CURING EFFECT ON MECHANICAL PROPERTIES OF NORMAL STRENGTH CONCRETE

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ABSTRACT

This paper aims at different types of curing effects on normal-strength concrete. By virtue, concrete is an important construction material, and curing imparts a significant role in its mechanical properties. Curing is a process that ensures adequate moisture helping the hydration of cement and subsequently gaining strength. In the laboratory three different types of curing for instance pond curing, gunny bag curing, and open-air curing were done on several concrete cylinders. The slump value was maintained at 50~60 mm during specimen preparation. The ambient temperature noted was 29 ± 2^0C. In this research work, it is found that at 7 days, compressive strength decreased by 19.84% for gunny bags and 40.43% for air curing in comparison to ponding. Again for 28 days, the compressive strength decreased by 14.52% for gunny bags and 22.42% for air curing compared to pond curing. At 28 days, the compressive strength increased by 30.08% for pond curing, 42.64% for gunny bag curing, and 66.8% for air curing compared to 7 days. As strength is the most common yet necessary phenomenon of concrete structures, curing plays a vital role in this case. The durability of concrete is an important aspect of structural integrity. And water permeability is an important durability indicator in this case. The pond-cured specimen had the least permeable value compared to the gunny bag and air-cured specimens. The air-cured specmien had the maximum water permeability; 150% higher than ponding which denotes less durability among all types. Thus for practical purposes, choosing curing methods is crucial for structural strength and durability in the long run.

Keywords: *Ponding, gunny bag curing, air curing, compressive strength, water permeability.*

1. INTRODUCTION

Of all the construction materials in the world, concrete is the most versatile one. A normal strength concrete (NSC) typically holds a compressive strength between 20 and 50 MPa at 28 days (V. Patel, 2015). The curing of concrete refers to maintaining sufficient moisture, temperature, and time to allow the concrete to gain its desired strength and durability. It is crucial as proper curing ensures the full hydration of the cement in the concrete, developing a strong and durable material. Concrete is subjected to optimal curing conditions at an early stage to reduce bleeding and plastic shrinkage while increasing strength. The interaction between cement elements and water influences the strength of concrete. Concrete's characteristics enhance with age throughout the period as the curing circumstances keep the cement's internal moisture content over 80%. When the moisture content falls below 80% the strength of concrete gets apprehended and gets reactivated as soon as there is optimum moisture (ACI, 2006) (Kosmatka, 2002). But when adequate curing is carried out, it holds the relative humidity trapped within concrete's capillary pores at or above 80%. It stimulates cement hydration, as well as impacts the concrete's microstructure development (V.G. Papadakis, 1992) (M. Sarwar). Following the American Concrete Institute (ACI) definition curing can be expressed as: "an action taken to maintain moisture and temperature conditions in a freshly placed cementitious mixture to allow hydraulic cement hydration and (if applicable) pozzolanic reactions to occur so that the potential properties of the mixture may develop" (ACI CT-18, 2018).

There are two major forms of curing of concrete e.g., external curing and internal curing. Applying water or similar curing materials to the concrete's surface as a means to prevent moisture loss is known as external curing. To provide a source of moisture for hydration, pre-wetted aggregates or other components must be incorporated into the concrete mix which is known as internal. To achieve the intended mechanical and durability-related qualities during concrete laying, maintaining the optimum moisture level and temperatures is crucial (K. Kovler, 2007). There are several types of curing process. However, it is necessary to optimize an economical and effective curing technique. There are two ways to use external curing techniques, widely referred to as classic or conventional curing techniques: water curing and sealed curing techniques (Kalbande, 2017) (ACI 308R-01, 2008). Commonly exercised external curing of concrete is done in the presence of constant accessibility of water which in turn ensures optimum hydration. Again, water used for curing must be pure and free from contaminants that could potentially damage concrete (ACI 308R-01, 2008) (Mamlouk, 2006). The most common type of external curing is ponding which is accomplished by forming a water pond on top of the concrete specimen. It is carried out mostly in the laboratory which could be a concern in an area with a scarcity of water and a hot climate (M. Naderi, 2009). Two further instances of water-curing procedures are sprinkling and fogging. Sprinkling is typically used to provide moisture to the curing process, whereas fogging is utilized to enhance the relative humidity at the concrete outer surface to reduce evaporation. These methods work well when the temperature exceeds the freezing point, the wind is calm, and the humidity is low (Kosmatka, 2002) (P. Tighare, 2017), but they demand a great deal of water (Kalbande, 2017). For sealed curing methods, additives or sealers are applied to the concrete surface. These substances integrate to generate a coating that prevents moisture from evaporating. They can be either solvent- or water-based. Lastly, covering the concrete surface with wet burlap, cotton mats, or rags and keeping them moist to prevent drying is another curing method. When wet covering is applied in high temperatures, low humidity, or windy conditions, an uninterrupted supply of moisture is essential (P. Tighare, 2017). Although the wet curing process requires a significant amount of amenities for instance labor and water, they can optimize the long-term qualities of concrete in comparison with sealed curing methods (M. Safiuddin, 2007).

