MPRI-JECM | INTERNATIONAL JOURNAL OF ENV. DESIGN & CONSTRUCTION MGT.
VOL. 10 NO.4 DEC-2019 ISSN: 2166-3193

COMPARISON OF THE EFFECT OF USING RECYCLED CONCRETE AGGREGATE AS A REPLACEMENT OF FINE AGGREGATE AND COARSE AGGREGATE IN CONCRETE PRODUCTION.

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Abstract

This study access the reusing and recycling of waste gotten from construction and demolition. The negative impact of this C & D waste is alarming so measures are to be taken in order to achieve a healthy environment. In comparison with natural concrete and its component, recycled concrete aggregate is used in place of fine aggregate and coarse aggregates. The types of concrete used were; i.Natural concrete (which served as the control) ii.Concrete with recycled fine aggregates and natural coarse aggregates (gravel) iii.Concrete with recycled coarse aggregates and natural fine aggregates (sharp sand). iv.Concrete with both recycled fine and recycled coarse aggregates.This report examine the data from North central region of Nigeria precisely Landmark university, Omu-Aran, Kwara state. Different tests were carried out on concrete and the respective aggregates used for this project work, tests like compressive test, split tensile test, water absorption test, aggregate crushing value test, specific gravity test etc. Also density of the fine aggregate was determined.

[redacted]

KEYWORDS: *Comparism, Effect, Recycled, Aggregate, Replacement, Concrete Production*

Results showed that from slump test, all concrete types are workable, the compressive strength of concrete with recycled fine aggregates gained the highest strength at the end of 28days, and concrete with recycled coarse aggregate attained the highest strength at the end of 28days. It also showed *that recycled concrete aggregate absorb more water than natural concrete. This project work is recommended to be carried out for further research.In conclusion of this, recycled concrete aggregate can be used to replace natural aggregate in construction works.*

Aims and Objectives.

The aim of this study is to assess the comparison of the effect of using recycled concrete aggregate as a replacement of fine aggregate and coarse aggregate in concrete production.

The objectives are as follow:

1. To determine and compare the compressive strength and tensile strength of concrete with
   - Natural fine aggregate and natural coarse aggregates.
   - Recycled fine aggregate and natural coarse aggregates.
   - Natural fine aggregate and recycled coarse aggregates
   - Both recycled fine and recycled coarse aggregates.
2. To establish the feasibility of recycled concrete aggregate to the general public.
3. To determine the density, specific gravity and water absorption of recycled concrete aggregate and natural aggregate.

Method of Study

Study Area

The area of this study is Landmark University Omu-Aran which is located at the northern part of Nigeria, precisely Kwara state.

Material Sourcing

The various materials used for this experiment are, cement, fine aggregates, coarse aggregate, recycled fine and coarse aggregate and water. This materials are acquired from Omu-Aran community, Kwara State, Nigeria. The recycled concrete aggregate was gotten specifically from a demolished gutter slab in Abigail hall, Landmark University Omu-Aran, Kwara State.

RESULTS AND DISCUSSION

This entails all results obtained from the test on workability and strength of concrete, coarse aggregates and fine aggregates. The tests carried out were compressive strength test, slump test, split tensile test, aggregate crushing value test, specific gravity test etc.

SLUMP TEST

As stated earlier in chapter three, this test is carried out to determine the workability or consistency of concrete.

Table 4.1: Table showing the results from slump cone test

S/N	CONCRETE TYPE	HEIGHT OF CONCRETE SLUMP (mm)
1.	Normal concrete (control)	265
2.	Concrete with recycled fine aggregate	270
3.	Concrete with recycled coarse aggregate	265
4.	Concrete with both recycled fine and recycled coarse aggregate	250

The slump test carried out on all types of concrete was a true slump, where the concrete remained intact and retained a symmetric shape.

From the table shown above, the slump value of each of the concrete types fell within the range of 0 – 50mm which implies that the concrete types are of low workability. The normal concrete (control), concrete with recycled fine aggregates, recycled coarse aggregate and both recycled fine and coarse aggregate can be used for reinforced foundations and footings, plain footings caissons, substructure walls, beams, reinforced walls, building columns, pavements, slabs and mass concrete mix.

Table 4.2: table showing the range of slump for civil construction works.

Type of construction	Range of slump (mm)
Reinforced foundation walls and footings	20 – 80
Plain footings, substructure wall	20 – 80
Beams and reinforced wall	20 – 100
Building columns	20 – 100
Pavements and slabs	20 – 80
Mass concrete	20 – 80

COMPRESSIVE STRENGTH TEST

The compressive strength test which has been discussed earlier in chapter 3 was performed with mix ratio of 1:2:4 i.e. M15 on 36 concrete cubes;

- ✓ 9 cubes contained normal concrete, 3 each for 7, 21, and 28 curing days.
- ✓ 9 cubes contained concrete with recycled fine aggregate and 3 each for 7, 21 and 28 curing days.
- ✓ 9 cubes contained concrete with recycled coarse aggregate and 3 each for 7, 21 and 28 curing days.
- ✓ 9 cubes contained concrete with both recycled fine aggregate and recycled coarse aggregate, 3 each for 7, 21 and 28 curing days.

Compressive strength of concrete is gotten using this equation

$F = \frac{P}{A}$

Where F= Compressive strength of specimen in N/mm²

P = maximum load applied to the specimen in Newton

A= Cross sectional area of specimen in mm²

Table 4.3 table showing the required compressive strength of concrete at the end of 7 and 28The following tables show the different compressive strength obtained from the different concrete types used.

Curing days	Surface area (A) (mm²)	Maximum load (P)(KN)			Compressive Strength (N/mm²)			Average compressive strength (N/mm²)
		Cube1	Cube2	Cube3	Cube1	Cube2	Cube3	
7days	22500	298	286	292	13.24	12.71	12.98	12.98
21days	22500	441	435	428	19.60	19.33	19.02	19.32
28days	22500	508	498	535	22.58	22.13	23.78	22.83

Table 4.4: Results for compressive strength test on normal concrete (control) on their respective days of curing

Grade of Concrete	Minimum compressive strength N/mm² at 7days	Specified characteristic compressive strength (N/mm²) at 28days
M15	10	15
M20	13.5	20
M25	17	25
M30	20	30
M35	23.5	35

