Chapter

Construction Materials and Dam Foundation While Memve'ele Dam Building in the Craton's Region of South Cameroon

Sylvestre M. Ntomba, Christelle R. Magnekou Takamte, Dieudonné Bisso and Joseph Mvondo Ondoa

Abstract

This chapter mainly focuses on engineering geology for dam construction from the Memve'ele region in Cameroon. Here, it deals with geotechnical and geological proprieties of both construction and dam foundation materials. This study is done at the aim to ensure that these materials need to be improved and how they have been used during dam construction. Field investigations, borehole information, density and seismic velocity measurements have been used, and results indicate that soil deposits have slightly clay content, mechanically well for dam construction and display a weak thickness layer particularly on the dam site. These conditions suggest that soil materials can be used as construction (cushion, transition layers, etc.) and foundation materials after few amendments. Ntem Formations appear weathered and fractured sometimes, though their mechanical behaviors display a good character for civil applications. However, engineering processes have been used to improve it by GIN (Grouting Intensity Number) methods. These formations have been used as construction (rip rap crushing aggregate, etc.) and dam foundation materials. Thus, this chapter contributes to highlight materials and dam foundation conditions which are crucial criteria encountered in the dam with emphasis on both theoretical study and practical application during dam construction.

Keywords: geophysical measurements, geological assessment, geotechnical characters, quaternary deposits, Ntem Formations, Memve'ele dam, Cameroon

1. Introduction

The building for dam required a need for better understanding geological and mechanical properties of investigated sites. This process leads to a comprehensive site characterization and contributes bringing additional work when construction and dam foundation materials need some requirements in order to improve it. These additional works lead maintaining dam stable during his service life. Rock physical and mechanical properties are very important parameters for geological engineering design and construction of dams. Given the number of factors in the designing and construction of dams it can be referred primarily to locally available materials and dam foundation conditions whether these factors fulfilled both geological and geotechnical conditions. Thus evaluation of construction materials and dam foundation must be performed to ensure that these factors are satisfied. Geophysical techniques such as seismic velocity are used to derive quantitative engineering design values in order to assess geotechnical and geological properties during dam site investigations [1–4]. In this chapter, field investigations, borehole logging techniques and seismic velocity measurements are given in order to assess the geological and geotechnical of the Ntem formation and soil deposits that have been used both as construction and foundation materials during dam construction. Both refer to previously published work on Ntem formation characteristics [4] and unpublished data of soil deposit natures in the dam site at Memve'ele.

2. Application of geotechnical and geological results to an engineering assessment of construction materials and dam foundation site

2.1 Geological results

The in situ investigation in the Memve'ele dam site, comprised detail observation, description of geological units observed in the field and in the borehole cores and the laboratory tests include tests for petrographic analysis and on rock samples. The investigation resulted in the geology of dam site display two geological units based on borehole information and surface investigation (**Figures 1** and **2a**) [4]. These two geological units are named quaternary deposits and lower Precambrian Ntem Formations. Sometimes, Ntem Formations emerge and appear highly to moderately weathered down to elevation 386 m below which is slightly weathered diabase. The quaternary deposits are composed of full weathered soil covers with uneven thickness underlain by Ntem Formations in the dam site (**Figure 2a**). Full weathered soil covers with weak thickness occur up to Ntem Formations along the dam axis particularly. The plasticity index (15 < Ip < 40) and the clay content (A-7-5 type) of soil are generally on the high side, but the clay content roughly met the requirement. The subsurface strata are described in the **Figure 3**. The mineral assemblages of Ntem Formations indicate a high grade metamorphism which corresponds to granulite to amphibolite facies metamorphic conditions. Slightly

