View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by International Institute for Science, Technology and Education (IISTE): E-Journals

Civil and Environmental Research
ISSN 2224-5790 (Paper) ISSN 2225-0514 (Online)
Vol.7, No.10, 2015
www.iiste.org

Engineering Geological Characteristics of Quartzite Types for Concrete Production in Ghana

Anthony Woode David Kwame Amoah Bright Aforla Francis Avor Frank Kojo Kissi
Department of Civil Engineering, Accra Polytechnic, P.O.Box 561 Accra, Ghana

Abstract
The production of concrete in Ghana involves the use of several mineral aggregates such as gneisses, granites, granodiorites and quartzites. The use of quartzites for concrete, however, is well patronized especially by private low cost housing builders due to its low cost compared to other alternatives. Quartzites are known to have strength characteristics which are not uniform and as such vary from low to high depending on their metamorphic state.This research provides some Engineering Geological characteristics of quartzite types used for concrete works in parts of Southern Ghana and offers a classification of quartzites for easy field identification by Construction Engineers. The results of strength tests and petrologic examination confirm that there are different types of quartzites with strengths that correlate positively with their level of geologic state. In addition, the most metamorphosed quartzite was found to be resistant to weathering and useful for producing concrete for structural work.
Keywords: Quartzite types, aggregate strength, quartz, concrete

1. Introduction

Concrete production for construction purposes is an activity which goes on in almost every country. Concrete is a mixture of fine and coarse aggregates, an appropriate binder and water in specified ratios and is used for constructing foundation walls, floor slabs, columns and many other elements of buildings. The strength of concrete depends on several factors including aggregate characteristics such as aggregate size, aggregate type and aggregate strength.

The size of aggregate used for concrete production is known to have some effect on the strength of the concrete. Shetty, (2000) has indicated that when large size coarse aggregates are used in concrete the strength of the concrete is reduced due to weak bonds caused by greater heterogeneity, internal bleeding and the development of micro cracks. In another research, Woode et al. (2015) confirmed that the coarse aggregate with the smallest comparative size gave the maximum compressive strength of concrete and that concrete strength reduces after a critical maximum aggregate size is attained. They further observed that as the heterogeneity of aggregates increases the compressive strength of concrete reduces.

Bhikshma and Florence (2013) experimenting on three different mixes of M50 Grade concrete using maximum coarse aggregate sizes of 10mm, 12.5mm and 20mm, found that aggregate of 12.5 mm size gave the best results. Su and Cheng (2013) have also used different coarse aggregate sizes in a research and found that different aggregate sizes give different strength values.

Other researchers have also revealed that aggregate types could affect the compressive strength of concrete. Abdullahi (2012) and Aginam et al. (2013), used granite and quartzite mineral aggregates to produce concrete, which were then tested to determine their strength. They found that concrete made with granite and quartzite as mineral aggregates gave different concrete strength values.

In addition to granite and quartzite, Lollino et al (2014) have also listed other rocks for producing mineral aggregates including igneous rocks such as dolerite and gabbro.

Aitcin and Mehta (1990) investigated the effect of coarse-aggregate types made from diabase, limestone, granite and river gravels on the compressive strength and modulus of elasticity of concrete and observed that the diabase and limestone aggregates produced concretes with higher strength and modulus of elasticity than the granite and river gravel. They attributed the effect to mineralogical differences in the aggregate types.

In Ghana, several rock types for producing aggregates are available but the rocks which form the bulk of mineral aggregates used for construction include gneiss, granite, granodiorite, migmatite and quartzite (Kesse, 1985; Woode, 1994; Adom-Asamoah et al, 2014). The type of mineral aggregate used in a particular locality in Ghana depends on the requirements of the project involved and also proximity of the source of the aggregate to the project site. In the middle and northern sectors of the country granite and granodiorite are extensively used where as gneiss, migmatite and quartzite constitutes the main sources of mineral aggregates in the southern sector.

Gneisses and migmatites, which are converted to aggregates by crushing mechanically, are also exported for use in other regions of Ghana especially in the road sector. Due to the high cost of aggregates made from gneisses and migmatites, low cost housing construction works by indigenes are undertaken using quartzite which is comparatively cheaper.

