FOUNDATION SOIL CHARACTERISATION FOR A BUILDING WITH MULTIPLE CRACKS AT TARKWA, GHANA

ABSTRACT

Formation of cracks on buildings could be attributed to many factors such as properties of soils, geology, structural defects and climatic conditions. A public building at Tarkwa in the Western Region of Ghana developed cracks that rendered it unsafe and so it was demolished for a new structure to be put in place. Geotechnical investigations were undertaken to ascertain possible contributions of the foundation soils to development of these cracks before it was demolished. Site investigations on trial pits and laboratory analyses show that, the foundation soils were mainly dense silty sand, with average moisture content of 8.9% and specific gravity of 2.7 (characteristics typical of quartz sands). Plasticity range from 1.5% to 7.8% at an average of 4.9% and so consolidation immediately after structural loading was negligible and may not result in differential settling. Moisture content was larger than liquid limit as liquidity indices were between -0.326 to -12.653. These soils have minimal liquefaction potential, free draining, of high permeability and therefore could consolidate immediately after being subjected to structural load. Hence the foundation soils played little role in the formation of cracks on the building which was exposed to frequent ground vibration as it was close to a defunct underground mine, heavy vehicular traffic and a railway station; with surface mining activities at a permitted distance.

Keywords: *Soil Characterisation, Building foundation, Differential settling, Cracks*

1. INTRODUCTION

Building foundations need to be on stable and strong soils to avoid cracks, sinking, or falling. Geotechnical investigations before, during, and after construction are necessary to avoid the formation of cracks on buildings, walls and floors [1]. Cracks can result from external forces such as shrinking and swelling of some clay minerals when subjected to moisture variations, differential foundation movements, and poor compaction of foundation soils and settling from dimensional changes in the masonry work [2]. Formation of cracks on a building could also be attributed to many factors such as structural defects, geotechnical defects and geology [3]. The old Ghana National Fire Service building had cracks before it was pulled down for reconstruction in 2007. According to [4] the cracks on the structure could be attributed to geological structures in the foundation rocks. This paper presents geotechnical evaluation of foundation soils to verify if they contributed to the formation of the cracks on the building.

2. GEOLOGY OF TARKWA

Tarkwaian rocks in the Ashanti belt of Ghana stretch from near Axim in the Western Region to the edge of the Voltaian basin near Agogo in the Ashanti Akim District [5]. The Birimian consists of metamorphosed volcanic rocks and metasedimentary rocks. Initial subdivision by [6] placed the rocks into Lower

Birimian made up of metasedimentary rocks while the Upper Birimian mainly comprises of metavolcanic rocks. According to [7] these rocks are contemporaneous and form lateral facies and were intruded by belt granitoids into the volcanic rocks and basin granitoids into the metasedimentary rocks. The Tarkwaian is regarded as younger than the Birimian as the basal rock of the Tarkwaian which is the Kawere conglomerate consists of reworked pebbles from the Birimian and so it is made up of sub-rounded closely packed pebbles of Birimian metavolcanic, metasedimentary rocks, granitoids, carbonates, quartz and other vein minerals and rocks. A palaeoplacer gold bearing banket quartz conglomerate overlies the polymictic Kawere conglomerate. The Tarkwaian stratigraphy by [8] from the youngest above is as follows:

- Huni Sandstone and Dompim Phyllites
- Tarkwa Phyllites
- Banket Series
- Kawere Conglomerate

The Banket Series is subdivided into footwall and hanging wall quartzites separated by a sequence of mineralised quartz-pebble conglomerates and pebbly quartzites. The general orientation of pebbles show that fluvial transport was from east and north-east [9]. The Tarkwaian sequence has been subjected to low-grade regional metamorphism of greenschist facies and according to [10], subjected to five episodes of deformation accompanied by thrust faults and dolerite sills.

3. METHODOLOGY

Three test pits were excavated in the vicinity of the building with pick axe and shovel to a depth of 1 m from the ground surface. The purpose of excavation was to visually examine the soil profile and obtain seven clearly labeled and bagged undisturbed samples for laboratory evaluation of physical characteristics of soil properties. The following laboratory tests were carried out in accordance with BS 1377 [11]:

- Moisture content
- Specific gravity
- Atterberg Limits
- Particle Size Distribution

4. RESULTS AND DISCUSSION

The results of the laboratory tests are presented in Table 1 and particle size distribution curves shown in Figure 1.

