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Abstract

This study examines the flexural strength of reinforced and revibrated concrete beams using locust bean pod epicarp ash (LBPEA) as partial replacement for cement. The LBPEA used contained major oxides: Al_2O_3(12.046%), SiO_2(49.054%) and Fe_2O_3(8.925%). Fifty reinforced concrete beams (150mm x 150mm x 600mm) were cast for each percentage (0%, 5%, 10%, 15%, 20%) cement replacements by LBPEA: thirty-five revibrated; fifteen non-revibrated; and cured for 28days. Revibration was carried out for 20seconds at intervals of 10 minutes after initial vibration. Flexural strength test carried out using universal testing machine, showed that the maximum flexural strength occurred at 30thminutes revibration time interval for both 0% and 5% replacements, 9.2N/mm^2 for 0% and 9.0N/mm^2 for 5%, whilethat of non-revibrated beams had 9.17N/mm^2 and 8.33N/mm^2 at 0% and 5% replacements respectively, thus projecting an improved strength of concrete beams produced at an optimal replacement of 5% LBPEA which is recommendable.

Keywords: Flexural strength,reinforced concrete, beam, revibration, LBPEA.

1.0 INTRODUCTION

Ever since the introduction of concrete, researchers have not ceased to improve on the qualities of concrete production. Properties of concrete such as the compressive strength, fatigue strength, impact strength, abrasive strength and the flexural strength are very important in the construction of concrete structures. These therefore have inspired engineers/researchers to explore possible ways to improve upon these properties of concrete. In order to improve on the properties of hardened concrete produced, it has been found that revibration (this is the process of mechanically, intentionally and systematically vibrating a placed concrete after its initial setting-time) of the fresh concrete can improve greatly the strength of concrete (Auta, Akwu, and Saidu,2020; AMR, 2013; Krishna *et al*., 2008). Revibration as an aspect of concrete technology studies has the advantage of bonding layers of concrete in those that are preceding them. Examples are in deep walls, beams and columns where placing of concrete are done by layers. Revibration helps to improve the surface finishing of concrete wall and also improve the abrasive resistance of surface wall (Auta, *et al*., 2016a).

Furthermore, due to increase in the cost of concrete production for most concrete works, alternative options ofpartial substitutesfor ordinary Portland cement (OPC) are also being explored. Such materials should be pozzolanic in nature, such as locust bean pod extract (LBPE), saw dust ash (SDA)(Auta, Akwu, and Saidu, 2020), rice husks ash (RHA), coconut ash (CA) etc., which are classified as agro-wastes. These agricultural wastes are processed into useful forms for concrete production. This has added advantage of environmental cleanlinesscompromising strength of the concrete (Elinwa, and Mahmood, 2002).

The African locust bean tress with scientific name: *parkia biglobosa*, is a deciduous tree that grows 20m in height.

Plate I: Fresh locust bean pods (Auta, Tsado, Adebisi and Shiwua, 2016)

Plate II: Ripe locust bean pods (Aguwa, Alhaji, Jiya, and Kareem,2016).

The tree grows in most of sub-Sahara Africa, but commonly in Nigeria (Plate I). It has a large fruit pod that contains both sweet yellowish pulp and valuable black seed that is mostly used in food seasoning- and is of medicinal value. The pod epicarp(Plate II) of the locust bean is anagro-wastewhich constitutes nuisance when not disposed properly. However, it can be harnessed as a building material(Ndububa and Uloko, 2015).

According to the ASTM C618 (2005), a pozzolana is a siliceous materials which when in finely divided form, and in the presence of moisture, reacts with calcium hydroxide which is liberated during hydration of ordinary Portland cement (OPC) at ordinary temperature to form a compound that possess cementious properties. Pozzolanas have the characteristics of combining with free lime liberated during cement hydration to produce stable insoluble calcium silicate that reduces the process of mortar and concrete attack from sulphate, salts and chlorides.

Further research was conducted on the effect of using amorphous silica ash (ASA) obtained from rice husk as a partial replacement of ordinary Portland cement (OPC) on the compressive and flexural strength of mortar,it was observed that 5% replacement of cement with ASA attained the highest strength for all the curing ages and all the percentage replacements attained the targeted compressive strength(Usman, Ibrahim and Bala, 2018). However, in this study, focus is made to assess the effect of revibration on the flexural strength of reinforced concrete beams, using locust bean pod epicarp ash (LBPEA) as partial replacement for cement.

