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ENHANCED CURING TECHNIQUE OF VERTICAL CONCRETE MEMBERS

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ABSTRACT

Concrete curing is the essential key for the quality of a concrete. For achieving the design strength and durability there must be a proper curing. Curing process is done accordingly to the desired property of a concrete, the use of concrete, and its exposure. As per IS: 456 - 2000"Curing is the process of preventing the loss of moisture from the concrete. "Curing is the maintenance of a satisfactory moisture content and temperature in concrete for a period of time immediately following placing and finishing so that the desired properties may develop. Normally curing is done for the purpose of keeping the concrete moisture inside and gain the strength a day by day which is relatively done to prevent the strength loss, with no care and/or by doing it unsupervised or unguided the designed strength can't be achieved especially for the vertical concrete members which held the overall structure loads. In the present study, comparison of compressive strength, and tensile strength of concrete for normal curing method and enhanced curing concrete have been studied. Experimental results indicated that enhanced curing of concrete has the better result compared to the normal curing method normal used on sites. The study indicated that compressive strength, and split tensile strength of enhanced

curing technique for vertical concrete member are greater than normal curing technique for vertical concrete members about 29.32% and 22.7% after 28 days of curing respectively.

KEYWORDS: Normal curing, Enhanced curing, Concrete strength characteristics.

1. INTRODUCTION

In different countries with a tropical climate, that changes accordingly to different regions, e.g.: in East region there is slightly hot weather and in West-North region it also slightly cold, these difference in temperature allow the construction industries to use normal curing techniques such as wet covering and sprinkling, water spraying etc. Depending upon the site constraints, type of structure and other material parameters, different methods of curing techniques could be adopted in construction industries. The curing time of concrete is dependent on specific strength of Concrete, Grades of concrete, Atmospheric temperature etc(Sujay Raghavendra N 2010). "Curing" is likewise used to depict the move made to keep up dampness and temperature conditions in a crisply set cementitious blend to permit pressure driven concrete hydration and, if material, pozzolanic responses to happen with the goal that the potential properties of the blend may create. Current restoring strategies are displayed; generally acknowledged techniques, methodology, and materials are portrayed (Jayeshkumar R. Pitroda 2014).Techniques are given for restoring asphalts and different pieces on ground, for structures and structures, and for mass cement. Relieving techniques for a few explicit classifications of concrete based items are examined right now. Restoring measures, as a rule, are indicated in ACI 308.1. Relieving measures coordinated toward the support of good solid temperature under explicit natural conditions are tended to in more noteworthy detail by Committees 305 and 306 on Hot and Cold Weather Concreting, separately, and by ACI Committees 301 and 318.(ACI Committee 308, 2001).

The chemical reaction between hydraulic cement and water is called hydration. With insufficient water, the hydration will not proceed and the resulting concrete may not possess the desirable properties such as strength and durability. It is important to keep sufficient moisture in the concrete while the cement is actively hydrating, especially at early ages.The best known early work on the effects of cement hydration, and hence curing, on cement microstructure. Taylor (1997).

The concrete within approximately 30 to 50 mm of the depth is particularly sensitive to drying, while concrete deeper than 50 mm is usually relatively immune to drying and cementitious materials that develop properties slowly, such as those containing pozzolan, must be cured longer than systems not containing pozzolan or slag. According to the result obtained in the above study, it is clear that curing is required to help the concrete to achieve the hydration process without the loss of moisture inside. The lower the w/c used the more the compressive strength the concrete gained in early curing ages. This may be due to reduced aggregate cement transition zone that increases with increase in water-cement ratio. This is because the cement particles are held at a small interval in case of lower w/c ratio than higher w/c ratio. (Abaho G. Gershome et, 2018).

1.1 OBJECTIVES OF THE STUDY

The objectives of this study are to provide curing technique for vertical concrete members using curing membrane in order to determine and compare the concrete strength properties while using different curing techniques.

1. To design and provide the membrane to be used for curing of the vertical concrete members.
2. To study the compressive and split tensile strength of normal cured and enhanced cured vertical concrete members.
3. To compare the strength characteristics between normal and enhanced curing method for vertical concrete members.

2. LITERATURE REVIEW

2.1 INTRODUCTION

Curing is very important in construction activities. Curing is the process of preventing the loss of moisture from the concrete. "Curing is the maintenance of a satisfactory moisture content and temperature in concrete for a period of time immediately following placing and finishing so that the desired properties may develop. 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. **(IS:456-2000)**.

2.2 PREVIOUS RELATED STUDIES ON CONCRETE CURING

Rohit P. Kamble et al (2016), studies on the effect of curing method on compressive strength and durability of concrete, cement and aggregate. They found that early strength of immersed cured block is less as compared to other methods. However, final strength is highest among others. Early strength of experimental curing compounds is better than sprinkled cured blocks. External compounds got highest final compressive strength among all experimental compounds. Internal compound has got highest early strength and satisfactory final strength. The conclusion obtained from this research is that the external compound gives full 80% strength of hardened concrete than that of conventional method, and the initial strength gained in case of curing using internal compound than other curing methods.

S.B.Kulkarni AVP (2011), studied on the Significance of Curing of Concrete for Durability of Structures. in their research found 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 atleast 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 gets 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.

