cfms
COMITÉ FRANÇAIS DE MÉCANIQUE DES SOLS ET DE GÉOTECHNIQUE

ACADÉMIE DES SCIENCES INSTITUT DE FRANCE

ACADÉMIE DES TECHNOLOGIES POUR UN PROGRÈS RAISONNÉ, CHOISI ET PARTAGÉ

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LES TRAVAUX PUBLICS FÉDÉRATION NATIONALE

Charles-Augustin COULOMB - A geotechnical tribute

Paris, september 25 & 26, 2023

French practice for design of embedded walls

P.Schmitt

What is French practice for design of embedded walls ?

- Use of « traditional approaches », based on safety factors applied to global resistances (RFA) rather than partial factors directly applied to soil resistance parameters (MFA)

- Use of « traditional models », in combination with numerical models (as necessary) :
  - ✓ Earth pressure coefficients (Caquot, Kérisel & Absi)
  - ✓ Subgrade reaction software (1970's)

- Intensive use of geotechnical monitoring and observational method

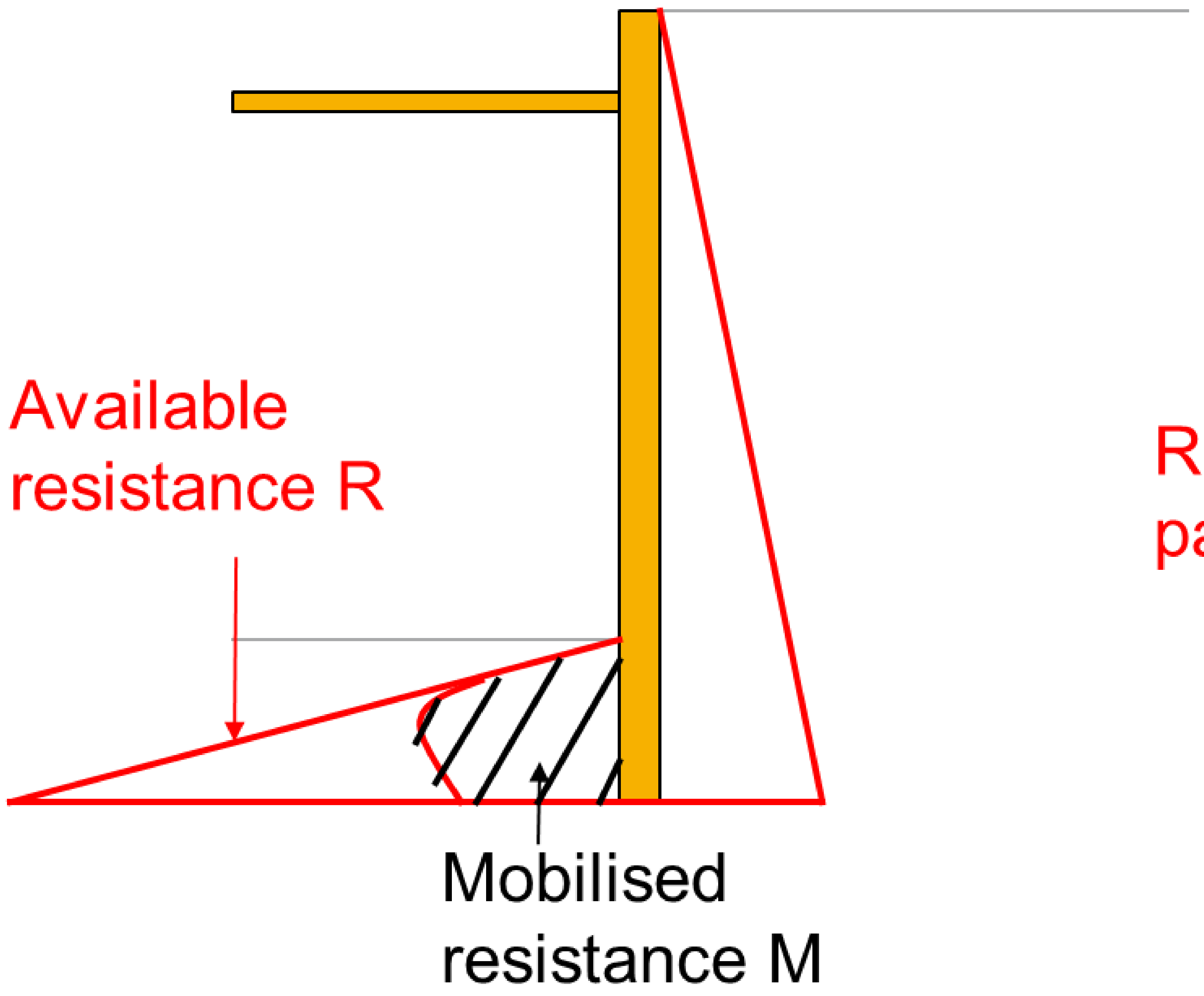
What is French practice for design of embedded walls ?

- **Use of soil parameters derived from in situ tests (in addition with lab tests)**

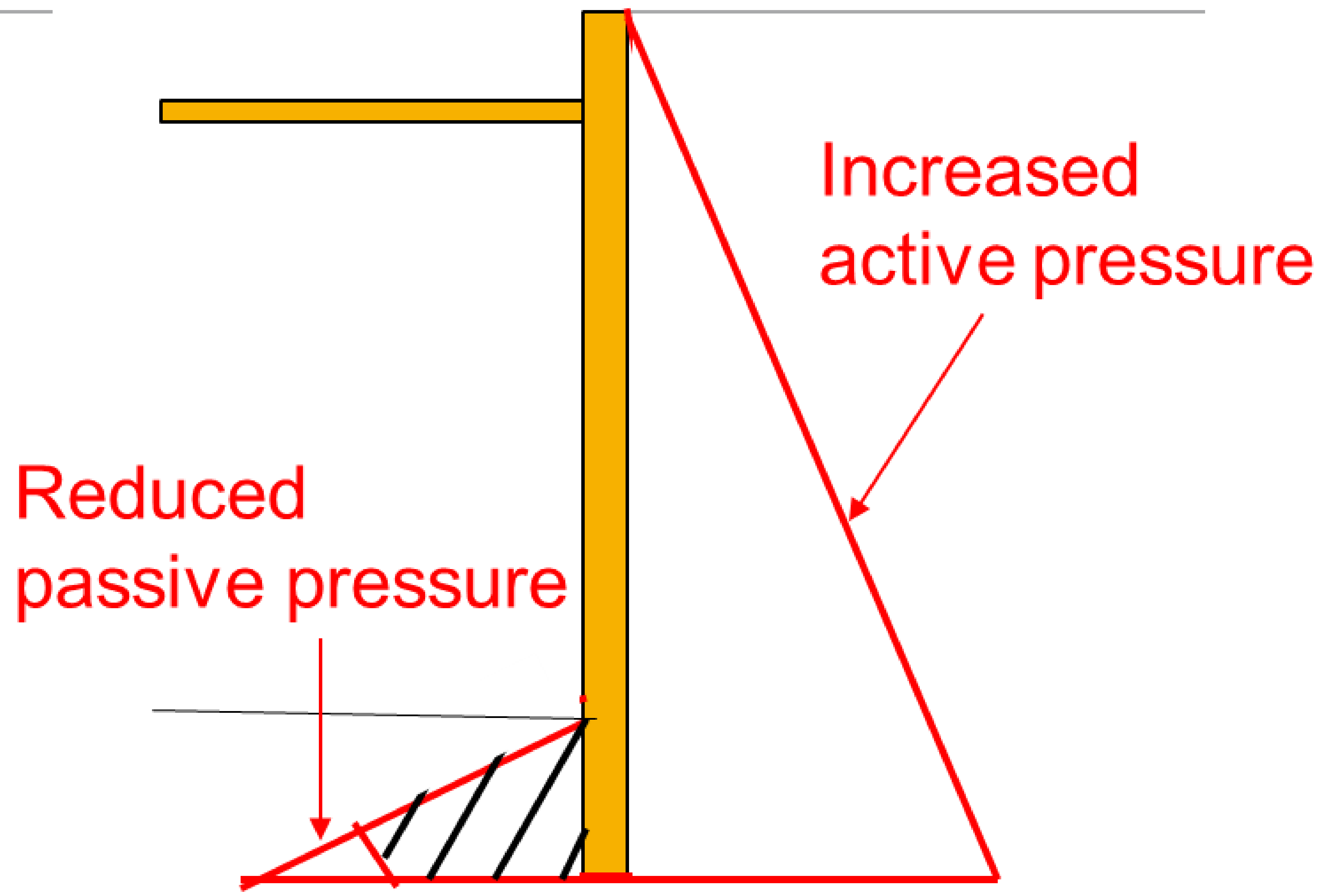
  ✓ **Pressuremeter tests (L.Ménard) => E_M, pl**
  E_M (deviatoric stress path) => **E_M/α** (oedometric or triaxial stress path)

  ✓ **Phicometer (G.Philipponnat) => Φ, c**
  ISO/DIS 22476-16 “Phicometer Borehole Shear Test”

French practice for ULS design

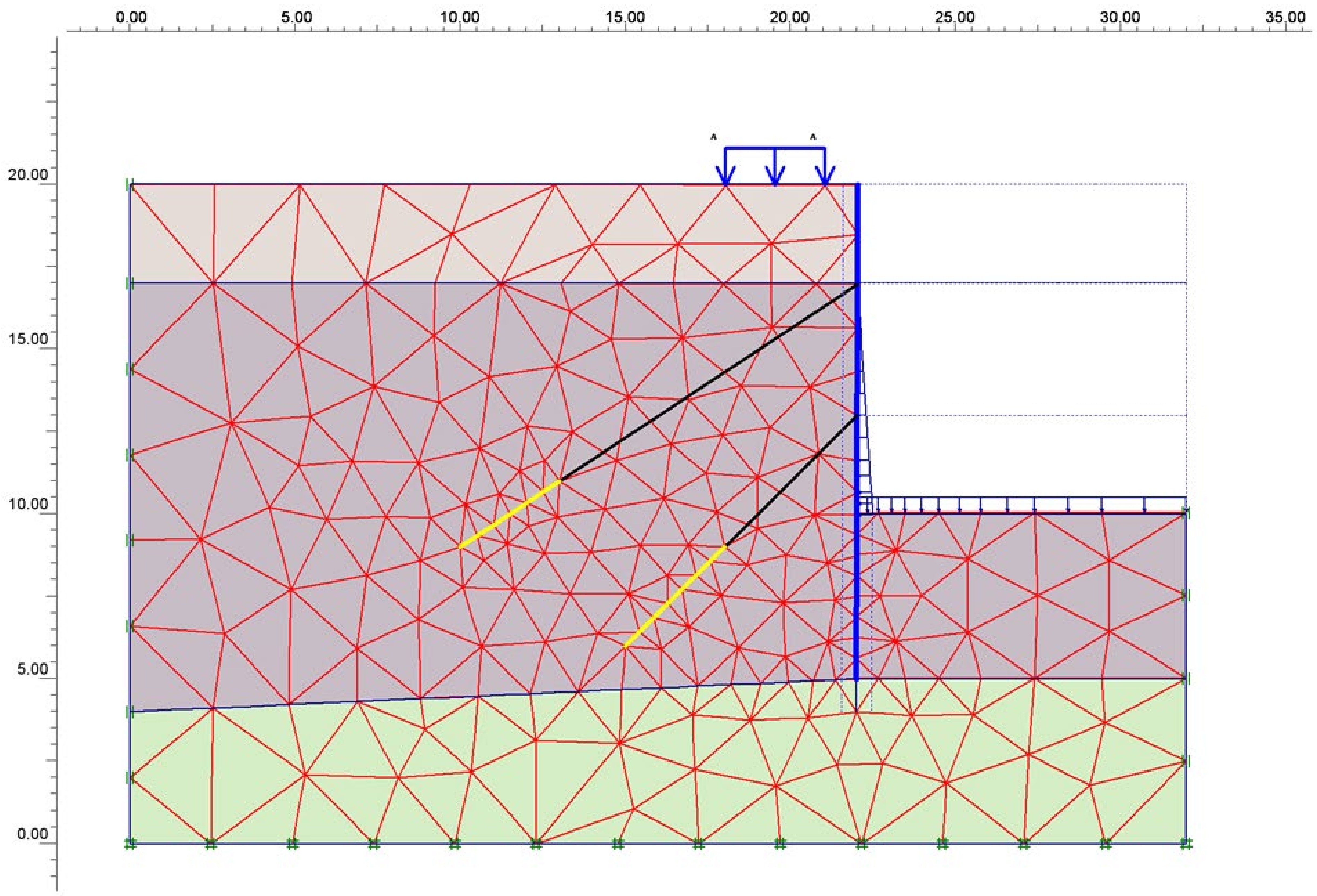


Traditional approach (RFA)

