Int. J. Advanced Design and Manufacturing Technology, 2023, Vol. 16, No. 4, pp. 49-59

DOI: 10.30486/ADMT.2023.873802 ISSN: 2252-0406 https://admt.isfahan.iau.ir

Non-Destructive Assessment of Concrete Quality Produced with Riverbed Sand and Drainage Sand as Fine Aggregates

Aderemi A. Alabi *, Ayobami E. Agboola
Department of Physics,
Federal University of Agriculture, Abeokuta, Nigeria
E-mail: derylab@yahoo.com, enihayor4real@gmail.com
(Corresponding author)

Joseph Olawale Akinyele
Department of Civil Engineering,
Federal University of Agriculture, Abeokuta, Nigeria
E-mail:joakin777@yahoo.com

Victor Makinde
Department of Physics,
Federal University of Agriculture, Abeokuta, Nigeria
E-mail: makindev@funaab.edu.ng

Received: 20 June 2023, Revised: 3 December 2023, Accepted: 10 December 2023

Abstract: In this work, the effect of fine aggregates from two different sources on the quality and strength of concrete was determined using UPV measurements. The concrete samples were produced using a nominal mix ratio of 1: 1½: 3 and water-cement ratio of 0.55, with three different aggregate sizes (3/8, ½ and ¾ inches) of granite mixed separately with sand obtained from Ogun river and a local drainage in Abeokuta, Southwestern, Nigeria. UPV was measured through each sample on days 1, 7, 14, 21 and 28 after curing using Pundit lab+ equipment. Comparison of the actual compressive strength and estimated compressive strengths from equations generated for each sample type using the crushed samples on the 7th and 28th days respectively shows that most estimations were within the acceptable ±20% variation. Results show that there is no significant difference between the samples made from using either of the two fine aggregates.

Keywords: Concrete, Concrete Quality, Fine Aggregate, Non-Destructive Testing, Ultrasonic Pulse Velocity

Biographical notes: **Aderemi A. Alabi** obtained his PhD in Solid Earth Physics from the Department of Physics, Federal University of Agriculture, Abeokuta, Nigeria. He is currently Associate Professor in the same Department. **Ayobami E. Agboola** obtained MSc in Geophysics from the Department of Physics, Federal University of Agriculture, Abekuta, Nigeria in 2022. He is a lecturer in the Department of Science Laboratory Technology, Moshood Abiola Polytechnic, Abeokuta, Nigeria. **Joseph Olawale Akinyele** is a Professor of Structural Engineering in the Department of Civil Engineering, Federal University of Agriculture, Abeokuta, Nigeria. **Victor Makinde** is a professor of Solid Earth Physics, in the Department of Physics, Federal University of Agriculture, Abeokuta, Nigeria.

Research paper

1 INTRODUCTION

Destructive tests are often performed to assess the properties of in-situ concrete for the quality control and assurance of concrete. However, non-destructive test methods are more practical and cost-effective in material evaluation. Changes in concrete properties with time and external effects could also be studied using non-destructive techniques; thus, it is plausible to assess quality assurance and quality control using non-destructive testing [1].

Non-destructive method of testing concrete is used to obtain the compressive strength and other properties of concrete from existing structures and also provide immediate results for the strength of concrete structure [2]. Avoiding damage and disturbance to the performance of structural components of concrete are the main advantages of the non-destructive method, with quick and simple application, the test results can be achieved easily on the site [2-3]. Non-destructive tests provide an opportunity to assess many properties of concrete which include fundamental parameters such as density, elastic modulus, strength surface hardness, surface absorption, reinforcement location, size and distance from the surface. The test is also useful for inspecting the quality of workmanship and structural integrity by its ability to detect voids, cracking and delamination [4].

Since the quality of some materials can be sometimes related to their elastic stiffness, therefore a measurement of the ultrasonic pulse velocity of the materials can often be used to study their quality and determine their elastic properties [5].

The quality of concrete is usually specified in terms of strength it is therefore helpful to use ultrasonic pulse velocity measurements to give an estimate of concrete strength. The relationship between ultrasonic pulse velocity and strength is affected by several factors such as the age of the concrete, mix proportions, moisture condition, curing conditions, type of cement and type of aggregate [6]. The principle that a wave travels faster in denser media is applied to determine the quality of a material from the velocity of the wave which can be applied to several types of materials such as wood, and concrete, among others [7]. The velocity of an ultrasonic pulse travelling in a solid depends on some properties of the material such as its density and elastic properties. The ultrasonic wave measurement is a useful tool in evaluating the dynamic modulus of elasticity of concrete [8] and is an important factor when assessing the quality and performance of structural concrete [9-10]. The Ultrasonic Pulse Velocity (UPV) is a suitable parameter for estimating static modulus of elasticity, dynamic modulus of elasticity, static Poisson's ratio and dynamic Poisson's ratio [11]. The concrete quality, homogeneity and compressive strength of existing structures can also be evaluated by the UPV testing [12]. Therefore, empirical relationships may be established between the pulse velocity and both the dynamic and static elastic moduli and the strength of concrete. The strength relationship is influenced by several factors including the type of cement, cement quality, admixtures, type and size of the aggregate, curing conditions and age of concrete [4]. Concrete, as a material with a very heterogeneous composition owes its heterogeneity to the nature of its constituents (cement, sand, and gravel), their dimensions, geometry and/or distribution. Thus, it is highly possible that defects and damages could exist in the concretes [7], [13].

Fine aggregates for concrete construction purposes are normally sourced locally and are available in natural deposits at various locations and along the courses of rivers, on the shores of lakes and the sea, and in arid regions, the quality of fine aggregate can vary significantly due to the geographic location and environmental condition. Fine aggregates have a great influence on the workability and cost of concrete, very coarse sands produce harsh and unworkable concrete mixtures, and very fine sands increase the water requirement and are therefore uneconomical [14]. The coarse aggregates commonly used are granites, trap-rocks, gravels, limestones, sandstones, slags, and coal cinders. These materials differ greatly in strength, hardness, porosity, and available gradation of the size of particles [14].

