IMPACT OF COARSE AGGREGATE ON COMPRESSIVE STRENGTH OF CONCRETE

[1]Jeriscot H. Quayson, MSc, [2]Zakari Mustapha, PhD
School of Engineering, Department Building Technology P. O. Box AD. 50, Cape Coast. Ghana.
E-mail: [1]papajerisco@yahoo.co.uk
[2]zakari.mustapha1967@gmail.com

ABSTRACT

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Over one-third of the volume of concrete is occupied by coarse aggregate and any changes in coarse aggregate type can affect its strength and fracture properties. The paper examined the impact of coarse aggregates on compressive strength of concrete. Slump and compaction factor tests were conducted on the mixture of quartzite and crushed granite course aggregates, and quarry dust (fine aggregate). Nominal mix (1:2:3) was adopted and mix compositions were calculated by absolute weight method. Twelve (12) cubes (150x150mm) of each type of coarse aggregate were cast for 7, 14, 21, and 28 days to determine their compressive strengths. Quartzite was found to have the highest average compressive strength of 24.48N/mm^2 with an average density of 2160kg/m^3, while compressive strength of crushed granite was 22.01N/mm^2 with an average density of 2300kg/m^3 on the 28 day of testing. Concrete made from granite had the highest workability, while concrete made from quartzite aggregate had the highest compressive strength. Densities and compressive strengths of the individual aggregates accounted for the variation in strengths of the concrete, due to differences in properties and strengths. In conclusion, the effect of any type of coarse aggregate on the compressive strength of concrete will be known and also enable contractors to determine the type of aggregate to be selected for a particular work.

Keywords: *Compaction factor test; slump test; strength; workability.*

INTRODUCTION

The use of granite in the construction industry as indicated by Ellis (2006) and Bremmer (2006) cannot be over emphasize, with dimension stone, cement manufacture, construction aggregates, rail track ballast and road construction. The physical properties of quartzite, including toughness and density, make this metamorphic stone particularly resistant to erosion and weathering Perdikaris and Romeo (2007). Properties of granite also include resistance of granite to heat, water, pressure, impact (Ezeldin and Aitcin, 2006). Granite is frequently selected because it is a prestige material, used in projects to produce impressions of elegance, durability and lasting quality (Anosike and Oyebande, 2012). The physical properties of quartzite depend on its formation (Ezeldin and Aitcin, 2006). The specific heat capacity of quartzite is 0.75 kJ/Kg and it is one of the important properties of quartzite. Properties of quartzite also include resistance of quartzite to heat, water, pressure, impact etc. (Ezeldin and Aitcin, 2006). Production of concrete requires water that is free from suspended particles, inorganic salts, acids and alkalis, contamination and algae (Elices and Rocco, 2008). Since the presence of impurities may affect the strength of the concrete which can cause strength variation on the various types of aggregates (Elices and Rocco, 2008).

Moreover, the type of machine used indirectly affects the strength of concrete for the moulding of the concrete cube (Duggal, 2003). Study has showed that the effects of poor curing method will reduce the compressive strength of concrete. Curing of concrete products may start after 24hours of casting the concrete and can be done in various ways and methods (sprinkling of water on the concrete, soaking the product in water etc.). When all the concrete products are not given the same treatment of curing, the formation of their chemical reactions would be different which will cause their strength to also differ. Improper batching of material and mix proportion may affect the strength of concrete and excess water may affect the strength of the concrete (Ruiz 2006). The paper examined the impact of coarse aggregate on compressive strength of concrete. The preceding section discusses the various literature on the materials and test on concrete. It also discusses relevance of compressive strength of concrete, average compressive strength of concrete with crush granite and quartzite and factors that accounts for the variation in strength.