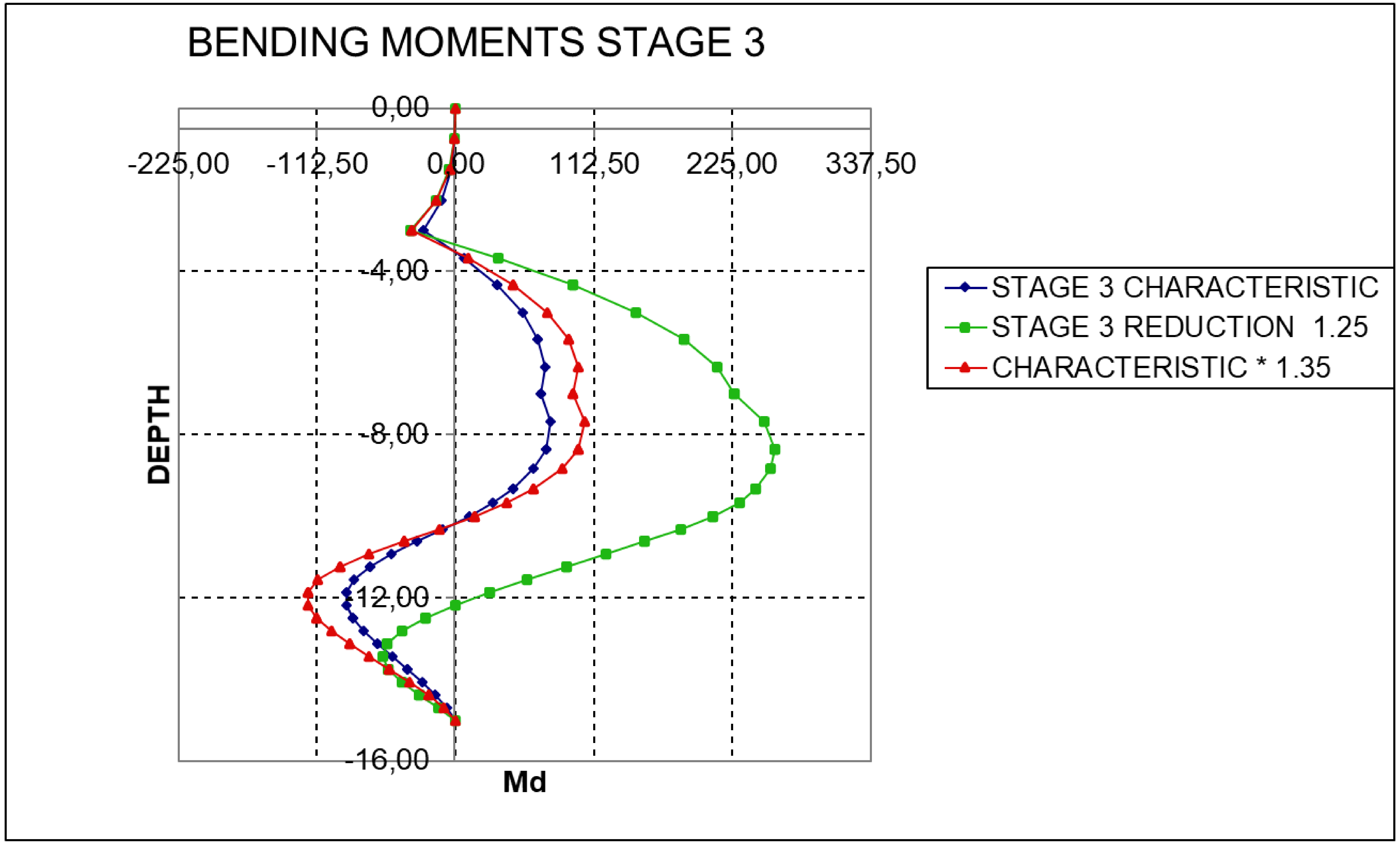


MFA

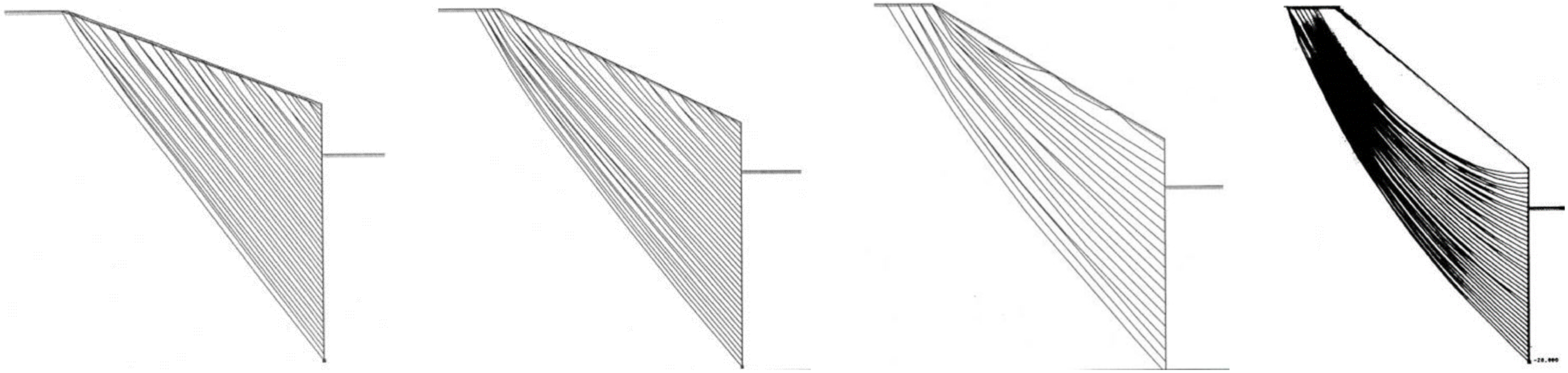
French practice for ULS design



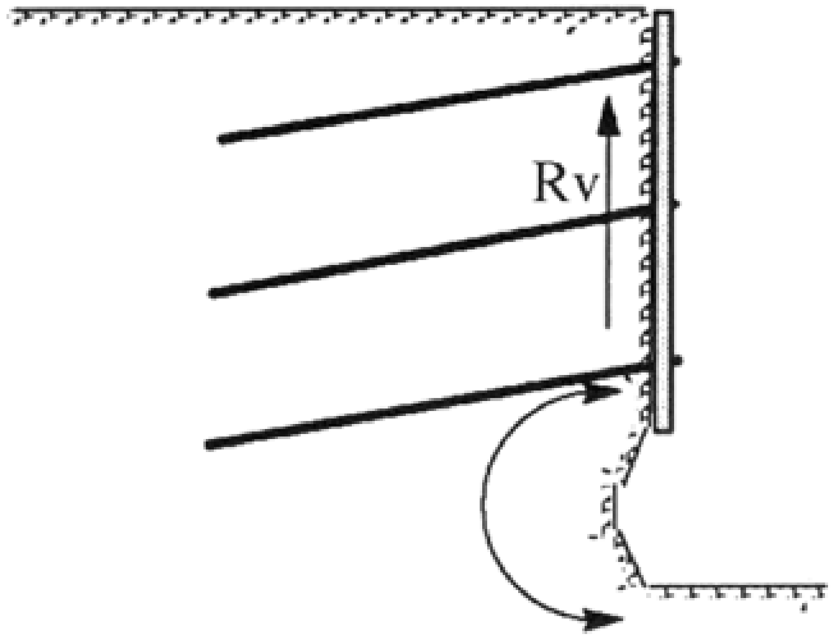
French practice for ULS design



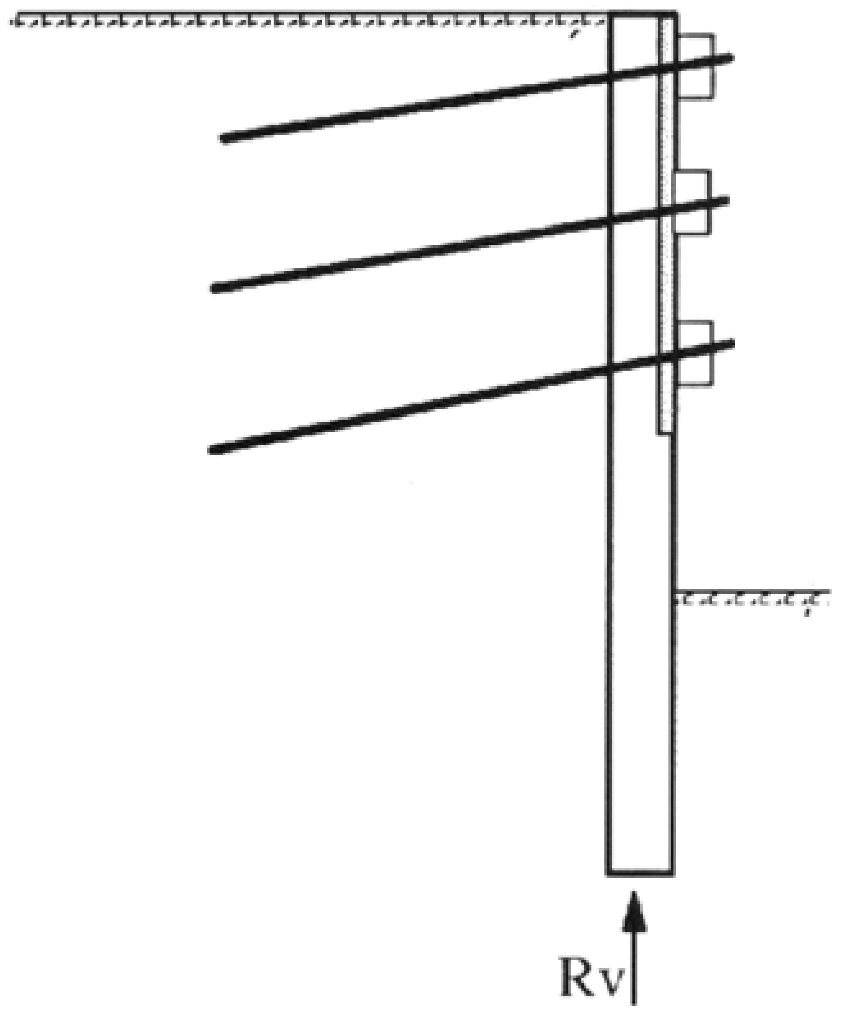
French practice for ULS design



