AN INTEGRATED APPROACH TO CRUSHED ROCK MATERIAL EVALUATION FOR ROAD CONSTRUCTION IN A TROPICAL ENVIRONMENT

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ABSTRACT

Deep weathering conditions in tropical terrains often lead to a general scarcity of outcrops of relatively fresh rocks which would otherwise provide sources of good quality materials for road surfacing. As such, road construction becomes an expensive venture since suitable construction materials may sometimes have to be hauled over long distances at high cost. Road projects within the Sefwi Wiawso District, a typical tropical environment in Ghana, are often fraught with problems of procuring suitable crushed rocks, a situation which has recently necessitated research into the crushed rock potential of the district. An investigation, involving desk study of the geoenvironmental setting of the district, conduct of field studies and performance of relevant laboratory tests, was undertaken to evolve strategies for obtaining suitable crushed rock materials for road construction in the area. Blending of crushed rock materials procured from two potential sources provided the requisite engineering properties for their utilisation in road surfacing because materials from no one source fully satisfied all the engineering geological requirements. This integrated approach can be readily employed for the effective evaluation of rock aggregates for road surfacing in similar geoenvironmental situations in Ghana and elsewhere.

Keywords: *Deep weathering, Tropical environment, Crushed Rocks, Blending, Road Constructtion, Ghana*

INTRODUCTION

Identification of suitable locations of good quality rock aggregates for road construction is one of the major problems confronting road engineers in most tropical countries like Ghana. Due to the relatively complex geoenvironmental setting of tropical terrains, potentially good rock outcrops may be obscured by thick vegetative cover and weathering mantle which often characterise the tropical environment. In this situation, crushed rock materials for road and other civil construction works may sometimes have to be hauled from far places, thus making these engineering ventures quite expensive. At times, one may be tempted to sacrifice quality for cost by having to use readily available but marginally suitable materials.

The Sefwi Wiawso District of the Western Region of Ghana has recently been facing problems related to the procurement of suitable road construction materials, particularly crushed rocks for its road network improvement activities. No established commercial crushed rock quarry exists in the district and most construction companies are forced to procure these materials from distant sources such as Kumasi and Sekondi which are respectively located about 100 km and 150 km away (Fig. 1).

This paper embodies a research study conducted on the crushed rock potential of the Sefwi Wiawso District with a view to providing the requisite information pertaining to a cost-effective procurement of these

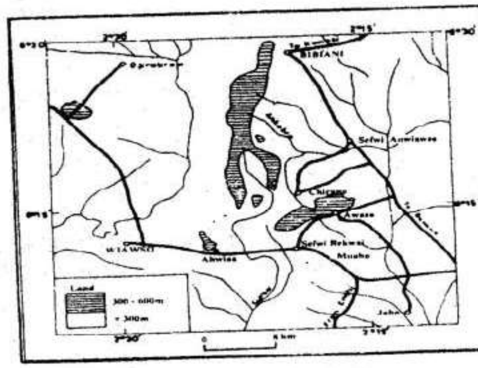

Fig. 1: Location of Study Area

construction materials in an area which typifies a tropical environment of relatively complex geoenvironmental setting.

GEOENVIRONMENTAL SETTING

The Sefwi Wiawso District is located in the southwestern part of Ghana and falls within the physiographic region of a forest-dissected plateau which is characterised by a fairly undulating relief. Topographic heights are generally 150 - 200 m, with hills occasionally reaching elevations of 700 m O.D. The area is drained by several tributaries of the Ankobra and Tano rivers which form a dendritic drainage pattern. (see Fig. 1).

A wet semi-equatorial type of climate is experienced in the district. This climatic type is characterised by two rainfall maxima of (May - July and September - October), with mean annual rainfall of 1500 mm, mean monthly temperatures of 26 – 30°C and mean monthly noon relative humidities vary from 70% to 80% [1].

The climax vegetation is a moist semi-deciduous forest type with most of the trees being evergreen all year round. However, extensive logging and farming activities coupled with indiscriminate bush burning have now turned this primary vegetation into a secondary forest of stunted trees, shrubs and tall grasses (Fig. 2).

Cocoa and timber industries are the economic mainstay of the study area, in addition to bauxite mining at Awaso. There are also a few commercial towns, notably Sefwi Wiawso, Sefwi Bekwai, Sefwi Ansawinso, Bibiani and Juabeso where food crops such as plantain, cocoyam and cassava are marketed.

The geology of the Sefwi District belongs to the Birimian System of Precambrian age, consisting predominantly of metasedimentary and metavolcanic rocks such as phyllite, metagreywacke, schist, metatuff and amphibolite (Fig. 3) Often associated with

Fig. 2: Panoramic view of Sefwi Wiawso District showing vegetation

these rocks are felsic (granitic) and mafic (doleritic) intrusives as well as quartz veins (which provide sources of good quality quartz gravel for road construction works).

