Comparative Analysis of Strength of Concrete Based on Different Types of Fine Aggregate

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Abstract: ***The increasing cost and scarcity of natural sand for concrete production*** *has led to the use of various types of fine aggregate for concrete production.* ***The paper compares the compressive strength of concrete produced with and without varied proportions of Quarry dust, Pit sand from Wiamoa and River sand from Okyi River (Mankessim). The paper was limited to the compressive strength of concrete for columns and beams with coarse aggregate size of 14mm nominal size and compressive strength of 30N/mm². Water-cement ratio of 0.5 was used for a mix ratio of 1:2:4 and proportion of sand, 50% each. A total of 72 specimens were cast and cured for 7, 14, 21, and 28 days respectively. Three cubes each were crushed using the compressive testing machine and the average taken as the compressive strength of the concrete. Results shows that river sand had the highest average compressive strength of concrete produced without varied proportion of sand with 37.78N/mm², while quarry dust and river sand had the highest average compressive strength for concrete produced with varied proportion. Quarry dust and river sand have the highest average compressive strength of 36.09N/mm². River sand should be used when producing concrete without varied proportion, whiles quarry dust and river sand should be used for varied proportion of sand for good compressive strength.***

Keywords: Quarry Dust, Compressive Strength, Pit Sand, River Sand, Slump Test

1. Introduction

Quarry dust, Pit sand and River sand have been the most popular used fine aggregate in the production of concrete. Khamput, 2006[1]; Jayawardena and Dissanayake (2006)[2]posited that the over use of these materials has contributed to environmental degradation risk. Many construction practitioners have devised varying proportion of sand, aimed at achieving specified compressive strength of concrete, due to the risk posed by environmental degradation. Shetty (2005) [3] indicated that sand is classified as pit sand, river sand, and sea sand or crushed stones (artificial sand). Quarry dust has also been used to wholly replace sand in concrete without any reduction in the quality of the concrete [4]and [5]. Priyadharshini and Krishnamoorthi (2014)[6] argued that high strength concrete can be produced with quarry dust, as the sole fine aggregate and with 10% of cement content replaced with silica fume. One notable disadvantage of wholly using quarry dust to replace sand or in producing higher grade of concrete (>40N/mm²) is that the concrete will have very low workability, necessitating the use of high water and reducing admixtures to improve workability.

Quarry dust is one of the alternatives that have yielded the most encouraging results. Research has shown that quarry dust can be used to partially, and sometimes, wholly replace natural sand in concrete. Works by [7] and [8], show that the compressive strength of concrete is greatly improved when sand is partially replaced with quarry dust. Similar result was obtained by [9]. Devi and Kannan, (2011a)[10] posited that the use of quarry dust has also been shown to improve not only the strength properties but also the durability and the mechanical properties. Devi and Kannan, (2011b)[11] also showed that the corrosion resistive property of concrete is enhanced when quarry dust is incorporated and the cement is partially replaced with ground granulated blast furnace slag. Fine quarry dust gives an added strength to concrete and mortar. This is evident in the works of [12]. They compared the compressive strengths of concrete in which the sand was partially replaced with quarry dust with its finer particles (<75 microns) removed to that in which they were included and found that the later gave relatively higher results. This is because the finer particles helped in creating a more dense structure by effectively filling the spaces between the bigger particles. Sukesh et al. (2013) [9] argued that the water demand for concrete with sand partially replaced with quarry dust is relatively higher than that without its inclusion for the same slump. This shows that the more the quarry dust content, the greater the water demands. The cement content when quarry dust is wholly used to replace sand in concrete is also relatively higher. These two factors may cause a substantial increase in the cost of the concrete. The strength property of green concrete was enhanced when quarry dust and marble sludge powder were used as fine aggregate in place of sand [13].The paper seek to compares the compressive strength of concrete produced with and without varied proportions of Quarry dust, Pit sand from Wiamoa and River sand from Okyi River (Mankessim).

