

Geosynthetic solutions in impressive projects

- TOPICS
- **2nd Niger Bridge Project in Nigeria by:**
 - *Max Nods (GeSySo, Netherlands)*
 - *Jeroen Dijkstra (Cofra, Netherlands)*
- **Two non-conventional piled embankments in Brazil by:**
 - *Werner Bilfinger (Vecttor, Brazil)*
- **Coastal protection with geotextile sand containers in Lubmin in Germany by:**
 - *Janne Kristin Pries (Naue, Germany)*

Nederlandse Geotextiel Organisatie – IGS Netherlands

Two non-conventional piled embankments in Brazil



Werner Bilfinger (Vecttor, Brazil)

Geotechnical Engineer - Partner

16-2-2022



International Geosynthetics Society

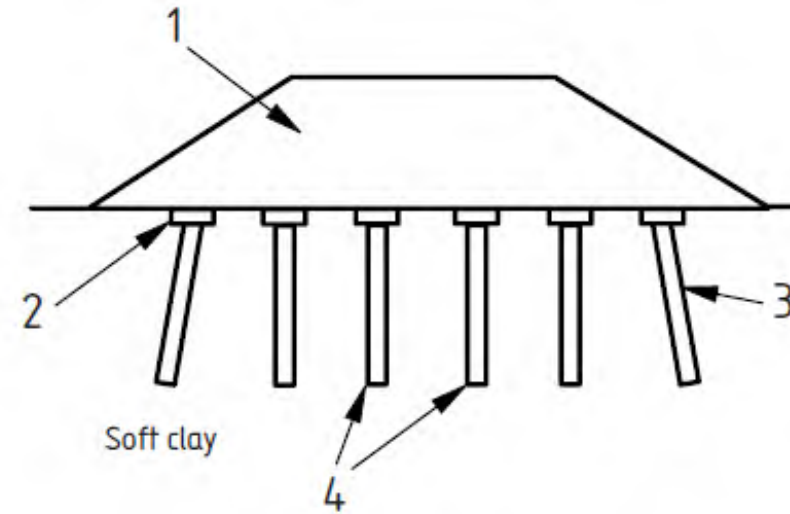


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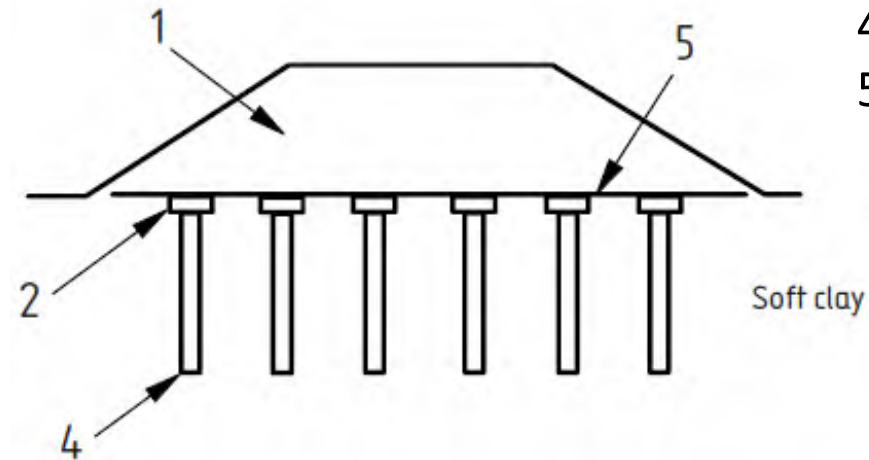
Introduction

- **Piled embankments**

- *Significant part of embankment weight is transferred to piles*
- *Safety improvement*
- *Settlement reduction*



a) Conventional piled embankment

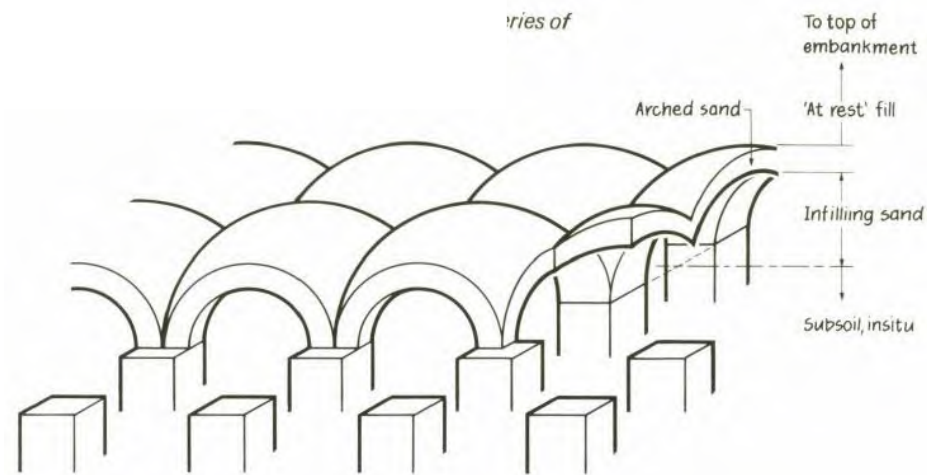
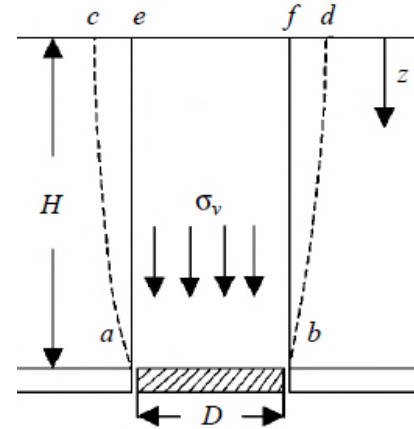


b) Piled embankment with basal reinforcement

- 1 – embankment
- 2 – pile cap
- 3 – raking pile
- 4 – piles
- 5 - reinforcement

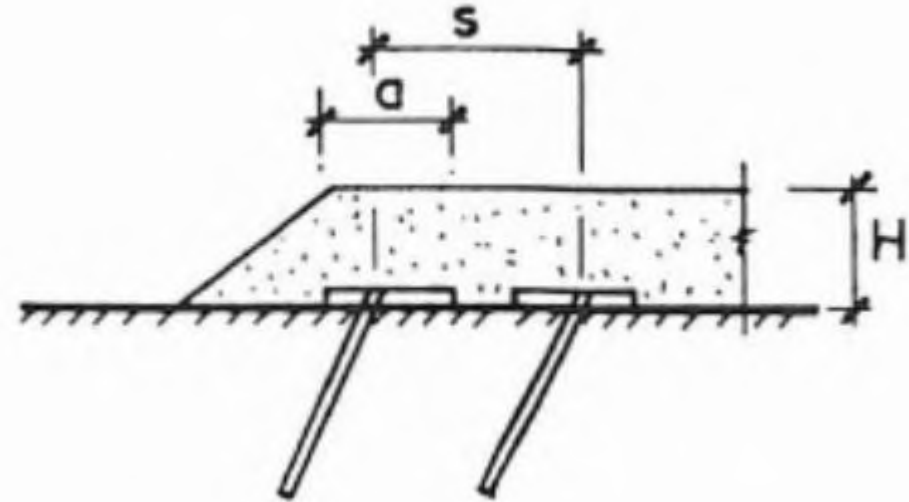
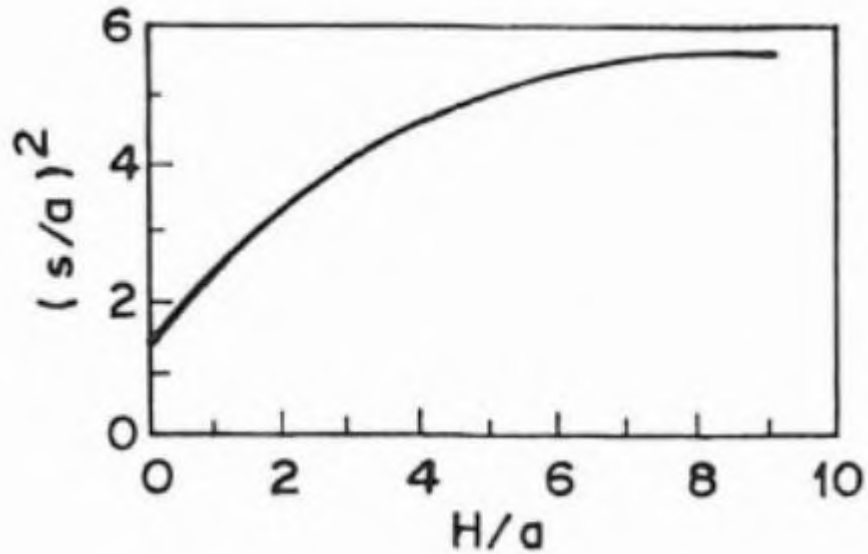
Main Principle

- Soil Arching
 - *Trap door by Terzaghi (1943)*
- *Piled Embankment – soil arches between piles or pile caps*



Hewlett & Randolph (1988)

