Y
-4.72199	61.0605
-4.72199	62.0707

Material boundary

X	Y
-4.72199	62.0707
-4.72199	64.0205
-4.72199	64.4305
-4.92	64.4305

Material boundary

X	Y
5.12346	64.4305
5.12346	64.0205
5.12346	61.0605
5.12346	58.1909
5.12346	54.1305

Material boundary

X	Y
4.72058	54.1305
4.72058	56.4699
4.72058	58.1909
4.72058	58.6994
4.72058	61.0605
4.72058	62.0707
4.72058	64.0205
4.72058	64.4305

Material boundary

X	Y
4.72058	54.1305
5.12346	54.1305

Material boundary

X	Y
4.72058	54.1305
-4.72199	54.1305

Material boundary

X	Y
-1	64.0205
-4.72199	64.0205

Material boundary

X	Y
1	64.0205
4.72058	64.0205

Material boundary

X	Y
-4.72199	64.0205
-5.11838	64.0205

Material boundary

X	Y
4.72058	64.0205

5.12346	64.0205
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Material boundary

X	Y
-4.72199	61.0605
-5.11838	61.0605

Material boundary

X	Y
4.72058	61.0605
5.12346	61.0605

Material boundary

X	Y
-4.72199	58.1909
-5.11838	58.1909

Material boundary

X	Y
4.72058	58.1909
5.12346	58.1909

Material boundary

X	Y
-5.65953	65.4805
-5.65953	64.4305
-5.65953	49.849

Material boundary

X	Y
5.77317	65.4805
5.77317	64.4305
5.77317	49.978

Phase2 Analysis Information

Project Settings

- Document Name: Sez 54+889_M_C_fondo scavo + carico.fez
- Project Title: Tunnel
- Number of Stages: 19
- Analysis Type: Plane Strain
- Solver Type: Gaussian Elimination
- Units: Metric, stress as kPa

Stress Analysis

- Maximum Number of Iterations: 3000
- Tolerance: 0.002
- Number of Load Steps: Automatic
- Convergence Type: Absolute Energy
- Tensile Failure: Reduces Shear Strength

Groundwater

- Method: Finite Element Analysis
- Pore Fluid Unit Weight: 9.81 kN/m³
- Maximum Number of Iterations: 500
- Tolerance: 1e-006

Field Stress

- Field stress: gravity
- Ground surface elevation: 0 m
- Unit weight of overburden: 27 kN/m³
- Total stress ratio (horizontal/vertical in-plane): 1
- Total stress ratio (horizontal/vertical out-of-plane): 1
- Locked-in horizontal stress (in-plane): 0
- Locked-in horizontal stress (out-of-plane): 0

Mesh

- Mesh type: graded
- Element type: 8 noded quadrilaterals
- Number of elements on Geostatico: 1877
- Number of nodes on Geostatico: 5630
- Number of elements on Piano di lavoro: 1741
- Number of nodes on Piano di lavoro: 5244
- Number of elements on Jet: 1741
- Number of nodes on Jet: 5244
- Number of elements on Approfondimento: 1649
- Number of nodes on Approfondimento: 4994
- Number of elements on I ribasso: 1631
- Number of nodes on I ribasso: 4948
- Number of elements on I puntone: 1631
- Number of nodes on I puntone: 4948
- Number of elements on II ribasso: 1528

- Number of nodes on II ribasso: 4671
- Number of elements on II puntone: 1528
- Number of nodes on II puntone: 4671
- Number of elements on III ribasso: 1433
- Number of nodes on III ribasso: 4398
- Number of elements on III puntone: 1433
- Number of nodes on III puntone: 4398
- Number of elements on Fondo scavo: 1325
- Number of nodes on Fondo scavo: 4088
- Number of elements on CARICO TRENO: 1325
- Number of nodes on CARICO TRENO: 4088
- Number of elements on Getto solettone: 1380
- Number of nodes on Getto solettone: 4251
- Number of elements on Rimozione puntone: 1380
- Number of nodes on Rimozione puntone: 4251
- Number of elements on Getto calotta: 1477
- Number of nodes on Getto calotta: 4545
- Number of elements on Rimozione puntone: 1477
- Number of nodes on Rimozione puntone: 4545
- Number of elements on Ritombamento: 1685
- Number of nodes on Ritombamento: 5117
- Number of elements on Rilevato ferroviario: 1924
- Number of nodes on Rilevato ferroviario: 5816
- Number of elements on Carico treno: 1924
- Number of nodes on Carico treno: 5816

Mesh Quality

- All elements are of good quality

Poor quality elements defined as:

- Side length ratio (maximum / minimum) > 30.00
- Minimum interior angle < 2.0 degrees
- Maximum interior angle > 175.0 degrees

Reset Displacements

- Displacements reset after: Geostatico

Material Properties

Material: Alluvionali

Initial element loading	body force only
Unit weight	20.5 kN/m ³
Elastic type	isotropic
Young's modulus	60000 kPa
Poisson's ratio	0.365
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	36 degrees

Peak cohesion	2 kPa
Material type	Plastic
Dilation Angle	1 degrees
Residual Friction Angle	35 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Properties changed in Piano di lavoro

- Young's modulus: 120000 kPa (factor = 2)Poisson's ratio: 0.30003 (factor = 0.822)

Material: Jet

Initial element loading	body force only
Unit weight	21 kN/m3
Elastic type	isotropic
Young's modulus	1e+006 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	75 kPa
Peak friction angle	36 degrees
Peak cohesion	500 kPa
Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	36 degrees
Residual Cohesion	500 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	1e-008 m/s
K2/K1	1
K Angle	0 degrees

Material: CLS

Initial element loading	body force only
Unit weight	25 kN/m3
Elastic type	isotropic
Young's modulus	3.12e+007 kPa
Poisson's ratio	0.3

Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	35 degrees
Peak cohesion	500 kPa
Material type	Elastic
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	1e-012 m/s
K2/K1	1
K Angle	0 degrees

Material: Riporto artificiale+Rilevato ferr new

Initial element loading	body force only
Unit weight	20.5 kN/m3
Elastic type	isotropic
Young's modulus	80000 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	36 degrees
Peak cohesion	0 kPa
Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	36 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Material: Rilevato ferr old

Initial element loading	body force only
Unit weight	21 kN/m3
Elastic type	isotropic
Young's modulus	100000 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	37 degrees
Peak cohesion	0 kPa

Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	37 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Material: Alluvionali_monte

Initial element loading	body force only
Unit weight	20.5 kN/m3
Elastic type	isotropic
Young's modulus	60000 kPa
Poisson's ratio	0.37
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	36 degrees
Peak cohesion	2 kPa
Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	35 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Properties changed in Piano di lavoro

- Young's modulus: 120000 kPa (factor = 2)Poisson's ratio: 0.30007 (factor = 0.811)

Material: Alluvionali pendio

Initial element loading	body force only
Unit weight	20.5 kN/m3
Elastic type	isotropic
Young's modulus	60000 kPa
Poisson's ratio	0.375
Failure criterion	Mohr-Coulomb

Tensile strength	0 kPa
Peak friction angle	36 degrees
Peak cohesion	5 kPa
Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	36 degrees
Residual Cohesion	5 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Properties changed in Piano di lavoro

- Young's modulus: 120000 kPa (factor = 2)Poisson's ratio: 0.3 (factor = 0.8)

Material: Alluvionali valle

Initial element loading	body force only
Unit weight	20.5 kN/m3
Elastic type	isotropic
Young's modulus	60000 kPa
Poisson's ratio	0.39
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	36 degrees
Peak cohesion	2 kPa
Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	35 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Properties changed in Piano di lavoro

- Young's modulus: 120000 kPa (factor = 2)Poisson's ratio: 0.3003 (factor = 0.77)

Material: Spritz

Initial element loading	body force only
Unit weight	25 kN/m ³
Elastic type	isotropic
Young's modulus	3e+007 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	35 degrees
Peak cohesion	500 kPa
Material type	Elastic
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	1e-008 m/s
K2/K1	1
K Angle	0 degrees

Properties changed in Rimozione puntone

- Ks: 1e-010 m/s (factor = 0.01) K Angle: 0 degrees (factor = 0)

Material: Ritombamento lungo ferr

Initial element loading	body force only
Unit weight	20.5 kN/m ³
Elastic type	isotropic
Young's modulus	60000 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	36 degrees
Peak cohesion	0 kPa
Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	36 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Excavation Areas

Original Un-deformed Areas

- External Boundary Area: 13642.937 m²
- External Boundary Perimeter: 523.510 m

Geostatico

- External Boundary Area: 13642.937 m² (0 m² change from original area)
- External Boundary Perimeter: 523.510 m (0 m change from original perimeter)

Piano di lavoro

- Values not available until this stage is viewed in a window

Jet

- Values not available until this stage is viewed in a window

Approfondimento

- Values not available until this stage is viewed in a window

I ribasso

- Values not available until this stage is viewed in a window

I puntone

- Values not available until this stage is viewed in a window

II ribasso

- Values not available until this stage is viewed in a window

II puntone

- Values not available until this stage is viewed in a window

III ribasso

- Values not available until this stage is viewed in a window

III puntone

- Values not available until this stage is viewed in a window

Fondo scavo

- Values not available until this stage is viewed in a window

CARICO TRENO

- Values not available until this stage is viewed in a window

Getto solettone

- Values not available until this stage is viewed in a window

Rimozione puntone

- Values not available until this stage is viewed in a window

Getto calotta

- Values not available until this stage is viewed in a window

Rimozione puntone

- Values not available until this stage is viewed in a window

Ritombamento

- Values not available until this stage is viewed in a window

Rilevato ferroviario

- Values not available until this stage is viewed in a window

Carico treno

- Values not available until this stage is viewed in a window

Liner Properties

Liner: Tubo_355.6_sp12/4m

Liner Type	Standard Beam
Formulation	Timoshenko
Area	0.00326 m ²
Moment of Inertia	4.78e-005 m ⁴

Elastic Properties

Young's modulus	2.1e+008 kPa
Poisson's ratio	0.2

Liner: TUbo _406.4_sp12.5/4m

Liner Type	Standard Beam
Formulation	Timoshenko
Area	0.00386 m ²
Moment of Inertia	7.5038e-005 m ⁴

Elastic Properties

Young's modulus	2.1e+008 kPa
Poisson's ratio	0.2
Liner Unit Weight	78.5 kN/m ³

Liner: Micropalo 168.3_sp10/1.45

Liner Type	Standard Beam
Formulation	Timoshenko
Area	0.00342 m ²
Moment of Inertia	1.78e-005 m ⁴

Elastic Properties

Young's modulus	2.1e+008 kPa
Poisson's ratio	0.2

Displacements

- Displacement data is not available for Geostatico until total displacement is viewed in a window
- Displacement data is not available for Piano di lavoro until total displacement is viewed in a window
- Displacement data is not available for Jet until total displacement is viewed in a window
- Displacement data is not available for Approfondimento until total displacement is viewed in a window
- Displacement data is not available for I ribasso until total displacement is viewed in a window
- Displacement data is not available for I puntone until total displacement is viewed in a window
- Displacement data is not available for II ribasso until total displacement is viewed in a window
- Displacement data is not available for II puntone until total displacement is viewed in a window
- Displacement data is not available for III ribasso until total displacement is viewed in a window
- Displacement data is not available for III puntone until total displacement is viewed in a window
- Displacement data is not available for Fondo scavo until total displacement is viewed in a window
- Displacement data is not available for CARICO TRENO until total displacement is viewed in a window
- Displacement data is not available for Getto solettone until total displacement is viewed in a window
- Displacement data is not available for Rimozione puntone until total displacement is viewed in a window
- Displacement data is not available for Getto calotta until total displacement is viewed in a window
- Displacement data is not available for Rimozione puntone until total displacement is viewed in a window
- Displacement data is not available for Ritombamento until total displacement is viewed in a window
- Displacement data is not available for Rilevato ferroviario until total displacement is viewed in a window
- Displacement data is not available for Carico treno until total displacement is viewed in a window

Yielded Elements

Yielded Mesh Elements

- Number of yielded mesh elements on Geostatico: 155
- Number of yielded mesh elements is not available for Piano di lavoro until the stage is viewed in a window
- Number of yielded mesh elements is not available for Jet until the stage is viewed in a window
- Number of yielded mesh elements is not available for Approfondimento until the stage is viewed in a window
- Number of yielded mesh elements is not available for I ribasso until the stage is viewed in a window
- Number of yielded mesh elements is not available for I puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for II ribasso until the stage is viewed in a window
- Number of yielded mesh elements is not available for II puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for III ribasso until the stage is viewed in a window
- Number of yielded mesh elements is not available for III puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for Fondo scavo until the stage is viewed in a window
- Number of yielded mesh elements is not available for CARICO TRENO until the stage is viewed in a window
- Number of yielded mesh elements is not available for Getto solettone until the stage is viewed in a window
- Number of yielded mesh elements is not available for Rimozione puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for Getto calotta until the stage is viewed in a window
- Number of yielded mesh elements is not available for Rimozione puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for Ritombamento until the stage is viewed in a window
- Number of yielded mesh elements is not available for Rilevato ferroviario until the stage is viewed in a window
- Number of yielded mesh elements is not available for Carico treno until the stage is viewed in a window

Yielded Bolt Elements

- Number of yielded bolt elements on Geostatico: 0
- Number of yielded bolt elements on Piano di lavoro: 0
- Number of yielded bolt elements on Jet: 0
- Number of yielded bolt elements on Approfondimento: 0
- Number of yielded bolt elements on I ribasso: 0
- Number of yielded bolt elements on I puntone: 0
- Number of yielded bolt elements on II ribasso: 0
- Number of yielded bolt elements on II puntone: 0
- Number of yielded bolt elements on III ribasso: 0
- Number of yielded bolt elements on III puntone: 0
- Number of yielded bolt elements on Fondo scavo: 0
- Number of yielded bolt elements on CARICO TRENO: 0
- Number of yielded bolt elements on Getto solettone: 0
- Number of yielded bolt elements on Rimozione puntone: 0
- Number of yielded bolt elements on Getto calotta: 0
- Number of yielded bolt elements on Rimozione puntone: 0
- Number of yielded bolt elements on Ritombamento: 0
- Number of yielded bolt elements on Rilevato ferroviario: 0
- Number of yielded bolt elements on Carico treno: 0

Yielded Liner Elements

- Number of yielded liner elements on Geostatico: 0
- Number of yielded liner elements on Piano di lavoro: 0
- Number of yielded liner elements on Jet: 0
- Number of yielded liner elements on Approfondimento: 0
- Number of yielded liner elements on I ribasso: 0
- Number of yielded liner elements on I puntone: 0
- Number of yielded liner elements on II ribasso: 0
- Number of yielded liner elements on II puntone: 0
- Number of yielded liner elements on III ribasso: 0
- Number of yielded liner elements on III puntone: 0
- Number of yielded liner elements on Fondo scavo: 0
- Number of yielded liner elements on CARICO TRENO: 0
- Number of yielded liner elements on Getto solettone: 0

- Number of yielded liner elements on Rimozione puntone: 0
- Number of yielded liner elements on Getto calotta: 0
- Number of yielded liner elements on Rimozione puntone: 0
- Number of yielded liner elements on Ritombamento: 0
- Number of yielded liner elements on Rilevato ferroviario: 0
- Number of yielded liner elements on Carico treno: 0

List of All Coordinates

External boundary

X	Y
-91.42	0
-17.365	4.59632e-014
4.44157	5.94927e-014
12.443	5.94927e-014
19.4976	6.88338e-014
41.4181	8.26006e-014
91.42	1.137e-013
91.42	38.7809
91.42	82.5506
91.42	85.0339
84.5659	83.7505
56.0805	78.417
46.4332	76.6107
41.4181	75.6717
36.8485	74.1058
28.5227	74.1058
27.222	73.1811
19.4976	73.1811
-20.1913	73.5072
-26.01	73.513
-27.8	73.5148
-29.7979	73.5169
-31.61	73.5187
-34.549	73.5217
-37.6918	71.3098
-53.8224	70.9177
-91.42	70.0037
-91.42	38.7809

Material boundary

X	Y
-37.6918	71.3098
-17.365	71.6502

Material boundary

X	Y
-12.5632	71.6502
-9.69723	69.7519
-8.71149	69.7553
8.80078	69.7457
9.67812	69.7457
13.2747	72.1308

Material boundary

X	Y
-8.71149	69.7553
-7.196	68.6789
-6.4179	68.6789
6.42	68.6789
7.20508	68.6819
8.80078	69.7457

Material boundary

X	Y
-6.4179	68.6789
-6.4179	65.4805
-6.4179	64.4305
-5.65953	64.4305
-5.11838	64.4305
-4.92	64.4305
-4.92	64.9555
-4.92	65.4805
-5.65953	65.4805
-6.4179	65.4805

Material boundary

X	Y
-4.92	64.9555
4.92	64.9555

Material boundary

X	Y
4.92	65.4805
4.92	64.9555

4.92	64.4305
5.12346	64.4305
5.77317	64.4305
6.42	64.4305
6.42	65.4805
5.77317	65.4805
4.92	65.4805

Material boundary

X	Y
4.92	64.4305
4.72058	64.4305

Material boundary

X	Y
-4.72199	62.0707
-1	64.0205
1	64.0205
4.72058	62.0707

Material boundary

X	Y
1.1e-015	63.0205
-1.21135	62.8286
-1.96	62.4953
-2.43158	62.0707
-3.39482	61.0605
-3.84483	60.0435
-3.84483	58.6994
-3.84483	58.1909
-3.62135	57.3061
-3.25564	56.4699
-2.15	55.9305
2.15	55.9305
3.25564	56.4699
3.62135	57.3061
3.84483	58.1909
3.84483	58.6994
3.84483	60.0435
3.39482	61.0605
2.43158	62.0707
1.96	62.4953

1.21135	62.8286
1.1e-015	63.0205

Material boundary

X	Y
-7.196	68.6789
-9.428	68.6789
-9.428	47.1304
9.428	47.1333
9.428	68.6819
7.20508	68.6819

Material boundary

X	Y
6.42	68.6789
6.42	65.4805

Material boundary

X	Y
-4.72199	62.0707
-2.43158	62.0707
2.43158	62.0707
4.72058	62.0707

Material boundary

X	Y
-4.72199	58.6994
-3.84483	58.6994
3.84483	58.6994
4.72058	58.6994

Material boundary

X	Y
41.4181	75.6717
41.4181	72.2733
41.4181	38.7809
41.4181	30.2862
41.4181	8.26006e-014

Material boundary

X	Y
19.4976	73.1811
19.4976	72.2733
19.4976	38.7809
19.4976	15.7913
19.4976	7.37376
19.4976	6.88338e-014

Material boundary

X	Y
-20.1913	73.5072
-17.365	71.6502
-17.365	38.7809
-17.365	4.59632e-014

Material boundary

X	Y
-91.42	38.7809
-17.365	38.7809
19.4976	38.7809
41.4181	38.7809
49.5451	38.7809
91.42	38.7809

Material boundary

X	Y
-3.84483	58.1909
3.84483	58.1909

Material boundary

X	Y
-3.84483	58.1909
-4.72199	58.1909

Material boundary

X	Y
3.84483	58.1909
4.72058	58.1909

Material boundary

X	Y
-3.25564	56.4699
-4.72199	56.4699

Material boundary

X	Y
3.25564	56.4699
4.72058	56.4699

Material boundary

X	Y
-26.01	73.513
-26.01	73.208
-27.8	73.208
-27.8	73.5148

Material boundary

X	Y
-29.7979	73.5169
-29.7979	73.209
-31.61	73.209
-31.61	73.5187

Material boundary

X	Y
-12.5632	71.6502
-17.365	71.6502

Material boundary

X	Y
13.2747	72.1308
17.0946	72.2733
19.4976	73.1811

Material boundary

X	Y
13.2747	72.1308
-4.95631	71.7917
-12.5632	71.6502

Material boundary

X	Y
27.222	73.1811
36.8485	73.1811
36.8485	74.1058

Material boundary

X	Y
19.4976	15.7913
4.44157	5.94927e-014

Material boundary

X	Y
12.443	5.94927e-014
19.4976	7.37376
41.4181	30.2862
49.5451	38.7809
91.42	82.5506

Material boundary

X	Y
19.4976	15.7913
41.4181	38.7809

Material boundary

X	Y
41.4181	38.7809
84.5659	83.7505

Material boundary

X	Y
17.0946	72.2733
19.4976	72.2733

41.4181	72.2733
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Material boundary

X	Y
41.4181	72.2733
46.4332	76.6107

Material boundary

X	Y
-3.39482	61.0605
-4.72199	61.0605

Material boundary

X	Y
-3.39482	61.0605
3.39482	61.0605
4.72058	61.0605

Material boundary

X	Y
-5.11838	64.4305
-5.11838	64.0205
-5.11838	61.0605
-5.11838	58.1909
-5.11838	54.1305

Material boundary

X	Y
-4.72199	54.1305
-4.72199	56.4699

Material boundary

X	Y
-4.72199	54.1305
-5.11838	54.1305

Material boundary

X	Y
-4.72199	56.4699
-4.72199	58.1909

Material boundary

X	Y
-4.72199	58.1909
-4.72199	58.6994

Material boundary

X	Y
-4.72199	58.6994
-4.72199	61.0605

Material boundary

X	Y
-4.72199	61.0605
-4.72199	62.0707

Material boundary

X	Y
-4.72199	62.0707
-4.72199	64.0205
-4.72199	64.4305
-4.92	64.4305

Material boundary

X	Y
5.12346	64.4305
5.12346	64.0205
5.12346	61.0605
5.12346	58.1909
5.12346	54.1305

Material boundary

X	Y
4.72058	54.1305
4.72058	56.4699

4.72058	58.1909
4.72058	58.6994
4.72058	61.0605
4.72058	62.0707
4.72058	64.0205
4.72058	64.4305