2. Literature

The strength of concrete is commonly considered as the most valuable property, although, in many practical cases, other characteristics, such as durability and permeability, may be more important [14]. Strength is directly related to the structure of the hydrated cement paste and it's usually gives an overall picture of the concrete's quality [14]. Several studies have been conducted on the compressive strength of concrete. It is almost invariably a vital element of structural design and it is specified for compliance purposes. Ephraim and Ode (2006) [15] in their work on the suitability of concrete made with the washed 10mm all-in aggregate yielded a characteristic strength value of about 20.80N/mm² at the optimum water-cement ratio of 0.50. The used of quarry dust as a fine aggregate [4], used 150 mm x 150 mm x 150 mm cube test specimens to determine its compressive strength. The result showed that the compressive strength of quarry dust concrete was comparatively 10-12 percent more than that of similar mix of conventional concrete. Waziri et al (2011) [16] tested the compressive strengths of concrete made with quarry dust as fine aggregate and found that the strength was greatly influenced by the water/cement ratio. Venkata et al. (2013) [17] were of the view that the amount of quarry dust from the crushing process is 20 -25% of the final product from stone crushing units. Jaywardena et al. (2006) [2] indicated that river sand can be obtained by dredging from river beds. However, [7] posited that its cost has gone up and this development has contributed to its limited supply for construction projects. Zongjin Li (2011) [18] was of the view that compacting can make concrete denser and stiffer and thus have a good compressive strength and low permeability. The purpose of compacting is to remove the air entrapped during concrete placement and to consolidate plastic concrete into all the spaces in the formworks and in the reinforcing steels. Without proper compacting, high-quality concrete cannot be achieved. Alilou and Teshnehlab (2010) [19] argued that ratio of water to cement is the chief factor for determining concrete strength. However, minimum amount of water is necessary for proper chemical action in the hardening of concrete whiles extra water increases the workability but reduces strength.

2.1 Characteristics of River Sand and Pit Sand

The characteristics of river sand would improve the workability of concrete and mortar compared to the use of their alternatives, such as crushed rock fine [7]. The use of river sand would for a given workability requirement, reduce the water demand and or super plasticizer demand, and thus allow a lower water content and a lower cement content to be adopted in the mix design. With lower silt and clay contents, the use of river sand would improve the quality control of the concrete/mortar production because the presence of too much silt and/or clay would adversely affect the workability and strength of the concrete/mortar produced [7]. Pit sand on the other hand is classified under coarse sand which is procured from deep pits of abundant supply and it is generally in grey-yellowish colour. The coarse grain is sharp and angular which is mostly employed in concreting [20].

2.2 Rate of Application of Load

Rate of application of load has a considerable influence on the strength test results. If the rate of application of load is slow, or there is some time lag, then it will result into lower values of strength, [21]. Due to slower application of load, the specimen will undergo some amount of creep which in turn increases the strain. And this increased strain is responsible for failure of test sample, resulting lower strength values. Mishra (2008) [22] indicated that the degree of hydration is synonymous with the age of concrete provided the concrete has not been allowed to dry out or the temperature is too low. It is generally accepted that about 90% of the strength is achieved by 28 days for convenience and most cases in practical applications.

