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Rate Of Strength Development Of Concrete Made Using Selected Nigerian Cement Brands

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ABSTRACT: Concrete is a versatile construction material. Its most critical property is the compressive strength. The basic constituents of concrete are a cementitious material and aggregates. The most common type of cementitious material used for concrete in Nigeria is Ordinary Portland Cement. The strength of concrete and the rates at which it is developed depends largely on the type and quality of cement. The rates of strength development of concrete using some selected brands of cement in the Nigerian market were investigated by means of laboratory tests. It was established that, the concrete develops an average of 26% of the 28 day strength in 1 day and 85% in 21 days. It is concluded that concrete develop strength rapidly at early age compared to later ages. Most cement brands in Nigeria develop strength at satisfactory rates.

Key words: Cement Brands, Concrete, Development, Rate, Strength

1 INTRODUCTION

Concrete is a versatile construction material. According to Hasan and Kabir [1], it is readily available, relatively cheap, flexible to handle and it gives shape and any desired form. The compressive strength is the most critical property that gives a very good overall idea of the quality of concrete, the tensile strength being negligible in comparison. In the broad sense, concrete is made of a cementitious material (cement, lime, pozolans etc., or any combination of these), aggregates (fine and/or coarse) and water. There may be some additives and/or admixtures added to the basic constituents to vary the properties of the concrete when it is green or hardened. Many researchers [2], [3] and [4] have carried out works to predict the strength of concrete at any given age using some developed models. They are many factors that affect the rate at which strength develops in concrete after mixing [5]. Among these factors are the richness of the mix, character and grading of the aggregate, the water content of the mix and the curing conditions [6], [7]. The porosity of concrete, changes with the degree of cement hydration [3]. The degree of cement hydration which is a function of water to cement (w/c) ratio has a direct effect on the porosity and consequently on the strength. As stated earlier, the richness of the mix is one of the factors that affect the rate of strength development in concrete. The richness of a concrete mix is a direct function of the quantity and quality of the cementitious material.

2 NEED FOR THE STUDY

In the Nigerian construction industry, the most commonly used cementitious material is the Ordinary Portland Cement (OPC). Of recent there has been a serious controversy as to whether the brands of OPC used in the country can attain adequate strength. In fact the Standard Organisation of Nigeria (SON) even attributes the incidences of building collapse in the country to this assumption. Concrete gains strength with increase in age, and this is regardless of the grade, but it is important to know how much of this strength is gained at any particular age between the ages of 1 to 28 days. It is also important to know whether the cement brands produced and used in Nigeria develop adequate strength when used to produce concrete to meet the desired strength. Also it is needful to know the rate of strength development to be able to decide on the time to strike the formwork during construction.

3 REVIEW OF LITERATURE

In the design of concrete structures, the characteristic strength of concrete is taken to be the strength at 28 days. There is no specific percentage of the ultimate strength of concrete that must be achieved at 28 days. However, concrete is believed to have attained over 70% of its full strength [8]. Also, concrete develops strength rapidly at its early age and, the rate of strength development decreases with the increase in age after mixing. There are some factors that influence the strength of concrete and the rate at which they develop.

3.1 Cement Based Parameters in the Strength of Concrete

The rate of strength development, and the final strength attained by concrete can be affected by the parameters relating to the composition of the cement constituents and their proportions in the cement [5]. These cement constituents include the following:

- Alite content (tri-calcium silicates)
- Belite content (di-calcium silicates)
- Sulphate contents

The strength development depends on the alite and belite reactivity. Alite happens to be the most reactive cement mineral which contributes significantly to the concrete strength. More of it in the cement will result in better early strength (i.e. up to seven days). Sulphate comes into cement both from the clinker and the added gypsum. Its presence in cement retards the hydration phase. Insufficient sulphate in cement results in flash set (i.e. rapid hardening of freshly mixed cement paste with appreciable amount of heat released). If on the other hand there is too much sulphate content, false setting may occur (i.e. rapid hardening of freshly mixed cement paste with negligible heat released). Some physical properties of cement have some effects in the strength development of concrete. Among these properties are cement surface area and then the particle size distribution. The fineness of cement is sometimes expressed in terms of total particle surface area. The higher the level of fineness of cement, the higher will be the rate of hydration of the cement [3]. Particle size distribution plays an important role in strength development in concrete. Cement which has very finely ground particles have slower rate of hydration.