Aggregates determine the quality and features of concrete and play an important role in concrete properties such as strength, stiffness, dimensional stability, durability, workability, and economy; therefore, the physical and chemical properties of aggregates are of interest [15]. Concrete is sensitive to the geological origin of natural aggregates, and its porosity plays an important role in affecting the elastic modulus of concrete because dense aggregates have better mechanical properties [15]. The modulus of elasticity used in concrete design computations is usually estimated from empirical expressions that assume direct dependence on the strength, unit weight and aggregate origin of the concrete [16].

Reported that the use of ultrasonic pulse velocity (UPV) as a non-destructive testing of concrete for assessment of concrete quality has been extensively investigated for decades and is more likely to assess the quality and characteristics of site concrete[17], [18] and described the development of pulse-echo techniques to permit the detection of defects and cracks from tests on one surface as well as the use of a vacuum coupling system, and the application of signal processing techniques to yield information about internal defects and features [19]. Another interesting development described by [20] involves the use of rolling transmitter and receiver scanners which do not need any coupling medium; giving room for a faster and effective way of measuring the pulse velocity. Reported the correlation between UPV and compressive strength of concrete for some typical mixes in simultaneous measurements of pulse velocity and compressive strength made on 150 mm cubes, at different ages from 1 day to 28 days, the result revealed a linear relationship between strength and velocity [21].

Studied the concrete setting time and concrete strength using the Impact-Echo method and found no difference in the correlation between ultrasonic velocity and concrete compressive strength when the water-cement ratio ranged from 0.57 – 0.5, whereas the aggregate content influenced their correlation [22]. A relationship between ultrasonic velocity and compressive strength of concrete was found [23] using different mineral admixtures such as high volume of fly ash (FA), Blast Furnace Slag (BFS) and combination of FA and BFS in replacement of Portland cement. The compressive strength and the ultrasonic pulse velocity values were determined at curing periods of the 3rd, 7th, 28th and 120th days. An exponential relationship between compressive strength and ultrasonic pulse velocity was reported.

Conducted an experimental investigation on the modulus of elasticity of concrete with a total of 60 mixtures and the effects of water/cement ratio, aggregate type, aggregate maximum size, and fly ash content were investigated [24]. The modulus of elasticity of the concretes was obtained besides compressive strength and ultrasound pulse velocities of the concrete. A model was also proposed to predict the dynamic modulus of concrete; the predicted model has a close association with experimental test results. Proposed an empirical equation between UPV and Cube Compressive strength of Concrete which revealed a strong correlation between the UPV and compressive strength [25].

Proposed a Non-destructive evaluation for Glass-Epoxy composite [26]. Impact-echo was used to investigate the thickness and integrity of composite plates. Four composite plates are made of epoxy and fibreglass with different thicknesses of which one comprises a predetermined internal flaw. The impact-Echo device was utilized to detect plate thickness and internal flaws. It was reported that the method is appropriate for thickness measurement and flaw detection of Epoxy-Glass composites within acceptable accuracy.

A warm accumulative roll bonding process (Warm-ARB) using Al-1060 and fine particles of Al2O3 was applied to produce Aluminum Metal Matrix Composite (AMMCs) [27]. The microstructure and mechanical properties of composites were studied after different Warm-ARB passes by tensile test, Vickers microhardness test and scanning electron microscopy. It was reported that as the ARB passes increase, the uniformity of clusters increases considerably and further submitted that the Al_2O_3 particles have an enhancing effect on the elongation after a certain number of passes and the tensile strength of the composites increases with ARB passes and enhances the tensile toughness of the composite with more passes. It was established that adding Al_2O_3 particles to AMMCs leads to an improvement of the hardness.

Aggregate is one of the major aspects of concrete that is generally more plentiful, rigid, and resistant part which influences the ultrasonic-compressive strength correlation and changes the elastic properties [28-29]. There have been different views on the impact of aggregate on compressive strength of concrete, studied the properties of normal-strength concrete as affected by coarse aggregate size and demonstrated that an increase in aggregate size from 10 mm (3/8 in.) to 64 mm (2½ in.) results in a decrease in the compressive strength of concrete, by as much as 10 per cent [30].

Investigated changes in concrete strength for mixes made with various aggregate sizes and different water-to-cement ratios and reported that an increase in maximum aggregate size from 19 mm (¾ in.) to 38 mm (1½in.) decreases the compressive strength by about 30 per cent for water-to-cement ratios (0.40 to 0.70) [31]. Compared the effect of four different coarse aggregate types on the behaviour of normal and high-strength concretes [32]. It was submitted that high-strength coarse aggregates typically yield higher compressive strengths in high-strength concretes, while coarse aggregate strength has little effect on compressive strength in normal-strength concretes. Showed that compressive strength increases with an increase in coarse aggregate size [33]. Studied the effect of coarse aggregate size on the compressive strength and flexural strength of concrete and reported that the compressive strength of concrete increases with an increase in coarse aggregate sizes [34].

Studied the effect of aggregate type on the compressive strength of concrete and reported that aggregate type affects the compressive strength of normal concrete [35]. The effect of aggregate mineralogy on the strength of concrete was assessed by [36] who reported that concrete with igneous aggregate performed better, followed by concrete with aggregate from sedimentary origin while concrete with metamorphic aggregate had the least compressive strength.

Aggregate sources are necessary for societal needs and cannot be obtained without causing environmental impacts. The environmental impacts can however be minimized by assessing different sources of aggregate and reducing the dependence of natural aggregate on a sole source of natural aggregate. Riverbed sand excavation has been one of the major sources of fine aggregates in Southwestern Nigeria because of the presence of many rivers in the region as well as because of recommendations of riverbed sands for use as fine aggregate [14]. Sand washes up into drainages which causes their blockage and thus flooding in most parts of the country can be another source of fine aggregate. By collecting this sand for use as fine aggregate, flooding which is a major problem in the region is greatly reduced.