3. Research Methodology

This section presents the procedures and methods used in gathering data for the research. Descriptive research which employs a quantitative research approach was used. Series of laboratory works conducted to measure the compressive strength of concrete produced with and without varied proportion of quarry dust, pit sand and river sand [23]. Concrete specimens were collected from the materials laboratory of Building Technology and Civil Engineering Departments of Cape Coast Technical University. The suitability of using the aggregates for construction work was determined at the laboratory. The paper was limited to the compressive strength of concrete for columns and beams with coarse aggregate size of 14mm nominal size and compressive strength of 30N/mm^2.Potable drinking water was found to be suitable for concrete work [24]. A nominal mix ratio of 1:2:4 (Cement: Fine Aggregate: Coarse Aggregate) was adopted for the purpose of this work and a water-cement ratio of 0.5 was used. The mix composition was computed using the batching by weight method. The casting, curing and testing of specimen were carried out on six sets of mix constituents as shown in Table 1. The required weight of the mix constituent was measured and mixed thoroughly, using a concrete mixer to ensure that homogenous mix was obtained. Slump of the concrete was measured in accordance to [25] before casting. For each type of mix 12 cubes (150x150mmx150mm) was cast in accordance to [26]. The concrete cubes were de-moulded, after a day of casting and transferred to a water tank for curing until the time of test. The curing of the cube was done in accordance to [27]. The concretes were tested for compressive strength at 7, 14, 21, and 28 days. Three cubes each was crushed using the compressive testing machine and the average taken as the compressive strength of the concrete.

Table 1: Mix Constituent

Fine Aggregate	Mix Proportion	Number of Specimen
Quarry dust	100%	12
Pit sand	100%	12
River sand	100%	12
Quarry dust + Pit sand	50% + 50%	12
Quarry + River sand	50% + 50%	12
Pit sand + River sand	50% + 50%	12

The test involved seventy-two (72) concrete specimen of standard cubes of size 150 x 150 x 150mm cast, cured and tested. Three (3) cubes each of the mix were used to determine the compressive strengths at various ages (7days, 14days, 21 days and 28days) at the proportions of 100% for control of all the sand and quarry dust (50%) and pit sand (50%) mix, quarry dust (50%) and rive sand (50%) mix, and pit sand (50%) and river sand (50%), therefore 12 concrete cubes each for the mix was tested. Concrete cubes (150mm) were mixes before they were cast and cured in water until testing on the 7th, 14th, 21st, 28thdays. Each mix of 12 cubes was cast. Three (3) cubes of each mix were tested each day with Digital Compressive Strength Machine with capacity of 1500KN. Compression was done in the laboratory to check that the cured concrete has obtained the required designed strength. Each cube was crushed once in the compression machine.

4. Results

This section presents the results from the laboratory experiments on concrete produced with and without varied proportion of quarry dust, pit sand and river sand to determine the compressive strength of concrete. Table 1 shows that the quarry dust and river sand had the highest average compressive strength with an average mean of 36.09 N/mm^2 during the four weeks period of experiment.

Table 1: Distribution of Descriptive Statistics for Compressive Strength of Concrete Produced with Varied Proportion of Sand

Days of Concrete	Concrete Type	Mean N/mm^2	Std. Dev.	No. of Samples
7days	Quarry Dust + Pit Sand	28.13	1.55	3
	Quarry Dust + River Sand	31.96	1.92	3
	River Sand + Pit Sand	28.80	3.39	3
	Total			**9**
14days	Quarry Dust + Pit Sand	31.30	2.10	3
	Quarry Dust + River Sand	36.97	2.24	3
	River Sand + Pit Sand	29.24	4.98	3
	Total			**9**
21days	Quarry Dust + Pit Sand	28.33	5.49	3
	Quarry Dust + River Sand	35.43	1.99	3
	River Sand + Pit Sand	33.80	1.42	3
	Total			**9**
28days	Quarry Dust + Pit Sand	34.69	3.01	3
	Quarry Dust + River Sand	36.09	1.60	3
	River Sand + Pit Sand	34.03	1.26	3
	Total			**9**

