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Foundation on Rock Mass Calculation Using Geomechanical and Finite Element Model on Western Senegal Massifs

Déthié SARR[1,*], Oustasse A. SALL[1], Hamath KEBE[1], Ibrahima K. CISSE[2], Mouhamadou NDOUR[1]

[1]Laboratoire de Mécanique et Modélisation des terrain, UFR Sciences de l'Ingénieur, Thiès, Sénégal
[2]Laboratoire de Matériaux et de géotechnique, Ecole Polytechnique de Thiès, Thiès, Sénégal
*Corresponding author: dethie.sarr@univ-thies.sn

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Abstract This paper analyzed foundations behaviour on the rock mass of west cornich in the sector of Fann-Ouakam-Almady. It is done using rock mass classification, topographic data, results of laboratory test and finite element modeling. Topographic data are collected in the excavation using a total station and permit to establish the logs of this area and a three-dimensional representation of the cavity with complex lithostratigraphy of the zone. Discontinuities of the scoriaceous basanitic dolerite show that the block has no possibility of movement. This scoriaceous basanitic dolerite is of good quality while massifs composed by block of scoriaceous dolerite included in lateritic soil (altered or not) are of fair to poor quality. Rock mass parameters for foundation calculation and modeling are defined using GSI and laboratory tests. Before loading, highest displacements are located at the layer composed by block of scoriaceous dolerite in laterite and are lower than 87 micrometers. When using finite element model all facies are stable but are not stable when using rock mechanic approach. Foundations calculation shows an acceptable settlement around millimeters for all layers but displacements are more important in the layer composed by block of rock in laterite and less in basanitic dolerite. Displacement is lower when finite element method is used.

Keywords: *pumice, behavior, topography, rock mass classification, foundation on rock*

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1. Introduction

Senegal is mostly composed of sedimentary formations (almost 95% of the land area), especially in its central and western part. These sedimentary formations are crossed by volcanic ones outcropping very well on the edge of the Atlantic Ocean at the level of the head of the peninsula of Cap-Vert. This offers to this part a wide variety of rock combinations with often very different stiffness categories. Despite this diversity, works in this sector are often designed either by using soil mechanics methods or by considering that the rock is strong enough to support any works applied on the basis of simple compression test in the laboratory. This consideration leads to premature ruins of the construction works and sometimes at the early stage due to the ignorance of the geomechanical terrain. It has become necessary to take into account the heterogeneous composition of the rocks since the works are getting heavier. The aim of this study is to check the design of the foundations placed on rock formations of various natures in Dakar city using geomechanical methods. To do this, a characterization of a very complex rock mass is carried out after excavation with explosives to find out whether the nature of the rock formation plays a role in the behavior of the structure. Those types of research are carried out around the world with established models [1,2] but remain innovative in Senegal. Scientific studies are carried out on rock massifs located in the area of Fann-Ouakam-Almady in order to characterize heterogeneous rock mass which constitute the subsoil of various foundations. An excavation is conducted at Fann and gives informations on rocks that are crossed during establishment of these foundations. This excavation is characterized by its morphology which is shaped into two slopes superimposed on a remarkable ledge of 10 m long. Consequently, this morphology leads a neat separation of the area into two superimposed fields. And it is followed by a window study opening at the place the geomechanical characteristics of the site will be determined. Geomechanical classifications and stereographic projection define the terms of instability of the excavation and corresponding parameters according Hoek-Brown [2,3,4]. These parameters are used to establish the model as well as for escarpment than for foundation calculation [5]. Rock foundation sizing will be done according result of rock mass classification.

2. Methodology and Carried Out Work

Topographic measurements: An overall of topographic measurements is achieved to delineate the field and also the two working faces. In addition to this, we determine the various outcrops of each working face in the excavated field. This work was done with a total station and the sea's level is positioned at the reference. The first station is at the entrance of the excavation. From this position a whole sighting is done towards the cutting face. The second station is at level of the ledge that sits at the top of the cutting face of the lower block. This station permits to target points that are inaccessible from the first station and also to target the sea level.

Geomechanical parameters: Geomechanical variables are defined by dividing the down escarpment into three stations and for the upper cutting face, it is considered as a single station because of its homogeneous aspect (Figure 1 and Figure 2). For each station where hard rock is present, a scanline is plotted and the poles of discontinuities intersected by the scanline are identified. From these measurements, Spacing's of discontinuities and their frequencies are determined. In each study window, mechanical parameters are determined. In doing so, the quality of the rock mass is also taken into account. This work has been determined by using tools such as decameters, markers, a Geological Strength Index (GSI) [6,7] table, a Rock Mass Rating (RMR) [8,9] table. For the higher escarpment, the GSI is determined by description. Rock parameters are deduced from these measurements [8]. So, the geomechanical rock mass classifications used in this work are Rock Mass Rating and Geological Strength Index. According to the morphology and the components of the rock mass, a rock mass classification system is used directly or indirectly to homogenize the latter. Functions below are used on different domains of analysis [8,10,11,12] to define the parameters of the rock masses [5-13]. The necessary parameters for foundation calculation have been defined using classification index

