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Comparison of Coren mix design with other international mix (ACI and DoE) design methods

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Abstract

Because of its quality, which allows for veracities, Today, concrete is the most frequently utilized civil engineering material. Concrete has a low tensile strength and a high compressive strength. Even though Nigeria is Africa's giant, it has been discovered that its local contractor does not have a well-used standard mix procedure. Local Nigerian contractors have relied on an international mix. COREN recently established a mix design. It is critical that we determine whether this design process will be suitable for usage by local contractors. To assess the effectiveness of the published local mix against defined international standards, a complete experimental analysis of the COREN mix design with ACI and DoE was used in this study. With a target compressive strength of 30N/mm², three concrete mix designs with 0.48 and 0.50 water/cement ratios were used, and this mix was subjected to compressive tests, split tensile tests, and three-point bending. With respect to all the test conducted and analyzed, this attests to the level of significance of COREN i.e. For 28days mix with 0.48w/c, compressive strength with COREN gave 32N/mm² against 31N/mm² and 30N/mm² for ACI and DoE mix, respectively. Splitting tensile strength of 2.7 N/mm² was achieved with COREN mix against 2.8N/mm² and 2.7N/mm² from ACI and DoE, respectively. Likewise, results of flexural strength are 4.7N/mm², 5.3N/mm² and 5.1N/mm² for COREN, ACI and DoE, respectively. For 28days mix with 0.50w/c, compressive strength with COREN gave 29N/mm² against 30N/mm² for ACI and DoE mix, respectively. Splitting tensile strength of 2.5N/mm² was achieved with COREN mix against 2.4N/mm² and 2.8N/mm² from ACI and DoE, respectively. Likewise, results of flexural strength are 5.1N/mm², 4.7N/mm² and 5.6N/mm² for COREN, ACI and DoE, respectively.

Keyword: Mix design methods; Concrete mix; Durability; Concrete; Coren; ACI; DoE

1. Introduction

Concrete is the most extensively used material in civil engineering construction because of its quality, which allows for veracities. Concrete is high in compression and low in tension. Concrete should achieve some qualities such as durability, strength, and most especially economical in production. The quality depends on the material used and the method of production, as the aggregates used are known to be normal weight, light weight, and heavy weight (1).

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Concrete is the most often used material in civil infrastructure building, notably shelters of several types and uses (2,3) stated that the sighting of concrete technology has brought different advanced ideas into its usage. The relevance of modern buildings and construction has increased the importance of improving concrete quality (4). These changes can be made by focusing on the tangible constituents such as binder (5), Natural and artificial fibers (6,7), & Aggregates (Fine & coarse aggregate).

With respect to (8), The procedure of selecting suitable concrete ingredients and calculating relative proportions to produce the requisite concrete that will withstand the test of time in terms of material strength, durability, and workability is known as concrete mix design. Concrete is a water-based mixture of cement, fine aggregates, and coarse aggregates that is used as a construction material at engineering sites (3), and all these are in right proportion to get target strength. The performance of concrete, whether fresh or hardened, is mostly determined by the behaviour of its constituent elements and the relationships that exist between them; hence, the concrete mix design is the most critical factor in producing concrete with certain properties (9). Concrete is the most important composite material utilized in the construction industry, and it is impossible to discuss development without mentioning concrete. According to (10), "all structural work or other construction activity cannot be isolated from the presence of concrete." As a result, nearly all work structures or other works on roads, buildings, bridges, and other construction are built of the same material as the structure being worked on - concrete. The process of creating a concrete mix, which involves selecting the appropriate amounts of cement, fine aggregate, coarse aggregate, and water to generate concrete with the specified qualities, is a crucial stage in the development of a new form of concrete. A great deal of research has led to a considerably better understanding of the structure and behaviour of concrete, particularly in the last twenty to thirty years (9). Understanding the behaviour of concrete has benefited many in devising a method to fulfil the enormous demand, resulting in the different Mix Methods that are presently recognized. Some of these popular mix designs are ACI and BS which depends on graphs and standard tables derived from past research and real concrete production, as well as analyses of the materials qualities (11), Double Coating Method (9), COREN Concrete Mix Method (Special Publication No. COREN/2017/016/RC), Three Equations Method also known as Bolomey Method) (9).

Existing standards recognize that concrete strength is a regularly distributed quantity that should be thought of in terms of mean strength and standard deviation rather than an absolute limit. There are many international standards and methods whose specification are approved for mix designs, however, according to (14), they are all connected, provide the same quantities of mix components, and are all capable of producing a good concrete mix.

1.1. Council for the Regulation of Engineering in Nigeria (COREN) Method of Concrete Mix Design

Any strength class of cement can be used to make concrete, according to COREN (2019), if the mix design technique is followed, and the governing standard or code is followed during production. Regarding the use of cement grades, The Council for the Regulation of Engineering in Nigeria in their Mix Design publication (COREN/2017/016/RC) informed people who had concerns that the grades (32.5 R and 42.5 R) are sufficient (COREN, 2016). Concrete mix design's main goal is to pick appropriate constituent materials and determine their required proportions to make concrete with desired properties and qualities at a low cost. Workability, strength, and durability are the most listed features. Other considerations, like density, thermal characteristics, elastic modulus, and so on, may be necessary. Only two or three qualities are usually defined, with the rest being changed to ensure a minimal degree of workability and economy. The goal of mix proportioning is to use as little cement as possible to lubricate the mixture while it is still fresh, allowing for accurate placement, but also binding the aggregates together and filling the spaces between them once the concrete has set (COREN, 2017).

1.2. American Concrete Institute (ACI) Method of Concrete Mix Design

The initial version of this proportioning method was published in 1944 by ACI committee 613 (12). The approach was enhanced in 1954, according to (13), to include, among other things, the utilization of entrained air. This best practice describes how to select proportions for hydraulic cement concrete that contain or exclude various cementitious ingredients and chemical admixtures (14). The American Concrete Institute, according to (15) provides a mix design method that considers the most cost-effective use of available materials to produce concrete with the best workability, durability, and strength. The design table, which comprises the basic attribute correlations, is helpful in determining the best part combination as defined by the standard. Both normal and heavyweight concrete can be proportioned using the ACI mix proportioning method. According to (16), According to the ACI method, the water content, amount of air entrained, and chemical admixture, rather than the proportions of the mix, determine the workability of a mix with a given maximum size of well-graded aggregates.

