ASSESSMENT OF THE PROPERTIES OF POWDERED LOCUST-BEANS-POD (*Makuba*) CONCRETE IN NORMAL AND AGGRESSIVE MEDIA

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Aaron Aboshio[1]* and Ibu Thomas Akata[2]
[1]Civil Engineering Department, Bayero University, Kano, Nigeria
[2]College of Health Technology, Mary Slessor Avenue, Calabar, Cross River State, Nigeria
*Corresponding author: aaboshio.civ@buk.edu.ng

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Abstract: This paper presents findings on the use of powdered locust beans pod (makuba) as an additive in concrete cured in normal and aggressive medium. *Makuba* is an air dried powdery substance obtained from the pod of the locust bean tree (parkia folicoidea). *Makuba* in concrete grades of 20 and 30 N/mm^2 were investigated to determine its suitability as an additive in the concrete mixes in normal and aggressive environment. To each grade of Concrete, *Makuba* was added in varying concentration of 0, 2.5, 5.0 and 10% cured in 0, 5 and 10% concentration of acid of Tetraoxsulphate (vi), TrioxoNitrate (v) and Hyrochloric acids, and tested for compressive strength after a period of 7, 28 and 56 days, respectively. Results on the compressive strength of the concrete revealed generally a decrease in strength for every increase in *Makuba* and concentration of acid. However, for cubes cured in normal water (0% of acid), there have been progressive increase in the trend of the strength up to 56 days. For cubes cured in 5 and 10% of acid, there was an increase in strength up to 28 days and a decrease after then up to the 56 days.
Keywords: Concrete, Makuba, additive, acid, aggressive environment, curing

Introduction

Concrete materials are widely used in construction of facilities that operate in normal and sometimes aggressive environments due to its adjudged versatility, good strength and durability. These properties of concrete are considered most valuable especially in the industry where it is mostly applied. However, in most practical cases, other characteristics such as workability, impermeability etc., may be as important depending on the desired interest.

Compressive strength being the primary requirement of a good concrete in its hardened state is aimed at, not just, to ensure that the concrete withstands a prescribed compressive stress but also to ensure that other desirable properties concomitant with the strength achieved (Ogork and Ibu, 2009). To attain an acceptable strength requirement of concrete, proper attention must be given to the ratio of constituent mix and mode of production in a prescribed standard largely based on recommendation by the British Cement Association (2006) and ACI (1996). In some occasions, other materials in liquid or powder forms, called admixtures, in varying proportion are added to alter or modify one or more of the properties of concrete. Neville (2003) defines such materials (admixtures) as chemical substance added to concrete for the purpose of achieving a specific modification(s) to the normal properties of concrete. Among these admixtures are accelerators, retarders, water reducers, pigments etc.

Admixtures, depending on the type, may be imported or sourced locally. The ones imported from overseas are often too expensive and beyond the reach of many local producers of concrete mixes, as such local materials, meeting requisite conditions may be suitably used as an altenative to save time and money because they are relatively cheaper.

Example of such locally sourced admixtures is *Makuba* which was assessed to be composed of at least 15 elements, top most of which are Magnesium (24%), Potassium (20%), Calcium (17%), Aluminum (16%), Sodium (12%) and Chlorine (11%) in high concentration (Ogork and Ibu 2009). *Makuba* has been used locally in improving on the strength of laterite blocks owing to the chemical composition and its abundant supply (Ogork, and Rimi 2007); other application is being explored as is the subject of this paper.

This study thus seeks to investigate on the suitability or otherwise of *Makuba* as an additive in concrete in normal (water) and aggressive environments. This is necessary giving that most industries like Tanneries and other Chemical and Allied Industries uses chemical such as H_2SO_4, HNO_3 and HCl acids in their daily work either as a major component or are given out as effluent to the surroundings via concrete structures. As a result of which the normal concrete structures suffer severe attack, some deteriorating, within few years of construction. *Makuba* concrete here being studied is with a view to improve on the strength and durability properties of the concrete in both normal and aggressive conditions.

Materials and Methods

Materials

Makuba

Powdered *Makuba* was bought from Kurmi market of Kano State of Nigeria and sieved through 425 µm sieve in the laboratory.

Cement

The cement used in this research is the ordinary Portland cement manufactured by the Ashaka cement Company Plc, Bauchi.