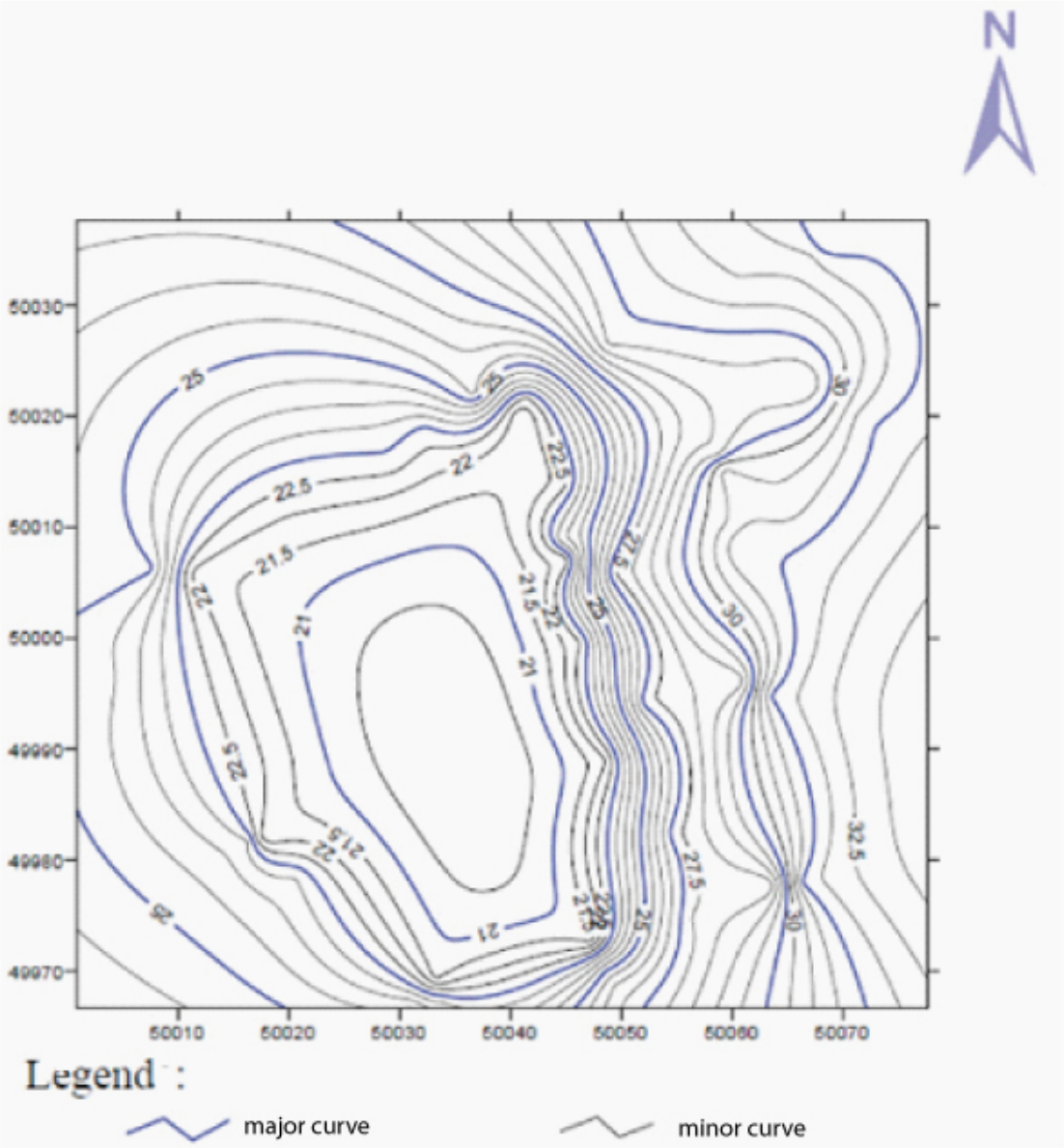

Figure 1. Topographical map of the excavated site

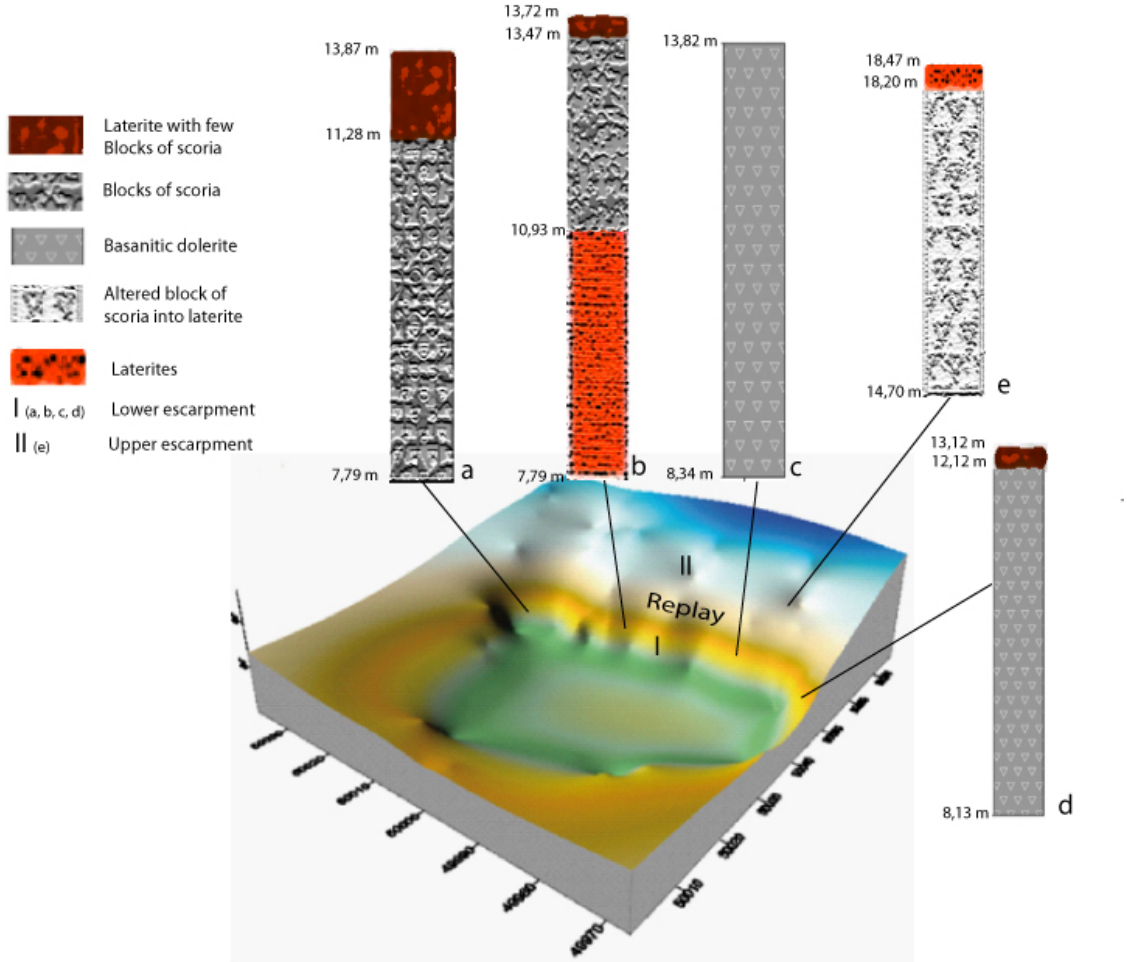

Figure 2. 3D model of the excavation area (a, b, c, d and e are stratigraphic logs)

$$m_b = m_i \exp\left(\frac{GSI-100}{28-14D}\right) \quad (1)$$

$$s = \exp\left(\frac{GSI-100}{9-3D}\right) \quad (2)$$

$$a = \frac{1}{2}+\frac{1}{6}\left(\exp\left(-\frac{GSI}{15}\right)-\exp\left(-\frac{20}{3}\right)\right) \quad (3)$$