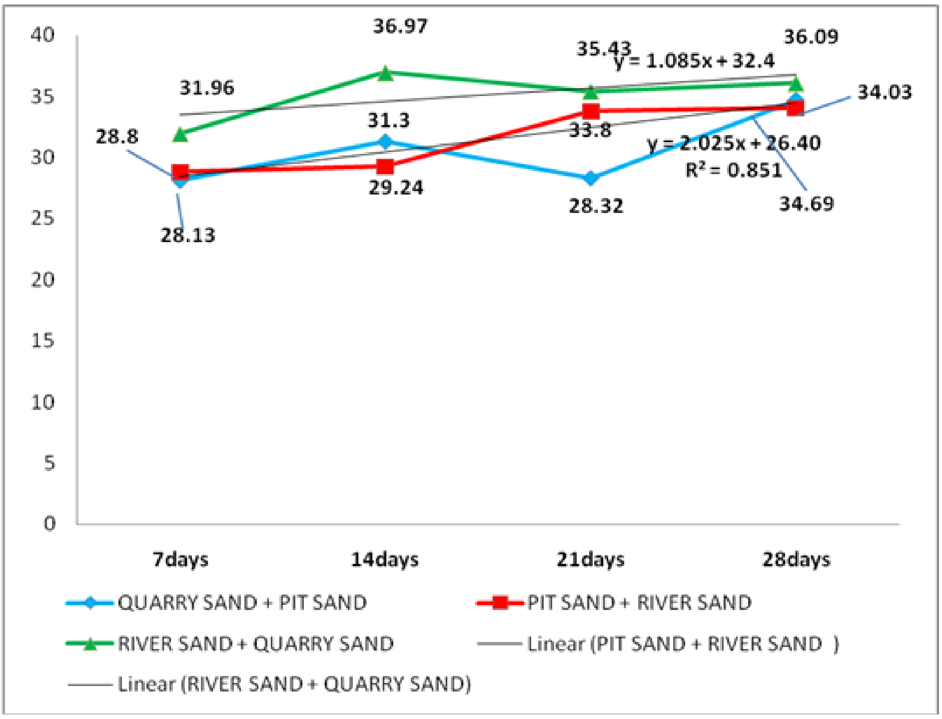

Figure 1: Distribution of Average Trend of Compressive Strength of Concrete Produced With Varied Proportion of Sand

The paper further checked the trend of compressive strength of concrete produced with varied proportion of sand as in figure 1. It shows that the compressive strength of other concrete produced with varied proportion of sand varied in strength over a period of time. There was also a steady rise of compressive strength of concrete produced from pit + river sand as compared with that of quarry dust + river sand with a slope equation of ***y***= 2.025x +28 and R^2=0.851**.**The R^2 means that 85.1% variation of the compressive strength of concrete produced from pit + river sand has been explain. Again, the paper sought to find out whether concrete produced with varied proportion of sand have the same compressive strength with respect to days even though the descriptive and the trend show some differences. The paper used 7days, 14days, 21day and 28days, and varied quarry dust and pit sand, quarry dust and river sand, and pit and river sand.

Table 2: Distribution of the Results of ANOVA Test for Compressive Strength of Concrete Produced with Varied Proportion of Sand

Source	Sum of Squares	dff	Mean Square	F	Sig.
Corrected Model	338.105[a]	11	30.737	3.650	0.004
Intercept	37784.880	1	37784.880	4487.040	0.000
Days	127.085	3	42.362	5.031	0.008
Varied Sand	137.070	2	68.535	8.139	0.002
Days * Varied Sand	73.950	6	12.325	1.464	0.233
Error	202.101	24	8.421		
Total	38325.087	36			
Corrected Total	540.206	35			
R Squared = 0.626 (Adjusted R Squared = 0.454)					

The two-way ANOVA test provides information about the main and interaction effects as shown in table 2. For the day's main effect, $F_{0.05}$ = 5.031and has an obtained probability of 0.008. Since 0.008<0.05, it can be concluded that there is a significant day's main effect on the concrete strengths. Since the independent variable is "days of concrete", meaning the "days of concrete" has a significant main effect on concrete strength. Table 2 also shows that for the varied sand main effect, $F_{0.05}$ = 8.139, has a probability of 0.002. Since 0.002< 0.05, it can be concluded that there is a significant varied sand main effect on concrete strength. Since the varied sand independent variable was "type of varied sand", it means that type of varied sand has a significant main effect on the concrete strength. It was also shown that for the day's X varied sand interaction, $F_{0.05}$ = 1.464, with a probability of 0.233. Since 0.233>0.05, it means that there was no significant day's X sand interaction. This implies that days of varied concrete and type of varied sand used determined the compressive strength of concrete produced.

