

P33

International Symposium
Switzerland, September 5-8, 1983

TAKAMAKA DAM (REUNION ISLAND):
GEOTECHNICAL SURVEY

by P.Deletie (1), J.Lakshmanan (2), Y.Lemoine (2), A.Martinet (1)

I INTRODUCTION

The hydroelectrical project of Takamaka II, in the island of Reunion, on the Riviere des Marsouins, consists of:

- a concrete spillway dam, 20 meters high, with a reservoir at an altitude of 840 NGR, (Hirondelles basin, on the Riviere des Marsouins),
- a main intake on the left bank similar to the present Takamaka I hydroelectrical plant,
- three torrent intakes just downstream of the dam,
 - an intake tunnel in reduced section, 4,300 meters long,
 - a well between altitudes 795.8 and 520.0,
 - an underground plant, an access tunnel and an evacuation tunnel, which communicates directly with the existing Takamaka I input tunnel.

The whole project is in the old volcanic circus of the Marsouins. this circus was quite similar to those of Salazie, Mafate or Cilaos before it was filled by various basalt flows. The Marsouins circus is part of the oldest volcanic massif of the Reunion, the Piton des Neiges.

Due to the very variable nature of rocks met, the designers needed many geotechnical tests, particularly for the Hirondelles basin.

- (1) Direction de l'Equipement, Electricite de France, Paris
(2) Compagnie de Prospection Geophysique Francaise, Rueil Malmaison

II GEOLOGICAL SITUATION

The formations having filled the Marsouins circus are several hundreds of meters thick and show out well in the topography around the dam site, forming a plateau. The margin of the circus is formed by the oldest formations (Phase II of G.Billard), aged between 2,100,000 and 430,000 years. These formations are formed of alternate metric layers of lavas and scorias. In the project area, the formations having filled the circus correspond to phases III and IV of G.Billard. They include:

Phase III : Pyroclastic formations , 500 meters thick, filled the interior of the circuses. They are a homogeneous mixture of small angular elements cemented by ashy products. They are pyroclastic flows, ressembling ignimbrites.

Phase IV : These rocks have been dated between 230,000 and 70,000 years old or less. Some recent flows are aphyric, the last ones having an agglomeratic facies. During a calmer period, pedologic weathering occurred.

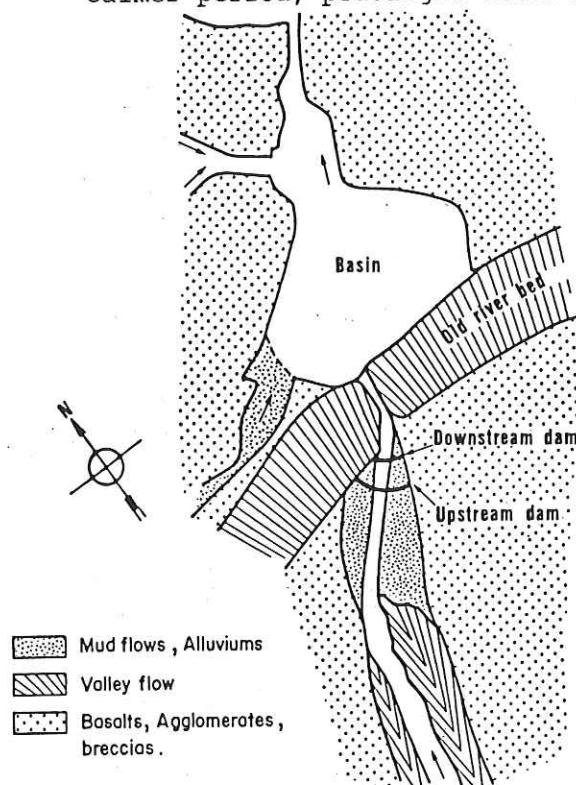


Fig.1 : Hirondelles Basin

Active geological phenomena on the whole island, and particularly in the project area, have given important recent deposits: valley flows have often filled old valleys, creating natural dams. Very often, local changes in torrent beds have occurred.

