

Second International Symposium on Rockfill Dams

October 27 to 28, 2011

Windsor Barra da Tijuca Hotel - Rio de Janeiro - Brazil



XXVIII SNGB

National Seminar on Large Dams

October 25 to 28, 2011

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EVALUATION OF ROCKFILL PROPERTIES BASED ON INDEX TESTS

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Lisbon

STRUCTURAL BEHAVIOUR OF ROCKFILL DAMS

- STATE OF STRESS
- STATE OF COMPACTNESS
- **STRENGTH OF ROCK FRAGMENTS**
- GRAIN SIZE CURVE

MECHANICAL PROPERTIES OF ROCKFILLS CONTINUOUS MODEL

MATERIAL

LARGE EQUIPMENT



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INDEX-PROPERTIES

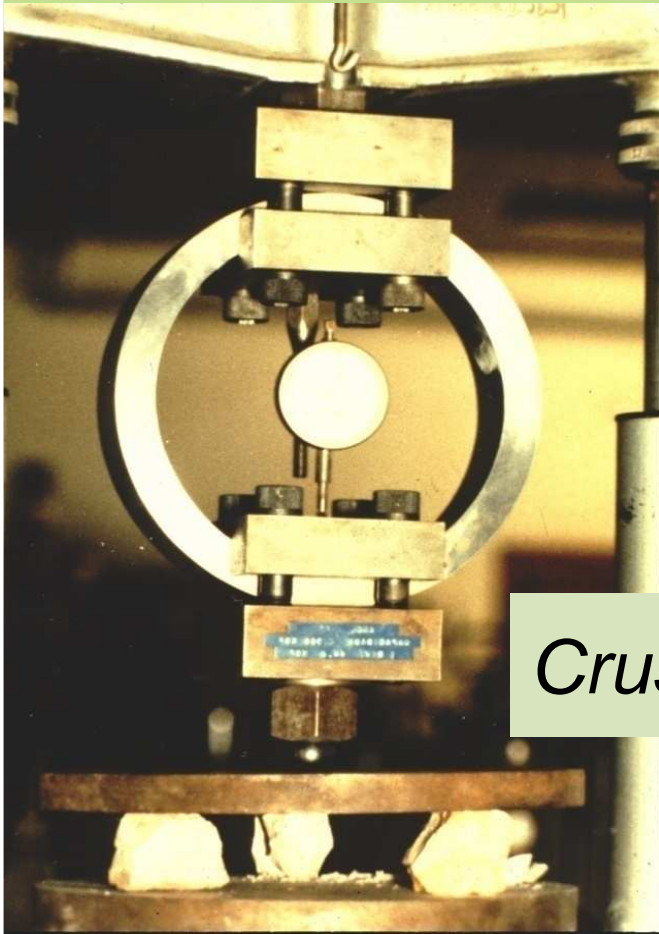
DISCRETE MODEL

- > **The strength of rockfill blocks to crushing** is one of the main factors that influence stress-strain behaviour of this particulate medium.
- > The physical-mechanical characteristics of rockfill fragments are usually designated as index-properties.
- > **Those properties**, which are determined in tests in a rather expedite and inexpensive way, have made it possible **to estimate the mechanical characteristics of rockfill materials**.

