EXAMINING THE EFFECT OF DIFFERENT CURING METHODS ON COMPRESSIVE STRENGTH OF CONCRETE IN WOLAITA SODO, ETHIOPIA

Matusala Bassa[1], Ashenafi Reta[2], Ashebir Alyew[3] Elsabeth Alelegn[4]

[1]*Lecturer, Department of Civil Engineering, Wolaita sodo University, Ethiopia,*

[2]*Lecturer, Department of Civil Engineering, Wolaita Sodo University, Ethiopia,*

[3]*Lecturer, Department of Civil Engineering, Wolaita Sodo University, Ethiopia,*

[4]*Lecturer, Department of Civil Engineering, Wolaita Sodo University, Ethiopia.*

ABSTRACT: *Various curing methods are usually embraced to measure the compressive strength of concrete. The study of this paper examines the experimental results from the laboratory tests on the effect of different curing methods on the compressive strength concrete. Concrete is the mixture of cement (binding), sand (fine aggregate), course aggregate, water and sometimes chemical admixtures. It is one of the main construction materials in building construction industry and needs to be strong and durable. In order to achieve this curing is one practice performed by contractors. Curing means allowing the concrete to hydrate by providing water at the surface of the concrete. Therefore the objective of this study is to examine the effect of curing on compressive strength of concrete. The effect of curing in compressive strength of concrete is significant in hot weathered areas. Therefore, to see the effect of curing, the researcher used the conducted experiment in laboratory to evaluate the effect of curing in concrete properties of compressive strength. Totally, five batches (45 sample cubes) in different curing methods to understand the effect of curing in concrete strength is conducted. The strength of immersion curing 8% greater than burlap cover with water spraying twice per day, 16% greater than controlled room with water spraying twice per day and 31.5% greater than the open air and open air with burlap covers concrete strength. Finally, from field observation and laboratory results the contractors should take attention on the effect of curing.*

Index Terms: *Curing, concrete, temperature, burlap cover, compressive strength.*

I. Introduction

Curing is the process of maintaining satisfactory moisture content and a favorable temperature in concrete during the hydration period of the cementitious materials so that desired properties of the concrete can be developed [1]. Curing is essential in the production of quality concrete; it is critical to the production of high strength concrete. The potential strength and durability of concrete will be fully developed only if it is properly cured for an adequate period prior to being placed in service. Proper curing of concrete is crucial to obtain design strength and maximum durability, especially for concrete exposed to extreme environmental conditions at an early age and which is adopted to keep adequate moisture content and temperature as soon as the concrete is placed and finished [2]. Also, high-strength concrete should be water cured at an early age since partial hydration may make the capillaries discontinuous. On renewal of curing, water would not be able to enter the interior of the concrete and further hydration would be arrested. When concrete made with Portland cement is cured at temperatures greater than 30°C, an increase in strength occurs at early ages but a marked decrease in strength in the mature concrete [3]. The research showed that decline in 28-day compressive strength in pastes cured at high temperatures was attributed to their higher porosity and less uniform microstructure [4]. Hot weather job-site conditions that accelerate the rate of moisture loss or rate of cement hydration of freshly mixed concrete, including an ambient temperature of 27°C (80°F) or higher, and an evaporation rate that exceeds 1kg/m2/hr, or as revised by the Architect/Engineer [5]. The precautions should be planned in advance to counter the effects of a high concrete temperature when the concrete placed is somewhere between 25°C and 35°C [6]. Furthermore, Ethiopia standard of concrete structure [7] stated that:

1. If concrete temperatures as placed are expected to be abnormally high, preparation shall be made to place, consolidate and finish the concrete at the fastest possible rate.
2. For best assurance of good results with concrete placing in hot weather, the initial concrete placement should be limited between 25°C and 40°C. Every effort shall be made to keep the concrete temperature uniform.
3. Under extreme conditions of high ambient temperature, exposure to direct rays of the sun, low relative humidity, and wind, it is suggested to restrict concrete placement to late afternoon or evening.