4.1 Compressive Strength of Concrete Produced Without Varied Proportion of Sand

Table 3 shows that the river sand recorded the highest average for the 28days. This implies that river sand had the highest average compressive strength with an average mean of 37.78 N/mm^2

Table 3: Distribution of Descriptive Statistics for Compressive Strength of Concrete produced Without Varied Proportion of Sand

Days of Concrete	*Concrete Type*	*Mean N/mm^2*	*Std. Dev.*	*No. of Samples*
7days	Quarry Dust	19.52	7.30	3
	Pit Sand	25.19	0.56	3
	River Sand	29.53	2.55	3
	Total			**9**
14days	Quarry Dust	22.17	1.98	3
	Pit Sand	23.20	3.54	3
	River Sand	34.76	2.36	3
	Total			**9**
21days	Quarry Dust	22.61	3.55	3
	Pit Sand	26.88	4.79	3
	River Sand	37.19	1.00	3
	Total			**9**
28days	Quarry Dust	23.12	1.67	3
	Pit Sand	23.57	5.53	3
	River Sand	37.78	1.00	3
	Total			**9**

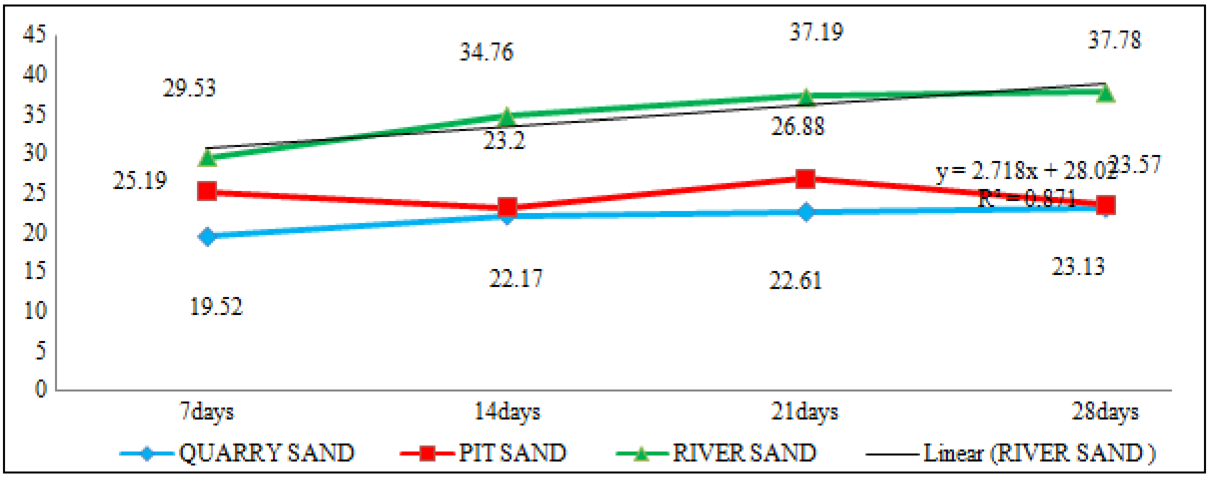

Figure 2: Distribution of Average Trend of Compressive Strength of Concrete Produced Without Varied Proportion of Sand

Figure 2 shows the compressive strength of concrete produced without varied proportion reduced over a period of time. There was also a steady rise of compressive strength of concrete produced from river sand with a slope equation of $y= 2.718x +28.02$ and $R^2=0.871$ indicating 87.1% variation of the compressive strength of concrete produced from river sand was been explain.

