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Effects of Water-Cement Ratio and Cure Days on the Strength and Workability of Normal Concrete Blocks

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ABSTRACT

In this research the effect of water cement ratio (W/C) and curing time on the compressive, flexural and split tensile strength(s) of M40 normal concrete block was evaluated. The effect of W/C on workability of the fresh concrete mix was also examined. The results showed that higher W/C of 0.8 and 0.9 gave the lowest compressive, split tensile and flexural strength(s). The compressive strength at 28days cure showed a gradual reduction of 46.13MPa, 45.15MPa, 43.11MPa, 38.11MPa, and 37.15MPa for the 0.5, 0.6, 0.7, 0.8 and 0.9 W/C respectively for the M40 concrete produced. This was attributed to more capillary pores within the concrete which increased as the W/C increased. Concrete maturity with time during wet curing in water increased the strength of the M40 concrete produced. There was gradual increase in compressive strength at 0.5 W/C of 32.64MPa, 38.31MPa, 40.12MPa and 46.13MPa for the 7, 14, 21 and 28 days respectively as a result of continuous hydration within the concrete. This trend was also observed in the split tensile and flexural strength(s) of the M40 concrete blocks. The 0.8 and 0.9 W/C(s) showed a shear and collapse slump respectively. The slump of the fresh concrete mix increased as the W/C increased which showed that although a higher workability of fresh concrete was produced when the 0.8 and 0.9 W/C was used, the concrete mix were lean and harsh and showed a high tendency to leaching effects. The results indicated that a well-proportioned and apportioned concrete mix of appropriate workability and strength are essential in the production of good quality normal concrete blocks.

Keywords: Concrete; Compressive Strength; Flexural Strength; Water-Cement Ratio, Workability; Slump.

1.0 INTRODUCTION

Concrete integrity during structural application is of tremendous importance for the durability of the structure to stand the test of time most especially during harsh environmental conditions. The evaluation of how important these factors should be taken into cognizance depends on the region the structure is domiciled. A lot of factors are responsible for the strength of concrete structure and these include, quality of raw materials, water-cement ratio (W/C), coarse/fine aggregate ratio, age of concrete, compaction of fresh concrete mix, temperature, relative humidity and duration of curing the concrete (Constructor, 2017).

Shamsai, *et al*. (2012) reported that the reduction of W/C in Nano-silica concrete caused the abrasive strength to increase however, the conductivity coefficient and the porosity of the Nano-silica decreased. By reduction of W/C from 0.50 to 0.33, the abrasive strength of concrete was improved by 36%. The water requirement increased as laterite cement ratio increased for a given mix proportion. An increase in the laterite/cement ratio increased the strength and decreased workability for a given W/C and the variation of workability and strength with W/C for normal concrete is valid for laterized concrete (Falade, 1994).

Apebo, *et al.* (2013) reported that crushed over burnt bricks can also be used to produce concrete with higher compressive strength with reduced weights if the bricks are properly burnt and reducing W/C increases the compressive strength.

The compressive strength for fresh concrete mixes decreased with increasing W/C (Neville, 2011). The more the free water content of the fresh concrete mix the greater the volume of pores left in the hardened concrete and therefore the less the gel/space ratio and this trend is true for quarry sand concrete (QSC), and is a useful parameter in practical field construction (Waziri *et al.*, 2011).

Kumar, *et al*. (2017) concluded that crushed bricks produced higher strength with reduction in weights and reducing the water-cement ratio increased the compressive strength of the bricks.

Shetty, (1982) in his book stated that higher compressive strength exhibited by the concrete as the W/C reduced can be attributed to the lower air voids in the concrete, which reduced when the water content reduced.Curing is the maintenance of a satisfactory moisture content and temperature in concrete for a period of time immediately following placing and finishing so that the desired properties may develop . The need for adequate curing of concrete cannot be overemphasized. Curing has a strong influence on the properties of hardened concrete; proper curing will increase durability, strength, watertight-ness, abrasion resistance, volume stability, and resistance to freezing and thawing and deicers. With proper curing, concrete becomes stronger, more impermeable, and more resistant to stress, abrasion, and freezing and thawing. The improvement is rapid at early ages but continues more slowly thereafter for an indefinite period (Kosmatka, *et al.,* 2003).

Park, *et al.* (2015) concluded that the strength development of K-Ultra High Performance Concrete was also proportional to the duration of curing, regardless of the curing temperature. In order to ensure the specified strength in 7 days, the curing time of 48 to 72hrs was appropriate for a curing temperature of 60˚C, while a longer period of at least 96hrs may be necessary for 40˚C.

Ewa, *et al.* (2013) in his study showed that increasing the curing days caused a coresponding increase in the compressive strengths of sandcrete blocks. He further concluded that by deploying better curing practices and appropriate cement content, the sandcrete blocks produced in commercial block industries in Calabar can be improved.