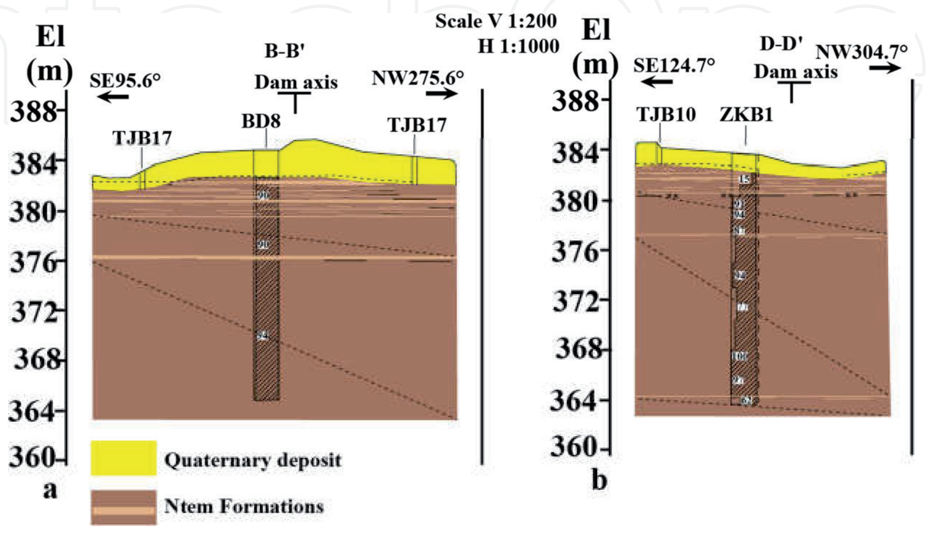

Figure 1.
Geological units in the Memve'ele displaying quaternary deposit underlain by Ntem formation based on borehole information. Note uneven thickness of quaternary deposit between (a) and (b).

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Figure 2.
(a) Quaternary soil deposits underlain by Ntem formations that represent two geological units found in the whole dam site and (b) fractured and slightly weathered rock mass.