French practice for ULS design



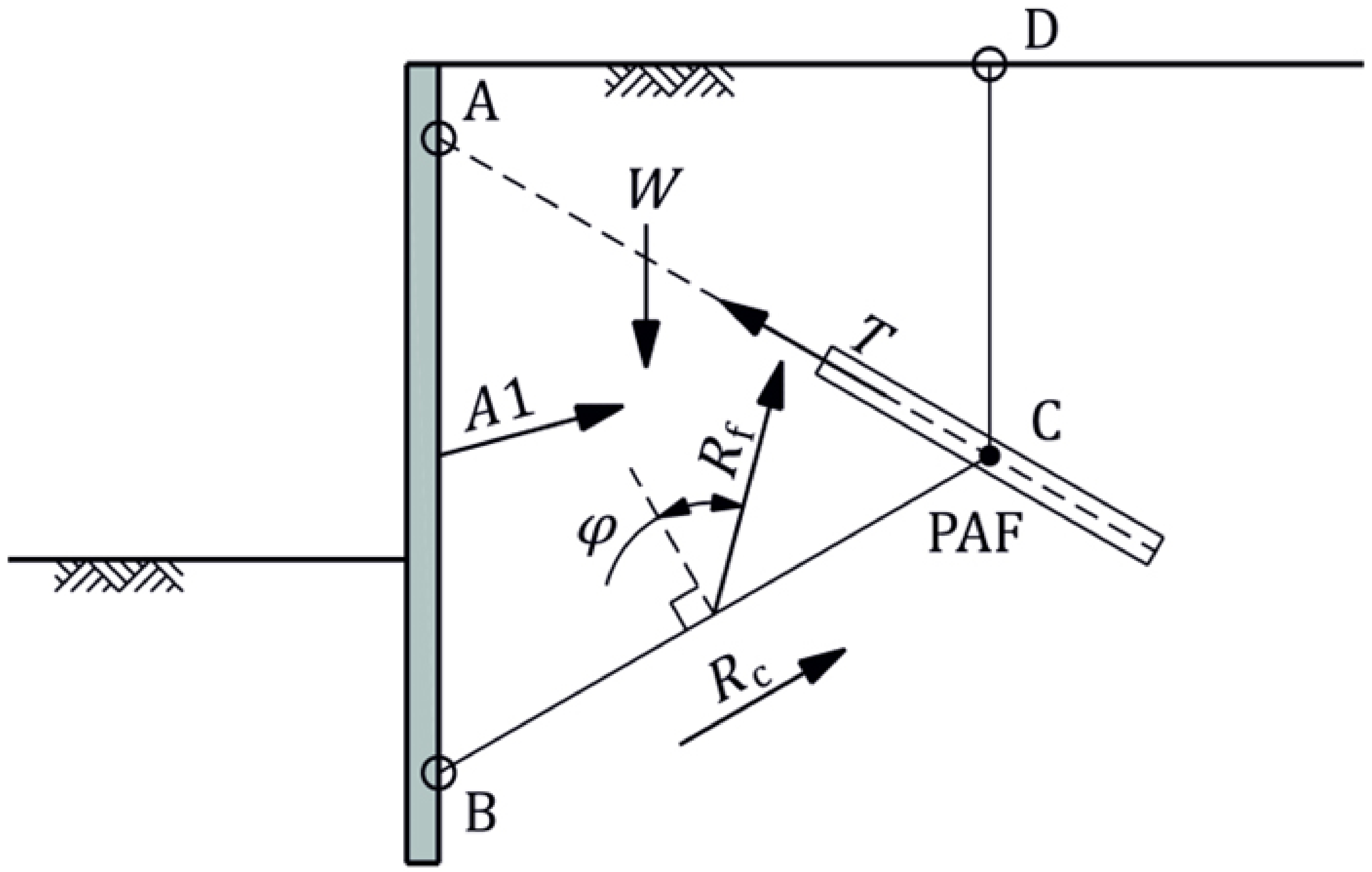
Nailed structures => MFA

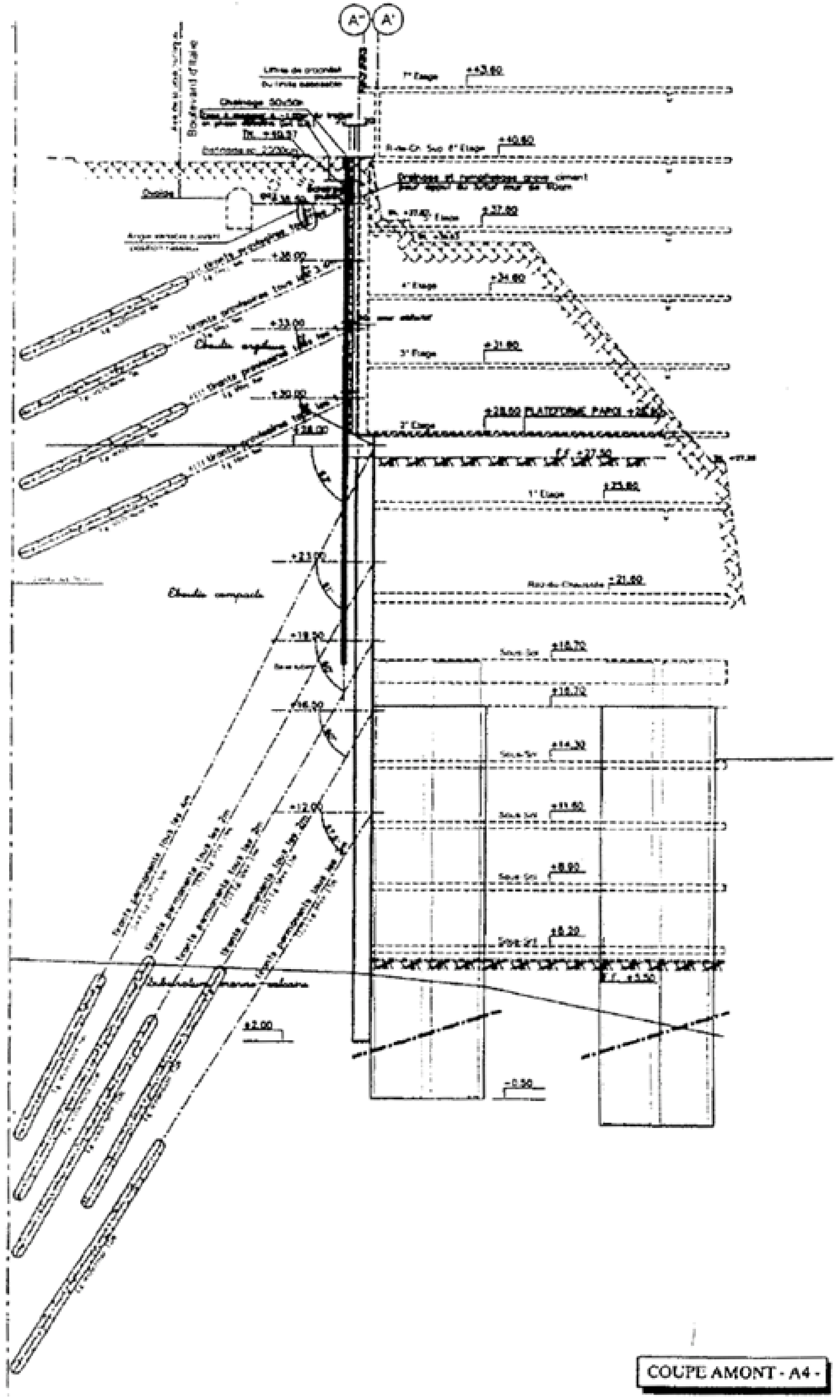


Embedded walls => RFA

Limitations of traditional models

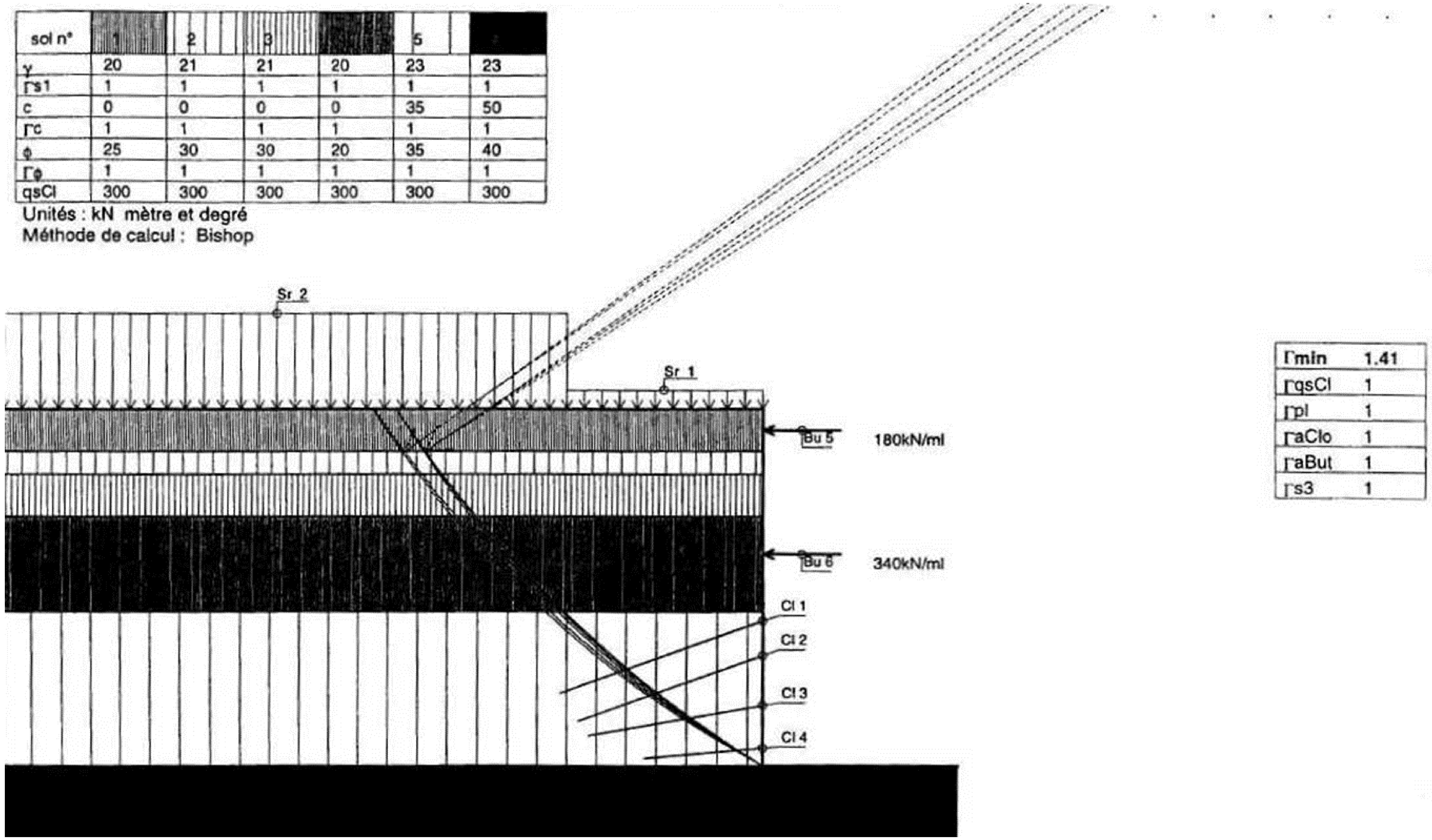
- **Limitations relative to anchored walls**





