Experimental Study on Strength Variation in Concrete by Using Different Curing Techniques

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Abstract: The advances in the construction and chemical industry opened the way for the development of the latest curing methods and building materials. Since water is a scarce resource on a regular basis, there is an immediate need to carry out study work on water conservation in concrete manufacturing and construction. Concrete curing puts an important role in the production of concrete strength and hardness which contributes to improved durability and performance. Curing is important if concrete is to serve the expected purpose over the structure's design life, although excessive curing time can contribute to project rising costs and excessive delays in construction. This project is intended to test the effectiveness of various curing techniques and to analyse concrete's strength properties. Normal concrete was prepared with a water cement ratio of 0.5 and 0.35 with mixing method IS was introduced, since the standard strength curing concrete of grade M20 and M50 of concrete is construction based on trial and error. The strength properties of Normal Strength Concrete and high strength concrete, cast with the Super plasticizer Conplast SP430 has tested in this experimental investigation and compared with the same conventionally cured concrete. The cubes are casted for measuring compressive strength at 7 , 14 and 28 days of curing, respectively, using methods of curing that are immersion, accelerated curing, membrane curing (i.e.; plastic sheeting method), dry air curing, water proofing compound, wax based and acrylic based curing to cure the cubes until the test day. The result obtained indicates the best method of curing for obtaining improved compressive strength.

***Index Terms* - Immersion curing, accelerated curing, membrane curing, dry air curing, compressive strength.**

I. INTRODUCTION

Construction industry is growing day by day even in remote areas and desert regions. Even India and other countries are facing lot of problems in supplying drinking water to their citizens. Construction companies are now under pressure to develop new ways of curing concrete. Concrete curing is the maintenance of satisfactory concrete moisture content during its early stages in order to develop the desired concrete properties. Concrete is world's most commonly used construction material. It consists essentially of two components that are paste and aggregates regulated by specifications of fresh concrete workability, durability and strength based on concrete recovery process. Proper curing is expected to achieve optimal concrete strength and efficiency. The curing is achieved in traditional concrete after different stages such as mixing, placing and finishing. Concrete requires comfortable environment by supplying moisture for good hydration for a minimum duration of 28 days and to achieve required strength. The quality and durability of concrete would be seriously impacted by any laxity of curing. The need for adequate curing of concrete cannot be overemphasized because curing has a strong influence on the properties of hardened concrete, proper curing will increase durability, strength, water tightness, abrasion resistance, volume stability, and resistance to freezing and thawing effect. In concrete to achieve its maximum strength and durability, curing must be performed for a suitable period of time. Curing can be achieved in a variety of ways whereas the most appropriate means of cure can be determined by the circumstances of the location or the process of construction.

Role of Concrete Curing:

Curing plays an important role on strength development and durability of concrete. Curing takes place shortly after concrete preparation and completion, which requires preserving the appropriate moisture and temperature levels for prolonged periods of time, both at depth and at the surface. Properly cure concrete has an adequate amount of moisture for continued hydration and development of strength, volume stability, resistance to freezing and thawing.

The amount of adequate curing time depends on the following factors:

- Mixture proportions
- Specified strength
- Size and shape of concrete member
- Ambient weather conditions
- Future exposure conditions

II. OBJECTIVES OF STUDY

Many researchers have reported research works on concrete must be workable and cohesive when plastic, then set and harden to give strong and durable concrete. Thus, to make a concrete structure that workable should be taken into action. The purpose of this study is to investigate the performance/ strength of concrete with different concrete curing techniques.

Objectives of this study are as follow.

- To study the material properties of concrete.
- To study the workability of the M20 and M50 concrete.
- To study the compressive strength of M20 and M50 concrete with different curing techniques.
- To study the comparisons of Normal concrete and High Strength concrete

Curing is the process of controlling the rate and extent of moisture loss from concrete during cement hydration. If the concrete is to achieve its full strength and durability curing, temperature regulation must also be required as this influences the rate of hydration of cement.

As per ACI-308R:- The term "curing" is also used to describe the mechanism by which hydraulic cement concrete matures and, in the presence of sufficient water and heat, produces hardened properties over time as a result of continuous hydration of the cement.

