„Red Earth is a problem soil.“
(rule of thumb of geotechnical engineers)

„A problem exists when an individual becomes aware of a significant difference between what actually is and what is desired.“

What is the desire of a geotechnical engineer?

The knowledge of the properties and engineering parameters of concerned soils!

FICHTNER

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LONG TERM BEHAVIOUR OF DAMS
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Graz University of Technology

Topic

Lateritic Soils for Dam Foundations and Dam Cores -Two Case Studies and Their Typical Properties

Session A2

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Occurrence & Genesis

Definition, Classification and Identification of Lateritic Soils

- Lateritic Soils are more precisely Ferralsols (FR), also called Ferrallitc Soils, Ferralites, Red Earth, Tropical Red Clays or Latossolo, Latosol and Kaolisols
- A uniform soil and rock classification system for tropical soils does not exist
- Existing classification systems are established for transported or remolded soils
- Color is reddish to yellowish
- Clay layer on top dependent on the stage of genesis
- No distinctive stratification
- Laboratory tests may be misleading due to in-situ structure of lateritic soils
- Existing correlations or empirical relationships may not be valid for in-situ lateritic soils

Occurrence & Genesis

Definition, Classification and Identification of Lateritic Soils

Consequences

- *"It is unfortunate that the terms "lateritic clays" and even "laterite" are still used by some engineers to describe any reddish tropical soils"* (Northmore et al., 1992)

- Fortunately for engineering purposes it does not matter whether the classification is correct, but that the geological and engineering properties as predicted or derived from testing are reliable.

Engineering recommendation

- Excavation of residual soils within foundations is preferable

- Application as dam core material (or foundation if required)

Occurrence & Genesis

Typical Lateritic Weathering Profile

Classes [A]	Weathering Profile [A]	Description [A]	Fichtner (Uganda) – Classification [C]		Classes [B]
			Description (Rock: Amphibolite)	Project Classes	
Top soil		Influenced also by bioturbation and climate (changes).			
VI Residual Soil	discoloured rock	All rock material converted to soilstructure and fabric destroyed	Reddish Brown Clay variable lateritization stage, typical depth 0-4m	WVI	IA
V Compl. Weathered	decomposed rock	All rock material decomposed and/or disintegrated to soil. Original mass structure still largely intact	Pale pink clay/silt, ferruginous, relic minerals and structures, typical depth 4-20m	WV	IB
			Pale greenish yellow silt/clay with fine sand, relic miner. and struct., typical depth 20-30m		IC
IV Highly weathered		>50% rock material decomposed and/or disintegrated. Fresh/discolored rock present as discontinuous framework or corestones	Brownish grey, coarse grained, weak strength	WIV/III	II A
III Moderat. Weathered		<50% rock material decomposed and/or disintegrated to soil. Fresh/discolored rock present, discontinuous framework or corestones	Grey, coarse grained, moderately strong/strong		
II Slightly weathered		Discoloration due to weathering of rock and discontinuity may weaker than fresh rock.	Dark grey, coarse grained, very strong, joint surfaces iron stained	WI/II	IIB
IB Faintly weath.	Fresh rock	Discoloration on major discontinuity surfaces	Dark grey, coarse grained, very strong, joint surfaces fresh.		III
IA Fresh		No visible spot of rock material weathering			

Residual Clay

Saprolites

Fresh rocks

Notes:

[A] Classification proposed by the Geological Society of London (Fookes, 1997)

[B] Typical Weathering grades for Igneous and Metamorphic Rocks (Deere & Patton, 1971)

[C] Highly weathered and moderately weathered are treated equally in terms of engineering properties; this was also done for WI/II.