The method also holds that the appropriate coarse aggregate bulk volume to total concrete volume ratio is determined only by the fineness modulus' maximum size (17). Given the volume of water, coarse aggregates, and cement, the absolute volume technique is used to calculate the number of fine aggregates required, taking into consideration the amount of air entrained in the mix. However, with any necessary field mix revisions, the final mix proportion should be determined by trial and error.

1.3. Department Of Environment (DOE) Method of Concrete Mix Design

The DOE approach, often known as the British way of concrete mix design and has a long track record and is commonly used in the United Kingdom and other parts of the world. The method is based on the United Kingdom's Road Note No. 4, which was revised in 1975 by the British Department of the Environment's standard concrete mixtures design (18,19).

1.4. Problem Statement

The problem statement focuses on the dependability of COREN mix design. It was observed that Nigeria does not have a well utilized standard mix method for her local contractors even as it stands as the giant of Africa. Our local contractors have depended on an international mix. Recently, a mix design was established by "The Council for the Regulation of Engineering in Nigeria" COREN. It is important we check if this method of design will be adequate for use by local contractors.

2. Result and Discussion

A comparison test was performed on concrete using 3 different mix designs as stated in the previous section involving mechanical properties using Compressive test, Tensile test, and Flexural test. To produce this mix design quantities, several tests were conducted on the materials as specified by the method of design. Table 1 shows the test checklist.

Table 1 Test Checklist

No	Test Description		Day		
		7days	14days	21days	28days
1	Compressive test	X	X	X	X
2	Splitting Tensile Test	O	O	O	X
3	Flexural Test	O	O	O	X

Legends: X = Applicable O = Not Applicable

2.1. Materials

Some of the most significant concrete mix design approaches require familiarity with statistical quality control procedures, which are common to all mix design methods using a w/c ratio of 0.48 and 0.5. Equation 1.0 was utilized for the mix design in this research. After design, material quantity summary was developed as shown in Table 2.

$$F_m = F_{min} + k\sigma \quad \text{………………… Eqn. 1.0}$$

Where.
Fm = Mean strength
Fmin = Minimum strength
K = 1.64
σ = Standard Deviation

The main materials that are to be used during this research work include the following:

- Fine Aggregate
- Coarse Aggregate -12.5mm
- Marine Board
- Limestone Portland Cement (Grade 42.5N BUA)

Table 2 Quantity summary, Kg

S/N	Material (Kg)	Mix Type			Total Mass For 3 Samples	Total Mass for 4 days (7,14,21,28)
		Coren Mix	ACI 211	DOE		
1	Water	15.64	14.3	14.97	44.91	179.64
2	Cement	23.28	29.81	29.94	83.03	332.12
3	Fine aggregate	40.52	44.04	47.24	131.8	527.2
4	Coarse aggregates	75.25	65.86	70.85	211.96	847.84

2.2. Cementitious

Limestone Portland Cement (LPC) 43.5N grade conforming to BS 4550: Part 3 while table 3 shows it physical Test. Regarding the binder, a chemical test was conducted which Table 4 shows the chemical composition, table 5 shows the qualitative result and it phase diagram In Fig. 2. Fig. 1 are the scanning Electron Microscopy (SEM) and Energy Dispersive X-ray Spectrometry (EDS) of the material.

Table 3 Physical Test on Cement (Grade 43.5N)

1	Water Added	132	ml
2	Time Started	3.17PM	
3	Initial Setting Time	3.33PM (16mins)	
4	Final Setting Time	07.40 pm (247 mins)	
5	Standard Consistency	33.00	%
6	Final Measurement	15	mm
7	Initial Measurement	13	mm
8	Expansion	2	mm
9	Temperature	25	^{o}C

Table 4 Chemical composition of LPC

Element Number	Element Symbol	Element. Name	Region (1)		Region (2)		Spot	
			Atomic Conc.	Weight Conc.	Atomic Conc.	Weight Conc.	Atomic Conc.	Weight Conc.
52	Te	Tellurium	33.78	70.31	33.99	55.91	24.94	50.09
74	W	Tungsten	-	-	10.40	24.65	8.38	24.25
20	Ca	Calcium	27.53	18.00	25.67	13.27	20.78	13.11
8	O	Oxygen	30.62	7.99	29.94	6.18	40.74	10.26
14	Si	Silicon	8.07	3.70	-	-	5.17	2.28

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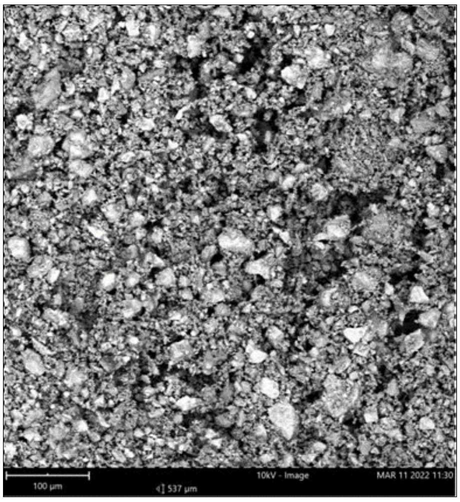
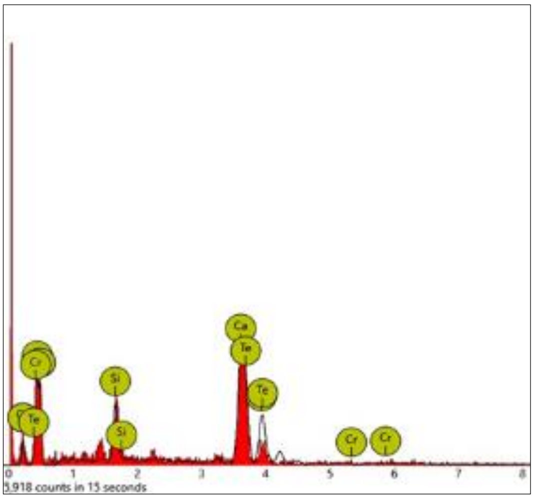
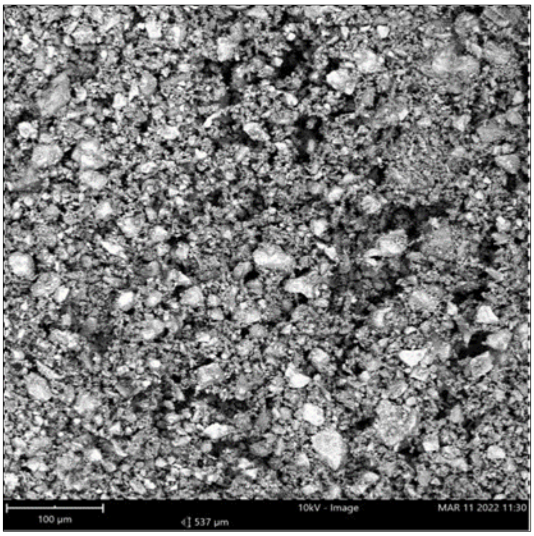


