ISSN 2229-5518

Effect on Workability and Strengthof Concrete due to Variation in Mixing Water Temperature

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Abstract— This project was aimed at determining the effects of mixing-water temperature on the compressive strength and workability of concrete. Locally available materials were used. The temperatures of the water used were variously: – 5^{o}C, 15^{o} C, 27^{O}C, 35^{0}C, 45^{0}C and 55^{0}C.The mix design was prepared for M20 mix after studying the material properties.A mix proportion was thus adopted with a water cement ratio 0.55.Tests were done on fresh and hardened concrete. It was found that at early ages for higher temperature, the strength is higher but decreases in gaining strength as the number of days increases.Compression tests were done on concrete cubes on 3, 7 and 28^{th} day.On 3 day test, higher value of 15.385 Mpa is obtained for 45^{o}C and lower value of 6.342 Mpa for 5^{o}C.Similarly a higher value of 25 Mpa at 45^{o}C and lower value of 10.306 Mpa at 5^{o}C is obtained from 7^{th} day testing. Also the higher value of 24.08 Mpa and a lower value of 15.85 Mpa is obtained at 27^{o}C and 5^{C}C respectively from 28^{th} day testing. In terms of workability, the workability of the concrete decreased as the temperature of the mixing-water increased, getting to a high of 87 mm slump at 55^{0}C and. The study has revealed that water temperature has a significant influence on the strength and workability. Also, it was shown that the optimal temperature to achieve a high strength at 28 days was 45 ^{0}C.

Index Terms — Concrete, compressive strength, workability, aggregetes, temperature, slump

1 INTRODUCTION

Concrete is defined as a material used in building construction, consisting of a hard, chemically inert particulate substance known as aggregate (usually made from different types of sand and gravels), that is bonded together by cement and water. The first concrete was made by a British engineer, John Smeaton by adding pebbles as a coarse aggregate and mixing powdered brick into the cement. Many factors such as aggregate properties, weather conditions, and water purity level and water temperature affect the strength development of concrete. To a large extent, the durability of concrete depends on the type of aggregate used. Aggregates can be either fine or coarse. Water being an essential component in concrete mix has a direct influence on the strength, workability, durability and performance of concrete. A mechanical property of aggregates is water absorption.

2 WATER IN CONCRETE

Water is an important constituent in concrete. It chemically reacts with cement (hydration) to produce the desired properties of concrete. Mixing water is the quantity of water that comes in contact with cement, impacts slump of concrete and is used to determine the water cementitious materials ratio (w/cm) of the concrete mixture. Strength and durability of concrete is controlled to a larger extend by its w/cm. Mixing water in concrete includes batch water measured and added to the mixer at batch plant, ice, free moisture on aggregates, water included in any significant quantity with chemical admixtures, and water added after batching during delivery or at the job site. Water absorbed by aggregates is excluded from mixing water.

Besides its quantity, the quality of mixing water used in concrete has important effects on fresh concrete properties, such as setting time and workability; it also has important effects on the strength and durability of hardened concrete.

2.1 Physical and Chemical components of water

- Carbonates and bicarbonates of sodium and potassium have different effects on the setting times of different cements. Sodium carbonate can cause very rapid setting; bicarbonates can either accelerate or retard the set. In large concentrations, these salts can materially reduce concrete strength.
- Concern over high chloride content in mixing water is chiefly due to the possible adverse effect of chloride ions on the corrosion of reinforcing steel or prestressing strands.
- Concern over a high sulfate content in mix water is due to possible expansive reactions and deterioration by sulfate attack, especially in areas where the concrete will be exposed to high sulfate soils or water.
- Carbonates of calcium and magnesium are not very soluble in water and are seldom found in sufficient concentration to affect the strength of concrete. Bicarbonates of calcium and magnesium are present in some municipal waters. Concentrations up to 400 ppm of bicarbonate in these forms are not considered harmful.
- Natural ground waters seldom contain more than 20 to 30 ppm of iron; however, acid mine waters may carry rather large quantities. Iron salts in concentrations up to 40,000 ppm do not usually affect concrete strengths adversely.
- Salts of manganese, tin, zinc, copper, and lead in mixing water can cause a significant reduction in strength and large variations in setting time. Of these, salts of zinc, copper, and lead are the most active. Salts that are especially active as retarders include sodium iodate, sodium phosphate, sodium arsenate, and sodium borate. All can greatly retard both set and strength development when present in concentrations of a few tenths percent by mass of the cement. Generally, concentrations of these salts up to 500 ppm can be tolerated in mixing water.