From above scholars if curing of concrete is carried out in hot weather conditions, it will adversely affect the strength of concrete in two ways. Curing at higher temperature increases the rate of hydration rapidly at early ages, producing protective coating on the hydrating cement grains, and therefore retarding later age rate of hydration. This causes reduction in strength. Secondly the amount of water available for hydration is reduced due to rapid evaporation of water from the burlap coverings resulting in insufficient hydration of cement and hence reduction in strength of concrete. The highest compressive strength was obtained for concrete cured by immersion in lime water, until after the 28-day curing period [8]. The research conducted South Africa showed that compressive strength development beyond 28 up to 90 days, there was observed a significant reduction in the late compressive strength development of all concrete specimen cured in both ambient air and solar chamber, compared to water cured specimen. For control samples up to 90 days of curing, the percentage increase in the compressive strength for water cured specimen compared, to the solar chamber and ambient air were respectively 8.5 and 12%. The late strength development was high for water cured specimen followed by solar and ambient air. This trend was similar for all pulverized copper slag concrete samples. The higher late strength development for concrete samples cured in water was attributed to water providing adequate moisture for further hydration as compared to the solar chamber and ambient air [9]. The cubes were cured in the laboratory at an average temperature of 28◦C (82.4◦F). The results obtained showed that the average compressive strength values for 7, 14, 21 and 28 days, vary with curing methods. The results show that ponding had the highest compressive strength and density, followed by wet covering, sprinkling, then uncured for two days, with the totally uncured cubes having the least compressive strength and density as well as highest shrinkage limit. Ponding method of curing was recommended to be the best of all the curing methods [2].

II. Curing methods

Concrete can be kept moist (and in some cases at a favorable temperature) by three curing methods:

A. Methods that maintain the presence of mixing water in the concrete during the early hardening period. These include ponding or immersion, spraying or fogging, and saturated wet coverings. These methods afford some cooling through evaporation, which is beneficial in hot weather.

2.1. Ponding and Immersion

Ponding is typically used to cure flat surfaces on smaller jobs. Care should be taken to maintain curing water temperature at not more than 20 degrees Fahrenheit cooler than the concrete to prevent cracking due to thermal stresses. Immersion is mainly used in the laboratory for curing concrete test specimens.

2.2. Spraying and Fogging

Spraying and fogging are used when the ambient temperatures are well above freezing and the humidity is low. Fogging can minimize plastic shrinkage cracking until the concrete attains final set.

2.3 Saturated Wet Coverings

Wet coverings saturated with water should be used after concrete has hardened enough to prevent surface damage. They should be kept constantly wet.

2.4. Left in Place Forms

Left in place forms usually provide satisfactory protection against moisture loss for formed concrete surfaces. The forms are usually left in place as long as the construction schedule allows. If the forms are made of wood, they should be kept moist, especially during hot, dry weather

B. Methods that reduce the loss of mixing water from the surface of the concrete. This can be done by covering the concrete with impervious paper or plastic sheets, or by applying membrane forming curing compounds.

2.5 Covering concrete with impervious paper or plastic sheets

Impervious paper and plastic sheets can be applied on thoroughly wetted concrete. The concrete surface should be hard enough to prevent surface damage from placement activities.

2.6. Applying membrane forming curing compounds

Membrane-forming curing compounds are used to retard or reduce evaporation of moisture from concrete. They can be clear or translucent and white pigmented. White-pigmented compounds are recommended for hot and sunny weather conditions to reflect solar radiation. Curing compounds should be applied immediately after final finishing. Curing compound shall comply with ASTM C3094 or ASTM C13155.

C. Methods that accelerate strength gain by supplying heat and additional moisture to the concrete. This is usually accomplished with live steam, heating coils, or electrically heated The method or combination of methods chosen depends on factors such as availability of curing materials, size, shape, and age of concrete, production facilities (in place or in a plant), esthetic appearance, and economics.

III. Materials and Methods

3. Materials

For this study ordinary Portland cement, fine Aggregate, coarse aggregate, water is used and the physical properties of the material is described below.