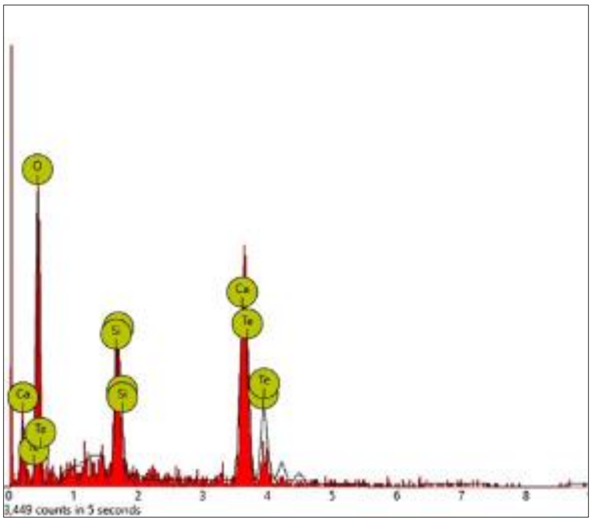
SEM Region - FOV: 537 µm, Mode: 10kV



(b)EDS Analysis Region



(c)SEM Spot - FOV: 537 µm, Mode: 10kV



(d) EDS Analysis Spot

Figure 1 SEM Micrograph and EDS Analysis

Table 5 XRD Qualitative Analysis Results

Phase Name	Formula	Figure of merit
Calcite	$CaCO_3$	1.981
Portlandite	$CaOH_2O$	3.242
Anhydrite	$CaSO_4$	3.395
Orthoclase	$AI_2O_3K_2O6SiO_2$	2.956
Muscovite	$KAI_2(Si_3\ AI)\ O_{10}(OHF)_2$	2.056
Wollastonite	$CaSiO_3$	2.241
Quartz	SiO_2	2.856
Osumilite	K-Na-Ca-Mg-Fe-AI-S….	3.606
Gypsum	$CaSO_4.2H_2O$	3.618
Garnet	3(Ca, Fe, Mg) O (AI. Fe….)	3.184

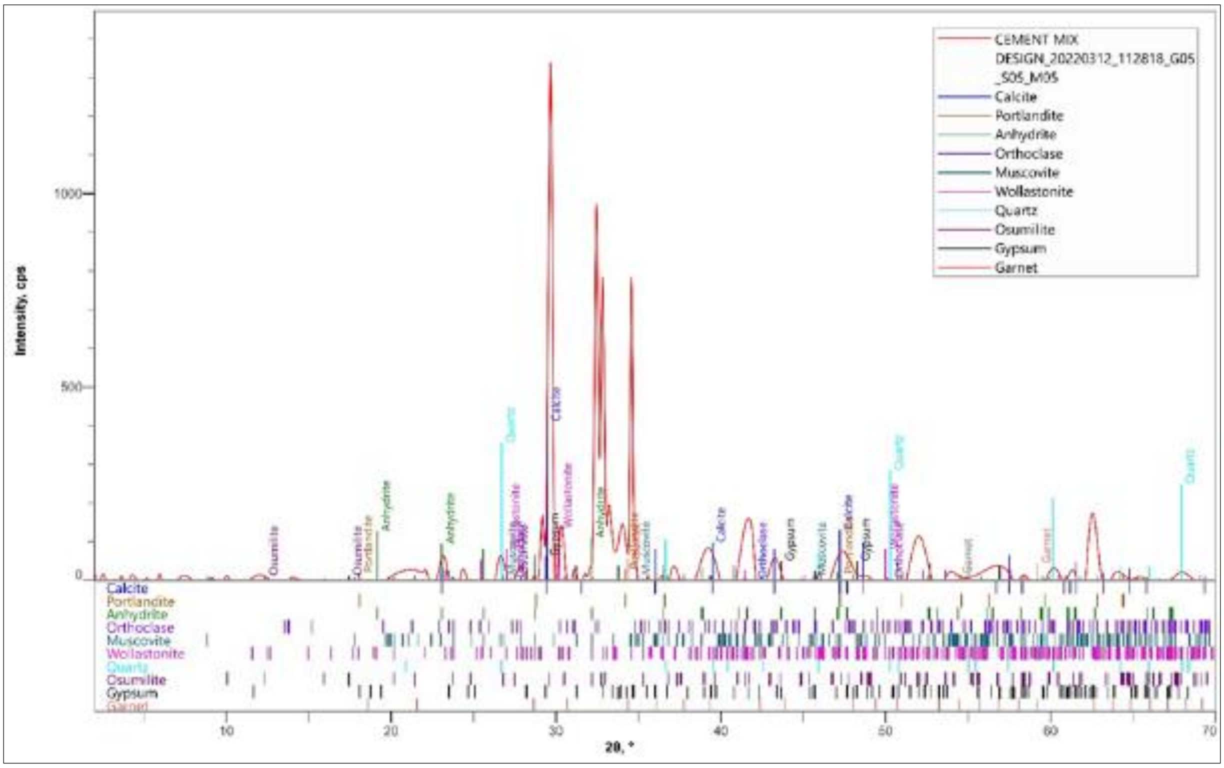


Figure 2 XRD Qualitative Analysis Phase Diagram

2.3. Aggregates

Table 6. show the data collected from the sieve analysis for fine and Coarse aggregate, and Fig. 3 and Fig. 4 shows the graph obtained for fine and coarse aggregate, respectively, indicating that the sand conforms with code of practice used. Table 7. Shows the result of the specific gravity which was used in estimating the mix designs.

