VOL. 11, NO. 17, SEPTEMBER 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

EFFECT OF TEMPERATURE ON RECYCLED AGGREGATE CONCRETE (RAC)

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ABSTRACT

This work studied the effect of temperature on concrete made from recycled aggregates. In the investigation, compressive strength test were carried out using a total of seven batches of concrete mixes. The concrete mixes consists of 0%, 10%, 20%, 30%, 40%, 50% and 100% replacements of natural aggregates with recycled aggregate sourced from the base course of a failed highway at Mgbirichi, Umuagwo, Owerri west local Government of Imo State, Nigeria. Water-cement ratio of 0.55 was used and batching of concrete was done by weight in accordance with the American Standard for testing and Materials (ASTM). The workability of the concrete was measured using the slump test apparatus. The results showed that the workability of the recycled aggregate concrete reduced considerably as the amount of recycled aggregate increased. The specimen were cured for 28days and afterwards were subjected to temperatures of 400°C, 800°C and 1200°C for 2hours in a kiln.As the temperature increased from 0 °C to 1200 °C, the compressive strength for all the percentage replacements, reduces consistently. However, at the maximum temperature of 1200 °C, the maximum compressive strength of 27.56 N/mm^2 was realized for the 20% replacement. When exposed to a temperature of 1200°C, recycled aggregate concrete showed percentage reduction in compressive strength of 16.10%, 16.31%, 14.67%, 26.06%, 29.28% and 17.54% for 10%, 20%, 30%, 40%, 50% and 100% replacements of natural aggregates with recycled aggregates respectively; meanwhile the natural aggregate concrete showed a percentage reduction in compressive strength of 47.22%. It was therefore concluded that, at various percentage replacements of natural aggregates with recycled aggregates, the RAC showed a higher resistance to reduction in compressive strength when exposed to extreme temperature rise than its natural aggregate concrete counterpart

Keywords: workability, temperature, recycled aggregates, Kiln, concrete.

1. INTRODUCTION

According to Dhir and Paine [1], Recycled aggregates are aggregates resulting from the processing of inorganic materials previously used in construction, e.g. crushed concrete, masonry brick. Within this family of materials, a recycled aggregate that is made predominantly from crushed concrete is called recycled concrete aggregate (RCA).

The applications of recycled aggregates in construction are wide and have been used for a long time now. According to Wilmot and Vorobieff [2], recycled aggregate have been used in the road construction industry for the last 100 years in Australia. They also stated that the use of recycled aggregates for the construction and rehabilitation of local government roads have shown great improvement in the last five years.

According to Patani and Alagendran [3], C and D recycling industry, the fact file stated that from the time of the Romans, the stones from the previous roads were reused when building their vaunted sets of roads. According to Chai NGO [4], Seecharan (2004) reported that the Detroit news stated that in 1980s, old concrete crushed into powder was popular road filler in Michigan, USA.

Thus the application of recycled aggregate in construction is of economic value and isalso a powerful tool that aids environmental remediation. Recycling industries in many parts of the world at present, convert low-value waste into secondary construction materials such as a variety of aggregate fines. Often, these materials are used for road construction, as backfill for retaining walls, for low-grade concrete production, drainage, brickwork and block work for low-cost housing. The wastes from construction and demolition works are of large volume and kept increasing with time. To overcome this issue, sustainable concrete construction is one of the strategies to be considered by construction industries. This can be achieved by the introduction of recycled aggregates from these wastes of construction and demolition works into the production of concrete. In Nigeria, the cost of natural aggregate is on the increase; thus the reuse of recycled aggregates to make new concrete (RAC) which is not yet very common in the Nigerian Construction Industry, is obviously one of the tools that will check the escalation in prices of natural aggregates.

The use of recycled aggregate in replacing natural aggregate in concrete construction has become popular among researchers. They compare the performance and characteristics of these two aggregates. Concrete must at times resist the effects of artificially induced high temperatures such as might be encountered near furnaces, in atomic reactors, in pavements subjected to jet engine blast, in areas exposed to fire etc.

