# Comparative Study Of Diverse Concrete Curing Methods

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***Abstract*—Different curing methods are usually adopted to evaluate the compressive strength of concrete. This study reports the laboratory results of the effect of curing methods on the compressive strength as well as the density of concrete. A total of 72 cubes of mix ratio 1:2:4 were investigated after subjecting them to various curing conditions, with the aim of finding which of the curing method is best. 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. Based on the results and discussion of this study, the following conclusions can be drawn: 1. Ponding was the most effective method of curing. It produced the highest level in compressive strength and cube densities. 2. Increase in both compressive strength and cube densities is a function of curing method. 3. Totally uncured method of curing produced the least compressive strength as well cube densities. 4. Totally uncured concrete shrinks faster when compared to other curing methods.**

***Keywords—Concrete, Curing, Casting, Cube***

## I INTRODUCTION

Concrete is a mix of cementitious (binding) solids [e.g., cement (calcium silicates, calcium aluminates, and calcium alumino-ferrites) and sometimes fly ash (aluminates and silica) and micro-silica], aggrgegate (sand and stones), and water(C. Selvamony et al, 2011)The cementitious solids of concrete, upon mixing with water, react in highly exothermic, temperature-dependent hydration reactions (the higher the temperature, the faster the hydration reactions) producing a firm, hard mass.

There are four major stages in the hydration reactions (Nagesh, et al 2011)

(i) Surface reactions produce a ‘‘gel’’ on cementitious particles and release heat, lasting about 30 min.

(ii) Hydration is slowed for several hours because diffusion of water into the cement particle is inhibited by the gel.

(iii) Vigorous hydration and heat development occur for up to 20 h as water reaches un-hydrated cement inside the gel coating (stiffening of the concrete occurs during this stage).

(iv) Hydration continues to decline for years.

Concrete curing is one of the most important and final steps in concrete construction though it is also one of the most neglected and misunderstood procedures. It is the treatment of newly placed concrete during the period in which it is hardening so that it retain enough moisture to immunize shrinkage and resist cracking (Lambert Corporation, 2010). Curing of concrete is a pre requisite for the hydration of the cement content. For a given concrete, the amount and rate of hydration and furthermore the physical make-up of the hydration products are dependent on the time-moisture-temperature history (C.ChellaGifta, et al, 2013).

The necessity for curing arises from the fact that hydration of cement can take place only in water-filled capillaries. This is why loss water must be prevented. Furthermore, water lost internally by self-dedication has to be replaced by water from outside,i.e.ingress of water into the concrete must take place. (C.ChellaGiftaet al, 2013). Thus, for complete and proper strength developments, the loss of water in concrete from evaporation should be prevented, and the water consumed in hydration should be replenished. This the concrete continues gaining strength with time provided sufficient moisture is available for the hydration of cement which can be assured only by creation of favourable conditions of temperature and humidity. This process of creation of an environment during a relatively short period immediately after the placing and compaction of the concrete, favourable to the setting and the hardening of concrete is termed curing (Amal Francis k andJinoJohn, 2013).

The rate at which crack occurs at concrete slabs, causing building collapse in many cities of Nigeria calls for the examination of curing methods for concrete.

The study present the effect of different curing methods on the compressive strength of concrete using Portland cement and finally identifies the most effective curing process for normal concrete. 100mm x 100mm x 100mm cubes are the sizes of the moulds used in moulding the concrete into cubes.

Advantages of proper curing includes: a less permeable, more water-tight concrete; reduced permeability means the concrete will be more resistant to freezing, salt scaling and attack by chemicals; prevents formation of plastic shrinkage cracks caused by rapid surface drying; increases abrasion resistance as the surface concrete will have a higher strength and significant reduction in scaling problems. A proper curing maintains a suitably warm and moist environment for the developments of hydration products, and thus reduces the porosity in the hydrated cements paste and increases the density of microstructure in concrete. The hydration products extend from the surfaces of cement grains, and the volume of pores decreases due to proper curing under appropriate temperature and moisture (A.AielsteinRozarioet al, 2013). A proper curing greatly contributes to reduce the porosity and drying shrinkage of concrete, and thus to achieve higher strength and greater resistance to physical or chemical attacks in aggressive environments. Therefore, a suitable curing method such as water ponding (immersion), spraying or sprinkling of water, or covering with polythene sheet material is essential us order to produce strong and durable concrete.

## II Aim and Objectives

The aim of this study is to determine the different ways of curing concrete. To achieve the aim, the following are the objectives;

i. To examine the different methods of curing concrete. i.e Membrane curing, sprinkling of water, water curing, wrapping with plastic and Natural air dried.
ii. To determine properties of the constituent materials of concrete.
iii. To determine the compressive strength of concrete cast with different modes of curing

## III LITERATURE REVIEW

### Curing

Curing of cement concrete is defined as the process of maintaining the moisture and temperature conditions of concrete for hydration reaction to normally so that concrete develops hardened properties over time. The main components which need to be taken care are moisture, heat and time during curing process. (Hutton, 2012)

Curing is the process in which the concrete is protected from loss of moisture and kept within a reasonable temperature range. This process results in concrete with increased strength and decreased permeability (The Portland Cement Association, PCA)

Curing of cement concrete is required for the following reasons:

- To prevent the concrete to dry out prematurely due to solar radiation and wind. This prevents plastic shrinkage of concrete.
- It helps to maintain the concrete temperature by allowing the hydration process. Hydration process requires water to carry on and releases heat.
- Curing helps the concrete to harden and bond with internal materials and

reinforcement. This helps to prevent damage to bond between concrete and reinforcement due to vibration and impact.