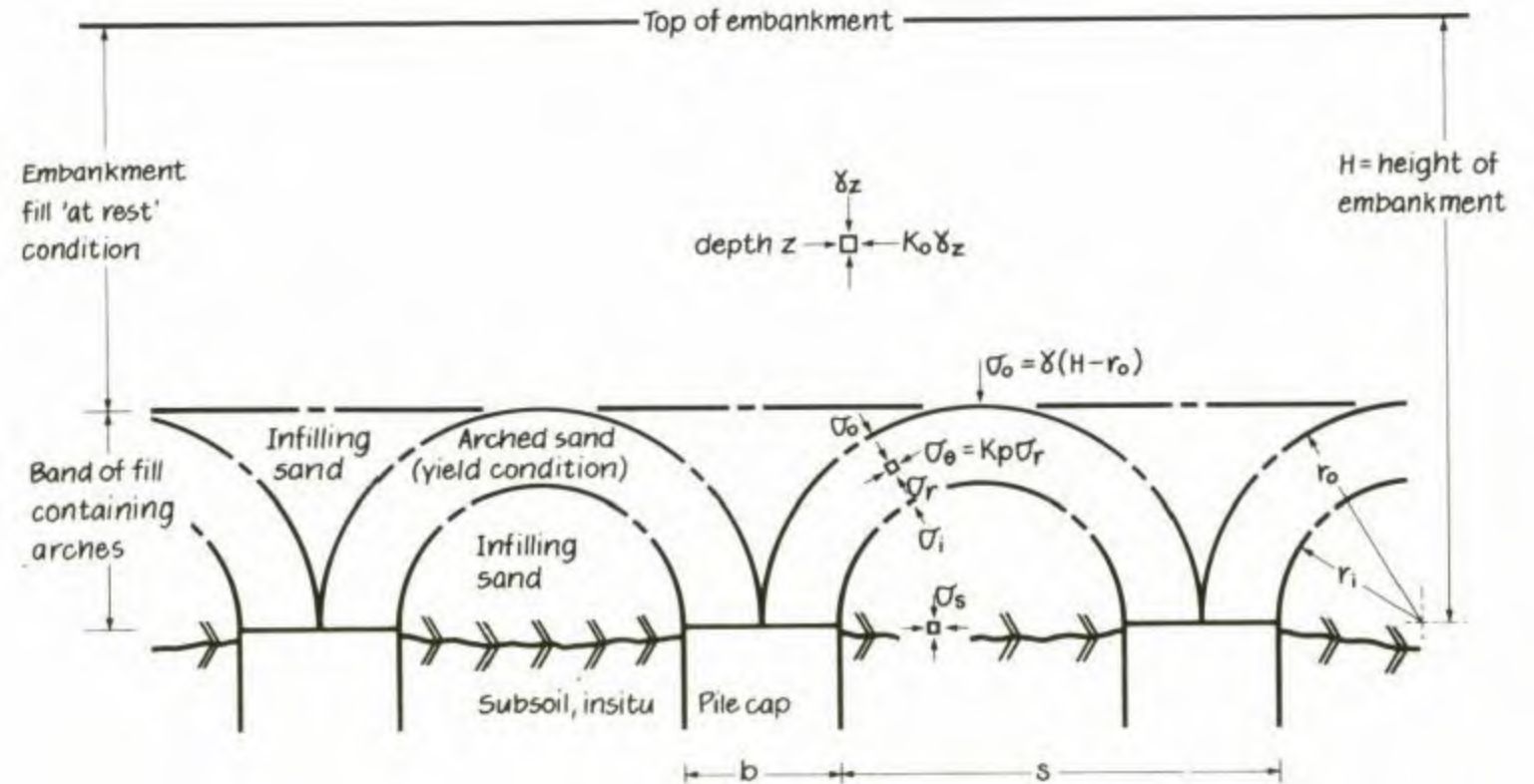
Simplified Models



(Swedish Road Board 1974)

Simplified Models

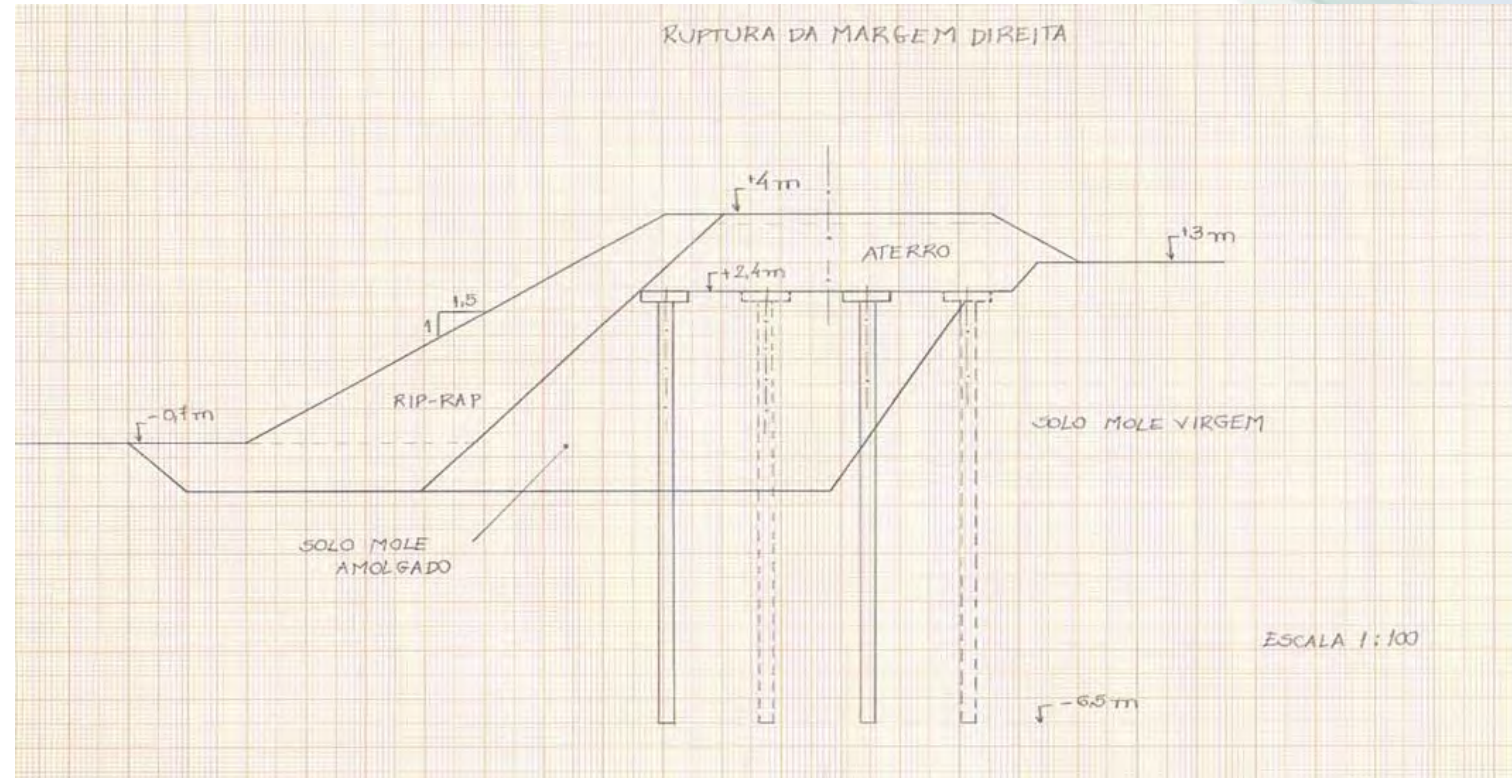
- Embankment – load
- “Distribution layer”



Hewlett & Randolph (1988)

Simplified Models

- First personal experience in the 1990's
- Failures of embankments on soft soils in the Amazon
- Limited resources – idea of using piled embankments founded on timber piles and pre-cast concrete caps





Evolution to Sophisticated Models

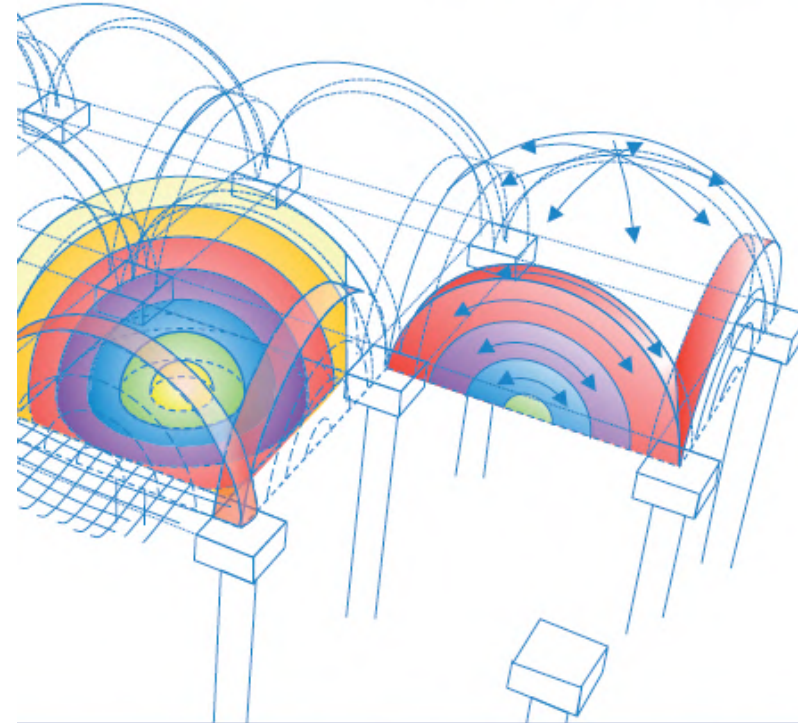
- Van Eekelen - 2015: intuitive model, confirmed by laboratory, numerical and field test

- *complete review of the past*
- *important breakthrough*

- Free download:

<https://repository.tudelft.nl/islandora/object/uuid:492dc4f3-9345-439e-9268-7c27c57e110b/datastream/OBJ/download>

Suzanne J. M. van Eekelen

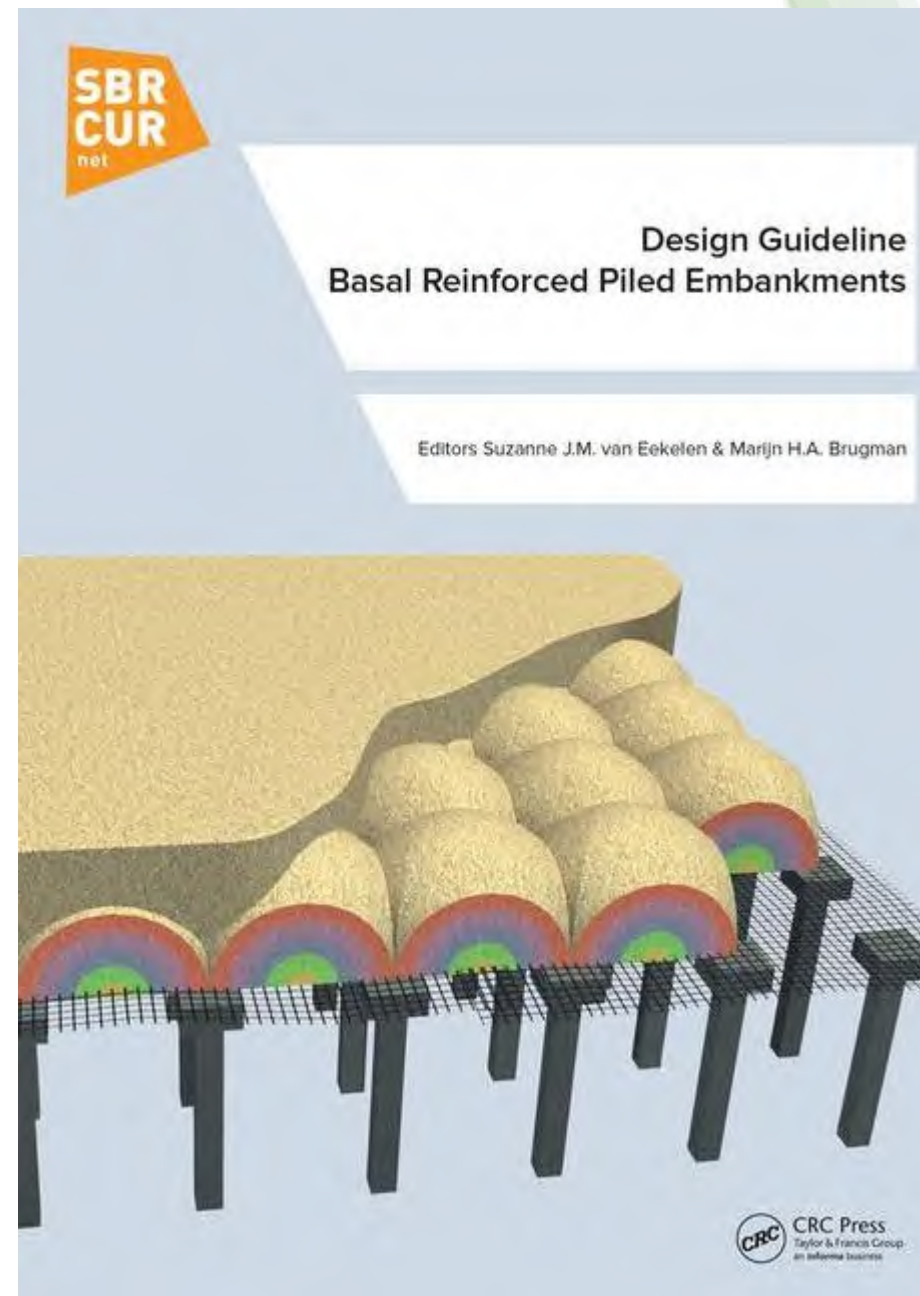


Basal Reinforced Piled Embankments

Experiments, field studies and the development and validation of a new analytical design model

CUR226

- Van Eekelen's work was adopted in the Dutch Design Guideline CUR226 for geosynthetic-reinforced pile-supported embankments.