Table 6 Sieve analysis for fine and coarse aggregate

Type	Fine Aggregate						12.5mm Aggregate					
Sample	A	B	C	A	B	C	A	B	C	A	B	C
Sieve Size (mm)	Soil Retained (%)			Passing (%)			Soil Retained (%)			Passing (%)		
19.05	0	0	0	100	100	100	0	0	0	100	100	100
12.72	0	0	0	100	100	100	34.9	13	34.5	65.1	87.00	65.5
9.52	0	0	0	100	100	100	46.7	63.1	43.8	18.4	23.90	21.7
6.35	0	0	0	100	100	100	16.6	22.6	21	1.8	1.30	0.7
4.76	0	0	0	100	100	100	1.2	1	0.7	0.6	0.30	0.0
Pan	0	0	0	100	100	100	0.6	0.3	0	0	0	0
2.36	7.5	6.5	6.5	93	94	94	100	100	100	100	100	100
1.18	24.5	26.5	24	68	67	70	100	0	0			
0.60	48	48	49	20	19	21	100	100	100	0	0	0
0.43	14	13	14	6	6	6.5	100	100	100	0	0	0
0.30	4.5	4	5	1.5	2	1.5	100	100	100	0	0	0

0.21	1.5	2	1.5	0	0	0	100	100	100	0	0	0
0.15	0	0	0	0	0	0	100	100	100	0	0	0
0.075	0	0	0	0	0	0	100	100	100	0	0	0