$$\sigma_c = \sigma_{ci} s^a \quad (4)$$

$$\sigma_t = -\frac{s\sigma_{ci}}{m_b} \quad (5)$$

$$E_m = \left(1-\frac{D}{2}\right)\sqrt{\frac{\sigma_{ci}}{100}}.10^{((GSI-10)/40)} \quad (6)$$

$$\varphi = \sin^{-1}\left[\frac{6am_b\left(s+m_b\sigma_{3n}\right)^{a-1}}{2(1+a)(2+a)+\left(6am_b\left(s+m_b\sigma_{3n}\right)^{a-1}\right)}\right] \quad (7)$$

$$c = \frac{\sigma_{ci}\left[s(1+2a)+(1-a)m_b\sigma_{3n}\right]\left(s+m_b\sigma_{3n}\right)^{a-1}}{(1+a)(2+a)\sqrt{\frac{1+\left(6am_b\left(s+m_b\sigma_{3n}\right)^{a-1}\right)}{((1+a)(2+a))}}} \quad (8)$$

$$\sigma_{3n} = \sigma_{3\max} / \sigma_{ci}$$

$$\sigma_{cm} = \sigma_{ci}.\frac{\left(m_b+4s-a\left(m_b-8s\right)\right)\left(m_b/4+s\right)^{a-1}}{2(1+a)(2+a)} \quad (9)$$

The calculation of the bearing capacity will be done using the parameters of the Hoek criterion through different methods [13,14]. The foundation is of a superficial type and the footing rests on the rock or anchored at a very shallow depth. The bearing capacity and settlement under the foundation will be defined by the following functions

$$\sigma_1 = \sigma_3 + \sigma_{ci}\left(m_b\left(\sigma_3/\sigma_1\right)+s\right)^a \quad (10)$$

$$q_u = C_{f1}\sigma_{ci}\sqrt{s}\left(1+\sqrt{m/\sqrt{s}+1}\right) \quad (11)$$

According to Goodman

$$q_u = 2c\tan\left(45+\varphi/2\right) \quad (12)$$

In the case of footing recessed into rock mass, we get

$$q_u = C_{f1}\left(m\sigma_{ci}\sigma_3 + s\sigma_{ci}^2\right)^{1/2} + \sigma_3 \quad (13)$$

$$\sigma_3 = C_{f1}\left(m\sigma_{ci}q_s + s\sigma_{ci}^2\right)^{1/2} + q_s \quad (14)$$

with qs, the average stress due to the rock weight above the footing.

For the case of a footing placed on the layer consisting of block of dolerites in laterite

$$q_u = C_{f1} c N_c + C_{f2} \left(B\gamma_r / 2 \right) N_\gamma + \gamma D N_q \qquad (15)$$

$$N_c = 2\sqrt{N_\phi} \left(N_\phi + 1 \right)$$

$$N_\gamma = \frac{1}{2}\sqrt{N_\phi} \left(N_\phi^2 - 1 \right)$$

$$N_q = N_\phi^2$$

$$N_\phi = \tan^2 \left(45 + \varphi / 2 \right)$$

For settlement, the following function will be used and for different conditions. First the footing is placed on the level of the laterite layer containing scoriate dolerite basanite blocks, then the footing is placed on the dolerite basanite layer. The succession of layers is shown in the Figure 2 and they are suffisently thick.

$$\delta_v = C_d q B \left(1 - v^2 \right) / E \qquad (16)$$

m, s and a are constant of Hoek-Brown criterion.

σci, σcm is unconfined compressive strength of intact rock and unconfined compressive strength of the massif. σt is the uniaxial tensile strength. D, c, φ are factor of disturbence, cohesion and friction angle.

Cf1, Cf2 and Cd are correction factor for foundation shape

qu and qa respectivly ultimate bearing and beaing pressure

Nc, Nγ and Nq are respectively factor due to the cohesion, to the weigth of terrain and to the surcharge.

3. Geographical and Geological Setting

Geographically speaking, the excavation is located at the west frontage of the coast head of the peninsula of Cap-vert between Ngor and Cap Manuel, near Cheikh Anta Diop University, and around hotel Radison. This very part of the peninsula is impacted by the NW swell during the whole year. This swell modulates frequently its morphology. The altitudes of the excavated part of field are highlighted on Figure 1. The representation of topographic data plays a major roles because it permits to identify the topographic level corresponding with the escarpments. The equidistance of level's curves is 0.5 m and the major curves are separated by four graduations. The first escarpment is located between the level's curves 21 m and 27.5 m on average where the dip slope is vertical. The second escarpment, with sub-vertical slope, is delimited by the level's curves of 28.5 m and 32.5 m. Beyond that, the surface of the ground on the ledge is almost flat. Other swells, SW and tidal waves, more intense and less frequent are also noted. On this frontage, volcanic rocks of quaternary outcrop. The lithology of this volcanic formation is characterized by it interstratifications with the quaternary sands [15]. It is subdivided into three sequences':

- The lower volcanism corresponding with flow of basalts with bubbles that are altered now and surrounded by cinerits ;
- The medium volcanism represented by some flows of which the highest part, the thickest one, is a dolerite and the others are four layers of basanits or basanitic dolerites which alternated with fine layers of sands and tuffs ;
- The upper volcanism that corresponds with successive flows of basanits taking palace on the tufs. The highest entity is dolerite located on the basanits.

In tectonic point of view [15,16], the Senegalese basin shows two major fractures: the one oriented E-W is the consequence of the separation of African and south American blocs that results in formation of the Cap-vert peninsula elevation. The second one oriented N-S was formed after the toppling of blocs during the rifting phenomenon which conducted to the fracture that has later growth mentioned. The discontinuities of the quaternary are essentially the consequence of the replay of the sus-nommed structures. There are also others that were formed by withdrawal of lavas that conducted to the formation of prismatic basalts. It is also important to note that volcanic process generated secondary fractures because of the high stress of the lavas on the rocks.

The aquifer of this sector is represented by the infrabasaltic sands wich separate the Tertiary that is composited by marl and claystones and by the quaternary volcanic. This aquifer is around of the ocean and this geometry led to the apparition of salter bevel [16].

The western edge of the Cap-vert Peninsula presents an orientation depending on the location. Between Ngor and Yoff, The coastal cliffs are oriented ENE-WSW. Between Yoff and the Cap Manuel, the global orientation of the coast is NNW-SSE and at last between Cap Manuel and Bel air the orientation is N-S. These orientations depend on the relation between the tectonic and the fragmentation of Pangaea.

