GEOTEXTILE ANTI-PIPING BARRIER FOR METABASIC FOUNDATION SOIL TUCURUI DAM, BRAZIL

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A geotextile was used as an anti-piping barrier on the downstream face of the cut-off trench of Tucurui Dam, Brazil. The geotextile was used in areas where the foundation rock had a high coefficient of permeability. This high permeability was due to a great concentration of tubular cavities in the region known as "metabasic".

DESCRIPTION

Tucurui Dam is a zoned earthfill dam situated in the north of Brazil (Amazonian region), in the valley of the Tocantins River. Its construction began in 1976 and the dam was inaugurated in 1984. The dam is part of a very big power generating plant (capacity 8,000 MW) and has the following characteristics:

- total length of the dam: 8,530 m;
- compacted earthfill: 80,000,000 m^3;
- soil excavation: 23,000,000 m^3;
- rock excavation: 22,000,000 m^3;
- reservoir area: 2,160 km^2;
- maximum height of the embankment dam: 103 m.

The area of the foundation soil, known as "metabasic", extends a length of 250 m. It is situated on the right bank of the Tocantins River. The depth profile of the metabasic stretch is given in Table 1.

The lower horizon varies from highly fractured rock interbedded with soil, to hard altered rock and/or very slightly fractured solid rock. The altered rock exhibited high loss of water, with a coefficient of permeability in the range of 1 μm/s. The solid rock, although less permeable, revealed some areas with high loss of water.

Although the metabasic residual and saprolitic soils had coefficients of permeability less than 1 μm/s, they exhibited areas of high permeability that were considered abnormal for the type of soil tested.

Table 1. Cross-section of the metabasic stretch (from the ground surface to the deepest layer)

Soil Characteristics	Thickness
Colluvial deposits, 2<N<4	about 2 m
Alluvial terrace	0 to 3 m
Metabasic residual soil, 6<N<9	3 to 15 m
$k = 1 \times 10^{-6}$ m/s	
Saprolitic soil, N>11	3 to 15 m
Soft altered rock (highly fractured)	4 to 6 m
$k = 1 \times 10^{-6}$ m/s	

Further investigations showed that these high permeabilities were due to a great concentration of tubular cavities. The cavity diameters varied from a few millimetres to more than 200 mm. The cavities form sub-vertical developments that can reach great depths (over 20 m). Some cavities are interconnected with the open fractures of the underlying altered rock. The cavities proved to be more subject to erosion when submitted to concentrated flows of water.

DESIGN

The foundation treatments which were implemented are presented in Figure 1.

The geotextile was applied on the downstream face of the cut-off. Its function was to stop possible piping of soils from the compacted earthfill through a possible undetected or unplugged cavity.

The self-sealing soil (slightly clayey alluvial gravelly sand) placed on top of the geotextile was used as a complement to the anti-piping barrier.

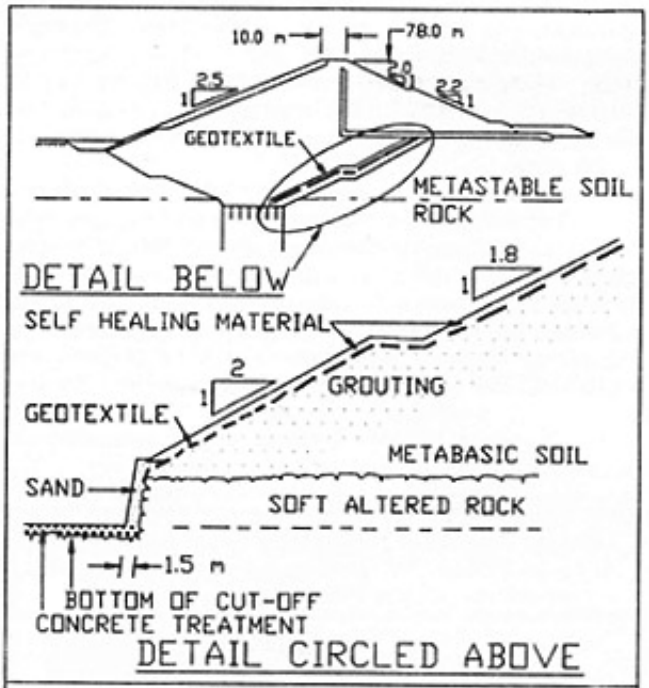

Figure 1. Cross-section of the dam and detail of the geotextile application.

