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EFFECT OF MIXING WATER QUALITY ON COMPRESSIVE STRENGTH OF CONCRETE

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ABSTRACT: Mixing water serves as a binding agent between cement and aggregates. Its addition to concrete ingredient results in plasticity of concrete at fresh stage. This paper presents an assessment on the effect of quality of mixing water on compressive strength of concrete using three different types of mixing water such as; drainage water, tap water and well water. A concrete of nominal mix 1:2:4 using w/c ratio of 0.6 was employed to produce concrete cubes of 150mmx150mmx150mm. Three sets of concrete were cast due to three mixing waters adopted. For each mixing water used in the concrete production, 9 cube samples were produced and three curing (hydration) periods were also adopted. These are 14, 21 and 28 days respectively. At each hydration period, three cubes were produced. However, a total of 27 cube samples were cast and tested for mechanical properties (i.e. compressive strength). Thus, at each stipulated curing period, the cube samples were removed from curing tanks and subjected to compressive strength test. The results of compressive strengths of concrete mixed with drainage water (CMD), concrete mixed with tap water (CMT) and concrete mixed with well water (CMW) from this study are 22.44N/mm^2, 27.07N/mm^2 and 23.64 N/mm^2 at 28 days. All the three results are within what is specified in BS 8110 (1997) (i.e. 20-40 N/mm^2). This indicated that the three mixing waters can be used from concrete mixes, but tap water which produced concrete with highest compressive strength is the most suitable mixing water. It was also revealed from this study that the densities of concrete in three categories of mixing water at 28 days concurred with Neville (1996) (i.e.2200-2600kg/m^3).
Keywords: compressive strength, concrete, cubes, curing period, mixing water

1.0 INRODUCTION

It is generally believed that water is life. However, water is as well very important in building construction especially in concrete production, block making, mixing of mortar (for plastering, rendering and screeding) etc. According to Gleick (1993) water is transparent fluid which forms world's streams, lakes, oceans and rain, and is the major constituents of the fluids of living things. He further argued that water is a chemical compound in which it molecule contains one oxygen and two hydrogen atoms that are connected by covalent bonds. And it is a liquid at standard ambient temperature, but it often co-exist on earth with it solid state, ice and gaseous state, steam (water vapour).

Water is the most important resource. Without water life is not possible. Water from various sources contains dissolved gases, minerals, organic and inorganic substance. When vapour is cooled, clouds and rain develop. Some of the rain percolates through the soil and into the underlying rocks. The water in the rocks is ground water, which moves slowly. Natural water contains metal ions. Water contains calcium, magnesium and their counter anion are called hard water. These metal ions are contained in river water, spring water, underground water (such as well water), lakes etc. Salami (2001) describes ground water as the simplest and usually most economical both to implement and to operate. Ground water is normally good in quality if not polluted it requires minimums treatment (Uchengbur, 1998). Water is essential element for every human being for personal consumption, cooking, growing crops, maintaining live stocks, personal hygiene, washing, industrial uses and other domestic activities. The qualities of the source vary and may be susceptible if they are not subject to any intense quality standard like pipe borne water.

Water in township drains originate from two sources such as; run off from precipitation and effluents from domestic or household waste water. In addition to the sources above, commercial and small medium scale, industrial outfits also contribute to drainage water within any metropolis.

Drainage water is not different from any other water supply and is always usable for some purpose within certain quality ranges. Also, drainage water from different locations and/or facilities will have different quality and characteristics (Dennis, 2014). When rain falls, the soil replenishes its water contents with the water contents with the water until its infiltration capacity is reached and then water tends to gather and subsequently flow into the drains or to join the surface water channel.

On the other hand, a well water or water well is an excavation or structure created in the ground by digging, driving, boring, or drilling to access ground water in underground aquifers. It's drawn by a pump, or using containers, such as bucket, that are raised mechanically or by hand. Well can vary greatly in depth, volume, and water quality. Well water typically contains more minerals in solution than surface water and may require treatment to soften the water (Wikpedia Encyclopedia, 2014).

Concrete is the most widely used construction materials worldwide. This is due to its versatility strength, durability, easy to make to any forms and shapes (Dadu, 2011). Mamman and Abdulsalam (2011) are also of the same opinion but further stated that concrete commonly made by mixing Portland cement with sand, crushed rock and water.