The quartzite rock aggregates are usually produced by family groups who hand crush the quartzite rock from an outcrop using hammer and chisel. The rock is hand crushed apparently because the miners lack the resources for mechanical crushing apart from the fact that mechanical crushing may completely pulverize the rock into sand due to its inherent weak strength.

The quartzite, which is low in uranium but high in scandium, occurs mainly in the Togo Structural Unit in Southern Ghana alongside quartzitic sandstones, chert, phyllites and mica schist. The Togo Structural Unit has undergone at least two structural deformations, including a low greenschist facies metamorphism that has resulted in the straining of quartz which constitute the major mineral present in the rock (Kesse, 1985; Hammond and Woode, 1988; Nyarku et al., 2011).

Field evidence has shown that different types of quartzite occur in the Togo Structural Unit. The different quartzite types have not been clearly identified and categorized in terms of strength and geological features for concrete production. The lack of proper categorization of the quartzite has resulted in a situation where producers of quartzite rock aggregates mix up the various types before being offered for sale. The outcome of this mixing is that the strength of the resulting quartzite rock aggregates is compromised and may be unpredictable.

The aim of this research, therefore, is to identify and classify the different types of quartzite used in some parts of Southern Ghana and to test for their strength properties so as to determine their suitability for use in construction activities.

2. Materials and Methods

2.1. Materials

Different types of quartzites were selected from rock outcrops of the Togo Structural Unit in Pokuasi (5°41'0"N, 0°16'36"E) in the Greater Accra region of Ghana and differentiated by physical examination. The Togo Structural Unit consists of other rocks such as phyllite, mica schist and chert and stretches from Senya Breku (5°42’0" N, 0°37’0" W) and Gomoa Nyanyano (5°31'29"N, 0°25'20"E) in the Central region of Ghana and Kokrobite (5°30'0" N, 0°22'0" W) in the Greater Accra region to Fodome (7°4' 0" N, 0°30' 0" E) in the Volta region of Ghana. The different quartzite types are readily accessible to the communities along the formation.

2.2. Methods

Tests performed on the aggregates include aggregate impact value, aggregate abrasion value, 10% fines value, aggregate crushing value, water absorption test and petrologic examination of quartzite samples.

2.2.1. Aggregate Impact Value Test

The material used for the Aggregate Impact Value (AIV) is aggregate passing a 12.70 mm sieve and retained on a 9.52 mm sieve. The test samples were placed in the steel mould and compacted by a single tamping of 25 strokes of the tamping rod and subjected to 15 blows of the hammer dropping through a height of 381 mm (BS 812-112).

The crushed aggregate was sieved over a 2.36 mm sieve and the fraction passing 2.36 mm was weighed. The fraction retained on the sieve was also weighed and the aggregate impact value determined.

2.2.2. Aggregate Abrasion Value Test

The test sample weighing 5000g was placed in the Aggregate Abrasion Value (AAV) testing machine and steel balls were added for the crushing as outlined in ASTM C131. The drum of the machine was rotated for 500 revolutions at a speed of 30 to 33 revolutions per minute and the crushed aggregate was discharged and sieved through a 1.70mm sieve and then weighed. The abrasion value of the coarse aggregates was then determined.

2.2.3. Ten Percent Fine Value Test

Ten percent fines value is an indication of the resistance of aggregate to crushing when subjected to loading. The test which was carried out in line with BS 812-111, determined the forces required to produce 10% of fine values.

2.2.4. Aggregate Crushing Value Test

The Aggregate Crushing Value (ACV) is a measure of the resistance of an aggregate crushing under gradually applied compressive load. In the test the aggregate passing through 12.5mm and retained on sieve size 10mm is placed in 3 layers into the cylindrical mould, each layer being tamped with 25 strokes. The aggregate in the mould is then weighed, its surface leveled and the plunger inserted. The apparatus is then placed in the compression testing machine and loaded at a uniform rate. After releasing the load the sample is then sieved through a 2.36mm sieve and the fraction passing through the sieve is weighed. The Aggregate crushing value is the weight of the fraction passing through the sieve / weight of aggregates expressed as a percentage (BS 812-110:1990).

