International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 9 Sep 2021, pp: 371-383 www.ijaem.net ISSN: 2395-5252

Tensile Strength of High Strength Concreteusing Micro-Silica and Recycled Aggregate Concrete

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Submitted: 30-08-2021 Revised: 03-09-2021 Accepted: 05-09-2021

ABSTRACT: The aim of this study was to experimentally investigate the mechanical properties of high strength concrete using micro-silica (MS)and recycled aggregate concrete. In order to measure the contribution of micro silica to the hardened state properties, micro-silica was used to replace cement with ratios of 5%, 10%, 15%and 20% at varying water cement ratio of (0.2, 0.24, 0.28, &0.32). A control mix (0% micro-silica) was prepared for each water cement ratio, which were used for comparison, and 1.2% superplasticizer dosage was added to the mixtures. A concrete mix design was carried out using Absolute volume method for recycled aggregate concrete (RAC).A total of two hundred and forty (240) cubes were tested to obtain the compressive strength, while one hundred and twenty (120) cylinder samples were used to determine the split tensile strength. The maximum compressive and split tensile strength of control mix is 105Mpa and 3.67Mpa respectively. Whereas the 15%MS and 0.2% of micro-silica inclusion give the maximum compressive and split tensile strength of 103Mpa and 3.63Mpa respectively. The adopted absolute volume method in this study is recommended for future purpose. The fresh state properties blended with Microsilica satisfied compatibility, (i.e. filling ability, passing ability and segregation resistance) in accordance with EFNARC recommendations.

KEYWORDS: Micro-silica,Recycled Aggregate Concrete, Compressive Strength, Split Tensile Strength.

I. INTRODUCTION

Amongst sustainable concrete, recycled aggregate concrete is the most viable in terms of economic and environmental sustainability. Depletion of natural aggregate (Granite) has necessitated the alternate use of recycled aggregate (Ali, 2017).

Enormous studies have been carried out and confirmed that Recycle Aggregate Concrete (RAC) exhibits decrease in both strength and durability compared to the normal strength concrete (Peem, 2018). Therefore, any measure to improving the strength and durability characteristics should be explored. Porosity was identified as the most significant deficiency of recycle aggregate concrete; therefore, the application of finer supplementary cementitious materials is anticipated for enhancement of mechanical properties. The production of concrete has rapidly grown in the recent years because of the overwhelming increase in the demand for infrastructure development, an estimated 12 billion tons of concrete is used annually globally. Canter (2018) satisfying this demand requires an immense supply of cement or any partial replacement material(Malhotora, 2002), Demolition of old structures and construction of new ones are frequent phenomena due to change of purpose, structural deterioration, rearrangement of a city, expansion of traffic directions and natural disasters. About 850 million tons of construction and demolition wastes are generated in the European Union each year, which represents 31% of the total waste generation (Malesev, 2010).

The production of cement surpassed 4.1 billion tons a year, which is the highest production of any material after water, cement production is a very energy intensive process with the cement industry produced about 5% of global CO2 (carbon iv oxide). It is expected that the increase in the demand will be more than 8% for the coming years, which is particularly high for one industry. It is also reported that replacing 30% of cement used with Supplementary Cementitious Materials (SCMs) will reverse the rise in CO_2 emission. Moreover, in the recent decades, a massive amount of concrete waste had been produced due to development of rural areas. The waste from the demolished concrete cause environmental hazed when it is disposed of in landfill sites. Instead the wastes can be turn into a valuable material by crushing them into a suitable size used as concrete aggregate. The crushed materials are ground, sieved, and cleaned to be turned into what is known as Recycled Concrete Aggregate (RCA). The use of crushed aggregate also reduces the extraction of raw materials from the earth, further diminishing the adverse environmental impact. The recycled aggregates contained 50-60% natural aggregate by volume, followed by 30-35% old cement mortars. Compressive strength and other properties of concrete containing RCA are affected by the properties of parent concrete, mix proportion, workability (Romildo, 2017),On the other hand, recycle aggregate has another environmental advantage, that of decreasing the consumption of natural aggregate recycle aggregate have been proved to be economically viable as well as having a positive environmental impact however, for that to be true it is essential that the output from recycle aggregate can be absorbed by the industries. In other words, there is a strong need to diversify the industrial applications of Construction and Demolition Waste (CDW) (Quattrone, 2016).

AIM AND OBJECTIVE

The aim of this research is to examine the mechanical properties of recycled aggregate concrete enhanced with micro-silica as partial replacement of cement.