2.0 MATERIALS AND EQUIPMENT

2.1 Materials

The materials used for this study include the following:

Cement: Portland Cement (ASTM C150) was used as a binder which conforms to type 1 cement (BS EN 197-1: 2011).

Coarse Aggregate: The gravel that was used was also clean from particles and the gravel particle size falls between 10mm to 14mm B.S sieve. Quarry gravel was bought from Kpankugu in Minna, Niger state, Nigeria. It conforms to BS EN 12620 (2008).

Fine Aggregate: The fine aggregate (sand) used was clean sharp river sand that is free of clay, loam, dirt, and any Organic or chemical matter. It sand is passed through 5mm British Standard Test Sieves. It conforms to BS EN 12620 (2008).

Steel Reinforcement: For each specimen, two numbers of steel bars of size 12 mm (Y12) were used as the tension bars and also two numbers of 12 mm steel bars as compression bars and 8 mm links was used (BS 8110-1: 1997).

Water: Fresh, colourless, odourless and tasteless potable water that is free from organic matter of any kind was used. This complies with the specification in BS EN 1008 (2002).

Locust Bean Pod Epicarp Ash (LBPEA): The locust bean epicarp was sourced from Gombe state. It was burnt at a temperature of about $800^{o}C$ to produce LBPEA that was used in this work.

2.2 Equipment

The equipment that was used for the experiment are: a weighing machine, British standard sieves, concrete mixer, 150mm x 150mm x 600mm beam moulds, head pan, hand trowels, tamping rod, buckets, vibrator and Universal testing machine.

3.0 EXPERIMENTAL PROCEDURE

3.1 Procedure

Chemical analysis of LBEA: A sample of the locust bean epicarp ash (LBPEA) was taken to chemical laboratory where the oxide composition was determined using the X-Ray fluorescent (XRF) test.

Aggregate Characterization: The aggregates were tested for the physical properties such as: specific gravity, Particle distribution (sieve analysis) test and bulk density.

Preparation of the reinforced concrete beam specimen: Absolute volume method was used to carry out the concrete mix design using a mix ratio of 1:2:4 with water cement ratio of 0.5 for every replacement of OPC for LBPEA. Fifty concrete rectangular prismatic beams of sizes 150mm x 150mm x 600mm were produced for this study. 12mm tensile steel bar (Y12) was used as the main reinforcement and 20mm concrete cover was used for the beam specimen, in accordance with specifications (Mott, *et al*., 2018; Auta, *et al*., 2016b;BS 8110, 1997). The size of the links provided was 10mm (Y10) steel bar each at regular spacing of 125mm c/c. Thirty-five beam specimens were produced for revibrated and fifteen non-revibrated (15 beams). Seven beams were cast and revibratedfor each percentage replacements(0, 5, 10, 15 and 20 %) of OPC for LBPEA. For the revibrated beams, revibration of 20seconds duration at 10 minute successions through 1 hour was achieved using poker vibrator after initial vibration, while that of the non-revibrated beams only three beams were produced for each percentage replacement (0, 5, 10, 15 and 20 %). The beams were de-moulded after 24 hours and then cured for 28days after which were tested flexural strength using the universal flexural testing machine. The placement for flexural test was by three point centre-point load method as shown on Figure 4.

Figure 4a. Beam under three point load

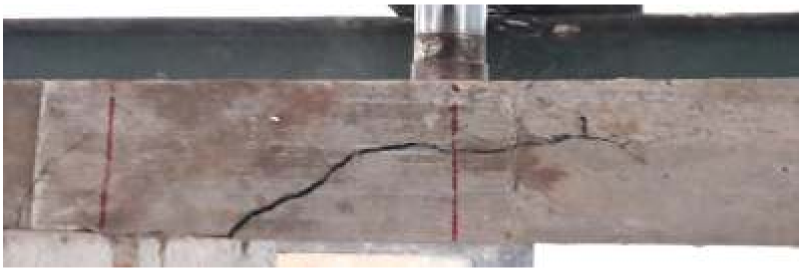

Figure 4b. Failed beam

4.0 RESULT AND DISSCUSION

The results of the laboratory tests which include: chemical composition of the LBEA, aggregate characterization and test on concrete (fresh and hardened properties) are presented in Tables 1, 2, 3, 4, 5, 6, 7 and Figures 1, 2, 3 and 4.

