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The Effect of Regular and Irregular Curing on the Mechanical Property of Normal Strength Concrete in Hot and Humid Weather

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Abstract

Curing is played a vital role for the maturity of concrete. This keeps the concrete moist for a certain period of time which is essential to complete its hydration process. Irregular curing is visible in many places in Bangladesh especially where pause of supervision is observed. This work is conducted to find out the effect of these irregularities in terms of strength and permeability. For this, 350 nos concrete cylindrical samples (100 mm x 200 mm) are made and cured in eight irregular curing methods which are commonly observed in surroundings of Khulna city. Out of these eight, four types are water submerged curing and remaining four types are sprinkling curing (three times in a day) followed by 12h, 24h, 48h and 72h delay from its casting time. All of these eight types of specimens are cured for 7 days from the starting time of curing and kept in open air condition until the test time. These results are compared with the sample result which are stayed 28 days in water submersed curing system and de-molded after 24 hours of its casting. Tests are conducted at 28th and 180th days of its age. It is observed that the compressive strength decreases 24%, 16%, 27% and 34% for 12h, 24h, 48h and 72-hours delay curing in water submerged condition respectively. And 29%, 26%, 43% and 48% for 12h, 24h, 48h and 72-hours delay curing in sprinkling condition respectively.

Keywords: *Curing, Irregular curing, open air condition, Strength and permeability.*

1Introduction

At present, no construction work can be thought of without cement concrete. Cement concrete has long lasting properties against adverse weather conditions. The most important property of cement concrete is its compressive strength and durability. The strength and durability of cement concrete depends on its proper curing system. Usually the compressive strength of concrete is calculated subject to 28 days of its age. Although there are many methods of concrete curing, curing methods are applied to construction site depending on the type of works, location, importance, construction site temperature, humidity, and cost. Although there are many modern methods of concrete curing, generally concrete curing is done by water submerge for horizontal members and by membrane/sprinkling in case of vertical members. In the sprinkling method usually involves watering two or three times a day in practice. This moistens the concrete for a very short time and remains lost its internal moisture in hot weather. On the other hand, curing is not seen for more than 7 days in many cases especially for vertical member. In which cases where there is a provision for checking the quality of concrete through lab tests, it can be seen that the sample concrete cylinders are properly cured in submerged water for 28 days and sent to the lab for testing. On the other hand the infrastructure is not properly curing for 28 days. In some cases, even with proper curing, the air temperature is much higher than the ideal temperature for concrete curing during most of the year. As a result, satisfactory results are obtained in lab tests, but the reality is completely different. Therefore, it is necessary to verify that if the concrete is irregularly curing in hot and humid weather, what changes occur in its properties. (Ruhal et al., 2018). Published the effects of improper curing on the properties of normal strength concrete. This study unequivocally reveals that the number of curing days should be kept to a minimum. To this end, in this study, examined 1 to 7 days of curing and compares it to 28 days of curing concrete. Three grades of normal concrete strength were produced: Grade 30, Grade 35 and Grade 40. After curing, the concrete was subjected to two exposure conditions: a controlled laboratory environment and an outdoor environment. The results showed that slump increases with cement content in the DOE method at constant water content. All grades of concrete lost density when they are subjected to compressive internal stresses due to external stresses. Moisture