M40	27	40
M45	30	45

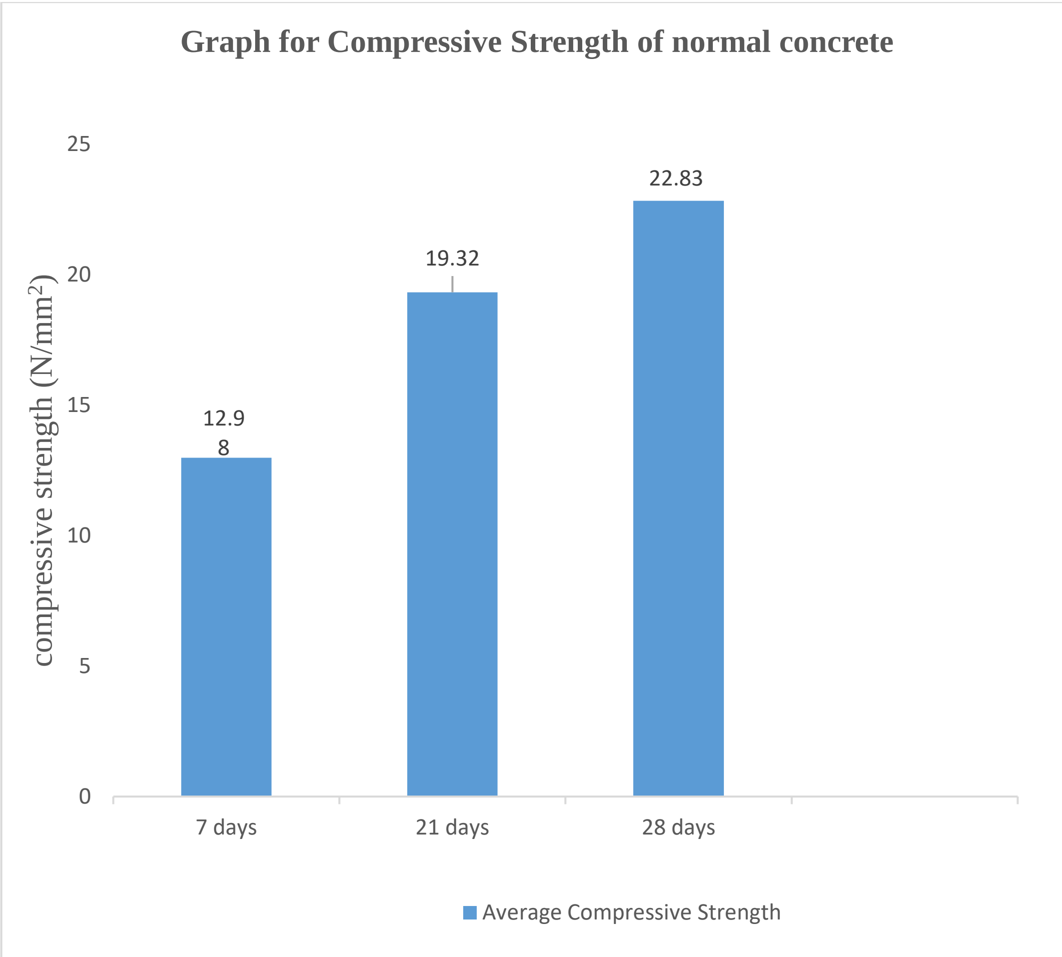

Figure 4.1: graph showing the compressive strength of natural concrete against curing days

The figure above shows that the compressive strength for natural concrete at the end of each curing days. It shows that at the end of 7days, compressive strength attained was 12.98N/mm^2 which met the required strength and at the end of 28days, compressive strength attained was 22.83N/mm^2 which is above the minimum requirement of 15N/mm^2. Hence the strength of concrete cube is satisfactory. It can be used for pavement floors, floor binding, domestic floors and foundations (where the pressure exerted by the structure is low). It is also good for workshop bases, garages, driveways and internal floor slabs.

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Table 4.5: Results for compressive strength test on concrete with recycled fine aggregate on their respective days of curing

Curing days	Surface area (A) (m m²)	Maximum load (P)(KN)			Compressive Strength (N/mm²)			Average compressive strength (N/mm²)
		Cube1	Cube2	Cube3	Cube1	Cube2	Cube3	
7days	22500	149	124	144	6.62	5.51	6.40	6.18
21days	22500	482	477	421	21.42	21.20	18.71	20.44
28days	22500	514	550	531	22.84	24.44	23.60	23.63

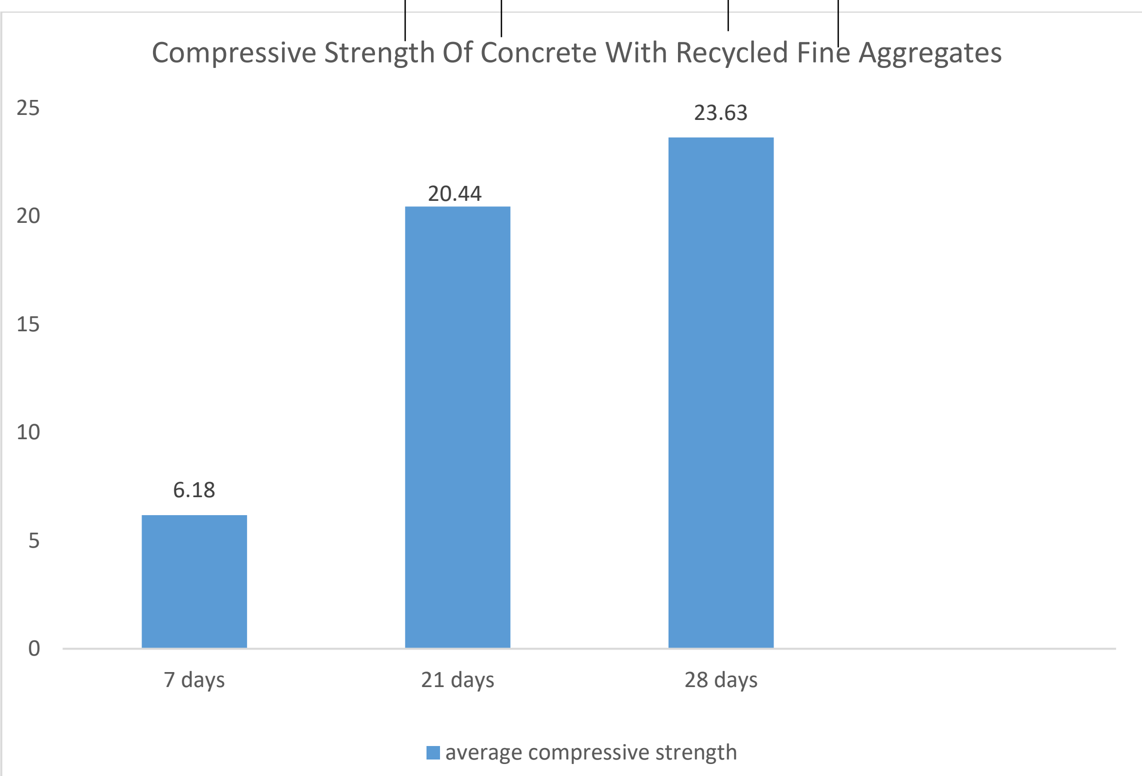

Figure 4.2: Graph of compressive strength of concrete with recycled fine aggregate against curing days.