The choice of fine aggregate in concrete production is crucial, as it influences the workability, strength, and durability of the resulting concrete. Riverbed sand is often preferred for its naturally rounded particles, while drainage sand, sourced locally, may offer economic advantages. However, the influence of these sand sources on the overall quality of concrete is not fully understood. By employing non-destructive assessment techniques, this study aims to investigate the qualities of concretes produced using riverbed sand and drainage channels as fine aggregate by providing a comprehensive analysis of concrete quality, considering factors such as compressive strength, ultrasonic pulse velocity, and other relevant parameters.

The knowledge provided by this study can be used as a prerequisite for selecting suitable sand to be used as fine aggregate for concrete production.

2 EXPERIMENTAL MATERIALS

Limestone Portland cement (LPC) (42.5N) was used as the binder for the concrete. The cement complies with the relevant Nigerian Industrial Standards, [37-42]. The coarse aggregate used was granite obtained from a quarry and crushed into three different sizes 9.5 mm (3/8 inch), 12.5 mm (½ inch) and 19 mm (¾ inch) respectively with sands obtained from local drainage and along the bank of Ogun river used as fine aggregate (all aggregates were obtained in Abeokuta). Impurities and larger aggregates were separated from the fine aggregates using a 5 mm sieve [43] and sieve analysis was carried out on all the aggregates [44]. “Table 1” shows the physical properties of the aggregate used and “Figs. 1 and 2” show the sieve analysis for the coarse and fine aggregates, respectively.

Table 1 Physical properties of coarse aggregates

Material	Density (g/cm^3)	Fineness Modulus
Granite	2.67	-
Drainage sand	1.53	2.51
Ogun riverbed sand	1.65	2.58

The water of drinkable quality was used for mixing the concrete constituents with a mix ratio of 1: 1½: 3 [45] and a water-cement ratio of 0.55 for non-air entrained concretes for compressive strength of 30MPa. There were six sample types [1GO (3/8 inch granite and Ogun riverbed sand), 1GL (3/8 inch granite and local drainage sand), 2GO (½ inch granite and Ogun riverbed sand), 2GL (½ inch granite and local drainage sand), 3GO (¾ inch granite and Ogun riverbed sand) and 3GL (¾ inch granite and local drainage sand)]. Each sample was cast in a metal cube mould (150 mm) to produce ten standard concrete cubes (150 × 150 × 150 mm) for each sample type. The samples were initially cured in the air for 24 hours. The moulds were removed and concrete cubes were immersed in a curing tank containing clean water for 28 days [46].

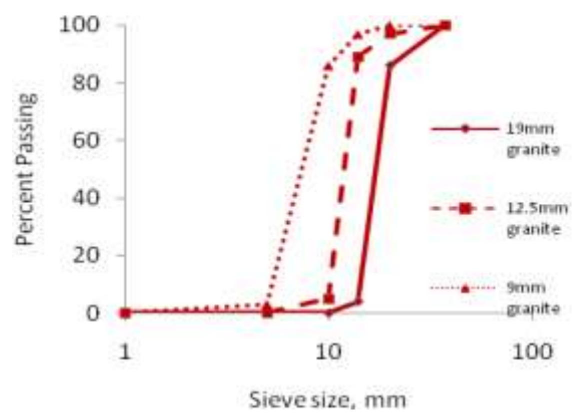

Fig. 1 Coarse aggregate particle size distribution.

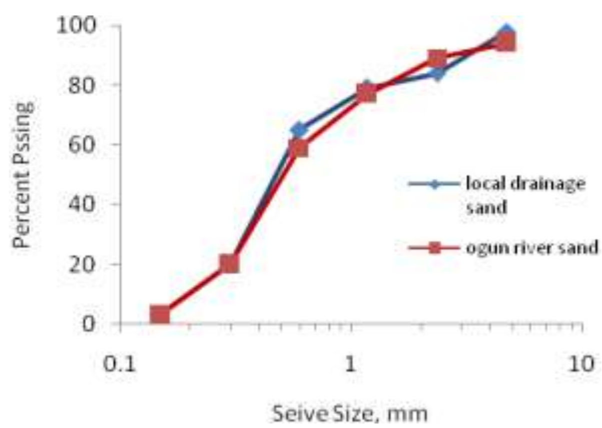

Fig. 2 Fine aggregate particle size distribution.

3 EXPERIMENTAL METHOD

Ten similar sample specimens were made for each sample type to guarantee statistical validity. Statistical analysis was performed on the ultrasonic pulse velocity for each measurement day, the parameters calculated were; mean, standard deviation, coefficient of variation and p-value.

3.1. Ultrasonic Pulse Velocity (UPV)

UPV test, as one of the non-destructive tests, operates by sending high-frequency elastic waves into a medium and the travel time for the pulse to propagate through the medium is measured [47]. Pundit lab+ equipment was used to measure ultrasonic pulse velocities through the concrete samples, the pulse was generated by a transmitter and received by a receiver ("Fig. 3") using the direct transmission mode because the transfer of energy between transducers is at its maximum and the accuracy of the path length measurement is principally governed by the accuracy of velocity determination. The pulse velocity (v) can be calculated when the measured time (t) and the path length (L) are known as follows:

$$V = L/t \quad (1)$$

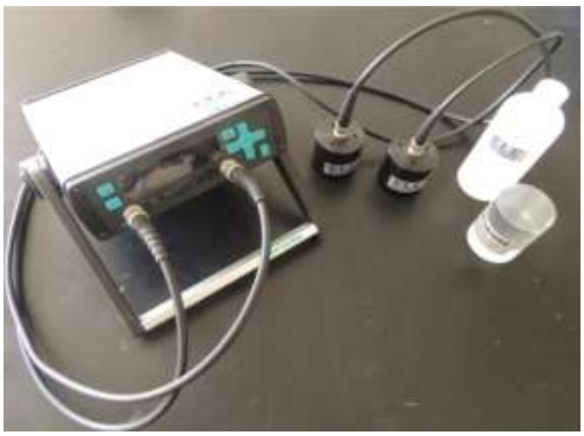

Fig. 3 Pundit Lab+ Equipment.

"Table 2" shows the use of UPV to classify the quality of concrete. The ultrasonic wave velocity measurement was taken on each concrete cube five times at a weekly interval for 28 days. The concrete cube samples were removed from the curing tank; the water was allowed to drain before subjecting each cube to an ultrasonic pulse velocity test [48-49].