.a.To investigate the physical and workability of RAC enhanced by Micro Silica at varying incorporation levels of 4%, 8% and 12%..

b.To design an appropriate mix to get maximum compressive/ tensile strength values.

c. To investigate the compressive strength of RAC enhanced by Micro Silica at varying incorporation levels of 4%, 8% and 12%.

d.To investigate the tensile strength of RAC enhanced by Micro Silica inclusion at 4%, 8% and 12%.

II. LITERATURE REVIEW

Micro silica in concrete contributes to strength and durability two ways: as a pozzolan, micro silica provides a more uniform distribution and a greater volume of hydration products; as a filler, micro silica decreases the average size of pores in the cement paste. Used as an admixture, micro silica can improve the properties of both fresh and hardened concrete. Used as a partial replacement for cement, micro silica can substitute for energy-consuming cement without sacrifice of quality. (Sharma, 2014).

Chaocan (2018) examined the mechanical properties of recycled concrete with demolished waste concrete aggregate and clay brick aggregate with target strength of 65MPa. It was observed that the compressive strength of the hardened concrete decreases with the increased replacement of NCA by RCA and in general, the concrete with RCA has better performance than the concrete with Recycled Brick Aggregate (RBA).

Farhad (2018), studied the development of high-performance self-compacting concrete using waste recycled concrete aggregates and rubber granules: with target strength of 75MPa. It was observed that an increase in the percentage of coarse recycled aggregate shows a decrease in compressive strength. The worst sample being the RA40 mix with 40% replacement yielding a 13% decrease in compressive strength when compared to the control mix.

Lotfi (2017), carried out a research work on the performance of RAC based on new concrete recycling technology which consists of a combination of smart demolition, gentle grinding of the crushed concrete in an autogenous mill and a novel dry classification technology to remove fines.

Pedro (2017), investigated the influence of the use of recycled concrete aggregates from different sources in structural concrete evaluating the capacity of producing concrete with pre-established performance in terms of mechanical strength incorporating RCA from different sources. Only total replacement of Coarse Natural Aggregates (CNA) by coarse recycled aggregates were tested. The observations observed is as follows;

I. The compressive strength in cubes and cylinders decreased between 3% - 20% for the various target strengths due to the incorporation of RA.

II. The modulus of elasticity of the RCA indicate a decrease varying from 15% - 22%.

III. The use of RA with low mechanical properties emphasizes the negative effects of the RA.

IV. Shrinkage was one of the properties most impaired by the incorporation of Crushed Recycled Concrete Aggregate (CRCA) at 91 days, there were increases of 47%, 43% and 68% relative to the RC.

The limitation of this study regards the SC influence where there were no significant differences in the mixes using different RA, unlike in all the other properties which needs to be investigated further.

According to Ogar (2017), the early compressive strength of RCA concrete is higher than that of NCA concrete although the water cement ratio and mix design are kept constant. However, the compressive pressure of NCA concretes was marginally higher than that of RCA concretes at later ages, by a range to about 10%. The productivity of concrete with RCA was observed to be considerably lower than that of NCA. It was also reported that RCA-produced concrete had lower compressive strength than NCA-produced concrete. However, since this reduction is so minor, RCA can be used in concrete systems with minor changes to achieve unique and desirable purposes.

Garg et al. (2013) from their research study concluded that 50 to 100 % replacement of virgin aggregates with recycled aggregate decreases the compressive strength by 5 to 25 %. However, it was found that up to 30 % virgin aggregate can be substituted with RCA without any effects on concrete strength. Strength gain for RCA concrete is lower than normal aggregate concrete (NAC) for the first 7 days. On the other hand, fine RA has a more detrimental effect on compressive strength than coarse RA.

From the previous studies confirmed that recycled aggregate without incorporated with a supplementary cementitious material will influence the strength of concrete negatively. This indicates that the strength of high strength concrete (HSC) is principally governed by the water/cement ratios and replacement levels of micro-silica. More heterogeneous high strength concrete (HSC), could b adequately obey linear relationship. Therefor , this studies are tailored towards addressing these gaps. First, control specimens were prepared at variable water/cementations ratio of 0.2, 0.24,0.28 and 0.32 as well as a partial replacement levels with micro-silica of 5%, 10%, 15% and 20% of micro silica. Secondlycompressive assessment on the effects of principal variables that influence compressive and tensilestrengths.