lost from concrete decreases with increasing curing time. For all concrete qualities, curing time increases with increasing numbers. For concrete homogeneity, the ultrasonic pulse rate showed this with increasing curing days. The concrete became denser and a little hollow. This result indicates that increasing the curing time also improves the surface quality of the concrete. Importantly, found no significant difference in concrete properties for all grades between the 7-day curing and 28-day curing. (Ajay et al., 2013). Published a comparative study on the effect of curing on concrete strength. Curing for 3, 7, 28, and 56 days was used in this study. Curing methods were air curing, plastic sheet curing, and water immersion curing. The cement type was Portland Pozzolona cement, grade 47. Cubes, cylinders and beams were casted and hardened before testing under various conditions. When tested for air curing, it showed nearly the same results as plastic film, but when immersed in water, curing strength increased with age. This study showed that the type and duration of curing had a significant impact on the strength properties of concrete. Quality control was therefore paramount to proper on-site care. From the test results, a 41.70%, 31.70%, and 42.1% increased in compressive strength after 7 days was observed compared to the strength after 3 days for the air-curing, plastic-film-curing, and water-immersion-curing samples. (Marzouk and Hussein, 1995). Published the effects of hardening of high-strength concrete at low temperatures. This study dealt with the effect of setting age on strength development of high-strength concrete containing silica fume and fly ash under low temperature conditions. The tests were performed on three sets of samples with initial curing ages of 1, 14, and 28 days at room temperature. Test samples were exposed to five temperatures ranging from -10°C to 20°C for three months in cold sea water. The increase in compressive and tensile strength over time had been found to be directly proportional to the increase in temperature. The increase in intensity over time was recorded at 20 °C for all three sets, with the lowest at -10 °C. For sets that were initially recovered for 1 day, the slowdown in power gain was severe. However, first they were small in the set where they were curing for 14 days, and initially they were negligible in the set where they were curing for 28 days. A maturity analysis was performed using a hyperbolic function. The aging function showed reasonable agreement with the three sets of samples at different temperatures, except for the samples curing for 1 day and exposed for up to 7 days. (Osama and Omar, 2019). Published the effect of hardening method on the compressive strength of sustainable self-compacting concrete. Concrete members and systems are generally designed to withstand compressive strength for 28 days. Despite this, concrete structures usually harden for only 3-7 days. The use of curing techniques involving compounds such as acrylics was increasing. There used three curing methods: immersion in water, high temperature air curing, and compound curing. They used a 150mm x 150mm x 150mm concrete cube. It consists of a sustainable, self-solidifying concrete that replaces 90% of the normal Portland cement content with a combination of large amounts of blast furnace crushed slag, fumed silica and fly ash. A total of 20 blends were tested, the first group of 10 blends was made with water to a binder ratio of 0.33 and the second group of 10 blends was made with water to a binder ratio of 0.36. Created with It is air curing at 45°C and delivered 28-day compressive strength, higher than any other curing method. A sustainable SCC mixture with a maximum compressive strength of 76.22 MPa under air curing was produced with a W/B ratio of 0.33, a slag exchange ratio of 72.5, a slag exchange ratio of 12.5% and 10% fly ash. It accounts for only 10% of the total binder content. (SAMIR and MOKDAD, 1988). Published the effects of setting time and setting retardation on concrete at elevated temperatures. They showed that the effects of wet burlap curing time and curing delay on several properties of concrete with different mixing ratios (cement content, moisture content) in hot weather had been studied. The results showed that the thick mixture required at least 3 days curing, while the lean mixture required a longer period of time (at least 7 days). Curing delays adversely affected concrete, with the first day of delays having the greatest impact. Curing after the delay increased the compressive strength of the concrete, but did not compensate for the strength loss caused by the delay in curing.

2 Materials and Methodology

Materials and methods which are used in this work are described below.

2.1Materials of Concrete Specimens

The following materials are used to cast concrete cylinder specimens for this study.

a. Fine aggregate: river bottom sand collected from local market as fine aggregate in this work. Its fineness modulus (F.M) is 2.77.

b. Coarse aggregate: Crushed gravel 20 mm down well graded is used here as coarse aggregate, which is free from any other foreign materials. Gradation of this coarse aggregate is shown inFigure1 .