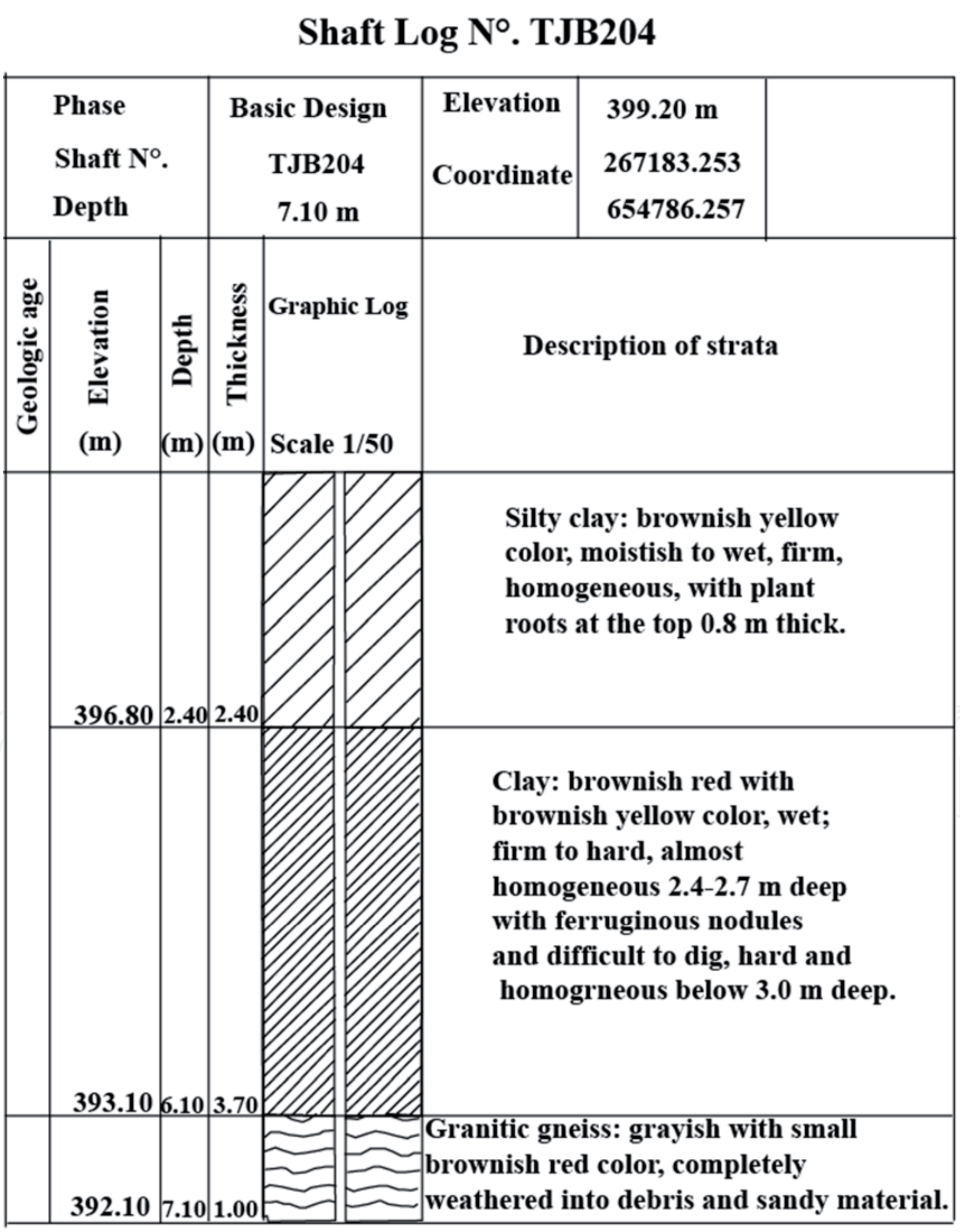

Figure 3.
Description of strata.

(**Figure 2b**) and densely jointed zones are found at rocky outcrops, dominantly striking NE30° ~ 40° and E-W with moderate to steep dipping angles (**Figure 4a** and **b**), indicating an outline sub-parallel for all tectonic features (gneissosity, shear zone, fault and jointed rocks). The quantitative description and statistical distributions of discontinuities of Ntem Formations derived from boreholes and those obtained from the geomechanical mapping through scan line at the dam site [5]. The stereographic projection can give an overall view of the number of dominant discontinuity sets of joint and bedding directions within the rock mass. A plot of contoured pole concentration is dominant along the mean direction of N034.44 SE (**Figure 4c**). Quantitative description of discontinuities shows that spacing is extremely close to moderate (0–0.1 m and 30–40 m), their length vary from 1 to 50 m with small