Princy K.P, et al(2015) Study on the Effectiveness of Various Curing. Methods on the Properties of Concrete. Conventional water curing is the most efficient method of curing as compared to Membrane curing, 7days, 14days water curing and dry air curing methods. Using wax based curing compound and acrylic resin based curing compound can achieve 99% and 96% of compressive strength compared to Conventional Curing method. Membrane curing compounds are most practical and widely used method it is most suitable in water scarce area. Compare to normal water curing, concrete with water curing water proofing compound attained maximum compressive strength. Compared to normal water curing, concrete with waterproofing compound showed 12%, concrete with wax based curing compound showed 21%, and concrete with acrylic resin based curing compound showed 26 % decrease in flexural strength. 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. The study demonstrates that the method and duration of curing greatly affects the strength characteristic of concrete.

M.V. Krishna Rao et al(2010). studied on the influence of curing on the strength of a standard grade concrete mix. The rate of increase of strength from 3 days to 7 days and 3 days to 28 days, for OPC, PPC and OPC with 10% silica fume concretes, when cured by conventional wet curing and by curing compound, are in the ranges of 20.11% to 63.47% and 65.08% to 148.64% respectively. The 28-day compressive strength of concretes with OPC, PPC & 10% OPC replaced by silica fume and cured by conventional wet curing have been more than the corresponding ones cured by compound curing. Curing compound produces nearly same results as that of conventional wet curing for concrete with OPC while a marginal decrement is observed in concrete made of PPC and the one in which 10% of OPC is replaced by silica fume.

Emmanuel Nana Jackson et al(2018). studied on the Comparative Analysis of The Strength of Concrete With Different Curing Methods In Ghana. There was no controlled temperature for any of the curing techniques. All the samples under the four different methods were cured under the same temperature. Based on the uniform platform that was created for all the samples, the study shows that the water curing and jute bag methods are the most efficient methods of curing. This is because the two yielded better compressive strength than the other two. The wet sand method was however, the least performing curing method. Its compressive strength recordings were lower at all ages than the other methods.

A. E. Abalaka et al(2013) studied on the Effects of limited initial curing duration on mechanical properties of concrete. The stage I study results shows that water cured specimens, as expected had higher compressive strength at 90 days compared to air cured specimens. The compressive strength of air cured cubes were 9.53% less than that of water cured at 90 days. The results presented in this study have shown that limited initial water curing is very important in improving mechanical properties of concrete. It also shows that the initial 4 days of curing was sufficient to develop compressive strength higher than the compressive strengths at 28 and 90 days of continuous water curing. From the sorptivity and coefficient of water absorption values of specimens that were continuous water cured, continuous water curing resulted in an improved microstructure of the concrete specimens.

Dinesh W.Gawatreet al(2017) studied on the Effectiveness of Curing Compound on Concrete material used; Cement: Cement (kumar cement) 53grade has been used for mix proportion of M50 and M20 grade of concrete. Aggregate: Two size aggregates are used

20mm and 10mm size. Artificial sand: In Pune region artificial sand will be used in study. GGBS: Ground granulated blast-furnace slag. Physical of GGBS: Fineness modulus-3.35, specific gravity -3.44. Chemical composition: carbon(C) 0.23%, iron (Fe) 93.83%, Silica 5.37%. After experimental study we are concluding that the strength of membrane curing is not efficient as compared to conventional curing by using GGBS. By using membrane curing method strength will not gain properly by using GGBS, also observed that by using conventional method, increased percentage of GGBS strength will increased but by membrane curing not gain properly.

D.Gowsika et al(2017). studied on the found that The precast concrete items are normally submerged in curing tanks for a certain duration. Pavement slabs, roof slab etc. are covered under water by making small ponds. Vertical retaining wall or plastered surfaces or concrete columns etc. are cured by spraying water. In some cases, wet coverings such as wet gunny bags, hessian cloth, jute matting, straw etc., are wrapped to vertical surface for keeping the concrete wet. For horizontal surfaces saw dust, earth or sand are used as wet covering to keep the concrete in wet condition for a longer time so that the concrete is not unduly dried to prevent hydration.

Akeem Ayinde Raheem1et al (2013) Effect of Curing Methods on Density and Compressive Strength of Concrete. The materials used for the production of concrete test specimens are ordinary Portland cement, sharp sand, granite and tap water. Locally available crushed granite was used as coarse aggregates and sharp sand as fine aggregate. All aggregates were ensured to be free from deleterious substances such as organic impurities, clay and other unsound particles. Burham brand of ordinary Portland cement was used as binder in this study. On their results, density of the specimens ranged from 2432.59 to 2502.72 Kg/m3. This lies within the range of 2200 to 2600 Kg/m3 specified as the density of normal weight concrete (Neville, 2000). The moist sand curing method produced concrete specimen with the highest mean density of 2502.72 Kg/m3, followed by the polythene and water submerged methods with mean values of 2484.94 Kg/m3and 2461.23 Kg/m3 respectively. The polythene curing method produced the highest range of density and standard deviation indicating that the method is highlyunreliable. The specimens cured by burlap method produced the lowest range of density and standard deviation indicating that the method is reliable.

T. James et al(2011). studied on the effect of curing methods on the compressive strength of concrete. Material used: 1. Fine aggregate (river sand). 2. Coarse aggregate (crushed gravel)

20 mm sizes. 3. Ordinary Portland cement (Ashaka cement). 4. Portable Water. It could be seen that there was a significant increase in concrete strength with age depending on the curing method adopted.Compressive strength when arranged in descending order for all the curing methods, it could also be seen that ponding gave the highest result for the curing periods. This is due to improved pore structure and lower porosity resulting from greater degree of cement hydration and pozolanic reaction without any loss of moisture from the concrete cubes. Followed by wet covering, sprinkling, plastic sheeting, uncured for two days; the totally uncured method gave the lowest compressive strength. Since the concrete left total uncured gave the lowest result, this therefore suggests that curing is very important and necessary for all concrete structures.