- This helps development of impermeable, crack free and durable concrete.

Concretes harden because of hydration of the chemical reaction between Portland cement and water. Each bag of Portland cement needs three gallons of water for hydration. Excessive evaporation of water from newly placed concrete can cause the cement hydration to stop too soon. To prevent loss of water, the placed concrete should be protected and needs to be cured. A rapid loss of water causes the concrete to shrink and create tensile stresses when the surface is dried. The stresses may result in plastic shrinkage and cracks. (Amal Francis k, and Jino john, 2013).

**Time for curing of concrete**

The time to start curing of concrete depends on the evaporation rate of moisture from the concrete. The evaporation rate is influenced by wind, radiant energy from sunshine, concrete temperature, climatic conditions, relative humidity. The evaporation of moisture is driven by the difference in vapor pressure on concrete surface and the in surrounding air. When the difference is high, evaporation rate is high. (Akeem, 2012)

**ACI 308 – Guide to Curing Concrete** suggests three phases of concrete curing. These phases are shown in figure 1.6 of ACI 308. The right time of curing of concrete depends on:

**1. Initial Curing – Bleeding of Concrete:**

When the concrete is placed and compacted, bleeding of water occurs and rises through the surface of concrete due to settlement of concrete. The rate and duration of bleeding depends on many factors including concrete mix properties, depth or thickness of concrete, method of compaction of concrete etc.

These bleed water starts to evaporate from the surface. When all the bleeding water has disappeared from the surface, the drying of concrete starts, then initial curing of concrete is required to minimize the moisture loss and prevent plastic shrinkage cracks to concrete before and during finishing operations. The initial curing of concrete can be done by techniques such as fogging or using the evaporation reducers, or by providing the sunshades and windscreens. (Ndoke, 2012)

**2. Intermediate curing:**

Intermediate curing is done when the concrete surface finishing operations has been carried out before the final setting of concrete. This happens when the required surface texture of concrete member is achieved rapidly or when the setting of concrete is delayed.

**3. Final Curing:**

When the concrete is finished after the final setting of concrete, the final curing of concrete should be done. This helps to prevent surface drying of concrete because the loss of moisture from the concrete surface occurs immediately.

**The Importance Of Curing Concrete**

Curing is the process of controlling moisture loss from concrete that has already been placed. Curing ensures hydration of the cement, which in turn enhances it, s strength and durability. Curing takes place immediately after placing of the concrete and deals with maintenance of the desired temperature and moisture for extended periods of time. The length of curing time depends upon many factors such as the weather conditions, the size and shape of the concrete member, mixture proportions and strength of the mixture. (Adelekan, 2012)

The chemical reactions between cement & water produces C-S-H gel which bonds the ingredients of concrete, viz. coarse & fine aggregates, mineral admixtures, etc, and converts these fragments into a rock solid mass. This is possible only if continuous curing is done for at least 14 days; irrespective of the type of cement used. It is understood that blended cements require prolonged curing to convert calcium hydroxide into C-S-H gel. However, in case of OPC as well, voids within the concrete mass are filled up and disconnected by the formation of C-S-H gel after about 10 days of curing.

To have a dense microstructure and impermeability, prolonged curing is a must which leads to enhanced durability. Well-designed concrete may give poor durability if not properly cured and on the other hand a moderately designed concrete if well cured can give a better durability. Hence importance of curing should never be ignored.

Curing has a strong influence on all properties of concrete and therefore it should not be taken lightly. Properly cured concrete has better surface hardness and can better withstand surface wear and abrasion. Curing also makes concrete more impermeable, which prevents moisture and water-borne chemicals from entering into the concrete, thereby increasing durability and service life.

Proper curing helps to prevent grazing, dusting, surface disintegration and scaling. Adequate curing reduces shrinkage, gives better resistance to wear and improves long-term appearance. Without proper curing, the chemical process of hydration is not complete. You will never be able to get the designed strength of concrete and please note that this is a loss of strength for a lifetime and there is no easy alternative to strengthen such poorly cured weak concrete. So always be careful and cure with care.

**Effects of improper curing**

Following are the major disadvantages of improper curing of concrete:

- The chances of ingress of chlorides and atmospheric chemicals are very high.
- The compressive and flexural strengths are lowered.
- The cracks are formed due to plastic shrinkage, drying shrinkage and thermal effects.
- The durability decreases due to higher permeability.
- The frost and weathering resistances are decreased.
- The rate of carbonation increases.
- The surfaces are coated with sand and dust and it leads to lower the abrasion resistance.

The above disadvantages are more prominent in those parts of structures which are either directly exposed or those which have large surfaces compared to depth such as roads, canals, bridges, cooling towers, chimneys, etc. It is therefore necessary to protect the large exposed surfaces even before setting. Otherwise it may lead to a pattern of fine cracks.

**Methods Used For Curing of Concrete**

There are various methods of curing. The adoption of a particular method will depend upon the nature of work and the climatic conditions. The following methods of curing of concrete are generally adopted.