Occurrence & Genesis

Case Studies

HEPP Laos

Feasibility Study
120MW
140m Dam
(RCC or Rockfill)
Parent Rock: Andesite
Extensive Field / Laboratory Investigations in 2008

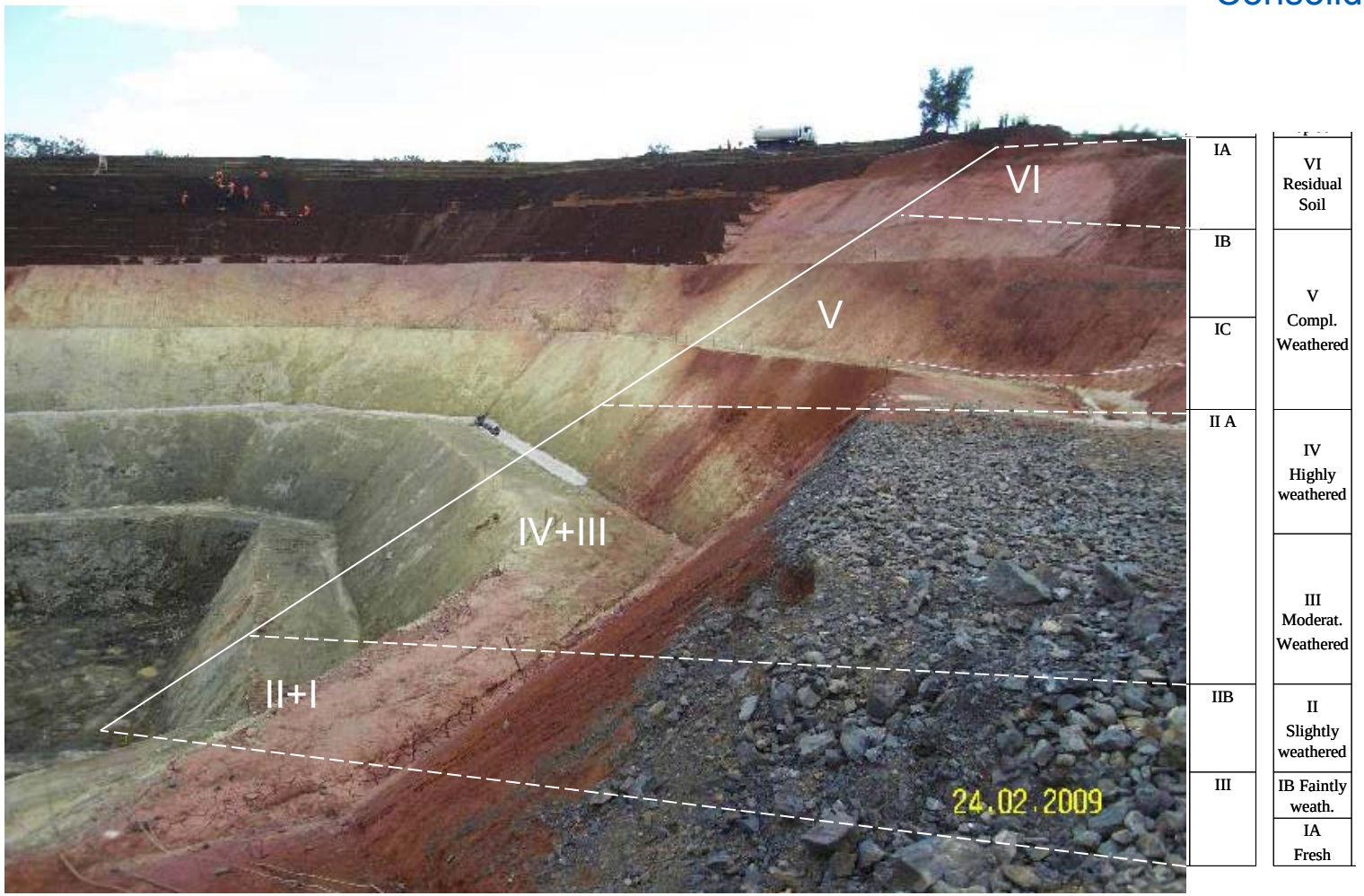
HEPP Uganda

Contractor's Engineer
250MW
35m high Dams under construction
(Concrete & Rockfill)
Parent Rock: Amphibolite
Limited Field / Laboratory Investigations since 1990

Occurrence & Genesis

Typical Lateritic Weathering Profile - Uganda

Occurrence & Genesis
Properties & Eng. Parameters
Consolidation



Properties & Engineering Parameters

Surface Erosion - Uganda

Damages at abutments

Properties & Engineering Parameters

Surface Erosion - Uganda

Difficulties regarding subsoil treatment → Combination of jet grouting, cutoff walls and conventional grouting