As per IS: 456-2000:- "Curing is the method of stopping the concrete from losing moisture. "Curing is the maintenance in concrete of a sufficient moisture content and temperature for a period of time immediately after installation and finishing such that the desired properties may grow. Curing has a strong influence on the properties of hardened concrete; proper curing will increase durability, strength, water tightness, abrasion resistance, volume stability, and resistance to freezing and thawing etc.

Duration of curing

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 variation between vapour pressure on the concrete surface and the surrounding air is caused by the evaporation of moisture. If the difference is high then the rate of evaporation is high.

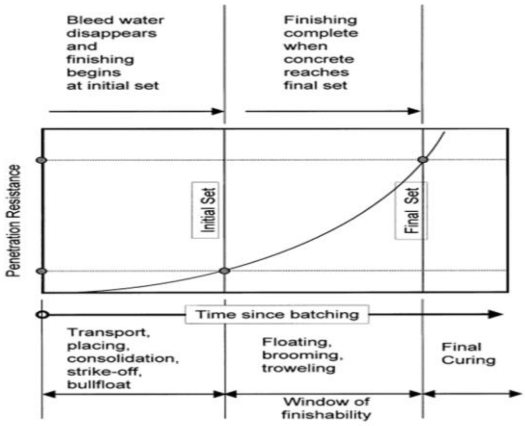

Figure 1 Curing of cement concrete – Time & Duration

III. TYPES AND METHODS OF CONCRETE CURING

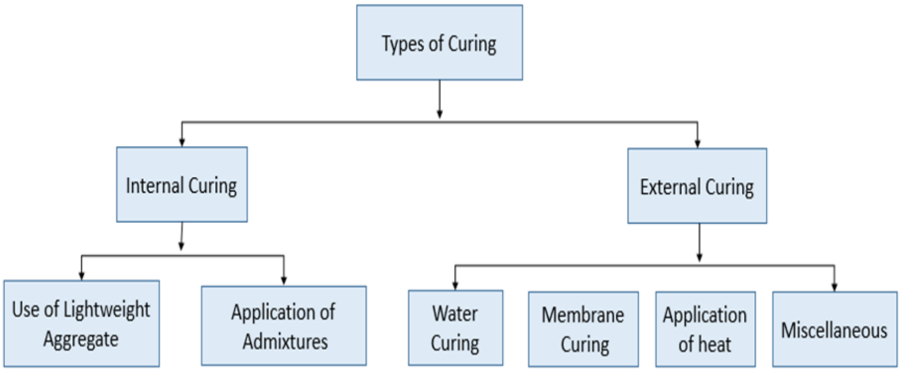

Figure 2 Flow chart for types of curing

3.1 Water Curing

3.1.1 Ponding and Immersion: - On flat surfaces, such as pavements and floors, concrete can be cured by ponding. Earth or sand dikes around the perimeter of the concrete surface can retain a pond of water. Ponding is an ideal method for preventing loss of moisture from the concrete; it is also effective for maintaining a uniform temperature in the concrete. The curing water should not be more than about 11°C (20°F) cooler than the concrete to prevent thermal stresses that could result in cracking. The most thorough method of curing with water consists of total immersion of the finished concrete element. This method is commonly used in the laboratory for curing concrete.

3.1.2 Spraying water: - This is the simplest method for curing. In this method, after removal of shuttering or the framework/form work, water is sprayed on the concrete surface through a hose or by bucket, a number of times during each day. This method is suitable for small works. It requires great care in supervision, and as soon as the concrete dries, water has to be sprayed.

Ponding	**Immersion**	**Spraying**

Figure 3 Curing of concrete by ponding, immersion, spraying

3.1.3 Wet Coverings: - The most effective method of curing is to keep the exposed concrete surfaces continuously moist. The concrete is saturated for a long term period after setting, the ideal condition for strength development and hydration of cement. As a result, the concrete strength increased. Fabric coverings saturated with water, such as burlap, cotton mats, rugs, or other moisture-retaining fabrics, are commonly used for curing. Treated burlaps that reflect light and are resistant to rot and fire are available.