One of the most notable products of the cement hydration process is Calcium silicate hydrate (CSH). Though CSH is influenced by the moisture content and relative humidity, the strength, volume stability, and permeability of hardened cement paste all are greatly influenced by CSH (H.M. Jennings, 2002). The findings of many research studies show that the effectiveness of curing depends on the type of curing, the kind of sample that is cured, the environment, and the length of the curing process. In addition, the curing process exposed to environmental conditions and storage with or without water sprinklers indoors or outdoors has a significant role in the strength properties of concrete.

Curing conditions play a pivotal role in concrete properties. It helps to increase the compressive strength over age which is a quality control criterion for concrete. The external curing method requires a large number of resources for which it is often neglected or carried out partially.

Under ACI 201.2R-01, the "Durability of hydraulic-cement concrete is defined as its ability to resist weathering action, chemical attack, abrasion, or any other process of deterioration. Durable concrete will retain its original form, quality, and serviceability when exposed to its environment." (Butler, 2001) Again, the durability of concrete structures is mainly struck by environmental factors, such as facilitating a path of ingress for water, chlorides, and other agents from the environment into structural elements. Water penetration has a significant impact on strength properties causing freezing-thawing, cracking, and spalling especially in cold regions (Muhammed Maraşlı, 2023). The durability of structural concrete is directly impacted by the transport properties of concrete, for instance, permeability (Nemkumar Banthia, 1989). Cracks in concrete connect flow pathways and promote concrete permeability. The rise in concrete permeability caused by crack advancement permits more water or hostile chemical ions penetration into the concrete, triggering degradation (Kejin Wang, 1997). The main objective of this present research is to evaluate the effect of various external curing methods, for instance, ponding, gunny bag curing, and no curing on NSC. The study of mechanical properties of concrete for different curing methods is also carried out. Investigation on compressive strength and durability of differently cured concrete specimens has been done to study the field's concrete quality.

2. METHODOLOGY

2.1 Material Property

2.1.1 Cement

Cement works as a binding agent in concrete. Seven Rings OPC cement (CEM-I) was used to prepare samples.

2.1.2 Coarse Aggregate

The specific gravity of coarse aggregates was determined using ASTM C 127. The unit weight of coarse was found out following ASTM C 29. For coarse aggregates black stones were used. 19 mm passing and No 4 retained aggregates were employed for the mix.

- Specific Gravity of Coarse Aggregate: 2.83
- Unit Weight of Coarse Aggregate: 1473.87 kg/m3

2.1.3 Fine Aggregate

The specific gravity of fine aggregates was determined using ASTM C 128 respectively. The unit weight of fine aggregates was found out following ASTM C 29. For fine aggregates, Sylhet sand was used. The sieve analysis was performed following the ASTM C136 standard test method for fine and coarse aggregates (ASTM C143/C143M−20, 2014).

- Unit Weight of Fine Aggregate: 1542.34 kg/m3
- Specific Gravity of Fine Aggregate: 2.56
- Fineness modulus of Fine Aggregate: 2.65

2.2 Mix Proportion

The materials were properly weighed and mixed. The aggregates were made SSD (saturated surface dry) condition before mixing. The potable water was used for mixing. Mix design was done following ACI 211.1-91. The mix ratio was maintained at 1:2:3. The mixes of NSC with a w/c ratio of 0.4 were investigated. And the slump value was found out to be 50~60mm following the slump-cone test.

2.3 Curing Methods

External curing procedures were carried out de-moulding the concrete samples after 24±1 h. Constant wet curing or ponding was conducted in a tank containing water. The concrete samples labelled as 7 P and 28 P were in the tank for 7 days and 28 days, respectively. On the contrary, the other concrete samples were cured with a gunny bag providing water two times a day. The remaining samples were left out for air-curing for 7 and 28 days. The ambient temperature noted was 29±20C. The average relative humidity was found 75~80%.

2.4 Testing Procedure

The properties of the fresh concrete mixes were evaluated through different tests. The slump value of all fresh concrete mixes was determined according to the ASTM C143. The compressive strengths of concrete specimens were measured according to ASTM C 39. The concrete cylinders were subjected to compressive strength tests at 7 and 28 days. After the curing period, the samples were tested to determine their durability. The water permeability of concrete specimens was evaluated according to BS-EN 12390-8. For water penetration value, the driving pressure was maintained at 70 Psi or 50 Bar for 72 hours. Then the samples were taken off from the U test machine and went through splitting to determine the water penetration.