LITERATURE REVIEW

This section presents literature relevant to compressive strength of concrete, average compressive strength of concrete with crush granite and quartzite, and factors that accounts for the variation in strength. The compressive strength of concrete depends on the water to cement ratio, degree of compaction, ratio of cement to aggregate, bond between mortar and aggregate, and grading, shape, strength and size of the aggregate Mindess, Young and Darwin (2003). Concrete can be visualized as a multi-phase composite material made up of three phases; namely the mortar, mortar/aggregate interface, and the coarse aggregate phase. The coarse aggregate in normal concrete are mainly from rock fragments characterized by high strength. Therefore, the aggregate interface is not a limiting factor governing the strength requirement (Beshr, Almusallam, and Maslehuddin 2003). The onset of failure is manifested by crack growth in the concrete. For normal concrete, the crack growth is mainly around the cement paste or at the aggregate/cement paste interfacial zone. The strength of concrete at the interfacial zone essentially depends on the integrity of the cement paste and the nature of the coarse aggregate. The effect of using crushed quartzite, crushed granite, limestone and marble as coarse aggregate on the mechanical properties of high-performance concrete as indicated by Wu, Chen, Yao, and Zhang (2007) in their study were that the strength, stiffness and fracture energy of concrete for a given water/cement ratio depend on the type of aggregate. Özturan, and Çeçen (2007) posited that basalt, limestone and gravel have been used as coarse aggregate to produce normal and high-performance concrete. High performance concrete at 28 days, basalt produced the highest strength, whereas gravel gave the lowest compressive strength. Normal strength concrete made with basalt and gravel gave similar compressive strength while the concrete containing limestone attained higher strength.

Meddah, Zitouni, and Belâabes (2010) conducted a research on the effects of content and particle size distribution of coarse aggregate on the compressive strength of concrete. Three types of coarse aggregates were mixed in four different proportions for concrete production. Plasticizers and Super plasticizers were used in some mixes to reduce the water to cement ratio. The outcome of their work showed that the mixture with a ternary combination of granular fraction with a maximum size of 25mm, without admixtures have shown the highest compressive strength. At a lower water to cement ratio, the binary granular system produced the highest compressive strength. Elices and Rocco (2008) compared concretes with the same mix proportions containing four different coarse aggregate types. They concluded that in high-strength concretes, higher strength coarse aggregates typically yield higher compressive strengths, while in normal-strength concretes; coarse aggregate strength has little effect on compressive strength. While Özturan and Çeçen (2007) compared the effects of limestone and basalt on the compressive strength of high-strength concrete in their research and concluded that concrete containing basalt as coarse aggregate exhibit higher bond strengths with reinforcing steel than concretes containing limestone. A test conducted by Kyoung-Min, Lee and Jae-Yeol (2018) for mortar and concrete specimens with various maximum aggregate sizes showed that the larger maximum coarse aggregate sizes induce larger heterogeneity of specimens.

Meddah, Zitouni and Belâabes (2010) posited that compressive strength increases with the type of aggregate used. While, Walker and Bloem (2007) attest that the type of coarse aggregate used results in a decrease in the compressive strength of concrete. Ruiz (2006) on the other hand, found that the compressive strength of concrete increases when the content of the coarse aggregate increases until a critical volume is reached. Mindess, Young and Darwin (2003) also indicated that compressive strength of concrete depends on the water to cement ratio, degree of compaction, ratio of cement to aggregate, bond between mortar and aggregate, grading, shape, strength and size of the aggregate. The preceding section discusses the methods adopted in this research. It further describes the instruments and materials used during the experiment, as well as how the experiments were carried out.

RESEARCH METHODOLOGY

This chapter describes the methods adopted for the research work. Materials used for the laboratory work were obtained from Cape Coast in the Central Region of Ghana. The instruments used for the laboratory work include, digital compressive machine of capacity 3000KN, 250ml measuring cylinder, digital weighing scale, compacting factor apparatus, slump cone apparatus, base plate, mechanical shaker,16mm tamping rod, concrete mixer and 150mm x 150mm x 150mm cube mould. Materials used include coarse aggregates (crush granite and quartzite), fine aggregate, Dangote cement, Grade 45.5R) and portable pipe-borne water from Ghana Water Company. The materials were batched by weight with cement, sand to stone in proportion of 1:2:3, with water-cement ratio of 0.70. The material was mixed and cast in mould and was cured for 7days, 14days, 21days and 28days before crushing. Compressive test was conducted by mixing the materials in a concrete mixer, in accordance to American Standard of Testing Materials (ASTM 192). The specimen was cast into 150mm x 150mm x 150mm steel moulds and compacted with a tamping rod in three layers. A weighing scale was used in batching the components of the concrete. The sample was demoulded and cured in water after 24hours. The compressive strength of the cubes was determined by crushing them in a digital compressive machine in accordance to British Standard. Three (3) cubes were tested to determine their compressive strength at various ages of curing. Batching and mix proportions were done by weight using a weighing scale. Since the mix ratio is 1:2:3, the batched were in relation to the ration. Mix proportions of concrete had weights (kg) of materials as follows: Dangote cement –15kg, fine aggregate -30kg, coarse aggregates – 45kg and pipe-borne water -10.5kg. Twenty-four (24) cubes, twelve (12) from each type of coarse aggregate (crushed granite and quartzite) were moulded, cured and tested to determine the compressive strengths of the various cubes. Out of the 12 cubes from each of the aggregate type (3 cubes) was tested for seven days, 14 days, 21 days and 28 days respectively. Inferential statistics was used in data analysis.