III. MATERIALS AND METHODS

3.1 MATERIALS

The following experimental materials were used in this study;

iPortland Limestone of grad 42.5 cement manufactured by Dangote Cement Company conforming to NIS 444-1:2014

ii.Micro Silica -Elkem Micro silica 920D in accordance to ASTM C 1240

iii. Natural time sand aggregates of 5mm maximum size (river sand) conforming to BS 882 (1992),

iv.Natural granite aggregate of maximum size (20mm) obtained from crushed rock industries in Port Harcourt.

v.Portable water obtained from Rivers Stat University mains in the civil engineering laboratory conforming to BS 3148 (1970

vi.Recycled aggregate concrete obtained from G.R.A and Eliozu demolished sit Port Harcourt.

vii. Superplasticizer (SP) Poly Carboxylate Ether (PCE) was used.

vii. SP: Superplasticizer dosage for developing a flowable compacting concrete , poly-carboxylate either (PCE) based superplasticizer was used in this study. Based on the manufacturer's prescription, dosage level should b between 1% - 1.3% of the total cementitious or powdercontent of superplasticizer conforming to EN 934-2

3.2 TEST METHODS

The specimen preparation and tests were carried out in the Civil Engineering structural laboratory of Rivers State University, Port Harcourt Nigeria.

The tests to evaluate the mechanical and fresh state properties ofMicro-Silica and recycled aggregate concrete were conducted.

A total of two hundred and forty (240) cubes were tested to obtain the compressive strength, while one hundred and twenty (120) cylinder samples were used to determine the split tensile strength, asare presented in Table 3.1

Table 3.1: Details of Sample Used and Test Conducted

Type of tests conducted	Size of sample	No. of sample (for each mix)	Total No. of sample
Compressive strength	100x100x100mm, cubes	12x20	240
Split Tensile Strength	150x300mm, cylinder	3x40	120

3.3 Concrete Mix Design

It is well known that concrete□ physical and mechanical properties depend on the mix design. Mix design can b□ defined as the combination of optimum proportions of the constituent materials to fulfil the requirements of fresh and hardened concrete□ for a specific application (D□ Schutter, 2008).

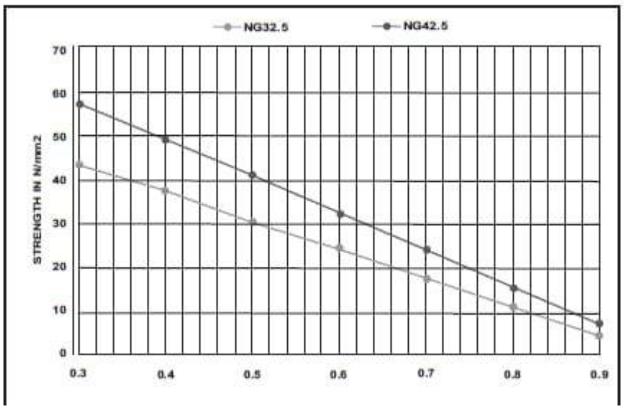
For HSC, achievement of high strength is the prim□ target of the mix design.

3.4 Mix Design Procedure

The mix design method adopted in this researched work is absolute volume□ method

For this method a suitable□ water/cement ratio was assumed to determine thetargetstrengthbased on the curing ag□ as presented below.

i. Determination of the free water-cementitious ratio: It can be obtained directly from chart in Figure. 3.1. The curve□ shows an inverse□ relationship between mean. ii. 3compr□ssiv□ strength and the water/cement ratio at different curing ages



Figure□ 3.1:Compressive□ Strength Water/Cement Ratio Curve□ (COREN, 2017).

Alternatively, the □empiricalrelationship of Eqn. 3.1provided by (Lyndon, 2002) can b□ used to compute□ thecompressive□ strength at a specifiedwater/cement ratio.

Fc=140.44/ (10.92) ^ (w/c) (3.1)

Watercontent is obtained from thetable□ blowbased on the expected slump value□. For thepurpose□ of strength, thewatercontent is lower than 180 kg/m3.

i. **Mix DesignComputation for Mix 1 (w/c = 0.20)**

Mix d□sign computation for mix 1 w/c = 0.20

$$f_c = \frac{140.44}{(10.92)^{w/c}} = \frac{140.44}{(10.92)^{0.20}} = 87.07\text{N/mm}^2$$

Targ□tstr□ngth for W/C = 0.20

Void cont□nt $= \frac{\text{bulk density} - \text{specific gravity}}{\text{specific gravity}} \times 100$ (3.2)

% void = $\frac{1774-1730}{1730} \times 100 = 2.5\%$

Bas□d on th□ assum□d w/c ratio of 0.2

C□m□nt cont□nt $= \frac{128}{0.2} = 640\text{kg/m}^3$

Total volum□ = 1000m^3

Air cont□nt = 2.5% Air = 25m^3

L□t th□ c□m□nt and wat□r cont□nt b□ Cs and Ws (kg/m^3) r□sp□ctiv□ly.