3. RESULTS AND DISCUSSION

3.1 Compressive Strength

The compressive strength of concrete cylinders was evaluated at 7 and 28 days. At 7 days, the compressive strength for pond curing was 25.2 MPa, for the gunny bag the value was 19.3 MPa, and 15.11 MPa for air cured. So, it can be seen that the strength drop was 23.41% for gunny bag curing and 40.04% for air-curing concerning pond curing. Again for 28 days, the compressive strength was found to be 32.78 MPa for ponding whereas the value was 28.1 MPa and 25.43 MPa for gunny bag curing and air-curing respectively. Figure 2 illustrates this deviation in compressive strength for varied methods of curing. Compared to ponding, the compressive strength drop was 14.28% for gunny bags and 22.42% for air-curing. The strength drop was explicitly seen at an earlier stage of curing than at the matured stage. The air-cured specimen had the least compressive strength in both stages of curing. At 28 days, the compressive strength increased by 30.1% for ponding, 45.6% for gunny bags, and 68.3% for air-curing respective to their 7 days strength.

Figure 1: Compressive strength test of concrete specimen using CTM

Compressive strength is the most common yet important characteristic of any concrete structure. Structures with low compressive strength can not withstand high loads for a greater service life. To have greater serviceability, it is undeniable for concrete structures to contain greater compressive strength. In the field for large structures, it becomes a great problem to do pond curing. Gunny or burlap curing is carried out in these cases. But it also brings some loss of compressive strength compared to pond curing. From the current analysis, it can be noticed that compressive strength varies with curing methods. The pond-cured specimens have shown better performance than gunny bags and air-cured specimens in the strength criterion at both 7 and 28 days. The air-cured specimens did not possess much strength in comparison to ponding.

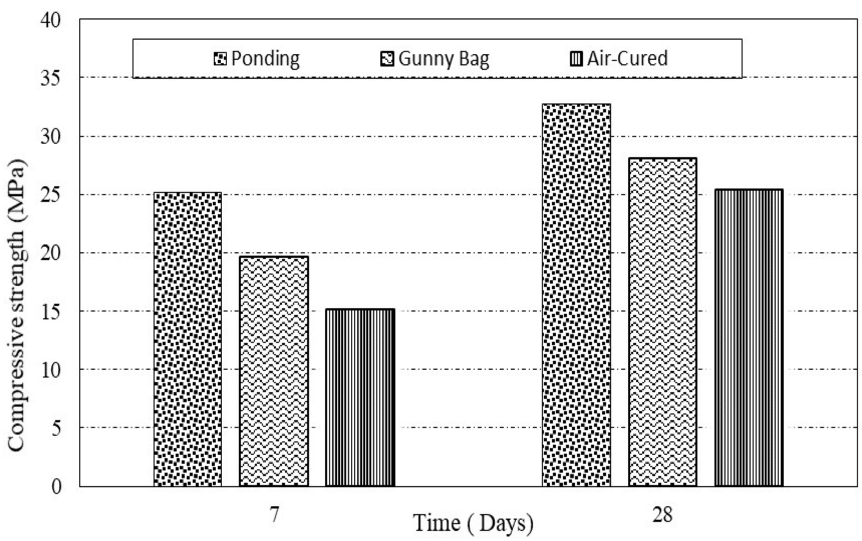

Figure 2: Compressive strength of concrete specimen cured in various methods and time

3.2 Water Permeability

Water permeability is a durability indicator for concrete structures. Permeability controls the rate of water penetration. The more permeable the structure is, the less durable it is. After placing concrete cylinders in U-test equipment for 72 hours, the split cylinder test was done. The penetration value for ponding was 50 mm, for gunny bags 65 mm and for air-cured specimens, it was 125 mm respectively. In Figure 5, the variation in the water penetration value of different specimens is expressed. It can be seen that the penetration value is the least for ponding and the maximum for air-curing. Numerically, it is 1.3 times higher for gunny bags curing and 2.5 times higher for air-cured in comparison with ponding. Thus, concrete specimens that are pond-cured are more durable in comparison with gunny bags and air-cured specimens. Because water exhibits an important role in the chemical and physical reactions in concrete, it imparts both the required and damaging functions. Reducing the permeability of concrete structures leads to lowering deterioration and increasing concrete durability.

Figure 3: Water permeability test of concrete specimens

The water permeability value of concrete specimens is shown below.

