EVALUATING THE EFFECTS OF DIFFERENT CONTAMINATED WATER ON COMPRESSIVE STRENGTH OF CONCRETE

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ABSTRACT

In this paper, the evaluation of the effects of different contaminated water on the compressive strength of concrete was investigated. It analyzed the effects of impurities such as salt and detergent in water on the compressive strength of concrete. The samples of contaminated water from three different sources (Tap water, salty water and detergent water) were collected and used as mixing water to form concrete paste. 150 x 150 x 150mm cube specimens were cast, 6-each for salt water, detergent water and potable water with water-cement ratio of 0.45 and mix proportioning of 1:2:5. The compressive strength test was carried out on the cubes and the results revealed that the applied crushing load (KN) of each of the three specimens differs at 28 days significantly. The average compressive strength of portable water cubes was 16.70N/mm^2, salty cubes was 13.60N/mm^2 while that of detergent cubes was 15.60N/mm^2. It is concluded that salt and detergent in mixing water have significant effects on the compressive strength of concrete and detergent water have better performance compare to saline. Only in the absence of tap water, contaminated water can be used as mixing water. It is then recommended that further research on the strength properties of concrete should be consider on the uses of the contaminated water.

Keywords: Concrete, Cement, Aggregate, Compressive Strength, Impurities and Mixing Water.

INTRODUCTION

Concrete is a composite material composed of cement, aggregate (generally a coarse aggregate made of gravels or crushed rocks such as limestone or granite plus a fine aggregate such as sand) water and admixtures. Concrete solidifies and hardens after mixing with water as a result of a chemical process known as hydration. Water is the key ingredient which involves in a chemical reaction with cement (hydration) and forms a paste that binds aggregate together. Hydration is a chemical reaction in which the major compounds in cement form chemical bonds with water molecules to become hydrates or hydration products. The water needs to be pure in order to prevent side reactions from occurring which may weaken the concrete or otherwise interfere with the hydration process. The role of water is important because the water- cement-ratio is the most critical factor in the production of "perfect" concrete. If water is too much, it reduces concrete strength, while on the other hand if it's too little it makes it unworkable. Impurities and deleterious substances which are largely introduced from water used in mixing concrete are likely to interfere with the process of hydration, preventing effective bond between the aggregates and matrix. Thus the quantity, quality and proportioning of concrete mixture ingredients help to achieve durable and strong concrete because proportioning of the mixture constituents influences the availability of cementing paste and voids in the concrete aggregates to ensure improved strength characteristics of the concrete. The proportioning is expected to ensure that the material consumption is optimized i.e., the right quality and quantity of the mixture ingredients to obtain desired concrete strength and durability property is utilized (Al-Gahtani et al. 1998; Alaneme et al. 2021a).

The strength and durability of concrete is reduced due to the presence of chemical impurities in water. Most of the specifications recommended the use of potable water for making concrete. A practical solution would be tests for time of set and strength of concrete between the water under consideration and the water of proven quality. When non-potable water is used which possess dissolved salts, grease and oil; it is important to assess the level of impurities to ensure the water do not inhibit concrete performance. Several research studies had been successfully carried out in order to evaluate the effects of water quality and its inherent properties on the mechanical strength characteristics of concrete produced.

This study explored the scenario of concrete mix and determines the consequent effects on concrete strength characteristics. Concrete were casted using different water like salty water and detergent water while tap water was used as a control experiment. A mix ratio of 1:2:4 was adopted for the experiment. Characteristics observed for a period of 7 and 28 days. Both the tap water, salty water and detergent water samples were tested for compressive strength in UTM machine. Compressive strength is measured at 7 and 28 days. On 28 day tap water sample has 16.7N/mm^2 as against 13.6N/mm^2 and 15.6N/mm^2 recorded for salty water and detergent water samples. This research aims to investigate the effects of different contaminated water on the compressive strength of concrete. Then, tests were conducted on concrete and the attention was focused on different water containing salt and detergent for concrete mix.

LITERATURE REVIEW

Researches Involving Contaminated Water.

Concrete is one of the most durable construction material and cement is one of the most energy intensive structural materials in concrete. After thoroughly mixing the concrete ingredients with water, it is placed in formwork and allowed to stiffen with time. Curing starts after the concrete's surface exposed to moisture have hardened to resist marring; it serves as an extension of the cement hydration so that the strength development of the concrete is enhanced. Hydration causes rapid gain in strength from 7 to 28 days but this increment rate becomes slower for longer hydration periods (Zeyad 2017; Alaneme et al. 2021).