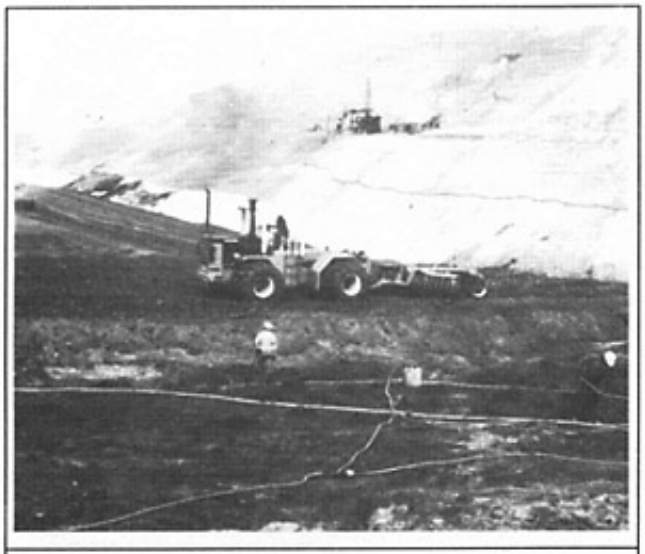

Photo 1. Placement of geotextile over the metabasic soil.

GEOTEXTILE REQUIREMENTS

In this application, the geotextile must fulfil the requirements discussed below.

Mechanical Requirements

In the metabasic stretch, even after filling the tubular cavities, it is reasonable to assume that any undetected cavities with a maximum diameter of 50 mm may remain unfilled. The portions of the geotextile in contact with an unfilled cavity may become deformed under the applied stresses. The maximum value of these stresses was calculated to be 800 kPa. In other words, the bursting strength of the geotextile should be 800 kPa on a 50 mm opening or 800 x 50/35 = 1,143 kPa, if measured with testing equipment having a 35 mm opening.

Due to the low shearing resistance of the foundation material, puncturing of the geotextile on the edges of the cavity was considered an unlikely event and no puncture requirement was specified.

Retention of Fines Requirements

Retention of fine soil particles is the main function of the geotextile in the metabasic stretch. The geotextile must act as an anti-piping barrier, retaining the clayey gravelly sand of the cut-off. Using Giroud's retention criterion [1982], the geotextile opening size (O_{95}) should be less than 380 μm.

Permeability Requirements

The gradients in the clayey gravelly sand, in the proximity of the geotextile, are on the order of 1. This was judged insufficient to cause clogging of the geotextile. The minimum permeability required for the geotextile is on the order of 500 nm/s using Giroud's permeability criterion [1982].

GEOTEXTILE SELECTION AND INSTALLATION

The geotextile used was a polyester continuous filament nonwoven (Bidim OP-60). Its main characteristics, measured according to the recommendations made by CFGG (French Committee on Geotextiles and Geomembranes), are the following:

- Tensile strength 38 kN/m
- Strain at failure 41%
- Permeability (no load) 2,200 mm/s
- Permeability (under 800 kPa) 40 mm/s
- Opening size (O_{95}) 59 μm
- Bursting strength (AFNOR-G-07112) 6,000 kPa

The factors of safety are 6,000/1,143 = 5.25 for bursting strength and $40 \times 10^{-3}/500 \times 10^{-9}$ = 800 for permeability. These factors of safety are high, which is justified by the fact that the geotextile application was done in a zone that is inaccessible after construction of the dam.

The quantity of geotextile used was 11,000 m^2. The geotextile was placed over the previously regularized cut-off face with overlapping of 500 mm. Special care was taken during compacting to avoid damage to the geotextile. During work interruptions the geotextile was protected from sunlight and rain using opaque plastic covering sheets.

PERFORMANCE

Three years after the reservoir filling, it was observed that the water flow through the compacted fills of the cut-off was slow as expected, due to the low permeability of the earthfills. No piping was observed, which indicates that the anti-piping system composed of the geotextile barrier and the self-healing clayey gravelly sand performed satisfactorily.

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