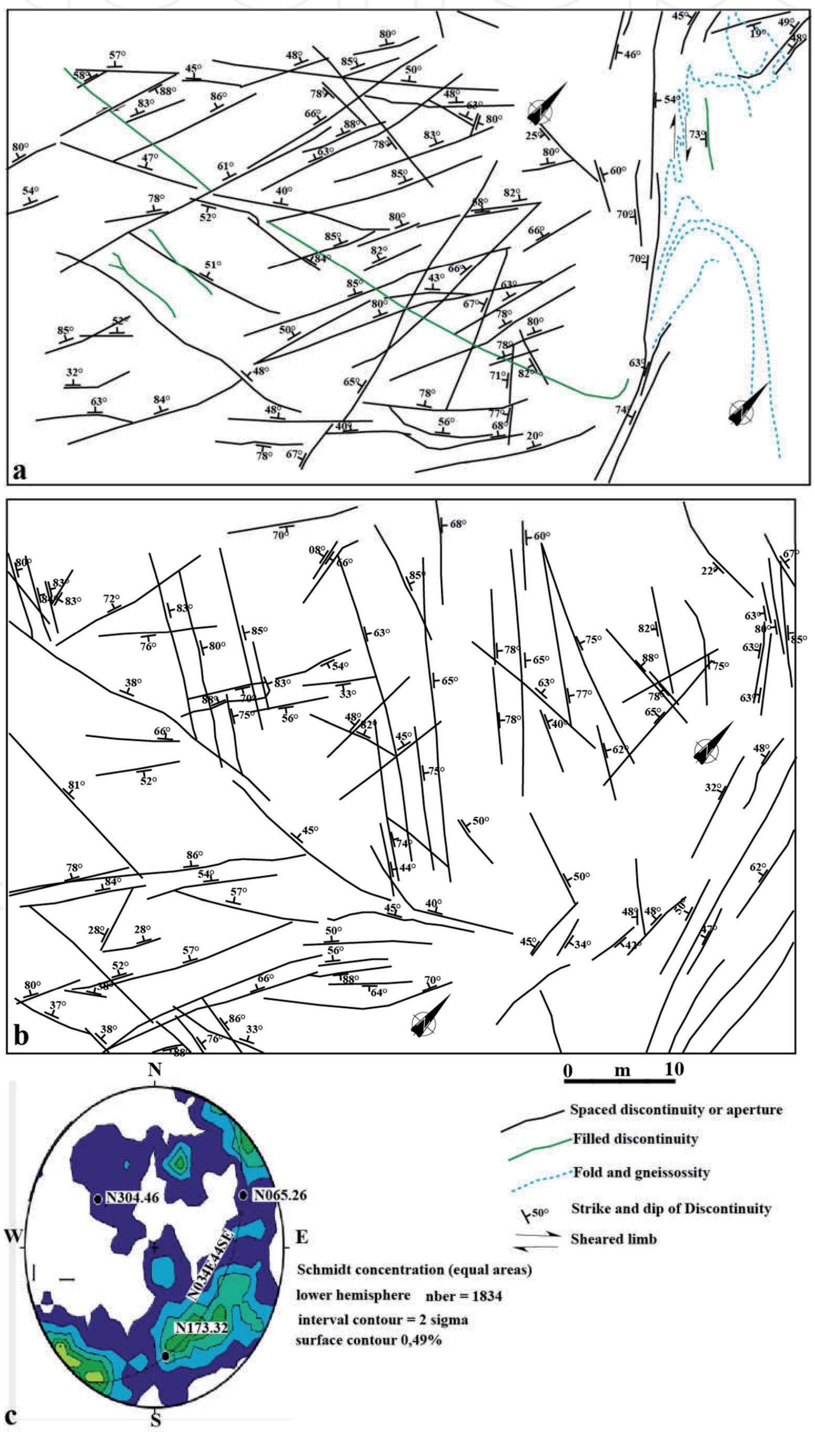

Figure 4.
(a) and (b) Engineering discontinuity map, displaying some discontinuity natures, fold and gneissossity; (c) plot of contoured concentration displaying great circle direction.

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Sample N°.	Depth (m)	Physical properties					Atterberg limits			
		Specific gravity	Wet density (g/cm^3)	Dry density (g/cm^3)	Degree of saturated (%)	Porosity	LL (%)	PL (%)	PI	LI
							W_1	W_p	I_p	I_l
Dam site										
TY 07	6.0	2.65	1.60	1.21	72.34	1.200	53.8	36.8	17.0	−0.24
TY 08	2.0	2.64	1.62	1.29	64.86	1.050	51.8	31.0	20.8	−0.25
TY 09	2.0	2.69	1.71	1.41	62.72	0.910	51.4	28.6	22.8	−0.33
TY 10	2.2	2.67	1.64	1.23	75.73	1.170	60.3	33.3	27.0	−0.01
Borrow areas										
TJB101	3.0	2.76	1.65	1.33	61.02	1.070	71.6	38.0	33.6	−0.43
TJB102	3.2	2.71	1.64	1.37	55.14	0.980	58.4	28.3	30.1	−0.28
TJB103	4.0	2.72	1.51	1.26	46.83	1.160	76.2	35.1	41.1	−0.37
TJB204	3.5	2.69	1.75	1.45	65.69	0.860	52.1	27.6	24.5	−0.27
TJB205	3.5	2.69	1.64	1.31	64.03	1.050	83.6	43.5	40.1	−0.46
TJB206	3.8	2.68	1.80	1.46	73.96	0.830	68.0	36.4	31.6	−0.43
TJB402	3.5	2.64	1.56	1.32	47.30	0.990	69.9	32.3	36.6	−0.40
TJB403	3.0	2.60	1.64	1.31	67.15	0.990	74.4	41.2	33.2	−0.47
TJB405	3.2	2.65	1.70	1.37	68.85	0.940	66.4	30.4	36.0	−0.17