A number of factors will have to be considered when deciding the type of concrete to be used under conditions of elevated temperatures. These factors include the type of aggregate used, the type of cement used, the aggregate/cement ratio, the loading condition at the time of exposure of the concrete, the length of exposure, the rate of temperature rise of the concrete, the temperature to which the concrete mass will be raised, the temperature of

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concrete at the initial time of exposure to high temperature, the degree of water saturation of the concrete and the age of concrete.

Concrete appears to sustain no appreciable damage when exposed to temperatures up to 204^0C. If temperatures above 204^0C are to be experienced, it is necessary to investigate the exposure condition and the concrete which will be employed.

Due to the fact that recycled aggregates may be used in concrete structures in areas of elevated temperatures, the study on the effects of temperature on recycled aggregate concrete becomes very necessary.

2. PREVIOUS STUDIES

2.1 strength properties of recycled aggregate concrete

M. Tavakoli and Soroushian [6], found that the strength characteristics of recycled aggregate concrete were influenced by the strength of the original concrete, the ratio of coarse aggregate to fine aggregate in the original concrete, and the ratio of top size of aggregate in the original concrete used in the recycled aggregate concrete. They also mentioned that water absorption and Los Angeles abrasion loss will influence the water content ratio and the top size ratio for the strength characteristics of recycled aggregate. On the compressive strength, Basil *et al* [7], reported that Amnon Katz studied on the properties of concrete made with recycled aggregates from partially hydrated old concrete and reported that “concrete made with 100% recycled aggregate, were weaker than concrete made with natural aggregates at the same water to cement ratio”.

Sagoe, Brown and Taylor [8], explained that the differences between the characteristics of fresh and hardened recycled aggregate concrete and natural aggregate concretes are relatively narrower than reported for laboratory crushed recycle aggregate concrete mixes. They further explained that there was no difference at the 5% significance level in the compressive and tensile strength of both the recycled aggregate concrete and the control normal concrete made from natural aggregate.

According to Poon [9], there were no much effects on the compressive strength of brick specimen made with the replacement of 25% and 50% of recycled aggregate; but when the percentage of recycled aggregate replacement increased, the compressive strength of the specimen reduced.

Limbachiya *et al* [10] reported that there is no effect on the concrete strength with the replacement of 30% of the recycled aggregate but the compressive strength gradually decreases as the percentage replacement of recycled aggregates increases. They concluded that the properties and the strength characteristics of recycled aggregate concrete were deficient when compared to its natural aggregate counterpart. In contrast, Dhir *et al* [11] stated that in all cases, the use of recycled aggregate in concrete led to lower cube strength after 28days when compared with the cube strength of the equivalent natural aggregate concrete. Therefore, it is necessary to reduce the w/c ratio to achieve equal cube strength. Hence, according to Dhir *et al*. [11], it was decided to set a maximum w/c ratio correcting factor of approximately 0.9. This means that a concrete designed using natural aggregate with a w/c ratio of 0.5, must have a w/c ratio not less than 0.45 when part of the coarse natural aggregate are replaced mass-for-mass by recycled aggregate.

3. MATERIALS AND METHODS

Ibeto brand of Ordinary Portland Cement (hydraulic binder that sets and hardens by chemical interaction with water), having an initial setting time of 45minutes and a final setting time of 297 minutes and conforming to BS 12, [12] was used for this work. The fine aggregate was sharp river sand, which was free from clay, silt, and organic matter. The maximum size was 5mm and the bulk density was 1428.57kgm^{-3}. Both the recycled aggregates and the natural aggregates (coarse aggregates) were crushed granites. The recycled aggregates were sourced from the base course of a demolished asphalt road at Mgbirichi along Owerri-Port-Harcourt Express way, Imo State. The maximum aggregate size for both the recycled and the natural aggregates were 20mm. The natural aggregates had a bulk density of 1258.5kgm^{-3} while the recycled aggregates had a bulk density of 1326.5kgm^{-3}.

