Studies of soil degradation, synthetic evaluation of the direct consequences on the landslides of bridges in Southern-Guinea

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Abstract. The lifespans of bridges have become very short in Guinea. They partially collapse, until they fall completely. To understand this scourge and provide some answers, we have conducted more than fifty surveys among neighboring populations and certain professional services (those in charge of studies: climatic; hydrological; agricultural and public works). One problem emerges in common: soil degradation. Lola (border town with the Ivory Coast) is said to have cut itself off from the rest of Guinea after heavy rain. Because? The bridge that linked it to the rest of the country would have collapsed after a complete degradation of its support: the ground. In Kérouané (another city in Guinea), landslides are permanent and cause certain bridges to collapse. The results of our surveys show that with the alternation of the seasons, these soils (lacking scientific and professional studies) undergo degradation and lose their initial states of stability. Our research work and their results support the need for a basic geotechnical study before the start of any project. This could prevent any probable socio-economic impact caused by soil degradation in the regions.
1. Introduction
The degradation of soils (mentioned here to designate all the causes of their transformations: chemical, mineralogical, structural, textural and volume) is a phenomenon whose realities are on a planetary scale. Although known in most nations around the world this, involving studies of several disciplines (such as geotechnics, soil science, public works, buildings, agriculture etc.); large professional firms and scientific institutions, it’s still unknown in almost all African countries.

In West Africa in general, in Guinea in particular, over the past 80 years, several studies on soils have been carried out by different authors and for different reasons. Despite this multiple work, given the importance and the socio-economic issues that undermine them on a daily basis, another work of capital importance remains to be done: that of being closely involved in their understanding before their implementation, during their moment of stability (with their parameters of stability) and what they could become after their training when they are subjected to new conditions of stability.

Several studies [16,23] index the climate as being the main factor of this phenomenon. This’s the case of Guinea-Conakry where the latter, said to be tropical, is characterized by two seasons: one dry (hot) and the other heavily rainy (wet). The nature of the bedrock (involving their chemistry and mineralogy) of soils (their physical, mechanical and hydromorphic characteristics); the topography and the time factor are, among other things, not insignificant causes in the degradation of soils in Forest Guinea (southern of Guinea). This explains the findings of residents of the gradual destruction of bridges.

Given the logic of the objective of the work, namely to be based on all the previous geological, hydrological, climatic, pedological and geotechnical data available and within our reach, to situate the problem of soil degradation, we’ll follow as a drafting process, a combined set of the IMRAD model with a dynamic that will allow us to present our added value.

This’s how, with a triple aim, we’re carrying out this review of articles [1,2,14]: first by evoking in detail the soils of Forest Guinea as seen by various authors, from their formation, to bad weather and factors (internal and external) which affect them post-formation and cause their degradations. Then, to explain the collapses of bridges (as in Lola and Kérouané) this, by providing our experience feedback on magazines related to soils. Finally, to open up a hypothetical and justified range of geotechnical solutions to prevent and prevent possible bridge collapses.

To achieve this, we’ll discuss:
(a) A presentation (geographic and geological) of the study region;
(b) Materials and methods: for data acquisition and processing;
(c) Results and discussions, then geotechnical suggestions: to identify the causes responsible for soil degradation in the region and prevent them.

2. Methods
2.1 Study Area
Guinea includes four natural regions: Lower Guinea, Middle Guinea, Upper Guinea and Forest Guinea (main target area for this work).
2.2 Geology and hydrology of the region

In its entirety (including its West African context) and in specific ways, the geology of Guinea has been studied by several authors [10,2,3,5,8] Southern-Guinea includes the oldest rocks in the country and some of the oldest in the world. They’re characterized by Neoarchean and Paleoproterozoic formations, surmounted by the Mesozoic and Tertiary-Quaternary.
Fig. 2 Geology of southern Guinea

The hydrological system of Guinea has known old and recent studies, made for various reasons, by various authors [11, 13, 14]. That of the Southern-Guinea has at least six (6) watersheds and is intimately linked to its climate which, according to the National Meteorological Directorate (DNM), is twofold: one known as forest or subequatorial Guinean and the other Sudanese. The region experiences a rainfall (lower during the harmattan) which can last 8 months and which would be due, like the dew, to the saturation of humidity. Temperatures are almost stable all year round. The air masses circulating there are humid (monsoon) and dry (harmattan).