The Hirondelles dam site is located a few tens of meters upstream of a valley flow forming a cascade about 30 meters high. This flow filled an old bed of the Marsouins river, which ran in Phase IV agglomerates and breccia.

Laterally, on the left bank, the recent basalt flow is covered by a mud flow.

III INVESTIGATIONS CARRIED OUT :

III A. PURPOSE OF SURVEYS :

Surveys made on the site had the following aims:

- obtaining a more complete knowledge of geological structure,
- position and nature of different contacts between the main lithological units,
- petrography and physical characteristics of the different rock

types.

III B. CONSISTANCE OF SURVEYS :

- field geology,
- 23 drill-holes for determination of recent flow geometry (fig.2),
- in-situ tests: Lugeon tests and Mederatec-dilatometer tests,
- laboratory tests.

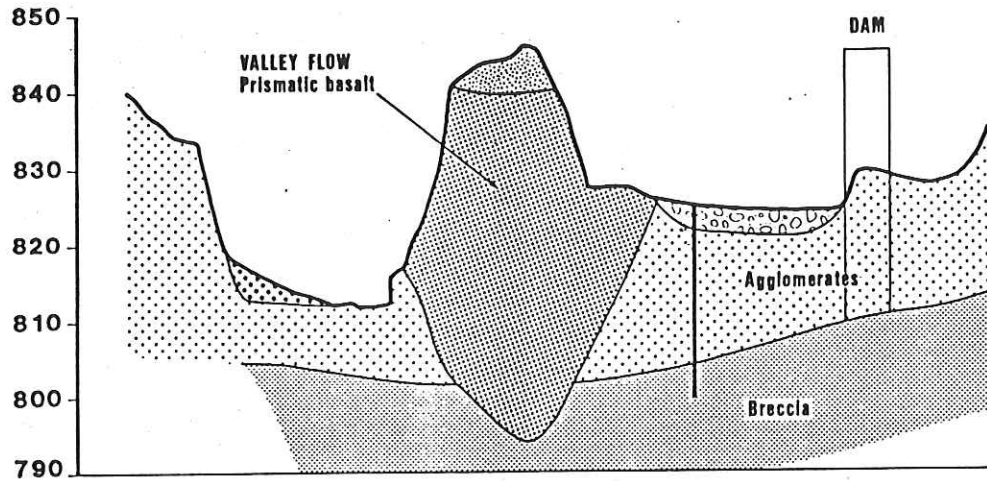


Fig.2 : Geological cross-section at the Hirondelles dam-site

III B.1 Mederatec-dilatometer tests :

The apparatus, patented by Electricite de France, makes large volume in-situ deformation tests : maximum stress 16 Mpa, diameter 95 or 105 mm, length 1 meter, maximum force 600 Tonnes. The volume under stresses exceeding 0.5 Mpa is of approximately 10 cubic meters.

30 tests were carried out following EdF's normalized procedure, including several cycles of stress and recovery, with increasing maximum pressures.

The main parameters measured were the following (figure 3):

- Elastic modulus E ,
- deformation modulus Γ ,
- deformability gradient, $GD = \Gamma_{4th\ cycle} / \Gamma_{2nd\ cycle}$