**Shading of Concrete Work**

The object of shading concrete work is to prevent the evaporation of water from the surface even before setting. This is adopted mainly in case of large concrete surfaces such as road slabs. This is essential in dry weather to protect the concrete from heat, direct sun rays and wind. It also protects the surface from rain. In cold weather shading helps in preserving the heat of hydration of cement thereby preventing freezing of concrete under mild frost conditions. Shading may be achieved by using canvas stretched on frames. This method has a limited application only.

**Covering Concrete Surfaces with Hessian or Gunny Bags**

This is a widely used method of curing, particularly for structural concrete. Thus exposed surface of concrete is prevented from drying out by covering it with hessian, canvas or empty cement bags. The covering over vertical and sloping surfaces should be secured properly. These are periodically wetted. The interval of wetting will depend upon the rate of evaporation of water. It should be ensured that the surface of concrete is not allowed to dry even for a short time during the curing period. Special arrangements for keeping the surface wet must be made at nights and on holidays.

Sprinkling of Water

Sprinkling of water continuously on the concrete surface provides an efficient curing. It is mostly used for curing floor slabs. The concrete should be allowed to set sufficiently before sprinkling is started. The spray can be obtained from a perforated plastic box. On small jobs sprinkling of water may be done by hand. Vertical and sloping surfaces can be kept continuously wet by sprinkling water on top surfaces and allowing it to run down between the forms and the concrete.

For this method of curing the water requirement is higher.

**Ponding Method**

This is the best method of curing. It is suitable for curing horizontal surfaces such as floors, roof slabs, road and air field pavements. The horizontal top surfaces of beams can also be ponded. After placing the concrete, its exposed surface is first covered with moist hessian or canvas. After 24 hours, these covers are removed and small ponds of clay or sand are built across and along the pavements. The area is thus divided into a number of rectangles. The water is filled between the ponds. The filling of water in these ponds is done twice or thrice a day, depending upon the atmospheric conditions. Though this method is very efficient, the water requirement is very heavy. Ponds easily break and water flows out. After curing it is difficult to clean the clay.

**Membrane Curing**

The method of curing described above come under the category of moist curing. Another method of curing is to cover the wetted concrete surface by a layer of water proof material, which is kept in contact with the concrete surface of seven days. This method of curing is termed as membrane curing. A membrane will prevent the evaporation of water from the concrete. The membrane can be either in solid or liquid form. They are also known as sealing compounds. Bituminized water proof papers, wax emulsions, bitumen emulsions and plastic films are the common types of membrane used.

Whenever bitumen is applied over the surface for curing, it should be done only after 24 hours curing with gunny bags. The surface is allowed to dry out so that loose water is not visible and then the liquid asphalt sprayed throughout. The moisture in the concrete is thus preserved. It is quite enough for curing. This method of curing does not need constant supervision. It is adopted with advantage at places where water is not available in sufficient quantity for wet curing. This method of curing is not efficient as compared with wet curing because rate of hydration is less. Moreover the strength of concrete cured by any membrane is less than the concrete which is moist cured. When membrane is damaged the curing is badly affected.

**Steam Curing**

Steam curing and hot water curing is sometimes adopted. With these methods of curing, the strength development of concrete is very rapid. These methods can best be used in pre-cast concrete work. In steam curing the temperature of steam should be restricted to a maximum of $75^0$C as in the absence of proper humidity (about 90%) the concrete may dry too soon. In case of hot water curing, temperature may be raised to any limit, ay $100^0$C. At this temperature, the development of strength is about 70% of 28 days strength after 4 to 5 hours. In both cases, the temperature should be fully controlled to avoid non-uniformity. The concrete should be prevented from rapid drying and cooling which would form cracks

**Concrete**

Concrete is defined in student Encarta as a mixture of sand, cement, aggregate and water in specific proportions that hardens to a strong stony consistency over varying length of time. The aggregate in this context refers to rock particles of size above $5mm^2$.American concrete institute also sees concrete as an engineering material made from a mixture of Portland cement, water, fine and coarse aggregate and small amount of air. Handoo, (2010) defines concrete as a composite material consisting of a binding medium within which the particles are embedded.

Other scholars also define concrete as a combination of aggregates and a paste composed of a Portland cement and water. The aggregate refer to sand and gravels or crushed stones, (Nanak J Pamnani, et al 2013).

## IV RESEARCH METHOD

### Materials and Methods

Locally available crushed granite stones and fine aggregate (quartzite sand) will be used as coarse and fine aggregate respectively. The fractions of different sizes of crushed granite stone and fine aggregates.

Ordinary Portland cement will be used as the main binder. Portable water from borehole will be used for preparing the concrete. It will also be used for curing purposes.

**Preparation of Test Specimens**

A total of 40 cubes having dimensions 100mm x 100mm x 100mm each will be cast of mixing ration 1:2:4. The specimens were molded in oiled timbers moulds using three layers of filling and each layer tamped 25 times to expel the entrapped air. The tops of the cubes will be marked after a while for identification purpose. Immediately after this, the specimens will be kept in a cool place in the laboratory. The specimens will be removed from the moulds at the age of 24 hours. The curing age will be in 7days, 14days, 21days and 28days

**Curing Methods**

The test specimens will be cured under three types of curing until the day of testing. These are;Membrane curing, sprinkling of water, water curing, wrapping with plastic and Natural air dried.

**Membrane Curing**

Membrane curing is used in areas of acute water scarcity. Water mixed while preparing fresh concrete is generally sufficient for the entire hydration reaction. In this method a sealing membrane is applied over concrete which will trap the water inside and avoid its escape through evaporation. Membrane may be actually a sheet of polythene or formed by application of chemicals.