3.2 Water-Cement Ratio

The amount of water used in making concrete measured as water-cement (w/c) ratio has an impact on the strength of concrete. Jankovic et al [3] reported that Duff Abrams established this fact since 1918. Increase in water-cement ratio increases with the level of porosity of the concrete when it hardens. This is because the excess water in concrete after drying up from the concrete matrix leaves pores in the concrete. The increase in the water-cement ratio therefore, the higher the volume of voids after the concrete hardens which thereby reduces the strength of the resulting concrete.

3.3 Aggregate

In normal concrete, the influence of the strength of aggregate is usually not appreciated. This is because the strength of the aggregate is far greater than the concrete matrix and the interfacial transition zone inside the concrete. Therefore where natural aggregates are used in concrete, their strengths are usually not utilized as the other two phases determine failure. Some other aggregate characteristics like size, shape, surface texture, grading (particle size distribution) and mineralogy have effects on the strength of the concrete.

3.4 Mixing Water

The impurities contained in mixing water may affect some properties of concrete, among which is strength. The concrete production requirement for water is that the water should be portable. This makes the water obtained directly from the tap to be very suitable for concrete mixing. This does not however mean that water that is unsuitable for drinking is not appropriate for concrete production. Due to water shortage in some places, slightly acidic, alkaline, salty, coloured water or water with unsuitable smell for drinking can be used for mixing concrete.

3.4 Curing Conditions

The process that involves a combination of conditions that facilitate the hydration of cement in concrete after it has been cast is described as curing [9]. These conditions are time, temperature and humidity conditions. For a given water-cement ratio, the porosity of hydrated cement paste depends on the degree of cement hydration. At normal temperature, some of the constituents of Ordinary Portland Cement begin the hydration process as soon as water is added. This process slows down significantly when the dry cement grains become coated with the product of hydration. This implies that hydration can be achieved satisfactorily when there is saturation of water. It will almost stop completely when the humidity in the capillaries falls below 80%. This makes humidity and duration of hydration to be of significance in the hydration process. The rate of hydration reaction has a direct relationship with temperature. Generally, the time-strength relationship in concrete assumes moist curing conditions and temperature. Air entrainment, admixtures and additives are also some factors that may affect the strength of concrete.

4 MATERIALS AND METHOD

4.1 Materials

Cement

Ordinary Portland Cement (OPC) of grade 32.5 was used. The cement brands were obtained from the open market in Kaduna, Nigeria. It was supplied in 50kg bags for each of the brands. There cement brands used in the investigation were five in number, namely; Ashaka cement, Sokoto cement, Dangote cement, Elephant cement and Rhino cement.

Fine Aggregates

Good quality sand is good for the production of concrete that will develop the desired properties. Natural clean sand obtained from River Kaduna was used for fine aggregate.

Coarse Aggregates

In the Nigerian construction industry, 20mm coarse aggregates are used in most construction work. Crushed, angular granite of nominal maximum size of 20mm was used for the investigation. The aggregate used was free of dust and other impurities.

Water

The water used for producing and curing the concrete was obtained directly from the tap in the laboratory.

4.2 Experimental Methods

Mix Design

There was no effort aimed at designing a concrete mix to achieve any specific target strength. A prescribed mix of 1:2:4 with a water-cement ratio of 0.4 was used for the experiment. Batching of the materials was by weight.

Mixing

Dry cement and aggregates were thoroughly mixed before water was added. After the water was added, it was mixed for another four minutes to produce a concrete of homogenous consistency.

Compaction

The moulds were assembled, filled with the concrete and then placed on a vibrating table. The moulds were properly vibrated at 1200 vibrations per minute for two minutes.

Curing

The moulds with the compacted concrete were covered with polythene sheets immediately after casting and left for twenty four hours. The cubes were demoulded after twenty four hours and then immersed in clean water, and kept at the laboratory temperature. They were all kept in this condition until the time just before the tests for set of the specimens.

Testing

A total of ninety 150mm cubes were cast for the experiment. Three specimens were tested for each of the five brands of cement for any given age. The strength was taken to be the mean of the three values obtained for each set of three. The tests were carried out at the ages of 1 day, 4 days, 7 days, 14 days, 21 days and 28 days. The mean compressive strength was measured to the nearest 0.5N/mm2.