- [Routeledge](#)
- [Amazon.com](#)
- [Amazon.com.br](#)
- [Amazon.cn](#)

Evolution to Sophisticated Models

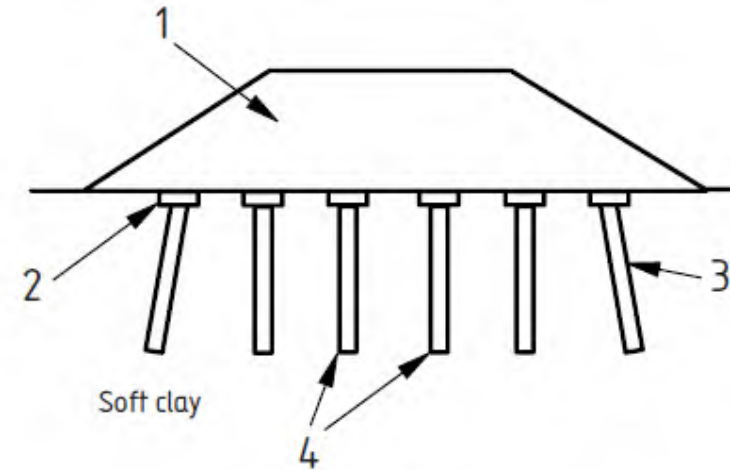


<https://publicwiki.deltares.nl>

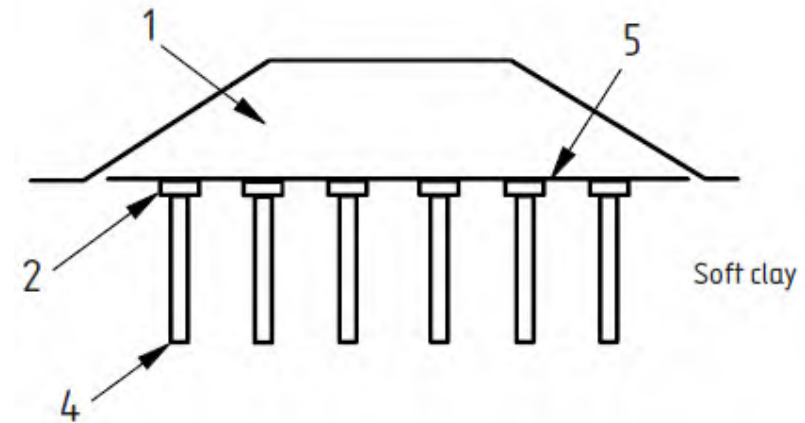
Diference in pile and pile cap spacing!

Horizontal Equilibrium

- Without basal reinforcement – raking piles
- With basal reinforcement – self equilibrated in symmetrical conditions



a) Conventional piled embankment



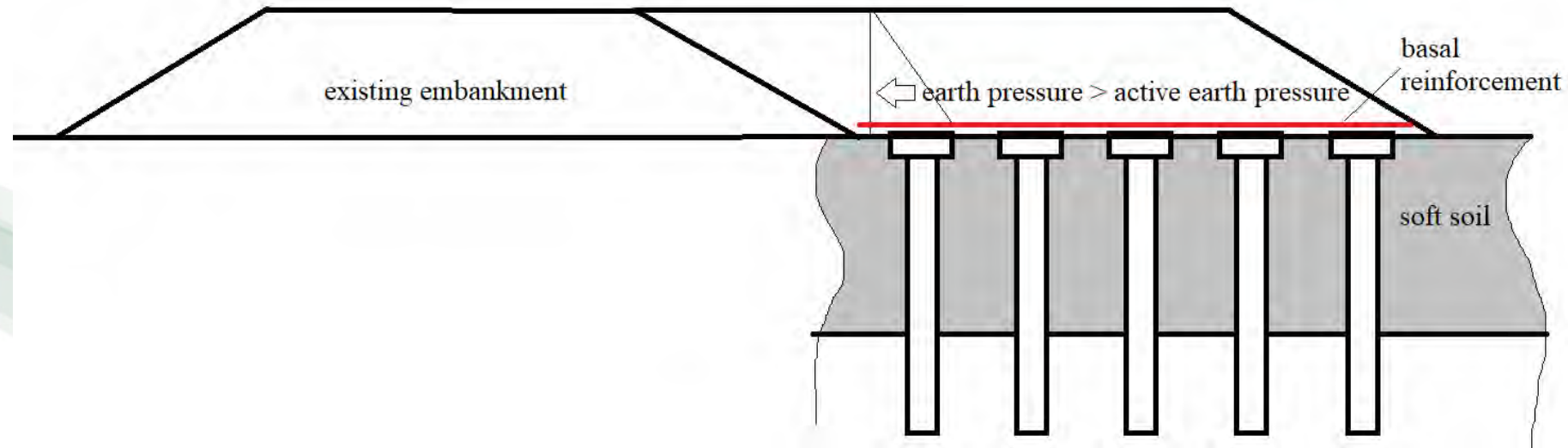
b) Piled embankment with basal reinforcement

- 1 – embankment
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BS 8006 (2010)

Horizontal Equilibrium

- In non-symmetrical conditions, horizontal equilibrium is not “automatic”
- Earth pressure will only be equilibrated if:
 - *Piles (or soil) are able to support horizontal loads, or,*
 - *Basal reinforcement is anchored in existing embankment*



Case Histories

- Non “greenfield” cases => not built on ideal horizontal surface
 - *Case 1: embankments built as enlargement of existing embankment of important highway*
 - *Case 2: embankment built to solve potential stability problem close to the quay of a container terminal*

Case History 1



- Enlarged Highway
- Larger curve radii
- Need for enlargement of embankments on soft soil

