IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 13, Issue 3 Ver. VII (May- Jun. 2016), PP 66-72
www.iosrjournals.org

Evaluation of the Strength Properties of Concrete Produced with Seasonal Change Alternative Surface Water in the Savannah Ecological Zone

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Abstract: *Water from alternative surface sources such as rivers and dams are commonly used for concrete production in most communities in the savannah ecological zone due to inadequate accessibility to tap or fresh water sources. However, the doubtful quality of these water sources for domestic and industrial use due to the impact of the harmattan and human activities especially during the dry season has been reported. In this paper, the chemical composition/content of river and dam water in the rain season were analyzed and compared with that of the dry season. The chemical contents in the water samples were extremely high in the dry season and low in the rain season. The effect of these water samples on setting time in the rain and dry seasons were examined. Setting times were high in all cases in the rain season and low in the dry season. Four concrete cubes were made for each water type in which three cubes were randomly chosen from each water type and tested for compressive strength at three stages of curing ages (7, 14 and 28 days) in the rain season. The test was repeated in the dry harmattan season. From the results, compressive strength was high in all cases in the rain season than in the dry season. Cubes made with river water obtained the highest compressive strength in the rain season test, an increase of 13% over that of tap water. In the dry season test, tap water cubes obtained the highest strength with a marginal increase of 4% over that of river water. Dam water cubes obtained the lowest strength in all cases.*

Keywords: *Surface water, Rain season, Dry season, Setting time, Compressive strength*

I. Introduction

Various concepts exist as to what constitute concrete as a building material. In terms of strength and durability, concrete is described as a mixture of Portland cement, aggregates and water, in addition, admixtures are incorporated to impart certain characteristics, and reinforcement is used to increase tensile strength [1] and [2]. In material terms, three components of concrete have been identified as Portland cement, aggregates and water mixed together and cast to take the shape and texture of its mould or formwork, on site, and allowed to harden under controlled conditions [3] and [4]. Previous studies on concrete work and production point out that given a proper gradation of satisfactory aggregates, the strength and durability of concrete is primarily dependent on the amount of cement and quality of water used in the mix [3], [5] and [6].

The importance of quality water for concrete production and water availability for both domestic and construction purposes has been documented. Findings in previous works recommended that, to achieve the required workability and strength of concrete in both its fresh and hardened state, the water used for mixing and curing needs to be of appropriate quality, that is, it should be free from impurities such as suspended solids, organic matter and salts which may adversely affect the setting, hardening, strength and durability of the concrete [7] and [2]. It has also been found that the chemical constituents present in water may actively participate in the chemical reactions and thus affect the setting, hardening and strength development of the concrete [8].

While some studies reported that water is the most important and least expensive ingredient of concrete [4], others studies on continental water quality reported that most of the fresh water that is needed for domestic and construction purposes is locked up as ice, mainly in the polar ice caps, thereby leaving relatively little surface or subsurface water for potential fresh water sources [9]. Much of the water on and in the continents is not strictly fresh, even rain water, contain dissolved chemicals of various kinds [10], and [11]. The possible utilization of brackish water from doubtful sources in areas where it may be difficult to obtain sufficient quantities of fresh water for concrete production had been documented. For instance, some material engineers had reported that brackish and doubtful surface water from rivers, streams, dams, ponds, sea and even treated effluents are being used for concrete production in most arid and drought affected regions [8].

The impact of water on concrete strength has been studied. Previous experimental works on concrete production observed that water is the chemical means by which cement used in concrete production is converted from a powder into a hardened material and strength and durability, and as such the water needs to be of appropriate quality [11]. Other experimenters on concrete production also found that the setting time and compressive strength of concrete are mostly affected by the water type used [12], [13] and [8]. These were supported by the recent observations of other researchers in the arid regions, who studied the effect of the Nile river water, ground water and sea water on concrete and found that the setting time was reduced by 4% with the use of the Nile river water and 25% with the ground and sea water when compared with tap water [14].

Though the search for alternative surface water from doubtful sources for concrete production is widespread, the studies are concentrated in countries in the arid regions such as Egypt, Qatar and Dubai. However, the savannah ecological zone that stretches across a number of countries in West Africa, including Ghana, is also one of such regions with low rainfall pattern and prolong dry season that affect the quality and availability of water all year round. The Ghana Statistical Service reported that 54% of Ghana's landmass is occupied by the savannah vegetation [15]. The report states that the rainfall pattern in the area is monomodal and ranges between 100cm and 115cm per annum starting from April and ends in October with high temperatures varying from 36 degrees Celsius in March to 27 degrees Celsius in August. The area comes under the strong influence of the harmattan winds which is very dry and as a result, humidity may be as low as 10 – 20% during the dry season [16].