Arora and Bindra (2008) asserted that in building industry, concrete is mainly used for structural components such as foundations, columns, beams, slabs, staircase, lintel, shielding, water storage etc. And according to MCPDP (2014), concrete is a relatively new construction material to earth, stone, timber and steel. However, it is now the most widely used material for building and civil engineering construction.

In 2011 alone over 27 billion tones were used (in comparison to only about 0.7 billion used in 1993), this could be attributed to its abundant advantages such as, durability, fire resistance, affordability, strength and thermal insulation etc. (MCPDP,2014). Hence, care should be taken to ensure an adequacy in its production.

1.1 Mixing Water for Concrete

ACM (2014) posited that non-portable water and water resulting from concrete productions operations can be used as mixing water in concrete provided the acceptance criteria given in ASTM C 1602 are met. For instance, waste water from mixers, water collected in a basin as a result of storm water runoff at a concrete production facility or other water that contains quantities of concrete ingredients. The mixing water initiates hydration process (which is responsible for strength development), assists in workability (which enables concrete to be easily mixed, transported, placed and compacted), (MCPDP, 2014). Gibbons and Taha (2012) pointed out the fact that mixing water is combined with a cementations material and form a cement paste by the process of hydration. And that the cements paste glues the aggregates together fills voids within it and make it flow more freely.

The quality of the water plays a significant role in concrete mixes. The impurities in water may interfere with the setting of the cement, may adversely affect the strength of the concrete or cause staining of its surface, and may also lead to corrosion of the reinforcement (Neville, 2000). The quality of mixing water must be good and mixing water should be free from substance like clays, silts, oils, acids, alkalis, salts, sugars and sugar derivatives, organic matter and sewage. Generally, any material that can retard hydration process, affect durability of concrete or cause corrosion of embedded steel reinforcement should be avoided (MCPDP, 2014). As such, the suitability of water for mixing and curing purposes should be given special attention on building construction sites. Neville (2000), further stated that mixing water should not contain undesirable organic substance or inorganic constituents in excessive proportion. It has been proven in previous researches that low w/c ratio gives high comprehensive strength and the reverse is the case when the higher w/c ratio is adopted.

This paper reports the assessment of the effect of the quality of water used as mixing water on comprehensive strength of concrete with a view of asserting the best water for concrete mixes.

2.0 MATERIALS AND EXPERIMENTAL PROCEDURES

2.1 Materials

The materials used for the research work are ordinary Portland cement (OPC i.e Sokoto Cement), tap water, well water, drainage water. They nature and the quality of these materials were stated below:

- **Cement**: the type of cement used for this study was ordinary Portland cement. The cement name is Sokoto cement, produced by cement Company of Northern Nigeria in Kalambaina, Sokoto.
- **Sand:** sharp sand from river that has been air-dried was used. The sand was obtained from a river in Wammako local government area Sokoto state. The range size of the sand/fine aggregate is from 600micro - 4.75mm on the BS test sieve.
- **Gravel:** the coarse aggregates used for this study were crushed granite stone bought from a dealer behind male hostel of Sokoto Polytechnic of Sokoto State, Sokoto. The aggregates were sieved using standard sieves and the ones retained in both 10mm and 20mm sieves were used.
- **Tap Water:** tap water fit for drinking which has been treated by Sokoto State water board was used.
- **Well Water:** the well water used for this research was obtained at Arkilla, Wammakko Local Government area, Sokoto.

- **Drainage water:** drainage water was sourced at Mabera area in Sokoto South Local Government, Sokoto.

2.2 Experimental procedures

The concrete ingredients were batched, mixed and cast in laboratory of department of Building Technology, the Polytechnic of Sokoto State, Sokoto. Absolute volume of batching was used to produce concrete of nominal mix of 1:2:4 using w/c ratio of 0:6. The water-cement ratio selected was in accordance with Taylor (1977) cited in Garba and Zubairu (2002). A total of 27 cubes were cast for the experiment and 9 cubes were produced at each selected mixing water for the production. That is, 9 cubes were produced for tap water, well water and drainage water.

Each mould was cast in three layers and each layer was compacted and tapped 25 times as specified by BS 1881:108 (1983). It states that mould should be filled in three layers, each layers of concrete is compacted by vibrator or otherwise (manual method). Other relevant standard for the casting of fresh concrete was adhered to, such as, BS 1881:124 (1988) and BS 1881:125 (1986). After casting, the concrete samples were allowed for 24hours before the moulds were loosed and placed (immersed) in curing tank for the stipulated curing period. The curing period adopted for the research are; 14, 21 and 28 days respectively. At each curing period, three cubes were produced. However, after each stipulated curing days, the cubes were removed and subjected to compressive strength test. This was done in accordance with BS 1881:116 (1983) which specifies that the cube is placed with the platens of the testing machine, that is, the position of the cubes tested is at right angle to the position as cast.

