INVESTIGATING THE EFFECT OF HOT AND FLUCTUATING WEATHER ON CONCRETE PROPERTIES

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1. Introduction

Whether concrete's environmental credentials or environment impact on concrete to be put to scrutiny, both cases affect our build up environment and natural environments. In 2012 Japan Society of Civil Engineers set "The upper limit of concrete temperature at the time of placing is less than 35°C as a standard". This limit was increased from JSCE specification of 1951 setting 30°C as the maximum temperature for casting concrete. However, in the past few decades due to effect of global warming there is rise in temperature. Japan has experienced record-breaking 41.1°C in Kumagaya city, near Tokyo in 2018 and South Sudan temperature level reaching maximum 41°C. And with the expected projection of increase in rising temperature in the next decades, it posed challenges to concrete materials. Higher concrete temperature above 35°C primarily leads to loss of slump loss, accelerated hydration, plastic-shrinkage cracking, thermal cracking, and drying shrinkage which greatly affect strength and durability properties of concrete structures.

2. Literature review

Due to the effort to reduce the CO_2 emission resulting from cement production, other cementitious materials are used for partial replacement of ordinary Portland cement (OPC) namely: Blast furnace slag (BFS) and Fly ash (FA) in this research. Despite some few existing researches and in the field of hot weather concreting. Nevertheless, these literatures seldom explain or clearly explained the effect of rise and fluctuation of the temperature on concrete material properties.

3. The Methodology

In this research, concrete experiments for temperatures 20°C, 35°C, 39°C and 45°C were conducted on laboratory scale and prediction on real situation by taking into consideration the temperature rise and fluctuation. Different types of cement binder were used namely; ordinary Portland cement (OPC), Blast furnace slag (BFS) and Fly ash (FA). Partial replacement of 50%, 70% for BFS and 30% of FA are designed in the mix proportions. The fresh, hardened and the durability properties were studied and experimented as rate of hydrations increases with rise in temperature.

4. The results and discussion

4.1 Fresh properties

During the casting and placing of the concrete materials there was loss of slump and difficulties in controlling air of the mixes at higher temperature, there was a reduction of entrained air noticed from the experiment. For example, the slump loss due to increase of temperature from 20°C to 35°C is 5cm. This make it difficult on casting and finishing of the concrete materials surfaces.

4.2 Compressive strength results

Concrete specimen at curing temperature of 35°C, 39°C and 45°C have lower compressive strength than 20°C as shown in figure 1,2 and 3. This happens due to rapid hydration reaction during the early age when curing under the different temperatures and then, fluctuation temperature. Figure 4 shows clearly how concrete compressive strength with different partial replacement affected with rise and fluctuating temperature. Note, letter (F) for fluctuating temperature. Concrete with FA 30% replacement shows significant drop below 20N/mm^2. It is worth mentioning that, high replacement of cementitious materials especially in the mixes with partial replacement BFS 70% and FA 30% tends to reduce the compressive strength as shown in figure 4.

4.3 Durability results

With the exception of 45°C all the results of 20°C, 35°C, 39°C durability tests in the research; The Chloride ion penetration, carbonation, air and water permeability show less durability problems in the various concrete mixes used. However the transport behavior at the concrete surface remain a challenge in extreme weather conditions as shown in figures 5, 6, 7 and 8.

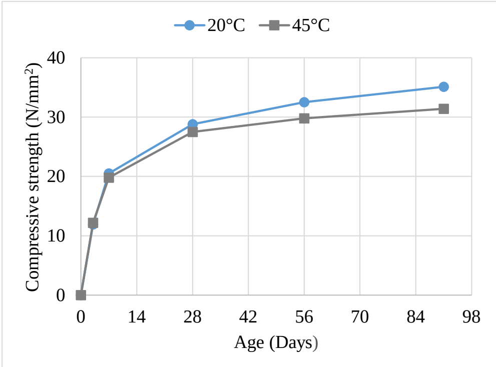

Fig. 1. Showing concrete of OPC: BFS 50% casted at different temperatures and cured under 20°C after 24 hours

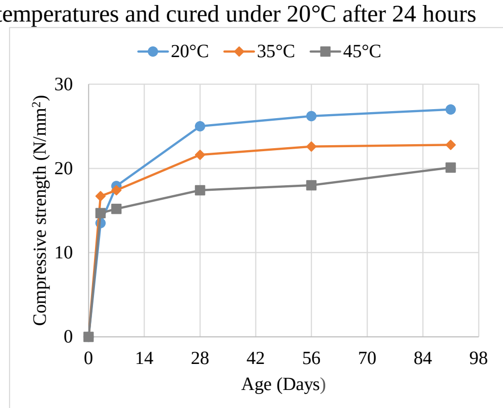

Fig. 2. Showing concrete of OPC: BFS 70% casted at different temperatures and cured under 20°C after 24 hours

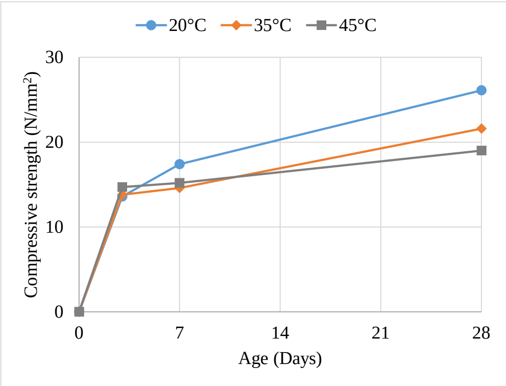

Fig. 3. Showing Concrete OPC: FA 30% casted at different temperatures and cured under 20°C after 24 hours