Yash Nahataa et al(2013) studied on the Curing techniques and curing duration significantly affects curing efficiency" Various degree of efficiency can be achieved by various in situ-curing methods. The effectiveness of the concrete curing method depends on the material used, method of construction and the intended use of the hardened concrete. Techniques used in concrete curing are mainly divided into two groups namely, Water adding techniques and Water- retraining techniques. Reliability and effectiveness of such curing methods are still under debate. In their result they found that, Using membrane curing and saturated wet covering, one can achieve 80 to 90% efficiency (in terms of compressive strength) as compared to conventional water immersion method. Saturated wet covering is suitable for pavement structure but not suitable for vertical structures or high rise structures. Dry-Air curing should be avoided in construction, because desired strength cannot be achieved by this method. Membrane curing is a practical and widely used curing method suitable in water scarce areas.

3. Materials Used For Experimental Study And Their Properties

1. Porous material

The porous materials are a material containing pores (voids). The pores are normally loaded up with a liquid (fluid or gas). The skeletal material is normally strong; however, structures like froths are regularly additionally helpfully broken down utilizing the idea of permeable media. Some of the porous materials are Paper, cardboard, sponges, pumice stones, untreated wood, and cork. The specification/focus usage is the sponges as the porous material to be used in the membrane manufacturing which will hold the water sprayed until the desired strength reaches.

Figure 1: Sponge porous material.

1. Steel-plate

Sheet metal will be metal framed by a mechanical procedure into dainty, level pieces. Sheet metal is one of the basic structures utilized in metalworking, and it very well may be cut and bowed into an assortment of shapes. Incalculable regular items are created from sheet metal.

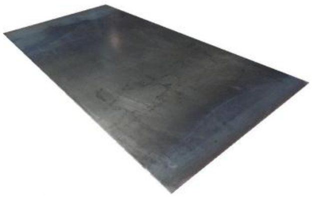

Figure 2: Metal plate.

2. Plastic pipes

Plastic funnel or plastic pipe is a cylindrical area, or empty chamber, made of plastic. It is as a rule, yet not really, of round cross-segment, utilized predominantly to pass on substances which can stream fluids and gases (liquids), slurries, powders and masses of little solids. The plastic pipes used is solid wall pipes because they are flexible and they are not expensive, available and even not require many fittings for their installation. The Solid wall pipes is expelled pipes consisting of one layer of a homogeneous network of thermoplastic material, which is prepared for use in a pipeline.

Figure 3: Plastic flexible pipe.

3. Plumbing fittings

Fittings are used when installing pipes to go around corners, to join pipes, to reduce the diameter of the pipes and to set water taps.

4. Storage tank

The Storage tank used was a water tank for storing water. Water tank parameters incorporate the general plan of the tank, and decision of development materials. Different materials are utilized for making a water tank. The storage tank used was made of plastic of 500 l capacity.

Figure 4: Storage tank.

5. Hinges

Hinge is a device for holding together two parts such that one can swing relative to the other, typically having two interlocking metal leaves held by a pin about which they pivot. As the equipment will be a one piece that goes around the column or any vertical structure the hinges, make it easier to be as a folding one. It is better as they are made in metal they will be capable of being used at outdoor and resist to weather changes like rain and sun rays. Steel hinges are better in indoor but not outdoor that is why we chosen the stainless hinges for better results.

Figure 5: Hinge (butt hinge joining the door shutter and a frame).

6. Water

Water is an important ingredient of concrete as it actually participates in the chemical reaction with cement. The water used for mixing and curing should be clean and free from harmful materials and substances that may be deleterious to concrete properties and steel. Portable water is generally considered satisfactory for concrete mixing process. The PH value of water to be used should not be less than six. The portable water available in the laboratory taps conforming to the requirements of water for concreting and curing as per IS: 456-2000 was used in this project work for concrete production process.

7. Cement

Cement is defined as the bonding and binding material in concrete production having cohesive and adhesive properties which makes it capable to join uniformly the different construction materials and compacted assembly.

- **Ordinary Portland Cement (OPC)**

Ordinary Portland cement of OPC 42 grade is used.It is one of the most widely used types of Portland cement. Ordinary Portland Cement (OPC) is the most commonly used cement in general concrete construction as per IS: 8112-1989.

Table 1: Properties of Ordinary Portland Cement used.

Properties		**Values**
Final Setting time		275 min
Fineness		330 kg/m^2
Soundness		2.5mm
specific gravity	3.1g/cm^3	
Bulk Density		830-1650 kg/m^3

1. AGGREGATES

Aggregates are inert granular materials such as sand, gravel or crushed stones that are an end product in their own right. They are also the raw materials that are an essential ingredient in concrete production. For a good concrete mix, aggregates need to be clean, hard, strong particles free from absorbed chemicals or coating of clay and other fine materials that could cause the deterioration of concrete. Aggregates are broadly classified into two types namely coarse aggregate and fine aggregate.

Table 2: Properties of coarse aggregate and fine aggregate used.