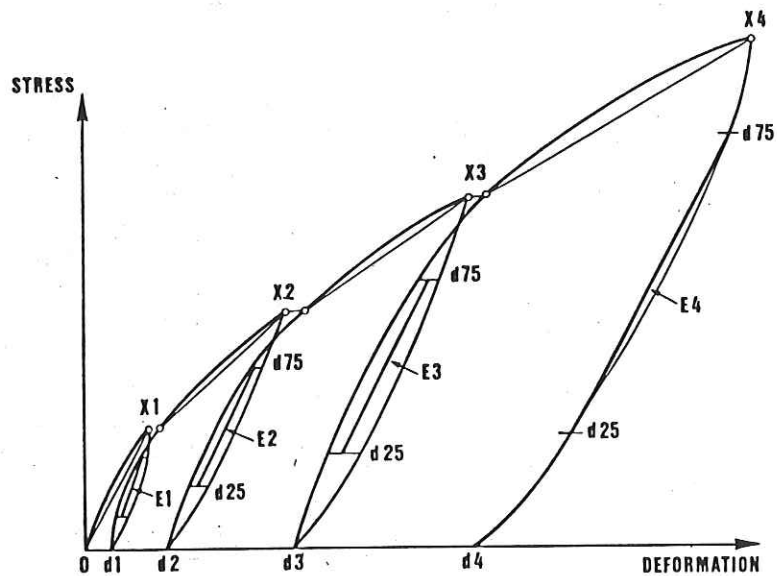


Fig.3 : Dilatometer test, schematic of computed moduli

III B.2 Laboratory tests :

Among the numerous tests carried out, the main were:

- identification tests: porosity
- resistance tests: R_c , uniaxial compressional strength
- deformation tests: E_s , secant modulus, and E_t , tangential modulus.

IV RESULTS

IV A. GEOTECHNICAL PARAMETERS :

IV A.1 Prismatic basalts :

This flow is more than 50 meters high near the Hirondelles basin. It is formed of a prismatic dacite. This rock is very fissured and the fissure's edges are often mineralogically weathered. The flow, which filled up an ancient topography, has certainly a complicated shape.

Fractures:

Fissures related to the prismatic structure of the valley flow, are very frequent and of various directions. At outcrops, these fractures seem closed.

Permeability:

The river valley flow's permeability, mainly due to fractures, is quite low: in 70 % of the tests, the absorptions were lower than 10 Lugeon Units.

Average physical properties :

In-situ Mederatec tests :

- * Elastic modulus E : 25,000 Mpa
- * Tangent modulus : 12,500 Mpa

Laboratory tests :

- Dry volumic mass : 2.2 to 2.6 gm/cc
- Measured open porosity : 0.5 %
- Non communicating porosity : estimate, 15 to 20 %
- Compressional strength Rc : 230 Mpa
- Brazilian strength: 10.3 Mpa
- Deformation modulus : 20,000 Mpa

IV A.2 Brecciated basalts :

Lithology : They are in fact volcanic microbreccia and outcrop at the upstream end of the future reservoir, and probably in the gorges of the Marsouin river, downstream of the Hirondelles basin. The cement of these breccia is very compact and fine grained.

These brecciated basalts are in fact the "basement" of the Hirondelles dam site.

Fractures :

The brecciated basalts are affected by a series of joints, with a regular N30°E direction and an important dip (70° to vertical).

Near contacts or near the surface, these fissures can be open, and their edges very weathered.

Permeability :

Mainly a permeability of fissures which can be locally very important. Apart from these fractured zones, in most of the tested zones, absorptions are less than 5 Lugeon Units.

Average physical and mechanical properties :

in-situ dilatometer tests :

- elastic modulus E : 50,000 Mpa
- last deformation modulus Γ : 50,000 Mpa

laboratory tests :

- dry volumic density : 2.7 to 2.8 gm/cc
- open porosity (n) : 1.5 %
- compressional strength (Rc) : 120 to 150 Mpa
- tensile strength (Brazilian test) : 6 to 10 Mpa
- deformation modulus : 25,000 to 40,000 Mpa
- longitudinal velocity : 3100 m/s (1000 to 4000 m/s)

IV A.3 Agglomerates :

This name covers all brecciated or conglomeratic rocks having a porous or friable cement. These formations sometimes form cliffs, but are very difficult to core.

Fractures :

Like the brecciated basalts, the agglomerates are affected by a series of joints, strike N30°E, dip 70° to 90°.

Permeability :

The agglomerates show both a fissure permeability and a permeability related to the high porosity of the matrix. The total permeability is still relatively low and in the majority of tests absorption was less than 2 Lugeon Units.