Volum□ of c□m□nt $V_c = \frac{C_s}{G_s}(\text{m}^3)$ (3.3)

Wh□ r□ G_c is th□ S.G
$G_c = 3.10$
$V_c = \frac{640}{3.10} = 206.45\text{m}^2$
Volum□ wat□ r $(V_w) = \frac{W_s}{G_w}\text{m}^3$ (3.4)

S.G of wat□ r 1.0
$V_w = \frac{128}{1.0} 128\text{m}^3$
Volum□ of S.P $(V_{s.p}) = \frac{W_{s.p}}{G_{s.p}}\text{m}^3 \frac{1.2\times640}{100} \div 1.6 = 4.8\text{m}^3$(3.5)
Volum□ of past□ $(V_{paste}) = \left(\frac{C_s}{G_s} + \frac{W_s}{G_w} + \frac{W_{sp}}{G_{sp}}\right)$(3.6)
$= (206.45 + 128 + 4.8) = 339.25\text{m}^3$

Primary past□ volum□ r□ quir□ d for filling ability
Th□ n□ xt volum□ = Total volum□ – void volum□ = 1000–25 =975m^3
Total volum□ of aggr□ gat□ (Vg) = 975-339.25=635.75m^3
Aggr□ gat□ ratio: th□ fin□ aggr□ gat□ is tak□ n as 42% and coars□ aggr□ gat□ tak□ n as 58%
Mix proportion by w□ ight:
W□ ight of c□ m□ nt = 0.624 x 339.25 x 3.1 = 656kg/m^3
W□ ight of fin□ aggr□ gat□ = 0.42 x 635.75 x 2.5 = 667.54kg/m^3
W□ ight of coars□ aggr□ gat□ = 0.58 x 635.75 x 2.54 = 936.589kg/m^3
W□ ight of wat□ r = 128kg/m^3
Sup□ rplasticiz□ r (S.P).
S.P = 1.2% of c□ m□ nt $= \frac{1.2}{100} \times 640 = 7.68\text{kg/m}^3$
Mix Ratio: 1.0: 1.02: 1.43: 0.20.

Oth□ r mixtur□ s w□ r□ d□ sign□ d using th□ sam□ proc□ dur□ as summariz□ d in th□ Tabl□ 3.2

Tabl□ 3.2: Mix D□ sign Proportion

W/C Ratio	P□ rc□ ntag□ r□ plac□ m□ nt (%)	C□ m□ nt (kg/m3)	Micro silica	Fin□ aggr□ gat□ (kg/m3)	Coars□ aggr□ gat□ (kg/m3)	R□ cycl□ d Concr□ t□ Aggr□ gat□	Wat□ r (kg/m3)	Sup□ rplasticiz□ r (% of C□ m□ nt)
0.2	0	640	0	667.54	936.59	0	128	1.2
	5	608	32	667.54	889.76	46.8	128	1.2
	10	576	64	667.54	842.93	93.66	128	1.2
	15	544	96	667.54	796.10	140.49	128	1.2
	20	512	128	667.54	749.27	187.32	128	1.2
0.24	0	533	0	725.613	1018.07	0	128	1.2
	5	506.35	26.65	725.613	967.09	50.9	128	1.2
	10	479.7	53.3	725.613	916.19	101.81	128	1.2
	15	453.05	79.95	725.613	865.28	152.7	128	1.2
	20	426.4	106.6	725.613	814.40	203.6	128	1.2

0.28	0	457	0	731.3	1026	0	128	1.2
	5	434.15	22.85	731.3	974.70	51.3	128	1.2
	10	411.3	45.7	731.3	923.40	102.6	128	1.2
	15	388.45	68.55	731.3	872.1	153.9	128	1.2
	20	365.6	91.4	731.3	820.80	205.2	128	1.2
0.32	0	400	0	750.72	1053.29	0	128	1.2
	5	380	20	750.72	1000.63	52.66	128	1.2
	10	360	40	750.72	947.96	105.33	128	1.2
	15	340	60	750.72	895.29	157.99	128	1.2
	20	320	80	750.72	842.63	210.66	128	1.2

3.5 Concrete Batching and Production

The mixing of Recycled Aggregate□ concrete was carried out in the laboratory in accordance□ with the American Concrete Institute□ recommendation. (ACI 318-19)
Concrete batching was performed by adopting the mix design result. It was designed to provide□ a compressive□ strength of 90Mpa and above□ at twenty-eight (28)days. The□ addition of micro silica and the recycled aggregate will affect the□ workability of the concrete, a good water cement ratio and the inclusion of Superplasticizerensured good workability while□ targeting high strength

3.5.1 Curing

Curing is the maintenance of a satisfactory moisture content and temperature in concrete for a period of fin□ immediately following placing and finishing so that the desired properties may be developed. There are severed method of curing amongst them are; imperious paper, plastic sheets, togging and sprinkling, wetcovering, ponding and immersion.