Properties	**Values**
Specific gravity of Fine Aggregate	2.61
Specific gravity of Coarse Aggregate:	2.65
Water Absorption FineAggregate Coarse Aggregate	 1% 0.2%
Free (surface) moisture Coarse Aggregate Fine Aggregate	 Nil Nil
Fine aggregate falls into	Zone-II

Properties	**Values**
Final Setting time	275 min
Fineness	330 kg/m^2
Soundness	2.5mm
specific gravity	
Bulk Density	830-1650 kg/m^3

SIEVE ANALYSIS OF AGGREGATES

A. Sieve analysis for coarse aggregates

Table 3: Sieve analysis of coarse aggregates.

sieve size(mm)	mass retained(grm)	cum. Mass retained(grm)	%retained	cum.% retained	%pass
40	0	0	0	0	100
25	3681.3	3681.3	46.01625	46.01625	53.98375
20	1398.3	5079.6	17.47875	63.495	36.505
16	1229.8	6309.4	15.3725	78.8675	21.1325
12.5	705.4	7014.8	8.8175	87.685	12.315
10	369.2	7384	4.615	92.3	7.7
6.3	236.9	7620.9	2.96125	95.26125	4.73875
pan	379.1	8000	4.73875	100	0
Total	8000			∑563.625	

Calculations

Fineness modulus=$\frac{\sum \text{Cumulative\% Wt.retained}}{100}$

$=\frac{563.625}{100} = 5.63625$

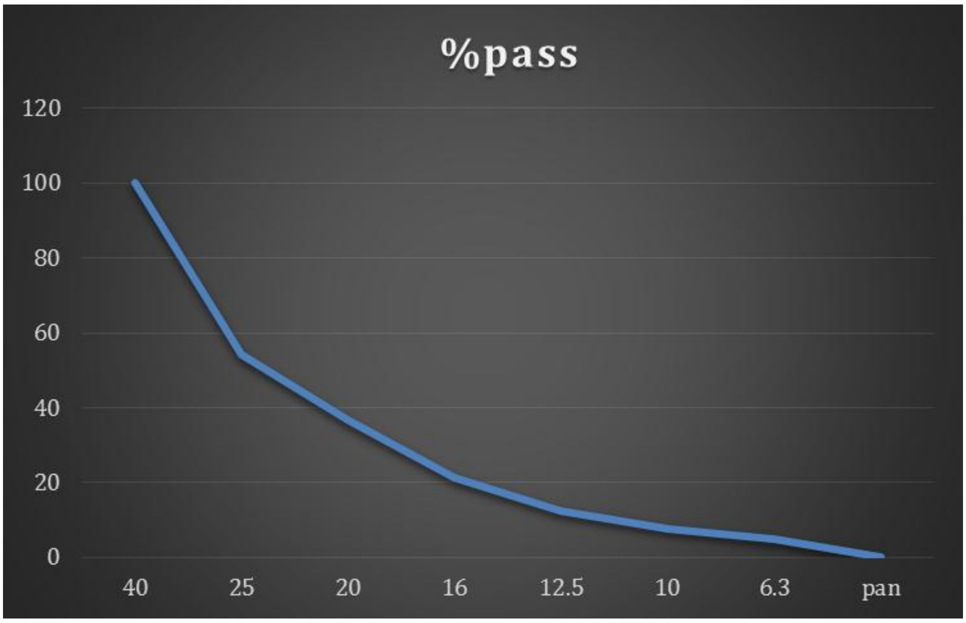

Figure 6: Coarse aggregates sieve graph.

B. Sieve analysis of river sand

Table 4: River sand sieve analysis.

SIEVE SIZE(mm)	wt retained (g)	cum. retained (g)	% retained	cum. % retained	cum. % pass
9.5	241.53	241.53	16.102	16.102	83.898
4.75	576.24	817.77	38.416	54.518	45.482
2.36	260.79	1078.56	17.386	71.904	28.096
1.18	109.59	1188.15	7.306	79.21	20.79
0.6	95.94	1284.09	6.396	85.606	14.394
0.3	79.59	1363.68	5.306	90.912	9.088
0.15	74.04	1437.72	4.936	95.848	4.152
0.08	50.19	1487.91	3.346	99.194	0.806
pan	12.09	1500	0.806	100	0
Total	1500			∑693.294	

Calculations

Fineness modulus= $\frac{\sum \text{cumulative\% Wt.retained}}{100} = \frac{693.294}{100} = 6.93294$

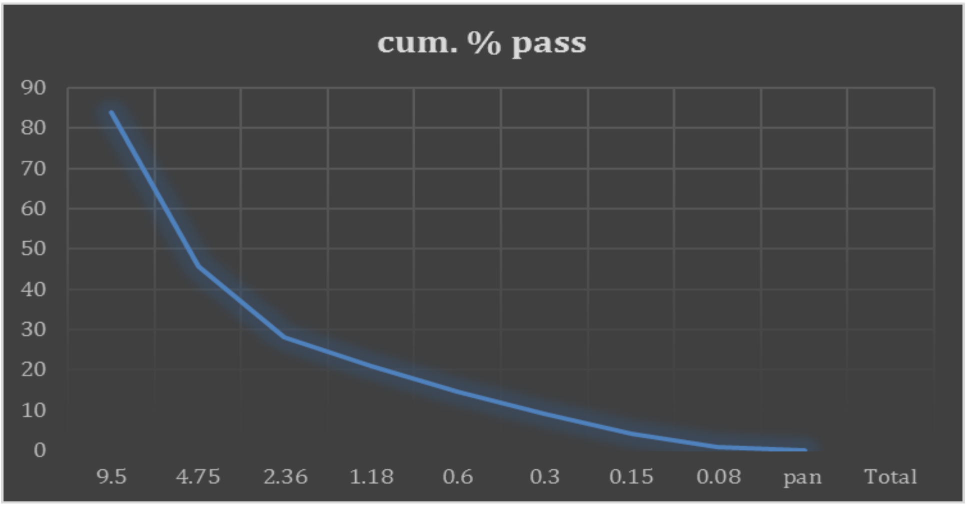

Figure 7: River sand sieve graph.