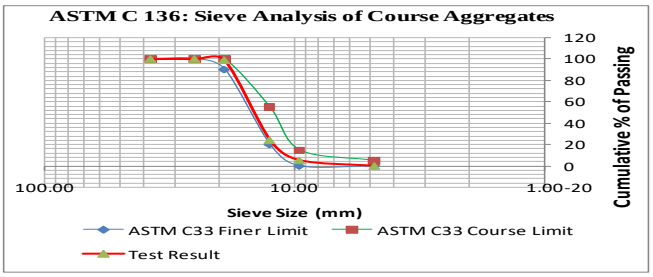

Figure1. Sieve analysis of course aggregates.

Unit weight of course aggregate is 1594 kg/cum, water absorption is 1.904%. And Los Angeles Abrasion (LAA) Value is 15.93%.

c. Ordinary Portland cement (OPC) is used in this work. Average Compressive Strength of the used cement at 7 days is 35.58MPa. Initial setting time is 139 minutes and final setting Time 265 minutes and water for normal consistency is 25%.

d. Potable Water is used as mixing water in this research work.

2.2 Preparation of concrete specimens

In this research the mixing ratio of concrete specimen is 1:1.5:3.0. Its water cement ratio is 0.45. The prepared concrete slump is 70±5 mm. Before mixing, the course aggregates are washed and cleaned properly by water. The ambient air temperature and humidity at the time of specimen casting are 32˚C ± 1˚C and 76% ± 2 %. Concrete mixers are made using concrete mixing machines. Concrete cylinders are made according to ASTM C31/31M. Concrete cylinders are cured by two methods in nine ways. Which are described in Table 1 with nine different ID (name). They are C-12-W, C-24-W, C-48-W, C-72-W, C-12-S3, C-24-S3, C-48-S3, C-72-S3 and C-24-W-28 (Base line).

Table 1. Curing information of specimens in field condition.

Sl. No	ID	Description	Curing duration	Remarks
1.	C-12-W	Curing starts after 12 hours of casting by water submerged method	Curing works are continued up to 7 days from the time of curing starts.	
2.	C-24-W	Curing starts after 24 hours of casting by water submerged method	Do	
3.	C-48-W	Curing starts after 48 hours of casting by water submerged method	Do	
4.	C-72-W	Curing starts after 72 hours of casting by water submerged method	Do	
5.	C-12-S3	Curing starts after 12 hours of casting by Sprinkling method. 3 times in a day	Do	
6.	C-24-S3	Curing starts after 24 hours of casting by Sprinkling method. 3 times in a day	Do	
7.	C-48-S3	Curing starts after 48 hours of casting by Sprinkling method. 3 times in a day	Do	
8.	C-72-S3	Curing starts after 72 hours of casting by Sprinkling method. 3 times in a day	Do	
9.	C-24-W-28	Curing starts after 24 hours of casting by water submerged method	Curing works are continued up to 28 days from the time of curing starts.	Base line

Air temperature and humidity play an important role in concrete curing. So the maximum and minimum air temperature is recorded every day from the time of preparation of concrete samples till the final test in field condition, where the samples are prepared and cured. This is shown in Figure 2.

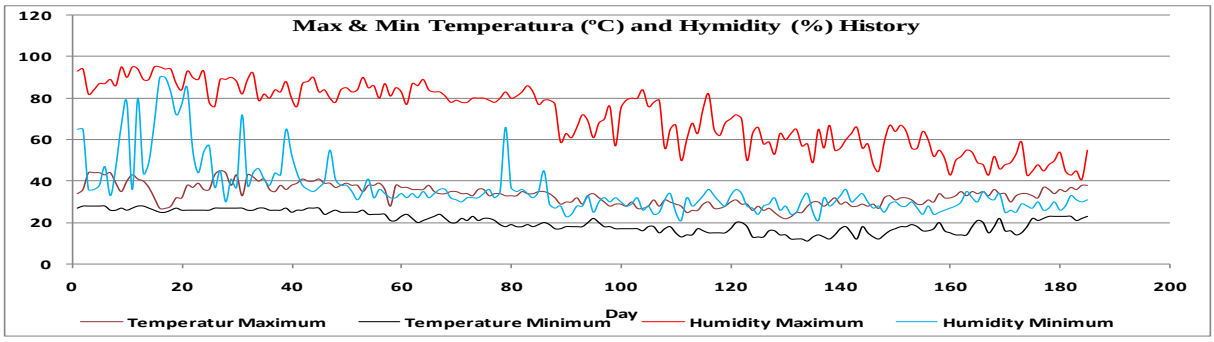

Figure 2.Daily maximum and minimum temperature and humidity data at sampling location from 28-August-2022 to 23-February-2023 (field condition)