The aggregates were air dried, and then passed through the following set of standard sieves sizes as specified in BS 812 [13]. 20mm, 16mm, 12.5mm 10mm, 6.3mm, 4.75mm, 3.35mm, 2.36mm, 1.18mm, 600μm, 300μm, 150μm and 75μm. The portion passing through the 20mm sieve and retained on the 5 mm sieve was used as the coarse aggregates while the portion passing through the 5mm sieve and retained on the 150μm sieve was used as the fine aggregates. The concrete mix design was done in accordance with the American Standard for Testing and materials (ASTM) and batching was done by weight following a mix ratio of 1:1.3:3.9 derived from the mix design results. Mixing of concrete in the laboratory was done manually on a clean surface using spades. In all the mixes, the natural aggregates were being replaced with the recycled aggregates in increasing mass of 0.5 kg from 0% to 100% at a constant w/c ratio of 0.55. Workability test was done using the slump cone apparatus in accordance with BS 1881-102 [14] the freshly mixed concrete was cast into standard 150x150x150mm cubic moulds in 3 layers of approximately 50mm each. Each of the layers were subject to 35 blows of the tamping rod. The concrete was kept in a damp condition for 24 hours before they were de-moulded and cured by immersion for 28days.

The samples were each wiped off from grit and placed centrally on a compression machine with the load being applied steadily at the rateof15N/mm^2 per minutes as specified in BS1881 [15] to destruction. The highest load reached was determined for each specimen crushed. This was used to compute the compressive strength of the specimen. The compressive strength is given as the ratio of the highest load to the cross sectional area of the sample. Its unit is theN/mm^2. Three samples were used for each test and the average results obtained from the three

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samples was adopted as the compressive strength of the given sample.

4. RESULTS AND DISCUSSIONS

Inordertoachievetheobjectiveofthisworkvariouslaboratorytestswereconductedontheindividual aggregates used and on the concrete derived from them (both at zero percent replacement and at 100 percent replacement) in their fresh and hardened states. Below is a detailed discussion on the results obtained. The analyses are carried out in tables and graphs, while the result s are discussed in comparison with works of previous researchers, codes of practice or research institutes as would be specified.

4.1 Bulk density and sieve analysis results

Bulk densities of crushed granite, recycled coarse aggregates and fine aggregates were found to be 1258.50 Kg/m^3, 1326.50 Kg/m^{3}and 1428.50Kg/m^{3}respectively. The densities of hardened concrete cube samples were found to be within the range of2391-2591Kg/m^3. This is with in the range for normal weight concrete. The results of particle size distribution for fine aggregates recycled aggregates and crushed granite are shown superimposed in Figure-1. The particle size distribution of fine aggregates is uniformly graded with a uniformity coefficient of1.713, while recycled aggregates and crushed granites have uniformity coefficientsof1.544 and 1.40 respectively. These results show that the aggregates are uniformly graded as can be confirmed by visual observation of the graphs shown.

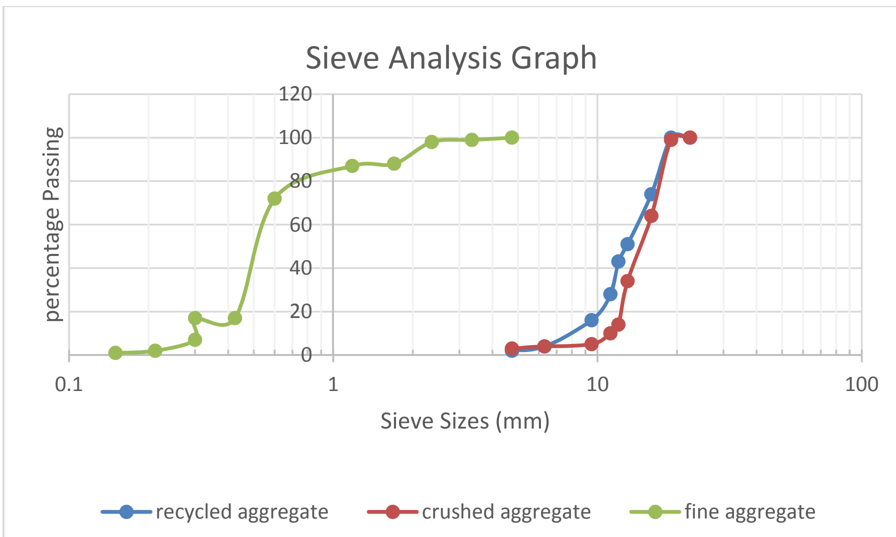

Figure-1. Sieve analysis results for sand, recycled aggregates and crushed aggregates.