Table 2 Quality of concrete as a function of the Ultrasonic Pulse Velocity (UPV)

UPV (km/sec)	Above 4.5	3.5 to 4.5	3.0 to 3.5	2.0 to 3.0	Below 2.0
Concrete Quality	Excellent (E)	Good (G)	Medium (M)	Poor (P)	Very Poor (V.P)

Source [25].

3.2. Compressive strength

The compressive strength of five concrete cubes from each sample type was determined on the 7th day while the compressive strength of another three concrete cubes from each sample type was determined on the 28th day using the hydraulic universal testing machine (WE 1000B).

3.3. Statistical Distribution

Kolmogorov-Smirnov and Shapiro-Wilk goodness-of-fit tests were applied to all the cases to check if the data can be modelled statistically following a normal distribution using the mean and standard deviation for the Kolmogorov-Smirnov test and distribution around the minimum and maximum values for the Shapiro-Wilk test. The proposed null hypothesis (H01) stated that "the means obtained from experimental observations data of Ultrasonic Pulse Velocity (UPV) behaved according to a normal distribution", and the Alternate Hypothesis (HA1) stated that "the means of the data does not behave according to a normal distribution". The p-value represented the probability of rejecting the null hypothesis, the smaller the p-value, the smaller the probability that there will be an error in the hypothesis. A recommended value often used is 0.05 which implies that the hypothesis should be rejected when the p-value is less than 0.05. The level of skewness and kurtosis of the distributions was also determined. A rule of thumb for interpreting skewness suggests that if the skewness is less than −1 or greater than +1, the distribution is highly skewed, if it is between −1 and −0.5, or between +0.5 and +1, the distribution is moderately skewed, however, the skewness is approximately symmetric if it is between −0.5 and +0.5. For the kurtosis, when the excess kurtosis is greater than 0, the distribution is platykurtic but leptokurtic when the excess kurtosis is less than 0 [50].

4 RESULTS AND DISCUSSION

4.1. Statistical Distribution

The statistical distribution analyses ("Table 3") revealed that all samples' UPV measurements behaved according to a normal distribution when subjected to the Kolmogorov-Smirnov normality test for all the measurement days. When subjected to the Shapiro-Wilk normality test, sample 1GL UPV behaved according to a normal distribution only on day 28 while that of 1GO deviated from a normal distribution only on day 28, sample 2GL's UPV deviated from normal distribution only on day 7 but 2GO behaved as a normal distribution throughout the measurement days, the UPV of sample 3GL deviated from normal distribution only on day 7 while sample 3GO's UPV also behaved according to a normal distribution throughout the measurement days.

Although some of the samples' p-value values were less than 0.05 (statistically significant) with the Shapiro-Wilk normality test, all sample distributions were however normally distributed when subjected to the Kolmogorov-Smirnov uniformity test.

Table 3 Statistical distribution test for the UPV measurements

Sample	Mean ± sd	Skewness	Kurtosis	Goodness-of-fit test (Normality)				
				Sample size = 10	**D$_{5\%}$ = 0.409**			
				Kolmogorov-Smirnov			Shapiro-Wilk	
				Dmax	P-value	Remark	P-value	Remark
Day 1								
1GL	3923±250	0.163	-2.050	0.288	0.378	Normal	0.039	Not Normal
1GO	3408±87	0.608	-1.255	0.243	0.594	Normal	0.072	Normal
2GL	3747±51	-1.545	2.617	0.147	0.982	Normal	0.511	Normal
2GO	3435±58	-0.100	-0.227	0.205	0.792	Normal	0.172	Normal
3GL	3920±104	-0.545	-0.828	0.201	0.815	Normal	0.481	Normal
3GO	3656±148	0.045	-1.440	0.148	0.981	Normal	0.601	Normal
Day 7								
1GL	4170±101	-1.545	2.617	0.201	0.816	Normal	0.045	Not Normal
1GO	4170±68	-0.100	-0.227	0.187	0.895	Normal	0.866	Normal
2GL	4218±90	-0.665	-1.487	0.281	0.407	Normal	0.020	Not Normal
2GO	4206±75	-0.053	-0.618	0.130	0.996	Normal	0.962	Normal
3GL	4187±57	-2.050	5.317	0.292	0.363	Normal	0.007	Not Normal
3GO	4251±45	-0.312	-0.822	0.142	0.988	Normal	0.562	Normal
Day 14								
1GL	4208±51	2.100	4.470	0.370	0.500	Normal	0.008	Not Normal
1GO	4150±58	0.975	1.892	0.255	0.902	Normal	0.651	Normal
2GL	4238±51	0.199	-0.644	0.150	1.000	Normal	0.956	Normal
2GO	4233±50	-0.276	-1.141	0.207	0.983	Normal	0.629	Normal
3GL	4363±76	1.486	2.461	0.284	0.814	Normal	0.245	Normal
3GO	4370±81	0.378	-1.376	0.235	0.945	Normal	0.753	Normal
Day 21								
1GL	4268±90	4.470	2.100	0.352	0.569	Normal	0.012	Not Normal
1GO	4236±97	1.892	0.975	0.294	0.782	Normal	0.172	Normal
2GL	4378±50	-1.142	0.409	0.192	0.993	Normal	0.717	Normal
2GO	4274±69	-0.471	-0.055	0.115	1.000	Normal	0.999	Normal
3GL	4530±103	0.261	0.847	0.169	0.999	Normal	0.765	Normal
3GO	4519±176	1.036	-0.802	0.204	0.986	Normal	0.840	Normal
Day 28								
1GL	4408±50	-0.664	0.816	0.246	0.923	Normal	0.594	Normal
1GO	4375±62	3.124	1.808	0.314	0.708	Normal	0.023	Not Normal
2GL	4420±82	-0.372	0.323	0.136	1.000	Normal	0.988	Normal
2GO	4412±46	0.241	0.062	0.158	1.000	Normal	0.983	Normal
3GL	4536±74	-2.137	0.012	0.211	0.979	Normal	0.645	Normal
3GO	4624±84	-3.186	-0.579	0.325	0.665	Normal	0.058	Normal

Also, when the strength of concrete does not exceed 70 MPa, the normal distribution is appropriate in most cases [51]. Therefore, from a general point of view, it is convenient to accept the initially proposed hypothesis that 'the experimental data follows a normal distribution'.