3.0 RESULTS AND DISCUSSION

The results of the experiment carried out in this study were presented in tabular forms and charts as shown below. And these were clearly discussed accordingly.

Table 1: Compressive Strength of Concrete Mixed with Drainage (CMD)

S/N	Curing Period (Days)	Average Weigth (kg)	Average Density (Kg/m^3)	Average Volume (mm^3)	Area (mm^2)	Average crusihing Load (N)	Average Compressive Strength (N/mm^2)
1	14	7.90	2341	3375000	22500	311000	13.82
2	21	7.93	2350	3375000	22500	415000	18.44
3	28	7.74	2293	3375000	22500	505000	22.44

Source: Experimental Work (2013)

Table 2: Compressive Strength of Concrete Mixed with Tap Water (CMT)

S/N	Curing Period (Days)	Average Weight (Kg)	Average density (kg/m^3)	Average Volume (mm^3)	Area (mm^2)	Average Crushing Load (N)	Average Compressive Strength (N/mm^2)
1	14	7.89	2332	3375000	22500	405000	18.00
2	21	8.03	2379	3375000	22500	510000	22.67
3	28	7.84	2323	3375000	22500	609000	27.07

Source: Experimental Work (2013)

Table 3: Compressive Strength of Concrete Mixed With Well Water (CMW)

S/N	Curing Period (Days)	Average Weight (Kg)	Average Density (Kg/m^3)	Average Volume (mm^3)	Area (mm^2)	Average crushing Load (N)	Average Compressive Strength (N/mm^2)
1	14	7.87	2332	3375000	22500	357000	15.87
2	21	8.04	2382	3375000	22500	452000	20.09
3	28	7.81	2314	3375000	22500	532000	23.64

Source: Experimental Work (2013)

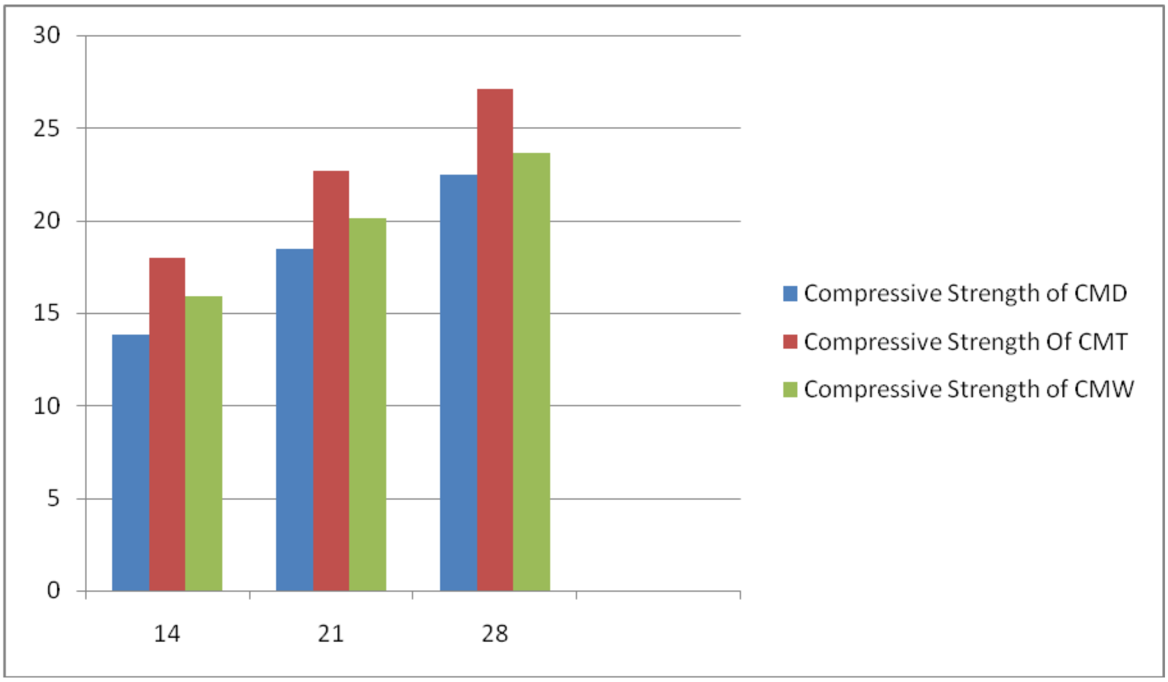
Looking at the result shown in table 1, 2 and 3, it can be deduced that the density of the concrete samples ranged from 2293 to 2382 Kg/m^3. Hence, this shows that all the densities presented in these tables fall within the normal weight categories of concrete of between 2200 and $2600kg/m^3$ (Neville, 1996). And according to Everret (1990), high density in concrete is associated with high strength, hardness, durability, imperviousness and thermal conductivity.