Material boundary

X	Y
4.72058	54.1305
5.12346	54.1305

Material boundary

X	Y
4.72058	54.1305
-4.72199	54.1305

Material boundary

X	Y
-1	64.0205
-4.72199	64.0205

Material boundary

X	Y
1	64.0205
4.72058	64.0205

Material boundary

X	Y
-4.72199	64.0205
-5.11838	64.0205

Material boundary

X	Y
4.72058	64.0205
5.12346	64.0205

Material boundary

X	Y
-4.72199	61.0605
-5.11838	61.0605

Material boundary

X	Y
4.72058	61.0605
5.12346	61.0605

Material boundary

X	Y
-4.72199	58.1909
-5.11838	58.1909

Material boundary

X	Y
4.72058	58.1909
5.12346	58.1909

Material boundary

X	Y
-5.65953	65.4805
-5.65953	64.4305
-5.65953	49.849

Material boundary

X	Y
5.77317	65.4805
5.77317	64.4305
5.77317	49.978

Phase2 Analysis Information

Project Settings

- Document Name: Sez 54+889_M_C_fondo scavo con carico.fez
- Project Title: Tunnel
- Number of Stages: 18
- Analysis Type: Plane Strain
- Solver Type: Gaussian Elimination
- Units: Metric, stress as kPa

Stress Analysis

- Maximum Number of Iterations: 3000
- Tolerance: 0.002
- Number of Load Steps: Automatic
- Convergence Type: Absolute Energy
- Tensile Failure: Reduces Shear Strength

Groundwater

- Method: Finite Element Analysis
- Pore Fluid Unit Weight: 9.81 kN/m³
- Maximum Number of Iterations: 500
- Tolerance: 1e-006

Field Stress

- Field stress: gravity
- Ground surface elevation: 0 m
- Unit weight of overburden: 27 kN/m³
- Total stress ratio (horizontal/vertical in-plane): 1
- Total stress ratio (horizontal/vertical out-of-plane): 1
- Locked-in horizontal stress (in-plane): 0
- Locked-in horizontal stress (out-of-plane): 0

Mesh

- Mesh type: graded
- Element type: 8 noded quadrilaterals
- Number of elements on Geostatico: 1877
- Number of nodes on Geostatico: 5630
- Number of elements on Piano di lavoro: 1741
- Number of nodes on Piano di lavoro: 5244
- Number of elements on Jet: 1741
- Number of nodes on Jet: 5244
- Number of elements on Approfondimento: 1649
- Number of nodes on Approfondimento: 4994
- Number of elements on I ribasso: 1631
- Number of nodes on I ribasso: 4948
- Number of elements on I puntone: 1631
- Number of nodes on I puntone: 4948
- Number of elements on II ribasso: 1528

- Number of nodes on II ribasso: 4671
- Number of elements on II puntone: 1528
- Number of nodes on II puntone: 4671
- Number of elements on III ribasso: 1433
- Number of nodes on III ribasso: 4398
- Number of elements on III puntone: 1433
- Number of nodes on III puntone: 4398
- Number of elements on Fondo scavo: 1325
- Number of nodes on Fondo scavo: 4088
- Number of elements on Getto solettone: 1380
- Number of nodes on Getto solettone: 4251
- Number of elements on Rimozione puntone: 1380
- Number of nodes on Rimozione puntone: 4251
- Number of elements on Getto calotta: 1477
- Number of nodes on Getto calotta: 4545
- Number of elements on Rimozione puntone: 1477
- Number of nodes on Rimozione puntone: 4545
- Number of elements on Ritombamento: 1685
- Number of nodes on Ritombamento: 5117
- Number of elements on Rilevato ferroviario: 1924
- Number of nodes on Rilevato ferroviario: 5816
- Number of elements on Carico treno: 1924
- Number of nodes on Carico treno: 5816

Mesh Quality

- All elements are of good quality

Poor quality elements defined as:

- Side length ratio (maximum / minimum) > 30.00
- Minimum interior angle < 2.0 degrees
- Maximum interior angle > 175.0 degrees

Reset Displacements

- Displacements reset after: Geostatico

Material Properties

Material: Alluvionali

Initial element loading	body force only
Unit weight	20.5 kN/m3
Elastic type	isotropic
Young's modulus	60000 kPa
Poisson's ratio	0.365
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	36 degrees
Peak cohesion	2 kPa
Material type	Plastic

Dilation Angle	1 degrees
Residual Friction Angle	35 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Properties changed in Piano di lavoro

- Young's modulus: 120000 kPa (factor = 2) Poisson's ratio: 0.30003 (factor = 0.822)

Material: Jet

Initial element loading	body force only
Unit weight	21 kN/m ³
Elastic type	isotropic
Young's modulus	1e+006 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	75 kPa
Peak friction angle	36 degrees
Peak cohesion	500 kPa
Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	36 degrees
Residual Cohesion	500 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	1e-008 m/s
K2/K1	1
K Angle	0 degrees

Material: CLS

Initial element loading	body force only
Unit weight	25 kN/m ³
Elastic type	isotropic
Young's modulus	3.12e+007 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa

Peak friction angle	35 degrees
Peak cohesion	500 kPa
Material type	Elastic
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	1e-012 m/s
K2/K1	1
K Angle	0 degrees

Material: Riporto artificiale+Rilevato ferr new

Initial element loading	body force only
Unit weight	20.5 kN/m3
Elastic type	isotropic
Young's modulus	80000 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	36 degrees
Peak cohesion	0 kPa
Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	36 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Material: Rilevato ferr old

Initial element loading	body force only
Unit weight	21 kN/m3
Elastic type	isotropic
Young's modulus	100000 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	37 degrees
Peak cohesion	0 kPa
Material type	Plastic
Dilation Angle	0 degrees

Residual Friction Angle	37 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Material: Alluvionali_monte

Initial element loading	body force only
Unit weight	20.5 kN/m3
Elastic type	isotropic
Young's modulus	60000 kPa
Poisson's ratio	0.37
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	36 degrees
Peak cohesion	2 kPa
Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	35 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Properties changed in Piano di lavoro

- Young's modulus: 120000 kPa (factor = 2)Poisson's ratio: 0.30007 (factor = 0.811)

Material: Alluvionali pendio

Initial element loading	body force only
Unit weight	20.5 kN/m3
Elastic type	isotropic
Young's modulus	60000 kPa
Poisson's ratio	0.375
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	36 degrees

Peak cohesion	5 kPa
Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	36 degrees
Residual Cohesion	5 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Properties changed in Piano di lavoro

- Young's modulus: 120000 kPa (factor = 2)Poisson's ratio: 0.3 (factor = 0.8)

Material: Alluvionali valle

Initial element loading	body force only
Unit weight	20.5 kN/m3
Elastic type	isotropic
Young's modulus	60000 kPa
Poisson's ratio	0.39
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	36 degrees
Peak cohesion	2 kPa
Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	35 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Properties changed in Piano di lavoro

- Young's modulus: 120000 kPa (factor = 2)Poisson's ratio: 0.3003 (factor = 0.77)

Material: Spritz

Initial element loading	body force only
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Unit weight	25 kN/m ³
Elastic type	isotropic
Young's modulus	3e+007 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	35 degrees
Peak cohesion	500 kPa
Material type	Elastic
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	1e-008 m/s
K2/K1	1
K Angle	0 degrees

Properties changed in Rimozione puntone

- Ks: 1e-010 m/s (factor = 0.01) K Angle: 0 degrees (factor = 0)

Material: Ritombamento lungo ferr

Initial element loading	body force only
Unit weight	20.5 kN/m ³
Elastic type	isotropic
Young's modulus	60000 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	36 degrees
Peak cohesion	0 kPa
Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	36 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Excavation Areas

Original Un-deformed Areas

- External Boundary Area: 13642.937 m²
- External Boundary Perimeter: 523.510 m

Geostatico

- External Boundary Area: 13642.937 m² (0 m² change from original area)
- External Boundary Perimeter: 523.510 m (0 m change from original perimeter)

Piano di lavoro

- Values not available until this stage is viewed in a window

Jet

- Values not available until this stage is viewed in a window

Approfondimento

- Values not available until this stage is viewed in a window

I ribasso

- Values not available until this stage is viewed in a window

I puntone

- Values not available until this stage is viewed in a window

II ribasso

- Values not available until this stage is viewed in a window

II puntone

- Values not available until this stage is viewed in a window

III ribasso

- Values not available until this stage is viewed in a window

III puntone

- Values not available until this stage is viewed in a window

Fondo scavo

- Values not available until this stage is viewed in a window

Getto solettone

- Values not available until this stage is viewed in a window

Rimozione puntone

- Values not available until this stage is viewed in a window

Getto calotta

- Values not available until this stage is viewed in a window

Rimozione puntone

- Values not available until this stage is viewed in a window

Ritombamento

- Values not available until this stage is viewed in a window

Rilevato ferroviario

- Values not available until this stage is viewed in a window

Carico treno

- Values not available until this stage is viewed in a window

Liner Properties

Liner: Tubo_355.6_sp12/4m

Liner Type	Standard Beam
Formulation	Timoshenko
Area	0.00326 m ²
Moment of Inertia	4.78e-005 m ⁴

Elastic Properties

Young's modulus	2.1e+008 kPa
Poisson's ratio	0.2

Liner: TUbo _406.4_sp12.5/4m

Liner Type	Standard Beam
Formulation	Timoshenko

Area	0.00386 m ²
Moment of Inertia	7.5038e-005 m ⁴

Elastic Properties

Young's modulus	2.1e+008 kPa
Poisson's ratio	0.2
Liner Unit Weight	78.5 kN/m ³

Liner: Micropalo 168.3_sp10/1.45

Liner Type	Standard Beam
Formulation	Timoshenko
Area	0.00342 m ²
Moment of Inertia	1.78e-005 m ⁴

Elastic Properties

Young's modulus	2.1e+008 kPa
Poisson's ratio	0.2

Displacements

- Displacement data is not available for Geostatico until total displacement is viewed in a window
- Displacement data is not available for Piano di lavoro until total displacement is viewed in a window
- Displacement data is not available for Jet until total displacement is viewed in a window
- Displacement data is not available for Approfondimento until total displacement is viewed in a window
- Displacement data is not available for I ribasso until total displacement is viewed in a window
- Displacement data is not available for I puntone until total displacement is viewed in a window
- Displacement data is not available for II ribasso until total displacement is viewed in a window
- Displacement data is not available for II puntone until total displacement is viewed in a window
- Displacement data is not available for III ribasso until total displacement is viewed in a window
- Displacement data is not available for III puntone until total displacement is viewed in a window
- Displacement data is not available for Fondo scavo until total displacement is viewed in a window
- Displacement data is not available for Getto solettone until total displacement is viewed in a window
- Displacement data is not available for Rimozione puntone until total displacement is viewed in a window
- Displacement data is not available for Getto calotta until total displacement is viewed in a window
- Displacement data is not available for Rimozione puntone until total displacement is viewed in a window
- Displacement data is not available for Ritombamento until total displacement is viewed in a window
- Displacement data is not available for Rilevato ferroviario until total displacement is viewed in a window
- Displacement data is not available for Carico treno until total displacement is viewed in a window

Yielded Elements

Yielded Mesh Elements

- Number of yielded mesh elements on Geostatico: 155
- Number of yielded mesh elements is not available for Piano di lavoro until the stage is viewed in a window
- Number of yielded mesh elements is not available for Jet until the stage is viewed in a window
- Number of yielded mesh elements is not available for Approfondimento until the stage is viewed in a window
- Number of yielded mesh elements is not available for I ribasso until the stage is viewed in a window
- Number of yielded mesh elements is not available for I puntone until the stage is viewed in a window

- Number of yielded mesh elements is not available for II ribasso until the stage is viewed in a window
- Number of yielded mesh elements is not available for II puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for III ribasso until the stage is viewed in a window
- Number of yielded mesh elements is not available for III puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for Fondo scavo until the stage is viewed in a window
- Number of yielded mesh elements is not available for Getto solettone until the stage is viewed in a window
- Number of yielded mesh elements is not available for Rimozione puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for Getto calotta until the stage is viewed in a window
- Number of yielded mesh elements is not available for Rimozione puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for Ritombamento until the stage is viewed in a window
- Number of yielded mesh elements is not available for Rilevato ferroviario until the stage is viewed in a window
- Number of yielded mesh elements is not available for Carico treno until the stage is viewed in a window

Yielded Bolt Elements

- Number of yielded bolt elements on Geostatico: 0
- Number of yielded bolt elements on Piano di lavoro: 0
- Number of yielded bolt elements on Jet: 0
- Number of yielded bolt elements on Approfondimento: 0
- Number of yielded bolt elements on I ribasso: 0
- Number of yielded bolt elements on I puntone: 0
- Number of yielded bolt elements on II ribasso: 0
- Number of yielded bolt elements on II puntone: 0
- Number of yielded bolt elements on III ribasso: 0
- Number of yielded bolt elements on III puntone: 0
- Number of yielded bolt elements on Fondo scavo: 0
- Number of yielded bolt elements on Getto solettone: 0
- Number of yielded bolt elements on Rimozione puntone: 0
- Number of yielded bolt elements on Getto calotta: 0
- Number of yielded bolt elements on Rimozione puntone: 0
- Number of yielded bolt elements on Ritombamento: 0
- Number of yielded bolt elements on Rilevato ferroviario: 0
- Number of yielded bolt elements on Carico treno: 0

Yielded Liner Elements

- Number of yielded liner elements on Geostatico: 0
- Number of yielded liner elements on Piano di lavoro: 0
- Number of yielded liner elements on Jet: 0
- Number of yielded liner elements on Approfondimento: 0
- Number of yielded liner elements on I ribasso: 0
- Number of yielded liner elements on I puntone: 0
- Number of yielded liner elements on II ribasso: 0
- Number of yielded liner elements on II puntone: 0
- Number of yielded liner elements on III ribasso: 0
- Number of yielded liner elements on III puntone: 0
- Number of yielded liner elements on Fondo scavo: 0
- Number of yielded liner elements on Getto solettone: 0
- Number of yielded liner elements on Rimozione puntone: 0
- Number of yielded liner elements on Getto calotta: 0
- Number of yielded liner elements on Rimozione puntone: 0
- Number of yielded liner elements on Ritombamento: 0
- Number of yielded liner elements on Rilevato ferroviario: 0
- Number of yielded liner elements on Carico treno: 0

List of All Coordinates

External boundary

X	Y
-91.42	0
-17.365	4.59632e-014
4.44157	5.94927e-014
12.443	5.94927e-014
19.4976	6.88338e-014
41.4181	8.26006e-014
91.42	1.137e-013
91.42	38.7809
91.42	82.5506
91.42	85.0339
84.5659	83.7505
56.0805	78.417
46.4332	76.6107
41.4181	75.6717
36.8485	74.1058
28.5227	74.1058
27.222	73.1811
19.4976	73.1811
-20.1913	73.5072
-26.01	73.513
-27.8	73.5148
-29.7979	73.5169
-31.61	73.5187
-34.549	73.5217
-37.6918	71.3098
-53.8224	70.9177
-91.42	70.0037
-91.42	38.7809

Material boundary

X	Y
-37.6918	71.3098
-17.365	71.6502

Material boundary

X	Y
-12.5632	71.6502
-9.69723	69.7519
-8.71149	69.7553
8.80078	69.7457

9.67812	69.7457
13.2747	72.1308

Material boundary

X	Y
-8.71149	69.7553
-7.196	68.6789
-6.4179	68.6789
6.42	68.6789
7.20508	68.6819
8.80078	69.7457

Material boundary

X	Y
-6.4179	68.6789
-6.4179	65.4805
-6.4179	64.4305
-5.65953	64.4305
-5.11838	64.4305
-4.92	64.4305
-4.92	64.9555
-4.92	65.4805
-5.65953	65.4805
-6.4179	65.4805

Material boundary

X	Y
-4.92	64.9555
4.92	64.9555

Material boundary

X	Y
4.92	65.4805
4.92	64.9555
4.92	64.4305
5.12346	64.4305
5.77317	64.4305
6.42	64.4305
6.42	65.4805
5.77317	65.4805
4.92	65.4805

Material boundary

X	Y
4.92	64.4305
4.72058	64.4305

Material boundary

X	Y
-4.72199	62.0707
-1	64.0205
1	64.0205
4.72058	62.0707

Material boundary

X	Y
1.1e-015	63.0205
-1.21135	62.8286
-1.96	62.4953
-2.43158	62.0707
-3.39482	61.0605
-3.84483	60.0435
-3.84483	58.6994
-3.84483	58.1909
-3.62135	57.3061
-3.25564	56.4699
-2.15	55.9305
2.15	55.9305
3.25564	56.4699
3.62135	57.3061
3.84483	58.1909
3.84483	58.6994
3.84483	60.0435
3.39482	61.0605
2.43158	62.0707
1.96	62.4953
1.21135	62.8286
1.1e-015	63.0205

Material boundary

X	Y
-7.196	68.6789

-9.428	68.6789
-9.428	47.1304
9.428	47.1333
9.428	68.6819
7.20508	68.6819

Material boundary

X	Y
6.42	68.6789
6.42	65.4805

Material boundary

X	Y
-4.72199	62.0707
-2.43158	62.0707
2.43158	62.0707
4.72058	62.0707

Material boundary

X	Y
-4.72199	58.6994
-3.84483	58.6994
3.84483	58.6994
4.72058	58.6994

Material boundary

X	Y
41.4181	75.6717
41.4181	72.2733
41.4181	38.7809
41.4181	30.2862
41.4181	8.26006e-014

Material boundary

X	Y
19.4976	73.1811
19.4976	72.2733
19.4976	38.7809
19.4976	15.7913
19.4976	7.37376

19.4976	6.88338e-014
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Material boundary

X	Y
-20.1913	73.5072
-17.365	71.6502
-17.365	38.7809
-17.365	4.59632e-014

Material boundary

X	Y
-91.42	38.7809
-17.365	38.7809
19.4976	38.7809
41.4181	38.7809
49.5451	38.7809
91.42	38.7809

Material boundary

X	Y
-3.84483	58.1909
3.84483	58.1909

Material boundary

X	Y
-3.84483	58.1909
-4.72199	58.1909

Material boundary

X	Y
3.84483	58.1909
4.72058	58.1909

Material boundary

X	Y
-3.25564	56.4699
-4.72199	56.4699

Material boundary

X	Y
3.25564	56.4699
4.72058	56.4699

Material boundary

X	Y
-26.01	73.513
-26.01	73.208
-27.8	73.208
-27.8	73.5148

Material boundary

X	Y
-29.7979	73.5169
-29.7979	73.209
-31.61	73.209
-31.61	73.5187

Material boundary

X	Y
-12.5632	71.6502
-17.365	71.6502

Material boundary

X	Y
13.2747	72.1308
17.0946	72.2733
19.4976	73.1811

Material boundary

X	Y
13.2747	72.1308
-4.95631	71.7917
-12.5632	71.6502

Material boundary

X	Y
---	---

27.222	73.1811
36.8485	73.1811
36.8485	74.1058

Material boundary

X	Y
19.4976	15.7913
4.44157	5.94927e-014

Material boundary

X	Y
12.443	5.94927e-014
19.4976	7.37376
41.4181	30.2862
49.5451	38.7809
91.42	82.5506

Material boundary

X	Y
19.4976	15.7913
41.4181	38.7809

Material boundary

X	Y
41.4181	38.7809
84.5659	83.7505

Material boundary

X	Y
17.0946	72.2733
19.4976	72.2733
41.4181	72.2733

Material boundary

X	Y
41.4181	72.2733
46.4332	76.6107

Material boundary

X	Y
-3.39482	61.0605
-4.72199	61.0605

Material boundary

X	Y
-3.39482	61.0605
3.39482	61.0605
4.72058	61.0605

Material boundary

X	Y
-5.11838	64.4305
-5.11838	64.0205
-5.11838	61.0605
-5.11838	58.1909
-5.11838	54.1305

Material boundary

X	Y
-4.72199	54.1305
-4.72199	56.4699

Material boundary

X	Y
-4.72199	54.1305
-5.11838	54.1305

Material boundary

X	Y
-4.72199	56.4699
-4.72199	58.1909

Material boundary

X	Y
-4.72199	58.1909
-4.72199	58.6994

Material boundary

X	Y
-4.72199	58.6994
-4.72199	61.0605

Material boundary

X	Y
-4.72199	61.0605
-4.72199	62.0707

Material boundary

X	Y
-4.72199	62.0707
-4.72199	64.0205
-4.72199	64.4305
-4.92	64.4305

Material boundary

X	Y
5.12346	64.4305
5.12346	64.0205
5.12346	61.0605
5.12346	58.1909
5.12346	54.1305

Material boundary

X	Y
4.72058	54.1305
4.72058	56.4699
4.72058	58.1909
4.72058	58.6994
4.72058	61.0605
4.72058	62.0707
4.72058	64.0205
4.72058	64.4305

Material boundary

X	Y
---	---

4.72058	54.1305
5.12346	54.1305

Material boundary

X	Y
4.72058	54.1305
-4.72199	54.1305

Material boundary

X	Y
-1	64.0205
-4.72199	64.0205

Material boundary

X	Y
1	64.0205
4.72058	64.0205

Material boundary

X	Y
-4.72199	64.0205
-5.11838	64.0205

Material boundary

X	Y
4.72058	64.0205
5.12346	64.0205

Material boundary

X	Y
-4.72199	61.0605
-5.11838	61.0605

Material boundary

X	Y
4.72058	61.0605
5.12346	61.0605

Material boundary

X	Y
-4.72199	58.1909

-5.11838	58.1909
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Material boundary