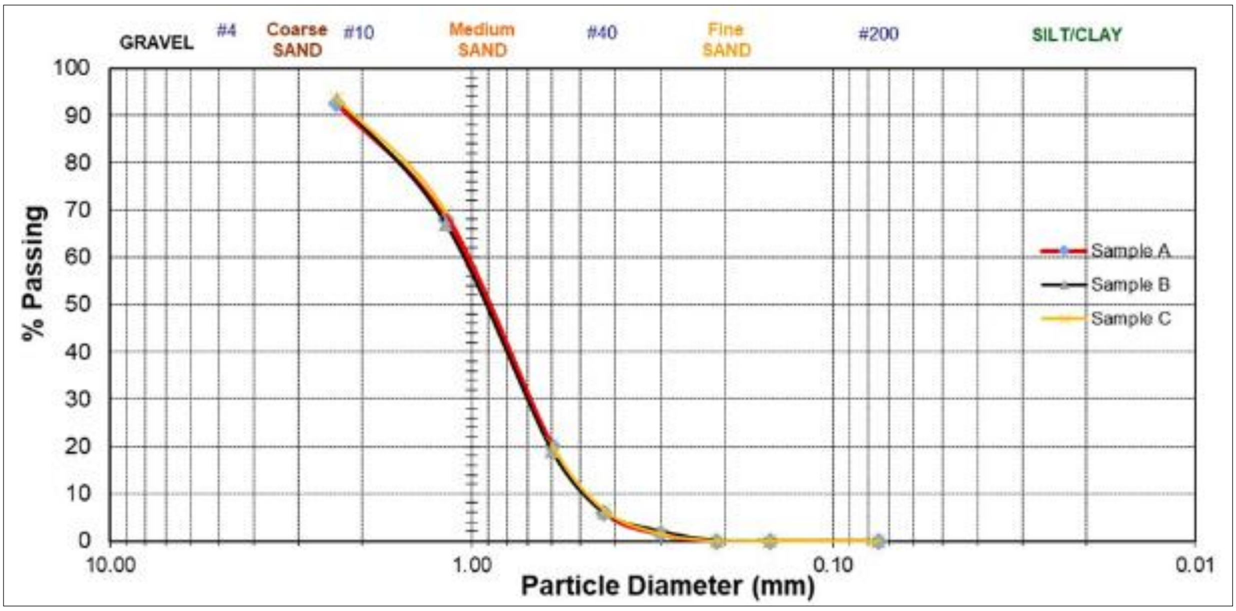


Figure 3 Sieve analysis for fine aggregate

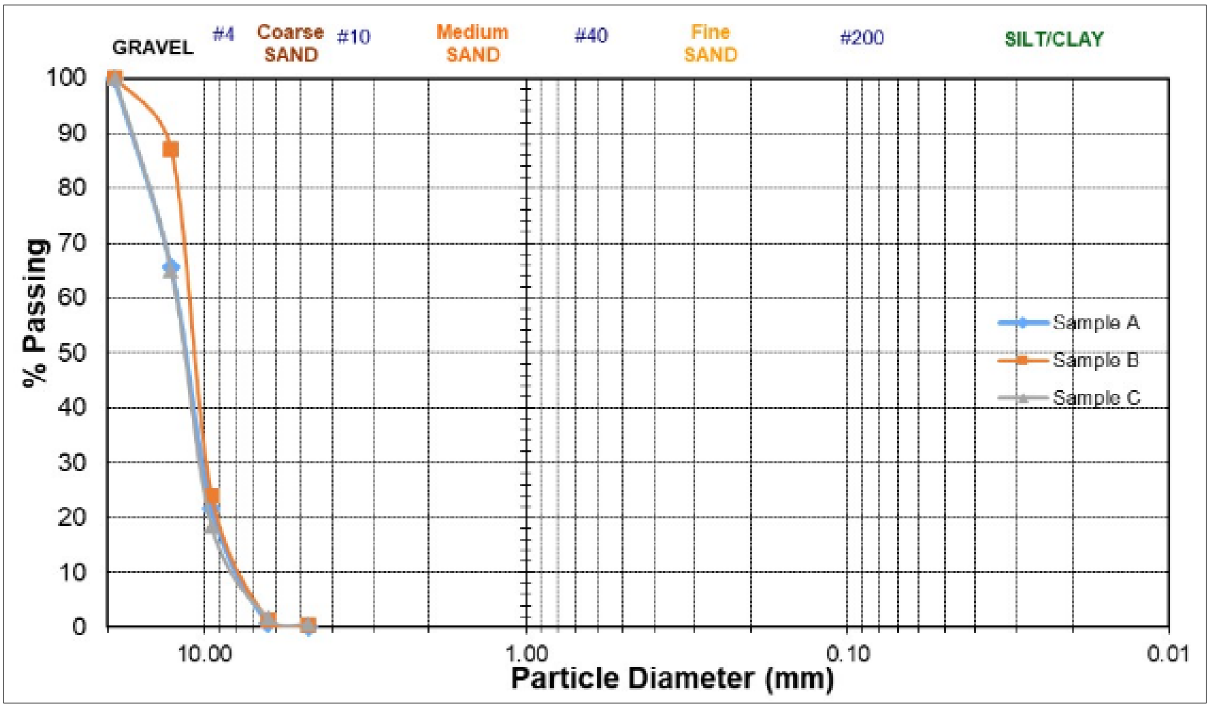


Figure 4 Sieve analysis for coarse aggregate

Table 7 Specific Gravity of Fine and Coarse Aggregate

Material	Fine Aggregate			12.5mm Aggregate		
DATA	A	B	C	A	B	C
Mass of Vessel (W1)	730	629	691	755	651	829
Mass of Vessel + Sand (W2)	1722	1633	1625	2906	2756	2892
Mass of Vessel + Water + Sand (W3)	2581	2546	2498	3745	3694	3674
Mass of Vessel + Water Only (W4)	1988	1946	1917	2433	2382	2397
Specific Gravity	2.49	2.49	2.65	2.56	2.65	2.62
Avg. Specific Gravity	2.54			2.61		

2.4. Mechanical Properties

Table 8 and 9 below shows summary of the compressive test conducted for 0.48 and 0.50 w/c ratio mix design, respectively. For splitting tensile test, Table 10 and 11. shows the result summary for 28days test for 0.48 and 0.50 w/c ratio mix design respectively while Table. 12 and 13 show the flexural result summary for 28days test for 0.48 and 0.50 w/c ratio mix design, respectively.

Table 8 0.48 W/C Ratio Compressive Test Summary

Mix Design Type	Tasks	Days	Mass of Sample (Average g)	Density Kg/m^3	Load (KN) (Average)	Strength N/mm^2
COREN	**CUBES**	**7**	8233	2440	540	24
		14	8367	2479	693	31
		21	8267	2449	720	32
		28	8633	2558	727	32
ACI	**CUBES**	**7**	8067	2390	583	26
		14	8067	2390	637	28
		21	7833	2321	630	28
		28	8767	2598	699	31
DoE	**CUBES**	**7**	8300	2459	540	24
		17	8367	2479	650	29
		21	8833	2617	643	29
		28	8267	2449	673	30