3.1.4 Steam Curing: - Steam curing is advantageous where early strength gain in concrete is important or where additional heat is required to accomplish hydration, as in cold weather. Steam curing is used for pre-cast concrete products. Due to steam, the components are heated uniformly and the strength is gained at a very fast rate. Steam can pass and penetrate through small gaps of stacked pre-cast concrete products and strength is achieved evenly from all sides.

3.2 Membrane Curing: - It is a method of curing concrete usually in pavements by which a material in liquid form is sprayed over the exposed surface shortly after the concrete is finished after which the material solidifies and becomes essentially impervious and thus holds the mixing water in the concrete so that it can hydrate the cement over a period of time.

3.3 Application of heat: - The concrete strength gaining process does not only be function time but also that of temperature. As the temperature of concrete increases, it accelerates the hydration process resulting in faster development of strength. The application of dry heat to accelerate the hydration process as the presence of moisture is also an essential requisite. Therefore, setting up the required temperature of concrete and maintaining the required wetness can be achieved by subjecting the concrete to steam curing.

3.4 Miscellaneous Curing: - Calcium chloride is used either as a surface coating or as an admixture. It has been used satisfactorily as a curing medium. This method is based on the fact that calcium chloride being a salt shows affinity for moisture. The salt not only absorbs moisture from atmosphere but also retains it at the surface. Keeping the formwork intact and sealing the joint with wax or any other sealing compound prevents the evaporation of moisture from the concrete. This procedure of promoting hydration can be considered as one of the miscellaneous methods of curing.

Burlap sheeting

Steam

Plastic sheeting

Figure 4 Curing of concrete by ponding, immersion, spraying

IV. LITERATURE REVIEW

Cano Barrita et. al. (2004), evaluated high performance concrete mixtures that can be used successfully in hot dry climates. In this research magnetic resonance imaging(MRI) was used to measure the effectiveness of extending the moist curing period by incorporating some saturated light weight aggregates into a concrete mixture being placed in hot dry climatic conditions. A series of concrete mixtures were prepared and moist cured for 0, 0.5, 1or 3 days, or by using a curing compound, followed by air drying at 38°C and 40% relative humidity. To accomplish this, 11% by volume of the total aggregate content was replaced with lightweight aggregate. Type I white Portland cement and quartz aggregate plus the lightweight aggregate were all selected for their low iron content to minimize adversely affecting the MRI measurements. The concrete mixtures were low strength concrete (W/C=0.60), self-consolidating concrete (W/C=0.33 containing 30% fly ash), and high strength concrete (W/ C=0.30 containing 8% silica fume).

Hans W. Reinhardt et. al. (1998) they demonstrated on self-cured high Performance concrete that a partial replacement of conventional weight aggregates by pre-wetted lightweight aggregates leads to an internal water supply for continuous hydration of cement. Despite water loss by evaporation there is continuous strength gain up to 25% more strength after 1 year compared to standard compressive testing after 28 days. Normal weight aggregate concrete reached considerably less strength at the same storage condition. Application of such concrete in practice means that no curing due to bad workmanship would not impair the concrete, i.e., it would be robust during construction. Current research deals with transport properties (diffusion, permeability) and long term strength.

V. METHODOLOGY

Mix designs of the concrete with the different concrete grades & curing techniques were developed separately. In this study, a total of 54 concrete cubes, 54 cylinders and 16 beams were cast and tested. A controlled beam and concrete cubes without any lightweight aggregate replacement were used for the comparison purposes. Upon preparation of concrete samples, they were cured in water with different concrete curing methods for different ages of 3, 7 and 28 days. Compressive strength test was conducted to measure the strength of the normal concrete & high strength concrete, comparisons is also made with various curing methods. In this study, for the M_{20} & M_{50} concrete cube, the observations will be more on the workability, density, and the compressive strength. Comparisons will lead to the effect of various curing techniques on the performance of the concrete.

VI. EXPERIMENTAL INVESTIGATIONS

6.1 Material properties

6.1.1 Cement: - Cement is one of the binding materials in this project. Cement is the important building material in today's construction. We are use 53 grade Ordinary Portland Cement in this project. The cement is conforming to IS: 8112-1989. The specific gravity of cement is 3.02 and fineness of cement is 97%.