The effect of the dry harmattan season on the quality and availability of surface water in the area for domestic and commercial purposes has been studied. It has been reported that ash produced by bush burning during the dry season increases nutrients such as calcium, magnesium, potassium, phosphate, chloride and sulphates which leach to increase the acidity of soil and water bodies [17]. The Ghana Environmental Protection Agency also indicated that the quality of surface water is further worsened by animal wastes especially cattle which compete with human beings for the little available surface water during the dry season [18]. This notwithstanding, there is no service record of the quality levels and suitability of these surface water in the rain season and dry season and the effect in each case on concrete strength achievement. It is against this backdrop that an attempt is made in this paper to study the chemical composition/content of river and dam water in both rain and dry seasons and the effect on concrete strength. The setting time of cement test blocks and compressive strength of concrete cubes made with these water samples in the rain and dry seasons are determined and compared to that of tap water (control water).

II. Materials And Methods

2.1. Materials Used

Three types of water samples were taken from tap, river and dam water sources in the Wa Municipal in the Upper West Region of Ghana. The tap water was obtained from the Ghana Water Company Limited (GWCL). The river water was gotten from the Black Volta which runs along the Ghana-Burkina Fasso border at Wechau and the dam water obtained from the "Wadea" dam, all in the Wa Municipality. The aggregates used were river sand and stones of nominal maximum size of up to 30mm obtained naturally. The cement used was a commercially ordinary Portland cement brand conforming to BS 12: 1996 specifications for Portland cement [19] produced and marketed in Ghana as "Ghacem".

2.1.2. Water Chemical Analysis

Testing of water plays an important role in controlling the quality of cement concrete. The quality of water is susceptible to change due to physical, chemical or biological reactions which may take place a particular season, hence the need for this test [7]. Mean values of the chemical composition and contents of the tap water, used in this study as the control water sample was readily provided by the Ghana Water Company Limited (GWCL) while that of the river and dam water used as the experimental water samples were analyzed in the laboratory in accordance with BS 1328 method of testing water [20]. Water samples were collected from midstream and midpoint of the river and dam water respectively at the beginning, middle and later part of the rain season, analyzed and the mean values for the rain season recorded. The testing procedure was repeated at the beginning, middle and later part of the dry season, and the dry season mean values recoded as well.

2.1.3. Aggregates Characteristics

The aggregate provides for about 75% of the body of concrete. It has been recommended that proper gradation of satisfactory aggregate is important since their physical, thermal and chemical properties greatly affect the performance of the concrete [2]. The quality and appropriateness of the natural aggregates used were studied at the Wa Polytechnic Building Technology laboratory in accordance with BS 812 specifications for testing aggregates [21]. The following characteristics were determined; specific gravity, water absorption, fineness modulus, abrasion, flakiness index and elongation index.

2.1.4. Setting Time and Compressive Strength

Limits and guidelines for certain chemical compositions and contents in water for mixing concrete have been established and set out in standard codes in order to produce concrete with the desired strength. The BS 1328 and ASTM 1602M – 06 codes maintained that the principal considerations on the quality of water are those related to the effect on setting time and compressive strength [20] and [22]. The codes recommend that the suitability of doubtful water should be determined by comparing the setting time of cement test blocks and the compressive strength of concrete cubes using the doubtful water in question with those obtained by using good water, preferably tap water or water fit for drinking. The initial setting time of the cement test block made with the water being tested shall not be less than 30 minutes and shall not differ by more than ±30 minutes from the initial setting time of the control cement test block prepared from tap or fresh water. The mean 28 day compressive strength of at least three cubes prepared with the water being tested shall not be less than 90% of the mean of strength of three similar cubes prepared with tap or fresh water.

Standard consistency test was first performed to get a paste of normal consistency for the setting time test using the Vicat needle apparatus in conformity with BS 4550 – 3.5 specifications for the determination of standard consistency [23]. The amount of each water type necessary for the standard consistency were obtained and used to prepare neat cement test blocks for the initial and final setting times in accordance with BS 4550 – 3.6 specifications for setting time test [23]. The initial setting time and final setting time were studied using the initial set needle and final set needle respectively in the Vicat apparatus.