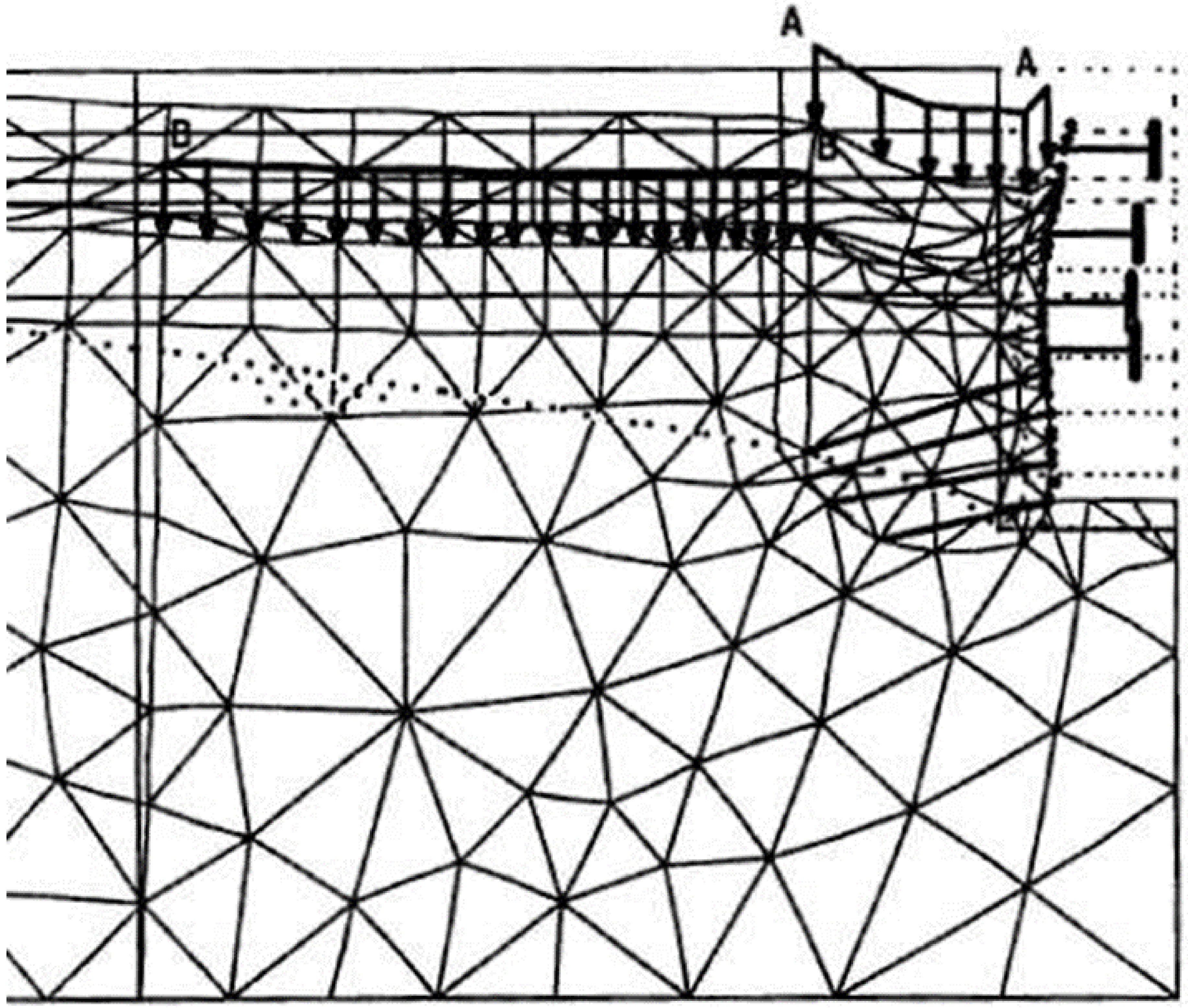
Limitations of traditional models

- **Limitations relative to arching effects**



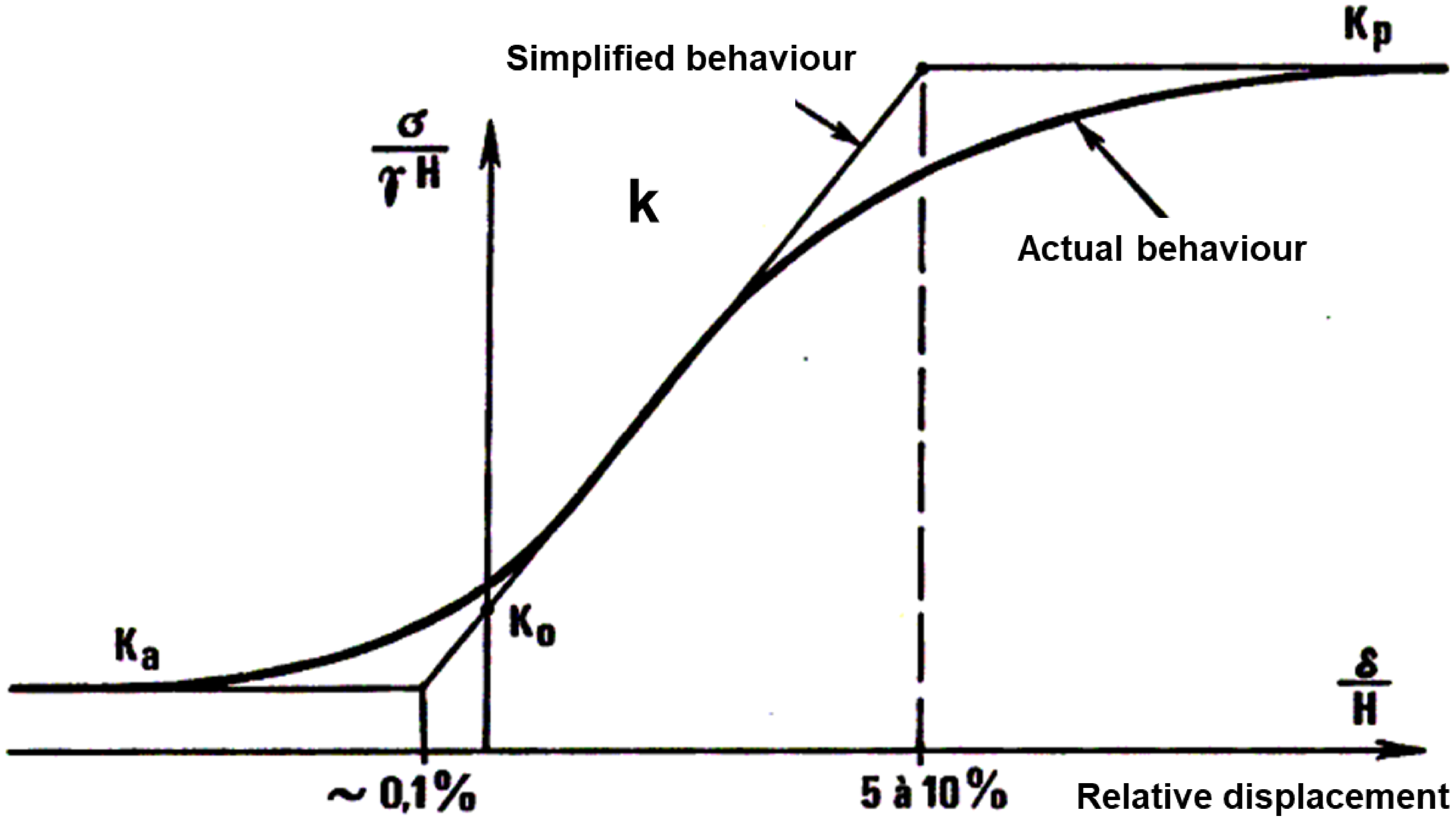
Limitations of traditional models

- **Limitations relative to arching effects**

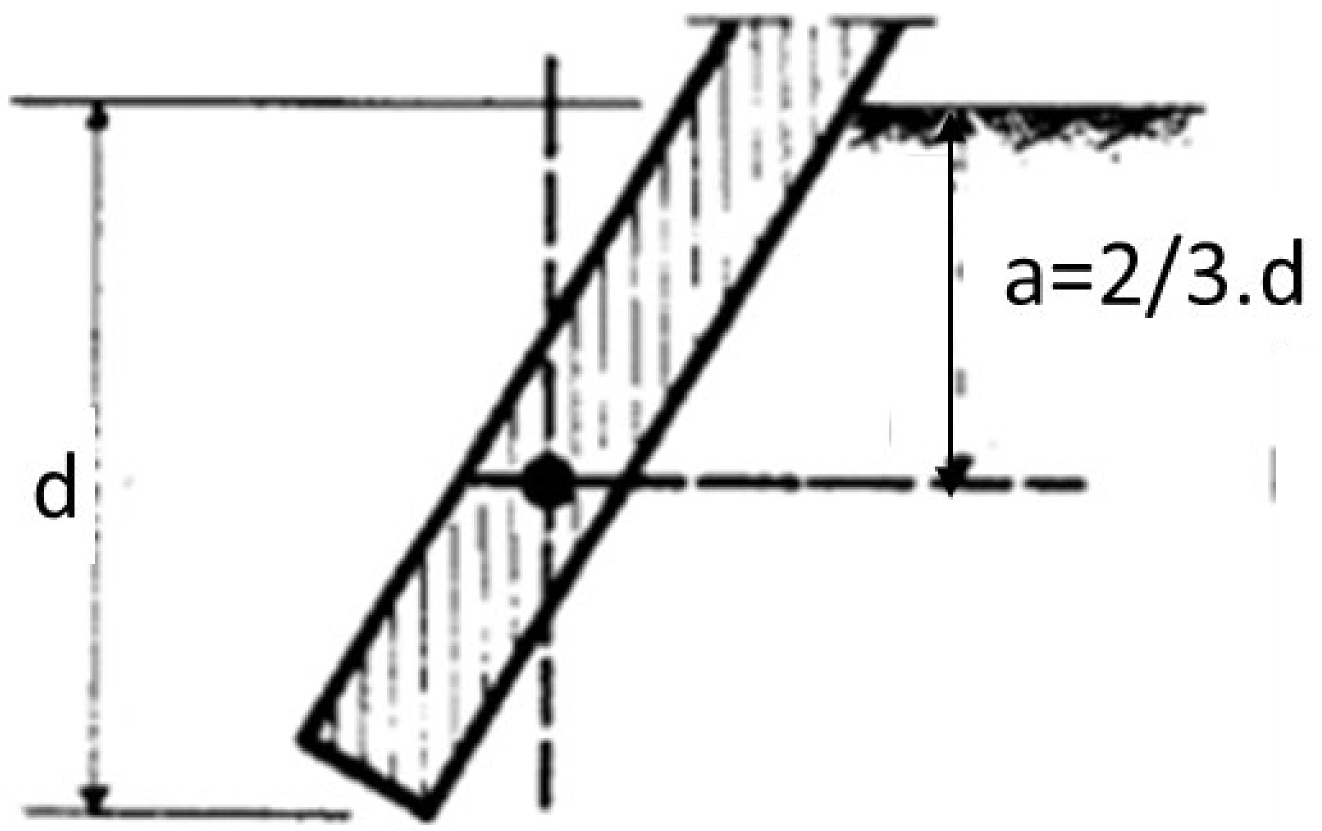


Subgrade reaction models

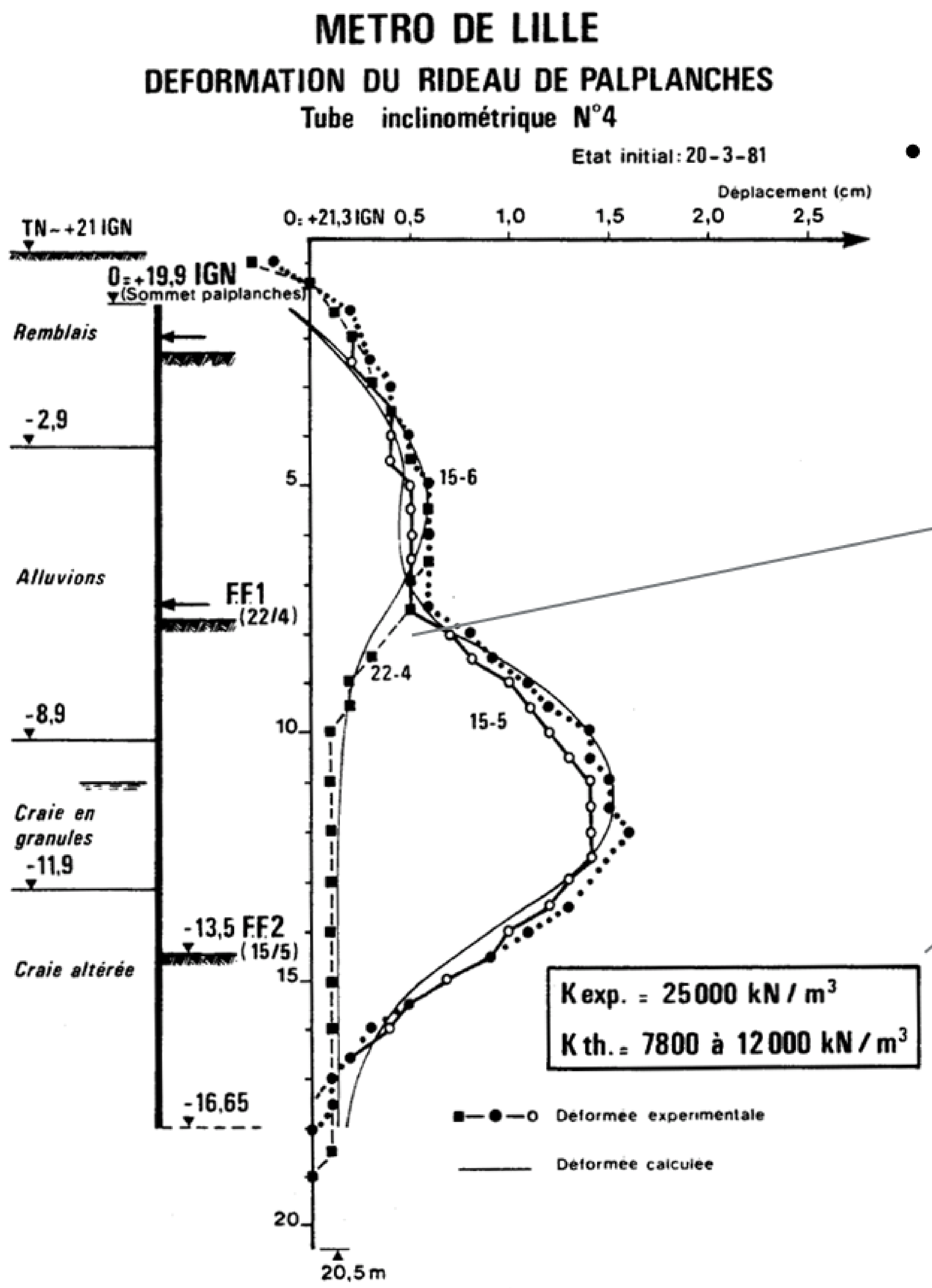
- **Limitations relative to the conceipt**



k ~ Es / a



Subgrade reaction models



- 1st conclusion:

  The validity area of the model is not 0 !