2.3 Curing Details

Generally in practical field concrete casting starts in the morning, cast normally till evening and curing starts on next morning. Due to some unavoidable reason and sometime due to laziness, concrete curing starts after one or two days of its casting especially for the vertical member at the construction site. First part of the concrete which starts at morning are faced 48 hours delay and last portion of concrete follow 60 hours delay. In case of vertical members generally the shuttering are not opened up to 36 hours of its casting. In that case the shuttering is opened with a delay of 2 days or 3 days. Considering this, this work try to find out the effect of delay curing on concrete. Here curing is started in natural environment with delays of 12 hours, 24 hours, 48 hours and 72 hours after casting of concrete specimens. Two types of curing methods are used in this study. 1) Water submerged curing and 2) Sprinkling curing (three times in a day). These two methods of curing are done in eight ways up to seven days. And these results are compared with the Base line curing which started after 24 hours of sample casting and is submerged in water up to 28 days.

3 Results and Discussions

3.1 Compressive Strength

In general compressive strength would be considered to check the quality of concrete. Concrete needs to be curing under a specific temperature, humidity and period. In reality the same temperature and humidity are not always found in nature. Temperature and humidity changes with the seasons as well as in day and night also. One of the objectives of this research work is to find out the effect of irregular curing that occur in real construction site. The results observed in the laboratory testing after 28 and 180 days age are shown in Figure3 and Figure4.

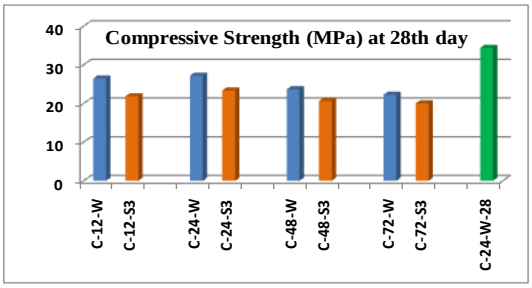

Figure 3. Compressive Strength at 28th day

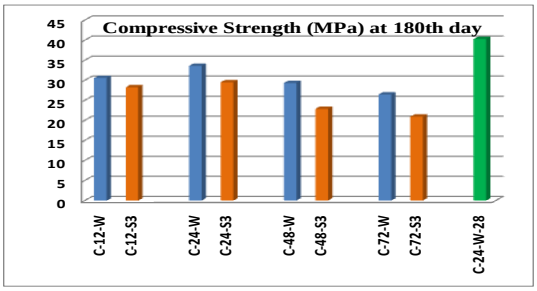

Figure 4. Compressive Strength at 180th day

Specimen concrete cylinders are cured by two methods in nine ways. One of the nine is base line (C-24-W-28) or regular curing (standard, assumed for this study) in which sample cylinders are cured in submerged water after 24 hours of casting for up to 28 days, to verify the effect of regular curing in field condition. Four types are water submerged curing and remaining four types are sprinkling curing (three times in a day) followed by 12h, 24h, 48h and 72h delay from its casting time. Each of these eight types of specimens are cured for 7 days from the time of curing starting in field condition, to verify the effect of irregular curing in field condition. In practice, in many cases, curing is not continued for more than 7 days, especially for vertical members. So this research is done on 7 days of irregular curing. The samples used in this research are kept in the natural environment under the open air from the time of preparation until the test, so that the results of regular and irregular curing in the concrete used in construction work can be verified. A test is done after 28 days to observe the effect on the sample after a short period of time. Compared to the base line after 28 days, it is observed that the compressive strength decreases 23%,