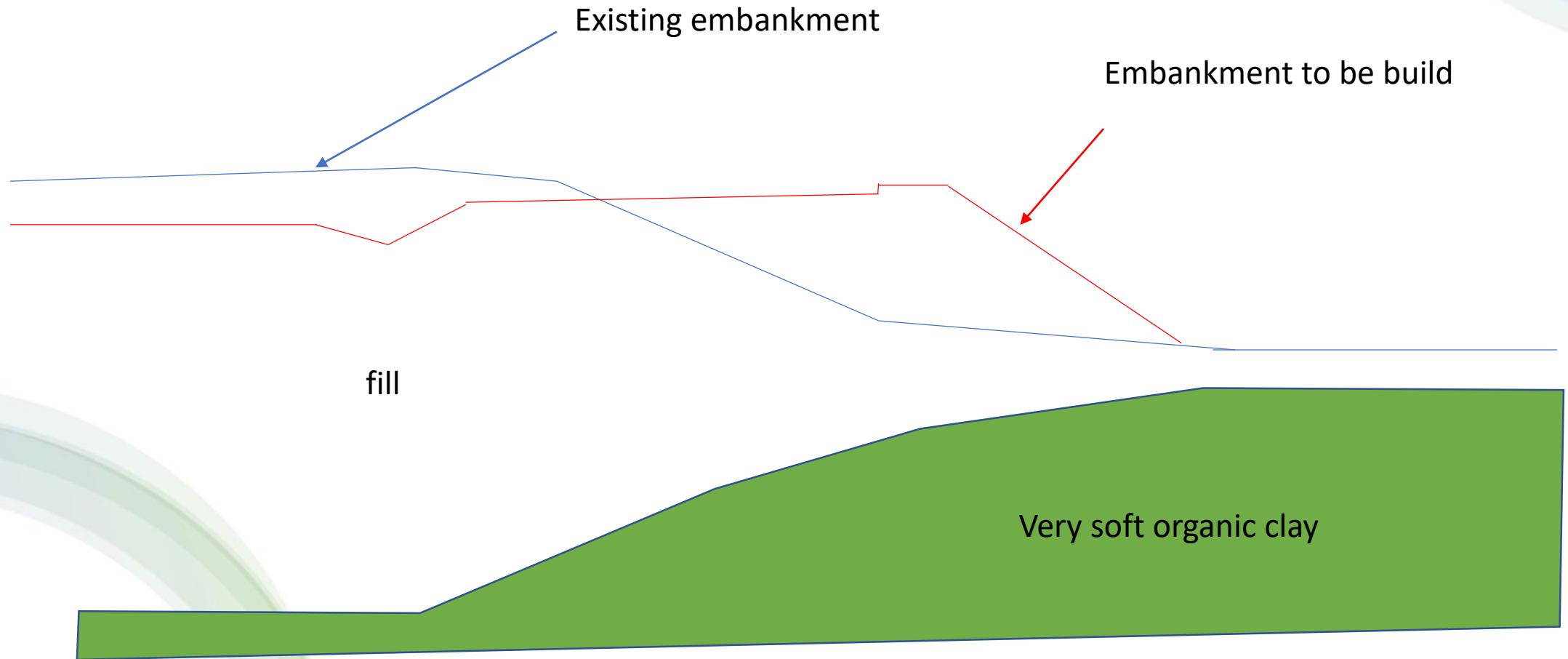


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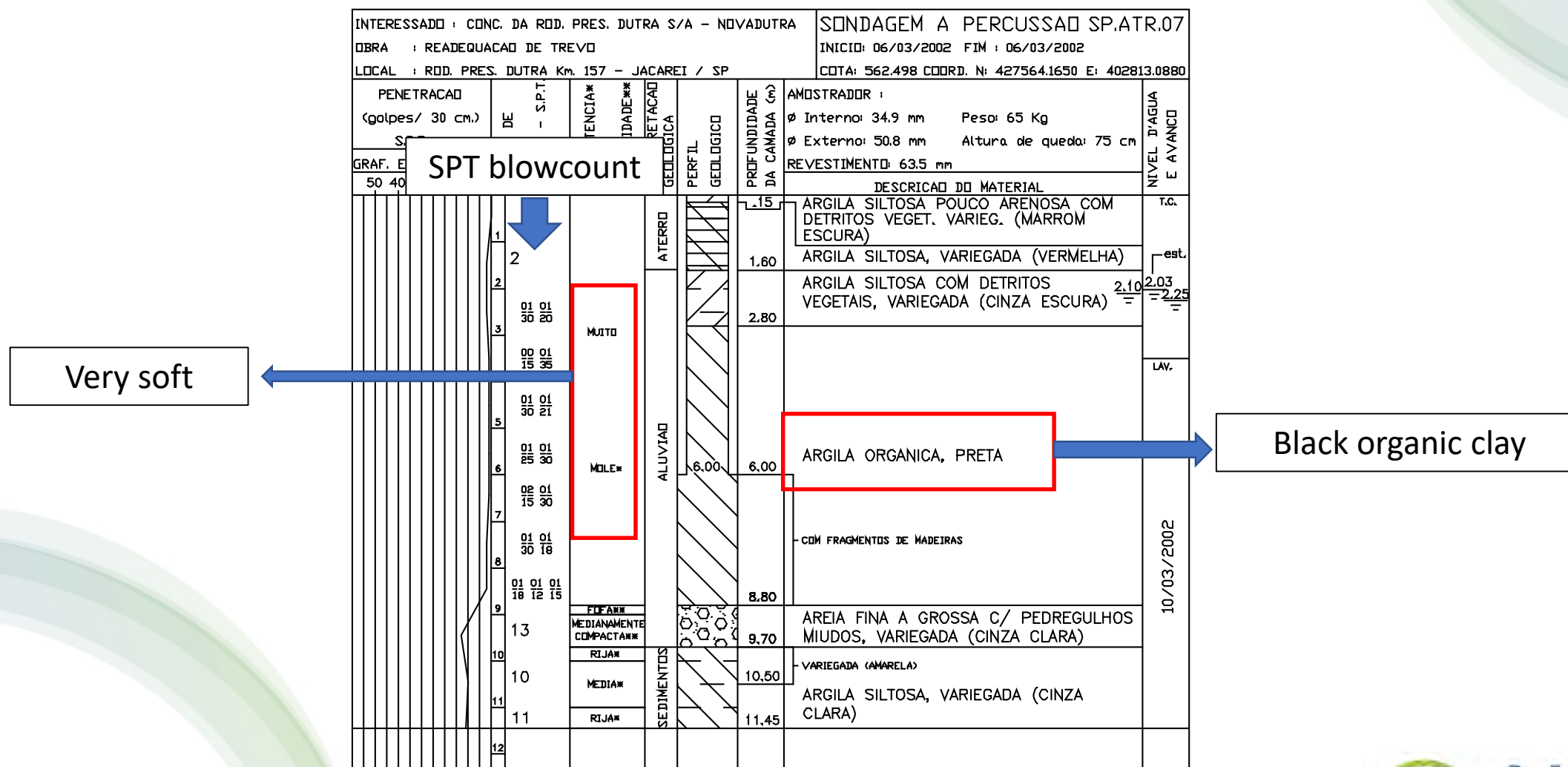


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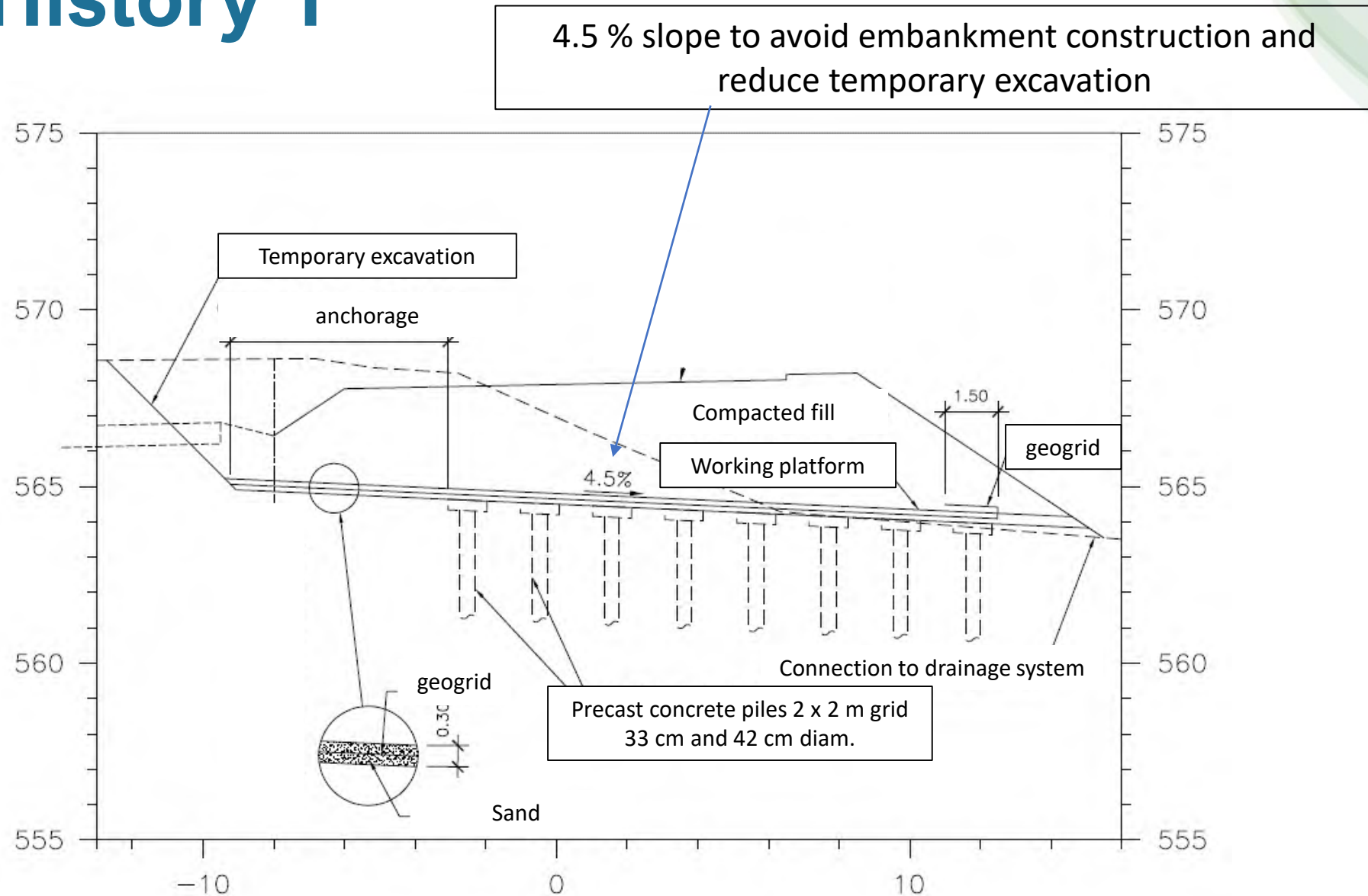
Case History 1



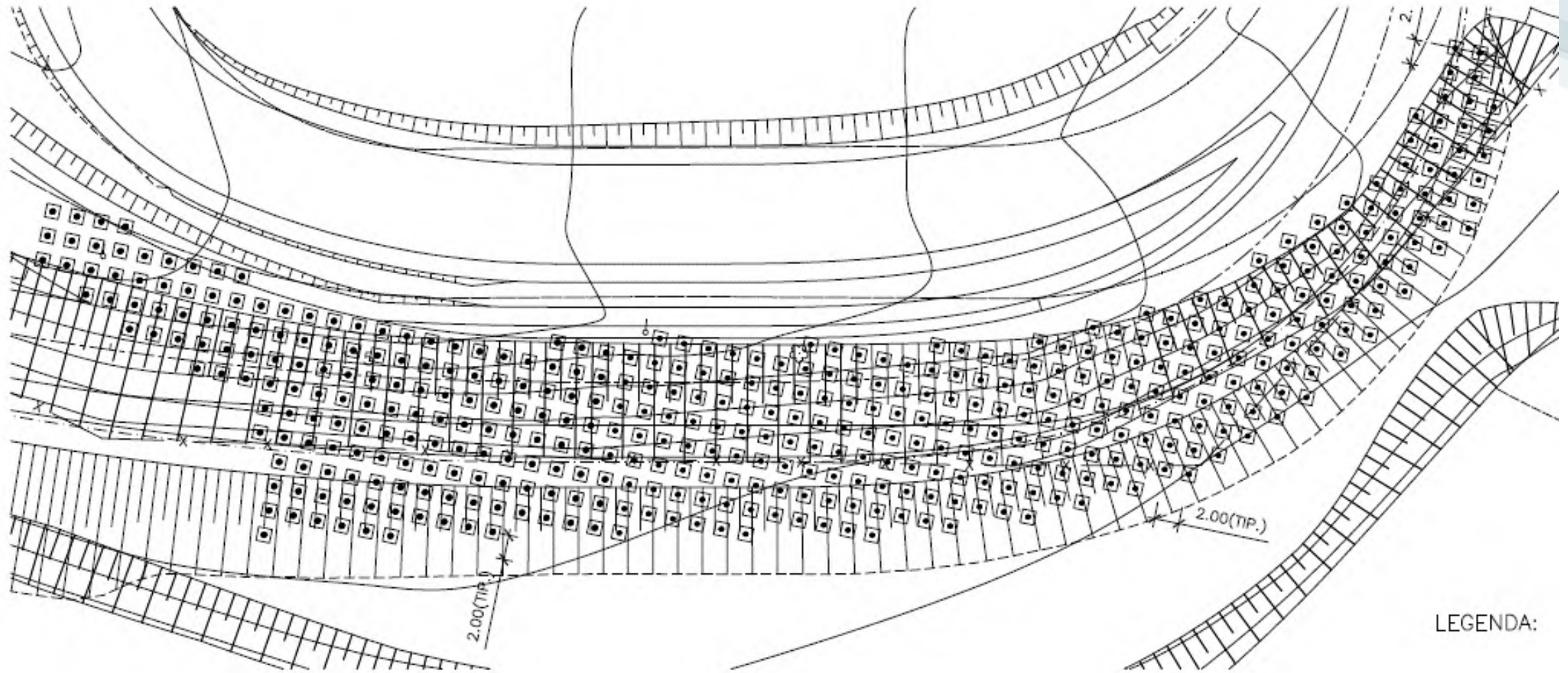
Case History 1



Case History 1



Case History 1



Case History 1



Case History 1



Case History 1



Case History 1



Case History 1



Case History 1



Case History 1



Case History 1



Case History 2



Case History 2

- Container terminal
- Quay structure on piles + sheet pile wall
- Container yard: soft soil treated with geodrains + surcharge
- During construction:
 - *very soft soil layer extended to greater depth than identified during design*
 - *top of sheet pile was not fixed to the quay structure prior to start of embankment construction*