Different sealing compounds used in membrane curing are: Rubber latex emulsions, Bituminous and asphalt emulsions and Emulsions of paraffin or boiled linseed oil.

**Sprinkling of water (SWC)**

In sprinkling method, the specimens will also be weighed and kept moist by sprinkling water on the specimens 2 times daily (morning and evening) until the date of testing.

**Water curing (WAC)**

In water curing, the specimens will be weighed and immersed in water. Portable borehole water will be used in water curing.

**Wrapping with plastic sheeting (PSC)**

In plastic sheeting, the specimens will be weighed and wrapped in flexible plastic sheets until the testing date. At least 2 layers of wrapping will be used to prevent moisture movement from concrete surface.

The curing temperature will be maintained at 27 + 2$^{o}$C in all the curing methods.

**Natural air dried.**

The object of natural air concrete work is to prevent the evaporation of water from the surface even before setting. This is adopted mainly in case of large concrete surfaces such as road slabs. This is essential in dry weather to protect the concrete from heat, direct sun rays and wind. It also protects the surface from rain. In cold weather natural air method helps in preserving the heat of hydration of cement thereby preventing freezing of concrete under mild frost conditions. Shading may be achieved by using canvas stretched on frames. This method has a limited application only

**Testing of Fresh Concrete**

The fresh concrete was produced using manual method of mixing in the civil engineering department, Esa-Oke. Immediately after mixing, the fresh concrete will be tested for slump and compacting factor.

Mixing ratio 1:2:4   1+2+4 = 7

Cement = 1

Sand = 2

Granite = 4

1+2+4 = 7

Weight of concrete = 2400g/m$^3$

No cubes to mould = 600

Dimension of cube = 100x100x100 = (0.1x0.1x0.1) = 0.001

0.001x2400 = 2.4

No of cubes x 2.4 = (60x2.4) 144

To know the weight of cement to use

1/7x144 = 20.57kg

Sand

2/7x144= 41.14kg
Granite
4/7x144 = 61.71kg

## V. RESULTS AND DISCUSION

### Membrane Curing

### Analysis of the result gotten from laboratory using SPSS

**Table 4.1:Analysis of Membrane Curing**

| **Days** | Cube I (N/mm) | Cube II (N/mm) | Cube III (N/mm) |
|---|---|---|---|
| 7DAYS | 13.0 | 14.5 | 15.3 |
| 14DAYS | 17.0 | 18.0 | 16.5 |
| 21DAYS | 16.5 | 17.0 | 17.5 |
| 28DAYS | 16.5 | 18.0 | 19.0 |

**Figure 4.1a: Line Chart of Membrane Curing**

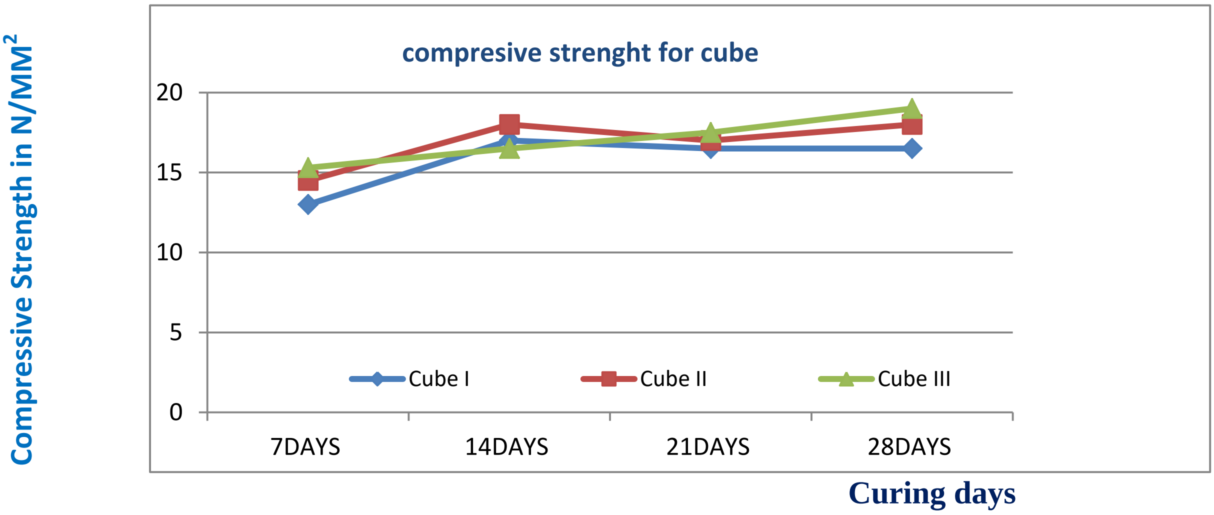
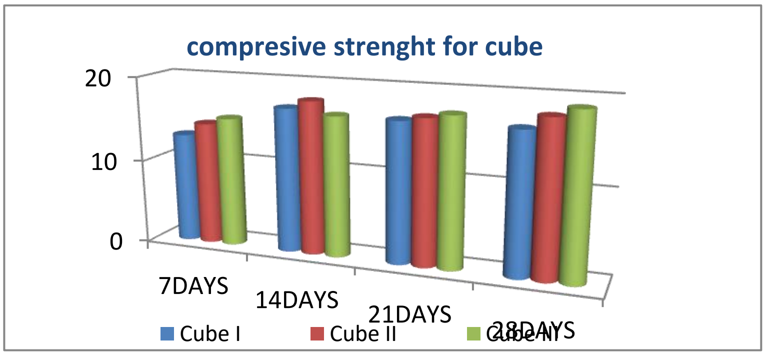