2.2.5. Water Absorption Test

Quartzite aggregates that are retained on the 10mm sieve size were collected into a perforated plate and thoroughly washed to remove dust, and then oven dried at a temperature of about 105°C for a day and weighed. The aggregates were soaked for a day in water after which they were reweighed. The difference in weight, expressed as a percentage, is the absorption (ASTM C127).

2.2.6. Procedure for classification of quartzites

Different types of quartzites were identified in the Togo Structural Unit formation, which is the main source of quartzite rock aggregates in Southern Ghana. The quartzites were subjected to petrologic examination for various geologic characteristics such as structure, thickness, friability, fracture pattern, flakiness, lustre and colour. Petrographic analysis of some samples of the quartzite rock occurring in Kasoa in the Central Region of Ghana was earlier done by Hammond and Woode (1988).

3. Results

The results below are the outcome of the field inspections of rock outcrops within the Togo Structural Unit and various strength tests conducted in the AESL Soil Laboratories in Ghana on the quartzite samples.

Table 1. Water absorption and strength tests results of quartzite types in Togo Structural Unit.

Sample	AIV %	10 % Fine	Force/KN	AAV %	ACV %	Force/ KN	Water Absorption %
Q1	36.37	18.29	110	59.85	32.17	400	1.19
Q2	19.49	17.1	200	38.75	31.4	400	0.39
Q3	15.30	13.14	260	27.45	17.75	400	0.31

Q1- Metasandstone; Q2- Thin layered quartzite; Q3- Metaquartzite

Table 2. A Geological Classification of quartzite types found in the Togo Structural Unit in parts of Southern Ghana.

Quartzite Type	**Description**					
	Structure	**Fracture**	**Thickness**	**Flakiness**	**Lustre**	**Colour**
Q1 Quartzitic sandstone (Metasandstone)	Individual grains of the source rock (sandstone) are visible Quartzitic layers are inter-bedded with friable sandstone.	Fractures around the grains of sand	Variable	Sandstone horizons are friable Quartzitic layers are easily broken with the hand Gives high amount of dust when crushed.	Earthy	Variable Different varieties of brown, dark brown and cream.
Q2 Thin layered quartzite	Moderately thick layers Individual grains of the source rock in some layers are visible only with the aid of hand lens. May be schistose.	Fractures between and across grains	Thinly layered 10-200mm	Flaky Layers cannot be broken with the hand due their thickness; Gives moderate amount of dust when crushed	Greasy	Variable Different varieties of brown, dark brown and cream.
Q3 Metaquartzite	Massive Individual grains of the source rock are not visible even with hand lens. All sedimentary structures have been erased. May be jointed.	Fractures through grains	Massive layers > 200mm	Gives very low amount of dust when crushed	Glassy	Variable Different varieties of brown, dark brown and cream.

4. Discussion

The results of the water absorption tests (Table 1) conducted on the three varieties of quartzites vary due to the fact that Q1 absorbs more water than Q2 and Q3 absorbs the least amount of water. This indicates that Q1 is the most porous of the three samples and therefore may be the weakest in terms of strength.

Other results in Table 1, which include the aggregate impact value, aggregate crushing value and aggregate abrasion value for the quartzite, are presented in Fig. 1. The high aggregate impact value for Q1 quartzite of 36.37% implies that Q1 is too weak to be used for road surfacing and may affect the compressive strength of concrete negatively. The low strength of Q1 quartzite is corroborated by its high 10% Fine value of 18.29%, the high aggregate abrasion value of 59.85% and the high aggregate crushing value of 32.17% compared to the values for Q2 and Q3. The Q3 quartzite has the highest strength and resistance to crushing as indicated by the aggregate impact value of 15.30%, low 10% Fine of 13.14, low aggregate abrasion value of 27.45% and low aggregate crushing value of 17.75%. It is, therefore, good coarse aggregate for all types of construction works including road works, blinding and all reinforced concrete works as well as C_{25}, and C_{30} concrete.