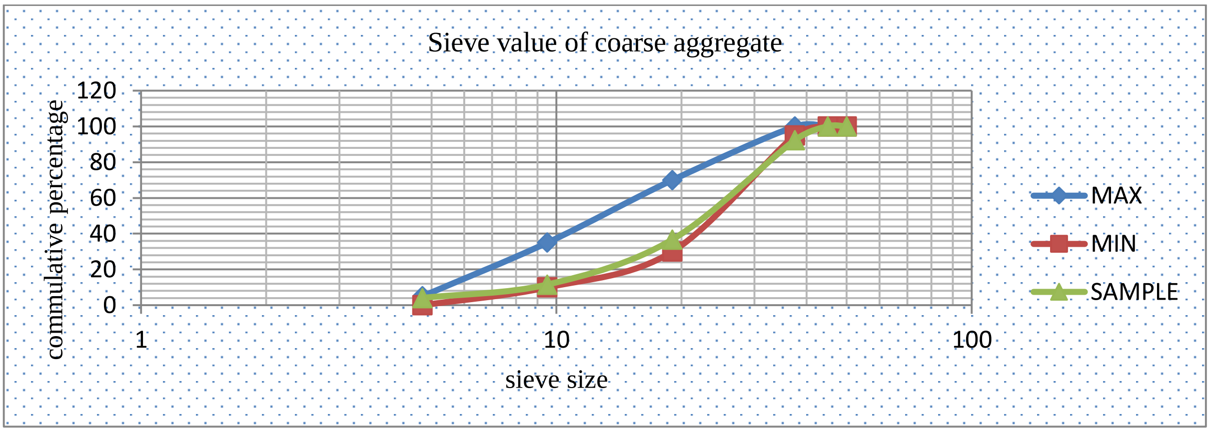

Figure 3.1: Sieve value of course aggregate

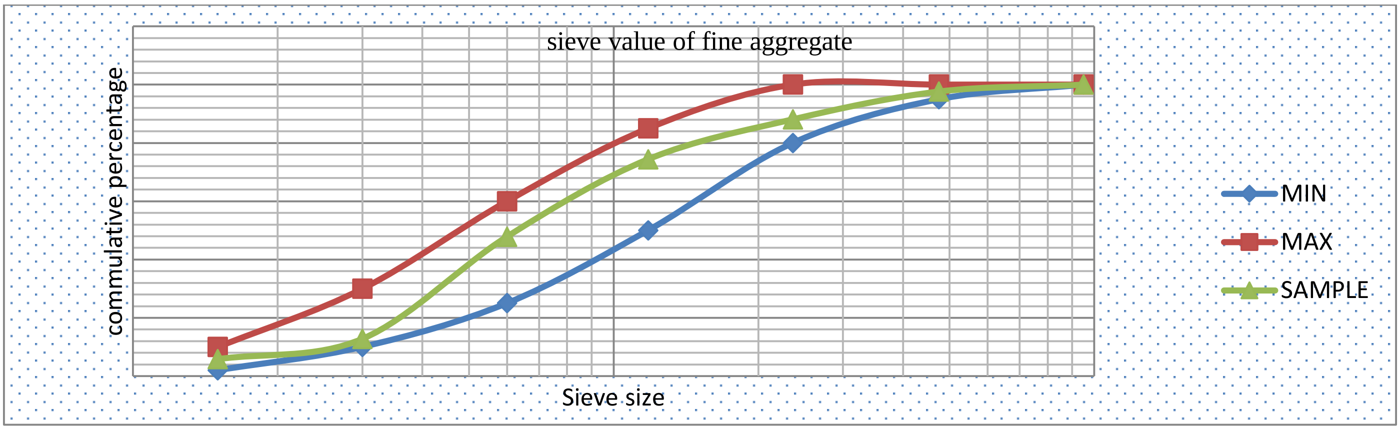

Figure 3.2: Sieve value of fine aggregate

Table 1: Summary of both fine and coarse aggregates physical properties

Properties of aggregates		Fine aggregate	Coarse aggregate
1	Absorption	2.56%	2.05%
2	Moisture Content	6.5%	0.75%
3	Bulk Specific Gravity of Aggregates	2.43	2.67
4	Bulk Specific Gravity of Aggregate (SSD Basis)	2.21	2.92
5	Apparent Specific Gravity of Aggregates	2.25	2.98
6	Fineness Modulus	2.74	-
7	Unit Weight	-	1590.3kg/m^3

Mix Design

The process of determining required and specifiable characteristics of a concrete mixture is called mix design. Concrete is mixture of coarse aggregate, fine aggregate, cementitious materials (Portland or blended cement), water and chemical admixtures. It may be containing some amount of entrapped air and may also contain purposely entrained air obtained by use of an admixture or air-entraining cement. The selection of concrete proportions involves a balance between economy and requirements for place ability, strength, durability, density, and appearance. The required characteristics are governed by the use to which the concrete will be put and by conditions expected to be encountered at the time of placement. These characteristics should be listed in the job specifications. The Proportion calculated by any method must always be considered subject to revision on the basis of experience with trial batches (ACI 211.1-91, 2002). By considering all environment condition and using local available materials and the proportion of materials is arrived by trial method and detail calculation as follows according to (ACI 211.1-91, 2002) and summarized table 2.