**Fig. 4.1b: The Bar Chart of Membrane Curing**




### Analysis of the result gotten from laboratory using SPSS

**Covering with green leave**

Table 4.2: **Analysis of** Curing Covering with Green Leave

| **Days** | Cube I (N/mm) | Cube II (N/mm) | Cube III (N/mm) |
|---|---|---|---|
| 7DAYS | 16.5 | 17.0 | 18.0 |
| 14DAYS | 19.5 | 18.0 | 18.5 |
| 21DAYS | 15.5 | 17.5 | 18.0 |
| 28DAYS | 18.5 | 20.0 | 19.5 |

**Curing days**

**Figure 4.2a: Line Chart of Curing Covering with Green**

Compressive Strength in N/MM$^2$

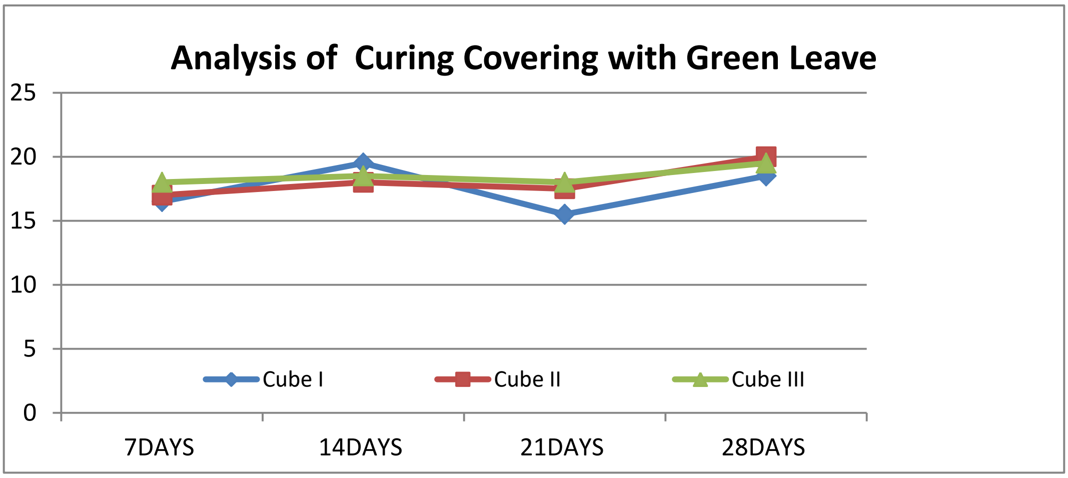
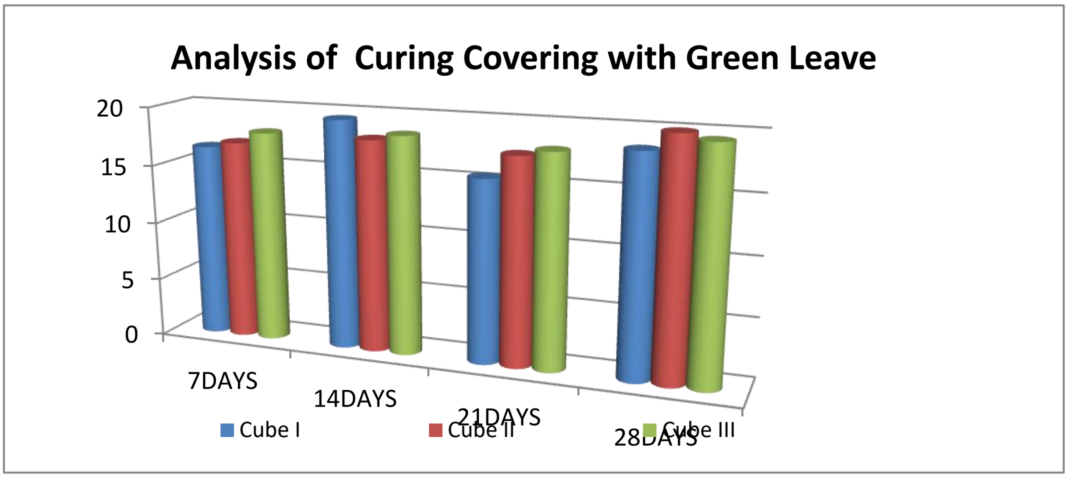



**Figure 4.2b: Bar Chart of Curing Covering with Green**



## Water Curing

### Analysis of the result gotten from laboratory using SPSS

Table 4.3:**Analysis of** Water Curing

| **Days** | Cube I (N/mm) | Cube II (N/mm) | Cube III (N/mm) |
|---|---|---|---|
| 7DAYS | 14.0 | 16.0 | 17.0 |
| 14DAYS | 14.5 | 16.0 | 18.0 |
| 21DAYS | 16.5 | 15.0 | 17.5 |
| 28DAYS | 19.5 | 21.5 | 22.5 |