6.1.2 Fine Aggregate: - The sand which was locally available and passing through 4.75mm IS sieve is used.

Table 1 Physical properties of Sand

PROPERTIES	SAND
Sieve Analysis	Zone-III
Void ratio	3.14
Specific Gravity	2.66
Water Absorption	1.67
Bulk density , Kg/m^3	1450
Bulking of aggregates	33%

6.1.3 Coarse Aggregate:- Locally available crushed blue granite stones conforming to graded aggregate of nominal size 12.5 mm as per IS: 383 –1970. Crushed granite aggregate with specific gravity of 2.77 and passing through 4.75 mm sieve and will be used for casting all specimens.

Table 2 Physical properties of Coarse aggregate

Properties	Granite aggregate
Aggregate size, mm	10-20
Bulk density, kg/m^3	1870
Specific gravity	2.72
Water absorption, %	0.75
Fineness modulus	6.9

6.1.4 Mixing water: - Clean drinking water available was used for casting as well as curing of the test specimens.

6.1.5 Super plasticizers: - Super plasticizers (Conplast SP430) was used in the concrete to improve the workability of the fresh concrete. Conplast SP430 is a high range water-reducing concrete admixture. It is a highly effective dual action liquid super plasticizer for the production of free-flowing concrete or as a substantial water reducing agent for promoting high early and ultimate strength.

Table 3 Properties of Super plasticizers

Aspect	Light brown liquid
Relative Density	1.08 ± 0.01 at 25°C
pH	>6
Chloride ion content	< 0.2%

6.1.6 Acrylic resin based curing compound:- Acrylic resin based curing compound is a non-degrading, membrane forming liquid based on specially formulated acrylic resin suitable for curing newly placed or freshly deshuttered concrete.

Table 4 Properties of Wax curing compounds

Appearance	: Clear/white liquid
Specific gravity Clear	: 0.82 ± 0.01 at 25º C
Dry film appearance	:Clear or white
Loss of Water	: < 0.55 kg /m2
Drying time	: 45 minutes at 25ºC

6.1.7 Wax based curing compound:- Wax based curing compound is a solvent free; membrane forming wax emulsion, suitable for curing newly placed or freshly deshuttered concrete assists in the retention of water during hydration.

Table 5 Properties of Wax curing compounds

Appearance	: Clear/white liquid
Specific gravity Clear	: 1.00 ± 0.05 at 25º C
Dry film appearance	:white solar reflective
Loss of Water (ASTM C156)	: < 0.55 kg /m2
Drying time (ASTM C309)	: less than 3 hours

6.2 Mix Proportion

Workability, compressive strength and density are the three main design variables that need to be fulfilled by a suitable proportioning method for various Concrete. By the traditional proportioning methodologies, the concrete strength is related to water-cement ratio.

The common methods used to proportion Normal concrete are also applicable to High strength concrete, taking into account the following aspects:

- The density is an additional variable and depends on the mix design.
- The properties of the fresh and hardened concrete are heavily influenced by the high strength concrete characteristics.
- The water absorption characteristics of the high strength concrete.

Therefore, the mix proportioning was done according to IS 10262:2009 and with reference to IS 456:2000. The target strength for mix proportioning for M20 & M50 grades concrete was 26.60 N/mm2 & 58.25 N/mm2. The w/c ratio remained at 0.5 & 0.35. Cement, fine aggregate and coarse aggregate were properly mixed together in the ratio of 1: 1.51: 3.54 & 1:1.47:3.04. Table 3 shows the details of quantity of constituent materials.

Table 6 Quantity of constituent materials

S. No	Material constituents	M_{20} Quantity, kg/m^3	Proportion M_{20}	M_{50} Quantity, kg/m^3	Proportion M_{50}
1	Cement	386.6	1	422	1
2	Fine aggregate	584	1.51	621	1.47
3	Coarse aggregate	1224	3.54	1284	3.04
4	Water	193.3	0.50	147.6	0.35

VII. PROPERTIES OF CONCRETE

7.1 Fresh properties of concrete

7.1.1 Workability of concrete: It is the property of concrete which determines the amount of useful internal work necessary to produce full compaction. Slump test was done to measure the workability of concrete. The compaction factor is the ratio of partially compacted to completely compacted concrete weights. Slump test and compaction factor test was done to measure the workability of concrete.