As shown in table 2, it can be seen that the highest compressive strength was recorded in 28 days. This indicates that concrete produced with tap as mixing water gives highest compressive strength value. It was also observed that all hydration periods (curing periods), the highest compressive strength were derived, compared to the compressive strength in table 1 and 3.

Apparently, the highest value of compressive strength attained in table 2 may be attributed to the removal of those metals ions that influences the strength of concrete. However, this occurred when the water is treated for drinking. The highest compressive strength here concurred with Neville (2000) who indicated that the use of portable drinking water as mixing water is generally satisfactory.

From table 1 and 3, it clearly indicated that highest compressive strengths were also presented at 28days hydration period. That is, $22.44N/mm^2$ for CMD and $23.64N/mm^2$ for CMW. As such, the compressive strength for CMW is slightly greater than that of CMD at 28days. This implies that well water is preferable to drainage water if at all the two types of water are the only alternative for concrete mixes.

Moreover, the values obtained at 28days of hydration period in table 1, 2 and 3 respectively are in line with BS 8110 (1997) which says that the minimum compressive strength required for concrete to be used for structural purposes at 28days is between $20\text{-}40N/mm^{2.}$ The values derived in table 1 (CMD) and table 3 (CMW) were also in conformity with Neville (2000) who asserted that some waters not fit for drinking may often be used satisfactorily in making concrete. He further argued that natural water that are slightly acid are harmless, but water containing humic or other organic acids may adversely affect the hardening of concrete, such waters as well as lightly alkaline water should be tested before use. And that the presence of algae in mixing water results in air entrainments with a consequent loss of strength. Also, some natural minerals water contain undesirable amount of alkali carbonates which could contribute to the alkaline-silica reaction should be avoided.



Hydration (Curing) Period (days)

Figure 1: Compressive strength development for concrete produced.

With reference to figure 1, it can be observed that compressive strength increases with increase in curing days in all the categories of mixing water used for production. It also shows that all concrete produced increased up to $4N/m^2$ at 7days interval of curing. The CMT presented the highest compressive strength of $3.43N/mm^2$ more than CMW while CMW is $1.2N/mm^2$ greater than CMD at 28days. The figure 1 signifies that CMT showed the highest compressive strength in all the hydration period.

Variation in compressive strength as depicted in figure 1 indicates that effect of some metal ion and their counter anion present in well water as described by Guilin (2014) may be one of the causes of reduction in strength of the concrete. Furthermore, the reduction in compressive strength of the concrete made with drainage water as mixing water as shown in figure 1 also agreed with Dennis (2014) who postulated that water that flows over or through the soil picked up a variety of dissolved and suspended substances including salts, organic compound and soil particles. Consequently, reaction of these substances with cement affects the strength of concrete.

4.0 CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

The fore-going discussion revealed that quality of mixing plays an important role on compressive strength of concrete. It is however shown from this study that treated portable drinking water is the best water for mixing concrete.

Conversely, some waters not fit for drinking such as drainage water and well water may often be used for concrete production. Meanwhile, it is suggested that those waters not fit for drinking should not be used in making concrete for the casting of structural member (such as foundation, slab. Column, beam e.t.c) of multi-storey building and heavy civil engineering works.

4.2 Recommendations

Based on the findings and conclusion, the following recommendations were made:

i. That tap water treated and certified for drinking should be recommended from concrete production.

ii. The compressive strengths derived from both CMW, CMD showed that well water and drainage water can as well be used for making concrete. Therefore, since the results is somehow closer to minimum value stipulated in the standard, it is recommended that drainage and well water should be used for mixing concrete of a ground floor buildings.

iii. Further research could be conducted on the chemical composition of untreated waters that are common in use for concrete production before they are recommended for concrete mixes.

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