Table 1: Water Penetration Value

Methods of Curing	**Water Penetration**		
	Sample-1	**Sample-2**	**Average**
Ponding	47 mm	54 mm	50 mm
Gunny bag	60 mm	69 mm	65 mm
Air	117 mm	133 mm	125 mm

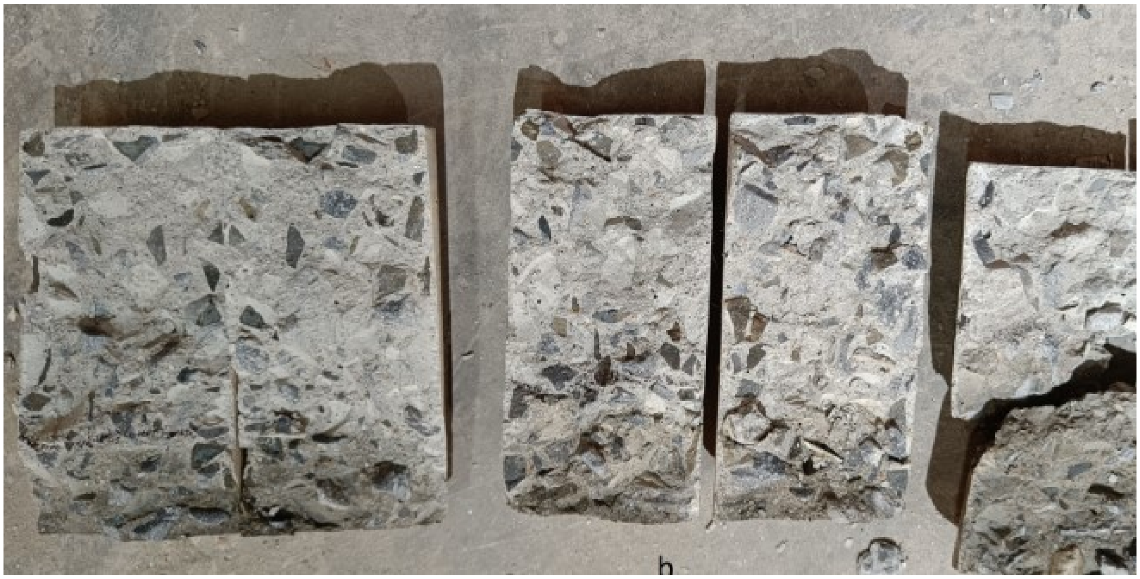

Figure 4: Water penetration in concrete specimens; (a)Ponding (b) Gunny Bag and (c) Air-cured

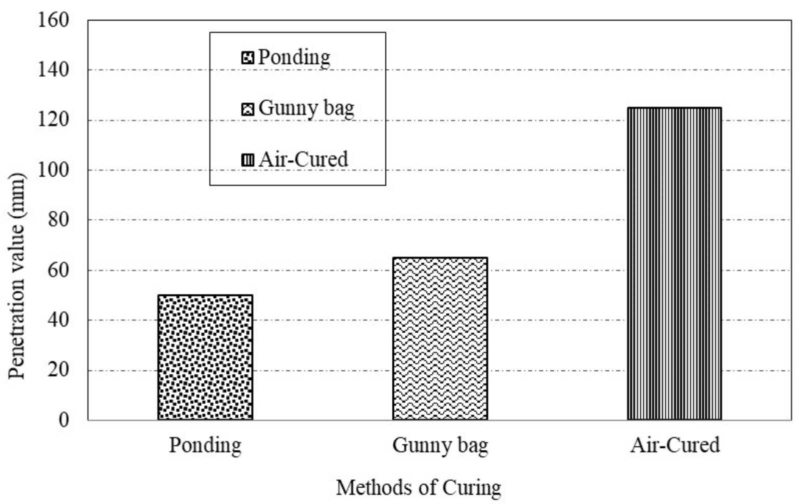

Figure 5: Water penetration value of differently cured specimens

For any structural element, durability is one of the design criteria. When the concrete element is susceptible to water penetration due to its porous structure, it subsequently results in corrosion of reinforcement and thus deteriorates. The specimen cured by ponding will be more durable due to its lower penetration value whereas the air-cured specimens are the least durable among all specimens due its higher water permeability.

4. CONCLUSIONS

The effects of curing methods on the mechanical properties of NSC (w/c 0.4) are examined experimentally and can be concluded as follows.

- Pond curing has a maximum of 7 days and 28 days compressive strength than gunny bags and air-curing concrete specimens.
- The air-cured specimens have the least compressive strength among all the methods mentioned.

- Water penetration is the lowest in pond curing indicating the most durable among the mentioned methods.
- Air-curing produces the least durable concrete specimens than ponding and gunny bags curing.

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