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EFFECT OF DYE RESIDUE ON SOME PROPERTIES OF CEMENT

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ABSTRACT

This is a paper that studies the effect of using dye residue (DR), as a partial replacement of cement, on some properties of cement. The main compound composition of cement, the setting times, drying shrinkage and soundness of cement were the main focus of the paper. DR-cement pastes containing 10, 20, 30, 40, and 50 percents of DR as partial replacement of cement together with cement paste (with zero percent DR) as control were prepared. Results of the investigations carried out show that the use of DR as a partial replacement of cement increased the percentage composition of tricalcium aluminate (C_3A), and dicalcium silicate (C_2S) in the resulting mixture from 10.83% to 15.18% and 16.35% to 80.00% respectively for 50% DR but decreased that of tetracalcium aluminoferrite (C_4AF) and tricalcium silicate (C_3S) in the mixture from 9.12% to 5.26% for 50% DR and 54.10% to 0.80% for 20% DR. It also increased both the initial and final setting times of the DR-cement mixtures from 105 minutes to 165 minutes and 183 minutes to 243 minutes respectively at DR content of 20%. The use of DR as a partial replacement of cement was found to be effective in reducing the drying shrinkage of the resulting DR-cement mixtures and is capable of removing unsoundness in cement.

Keywords: cement, dye residue, effect, properties

1. INTRODUCTION

In the quest for the use of local construction materials in place of or to compliment the modern ones, with the aim of reducing cost consistent with good characteristic performance, a lot of researches have been carried with strong margin of success. In line with this, a research was carried out on the use of *katsi* (dye residue) as an admixture in mud rendering and results indicated that it improved the performance characteristics of mud renders and thus recommended as a useful rendering admixture for mud rendering in areas with 500mm to 1250mm rainfall per annum [1]. Dye residue was also used as a partial replacement of cement in concrete and mortar and it was concluded that Dye residue could be used effectively as pozzolana in concrete and mortar [2, 3, 4].

Further studies on dye residue show that it could be used in concrete to effectively reduce the corrosive effects of acids on concrete [5].

This paper studies the effect of dye residue (DR), used as a partial replacement of cement, on some properties of cement notably, the main compounds in cement, setting times, shrinkage, and soundness.

Dye residue is the bye-product of indigo dyeing which is predominantly carried out in the northern part of Nigeria [1]. The residue is formed by the following process: the barks of oak tree *baba* in Hausa language) is soaked in water in a dye-pit and ashes from burnt wood and indigo (*shuni* in Hausa) is added and the mixture is stirred for days. The bottom deposit of the mixture used for dying clothes is removed, dried, fired to grey ash and pounded into powder called Dye residue.

2. EXPERIMENTAL PROCEDURES AND ANALYSIS

In order to find out the effect of DR (used as a partial replacement of cement) on the above mentioned parameters, Bouge's Equation was used to calculate the main compounds in DR-cement mixtures and DR-cement standard pastes were prepared for 0%, 10%, 20% 30%, 40% and 50% DR contents as a partial replacement of cement by weight. The experimental procedures are presented in the preceding section.

2.1 Calculation of the main compounds in DR-cement

Whenever DR is used to substitute some percentages of cement, the percentage composition of the main compounds in cement are affected. Using Bouge's Equation (see appendix I) and the chemical oxide compositions of DR and cement given in Table-1, the percentages of the main compounds in DR-cement were calculated and the results summarized in Table-2.

Table-1. Oxide composition of DR-cement.

Chemical	Percentage composition (%)	
	Katsi	**Cement**
S_1O_2	10.60	20.00
SO_3	26.64	2.00
CaO	7.84	63.00
Fe_2O_3	0.46	3.00
Al_2O_3	7.65	6.00

Table-2. Compound composition of DR-cement mixture.

DR content (%)	C_3A (%)	C_4AF (%)	C_3S (%)	C_2S (%)
0	10.83	9.12	54.10	16.35
10	11.70	8.36	31.00	31.32
20	12.57	7.57	0.80	46.00
30	13.44	6.81	-15.16	61.00
40	14.30	6.02	-39.19	75.00
50	15.18	5.26	-61.30	80.00

2.2 Setting time test

The setting times test was carried out in accordance with BS 4550: Part 2: 1970 test procedures [6] and the results are as presented in Table-3.

Table-3. Results of initial and final setting times.

DR contents (%)	**Initial setting times** (Min)	**Final setting times** (Min)
0	105	183
10	157	225
20	165	243
30	157	242
40	156	241
50	157	242

2.3 Drying shrinkage test

Using BS 1377: 1975 test procedures [7], and taking the necessary steps to obtain a homogeneous paste, the shrinkage test was carried out and the result is as shown in Table-4.