According to Kesse [2], the rocks are folded isoclinally on a NE - SW axis with dips varying between 30° and 90° SE. Faults and joints are the prominent structural discontinuities. It must be noted, however, that these rocks are often mantled by relatively thick blankets of residual soils formed due to intense chemical weathering which is typical of this part of the country. As a consequence, fresh rock outcrops are fairly scarce in the area while lateritic and alluvial soils tend to be abundant.

POTENTIAL ROCK QUARRY SITES

Following a comprehensive desk study of the available information relating to the geoenvironmental setting of the area locations of potential rock quarries, field surveys were carried out on rock outcrops and laboratory studies performed on rock materials procured therefrom. The fieldwork consisted primarily of locating rock outcrops within the study area with a view to identifying the types of rock and their weathering grade as well as collecting representative rock samples for the performance of laboratory petrographic analysis and engineering tests. Effort was also made to estimate the geometry of the rock outcrops and the volume of rock material available at each potential quarry site.

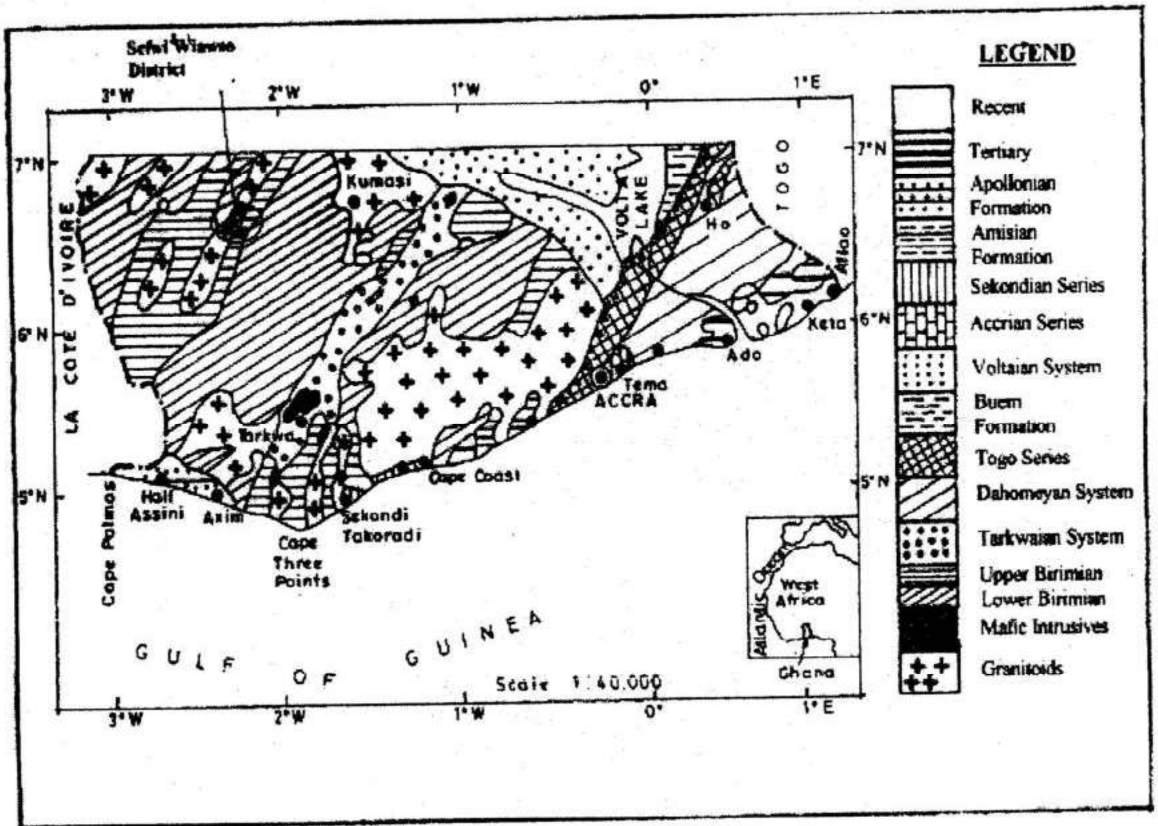

Fig. 3: Geology of Southern Ghana

During the field studies, two potential rock quarry sites were identified for the procurement of rock aggregates. These sites (see Fig. 1) are Ahwiaa (7 km from Sefwi Wiawso along the road leading to Sefwi Bekwai) and Muoho (5 km from Sefwi Bekwai on the Diaso motor road). They are within 15 km of each other and could serve as sources of procuring construction materials for the ongoing rehabilitation of the 18-km Sefwi Bekwai-Sefwi Wiawso road.