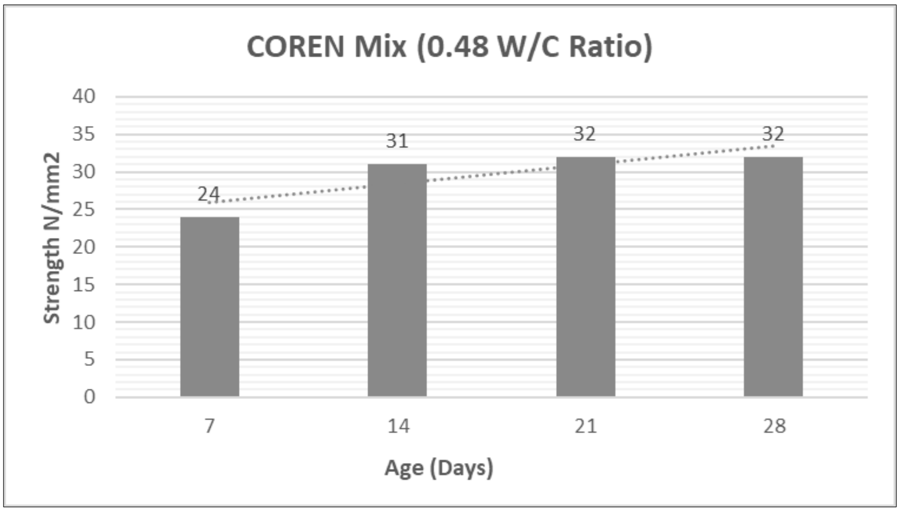


Figure 5 COREN Mix (0.48 W/C Ratio) - Compressive Strength Test Result

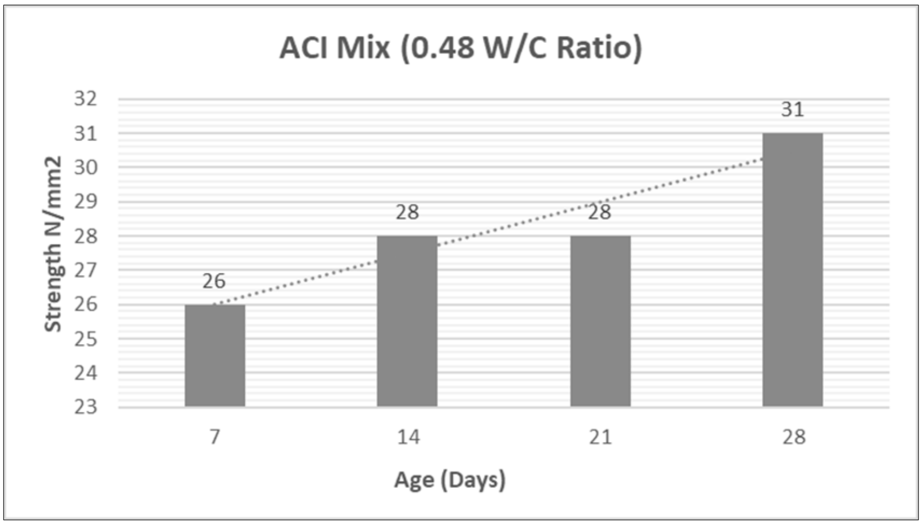


Figure 6 ACI Mix (0.48 W/C Ratio) - Compressive Strength Test Result

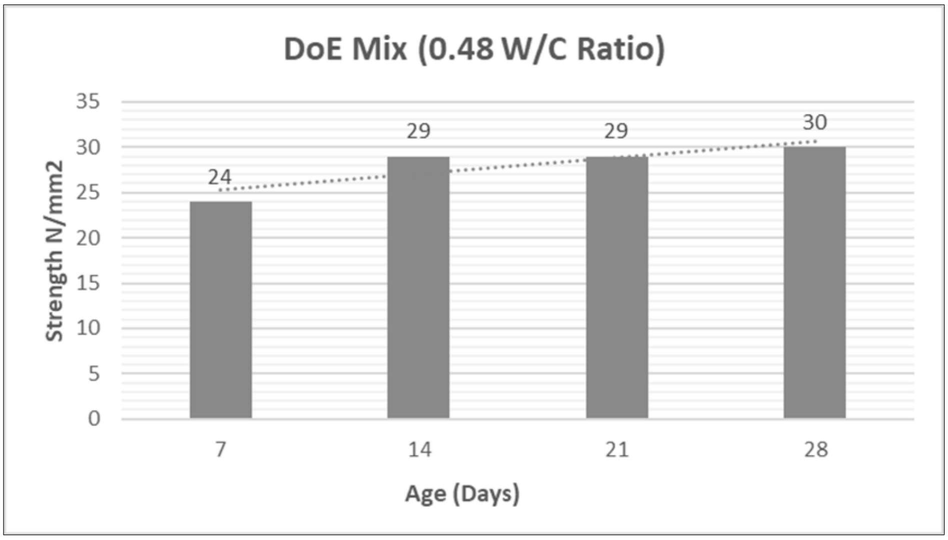


Figure 7 DoE Mix (0.48 W/C Ratio) - Compressive Strength Test Result

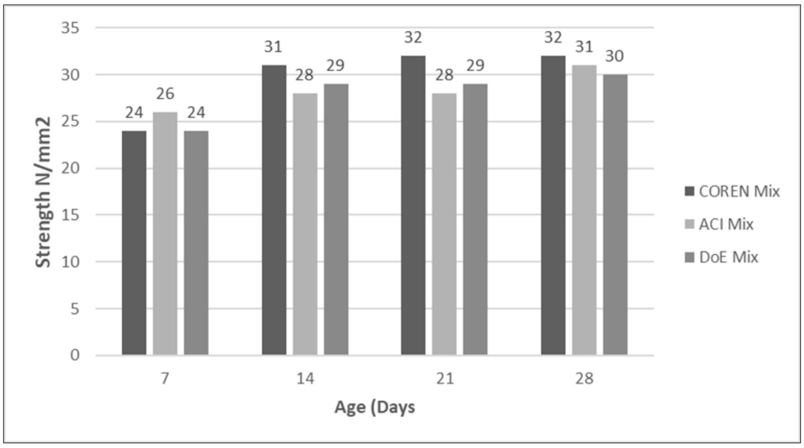


Figure 8 Comparison of COREN, ACI and DoE Mix (0.48 W/C Ratio) - Compressive Strength Test Result

Table 9 0.50 W/C Ratio Compressive Test Summary

Mix Design Type	Task	Days	Mass of Sample (Average g)	Density Kg/m³	Load (KN) (Average)	Strength N/mm²
COREN	CUBES	7	8467	2509	517	23
		14	8200	2430	553	25
		21	8300	2459	603	27
		28	8333	2469	543	29
ACI	CUBES	7	8367	2479	560	25
		14	8400	2489	580	26
		21	8667	2568	670	30
		28	8667	2568	667	30
DoE	CUBES	7	8267	2449	527	23
		14	8400	2489	513	23
		21	8667	2568	570	25
		28	8533	2528	680	30