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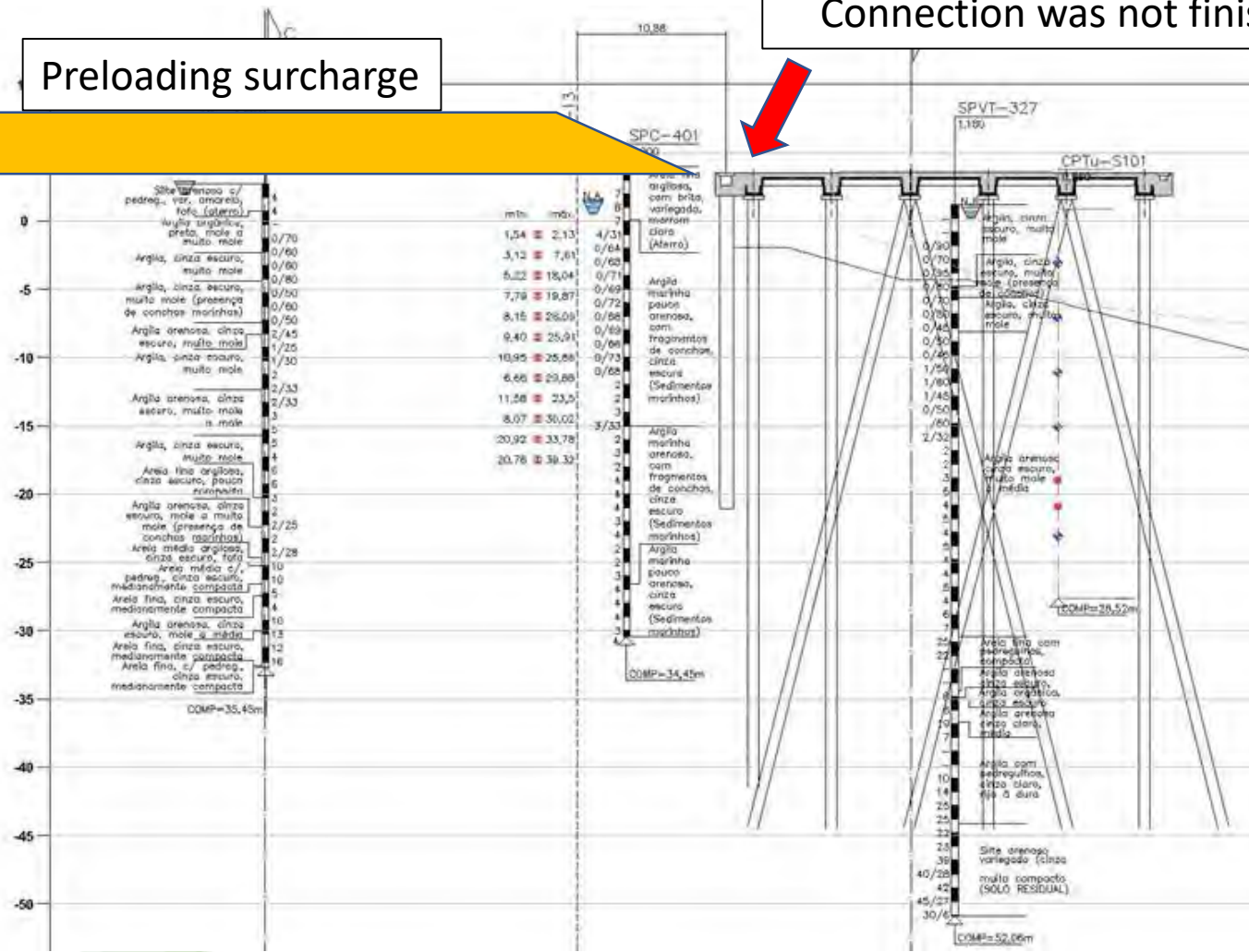


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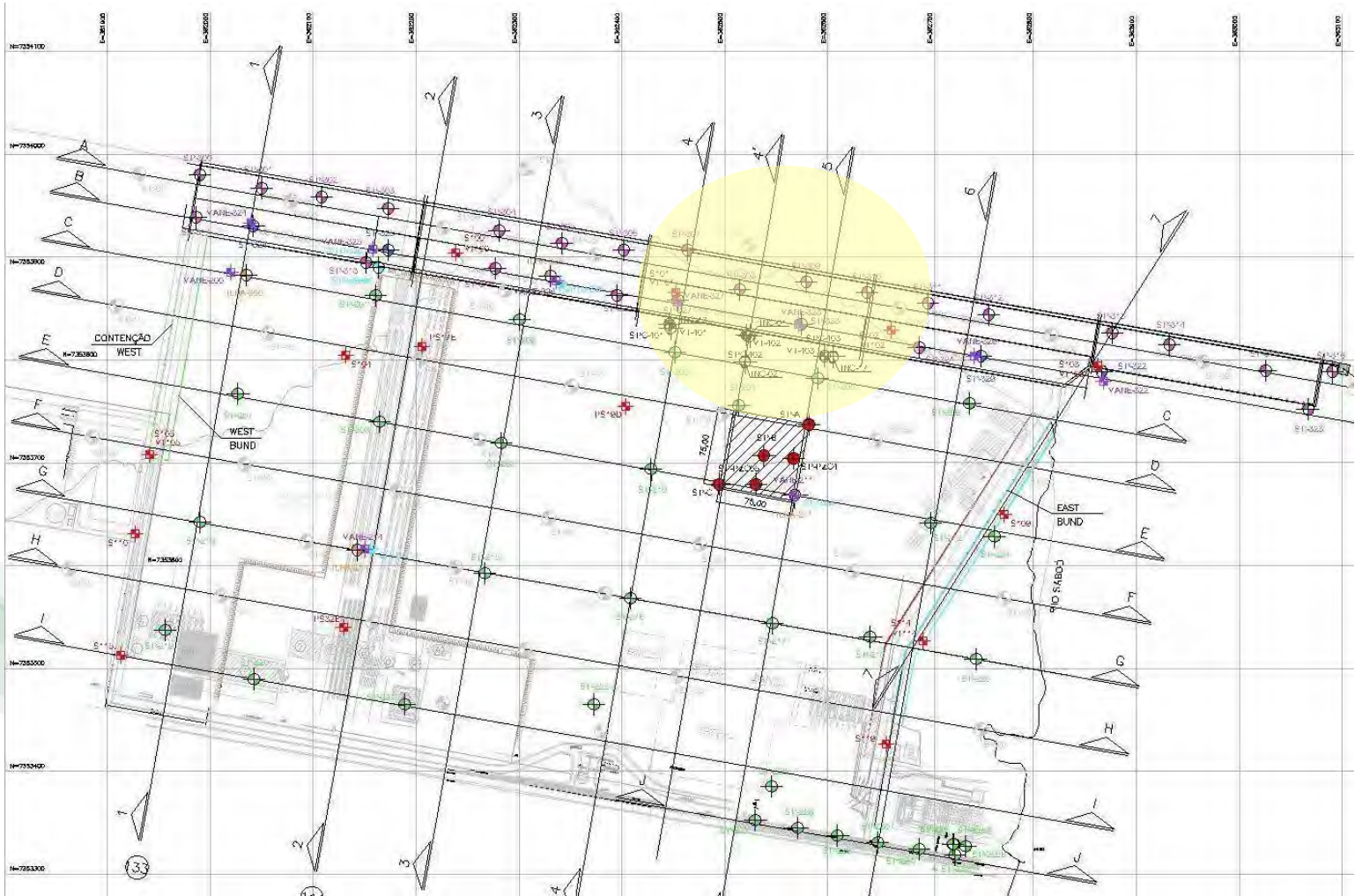
Case History 2