The figure above shows that the compressive strength for concrete with recycled fine aggregates at the end of each curing days. It shows that at the end of 7days, compressive strength attained was 6.18N/mm² which did not meet the required strength of 10N/mm² and at the end of 28days, compressive strength attained was 23.63N/mm² which is above the minimum requirement of 15N/mm². Hence the strength of concrete cube is satisfactory. It can be used for pavement floors, floor binding, domestic floors and foundations (where the pressure exerted by the structure is low). It is also good for workshop bases, garages, driveways and internal floor slabs.

Table 4.6: Results for compressive strength test on concrete with recycled coarse aggregate on their respective days of curing

Curing days	Surface area (A) (mm²)	Maximum load (P)(KN)			Compressive Strength (N/mm²)			Average compressive strength (N/mm²)
		Cube 1	Cube2		Cube 1	Cube 2	Cube3	
7days	22500	171	155	178	7.60	6.89	7.91	7.47
21days	22500	272	254	266	12.09	11.29	11.82	11.73
28days	22500	321	407	414	14.27	18.09	18.40	16.92

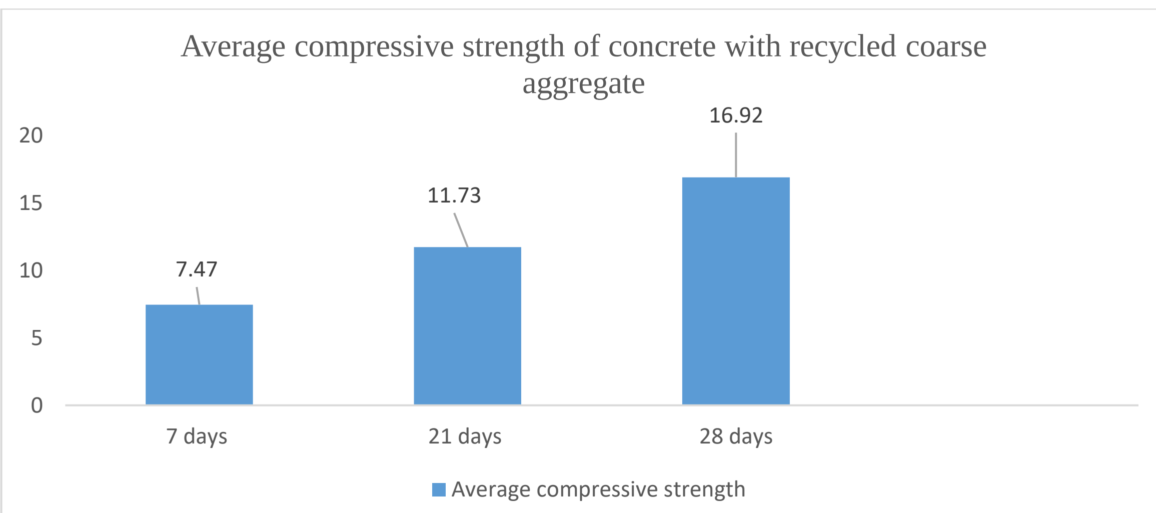

Figure 4.3: Graph of compressive strength of concrete with recycled coarse aggregate against curing days.

The figure above shows that the compressive strength for concrete with recycled coarse aggregates at the end of each curing days. It shows that at the end of 7days, compressive strength attained was 7.47N/mm^2 which did not meet the required strength of 10N/mm^2 and at the end of 28days, compressive strength attained was 23.63N/mm^2 which is above the minimum requirement of 15N/mm^2. Hence the strength of concrete cube is satisfactory. It can be used for pavement floors, floor binding, domestic floors and foundations (where the pressure exerted by the structure is low). It is also good for workshop bases, garages, driveways and internal floor slabs.

Table 4.7: Results for compressive strength test on concrete with both recycled fine aggregate and recycled coarse on their respective days of curing

Curing days	Surface area (A) (mm^2)	Maximum load (P)(KN)			Compressive Strength (N/mm^2)			Average compressive strength (N/mm^2)
		Cubic 1	Cubic 2	Cubic 3	Cubic 1	Cubic 2	Cubic 3	
7days	22500	162	166	159	7.20	7.38	7.07	7.22
21days	22500	187	176	190	8.31	7.82	8.44	8.19
28days	22500	274	209	247	12.18	9.29	10.98	10.82

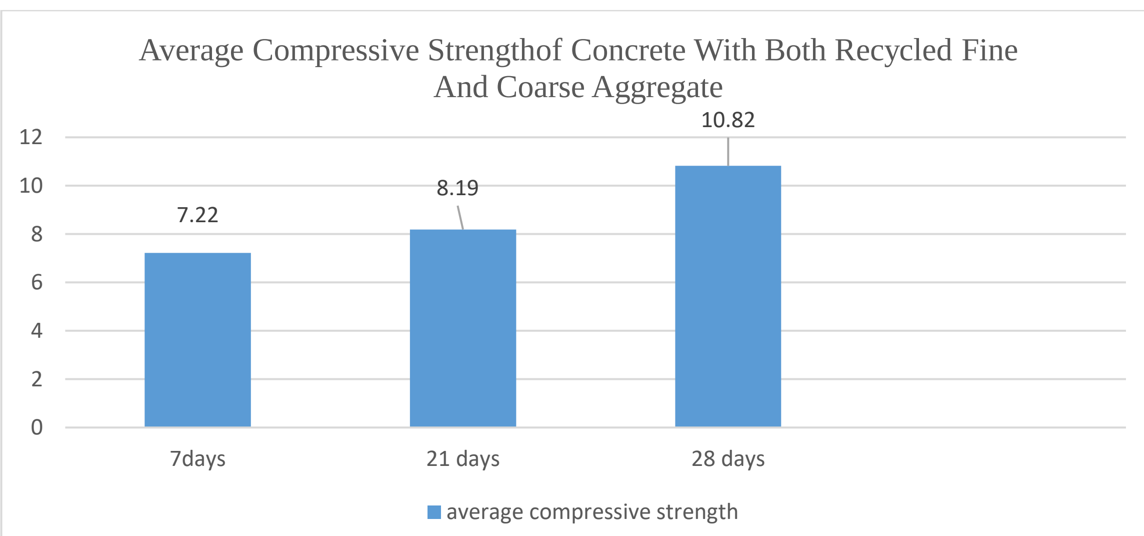

Figure 4.4: Graph of compressive strength of concrete with both recycled fine and coarse aggregate against curing days.

The figure above shows the compressive strength of concrete cube with both recycled fine aggregates and recycled coarse aggregates at the end of their different curing days. It shows that at the end of 7days, the compressive strength was 7.22N/mm² which did not meet the required strength of 10N/mm² and at the end of 28days, compressive strength attained was 10.82N/mm² which is not up to the minimum compressive strength of 15N/mm². Hence this kind of concrete is not satisfactory and thus should be used for civil works.