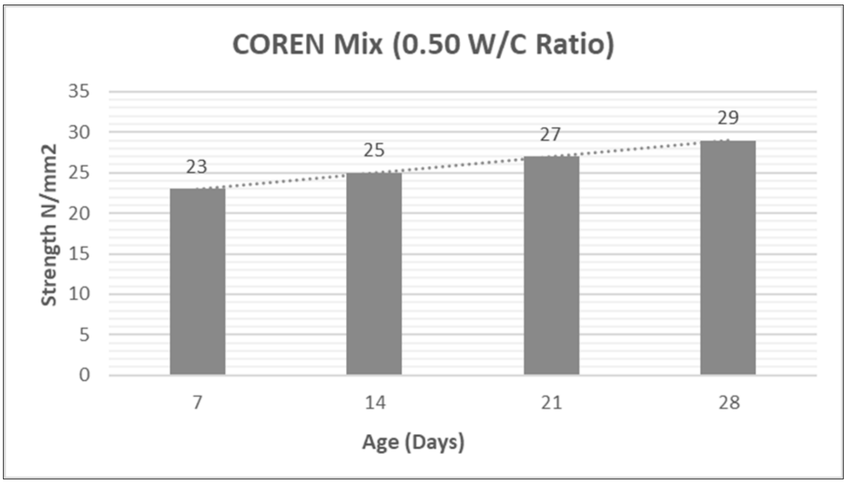


Figure 9 COREN Mix (0.50 W/C Ratio) - Compressive Strength Test Result

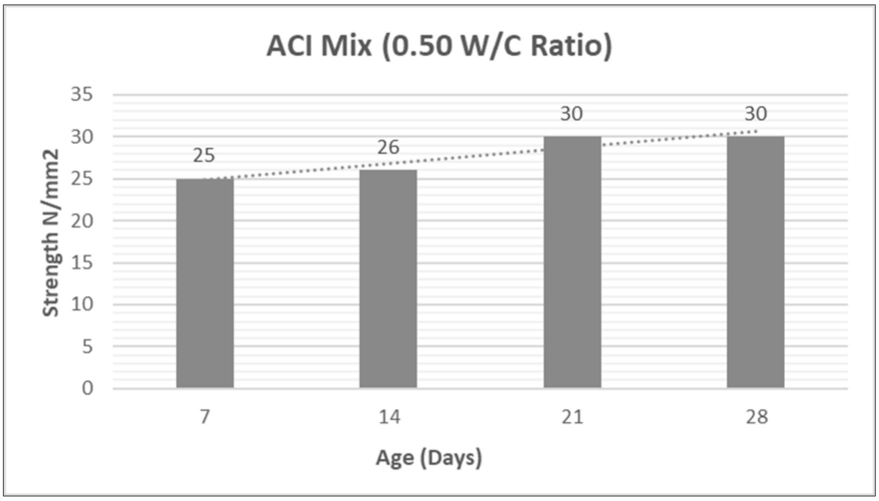


Figure 10 ACI Mix (0.50 W/C Ratio) - Compressive Strength Test Result

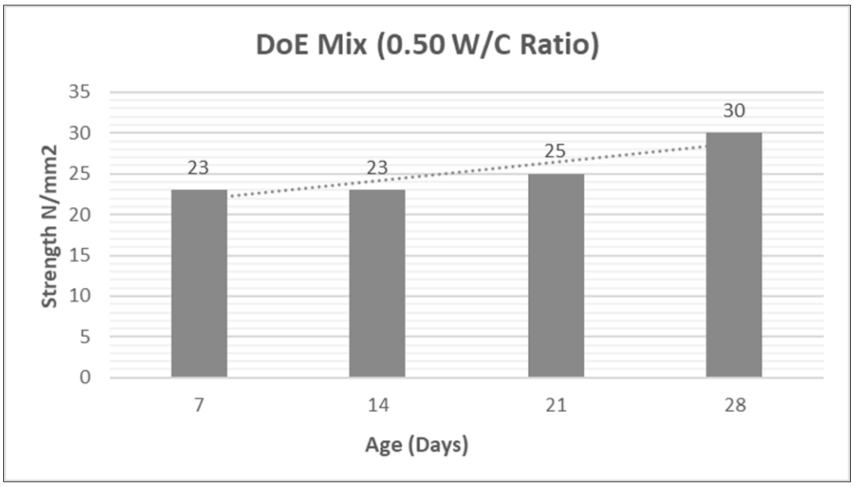


Figure 11 DoE Mix (0.50 W/C Ratio) - Compressive Strength Test Result

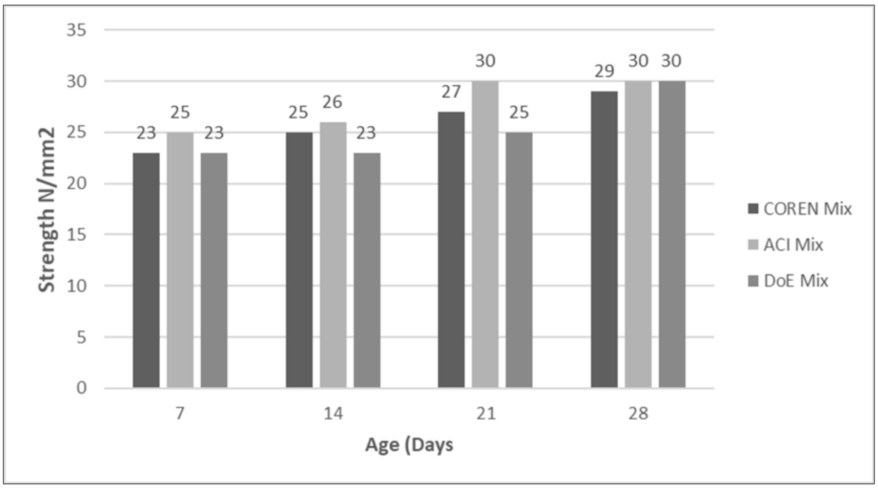


Figure 12 Comparison of COREN, ACI and DoE Mix (0.50 W/C Ratio) - Compressive Strength Test Result

Table 10 Split Tensile Test Summary For 0.48 W/C Ratio

Mix Design Type	Task	Days	Mass of Sample (Average g)	Density Kg/m³	Load (KN) (Average)	Strength N/mm²
COREN	**CYLINDER**	**28**	14000	2641	190	**2.7**
ACI	**CYLINDER**	**28**	13883	2619	200	**2.8**
DoE	**CYLINDER**	**28**	13433	2534	193	**2.7**

Table 11 Split Tensile Test Summary For 0.50 W/C Ratio

Mix Design Type	Task	days	Mass of sample (Average g)	Density Kg/m³	Load (KN) (Average)	Strength N/mm²
COREN	**CYLINDER**	**28**	13600	2565	177	**2.5**
ACI	**CYLINDER**	**28**	14267	2691	169	**2.4**
DoE	**CYLINDER**	**28**	14067	2653	200	**2.8**

Table 12 Flexural Test Summary For 0.48 W/C Ratio

Mix design type	Test	Days	Load (KN) (Average)	Strength N/mm²
COREN	Flexural	28	35	4.7
ACI	Flexural	28	40	5.3
DoE	Flexural	28	38	5.1

Table 13 Flexural Test Summary For 0.50 W/C Ratio

Mix design type	Test	Days	Load (KN) (Average)	Strength N/mm²
COREN	**Flexural**	**28**	38	5.1
ACI	**Flexural**	**28**	35	4.7
DoE	**Flexural**	**28**	42	5.6

2.5. Slump test

Below table 14. and fig. 10. shows the summary of the slump test conducted and its measurements respectively during the production of the samples.

Table 14 General Slump Test Summary

DESIGN	Water/Cement Ratio	Cube Slump (mm)
COREN	0.48	70
	0.5	90

ACI	0.48	45
	0.5	75
DoE	0.48	50
	0.5	80

2.6. Samples Check

0.48 COREN mix-70mm

0.50 COREN mix-90mm

0.50 COREN mix-80mm

0.50 COREN mix-75mm

0.48 DoE Mix - 50mm

0.48 ACI Mix - 45mm

Figure 13 Slumps Testing

Figure 14 Cubes, beams, and cylinders samples

Split tensile test sample after demoulding.

DoE (0.5 w/c ratio)

ACI (0.5 w/c ratio)

COREN (0.5 w/c ratio)

Figure 15 Split tensile test sample

	
Split tensile test before test.	Split tensile test after test.

Figure 16 Split tensile testing

	
Flexural test setup after conducting the test	Flexural test failure envelops

		
Failed beam	Flexural test sample after demoulding	Flexural test after sample failed.

Figure 17 Flexural test

2.7. ANOVA

Single factor for 28days compressive test summary for 0.48 w/c ratio Table 15. shows the ANOVA analysis for the comparison of the 0.48 w/c ratio mix. It was observed that there were no significant differences in the mix designs with 0.48 w/c ratio.

Table 15 0.48 ANOVA Summary Sheet

Groups	Count	Sum	Average	Variance
COREN	3	96.9	32.3	6.8
ACI	3	93.2	31.1	4.1
DOE	3	89.8	29.9	4.0

ANOVA						
Source of Variation	**SS**	**df**	**MS**	**F cal**	**P-value**	**F crit**
Between Groups	8.4	2.0	4.2	0.8	0.5	5.1
Within Groups	29.8	6.0	5.0			
Total	38.2	8.0				

2.8. ANOVA: single factor for compressive test summary for 0.50 w/c ratio

Table 16. shows the ANOVA analysis for the comparison of the 0.50 w/c ratio mix. It was observed that there were no significant differences in the mix designs with 0.50 w/c ratio.

