Embankment Failures on Soft Clay in Brazil

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Introduction

In the last 15 years a few well documented embankment failures have taken place at four different soft clay sites in Brazil (figure 1). The purpose of this note is to present a brief summary of this experience.

Case histories

Case 1 - A full scale instrumented trial embankment was carried out at site 1 on Rio de Janeiro clay, in 1977 [6]. The ground consists of soft marine clay with liquid limit (*LL*) from 120% to 160%. The water content (w) ranges from 120 to 180%, the plastic limit (*PL*) from 60 to 80% and mean plasticity index (*PI*) of around 80%. The field vane (*FV*) shear strength s_u of the clay varies from 8 to 18 kPa, as shown in the profile in figure 2, the mean value being 10 kPa [5]. Table 1 summarizes these soil properties.

Figure 2 shows the geometry of the embankment just prior to failure. A stability analysis using uncorrected *FV* strength profile using Bishop's simplified method gave a factor of safety (*FS*) close to one, which closely matches the observed behaviour. Still, Bjerrum's [2] field vane correction factor for a clay showing IP=80% is 1/1.6, which would result in a reduction of the strength to be used in analyses.

At the time of the trial, it was argued that the FV correction was not necessary. The reasons were: the high plasticity of the clay, marine origin, mineralogy and organic content of the clay. Additional experience was necessary to confirm this. Since then, additional case histories have been added to the Brazilian data base.

Case 2 - Another full scale instrumented embankment failure was carried out at site 2, about 150 km north of Rio de Janeiro, at the site of Juturnaiba Dam [3]. The soft ground has 7m of interlayered soft alluvial organic clay and peat, with *PI* between 40 to 80% for the clay layers. Mean *FV* strength value was 20 kPa, but data showed considerable scatter and its was difficult to select a design

Figure 1 Location of failures

Table 1
Summary of case histories of failures

Case Number	*PI* (%)	*FV* Strength s_u (kPa)	Calculated Factor of Safety
1	80	8 to 18	0.95 - 0.99
2	40 to 80	10 to 35	0.96
3	50	5 to 12	1.0
4	40	10 to 25	0.98