4. RESEARCH METHODOLOGY AND SAMPLE PREPARATION

4.1 Research procedures

The methodology conducted for this research work was determined and discussed. This investigation was carried out to study the behavior of normal and enhanced curing concrete within their ingredient materials. The followings are the methodologies adopted to achieve the objectives of this research work.

- To conduct comprehensive literature review related to subject of self curing and normal curing concrete.

- Selection of suitable ingredient materials required for concrete production including cement, aggregates, water and concrete curing compound to be applied on finished concrete surface.
- Determine the relative quantities of these materials in order to produce concrete mix design.
- Casting of concrete specimens and curing process by conventional curing and external self curing (by the application of curing compound on concrete surfaces) for both OPC and PPC mixes.
- Preparation materials for the assembling and be equipped with tools such as drilling tools, assembling tools like screwdrivers etc.
- Take the measurements of the materials to be assembled; Cut the plates according to the size desired.
- Join the plates together with the hinges in between with bolts and nuts; Bind the porous material on each plate with grout;
- Install the vertical plastic pipes and Perforate the pipes for the regular distribution of water.

Concrete mix design for both conventional and enhanced curing method

The Concrete mix design as the process of selecting suitable ingredients materials of concrete and determining their proportions with the object of producing concrete of certain minimum strength and durability as possible.

In this study, the concrete mix was designed according to IS: 10262:2009. The mix proportioning of concrete was done by selecting M15 grade concrete and water cement ratio of 0.6. The mix proportions obtained was determined based on the field condition such as free surface moisture and water absorptions of aggregates as per IS:2386(part 3) and the final concrete mix proportion per cubic meter obtained for OPC is determined in the **Table** below.

1. Concrete mix Design Stipulations

Table 5: Concrete mix design stipulations.

1	Grade of concrete (designation)	M15
2	Type of cement	OPC 42 grade
3	Minimum nominal size of aggregate	20 mm
4	Workability	75 – 100 mm (slum p)
5	Exposure condition	moderate
6	Method of concrete p lacing	normal
7	Degree of supervision	excellent
8	Specific gravity of cement	3.1g/cm^3
9	Specific gravity of coarse aggregate	2.65
10	Specific gravity of fine aggregate	2.61
11	Sieve analysis	zone 2 (IS 383 – 1 970)

2 Test data of material

The following materials are to be tested in the laboratory and results are to be ascertained for the concrete mix design for OPC mix.

a) Specific Gravity of OPC Cement: 3.1g/cm^3

c) Specific gravity

- Specific gravity of Fine Aggregate : 2.61
- Specific gravity of Coarse Aggregate: 2.65

d) Water Absorption

- FineAggregate:1%
- Coarse Aggregate : 0.2%

e) Free (surface) moisture

- Coarse Aggregate : Nil
- Fine Aggregate : Nil

F) Fine Aggregate Falls Into: Zone-II.

Table 1: Concrete mix design.

Water Cement Ratio (kg/m^3)	Cement (kg/m^3)	Fine Aggregate (kg/m^3)	Coarse Aggregate (kg/m^3)
0.6	328.6	704.178	1166.53
	1	2.14	3.55

4.2. SAMPLE PREPARATION

The concrete specimens were cast, cured and tested for mechanical properties of concrete such as compressive strength and split strength. The test specimens were cured in clean fresh water for both normal and enhanced curing. Specimens for enhanced curing were cured by the application curing membrane after removed from the moulds.

The method of assembling this membrane is quite reliable and easy to assemble, even in the case of the maintenance of the membrane it will facilitate the technician to do so quickly. The form of the membrane is flexible at any shape of the concrete member, so the metal plates are split into short width pieces and are joined by hinges between two plates with the bolts and nuts. As it is stated in the above procedures of making the membrane, the membrane will not work alone, it will need the distribution system of water all around the concrete member.

Figure 8: Fabrication of the membrane.

Figure 9: Enhanced curing technique of vertical concrete members using water reservoir.

5. EXPERMENTAL STUDY

Compressive strength testing for all specimens was carried out as per IS: 516-1959. The maximum load resisted divided by cross sectional area of specimen, gives the compressive strength. The compressive strengths of cement paste were determined for 3, 7 and 28 days. A set of three cubes specimens were taken and tested to get average results as tabulated and interpreted below. For the compressive strength of concrete mix, the size of the specimen was 150mm×150mm×150mm.

Split tensile strength test was performed on 150mm x 300mm cylinders for both normal and enhanced curing techniques. The three cylindrical specimens were taken to determine average result of split tensile strength for7 and 28 days.

6. RESULTS AND DISCUSSION

The results from the tests done for nominal curing and enhanced curing technique of vertical concrete members are given in details bellow. The laboratory investigation consisted of the compressive and tensile strengths of concrete for both curing methods (nominal curing and enhanced) are determined, discussed and presented in this section. The new way of curing is using the membrane made which is assembled together for matching the forms of the vertical concrete members, and they are based on their properties and functionalities for those members.

- **RESULT OF COMPRESSIVE STRENGTH TEST FOR BOTH ENHANCED CURING TECHNIQUE AND NORMAL CURING TECHNIQUE**

The three cube specimens were taken to determine average result of the compressive strength for 3, 7 and 28 days. The results on compressive strength are presented bellow. For 3, 7 and 28 days compressive strength results of enhanced and normal curing technique of vertical concrete members are given in details.

❖ **By using the enhanced curing method**

Table 7: Compressive strength result table using enhanced curing.