The compressive strength of five different compositions of cement increased with increasing curing time. Adequate curing at early ages as well as at later ages is essential in the strength development of port land composite cement concrete (Uddin *et al.,* 2012).

The slump test is a quality control test because changes in the measured slump indicates changes in mix proportions, mixing procedures, or other factors affecting the nature of fresh concrete. (Basham,1993).

Marar, *et al*. (2011) in their research work stated that; K-slump can be used instead of cone slump to predict the workability and consistency of concrete and K-slump could also be used to predict the VeBe time of fresh concrete.

The work takes into consideration the effects of W/C and the time of curing the concrete (age) on the strength of the concrete and its practical application in the construction industry.

2.0 MATERIALS AND METHOD

2.1 Materials

The materials utilized for the work were river sand, gravel, cement and water. The cement was Dangote Ordinary Port Land Cement Type-1, 42.5grade. The cement had a specific gravity of 3.15, bulk density of 1452kg/m^3, initial setting time of 35mins, final setting time of 300mins, and soundness of 0.18 satisfying (ASTM C 150, 2007). The sand was ordinary river sand with a maximum size of 4.75mm, loose bulk density of 1630 Kg/m^3, compacted bulk density of 1750Kgm^3, compaction factor of 0.93, water absorption of 1.2% and fineness modulus of 3.14 satisfying (ASTM C 33, 1997). The gravel had a maximum size of 20mm, loose bulk density of 1548Kg/m^3, compacted bulk density of 1647Kg/m^3, compaction factor of 0.94, water absorption of 1.1%, and fineness modulus of 6.95 satisfying (ASTM C 33, 1997). The water utilized for the work was ordinary portable water which satisfied (ASTM C 1602, 2004). The materials were obtained at Ahmadu Bello University Zaria, Building Department Laboratory.

2.2 Method

M40 concrete was produced with varying W/C of 0.5, 0.6, 0.7, 0.8 and 0.9 respectively. The targeted mean compressive strength was 45MPa and a workability of 25mm-100mm. The concrete was produced for mild exposure and ACI 211.1-91 mix design proportioning method was utilized for designing the concrete mixture (Day *et al.,* 2002). The fresh concrete was allowed to cure for 24hrs before it was demoulded and kept in water to undergo further curing for 7, 14, 21, and 28days respectively (ASTM C 192, 2002). All the aggregates were utilized in their surface saturated condition (Ejiogu *et al.,* 2017). Five specimens were produced for each test and the average results were taken. A total number of 240 samples of concrete were produced for the work.

2.2.1 Design Mix Proportion for the Fresh Concrete Mix

Table 1.1: Design Mix Proportion for the Fresh Concrete Mix

S/N	Method	Targeted Mean compressive Strength ((MPa) at 28 Days	W/C	Cement (CMT) Content(kg/m^3)	Water Content(Kg/m^3)	Sand Content(Kg/m^3)	Gravel Content(Kg/m^3)
1.	ACI 211.1	45.00	0.50	560.00	280.00	502.04	1085.80
			0.60	560.00	336.00	502.04	1085.80
			0.70	560.00	392.00	502.04	1085.80
			0.80	560.00	448.00	502.04	1085.80
			0.90	560.00	504.00	502.04	1085.80

2.2.2 Tests

2.2.2. Compressive test: - 100mm faced cubes were utilized. This was carried out according to (ASTM C 39, 2005)

2.2.2.2 Flexural test: - 50mm× 50mm× 150mm prisms were utilized for the test. Two points loading was utilized. This was carried out according to (ASTM C 78, 2002).

2.2.2.3 Split tensile test: - 100mm× 200mm cylinders were utilized for the study. This was carried out according to (ASTM C 496, 2004).

2.2.2.4 Workability: - Workability of the fresh concrete mix was determined using a slump mould according to (ASTM C 143, 2003).

RESULTS AND DISCUSSION

Table 2: Effect of W/C and cure days on the compressive strength, split tensile strength and flexural strength of concrete

S/N	Cure Days	W/C	Compressive Strength (MPa)	Split Tensile Strength(MPa)	Flexural Strength(MPa)
1.	7	0.5	32.64	3.98	3.90
		0.6	30.54	3.00	2.98
		0.7	28.12	2.85	2.80
		0.8	20.12	2.55	2.50
		0.9	18.25	2.00	1.99
2.	14	0.5	38.31	6.21	6.20
		0.6	32.11	6.12	6.00
		0.7	30.15	5.28	5.20
		0.8	26.15	4.00	3.98
		0.9	24.12	3.00	2.98
3	21	0.5	43.25	7.44	7.00
		0.6	40.12	7.40	6.98
		0.7	38.13	6.00	5.88
		0.8	34.12	5.02	5.00
		0.9	30.98	4.13	4.12
4.	28	0.5	46.13	8.11	7.76
		0.6	45.15	8.02	7.26
		0.7	40.11	7.89	6.50
		0.8	38.11	6.13	6.00
		0.9	37.15	5.19	5.00