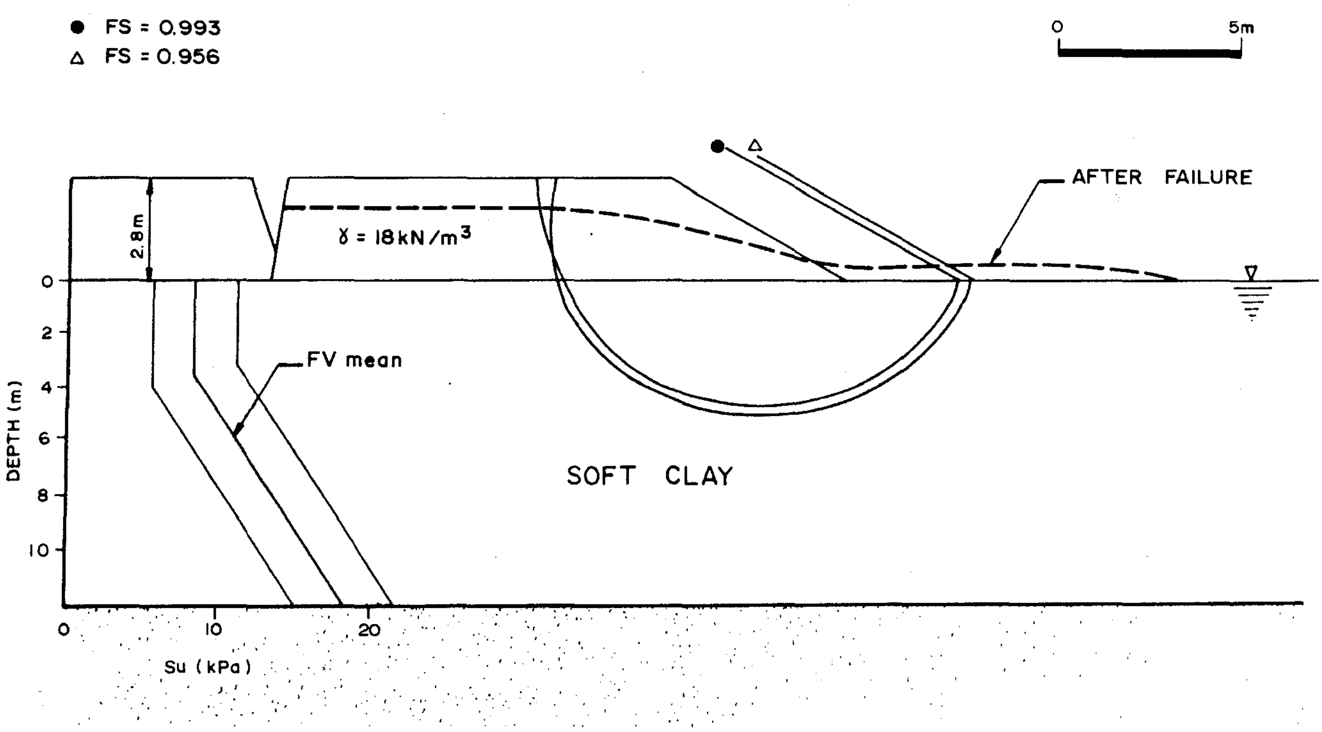

Figure 2 - Case 1 - Failure on Rio de Janeiro clay [6]

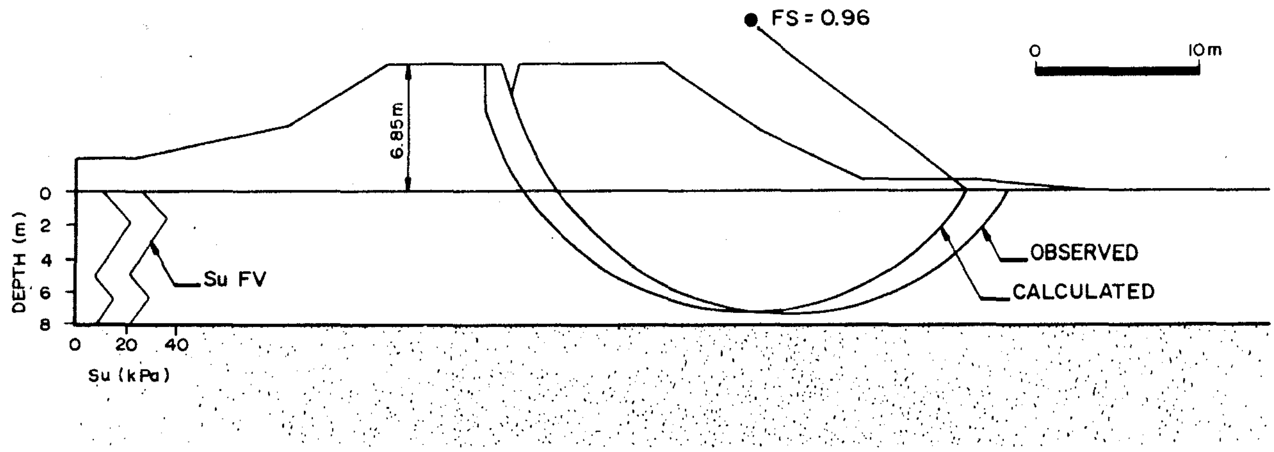

Figure 3 - Case 2 - Juturnaiba trial embankment [3]

s profile for the embankment dam.

Figure 3 shows the embankment cross section. The embankment failed when its height reached 6.85m. A total stress stability analysis employing the uncorrected mean strength profile and considering cracking in the embankment material (ie, reduced embankment strength) yielded a factor of safety of 0.96, closely matching the observed behaviour (table 1).