Table 4: Distribution of the Results of Two-Way ANOVA Test for Compressive Strength of Concrete Produced with Varied Proportion of Sand

Source	Sum of Squares	Dff.	Mean Square	F	Sig.
Corrected Model	1289.141[a]	11	117.195	9.193	0.000
Intercept	26491.360	1	26491.360	2078.060	0.000
Days	90.299	3	30.100	2.361	0.097
Sand	1113.251	2	556.625	43.663	0.000
Days * Sand	85.592	6	14.265	1.119	0.381
Error	305.955	24	12.748		
Total	28086.457	36			
Corrected Total	1595.096	35			
R Squared = 0.808 (Adjusted R Squared = 0.720)					

The two-way ANOVA test provides information about the main and interaction effects for compressive strength of concrete produced without varied proportion of sand as shown in Table 4. It reveals that for the day's main effect for compressive strength of concrete produced without varied proportion, $F_{0.05}$ = 2.361 has a probability of 0.097. Since 0.097>0.05, it means that there is no significant day's main effect on the concrete strengths. Since the days independent variable was "days of concrete", meaning "days of concrete" has no significant main effect on concrete strength. The sand main effect of $F_{0.05}$= 43.663, with a probability of 0.000. Since 0.000<0.05 it shows that there was a significant sand main effect on concrete strength. Since the sand independent variable was "type of sand", meaning, type of sand has a significant main effect on the concrete strength. The day's X sand interaction of $F_{0.05}$ = 1.119, with a probability of 0.381. Since 0.381>0.05, it shows that there were no significant day's X sand interaction. This implies that days of concrete and type of sand used determined the compressive strength of concrete produced.

4.2 Factors that Account for Variation in Strength

Table 5 shows the results of pit + river sand recording the highest partially compaction average weight of 11.22 with a standard deviation of 0.10. However, Quarry dust + river sand recorded the highest fully compaction average weight of 13.22, with a standard deviation of 0.104. This implies that pit + river sand and quarry dust + river sand have partially and fully compaction average weight for compaction factor test of the various concrete weights.

Table 5: Distribution of Descriptive Statistics for Compaction Factor Test of the Various Concrete

Compaction Type	Type of Concrete	Mean	Std. Dev.	No. of Samples
Partially Compaction	Quarry Dust	10.23	0.08	3
	Pit Sand	9.82	0.50	3
	River Sand	10.87	0.25	3
	Quarry Dust + Pit Sand	10.08	0.23	3
	Quarry Dust + River Sand	10.38	1.51	3
	Pit +River Sand	11.22	0.10	3
	Total			18
Fully Compaction	Quarry Dust	12.65	0.09	3
	Pit Sand	12.62	0.08	3
	River Sand	12.52	0.16	3
	Quarry Dust + Pit Sand	12.88	0.15	3
	Quarry Dust + River Sand	13.22	0.10	3
	Pit +River Sand	13.13	0.12	3
	Total			18

The paper sought to find out whether concrete produced without varied proportion of sand have the same compressive strength with respect to days. The descriptive and the trend show some differences with respect to river sand. Concrete was produced with quarry dust, pit sand and river sand and tested for 7days, 14days, 21day and 28days.

Table 6: Distribution of Two-Way ANOVA Tests Results of compaction types of the Various Concrete (Compacting Factor Test)

Source	Sum of Squares	Dff.	Mean Square	F	Sig.
Corrected Model	57.323[a]	11	5.211	22.645	0.000
Intercept	4872.738	1	4872.738	21174.565	0.000
Compaction	52.008	1	52.008	226.002	0.000
Sand	3.351	5	0.670	2.912	0.034
compaction * sand	1.964	5	0.393	1.707	0.171
Error	5.523	24	0.230		
Total	4935.584	36			
Corrected Total	62.846	35			
R Squared = 0.912 (Adjusted R Squared = 0.872)					