The preparation of the cubes for the compressive strength test was done in line with BS 1881 – 125: 1986 specifications [24]. The materials were batched by mass and prepared with a water/cement ratio of 0.65. The sand and cement were first mixed by hand in a clean head pan until they were completely blended before the stones were added. The mixing continued until the stones were evenly spread in the mix. Water was then added in two phases amid continuous mixing to ensure that the needed consistency was achieved. Enough moulds were available in the laboratory to ensure simultaneous casting of all the cubes of size 150 x 150 x 150mm in the same mix, in the same day. This prevented discrepancies such as variations in mix proportion, water content, temperature and compaction, which might have occurred if more than one mix was needed per casting. The cubes were removed from the moulds the next day and submerged in their respective water samples for curing. Three cubes from each water type were randomly removed from the curing water after 7, 14 and 28 days of submission and tested for the 7, 14 and 28 days compressive strength using the compression testing machine shown in Fig 1.

Figure 1: Compression machine used for the cube crushing test

III. Results And Discussions

3.1. Water Samples

The chemical composition and degree of concentrations in water affects the water quality for concrete production. Some of the chemical compounds are harmless no matter their concentrations while others are harmful even if their concentration is very minimal [25]. The chemical analysis results of the water samples used for the study in the rain season and the dry season are presented in Table 1.

Table 1: Water Samples Analytical Test Report

Parameters	BS Limits	Tap water	Rain Season Water		Dry Season Water	
			River	**Dam**	**River**	**Dam**
TDS	2000mg/L	82	348	981	1350	2460
pH	6.0 – 8.0	6.04	6.59	6.92	7.60	8.90
Chloride	500mg/L	3.4	5.3	21.1	19.6	620
Sulphate	1000mg/L	92	132	347	332	745
Total iron	3mg/L	0	0	0.1	0.9	2.10
Aluminium	0.2mg/L	0	0.01	0.03	0.3	1.80
Calcium	80ppm	6.3	4.7	17	8.10	37.2
Magnesium	80ppm	0	1.94	2.90	3.8	4.9
Turbidity	15FTU	1.1	3.6	4.70	5.1	21
Alkalinity	1000mg/L	61	126	648	598	1130

3.2. .Aggregate Characteristics

The characteristics of the aggregates used were studied and compared with BS Standards. The results of the various tests conducted are presented in Table 2.

Table 2: Characteristics of Aggregate Used

Test Conducted	Coarse Aggregate		Fine Aggregate	
	BS Limits	**Test Results**	**BS Limits**	**Test Results**
Bulk specific gravity	2.6 – 2.75	2.65	2.6 – 2.75	2.66
Apparent S. gravity	2.6 – 2.75	2.74	--------	-------
Water absorption	20% maximum	2%	20% maximum	19.9%
Fineness modulus	5.5 – 8.0	7.1	2.0 – 3.5	3.26
Abrasion	40% maximum	13.6%	--------	--------
Flakiness index	15% maximum	11.6%	---------	--------
Elongation index	10% maximum	9.3%	---------	--------

3.3. Setting Time

The results of the initial and final setting times are given in Table 3 and Fig 2. Setting times are low in the rain season than the dry season. This may be due to the high humidity and low temperatures in the rain season. Tap water retarded setting in the dry season than the others while river water also retarded setting in the rain season than the others. This may be due to the low calcium content in tap water in the dry season than in river water and vice versa. Calcium in water affects setting times, the higher the calcium content, the more the setting time and the lower the calcium content the less the setting time required [25].

Table 3: Results of Setting Time

Water used for test block	Initial Setting Time (minutes)		Final Setting Time (minutes)	
	Rain Season	Dry Season	Rain Season	Dry Season
Tap water	134	122	382	330
River water	157	105	411	293
Dam water	110	90	315	261

