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Effect of curing techniques on compressive strength of concrete

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Abstract

This paper presented the findings of an experimental investigation into how common Portland cement concrete develops its compressive strength in a simple setting, such as Lahore, Pakistan. Ten concrete cube specimens of mix 1:1.5:3 was prepared with water-cement ratio of 0.5 for each of the four curing techniques (air curing, water-submerged curing, polythene curing, curing by boiling) until testing ages of 3, 7, 14, 21 and 28 days when their compressive strengths were determined. The findings demonstrated that concrete specimens produced using the water-submergence technique of curing had the maximum 28-day compressive strength of 41.42MPa. The findings indicate avoiding boiling as a curing process and restricting the use of other curing techniques to a 28-day timeframe. It was determined that there is a positive link between concrete specimen curing, curing duration, and compressive strength. This study also offers details on the significance of curing and numerous different methods for carrying out the procedure on the spot.

Keywords: Building materials; Concrete; Construction engineering; Curing techniques; Compressive strength

1. Introduction

Curing may be described as the process of controlling the relative humidity and temperature of newly poured concrete for a certain amount of time after it has been cast or finished to ensure that the cement has been properly hydrated and the concrete has hardened [1]. Once curing is finished, the concrete can no longer grow strength since the cement can no longer be able to hydrate. The process requires adequate moisture, temperature and time [2]. If any of these parameters is missing in the early period of hydration of concrete, the desired strength of concrete cannot be obtained [3]. Hydration is the most significant part in the process of curing. Without enough water, hydration cannot occur, and the final concrete could not be as strong and impermeable as desired. Additionally, due to premature concrete drying, microcracks or shrinkage cracks would appear on the concrete's surface [4]. When concrete is exposed to the environment, water evaporates and the original water-to-cement ratio is reduced. This causes the cement to only partially hydrate, degrading the quality of the concrete [5]. The increase in compressive strength of concrete is governed by a number of variables, including wind speed, relative humidity, air temperature, water-to-cement ratio, and kind of cement used in the mix [6].

The pace at which strength develops can be adjusted by adjusting the curing temperature. Because cement paste and particles are thermally incompatible, fractures emerge in conventional concrete when temperatures rise (7). High-temperature-cured concrete often has greater early strength than concrete made and cured at lower temperatures, but typically exhibits less strength beyond 28 days. Concrete's strength increases with time; hence, a longer wet curing period is preferable if hydration of cement particles is to continue unabated (8). The fact that moisture curing only affects the outer 30 to 50 mm of a concrete element's surface is emphasised. Therefore, raising a building's compressive strength isn't the main reason for focusing on moisture management (9). However, it has a major influence on the

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surface's permeability and hardness, which in turn restricts the system's potential lifespan, especially in harsh conditions.

Curing has to play a very vital role in the development of compressive strength of concrete. It is required for completing the hydration reaction in cement and concrete [10]. It is further required for prevention of loss of water from concrete through evaporation and hence the self-desiccation (dryness due to internal water-loss and hence the weakening) of concrete, for capillary segmentation and maintaining a conductive temperature within concrete [11]. It is also very important to produce strong, durable, water-tight and impermeable concrete member. Contrary to this, if curing is not properly carried out, it can result in inadequate strength, drying and shrinkage of concrete, formation of cracks and poorly segmented capillaries [12]. Controlling the temperature of the concrete is an important part of the curing process. Cold structures or slabs can hydrate very slowly, if at all, in the first several hours following placement. Keeping forms in place for longer or installing safeguards against plastic shrinkage cracking might be necessary consequently [13]. Meanwhile, if the concrete is allowed to become too hot in the first few hours, the temperature differences between the inside and outside are more likely to cause cracking. High-temperature concrete hydrates more slowly, making it more vulnerable to assault from both internal and external chemical reagents [14].