4.2. Quality Assessment of Concrete Samples

The samples' quality assessment result (“Table 4”) shows that all samples made with local drainage fine aggregate were of good quality on the first day of measurement, samples made with Ogun riverbed sand were of medium quality except the sample which, was made with 19.5 mm aggregate size, the samples were all of the good quality on day 7 and remained good quality till day 28 but samples made with 19.5mm aggregate size achieved excellent quality on day 21. The samples' quality comparison revealed that all the concretes' quality increases with age, ANOVA was however used to determine if there were statistical differences between the samples' quality for each age (“Table 5”).

Table 4 Samples’ quality assessment

Sample	DAY 1		DAY 7		DAY 14		DAY 21		DAY 28	
	UPV (m/s)	Quality	UPV (m/s)	Quality	UPV (m/s)	Quality	UPV (m/s)	Quality	UPV (m/s)	Quality
1GL	3923	G	4170	G	4208	G	4268	G	4408	G
1GO	3408	M	4170	G	4150	G	4236	G	4375	G
2GL	3747	G	4218	G	4238	G	4378	G	4420	G
2GO	3435	M	4206	G	4233	G	4274	G	4412	G
3GL	3920	G	4187	G	4363	G	4530	E	4536	E
3GO	3656	G	4251	G	4370	G	4519	E	4624	E

Table 5 ANOVA result of statistical comparison of samples’ qualities

Aggregate size	9.5mm	12.5mm size	19mm size
Day 1	SSD	SSD	SSD
	F(2,27) = 37.98, p = 0.000	F(2,27) = 162.71, p = 0.000	F(2,27) = 21.34, p = 0.000
Day 7	NSSD	NSSD	SSD
	F(2,27) = 0.00, p = 0.998	F(2,27) = 0.11, p = 0.741	F(2,27) = 7.76, p = 0.012
Day 14	NSSD	NSSD	NSSD
	F(2,12) = 2.78, p = 0.134;	F(2,12) = 0.03, p = 0.875	F(2,12) = 0.02, p = 0.891
Day 21	NSSD	SSD	NSSD
	F(2,12) = 0.31, p = 0.592	F(2,12) = 7.33, p = 0.027	F(2,12) = 0.01, p = 0.909
Day 28	NSSD	NSSD	NSSD
	F(2,12) = 0.86, p = 0.380;	F(2,12) = 0.04, p = 0.843	F(2,12) = 3.10, p = 0.116

On day 1, the comparison revealed that there was a statistically significant difference between the quality of samples made with local drainage fine aggregate and Ogun riverbed fine aggregate for all aggregate sizes. Samples made with local drainage fine aggregate were statistically significantly of higher quality (3923±250, 3747±51 and 3920±104) than samples made with Ogun riverbed sand fine aggregate (3408±87, 3435±58 and 3656±148). On the 7th day, there was no statistically significant difference between the quality of samples for 9.5 mm size and 12.5 mm size granite coarse aggregates, however, samples made with local drainage fine aggregate were statistically significantly of lower quality (4187±57) than the samples made with Ogun riverbed fine aggregate (4251±45) for the 19 mm granite coarse aggregates size. No statistically significant difference was observed between the samples' qualities on the 14th day. On the 21st day, a statistically significant difference was only observed between the qualities of samples made with 12.5 mm aggregate size, the local drainage fine aggregate (4378±90) sample was statistically significantly of higher quality than the samples made with Ogun riverbed fine aggregate (4274±69). There was no statistically significant difference between the qualities of the samples on the 28th day.

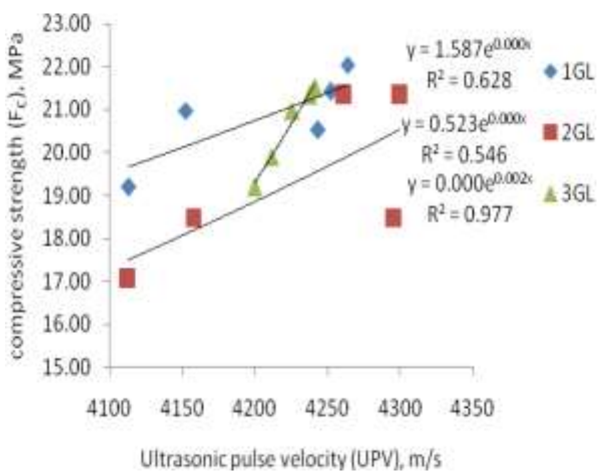

Fig. 4 Relationship between UPV and f_c for local drainage sand (Day 7).

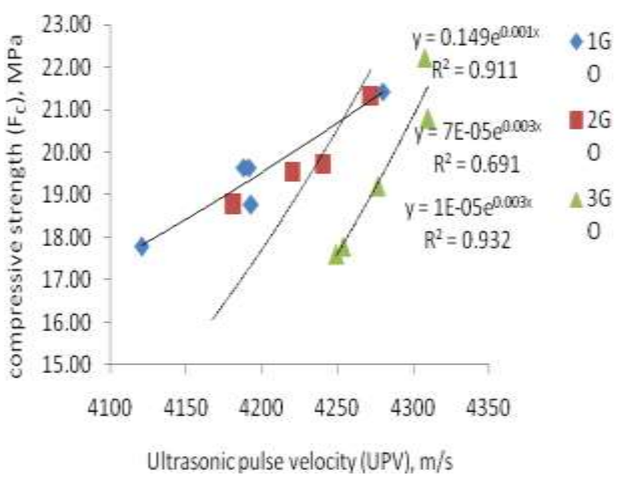

Fig. 5 Relationship between UPV and f_c for Ogun riverbed sand (Day 7).