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ISSN 2229-5518

- Seawater containing up to 35,000 ppm of dissolved salts is generally suitable as mixing water for concrete not containing steel. About 78% of the salt is sodium chloride, and 15% is chloride and sulfate of magnesium. Although concrete made with seawater may have higher early strength than normal concrete, strengths at later ages (after 28 days) may be lower. This strength reduction can be compensated for by reducing the water-cement ratio.
- Acceptance of acid mixing water should be based on the concentration (in parts per million) of acids in the water. Occasionally, acceptance is based on the pH, which is a measure of the hydrogen-ion concentration on a log scale. The pH value is an intensity index and is not the best measure of potential acid or base reactivity. The pH of neutral water is 7.0; values below 7.0 indicate acidity and those above 7.0 indicates alkalinity (a base).
- About 2000 ppm of suspended clay or fine rock particles can be tolerated in mixing water. Higher amounts might not affect strength but may influence other properties of some concrete mixtures.
- Various kinds of oil are occasionally present in mixing water. Mineral oil (petroleum) not mixed with animal or vegetable oils probably have less effect on strength development than other oils. However, mineral oil in concentrations greater than 2.5% by mass of cement may reduce strength by more than 20%.

3 Effect of Temperature of Water in Concrete

The cement in the concrete needs water to hydrate and form Calcium-Silicate-Hydrate (C-S-H) which is the glue that holds the concrete together. The rate of hydration reaction is temperature dependent. If the temperature increases the reaction also increases. This means that the concrete kept at higher temperature will gain strength more quickly than a similar concrete kept at a lower temperature. However, the final strength of the concrete kept at the higher temperature will be lower. This is because the physical form of the hardened cement paste is less well structured and more porous when hydration proceeds at faster rate. This is an important point to remember because temperature has a similar but more pronounced detrimental effect on permeability of the concrete.

4 Experimental Study of Strength of Concrete due to Variation in Temperature of Water

4.1 Materials and mix proportion

Ordinary Portland cement of grade 53 was used in the concrete mixture. Locally available aggregates were used in the research. Tap water available in the laboratory was used for mixing as well as for curing of concrete throughout the investigation. The mixture proportion as well as the properties of cement, fine aggregate, coarse aggregate and water used in the investigation are shown in Table below. Water-cement ratio was kept constant at 0.55. The workability of concrete under room condition is expected to be in the range of 40-75 mm slump.

Table 1. Mix base

Constituent material	Weight (kg/m³)
Water	191.6
Cement	383
Coarse Aggregate	1188
Fine Aggregate	925

MIX PROPOTION

1 : 1.425 : 3.10

Table 2. Material test results

Sl No	TEST	VALUE
I	TESTS FOR CEMENT	
1	Consistency	32
2	Specific gravity	3.15
3	Fineness	2%
II	TESTS FOR FINE AGGREGATES	
1	Specific gravity	2.73
2	Fineness	2.33
3	Water absorption	11.67%
III	TESTS FOR COARSE AGGREGATES	
1	Specific gravity	2.6
2	Fineness	5.41
3	Water absorption	6.52%

4.2 Casting and Curing

In this investigation, the temperature of mixing water was kept at 5°C, 15°C, 27°C, 35°C, 45°C and 55°C. The water was heated to the specified temperature and then added to the mixture during casting. The coarse and fine aggregates were mixed for 2 minutes. About half of the water needed was added and mixed for one minute. Cement was then added into the mix and the contents mixed for 30 seconds. The remaining water was then added and the contents mixed for 3 minutes. The concrete mixture was then tested for slump. Then, the mixture was filled into the 150 mm cube moulds. The moulds were tamped to eliminate entrapped air. The moulds were kept in the laboratory condition for one day and then placed into curing tanks. The temperature of water in the curing tanks was the normal temperature of water available in the laboratory. The cubes were taken out from the tanks before the testing date. Tests on hardened concrete were carried out at 3, 7 and 28 days.