Sample N°.	Depth (m)	Consolidation (Sat.)		Quick shear		Coef. of permeab.
		Coef. av^{1-2} MPa^{-1}	Modulus Es^{1-2} MPa	Cohe. C KPa	Fric. Φ°	Vertical K cm/s
Dam site						
TY 07	6.0	0.48	4.8	16.00	33.30	2.96E−05
TY 08	2.0	0.77	2.3	16.00	29.50	2.95E−05

TY 09	2.0	0.95	1.9	14.20	34.70	1.96E-05
TY 10	2.2	0.46	4.4	25.10	31.00	8.62E-04
			Borrow areas			
TJB101	3.0	0.50	4.0	55.30	28.80	4.76E-04
TJB102	3.2	0.66	3.0	23.10	35.10	2.61E-05
TJB103	4.0	0.20	9.9	2.20	41.90	
TJB204	3.5	0.28	5.9	17.00	50.10	9.35E-05
TJB205	3.5	1.00	2.2	14.00	38.00	1.55E-05
TJB206	3.8	0.35	4.8	65.00	38.20	3.73E-05
TJB402	3.5	0.52	3.6	11.10	37.10	4.77E-05
TJB403	3.0	0.26	6.9	40.10	33.10	3.14E-05
TJB405	3.2	0.41	4.8	48.80	21.60	3.32E-05

Table 1.
Geotechnical properties of soil deposits in the Memve'ele dam site.

discontinuity dominants [5]. The dam site area is considered to be passive tectonically and geological disasters are mainly composed by weathering, other phenomena such as landslide, collapsing and debris flow are rare found.

2.2 Geotechnical results investigated on quaternary deposits

A geotechnical investigation into quaternary deposits that have represented construction materials and dam foundation of Memve'ele dam is described in this topic. Many boreholes were drilled by drilling rig to assess the geotechnical of the quaternary deposits from borrow areas and in the dam foundation site. The investigation of three borrows areas and dam sites comprised mainly laboratory tests of soil deposits. The results of mechanical tests are presented in **Table 1**. The specific gravity values vary from 2.60 to 2.76; wet and dry densities are ranged from 1.51 to 1.61 g/cm^3 and 1.23 to 1.55 g/cm^3 respectively; porosity values vary between 0.700 and 1.190%; liquid limit values vary between 58.4 and 76.2 wt. %; plasticity limit values are ranged between 28.3 and 40.1 wt. %. The deformation modulus values vary between 1.9 and 9.9 MPa; the coefficient of permeability varies between 8.62E−04 and 3.35E−05 cm/s. As per the exploration well, the reserve estimations is 182.39 × 10^4 m^3. However, slope occurs with erosion marks (**Figure 5**) after raining seasons.

2.3 Geotechnical results investigated on lower Ntem Formations

A geotechnical investigation into mechanical behavior of Ntem Formations at Memve'ele has been described in detail by Bisso et al. [4]. The rock mass qualities of Ntem formations of the dam site were assessed using sonic well-logging in boreholes and sonic sounding on core samples. Acoustic logging is carried out of from bottom to top of a borehole; the spacing between two receiving detectors and the point distance of detections are 0.2 m respectively. Acoustic test of core consists to penetrate the couple of detector and core by butter. The compressional wave velocity and density results with low values at top and high at the bottom respectively help to interpret the geophysical layers (**Figure 6**). Layer at top is identified as quaternary deposits and layer in the bottom corresponds to Ntem Formations as previously shown in **Figure 2a** and description of strata (**Figure 3**). Thus, the compressional wave velocity and density in the rock mass

Figure 5.
Slope stability affected by raining water.

indicate that there is not only a correlation between velocity and formation layers, but also between rock conditions encountered in the Memve'ele dam site (**Figure 7**), velocities of <5000 m/s indicating highly fractured zone, low density and moderately weathered Ntem Formations with both widely and closely