Aggregates

Aggregates being fine and coarse were obtained from a local dealers in Kano. Sieve analysis was carried out on both the fine and coarse aggregate in accordance with BS 812: Part 1: 1975. The coarse aggregate was made of crushed granite which was sieved through 5 and 20 mm sieves to ensure that the maximum size of the aggregate is 20 mm.

Water

The water used for mixing and curing of the cubes was potable.

Acid

The acids used for this study were tetraoxosulphate (vi) acid, Hydrochloric acid and trioxonitrate (v) acid. The acids were measured in concentrations of 0, 5 and 10%, respectively.

Methods

The concrete materials were designed using the Department of Environment, United Kingdom –DoE- Teychem *et al.* (1975), method and batched by weight in accordance with the results obtained in the mix designs for grade 20 and 30, respectively as stipulated in BS8110, Part 1: 1985.

The batches were mixed manually and to each batch a slump test was carried out. The mixed concrete was cast into a 150 x 150 x 150 mm cube moulds and compacted manually, in three layers, with the aid of a tapping rod. After casting, the specimen were identified and left for at least 30 h to harden, (depending on the percentage of "*Makuba*" in the concrete) and then removed from the mould. This was because the presence of "*Makuba*" had increased the time taken for the concrete to set and harden as observed. The weights of the cubes after demoulding from the steel moulds were measured. Some concrete cubes were cured by complete immersion in water only and others in acid solutions of Tetraoxosulphate VI (H_2SO_4), Trioxonitrate V (HNO_3) and Hydrochloric acids (HCl). This curing process lasted for a period of 7, 28, 56 days respectively after which the cubes were removed for compressive strength test.

The compressive strength tests were carried out using the Avery universal testing machine of force capacity of 600KN at Bayero University, Kano. The test was carried out on the cubes at the end of 7, 28, 56 days of curing and the strength noted in accordance with BS 1881, part 116 (1983) on concrete samples of both grades. During this process, the machine applied load axially at the rate of 0.4 Mpa/second (60 psi/second) until the cube is crushed to failure. The failure point corresponds to the maximum (ultimate) compressive strength of the specimen recorded in this paper.

Results and Discussion

Tables 1 and 2 present results of the compressive strengths for grade 20 and 30 concretes, respectively for the varying curing conditions.

From the results presented in Table 1 and Table 2, generally the compressive strength of the concrete had decreased with an increase in the percentage addition of *Makuba* for all the curing media. However, concrete cured in 0% acid had gained strength progressively to 56 days for any particular percentage addition of Makuba. For concrete cured in 5 and 10% acid medium, for any particular percentage addition of Makuba, the concrete gained strength with age up to 28 days and dropped after then, up to the 56 curing days. This is also presented in Figs. 1 to 14. There is also a corresponding reduction in density for every increase in the concentration of *Makuba* and acid media. The possible causes of this decrease may be attributed to two factors; the action of "Makuba" on the concrete and secondly, the action of the acid medium on the concrete.

Table 1: Summary of average compressive strength and density for grade 20 concrete (N/mm²)

Curing Medium	**Age (Days)**	**Average compressive Strength (N/mm²) Percentage addition of Makuba (%)**							
		0		**2.5**		**5.0**		**10.0**	
		N/mm²	**kg/mm³**	**N/mm²**	**kg/mm³**	**N/mm²**	**kg/mm³**	**N/mm²**	**kg/mm³**
Water	**7**	29.41	2386	27.41	2285	22.82	1996	17.33	1894
	28	33.93	2506	29.04	2302	27.41	2197	21.48	2003
	56	37.33	2528	32.29	2456	29.04	2230	22.67	2007
5% H_2S0_4	**7**	26.08	2104	19.11	1933	15.41	1848	14.22	1752
	28	28.59	2120	20.15	1983	17.04	1882	15.85	1851
	56	22.52	2003	18.37	1846	14.37	1761	12.56	1511
5%HCL	**7**	26.82	2115	20.00	1959	18.67	1938	15.70	1837
	28	28.74	2124	22.37	1996	19.25	1980	19.11	1948
	56	24.44	2025	18.83	1858	16.74	1798	13.18	1702
5%HNO_3	**7**	28.00	2120	20.44	1980	19.70	1958	17.04	1864
	28	29.78	2271	23.25	2003	20.44	1997	20.00	1985
	56	26.07	2114	18.96	1885	17.04	1812	13.33	1711
10%H_2SO_4	**7**	19.56	1963	15.41	1830	14.52	1742	12.44	1523
	28	22.82	2010	19.26	1965	15.41	1860	14.52	1680
	56	17.34	1908	14.52	1743	12.59	1600	10.22	1478
10%HCL	**7**	20.44	1996	18.85	1952	17.04	1904	16.59	1855
	28	26.37	2114	20.00	1985	19.70	1958	17.78	1885
	56	18.52	1934	15.26	1804	14.23	1769	12.44	1559
10% HNO_3	**7**	24.44	2047	19.85	1968	18.52	1919	17.18	1863
	28	28.74	2123	21.18	2003	20.30	1979	19.11	1938
	56	21.04	2007	15.41	1810	14.52	1773	12.89	1614