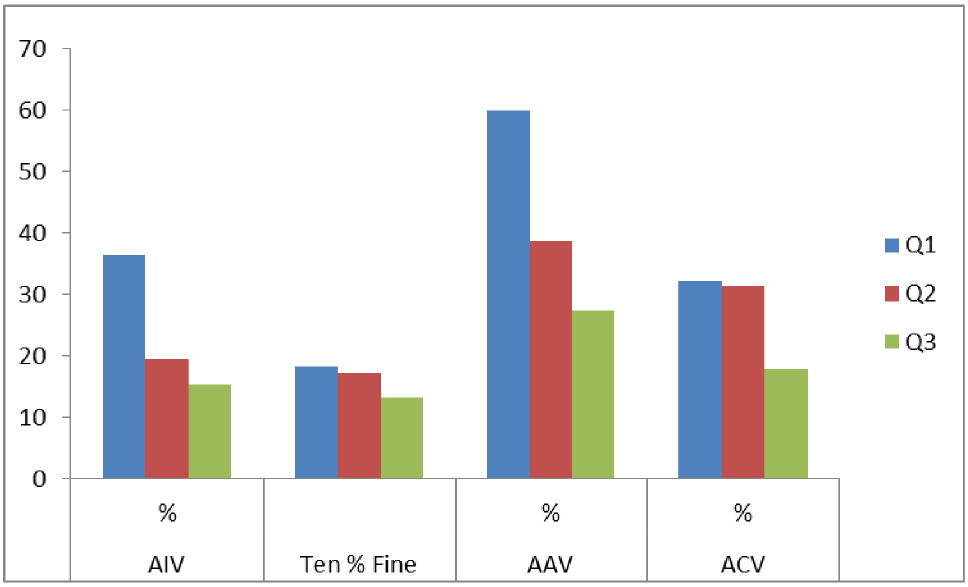

Figure1. A graph showing the average strength values of the different quartzite types.

Table 2 contains the different categorization of quartzite types found in parts of Southern Ghana which can be used for easy field identification. The three types of quartzites may occur together in an outcrop in which case they may be accidentally or ignorantly mixed after crushing before being offered for sale or construction, but careful inspection using the characteristics in Table 2 may serve as useful tool for categorization.

The Q1 quartzite (Table 2) has preserved a number of sedimentary features such as the bedding planes and friability. In terms of the level of metamorphism Q1 quartzite is the least metamorphosed as indicated by the fact that it has retained some sedimentary features. It is therefore, most susceptible to weathering. In terms of luster the Q1 quartzite can be described as being earthy. The Q3 quartzite is the most metamorphosed and as a result, has completely lost all traces of the original grains and sedimentary features. It is the most resistant quartzite type to weathering. The Q3 quartzite usually occurs as massive outcrops with glassy lustre and may be jointed. The jointed Q3 quartzite is likely to be weaker than those which are not jointed. When crushed Q3 quartzite fractures through grains and gives very low amount of dust compared to Q2 and Q1 types of quartzite. The Q2 quartzite however, is flaky, feels greasy and fractures between and across grains. They are often layered, and individual grains of the source rock are visible in some layers with the aid of hand lens. It is also susceptible to weathering, which may start in between layers as they represent weak zones.

The flakiness of Q2 quartzite is likely to lower the workability of a concrete mix and therefore affect its long term durability. Flaky aggregates could affect bituminous mixtures by causing crack development and possible break up during compaction and rolling.

The different samples of quartzite types exhibited varieties of colours which are due to iron oxide (Nyarku et al., 2011) and other impurities being incorporated during the metamorphic process.

According to Hammond and Woode (1988) the quartz, which is the dominant mineral in the quartzite, has undergone various degrees of deformation that are identifiable microscopically. Thin section microscopy analysis which they conducted revealed that the quartz display strained deformational characteristics including different types of mechanical twins. This implies that the deformed and strained quartz may be susceptible to reacting with alkalis. The quartzite aggregate, therefore, could be the source of alkali-silica reaction if it is used for concrete production. The alkali-silica reaction, which takes between 5 and 12 years to develop, may result in the spalling of fragments of surface concrete, cracking and expansion and misalignment of structural elements. The cracks provide passage to water to access the inner parts of the concrete so as to advance the deleterious activities (Swamy, 2003).