Preloading surcharge

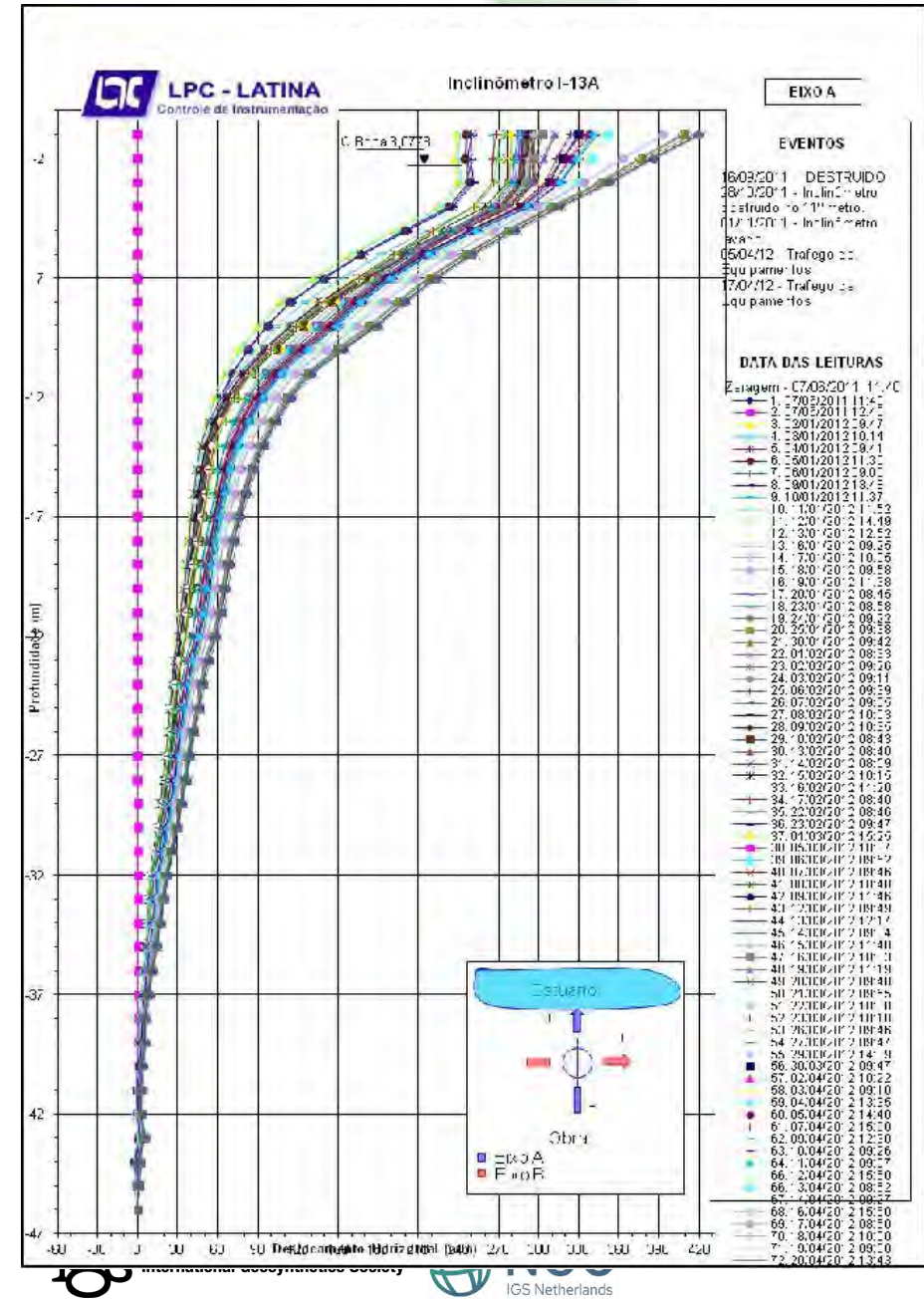
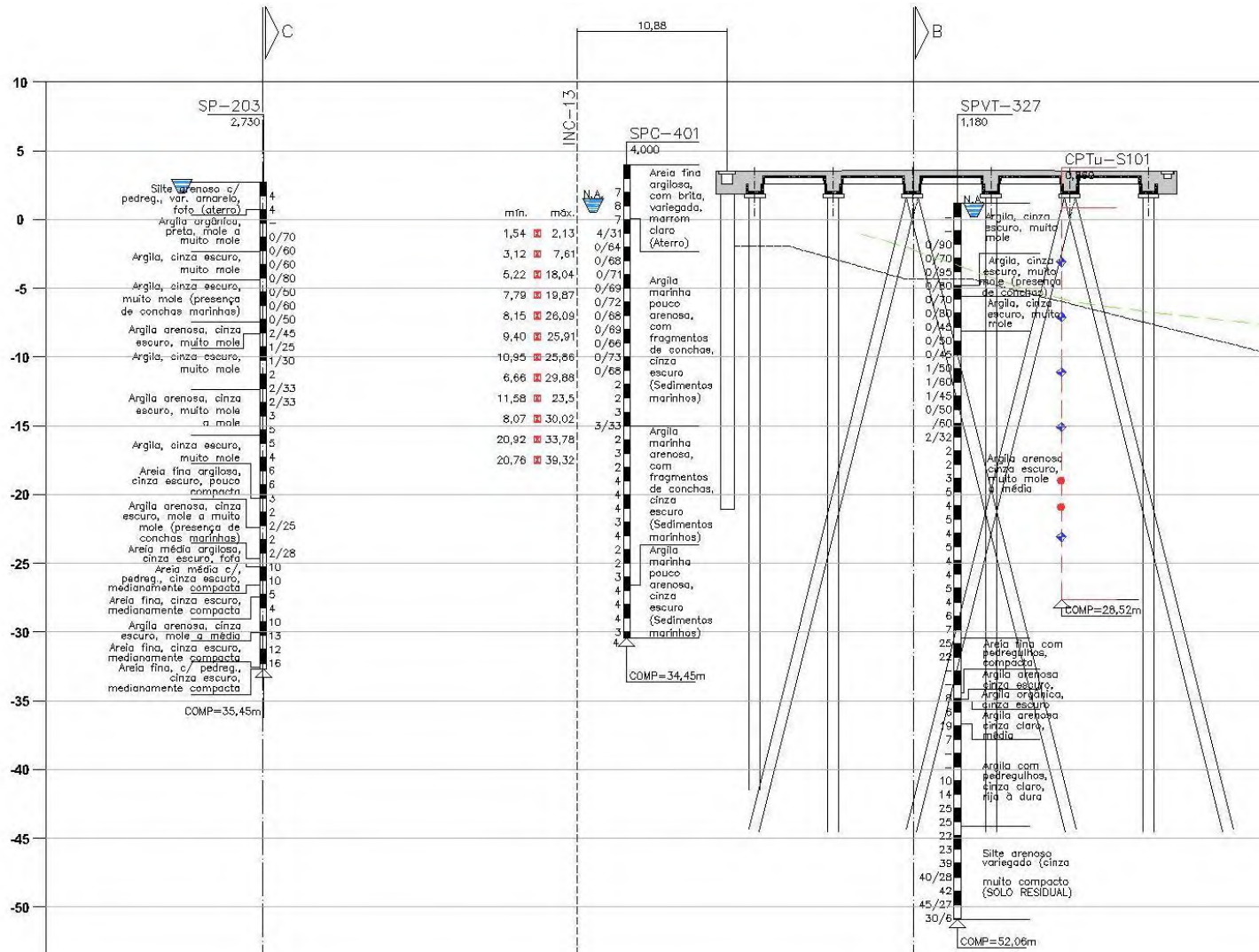
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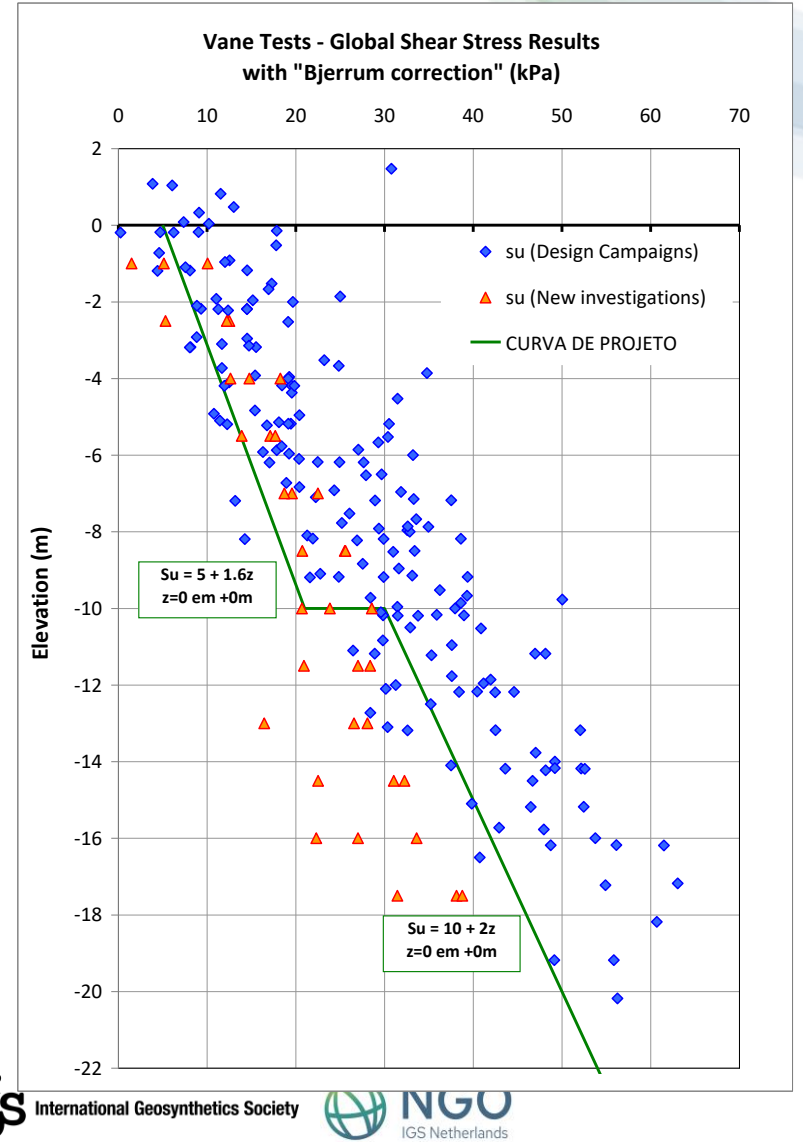
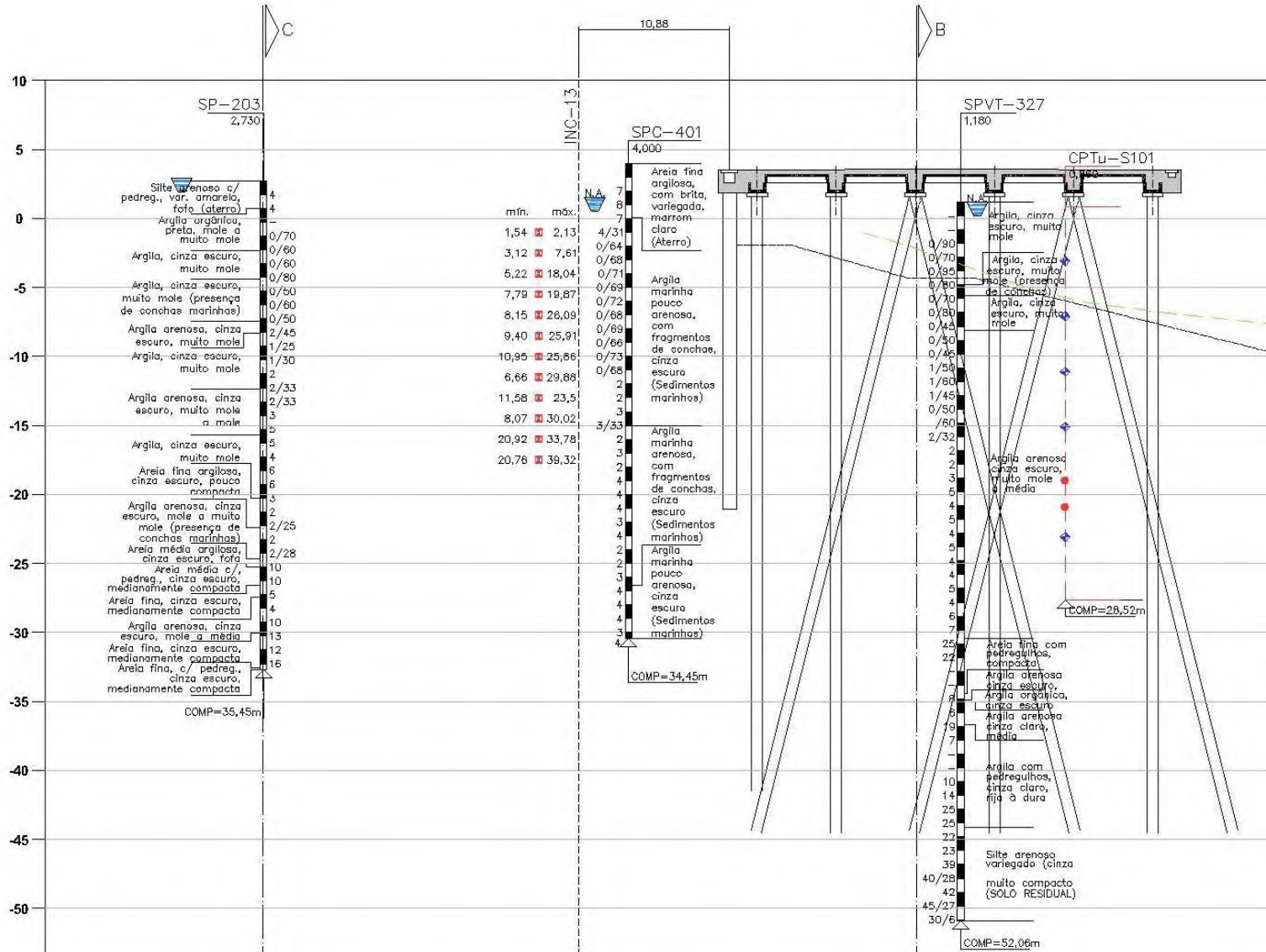
Case History 2