**Curing days**

**Figure 4.3a: Line Chart of Water Curing**

Compressive Strength in N/MM$^2$

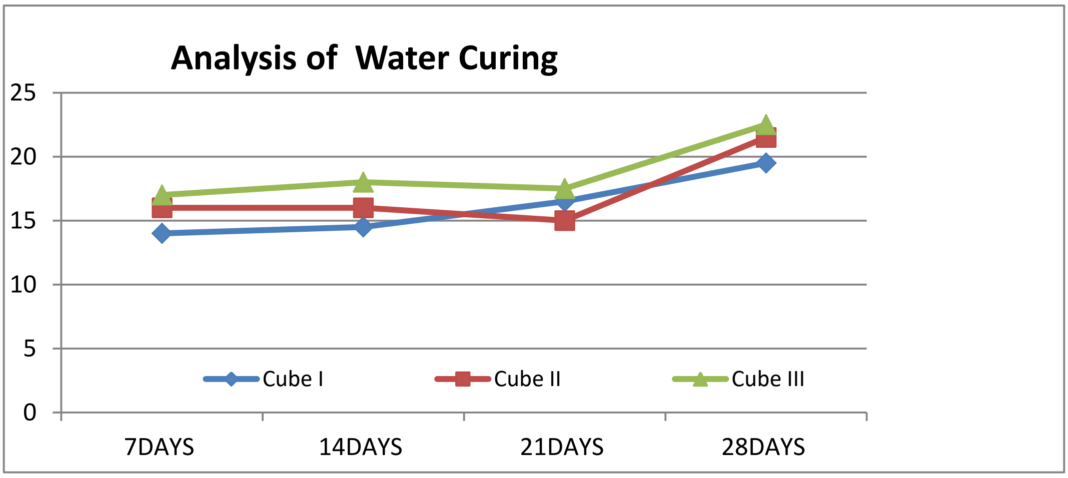
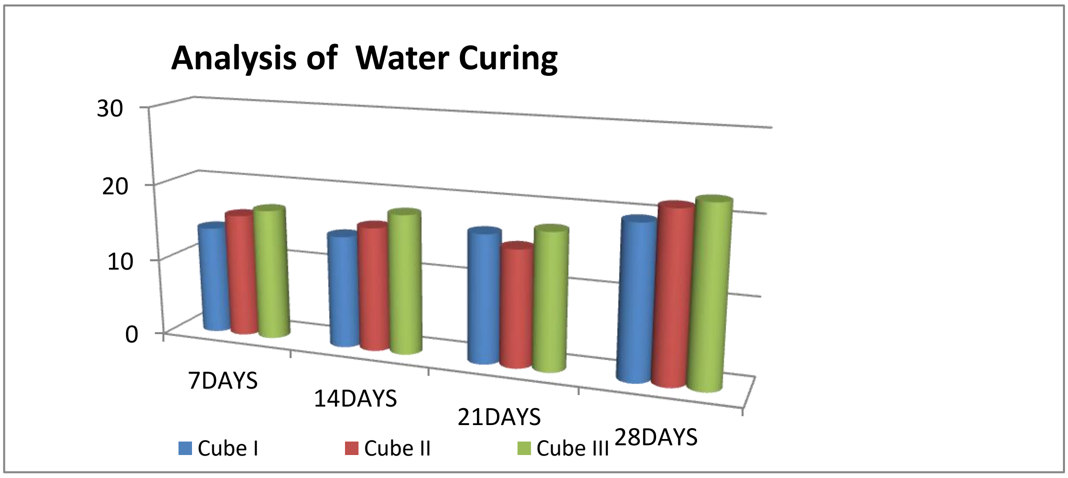



**Figure 4.3b:Bar Chart of Water Curing**



## Sprinkling of Water

### Analysis of the result gotten from laboratory using SPSS

Table 4.4: **Analysis of** Sprinkling of water

| **Days** | Cube I **(**N/mm) | Cube II **(**N/mm) | Cube III **(**N/mm) |
|---|---|---|---|
| 7DAYS | 12.5 | 14.0 | 15.5 |
| 14DAYS | 14.5 | 15.5 | 16.0 |
| 21DAYS | 16.5 | 18.0 | 19.0 |
| 28DAYS | 16.0 | 19.0 | 20.0 |