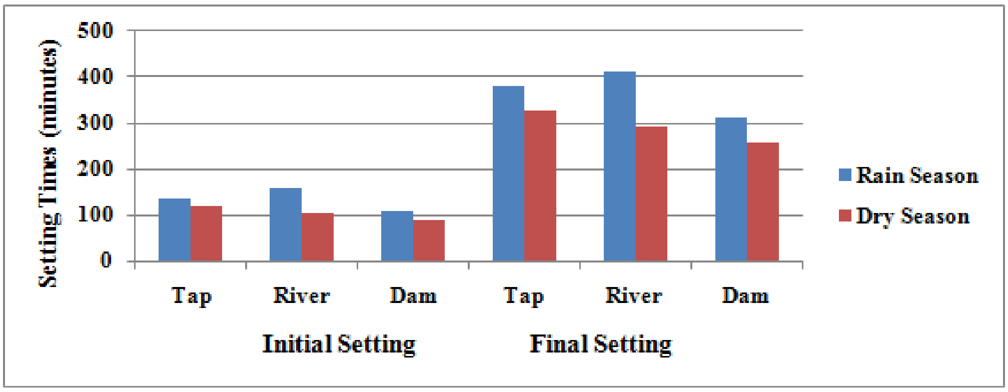

Figure 2: Type of water and setting time by season

3.4. Compressive Strength – Rain Season

The compressive strength results of cubes made with tap, river and dam water samples in the rain season are given in Table 4 and the plots of variations of strength with curing age shown in Fig 3. Compressive strength achievement at the 7, 14 and 28 curing and testing ages increased steadily for all the water types. Tap (control) water cubes obtained a maximum strength of 23.19N/mm^2 at the 28 days curing age while river water cubes had a maximum of 26.15N/mm^2, representing a 13% increase of strength over the tap water cubes. Though dam water obtained the lowest strength of 21.91N/mm^2, the decrease in terms of percentage is not less than 90% of the strength of the tap (control) water cubes. .

Table 4: Compressive Strength of Cubes in the Rain Season (N/mm^2)

Water source for cubes	7 days		14 days		28 days	
	Values	**Mean**	**Values**	**Mean**	**Values**	**Mean**
Tap water	18.17 18.52 18.01	18.23	19.41 20.03 19.71	19.72	23.17 23.41 22.98	23.19
River water	19.81 19.52 19.97	19.76	25.04 24.68 24.31	24.68	26.41 25.93 26.11	26.15
Dam water	16.81 17.37 17.86	17.35	18.31 18.02 18.22	18.18	21.91 22.23 21.60	21.91

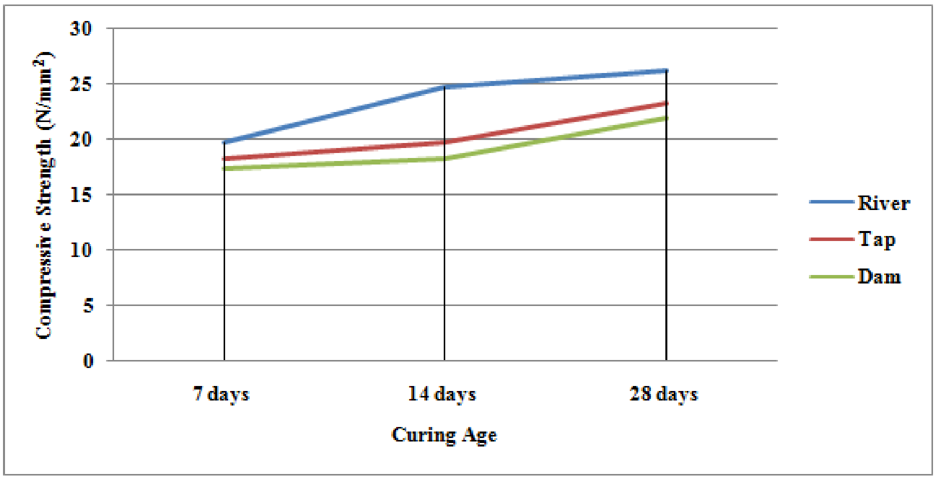

Figure 3: Variation of strength with curing and testing age – Rain season

3.5. Compressive Strength – Dry Season

The results of the dry season compressive strength of cubes prepared with tap, river and dam water samples are shown in Table 5 and the plot of variation of strength with curing and testing age given in Fig 4. Again, there is a steady increase of strength from the minimum curing age of 7 days to the maximum curing age of 28 days for all types of the water used. At the 28 days curing age, tap water obtained the highest maximum strength of 18.98N/mm^2, followed marginally by river water 18.15N/mm^2 and finally dam water 16.67N/mm^2. In this test, the compressive strength of river water cubes were reduced by 4% and the dam water cubes reduced by 11% when compared to the tap water. The percentage decrease of the compressive strength of river water cubes is not less than 90% of the strength of tap (control) water cubes hence the suitability of river water for concrete production in the dry season is not doubtful. However, the percentage decrease of the strength of dam water cubes is greater than 90% of the strength of tap (control) water cubes. The results therefore, suggest that dam water in the dry season may contain excessive amounts of strength reducing compounds than that of the river water.