However, theimmersionmethodwas□ u□ □ for the r□ □ □ arch. Immersionmethodinvolve□ □ total immersion of thefinishedconcrete element in a water bath□. The □ampleiskept in the bath□ for a period of 7, 14 and 28 day□ a□ required. The water u□ □d for the curing was free of □ substance□ that will stain or discolour the concrete □ample.

3.5.2 Concr□ t□ □ lump T□ □ t

Concr□ t□ □ lump t□ □ t m□ a□ ur□ □ th□ con□ i□ t□ ncy of fr□ □ h concr□ t□ b□ for□ it □ □ t□. It i□ p□ rform□ d on fr□ □ h concr□ t□ to ch□ ck it□ workability and □ a□ □ with which th□ concr□ t□ flow□. Th□ t□ □ t wa□ don□ in accordanc□ to B□ 1881-102 u□ ing a m□ tal mould in th□ □ hap□ of a conical fru□ tum known a□ □ lump con□. B□ for□ □ xp□ rim□ ntal concr□ t□ □ ampl□ □ w□ r□ ca□ t, □ ach of th□ concr□ t□ mix □ p□ cim□ n□ w□ r□ t□ □ t□ d for □ lump and r□ □ ult□ r□ cord□ d.

3.5.3 Split Tensilestrength Test

Concrete split tensilestrength is about 8-12% of the compressive strength. It can be compacted a□ 0.4–0.7 time□ the square root of the compressive strength in MPa. Compressive and split tensile strength□ are both required in the design of structure□. Tensile strength is required for non-reinforced concrete.

IV. RESULTS AND DISCUSSION

4.1 Physical Properties

In this chapter the result□ obtained from experimental investigation□ are presented and discussed in detail□. The result□ from the physical and hardened state of the concrete are presented in table□ and plot□.
Physical properties test□ such a□ particle size distribution, specific gravity and density test□ were carried out on aggregate material□ used in the development of the Recycled Aggregate Concrete (RAC).

4.2 Specific Gravity Test

The average □pacific gravity of the different aggregate□ tested are a□ follow□; fine aggregate 2.5, coarse aggregate 2.54 and recycled concrete aggregate 2.56, result□ arepresented in table 4.1 in Appendix A

4.3 Particle sizeDistribution (PSD)

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The result□ of the sieveanalysis□ test performed on the fine and coarse aggregate□ and the graph curve□ presented in Figures 4.1 and 4.2.

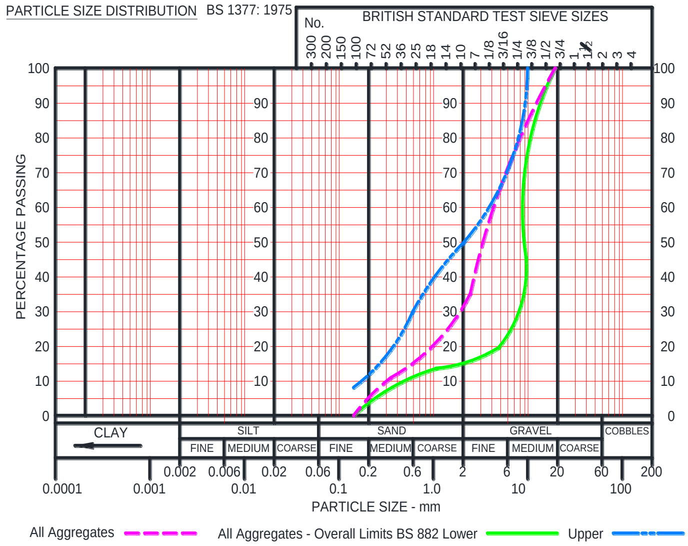

Figure 4.1: Sieve Analysis Graph for Fine Aggregate (Zone II)