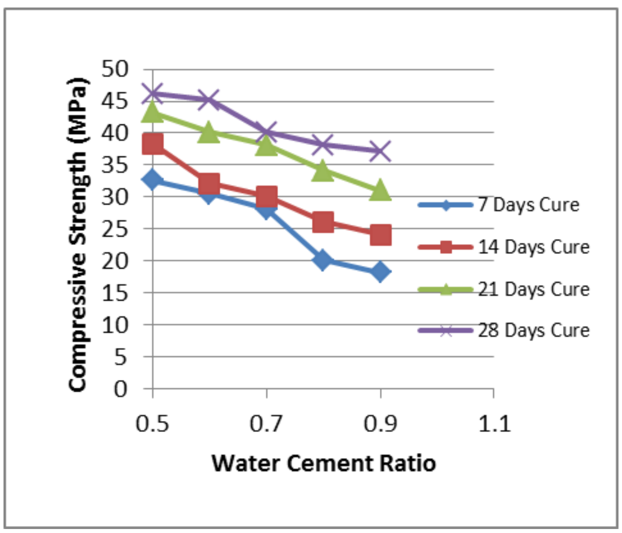

Figure 1: Compressive Strength vs. W/C for Various Cure Days of Concrete

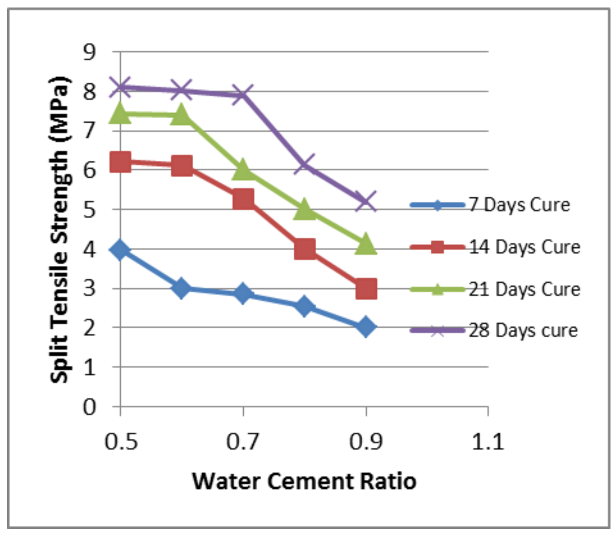

Figure 2: Split Tensile Strength vs. W/C for Various Cure Days of Concrete

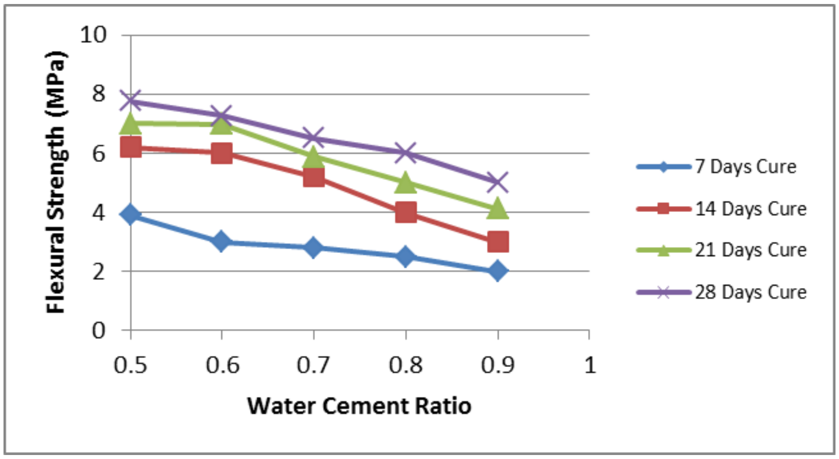

Figure 3: Flexural Strength vs. W/C for Various Cure Days of Concrete

3.1 Effect of Water-Cement Ratio and Curing Days on the Compressive, Split Tensile and Flexural Strength(S) of the M40 Grade Concrete

3.1.1 Water Cement Ratio Effect on Compressive, Split Tensile and Flexural Strength

The figures 1, 2 and 3 showed decreased compressive, split tensile and flexural strength(s) as the W/C increased. This can be attributed to the increase in capillary pores with increasing water cement ratio. Thus, excess water will cause undesirable capillary pores within the mass of the concrete produced. The more the pores the higher the porosity and higher porosity means lower strength of the concrete.