FINDINGS AND DISCUSSIONS

This section presents findings from the laboratory experiment conducted on compressive strengths of coarse aggregates (crush granite and quartzite).

Table 1: Compaction Factor and Slump Tests on Crushed Granite and Quartzite

Fine Aggregate Types	Partially Compaction Factor			Fully Compaction Factor			Compaction Factor	Average Slump (mm)
	Weight of Empty Cylinder (kg)	Weight of Concrete and Cylinder (kg)	Weight of Concrete P (kg)	Weight of empty cylinder (kg)	Weight of Concrete and Cylinder (kg)	Weight of Concrete F (kg)	P/F	
Crushed Granite	7.20	17.15	9.95	7.24	18.85	11.61	0.86	26.70
Quartzite	7.20	16.90	7.20	7.24	18.95	11.71	0.61	15.23

Table 1 shows the compaction factor test with concrete produced with crushed granite and quartzite. Crushed granite had a compaction faction of 0.86, whiles that of quartzite was 0.61. The average slump for crushed granite was found to be 26.70mm, which is 11.47mm higher than the average slump for quartzite.

Table 2: Average Compressive Strength of Concrete Produced with Crushed Granite

Age in Days	Sample	Date of Casting	Date of Test	Mix Ratio	Volume of Concrete (m^3)	Weight in Air (kg)	Weight in Water (kg)	Density (kg/m^3)	Cross-Sectional Area (mm^2)	Maximum Load (KN)	Compressive Strength (N/mm^2)
	A				0.003375	7.96	4.47	2.28		624.67	27.76
7	B	19/03/2018	26/03/2018	1:2:3	0.003375	7.72	4.29	2.25	22500	501.95	22.31
	C				0.003375	7.61	4.28	2.29		601.66	26.74
Average Compressive Strength			25.60N/mm^2								
Average Density			2.27kg/m^3								
	A				0.003375	7.96	4.43	2.26		454.24	20.19
14	B	19/03/2018	02/04/2018	1:2:3	0.003375	7.72	4.07	2.11	22500	449.64	19.98
	C				0.003375	7.62	4.27	2.28		457.77	20.35
Average Compressive Strength			20.17N/mm^2								
Average Density			2.22kg/m^3								
	A				0.003375	8.06	4.64	2.36		519.28	23.08
21	B	19/03/2018	09/04/2018	1:2:3	0.003375	7.86	4.51	2.35	22500	537.23	23.88
	C				0.003375	8.24	4.74	2.35		557.48	24.78
Average Compressive Strength			23.91N/mm^2								
Average Density			2.35kg/m^3								
	A				0.003375	7.67	4.32	2.29		624.67	27.76
28	B	19/03/2018	16/04/2018	1:2:3	0.003375	7.83	4.45	2.32	22500	521.28	23.17
	C				0.003375	7.83	4.42	2.30		339.81	15.10
Average Compressive Strength			22.01N/mm^2								
Average Density			2.30kg/m^3								

Table 2 shows the average compressive strength of concrete produced with crushed granite for the 7days, 14days, 21days and 28days. The age of the concrete produced 7days had the highest an average compressive strength of 25.60N/mm^2, with density of 2.27kg/m^3 followed by the age of the concrete produced in 21days, with an average compressive strength of 23.91N/mm^2 and density of 2.35kg/m^3, and 28days with an average compressive strength of 22.01N/mm^2 and density of 2.30kg/m^3. The least average compressive strength of 20.17N/mm^2 and density of 2.22kg/m^3 was recorded in the age of 14days.