Table 1 Summary of Laboratory Tests on Soils from Tarkwa

Sample ID	Depth (m)	Moisture Content (%)	Specific Gravity	ATTERBERG LIMITS TEST (%)			PARTICLE SIZE ANALYSIS (HYDROMETER) (%)				REMARKS
				W_L	W_P	I_P	Clay (C)	Silt (M)	Sand (S)	Gravel (G)	
MP	0.0 - 0.2	8.85	2.64	20.9	13.1	7.8	3.0	72.0	24.6	0.4	Sandy silt with some clay
MP	0.5 - 0.7	11.45	2.64	NON PLASTIC			0.0	12.4	77.8	9.8	Gravelly silty sand
MP	0.7 – 1.0	14.93	2.64	20.5	16.3	4.2	1.6	12.2	69.2	17.0	Silty gravelly sand with some clay
BS	0.0 - 0.5	5.42	2.68	25.9	24.4	1.5	0.0	24.0	63.6	12.4	Gravelly silty sand
BS	0.5 – 1.0	6.39	2.68	19.9	13.4	6.5	0.0	24.0	66.0	10.0	Gravelly silty sand
FS	0.0 - 0.5	9.08	2.68	NON PLASTIC			0.0	17.8	54.0	28.2	Silty gravelly sand
FS	0.5 – 1.0	6.42	2.68	NON PLASTIC			0.0	8.0	22.8	69.2	Sandy gravel with some silt

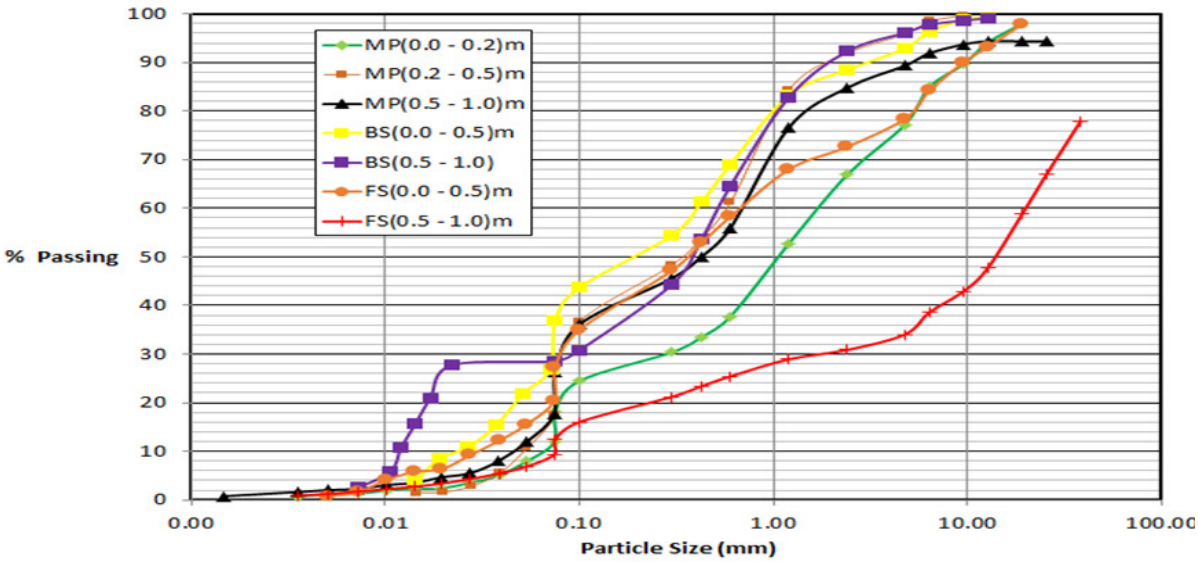

Figure 1: Particle Size Distribution of Soils at the Tarkwa Site

The area is underlain by dense silty sand with admixtures of gravel and minor clay. The average moisture content is 8.9% with average specific gravity of 2.7; typical of quartz sands.

The plasticity index ranges from 1.5% to 7.8% with an average of 4.9%. Figure 2 shows that the soil is silty with low plasticity.