Case History 2

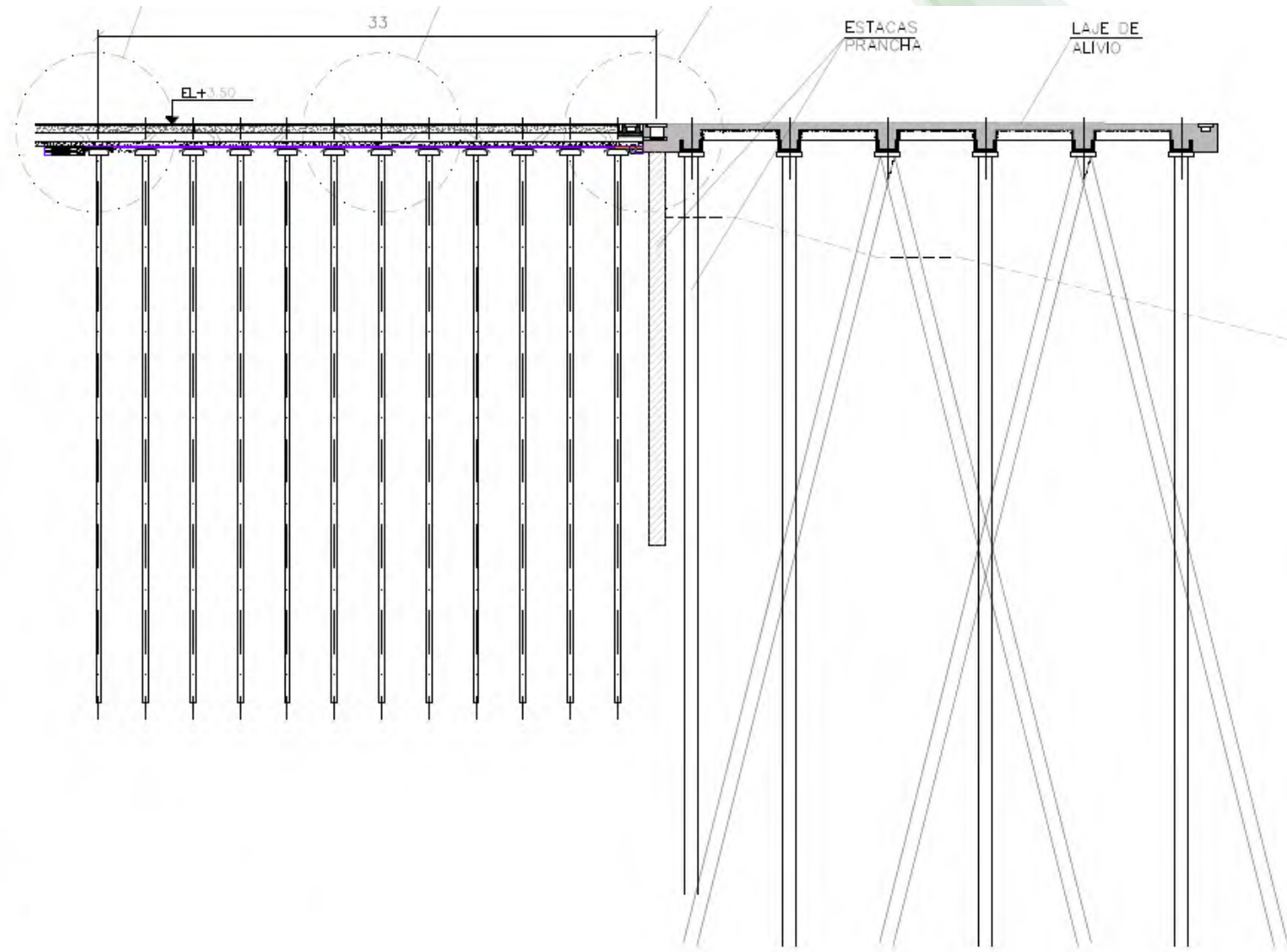


Case History 2



Case History 2

- Decision to build a piled embankment in the critical region to guarantee stability and performance close to the quay



Case History 2

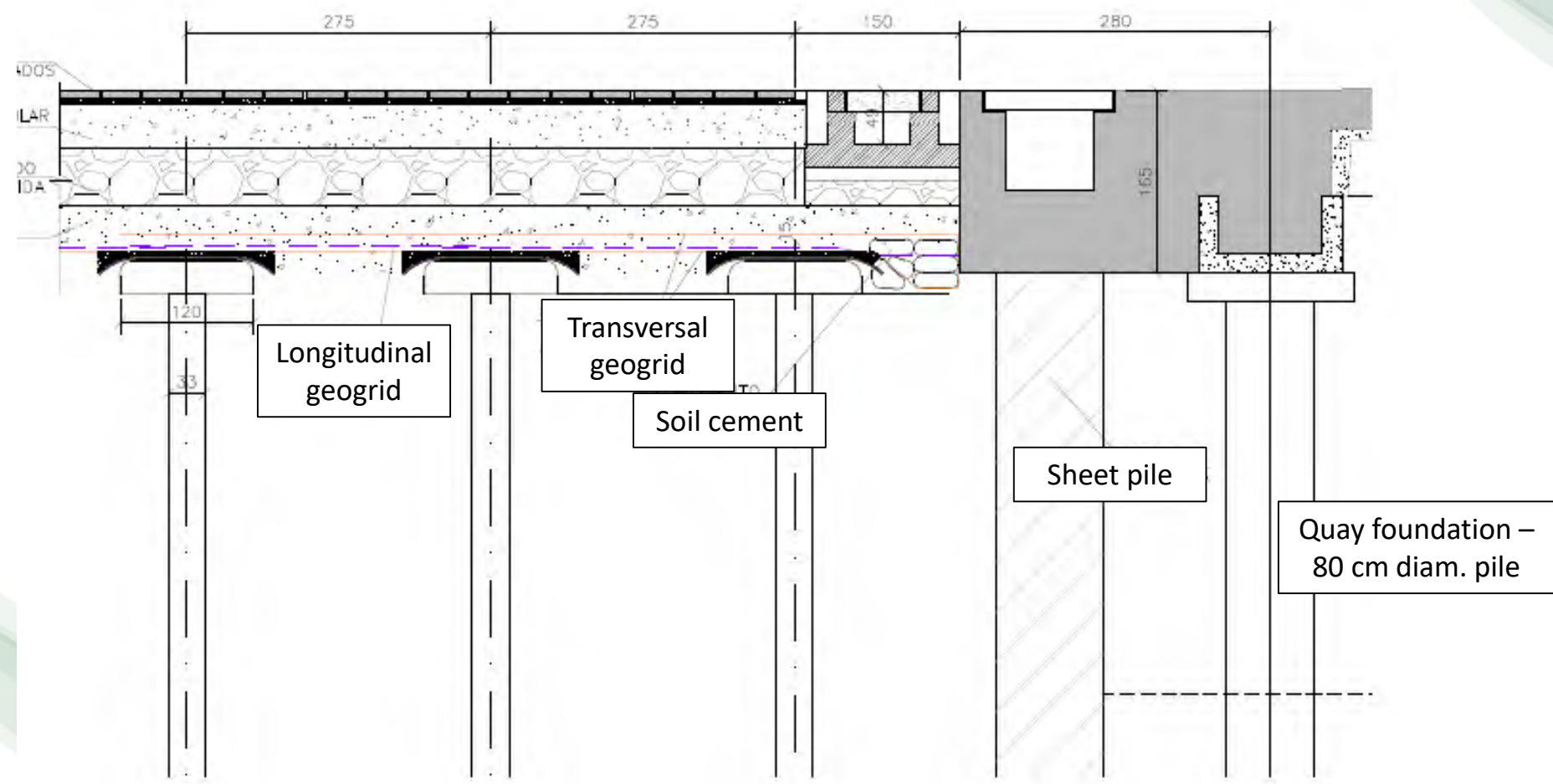
- **Non typical characteristics:**

- *Relatively small embankment height (1,5 m)*
- *High variable surcharge (5 containers and/or equipments) = aprox. 50 kPa*
- *Difficult anchorage conditions for geogrids*
- *Some utilities had to be built inside the embankment*
- *Residual settlement (20 Years) of 40 cm foreseen of the embankment that surrounds the piled embankment*