Table 2: Summary of average compressive strength and density for grade 30 concrete (N/mm²)

Curing Medium	**Age (Days)**	**Average compressive Strength (N/mm²) Percentage addition of Makuba (%)**							
		0		**2.5**		**5.0**		**10.0**	
		N/mm²	**kg/mm³**	**N/mm²**	**kg/mm³**	**kg/mm³**	**kg/mm³**	**N/mm²**	**kg/mm³**
Water	**7**	36.89	2482	28.00	2291	23.26	2035	18.22	1958
	28	41.33	2537	30.29	2310	28.59	2215	22.07	2117
	56	43.11	2551	32.45	2545	29.70	2247	23.70	2139
5% H_2S0_4	**7**	29.33	2154	19.40	1956	16.44	1887	14.81	1838
	28	31.56	2183	23.25	2130	17.49	2010	16.44	1854
	56	28.15	2135	19.41	1873	14.96	1788	12.89	1688
5%HCL	**7**	29.92	2167	20.74	1970	18.81	1952	17.78	1882
	28	32.89	2301	23.41	2262	20.44	2031	19.85	1985
	56	28.59	2143	19.85	1886	17.74	1867	15.26	1857
5%HNO_3	**7**	30.96	2184	20.89	1990	19.41	1969	17.93	1908
	28	34.22	2351	25.48	2348	20.89	2059	20.30	2050
	56	29.93	2167	20.15	1921	18.67	1915	15.70	1860
10%H_2SO_4	**7**	24.89	2073	17.04	1879	15.11	1840	14.37	1539
	28	28.00	2295	19.70	1970	15.85	1856	15.56	1697
	56	23.12	2119	14.82	1757	13.48	1651	11.11	1491
10%HCL	**7**	28.00	2275	18.96	1975	18.37	1940	16.74	1884
	28	29.78	2314	20.59	2049	20.30	2000	19.11	1964
	56	26.67	2149	16.00	1857	15.70	1853	12.59	1588
10% HNO_3	**7**	28.44	2286	20.00	2001	18.82	1964	17.63	1934
	28	30.37	2328	21.78	2145	20.45	2051	19.56	1971
	56	29.56	2219	16.44	1865	16.00	1859	13.18	1690