When hydration began, the mass of the anhydrous cement increased and this also gave a corresponding increase in the product of hydration, the increase in the mass of gel formed due to hydration will fill up the capillary pores created by water, however as the W/C increased above 0.7, the hydrated product will not be able to fill all the capillary pores, producing a porous concrete. This increases with increasing W/C; this was why there were pronounced reduction in strength from 0.7-0.9 W/C shown in the figures1, 2 and 3 (Shetty,1982).

3.1.2 Curing Days Effect on Compressive Split Tensile and Flexural Strength

The figures 1, 2 and 3 showed increased compressive, flexural and split tensile strength(s) as the curing days increased this was due to the hydration of cement. The short time strength of 7days was as a result of Tricalcium silicate (C_3S) because it readily reacts with water to produce heat of hydration.C_3S produces comparatively smaller quantities of calcium silicate hydrates and more quantities of calcium hydroxide $Ca_2(OH)$. The long term increase in strength 21- 28days or longer as cement hydrates indefinitely is a result of Dicalcium silicate (C_2S), it hydrates much slower and produces lesser heat of hydration. The calcium silicate hydrates formed are denser and produces less quantities of $Ca_2(OH)$ (Shetty, 1982).

$$2(3CaO.SiO_2) + 6H_2O \rightarrow 3CaO.2SiO2.3H_2O + 3Ca\,(OH)_2 \quad (1)$$

$$2(2CaO.SiO_2) + 4H_2O \rightarrow 3CaO.2SiO2.3H_2O + Ca(OH)_2 \quad (2)$$

Equation 1, showed the hydration of Tricalcium silicate in the fresh concrete mix, while Equation 2, showed the hydration of Dicalcium silicate in the fresh concrete mix during the hydration of cement.

3.2 Workability of Fresh Cement Mix

Table 3: Results of Slump Test on Fresh Concrete Mixes.

Water-Cement Ratio	Concrete Mixes	
	Slump (mm)	Type of Slump
0.50	30	True
0.60	50	True
0.70	75	True
0.80	90	Shear
0.90	200	Collapse

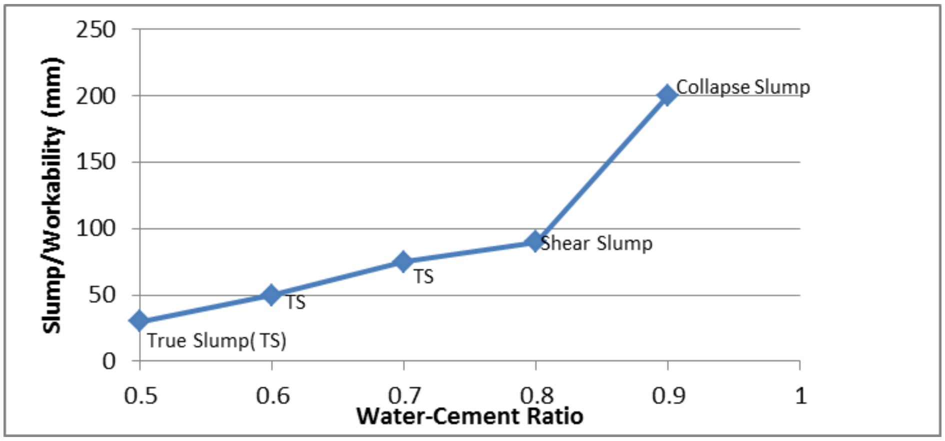

Figure 4: Workability vs. W/C for Fresh Concrete Mix

The workability of concrete is the ability of the concrete to flow, consolidated and finished. The slump tests measured the workability of fresh concrete. At W/C ratio of 0.5 to 0.7, the fresh concrete had good workability. This meant that there was good cohesion between the particles of the fresh concrete mixes. However, the 0.8 W/C showed a shear slump which indicated poor workability and a lack of cohesion in the fresh concrete mix; this also showed that the fresh concrete mix was quite harsh. The collapse slump shown by the 0.9 W/C generally indicated a very lean and harsh mix capable of undergoing serious leaching which can affect the integrity of the concrete, it also showed that the concrete contained a lot of water (Neville, 2011).

4.0 CONCLUSION

The results showed that there were higher compressive, split tensile and flexural strength(s) as the age of curing increased, as a result of continuous hydration within the concrete due to the presence of C_2S and C_3S in the fresh concrete mix. The increase in the strength of the concrete due to lower W/C can be attributed to lesser pores in the concrete due to the lower water content utilized in the fresh concrete mix. Required slump results between 25-100mm were achieved with W/C of 0.5 to 0.7, showing good workability of the concrete mix. However; the 0.8 and 0.9 showed shear and collapse slump respectively as a result of too much water in the fresh concrete mix. Higher water content in concrete could entail higher workability but would result to lower strength and leaching in the concrete which may compromise integrity, and this type of concrete may not be suitable for structural applications. Thus, the need for the concrete to remain within its stipulated slump range is recommended for structural integrity of the concrete.

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