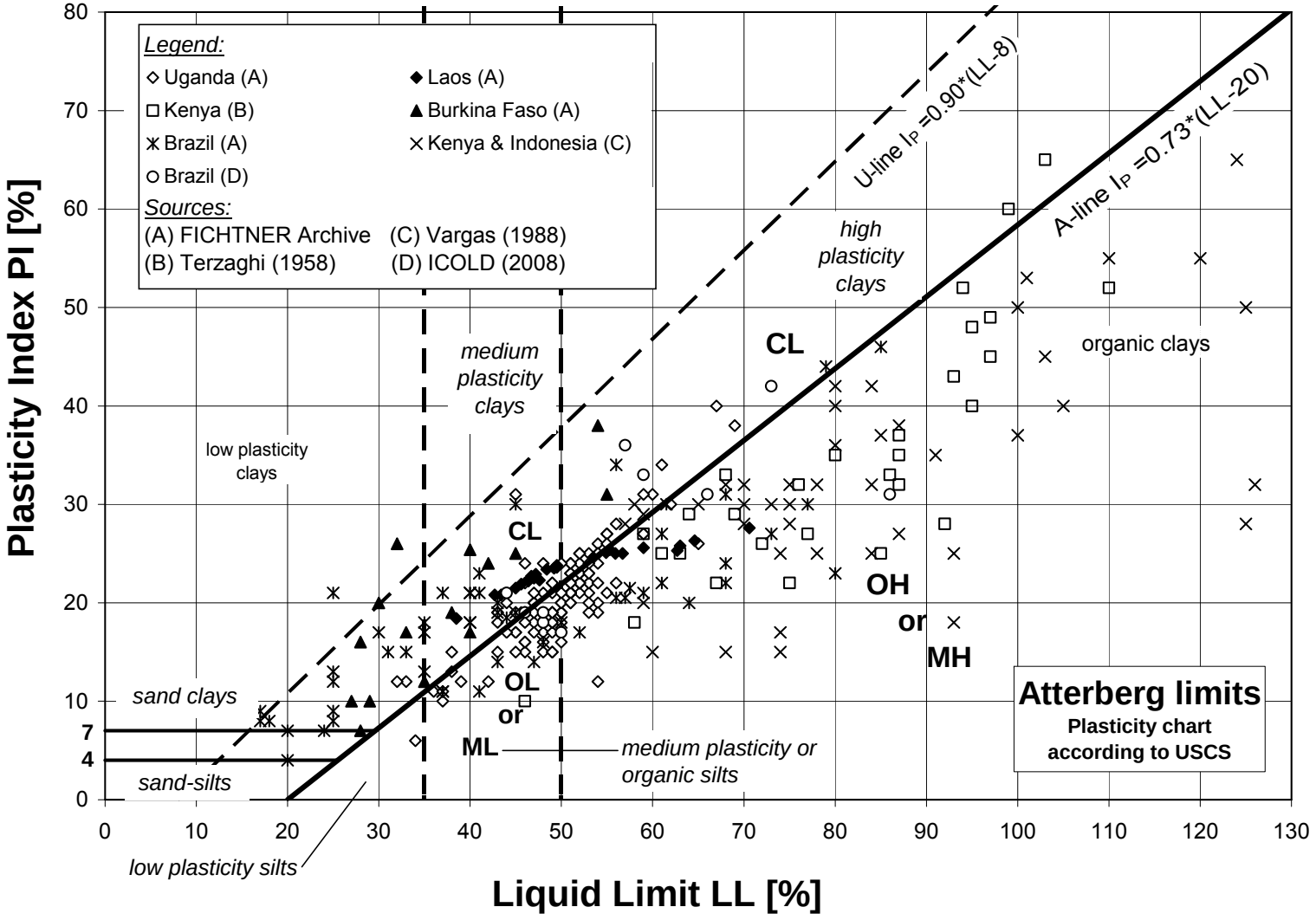
Properties & Engineering Parameters

Slope Failure – Uganda (Slickenside?)