Case 3 - Unlike the previous trials, this case was an accidental failure. It took place on a railway embankment that crossed a 20km length of marshy area near the city of Sao Luis. The embankment design was based on *FV* strength data obtained from 100m spaced boreholes along the proposed railway alignment. But, failure took place on a softer marine design stage (figure 4).

Again, the stability analysis based on detailed site investigation yielded *PI*=50%, *LL*=90% and *w*=70 to 110% and a factor of safety close to 1 for failure conditions and mean uncorrected *FV* profile (table 1).

Case 4 - An end-of-construction failure of a breakwater took place on a soft clay foundation at site 4 (figure 1). The foundation soils consisted of a 4m layer of fine sand, followed by 8 m of soft clay with *FV* strength ranging from 10 to 20 tkPa. Figure 5 shows a cross section of the breakwater. Post-failure stability analysis used Janbu's simplified method, polynomial slip surfaces and detailed site investigation. Uncorrected *FV* strength data yielded *FS*=0.98 (table 1).

Final comments

In the late 1970's it was surprising to find that *FV* corrections were not applicable to a high plastic clay, like the soft deposit of Rio de Janeiro clay. As more experience was obtained, it clearly

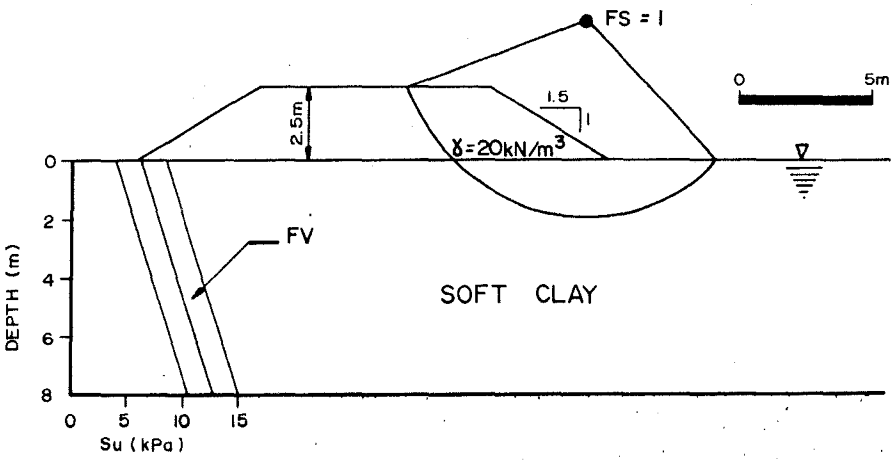

Figure 4 - Case 3 - Railway embankment failure near Sao Luis

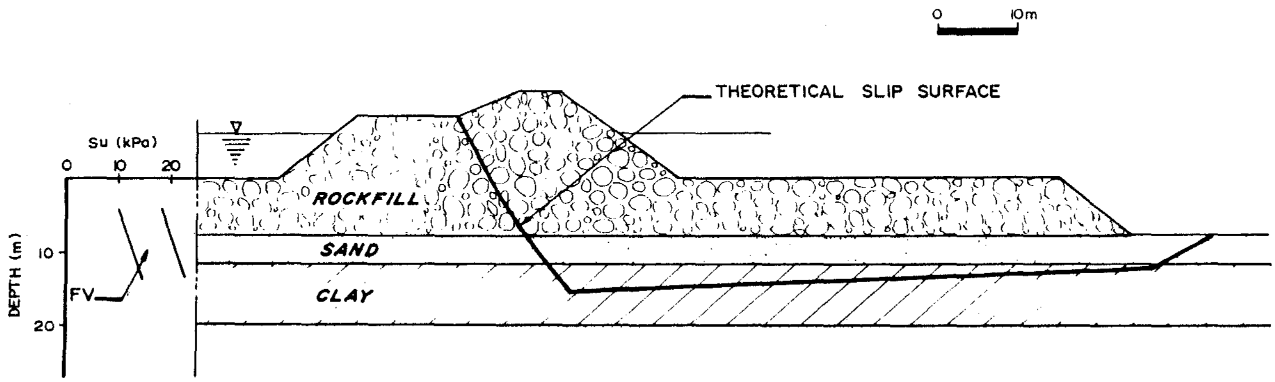

Figure 5 - Case 4 - Failure of a breakwater on soft soil

showed that site specific calibration data is very important.