The principal considerations on the quality of mixing water are related to performance in fresh as well as harden state. The quality of the water plays an important role in the preparation of concrete. Impurities in water may interfere with the setting of the cement and may adversely affect the strength and durability of the concrete also. The chemical constituents present in water may actively participate in the chemical reactions and thus affect the setting, hardening and strength development of concrete. In addition to that, health issues related to the safe handling of such water must be considered. The suitability of water can be identified from past service records or tested to performance limits such as setting times and compressive strength and durability test. Limits are specified for mixing water with their constituents such as total alkalis, chloride sulfate etc. Biological treatment and pathogen reductions are also ensure safety in handling of reclaimed water and saline water. The quantity of water in the mix plays a vital role on the strength of the concrete. Some water which have adverse effect on hardened concrete. Sometimes may not be harmless or even beneficial during mixing, so clear distinction should be made between the effect on hardened concrete and the quality of mixing water.

Water used in the mixing process impacts the workability properties of concrete and determines the required water-cementitious content ratio which affects the durability and strength properties of the concrete mix. Apart from the quantity of water used, its quality in terms of absence of impurities has significant effect on the durability, strength workability, and setting time characteristics of the concrete produced in both fresh and hardened state (Alaneme & Mbadike 2021).

Recommendations from Standards Regarding Mixing Water.

EN 1008 presents recommendations for the requirements of water that is considered suitable for concrete mixing which conforms with EN 206-1 and describes methods for assessing its suitability. This standard considers the use of water from different sources such as potable water, water recovered from processes in the concrete industry, water from underground sources, natural surface and industrial waste water for reinforced concrete, and seawater or brackish water for production of concrete without reinforcement or with other embedded metal. The requirements for water are summarized in the standard comprising preliminary assessment, chemical properties, setting time and strength development. Standard provides specific requirements for the use of water recovered from processes in the concrete industry. It further stated Sewage water is considered not suitable for production of concrete.

ASTM C94 recommended that, mixing water comprises, water and ice added to the batch, water occurring as surface moisture on the aggregates and, in the case of truck mixers, any wash water retained in the drum for use in the next batch of concrete. Water shall conform to ASTM C1602, which defines sources of water and provides requirements and testing frequencies for qualifying individual or combined water sources. ASTM C94 permits the use of non-potable water or water from concrete production operation in ready mix concrete plant, the limits qualified to meet the requirements and optional limits summarized in code. The levels of impurities permitted in the wash water should be below the maximum concentration criteria provided in standard.

IS 3025 recommended that, testing of water play an important role in controlling the quality of cement concrete work. Systematic testing of the water helps to achieve higher efficiency of cement concrete and greater assurance of the performance in regard to both strength and durability. Water is susceptible to being changed due to physical, chemical or biological reactions which may take place between at the time of sampling and analyzing. Hence it is necessary to test water before used for cement concrete production. Samples should be collected, as far as possible, from midstream at mid depth, Sites should be selected such that marginal changes in water observed with naked eyes, where there are major river discharges or obstructions occurred, sample from 100m away of the discharge point in downstream side is taken for small streams.

MATERIALS AND METHOD

Materials

Concrete cubes were prepared with standard metal moulds of size of 150mm^3 by volume. The cement content used were weighed using weighting balance. Standard sieves were used for the conduct of sieve analysis for the aggregate and Ordinary Portland cement (OPC) meeting the requirements of BS EN197-1 (2001) was used in the preparation of the concrete. Fine aggregate (sand) which passes sieve No. 4 and retain in sieve No 2, which has the water absorption of 0.8% and a specific gravity of 2.59 was used and Coarse aggregate used was that which passes through sieve No. 4 and retain in sieve No. 3. The particles are greater than 4.75mm, but generally range between 9.5mm to 37.5mm in diameter. They are in conformity with the grading requirements of BS EN (1999). Portable water is a water which is suitable for consumption by human. In case of this studies, the portable water used for concrete making is from tap water. Salty water is water that is mixed with salt and in study, water mix with salt was used as a mixing water for the production concrete. Detergent water is water that is mixed with detergent and detergent-water was used also for the concrete specimens.

Methods

The Concrete were prepared according to BS EN12390-2. A mix proportion of 1:2:5 with w/c ratio of 0.45 and method of batching by weight were adopted for the concrete production. A total of 18 concrete specimens of 150mm x 150mm x 150mm were cast in the laboratory with different sources of water (Tap water, salty water and detergent water) for the mixing of concrete samples. The harden concrete cubes were demoulded after 24 hrs. and immersed in a curing tank immediately at temperature of 25°C ± 2°C. The concrete specimens were left in the tank until the prescribed age ranging from 7 and 28 days was reached. The specimens were cured in accordance with BS EN 12390-2. the specimens were removed from the curing tank after 7days and 28days. The concrete cubes were air-dried and visual cross examination were conduct to assessed the physical changes before the compressive strength test were conducted and recorded.