4.3 Testing

The concrete mixture was tested for slump in its fresh state, as well as compressive strength and split tensile strength at hardened state. The workability and consistency quality of concrete mix can be determined using the slump test. The slump apparatus was a mould of 1.18mm thick galvanized metal in the form of frustrum of a cone with the base 200mm in diameter. The top was 100mm in diameter and the height 300mm. The taping end was a hemisphere 16mm in diameter.This test was carried out to determine the slump value of the concrete mix as an indicator of its workability and quality.

The compressive strength of concrete was tested on the compression testing machine in the laboratory. The test was carried out on three 150 mm cubes using for each temperature at 3, 7 and 28 days. The compression machine used in this research was Automatic Compression Tester having a loading capacity of 2000 kN. Loading on test specimen was applied at a constant rate of stress equal to 0.2 to 0.4 MPa/s.

5 Results and Discussion

This section describes the experiments conducted on fresh stage and hardened stage of concrete.

5.1 Slump test

Figure 1 shows the graph of slump (mm) at various water temperatures. The slump increased from 5mm at 50C to 87mm at 550C. In effect, the slump increased progressively as the water temperature increased.

Table 3. Slump

Temperature (°C)	Slump (mm)
5	5
15	17
27	70
35	78
45	83
55	87

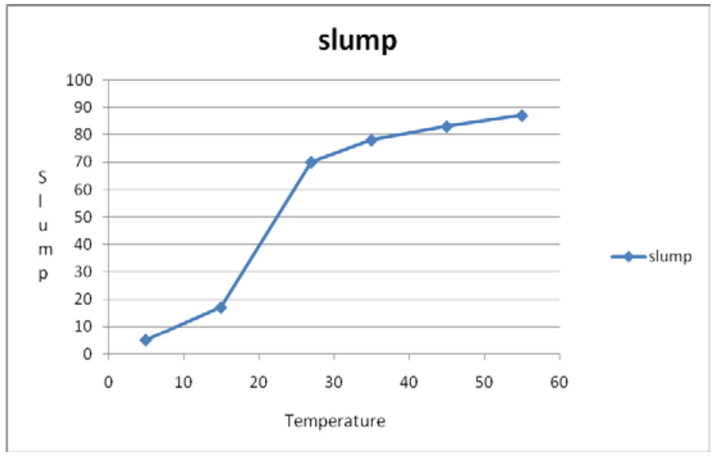

Fig.1: Graph of slump (mm) versus concrete mix water temperature (°C)

Slump values observed for all the mixtures are indicated as the relationship between casting water temperature and slump in Figure 1. It is indicated that slump decreases when the mixing water temperature increases. Hence, increasing the water temperature during mixing causes a loss in slump value and a decrease in the workability of concrete. During the casting of concrete at higher temperatures, it is found that the rates of water evaporation in concrete which contains high temperature water are higher than for concrete with normal water temperature, because there is more thermal energy available in the concrete to do the work of evaporation. Generally, water is the main component to control theoverall workability of the concrete mix in this research. Rapid slump loss often increases the demand for water, total water content and subsequently increases the potential of drying shrinkage . Hence, more water needs to be added to the concrete mix if the temperature of mixing water is increased. Concrete casted under high water temperature may lead to thermal shrinkage as it subsequently cools down.

5.2 Compressive strength test

Test was done on concrete cubes of size 150mm. Figure 2 shows the graph of the compressive strength in Mpa against temperature (Celsius) at 3, 7 and 28 th day. At the control temperature (27 0C), the compressive strength is 8.966 Mpa at day 3, 14.570 Mpa at day 7 and 24.08 Mpa at 28th day. At 5 degree Celsius, the compressive strength was 6.342 Mpa, 10.306 Mpa and 15.85 Mpa at 3, 7 and 28th day respectively. At 15 degree Celsius, the compressive strength varied from 7.061 Mpa at day 3 to 11.474 Mpa at day 7 and to 17.65 Mpa at 28th day. At 35 degree Celsius, the compressive strength ranged from 12.373 Mpa at 3rd day to 20.106 Mpa at 7th day and to 21.23 Mpa at 28th day. At 45 degree Celsius, the compressive strength varied from 15.385 Mpa at Day 3 to 25 Mpa at day 7 and finally to 19.23Mpa at day 28. At 55 degree Celsius, the compressive strength increased inn the range of 7.950 at 3rd day to 12.919 Mpa at 7th day and to 17.61 Mpa at 28th day.