Bjerrum's recommendations have recently being updated [1], but the new charts include considerable data scatter that makes the selection of a correction factor difficult.

When *FV* calibration data is not locally available, other forms of investigation, such as laboratory unconsolidated undrained triaxial tests, are recommended [4]. The results obtained should be compared with the *FV* strength. If there is a significant difference, corrections should be applied.

References

[1] Aas G., Lacasse S., Lunne T. & Hoeg K. (1986) Use of in situ tests for foundation design. ASCE Specialty Conf. on In Situ Tests in Geotechnical Engineering, Blacksburg, Virginia Tech., Geotechnical Publication no. 6, pp 1-30.

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[4] Ortigao J.A.R. & Almeida M.S.S. (1988) Stability and deformation of embankments on soft clay, Handbook of Civil Engineering Practice, Editors: P.N. Chereminisoff, N.P. Chereminisoff and S.L. Cheng, Technomics Publ., vol. 3, New Jersey, pp 267-336.

[5] Ortigao J.A.R. & Collet H.B. (1987) Errors due to soil-rod friction in field vane tests. ASTM Int. Symp. on Laboratory and Field Vane Shear Strength Testing, Tampa, ASTM STP 1014, pp 104-116.

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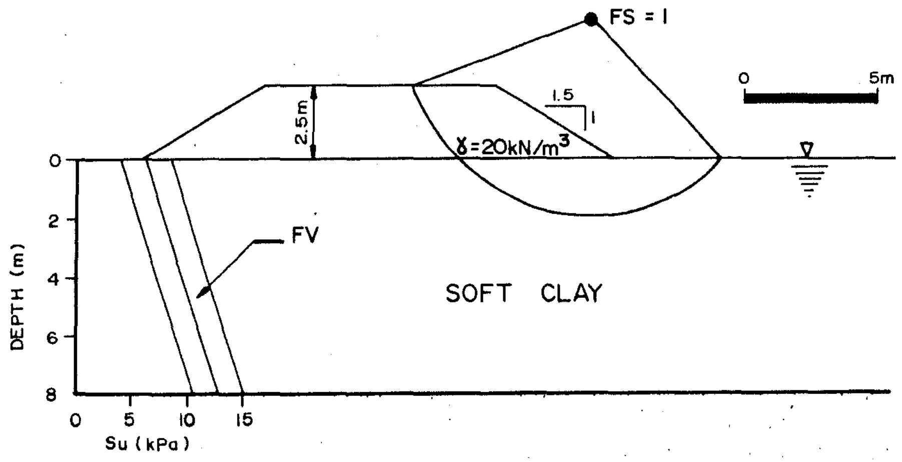