The three dimensional (3D) representation of topographical data draws the diagram block in the figure below (Figure 2). Therefore, the diagram shows the bottom level of the excavation area which colors vary from dark green to dark brown. This part of the figure represents the level's curves in three-dimensional and where different facies of the excavation are positioned. Then, the lower cutting face of the excavation with dark colors between green and ashy brown is characterized by the presence of rocks and some interlaid in laterits. It is followed by that scoriaceous basanitic dolerites in ashy grey color area and the lateritic associated with blocks of scoriaceous dolerites in the ochre color area. The ledge between the very cutting faces varies in dark pink color. This set corresponds with different facies of the low cutting face. The higher cutting face where we notice the blocks of scoria diffused through the lateritic soil is represented essentially into blue-shaded color. At last, this figure corresponds with the three dimensional representation of level's curves of Figure 1 and its lithological facies.

Geological characterization of the excavation: Despite the small dimensions of the excavation, we can notice a geologic complexity in the site. The geological component is summarized in the stratigraphical logs in the figure below (Figure 2). From a point to another, there is a change of the lithological sequence which components are highlighted in the half of the NE side of the excavation. This site has been divided into two superimposed excavations.

As for the lowest escarpment, from SSE to NNW, there is a stratigraphical log in the first part of the figure

(Figure 2a) which shows 3.5 m of scoria and 2.6 meters of laterite. This log is therefore 6.1 m thick. The second one (Figure 2b) corresponds with a bloc of scoria inserted between two layers of mixture of blocks of pumice and lateritic entities. The first layer is 3.2 m thick whereas the second layer is 0.3 m thick. The scoriaceos basanitic dolerite layer is 2.5 m thick. The third stratigraphical log (Figure 2c) is 5.5 m thick and it is exclusively composed by some dolerites. In the fourth log, we have a scoriaceous basanitic dolerite facies of 4 m of thick on which is deposed some layer of block of scoria intercalated in laterites with 1 meter thick (Figure 2d). For the higher escarpment, we have homogeneous facies represented by some blocks of scoria contained in some lateritic matrix. The dimensions of scoria blocks are variable with a thickness higher than 1 decimeter (dm) (Figure 2e). This lithological morphology of the excavation gives evidence the implementation of the dolerite in the lateritic soil or its lateritic alteration. Furthermore, this attests that the magmatic lavas percolate in the soil.

Structural analysis and stereographical stability: In this site the tectonic is characterized by a number of joint set restricted 3: They are characterized by a concentration of their poles in the NNW-SSE area, the WSW-ENE area and in the center of the stereograph (Figure 3). The two first joint sets show some high dip angles whereas the third one is a very low dip angle. The latter joint set is composed by mini-tension cracks that are discontinued cracks and which are average orientation of the discontinuity. Their layout and dimensions confer to them a certain rigidity and prevent them from contributing to the sliding of the rock blocks

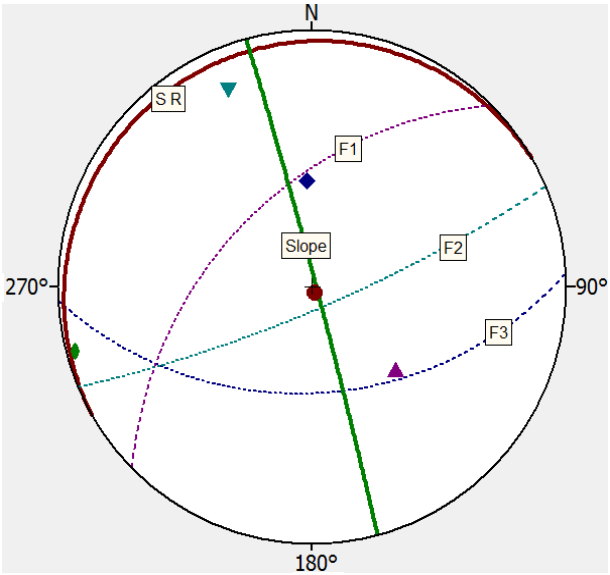

Figure 3. Pole density diagram of the basanitic dolerite rock mass

As for the stability analysis, the dolerite rocks form a whole dihedral seeing at the intersections between the plans (Figure 3). However; the bedrock is orientated in the direction of the sub-horizontal family. Consequently; its orientation is not favorable to sliding. Therefore, despite the formation of the dihedrals; the landslide appears to be very difficult. Joints are also discontinuous and for foundation works, they cannot cause dihedral movement. The friction angle makes impossible a movement of block.

4. Results and Discuss

4.1. Laboratory Test

A few identification tests have been done on the lateritic fraction of the rock mass. Among these tests, those of Atterberg limits, the Proctor test, the Californian Bearing Ratio (CBR) test and the specific weight of the solid grain were determinant in this work. In addition to these tests, uniaxial compression tests on the rock blocks and the shearing of the laterite have also been taken into account. For the tests of Attenberg limits, we have a liquid limit (LL) of 51.5% and plastic limit (LP) of 26.47%. So, the plastic index of this laterite (IP) is 25.03%. This value corresponds with a plastic soil. The Proctor test permits to define the maximum water content which permits to obtain the maximum density of compaction. So, after operating data of modified Proctor test, we have obtained maximum water content (ω %) of 13.06% corresponding with a maximum density of 16.4 kN/m^3. The CBR (Californian Bearing Ratio) test has also been carried out on the lateritic fraction of the rock mass. The value of the CBR is defined on the soil compacted and soaked for four days. The method of West African Compaction [17] is used and the index for 10 blows, 25 blows and 55 blows. The value of the CBR determined by this method is 54.74. The shearing tests are carried out on the lateritic fine fraction of the rock mass. These tests permit to obtain a cohesion of 77.29 kPa and a friction angle of 14.90° for argilaceous particles. These are characteristics of clay. Uniaxial Compression Tests are carried out on the basanitic dolerite, scoria and block of scoria into lateritic rock mass. Result are res pectivelly 60 Mpa, 41 Mpa and 31 Mpa.