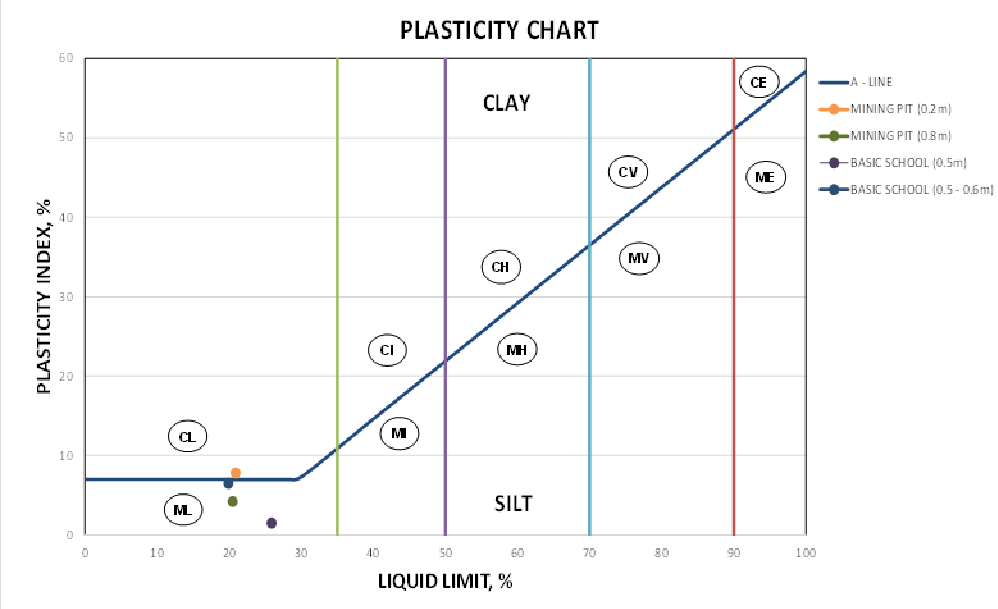

Figure 2: Plasticity Index vs. Liquid Limit of the Soils from Tarkwa Site

Ground vibration caused by mine blast and movement of heavy duty trucks in the project area is likely to subject the site to liquefaction due to the presence of silty sand with low clay content. Liquefaction potential analysis of the foundation soils showed that the moisture content (MC) is larger than liquid limit (W_L). Hence *in situ* water content is above the liquid limit. Soils under these conditions are unstable during ground vibrations as the larger the MC with respect to W_L, the greater the likelihood of liquefaction. Liquidity index (LI) was proposed by [12] to quantify liquefaction using the following relationship:

LI= (Moisture Content-Plastic Limit)/Plasticity Index

LI ≥1 is an indication for liquefaction potential

Hence liquidity Indices (LI) for soils at the Tarkwa site is between -0.326 to -12.653 and so cannot be subjected to liquefaction.

5. CONCLUSION

Subsurface soils at the building site at Tarkwa are mainly dense silty sand with low plasticity, usually free draining and highly permeable. The soils could consolidate immediately after being subjected to structural loads and have differential settling capacity. The cracks on the building could have been caused by improper settling of the foundation before the construction, making geological structures near the building as the main contributory factors [4].

REFERENCES

1. Amadi AN, Eze CJ, Igwe CO, Okunlola IA, Okoye NO. Architect's and Geologist's View on the Causes of Building Failures in Nigeria. Modern Applied Science.2012; 6(6):31-38.
2. Anonymous. Typical Foundation Problems. 2011; Accessed: 5 June 2015. Available: http://www.stonehengefoundations.com (May 22, 2011).
3. Yunusa GH, Hamza U, Abdulfatah AY, Suleiman A. Geotechnical Investigation into the Causes of Cracks in Building: A Case Study. Publication of EJGE. 2013; 18: 2823-2833.
4. Tetteh GM, Mensah FA. Evaluation of Cracks on a Building at Tarkwa in Ghana with respect to Foliations and Joints in Foundation Tarkwaian Rocks. International Journal of Mining Science. 2016; 2(1): 25-32.
5. Kesse GO. *The Mineral and Rock Resources of Ghana*. A. A. Balkema, Rotterdam; 1985; 610.
6. Junner NR. *The Geology of the Gold Coast and Western Togoland*. Gold Coast Geological Survey. 1940; 11:1-40.
7. Leube A, Hirdes W, Mauer R, Kesse GO. The Early Proterozoic Birimian Supergroup of Ghana and its associated gold mineralisation. Precambrian Research.1990; 46: 139–165.
8. Junner HR, Hirst T, Service H. *The Tarkwa Goldfields*. Gold Coast Geological Survey Memoir. 1942; 6:1-

75.

9. Hirdes, W and Nunoo, B. The Proterozoic Palaeoplacers at Tarkwa Gold Mine, SW Ghana. Geologisches Jahrbuch. D, H 100. 1994; 247-311.
10. Allibone, A, Teasdale J, Cameron G, Etheridge M, Uttley P, Soboh A, et al. Timing and Structural Controls on Gold Mineralisation at the Bogoso Gold Mine, West Africa. Economic Geology. 2002; 17: 949-969.
11. Anonymous. Methods of Test for Soils for Civil Engineering Purposes. British standard Institute BSI 1377-2. 1990, 68.
12. Bowles, JE. Foundation Analysis and Design. Fifth Edition, Mcgraw Hill Companies, United States; 1996; 237