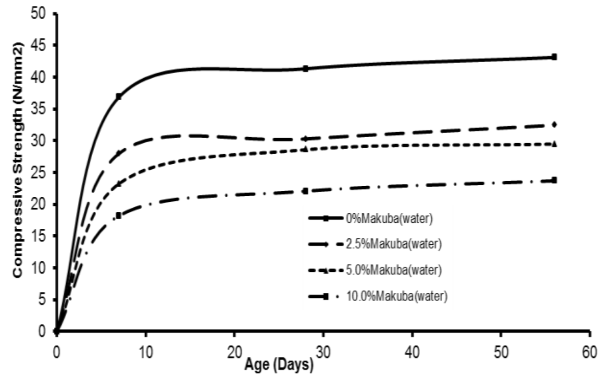

Fig. 1: Compressive strength of grade 30 concrete cured in water

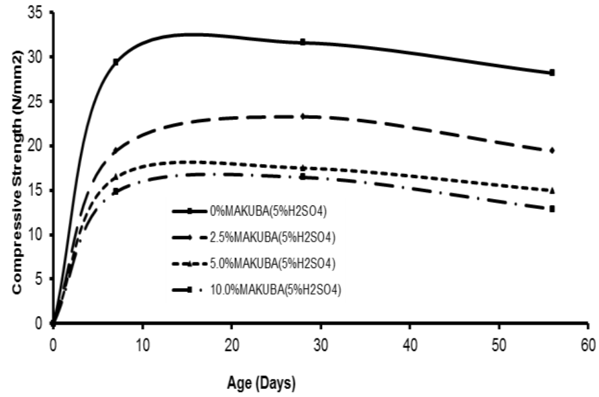

Fig. 2: Compressive strength of grade 30 concrete cured in 5% H_2SO_4

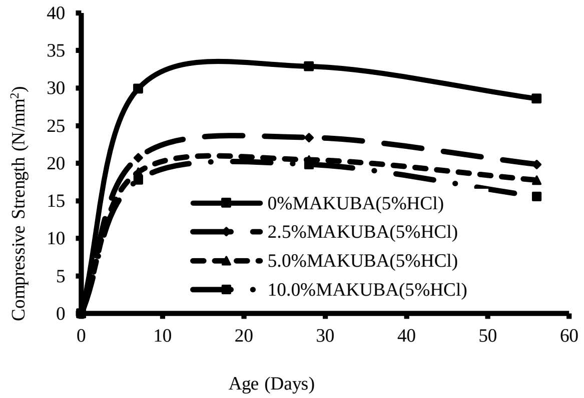

Fig. 3: Compressive strength of grade 30 concrete cured in 5% HCL

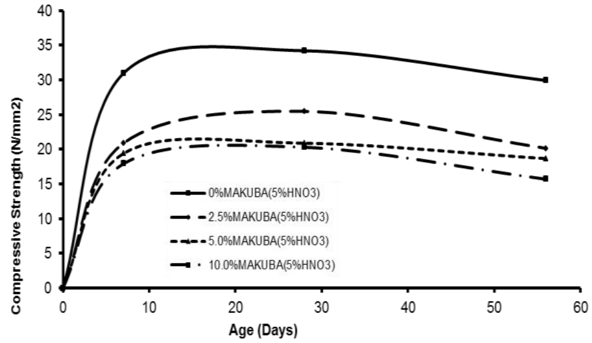

Fig. 4: Compressive strength of grade 30 concrete cured in 5% HNO_3

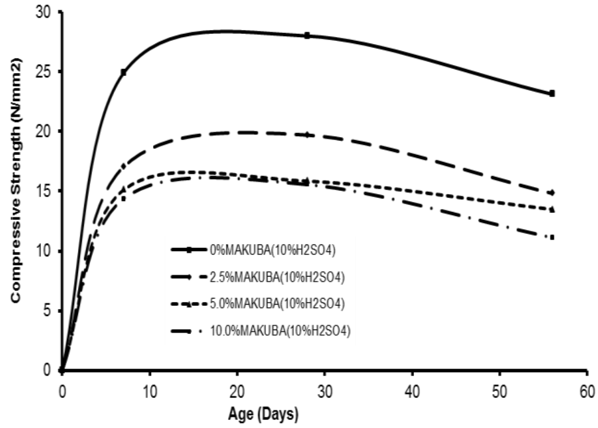

Fig. 5: Compressive strength of grade 30 concrete cured in 10% H_2SO_4

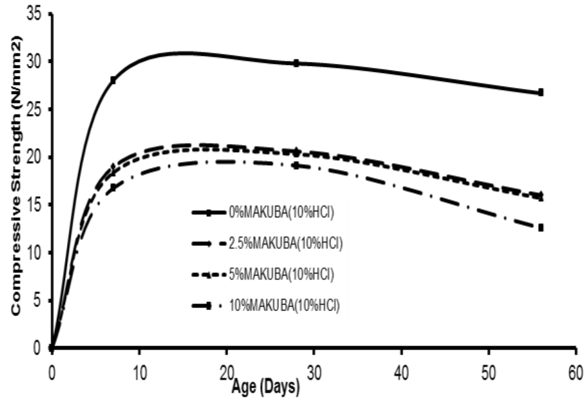

Fig. 6: Compressive strength of grade 30 concrete cured in 10% HCL

Considering the first factor, that is, the effect of *Makuba* on the concrete; according to Ibu (2008), Makuba contain elements such as magnesium, sodium and potassium, which react with water forming hydroxides (alkalis) and then reacts with hydrated cement to form salts which weakens the bonds in concrete. This assertion that magnesium, sodium and potassium reacts with water to form hydroxide and then with hydrated cement to form salts which weakens the bonds in concrete is supported by Neville (2003) and Schramm *et al.* (2004). In fact, Schramm *et al.* (2004) defines alkalis as compounds containing the alkaline metals. In concrete, they reported that the specific alkalis that can cause problems are potassium, magnesium and sodium. These elements have a tendency to continually react within the concrete breaking down the bonds formed and weakening its structural integrity. The salts; sodium silicate and magnesium silicate respectively breaks the bond integrity of concrete (after the early age of the concrete). Snow (1992) confirms this, as he stated in his book that hardened concrete consists of two major chemical compounds; calcium – silicate – hydrate and calcium hydroxide. The magnesium ions reacts with the cementitious compound