4.2. Slump test results

As shown in Figure-2, the slump test results showed that continuous increase in percentage replacement of crushed granite with recycled aggregates was accompanied by a continuous decrease in slump. 0% replacement gave the highest slump of 6mm while 100% replacement gave the least slump of 2.00mm. This implies that workability decreases as the percentage replacement increases. Thus the use of recycled aggregates in concrete reduces the workability of the concrete.

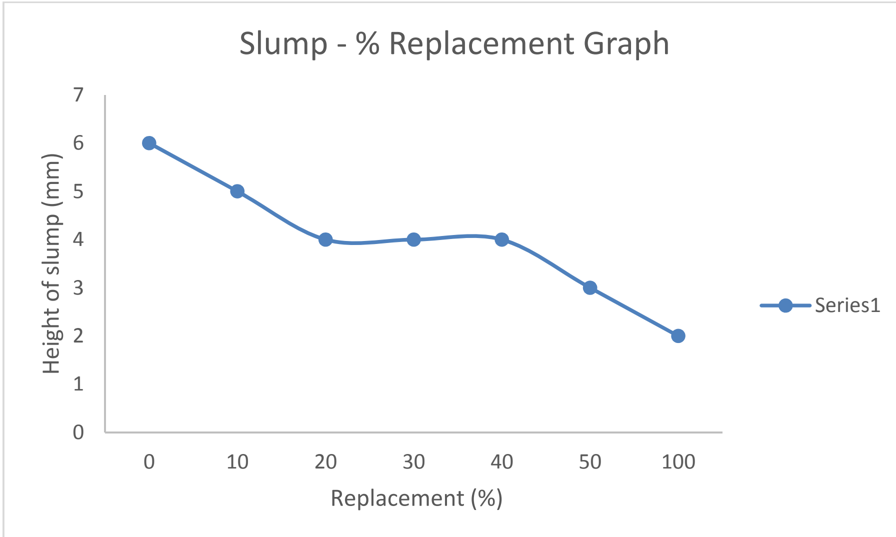

Figure-2. Graph of height of slump against percentage replacement.

4.3 Compressive strength test results

For a better assessment of the Compressive Strength of the samples at different temperature of exposure and percentage replacements, graphs of the individual tests at different percentage replacements, have been superimposed as shown on Figure-3. The detailed results are shown on the appendix attached.

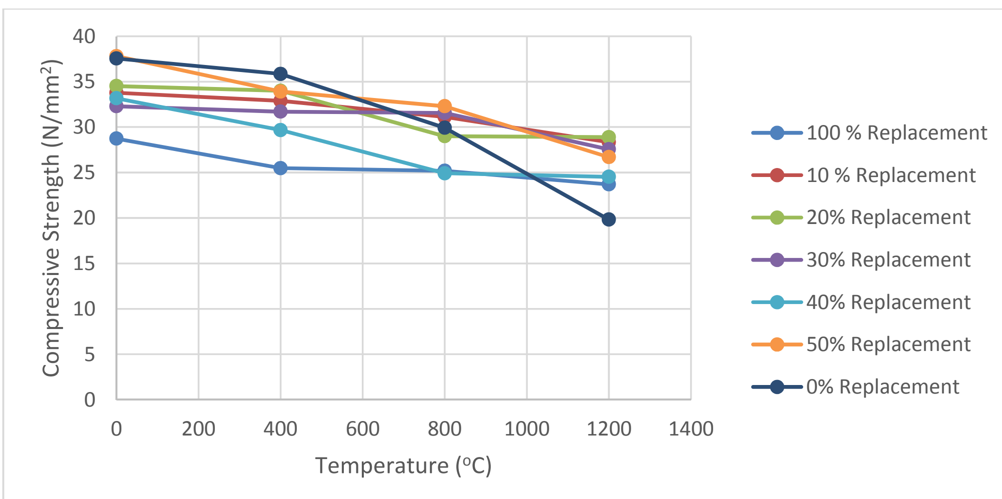

Figure-3. Compressive strength- Temperature graph superimposed for all percentage replacements.