4.2. Use of Rock Mass Rating Classification

Basanitic dolerite rock mass: With regards to rock mass classification, the assigned rates depend on uniaxial compression strength (UCS) of the intact rock, the average spacing of joints, the nature of discontinuities, Rock Quality Designation (RQD) and the hydrogeological conditions of the rock mass. According to field parameters and laboratory tests, assigned rates will permit to determine the RMR value. We obtain the following rates 4 for Uniaxial Compression Strength, 17 for the RQD, and 8 for the spacing of discontinuities. on top of these ratings, those related to the nature of discontinuities and the hydrological state are used. The joints observed in the study windows show global lengths comprised between 1 and 3 m. The most critical apertures are between 0.1 and 1 mm wide. In fact, the hanging walls are completely contiguous. Therefore their apertures are nil. The hanging walls are very rough and moderately altered with unfilled discontinuities corresponding with nature of discontinuities ratio of 22. The excavation has been processed in dry conditions. So, we can assign 15 as rate at the hydrological state of rock mass. And finally, the basic RMR value is 66. The site consists of opening an excavation. The excavation is shaped in a direction perpendicular to that of the discontinuities, in the same position as the dip direction. This implies an adjusting rock mass rate of -2. Finally,

Rock Mass Rating for the basanitic dolerite is 64 corresponding with good quality rock mass.

Lateritic mass and blocks of scoria contained into the laterite: The composition of the rock mass is very complex and blocks of scoria can either be contiguous or not. Furthermore, they can be separated by a lateritic matrix or a clayey shell which source would be derived from the basanitic dolerite or scoria. Therefore, the rock mass rate index is 21 to 24 corresponding with a poor rock mass quality.

4.3. Geological Strength Index (GSI) for Lower Escarpment

For the basanitic dolerite : This portion belonging to the lower face shows an undisturbed intact rock mass composed of scoriaceous basanitic dolerite, well interlocked and formed by 3 families of discontinuities (Figure 4a). The surfaces are sometimes in red hot iron color, rough and slightly altered. This corresponds with a GSI value of 62±5. Therefore, it is a good quality of rock mass.

Blocks of scoria scattered in a lateritic substance: This rock mass corresponds with a strongly crushed rock mass, badly assembled with a mixture of rounded and angular rock pieces (Figure 4b). The surface draws smooth outlines and is strongly altered coated or filled with plastic clay. These characteristics correspond with GSI of 21±5 and consequently a very poor-quality rock mass.

The Backfill: It corresponds with a heavily broken rock mass, poorly interlocked, with mixture of angular and rounded rock pieces (Figure 4c). It also draws characteristics as Slickensided rock, heavily weathered surfaces, with compact coatings or fillings by angular fragments. The GSI index of this mass is 21±5. The rock mass is of a very poor quality. But a foundation study will not be conducted on these materials because it serves for stabilization.

4.4. Geological Strength Index (GSI) for Upper Escarpment

This cutting face is very complex if we consider its configuration and morphology. It consists of a strongly crushed rock mass, badly assembled with a mixture of round and angular rock block (Figure 4d). The surface draws smooth outlines and it is strongly altered in coatings and filled with plastic clays. This corresponds with a GSI of 15±5.

4.5. - Definition of Rock Mass Properties and Foundation Calculation

For these rock masses, the study is done using the geomechanical characteristics resulting from the field studies and laboratory tests. These properties will make it possible to determine using the Mohr-Coulomb equivalence models in order to define parameters that are intrinsic (Table 1) to the massifs in order to use the finite element model code PLAXIS. Figure 5, Figure 6 and Figure 7 show the break curves for doleritic basanite and Block of scoria scattered in lateritic soil, respectively in principal stress space (Figure 5a and Figure 6a) and shear - normal stress sapce (Figure 5b and 6b). They permit to obtain results summarized in Table 1. The maximum value of the minor stress is higher for basanitic dolerite (10.25 MPa) than in Block of scoria scattered in lateritic soil (7.75 MPa). This variation is also noted for cohesion and angle of friction.

Figure 4. Image of studies facies (a. Basanitic dolerite; b. Block of scoria scattered in lateritic soil; c. Assembling blocks of gravel of dolerite; d. Rounded and angular blocks of dolerite linked by clay or laterite)

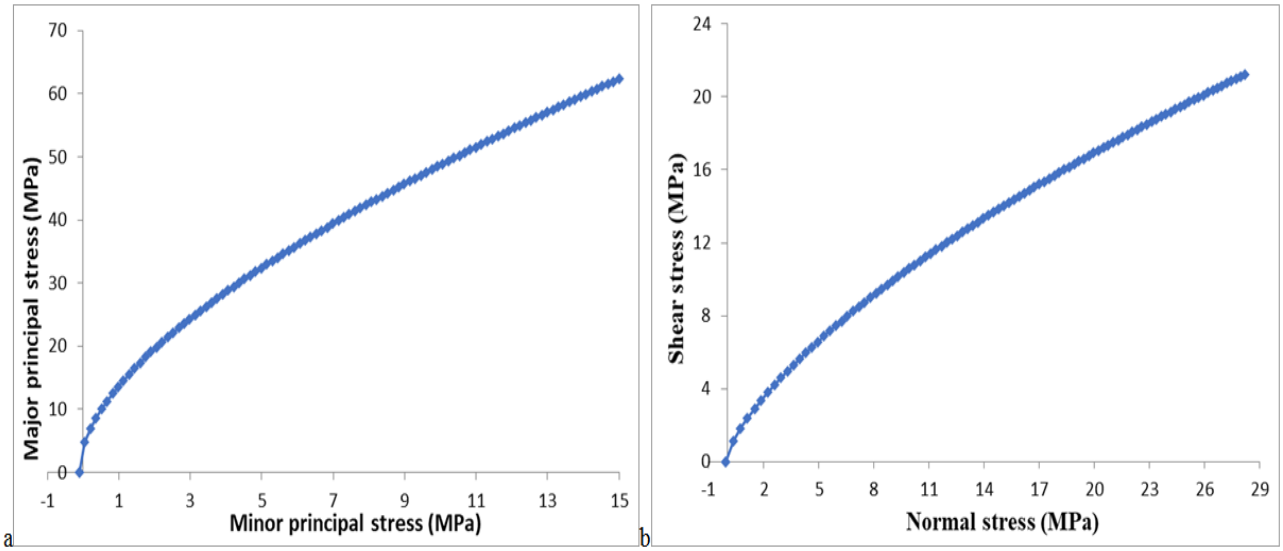

Figure 5. Stresses states of the basanitic dolerite (a. Principal stresses ; b. Shear stress vs Normal stress)