Chemical analysis of LBPEA

The chemical composition of LBPEA used in this study is presented in Table 1. The chemical compound of Silicon dioxide (SiO_2 = 49.054%), Iron oxide (Fe_2O_3 =8.925%) and Aluminium Oxide (Al_2O_3 =12.046%) which constitute a total sum of 70.025% of pozzolanic materials which is approximately 70%, but greater than 70%. According to ASTMC 618-9, (1991), pozzolanic classification is based on the summation of percentage composition (SiO_2+ Fe_2O_3 + Al_2O_3), if the sum is greater or equal to 70% then the ash is classified as Class F, while if it is greater than or equal to 50% it is class C. From this result, the LBPEA is a pozzolanic material and falls under class F.

Table 1: Chemical composition of LBPEA

Element	Concentration
Na_2O	1.012
MgO	6.905
Al_2O_3	12.046
SiO_2	49.054
P_2O_5	2.017
SO_3	3.212
Cl	2.412
K_2O	1.224
CaO	11.125
TiO_2	1.562
Cr_2O_3	0.000
Mn_2O_3	0.198
Fe_2O_3	8.935
ZnO	0.209
SrO	0.125

Aggregate Characterization

The aggregates were tested for physical properties according to specifications such as: specific gravity, particle distribution test and bulk density.

Particle size analysis for fine, coarse aggregates and LBPEA: The results of particle size analysis of LBPEA, fine and coarse aggregates used in the study are presented in Table 2, Figures1 and2 respectively.

From Table 2, the fineness modulus (FM) of 1.6 is less than fineness modulus of 2.3 -2.1 for fine aggregate suggested by American Society for Testing and materials (ASTM) C 33, hence LBPEA is finer than fine aggregate.

Specific gravity: The fine aggregate specific gravity value is 2.62; and that of coarse aggregate is 2.65. The specific gravity of both the coarse and fine aggregates is within limit of 2.5 to 3.0 for natural aggregate as specified by BS EN 12620 (2008). The specific gravity value of LBPEA was found to be 2.14. All this values were gotten on an average of three trials.

Bulk density: The value for compacted and uncompacted bulk densities of LBPEA are 562kg/$m^3$and 490kg/m^3. The compacted and uncompacted bulk densities of the sand are 1669g/$m^3$and 1590g/m^3 while that of coarse aggregate is 1352kg/m^3 for the uncompacted and 1534kg/m^3 for the compacted. These values correspond to the range of 1200-1800kg/m^3specified by BS EN 12620 (2008)for aggregates

Slump Value and Compacting Factor Test

Slump test: From the result of slump test shown in table 3. It is seen that there is a decrease in the slump value as the LBPEA content is increased. It can be inferred therefore that the amount of water for concreting will increase to get a workable concrete at higher percentage replacement for LBPEA.

Compacting factor test: A decrease in the compactor factor from 0.9 to 0.83 as shown in table 4 depicts a decrease in the workability of the fresh concrete as the percentage replacement for LBPEA increases from 0% to 20%. This also means that more water is need for the fresh concrete flow well as the percentage of LBPEA increases in the concrete mix. The high demand for water as the LBPEA content increases is due to increased amount of silica in the mixture. This is typical of pozzolana cement concrete as the silica-lime reaction requires more water in addition to water required during hydration of cement (Bui *et al*. 2005).

Table 2: Particle size analysis LBPEA

Sieve size (mm)	Sample weight retained (g)	Percentage retained (%)	Cumulative percentage retained (%)	Cumulative percentage passing (%)
0.850	0.00	0.00	0.00	0.00
0.600	0.00	0.00	0.00	0.00
0.425	0.00	0.00	0.00	0.00
0.300	25.42	12.71	12.71	87.29
0.150	99.32	49.66	62.37	37.63
0.075	44.68	22.34	84.71	15.29
Pan	27.72	13.86	-	-
Total			159.79	

Table 3: Slump test result of fresh concrete

Percentage replacement (%)	slump value (mm)
0	30
5	20
10	20
15	10
20	No slump

Table 4: Compacting factor test result of fresh concrete

Percentage replacement (%)	Compacting factor value
0	0.90
5	0.87
10	0.87
15	0.85
20	0.83