The compressive strength - Temperature graph (superimposed), show that the highest compressive strength of 37.81 N/mm^2 was obtained for a 50% replacement of crushed natural aggregates with recycled aggregate. This strength was obtained for cubes which were not subject to any form of heating meanwhile; the lowest compressive strength of 19.82N/mm^2 was recorded for cubes with 0% replacement of natural aggregate with recycled aggregate at a temperature of 1200°C. It is also observed from the graph that as the temperature increased from 0 °C to 1200 °C, the compressive strength for all the percentage replacements, reduces consistently, such that the 50 % replacement of natural aggregate with recycled aggregates which gave the best compressive strength of 37.81 N/mm^2 at 0 °C, gave a value of 33.91 N/mm^2, 32.2 N/mm^2 and 26.7 N/mm^2, at 400 °C, 800 °C and 1200 °C, respectively. Also the graph of figure 3 shows that the control concrete with 0% replacement of natural aggregates with recycled aggregates demonstrates a higher rate of reduction in compressive strength as the temperature was increased. It gave the least compressive strength of 19.82 N/mm^2 at a temperature of 1200°C. In general, as the temperature of exposure increases, the compressive strength for all percentage replacements reduces, however, at the maximum temperature of 1200 °C, the maximum compressive strength of 27.56 N/mm^2

VOL. 11, NO. 17, SEPTEMBER 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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was realized for the 20% replacement. It could also be deduced from the graph of Figure-3 that the recycled aggregate concrete gives a better compressive strength than concrete made with natural aggregate for extreme temperature of 1200 ºC.

The graphs of Compressive strength against percentage replacement of crushed granite with recycled aggregates is shown (superimposed) on the graph on Figure-4.

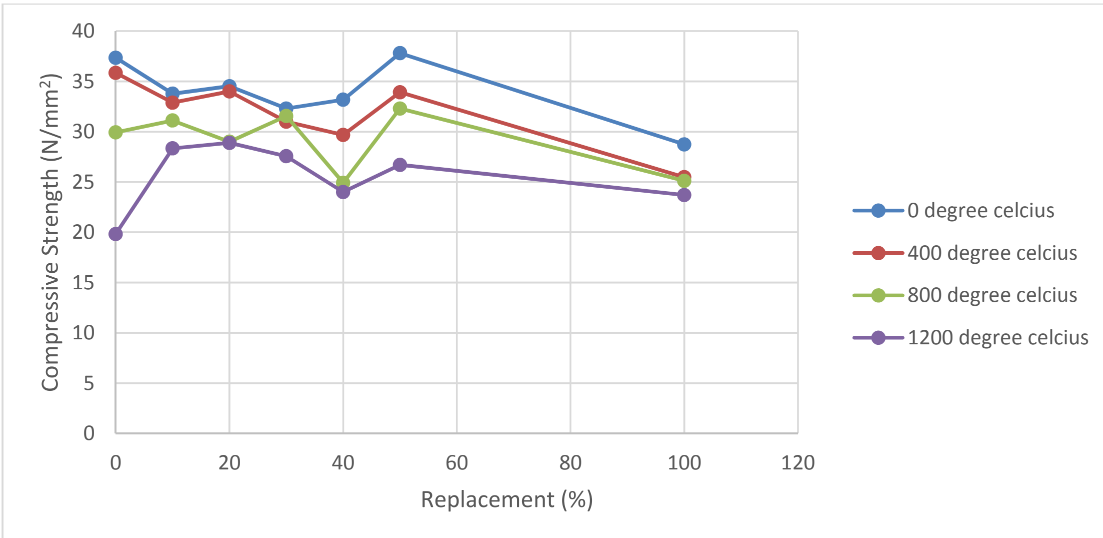

Figure-4. Compressive strength- Replacement graph (superimposed) for all temperatures.