SI.No	Failure Load (KN)	Compressive strength (N/mm^2)	Average compressive strength(N/mm^2)	Days
1.	218.816	9.725	9.802	3
	217.955	9.686		
	224.940	9.997		
2.	398.6	17.715	17.787	7
	425.5	18.911		
	376.7	16.737		
3.	540.765	24.034	24.476	28
	542.958	24.131		
	568.452	25.264		

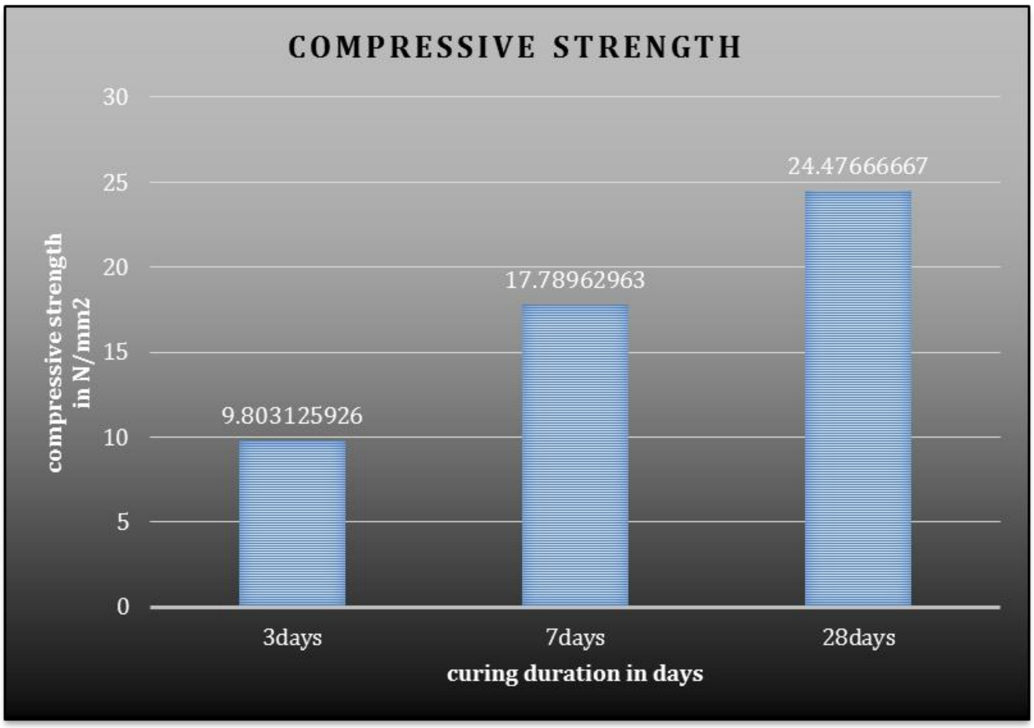

Figure 10: Compressive strength of concrete by enhanced curing technique.

❖ **By using the normal site curing method**

Table 8: Compressive strength result table using normal curing.

SI.No	Failure Load (KN)	Compressive strength (N/mm^2)	Average compressive strength(N/mm^2)	Days
1.	189.698	8.431	8.593	3
	197.453	8.775		
	192.932	8.574		
2.	312.6	13.893	15.343	7
	377.4	16.773		
	345.7	15.364		
3.	480.162	21.340	21.541	28
	485.405	21.573		
	488.522	21.712		

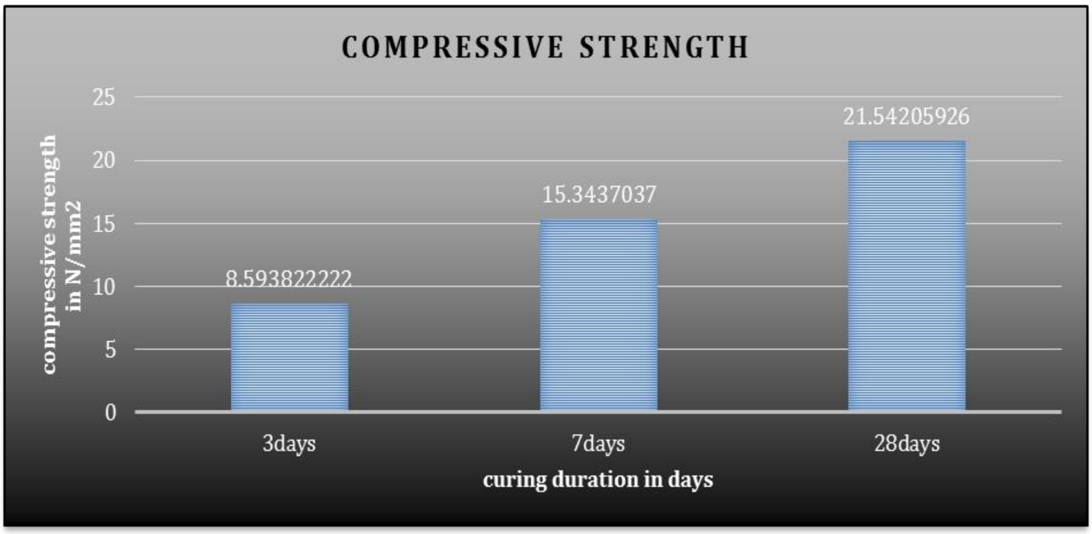

Figure 11: Compressive strength of concrete by normal curing technique.