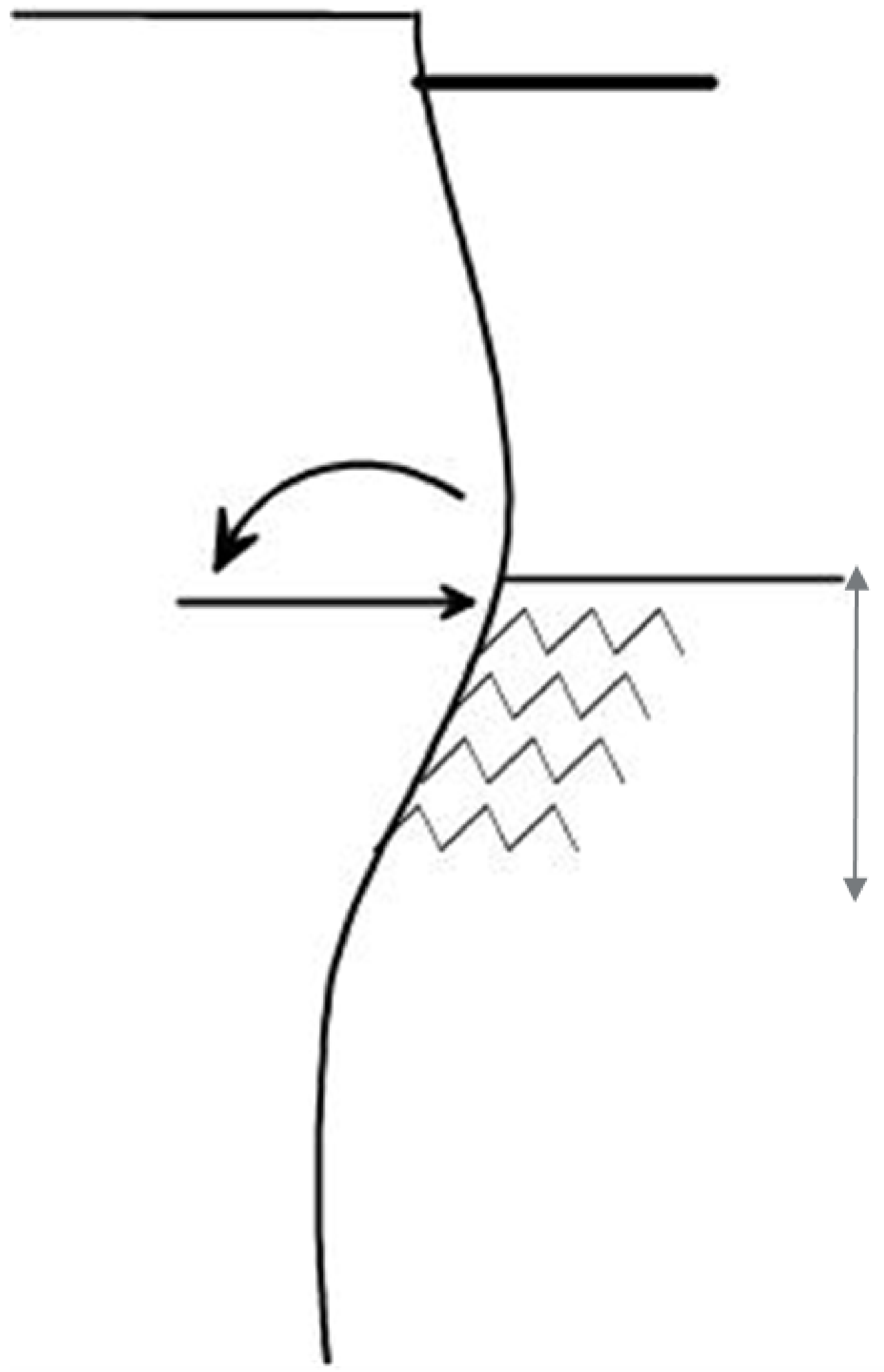
- 2nd conclusion:

  a = 2/3 . d is not relevant for intermediate stages

- 3rd conclusion :

  k was significantly underestimated by Terzaghi and Ménard

Subgrade reaction models

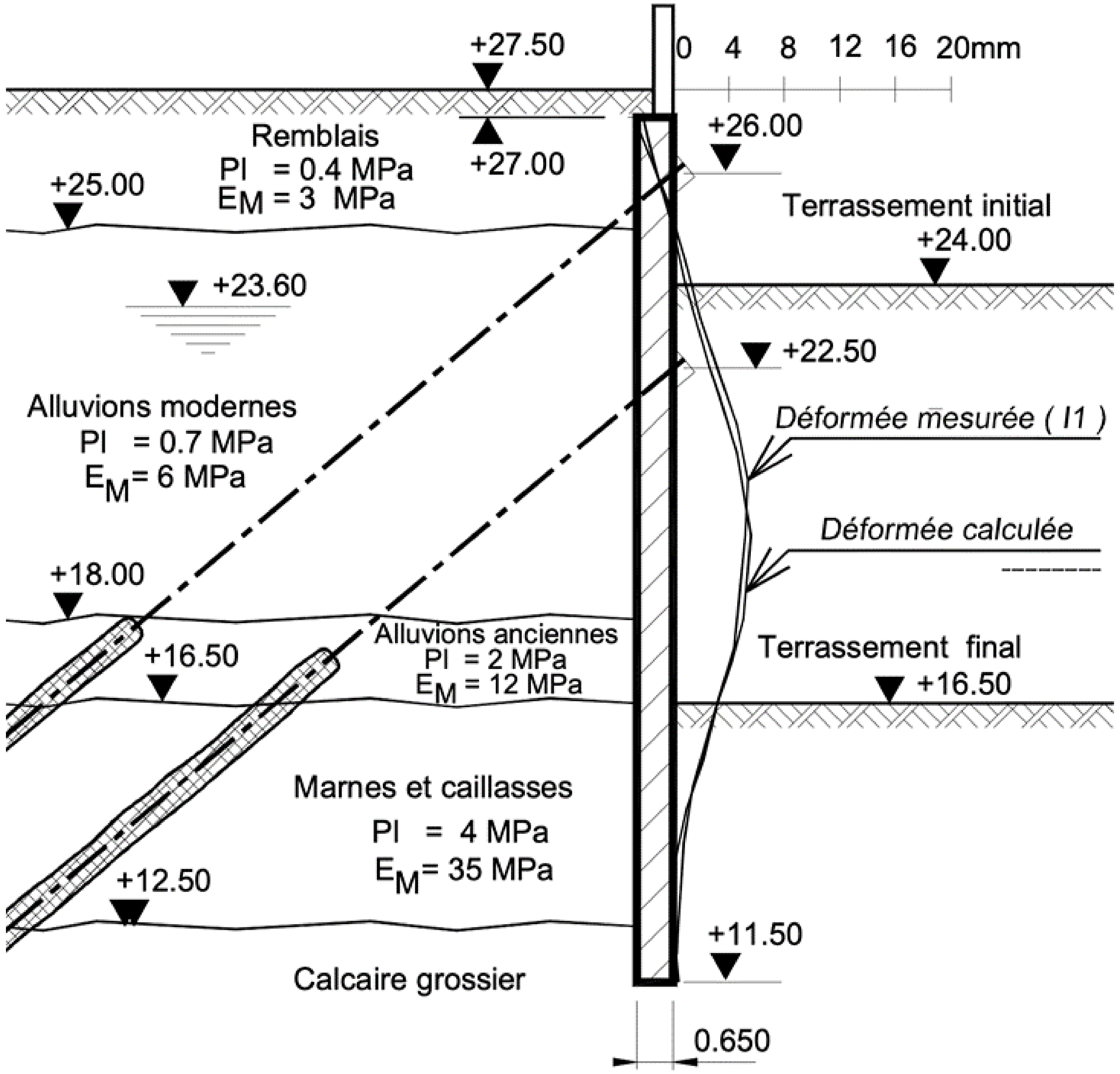


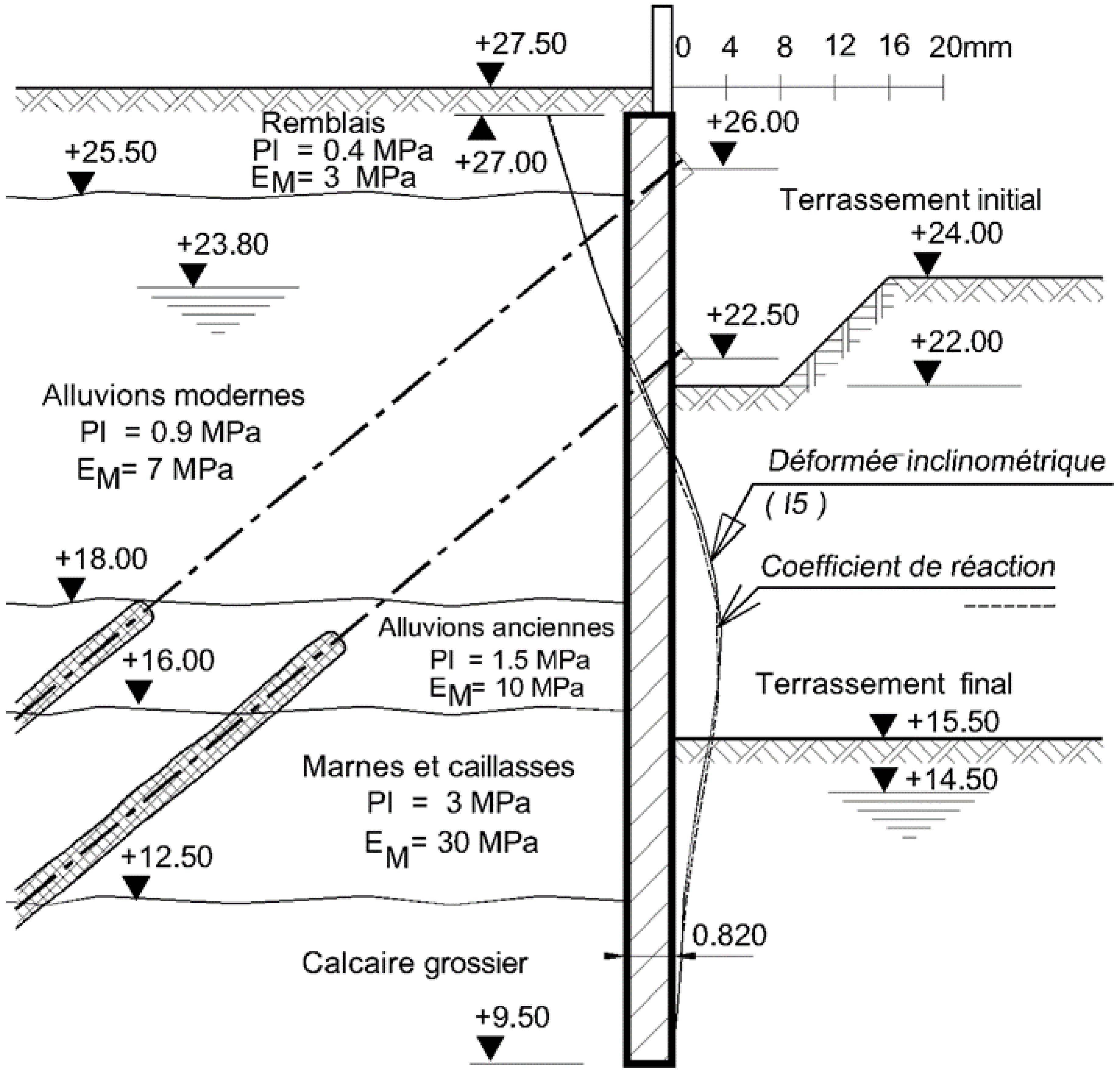
- **Synthesis of back-analysis:**
  $k \# 3.6 . (E_M/\alpha) / a$