7.2 Hardened properties of concrete

7.2.1 Compressive Strength: - It is the primary physical property of concrete and the one most used in design. It also a fundamental property used for quality control for concrete. Compressive strength can be defined as the ability of concrete specimen to sustain the axial load. 54 specimens were cast for each trial mix and compressive strength tests were conducted at the age of 7, 14 and 28 days. The equation for obtaining the compressive strength is as follows:

$$F_C = P/A$$

Where, F c is compressive strength (MPa), A is area of specimen (mm^2)
P is the maximum load applied during testing of specimen (kN)

Compressive strength | **Split Tensile strength** | **Flexural strength**

Figure 5 Compressive Strength Test of Concrete Cube

7.2.2 Split tensile strength Test: - For finding split tensile strength of concrete cylinders of size 150x300mm were made and applied various curing methods for specified time period. Hand compaction technique was adopted. Specimens were casted and tested on the 28th day.

7.2.3 Flexural strength Test: - The test was conducted on the beams at the age of 28 days. Before testing commenced, the test setup for the flexural test is shown in Fig 3.15. The test specimen was fixed in a Universal testing machine (UTM) of 1000kN capacity. The beams rested on a reinforced steel girder of length 1000mm at the supports. The effective length of the beam was 700mm.

VIII. RESULT AND DISCUSSION

8.1 Compressive Strength

Compressive strength test was conducted on the concrete cubes at the age of 7, 14 and 28 days. The cubes must be free from the cracks, chipped surface and other defects that can give inaccurate results. All specimens were tested at the loading rate of 7 kN/sec by using compressive machine. Figure shows the compressive strength test on concrete cubes.