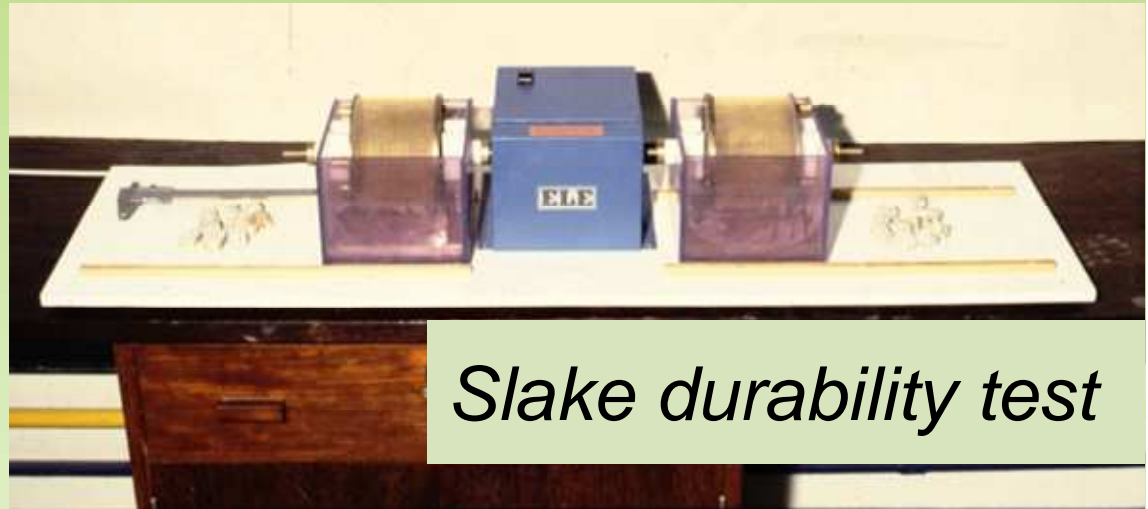
INDEX-PROPERTY TESTS

CHARACTERISATION OF	PARAMETER	SYMBOL
Texture	Porosity	n
	Bulk density	γ_{dg}
Compression strength	Uniaxial compressive strength	σ_c
	Point load test	PLS
	Crushing strength	P_a50
Durability	Los Angeles	LA
	Slake durability test	Id_2
Water sensitivity	Swelling strain	-
	Non-soluble residue	-

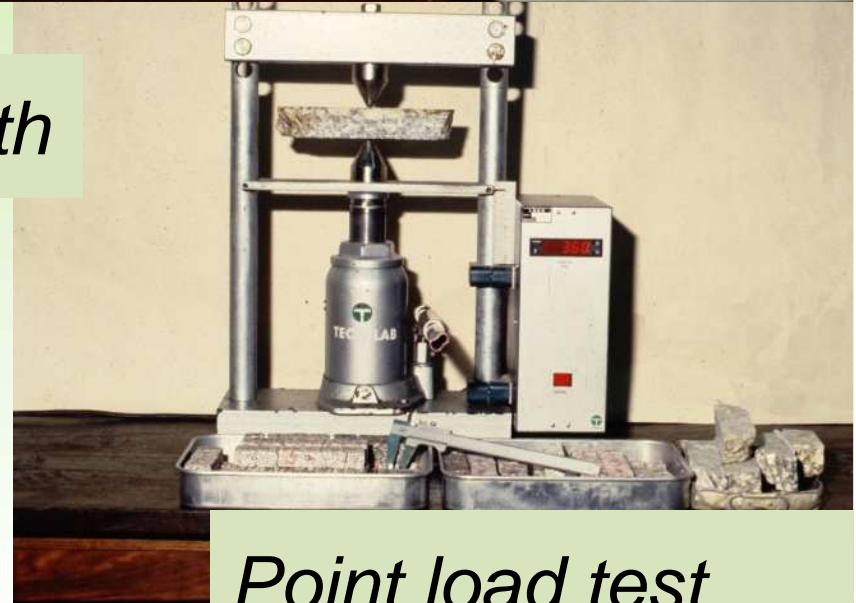
INDEX-PROPERTY EQUIPMENT TESTS



Crushing strength



Slake durability test



Point load test

CHARACTERISATION OF ROCKFILL MATERIALS

Rockfill embankments

- Dams, roadways, embankments to extend airports.

> Type of rock

- Granite (North of Portugal).
- Limestone (Centre and Algarve).
- Schist-greywacke (South).
- Basalts in Azores and Madeira Islands.