The graph also shows that, the highest compressive strength of 37.81 N/mm^2 was obtained for a 50% replacement of crushed natural aggregates with recycled aggregate. This strength was obtained for cubes which were not subject to any form of heating meanwhile; the lowest compressive strength of 19.82N/mm^2 was recorded for cubes with 0% replacement of natural aggregate with recycled aggregate at a temperature of 1200ºC. From the graph of figure 4, it is seen that as the temperature increases from 0 ºC to 1200 ºC, the compressive strength at various percentage replacement reduces. At 10% replacement, it is observed that the compressive strength of the concrete reduced for temperatures of 0 ºC and 400 ºC while for temperatures of 800 ºC and 1200 ºC, the compressive strength increased. At 0% replacement, the effect of temperature on the concrete is very significant as its compressive strength reduces from 37.35 N/mm^2 at 0 ºC to 19.83 N/mm^2 at 1200 ºC. It was observed that recycled aggregate concrete showed percentage reduction in compressive strength of 16.10%, 16.31%, 14.67%, 26.06%, 29.28% and 17.54% for 10%, 20%, 30%, 40%, 50% and 100% replacements of natural aggregates with recycled aggregates respectively; meanwhile the natural aggregate concrete showed a percentage reduction in compressive strength of 47.22%. This means that as the recycled aggregates replace the natural aggregates in the concrete, the concrete's resistance to reduction in compressive strength due to temperature rise, increases.

5. CONCLUSIONS

From the results of this study and the discussion made, the following conclusions have been arrived at from this study

a) Recycled aggregate concrete offers a higher resistance to strength loss due to temperature rise than its natural aggregate concrete counterpart.
b) For the given mix ratio of 1:1.3:3.9, all Concrete intended for use in areas of elevated temperatures of up to but below 1200ºC, should be considered as light weight concrete as the final strength after exposure to temperature reduces to about 19.82N/mm^2.
c) For concrete intended for use in areas of elevated temperatures of between 600ºC and 800ºC, a maximum percentage replacement of crushed aggregates with recycled aggregates of similar properties should be 50%, as this gave the highest compressive strength for temperatures within that range.

REFERENCES

[1] Dhir R.K and Paine K.A. 2007. Performance Related Approach to use of Recycled Aggregates. Waste and Resources Action Programme. ISBN 1-84405-302-4. Project Code: AGG0074.

[2] Wilmot T. and Vorobieff G. 1997. Is road recycling a good community policy? Ninth National.

[3] Aby V. Patani and M. Alagendran. 2015. Experimental study on High Strength Concrete with Recycled Aggregate. International Journal of Engineering and Technical Research. ISSN: 2321-0869. 3(5).

[4] Nelson Shing Chai NGO. 2004. High- Strength Structural Concrete with Recycled Aggregates. A Dissertation submitted to the faculty of Engineering and surveying, University of Southern Queensland.

[5] Dr. Kelvin J., Khaloo A. R. 2007. Properties of Concrete using Crushed Chiker Brick as Coarse Aggregates. ACI material Journal. 13(2):35-37.

[6] Mostafa Tavakoli and Parviz Soroushian. 1996. Strength of Recycled Aggregates Concrete Made using field- Demolished concrete as Aggregates. Materials journal. 93(2): 178-181.

[7] Basil Johny, M.V. George, Elson John. 2014. Study of Properties of Sustainable Concrete using Slag and Recycled Concrete Aggregate. International Journal of Engineering Research and Technology. ISSN 2278-0181. 3(9).

[8] Sagoe-Crentsil K., Brown T. 1998.Guide for Specification of Recycled Concrete Aggregates (Rca) for Concrete Production. Commonwealth Scientific Information and Research Organization, September 1998.

[9] Poon C.S., Lam L., Fok H., Kou S.C. 2004. Influence of moisture states of natural and recycled aggregates on the slump and compressive strength of concrete, Cement and Concrete Research. 34(1): 31-3.

[10] Limbachiya M.C., Leelwat T. and Dhir R.K. 2000. Use of Recycled Concrete Aggregate in High Strength Concrete. Materials and Structures. 33: 574-580.

[11] Dhir R.K., Limbachiya M.C., Leelawat T. 1999. Suitability of Recycled concrete aggregate for use in BS 5328 designated mixes. Proceedings of Inst. Civil Eng. Struct. Build. 134(August): 257-274.

[12] BS 12:1978. Specification for Ordinary and Rapid-Hardening Portland cement. British Standard Institute, London, U.K.

[13] BS 812- 103, Methods for Determination of particle size Distribution. British Standard Institute, London, UK.

[14] BS1881-102-1983. Testing Concrete- Method for determination of slump. British Standard Institute. London, U.K.

[15] BS 1881- 1983. Testing Concrete British Standard Institute, London, U.K.