Table 5: Compressive Strength of Cubes in the Dry Season 9N/mm^2)

Water source for cubes	7 days		14 days		28 days	
	Values	Mean	Values	Mean	Values	Mean
Tap water	17.24 16.98 17.38	17.20	18.67 18.62 18.89	18.73	19.02 18.76 19.16	18.98
River water	16.40 16.97 16.82	16.73	17.88 18.11 17.52	17.84	18.28 18.00 18.16	18.15
Dam water	14.40 13.60 12.80	13.60	15.11 15.73 14.89	15.24	16.60 16.34 17.08	16.67

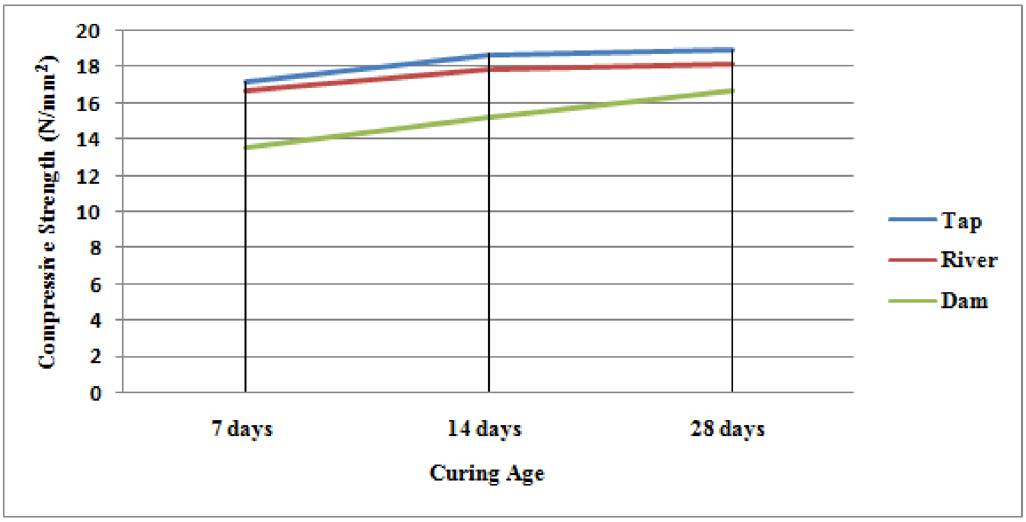

Figure 4: Variation of strength curing and testing age – Dry season

Notwithstanding the closeness of the mean values in both cases, a One-Way Analysis of Variance (ANOVA) at a confidence level of 95% was used purposely to determine whether there was any statistically significant difference among the water types in each curing age in each season. From Table 6, it could be noticed that there were large variations between the water types used compared to the variations within the water types. The results thus, confirm that the water type used influences the compressive strength of the cubes.

Table 6: Summary of ANOVA Results of Compressive Strength Test (N/mm^2)

	Rain Season			Dry Season		
	Curing and Testing Age (Days)			Curing and Testing Age (Days)		
	7	14	28	7	14	28
N	9	9	9	9	9	9
Missing	0	0	0	0	0	0
F – value	34.058	412.387	207.885	44.848	88.650	80.826
P – value	0.001	0.000	0.000	0.000	0.000	0.000

Significant at 0.05 (P – value)

IV. Conclusions

In Ghana, the assessment of surface water chemical contents between the rain and dry seasons for concrete production in the northern savannah ecological zone which climatic and environmental characteristics are different from that of the southern tropical rain forest have not been done. In this study, the rain/dry seasonal variation chemical compounds of two most commonly used surface water for concrete making in the study area has been assessed and their effect on concrete strength in the rain and dry seasons investigated.

The study concludes that the two water samples tested (river and dam) have proven to be undoubtedly suitable for concrete making in all the seasons except dam water which needs to be tested in the dry season before used or otherwise. Though tap water delays setting in the dry season than river and dam water due to its low calcium content in that season, it achieved the maximum compressive strength than the two water tested. In contrast, the calcium content in river water was low in the rain season and this retarded the setting and improved the compressive strength more than the other water samples. To produce concrete with higher compressive strength in the savannah zone, tap water though costly should be used in the dry season and river water used in the rain

The river water cubes obtained the highest maximum compressive strength at all the three curing ages in the rain season despite the high concentrations of some chemical compounds in it than the control (tap) water. This then suggests that some chemicals despite their high levels of concentrations in the river water in the rain season may be of the optimum amounts to produced concrete of higher compressive strength than tap water which has lower chemical contents. Therefore, further experimental research study is required to establish optimum contents of the individual chemicals in the water suitable to produce concrete with higher compressive strengths in all the seasons.

Acknowledgement

The effort of Gbeddy Alexander, a past student of the Department of Building Technology and Estate management, Wa Polytechnic, Wa, Ghana, is acknowledged for the preliminary role played in this experimental research. The kind support and co-operation extended by the laboratory technicians, of the Ghana Water Company Limited water chemical analysis laboratory, Wa and the Building Technology and Estate Management Department laboratory of the Wa Polytechnic, in all the endeavors of the authors is recorded with deep sense of gratitude.

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