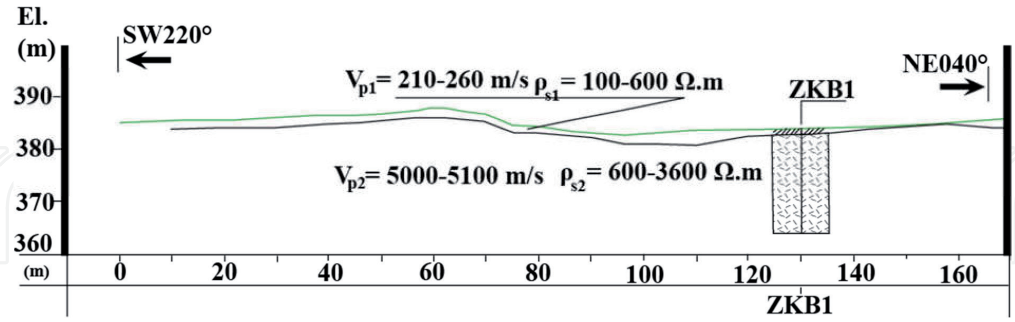

Figure 6.
Seismic velocities, density measurements and geophysical layers in the Memve'ele dam site.

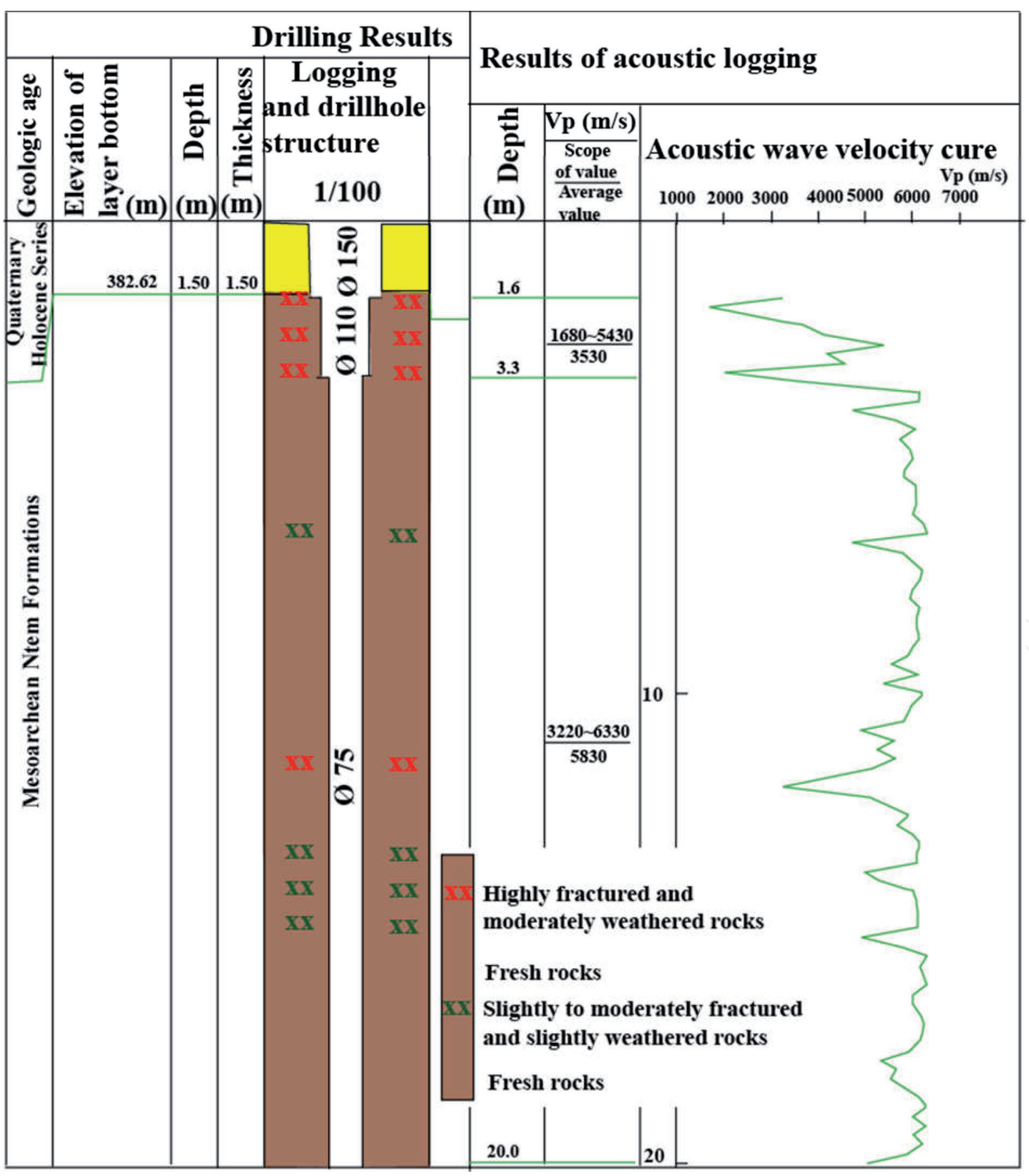

Figure 7.
Drillhole structure and cross plot of seismic velocity measurements.

spaced discontinuities, while velocities of >5000 m/s correlate with fresh to slightly weathered and high density Ntem Formations with very closely spaced discontinuities.

During core drilling, permeability tests were performed and the permeability of the rock mass is expressed in term of Lugeon values. According to Lugeon scale, the Ntem Formations display high, medium and low Lugeon values in the boreholes. However, evidence of two permeability areas is seen and consists to a permeability area with UL > 15, located between 0 and 13 m of depth and an impervious area with UL ≤ 5, beyond of 13 m of depth. The high Lugeon values observed to surface are because of highly jointed rock masses whereas the low Lugeon values correspond to sound rock with moderate fracturation rate. More detailed examination of the competence, softening, density; alkali reactive, hardening of Ntem Formations is displayed by Bisso et al. [4].

3. Interpretations

During Memve'ele dam constructions, geological and geomechanical assessment of quaternary deposits and Ntem Formations have been used to characterize construction and dam foundation materials. It is economically rentable to used construction materials which exist within a relatively short distance of dam site. Interpretation properties on the surface and of measured properties in the borehole logs as mentioned above, display that soil deposits are good to excellent performance in the civil application works [6–9] and thus have been used during Memve'ele dam construction [4]. According to Casagrande scale, soil materials are classified from low plasticity to plasticity and in addition, The coefficient of permeability are higher than those obtained in Kiri dam (from 1.5E−08 to 1.00E−6 m/s [10]) and recommended values of 7.00E−10 to 1.00E−06 m/s. This latter property indicates that soil materials are lesser ability to allow the passage of seeping water if they are use as embankment materials.