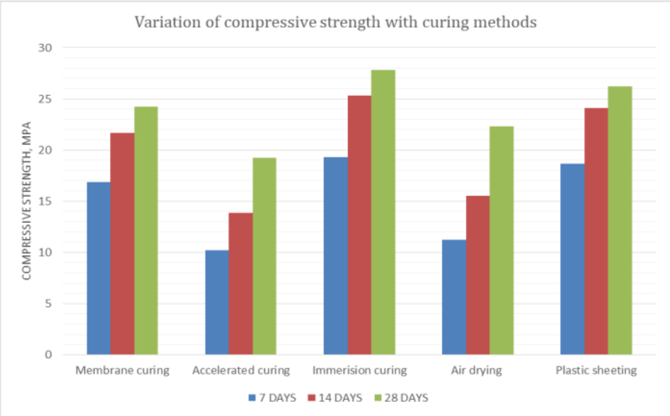

Figure 6 Strength variation of M_{20} grade concrete with curing methods

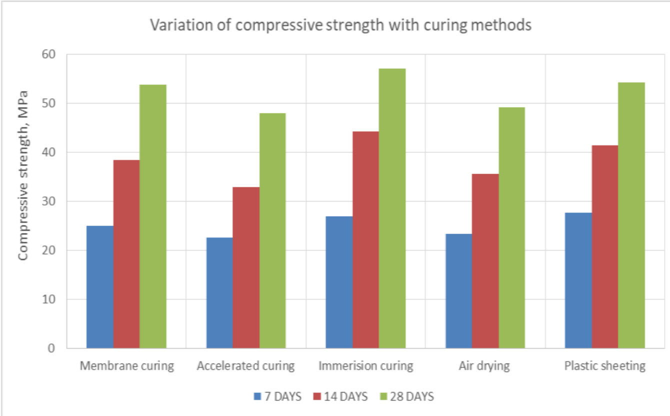

Figure 7 Strength variation of M_{50} grade concrete with curing methods

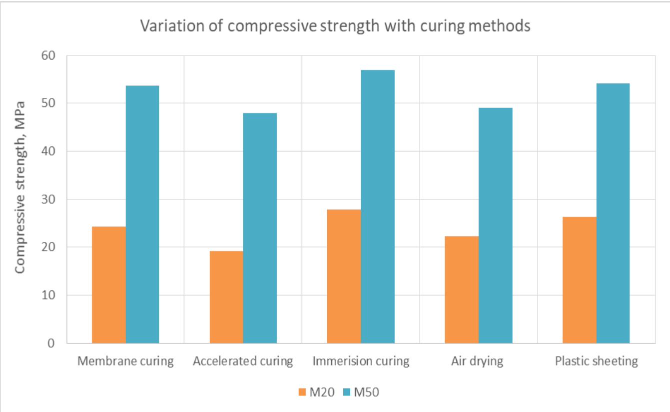

Figure 8 28 days of M_{20} & M_{50} grade concrete with curing methods

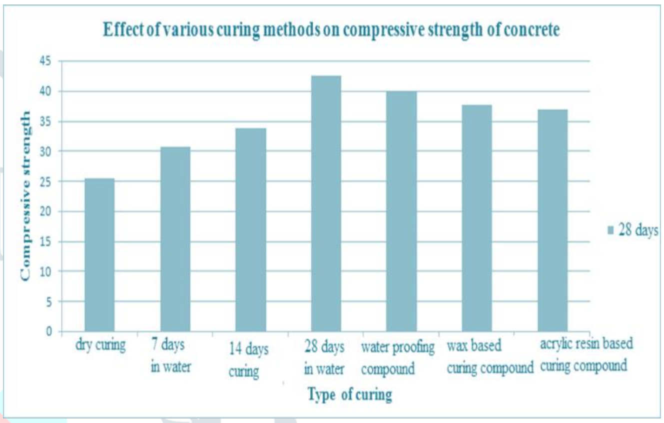

Figure 9 Effect of various curing methods on compressive strength

8.2 Shrinkage

The results of shrinkage limits for five curing methods, out of the five curing methods adopted, only Immersion curing is the best method. In an attempt to evaluate the advantages associated with the various curing methods used in this study, that ponding/ immersion method was ranked first, because water stored for curing can be used throughout the curing process, although this method can best be suitable for precast members

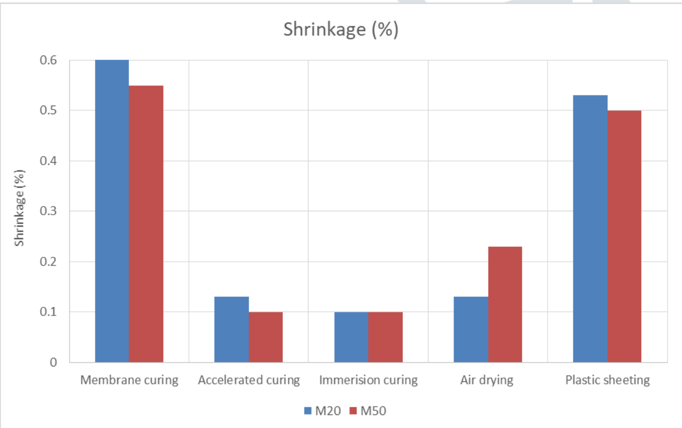

Figure 10 Variation of shrinkage with curing methods

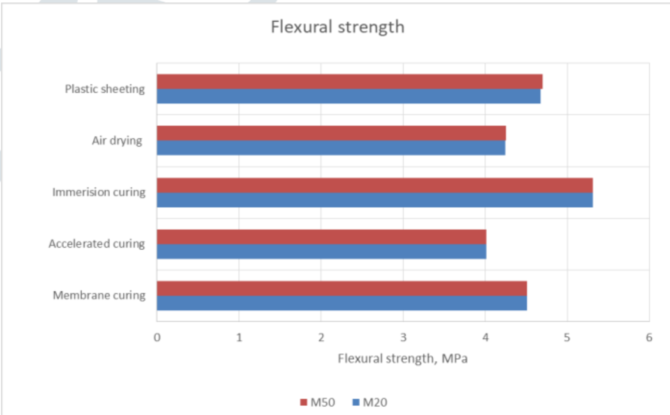

Figure 11 Effect of various curing methods on flexural strength M_{20} , M_{50}

8.3 Flexural strength: For finding flexural strength of concrete beams of size 150x150x700mm were made and applied various curing methods for specified time period. Hand compaction technique was adopted. Specimens were casted and tested on the 28^{th} day.