The water samples used for the research work were obtained from the following sources and were labeled as follows;

(i) Cubes cast with portable water are referred to as Sample A1, A2 and A3
(ii) Cubes cast with Salty water are referred to as Sample B1, B2 and B3
(iii) Cubes cast with Detergent water which serve as the control sample are referred to as Sample C1, C2 and C3.

RESULTS AND DISCUSSION

A. Sieve Analysis

The sieve analysis of fine aggregate (river sand) used for the casting of concrete cubes was carried out and the result is shown in table 1. As seen in Table 1, only 12.1% of the fine aggregates passed the 0.15mm sieve size and by Unified Soil Classification System (USCS) the sample is classified as Sand Well-Graded.

Table 1: Sieve analysis

S/N	Sieve size (mm)	Mass of empty sieve (g)	Mass of sieve + sand (g)	Mass of sand retained (g)	% retained (g)	Cumulative % passing (g)	Cumulative % Retained (g)
1	4.75	403.3	404.8	1.5	0.7	99.3	0.7
2	2.36	332.1	386.6	54.5	23.9	75.4	24.6
3	1.18	331.1	344.0	12.9	5.7	69.7	30.3
4	0.6	282.4	332.1	49.7	21.8	47.9	52.1
5	0.3	268.2	309.9	41.7	18.3	29.6	70.4
6	0.15	302.4	342.3	39.9	17.5	12.1	87.9
7	Mould	282	309.4	27.4	12.1	0	100
Total				227.6			366
Fineness Modulus							3.7

(Source: Lab. Work, 2021)

B. Constituent of Salty Water.

Constituent of salty water used for casting concrete was collected for analysis before the beginning of the laboratory work and after the completion of the laboratory work and the results of the analysis were presented in Table 2, which shows that Na, Cl, Mg and Ca have reduction in result compare to K and SO_4 which has an increment after the laboratory work.

Table 2: Element Content of Salt Water.

Elements	Value obtained Before Lab. Work (mg/1)	Results obtained After Lab. Work (mg/1)
Sodium (Na)	788.50	341
Chlorine (Cl)	35400	2471
Magnesium (Mg)	427.49	263
Potassium (K)	107.70	181
Sulphate (SO_4)	56.38	57
Calcium (Ca)	2935.80	2400

(Source: Lab work, 2021)

C. Percentage Composition by mass of dissolve Compound.

The Chemical concentrations of the water samples for mixing concrete on the percentage composition are presented in Table 3 and it was observed that Sodium chloride (NaCl) have the optimal composition of compound.

Table 3: Percentage composition by mass of dissolve compound.

Compound	% composition
NaCl	42.3
$MgCl_2$	28.8
$CaC0_4$	1.9
K_2SO_4	2.4
$MgSO_4$	1.6

(Source: Lab work, 2021)

D. pH Test Result.

These water samples from the four water sources namely; the tap water, the salty water, and detergent water were taken to laboratory for analysis. The parameters monitored were presented in Table 4. Going by findings of Neville (1995) that pH range between 6.0 and 8.0 have no significant effect on the compressive strength of concrete. And according to BS314 8: methods of test for water for making concrete, the permissible limit of total dissolved solids (TDS) is 2000 ppm (part per million). it is clearly shown that the two water sample tested have their TDs within the acceptable limit. For other metallic ions shown as constituents of water used in the research work as shown in the table, they are all regarded as impurities as pure water is expected to contain only two elements, "Hydrogen and oxygen (with allowance for negligible amount of other non-deleterious elements).

Table 4: Shows the pH values of water samples

Samples ID (source)	pH	TDS (ppm)	K (ppm)	Na (ppm)	Mn (ppm)	Cu (ppm)	Zn (ppm)	Pb (ppm)
Salty water	7.2	110	7.60	4.8	0.50	0.20	0.09	0.30
Detergent water	6.9	140.	7.23	3.80	0.07	0.00	0.02	0.00

ppm = Part per million, TDS = Total dissolve solids.
(Source: Lab. Work, 2021)

E. Visual Examination of Hardened Concrete Cubes

Visual examination was conducted on the concrete cube specimens to determine if any strange physical appearance could be noticed. Specimens made from tap water (control) was normal in terms of colour; they had the normal grey colour of a good concrete. However, specimens produced with the saline and detergent water were seen to be light grew. The light grew colour found on the specimens produced by the use of impurities in water can be attributed to the colour of the impurities in water itself. Signs of efflorescence were not noticed on any of the specimens. This may be attributed to the fact that the MgCl content in the various water samples was relatively low considering the reference standard.