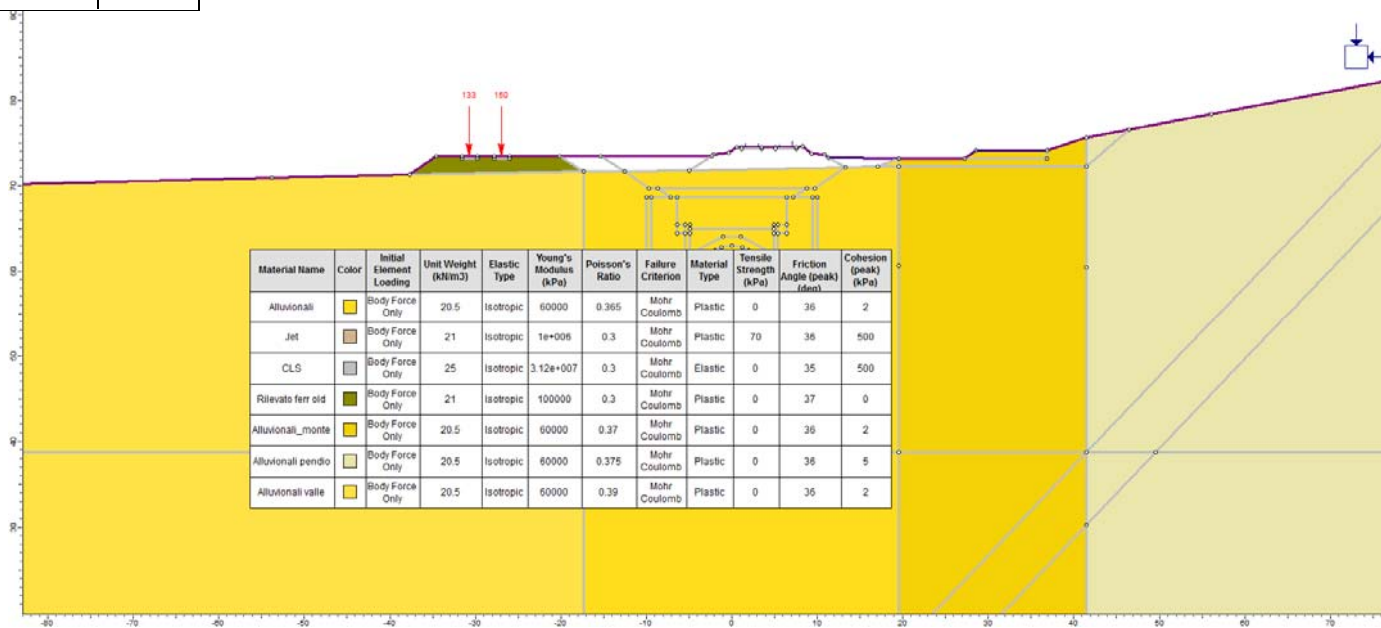
X	Y
4.72058	58.1909
5.12346	58.1909

Material boundary

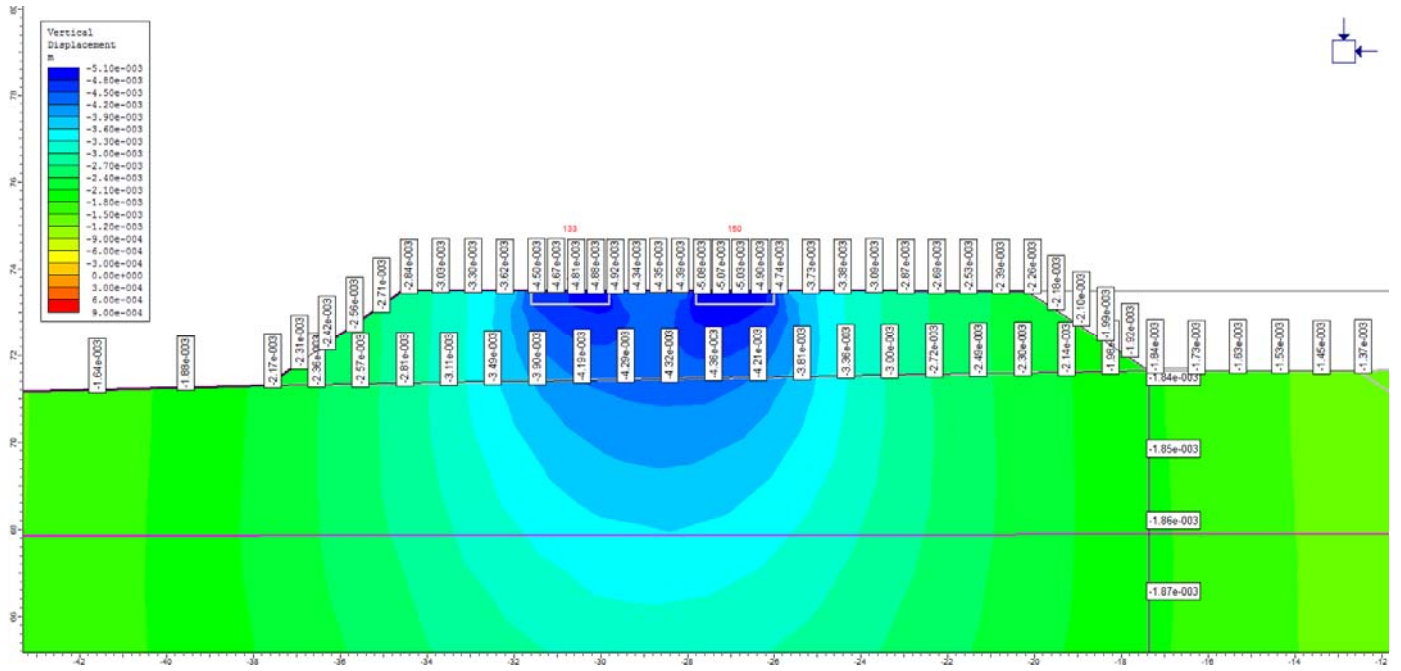
X	Y
-5.65953	65.4805
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-5.65953	49.849

Material boundary

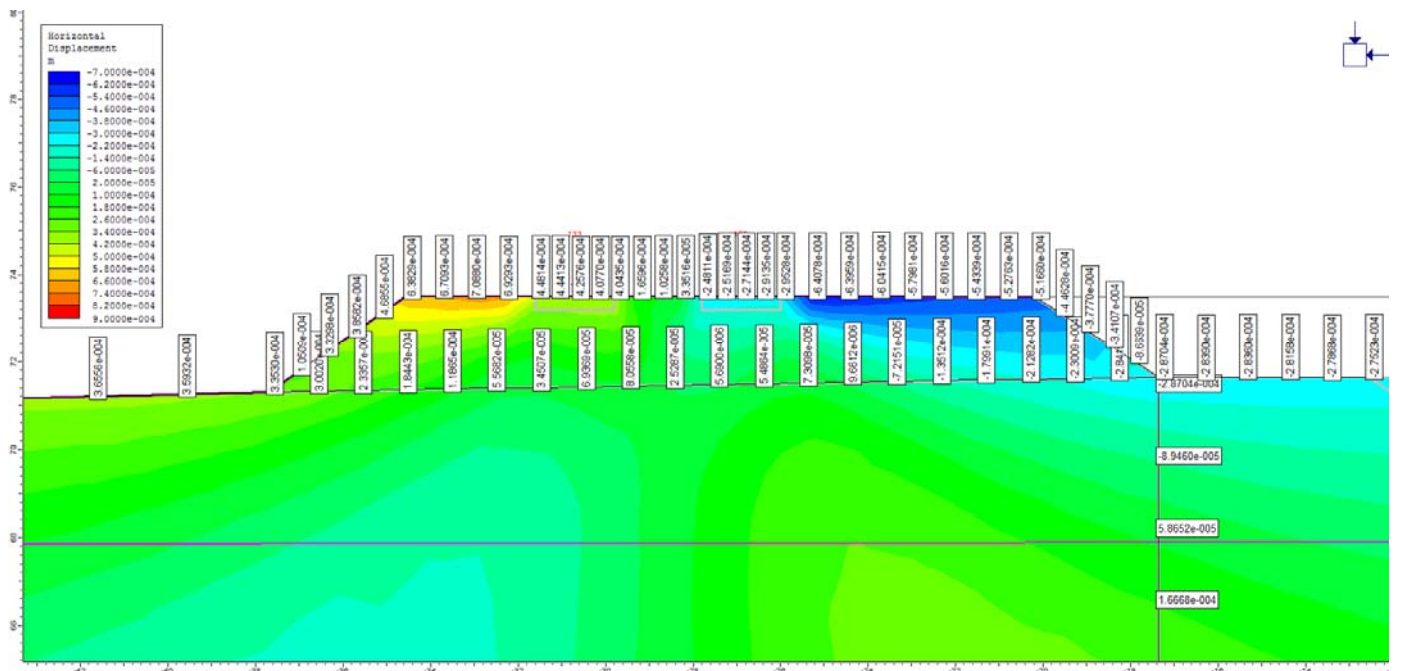
X	Y
5.77317	65.4805
5.77317	64.4305
5.77317	49.978



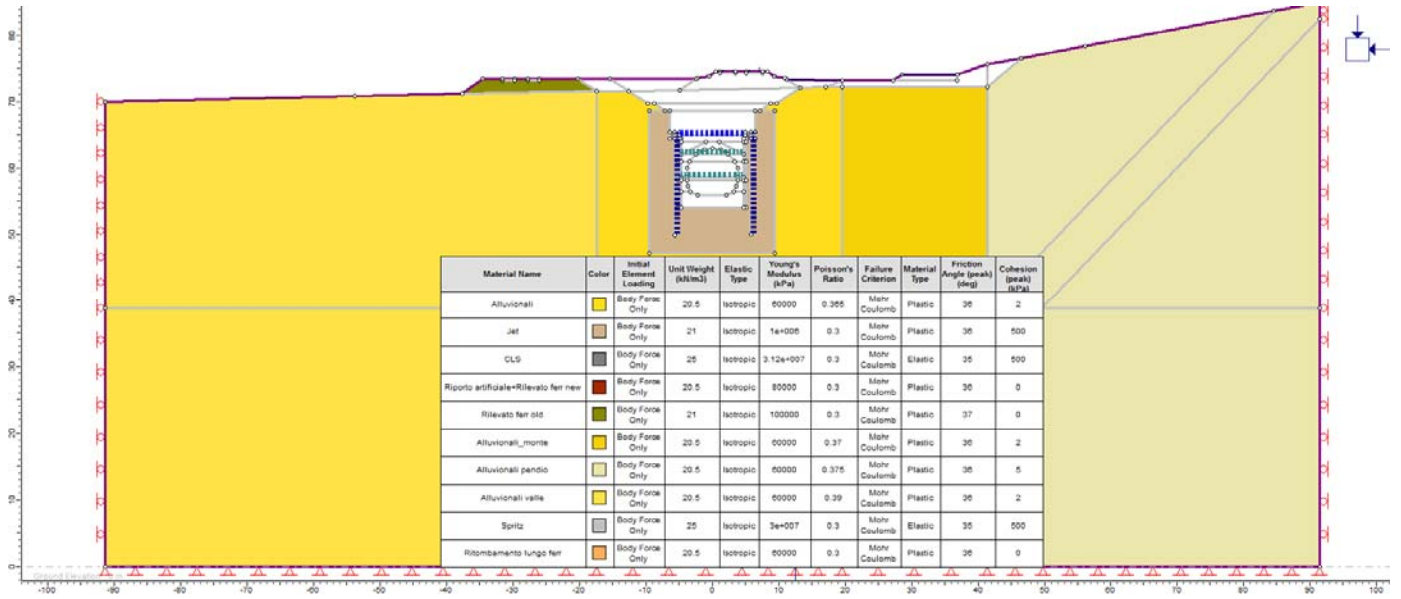
Geometria di calcolo per la Galleria di Base binario Pari. Progressiva pk_54+889. Carico del treno applicato al rilevato ferroviario prima dello scavo.



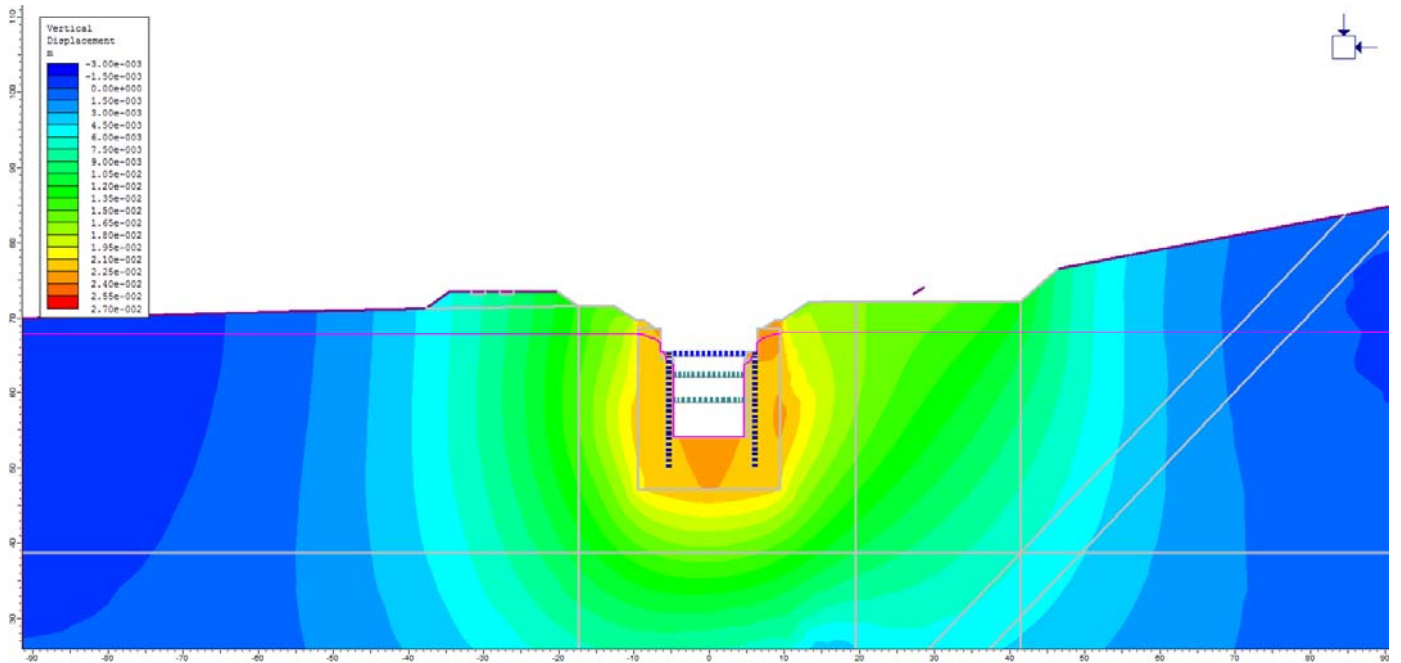
Galleria di Base binario Pari. Progressiva pk₅₄₊₈₈₉.
 Spostamenti verticali dY. Carico del treno applicato al rilevato ferroviario prima dello scavo. Carico non fattorizzato (SLE)



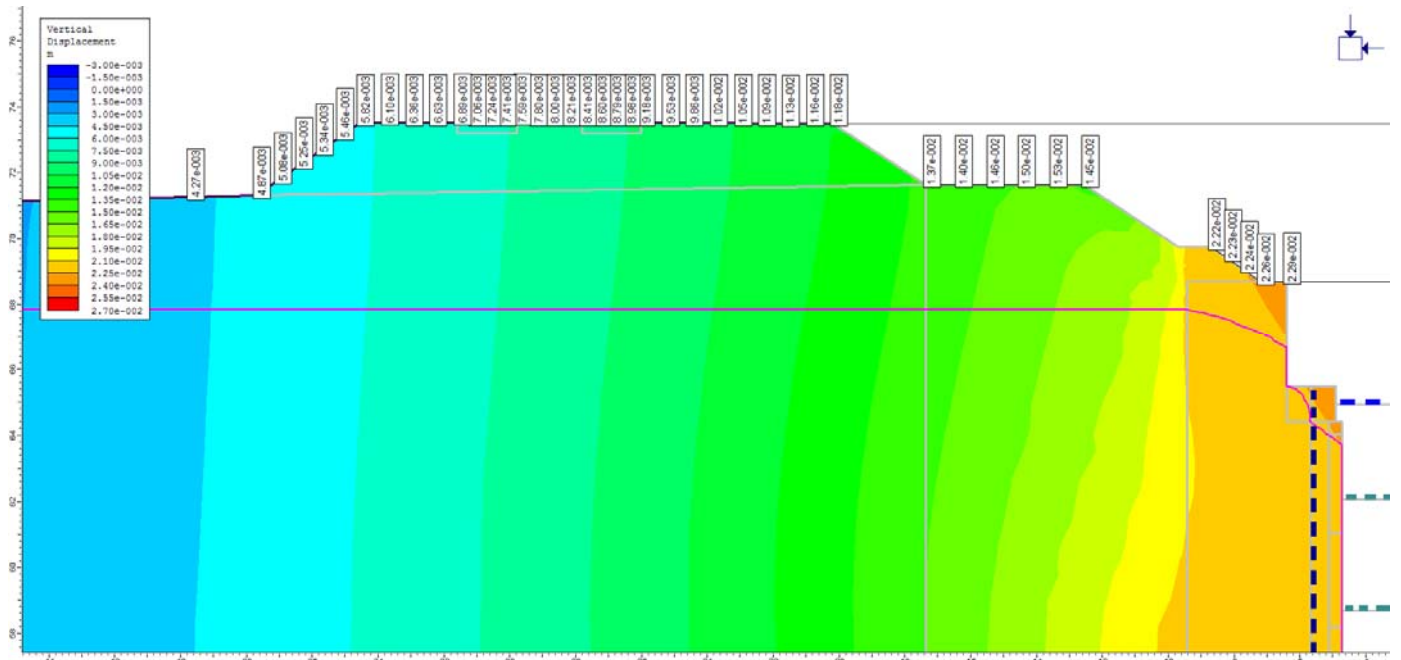
Galleria di Base binario Pari. Progressiva pk₅₄₊₈₈₉.
 Spostamenti verticali dX. Carico del treno applicato al rilevato ferroviario prima dello scavo. Carico non fattorizzato (SLE)



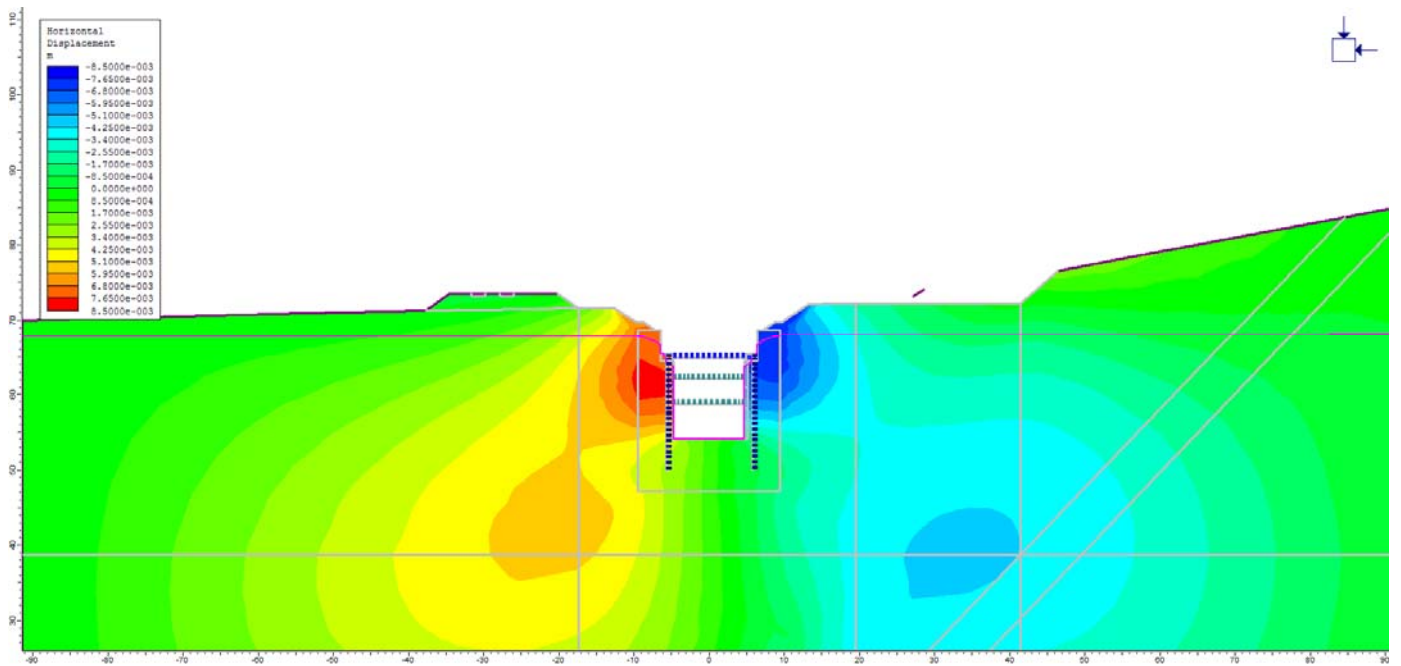
Geometria di calcolo per la Galleria di Base binario Pari. Progressiva pk_54+889. Fase finale di scavo più carico del treno.