> Influence of lithology of rock fragments on mechanical properties of rockfills

INDEX-PROPERTIES OF CARBONATE ROCKS

PARAMETER		CLASS 1	CLASS 2	CLASS 3
n	(%)	1-3	3-8	8-20
γ_{dg}	(kN/m ³)	26.4-27.6	25.2-26.4	22.0-25.2
σ_c	(MPa)	90-180	60-90	20-60
PLS	(MPa)	6.2-8.2	5.0-6.2	3.0-5.0
P _a 50	(kN)	12-15	8-12	5-8
LA	(%)	24-31	31-34	34-42
Id ₂	(%)	0.2-0.7	0.7-1.5	1.5-4.0
Swelling strain	($\Delta l/l \cdot 10^{-4}$)	0-1.2	1.2-5.0	5-50
Non-soluble residue	(%)	0-3	3-6	6-40

INDEX-PROPERTIES OF GREYWACKE ROCKS

PARAMETER		CLASS 1	CLASS 2	CLASS 3
n	(%)	1-3	3-5	5-12
γ_{dg}	(kN/m ³)	26.5-27.5	25.5-26.5	24.0-25.5
σ_c	(MPa)	150-220	100-150	50-100
PLS	(MPa)	8-11	6-8	2-6
P _{a50}	(kN)	14-18	8-14	4-8
LA	(%)	15-25	25-35	35-45
Id ₂	(%)	0.3-0.7	0.7-1.2	1.2-3.0
Swelling strain	($\Delta l/l \cdot 10^{-4}$)	2-6	6-10	10-15

INDEX-PROPERTIES OF GRANITIC ROCKS

PARAMETER		CLASS 1	CLASS 2	CLASS 3
n	(%)	0.5-2.0	2.0-4.0	4.0-8.0
γ_{dg}	(kN/m ³)	25.8-27.0	25.0-25.8	23.0-25.0
σ_c	(MPa)	80-120	40-70	15-40
PLS	(MPa)	5.0-7.0	3.0-5.0	1.5-3.0
P_{a50}	(kN)	10-18	7-10	3-7
LA	(%)	12-20	20-30	30-40
Id_2	(%)	0.3-0.7	0.7-1.4	1.4-1.8
Swelling strain	($\Delta l/l \cdot 10^{-4}$)	0.5-1.5	1.5-3.0	3-10

INDEX-PROPERTY ANALYSIS

- > Reduced number of basalt samples were tested; this type of material was the one exhibiting the best mechanical characteristics of rockfill materials.
- > The same class number of each different lithologic type roughly present identical structural behaviour in rockfills.
- > Those limits should therefore be taken into account in the analysis of results of new tested materials of the same type of rock.

COLLAPSE IN ROCKFILLS

Collapse in rockfills occurs when there are volumetric deformations by compression, due to the decrease in the strength of rock fragments in contact with water; collapse is related with the crushing of particles.

Limit relation of the potential collapse

		CARBONATE ROCKS	GREYWACKE ROCKS	GRANITIC ROCKS
$\sigma_c \text{ sat}/\sigma_c \text{ dry}$	(%)	70	70	-
PLS sat/PLS dry	(%)	90	80	90
Pa50 sat/Pa50 dry	(%)	90	90	90
Id ₂ dry/ Id ₂ sat	(%)	50	50	70

A rock sample is water sensitive when the values of the relations of index-properties in tested fragments, both in saturated and in dry states, are less than those indicated in this table.

General Reporter

How do the stress strength index tests affect the mechanical properties of the rockfills?

$$\bar{P} = k D^2$$

$$\bar{P}_a = \eta D^\lambda$$

$$\lambda = 1.5$$

$f(P, P_a)$

Crushing Strength

\bar{P} D_1 \bar{P}_a

\bar{P} D_2 \bar{P}_a

$$D_2 > D_1$$

Contact Force

Grain Breakage (B_g)

Higher Crushing

$$\phi' < e < E_{oed}$$

General Reporter

How can the index properties be used to help in the decisions of compaction procedures?