From the particle size distribution curve in Figure 1, the uniformity coefficient (CU) is calculated as equal to 6.0, while the coefficient of curvature (CC) is calculated as 1.63. Hence the aggregate is well graded gravel since the result agrees with the Unified Soil Classification System (USCS) of well graded sand with less than 5% fine has 1≤ Cc ≤ 3 as stated by Arora (2010).
From the particle size distribution curve in Figure 2, The uniformity coefficient C_U is calculated as equal to 1.5, while the coefficient of curvature C_C is calculated as 1.12. Hence the aggregate is well graded gravel because the result complies with the Unified Soil Classification System (USCS) of well graded sand with less than 5% fine has 1≤ Cc ≤ 3 as stated by Arora (2010).

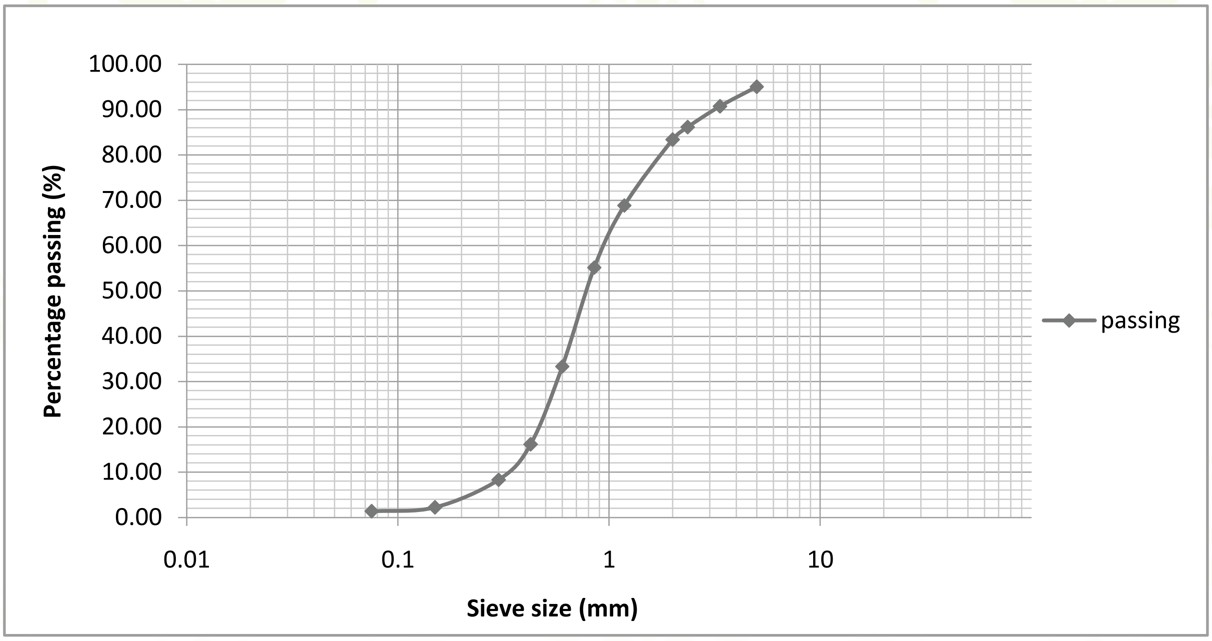

Figure 1: Particle size distribution of fine aggregate

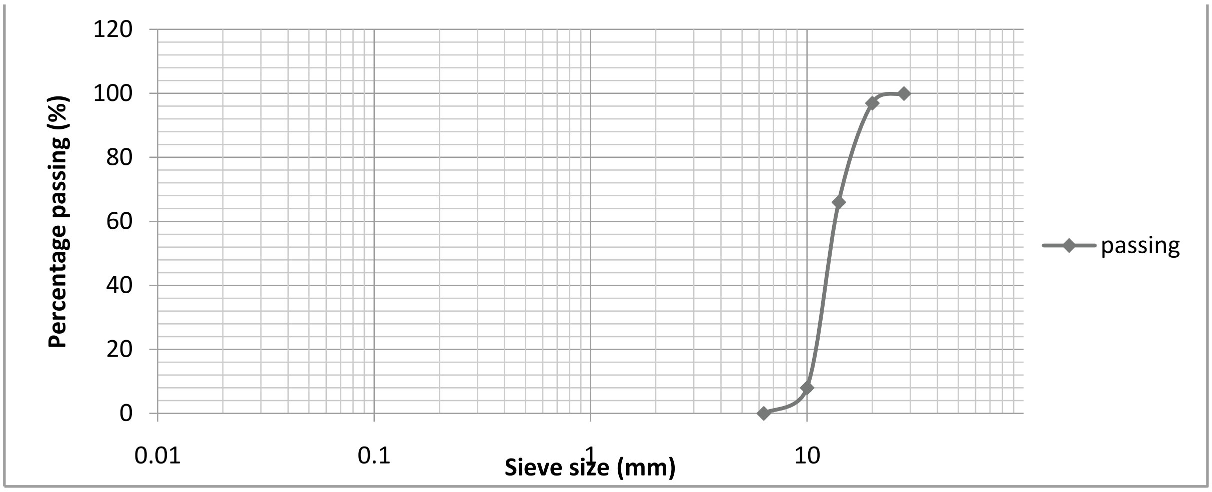

Figure 2: Particle size distribution of coarse aggregate

Flexural Strength of Revibrated and Non- revibrated Concrete Beams with SDA at 28 Days: The flexural strength test result of the fifty beam specimens is shown in table 5 (revibrated), table 6 (non-revibrated), table 7 (revibrated and non revibrated), figure 3 (revibrated). It can be seen from table 5 that the flexural strength increases at the initial stage of revibration at 10^{th} min and 20^{th} min interval, giving rise to a value of $10.5N/mm^2$ to $10.5N/mm^2$, but later a gradual decrease in strength from 30^{th} min respectively for the 0%. The trend is the 5%.

