Engineering of the Taironas circa 1200

L'ingéniérie des Taironas aux environs de 1200

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SYNOPSIS: Professor Jean Kerisel's "THE HISTORY OF GEOTECHNICAL ENGINEERING UP UNTIL 1700", published as a part of the Golden Jubilee Volume of the Eleventh International Conference on Soil Mechanics and Foundation Engineering, presents a thorough overview of the ancient history of geotechnical engineering. A possible addition could be the retaining structures of the Tairona people in the North of Colombia. These structures in the "Sierra Nevada of Santa Marta", are excellent examples of the "ingenuity" of Pre american cultures.

1 INTRODUCTION

Many of the Tairona cities were located in high placed in the Sierra Nevada. The topographic setting could not be more abrup; the Sierra, the highest mountain in the world that is adjacent to the sea, has few flat areas suitable for villages. Nevertheless, at heights of 800 to 1200 m above sea level, more than 200 cities have been discovered.

At the locations of these cities (containing up to 30.000 inhabitants), few rock exposures are found, and residual soils are the bearing strata and one of the construction materials, in this very rainy climate.

Besides residual soils, the Taironas had sedimentary and metamorphic rocks, which could be fractured along the sedimentary planes, such as quartzites and serpentines. These rocks were mined as slabs or blocks with lengths up to 3.2 m, widths of up to 0.9 m and thicknesses of 0.05 to 0.15 m. In some areas long stones of columnar form were mined as well. Most of the production at the stone quarries, consisted of blocks of 0.2 by 0.3 by 0.05 to 0.15 m tickness. These were the materials with which the Taironas had to make level surface.

The Taironas choose the top of the moderatly inclined ridges that abound in the area, as prefered places for the construction of terraces. Undoubtedly, at such locations there was the maximum mass stability, especially in wet residual soil conditions.

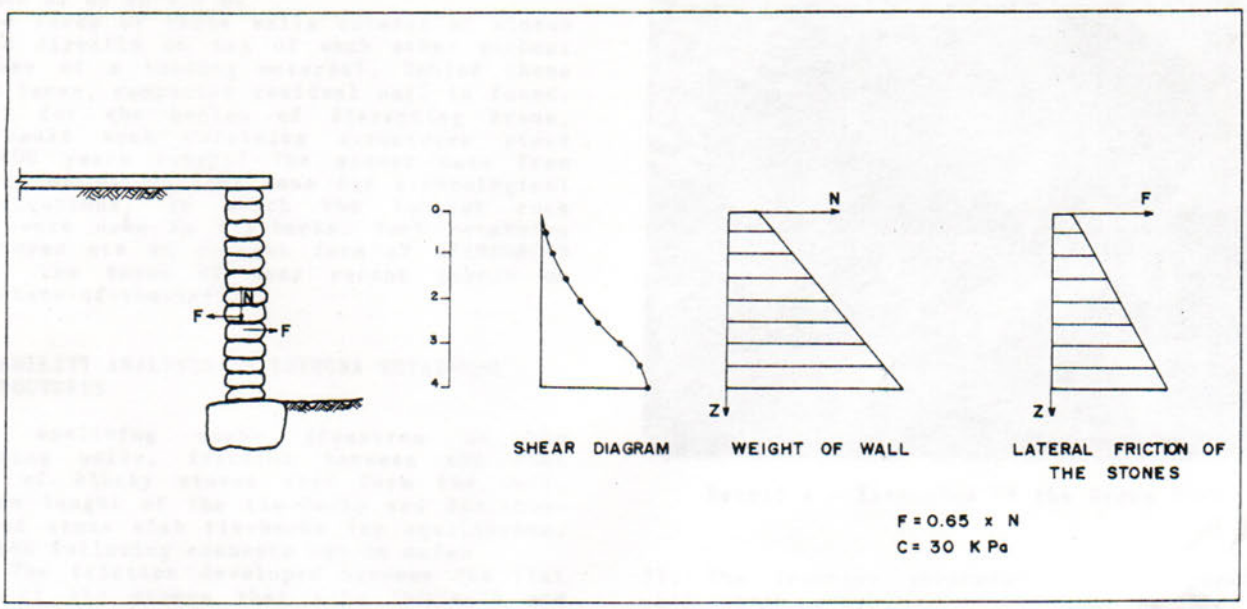

Figure 1. Configuration Hypothesis

Stone Wall

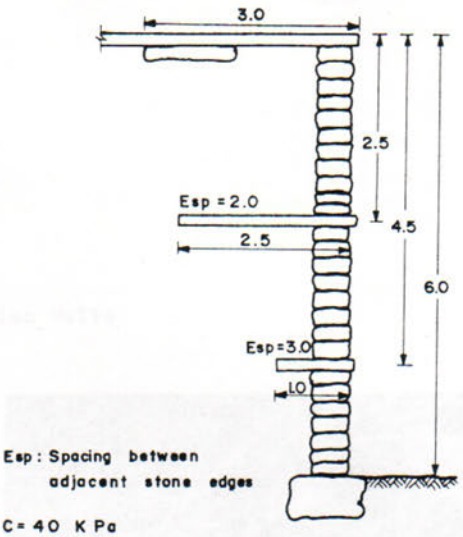

Figure 2. Wall with Stone Slabs

2 CHARACTERISTICS OF RETAINING WALLS

To our surprise, most retaining walls have a thickness of 0.2 to 0.3 m, in spite of their heights of up to 6.5 m.