2.3 Material

The geological material used for the knowledge of the facies is composed among others: compasses; GPS; magnifying glasses; hammers; backpacks; topographic backgrounds; pencils; scanning electron microscopes; old maps; satellite images; digital data processing software such as ArcGIS, MapInfo and Global Mapper. Knowledge of the hydrological network, as well as of all meteorological and climatic data was obtained by: at least 18 meteorological shelters comprising psychrometers (dry and wet thermometers), maximum thermometers, minimum thermometers, evaporometers, thermographs and hygrographs; rain gauges (composed of receiving rings of 400 cm², placed 1.5 meters above the ground surface, collecting buckets with a capacity of 7 liters or sometimes 12 liters and test tubes graduated in millimeters and fractions millimeters of rain); pluviographs; anemometers; weather vanes; heliographs; mercury barometers; barographs and satellite data collection and transmission systems; data processing software. Sampling (in trenches and in quarries for the most part) of the land was carried out by pickaxes; resistant metal cylinders (respecting standards) and shovels. The samples are put in plastic bags. The laboratory devices are: particle size sieves; volume ovens; the dome of Casagrande; charts and data processing software.

2.4 Methods

The method used to produce this summary article is that of a bibliographic collection (old theses, articles, reports from ministries, conferences, etc.); polyphase data mining and the creation of a final database. 164 documents were analyzed: 74 geological; 30 hydrological and 66 related to soils. These various data are complementary. Their sum will produce a (new) plural hypothesis which should lead to a range of soil stability. We’ve combined the results of all these data with the aim of going out to achieve a finality: to understand the degradations of the soils, by going back to their sources of formation. The strategy used makes it possible to make a correlation between the degradation factors, the degraded elements, their products and the durability of the latter.

3. Results and Discussion

The prefecture of Lola has formations of the Neoarchean; the Paleoproterozoic; Mesozoic and Quaternary. Kérouané (border with Kissidougou, Macenta and Beyla of Forest Guinea) is made up of
Neoarchean formations; Paleoproterozoic; Neoproterozoic (very local); Mesozoic and Quaternaries. The results obtained by the authors agree on the fact that geologically: the Neoarchean consists of Schists, Gneiss, Granites and Quartzites. The Paleoproterozoic mainly comprises: Quartzites; Gres quartzitoides, Schists; Potash and felsic gneisses; Amphibolites (Tholeitiques, MORB); Pegmatites and Basalts (TALE Mohamed Samuel Moriah, 2019; Geological map of Guinea 1 / 500,000). The Mesozoic includes Dunites; Peridotites; Gabbros, Norites; Pyroxenites; Syenites and Kimberlites (Geological map of Guinea 1 / 500,000). The Tertio-Quaternary would be little represented in the south and would include lateritized formations (Geological map of Guinea 1 / 500,000). By way of example, the chemistry and mineralogy of three types of Gneisses (G1, G2 and G3) are shown in the table below (Table 1).

Table.1 Chemical and mineralogical results of some Gneisses in southern Guinea [24]

| Chemistry | G1 % | G2 % | G3 % | Mineralogy | G1 % | G2 % | G3 % |
|-----------|------|------|------|------------|------|------|------|
| SiO₂      | 65.55| 74.55| 50.60| Quartz     | 24.44| 44.96| 2.64 |
| Al₂O₃     | 19.30| 14.85| 17.52| Ortho     | 9.82 | 21.41| 3.66 |
| TiO₂      | 0.12 | 0.18 | 0.70 | Albite    | 32.28| 11.83| 11.83|
| Fe₂O₃     | 2.93 | 0.70 | 6.50 | Anorthite | 19.19| 14.30| 39.64|
| FeO       | 0.42 | 0.22 | 1.25 | Al₂O₃ libre| 4.17 | 3.37 | -    |
| MnO       | 0.05 | 0.15 |     | Hypersthene|      |      |      |
| CaO       | 4.05 | 2.88 | 13.57| SiO₂, FeO | 4.83 | 0.90 | 5.90 |
| MgO       | 1.40 | 0.68 | 6.85 | SiO₂, MgO | 3.50 | 1.70 | 10.48|
| Na₂O      | 3.82 | 1.40 | 1.40 | Magnette  | 0.61 | 0.32 | 1.81 |
| K₂O       | 1.66 | 3.62 | 0.62 | Ilmenite  | 0.23 | 0.34 | 1.33 |
| P₂O₅      | 0.14 | -    | 0.21 | Apatite   | 0.33 | -    | 0.48 |
| H₂O⁺      | 0.74 | 0.52 | 0.62 | Diopside  |      |      |      |
| H₂O       | 0.16 | 0.17 | 0.05 | SiO₂, FeO, CaO | 4.36 | 7.03 |      |

In the West African sub-region, knowledge of soils and their uses have been the subject of several studies by different authors [22, 20, 19]. In Guinea, the subject is still very limited. The studies carried out are sometimes old [24]. Among recent studies, in combination with older ones, the ferrallitic trend is the most widespread throughout the territory. The encountered in Southern-Guinea(CPCSClassification) are: leached ferruginous soils; leached tropical ferruginous soils; ferrallitic soils; hydromorphic soils or gleysols [10]. They would be heavily armored at shallow depths [24]. The nature of their source rock and its composition play a very important role in the future chemical and mineralogical composition of the soil. As an example, we present below chemical analyzes carried out on soil crusts from diorite (Table 2).
Fig. 3 The soils of southern Guinea

Table 2 Results of a chemical analysis on a soil shell in the south

|        | H₂O | SiO₂ | Al₂O₃ | Fe₂O₃ | Insolubles |
|--------|-----|------|-------|-------|------------|
|        | 10.12% | 19.45% | 22.06% | 38.42% | 9.15% |

The average annual precipitation of southern Guinea is estimated between 1600 mm mini and 2800 mm maximum (1800 mm/year in Lola). The mean annual minimum daytime temperatures would vary between 25°C and 29°C (32°C and 34°C in March). The average humidity would be around 80% (90% max). Evaporation is very low (very high rainfall and humidity). It’s the seat of the watersheds: Sassandra; Cavally; Mani; Diani; Lofa and Makona [13].