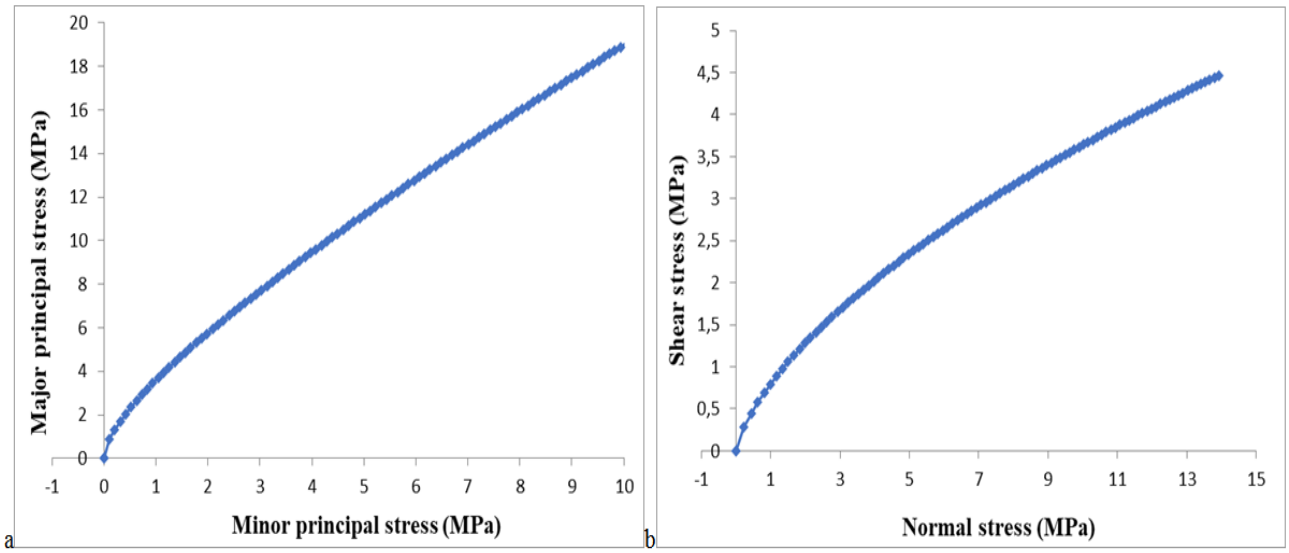

Figure 6. Stresses states of the Block of scoria (a. Principal stresses ; b. Shear stresses vs Normal stresses)

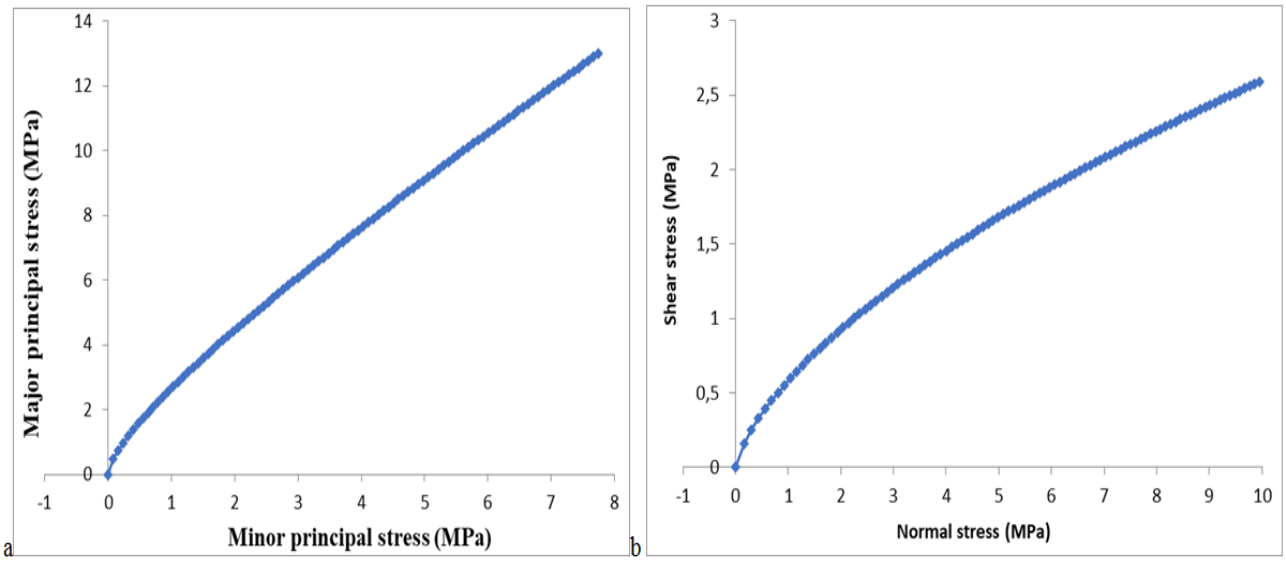

Figure 7. Stresses states of the Block of scoria scattered in lateritic soil (a. Principal stresses ; b. Shear stresses vs Normal stresses)

Table 1. Geomechanics' parameters of the site formations

	Parameters	Basanitic dolerite	Bloc of Scoria	Bloc in laterite
GSI classification	sigci (MPa)	60	41	31
	GSI	62	21	15
	mi	20	19	18
	D	0.7	0.7	0.7
Hoek Brown criterion	mb	2,47891	0,247531	0,168645
	s	0.00405726	1.07E-05	4.47E-06
	a	0.502459	0.540887	0.561101
Failure Enveloppe Range	sig3max (MPa)	15	10.25	7.75
Mohr-Coulomb Parameters	c (MPa)	3.40732	0.810674	0.459801
	phi (°)	33.8423	15.6058	12.8127
Rock Mass Parameters	sigt (MPa)	-0.0982027	-0.00176521	-0.00082108
	sigc (MPa)	3.77038	0.0838105	0.0308651
	sigcm (MPa)	12.774	2.13627	1.15223
	Em (MPa)	10045.9	783.981	482.608
Foundation calculation				
	H	5.48	3.49	3.5
	Semelle L=B	3		
	Cf1	0.7		
	Cd	0.99		
Bearing capacity results	qu	19.57760812	0.914899081	0.458193557
	qa	6.525869372	0.30496636	0.152731186
Bearing capacity results	equation (13)			
	qu	12.7734	2.13627	0.9659
	qa	4.2578	0.71209	0.32196667
Equation (14)				
Bearing capacity results	qu	17.9182971	1.69403506	1.07080801
	qa	5.97276569	0.56467835	0.356936
Equation (15)				
	Nc	6.85227975	7.20995081	4.62048
	Nɤ	1.12986552	1.32670305	0.17584045
	Nq	2.75412605	3.01383488	1.32762706
Bearing capacity results	qu	29.1848873	7.30614958	2.65562666
	qa	9.72829576	2.43538319	0.88520889
Settlement		5.84819E-05	0.000749384	0.001217351