The deformation modulus values further indicates the relatively clay contents in the soil deposits. These behaviors indicate that these materials can be used as base layer of dam and also can constituted the transition, cushion and filter materials. The total reserve of soil deposits found near the Memve'ele dam site is 182.39×10^4 m^3 and natural sand is to about 30.000 m^3. These values are more important and contribute to reduce costs if these materials have been brought far of site.

Ntem Formation conditions indicate that they are hard qualities in respect to physical properties and good resistance against scouring. The excavated quantity of rock material from the structure foundation is nearly 300×10^4 m^3 and it has been used for obtaining crushed aggregate and ripping rap materials for dam construction. However, conditions of site with rocks and alluvial deposits indicate very good and relatively poor geological conditions which can constitute dam foundation materials [11]. Concerning dam foundation, evidence of two dam foundation materials is observed and some requirement needs. The thickness of upper residual soil where is weak in the dam axis can be move to obtain Ntem Formations as foundation materials but where, soil deposit is more thickened, it can be used as also foundation materials. This study has shown that Ntem Formations are fractured and weathered. These site conditions have contributed to improve it in excavating the weathered materials and using vegetable cover and Grouting Intensity Number (GIN) [12] for cover slope and introducing the cement grouting through fractures (**Figure 8**). This method leads to reinforce Ntem Formations and slope stability. Overall dam structure can be fitted on the quaternary soil deposits and Ntem Formations.