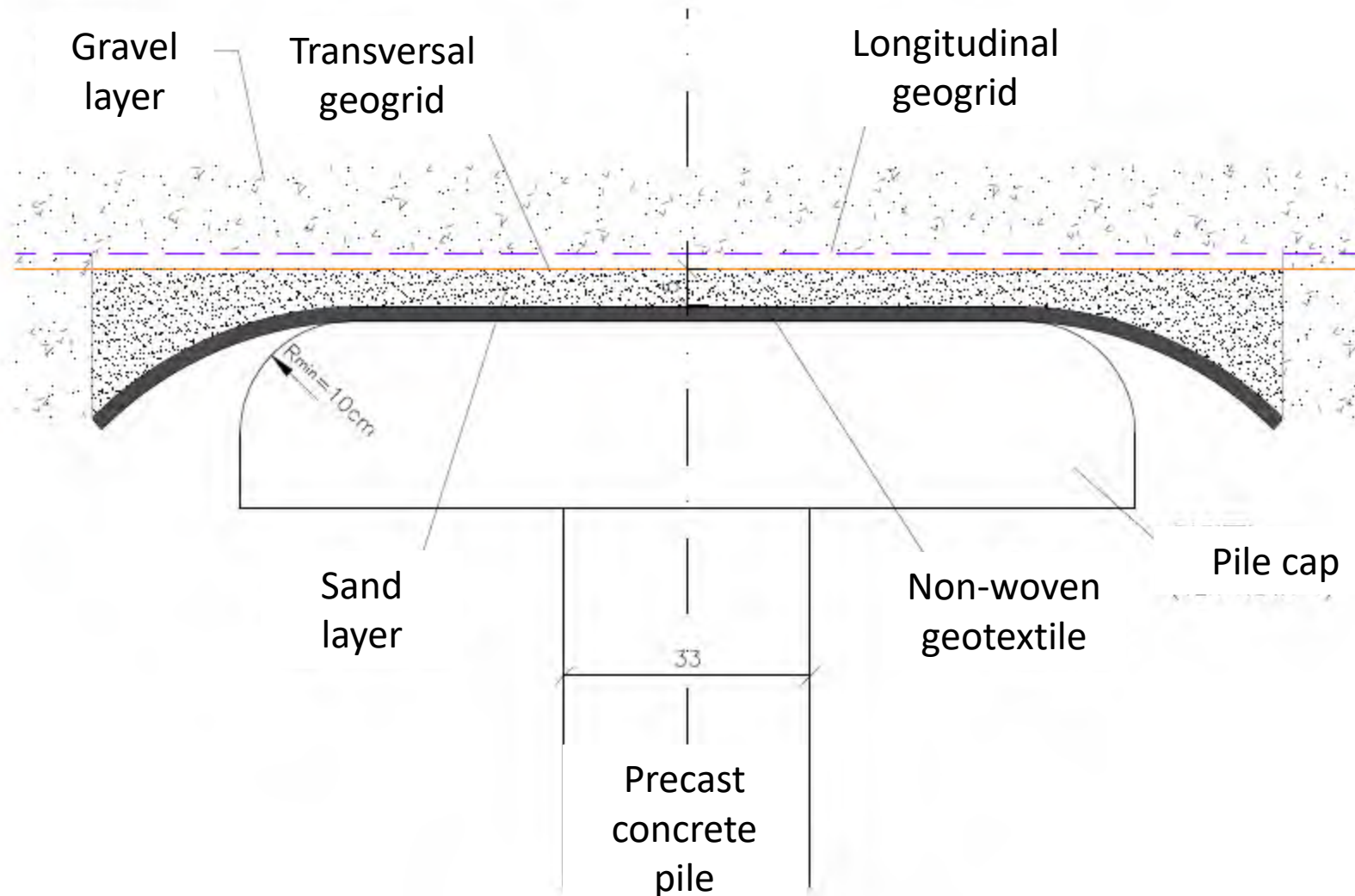
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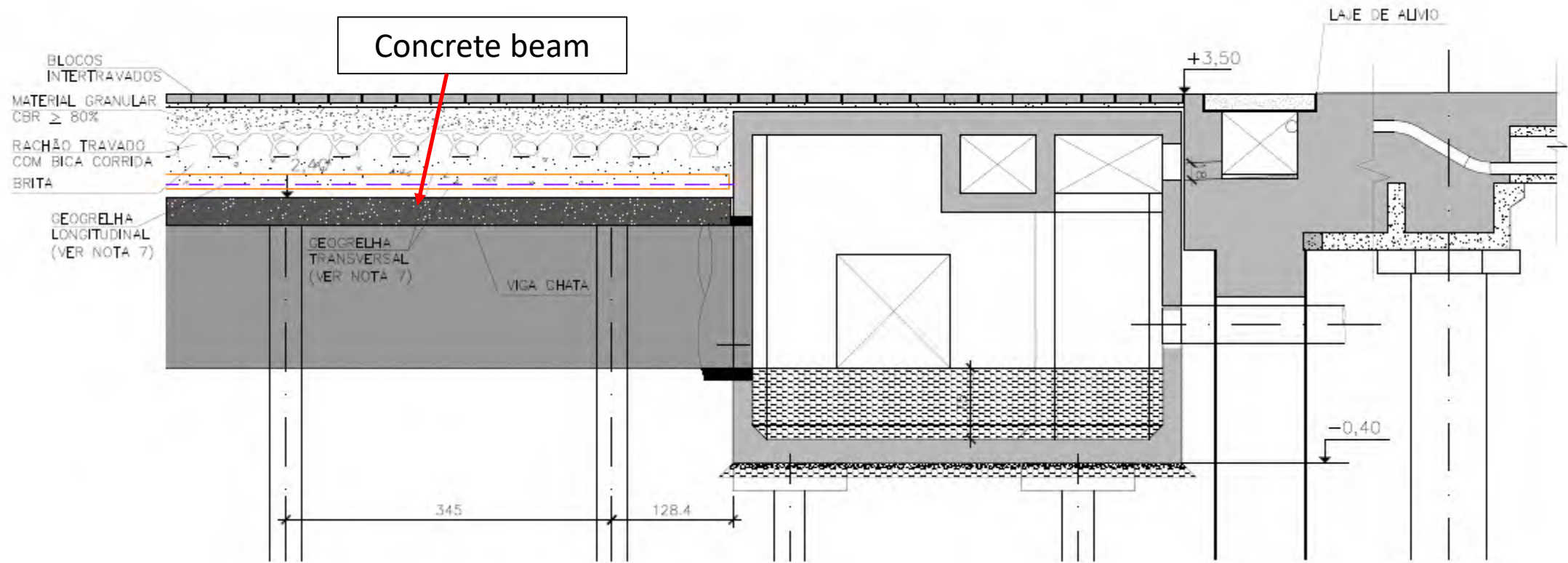
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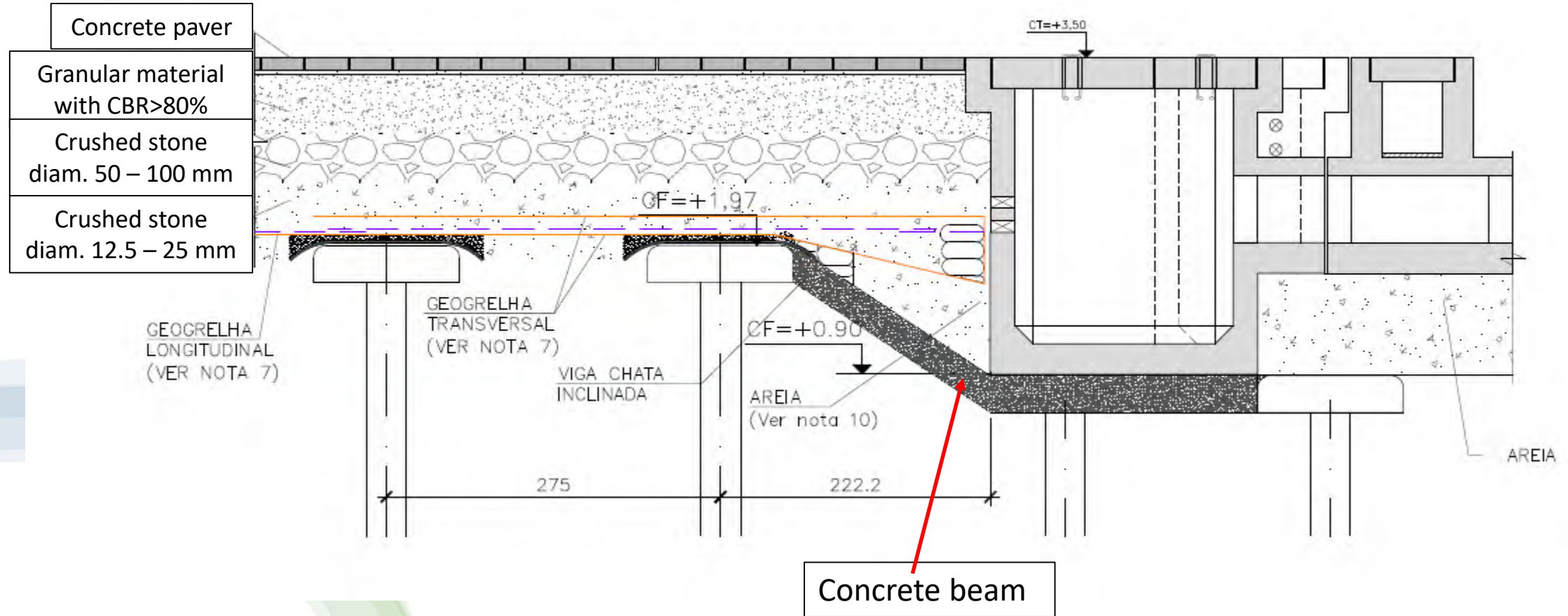
Case History 2



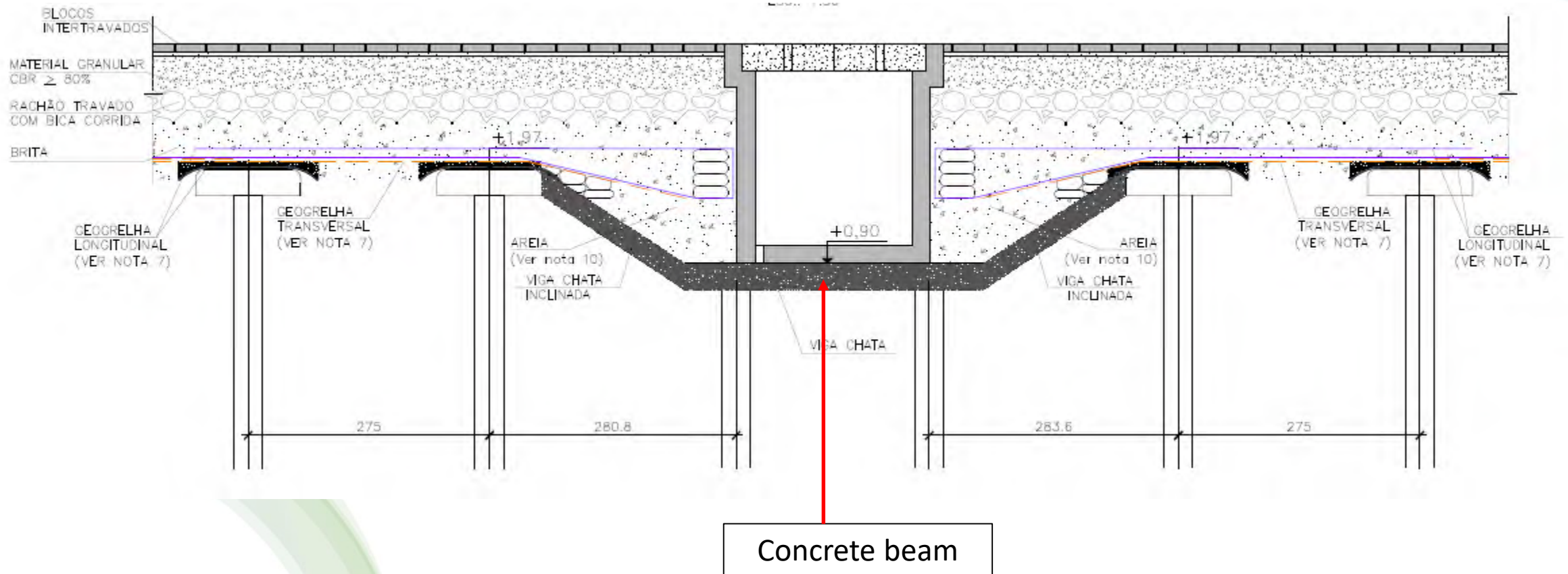
Case History 2



Case History 2



Case History 2



Case History 2



Case History 2



Case History 2



Case History 2



Case History 2



Case History 2



Case History 2



Some concluding remarks

- Piled Embankments are a proven geotechnical solution and have been used successfully for several decades.
- There is constant technical evolution – van Eekelens Thesis is the most recent key publication.
- Other important publications are BS 8006 and EBGEO.
- For design, in addition to soil arching between pile caps, other verifications and design details are important.
- The idealized conditions are seldom found.



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"In all history, there is no war which was not hatched by the governments, the governments alone, independent of the interests of the people, to whom war is always pernicious even when successful."

Leo Tolstoy



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Thank You!
Dank u wel!
Merci!
Grazie!
Vielen Dank!
Muchas Gracias!
Muito Obrigado!

Contact: werner@vector.com.br



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