Table 3: Average Compressive Strength of Concrete Produced with Quartzite

Age in Days	Sample	Date of Casting	Date of Test	Mix Ratio	Volume of Concrete (m^3)	Weight in Air (kg)	Weight in Water (kg)	Density (kg/m^3)	Cross-Sectional Area (mm^2)	Maximum Load (KN)	Compressive Strength (N/mm^2)
	A				0.003375	8.16	4.58	2.28		632.34	28.10
7	B	21/03/2018	28/03/2018	1:2:3	0.003375	8.24	4.32	2.10	22500	701.37	31.17
	C				0.003375	7.85	4.23	2.17		509.62	22.65
Average Compressive Strength									27.31N/mm^2		
Average Density						2.18kg/m^3					
	A				0.003375	7.89	4.42	2.27		521.13	23.16
14	B	21/03/2018	04/04/2018	1:2:3	0.003375	7.49	4.17	2.26	22500	464.37	20.64
	C				0.003375	7.80	4.40	2.29		514.68	22.87
Average Compressive Strength									22.22N/mm^2		
Average Density						2.27kg/m^3					
	A				0.003375	7.98	4.60	2.36		631.73	28.08
21	B	21/03/2018	11/04/2018	1:2:3	0.003375	8.05	4.63	2.35	22500	496.12	22.05
	C				0.003375	7.72	4.45	2.36		349.47	15.53
Average Compressive Strength									21.89N/mm^2		
Average Density						2.36kg/m^3					
	A				0.003375	8.16	4.59	2.29		721.93	32.09
28	B	19/03/2018	18/04/2018	1:2:3	0.003375	7.78	4.17	2.16	22500	325.23	15.65
	C				0.003375	8.05	4.60	2.33		578.11	25.48
Average Compressive Strength									24.48N/mm^2		
Average Density						2.26kg/m^3					

Table 3 shows the average compressive strength of concrete produced with quartzite for the 7days, 14days, 21days and 28days. The age of the concrete produced 7days had the highest an average compressive strength of 27.31N/mm^2 and density of 2.18kg/m^3, followed by the age of the concrete produced in 28days, with an average compressive strength of 24.48N/mm^2 and density of 2.26kg/m^3; and 14days with an average compressive strength of 22.22N/mm^2 and density of 2.27kg/m^3. The least average compressive strength of 21.89N/mm^2 and density of 2.36kg/m^3 was recorded in the age of 21 days.

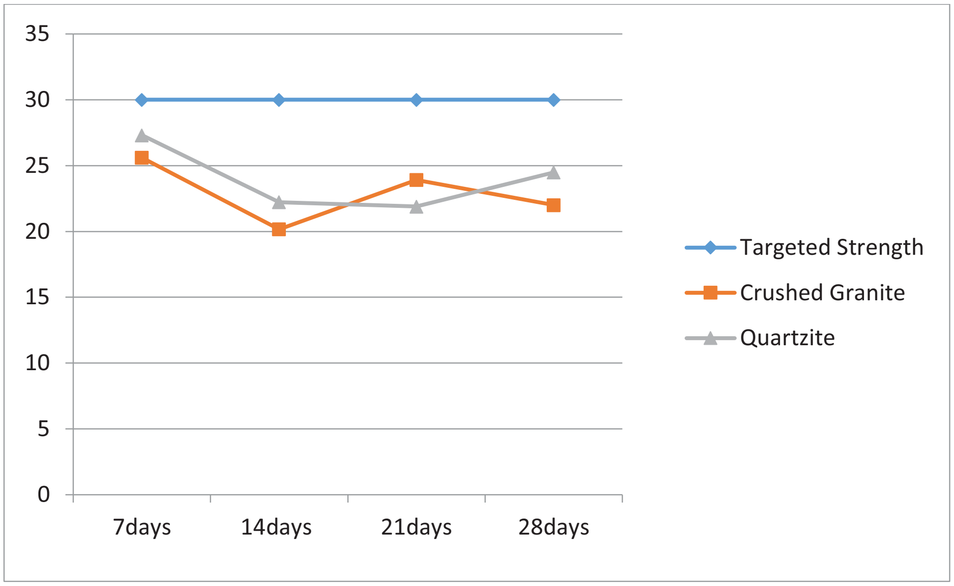

Figure 1: Comparative Analysis of Average Compressive Strength of Concrete Produced with Crushed Granite and Quartzite.