Proper curing improves the hardened concrete's durability, strength, volume stability, abrasion resistance, impermeability, and resistance to freezing and thawing [15]. It is important to consider the concrete's intended purpose, the building process, and the type of material utilised in determining the optimal curing procedure. To avoid surface damage and erosion, curing should begin as soon as the concrete becomes firm enough to do so. Concrete curing methods may be broadly classified into two categories: those that involve adding water and those that involve recycling previously used water [16]. Curing compounds and high early strength concrete have emerged as important components of rapid rigid pavement building in recent years, particularly in water-scarce areas. The objective of this experimental study was determination of compressive strength of concrete by using different curing techniques. It also aimed to study the effect of temperature and humidity on curing techniques and resulting compressive strengths. It also studied the results of compressive strength of concrete at different ages. It also compared the results obtained by different curing techniques to find out the most suitable technique (keeping in view strength and economic factors) for field and lab requirements. It also observed the concrete strength behavior in dry and saturated surface dry conditions to get familiar about different curing techniques being practiced in the field.

2. Methodology

2.1. Calculation of Materials

	80 cubes & cylinders
Mix Ratio used	1 : 1.5 : 3
Water Cement Ratio	0.5
Crush used	Margalla Crush Lawrencepur Sand Ordinary Portland Cement
Dimension of Cubes	150 x150 x 150 (Net Volume: 0.003375m3)
Dimension of Cylinders	150 x 300) (Net Volume: 0.00530m3)

Calculations for Cubes	Calculations for Cylinders
Volume of 1 cube = 0.003375m3 Surface Area of 1 cube = 0.0225m2 Volume of 40 Cubes =40 x 0.003375m3 = 0.135 m3 Mass of 40 cubes	Volume of 1 cylinder = 0.00530m3 Surface Area of 1 cylinder = 0.01767m2 Volume of 40 cylinders =40 x 0.00530m3 = 0.212 m3 Mass of 40 cylinders

= 2400 x 0.135 =324kg + 5% = 340.2kg Cement = $\frac{1}{5.5}$ x 340.2 = 61.85 kg Sand = $\frac{1.5}{5.5}$ x 340.2 = 92.78 kg Crush = $\frac{3}{5.5}$ x 340.2 = 185.561 kg Water = 0.5 (61.85) = 30.925 kg	= 2400 x 0.212 =508.8kg + 5% = 534.24kg Cement = $\frac{1}{5.5}$ x 534.24 = 97.134 kg Sand = $\frac{1.5}{5.5}$ x 534.24 = 145.702 kg Crush = $\frac{3}{5.5}$ x 534.24 = 291.403 kg Water = 0.5 (97.134) = 48.567 kg

- Total Amount of Cement = 158.984 kg (4 bags)
- Total Amount of Sand = 238.482 kg (approx. 5 cft)
- Total Amount of Crush = 476.963 kg (approx. 10 cft)

2.2. Techniques Performed

Following are the techniques that were used for carrying out the research work.

- Uncured Sampling
- Ponding
- Plastic Sheeting
- Boiling

2.3. Reasons for the Selection of Above-Mentioned Techniques

- The primary reason to use air curing as our first technique was to make a comparison between compressive strength of specially cured samples and to the compressive strength of samples which gained the strength of its own. No particular steps were taken and thus to more generalize our goal, this technique was referred as "Uncured Sampling". But it doesn't mean in any sense that uncured technique was completely void of moisture. The specimen got its moisture needs fulfilled from the atmosphere humidity. The weather was cold and thus evaporation loses were also les
- Ponding is a very famous, widely-practiced, easy and economical method of curing since ages. The reason to select this technique was to work on some field-practiced method of curing and determine whether the strength achieved through this method was the highest achievable under ordinary circumstances or it can be further increased by any method.
- Plastic Sheeting is also a very widely-practiced method of curing technique in countries where there is scarcity of water. The reason for opting this method was to check that if the escape of moisture is prohibited from the surface of a sample, what will be its significance on compressive strength of concrete. And secondly, if it can give comparable results to the highest value obtained, what other factors like sheet thickness, temperature or the method of wrapping (tight, loose, sealed or partially sealed) affect the results.
- Boiling is an accelerated method of curing and it can be used to predict the 28-days strength in laboratory in 4 hours. The basic reason to go for this curing technique was to check the fc' of the concrete specimen and compare the results using other curing techniques.

The following table was used to record the observations for "Investigating the Effect of Different Types of Curing on Compressive Strength of Concrete".