XINGÓ DAM

1989

Granites

Sluicing



Madeira Airport

1995

Density and grain size tests



Index tests

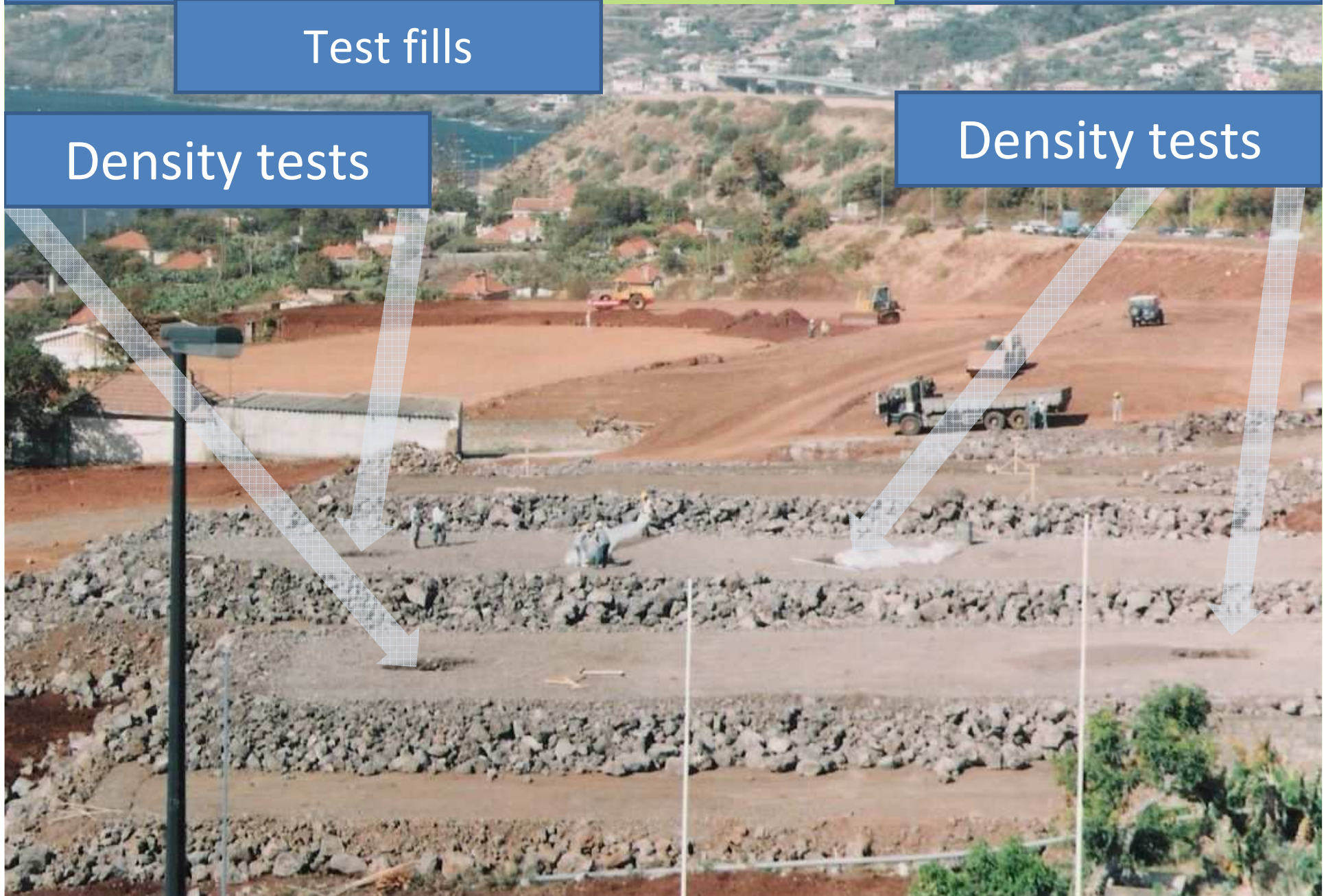
Madeira Airport

Basalts

Test fills

Density tests

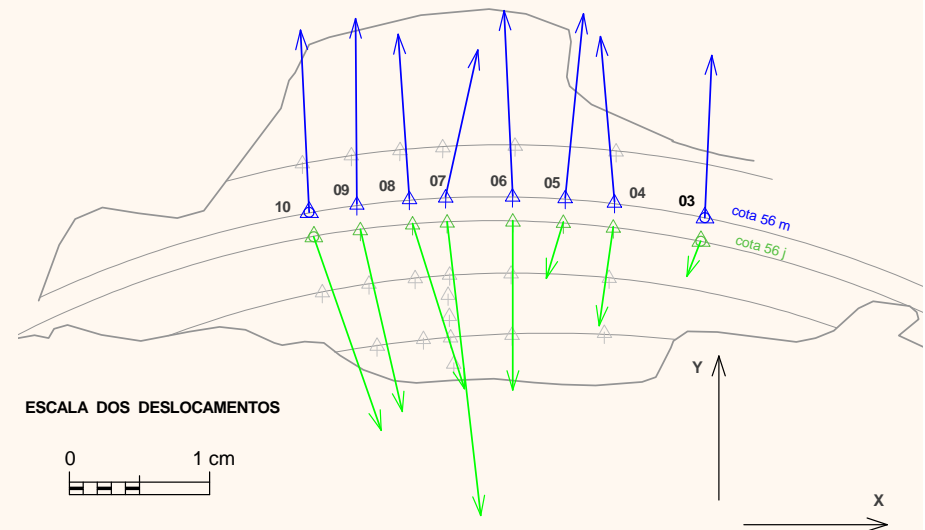
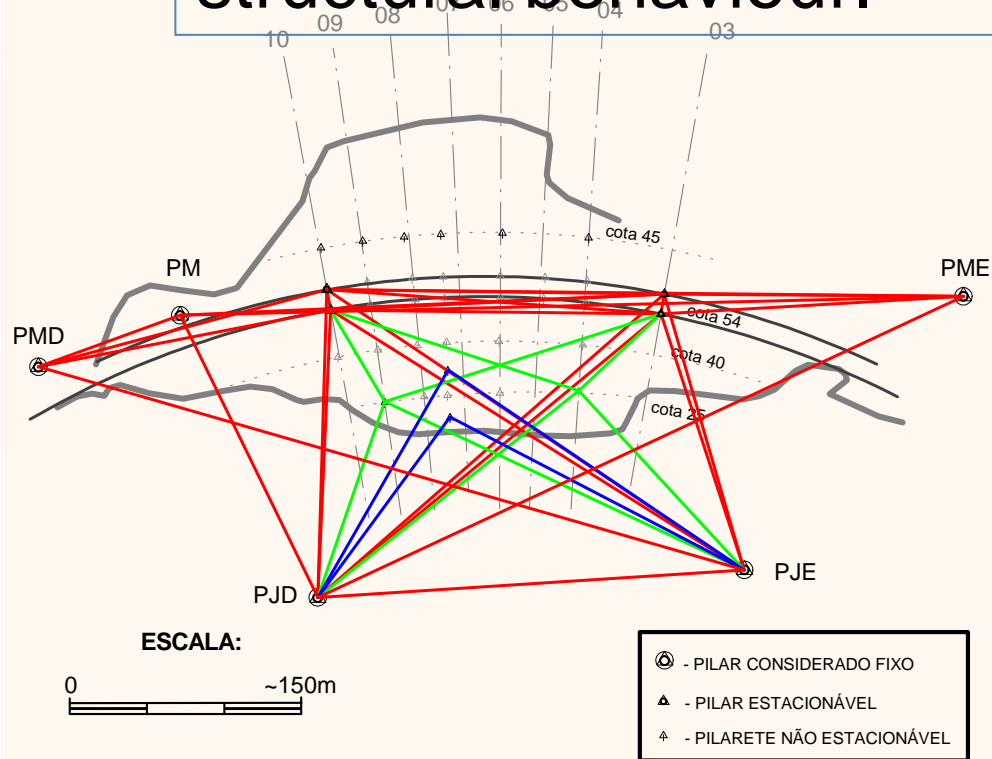
Density tests



General Reporter

The authors discussed collapse and the correlations of index properties of different lithology. Could the authors have shown these correlations?

Empirical Correlations between collapse and dam structural behaviour.



CONCLUSIONS

- > **The type of rock affects greatly the mechanical behaviour of rockfill materials.**
- > **Index-properties tests** can allow to estimate the **mechanical properties** of rockfills.
- > The rockfills with better mechanical characteristics are, by decreasing order, as follows:
 - **basalt**
 - **greywacke**
 - **limestone**
 - **granite**
 - **schist**
- > **Limestone, greywacke and schist** rock fragments must be tested to analyse the **effect of collapse**.

**Thank you
for your attention!**

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**Remember the benefits of the index
properties!**