Figure 1 shows that on the seventh (7) day, quartzite recorded the highest compressive strength of 27.31N/mm^2 with an average density of 2.18kg/mm^3, whiles that of crushed granite on the seventh (7) day recorded an average compressive strength of 25.60N/mm^2 with an average density of 2.27kg/m^3. Both results obtained were close to the targeted strength of 30N/mm^2. The results also show that the average compressive strength of quartzite on the 7, 14 and 28days were higher than the crushed granite, except for the 21 day which recorded a lower strength as compared to that of crushed granite. Even though, the results obtained were closed to the targeted strength of 30N/mm^2, yet there was a shortfall of 5.52N/mm^2 and 7.99N/mm^2 in favour of quartzite and crushed granite respectively.

Table 4 The Variation in Strength from Seven to 28 Days

Age in Days	Crushed Granite (N/mm^2)	Quartzite (N/mm^2)	Variation (N/mm^2)	Remarks
7	25.60	27.31	1.71	Plus for quartzite
14	20.17	22.22	2.05	Plus for quartzite
21	23.91	21.89	2.02	Plus for crushed granite
28	22.01	24.48	2.47	Plus for quartzite

Table 4 shows the variation in strength from seven to twenty-eight days with concrete produced with crushed granite and quartzite. It was revealed that quartzite has the higher strengths of (27.31N/mm^2, 22.22N/mm^2, 24.48N/mm^2) on the seventh ,14th and 28th days of testing, whiles crushed granite recorded a higher strength on the 21 day of testing (23.91N/mm^2 as against quartzite 21.89N/mm^2). The variation in strengths of both aggregates may be attributed to properties of the coarse aggregates and their composition, method of curing adopted and water cement ratio used. Both aggregates (crushed granite and quartzite) were given the same conditions in terms of the concrete production. Ezeldin and Aitcin (2006) indicated that crushed granite is porous and its density ranges between 2.65 - 2.75 g/cm^3. While its hardness is 6-7 and compressive strength of 175.00 N/mm^2. The specific gravity of granite ranges between 2.6 - 2.7, with specific heat capacity of 0.79 kJ/Kg. The strength of crushed granite reduces in the presence of water. Whereas, quartzite is porous and its density is 2.32 - 2.42 g/cm^3, which is lower than that of crushed granite. Both crushed granite and quartzite have similar hardness, but with difference in compressive strength of 60 N/mm^2 in favour of crushed granite. The specific gravity of both crushed granite and quartzite were similar and difference in specific heat capacity of 0.04 kJ/Kg in favour of quartzite (Ezeldin and Aitcin, 2006). Judging from the above discussion, it can be concluded that strength from seven to twenty-eight days, as shown in Table 4 may be attributed to the properties of the individual aggregates. Most especially, their densities and compressive strengths as shown in Tables 2 and 3, due to different properties in aggregates. Kyoung-Min, Lee and Jae-Yeol (2018) were of the view that the effect of coarse aggregate size can be based on the dynamic concrete compressive strength.

CONCLUSION

The paper examined the impact of coarse aggregates type on the compressive strength of concrete. Concrete made from quartzite aggregate had the highest compressive strength from the findings. Quartzite had the highest average compressive strength of 24.48N/mm^2 with an average density of 2.16kg/m^3, whiles that of Crushed Granite was 22.01N/mm^2 with an average density of 2.30kg/m^3 on the 28 day of testing. This shows that both aggregates (crushed granite and quartzite) could not meet the targeted strength of 30N/mm^2, used for concrete production. The average compressive strength of Quartzite on the 7, 14 and 28days were found to be higher than the Crushed Granite, except for the 21 day which recorded a lower strength as compared to that of Crushed Granite. The results were close to the targeted strength of 30N/mm^2, with difference of 5.52N/mm^2 and 7.99N/mm^2 for Quartzite and Crushed Granite respectively. Concrete strength of 25N/mm^2 should be chosen over 30N/mm^2, since all the average compressive strengths from the 7day to the 28day did not meet the required target strength of 30N/mm^2. Both crushed granite and quartzite aggregates should not be encouraged for producing concrete with a mix ratio 1:2:3 of strength 30N/mm^2, but rather 25N/mm^2. Quartzite aggregate had the highest strength on the 7, 14 and 28days compared to the crushed granite. Different cement type should be used in other to check the flow of its strength and aggregates with similar properties to produce the concrete cube. The factors that accounted for the variation in strength of the concrete are attributed to the properties of the individual aggregates (densities and compressive strengths) due to different properties and strength.

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