Table 1 Effect of Different Types of Curing on Compressive Strength of Concrete

Sr.	Technique	Calandar	Samples	Loads & Stresses	3 Days		7 Days		14 Days		21 Days		28 Days	
1.	Date of Testing				Dated: 8-12-14		Dated: 11-12-14		Dated: 18-12-14		Dated: 26-12-14		Dated: 1-1-15	
					Day: Monday		Day: Thursday		Day: Thursday		Day: Thursday		Day: Thursday	
	Uncured Technique	Date of Casting 4-12-14 Thursday	Cubes	P (Tons)	56	52	71	71	67	82	86	81	92	56
				Average	54		71		74.5		83.5		74	
				6 (MPa)	23.92		31.45		33		37		32.78	
			Cylinders	P (Tons)	44.8	41.6	56.8	56.8	53.6	65.6	68.8	64.8	73.6	44.8
				Average	43.2		56.8		59.6		66.8		59.2	
				6 (MPa)	19.136		25.16		26.4		29.6		26.224	
2.	Date of Testing				Dated: 10-12-14		Dated: 13-12-14		Dated: 20-12-14		Dated: 27-12-14		Dated: 3-1-15	
					Day: Wednesday		Day: Saturday		Day: Saturday		Day: Saturday		Day: Saturday	
	Ponding Technique	Date of Casting 6-12-14 Saturday	Cubes	P (Tons)	48	54	56	60	86	86	90	88	92	95
				Average	51		58		86		89		93.5	
				6 (MPa)	22.59		25.7		38		39.42		41.42	
			Cylinders	P (Tons)	38.4	43.2	44.8	48	68.8	68.8	72	70.4	73.6	76
				Average	40.8		46.4		68.8		71.2		74.8	
				6 (MPa)	18.072		20.56		30.4		31.536		33.136	
3.	Date of Testing				Dated: 17-12-14		Dated: 20-12-14		Dated: 27-12-14		Dated: 3-1-15		Dated: 10-1-15	
					Day: Wednesday		Day: Saturday		Day: Saturday		Day: Saturday		Day: Saturday	
	Plastic Sheeting Technique	Date of Casting 13-12-14 Saturday	Cubes	P (Tons)	46	54	60	65	71	77	79	82	69	75
				Average	50		62.5		74		80.5		72	
				6 (MPa)	22.14		27.68		32.78		35.65		31.89	
			Cylinders	P (Tons)	36.8	43.2	48	52	56.8	61.6	63.2	65.6	55.2	60
				Average	40		50		59.2		64.4		57.6	

				6 (MPa)	17.712		22.144		26.224		28.52		25.512	
4.	Date of Testing				Dated: 12-2-15		Dated: 18-2-15		Dated:		Dated: 11-3-15		Dated: 11-3-15	
					Day: Thursday		Day: Wednesday		Day:		Day: Wednesday		Day: Wednesday	
					Boiling		Ponding	Sheeting			Uncured (28 days)		Ponding	Sheeting
	Accelerated + Ponding + Sheeting + Uncured	Date of Casting 11-2-15 Wednesday	Cubes	P (Tons)	10	13.75	19 17	16 16			30	30	32 32	32 21
				Average	11.875		18	16			30		32	26.5
				6 (MPa)	11.83 (28 hours)		17.94	15.94			29.90		32.39	26.41
			Cylinders	P (Tons)	8	11	15.2 13.6	12.8 12.8			24	24	26.4 25.6	25.6 16.8
				Average	9.5		14.4	12.8			24		26	21.2
				6 (MPa)	9.464 (28 hours)		14.352	12.752			23.92		25.912	21.128

2.4. Uncured Sampling

Dry curing is a curing method in which concrete specimen are left in open air to be cured at room temperature. This type of technique is feasible in hilly areas where temperature is low and humidity level is high. With air-cured concrete, it is most probable that the cement does not fully hydrate; therefore, such concrete cannot reach its full design strength. However, if specimens are not allowed to dry properly between being removed from the curing tank and being tested for ultimate compressive strength, it may appear that air-cured specimens are stronger than wet-cured, due to the effect that excess water in the pore system has with the specific tests commonly employed for testing strength properties [17].