Rock Outcrop Geometry and Volume

The rock outcrops encountered at the Muoho site are dome-shaped, occurring as fairly flat-topped hillocks which rise up to 25 m above the general ground level. The volume of available material was estimated to be about 1.0 million m^3

At the Ahwiaa site, however, there were no outcrops, despite the presence of numerous rock boulders scattered over a wide area, some of which were embedded in a soil envelope (Fig. 4). The methodology adopted for establishing the presence of good quality rocks and evaluating the quantity available at this site involved a geoelectrical survey up to 30 m depth and trial pitting in the soil cover from which the geological situation at the site was also modelled (Fig. 5). The geology consists of 1 - 3 m of lateritic soil which thickens towards the west to about 5 m at the crest of the hill. Below this residual soil layer is a saprolite which interfaces with the bedrock at a depth of about 9 m. This interface is probably a perched aquifer on account of the very low apparent resistivity values at that depth. Corestones (boulders) from the saprolitic zone were sampled for laboratory testing. The volumme of quarriable rock material was estimated to be 1.5 million m^3.

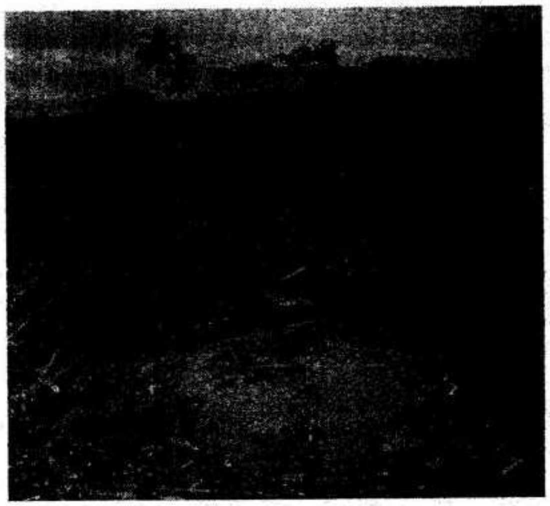

Fig.4 Rock boulders at Ahwiaa

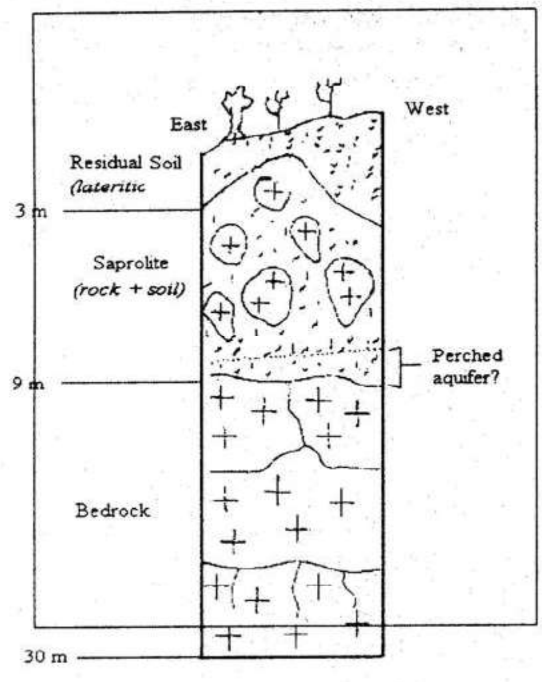

Fig. 5 Geological model at the Ahwiaa site

Engineering Petrography

The rocks encountered at both sites were essentially felsic (granitic), mafic (doleritic) and intermediate (dioritic) varieties. They are fresh to slightly weathered but usually covered with relatively thick vegetation and residual soil mantle, particularly at the Ahwiaa site (see Fig. 4). The weathering grades were established by adopting Dearman's [3] scheme.

Petrographic studies (both hand specimen and thin section analyses) carried out on relatively fresh rock samples obtained from the two sites revealed the following:

The rock at the Ahwiaa site is a dark grey medium-grained microgranodiorite with xenoliths of dolerite. The modal composition is feldspar (53%), amphibole (23%), quartz (21%) and epidote (3%). The rock exhibits a typical interlocking texture with some intergranular microcracks. The feldspars are fairly sericitised. A photomicrograph of this rock type is shown in Fig. 6. The Muoho rock is essentially a grey, coarse-grained, mica-rich granite with modal composition of feldspar (45%), quartz (35%), biotite (15%) and chlorite (5%) as shown in Fig. 7. Mineral grain boundaries are generally fairly straight and tight but occasionally open.