Increasing excavation works → Cost and construction period increase

Properties & Engineering Parameters

Atterberg Limits



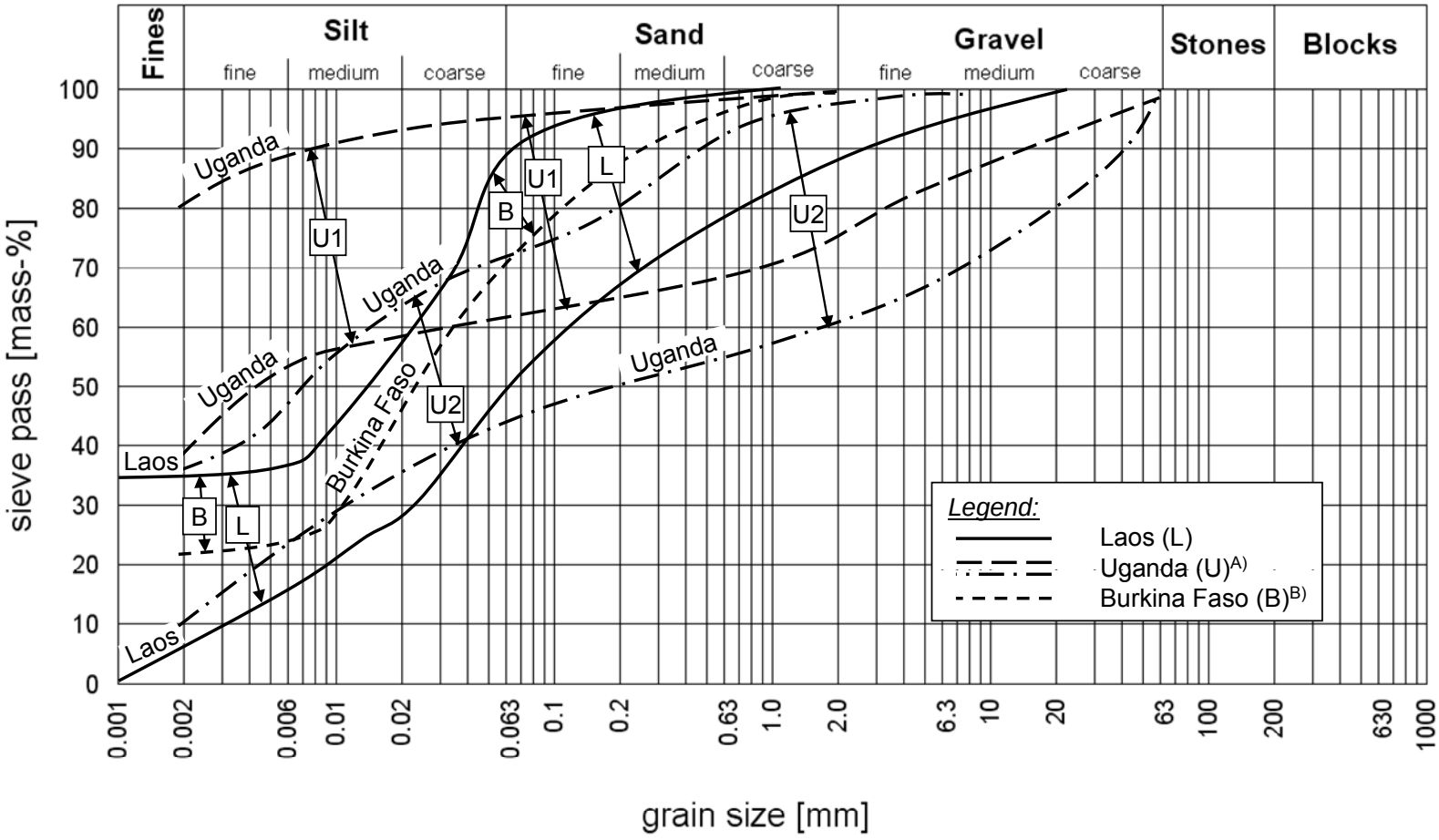
Properties & Engineering Parameters

Sieve Curves

Notes:

A) The lateritic soil of Uganda encountered to significant gradation ranges.

B) The upper limit of Burkina Faso Clay is also the upper limit of the Laos clay.