4.3. Compressive Strength Determination

The results of the measured compressive tests (f_c) were determined by averaging the result of crushing five specimens on the 7th day and 3 specimens on the 28th day and used to obtain a relationship between UPV and compressive strength (Figs. 4-7), an exponential relationship was proposed for both day 7 and day 28 in “Table 6” which was used to determine the predicted compressive strength (f_{cp}) (“Table 7”) of the samples. The predicted compressive strength was compared with the measured compressive strength and the percentage variations wase within the allowable ±20 per cent variation [52].

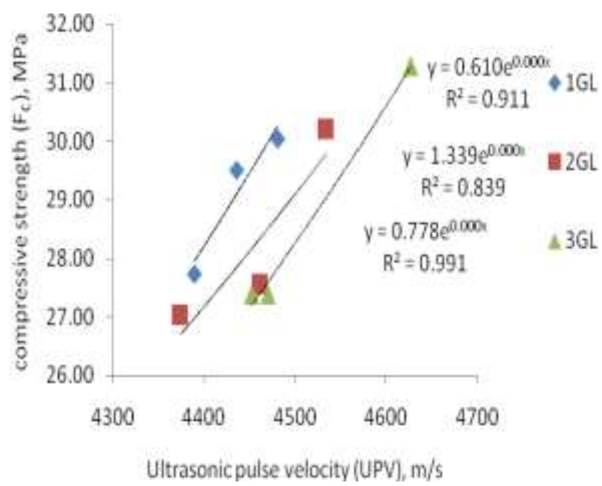

Fig. 6 Relationship between UPV and f_c for local drainage sand (Day 28).

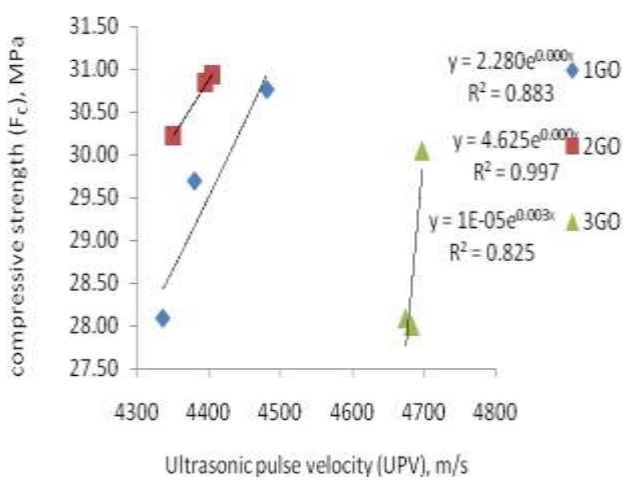

Fig. 7 Relationship between UPV and f_c for Ogun riverbed sand (Day 28).

Table 6 The proposed exponential relationship between UPV and compressive strength

	Day 7		Day 28	
Sample	Equation	R^2	Equation	R^2
1GL	$f_c = 1.5874e^{0.0006Vp}$	0.628	$f_c = 0.6108e^{0.0009Vp}$	0.911
1GO	$f_c = 0.1492e^{0.0012Vp}$	0.911	$f_c = 2.2803e^{0.0006Vp}$	0.883
2GL	$f_c=0.5231e^{0.0009Vp}$	0.546	$f_c = 1.3394e^{0.0007Vp}$	0.839
2GO	$f_c = 7E\text{-}05e^{0.003Vp}$	0.691	$f_c = 4.6251e^{0.0004Vp}$	0.997
3GL	$f_c = 0.0002e^{0.0028Vp}$	0.977	$f_c = 0.7789e^{0.0008Vp}$	0.991
3GO	$f_c = 1E\text{-}05e^{0.0034Vp}$	0.932	$f_c = 1E\text{-}05e^{0.0031Vp}$	0.825

Table 7 Variation between measured compressive strengths and estimated compressive strengths

	Day 7			Day 28		
Sample	f_c (MPa)	f_{cp} (MPa)	% Var	f_c (MPa)	f_{cp} (MPa)	% Var
1GL	20.84±1.07	19.41±1.13	-6.86	29.10±1.21	32.30±1.47	11.00
1GO	19.45±1.35	22.29±1.82	+14.60	29.51±1.34	31.5±1.19	6.74
2GL	19.34±1.91	23.37±1.86	+20.84	28.27±1.71	29.60±1.70	4.70
2GO	18.74±2.65	21.61±4.85	+15.31	30.67±0.39	27.07±0.50	-11.74
3GL	20.59±0.99	24.94±3.52	+21.13	28.68±2.26	29.37±1.74	2.41
3GO	19.52±1.99	19.10±2.84	-2.15	28.71±1.16	23.17±4.21	-19.30

5 CONCLUSIONS

In conclusion, the non-destructive assessment of concrete quality produced with riverbed sand and drainage sand using three different aggregate sizes yielded valuable insights into the performance of the concrete. The findings can be summarized as follows:

1. The study demonstrated the effectiveness of non-destructive assessment methods in evaluating the quality of concrete. Non-destructive techniques, such as ultrasonic pulse velocity, proved to be reliable tools for characterizing concrete properties without causing damage to the structure.
2. The quality of concrete samples was predominantly 'Good' at early ages, with a consistent improvement observed as the concrete aged. This suggests a positive correlation between concrete quality and curing time.
3. Concrete samples made with local drainage sand exhibited better quality compared to other sources. This indicates that the choice of fine aggregate source can significantly influence the overall quality of the concrete.
4. Despite variations in aggregate sources and sizes, there were generally no statistically significant differences detected in the quality of the concrete samples. This suggests that factors other than the ones investigated might be influencing concrete quality.
5. The study did not reveal a clear effect of both sand sources and aggregate size on the compressive strength of the concrete samples. This implies that factors beyond the chosen parameters might be more influential in determining compressive strength.
6. The relationship observed between compressive strength and ultrasonic pulse velocity suggests a potential method for estimating the compressive strength of similar concrete compositions. This finding could have practical applications in non-destructive testing.
7. The proposed equations for estimating compressive strength based on ultrasonic pulse velocity demonstrated reliability, with estimated values falling within the acceptable ±20% variation range. This strengthens the utility of these equations for practical applications.
8. The non-destructive assessments revealed that concrete produced with riverbed sand and drainage sand as fine aggregates exhibited comparable quality. This suggests that, at least within the parameters investigated, both sand sources can yield concrete of similar structural integrity, the choice between these two sand sources may not significantly impact concrete performance.