Figure 8.
(a–c) Display different usages of Ntem formations and quaternary soil deposits; (d and e) amendment of Ntem formations and slope formed by quaternary soil deposits with grouting cement.

4. Conclusion

Geological and geotechnical assessments have been applied to estimate degree of fracture and characterize both construction and dam foundation materials in order to use for engineering geological mapping purposes which can serve as guide while dam construction. The interpretation presented in this chapter shows that quaternary deposits can be used as both embankment materials and dam foundation particularly where his layer is more thickened. The weak thickness of this soil in the island site contributes to emplacement of dam on Ntem formations. Mapping fracture zones and thus weathered grade in the Ntem Formations lead to improve it by engineering processes as a GIN method that leads to improve it. In addition, it has been demonstrated that, cross plots of velocity, density values can be used to predict and identify zones of fracture, zone of weathering, nature and thickness of layers. Previous work [4], cited in this chapter has shown that Precambrian Ntem

Formation based on geological and geotechnical results have been used for engineering design and during Memve'ele dam construction. This approach may have application in other civil applications.

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Conflict of interest

The authors have no conflicts of interest.

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References

[1] Deere DU. Chapter 1: Geological considerations. In: Stagg KG, Ziekiewicz OC, editors. Rock Mechanics in Engineering Practice. New York: J. Wiley and Sons; 1968. pp. 1-20

[2] Hendron AJ. Chapter 2: Mechanical properties of rock. In: Stagg KG, Ziekiewicz OC, editors. Rock Mechanics in Engineering Practice. New York: J. Wiley and Sons; 1968. pp. 21-53

[3] Knill JL. The applications of seismic methods in the prediction of grout take in rock. In: Proceedings of Conference on In Situ Investigations in Soils and Rocks. London: British Geotechnical Society; 1969. pp. 93-100

[4] Bisso D, Ntomba SM, Mengbwa RC, Magnekou Takamte RC, Ondoa JM. Geological and geotechnical characteristics of Ntem formations: Insight of its applications in the Memve'ele dam construction (Southern Cameroon). Geotechnical and Geological Engineering Journal. 2020;**38**:4585-4601. DOI: 10.1007/s10706-020-01312-7

[5] ISRM. Suggested methods for the quantitative descriptions of discontinuies in rock masses. In: Rock Characterization, Testing and Monitoring. Oxford: Pergamon Press; 1981

[6] Paige-Green P, Pinard M, Netterberg F. A review of specifications for lateritic materials for low volume roads. Transportation Geotechnics. 2015;**5**:86-98

[7] Onana VL, Ngo'o Ze A, Medjo ER, Ntouala RFD, Nanga BMT, Ngono OB, et al. Geological identification, geotechnical and mechanical characterization of charnockite-derived lateritic gravels from southern Cameroon for road construction purposes. Transportation Geotechnics. 2017;**10**:35-46. DOI: 10.1016/j. trgeo. 201612.001

[8] Xing H-F, Gong X-N, Zhou X-G, Fu H-F. Construction of concrete-faced rockfill dams with weak rocks. Journal of Geotechnical and Geoenvironmental Engineering. 2016;**132**(6):778-785

[9] Chuka OC, Moruf SB, Ewoma O, Olatunbasun AM. The Kano-Kazaure highway, north Central Nigeria: The significance of the engineering geology in construction. Bulletin of Engineering Geology and the Environment. 2011;**70**(1):33-40

[10] Ahmed Bafeto M, Olugbenga BES, Daffi R, Amina SG. Seepage analysis of kiri dam using finite elements method. The International Journal of Engineering and Science. 2019; **8**(11. Series II):66-86

[11] Fraser AW. Engineering Geology Considerations for Specifying Dam Foundation Objectives. Geology Branch; Division of Safety of Dams California Department of Water Resources; 2001. p. 14. Available from: wfraser@water.ca.gov

[12] Deer D, Lombardi G. Grout slurries - Thick or thin? Issues in dam grouting. In: Proceedings of the Session Sponsored by the Geotechnical Engineering Division of the American Society of Civil Engineers in Conjunction with ASCE, Convention; Denver, Colorado. 1985