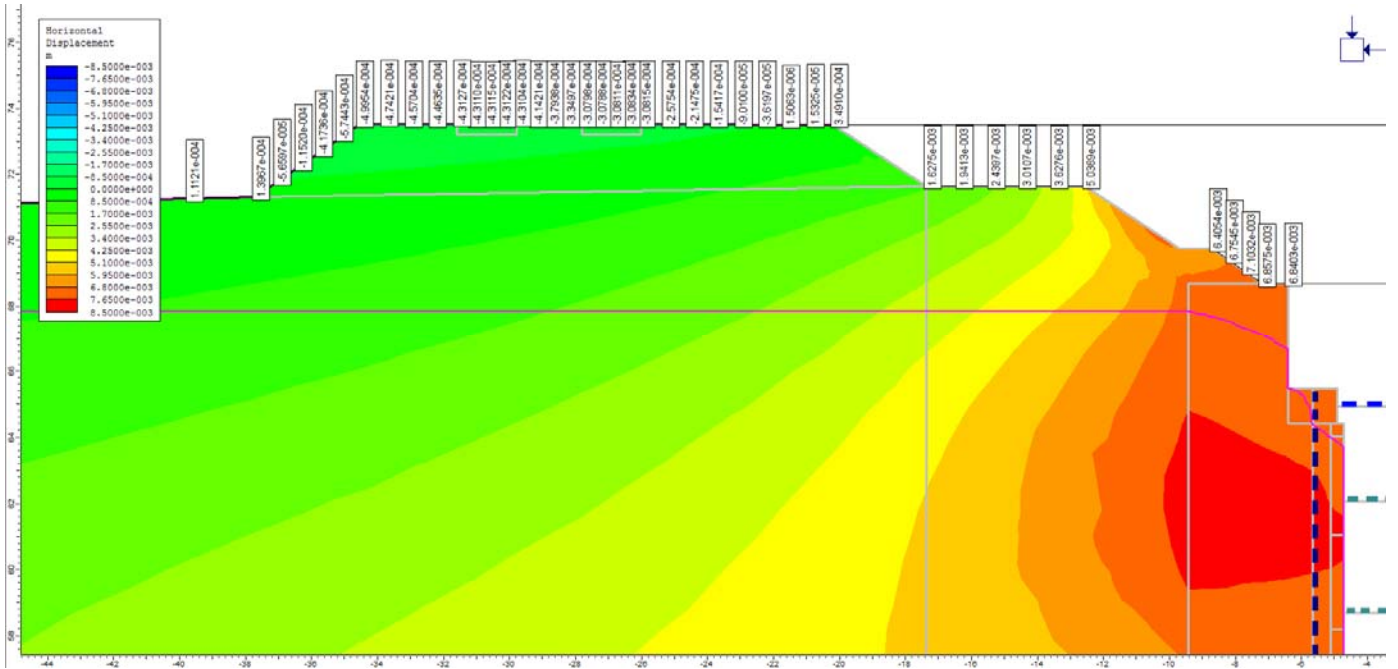
Galleria di Base binario Pari. Progressiva pk_54+889. Spostamenti verticali dY. Fase finale di scavo. Carico non fattorizzato (SLE)



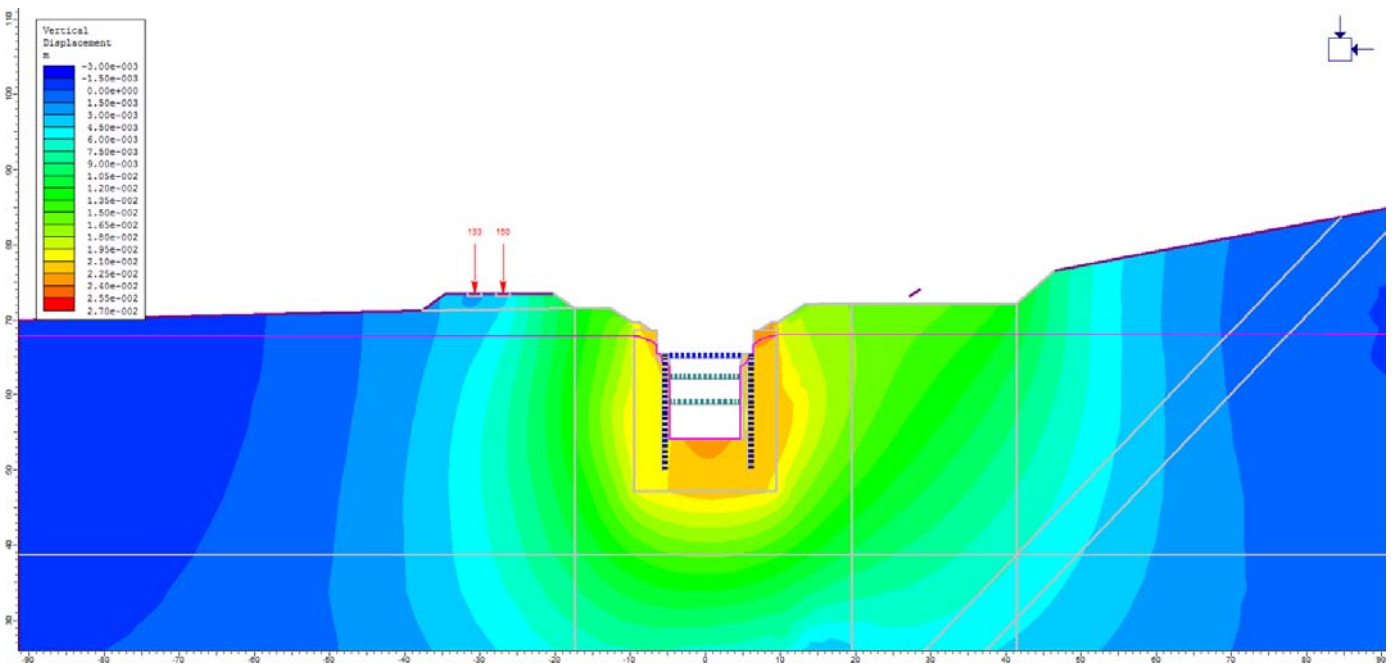
Galleria di Base binario Pari. Progressiva pk₅₄₊₈₈₉.
 Spostamenti verticali dY. Fase finale di scavo. Particolare del
 rilevato ferroviario. Carico non fattorizzato (SLE)



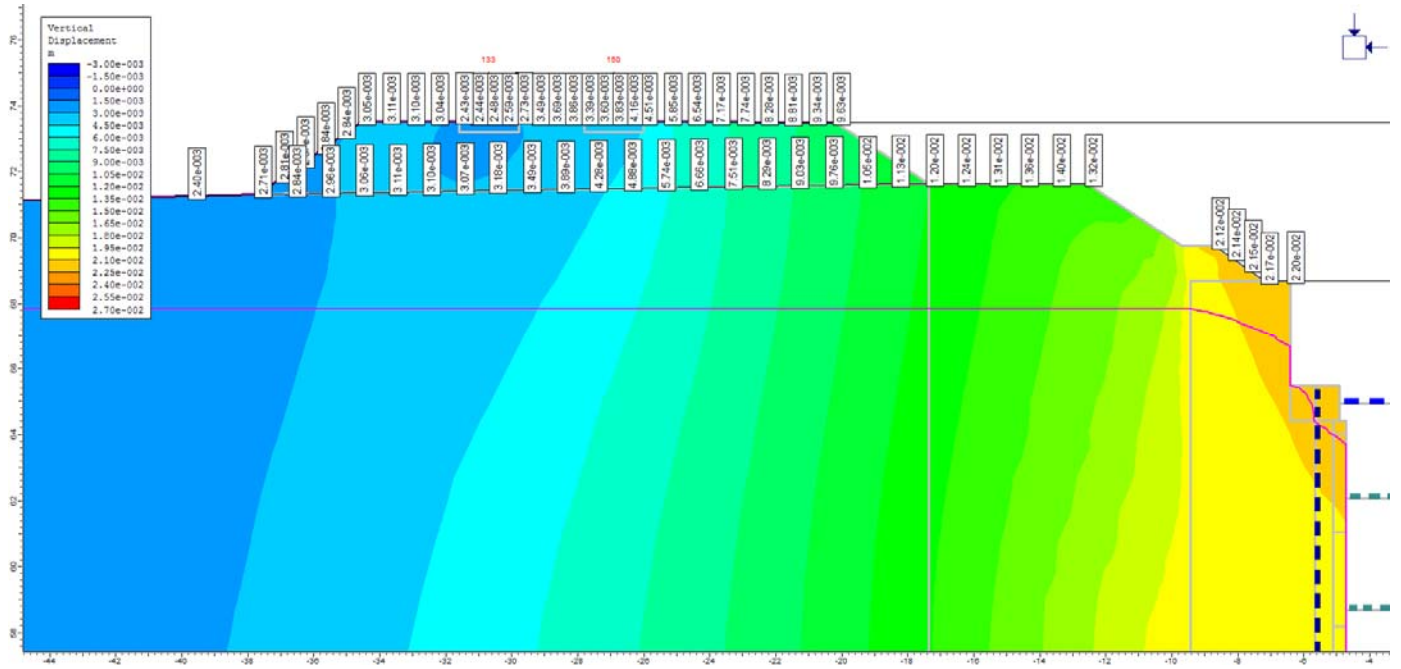
Galleria di Base binario Pari. Progressiva pk₅₄₊₈₈₉.
 Spostamenti orizzontali dX. Fase finale di scavo. Carico non
 fattorizzato (SLE)



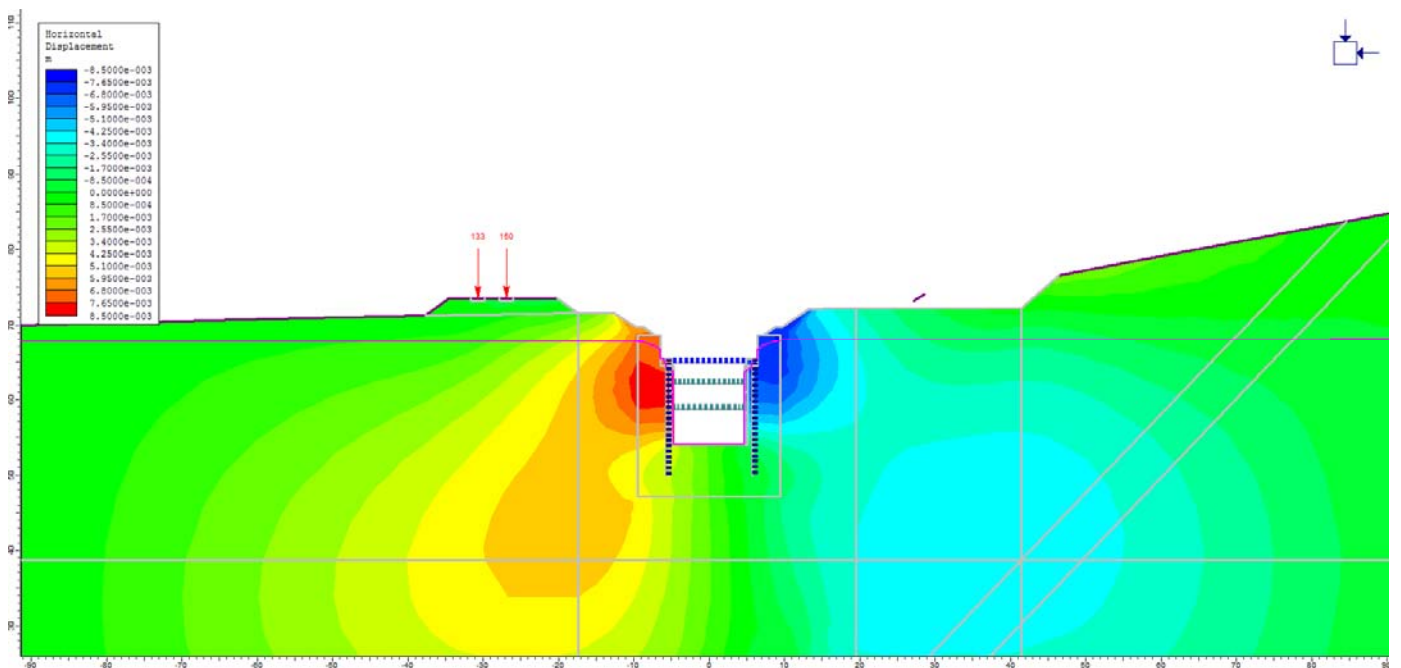
Galleria di Base binario Pari. Progressiva pk₅₄₊₈₈₉. Spostamenti orizzontali dX. Fase finale di scavo. Particolare del rilevato ferroviario. Carico non fattorizzato (SLE)



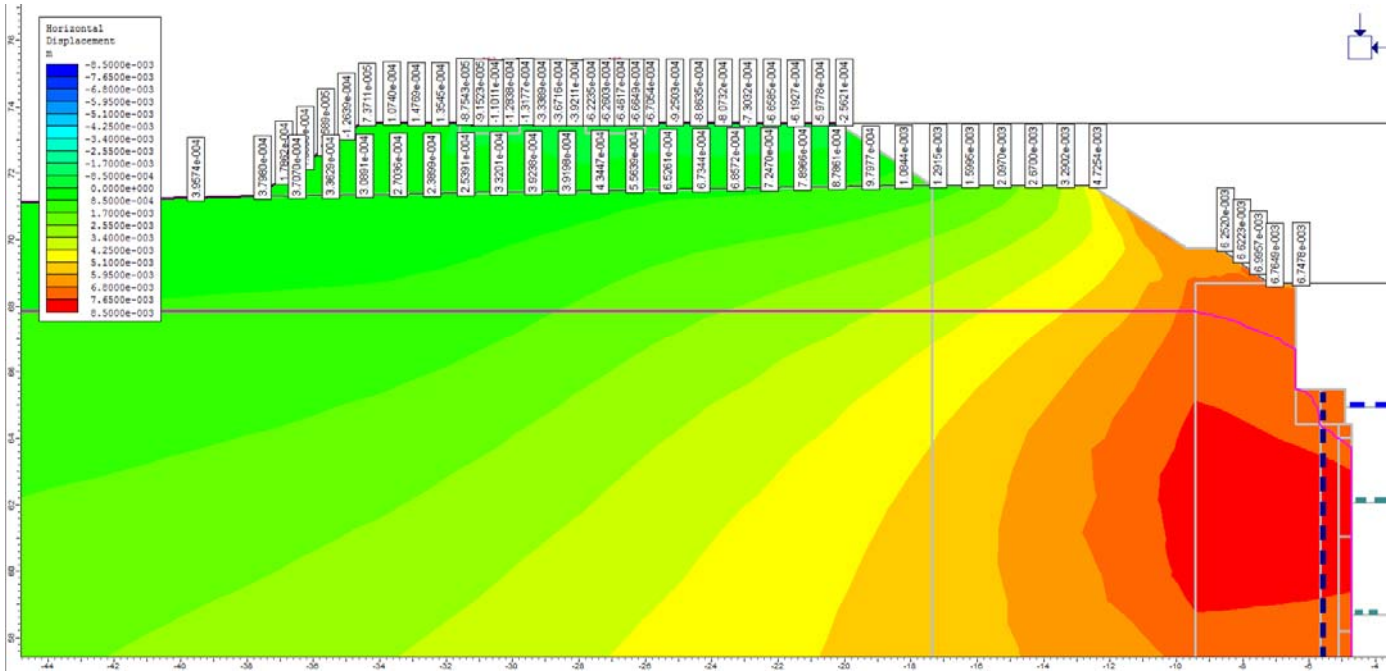
Galleria di Base binario Pari. Progressiva pk₅₄₊₈₈₉. Spostamenti verticali dY. Fase finale di scavo più carico del treno. Carico non fattorizzato (SLE)



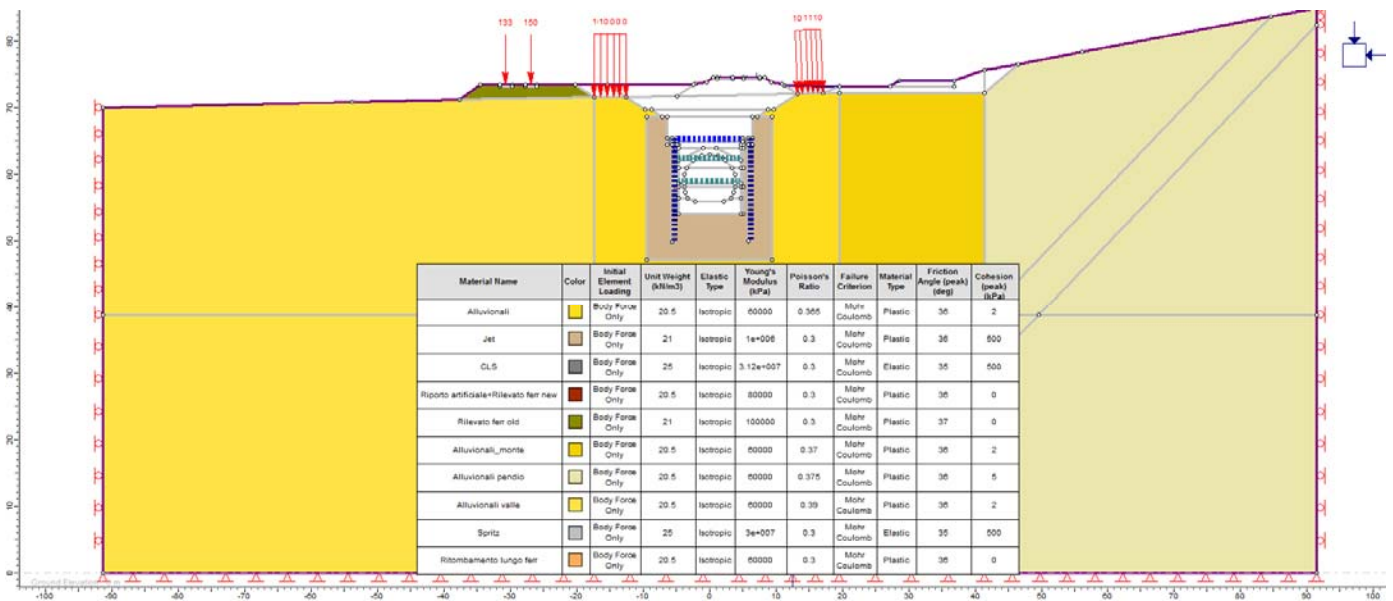
Galleria di Base binario Pari. Progressiva pk₅₄₊₈₈₉. Spostamenti verticali dY. Fase finale di scavo più carico del treno. Particolare del rilevato ferroviario. Carico non fattorizzato (SLE)



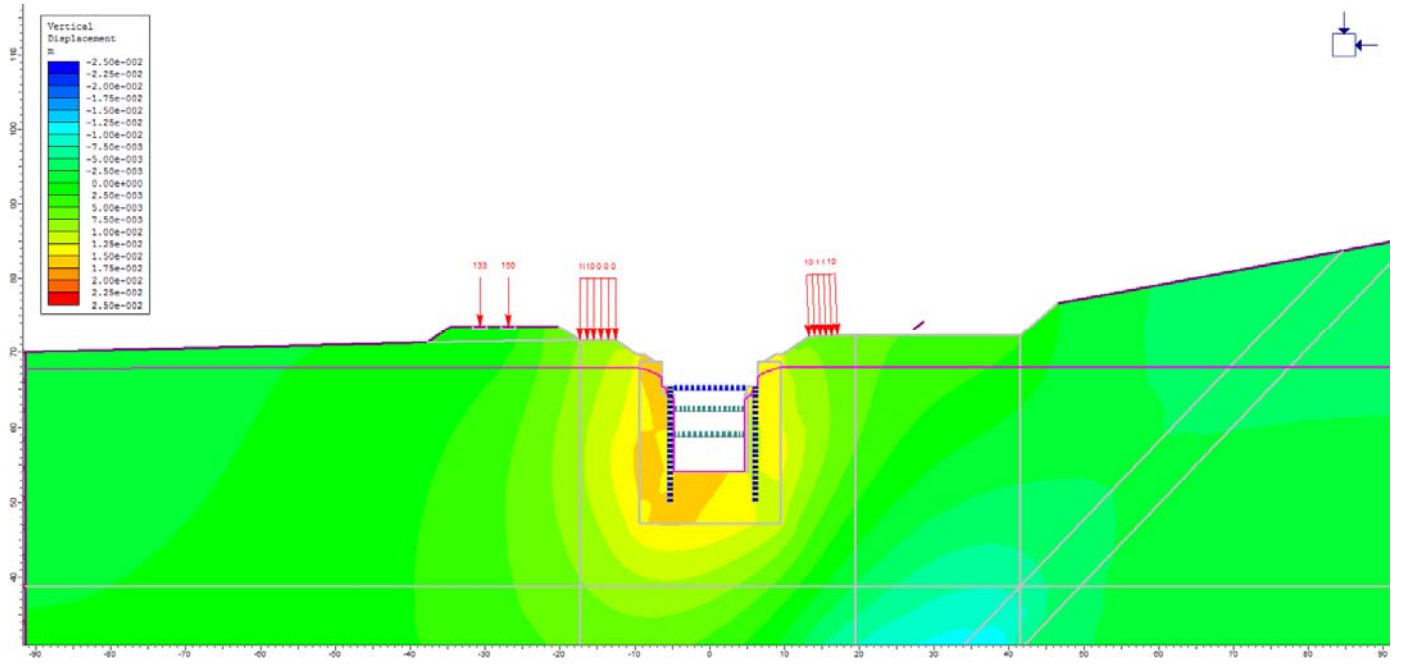
Galleria di Base binario Pari. Progressiva pk₅₄₊₈₈₉. Spostamenti orizzontali dX. Fase finale di scavo più carico del treno. Carico non fattorizzato (SLE)



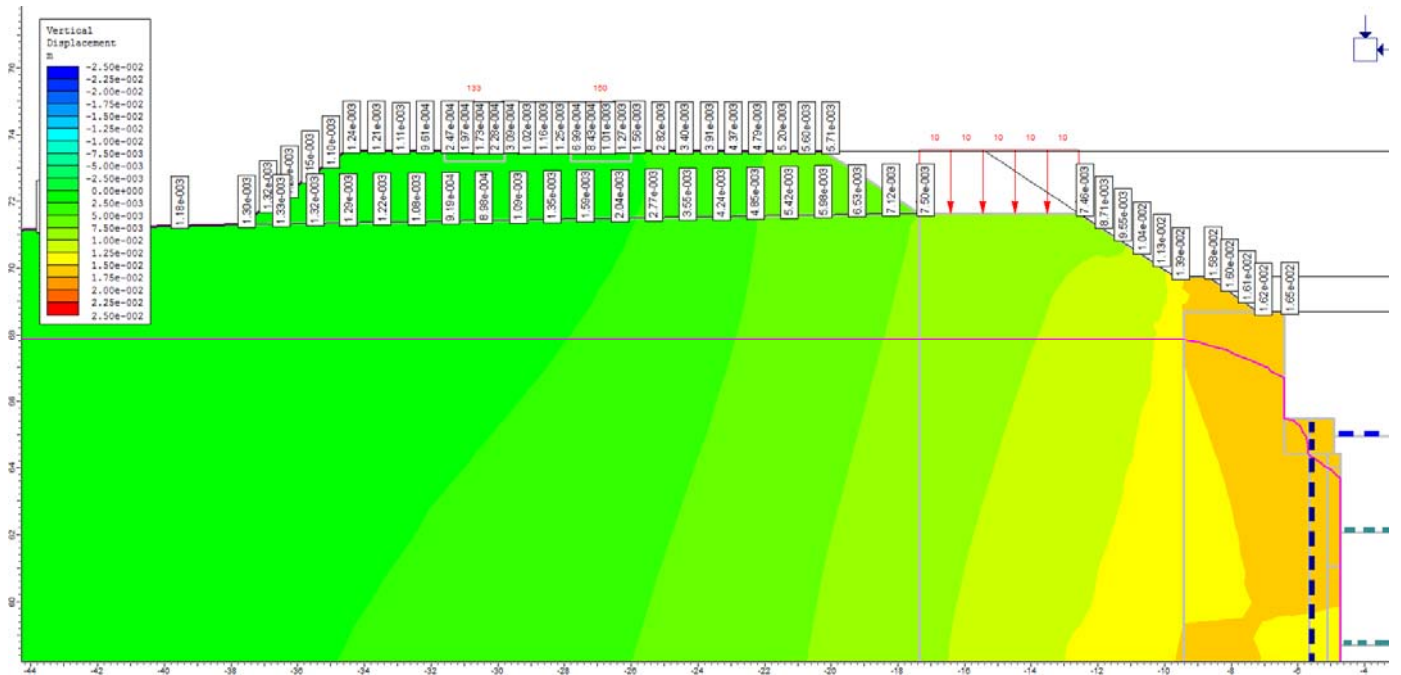
Galleria di Base binario Pari. Progressiva pk₅₄₊₈₈₉. Spostamenti orizzontali dX. Fase finale di scavo più carico del treno. Particolare del rilevato ferroviario. Carico non fattorizzato (SLE)