Table 16 0.50 ANOVA Summary Sheet

Groups	Count	Sum	Average	Variance
COREN	3	85.78	28.59	6.39
ACI	3	88.89	29.63	0.46
DOE	3	90.67	30.22	0.20

ANOVA							
Source of Variation	**SS**	**df**		**MS**	**F**	**P-value**	**F crit**
Between Groups	4.08		2	2.04	0.87	0.47	5.14
Within Groups	14.09		6	2.35			
Total	18.17		8				

3. Conclusion and Recommendations

At 7days, the percentage for 0.48 water cement ratio in the above result has 7.69% decrease in value for COREN when compared to ACI while the percentage for 0.5 water cement ratio above has 11.5% decrease in the value of COREN when compared to ACI. With respect to 28days result, the percentage for 0.48 water cement ratio increased by 3.13% and 6.25% in the value of COREN when compared to ACI and DOE respectively while the percentage for 0.5 water cement ratio decreased by 3.3% in the value of COREN when compared to both ACI and DOE.

From the percentage changes gotten, this shows that COREN achieves a lower compressive strength value at early age and attains a higher compressive strength value for final age using a w/c ratio of 0.48. When compared to ACI and DOE, COREN mix design achieves maximum strength for final age utilizing a water cement ratio of 0.48. It was also observed that the greater the w/c ratio, the lower the strength values obtained, leading us to the conclusion that a larger water cement ratio reduces the strength of a concrete mix.

Finally, with respect to all the test conducted and analysed in our previous chapter this attests to the level of significance of COREN i.e., In terms of compressive strength, tensile strength, desired slump, and modulus of rupture, COREN mix design with 0.48 & 0.50 is comparable to other mix designs.

After all considerations and test conducted. Considering the above conclusion, from the results gotten. Below is the recommendation of this research.

- The COREN mix proportioning as published can be utilized on site.
- Water Cement ratio should be controlled for the target strength of 30 N/mm2 and should not be more than 0.5 for concrete.
- The target slump was achieved, therefore can be used by local contractors for slump range 80 – 100mm.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Shetty MS, Jain AK. Concrete Technology (Theory and Practice), 8e. S. Chand Publishing;2019.

[2] Fapohunda, C.A., Famodimu, B.I., Adigo, B.C. and Jeje, A.S. (2020) Effect ofChanging Cement Grade on the Properties of Structural Concrete. Nigerian Journalof Technological Development, 17, 197-204. https://doi.org/10.4314/njtd.v17i3.6

[3] Ubi SE, Nkra PO, Agbor RB, Ewa DE, Nuchal M. Efficacy of Basalt and Granite as Coarse Aggregate in Concrete Mixture; 2020.

[4] Hachani MI, Kirker A, Seghiri M. Experimental study, and comparison between the use of natural and artificial coarse aggregate in concrete mixture. ("Testing of Rounded Valley Aggregate in Concrete Mix in Comparison with ...") Energy Procedia 2017;119-82-91

[5] Carballosa P, García JL, Calvo et al. Influence of cement and expansive additive types in the performance of self-stressing and self-compacting concretes for structural elements. ("Expansive concretes with photocatalytic activity for pavements ...") Construction and Building Materials 2015;223-29-93.

[6] Belferrag A, Kriker A, Khenfer ME. Improvement of the compressive strength of mortar in the arid climates by valorization of dune sand and pneumatic waste metal fibres. Construction and Building Materials 2013;(40):847-53.

[7] Nindyawati SM, Dewi A, Soehardjono. "The Comparison Between Pull-Out Test and Beam Bending Test to The Bond Strength of Bamboo Reinforcement in Light Weight Concrete." ("(PDF) The Comparison Between Pull-Out Test and Beam Bending Test to The ...") International Journal of Engineering Research and Applications; 2013:1497:1500-3.

[8] Sobera G, Jose V. Relationship between gas adsorption and the shrinkage and creep of recycled aggregate concrete, Cement, Concrete & Aggregates;2003. ("Relationship Between Gas Adsorption and the Shrinkage and Creep of ...")

[9] Abdelgader HS, Saud AF, Othman AM, Fahema, AH, El-Baden AS. Concrete mix design using double-coating method. Betonw Fert. Plant Precast Technol 2014;(30):66-74.

[10] Kamarul NC. Investigation of Coarse Aggregate Special Gradation on Concrete Strength 2018;6

[11] Neville AM. Properties of concrete. Pitman Books Limited, London. Third Edition;1981;779 pp.

[12] Rumman R. Mix design for durable and pumpable concrete using locally available materials; 2018.

[13] Nataraja MC. 'Professor of Civil Engineering, Sri Jayachamarajendra College of Engineering,' 2016; Mysore570006 Nataraja96@yahoo.com, Ph. 98804 47742.

[14] Anike EE, Saidani M, Ganjian E, Tyrer M, Olubanwo AO. ("Evaluation of conventional and equivalent mortar volume mix design ...") Evaluation of conventional and equivalent mortar volume mix design methods for recycled aggregate concrete. Materials and Structures 2020;53(1):1-15.

[15] "Ahmed M, Mallick J, AlQadhi S, Ben Kahla N. Development of concrete mixture design process using MCDM approach for sustainable concrete quality management." ("Sustainability | Free Full-Text | Development of Concrete ... - MDPI") Sustainability 2020;12(19):8110.

[16] Khayat KH, Libre NA. Roller compacted concrete: field evaluation and mixture optimization. Centre for Transportation Infrastructure and Safety/NUTC Program 2014. Missouri University of Science and Technology.

[17] Hasan M, Kabir SM, Monty AS. Effects of Maximum Size of Coarse Aggregate on Compressive Strength of Concrete 2020.

[18] Kale RS, Kute S. Five layers Artificial Neural Network system to design a concrete mix, based on DOE method. International Journal of Civil & Structural Engineering 2015;5(3):284-95.

[19] "Anike EE, Saidani M, Olubanwo AO, Tyrer M, Ganjian E. Effect of mix design methods on the mechanical properties of steel fibre-reinforced concrete prepared with recycled aggregates from precast waste." ("Mechanical characterization of concrete with additions of steel fiber ...") In Structures 2020;(27):664-72. Elsevier.

[20] Neville AM, Brooks JJ. Concrete Technology. Longman Scientific and Technical, London. First Edition; 1987:438 pp.