Due to the absence of a standard or recommandation, the choice of the sizing method is often free in Senegal and practitioners logically use the cheapest and least expensive ones. If the foundation is laid on the layer composed of dolerite blocks into laterite material resting on the rigid scoriaceous basanitic dolerite layer, then the displacements are more remarkable (Table 1) but remain acceptable. Even if the dolerite massif is cracked, these cracks being very closed and discontinuous, it would be preferable to lay the foundation there. The installation of the latter on the pumice basanitic dolerite block massif in the laterite is risky due to the strong heterogeneity of the environment even if the bearing capacity and settling seem to have remained below acceptable values. This study shows that by using different calculation methods, widely dispersed results are obtained both according to the difference in terrain and also for the same massif (Table 1). Settlements are more important for altered bloc of scoriaceous dolerite in laterite than for bloc of scoriaceous bloc of dolerite and at last pumice basanitic dolerite. Results are summarized in Table 1.

In another hand, Construction sites are visited on different locations and rocks supporting the structure correspond with one or another of the formations that are identified in the excavation area. It is noticed prematured cracks and sometimes before the end of the construction. The calculations done by the engineers give correct results. However, we noticed that they didn't take into account the composition and the complex behavior of the rocks. Those who take into account the complexity of the rock summarized their design with the use of the RQD whose value obtained depends only on the location of the borehole and its inclination. Case of buildings with prematured cracking are shown in the figure below.

4.6. Stability and Foundation Analysis Using the Code PLAXIS

This model represents the first stratigraphic log where we have a rock mass composed by blocky scoria associated to some laterite and which is deposed on a massive scoriaceous basanitic dolerite that is fractured. The deformations of this domain are focused on the upper escarpment corresponding with the blocky scoria included in the laterite. The total displacement of the unload rock mass is estimate to 87 micrometers (Figure 8). Some instabilities are noted in this escarpment.

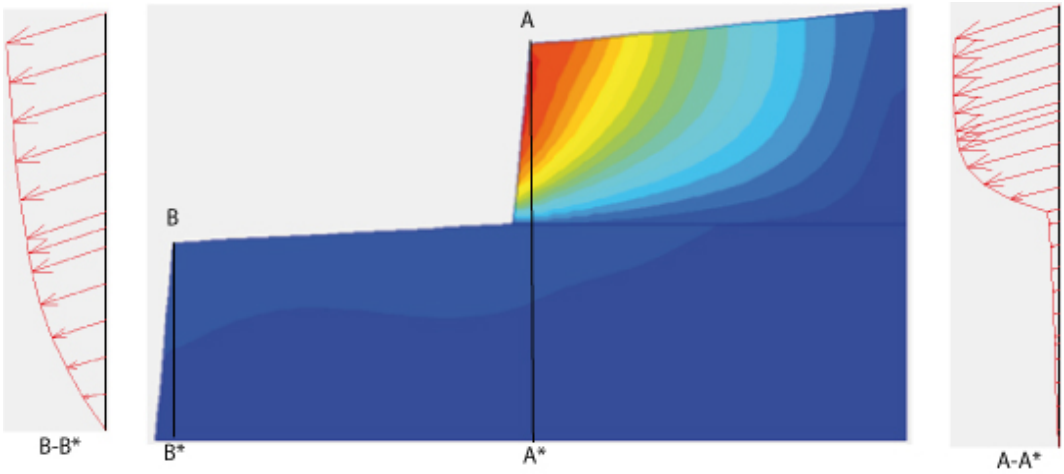

Figure 8. Behavior model of the rock mass of Figure 2a (Total displacement Extreme total displacement (86.21 10^{-6} m (A-A*) and 6.62 $^{10-6}$ m (B-B*))

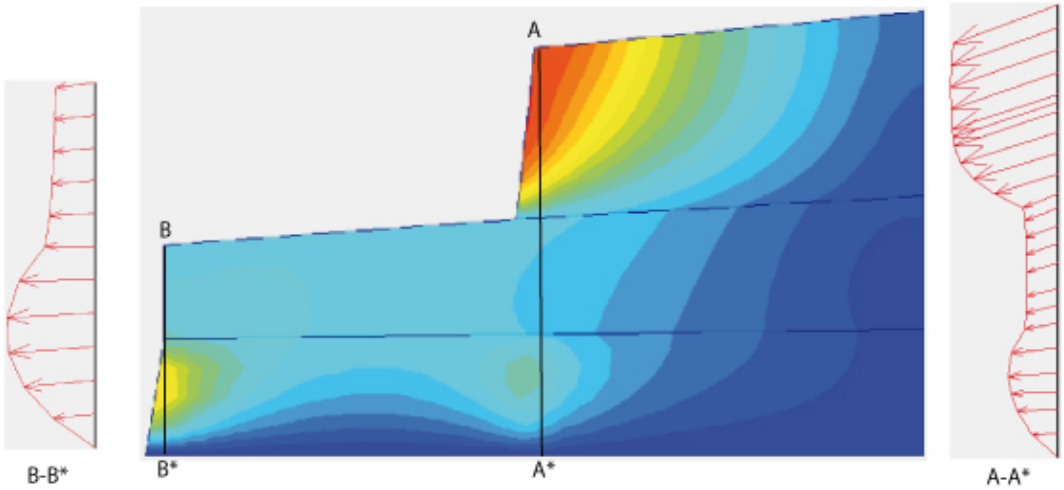

Figure 9. Behaviour model of the rock mass in Figure 2b (Total displacement Extreme displacement (84.99 10^{-6} m (A-A*), 35. 18 10^{-6} m for the middle layer and 63.32 10^{-6} m (B-B*))