21%, 31% and 35% for 12h, 24h, 48h and 72-hours delay curing in water submerged condition respectively. And 36%, 32%, 39% and 41% for 12h, 24h, 48h and 72-hours delay curing in sprinkling condition respectively. A final test is done after six months to observe the effect on the sample after a long period of time. Compared to the base line after six months, it is observed that the compressive strength decreases 24%, 16%, 27% and 34% for 12h, 24h, 48h and 72-hours delay curing in water submerged condition respectively. And 29%, 26%, 43% and 48% for 12h, 24h, 48h and 72-hours delay curing in sprinkling condition respectively. Similar trending was observed by (Akeem et al., 2013). In his research, Sample concrete cylinders were casted in 1:2:4 ratios. Water-cement ratio of casting is 0.65. Samples were cured in six methods. They were polythene curing, air curing, moist sand curing; water submerged curing, burlap curing and spray curing. Maintain average curing temperature 27ºC and 75% relative humidity. Samples were tested at 3, 7, 14, 21 and 28 days. It was observed that the highest compressive strength (30.5 N/mm2) is obtained in moist sand curing at 28 days. And after that the 2nd highest compressive strength (24.4 N/mm2) is obtained in air curing at 28 days.

3.2 Split Tensile Strength

When designing structural lightweight concrete elements, split tensile strength is utilized to gauge the concrete's shear resistance and establish the length of the reinforcement's development. One of the fundamental and crucial characteristics of concrete that significantly influences the size and degree of cracking in buildings is its tensile strength. Additionally, because concrete is brittle, it is particularly weak under strain. It is important to measure the tensile strength of concrete. That is why split test is included in this research. The method is based on ASTM C496. The results obtained by testing the samples after 28 days and 180 days are shown graphically in Figure-5 and Figure-6.

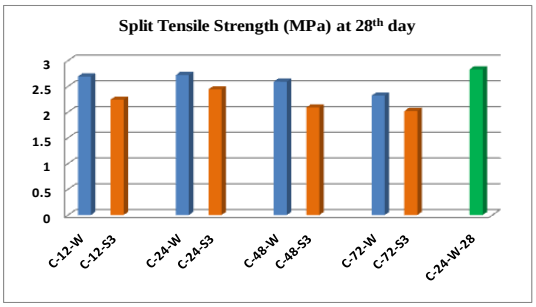

Figure 5. Split Tensile Strength Test at 28th day

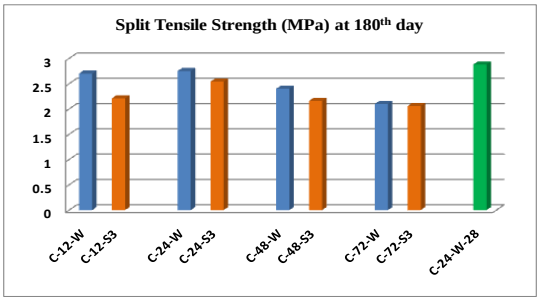

Figure 6. Split Tensile Strength Test at 180th day

In this study, the lowest tensile strength is obtained in the samples which curing started after 72 hours of casting. Closer values are found at 28 days and 180 days testing. All that samples curing start after 24 hours and carry out up to 7 days have values close to the base line. The later the curing is started; the value of split tensile strength decrease in both methods (Sprinkling & Water submerged curing). Compared to the base line after 28 days, it is observed that the split tensile strength decreases 5.11%, 3.89%, 8.78% and 18.25% for 12h, 24h, 48h and 72-hours delay curing in water submerged condition respectively. And 20.92%, 13.87%, 26.28% and 28.71% for 12h, 24h, 48h and 72-hours delay curing in sprinkling condition respectively. Compared to the base line after six months, it is observed that the split tensile strength decreases 6.46%, 4.55%, 16.75% and 27.27% for 12h, 24h, 48h and 72-hours delay curing in water submerged condition respectively. And 23.44%, 11.72%, 24.88% and 28.47% for 12h, 24h, 48h and 72-hours delay curing in sprinkling condition respectively.