Table 2: Quantities determined from mix design including wastage and shrinkage for 1m^3 concrete

Materials	**weightages**
Water (added)	154 kg
Cement	353 kg
Coarse aggregate (wet)	1170 kg
Fine aggregate (wet)	695 kg
Total	2372

3. Methods

Proper curing of fresh concrete surfaces plays a major role in increasing the abrasion resistance and in turns the durability of hardened concrete surface. Factors such as ambient temperature, humidity and wind speed will also affect the degree of evaporation of surface moisture which directly affect the curing condition. In this research the effects of ambient temperature on abrasion resistance of Portland cement concrete surfaces were analyzed based on ASTM C944. The specimens were cured in the following conditions

1. Specimens prepared by OPC cement types at room temperature ingredient materials and cured inside the laboratory at normal temperature and on site.
2. Specimens prepared inside the laboratory at normal temperature but cured by Immersion, Wet Coverings and spraying twice per day. These represents the situations in which necessary precaution are taken to reduce the temperature of concrete mix at preparation.

3. The specimens prepared and cured outside the laboratory in hot weather at different concrete temperature and cured by on site by water spraying twice per day.

All the specimens were cured after remolding by keeping them covered with moist burlap to simulate actual field conditions. Water was sprayed over the specimens twice a day.
In order to evaluate the effect of temperature in concrete construction in hot weather area the following mix specimens are generated. The ingredients are stored both in exposed sun radiation and normal condition. The standard compressive strength of concrete is C-25, the ingredient proportion is one part of cement, two parts of fine aggregate and three parts of coarse aggregate (1:2:3).

4. Testing of Concrete Specimens

Compressive strength tests were carried out at the age of 7, 14 and 28 days. To determine the effect of curing on compressive strength property of concrete for elevated ambient temperature environmental condition specifically for the study area climate 45 cube samples total specimens were prepared. The specimens were uncovered and placed in the air inside the laboratory for about two hours and were capped on uneven top surface. Compressive strength tests were carried out using a hydraulically operated compression testing machine of 25.4mm ram. Three cube samples were tested at each age of concrete.

IV. Results and discussion

Table 3: Summaries of Compressive Strength due to different curing condition

cement type	**Selected curing methods**	**concrete ages**		
		7 days	14 days	28 days
OPC	Immersion	22.5	33.3	37.1
	Open air by water spraying	24.5	28.4	29.4
	Open air/ exposed to environment	23	24.5	25.4
	Open air by wet covering with water spray	22.5	31.2	34.5
	Controlled room by water spraying	21.5	30.2	31.5