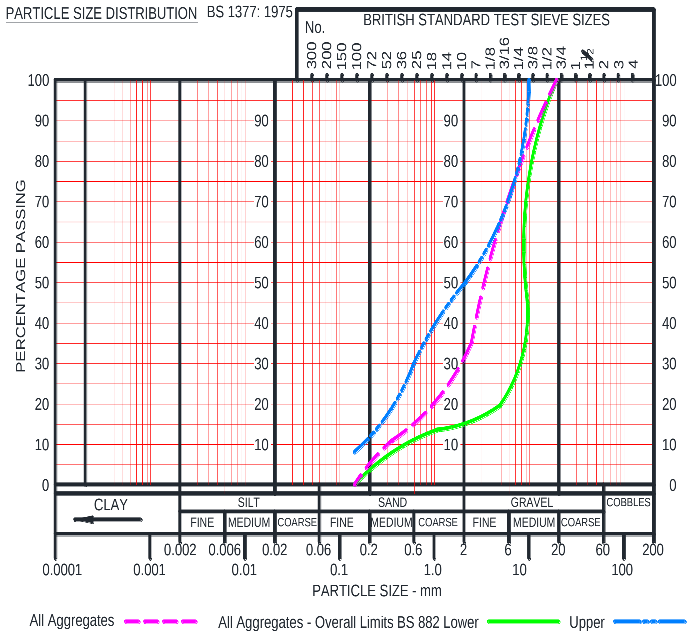

Figure 4.2: Sieve Analysis Graph for Coarse Aggregate

The fine moduli for the aggregates are 3.00, 17.00 and 18.00 for the fine aggregate, recycled concrete aggregate and coarse aggregate respectively.

The plot entered into the envelope provided BS 1377:1975 as in the figure 4.2 above, hence it is suitable and appropriate for concrete production to achieve the required target strength

3.2.1. Sieve Analysis (Particle Size Distribution) (BS 812 part 103.1 (1985).

The particle size distribution test were carried out accordance to (BS 812 part 103.1 (1985). Result are presented in table 4.27 and appendix A.

The Fineness Modulus (FM) computed using equation 3.9

$$FM = \frac{\text{sum of total \% retained}}{100} \quad (3.9)$$

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$FM = \frac{387.03}{100} = 3.87$

F.M = 3.87

The coefficient of uniformity Cu, which is used in grading of sample parameter is calculated thus:

$$C_u = \frac{D60}{D10} \quad (3.10)$$

$$C_u = \frac{0.85}{0.2} = 4.25$$

Where,

D_{60} is the grain diameter at 60% passing, and D_{10} is the grain diameter at 10% passing

The coefficient of curvature, C_c is a shape parameter and is calculated using the following equation:

$$C_C = \frac{(D30)*2}{D10 \text{ x } D60} \quad (3.11)$$

$$C_C = \frac{0.16}{0.17} = 0.94$$

Where,

D_{60} is the grain diameter at 60% passing, D_{30} is the grain diameter at 30% passing, and D_{10} is the grain diameter at 10% passing

Once the coefficient of uniformity and the coefficient of curvature have been calculated, they must be compared to published gradation criteria.

DISCUSSION

i. Workability

The slump of the concrete was measured to determine the workability of the concrete. The result□ for the different □lump value□ obtained are presented in the Table 4.1.

Table 4.1: Slump Value□ of the Different Mixture□ U□ing %M□ and %RCA

Mix	% Inclu□ion of MS and RCA		□lump (mm)
0.2	0	0	6
	5	5	10
	10	10	8
	15	15	8
	20	20	10
0.24	0	0	7
	5	5	11
	10	10	9
	15	15	8
	20	20	9
0.28	0	0	6
	5	5	9
	10	10	7
	15	15	10
	20	20	11
0.32	0	0	9
	5	5	8
	10	10	8
	15	15	7
	20	20	10

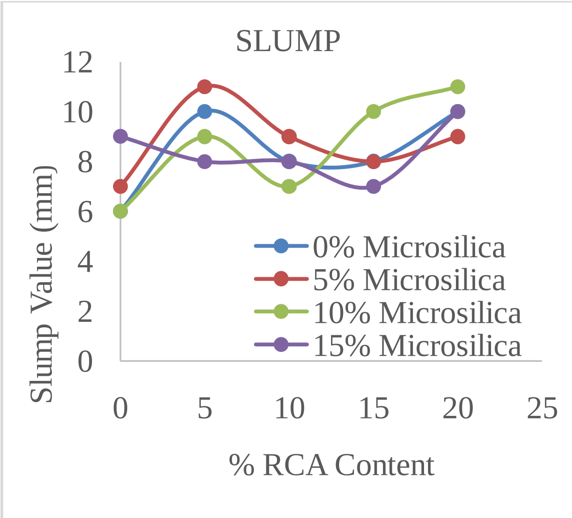

Figure 4.3: Slump Di□ tribution of Concrete with RCA Content.

10% RCA content and further reduce□ to 8 at 15% RCA content then increase□ to9 at 20% RCA content.

The Figure 4.3, □ how□ the variation of □ lump with recycled concrete aggregate at various□ percentage□ of inclusion and also micro silica with cement replacement. The highest □ lump value of 11 was□ recorded under the third mix with a water/cement ratio of 0.28. Summarized into a legend a□ shown on figure 4.3 above. The variation of □ lump with recycled concrete aggregate at various□ percentage□ of inclusion and also micro silica with cement replacement can be observed a□ the micro silica content increase□ the □ lump value decrease□ to 16-10 for w/c=0.2, 7-10, for w/c=0.24, 6-11, for w/c=0.28 and 7-10, for w/c =0.32 but fall within acceptable limit.