Figure 1 Concrete cubes being placed in moulds

2.5. Methodology

- The mix was made according to the given design mix (1 : 1.5 : 3) and before the cubes were casted in the moulds, its slump value was checked which came out to be 1”.
- After concrete is placed, the concrete increases in strength very quickly for a period of 3-7 days. Therefore, after 24 hours of placement of concrete, it had hardened enough to get it out of the moulds.
- The moulds were removed and the concrete cubes were taken out and placed in laboratory to gain strength all by themselves and the moisture within air.
- Prepare 5 batches each consisting of two cubes and find compressive strengths of the samples after 3, 7, 14, 21 and 28 days.

2.6. Ponding

Figure 2 Concrete cubes being cured in Ponding Tank

Concrete may be healed by ponding on flat surfaces like floors and pavement. A pond of water can be kept inside the concrete surface by using earth or sand dikes as a border. Ponding is a great way to keep moisture in the concrete from evaporating, and it also works well to keep the concrete's temperature consistent. To avoid thermal tensions that might cause cracking, the curing water shouldn't be more than 11°C (20°F) colder than the concrete. Ponding is usually only employed for modest operations due to the high labour and management requirements. The final concrete part is completely submerged to complete the water-based curing process [18]

2.7. Methodology

- Mix the ingredients in required proportion and check the slump of the batch. The slump value should not exceed 1”.
- Make 5 batches of concrete cubes each consisting of 2 cubes.
- After the placement of concrete, when it has gained enough strength, the moulds are re-opened and the hardened concrete cubes are placed in the curing tank.
- It must be noted that the water in the curing tank must be clean and should be replaced at regular intervals of 2 days. It should be free from heavy amount of dissolved salts.
- The cubes are then tested at 3, 7, 14, 21 and 28 days.
- This method of curing yields the best results of all if all the standards are to be followed.

2.8. Plastic Sheeting

The major goal of this technique is to keep the moisture contained and stop concrete from evaporating. The most popular materials for sealed curing are waterproof paper, plastic sheeting, and curing membranes, which have higher compressive strength, higher pulse velocity, higher dynamic modulus of elasticity, and lower surface permeability. Simply said, each of these substances lessens the volume of water lost through evaporation. The versatility of application to several concrete constructions of various forms and sizes is the main benefit [19].

Figure 3 Concrete cubes after de-moulding, in wrapped state

2.9. Methodology

- Mix the ingredients in required proportion and check the slump of the batch. The slump value should not exceed 1”.
- Make 5 batches of concrete cubes each consisting of 2 cubes.
- When the cast concrete is hardened enough, it is removed from the moulds.
- The cast samples are then wrapped tightly with a 0.2” polythene with the help of scotch tape.
- It should be noted that no surface of the cube should be exposed to the atmosphere to prevent any further loss through evaporation
- Furthermore, the cubes were kept in an atmosphere where the humidity is relatively higher and the samples are kept undisturbed.

Figure 4 Slump Value Test; Slump Value coming out to be more than 1”

2.10. Accelerated Curing by Boiling

Any technique that produces high early age strength in concrete is known as accelerated curing. These methods are particularly helpful in the prefabrication sector, where the formwork can be removed within 24 hours thanks to high early age strength, shortening the cycle time and providing cost-saving advantages. Second, this method can be used to assess the early strength of concrete [20].

Figure 5 Cubes left for curing in a boiling tank

2.11. Methodology

- Mix the ingredients in required proportion and check the slump of the batch. The slump value should not exceed 1”.
- Make 5 batches of concrete cubes each consisting of 2 cubes.
- When the cast concrete is hardened enough, it is removed from the moulds.
- After the test specimens (whose 28 days strength to be determined) have been removed, store it in moist air of at least 90 percent humidity for 23 hours + 15 min.

- Cover the specimens with flat steel cover plate to avoid distortion during the use.
- Carefully and gently lower the specimens into the boiling tank and shall remain totally immersed for a period of 3½ Hours + 15 min.
- The temperature of water in the curing tank shall be at boiling (100 ^{o}C) when the specimens are placed.
- After curing for 3 ½ hours in boil water, the specimen shall be carefully removed from the boiling water and cooled by immersing in cooling tank at 27 +2 ^{o}C for 2 hrs.
- After cooling remove the specimens from the mould and tested for its accelerated compressive strength (Ra) in N/mm2.
- The 28 days can be found out using following formula.