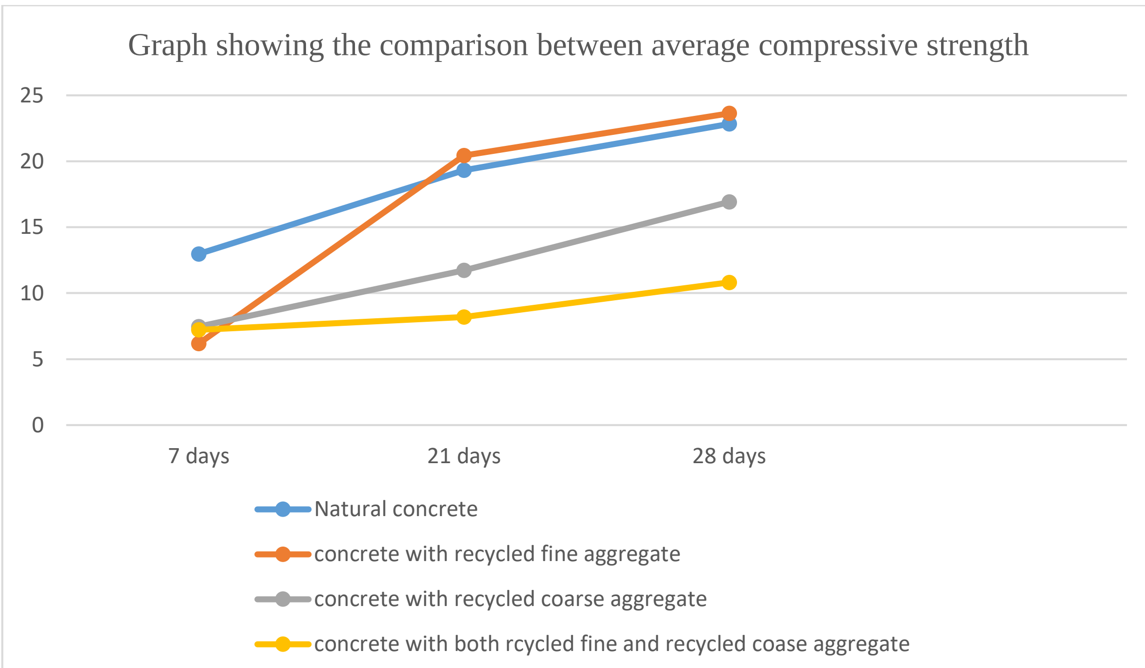

Figure 4.5: Graph showing the comparison between average compressive strength of all concrete types

The figure above shows the comparison between average compressive strength of natural concrete, concrete with fine aggregates, concrete with coarse aggregate and concrete with both recycled fine aggregates and recycled coarse aggregates in respect to their curing days. It illustrates that concrete with recycled fine aggregate is of the highest strength at the end of 28days followed by natural concrete then concrete with recycled coarse aggregates and lastly concrete with both recycled fine and coarse aggregate.

This implies that waste concrete can be used as replacement for either fine aggregate (sand) and coarse aggregate (gravel) to be used as a concrete component. Using both recycled fine and recycled coarse aggregate is not advisable because it may contain contaminants that can alter its strength and its durability (M. Sonebi,2016)

SPLIT TENSILE STRENGTH TEST

The Split tensile strength test procedures which has been discussed earlier in chapter 3 was performed with mix ratio of 1:2:4 i.e. M15 on 36 concrete cylinders;

- ✓ 9 cylinders contained normal concrete, 3 each for 7, 21, and 28 curing days.
- ✓ 9 cylinders contained concrete with recycled fine aggregate and 3 each for 7, 21 and 28 curing days.
- ✓ 9 cylinders contained concrete with recycled coarse aggregate and 3 each for 7, 21 and 28 curing days.
- ✓ 9 cylinders s contained concrete with both recycled fine aggregate and recycled coarse aggregate, 3 each for 7, 21 and 28 curing days.

Split tensile strength is obtained using the equation

Resultant split tensile strength = $\frac{2P}{\pi DL}$

Where P= load at which the specimen breaks

D = diameter of specimen

Curing days	Surface area (A)(mm²)	Maximum load (P)(KN)			Compressive Strength (N/mm²)			Average compressive strength (N/mm²)
		cylinder1	Cylinder 2	Cylinder 3	Cylinder 1	Cylinder 2	Cylinder 3	
7days	70685.83	56	55	46	1.584	1.556	1.302	1.481
21days	70685.83	69	51	51	1.952	1.443	1.443	1.613
28days	70685.83	51	61	62	1.443	1.726	1.754	1.641

L = length of specimen

The tensile strength of concrete is said to be between $^1/_8$ and $^1/_{10}$ of the compressive strength derived.

The following tables show the different split tensile strength obtained after 7, 21 and 28days respectively for different concrete types used

Table 4.8: Results for split tensile test on natural concrete on their respective days of curing

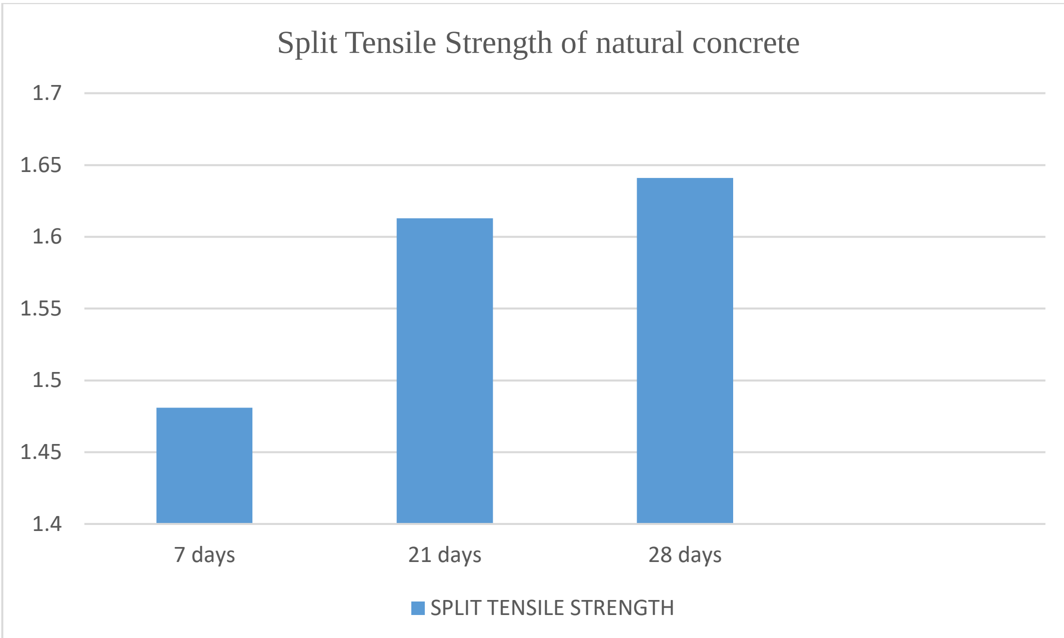

Figure 4.6: Graph of split tensile strength of natural concrete against curing days.