Average physical and mechanical properties :**in-situ dilatometer tests :***** downstream part of the site :**

- elastic modulus (E) : 1000 to 3000 Mpa
- deformation modulus (Γ) : 800 Mpa (400 to 2000 Mpa)

*** upstream part of the site :**

- elastic modulus (E) : 5000 Mpa
- deformation modulus (Γ) : 1200 Mpa

laboratory tests :

- dry volumic mass : 2 to 2.25 gm/cc
- porosity (n) : 11 to 25 %
- compressional strength (Rc) : 16.5 Mpa
- tensile strength (RTB) : 10.0 Mpa
- deformation modulus : 5000 Mpa (750 to 11,000 Mpa)
- longitudinal velocities : 3000 m/s (1500 to 5000 m/s)
- cyclic monoaxial loading tests give an elastic modulus of 1600 Mpa (600 to 4000 Mpa)

Remarks :

The agglomerates' parameters are very variable. No significant increase is noted with depth, either vertically or horizontally. Heterogeneities are due to the formation's nature and to the degree of fracturation. Despite certain local anomalies, it can be noted that the upstream part of the site has better geotechnical properties than the downstream part.

IV B. CORRELATION BETWEEN THE DIFFERENT GEOTECHNICAL PROPERTIES :

The in-situ dilatometer tests and the laboratory tests were not made in the same drill-holes nor at the same locations.

Despite that, we have obtained satisfactory correlations by grouping the different rock-types as follows :

Brecciated basalts :

- B1 between altitudes 800 and 810
- B2 between altitudes 790 and 800

Prismatic basalts :

- between depths of 0 and 20 meters
- P2 between depths of 20 and 40 meters

Agglomerates, upstream site :

- A1 between altitudes 840 and 850
- A2 between altitudes 830 and 840
- A3 between altitudes 820 and 830

Agglomerates, downstream site :

- A5 between altitudes 820 and 830
- A6 between altitudes 810 and 820
- A7 between altitudes 800 and 810

IV B.1 Correlation between identification tests and deformation tests :