The two-way ANOVA test provides information about the main and interaction effects for compaction types of the various concrete as indicated in the Table 6. The tests results shows that compaction types of the various concrete was $F_{0.05}$ = 226.002 and a probability of 0.00**.** Since 0.00<0.05**,** and the compaction independent variable was "type of compaction", it's indicate that "type of compaction" has a significant effect on weight of concrete. It further shows the sand main effect of $F_{0.05}$ = 2.912**,** with a probability of 0.032**.** Since 0.032<0.05**,** it indicates that since the sand independent variable was "type of sand", meaning, the type of sand has a significant effect on the weight of concrete. Compaction X sand interaction of $F_{0.05}$ = 1.707, has a probability of 0.171. Since 0.171>0.05**,** it can be concluded that there was no significant compaction X sand interaction.

5. Discussion of Results

From the laboratory experiments results analysed, it was clear that Quarry Dust + River Sand had the highest compressive strength of concrete produced with varied proportion of sand with an average mean of 36.09N/mm^2. Whiles River sand had the highest average compressive strength for the concrete produced without varied proportion with an average mean of 37.78 N/mm^2. These values fall above the specified minimum compressive strength of 30N/mm^2 as referred to by the paper for columns and beams with coarse aggregate size of 14mm nominal size by practicefor the 28days result. From the results, Quarry dust + river sand also recorded the highest fully compaction average weight of 13.22, with a standard deviation of 0.10. This implies that the particle shape and texture of quarry dust and river sand could lead to improvements in area of compacting factor test of concrete due to better interlocking between particles. Though, other characteristics such as mineralogy and surface texture are not necessarily measured by typical tests according to [28] however, they may strongly influence overall performance. Another significant main effect of the river sands on the concrete compressive strength was that River sand is obtained by dredging from river beds according to [2]. Since it has been subjected to years of abrasion, its particle shape is more or less rounded and smooth, and because it has been subjected to years of washing, it has very low silt and clay contents. The use of river sand improves the quality control of the concrete/mortar production and workability of concrete and mortar compared to the use of alternatives. The presence of too much silt and/or clay, adversely affect the workability and strength of the concrete/mortar produced. For this reason, the trend of compressive strength of concrete produced without varied proportion of sand was observed to have increased gradually in compressive strength at each curing stage.

6. Conclusions and Recommendations

The paper compares the compressive strength of concrete produced with and without varied proportions of Quarry dust, Pit sand from Wiamoa and River sand from Okyi River (Mankessim). River sand had the highest average compressive strength for concrete produced without varied proportion. Moreover quarry dust + river sand have the highest average compressive strength for concrete produced with varied proportion. Pit + river sand and quarry dust + river sand were found to have the highest partially and fully compaction average weight for concrete respectively. Compressive strength of concrete produced from river sand had a slope equation to indicate that an increase in river sand will increase the compressive strength of the concrete by 2.718 and the R^2 means that 87.1% variation of the compressive strength of concrete produced from river sand. Moreover, the compressive strength of concrete produced from pit + river sand had a slope equation to indicate that an increase in pit + river sand will increase the compressive strength of the concrete by 2.025 and the R^2 means that 85.1% variation of the compressive strength of concrete produced from pit + river sand. Days of curing concrete were also found to have a significant main effect on concrete compressive strength for concrete produced without varied proportion. This implies that the higher the days, the higher compressive strength. Sand type had significant main effect on the concrete compressive strength. Concrete produced without varied proportion point out river sand with the best compressive strength. Additionally, age of concrete had no significant main effect on compressive strength for concrete produced with varied proportion. However, type of varied sand had a significant main effect on the concrete compressive strength for concrete produced with varied proportion in which Quarry Dust + River Sand had the best varied compressive strength. The Construction industry should start using more of quarry dust + river sand when producing concrete with varied proportion of sand for quality work and good compressive strength. River sand should be used when producing concrete without varied proportion of sand for good compressive strength.

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