**Figure 4.4a: Line Chart of Sprinkling of water** **Curing days**

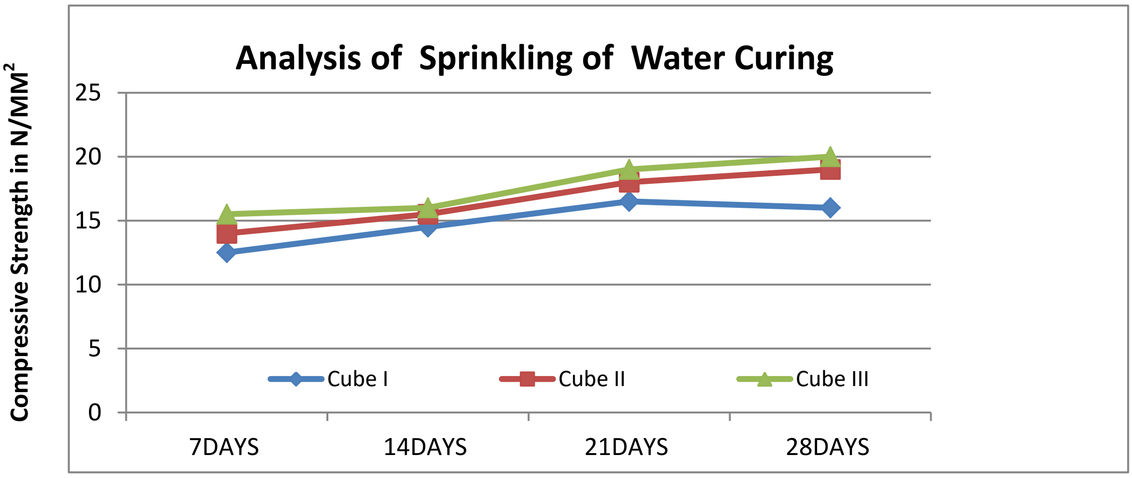
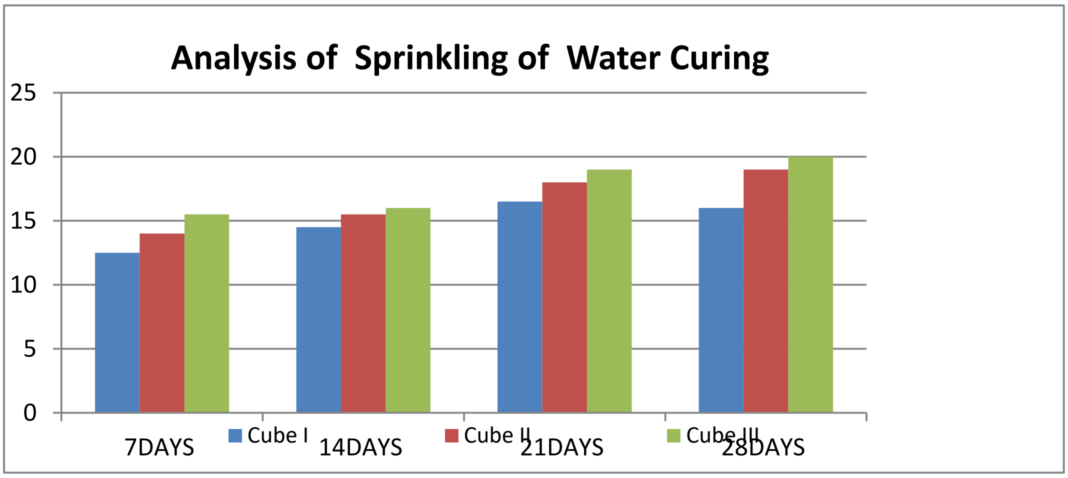



**Figure 4.4b: Bar Chart of Sprinkling of water**



## Natural Air Curing

### Analysis of the result gotten from laboratory using SPSS

**Table 4.5:** Analysis of Natural air curing

| **Days** | Cube I **(**N/mm) | Cube II **(**N/mm) | Cube III **(**N/mm) |
|---|---|---|---|
| 7DAYS | 13.0 | 15.5 | 17.5 |
| 14DAYS | 14.0 | 16.0 | 17.5 |
| 21DAYS | 15.0 | 18.0 | 19.0 |
| 28DAYS | 16.0 | 18.0 | 22.0 |

**Curing days**

**Figure 4.5a:Line Chart of Natural Air Curing**

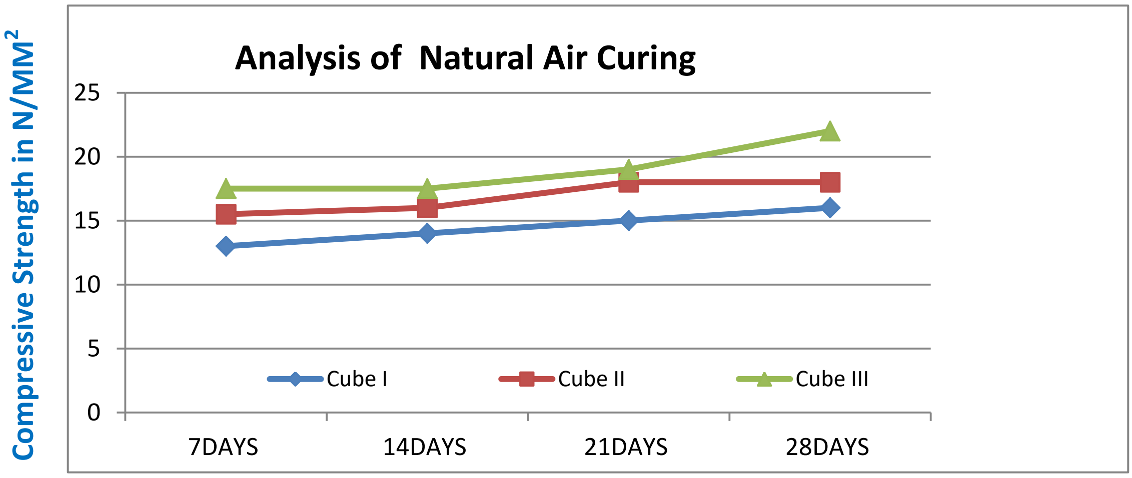
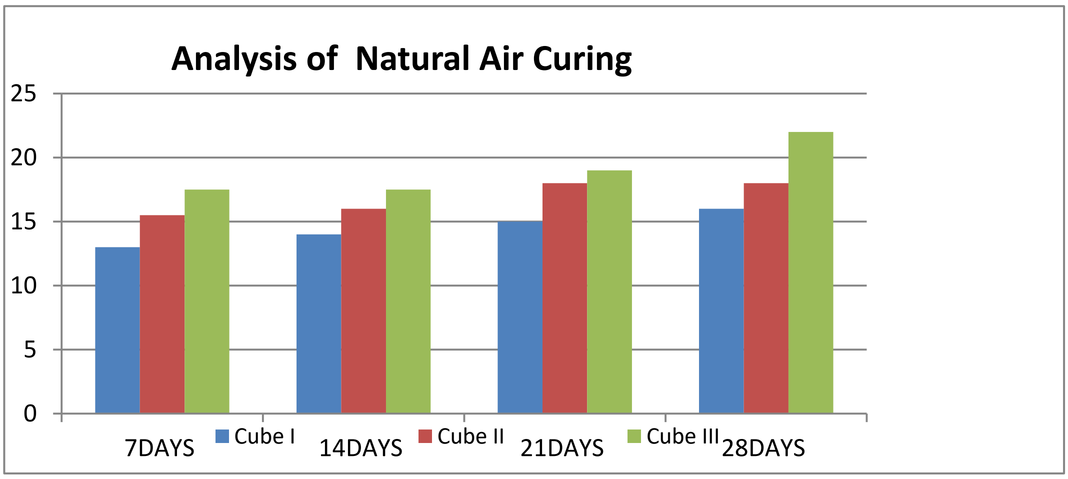