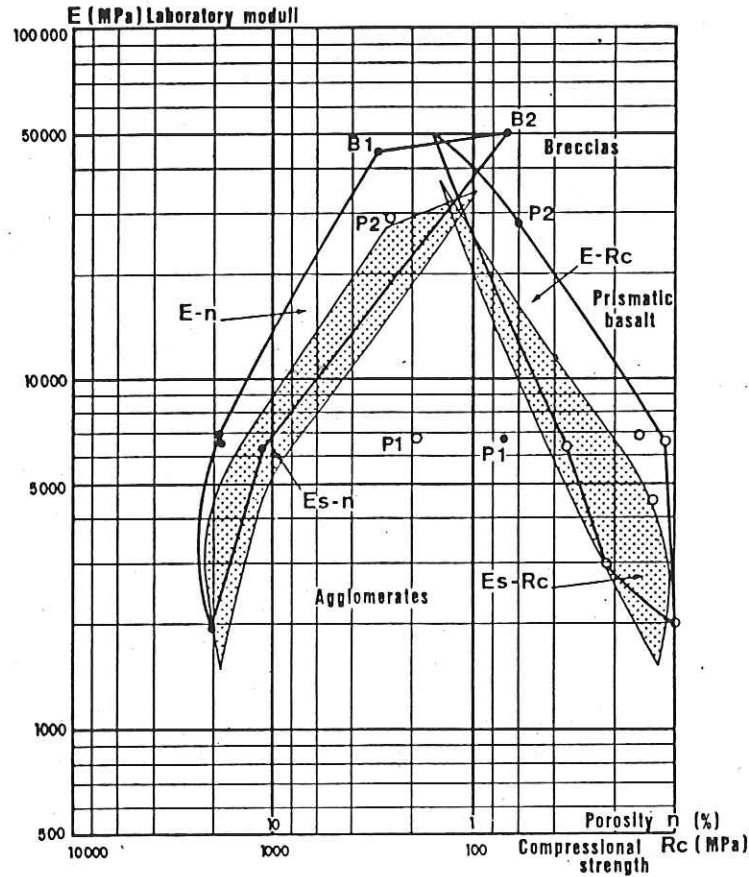


Fig.4 : Correlation between in-situ and laboratory moduli

There appears to be a satisfactory relationship between laboratory moduli E_s and E_t on one hand, and compressional strength R_c and porosity n on the other hand, at least for the agglomerates and for the breccias. The prismatic basalts do not follow the same laws, their porosities being lower and their compressional strengths higher. Quite logically, the best relationships are obtained between E_t and R_c on one hand and E_s and n on the other.

Replacing laboratory moduli by dilatometer in-situ moduli E and Γ , similar relationships are obtained, however with less good adjustments (see figure 4).

IV B.2 Relationship between in-situ and laboratory moduli :

Figure 5 shows :

- a satisfactory general correlation between the elastic in-situ modulus (E), and both laboratory moduli (Es and Et). Despite an appreciable dispersion, the in-situ and laboratory moduli are comparable.
- in-situ deformation moduli Γ are on the opposite much lower than those measured on samples; the latter do not take into account the general rock-mass fracturation.
- the breccia appear to be compact, while the prismatic basalts are fractured in their upper part (P1). The agglomerates' poor quality seems to be due to the formation's lithology itself, as well as to the rock-mass fractures.

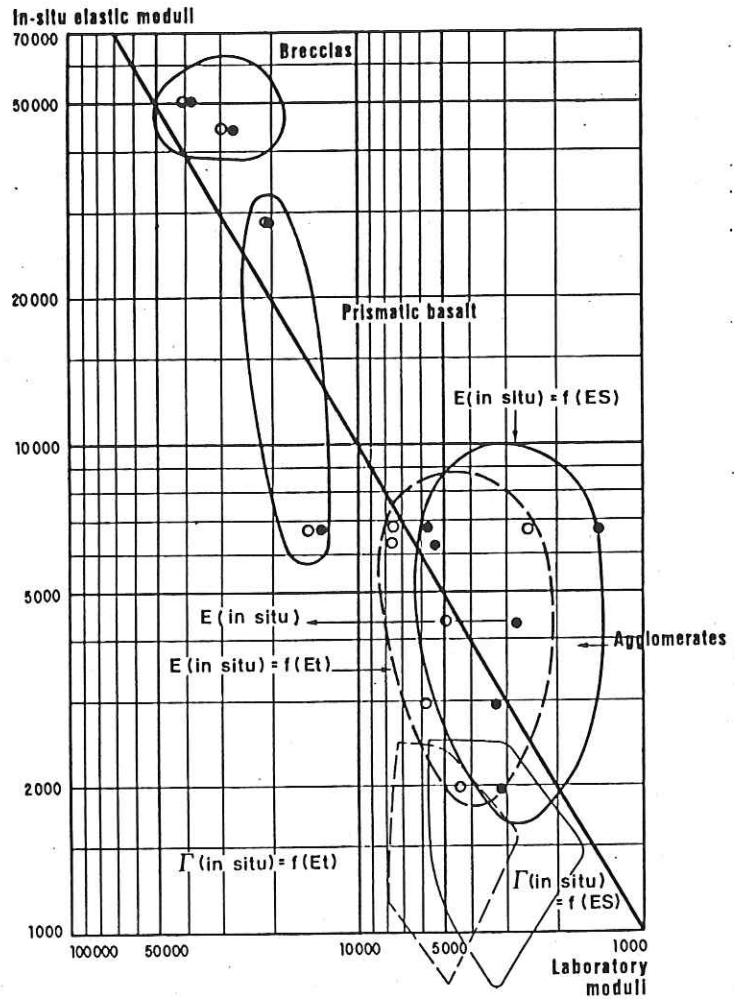


Figure.5 Correlation between in-situ and Laboratory tests

IV C. CHARACTERIZATION OF DIFFERENT ROCK-TYPES BY DILATOMETER TESTS :

TESTS :

Figure 6 shows a summary of the results obtained on different rock-types :

- brecciated basalts : compact to very compact, with high moduli and good deformability gradient (moduli increase with stress),
- prismatic basalts : very compact but fragile; properties improve with depth,
- agglomerates : better quality upstream than downstream, but overall poor properties : low moduli decreasing with stress, because of lithology (high porosity).