The early increase in flexural strength may be attributed to the calcium hydroxide in the OPC and revibration which enhanced densification and volumetric compaction of the concrete beam, but later revibration will debone the chemical compound of C_3S which leads to a decrease in strength from 30^{th} minute to 60^{th} minute. It can also be seen from table 7 that the average flexural strength value obtained after revibration at 10^{th} minute time lag interval to duration of 1 hour seem to have an improved strength compare to the value obtained for the non-revibrated concrete beam containing corresponding 0%, 5%, 10%, 15% and 20% LBPEA after a curing period of 28 days, thus indicating that revibration has improved the strength of concrete (Krishna *et al*., 2008).

Table 5: Flexural strength of revibrated concrete beams for 28 days of curing

Percentage of cement for LBPEA (%)	Revibration time interval (minutes)	Weight (kg)	Flexural strength (bar)	Flexural strength (N/mm^2)	Averageflexural strength (N/mm^2)
	0	34.41	100	10.0	
	10	34.53	105	10.5	
	20	33.94	105	10.5	
0	30	33.01	90	9.0	9.2
	40	32.98	85	8.5	
	50	33.75	80	8.0	
	60	33.73	80	8.0	
	0	35.75	90	9.0	
	10	36.54	100	10.0	
	20	36.60	95	9.5	
5	30	36.72	90	9.0	9.0
	40	36.81	90	9.0	
	50	36.31	85	8.5	
	60	36.06	80	8.0	
	0	34.53	75	7.5	
	10	34.95	75	7.5	
	20	35.28	80	8.0	
10	30	35.54	80	8.0	7.79
	40	36.68	85	8.5	
	50	34.97	75	7.5	
	60	35.70	70	7.0	
	0	34.95	65	6.5	
	10	35.56	70	7.0	
	20	35.90	70	7.0	
15	30	35.24	70	7.0	6.57
	40	36.82	65	6.5	
	50	36.21	60	6.0	
	60	36.63	60	6.0	
	0	35.59	35	3.5	
	10	35.69	40	4.0	
	20	35.77	50	5.0	
20	30	35.47	50	5.0	4.5
	40	35.32	50	5.0	
	50	36.19	45	4.5	
	60	36.37	45	4.5	