Table-4. Results of drying shrinkage test.

DR Contents (%)	**Average drying shrinkage** (%)
0	2.86
10	2.55
20	2.30
30	2.04
40	1.73
50	1.47

2.4 Soundness test

The soundness test was carried out in accordance BS 4550: Part 2: 1970 test procedures [6]. The results of the test are as given in Table-5.

Table-5. Results of Soundness Test.

DR contents (%)	**Average expansion** (mm)
0	6.0
10	4.5
20	3.0
30	0.0
40	0.0
50	0.0

3. ANALYSIS AND DISCUSSION OF RESULTS

3.1 The main compounds of cement

The effect of DR on the main compounds of cement is illustrated in Figure-1.

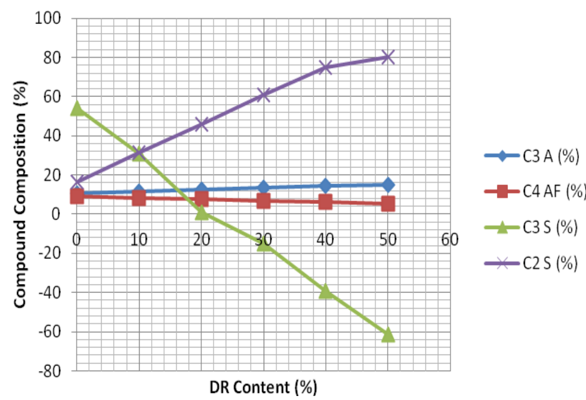

Figure-1. Effect of DR on the compound composition of cement.

The percentage of tricalcium aluminate (C_3A) increases as the DR content increases. This is because, in the calculation, the percentage of C_3A is dependent mainly on Al_2O_3 in the combined DR-cement mixture, which increases as the DR content increases.

The percentage of tetracalcium aluminoferrite (C_4AF) decreases as the DR content increases because it is dependent mainly on Fe_2O_3 in the combined DR-cement which also decreased as the DR content increases.

The composition of tricalcium silicate (C_3S) decreases as the DR content increases but becomes zero at a DR content of 22.48 percent, beyond this value of DR, C_3S seems not to exist at all as indicated by the negative values obtained. This phenomenon can be explained from the fact that C_3S is dependent mainly on the percentage of CaO. As the DR content with CaO percentage of 7.84 increases while cement with 63% of CaO reduces, the resulting CaO percentage in the mixture reduces and even reduced by half of the amount required in normal cement at DR content of 50%.

The percentage of dicalcium silicate (C_2S) on the other hand increases as the DR content increases because

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it is dependent on C_3S which reduction increased the percentage of C_2S.

3.2 Setting times

The results of the setting times test illustrated in Figure-2 shows that the 'Ashaka' brand of the ordinary Portland cement used has an initial setting time of 105 minutes and a final setting time of 183 minutes which met the standard values given by BS 12: 1978 [8] and NIS II: 1974 [9]. The standard values are 45 minutes minimum and 6000 minutes maximum for initial and final setting times, respectively.

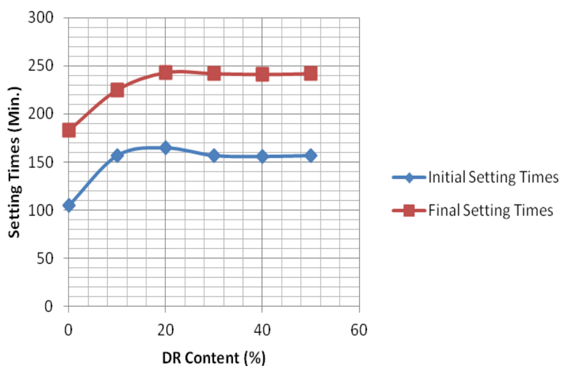

Figure-2. Effects of DR on setting times of cement.

Both the initial and final setting times of the DR-cement pastes increases with increase in DR contents up to 20% and then became almost constant at higher DR contents.

The substitution of DR by cement increases the setting times of cement because of the following reasons: Setting is as a result of selective hydration of cement compounds, C_3A and C_3S: C_3S sets first because the gypsum added to cement during manufacturing delays the setting of C_3A. C_2S on the other hand sets in more gradual manner than C_3S [10]. The substitution of DR with some part of cement increases the percentage composition of C_3A which hydrates more rapidly than C_2S and for the fact that C_2S that sets gradually is decreased it becomes imperative that as the DR content increases, the setting times of the mixtures will increase. Again, since C_4AF in the DR-cement mixture, which may accelerate the hydration of the silicates (C_3S and C_2S) [10], decreases with the substitution of DR with some part of the cement, one would again expect delay in the setting of the mixture.