VOL. 11, NO. 17, SEPTEMBER 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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Appendix 1: Particle size distribution results for recycled aggregate. (Initial mass = 5000g)

Sieve size (mm)	**Mass** (g) **mass retained**	**Percentage mass retained** (%)	**Cumulative mass retained** (g)	**Cumulative percentage retained** (%)	**Percentage passing** (%)
22.40	0.00	0.00	0.00	0.00	100.00
19.00	0.00	0.00	0.00	0.00	100.00
16.00	1300.00	26.00	1300.00	26.00	74.00
13.00	1150.00	23.00	2450.00	49.00	51.00
12.00	400.00	8.00	2850.00	57.00	43.00
11.20	750.00	15.00	5600.00	72.00	28.00
9.5	600.00	12.00	4200.00	84.00	16.00
6.3	600.00	12.00	4800.00	96.00	4.00
4.75	100.00	2.00	4900.00	98.00	2.00
Pan	100.00	2.00	5000.00	100.00	0.00

Appendix 2: Particle Size Distribution Results for crushed granite (Initial mass = 1000g)

Sieve size (mm)	**Mass retained** (g)	**Percentage mass retained** (%)	**Cumulative mass retained** (g)	**Cumulative percentage retained** (%)	**Percentage passing** (%)
22.4	0.00	0.00	0.00	0.00	100
19.00	10.00	1.00	10.00	1.00	99.00
16.00	350.00.00	35.00	360.00	36.00	64.00
13.20	300.00	30.00	660.00	66.00	34.00
12.50	200.00	20.00	860.00	86.00	14.00
11.20	40.00	4.00	900.00	90.00	10.00
9.50	50.00	5.00	450.00	95.00	5.00
6.30	10.00	1.00	960.00	96.00	4.00
4.75	10.00	1.00	970.00	97.00	3.00
Pan	30.00	3.00	100.00	100.00	0.00

Appendix 3: Particle Size Distribution Results for fine aggregates (Initial mass = 1000g)

Sieve size (mm)	**Mass retained** (g)	**Percentage mass retained** (%)	**Cumulative mass retained** (g)	**Cumulative percentage retained** (%)	**Percentage passing** (%)
4.75	0.00	0.00	0.00	0.00	100.00
3.35	10.00	1.00	10.00	1.00	99.00
2.36	10.00	1.00	120.00	12.00	98.00
1.70	100.00	10.00	120.00	12.00	88.00
1.18	100.00	1.00	130.00	13.00	87.00
0.60	150.00	15.00	280.00	28.00	72.00
0.425	550.00	55.00	830.00	83.00	17.00
0.30	100.00	10.00	930.00	93.00	17.00
0.30	100.00	10.00	930.00	93.00	7.00
0.212	50.00	5.00	980.00	98.00	2.00
0.15	10.00	1.00	990.00	99.00	1.00
Pan	10.00	1.00	1000.00	100.00	0.00

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Appendix 4: Results of slump test for mix ratio 1:1.3:3.9 at w/c =0.55

Height of slump (mm)	**Replacement** (%)
6.00	0
5.00	10
4.00	20
4.00	30
4.00	40
3.00	50
2.00	100

Appendix 5: Average compressive strength (N/mm^2) for different temperatures and percentage replacements

	Temperature			
Percentage replacement	0°C	400°C	**800°C**	**1200°C**
0%	37.55	35.85	29.93	19.82
10%	33.78	32.89	31.11	28.34
20%	34.52	34	29.07	28.89
30%	32.3	31.7	31.56	27.56
40%	33.18	29.67	24.92	24.53
50%	37.81	33.92	32.3	26.74
100%	28.74	25.48	25.19	23.7

Appendix 6: Compressive Strength Reduction of Different Specimen on Exposure to Heat.

Percentage replacement of recycled aggregates with natural aggregates	**Compressive strength at 0°C** (N/mm^2)	**Compressive strength at 1200°C** (N/mm^2)	**Percentage reduction in strength**
0%	37.55	19.82	47.22%
10%	33.78	28.34	16.10%
20%	34.52	28.89	16.31%
30%	32.30	27.56	14.67%
40%	33.18	24.53	26.06%
50%	37.81	26.74	29.28%
100%	28.74	23.70	17.54%