calcium – silicate – hydrate converting it to magnesium – silicate – hydrate (or a mineral called brucite), which is non – cementitious in nature. In other words, a fundamental major mineralogical product of solidified concrete has now been chemically altered (completely changed). Formation of magnesium – silicate – hydrate breaks down the "glue" that binds aggregate together and concrete surfaces begin to deteriorate. The net effect is chemical and physical attack that concrete is not designed to withstand, nor be subjected to. Ogork and Rimi (2007) also gave an explanation concerning the effect of Potassium in concrete. They stated that Potassium reacts with hydrates of C_2S and C_3S in cement to give Potassium silicate, which is responsible for the high early strength in concrete, but with higher percentage of Potassium displaces more of the calcium in the cement to form potassium silicates with less calcium silicates left. This leads to a reduction in strength of the concrete.

It has been established that their makuba contain Magnesium, Sodium, and Potassium and that their salts affects concrete aggressively. With this percentage (56%), one may be right attributing the decrease in the strength of concrete to this (for concrete cured in 0% acid), and also with the presence of acid media (for concrete cured in 5 and 10% acids). Acid attack on concrete is obvious because acids attack concrete by digesting part of the set cement. This attack progressively leads to weakening the materials by removing the cementing constituents, leaving a soft and mushy mass. It is essential to note here that concentrated acids dissolve rapidly every cementing material and possible admixture used. In fact, a one percent solution of Tetra-oxo-sulphate (VI) acid, Tri-oxo-nitrate (v) acid or Hydrochloric acid will corrode concrete deeply within a few months, which explains the reduction in strength and density.

