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Strength assessment of concrete with waste glass and bankoro (*Morinda Citrifolia*) as partial replacement for fine and coarse aggregate

O.D. Atoyebi *, A.J. Gana, J.E. Longe

Department of Civil Engineering, Landmark University Omu-Aran, Kwara State, Nigeria

A B S T R A C T

In Nigeria, the high rate generation of waste has resulted in lots of environmental pollution and high cost of waste management. These have led to the reuse of wastes for different purposes including replacements for concrete constituents. In this study, both fine aggregate and coarse aggregate were replaced with waste glass and bankoro respectively for 5%, 10%, 15% and 20%. The result proves that the use of waste glass and bankoro as a partial replacement for the aggregates is possible and acceptable at 5%–15%.

1. Introduction

Sustainability of concrete has become a point of interest to researchers and engineers due to the accelerated degradation of the present and future environment. In recent times, different researches have been conducted to improve concrete in ways it can be safe and can perform more specific purposes [1–7]. The increase in solid waste leads to the use of agricultural waste and industrial waste in the production of concrete [8–11]. Researches in the past have considered replacing only one concrete constituent but this work presents the replacement of both fine and coarse aggregate simultaneously and also newly considering the use of Bankoro (Morinda Citrifolia). Bankoro is a plant which has about 200 phytochemical compounds with bioactive properties such as acids, anthraquinones, carotenoids, esters, triterpenoids, flavonoids, glycosides, lactones, iridoids, ketones, lactones, lignans, nucleosides, triterpenides, sterols, aromatic compounds etc. Bankoro is unnoticed and seen as a waste in Africa as its use in the food industry and medicine is profound only in Asian countries [12]. It has a density of $1.13g/cm^3$ which is very close to the density of gravel.

2. Method of study

The materials used in the production of concrete cubes ($150\,x\,150\,x\,150mm$) and cylinders ($150mm\ diameter\ x\ 300mm\ long$) in this research are Portland cement (Ce), fine and coarse aggregate, water, waste glass (WG) and Bankoro (BK) (*Morinda citrifolia*). WG was used as partial replacements for fine aggregates and BK was used as partial replacements for coarse aggregates (Table 1). The waste glass used is a mixture of both float and laminated glass (Fig. 1). Water-Cement ratio of 0.4 was used to produce the concrete with a target strength of $17.5N/mm^2$. The study involved laboratory tests such as the compressive strength test, split tensile strength test, slump test, compaction factor test and sieve analysis test. The sieve analysis test was carried out on the fine and coarse aggregates. The slump test was done to check the consistency of the concrete. The compaction factor test was carried out to determine the workability of the concrete. Concrete cube and cylinder samples were cured in water by total immersion for 7, 14, 21, 28 days. The compressive strength test and split tensile test of concrete were carried out on three samples each of the different replacement proportions.

3. Result and discussion

The concrete slump reduced with increase in the percentage of waste glass and bankoro content (Table 2), despite the reduction in the slump value as the percentage of waste glass and bankoro increased, the lowest slump test attained at 20% is workable. The compaction factor of the concrete increased as the percentage of waste glass and bankoro content

Table 1
Material proportion in concrete mix.

Mix Ratio	Cement (%)	Waste Glass (%)	Bankoro (%)
$CeWG_0BK_0$	100	0	0
$CeWG_5BK_5$	100	5	5
$CeWG_{10}BK_{10}$	100	10	10
$CeWG_{15}BK_{15}$	100	15	15
$CeWG_{20}BK_{20}$	100	20	20

* Corresponding author.
E-mail address: atoyebi.olumoyewa@lmu.edu.ng (O.D. Atoyebi).

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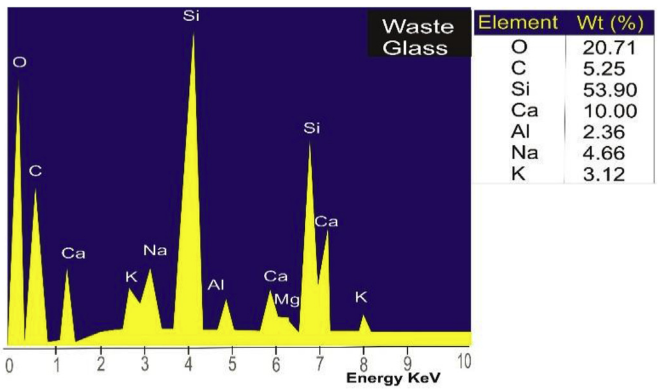

Fig. 1. Waste glass chemical composition.

Table 2
Slump value and compaction value.

Mix Ratio	Slump Value (mm)	Compaction Factor Value (mm)
$CeWG_0BK_0$	74	0.86
$CeWG_5BK_5$	67	0.87
$CeWG_{10}BK_{10}$	62	0.89
$CeWG_{15}BK_{15}$	58	0.92
$CeWG_{20}BK_{20}$	54	0.94

Table 3
Average Split Tensile Strength for different Mix Ratios.

Mix Ratio	Split Tensile Strength (N/mm^2)			
	7 Days	14 Days	21 Days	28 Days
$CeWG_0BK_0$	1.45 ± 0.11	1.82 ± 0.19	2.09 ± 0.12	2.37 ± 0.16
$CeWG_5BK_5$	1.4 ± 0.09	1.66 ± 0.15	1.8 ± 0.14	2.07 ± 0.27
$CeWG_{10}BK_{10}$	1.34 ± 0.11	1.42 ± 0.15	1.49 ± 0.09	1.82 ± 0.34
$CeWG_{15}BK_{15}$	1.21 ± 0.05	1.3 ± 0.07	1.4 ± 0.17	1.78 ± 0.15
$CeWG_{20}BK_{20}$	1.19 ± 0.12	1.37 ± 0.12	1.29 ± 0.09	1.64 ± 0.29

Table 4
Average compressive strength values.

Mix Ratio	Compressive Strength (N/mm^2)			
	7 Days	14 Days	21 Days	28 Days
$CeWG_0BK_0$	11.61 ± 0.70	12.73 ± 0.62	16.89 ± 0.55	20.01 ± 1.27
$CeWG_5BK_5$	10.21 ± 0.41	12.7 ± 0.30	17.3 ± 0.84	18.47 ± 0.63
$CeWG_{10}BK_{10}$	9.48 ± 0.56	11.07 ± 0.81	14.19 ± 1.13	17.79 ± 0.42
$CeWG_{15}BK_{15}$	8.77 ± 0.64	10.46 ± 0.59	13.81 ± 0.80	15.44 ± 1.21
$CeWG_{20}BK_{20}$	8.33 ± 0.76	9.66 ± 1.10	13.24 ± 0.37	15.24 ± 0.41

increased (Table 2), this is due to the weight of the bankoro used as replacement for the coarse aggregate. The highest tensile strength attained is 2.37 for 0% (control) and the lowest split tensile strength attained is 1.64 for 20% waste glass and bankoro replacement (Table 3).

It can be observed that the addition of waste glass and bankoro led to a decrease in the split tensile strength of the concrete cubes. The target compressive strength was achieved with a maximum 10% replacement with both waste glass and bankoro (Table 4).

4. Conclusion

Waste glass and bankoro can be used as partial replacement for fine and coarse aggregate respectively especially in areas with scarce concrete aggregate materials, replacement from 5% to 15% gave a positive slump, compaction factor and compressive strength result.

Declaration of competing interest

It is assured by the authors that this publication does not have any known conflict of interest. In addition, there has been no significant financial support for this research that could have influenced its funding.

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