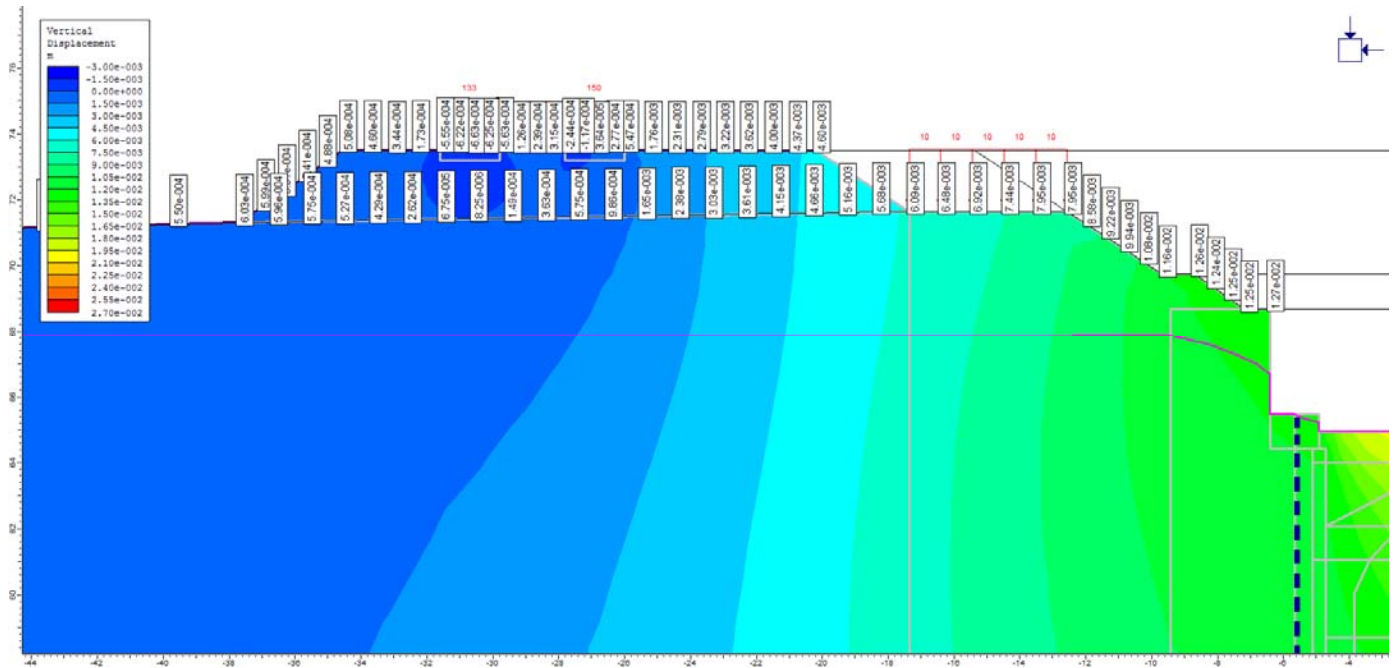
Geometria di calcolo per la Galleria di Base binario Pari. Progressiva pk₅₄₊₈₈₉. Fase finale di scavo con carico del treno e carico distribuito durante costruzione.



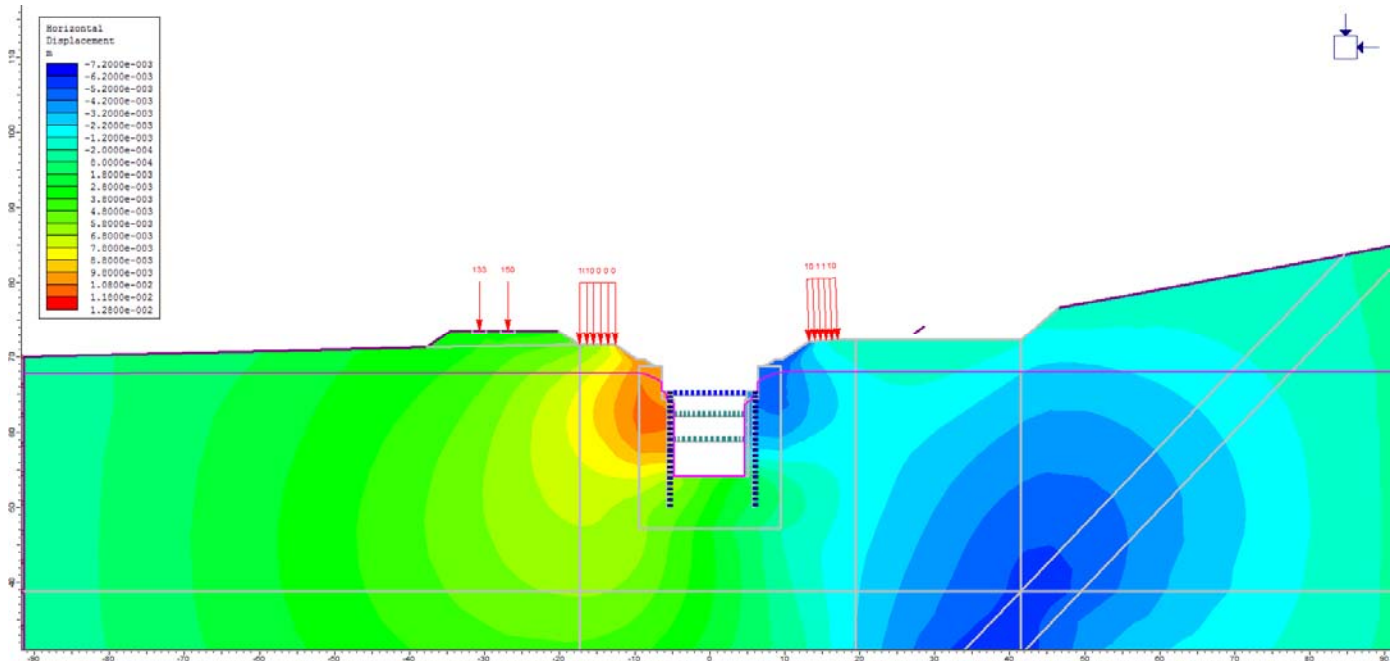
Galleria di Base binario Pari. Progressiva pk₅₄₊₈₈₉. Spostamenti verticali dY. Fase finale di scavo, eseguito con carico del treno e carico distribuito durante costruzione. Carico non fattorizzato (SLE)



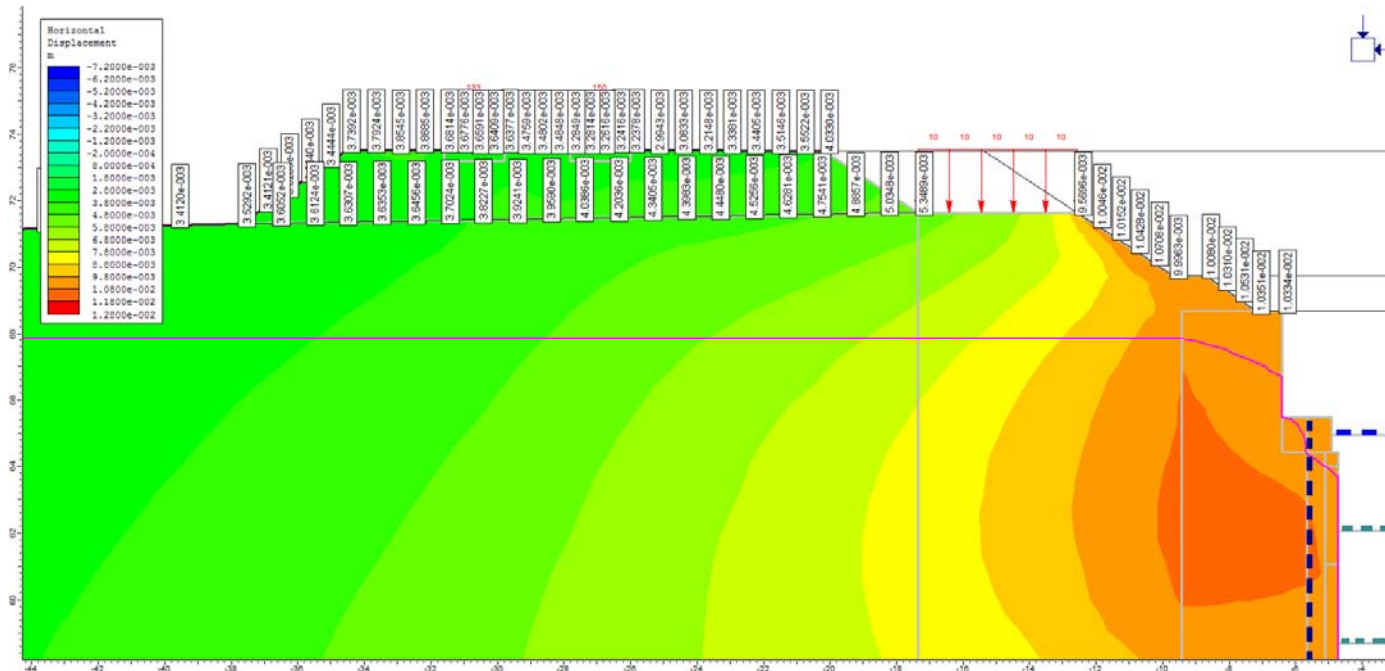
Galleria di Base binario Pari. Progressiva pk₅₄₊₈₈₉. Spostamenti verticali dY. Fase finale di scavo, eseguito con carico del treno e carico distribuito durante costruzione. Particolare del rilevato ferroviario. Carico non fattorizzato (SLE)



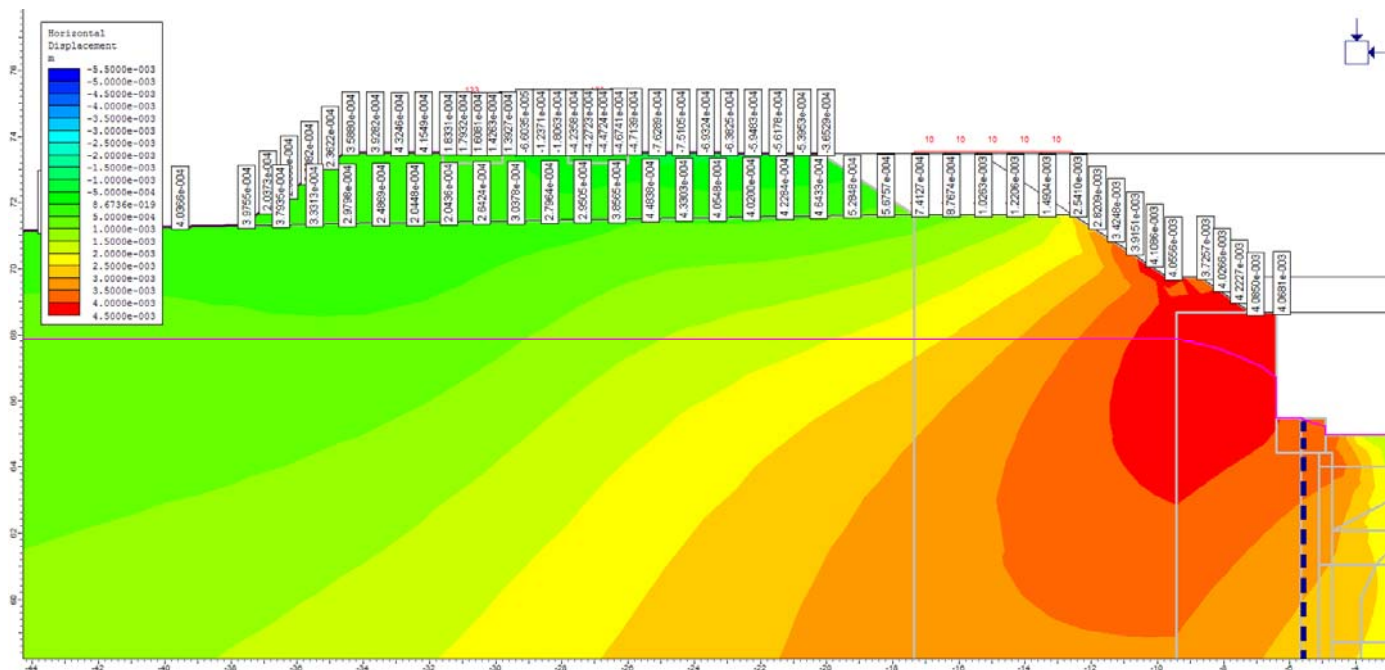
Galleria di Base binario Pari. Progressiva pk₅₄₊₈₈₉. Spostamenti verticali dY. Fase di scavo fino a raggiungere quota del piano di lavoro del Jet grouting. Particolare del rilevato ferroviario. Carico non fattorizzato (SLE)



Galleria di Base binario Pari. Progressiva pk₅₄₊₈₈₉. Spostamenti orizzontali dX. Fase finale di scavo, eseguito con carico del treno e carico distribuito durante costruzione. Carico non fattorizzato (SLE)



Galleria di Base binario Pari. Progressiva pk₅₄+889. Spostamenti orizzontali dX. Fase finale di scavo, eseguito con carico del treno e carico distribuito durante costruzione. Particolare del rilevato ferroviario. Carico non fattorizzato (SLE)



Galleria di Base binario Pari. Progressiva pk₅₄+889. Spostamenti verticali dX. Fase di scavo fino a raggiungere quota del piano di lavoro del Jet grouting. Particolare del rilevato ferroviario. Carico non fattorizzato (SLE)

ANLAGE B	ALLEGATO B
	Analisi dei cedimenti del rilevato della Nuova linea ferroviaria alle progressive pk 0+325 sopra la Galleria di Base binario Dispari e pk 0+425 sopra la Galleria di Base binario Pari

OGGETTO E SCOPO

In seguito, sono riassunti i risultati delle analisi FEM non lineari eseguite per verificare i cedimenti del rilevato della nuova linea ferroviaria che corre sopra e nei pressi delle Gallerie artificiali di Base del Brennero, binario dispari e binario pari .

Il calcolo è stato eseguito con il software Phase2 con l'ipotesi di stato piano 2D ed è rappresentativo delle sezioni critiche della nuova linea ferroviaria alle progressive pk_0+325 sopra la Galleria di Base binario Dispari e pk_0+425 sopra la Galleria di Base binario Pari.

Il modello consente di accoppiare la sollecitazione dovuta a carichi statici, con la sollecitazione dovuta alla pressione dell'acqua in un regime di filtrazione ed ottenere i risultati in termini di Tensioni efficaci. L'analisi inoltre comprende le varie fasi di costruzione dell'opera di sostegno dello scavo ed in particolare: la creazione delle colonne di Jet-grouting e del tappo di fondo dal piano campagna, l'inserimento di micropali laterali allo scavo e tiranti, una prima fase di scavo, l'installazione del Primo puntone di contrasto, un secondo approfondimento dello scavo, installazione del Secondo puntone, un terzo approfondimento fino a fondo scavo e la rimozione dei puntoni una volta gettata la galleria. Alla fine si eseguono le fasi di ritombamento, creazione del nuovo rilevato ferroviario e di applicazione del carico dovuto al transito dei treni.

L'output del programma ed i risultati in termini di spostamenti orizzontali e verticali, sono di seguito riportati.

OUTPUTS DI CALCOLO E RISULTATI ANALISI
TENSO-DEFORMATIVA SEZIONE DELLA NUOVA
LINEA FERROVIARIA PK_0+325

Phase2 Analysis Information

Project Settings

- Document Name: Sez 54+997_M-C_scavo+rilev fs.fez
- Project Title: Project1
- Number of Stages: 17
- Analysis Type: Plane Strain
- Solver Type: Gaussian Elimination
- Units: Metric, stress as kPa

Stress Analysis

- Maximum Number of Iterations: 1500
- Tolerance: 0.001
- Number of Load Steps: Automatic
- Convergence Type: Absolute Energy
- Tensile Failure: Reduces Shear Strength
- Joint tension reduces joint stiffness by a factor of 0.01

Groundwater

- Method: Finite Element Analysis
- Pore Fluid Unit Weight: 9.81 kN/m³
- Maximum Number of Iterations: 500
- Tolerance: 1e-006

Field Stress

- Field stress: gravity
- Using actual ground surface
- Effective stress ratio (horizontal/vertical in-plane): 1
- Effective stress ratio (horizontal/vertical out-of-plane): 1
- Locked-in horizontal stress (in-plane): 0
- Locked-in horizontal stress (out-of-plane): 0

Mesh

- Mesh type: graded
- Element type: 8 noded quadrilaterals
- Number of elements on Geostatico: 2400
- Number of nodes on Geostatico: 7257
- Number of elements on Paratia: 2400

- Number of nodes on Paratia: 7257
- Number of elements on Piano lavoro: 2297
- Number of nodes on Piano lavoro: 6968
- Number of elements on Jet: 2297
- Number of nodes on Jet: 6968
- Number of elements on I ribasso: 2155
- Number of nodes on I ribasso: 6582
- Number of elements on I puntone: 2155
- Number of nodes on I puntone: 6582
- Number of elements on II ribasso: 2046
- Number of nodes on II ribasso: 6271
- Number of elements on II puntone: 2046
- Number of nodes on II puntone: 6271
- Number of elements on Fondo scavo: 1916
- Number of nodes on Fondo scavo: 5901
- Number of elements on Solettone: 1979
- Number of nodes on Solettone: 6084
- Number of elements on Rimozione puntone: 1979
- Number of nodes on Rimozione puntone: 6084
- Number of elements on Getto calotta: 2080
- Number of nodes on Getto calotta: 6396
- Number of elements on Rimozione puntone: 2080
- Number of nodes on Rimozione puntone: 6396
- Number of elements on Ritombamento: 2268
- Number of nodes on Ritombamento: 6922
- Number of elements on Rilevato ferroviario: 2528
- Number of nodes on Rilevato ferroviario: 7714
- Number of elements on Carico treno: 2528
- Number of nodes on Carico treno: 7714
- Number of elements on Degrado jet: 2528
- Number of nodes on Degrado jet: 7714

Mesh Quality

- All elements are of good quality

Poor quality elements defined as:

- Side length ratio (maximum / minimum) > 30.00
- Minimum interior angle < 2.0 degrees
- Maximum interior angle > 175.0 degrees

Reset Displacements

- Displacements reset after: Geostatico
- Displacements reset after: Paratia

Material Properties

Material: Alluvionali

Initial element loading	field stress & body force
Unit weight	20.5 kN/m ³
Elastic type	isotropic

Young's modulus	60000 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	36 degrees
Peak cohesion	2 kPa
Material type	Plastic
Dilation Angle	1 degrees
Residual Friction Angle	35 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Properties changed in Paratia

- Unit weight:

Properties changed in Jet

- Unit weight: Young's modulus: 120000 kPa (factor = 2) Field Stress Gravity Ground surface elevation 0 m Unit weight of overburden 0.027 kN/m³ Effective stress ratio (horizontal/vertical in-plane) 0.413 Effective stress ratio (horizontal/vertical out-of-plane) 0.413 Locked-in horizontal stress (in-plane) 0 Locked-in horizontal stress (out-of-plane) 0

Material: Jet grouting

Initial element loading	body force only
Unit weight	21 kN/m ³
Elastic type	isotropic
Young's modulus	1e+006 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	70 kPa
Peak friction angle	36 degrees
Peak cohesion	500 kPa
Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	36 degrees
Residual Cohesion	500 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	1e-008 m/s

K2/K1	1
K Angle	0 degrees

Material: Rilvato

Initial element loading	body force only
Unit weight	21 kN/m3
Elastic type	isotropic
Young's modulus	100000 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	37 degrees
Peak cohesion	0 kPa
Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	37 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Material: CLS

Initial element loading	body force only
Unit weight	25 kN/m3
Elastic type	isotropic
Young's modulus	3.12e+007 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	35 degrees
Peak cohesion	500 kPa
Material type	Elastic
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	1e-012 m/s
K2/K1	1
K Angle	0 degrees

Material: Ritombamento lungo ferrovia

Initial element loading	body force only
Unit weight	20.5 kN/m ³
Elastic type	isotropic
Young's modulus	60000 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	36 degrees
Peak cohesion	0 kPa
Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	36 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Material: Riporto artificiale+rilevato ferr new

Initial element loading	body force only
Unit weight	20.5 kN/m ³
Elastic type	isotropic
Young's modulus	80000 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	36 degrees
Peak cohesion	0 kPa
Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	36 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Areas of Excavated and Filled Elements

Fondo scavo

- Material: Alluvionali, Area Excavated: 39.955 m2

Solettone

- Material: CLS, Area Filled: 20.104 m2

Getto calotta

- Material: CLS, Area Filled: 23.544 m2

Ritombamento

- Material: Riporto artificiale+rilevato ferr new, Area Filled: 82.088 m2

Rilevato ferroviario

- Material: CLS, Area Filled: 1.199 m2
- Material: Ritombamento lungo ferrovia, Area Filled: 195.318 m2
- Material: Riporto artificiale+rilevato ferr new, Area Filled: 88.580 m2