Fig. 4 Rainfall, temperature, humidity and winds in southern Guinea
Several studies to reconcile climates and soils have been carried out in West Africa in general, in Guinea in particular [17, 16, 23]. The climatic characteristics of southern Guinea, coupled with the hydrological ones presented above, define a most favorable environment for the physicochemical and permanent decomposition of rocks. Following the hydrolysis phenomenon, the latter deteriorate and release their compounds (oxides and hydroxides of iron and aluminum; oxides of titanium and manganese, as well as siliceous compounds). These alteration products accumulate over time and form soils with a composition mainly made of Kaolinite (OH)₄Al₂Si₂O₅ (which marks the state of mineralogical stability of the majority of ferruginous soils) or Gibbsite: yA1208.3H2O (which marks the state of mineralogical stability of the majority of ferrallitic soils); Corundum (αAl₂O₃); then incidentally Goethite (αFe₂O₃, H₂O); Hematite (Fe₂O₃); Magnetite (Fe₃O₄); Ilmenite (FeTiO₂) and Quartz (SiO₂: strongly affected in rocks because of ferrallitization which’s intense in the south. It disappears completely in dolerites, unlike Gneiss and Granites). These are often wet for reasons of low evaporotranspiration. Generally saturated, they undergo oblique movements of the water which has a high degree of leaching, thus creating horizons: leached, hydromorphic and impermeable. In addition to these minerals, we can note, in descending order, the ease of alteration of pyroxenes, amphiboles, chlorites and peridots; then biotite, foids and feldspars. Unlike zircon, rutile, etc., which are very resistant.

Due to the very advanced rainfall, very low evaporation, favorable environmental conditions, very advanced drainage, the soils of southern Guinea see their conditions of stability destroyed. Ferrallitic soils (SiO₂ / Al₂O₃ between 1.3 and 2 or less than 1.3) contain free alumina, in the form of Gibbsite (γA12O₃.3H₂O). Ferruginous ones, very leached (iron migrates easily within them), are rich in sesquioxides of iron and non-free alumina in the form of Kaolinite (OH) 4Al₂Si₂O₅. These two previous types often reach so-called hydromorphic stages when they are in favorable drainage and topographic conditions. They, then form hydromorphic soils rich in organic matter in their surface parts. Constantly subjected to these bad weather conditions, not leaving them in their so-called formation state of stability, it’s important, even essential, to devote to them a basic in-depth geotechnical study before imposing on them any bridge or other work. It’s within this framework, that taking into account their realities exposed in this present synthesis, we suggest to follow the following strategy which we ourselves intend to carry out in our close studies to alleviate the problems of landslides of bridges recorded in the southern of Guinea, in particular in Lola and Kérouané: a- to know in detail their grain sizes; b- evaluate their water content; c- determine their plasticity and liquidity; d- to evaluate their rupture and consolidation parameters, especially the permeability, the main characteristic of which’s to drain water within the soil and destroy their cohesion, then e- the limiting pressures that they are able to withstand. Do this study before and during the peak rainy season.

4. Conclusion
The south of Guinea has decidedly unstable soils. This’s due to several factors, the main ones being: source rocks providing chemistry and mineralogy which are not very resistant to weathering once they become major components of soils; topographic areas accessible to water and favorable to drains; very low evaporation and evaporotranspiration due to the very recurrent rainfall in the region (up to 8 months / year) when the monsoon with very high and permanent humidity. During harmattan, the wind is very dry and dusty. Both for ferrallitic and ferruginous soils, the meteorological and hydrological conditions are such that over time they evolve towards a hydromorphic tendency. Once they reach saturation, their stability limits are strongly impacted and they then lose their cohesion. In strongly drained environments, Kaolinite undergoes destruction of its sheets, the alumina becomes free and tends towards Gibbsite. This makes the soils more vulnerable. To prevent these works collapses in southern Guinea in general, Lola and Kérouané in particular, in-depth geotechnical studies remain essential. These must be used as a basis for the civil engineering calculations on which the structures must be dimensioned. Given the main factors in the destruction of soil stability states in the region, it’s important to accurately assess all their hydromorphic physical and mechanical parameters, while defining the correct anchoring depth for the structures they will have to bear.
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