3.3 Rapid Chloride Permeability Test (RCPT)

Due to its ease of use and speed, the rapid chloride permeability test (RCPT) as per ASTM C-1202 is frequently used to gauge concrete's resistance to chloride ions intrusion. RCPT test is one of the concrete tests to determine the durability of concrete. In the building industry, concrete is one of the most adaptable and popular materials. The most important factor in determining how long a structure will last is its durability. Concrete's resilience to degradation processes such as abrasion, chemical assault, weathering, and other processes is what is meant by the term "durability." When subjected to adverse environmental conditions, durable concrete can nevertheless maintain its original shape, quality, and usability. Concrete that has been properly prepared tested and applied can last for decades with little to no maintenance. That is why RCPT is included in this research. That is, to observe the effect of regular and irregular curing on the concrete. The main purpose of this research is to verify what actually happens in the construction project practically. Below is Figure 7 showing RCPT values of concrete cylinder specimens curing in different ways (regular and irregular) at 180th day.

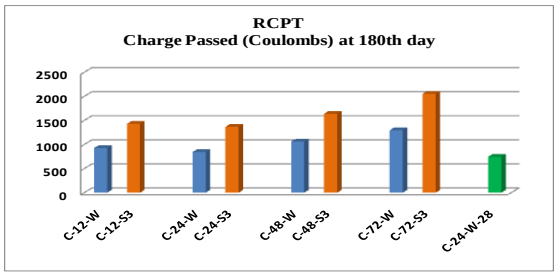

Figure 7. RCPT at 180th day

According to ASTM C1202, if Charge Passed (Coulombs) > 4000 Coulombs, it is very poor-quality concrete. If it is 2000-4000 Coulombs, it is poor quality concrete. If it is 1000-2000 Coulombs, it is Normal quality concrete. If it is 100-1000 Coulombs, it is good quality concrete. If it is less than 100 Coulombs, it is very good quality concrete. In this study, good quality concrete is obtained at 180thday's cylinder testing for regular curing (Base line sample) of 28 days. In sprinkling curing poor quality concrete obtain when curing starts after 72 hours and curing up to 7 days. One the other hand in water submersed curing normal quality concrete obtain when curing starts after 72 hours and curing up to 7 days. Water submerged curing is better than Sprinkling curing in regular and irregular curing system.

4 Conclusions

This study is not dependent on any specific temperature and humidity rather depending on the ambient temperature and humidity. In practical aspect the ambient temperature and humidity cannot be controlled at the construction site as well as the curing condition and time also influenced on the construction nature and monitoring performances. The following conclusions can be drawn from this work:

a. During rapid chloride permeability test (180th day testing) in water submersed curing, normal quality concrete obtain when curing starts after 72 hours and curing up to 7 days (C-72-W). It is 1296 (Coulombs). But in sprinkling curing poor quality concrete obtain when curing starts after 72 hours and curing up to 7 days (C-72-S3). It is 2052 (Coulombs).
b. During split tensile strength test (180th day testing) in water submersed curing, lowest tensile strength is obtain when curing starts after 72 hours and curing up to 7 days (C-72-W). It is 2.10 MPa. But in sprinkling curing, same quality concrete obtain when curing starts after 72 hours and curing up to 7 days (C-72-S3). It is 2.06 MPa.
c. During compressive strength test (180th day testing) in water submersed curing, normal quality concrete obtain when curing starts after 72 hours and curing up to 7 days (C-72-W). It is 26.46 MPa. But in sprinkling curing, almost the same quality concrete obtain when curing starts after 72 hours and curing up to 7 days (C-72-S3). It is 20.93 MPa.

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