F. Compressive Strength Behavior

The compression strength is the capacity of a material or structure to withstand loads per cross sectional area. After the concrete cubes were cured at 28 days. At the end of the 7day and 28day curing age and cubes from each batch were taken for compressive strength tests according to BS1881: Part 116. The results of the average compressive strength of concrete cubes are recorded in Table 5. The weight of the cube (kg), applied load (kN), and crushing strength (N/mm^2) were all tested and known and the compressive strength were performed on the three types of concrete mixed with different source of water. As in table 5, the weight of the cubes varies significantly. As presented below, the applied load (kN) for each of the concrete cubes made with detergent differ and the applied load of each cube varies significantly. The applied load (KN) of cubes made with tap water has optimum value of Crushing Strength: 16.70N/mm^2. Thus, the performance of concrete strength decreases in compressive strength with a corresponding varying the source of water at 28days of curing.

Table 5: Compressive strength of concrete at the age of 28 days

Concrete mix	Mix Proportions	Cube Weight (Kg)	Applied Load (kN)	Crushing Strength (N/mm^2)	Average Crushing Strength (N/mm^2)	Exposure Periods (Days)
A1	1:2:5	8.4	407.30	15.90	16.70	7 - 28
A2	1:2:5	8.2	421.10	17.30		7 - 28
A3	1:2:5	8.1	389.40	16.90		7 - 28
B1	1:2:5	8.2	320.20	13.80	13.60	7 - 28
B2	1:2:5	7.9	345.60	12.90		7 - 28
B3	1:2:5	7.8	349.10	14.00		7 - 28
C1	1:2:5	7.9	318.71	16.30	15.60	7 - 28
C2	1:2:5	8.0	378.20	14.30		7 - 28
C3	1:2:5	8.3	372.40	16.10		7 - 28

(Source: Lab work, 2021)

CONCLUSIONS

The comparative study was carried out to investigate the effect of different contaminated water on mixing properties of concrete especially compressive strength. Based on the results from this study, the following conclusions were drawn.

i. Portable water or tap water is more favorable for mixing concrete without any significantly effect on the compressive strength.
ii. Different water sources contain different levels of impurities and these generally impacts significantly on the concrete strength.
iii. Regardless of the sources for mixing water, the compressive strength of concrete increases with increase in age or period.
iv. Concrete specimens made with salty water showed some change in color from dark to light grew as compared to other water sources.
v. Contaminated water affects the gain in strength of concrete when used for mixing and curing it increases the early strength gaining but ultimately the strength decreases.
vi. Contaminated water affects the rate of gain in strength of concrete when used for mixing, the strength of concrete made by using detergent and salty water is observed to be decreased by about 10% at 7 days compared to the strength of concrete made from portable water.
vii. There are slight differences in compressive strength values of concrete made using detergent and salty water.

REFERENCES

Alaneme, G.U. & Mbadike E.M. 2021. Optimisation of strength development of bentonite and palm bunch ash concrete using fuzzy logic. International Journal of Sustainable Engineering. DOI: 10.1080/19397038.2021.1929549.

Al-Gahtani, H.J., Abbasi, A.G.F. & Al-Amoudi, O.S.B. 1998. Concrete mixture design for hot weather: experimental and statistical analyses. Magazine of Concrete Research 50(2): 95–105.

ASTM C1602/C1602M-12. 2021. Standard specification for mixing water used in the production of hydraulic cement concrete.

ASTM C1602-06, Standard specification for mixing water used in the production of concrete.

ASTM C163, Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates, American.

British Standard Institution (1999). Tests for general properties of aggregates, BS EN 932, BSI, London.

British Standard Institution (2000). Testing hardened concrete, BS EN 12390: Parts 1-8, BSI, London.

British Standard Institution (2001). Composition, specification and conformity criteria for common cements, BS EN 197: Part1, BSI, London.

BS 1881: Part 116: Method for determination of compressive strength of concrete. British Standard Institute, London; 1983.

BS 3148- Methods of test for water for making concrete. British Standards Institute, London, United Kingdom, 1980.

EN 1008 Mixing water for concrete – specification for sampling, testing and assessing the suitability of water, including water recovered from processes in the concrete industry, as mixing water for concrete.

IS 3025(1-56 parts) ―Methods of sampling and test (physical and chemical) for water and wastewater. ASTM C-94 ―Standard Specification for Ready Mix Concrete-1996.

Zeyad, A.M. 2017. Effect of curing methods in hot weather on the properties of high-strength concretes. Journal of King Saud University–Engineering Sciences.