**Figure 4.5b: BarChart of Natural Air Curing**

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## CONCLUSION AND RECOMMENDATION

Water curing was the most effective method of curing. It produce the highest level of compressive strength. This is due to improve pore structure and lower porosity resulting from greater degree of cement hydration reaction without any loss of moisture from the concrete specimen.

Membrane method of curing produces higher compressive strength than sprinkling method. This is attributed reduced the moisture movement from concrete specimen leading to enhanced degree of cement hydration.

Natural air curing method of concrete produces lowest level of compressive strength. This is because the moisture movement from the concrete specimen is higher in sprinkling method, which did not provide any protection against any drying out of concrete. Hence hydration of cement reaction was abated.

The extent of moisture movement was greatly depending on method of curing. Greater moisture movement occurs under natural air curing method, and it significantly affected the strength property of the concrete.

Normal concrete should be cured by water curing (immersion) method in order to achieve good hardened properties. Water curing produced no loss of moisture, and therefore enhances cement hydration reaction. In case of water shortage, sprinkling curing can be adopted instead of wrapped (plastic sheeting) curing.

## RECOMENDATIONS

Based on the results and discussion of this study, the following recommendation are made

1. Immersion in water (WAC) method of curing is recommended to be the best of all the curing methods
2. Membrane method is also recommended in curing of concrete

## REFERENCES

[1] A.AielsteinRozario, Dr.C.Freeda Christy, M.HannahAngelin, “ Experimental studies on effects of sulphate resistance on self-curing concrete”, IJERT, vol 2 issue 4, April 2013

[2] Amal Francis k, Jino john, “Experimental investigation on mechanical properties of self-curing concrete”, International Journal of Emerging Trends in Engineering and Development, Vol 2, 641-647, March 2013

[3] A.S.EI-Dieb, T.A.EI-Maaddawy and A.A.M. Mahmoud, “water soluble polymers as self-curing agent in silica fume Portland cement mixes”, in ACI special publications, 278; 13-30, march 1, 2011.

[4] C.ChellaGifta, S.prabavathy and G.YuvarajKumar , “ Study on internal curing of high performance concrete using super absorbent polymers and light weight aggregates”, Vol 14, Pg 773-781, 2013.

[5] C. Selvamony, M. S. Ravikumar, S. U. Kannan and S. Basil Gnanappa, “investigations on self-compacted self-curing concrete using limestone powder and clinkers”, ARPN Journal of Engineering and Applied Sciences, vol 5, No 3, pg 1-6, March 2010.

[6] C. Selvamony, M. S. Ravikumar, S. U. Kannan and S. Basil Gnanappa, “Behavior of self-compactedself-curing kiln ash concrete with various admixtures”, ARPN Journal of Engineering and Applied Sciences, vol 4, No 8, pg 25-30, Oct 2009.

[7] H.Famili, M.KhodadadSaryazd, T.Parhizkar, “Internal curing of high strength self-consolidating concrete by saturated lightweight aggregate-effect on material properties”, International Journal of Civil Engineering, Vol. 10, No. 3, pg 210-221, September 2012.

[8] M.Geetha, Dr.R.Malathy, “Comparative study of strength and durability properties of polymeric materials as self-curing agent”, IJEST, vol 3, 766-771, Jan 2011

[9] M.Manoj Kumar and D.Maruthachalam, “Experimental investigation on self-curing

2013.

concrete.”, International Journals of Advanced Scientific and Technical Research, issue 3 vol 2, 300- 305, March-April 2013.

[10] M.V.JagannadhaKumar, M.Srikanth, and Dr.K.jagannadhaRao, “Strength characteristics of self-curing concrete”, IJRET, vol.1, 51-57, Sep2012.

[11] NageshTatobaSuryawanshi, “Assessment of the properties of self-cured concrete”, Civil engineering portal, 2011.

[12] Prof. Nanak J Pamnani, Dr. A.K. Verma, Dr. D.R. Bhatt, “Comparison of compressive strength of medium strength compacted concrete by different curing techniques”, IJETT, vol4, pg 1451-1457, May