The figure above shows that the split tensile strength within 7days to 28days fell within the same range. There was no much difference after the different curing days though there was an increase. As stated earlier the split tensile strength is equal to one-eighth to one-tenth of compressive strength, the split tensile strength after 7days met the required strength unlike that of 21days and 28days which didn't meet the required tensile strength.

Curing days	Surface area (A)(mm^2)	Maximum load (P)(KN)			Compressive Strength (N/mm^2)			Average compressive strength (N/mm^2)
		cylinder 1	Cylinder 2	Cylinder 3	Cylinder 1	Cylinder 2	Cylinder 3	
7days	94247.78	41	64	63	0.870	1.358	1.337	1.188
21days	94247.78	82	40	62	1.740	0.849	1.316	1.302

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28days	94247.78	65	60	85	1.379	1.273	1.804	1.485

Table 4.9: Results for split tensile test on concrete with recycled fine aggregates on their respective days of curing

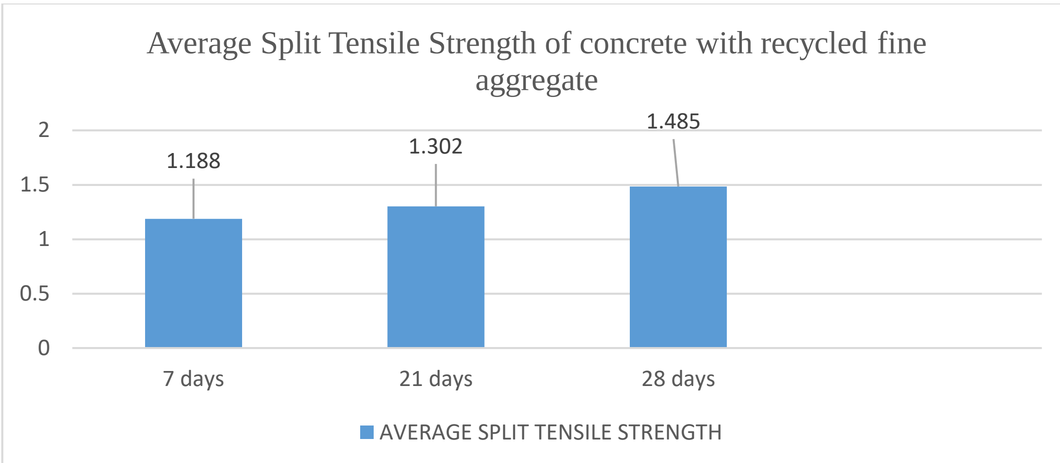

Figure 4.7: Graph of split tensile strength of concrete with recycled fine aggregate against curing days.

From the above figure, the split tensile strength at the end of each curing days was equal to one-tenth of its compressive strength and as such the split tensile strength is satisfactory.

Table 4.10: Results for split tensile test on concrete with recycled coarse aggregates on their respective days of curing

Curing days	Surface area (A) (mm²)	Maximum load (P)(KN)			Compressive Strength (N/mm²)			Average compressive strength (N/mm²)
		cylinder1	Cylinder 2	Cylinder 3	Cylinder 1	Cylinder 2	Cylinder 3	
7days	94247.78	96	97	100	2.037	2.058	2.122	2.072
21days	94247.78	110	104	98	2.334	2.207	2.161	2.234
28days	94247.78	115	112	104	2.440	2.377	2.207	2.341

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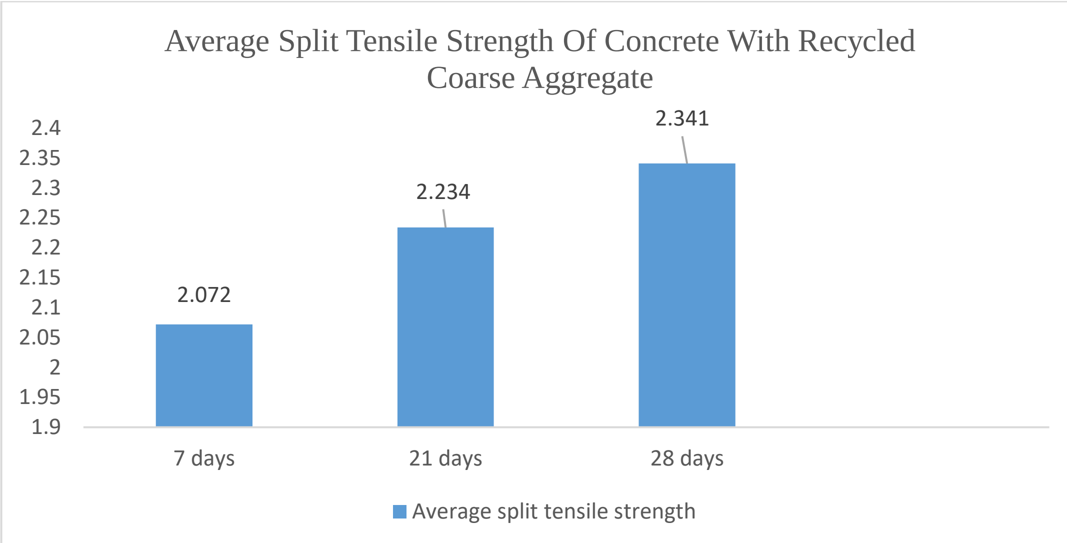

Figure 4.8: Graph of split tensile strength of concrete with recycled coarse aggregate against curing days.

From the figure above, it shows that the split tensile strength was much higher than the value gotten after calculating one-tenth of the compressive strength. This implies that the tensile strength for concrete with recycled coarse aggregate is high, hence it can withstand great tensile force that may be exerted on the concrete.

Table 4.11: Results for split tensile test on concrete with both recycled fine and coarse aggregates on their respective days of curing

Curing days	Surface area (A)(mm^2)	Maximum load (P)(KN)			Compressive Strength (N/mm^2)			Average compressive strength (N/mm^2)
		cylinder 1	Cylinder 2	Cylinder 3	Cylinder 1	Cylinder 2	Cylinder 3	
7days	94247.78	46	42	44	0.976	0.891	0.934	0.934
21days	94247.78	51	55	45	1.082	1.167	0.955	1.068
28days	94247.78	56	49	49	1.040	1.188	1.040	1.089