Table 6: Flexural strength of non-revibrated concrete beam after 28 days

S. No.	Percentage of cement for LBPEA (%)	Weight (Kg)	flexural strength (Bar)	flexural strength (N/mm^2)	Average flexural strength (N/mm^2)
1	0	34.30	95	9.5	
		35.10	90	9.0	9.17
		33.25	90	9.0	
2	5	35.24	80	8.0	
		34.97	85	8.5	8.33
		35.12	85	8.5	
3	10	38.00	80	8.0	
		36.57	75	7.5	7.77
		38.05	78	7.8	
4	15	35.06	60	6.0	
		33.50	50	5.0	5.50
		34.00	55	5.5	
5	20	36.77	50	5.0	
		36.84	50	5.0	5.17
		35.89	55	5.5	

Table 7: Flexural strength of non-revibrated and revibrated concrete beams

Description	0%	5%	10%	15%	20%
Flexural strength of revibrated beams	9.2	9.0	7.79	6.57	4.5
Flexural strength of non-revibrated beams	9.17	8.33	7.77	5.50	5.17

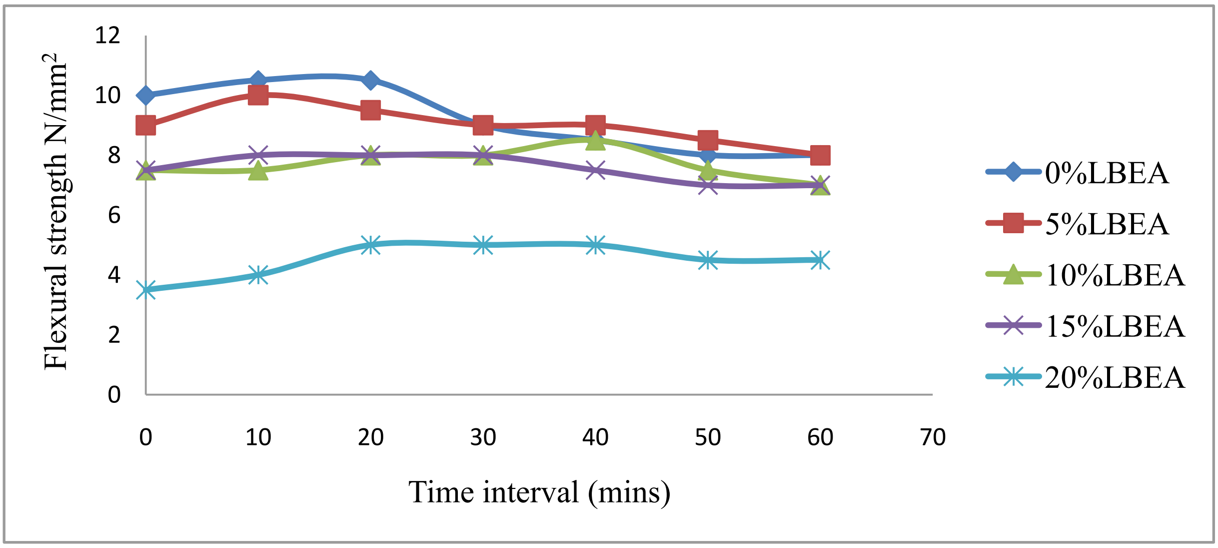

Figure 3: Effect of revibration on the flexural strength with time for all percentages

5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Effect of revibration on the flexural strength of concrete, using locust bean pod epicarp ash as partial replacement for cement is presented. From the study, the following conclusion can be drawn:

Chemical analysis LBEA indicated that the major constituents of LBEA includes; calcium oxide (CaO), Silicon dioxide (SiO_2), iron oxide (Fe_2O_3) and Aluminium Oxide (Al_2O_3) and other minor oxides in proportions Magnesium Oxide (MgO), Sodium Oxide (Na_2O) and Potassium Oxide (P_2O_5) placing LBPEA in the Class F as specified by ASTM C 618- 78 (2005) for pozzolana;

The indication of flexural strength of revibrated LBEA concrete beams for 0% and 5% replacements gaining increase from 0^{th} to 20^{th}minutes of revibration and correlating withmean flexural strengths of revibrated and non-revibrated beams, flexural strengths for revibrated beams are higher than that of non-revibrated. Thus it is pertinent to deduce that LBEA can be used up to 5% to replace cement, while revibration in the same vein, has had positive effect on the flexural strength of LBEA concrete.

5.2 Recommendations

Based on the experimental works the following recommendations were made:

The process of re-vibration should be encouraged in concrete work in other to ensure improvement in quality.

LBPEAif properly burnt can be used up to 5% to replace cement in structural concrete work.

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