- **COMPARISON OF CONCRETE COMPRESSIVE STRENGTH FOR ENHANCED AND NORMAL CURING TECHNIQUES**

It was observed that the strength of concrete for 3 days, enhanced curing technique was greater than about 12.1% for that of normal curing techniques for concrete vertical members. For 7 days, the compressive strength of concrete for enhanced curing technique was greater than about 24.46% for that of normal curing technique. For 28 days, the compressive strength of the concrete for enhanced curing technique was greater than about 29.32% for that of normal curing technique.

It was observed that the strength of concrete for 3, 7, 28 days, the results of compressive strength for enhanced curing was greater than that of normal curing in all curing periods.

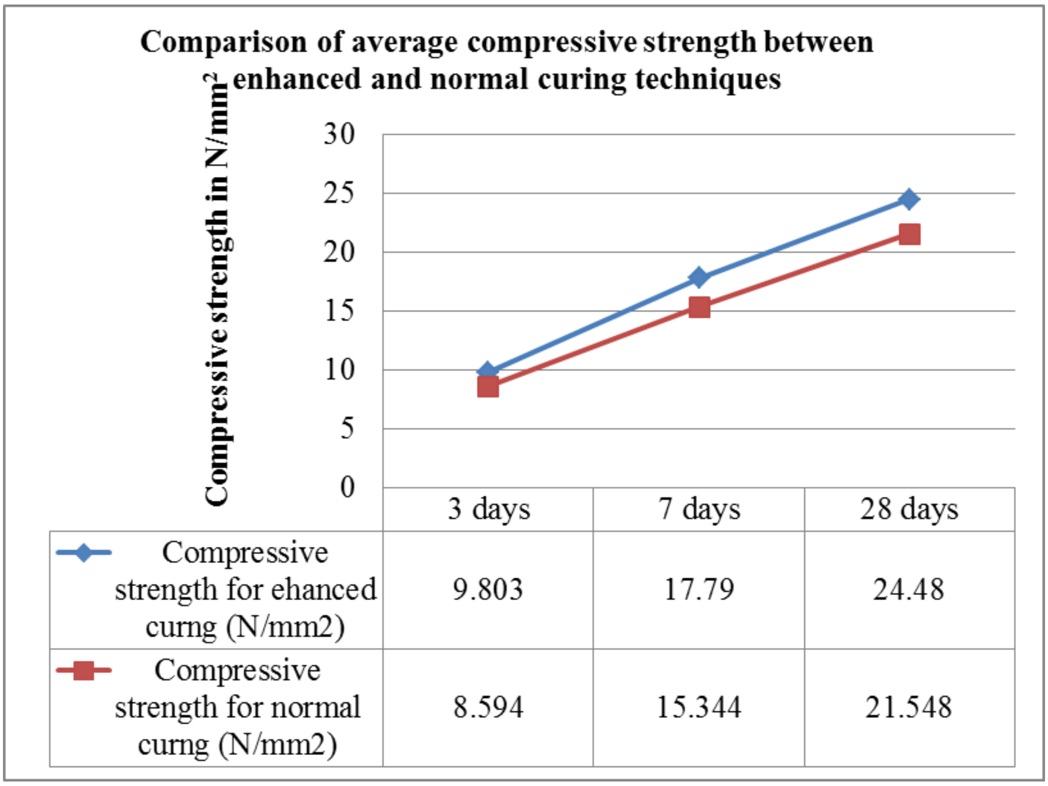

Figure 9: Comparison of both enhanced and normal curing techniques' compressive strength.

2. TENSILE STRENGTH TEST RESULTS FOR BOTH CURING TECHNIQUES

The three cylindrical specimens were taken to determine average result of split tensile strength for7 and 28 days. The results on split tensile strength are presented bellow**.**

- **By using the enhanced curing method**

Table 9: Tensile strength result table for enhanced curing.

SI.No	Failure Load (KN)	Split tensile strength (N/mm^2)	Average Split tensile strength (N/mm^2)	Days
1.	82.5	1.167	1.186	7
	85.1	1.203		
	84.05	1.189		
2.	197.433	2.793	2.838	28
	206.321	2.918		
	198.138	2.803		

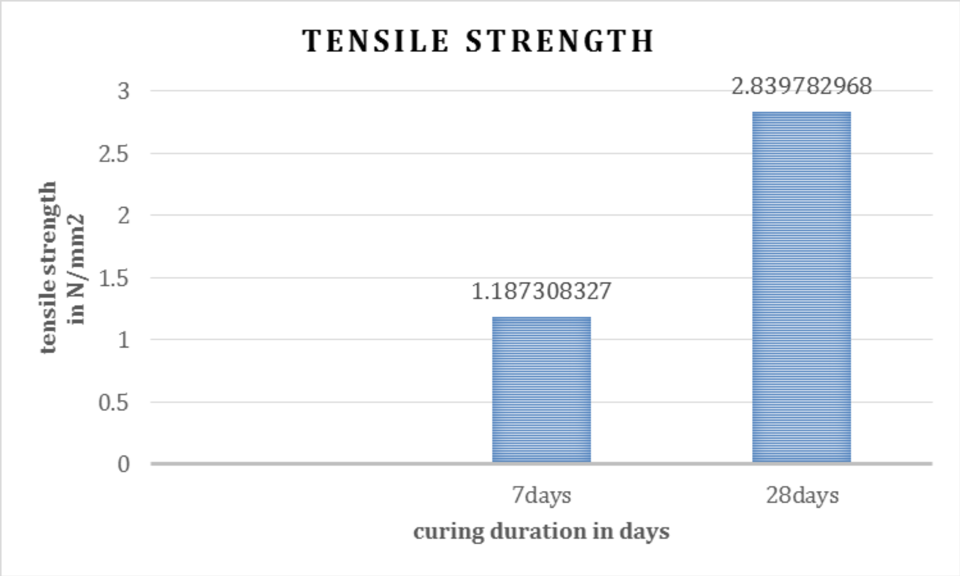

Figure 12: Tensile strength of concrete by enhanced curing technique.