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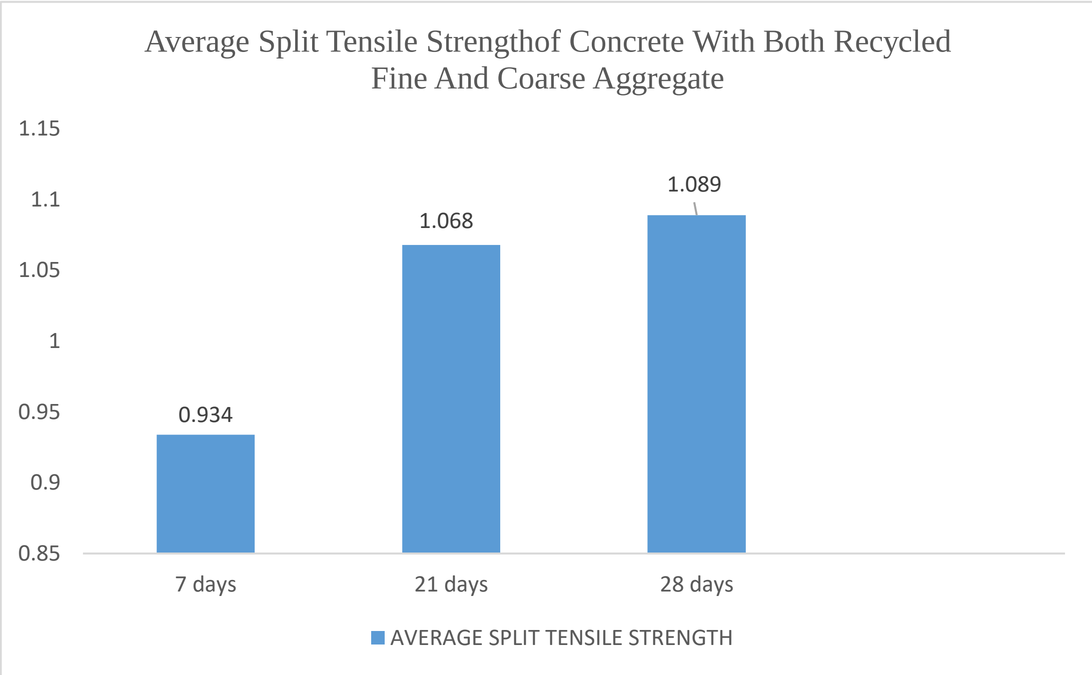
Figure 4.9: Graph of split tensile strength of concrete with both recycled fine and coarse aggregate against curing days.



From the figure above, the split tensile strength at the end of 7days met the required strength but at 21days and 28days it didn't attain the required strength.

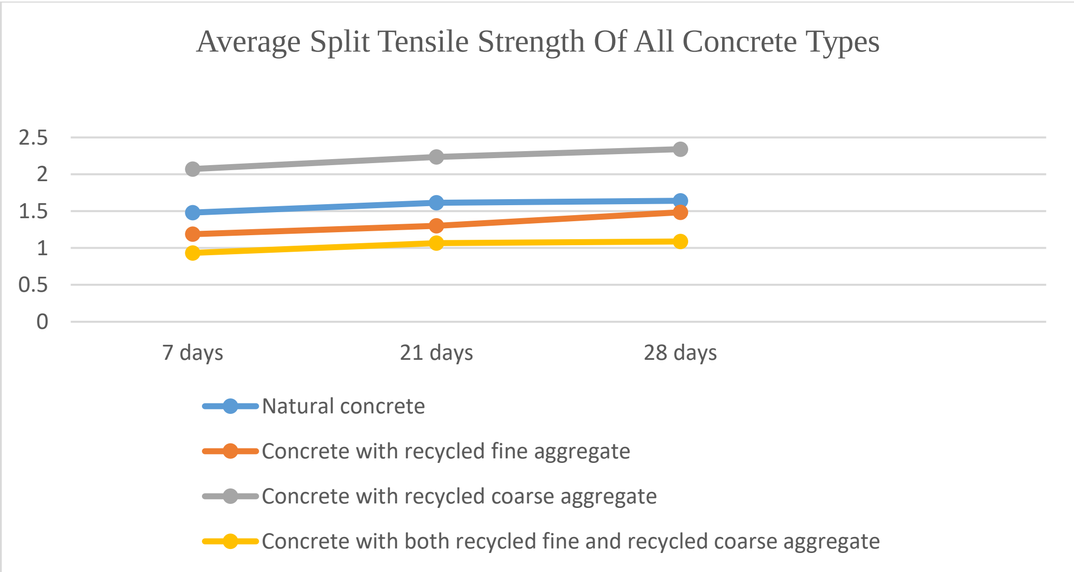


Figure 4.10: Graph showing the comparison between average split tensile strength of all concrete types

From the figure above, it shows the graph of comparison of the split tensile strength of all concrete types used. It shows that tensile strength of concrete with recycled coarse aggregate had the highest tensile strength and this could be as a result of the size of aggregate used. The tensile strength of natural concrete followed, then concrete with recycled fine aggregate and lastly concrete with both recycled fine and coarse aggregate. The latter (concrete with both fine and coarse aggregate) should be avoided in civil engineering works due to its weak tensile strength.

Though tensile strength is neglected in the design of a building, it is important to be able to tell the tensile strength of concrete used.

WATER ABSORPTION TEST.

Percentage of water absorption $= \frac{B-A}{A} \times 100$

Where A = weight of oven dried sample in air.

B = weight of surface dry sample in air after immersion in water

The following tables show the different water absorption values obtained from the different concrete types used.

Sample No.	Weight of oven dried sample (A) (kg)	Weight of sample after immersion in water (B) (kg)	% of water absorption
1	7.240	7.717	6.5883
2	7.240	7.777	7.4171
3	7.030	7.564	7.5960
Average	7.170	7.686	7.200

Table 4.12: Water absorption results for natural concrete

Sample No.	Weight of oven dried sample (A) (kg)	Weight of sample after immersion in water (B) (kg)	% of water absorption
1	7.0705	7.7095	9.0376
2	6.6545	7.2390	8.7835
3	7.0700	7.7085	9.0311
Average	6.9317	7.5523	8.9531

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Table 4.13: Water absorption results for Concrete with recycled coarse aggregate

Sample No.	Weight of oven dried sample (A) (kg)	Weight of sample after immersion in water (B) (kg)	% of water absorption
1	7.3120	7.8060	6.7560
2	7.3885	7.8560	6.3274
3	7.5350	8.0060	6.3920
Average	7.4118	7.8893	6.4918

Table 4.14: Water absorption results for concrete with recycled fine aggregate

Sample No.	Weight of oven dried sample (A) (kg)	Weight of sample after immersion in water (B) (kg)	% of water absorption
1	6.8050	7.5830	11.4328
2	6.7845	7.4940	10.4577
3	6.2145	6.8890	10.8536
Average	6.6013	7.3220	10.9147

Table 4.15: Water absorption results for concrete with both recycled fine and recycled coarse aggregate.