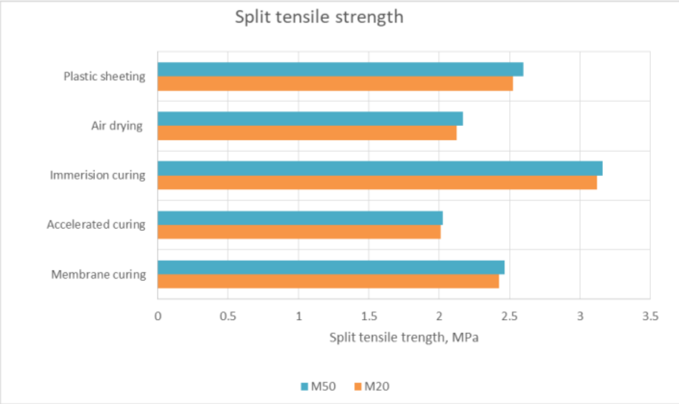

Figure 12 Effect of various curing methods on splitting tensile strength M_{20} & M_{50}

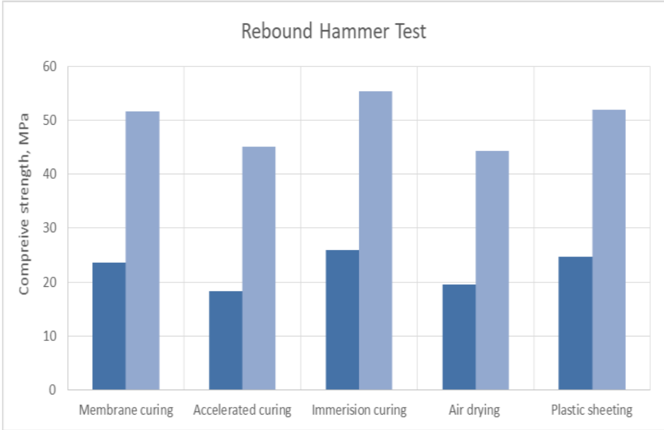

Figure 13 Non Destructive Test results

8.4 Splitting tensile strength of hardened concrete

As compared with normal water curing, concrete with waterproofing compound showed 7%, concrete with wax based curing compound showed 10%, and concrete with acrylic resin based curing compound showed 16% decrease in splitting tensile strength as shown in figure

8.5 Rebound Hammer Test

Rebound hammer also named as Schmidt hammer that is normally used for testing the quality of hardened concrete in a structure. It is a non-destructive and hand held testing device. It could be used on the hard-concrete surfaces, but strict procedures must be followed. In this study, the tests were conducted at the age of 28 days under water wet curing. The quality of the M_{20} & M_{50} concrete produced according to Figure 4.

IX. CONCLUSIONS

After the series of lab tests, the overall results, analysis and comparisons in terms of the workability and compressive strength, the conclusions that can be drawn are as follows:

- Different curing systems have different effects on the compressive strength of concrete.
- Ponding/ Immersion curing was the most effective method of curing. It produced the highest level in compressive strength and cube densities.
- Increase in both compressive strength and cube densities is a function of curing method.
- Totally accelerated method of curing produced the least compressive strength as well cube densities.
- Totally membrane concrete curing shrinks faster when compared to other curing methods
- Compared with immersion curing systems, leaving the cubes in open air and dry laboratory conditions after 24 hours of casting, tends to produce lower compressive strength.
- Concrete samples cured with water always shows higher strengths as compared to the samples without curing and samples cured with curing compound. The abnormalities in Schmidt rebound hammer testing might be due to the fact that Schmidt hammer testing gives only surface hardness.
- Where the plunger of the Schmidt hammer strikes the surface of an aggregate, a higher number achieved without any effect of curing. If the plunger of Schmidt hammer strikes a surface formed with paste, a lower number will be achieved. Schmidt rebound hammer testing is less reliable in estimating the compressive strength of concrete samples.

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