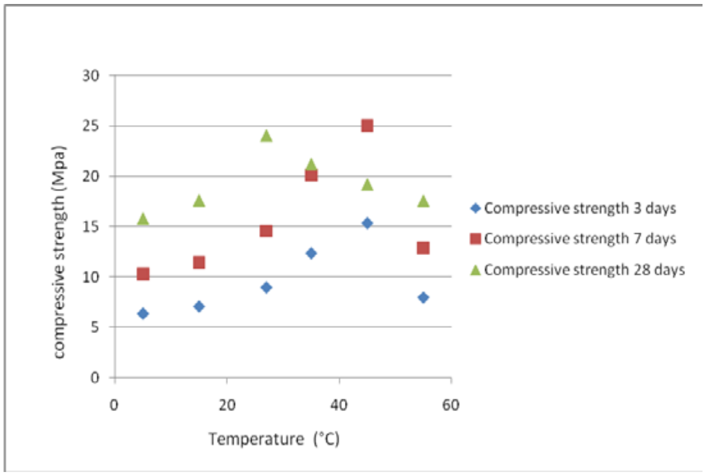

Fig.2: Graph of compressive strength (Mpa) versus concrete mix water temperature (°C)

5 Conclusion

Based on the findings of the investigations, the following conclusions can be drawn:

- An increase in water casting temperature reduces the workability of fresh concrete. Thus, additional water or suitable admixtures should be added to the mix in order to obtain sufficient workability.
- Increase in water casting temperature leads to increases in hardened properties such as compressive strength, split tensile strength. However, further increase in water casting temperature reduces the hardened properties of concrete.
- It is recommended that concrete be casted at a temperature of 25°C or less in order to get optimum performance with regard to various properties.

Acknowledgement

The authors wish to acknowledge the facilities provided by concrete technology laboratory of UKF College of Engineering and Technology, Parippally in conducting the research.

References

[1] Neville, A. M., *Properties of Concrete, Third Edition,* Pearson Education, Delhi, India, 2003, pp.268-358.

[2] Jackson, N and Dhir, R.K.,Civil Engineering Material, Macmillian ELBS, Hampshire RG21 2XS, England, 1988, pp. 10 – 32.

[3] Munoz, J.F., Tejedor, I., Anderson, M.A., and Cramer, S.M. *Effect Of Coarse Aggregate Clay-Coating OnConcrete Performance*, Innovative Pavement Research Foundation, Report, 2005, p. 35.

[4] Verbeck, G.J., and Helmuth, R.A., Structures and Physical Properties of Cement Paste, Proc. 5th Int. Symp. On the Chemistry of Cement, Tokyo, 1968, pp. 1 – 32.

[5] Kaplan, M. F., Flexural and Compressive Strength of Concrete as Affected by the Properties of Coarse Aggregates, J. Amer. Concr. Inst.,55, 1959, pp. 1193 -1208.

[6] BS 882 *Specification for aggregates from natural sources for concrete*. British Standards Institution Publication, London, 1992, pp.2 – 6.

[7] ASTM. Standard C125 *Standard Terminology Relating To Concrete And Concrete Aggregates*, American Society for Testing and Materials Publication, New York, 2003, pp.10 – 12.

[8] Eurolightcon *Mechanical Properties of Lightweight Aggregate Concrete*, BE 96, 2000, pp.23.

[9] BS 3148 *Tests for water for making concrete*. British Standards Institution Publication, London, 1980, pp. 1 – 8.

[10] British Standard 1881: Part 108 *Method for making test cubes from fresh concrete*. British Standards Institution Publication, London, 1983,pp. 1 -4.

[11] British Standard 1881: Part 111 *Method of normal curing of test specimens (20 oC)*. British Standards Institution Publication, London, 1983, pp. 1 -5.

[12] British Standard 1881: Part 116 *Method for determination of compressive strength*. British Standards Institution Publication, London, 1983, pp. 20 -30