Degrado jet

- Material: Alluvionali, Area Filled: 269.156 m2
- Material: Jet grouting, Area Excavated: 269.156 m2

Excavation Areas

Original Un-deformed Areas

- External Boundary Area: 12630.849 m2
- External Boundary Perimeter: 501.016 m

Geostatico

- External Boundary Area: 12630.849 m2 (0 m2 change from original area)
- External Boundary Perimeter: 501.016 m (0 m change from original perimeter)

Paratia

- Values not available until this stage is viewed in a window

Piano lavoro

- Values not available until this stage is viewed in a window

Jet

- Values not available until this stage is viewed in a window

I ribasso

- Values not available until this stage is viewed in a window

I puntone

- Values not available until this stage is viewed in a window

II ribasso

- Values not available until this stage is viewed in a window

II puntone

- Values not available until this stage is viewed in a window

Fondo scavo

- External Boundary Area: 12631.039 m² (0.190401 m² change from original area)
- External Boundary Perimeter: 501.013 m (-0.00272633 m change from original perimeter)

Solettone

- External Boundary Area: 12630.992 m² (0.143228 m² change from original area)
- External Boundary Perimeter: 501.013 m (-0.00287734 m change from original perimeter)

Rimozione puntone

- External Boundary Area: 12630.992 m² (0.142876 m² change from original area)
- External Boundary Perimeter: 501.013 m (-0.00289841 m change from original perimeter)

Getto calotta

- External Boundary Area: 12630.936 m² (0.0874817 m² change from original area)
- External Boundary Perimeter: 501.013 m (-0.00305406 m change from original perimeter)

Rimozione puntone

- External Boundary Area: 12630.936 m² (0.0874496 m² change from original area)
- External Boundary Perimeter: 501.013 m (-0.00322296 m change from original perimeter)

Ritombamento

- External Boundary Area: 12630.852 m² (0.00282424 m² change from original area)
- External Boundary Perimeter: 501.012 m (-0.00372863 m change from original perimeter)

Rilevato ferroviario

- External Boundary Area: 12628.407 m² (-2.44191 m² change from original area)
- External Boundary Perimeter: 500.985 m (-0.0305544 m change from original perimeter)

Carico treno

- External Boundary Area: 12628.294 m² (-2.55448 m² change from original area)
- External Boundary Perimeter: 500.984 m (-0.0315192 m change from original perimeter)

Degrado jet

- External Boundary Area: 12628.326 m² (-2.52297 m² change from original area)
- External Boundary Perimeter: 500.984 m (-0.0315083 m change from original perimeter)

Liner Properties

Liner: Micropalo_F178_sp10/1.2m

Liner Type	Standard Beam
Formulation	Timoshenko
Area	0.00439 m ²
Moment of Inertia	1.551e-005 m ⁴

Elastic Properties

Young's modulus	2.1e+008 kPa
Poisson's ratio	0.2

Liner: Micropalo_F178_sp10/0.75m

Liner Type	Standard Beam
Formulation	Timoshenko
Area	0.007025 m ²
Moment of Inertia	2.481e-005 m ⁴

Elastic Properties

Young's modulus	2.1e+008 kPa
Poisson's ratio	0.2

Liner: Tubo_F355_sp12/4m

Liner Type	Standard Beam
Formulation	Timoshenko
Area	0.003236 m ²
Moment of Inertia	4.782e-005 m ⁴

Elastic Properties

Young's modulus	2.1e+008 kPa
Poisson's ratio	0.2
Liner Unit Weight	78.5 kN/m ³

Liner: Tubo_F406_sp12.5/4m

Liner Type	Standard Beam
Formulation	Timoshenko
Area	0.003865 m ²
Moment of Inertia	7.503e-005 m ⁴

Elastic Properties

Young's modulus	2.1e+008 kPa
Poisson's ratio	0.2
Liner Unit Weight	78.5 kN/m ³

Bolt Properties

Bolt name	Tirante
Bolt Type	End anchored bolt
Diameter	22.5 mm
Young's modulus	2.1e+008 kPa
Tensile capacity	450 kN
Residual Tensile capacity	450 kN
Pre-tensioning	430 kN
Out-of-plane spacing	3 m

Displacements

- Displacement data is not available for Geostatico until total displacement is viewed in a window
- Displacement data is not available for Paratia until total displacement is viewed in a window
- Displacement data is not available for Piano lavoro until total displacement is viewed in a window
- Displacement data is not available for Jet until total displacement is viewed in a window
- Displacement data is not available for I ribasso until total displacement is viewed in a window
- Displacement data is not available for I puntone until total displacement is viewed in a window
- Displacement data is not available for II ribasso until total displacement is viewed in a window
- Displacement data is not available for II puntone until total displacement is viewed in a window
- Displacement data is not available for Fondo scavo until total displacement is viewed in a window
- Displacement data is not available for Solettone until total displacement is viewed in a window
- Displacement data is not available for Rimozione puntone until total displacement is viewed in a window
- Displacement data is not available for Getto calotta until total displacement is viewed in a window
- Displacement data is not available for Rimozione puntone until total displacement is viewed in a window
- Displacement data is not available for Ritombamento until total displacement is viewed in a window
- Displacement data is not available for Rilevato ferroviario until total displacement is viewed in a window
- Displacement data is not available for Carico treno until total displacement is viewed in a window
- Displacement data is not available for Degrado jet until total displacement is viewed in a window

Yielded Elements

Yielded Mesh Elements

- Number of yielded mesh elements on Geostatico: 269
- Number of yielded mesh elements is not available for Paratia until the stage is viewed in a window
- Number of yielded mesh elements is not available for Piano lavoro until the stage is viewed in a window
- Number of yielded mesh elements is not available for Jet until the stage is viewed in a window
- Number of yielded mesh elements is not available for I ribasso until the stage is viewed in a window
- Number of yielded mesh elements is not available for I puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for II ribasso until the stage is viewed in a window
- Number of yielded mesh elements is not available for II puntone until the stage is viewed in a window
- Number of yielded mesh elements on Fondo scavo: 445
- Number of yielded mesh elements on Solettone: 445
- Number of yielded mesh elements on Rimozione puntone: 445
- Number of yielded mesh elements on Getto calotta: 446
- Number of yielded mesh elements on Rimozione puntone: 450
- Number of yielded mesh elements on Ritombamento: 498
- Number of yielded mesh elements on Rilevato ferroviario: 600
- Number of yielded mesh elements on Carico treno: 621
- Number of yielded mesh elements on Degrado jet: 317

Yielded Bolt Elements

- Number of yielded bolt elements on Geostatico: 0
- Number of yielded bolt elements on Paratia: 0
- Number of yielded bolt elements on Piano lavoro: 0
- Number of yielded bolt elements on Jet: 0
- Number of yielded bolt elements on I ribasso: 0
- Number of yielded bolt elements on I puntone: 0
- Number of yielded bolt elements on II ribasso: 0
- Number of yielded bolt elements on II puntone: 0
- Number of yielded bolt elements on Fondo scavo: 0
- Number of yielded bolt elements on Solettone: 0
- Number of yielded bolt elements on Rimozione puntone: 0
- Number of yielded bolt elements on Getto calotta: 0
- Number of yielded bolt elements on Rimozione puntone: 0
- Number of yielded bolt elements on Ritombamento: 0
- Number of yielded bolt elements on Rilevato ferroviario: 0
- Number of yielded bolt elements on Carico treno: 0
- Number of yielded bolt elements on Degrado jet: 0

Yielded Liner Elements

- Number of yielded liner elements on Geostatico: 0
- Number of yielded liner elements on Paratia: 0
- Number of yielded liner elements on Piano lavoro: 0
- Number of yielded liner elements on Jet: 0
- Number of yielded liner elements on I ribasso: 0
- Number of yielded liner elements on I puntone: 0
- Number of yielded liner elements on II ribasso: 0
- Number of yielded liner elements on II puntone: 0
- Number of yielded liner elements on Fondo scavo: 0
- Number of yielded liner elements on Solettone: 0
- Number of yielded liner elements on Rimozione puntone: 0
- Number of yielded liner elements on Getto calotta: 0
- Number of yielded liner elements on Rimozione puntone: 0
- Number of yielded liner elements on Ritombamento: 0
- Number of yielded liner elements on Rilevato ferroviario: 0

- Number of yielded liner elements on Carico treno: 0
- Number of yielded liner elements on Degrado jet: 0

List of All Coordinates

External boundary

X	Y
-90	0
90	0
90	68.4018
90	71.1356
33.3307	71.1356
20.9042	71.1356
8.24702	70.9375
7.59471	71.3726
5.47702	71.4244
4.482	72.1706
3.932	72.1706
1.532	72.1706
-0.068	72.171
-2.468	72.171
-3.25001	72.171
-4.28064	71.4003
-5.63332	71.3697
-7.09903	70.9306
-11.395	70.8274
-11.7665	70.8274
-12.4217	70.8274
-12.7553	70.8274
-15.8378	70.8274
-17.603	70.8274
-19.6031	70.8274
-21.416	70.8274
-23.7323	70.8274
-27.127	68.3922
-42.8683	68.3922
-90	68.3922

Material boundary

X	Y
-11.395	70.8274
-11.395	68.4018
-11.395	66.3697
-11.395	47.8277

-12.7553	47.8277
-12.7553	68.401
-12.7553	70.8274

Material boundary

X	Y
-11.395	68.4018
-11.7665	68.4016
-12.4217	68.4012
-12.7553	68.401
-27.127	68.3922

Material boundary

X	Y
-12.4217	70.8274
-12.4217	68.4012
-12.4217	48.8274

Material boundary

X	Y
-11.7665	70.8274
-11.7665	68.4016
-11.7665	48.8274

Material boundary

X	Y
-9.99101	66.3697
-11.395	66.3697

Material boundary

X	Y
-9.99101	66.3697
-9.99101	45.6998
-4.89101	45.6998
4.94898	45.6998
10.0494	45.6998
10.0494	66.3708
9.39918	66.3708
7.33876	66.3707

Material boundary

X	Y
7.33876	66.3707
10.2799	68.4018
16.2042	68.4018
20.9042	71.1356

Material boundary

X	Y
9.39918	66.3708
9.39918	48.5498

Material boundary

X	Y
6.44898	64.8496
6.44898	63.8496
5.62885	63.8496
4.94898	63.8496
4.94898	64.4023
4.94898	64.8496
5.62885	64.8496
6.44898	64.8496
6.44898	66.3706

Material boundary

X	Y
5.62885	64.8496
5.62885	63.8496
5.62885	48.5498

Material boundary

X	Y
-6.39101	64.85
-5.63996	64.85
-4.89101	64.85
-4.89101	64.4023
-4.89101	63.85
-5.63996	63.85
-6.39101	63.85
-6.39101	64.85

Material boundary

X	Y
-6.39101	64.85
-6.39101	66.37

Material boundary

X	Y
-5.63996	64.85
-5.63996	63.85
-5.63996	48.519

Material boundary

X	Y
-9.3605	66.3699
-9.3605	48.5498

Material boundary

X	Y
-4.89101	61.49
-0.971016	63.4398
1.02898	63.4398
4.94898	61.49
4.94898	58.6058
4.94898	57.6103
4.94898	55.8893
4.94898	53.5496

Material boundary

X	Y
-4.89101	64.4023
4.94898	64.4023

Material boundary

X	Y
-4.89101	61.49
-2.40259	61.49
2.46056	61.49

4.94898	61.49
---------	-------

Material boundary

X	Y
-2.12102	55.3498
2.17898	55.3498
3.28462	55.8893
3.65034	56.7254
3.87381	57.6103
3.87381	58.6058
3.87381	59.4628
3.4238	60.4798
3.20033	60.8239
2.46056	61.49
1.98898	61.9146
1.24033	62.2479
0.0289837	62.4398
-1.18236	62.2479
-1.93102	61.9146
-2.40259	61.49
-3.14236	60.8239
-3.36584	60.4798
-3.81584	59.4628
-3.81584	58.6058
-3.81584	57.6103
-3.59237	56.7254
-3.22666	55.8893
-2.12102	55.3498

Material boundary

X	Y
-3.81584	57.6103
-4.89101	57.6103

Material boundary

X	Y
3.87381	57.6103
4.94898	57.6103

Material boundary

X	Y
---	---

-3.81584	58.6058
-4.89101	58.6058

Material boundary

X	Y
3.87381	58.6058
4.94898	58.6058

Material boundary

X	Y
-11.395	70.8274
-7.58693	68.4018
-11.395	68.4018

Material boundary

X	Y
-4.89101	61.49
-4.89101	63.85

Material boundary

X	Y
4.94898	61.49
4.94898	63.8496

Material boundary

X	Y
-15.8378	70.8274
-15.8378	70.534
-17.603	70.534
-17.603	70.8274

Material boundary

X	Y
-19.6031	70.8274
-19.6031	70.524
-21.416	70.524
-21.416	70.8274

Material boundary

X	Y
-3.22666	55.8893
-4.89101	55.8893

Material boundary

X	Y
3.28462	55.8893
4.94898	55.8893

Material boundary

X	Y
6.44898	66.3706
-6.39101	66.37

Material boundary

X	Y
-9.99101	66.3697
-9.3605	66.3699

Material boundary

X	Y
-6.39101	66.37
-9.3605	66.3699

Material boundary

X	Y
6.44898	66.3706
7.33876	66.3707

Material boundary

X	Y
-7.58693	68.4018
10.2799	68.4018

Material boundary

X	Y
---	---

-2.468	72.171
-2.468	71.921
-0.068	71.921
-0.068	72.171

Material boundary

X	Y
1.532	72.1706
1.532	71.921
3.932	71.921
3.932	72.1706

Material boundary

X	Y
16.2042	68.4018
33.3342	68.4018
90	68.4018

Material boundary

X	Y
-4.89101	53.55
-4.89101	51.7

Material boundary

X	Y
-4.89101	53.55
-4.89101	55.8893
-4.89101	57.6103
-4.89101	58.6058
-4.89101	61.49

Material boundary

X	Y
-4.89101	51.7
-4.89101	50.7

Material boundary

X	Y
---	---

4.94898	51.7
4.94898	53.5496
-4.89101	53.55

Material boundary

X	Y
-4.89101	50.7
-4.89101	49.7
4.94898	49.7
4.94898	50.7
-4.89101	50.7

Material boundary

X	Y
4.94898	50.7
4.94898	51.7
-4.89101	51.7

Material boundary

X	Y
-4.89101	49.7
-4.89101	48.7
4.94898	48.7
4.94898	49.7

Material boundary

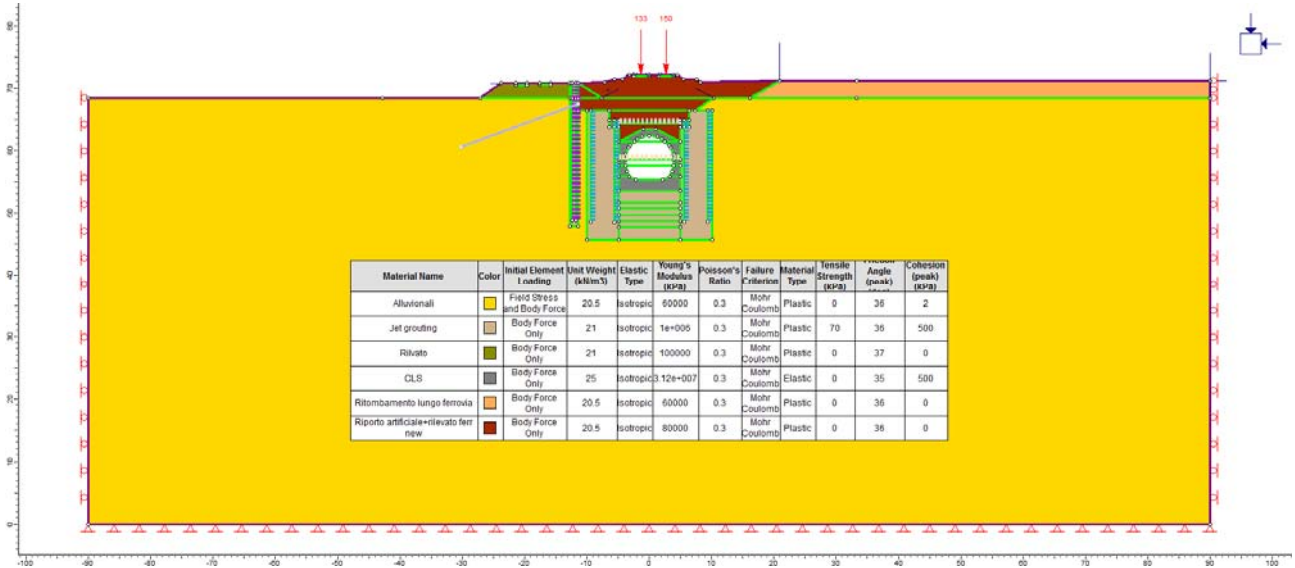
X	Y
-4.89101	48.7
-4.89101	47.7
4.94898	47.7
4.94898	48.7

Material boundary

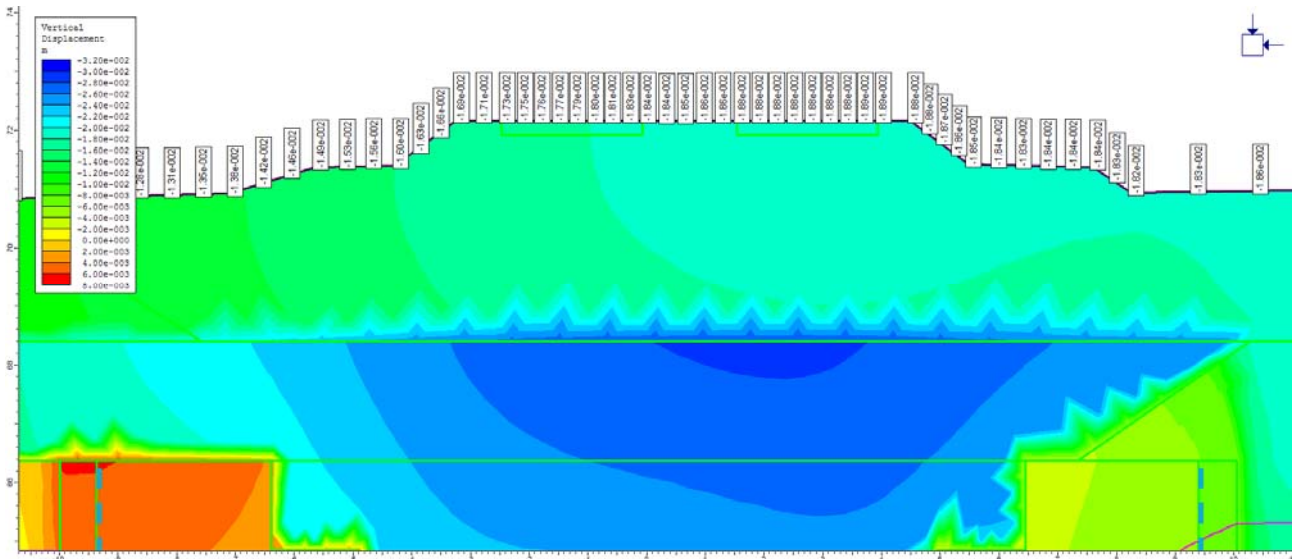
X	Y
-4.89101	47.7
-4.89101	45.6998

Material boundary

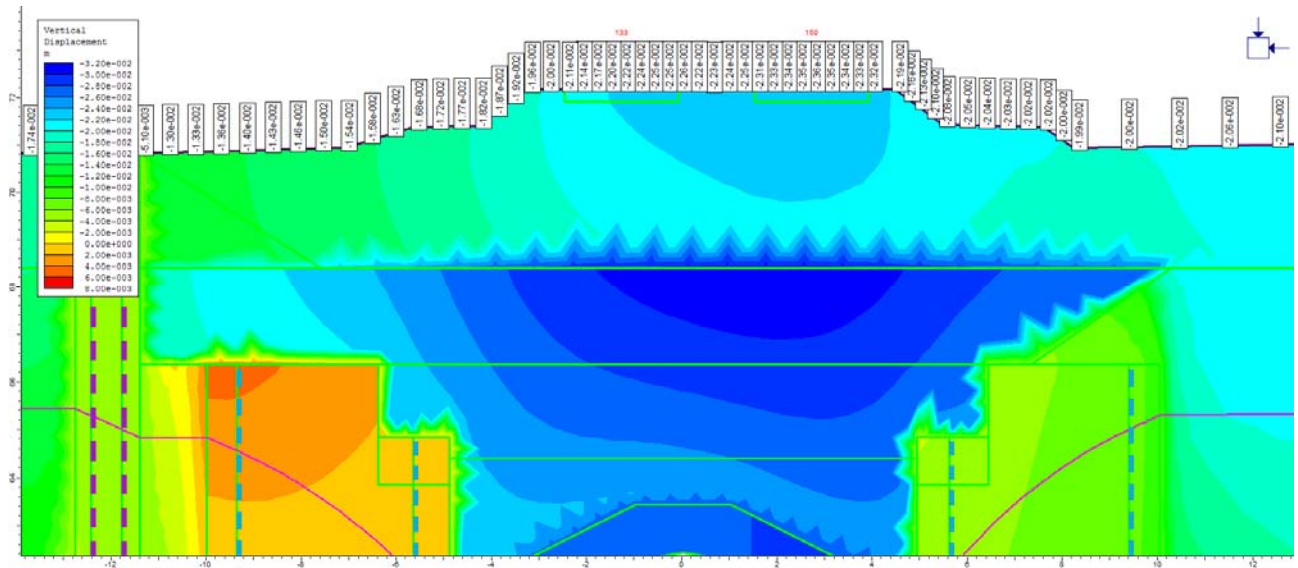
X	Y
4.94898	47.7
4.94898	45.6998



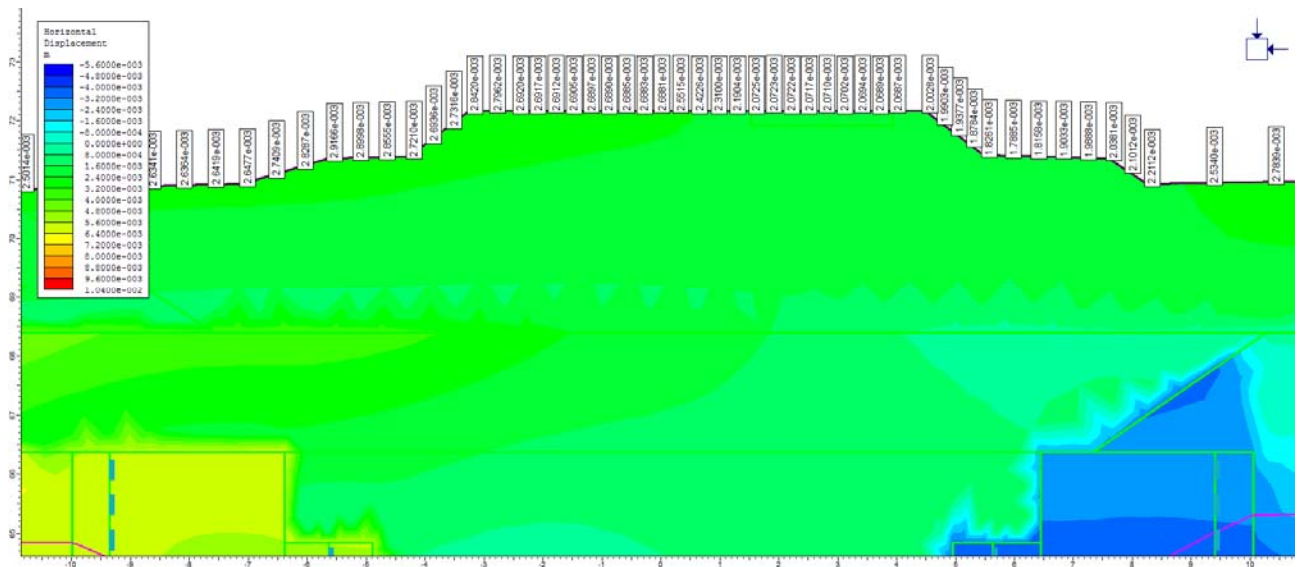
Geometria di calcolo per la Galleria di Base binario Dispari .
Sezione rappresentativa per la progressiva nuova linea ferroviaria pk_0+325