- **Theoretical prediction:**
  $a \# 1.5 . l_0$ with $l_0 = (4 . EI / k)^{1/4}$

- **Finally: $a \# 1.7 . (EI / (E_M/\alpha)^{1/3}$**
  and:
  $k \# 2 . (E_M/\alpha)^{4/3} / (EI)^{1/3}$

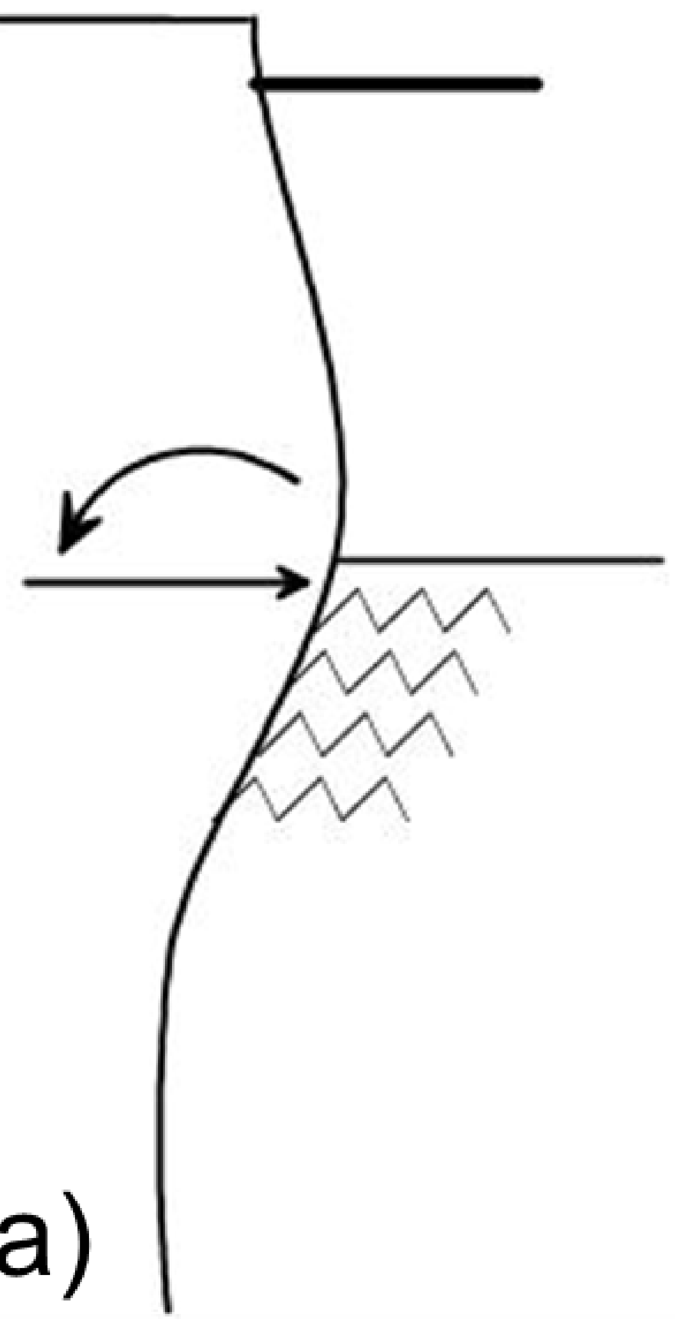
Subgrade reaction models





Subgrade reaction models

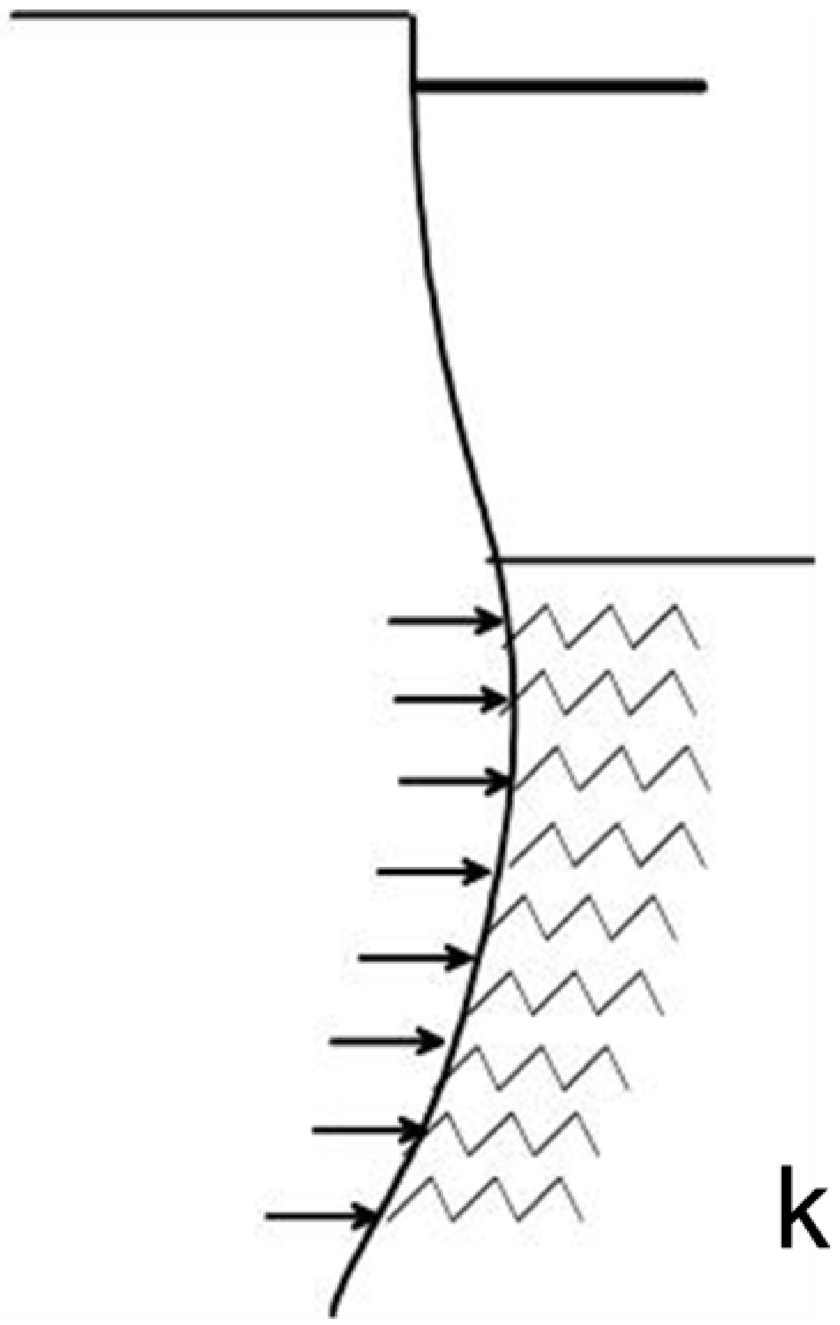
- **Limitations relative to deep water pressures**