In summary, the non-destructive assessment of concrete quality with riverbed sand and drainage sand as fine aggregates demonstrates the reliability of these methods in evaluating structural properties. The study supports the notion that both sand sources can produce concrete of comparable quality, emphasizing the importance of considering non-destructive techniques for quality control and monitoring in concrete construction.

REFERENCES

[1] Birgul, R., Hilbert Transformation of Waveforms to Determine Shear Wave Velocity in Concrete, Cement and Concrete Research, Vol. 39, 2009, pp. 696–700.

[2] Hamidian, M., Shariati, M., Arabnejad, M. M. K., and Sinaei, H., Assessment of High Strength and Light Weight Aggregate Concrete Properties Using Ultrasonic Pulse Velocity Technique, Int. J. Phys. Sci., Vol. 6, No. 22, 2011, pp. 5261–5266.

[3] Hobbs, B., Tchoketch, K., Nondestructive Testing Techniques for The Forensic Engineering Investigation of Reinforced Concrete Buildings, Forensic Science Inter-national, Vol. 167, No. 2-3, 2007, pp. 167-172, doi:10.1016/j.forsciint.2006.06.065.

[4] International Atomic Energy Agency, (IAEA), Training Course Series, Guide Book on Non-Destructive Testing of Concrete Structures, No. 17, 2002, pp. 100-127.

[5] Uday, B., Application of Ultra-Sonic Pulse Velocity Techniques for Concrete Quality Measurements, NBMCW, 2001, http://www.nbmcw.com/articles/concrete/23866-techniques-for-concrete-quality-measurements.html.

[6] Lorenzi, A., Reginato, L. A., Fávero, R. B., Carlos, L., and Filho, S., 3D Ultrasonic Tomography Technique as a tool to Evaluate Concrete Structures, EJ. Nondestr. Test., Vol. 21, 2016.

[7] Ali, B. A., Assessment of Concrete Compressive Strength by Ultrasonic Non-Destructive Test, University of Baghdad, 2008, pp. 3.

[8] Jones, R., Facaoaru, I., Recommendations for Testing Concrete by The Ultrasonic Pulse Method, Materials and Structures, Vol. 2, No. 10, 1969, pp. 275–284.

[9] Kar, A., Halabe, U. B., Ray, I., and Unnikrishnan, A., Nondestructive Characterizations of Alkali Activated Fly Ash And/Or Slag Concrete, Eur. Sci. J., Vol. 9, No. 24, 2013, <http://www.eujournal.org/index.php/esj/article/view/1695/1684>.

[10] Singh, G., Siddique, R., Effect of Waste Foundry Sand (WFS) as Partial Replacement of Sand on The Strength, Ultrasonic Pulse Velocity and Permeability of Concrete, Constr. Build. Mater, Vol. 26, No. 1, 2012, pp. 416–422. http://dx.doi.org/10.1016/j.conbuildmat.2011.06.041.

[11] Qixian, L., Bungey, J. H., Using Compression Wave Ultrasonic Transducers to Reassure the Velocity of Surface Waves and Hence Determine Dynamic Modulus of Elasticity for Concrete Construction and Building Materials, Elsevier, Construction and Building Materials, Vol. 10, No. 4, 1996, pp. 237-242.

[12] Breysse, D., Nondestructive Evaluation of Concrete Strength: An Historical Review and A New Perspective by Combining NDT Methods, Construction and Building Materials, Vol. 33, 2012, pp. 139-163, ISSN 0950-0618, https://doi.org/10.1016/j.conbuildmat.2011.12.103.

[13] Corneloup, G., Garnier, V., Etude D'uneméthodeultrasonoreadaptée À La Mesure De L'endommagement des Bétons: Étudebibliographiqueet Analyse des Solutions, Contrat IUT-EDF, 1995.

[14] Ajagbe, W. O., Tijani, M. A., and Oyediran, I. A., Engineering and Geological Evaluation of Rocks for Concrete Production, Lautech Journal of Engineering and Technology, Vol. 9, No. 2, 2017, pp. 67-79.

[15] Langer, W. H., Knepper, D. H., Geologic Characterization of Natural Aggregate: Afield Geologist Guide to Natural Aggregate Resource Assessment, Open File Report, 1995, pp. 95-582.

[16] Mehta, P. K., Monteiro, P. J. M., Concrete Microstructure, Properties and Materials, McGraw Hill, 2006.

[17] Solís-Carcaño, R., Moreno, E., Evaluation of Concrete Made with Crushed Limestone Aggregate Based on Ultrasonic Pulse Velocity, Construction and Building Materials, Vol. 22, No. 6, 2008, pp. 1225-1231.

[18] Hillger, W., Imaging of Defects in Concrete by Ultrasonic Pulse-Echo Technique, Proc. Struct. Faults and Repairs 93, Eng. Technics Press, Edinburgh, Vol. 3, 1993, pp. 59–65.

[19] Kroggel, O., Ultrasonic Examination of Crack Structures in Concrete Slabs, Proc. Struct. Faults and Repairs 93, Eng. Technics Press, Edinburgh, Vol. 3, 1993, pp. 67–70.

[20] Sack, D. A., Olson, L. D., Advanced NDT Methods For Evaluating Concrete Bridges and Other Structures, Proc. Struct. Faults and Repairs 93, Eng. Technics Press, Edinburgh, Vol. 1, 1993, pp.65–76.

[21] Rajagopalan, P. R., Prakash, J., and Naramimhan, V., Correlation Between Ultrasonic Pulse Velocity and Strength of Concrete, Indian Concrete J., Vol. 47, No. 11, 1973, pp. 416-418.

[22] Pessiki, S. P., Carino, N. J., Setting Time and Concrete Strength Using the Impact-Echo Method, ACI Mater. J., Vol. 85, 1989, pp. 389–399.

[23] Demirboga, R., Turkmen, I., and Karakoc, M. B., Relationship Between Ultrasonic Velocity and Compressive Strength for High-Volume Mineral-Admixture Concrete, Cem. Concr Res., Vol. 34, 2004, pp. 2329–2336.