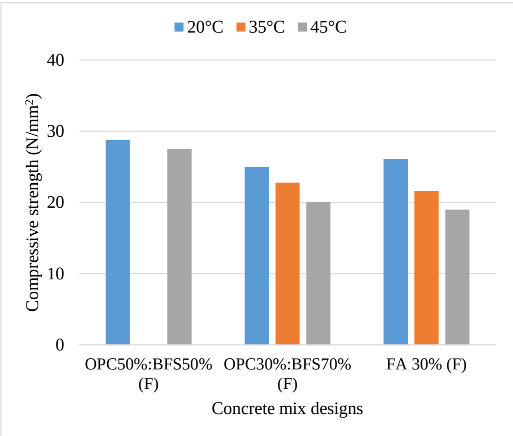

Fig.4. Showing the effect of temperature on various concrete mix designs compressive strength at 28 days (Fluctuation)

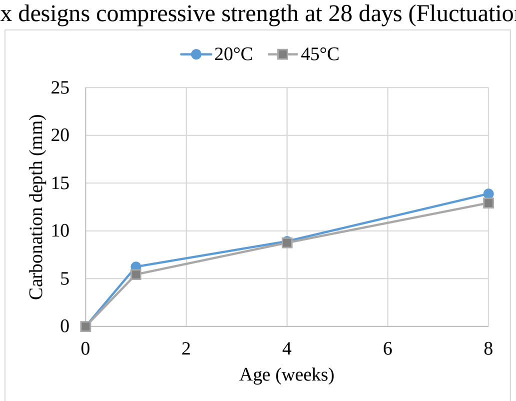

Fig. 5. Showing carbonation in concrete of OPC: BFS 50% casted at different temperatures and cured under 20°C after 24 hours

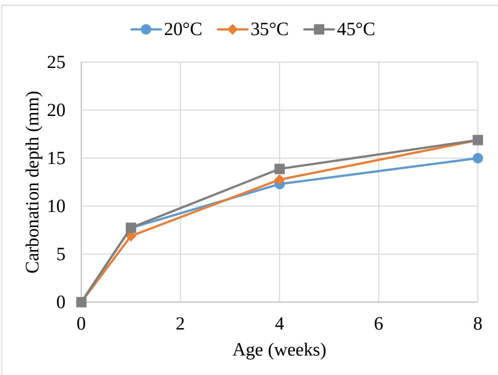

Fig. 6. Showing carbonation in concrete of OPC: BFS 50% casted at different temperatures and cured under 20°C after 24 hours

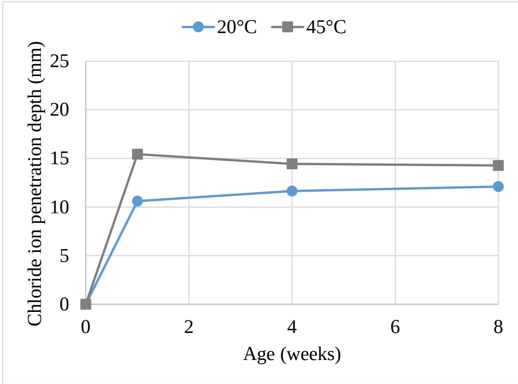

Fig. 7. Showing chloride ion penetration in concrete of OPC: BFS 50% casted at different temperatures and cured under 20°C after 24 hours

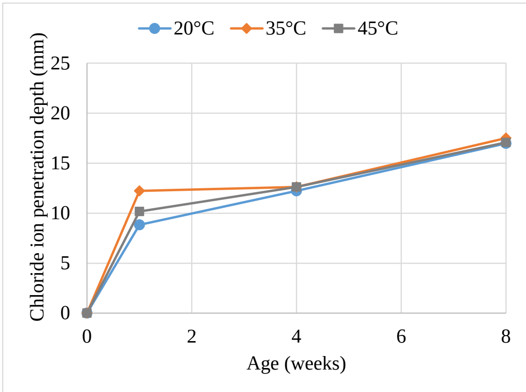

Fig. 8. Showing chloride ion penetration in concrete of OPC: BFS 50% casted at different temperatures and cured under 20°C after 24 hours

5. Conclusion

Considering the most valued properties of concrete from fresh to harden concrete i.e. compressive strength and durability, concrete of different partial replacement mixes have different results of compressive strength but almost similar durability results with reference to rise and fluctuating temperature. Thus, concrete can be casted at temperature 39°C with insignificant durability problems, but reduced compressive strength. Therefore, unless otherwise high compressive strength of concrete is required, casting at temperature up to 39°C has no significant durability problems.

6. Research Achievements

1. Clarification of concrete durability properties beyond the maximum specified 35°C by JSCE. Therefore, the research results are for counter measure to any scenario of rising and fluctuation in temperature phenomena.

2. Proposed increment of maximum temperature to 39°C as, results of compressive strength and durability tests show no significant differences to 35°C.

Reference

1. Japan Society of Civil Engineers specification (JSCE 2012).

2. Mark A., Arnon B., Sidney M. 2017, Durability of concrete, Design and construction, modern concrete technology 20.

3. I. Soroka, 1993, concrete in Hot Environments, Modern concrete Technology 3, 1st edition.