$a = 1.5 \, . \, l_0$

$k = 3.6 \, . \, E_M/(\alpha.a)$

$\Rightarrow k \# 2 \, . \, (E_M/\alpha)^{4/3} \, / \, (EI)^{1/3}$



$a \gg 1.5 \, . \, l_0$

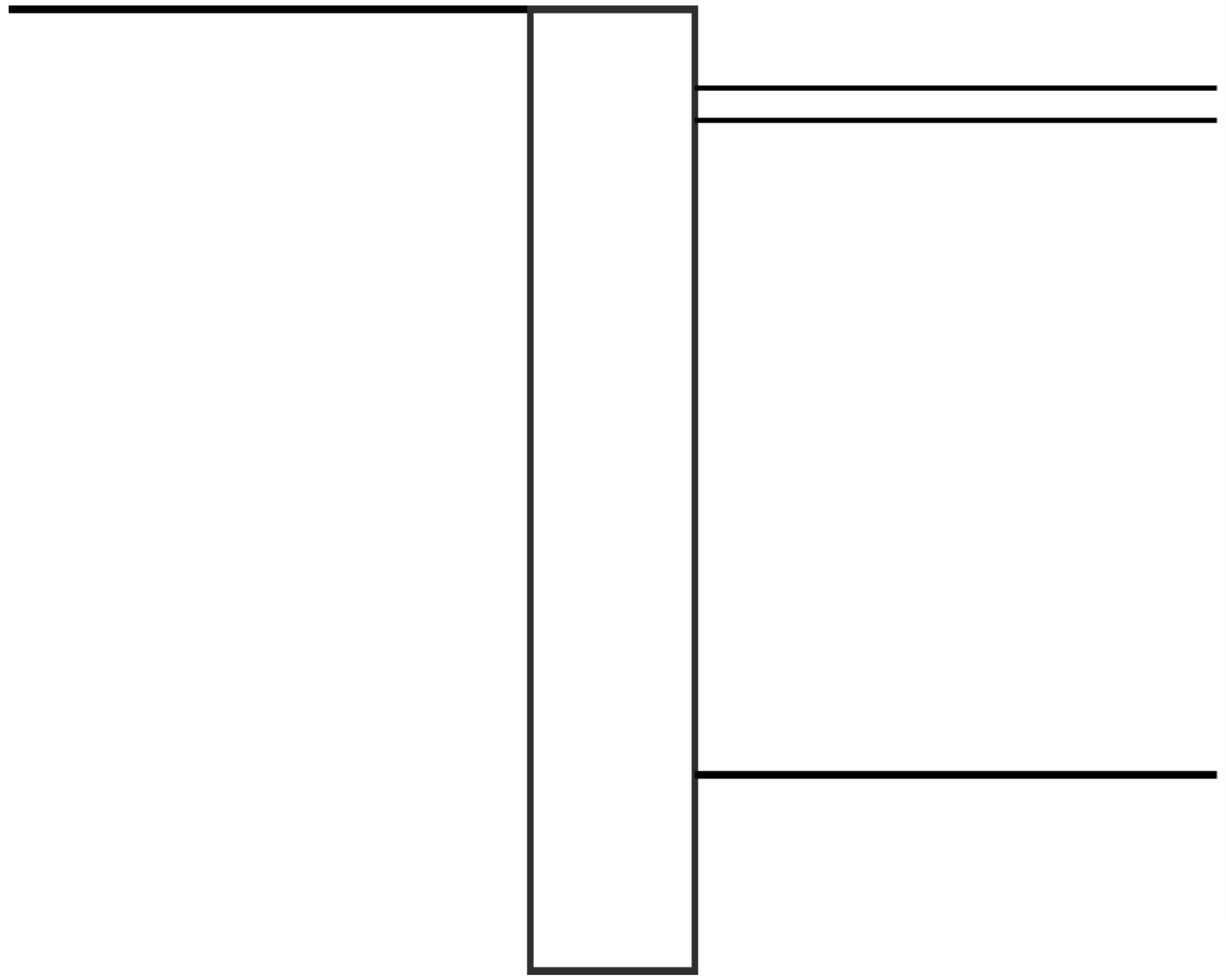
$k = 3.6 \, . \, E_M/(\alpha.a)$

$a = 2/3 \, . \, d$

$\Rightarrow k = 5.4 \, . \, E_M/(\alpha.d)$

Subgrade reaction models

- **Limitations relative to the geometry of the wall**



$d << 1.5 \, . \, l_0$

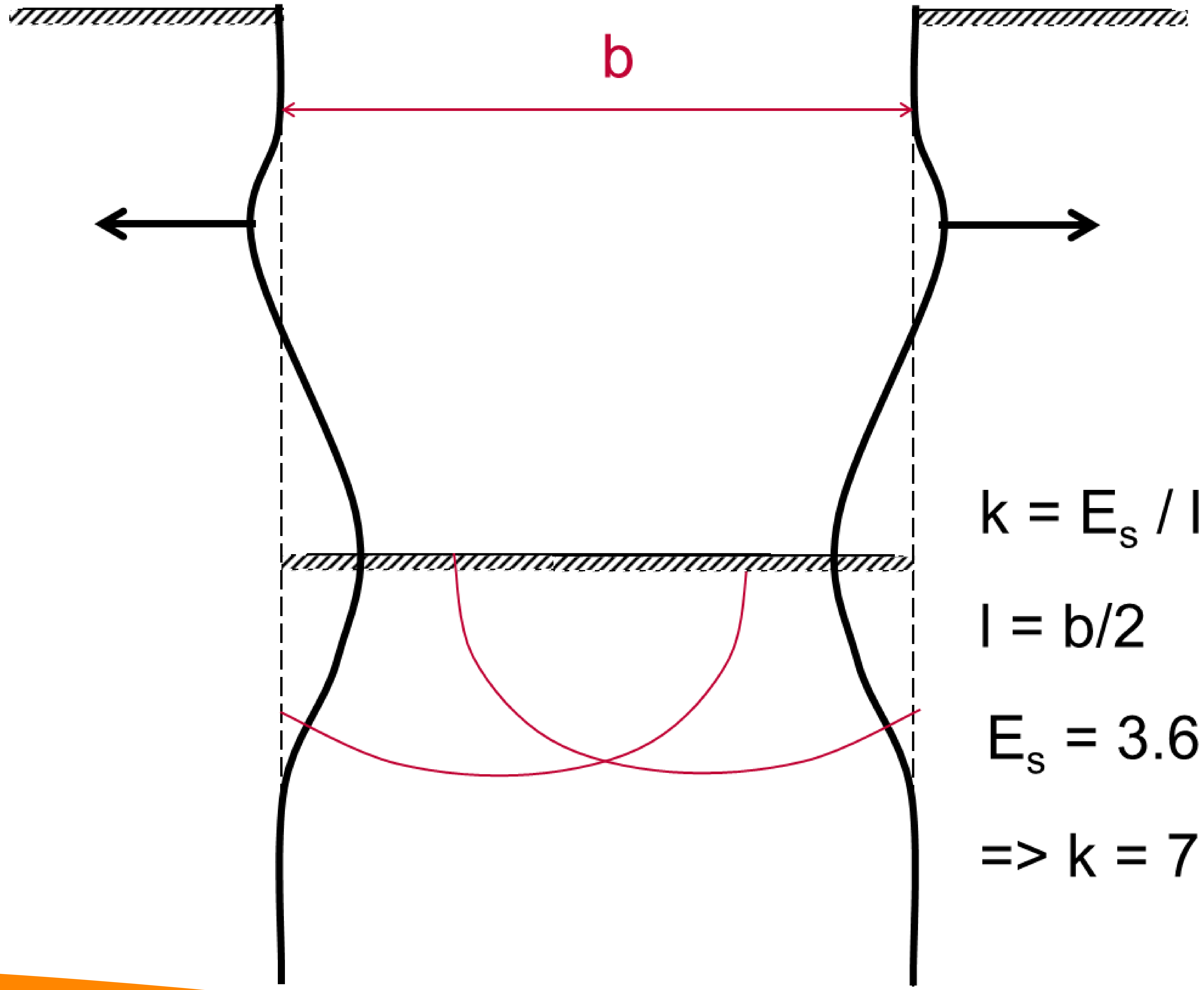
$k = 3.6 \, . \, E_M \, / \, (\alpha.a)$

$a = 2/3 \, . \, d$

$\Rightarrow k = 5.4 \, . \, E_M/(\alpha.a)$

Subgrade reaction models

- Limitations relative to the geometry of the excavation



$k = E_s / l$

$l = b/2$

$E_s = 3.6.\ E_M/\alpha$

$\Rightarrow k = 7.2\ .\ E_M/(\alpha.b)$

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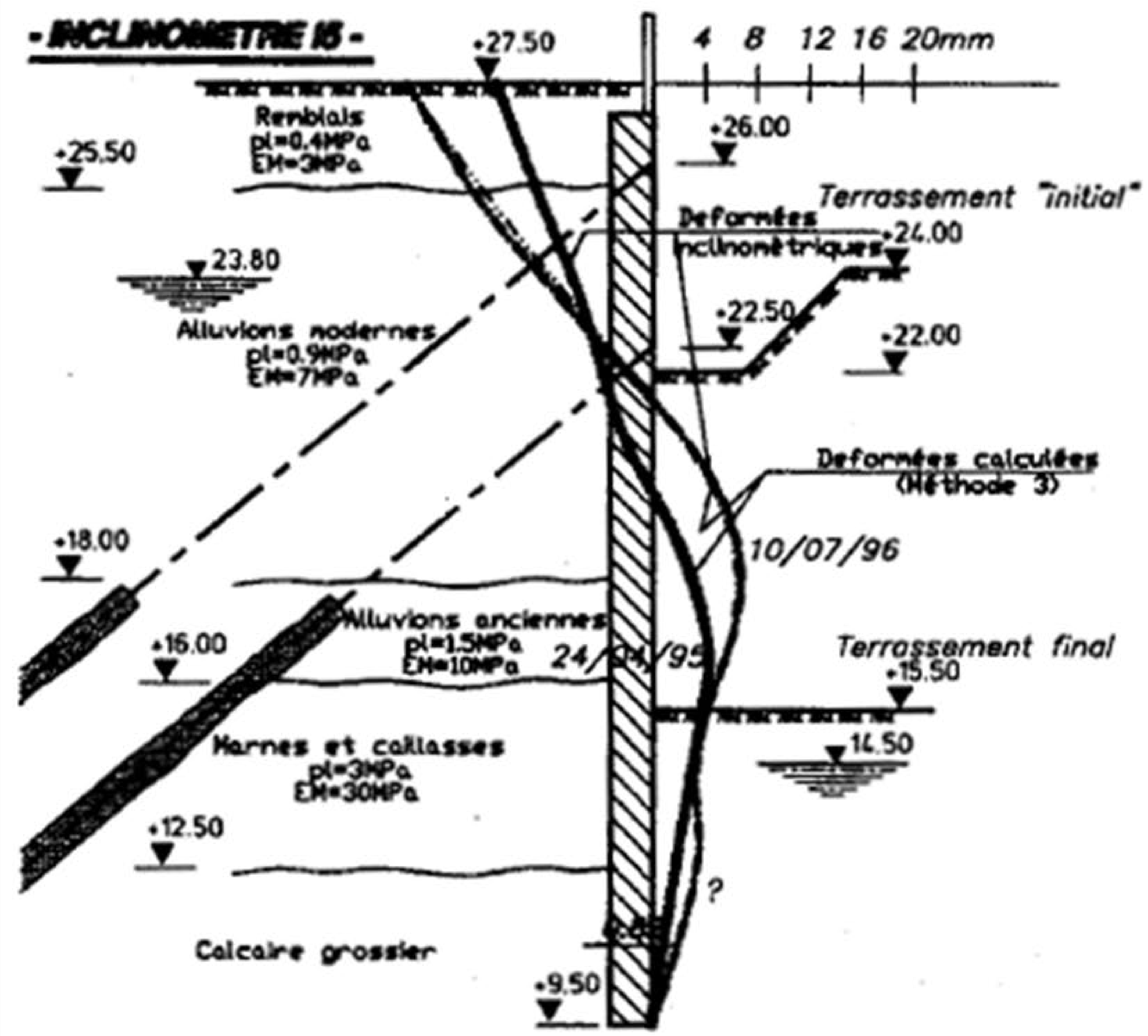
Subgrade reaction models