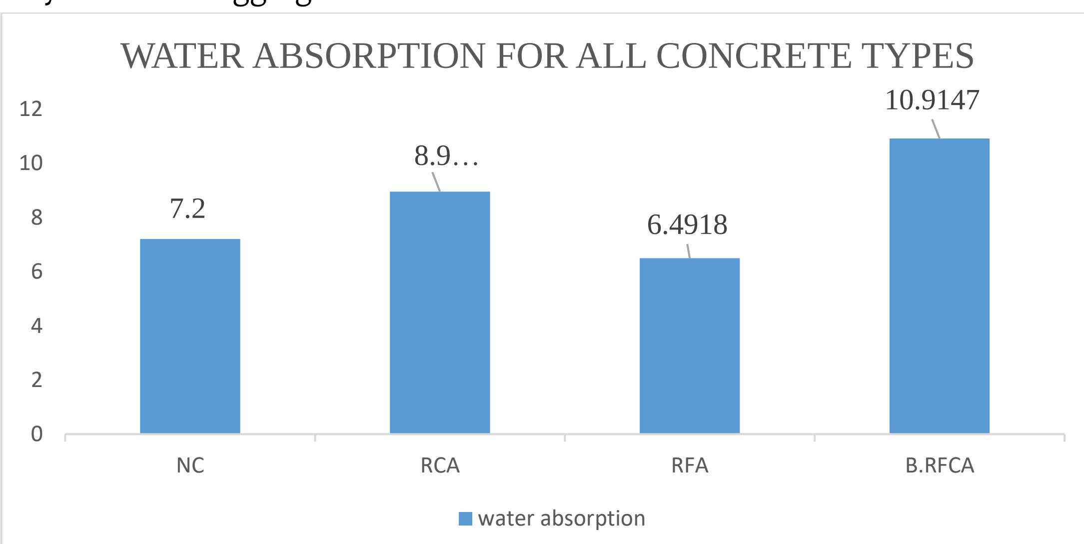

Figure 4.11: graph of average water absorption values for all concrete types used

Where NC = natural concrete

RCA = concrete with recycled coarse aggregate

RFA= concrete with recycled fine aggregates

B. RFCA= concrete with both recycled fine and recycled coarse aggregates

From the figure above, the water absorption level of concrete with both recycled fine and coarse aggregate was the highest. Due to the original cement mortar present in the recycled concrete, it tends to absorb more water.

Compared to natural concrete, concrete with recycled coarse aggregate was higher at about 9% and concrete with recycled fine aggregate was lower at 6.5%.

SPECIFIC GRAVITY TEST

Specific Gravity = $\frac{(c-a)}{(b-a)-(d-c)}$

Where a= weight of pycnometer

b = weight of pycnometer filled with distilled water

c = weight of pycnometer half filled with sample

d = weight of pycnometer about half filled with the sample and the rest with distilled water.

The following tables show the different specific gravity values obtained from natural fine aggregate and recycled fine aggregate

Table 4.16: Result for specific gravity of natural fine aggregate (sharp sand)

Sample No.	Weight of pycnometer	Weight of pycnometer + water	Weight of pycnometer + sample	Weight of pycnometer + water +sample	Specific gravity value
1	20	73	44.5	88.0	2.579
2	20	73	43.0	87.5	2.706
3	20	73	43.5	87.5	2.611
Average	20	73	43.67	87.67	2.632

Table 4.17: Result for specific gravity recycled fine aggregate

Sample No.	Weight of pycnometer	Weight of pycnometer + water	Weight of pycnometer + sample	Weight of pycnometer + water +sample	Specific gravity value
1	16.0	67.0	46.0	85.0	2.5
2	16.0	67.0	42.5	83.0	2.52
3	16.0	67.0	42.0	82.5	2.48
Average	16.0	67.0	43.5	83.5	2.5

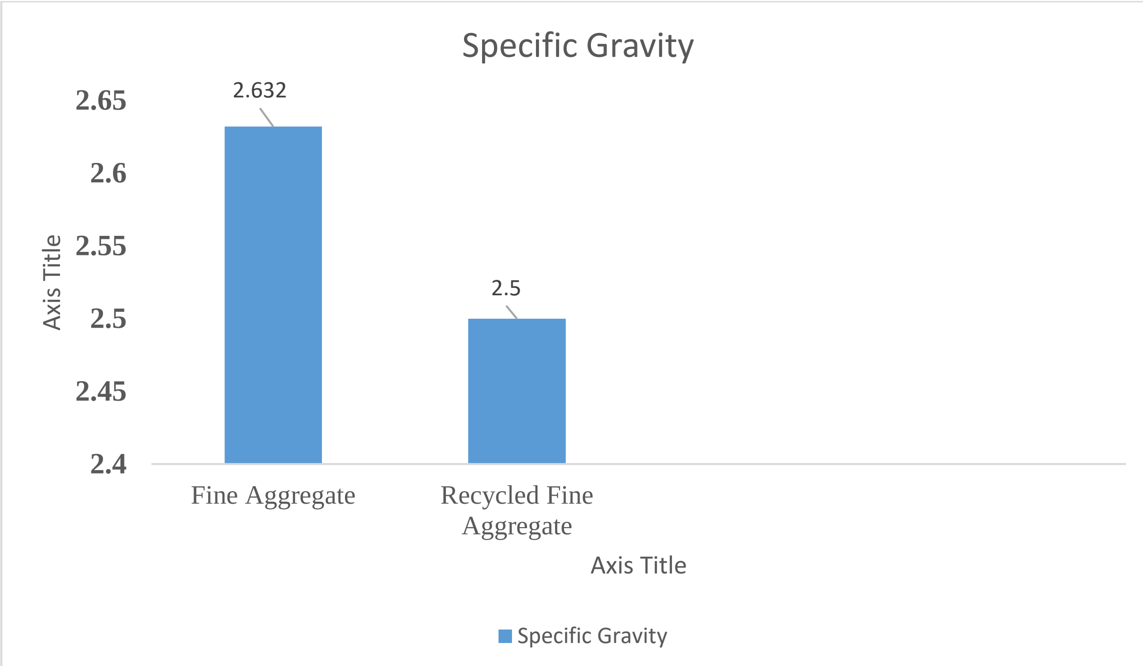

Figure 4.12: graph of specific gravity of natural fine aggregate and recycled coarse aggregate

From the figure above, specific gravity of natural fine aggregate (sand) was higher than the recycled fine aggregate.

DENSITY OF RECYCLED FINE AGGREGATE

To determine the density of recycled fine aggregate, its specific gravity value is required.

Specific gravity is given as; $\frac{\text{density of object}}{\text{density of water}}$

Density of water = 997kg/m^3 or 1g/cm^3

Density of recycled fine aggregate = S.G ×density of water

=2.5 × 997

= 2492.5kg/m^3 or 2.493g/cm^3

AGGREGATE CRUSHING VALUE TEST.

Aggregate crushing value= $\frac{(W2\ )}{(W1)}$ × 100

Where W_2 = weight of fraction passing through the appropriate sieve.

W_1 = weight of surface dry sample.