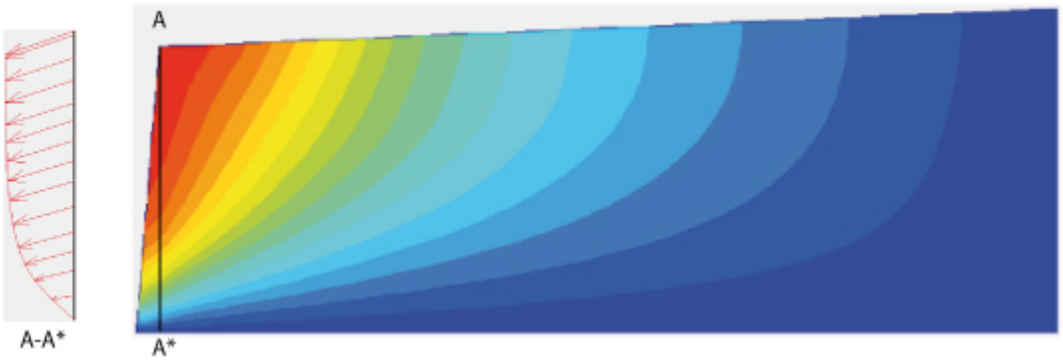

Figure 10. Behavior model of the back fill (Total displacement Extreme total displacement (82,72 10^{-6} m (A-A*))

The model of the Figure 9 corresponds with a succession of three layers represented by a scoriaceous basanitic dolerite entrapped between two layers of blocky scoria associated to some laterites. Model of this section shows displacements on all the three layers. The total displacement is around 85 micrometers. Instabilities can arise from any one of the three layers. But they are most represented on the upper and the lower layers. They can be neglect in the scoriaceous basanitic dolerite layer.

Model of the figure (Figure 10) shows the behavior of the SE section of the excavation where the rock mass is composed of some nested blocks and gravels. This facies corresponds with the backfill. It is characterized by the lack of fine clay particles. The total displacements are around 83 micrometers. This part of the rock mass shows low values of displacement regarding layers which deformed.

When using PLAXIS finite element code stresses applied on coriaceous basanitic dolerite by the foundation do show acceptable loads and displacements. It is only necessary to support the rock mass that is constituted by scoriaceous bloc of dolerite contained in lateritic matrix (Figure 11).

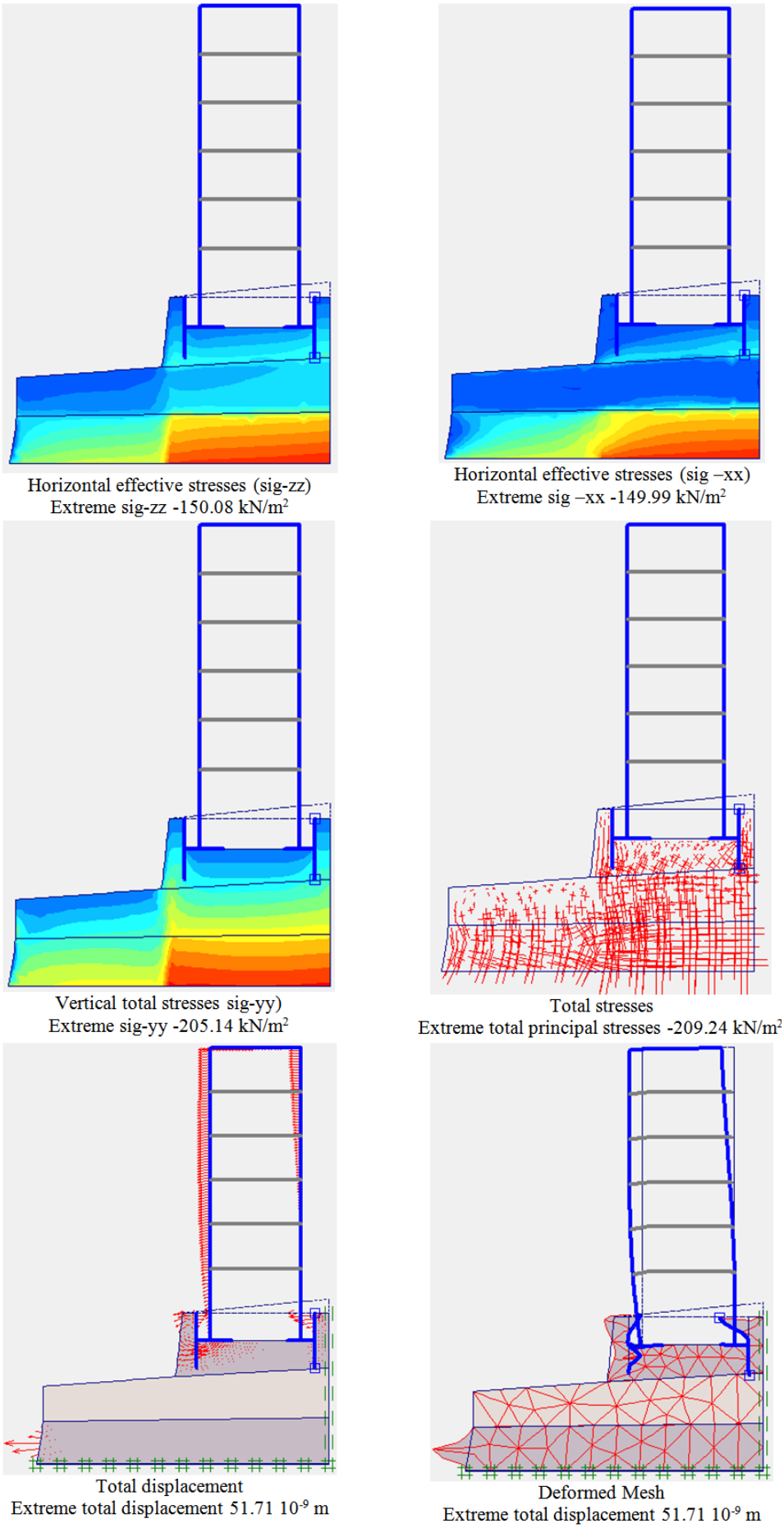

Figure 11. Model of the interaction between foundation and Rock

5. Conclusions

The study area corresponding with the area of Fann-Ouakam-Almady is composed by rock facies that are summarized in an excavation composed of three rock facies. The first facies is a massive scoriaceous basanitic dolerite corresponding with a good quality igneous rock. The second one is a mixture of scoriaceous dolerite blocks and laterite whose proportions and alteration for one or another of these facies vary which show fair to poor quality rock mass. The blocks in these rock mass that may support foundation stable. Even if the bearing capacity remain admissible, the impact of the structure on the behaviour will remain largely dominated by the difference in stiffness between the rock blocks and the argilo-lateritic component. It is now more than important in Senegal (especially in the western cornice) to look for a model of sizing more adapted according the rock masses that will support foundation. These foundation studies do show that using the PLAXIS code, the main instabilities are observed on the materials constituted by blocks of scoriaceous dolerite associate to some laterites. Numerical Distinct Element would be used in these cases of study to account more.

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