- **By using the normal site curing method**

Table 10: Tensile strength result table using normal curing method used on site.

SI.No	Failure Load (KN)	Split tensile strength (N/mm^2)	Average Split tensile strength (N/mm^2)	Days
1.	73.4	1.038	1.186	7
	85.4	1.208		
	76.7	1.085		
2.	190.346	2.692	2.610	28
	186.400	2.637		
	176.941	2.503		

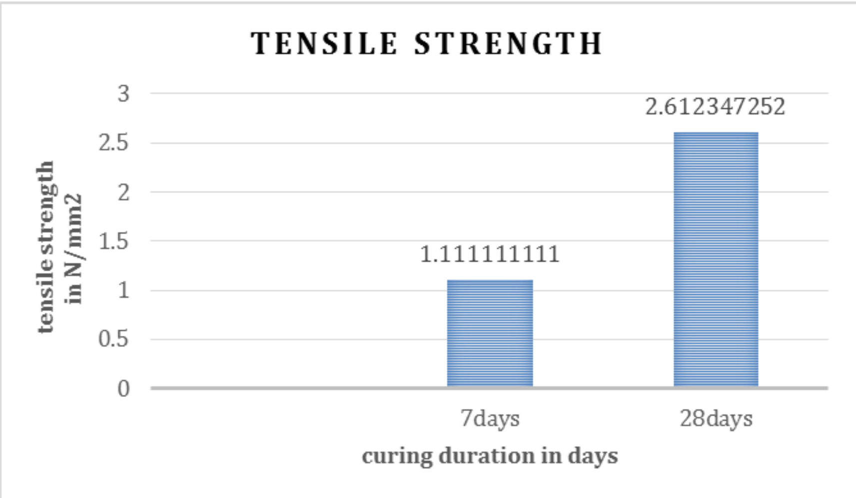

Figure 13: Tensile strength of concrete by normal curing technique.

- **COMPARISON OF CONCRETE SPLIT TENSILE STRENGTH BETWEEN ENHANCED AND NORMAL CURING TECHNIQUES**

It was observed that the split tensile strength of concrete for 7 days, the split tensile strength of concrete for enhanced curing technique was greater than about 7.6% for normal curing techniques of concrete vertical members. For 28 days, the split tensile strength of the concrete for enhanced curing technique was greater than about 22.7% for that of normal curing technique.

The results of split tensile strength of vertical concrete members for enhance curing technique were observed to be greater than that of normal curing for both 7, 28 days.

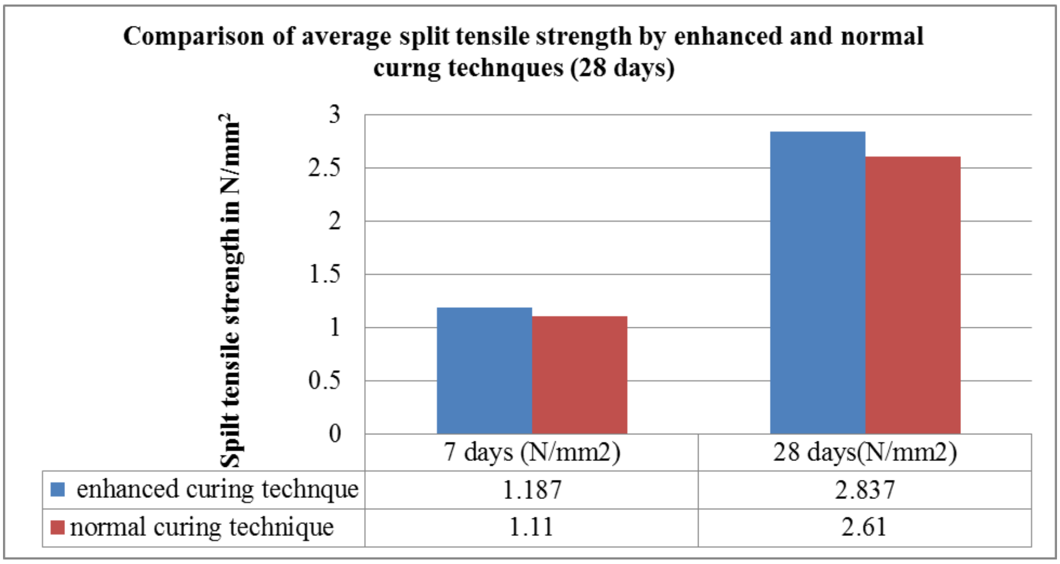

Figure 14: Comparison of enhanced and normal curing techniques' tensile strength.

7. CONCLUSIONS

On the basis of the results obtained from the present study, the following conclusions can be drawn.

- For 3 days, the compressive strength for enhanced curing technique of vertical concrete members was greater than the ones for normal curing technique about 12%.
- For 7 days, the compressive strength and split tensile strength of concrete vertical members by enhanced curing was greater than that of normal curing technique about 24.46% and 7.6% respectively.
- For 28days, the compressive strength and split tensile strength of enhanced curing technique for vertical concrete member was greater than normal curing technique for vertical concrete members about 29.32% and 22.7% after 28 days of curing respectively.

- Enhanced curing technique of concrete is the best solution to the problems faced for curing vertical concrete members, so this method can be implemented in construction industries.

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