The table below shows limit of aggregate crushing value for different types of road construction

Table 4.18: table showing limit of aggregate crushing value for different types of road construction

Types of roads/ pavements	Aggregate crushing value limit
Flexible pavements	
Soling	50
Water bound macadam	40
Bituminous macadam	40
Bituminous surface dressing or thin premix carpet	30
Dense mix carpet	30
Rigid pavements	
Other than wearing course	45
Surface or wearing course	30

The following tables show the different aggregate crushing values obtained from natural coarse aggregate and recycled coarse aggregate

Table 4.19. Results for aggregate crushing value for natural coarse aggregates

SampleNo.	Weight of surface dry sample (W_1)(kg)	Weight of sample passing through 2.36mm IS sieve (W_2)(kg)	Aggregate crushing value (%)
1	1.6600	0.0965	5.810
2	1.6455	0.0735	4.467
3	1.6755	0.1345	8.030
Average	1.6603	0.1015	6.1023

Table 4.20: Results for aggregate crushing value for recycled coarse aggregates

Sample No.	Weight of surface dry sample (W_1)(kg)	Weight of sample passing through 2.36mm IS sieve (W_2)(kg)	Aggregate crushing value (%)
1	1.6805	0.3705	22.05
2	1.6605	0.3340	20.11
i3	1.6490	0.4585	27.80
Average	1.6633	0.3877	23.32

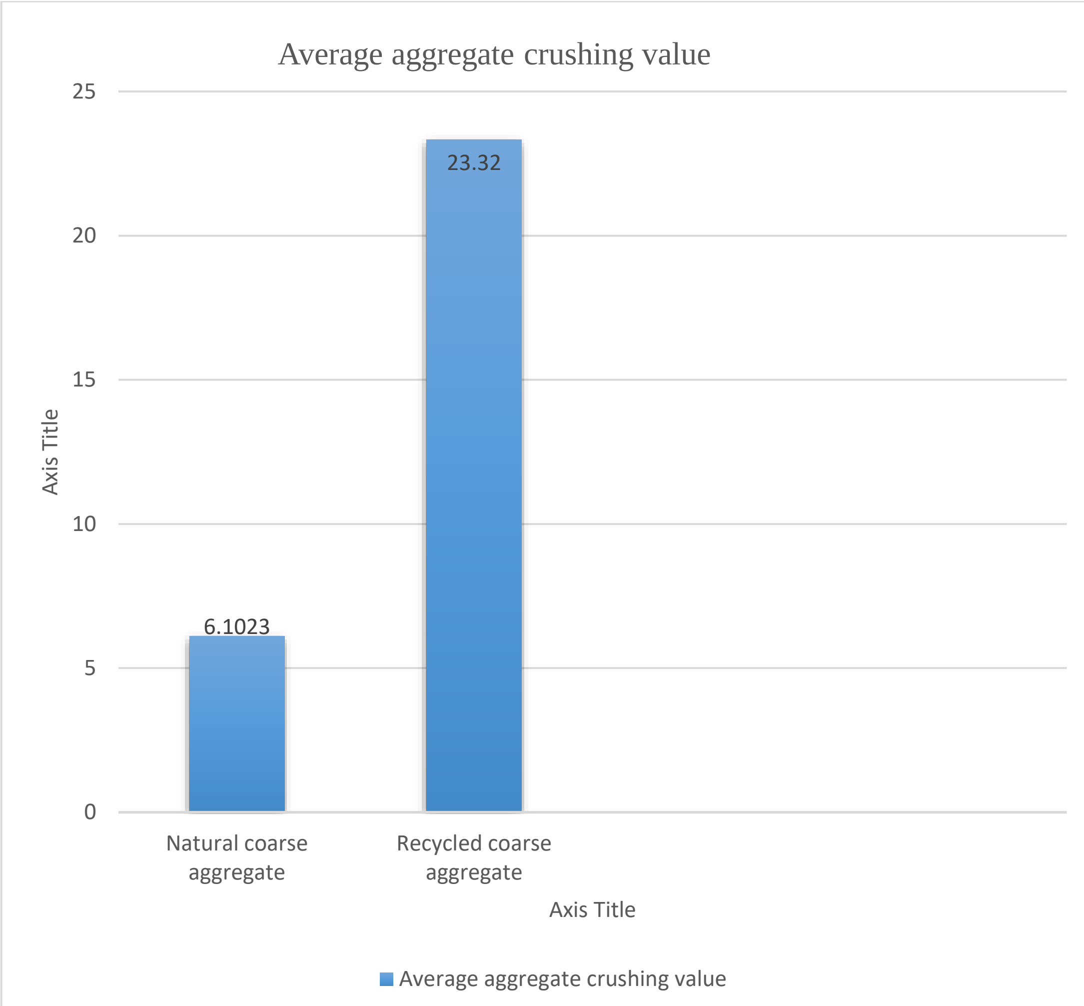

Figure 4.13: graph of aggregate crushing value of natural coarse aggregate and recycled coarse aggregates.

From the figure above, the aggregate of natural coarse aggregate was 6.1023 and that of recycled coarse aggregate was 23.32. The difference in the crushing value is much, the recycled fine aggregate though attained less than 30 is not as resilient as the natural coarse aggregate.

CONCLUSION AND RECOMMENDATION

Conclusion

1. The slump test showed that each of the concrete types are workable. Though some cannot be used for certain construction work. The concrete with recycled fine aggregate had the lowest slump height hence it can be

used for major types of construction while concrete with both recycled fine and recycled coarse aggregate is limited and should not be used to construction with much load or pressure.

2. The compressive strength test result showed that concrete with recycled fine aggregate had the highest compressive strength than the rest. However, concrete with both recycled fine and coarse aggregate did not meet the required compressive strength. Therefore it is unsatisfactory and should not be used as a construction material.
3. Split tensile strength test showed that concrete with recycled coarse aggregate had the highest value hence can withstand tension.
4. The water absorption test showed that due to the pre-existence of cement mortar in the aggregate, recycled concrete aggregate tends to absorbs more water especially concrete with both recycled fine and coarse aggregate.
5. Specific gravity of natural fine aggregate is higher than that of recycled fine aggregate as shown in figure 4.5.1
6. The density of recycled fine aggregate is given as 2492.5kg/m^3 or 2.493g/cm^3.
7. The aggregate crushing value of natural coarse aggregate was lower than that of recycled fine aggregate. Thus; natural aggregate can withstand more pressure and force that the recycled concrete
8. From the various tests carried out, it is seen that concrete with recycled fine aggregate and recycled coarse aggregate is feasible and can be used in place of natural concrete since it is strong and meet the required standard. Using concrete with both recycled fine and recycled coarse should be avoided as much as possible.

Recommendation

1. Replacement of fine aggregate and coarse aggregate with recycled fine and coarse aggregate respectively can be adopted for construction of low bearing structures, slab and beams.
2. As to sustainable development, construction/demolition waste can be recycled and used for construction since it’s cheaper and reduces negative environmental impact.
3. Further research should be carried out on the specific gravity of recycled coarse aggregate so the density of recycled coarse aggregate can be known.

4. I recommend that Construction Companies should recycle and reuse construction/demolition waste after cleaning since it meets required properties.

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