[24] Yıldırım, H., Sengul, O., Modulus of Elasticity of Substandard and Normal Concretes, Constr. Build. Mater, Vol. 25, No. 4, 2011, pp. 1645–1652. http://dx.doi.org/10.1016/j.conbuildmat.2010.10.009.

[25] Qasrawi, H. Y., Concrete Strength by Combined Non-Destructive Methods Simply and Reliably Predicted, Cem. Concr. Res., Vol. 30, 2000, pp. 739–746.

[26] Amiri, M., Tabatabaee Ghomi, M., and Liaghat, Gh., Non-Destructive Evaluation of Glass-Epoxy Composite Using Impact-Echo Method, Int J of Advanced Design and Manufacturing Technology, Vol. 10, No. 1, 2017, pp. 85-91.

[27] Heydari Vini, M., Farhadipour, P., Fabrication of

AA1060/Al2O3 Composites by Warm Accumulative Roll Bonding Process and Investigation of Its Mechanical Properties, Int J of Advanced Design and Manufacturing Technology, Vol. 10, No. 4, 2017, pp. 91–98.

[28] Sturrup, V., Vecchio, F., and Caratin, H., Pulse Velocity as A Measure of Concrete Compressive Strength, Situ/Nondestructive Testing of Concrete, ACI SP-82, 1984, pp. 201-227.

[29] Ravari, A. K., Othman, I. B., and Ibrahim, Z. B., Finite Element Analysis of Bolted Column Base Connection Without and With Stiffeners. Int. J. Phys. Sci., Vol. 6, No. 1, 2011, pp. 1-7.

[30] Walker, S., Bloem, D. L., Effects of Aggregate Size on Properties of Concrete, ACI Journal, Proceedings, Vol. 57, No. 3, 1960, pp. 283-298.

[31] Cordon, W. A., Gillespie, H. A., Variables in Concrete Aggregates and Portland Cement Paste Which Influence the Strength of Concrete, ACI Journal, Proceedings, Vol. 60, No. 8, 1963, pp. 1029-1052.

[32] Ezeldin, A. S., Aitcin, P. C., Effect of Coarse Aggregate on The Behavior of Normal and High-Strength Concretes, Cement, Concrete, and Aggregates, CCAGDP, Vol. 13, No. 2, 1991, pp. 121-124.

[33] Zhou, F. P., Lydon, F. D., and Barr, B., Effect of Coarse Aggregate on Elastic Modulus and Compressive Strength of High-Performance Concrete, Cement and Concrete Research, Elsevier, 1995,

[34] Ajamu, S. O., Ige, J. A., Effect of Coarse Aggregate Size on The Compressive Strength and The Flexural Strength of Concrete Beam, Journal of Engineering Research and Applications, Vol. 5, No. 4, 2015, pp. 2248-2267.

[35] Abdullahi, M., Effect of Aggregate Type on Compressive Strength of Concrete, International Journal of Civil and Structural Engineering, Vol. 2, No. 3, 2012, pp. 791-800.

[36] Buertey, J. T., Atsrim, F., and Ofei, W. S., An Examination of the Physiomechanical Properties of Rock Lump and Aggregates in Three Leading Quarry Sites Near Accra, American Journal of Civil Engineering, Vol. 4, No. 6, 2018, pp. 264-275.

[37] NIS 11, Specification for Ordinary Portland Cement, Standards Organisation of Nigeria, 1974.

[38] NIS 444-1, Composition, Specification and Conformity Criteria for Common Cements, Standards Organization of Nigeria, 2003.

[39] NIS 447, Methods of Testing Cement-Determination of Setting Time and Soundness, Suite 1, 24 Greenville Estate Badore, Lekki-Ajah, Lagos Nigeria, 2003.

[40] NIS 455, Methods of Testing Cement-Taking or Preparing Samples of Cement, Suite 1, 24 Greenville Estate Badore, Lekki-Ajah, Lagos Nigeria, 2003.

[41] BS 12, British Specification for Portland Cement. British Standard Institution, London, 1996.

[42] EN 197-1, Standard Test Method for Ordinary Portland Cement, European Committee for Standardization (CEN). Brussels, 2000.

[43] BS 112., Determination of Properties of Fine Aggregate BSI, Linfordwood, MiltonKeynes MK14 6LE, U. K, 1971.

[44] BS 933: 1, Determination of Particle Size Distribution-Sieving Method, BSI, 1997.

[45] Anum, I., Williams, F. N., Adole, A. M., and Haruna, A. C., Properties of Different Grades of Concrete Using Mix Design Method, IJGAES., Vol. 2 No. 6, 2014.

[46] Aminur, M. R., Harunur, D., Teo, C., L. and Abu, Zakir, M. M., Effect of Aggregates and Curing Conditions on The Compressive Strength of Concrete with Age,UNIMAS E-Journal of Civil Engineering, Vol. 1, No. 2, 2010, pp. 1– 6.

[47] Ji-Hwan, A., Jeong-Hee, N., Soo-Ahn, K., and Sung-Ho, J., Estimation of the Compressive Strength of Concrete Using Shear Wave Velocity Geotechnical Special Publication. GeoHunan International Conference, No. 196, 2009, pp. 154-164.

[48] BS 1881, Testing Concrete: Recommendations for Measurement of Velocity of Ultrasonic Pulses in Concrete Part 203, 1986.

[49] ASTM-C597, Standard Test Method Pulse Velocity Through Concrete, American Society for Testing and Materials, 2009.

[50] Brown, 2011, http://www.tc3.edu/instruct/sbrown/stat/shape.htm.

[51] Lizarazo-Marriaga, J., LópezYépez, G. L., Effect of Sedimentary and Metamorphic Aggregate on Static Modulus of Elasticity of High-Strength Concrete-Dyna, Year 78, Nro., Vo. 170, 2011, pp. 235-242. Medellin. ISSN 0012-7353.

[52] IS: 13311 (Part-1), Non-Destructive Testing of Concrete – Methods of Tests, Bureau of Indian Standard, New Delhi, India, 1992.