Properties & Engineering Parameters

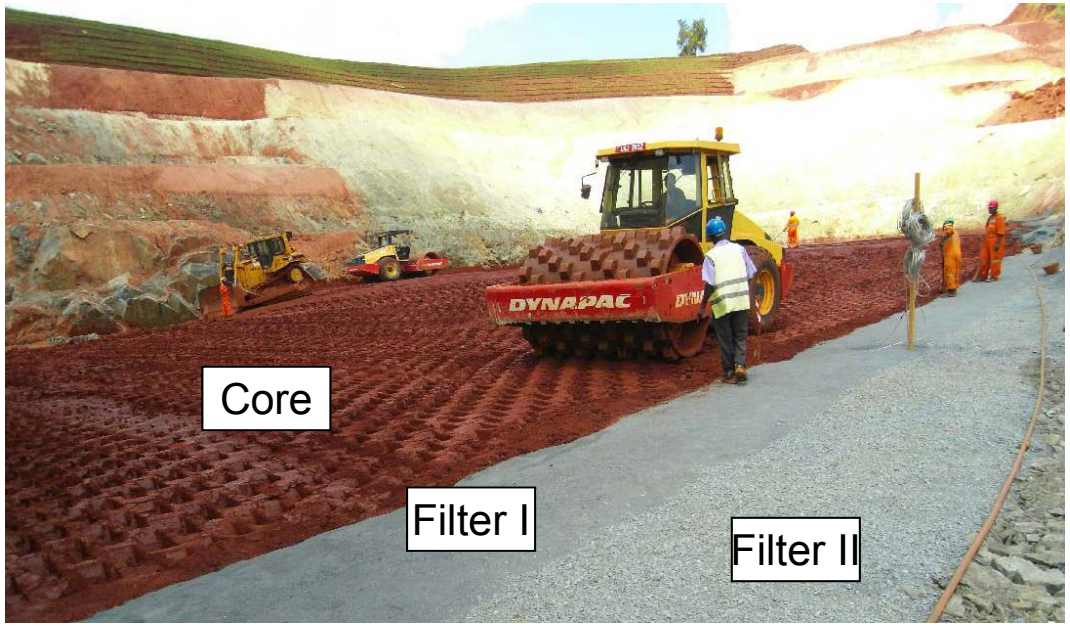
Selected Engineering Parameter

Parameter	Unit	General Range	Laos	Uganda
Permeability k_{Sat}	m/s	10^{-2}-10^{-11}	10^{-4}-10^{-7}	10^{-4}-10^{-9}
Permeability Lugeon	Lu	>2	4-30	2-30
Unit Weight γ	kN/m³	14-22	15-18	16-22
Porosity n	%	25-60	45-54	26-46
Liquid Limit LL	%	>25	38-50	32-69
Plasticity Index PI	%	5-65	20-26	6-40
Fines Content	%	10-100	50-90	13-98
OWC	%	10-35	20-32	14-32
Depth of Bed. Rock (WIII-IV)	[m]	~6-50	~50	~30

- High permeabilities in Saprolite ´zones (IC & IIA) → Water losses, Erosion
- Collapsibility
- Residual water content close to OWC

Properties & Engineering Parameters

Dam Core Material



DESCRIPTION	QUALITY REQUIREMENTS
Clay	Clay from the tested borrows area. Moisture content: ± 2 % OMC Liquid limit ≤ 90. Plasticity index ≤ 65. Organic content ≤ 3 %. Passing at 200 mesh: 40 ÷ 90 %.

Properties & Engineering Parameters

Shear Strength Parameter

Soil Characteristic	Cohesion [kN/m²]		Friction Angle [°]	
General Range				
Peak	c'	0-25	φ'	5-37
Uganda[C)]				
Peak	c'	15	φ'	25
Undrained	c_U	50[B)]	φ_U	0[A)]
Residual	c_R	0[A)]	φ_R	23
Laos				
Peak	c'	24	φ'	17
Undrained	c_U	30[B)]	φ_U	(18)[A)B)]

Notes:

A) Set to "Zero" due to safety aspects.