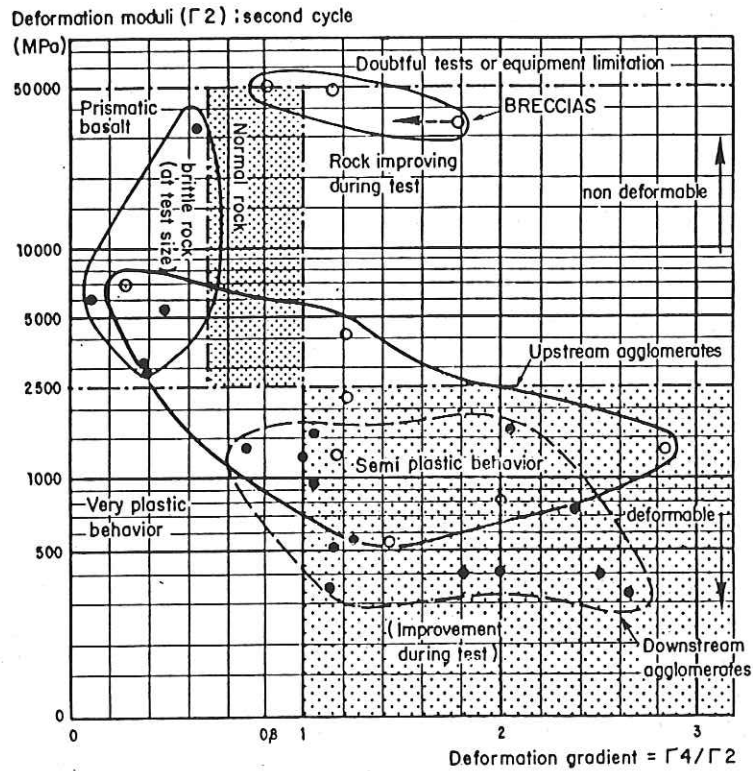


Fig.6 : Correlation between in-situ moduli and deformation gradient

V CONCLUSIONS :

The results of the deformation tests carried both in the laboratory and in-situ with the Mederatec-dilatometer, confirm the identification tests, particularly for the breccias and the agglomerates.

In addition, the moduli measured on samples and the in-situ reversible elastic moduli are very comparable. A good idea of general rock-mass fracturation is obtained from the in-situ deformation modulus Γ , often much lower than the laboratory modulus.

From a methodological point of view, the Takamaka survey has shown the importance of large in-situ testing (such as supplied by the Mederatec-dilatometer) for evaluation of rock properties taking into account large scale fracturation.

REFERENCES :

G.Billard, Geological map of France, La Reunion, scale 1/50,000th, "Notice Explicative".

Electricite de France, Takamaka hydroelectrical project (unpublished).

G.Comes, 1965, "Contribution a la determination des caracteristiques mecaniques d'une fondation rocheuse", Travaux, Paris Nov. 1965.

B.Schneider, 1967, "Moyens nouveaux de reconnaissance des massifs rocheux", Annales de l'I.T.B.T.P., no. 235-236, serie Sols et Fondations, no.6.

N.Dinia, P.Londe, M.Salembier, B.Schneider, A.Haberstroh, Y.Lemoine, J.Lakshmanan, 1983, "Methodologie des essais au dilatometre, application a quatre grands barrages Marocains", Symp. Int. Essais en Place, Paris, May 1983.