- **Limitations relative to project duration**

k x ½ between 1995 and 1996



Finite element models

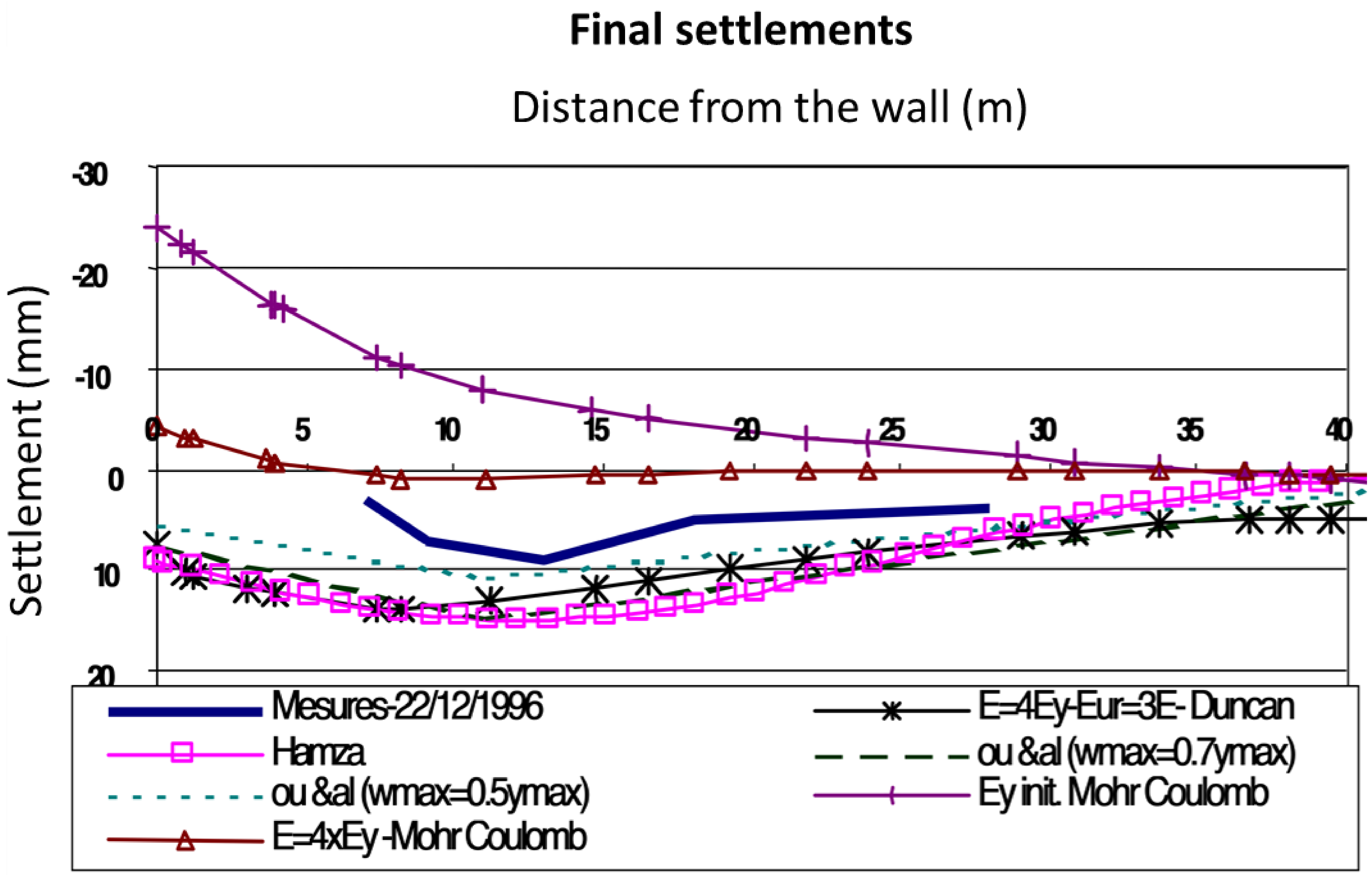
- **General limitations**

    -Same as MFA

    -Anisotropy

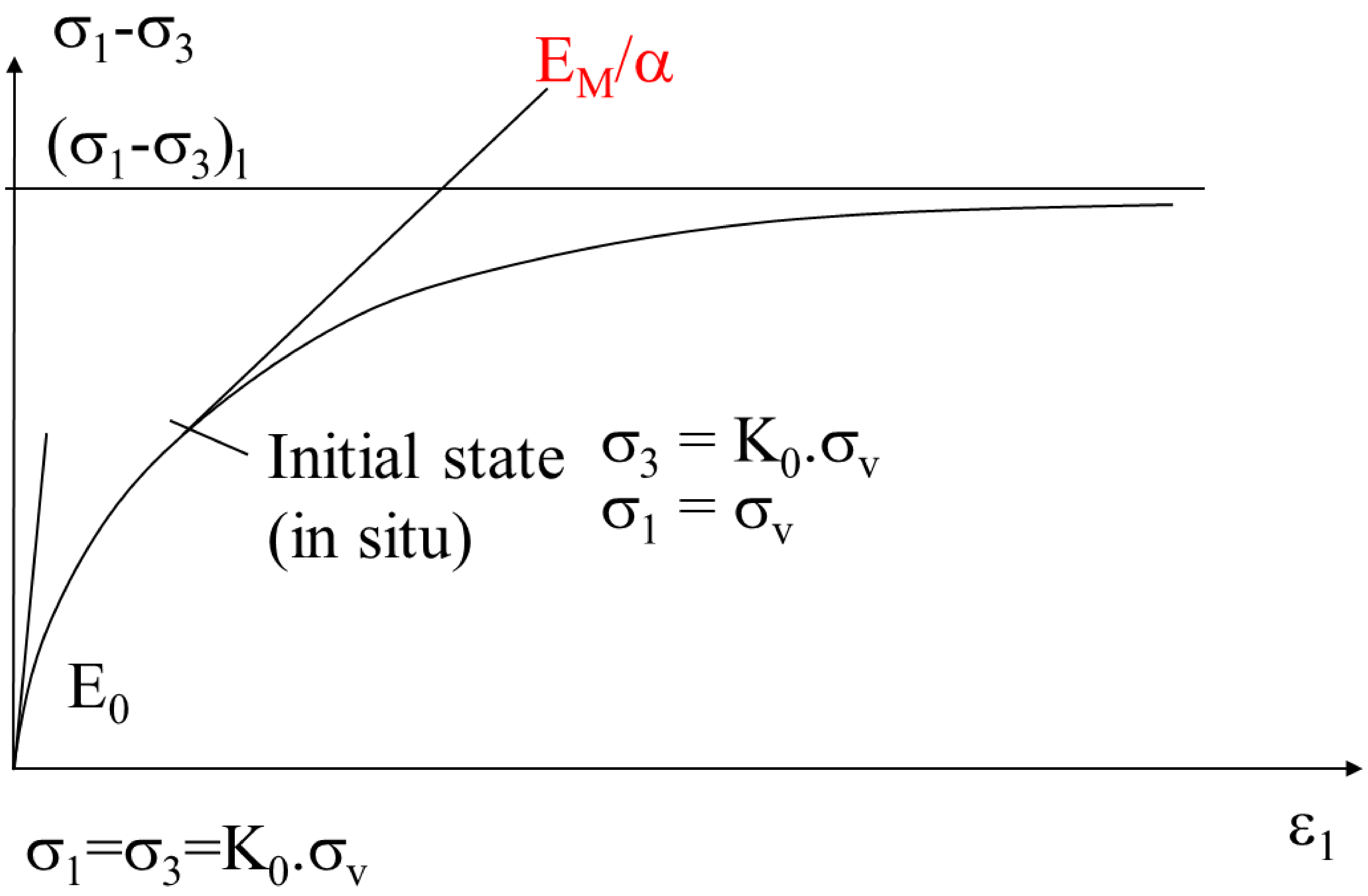
- **Limitations specific to linear models**

Linear models



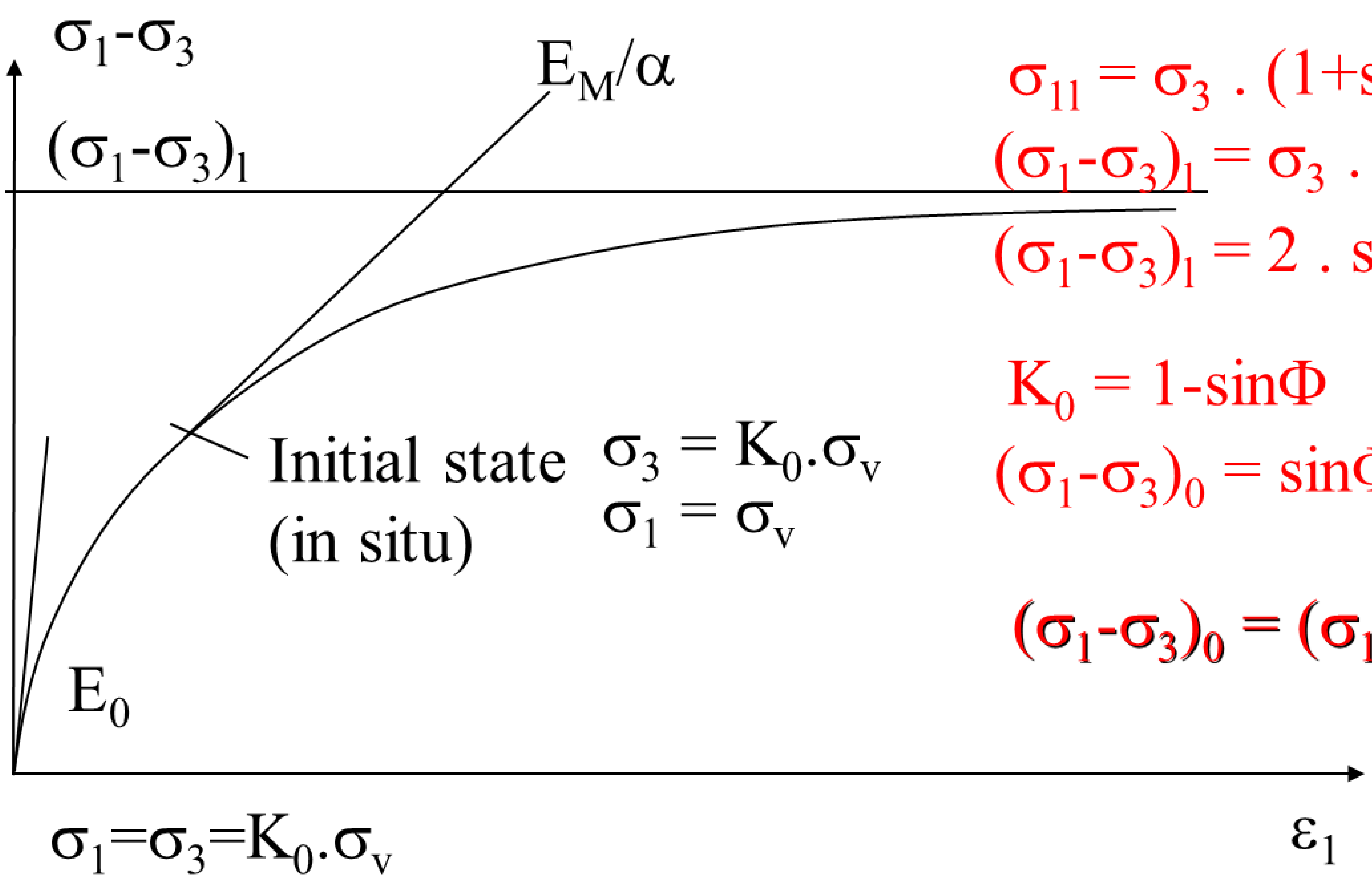
Linear models

- « Equivalent » modulus ?



Linear models

- « Equivalent » modulus ?



Normally consolidated soil :

$\sigma_{1l} = \sigma_3 \,.\, (1+\sin\Phi) / (1-\sin\Phi)$

$(\sigma_1-\sigma_3)_l = \sigma_3 \,.\, 2 \,.\, \sin\Phi / (1-\sin\Phi)$

$(\sigma_1-\sigma_3)_l = 2 \,.\, \sin\Phi \,.\, \sigma_v$

$K_0 = 1-\sin\Phi$

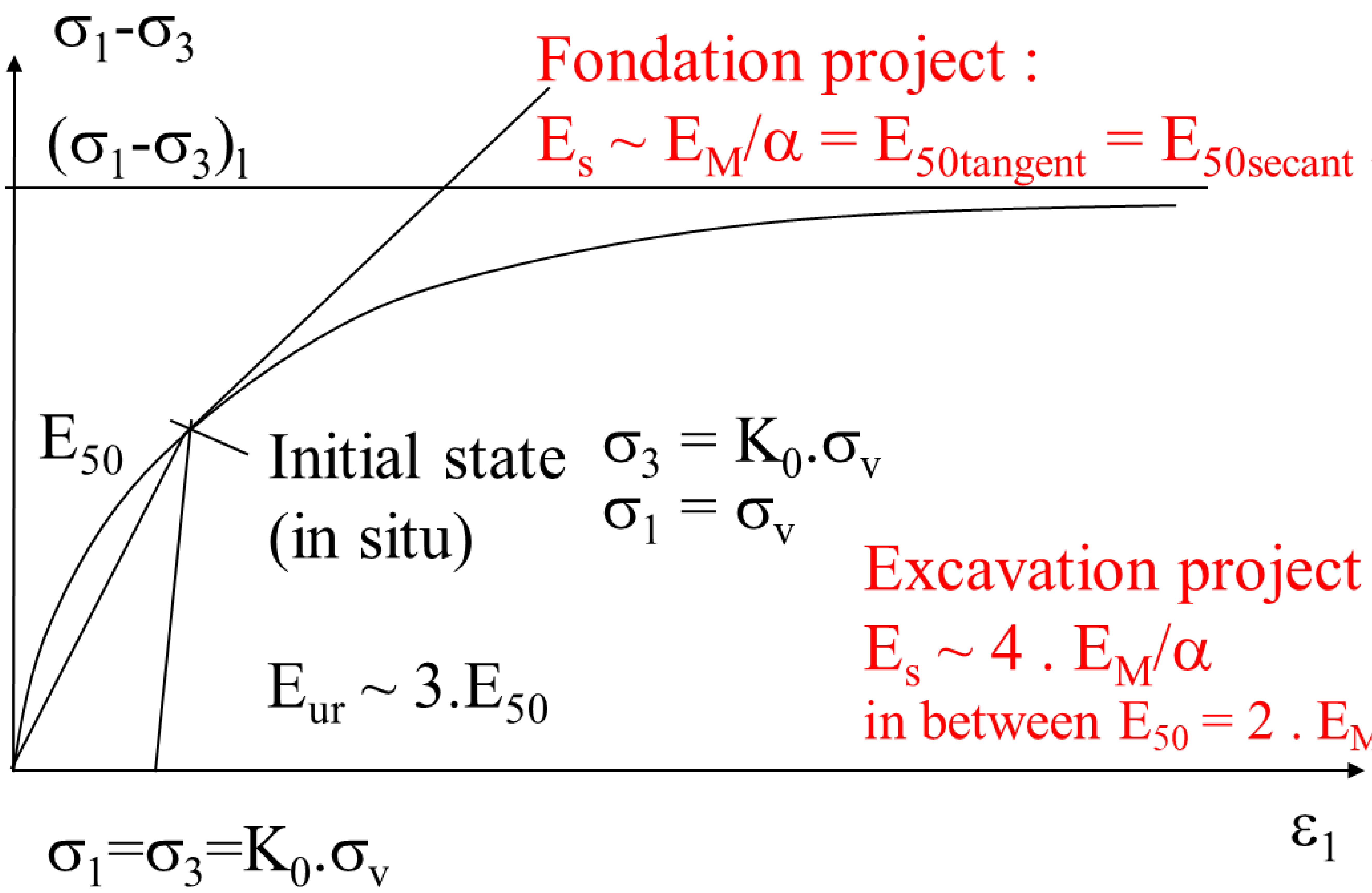
$(\sigma_1-\sigma_3)_0 = \sin\Phi \,.\, \sigma_v$

$(\sigma_1-\sigma_3)_0 = (\sigma_1-\sigma_3)_l / 2$

Linear models

- « Equivalent » modulus ?

Normally consolidated soil :



Fondation project :

$E_s \sim E_M/\alpha = E_{50tangent} = E_{50secant} / 2$

Excavation project :

$E_s \sim 4 \,.\, E_M/\alpha$

in between $E_{50} = 2 \,.\, E_M/\alpha$ and $E_{ur} = 6.\, E_M/\alpha$

Conclusions

- Traditional and numerical models are consistent with each other.
- Both MFA and RFA design approaches are relevant.
- Geotechnical monitoring remains necessary to improve our knowledge of validity ranges of calculation models.
- Standardization works are an efficient way to progress, maybe not towards a universal geotechnical practice, but rather towards a universal understanding of geotechnical practices.