3.3 Drying shrinkage

The effect of DR on the drying shrinkage of cement given in Table-4 is illustrated in Figure-3.

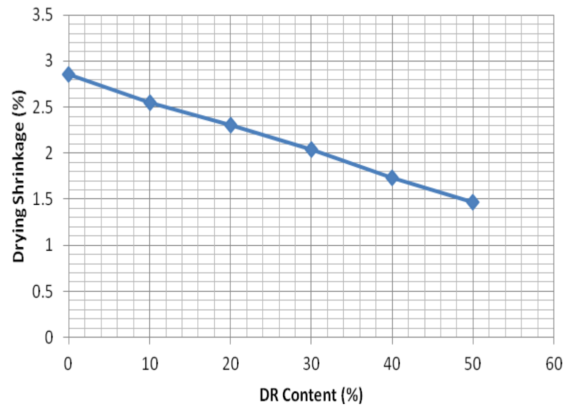

Figure-3. Effects of DR on the drying Shrinkage of Cement

From figure-3, it could be seen that the drying shrinkage of cement decreases as the DR content increases which means that DR can be used as a partial replacement of cement to reduce drying shrinkage.

3.4 Soundness

The influence of DR on the soundness of cement presented in Table-5 is illustrated in Figure-4.

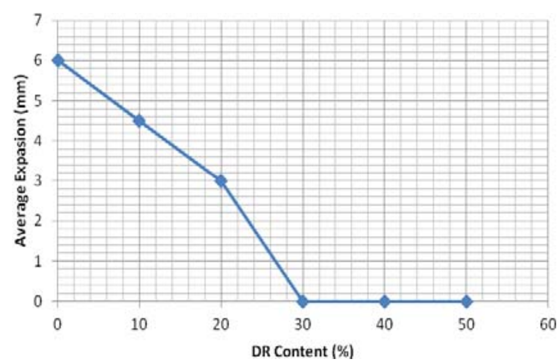

Figure-4. Effects of DR on soundness of cement

When DR is used as a partial replacement of cement, the soundness of the mixture improves. That is to say that DR is capable of removing unsoundness in cement. As the percentage replacement of DR increases, the soundness of the mixture increases, this means that the expansion due to unsoundness of cement reduces in proportion with the katsi content and even reduced to zero at katsi content above 20%.

4. CONCLUSIONS AND RECOMMENDATION

From the foregoing analysis and discussions of the results of the various tests carried out to find the effect of dye residue on some properties of cement, the following conclusions and recommendations are eminent.

On the main compound of cement, it was found that the use of dye residue as a partial replacement of cement increases the percentage composition of tricalcium aluminate (C_3A), and dicalcium silicate (C_2S) in the resulting mixture but decreases that of tetracalcium aluminoferrite (C_4AF), and tricalcium silicate (C_3S) in the mixture.

The initial and final setting times of the Ashaka brand of the Portland cement used in the research is 105 minutes and 183 minutes respectively. The use of dye residue as a partial replacement of cement increases both the initial and final setting times of the DR-cement mixtures up to 20 percent dye residue contents and then become almost constant at higher dye residue contents.

The use of dye residue as a partial replacement of cement is effective in reducing the drying shrinkage of the resulting DR-cement mixtures.

When dye residue is used as a partial replacement of cement the soundness of the DR-cement mixture improves. That is to say that dye residue is capable of removing unsoundness in cement.

Based on the positive performance of dye residue used as a partial replacement of cement, its use is highly recommended where there is the need to reduce drying shrinkage, or to remove unsoundness due to expansion of cement, or to cause delay in the setting of cement, or a combination of the above. 20% dye residue is recommended for best results.

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APPENDIX I: BOGUE'S EQUATION

Bogue's equations for the percentages of the main compounds in katsi-cement are given below: the terms in brackets represent the percentage of the given oxide in the total weight of katsi and cement.

$C_3S = 4.07\ (CaO) - 7.60\ (SiO_2) - 6.72\ (Al_2O_3) - 1.43\ (Fe_2O_3) - 2.85\ (S0_3)$

$C_2S = 2.87\ (SiO_2) - 0.754\ (C_3S)$

$C_3A = 2.65(Al_2O_3) - 1.69(Fe_2O_3)$

$C_4AF = 3.04(Fe_2O_3)$