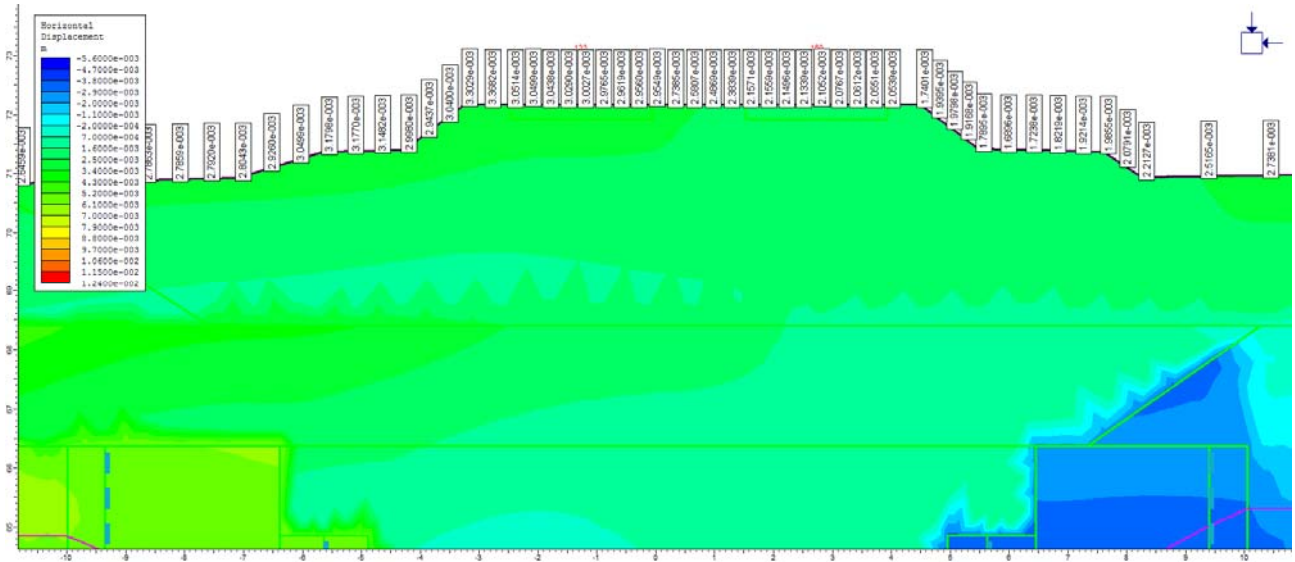
Cedimenti verticali del nuovo rilevato ferroviario per la Galleria di Base binario Dispari. Sezione rappresentativa per la progressiva nuova linea ferroviaria pk_0+325



Cedimenti verticali del nuovo rilevato ferroviario per la Galleria di Base binario Dispari con carico del treno. Sezione rappresentativa per la progressiva nuova linea ferroviaria pk_0+325



Cedimenti orizzontali del nuovo rilevato ferroviario per la Galleria di Base binario Dispari. Sezione rappresentativa per la progressiva nuova linea ferroviaria pk_0+325



Cedimenti orizzontali del nuovo rilevato ferroviario per la Galleria di Base binario Dispari con carico del treno. Sezione rappresentativa per la progressiva nuova linea ferroviaria pk_0+325

Phase2 Analysis Information

Project Settings

- Document Name: Sez 54+889_M_C_fondo scavo con carico_fs new.fez
- Project Title: Tunnel
- Number of Stages: 18
- Analysis Type: Plane Strain
- Solver Type: Gaussian Elimination
- Units: Metric, stress as kPa

Stress Analysis

- Maximum Number of Iterations: 3000
- Tolerance: 0.002
- Number of Load Steps: Automatic
- Convergence Type: Absolute Energy
- Tensile Failure: Reduces Shear Strength

Groundwater

- Method: Finite Element Analysis
- Pore Fluid Unit Weight: 9.81 kN/m³
- Maximum Number of Iterations: 500
- Tolerance: 1e-006

Field Stress

- Field stress: gravity
- Ground surface elevation: 0 m
- Unit weight of overburden: 27 kN/m³
- Total stress ratio (horizontal/vertical in-plane): 1
- Total stress ratio (horizontal/vertical out-of-plane): 1
- Locked-in horizontal stress (in-plane): 0
- Locked-in horizontal stress (out-of-plane): 0

Mesh

- Mesh type: graded
- Element type: 8 noded quadrilaterals
- Number of elements on Geostatico: 1877
- Number of nodes on Geostatico: 5630
- Number of elements on Piano di lavoro: 1741
- Number of nodes on Piano di lavoro: 5244
- Number of elements on Jet: 1741
- Number of nodes on Jet: 5244
- Number of elements on Approfondimento: 1649

- Number of nodes on Approfondimento: 4994
- Number of elements on I ribasso: 1631
- Number of nodes on I ribasso: 4948
- Number of elements on I puntone: 1631
- Number of nodes on I puntone: 4948
- Number of elements on II ribasso: 1528
- Number of nodes on II ribasso: 4671
- Number of elements on II puntone: 1528
- Number of nodes on II puntone: 4671
- Number of elements on III ribasso: 1433
- Number of nodes on III ribasso: 4398
- Number of elements on III puntone: 1433
- Number of nodes on III puntone: 4398
- Number of elements on Fondo scavo: 1325
- Number of nodes on Fondo scavo: 4088
- Number of elements on Getto solettone: 1380
- Number of nodes on Getto solettone: 4251
- Number of elements on Rimozione puntone: 1380
- Number of nodes on Rimozione puntone: 4251
- Number of elements on Getto calotta: 1477
- Number of nodes on Getto calotta: 4545
- Number of elements on Rimozione puntone: 1477
- Number of nodes on Rimozione puntone: 4545
- Number of elements on Ritombamento: 1685
- Number of nodes on Ritombamento: 5117
- Number of elements on Rilevato ferroviario: 1924
- Number of nodes on Rilevato ferroviario: 5816
- Number of elements on Carico treno: 1924
- Number of nodes on Carico treno: 5816

Mesh Quality

- All elements are of good quality

Poor quality elements defined as:

- Side length ratio (maximum / minimum) > 30.00
- Minimum interior angle < 2.0 degrees
- Maximum interior angle > 175.0 degrees

Reset Displacements

- Displacements reset after: Geostatico

Material Properties

Material: Alluvionali

Initial element loading	body force only
Unit weight	20.5 kN/m ³
Elastic type	isotropic
Young's modulus	60000 kPa
Poisson's ratio	0.365

Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	36 degrees
Peak cohesion	2 kPa
Material type	Plastic
Dilation Angle	1 degrees
Residual Friction Angle	35 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Properties changed in Piano di lavoro

- Young's modulus: 120000 kPa (factor = 2)Poisson's ratio: 0.30003 (factor = 0.822)

Material: Jet

Initial element loading	body force only
Unit weight	21 kN/m3
Elastic type	isotropic
Young's modulus	1e+006 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	75 kPa
Peak friction angle	36 degrees
Peak cohesion	500 kPa
Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	36 degrees
Residual Cohesion	500 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	1e-008 m/s
K2/K1	1
K Angle	0 degrees

Material: CLS

Initial element loading	body force only
Unit weight	25 kN/m3

Elastic type	isotropic
Young's modulus	3.12e+007 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	35 degrees
Peak cohesion	500 kPa
Material type	Elastic
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	1e-012 m/s
K2/K1	1
K Angle	0 degrees

Material: Riporto artificiale+Rilevato ferr new

Initial element loading	body force only
Unit weight	20.5 kN/m3
Elastic type	isotropic
Young's modulus	80000 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	36 degrees
Peak cohesion	0 kPa
Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	36 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Material: Rilevato ferr old

Initial element loading	body force only
Unit weight	21 kN/m3
Elastic type	isotropic
Young's modulus	100000 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb

Tensile strength	0 kPa
Peak friction angle	37 degrees
Peak cohesion	0 kPa
Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	37 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Material: Alluvionali_monte

Initial element loading	body force only
Unit weight	20.5 kN/m3
Elastic type	isotropic
Young's modulus	60000 kPa
Poisson's ratio	0.37
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	36 degrees
Peak cohesion	2 kPa
Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	35 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Properties changed in Piano di lavoro

- Young's modulus: 120000 kPa (factor = 2)Poisson's ratio: 0.30007 (factor = 0.811)

Material: Alluvionali pendio

Initial element loading	body force only
Unit weight	20.5 kN/m3
Elastic type	isotropic

Young's modulus	60000 kPa
Poisson's ratio	0.375
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	36 degrees
Peak cohesion	5 kPa
Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	36 degrees
Residual Cohesion	5 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Properties changed in Piano di lavoro

- Young's modulus: 120000 kPa (factor = 2)Poisson's ratio: 0.3 (factor = 0.8)

Material: Alluvionali valle

Initial element loading	body force only
Unit weight	20.5 kN/m3
Elastic type	isotropic
Young's modulus	60000 kPa
Poisson's ratio	0.39
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	36 degrees
Peak cohesion	2 kPa
Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	35 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1
K Angle	0 degrees

Properties changed in Piano di lavoro

- Young's modulus: 120000 kPa (factor = 2)Poisson's ratio: 0.3003 (factor = 0.77)

Material: Spritz

Initial element loading	body force only
Unit weight	25 kN/m3
Elastic type	isotropic
Young's modulus	3e+007 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	35 degrees
Peak cohesion	500 kPa
Material type	Elastic
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	1e-008 m/s
K2/K1	1
K Angle	0 degrees

Properties changed in Rimozione puntone

- Ks: 1e-010 m/s (factor = 0.01)K Angle: 0 degrees (factor = 0)

Material: Ritombamento lungo ferr

Initial element loading	body force only
Unit weight	20.5 kN/m3
Elastic type	isotropic
Young's modulus	60000 kPa
Poisson's ratio	0.3
Failure criterion	Mohr-Coulomb
Tensile strength	0 kPa
Peak friction angle	36 degrees
Peak cohesion	0 kPa
Material type	Plastic
Dilation Angle	0 degrees
Residual Friction Angle	36 degrees
Residual Cohesion	0 kPa
Unsaturated Shear Strength Angle	0 degrees
Air Entry Value	0 kPa
Hydraulic model	Simple
Ks	0.0001 m/s
K2/K1	1

K Angle	0 degrees
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Areas of Excavated and Filled Elements

Ritombamento

- Material: Riporto artificiale+Rilevato ferr new, Area Filled: 127.915 m2

Rilevato ferroviario

- Material: CLS, Area Filled: 1.241 m2
- Material: Riporto artificiale+Rilevato ferr new, Area Filled: 33.404 m2
- Material: Ritombamento lungo ferr, Area Filled: 79.255 m2

Excavation Areas

Original Un-deformed Areas

- External Boundary Area: 13642.937 m2
- External Boundary Perimeter: 523.510 m

Geostatico

- External Boundary Area: 13642.937 m2 (0 m2 change from original area)
- External Boundary Perimeter: 523.510 m (0 m change from original perimeter)

Piano di lavoro

- Values not available until this stage is viewed in a window

Jet

- Values not available until this stage is viewed in a window

Approfondimento

- Values not available until this stage is viewed in a window

I ribasso

- Values not available until this stage is viewed in a window

I puntone

- Values not available until this stage is viewed in a window

II ribasso

- Values not available until this stage is viewed in a window

II puntone

- Values not available until this stage is viewed in a window

III ribasso

- Values not available until this stage is viewed in a window

III puntone

- Values not available until this stage is viewed in a window

Fondo scavo

- Values not available until this stage is viewed in a window

Getto solettone

- Values not available until this stage is viewed in a window

Rimozione puntone

- Values not available until this stage is viewed in a window

Getto calotta

- Values not available until this stage is viewed in a window

Rimozione puntone

- External Boundary Area: 13642.747 m² (-0.190377 m² change from original area)
- External Boundary Perimeter: 523.505 m (-0.00573996 m change from original perimeter)

Ritombamento

- External Boundary Area: 13642.658 m² (-0.279668 m² change from original area)
- External Boundary Perimeter: 523.505 m (-0.00548836 m change from original perimeter)

Rilevato ferroviario

- External Boundary Area: 13641.673 m² (-1.26433 m² change from original area)
- External Boundary Perimeter: 523.505 m (-0.00545523 m change from original perimeter)

Carico treno

- External Boundary Area: 13641.550 m² (-1.38706 m² change from original area)
- External Boundary Perimeter: 523.504 m (-0.00653835 m change from original perimeter)

Liner Properties

Liner: Tubo_355.6_sp12/4m

Liner Type	Standard Beam
Formulation	Timoshenko
Area	0.00326 m ²
Moment of Inertia	4.78e-005 m ⁴

Elastic Properties

Young's modulus	2.1e+008 kPa
Poisson's ratio	0.2

Liner: TUbo_406.4_sp12.5/4m

Liner Type	Standard Beam
Formulation	Timoshenko
Area	0.00386 m ²
Moment of Inertia	7.5038e-005 m ⁴

Elastic Properties

Young's modulus	2.1e+008 kPa
Poisson's ratio	0.2
Liner Unit Weight	78.5 kN/m ³

Liner: Micropalo 168.3_sp10/1.45

Liner Type	Standard Beam
Formulation	Timoshenko
Area	0.00342 m ²
Moment of Inertia	1.78e-005 m ⁴

Elastic Properties

Young's modulus	2.1e+008 kPa
Poisson's ratio	0.2

Displacements

- Displacement data is not available for Geostatico until total displacement is viewed in a window
- Displacement data is not available for Piano di lavoro until total displacement is viewed in a window

- Displacement data is not available for Jet until total displacement is viewed in a window
- Displacement data is not available for Approfondimento until total displacement is viewed in a window
- Displacement data is not available for I ribasso until total displacement is viewed in a window
- Displacement data is not available for I puntone until total displacement is viewed in a window
- Displacement data is not available for II ribasso until total displacement is viewed in a window
- Displacement data is not available for II puntone until total displacement is viewed in a window
- Displacement data is not available for III ribasso until total displacement is viewed in a window
- Displacement data is not available for III puntone until total displacement is viewed in a window
- Displacement data is not available for Fondo scavo until total displacement is viewed in a window
- Displacement data is not available for Getto solettone until total displacement is viewed in a window
- Displacement data is not available for Rimozione puntone until total displacement is viewed in a window
- Displacement data is not available for Getto calotta until total displacement is viewed in a window
- Displacement data is not available for Rimozione puntone until total displacement is viewed in a window
- Displacement data is not available for Ritombamento until total displacement is viewed in a window
- Displacement data is not available for Rilevato ferroviario until total displacement is viewed in a window
- Displacement data is not available for Carico treno until total displacement is viewed in a window

Yielded Elements

Yielded Mesh Elements

- Number of yielded mesh elements on Geostatico: 155
- Number of yielded mesh elements is not available for Piano di lavoro until the stage is viewed in a window
- Number of yielded mesh elements is not available for Jet until the stage is viewed in a window
- Number of yielded mesh elements is not available for Approfondimento until the stage is viewed in a window
- Number of yielded mesh elements is not available for I ribasso until the stage is viewed in a window
- Number of yielded mesh elements is not available for I puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for II ribasso until the stage is viewed in a window
- Number of yielded mesh elements is not available for II puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for III ribasso until the stage is viewed in a window
- Number of yielded mesh elements is not available for III puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for Fondo scavo until the stage is viewed in a window
- Number of yielded mesh elements is not available for Getto solettone until the stage is viewed in a window
- Number of yielded mesh elements is not available for Rimozione puntone until the stage is viewed in a window
- Number of yielded mesh elements is not available for Getto calotta until the stage is viewed in a window
- Number of yielded mesh elements on Rimozione puntone: 313
- Number of yielded mesh elements on Ritombamento: 420
- Number of yielded mesh elements on Rilevato ferroviario: 502
- Number of yielded mesh elements on Carico treno: 528

Yielded Bolt Elements

- Number of yielded bolt elements on Geostatico: 0
- Number of yielded bolt elements on Piano di lavoro: 0
- Number of yielded bolt elements on Jet: 0
- Number of yielded bolt elements on Approfondimento: 0
- Number of yielded bolt elements on I ribasso: 0
- Number of yielded bolt elements on I puntone: 0
- Number of yielded bolt elements on II ribasso: 0
- Number of yielded bolt elements on II puntone: 0
- Number of yielded bolt elements on III ribasso: 0
- Number of yielded bolt elements on III puntone: 0
- Number of yielded bolt elements on Fondo scavo: 0
- Number of yielded bolt elements on Getto solettone: 0
- Number of yielded bolt elements on Rimozione puntone: 0
- Number of yielded bolt elements on Getto calotta: 0
- Number of yielded bolt elements on Rimozione puntone: 0
- Number of yielded bolt elements on Ritombamento: 0

- Number of yielded bolt elements on Rilevato ferroviario: 0
- Number of yielded bolt elements on Carico treno: 0

Yielded Liner Elements

- Number of yielded liner elements on Geostatico: 0
- Number of yielded liner elements on Piano di lavoro: 0
- Number of yielded liner elements on Jet: 0
- Number of yielded liner elements on Approfondimento: 0
- Number of yielded liner elements on I ribasso: 0
- Number of yielded liner elements on I puntone: 0
- Number of yielded liner elements on II ribasso: 0
- Number of yielded liner elements on II puntone: 0
- Number of yielded liner elements on III ribasso: 0
- Number of yielded liner elements on III puntone: 0
- Number of yielded liner elements on Fondo scavo: 0
- Number of yielded liner elements on Getto solettone: 0
- Number of yielded liner elements on Rimozione puntone: 0
- Number of yielded liner elements on Getto calotta: 0
- Number of yielded liner elements on Rimozione puntone: 0
- Number of yielded liner elements on Ritombamento: 0
- Number of yielded liner elements on Rilevato ferroviario: 0
- Number of yielded liner elements on Carico treno: 0

List of All Coordinates

External boundary

X	Y
-91.42	0
-17.365	4.59632e-014
4.44157	5.94927e-014
12.443	5.94927e-014
19.4976	6.88338e-014
41.4181	8.26006e-014
91.42	1.137e-013
91.42	38.7809
91.42	82.5506
91.42	85.0339
84.5659	83.7505
56.0805	78.417
46.4332	76.6107
41.4181	75.6717
36.8485	74.1058
28.5227	74.1058
27.222	73.1811
19.4976	73.1811
11.32	73.3258
10.849	73.6399
9.32312	73.8057

8.30783	74.5672
7.532	74.564
5.13	74.56
3.532	74.553
1.13	74.548
0.569341	74.5456
-0.407175	73.8132
-2.18545	73.6399
-2.38627	73.5072
-15.372	73.5072
-20.1913	73.5072
-26.01	73.513
-27.8	73.5148
-29.7979	73.5169
-31.61	73.5187
-34.549	73.5217
-37.6918	71.3098
-53.8224	70.9177
-91.42	70.0037
-91.42	38.7809

Material boundary

X	Y
-37.6918	71.3098
-17.365	71.6502

Material boundary

X	Y
-15.372	73.5072
-12.5632	71.6502
-9.69723	69.7519
-8.71149	69.7553
8.80078	69.7457
9.67812	69.7457
13.2747	72.1308

Material boundary

X	Y
-8.71149	69.7553
-7.196	68.6789
-6.4179	68.6789
6.42	68.6789

7.20508	68.6819
8.80078	69.7457

Material boundary

X	Y
-6.4179	68.6789
-6.4179	65.4805
-6.4179	64.4305
-5.65953	64.4305
-5.11838	64.4305
-4.92	64.4305
-4.92	64.9555
-4.92	65.4805
-5.65953	65.4805
-6.4179	65.4805