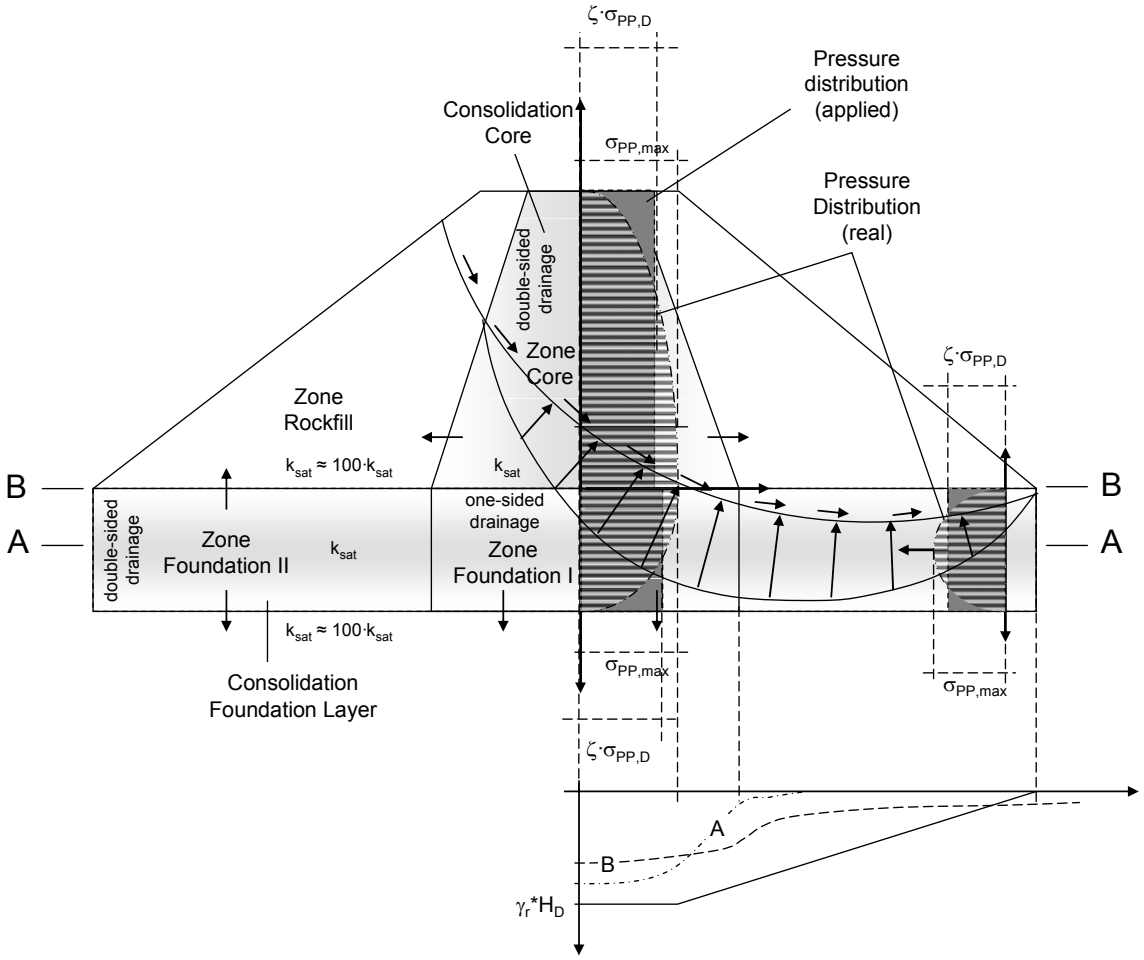
B) Applying full excess pore water pressures, the undrained cohesion c_u and the undrained friction angle $\varphi_u = 0°$ is one conservative method to evaluate the stability during consolidation phase.

C) Due to safety aspects the same shear strength parameters were applied both for the clay core and the residual soil, although higher values would have been justified for the clay core.

- Slickensides with phi' = 5-10° and c' = 0kN/m²
- Determination of c_U is difficult
- Residual values for earthquake load cases