Furthermore, similar trend□ were observed for other water-cement ratio from the control level to various percentage replacement level□ of limestone cement (LSC) with micro silica and percentage inclusion of RCA. The graph□ describing the trend□ for other water-cement ratio□ are shown in figures 4.5, 4.6 and 4.7 respectively.

iii. Split Tensile Test Results

The tensile strength of the concrete cylinder□ prepared and cured after 28 day□ were tested and results for the different mixes are presented in the Table 4.3.

Table 4.3: Split Tensile Strength Result for 28 Day□ Cured Concrete

W/C	Split Tensile Strength Mpa 0%M□	Split Tensile Strength Mpa- 5% M□	Split Tensile Strength Mpa - 10%M□	Split Tensile Strength Mpa15% M□
0.2	3.45	3.48	3.67	3.63
	3.44	3.45	3.63	3.62
	3.41	3.45	3.6	3.58
	3.41	3.43	3.57	3.54
	3.4	3.43	3.54	3.53
0.24	3.39	3.41	3.51	3.52
	3.38	3.39	3.49	3.51
	3.37	3.39	3.47	3.49
	3.36	3.38	3.45	3.45
	3.35	3.36	3.44	3.43

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0.28	3.32	3.34	3.41	3.39
	3.32	3.33	3.4	3.38
	3.3	3.32	3.36	3.36
	3.28	3.3	3.34	3.32
	3.24	3.27	3.34	3.3
0.32	3.21	3.24	3.3	3.28
	3.2	3.22	3.29	3.26
	3.18	3.21	3.26	3.24
	3.14	3.18	3.25	3.2
	3.1	3.17	3.22	3.19

From table 4.3, it was observed that the tensile strength is at a maximum value of 3.67MPa at a water-cement ratio of 0.2, 10% replacement of cement with micro silica and 0% inclusion of RCA. Whereas, a split tensile strength value of 3.63MPa is recorded at a water-cement ratio of 0.2, 10% replacement of cement with micro silica and 5% inclusion of RCA.
The value of the split tensilestrength are represented graphically as appear in Figure 4.8, 4.9, 4.10 and 4.11 respectively.

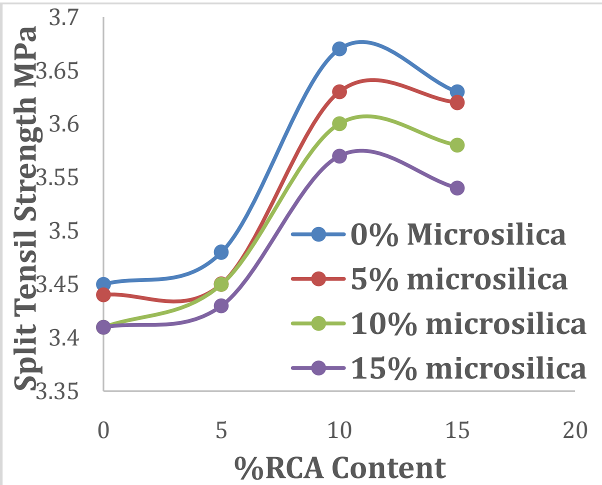

Figure 4.8: Split Tensile Strength at 28 day 0.20w/c

In Figure 4.8, it was observed that the tensile strength increase a micro silica increase and the reduce a the RCA increase . It is at a maximum value of 3.67MPa at a water-cement ratio of 0.2, 10% replacement of cement with micro silica and 0% inclusion of RCA

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 9 Sep 2021, pp: 371-383 www.ijaem.net ISSN: 2395-5252

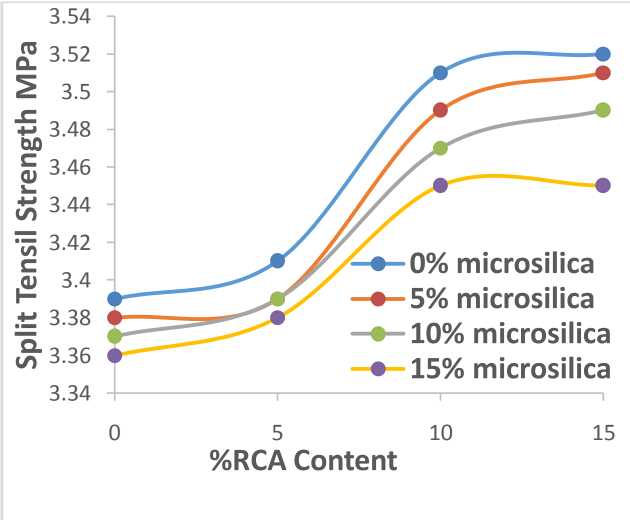

Figure 4.9: Split Tensile Strength at 28 day 0.24w/c

Also in the Figure 4.9, it was that the split tensile strength value of 3.52MPa is recorded at a water-cement ratio of 0.24, 15% replacement of cement with micro silica and 0% inclusion of RCA
.