Material boundary

X	Y
-4.92	64.9555
4.92	64.9555

Material boundary

X	Y
4.92	65.4805
4.92	64.9555
4.92	64.4305
5.12346	64.4305
5.77317	64.4305
6.42	64.4305
6.42	65.4805
5.77317	65.4805
4.92	65.4805

Material boundary

X	Y
4.92	64.4305
4.72058	64.4305

Material boundary

X	Y
---	---

-4.72199	62.0707
-1	64.0205
1	64.0205
4.72058	62.0707

Material boundary

X	Y
1.1e-015	63.0205
-1.21135	62.8286
-1.96	62.4953
-2.43158	62.0707
-3.39482	61.0605
-3.84483	60.0435
-3.84483	58.6994
-3.84483	58.1909
-3.62135	57.3061
-3.25564	56.4699
-2.15	55.9305
2.15	55.9305
3.25564	56.4699
3.62135	57.3061
3.84483	58.1909
3.84483	58.6994
3.84483	60.0435
3.39482	61.0605
2.43158	62.0707
1.96	62.4953
1.21135	62.8286
1.1e-015	63.0205

Material boundary

X	Y
-7.196	68.6789
-9.428	68.6789
-9.428	47.1304
9.428	47.1333
9.428	68.6819
7.20508	68.6819

Material boundary

X	Y
6.42	68.6789

6.42	65.4805
------	---------

Material boundary

X	Y
-4.72199	62.0707
-2.43158	62.0707
2.43158	62.0707
4.72058	62.0707

Material boundary

X	Y
-4.72199	58.6994
-3.84483	58.6994
3.84483	58.6994
4.72058	58.6994

Material boundary

X	Y
41.4181	75.6717
41.4181	72.2733
41.4181	38.7809
41.4181	30.2862
41.4181	8.26006e-014

Material boundary

X	Y
19.4976	73.1811
19.4976	72.2733
19.4976	38.7809
19.4976	15.7913
19.4976	7.37376
19.4976	6.88338e-014

Material boundary

X	Y
-20.1913	73.5072
-17.365	71.6502
-17.365	38.7809
-17.365	4.59632e-014

Material boundary

X	Y
-91.42	38.7809
-17.365	38.7809
19.4976	38.7809
41.4181	38.7809
49.5451	38.7809
91.42	38.7809

Material boundary

X	Y
-3.84483	58.1909
-4.72199	58.1909

Material boundary

X	Y
3.84483	58.1909
4.72058	58.1909

Material boundary

X	Y
-3.25564	56.4699
-4.72199	56.4699

Material boundary

X	Y
3.25564	56.4699
4.72058	56.4699

Material boundary

X	Y
-26.01	73.513
-26.01	73.208
-27.8	73.208
-27.8	73.5148

Material boundary

X	Y
---	---

-29.7979	73.5169
-29.7979	73.209
-31.61	73.209
-31.61	73.5187

Material boundary

X	Y
-12.5632	71.6502
-17.365	71.6502

Material boundary

X	Y
13.2747	72.1308
17.0946	72.2733
19.4976	73.1811

Material boundary

X	Y
13.2747	72.1308
-4.95631	71.7917
-12.5632	71.6502

Material boundary

X	Y
11.32	73.3258
13.2747	72.1308

Material boundary

X	Y
-2.38627	73.5072
-4.95631	71.7917

Material boundary

X	Y
1.13	74.548
1.13	74.298
3.532	74.298
3.532	74.553

Material boundary

X	Y
5.13	74.56
5.13	74.298
7.532	74.298
7.532	74.564

Material boundary

X	Y
27.222	73.1811
36.8485	73.1811
36.8485	74.1058

Material boundary

X	Y
19.4976	15.7913
4.44157	5.94927e-014

Material boundary

X	Y
12.443	5.94927e-014
19.4976	7.37376
41.4181	30.2862
49.5451	38.7809
91.42	82.5506

Material boundary

X	Y
19.4976	15.7913
41.4181	38.7809

Material boundary

X	Y
41.4181	38.7809
84.5659	83.7505

Material boundary

X	Y
---	---

17.0946	72.2733
19.4976	72.2733
41.4181	72.2733

Material boundary

X	Y
41.4181	72.2733
46.4332	76.6107

Material boundary

X	Y
-3.39482	61.0605
-4.72199	61.0605

Material boundary

X	Y
3.39482	61.0605
4.72058	61.0605

Material boundary

X	Y
-5.11838	64.4305
-5.11838	64.0205
-5.11838	61.0605
-5.11838	58.1909
-5.11838	54.1305

Material boundary

X	Y
-4.72199	54.1305
-4.72199	56.4699

Material boundary

X	Y
-4.72199	54.1305
-5.11838	54.1305

Material boundary

X	Y
-4.72199	56.4699
-4.72199	58.1909

Material boundary

X	Y
-4.72199	58.1909
-4.72199	58.6994

Material boundary

X	Y
-4.72199	58.6994
-4.72199	61.0605

Material boundary

X	Y
-4.72199	61.0605
-4.72199	62.0707

Material boundary

X	Y
-4.72199	62.0707
-4.72199	64.0205
-4.72199	64.4305
-4.92	64.4305

Material boundary

X	Y
5.12346	64.4305
5.12346	64.0205
5.12346	61.0605
5.12346	58.1909
5.12346	54.1305

Material boundary

X	Y
4.72058	54.1305
4.72058	56.4699

4.72058	58.1909
4.72058	58.6994
4.72058	61.0605
4.72058	62.0707
4.72058	64.0205
4.72058	64.4305

Material boundary

X	Y
4.72058	54.1305
5.12346	54.1305

Material boundary

X	Y
4.72058	54.1305
-4.72199	54.1305

Material boundary

X	Y
-1	64.0205
-4.72199	64.0205

Material boundary

X	Y
1	64.0205
4.72058	64.0205

Material boundary

X	Y
-4.72199	64.0205
-5.11838	64.0205

Material boundary

X	Y
4.72058	64.0205
5.12346	64.0205

Material boundary

X	Y
-4.72199	61.0605
-5.11838	61.0605

Material boundary

X	Y
4.72058	61.0605
5.12346	61.0605

Material boundary

X	Y
-4.72199	58.1909
-5.11838	58.1909

Material boundary

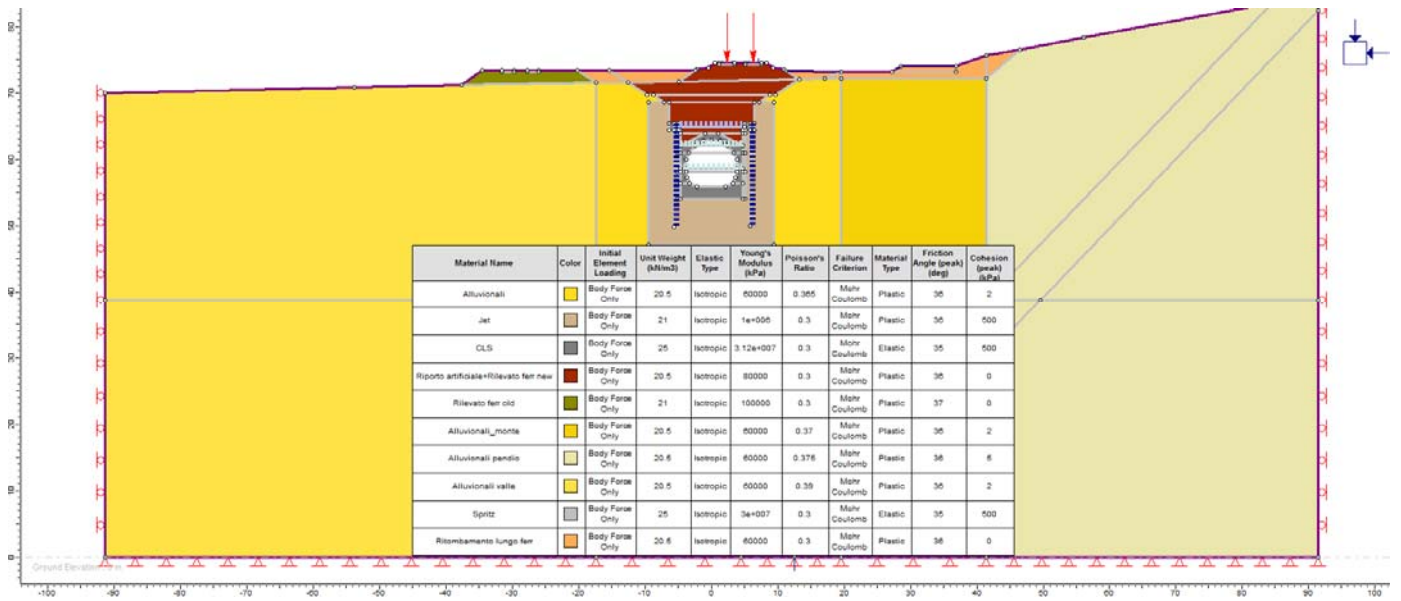
X	Y
4.72058	58.1909
5.12346	58.1909

Material boundary

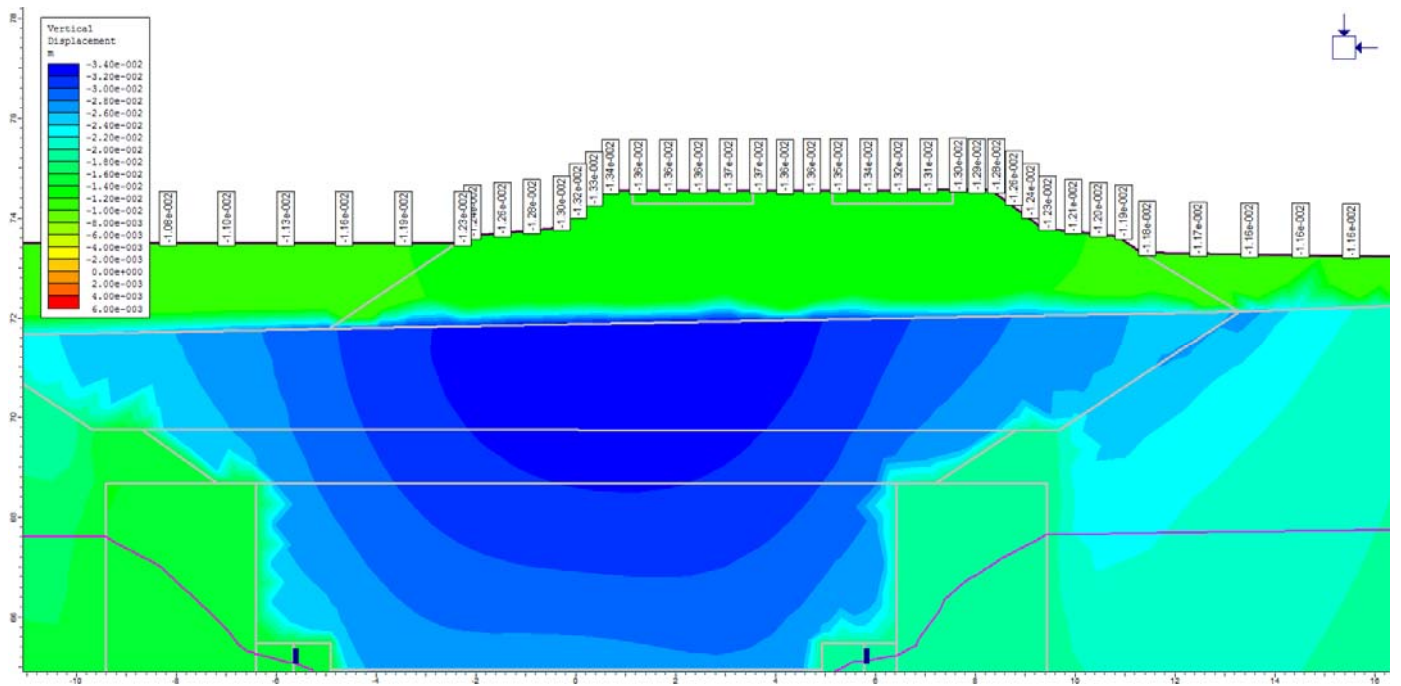
X	Y
-5.65953	65.4805
-5.65953	64.4305
-5.65953	49.849

Material boundary

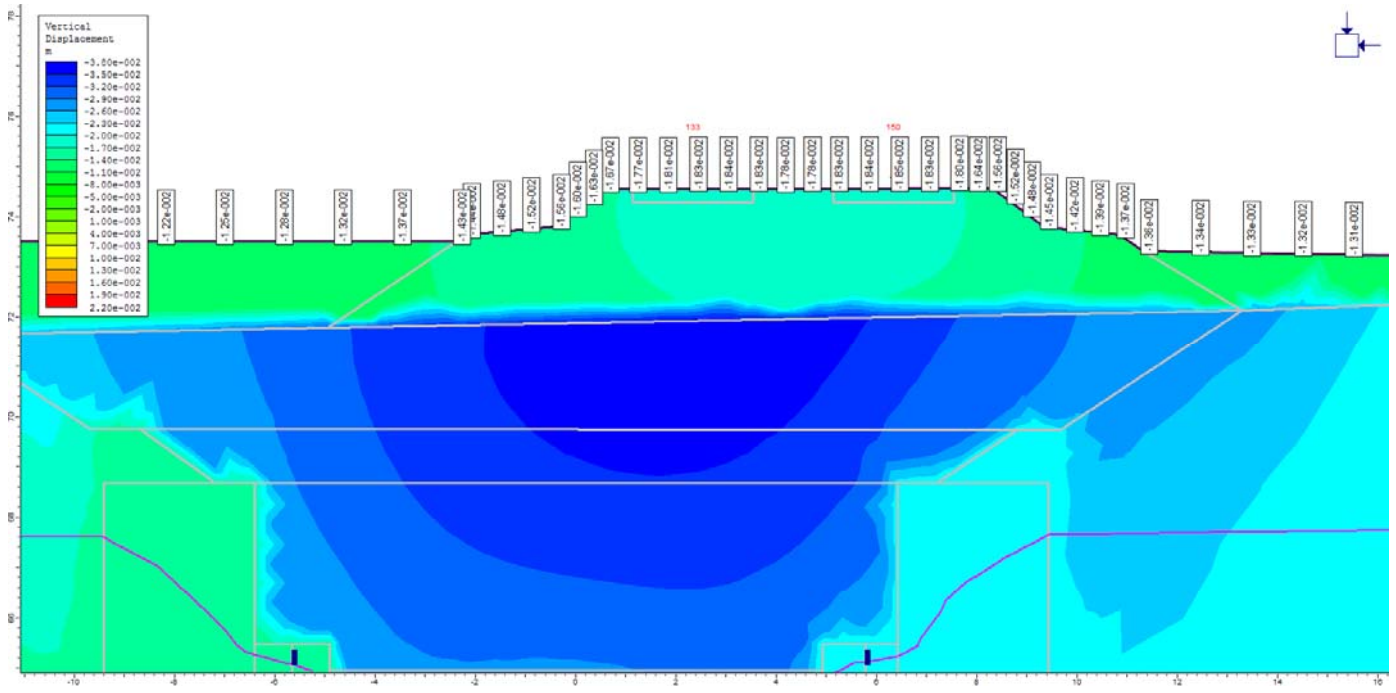
X	Y
5.77317	65.4805
5.77317	64.4305
5.77317	49.978



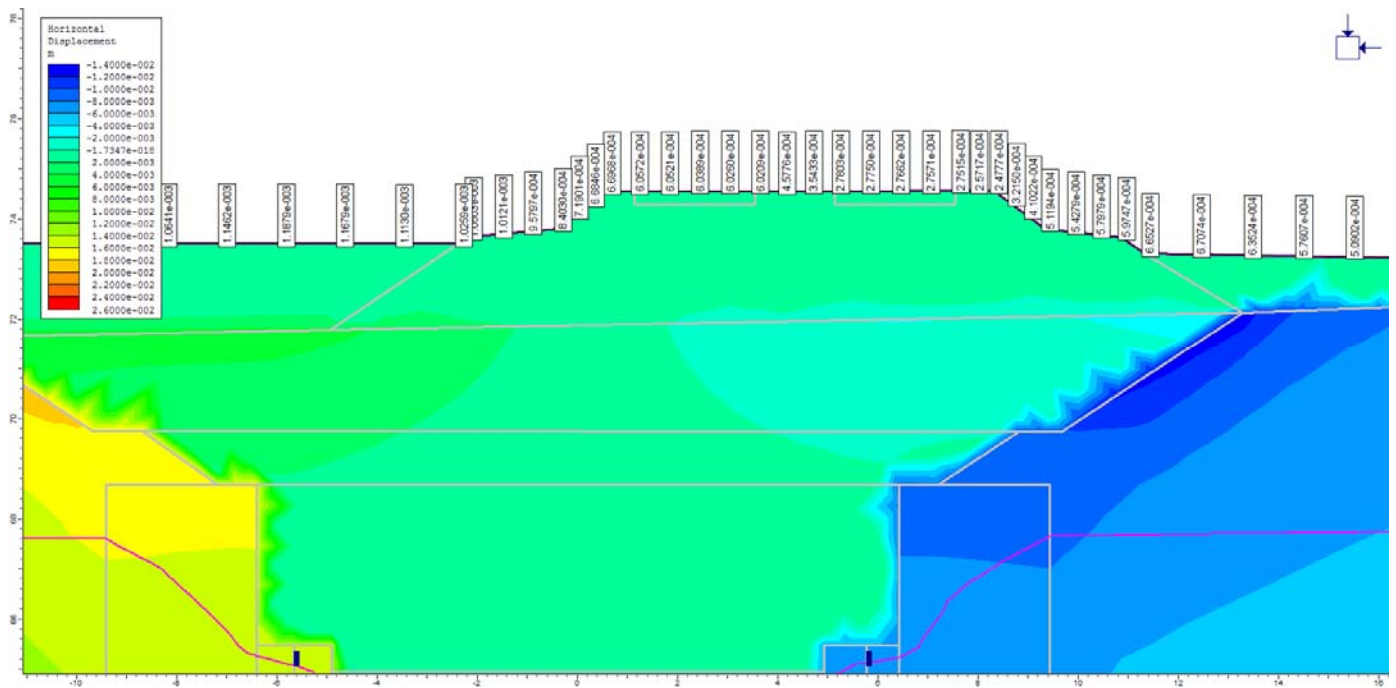
Geometria di calcolo per la Galleria di Base binario Pari. Sezione rappresentativa per la progressiva nuova linea ferroviaria pk_0+425



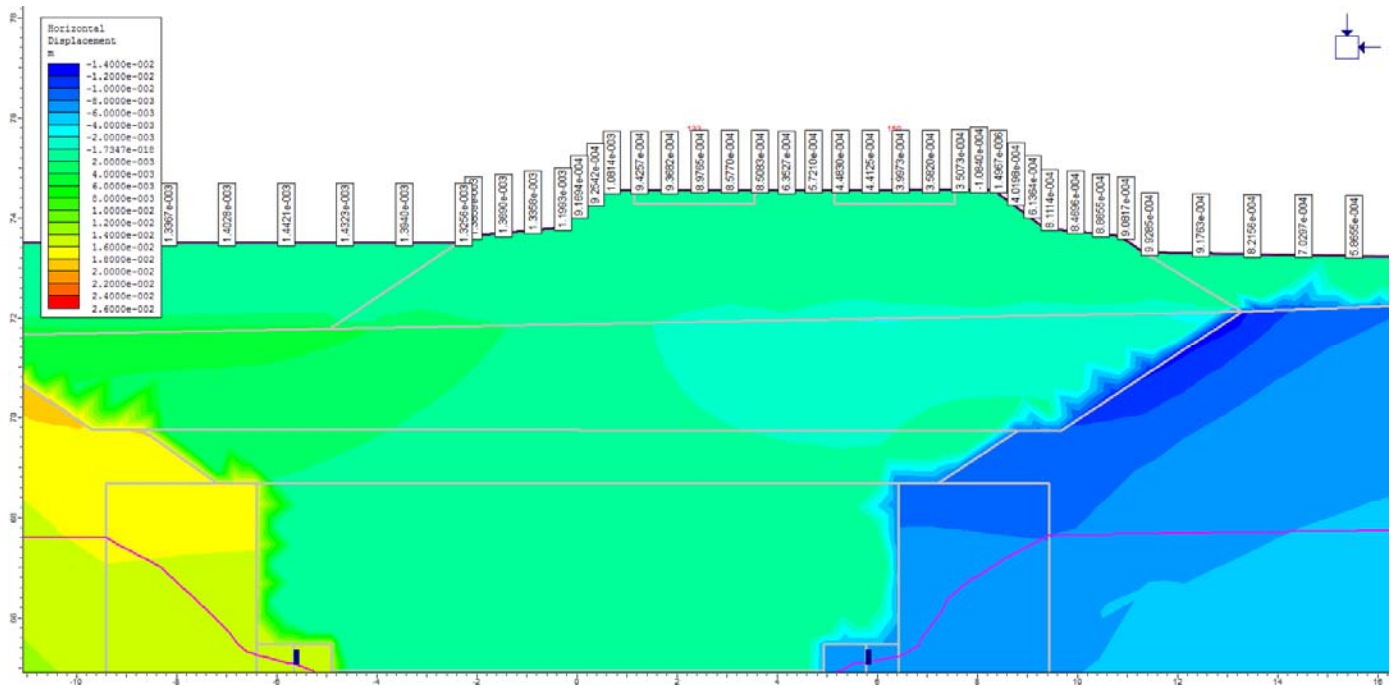
Cedimenti verticali del nuovo rilevato ferroviario per la Galleria di Base binario Pari. Sezione rappresentativa per la progressiva nuova linea ferroviaria pk_0+425



Cedimenti verticali del nuovo rilevato ferroviario per la Galleria di Base binario Pari con carico del treno. Sezione rappresentativa per la progressiva nuova linea ferroviaria pk_0+425



Cedimenti orizzontali del nuovo rilevato ferroviario per la Galleria di Base binario Pari. Sezione rappresentativa per la progressiva nuova linea ferroviaria pk_0+425



Cedimenti orizzontali del nuovo rilevato ferroviario per la Galleria di Base binario Pari con carico del treno. Sezione rappresentativa per la progressiva nuova linea ferroviaria pk_0+425