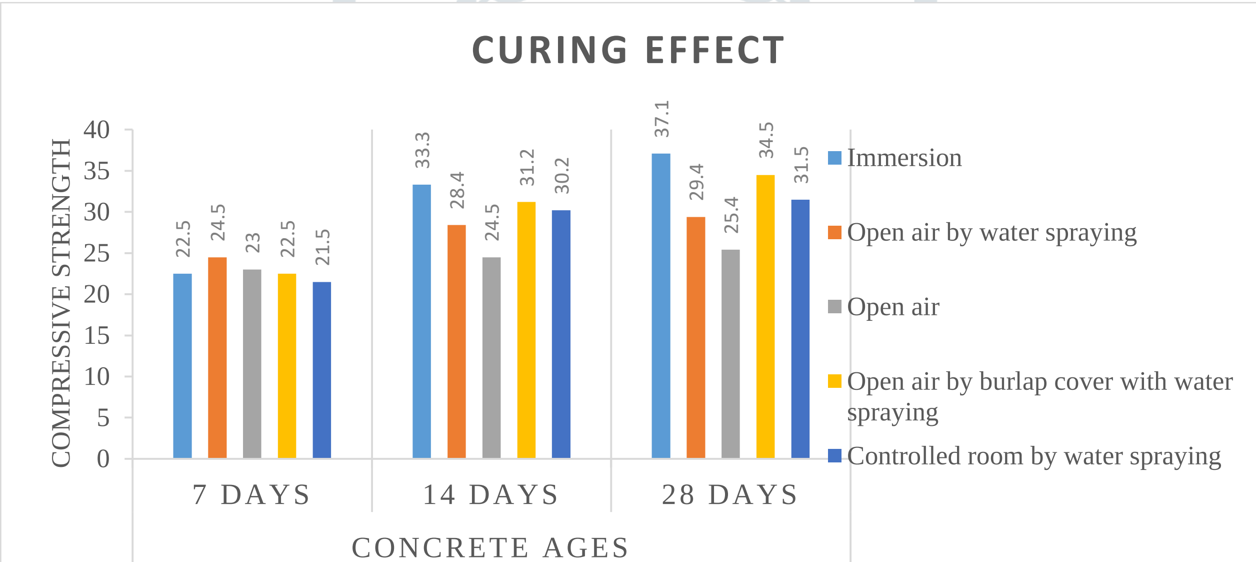

Figure 3.1: Compressive strength of different curing condition concrete

From the result above Table 2 and Figure 1 shows clearly the merit of curing method in concrete strength for the study area. It can easily observed from figure 1 the 28-days strength of concrete compressive strength of immersion 8% greater than burlap cover with water spraying twice per day and 16% greater than controlled room with water spraying twice per day 31.5% greater than the open air and open air by water spraying concrete strength. It means than the moist of curing condition decreases the compressive strength also decreases. This is because of bleed water arriving at an unprotected concrete surface will be subject to evaporation. If the rate of evaporation is greater than the rate of arrival of water at the surface, then there will be a net reduction in water content of the surface concrete and plastic shrinkage is introduced in concrete surface. Except immersion all curing methods cases the 7 day compressive strength is nearly similar this is due to concrete gain normal strength in 13^0 temperatures but in the study are air temperature in control room and relative humidity is similar with outside except sun light radiation. In case of immersion the tank water temperature also around 27^0 which was enough to accelerate the reaction of cement.

Generally curing has two main role in concrete construction to attain the required compressive strength and durability in hot weather area. Therefore, curing concrete in covering burlap with water spraying twice a day and kept in controlled room (using sun light and wind breaks) with water spraying twice a day are maintaining the presence of mixing water in the concrete during the early hardening period and reduce the loss of mixing water from the surface of the concrete by evaporation respectively. This is because of concrete gain compressive strength from cement hydration. Concrete is a composite material that consists mainly of mineral aggregates bound by a matrix of hydrated cement paste. The matrix is highly porous and contains a relatively large amount of free water unless artificially dried. When exposed to high temperatures, concrete undergoes changes in its chemical composition, physical structure and water content. These changes occur primarily in the hardened cement paste in unsealed conditions. Such changes are reflected by changes in the physical and mechanical properties of concrete that are associated with temperature increase. When concrete is subjected to elevated temperatures the incompatibility of thermal deformations of the constituents of concrete initiates cracking. Internal stress is caused by a microstructure change due to dehydration and steam pressure buildup in the pores. The maximum exposure temperature, exposure time, heating and cooling rates are among the most important factors. In these processes, the removal of free water, absorbed and chemically bounded water affected the porosity, capillary and the microstructure of cements.

V. CONCLUSIONS

The application of proper curing method through age increases the strength of concrete. Extreme premature loss of water due to unsatisfactory curing of concrete could lead the concrete to reduced strength, increased permeability, increased crack and increased shrinkage. Generally curing has two main roles in concrete construction to attain the required compressive strength and durability in hot weather area. From experimental result the 28-days strength of concrete compressive strength of immersion 8% greater than burlap cover with water spraying twice per day and 16% greater than controlled room with water spraying twice per day 31.5% greater than the open air and open air with burlap covers concrete strength.

REFERENCES

[1] ACI 308R-01, Guide to Curing Concrete,ACI Committee 308, American Concrete Institute., 2001.

[2] T. James , A. Malachi , E.W. Gadzama and V. Anametemfio, "Effects of Curing Methods on the Compressive strength of Concrete," *Nigerian Journal of Technology*, vol. 30, no. 3, 2011.

[3] Edward G. and Nawy, Concrete construction engineering hand book, second ed., CRC press, 2008.

[4] Imad Elkhadiri, Marta Palacios and Francisca Puertas, "Effect of curing temperature on cement hydration," *Eduardo Torroja Institute for Construction Sciences*, 2009.

[5] ACI 305.1-06, Specification for Hot Weather Concreting an ACI Standard,ACI Committee 305, American Concrete Institute, 2007.

[6] Steven H Kosmatka, Beatrix Kerkhoff and William C. Panarese, Design and control of concrete mixteres, 14th ed., united states of America: PCA, 2003.

[7] Ethiopian Standard, Europea Norm, Structural Use of Concrete, Addis Ababa: Ministry of construction, 2015.

[8] Akinwumi, I.I. and Gbadamosi, Z.O, "Effects of Curing Condition and Curing Period on the Compressive Strength Development of Plain Concrete," *International Journal of Civil and Environmental Research*, vol. 1, no. 2, pp. 83-89, 2014.

[9] Daniel M. Boakye , Herbert C. Uzoegbo, Nonhlanhla Mojagotlhe and Moeti Malemona , "Effect of different curing methods on the compressive strength development of pulverized copper slag concrete," *JOURNAL OF MATERALS AND ENGINEERING STRUCTURES*, vol. 1, no. 1, pp. 11-21, 2014.