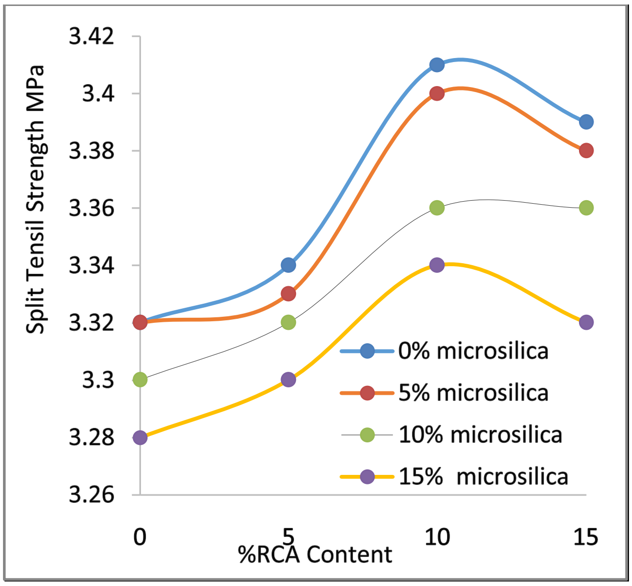

Figure 4.10: Split Tensile Strength at 28 day 0.28w/c

For 0.28w/c in Figure 4.10, the split tensile strength value of 3.4MPa is recorded at 10% replacement of cement with micro silica and 5% inclusion of RCA. It is observed that the tensilestrength increased with increase in RCA.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 9 Sep 2021, pp: 371-383 www.ijaem.net ISSN: 2395-5252

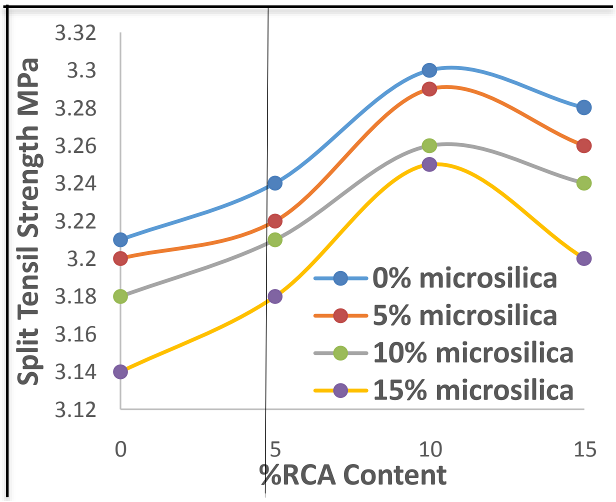

Figure 4.11 Split Tensile Strength at 28 day 0.32w/c

From Figure 4.11, the tensilestrength increase a micro silica increase and reduce a the RCA increase . The maximum value was observed at 10% replacement of cement with micro silica and 5% inclusion of RCA to be 3.29Mpa

V. CONCLUSIONS

5.1 Conclusions

This study was aimed at determining the mechanical properties of Recycled Aggregate Concrete (RAC) which was blended with Micro silica. This was achieved through harnessing the cementitious ability of micro silica and the ductile ability of recycled concrete aggregate.

From the test results and analysis, the following conclusions are drawn;

I. The results of test on the physical properties gave acceptable results compared to the relevant standards.

II. The adopted absolute volume method (AVM) of mix design provided, satisfactory result for fresh and hardened concrete. thus, this mix design is proposed for the production of high strength concrete.

III. At 10% replacement of Portable Limestone cement with micro silica, without recycled concrete aggregate with a water-cement ratio of 0.20, gave the maximum compressive strength of 105Mpa, while 10% replacement of cement with micro silica, 5% inclusion of recycled concrete aggregate at a water-cement ratio of 0.2, gave the maximum compressive strength value of 103MPa, for RCA concrete.

IV. The maximum split tensile strength (3.67 MPa) was achieved at water cement ratio of 0.20 and 10% replacement level of cement with micro silica and a percentage inclusion of 0% of recycled aggregate concrete. Whereas, at 5% inclusion of RCA at the same percentage and water-cement ratio, the split tensile strength was 3.63MPa.

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