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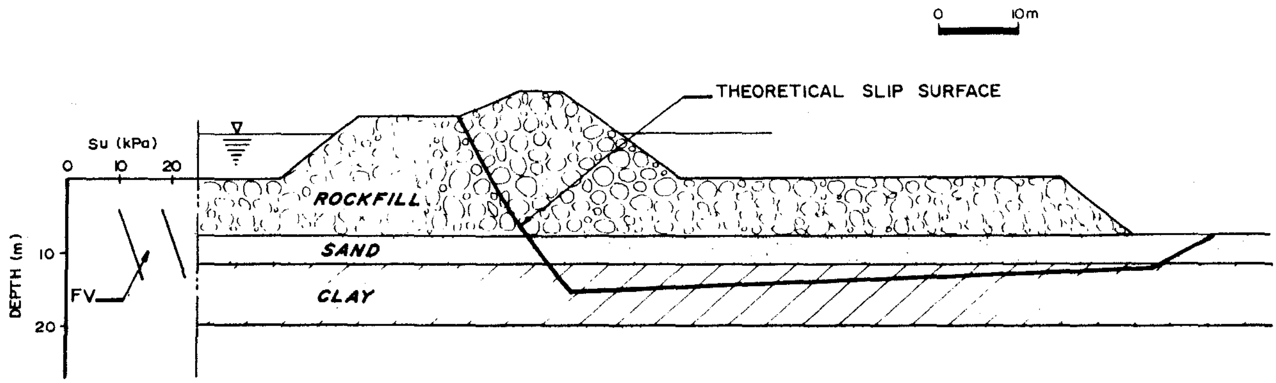

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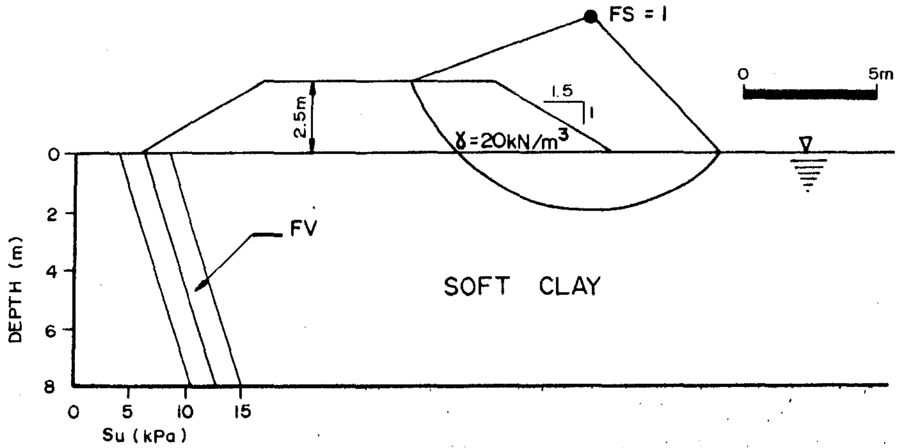

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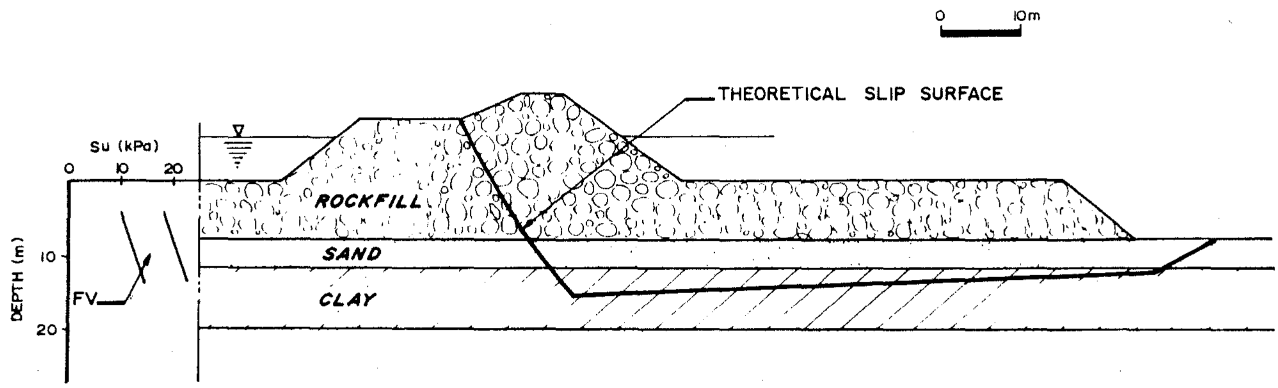

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