In view of its resistance to weathering Q3 quartzite may be valuable for highway construction and as a base material for buildings. The glassy luster of Q3 quartzite however, may cause weak bonding between the aggregate and cement mortar due to its smooth surface. The Q3 quartzite rock aggregate have angular shapes and could form good interlocking network which makes it superior aggregate over rounded aggregates in terms of strength.

Thin Layered Quartzite (Q2 Quartzite)

Thin Layered Quartzite (Q2 Quartzite)

Jointed Metaquartzite (Q3 Quartzite)

Metasandstone (Q1 Quartzite)

5. Conclusion

Three different types of quartzite have been identified as the source of mineral aggregates for concrete production in parts of Southern Ghana. They include quartzitic sandstones, thin layered quartzite and metaquartzite and have been classified as Q1, Q2 and Q3 quartzite types. The quartzite types have presented different strength values which correspond to their degrees of metamorphism. The Q3 quartzite has the highest strength and metamorphism and may be most useful for concrete suitable for structural work. The Q1 quartzite is the least metamorphosed as indicated by the presence of some sedimentary features.

References

Abdullahi. M. (2012), "Effect of aggregate type on Compressive strength of concrete", *International Journal of Civil and Structural Engineering* 2(3), 791-800.

Adom-Asamoah, M., Tuffour, Y. A., Afrifa, R. O. & Kankam, C. K. (2014), "Strength Characteristics of Hand-Quarried Partially-Weathered Quartzite Aggregates in Concrete", *American Journal of Civil Engineering* 2(5), 134-142.

Aginam, C.H., Chidolue, C.A. & Nwakire, C. (2013), "Investigating the Effects of Coarse Aggregate Types on The Compressive Strength Of Concrete", *International Journal of Engineering Research and Applications* 3(4), 1140-1144.

Aitcin, P. C. & Mehta, P. K. (1990), "Effect of Coarse Aggregate Characteristics on Mechanical Properties of High-Strength Concrete", *Materials Journal* 87(2), 103-107.

Bhikshma, V. & Florence ,G. A. (2013), "Studies on effect of maximum size of aggregate in higher grade concrete with high volume fly ash", *Asian Journal of Civil Engineering* 14 (1), 101-109.

Hammond, Q. N. and Woode, A. (1988), "The geology of Kasoa and surrounding areas", *Upublished BSc. Thesis, University of Ghana, Legon.*

Lollino, G., Manconi, A., Guzzetti, F., Culshaw, M., Bobrowsky, P., & Luino, F. (2014), "Engineering Geology for Society and Territory", *Urban Geology Science* 5.

Kesse, G. O. (1985), "The mineral and rock resources of Ghana", *A. A. Balkerma*.

Nyarku, M., Ganyaglo, S., Glover, E. & Serfor-Armah, Y. (2011), "Major elements and lithostratigraphic study of the contact rocks of the Togo and the Dahomeyan formations in Ghana", *Natural Science*, 3, 646-650.

Su, R.K. L. & Cheng, B. (2008), "The Effect of Coarse Aggregate Size on the Stress-strain Curves of Concrete under Uniaxial Compression", *Transactions of Hong Kong Institution of Engineers* 15(3), 33-39.

Shetty, M.S. (2000), "Concrete technology theory and practice". *Pub. By S.Chand and company Ltd New Delhi.*

Swamy, R.N., (2003), "The alkali-silica reaction in concrete", *Pub. By Blackie and Son, Ltd.*

Woode, A. (1994), "A petrological study of the igneous and metamorphic rocks of Nsawam S.E. Ghana", *Unpublished MPhil. Thesis, Univ. of Ghana, Legon.*

Woode, A., Amoah, D. K., Aguba, I.A. & P. Ballow, (2015), "The Effect of Maximum Coarse Aggregate Size on the Compressive Strength of Concrete Produced in Ghana", Civil *and Environmental Research* 7(5), 7-12.