The faces of these walls consist of stones placed directly on top of each other without the use of a bonding material. Behind these stone faces, compacted residual soil is found. Except for the action of disrupting trees, how could such retaining structures stand for 800 years intact? The answer came from records of excavations done for archeological investigations, in which the longest rock slabs were used as tie-backs. Such retaining structures are an ancient form of REINFORCED EARTH, the topic of many recent papers on "the-state-of-the-art".

3 STABILITY ANALYSIS ON TAIRONA RETAINING STRUCTURES

After analizing earth pressures on the retaining walls, friction between the flat faces of blocky stones that form the wall, minimum lenght of the tie-backs and distribution of stone slab tie-backs for equilibrium, etc, the following comments can be made:

1. The friction developed between the flat faces of the stones that make the wall and the "tie-backs" is proportional to the weight acting on them, regardless of their area. (Coulomb principle). According to this, the maximum resistance to lateral forces due to friction between stones, exists at the bottom of the wall where the maximum vertical load acts and where the maximum retaining forces are needed. (See figure Nº 1).

2. A height is reached where the lateral friction resistance generated by the weight of the stone face is no longer capable of resisting lateral retaining forces. At such a point, an additional stability factor would have to act in order to maintain equilibrium.

3. This additional force was built up by means of stone slabs placed on top and perpendicular to the stone wall. (See figure Nº 2). The friction generated by the compacted soil which eventualy surrounded the tie-back slab created the anchoring force that permited the retaining wall to achieve such heights.

Detail A - Extension of the Stone Slab

4. As height was gained, a new tie-back slab was placed. This was repeated until the desired height was reached, and at this point a final slab was placed. According to the archeologists walls built in this manner have achieved heights of 10 m.

5. Tie-back stone slabs were not continuos, horizontally or vertically, but their action relied on the friction distribution capacity of the stone face. When no large stone slabs were available, the tie-backs were built using overlaped columnar shaped stones.

6. The walls were built in many forms, completely vertical, stepped as shown in figure Nº 3, elliptical in plain view, and round

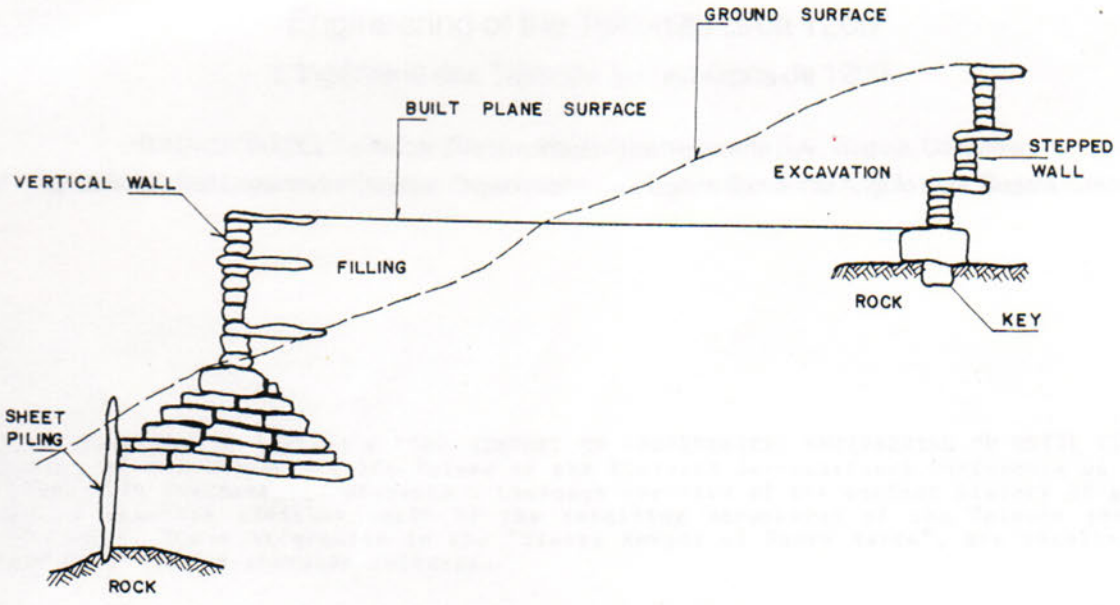

Figure 3. Types of Foundation Walls

stone covering of a slope, etc. Apparently, the Taironas changed their retaining wall design according to; the materials available, the topography, the available space and the height required.

7. The few foundations that could be observed, were built by means of larger stones with key notches in the footings and by means of pyramidal transverse stone arrangements with 45 degree spreads on soil. In some cases vertical stone slabs were used as sheet piles placed next to the edge of footings when slope stability was precarious.

The paramenters used in stability computations were the following, cohesion of the compacted residual soil: 30 to 40 Kpa, maximum length of tie-backs: 3.2 m, at rest pressures, friction coefficient: 0.65, compacted soil density: 16 KN/m' and stone density: 28 KN/m'.

From these computations, factors of safety of the order of 1.3 to 1.5 were deduced. Such factors of safety are very small compared to the factors of safety used in the design of retaining structures today. Inspecting some of the walls after doing theoretical computations, the tie-backs were found where predicted according to the height of the wall. The other properties also matched the theoretical calculations. Undoubtedly, not all resistant factors have been taken into account and errors in the geometry of the walls are probable, since no complete excavations have been inspected. But such factors of safety reveal that the Taironas masterfully handled the variables involved.

Foundation Stone Wall

CONCLUSIONS

The Taironas handled the variables of retaining walls and reinforced earth to a degree that is beyond the stage of cook rules.

This study opens the possibility for further investigation on the development of engineering in the Tairona Culture.