*A.= amphibole, F= feldspar, Q = **quartz***

Fig. 6 Photomicrograph of **Ahwiaa micro-granodiorite** (crossed **polars x 40)**

F = feldspar, M = Mica, Q = quartz

Fig. 7: Photomicrograph of Muoho mica granite (crossed polars x 25)

Some quartz-straining occurs in the rock probably due to active tectonism in the area. This petrographic characteristic of the Muoho rock tends to suggest that it may not be suitable as a concrete material due to a possible alkali-silica reactivity (ASR).

ENGINEERING PROPERTIES

Engineering tests were performed on laboratory crushed aggregates of on two size fractions (20 -14 mm and 14-10 mm) of the two rock materials in order to determine the following physico-mechanical properties: relative density (RD), water absorption (WA), flakiness index (FI), elongation index (EI), aggregate crushing value (ACV), aggregate impact value (AIV), 10% fines and Los Angeles Abrasion Value (LAAV). These tests which were carried out in accordance with procedures outlined in the British Standards Institution, (BSI) [4] and the American Society for Testing and Materials, (ASTM) [5] gave results that are summarised in Table 1.

Generally, the engineering characteristics of the rocks studied compare quite favourably with those reported for most Ghanaian granitic rocks [6]. The Ahwiaa microgranodiorite, in particular, being finer is reasonably resistant to impact and crushing but the flakiness index value for the 20 mm nominal size significantly exceeds the recommended threshold value of 35%. The Muoho rock, although having satisfied the shape requirements for both size fractions, is weaker and, hence, may not be suitable for road surfacing.

Since rock aggregates from neither source wholly satisfied all the suitability criteria adopted in Ghana (evolved from ASTM and BSI) it became necessary to perform mix design studies by blending the two rock aggregates in different proportions from which it was revealed that 75% Ahwiaa + 25% Muoho mix (i.e. 3:1 ratio), particularly of the 14 - 10mm size fraction, gave the best results in terms of strength and shape indices (see Table 1). It was proposed, however, that this mix proportion be used to construct a trial road section whose performance should be monitored for a reasonable period of time to authenticate the industrial usage of the granitic rocks in the district.

CONCLUSIONS

The engineering geological investigations conducted on the Ahwiaa and Muoho rocks located in a relatively complex geoenvironmental setting gave promising indications that these rocks are potentially good materials which could be quarried for road and concrete works, especially when blended as 75% Ahwiaa + 25% Muoho. Nevertheless, the presence of substantial amounts of strained quartz in the Muoho rock could be an indication of probable ASR, which would have to be thoroughly investigated before using the aggregates for any concrete works.

Moreover, in establishing the quarries, access to the rock outcrops could pose a problem due to the relatively thick vegetative cover. At the Muoho site, there is also the possibility of the quarry becoming flooded during periods of intense rainfall since some portions of the outcrops are located within a stream valley.

Table 1: Summary of engineering tests on Ahwiaa and Muoho rock aggregates

Parameters	A	B	C	D	E	F	G	H	I	J	BSI/ASTM Value for Good Material
RD (-)	2.82	2.82	2.68	2.68	2.76	2.73	2.71	2.74	2.73	2.69	-
WA (%)	0.37	0.49	0.67	0.84	0.73	0.75	0.78	0.54	0.56	0.58	<1.00
EI (%)	30	21	20	33	28	29	29	25	23	22	< 35
FI (%)	49	32	34	24	29	24	28	39	40	33	< 35
AIV (%)	7	6	18	23	11	16	19	9	15	17	< 35
ACV (%)	6	6	15	21	9	12	17	7	11	13	< 35
LAAV (%)	11	13	43	48	23	32	38	21	30	34	< 40
10% Fines (kN)	667	652	267	190	445	334	235	570	364	308	> 210

A= Ahwiaa (20-14mm), B= Ahwiaa (14-10mm), C = Muoho (20- 14mm), D = Muoho (14- 10mm) E = 75%Ahwiaa + 25%Muoho (14-10mm), F = 50%Ahwiaa + 50%Muoho (14-10mm), G= 25% Ahwiaa +75% Muoho (14-10mm), H = 75% Ahwiaa + 25% Muoho (20-14mm), I = 50% Ahwiaa + 50% Muoho (20-14mm), J = 25%Ahwiaa + 75% Muoho (20-14mm).

Furthermore, the environmental aspects of quarry operations with particular reference to noise, dust, ground vibrations and flyrocks would have to be given serious attention since the locations of the proposed quarries are within a radius of 750 m of the Ahwiaa and Muoho townships. Additionally, the quarries, once in operation, should be constantly monitored by a competent engineering geologist who should advise on any problems relating to the stability of the quarry faces and incidence of abnormal rock material behaviour. Quality assurance is very essential.

The usefulness of this integrated approach lies in the fact that it can be readily employed in evaluating rock aggregates for road surfacing in similar geoenvironmental situations in Ghana and elsewhere.

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