Prediction of Consolidation Behavior

Slope Stability Model – Estimation of Excess PWP

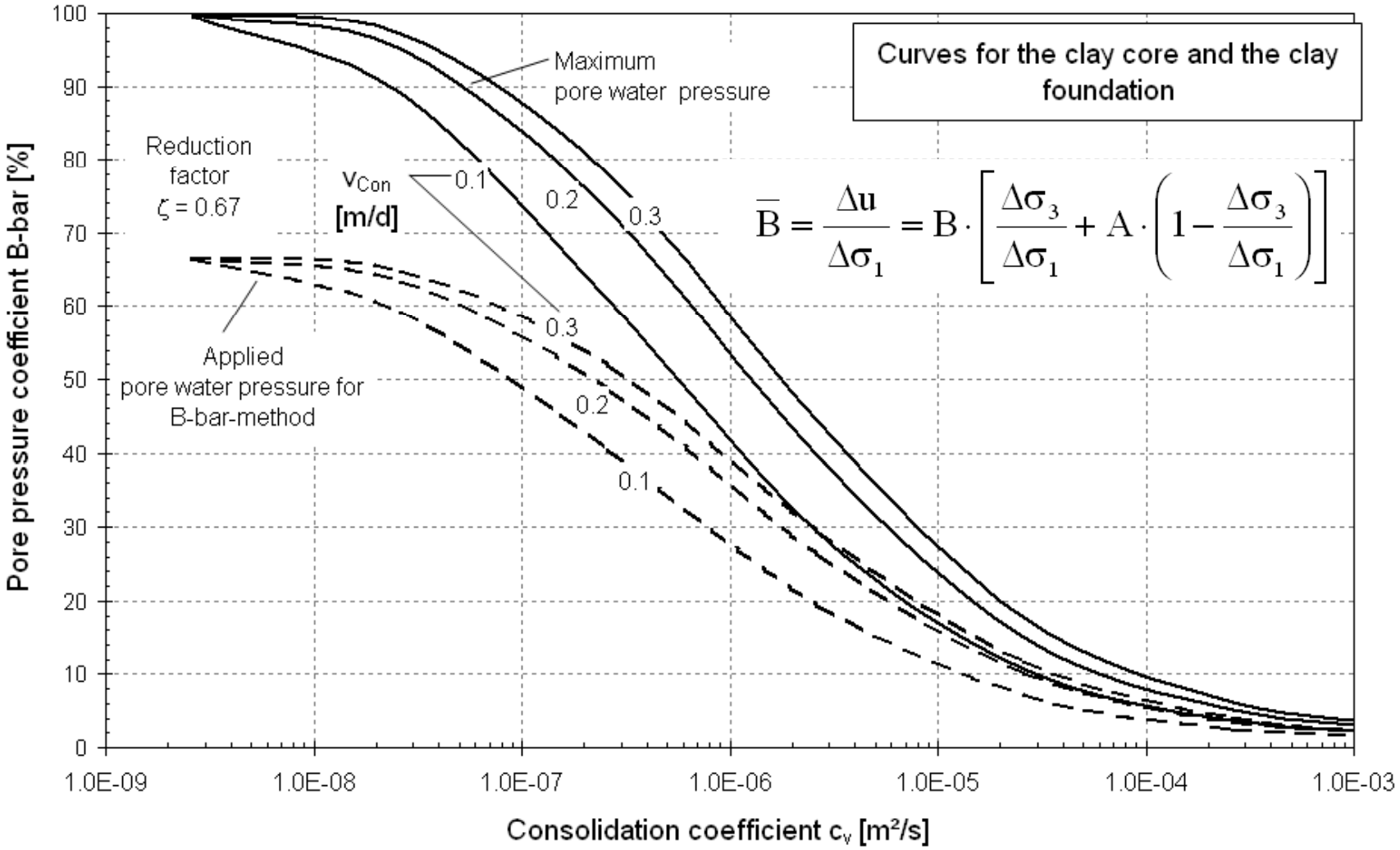


Input Parameters & Assumptions

- Consolidation coefficient c_V [m²/s]
- Rate of construction [m/d]
- Layer thickness and number
- PWP dissipation ~ consolidation
- Characteristic dissipation curve
- Height and thickness dam core and foundation

Prediction of Consolidation Behavior

Excess PWP Coefficients (B-Bar-Values)



Conclusion

- Lateritic soils have a wide range of engineering parameters and properties
- A comprehensive investigation program of field and laboratory testing is necessary
- Determination of shear strength parameters (!) in-situ vs. lab
- Determination of the consolidation behavior & excess PWP
- Aspects and requirement of dealing with lateritic soils should not be underestimated
- But, an early awareness may help to avoid mistakes and misinterpretation and may lead to a correct and cautious handling of the Red Earth.

Red Earth is a „problem soil“.
But, the knowledge of its properties and parameters will avoid problems.