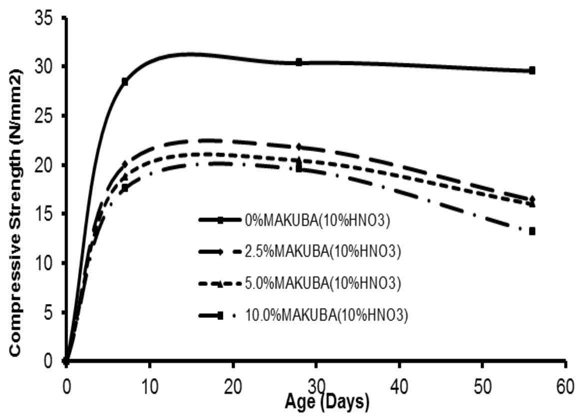

Fig. 7: Compressive strength of grade 30 concrete cured in 10% HNO_3

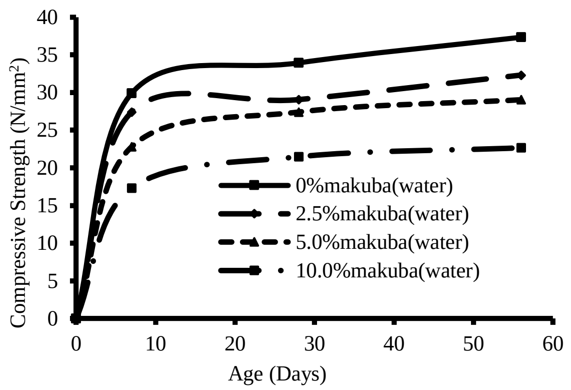

Fig. 8: Compressive strength of grade 20 concrete cured in Water

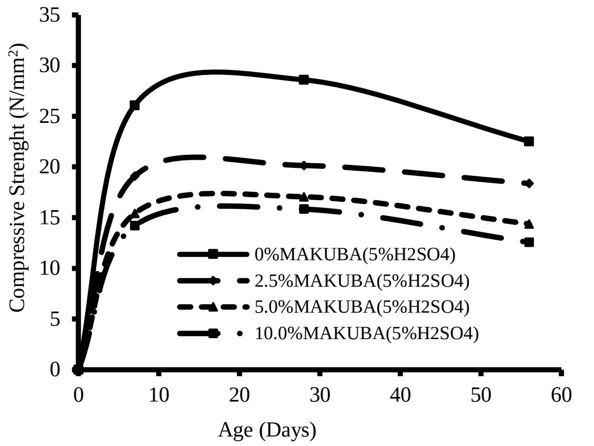

Fig. 9: Compressive strength of grade 20 concrete cured in 5% H_2SO_4

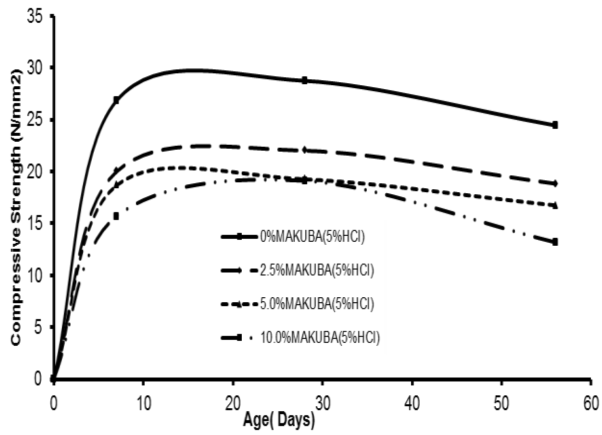

Fig. 10: Compressive strength of grade 20 concrete cured in 5% HCL

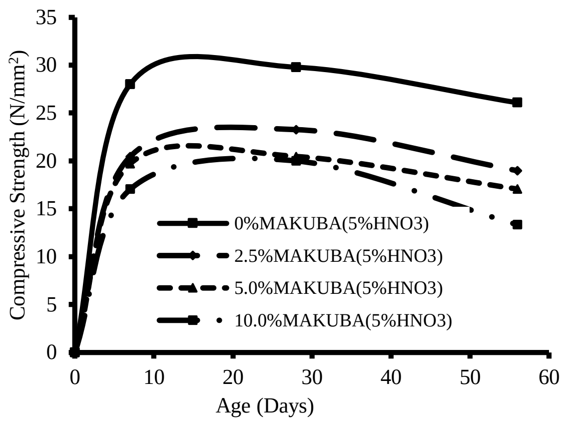

Fig 11: Compressive strength of grade 20 concrete cured in 5% HNO_3

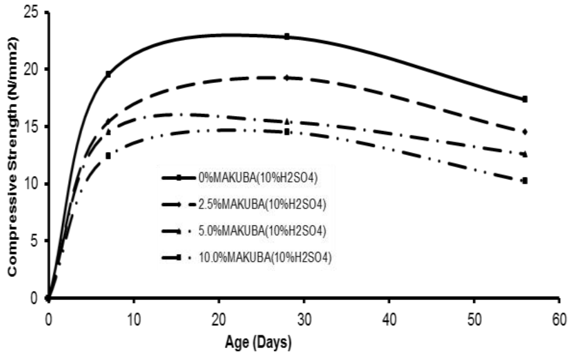

Fig. 12: Compressive strength of grade 20 concrete cured in 10% H_2SO_4

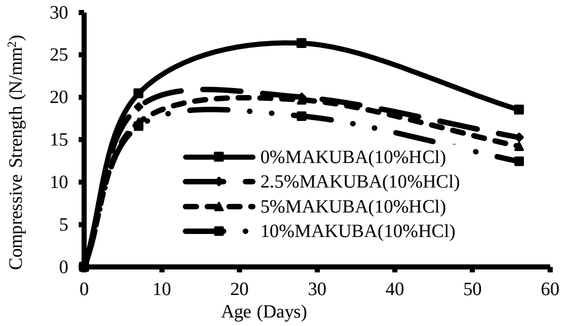

Fig. 13: Compressive strength of grade 20 concrete cured in 10% HCL

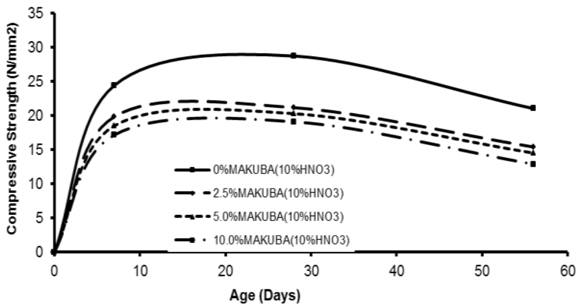

Fig. 14: Compressive strength of grade 20 concrete cured in 10% H_2NO_3

Concrete is in fact susceptible to acid attack because of its alkaline nature. The components of the cement paste break down during contact with acids. Most pronounced is the dissolution of Calcium hydroxide.