5 RESULTS AND DISCUSSION

5.1 General Observations

From the tests carried out on the samples of concrete cubes made with all five selected brands of Portland cement, the average compressive strength are not very different from one another for four out of the five brands of cement. Compressive strength of concrete made with Ashaka cement, Dangote cement and Sokoto cement at the age of 28 days have the max-

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imum strength of 33.5N/mm2 each. Rhino cement had a value of 34.5N/mm2 which was the highest compared to those of the other brands of cement. Elephant cement at the age of 28 days had an average strength of 23.5N/mm2 which was the least compared to other samples tested. However, all samples tested met the minimum requirements of strength of concrete cubes in 3 days and 7 days which should not be less than 8N/mm2 and 14N/mm2 respectively specified by BS EN 197-1:2011 [10]. In determining the rate of development of strength, the target strength is the value at 28 days which is taken as 100%. The values for the various brands of cement were as follows: Ashaka, Dangote and Sokoto brands had 33.5N/mm2, Rhino brand had 34N/mm2, while Elephant brand had 23.5N/mm2. These values were used to determine the rate of strength development in concrete made using the selected brands of cement.

5.2 Test Results

The results for the compressive strength tests for all the selected brands of cement are given in Tables 1 to 6

TABLE 1
COMPRESSIVE STRENGTH TEST RESULTS FOR ASHAKA CEMENT

Age (Days)	Weight Of Cubes (kg)	Compressive Strength (N/mm^2)	Rate of strength dev. (%)
1	7.93	8.0	25
4	8.16	10.5	37
7	8.03	15.5	47
14	7.95	22.0	66
21	7.93	29.0	87
28	7.97	33.5	100

Source: Laboratory investigation.

TABLE 2
COMPRESSIVE STRENGTH TEST RESULTS FOR SOKOTO CEMENT

Age (Days)	Weight Of Cubes (kg)	Compressive Strength (N/mm^2)	Rate of strength dev. (%)
1	8.10	9.0	27
4	8.07	10.0	29
7	8.00	15.0	45
14	8.03	21.0	63
21	8.08	27.0	81
28	8.02	33.5	100

Source: Laboratory investigation.

TABLE 3
COMPRESSIVE STRENGTH TEST RESULTS FOR DANGOTE CEMENT

Age (Days)	Weight Of Cubes(kg)	Compressive Strength (N/mm^2)	Rate of strength dev. (%)
1	7.89	8.5	26
4	8.10	9.5	28
7	8.10	15.5	46
14	8.08	23.5	70
21	7.95	29.0	87
28	8.10	33.5	100

Source: Laboratory investigation.

TABLE 4
COMPRESSIVE STRENGTH TEST RESULTS FOR RHINO CEMENT

Age (Days)	Weight Of Cubes(kg)	Compressive Strength (N/mm^2)	Rate of strength dev. (%)
1	7.87	8.5	25
4	8.10	9.5	29
7	8.10	16.0	46
14	8.08	23.5	70
21	7.95	29.0	86
28	8.10	34.0	100

Source: Laboratory investigation.

TABLE 5
COMPRESSIVE STRENGTH TEST RESULTS FOR RHINO CEMENT

Age (Days)	Weight Of Cubes(kg)	Compressive Strength (N/mm^2)	Rate of strength dev. (%)
1	8.25	9.0	39
4	8.20	9.5	41
7	8.37	13.0	56
14	8.02	15.0	65
21	8.12	19.0	81
28	8.02	23.5	100

Source: Laboratory investigation.

5.3 Discussion

From the results obtained, the strength developed at the age of 1 day ranges from 25% to 27% of the strength of concrete at 28 days for four out of the five brands used for the investigation. The value of 39% obtained for the Elephant brand of cement is due to the comparatively low value of the strength at 28 days obtained. The most probable reason for this development is that the cement batch supplied for the experiment may have been in the market for a long time. This makes this value to be an outlier from statistical point of view and therefore not included in calculating the average rate of strength development. From the results obtained the average rate of development concrete for the selected brands of cement with acceptable results are 26% for 1 day, 30% for 4 days, 46% for 7 days, 67% for 14 days, 85% for 21 days and 100% for 28 days. It is also seen that the rate of strength development is gradual and is more rapid at the early ages and decreases as the age of the concrete increases.

6 CONCLUSION

At a range of between 33.5N/mm2 to 34.0N/mm2, the strength of concrete made using most of the selected brands of cement meet the minimum strength requirement of 32.5 N/mm2 for grade 32.5 cement used for the investigation. The rate of strength development for the concrete is adequate for the supports for such concrete made using these brands of cement to be removed at 21 days. The strength of 85% is adequate to carry construction loads before the structure will be fully loaded. For the Elephant brand of cement, it is required that the supports for such strucutres be kept in place for a longer period than 21 days specified for the other brands. The rate of strength development of concrete made using most of the cement brands available in the Nigerian market is enough

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for safe construction. It should however be pointed out that high quality materials in themselves do not produce safe structures without adequate professional input at all levels.

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