The decomposition of the concrete depends on the porosity of the cement paste, on the concentration of the acid, the solubility of the acid, Calcium salt and on the fluid transport through the concrete. Soluble Calcium salts attack concrete. Acids such as Tri-oxo-nitrate (v) acid, hydrochloric acid and acetic acid are very aggressive as their Calcium salts are readily soluble and removed from the attack front. Tetra-oxo-sulphate (vi) acid is very damaging to concrete as it combines an acid attack and a sulphate attack.

Therefore, their solubility and the structure of the layer of the reaction products determine to a considerable degree the rate of concrete deterioration. The higher the solubility of the reaction products and the more quickly they are removed with aggressive solution, the faster the destruction of the hardened cement. In fact, the solubility of calcium salts and the end products of the decomposition of silicates, aluminates, and ferrites in the form of gels of hydroxides of silica, aluminum, and iron, formed as a result of the reaction between the acid the hardened cement components, determines the structure and diffusion permeability of the reaction product layer and, accordingly, the rate of deterioration. The progressive increase in strength and density up to 28 days may be attributed to the fact that the constituents' material in the concrete is still on the verge of gaining strength. After the age of 28 days, the concrete would have gained its maximum compressive strength, but the action of the aggressive environment (the acids); digest the constituents' materials in concrete which may ultimately reduce its strength.

Conclusion

Based on the results obtained from all the tests conducted, the following conclusions can be drawn.

1) The compressive strength and density of the concrete decreases with an increase in the addition of *Makuba* for both grades of concrete considered in this study.
2) The compressive strength and density of the concrete decreases with increase in the concentration of the acid solution as a curing medium.
3) *Makuba* is not suitable as additive in concrete with a view to increasing the compressive strength. It may however be suitable when used in very small quantity.
4) From physical observation, it takes longer time for initial and final setting of the concrete to take place, when *Makuba* is added; the final setting time of the concrete increases as the quantity of *Makuba* increases. *Makuba* may therefore, be suitably used as a retarder in concrete.

References

American Concrete Institute 1996. Standard practice for selecting proportions for normal, heavyweight, and mass concrete. ACI Manual of Concrete Practice, Part 1. Detroit.

BS 1881, Part 116 1983. Method for the determination of compressive strength of concrete cubes. Her Majesty Stationery Office, London

BS 812: Part 1: 1975. Methods for determination of particle size and shape. British Standard Institute, London.

BS 8110: Part 1: 1985. Structural use of concrete code of practice for design and construction. British Standard Institute, London.

British Cement Association 2006. Concrete and sustainability. http/www.sustainable.concrete.org.uk/main.asp?

Ibu TA 2008. The effect of curing medium on makuba concrete. Unpublished M.Eng Thesis. Department of Civil Engineering. Bayero University, Kano Nigeria.

Neville AM 2003. Properties of concrete. Fourth edition. Pearson Education Ltd. Singapore.

Ogork EN & Ibu TA 2009. Properties of powdered locust bean pod (*Makuba*) concrete. *Journal of Engineering and Technology (JET)*, 4(2): 32-37.

Ogork EN & Rimi MK 2007. 'Kargo' (Poliostigma Thonningi) Fruits Powder as admixture in concrete. *Journal of Engineering and Technology*, 2(1): 9-11.

Schramm D, Shamp A & Zumbach D 2004. A Report on Concrete Sealants with Emphasis on Their Radon Blocking Capabilities and Their Green Values. www.stolfa.edu/jackson/gbreport/concrete seal.j04.pdf

Snow PG 1992. Magnesium Chloride as A Road Deicer: A Critical Review. Burns Concrete, inc. Idaho Falls, Idaho.

Teychem DC, Franklin RE & Entroy HC 1975. Design of Normal Concrete Mixes, Department of Environment. Her Majesty, Stationery Office, London.