Predicted 28 days compressive strength = R_{28} = 8.09 + 1.64 Ra

where R_a = accelerated compressive strength

R_{28} = predicted compressive strength at 28 days

Figure 6 Concrete being tested under Compression Testing Machine

2.12. Safety and Precautionary Measures

- Use of hand gloves, safety shoes, while removing containers from curing tank after switching off the curing tank & place sample in machine properly was ensured.
- Equipment s was cleaned to as much extent as possible thoroughly before testing & after testing.
- 300 ml of water was added in every batch for wetting the periphery of the mixer.
- It was made sure to the best that the cubes were clean before the application of oil in the moulds.
- Special attention was given to de-moulding of cubes and was ensured that the surface texture of the cubes was smooth and even and their edges were not damaged.

3. Results and Discussions

The results of the tests conducted as well as a discussion of the results are presented in this chapter. The figures and graphs shown in this chapter are organized in a way that the data is primarily presented according to our performed curing techniques in the lab and the compressive strength of concrete that is achieved by them is also presented as per external environmental conditions (Humidity, temperature, water content). Afterwards the comparison between all the curing techniques has been done, which helps us in sorting out the most feasible technique (21) which is suitable for the field conditions which require in-depth examination of facts and figures.

3.1. Compressive Strength by Test Performance with 1'' Slump

Table 2 The compressive strength results of all the techniques are presented in the graphs according to their ages of testing

Test Performance with 1'' Slump					
Techniques	Age	Stresses (MPa)			
	Days	Cubes	% strength gain of fc'	Cylinder	% strength gain of fc'
Uncured	0	0	0	0	0
	3	23.92	72.97132398	19.136	72.97132398
	7	31.45	95.94264796	25.16	95.94264796
	14	33	100.6711409	26.4	100.6711409
	21	37	112.8737035	29.6	112.8737035
	28	32.78	100	26.224	100
Ponding	0	0	0	0	0
	3	22.59	54.53887011	18.072	54.53887011
	7	25.7	62.04732014	20.56	62.04732014
	14	38	91.74311927	30.4	91.74311927
	21	39.42	95.17141478	31.536	95.17141478
	28	41.42	100	33.136	100
Plastic Sheeting	0	0	0	0	0
	3	22.14	69.4261524	17.712	69.4261524
	7	27.68	86.79836939	22.144	86.79836939
	14	32.78	102.7908435	26.224	102.7908435
	21	35.65	111.7905299	28.52	111.7905299
	28	31.89	100	25.512	100

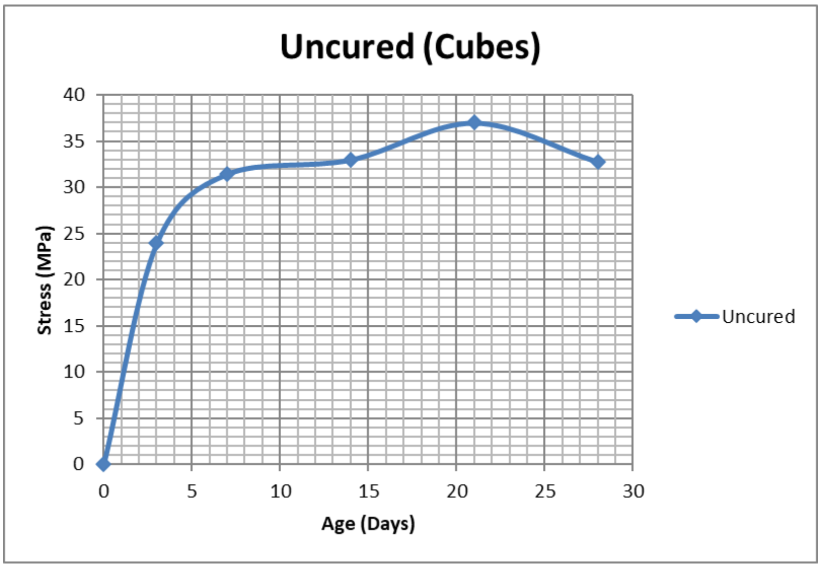

Figure 7 Compressive Strength for Uncured Cube Samples for curing duration of 28 days

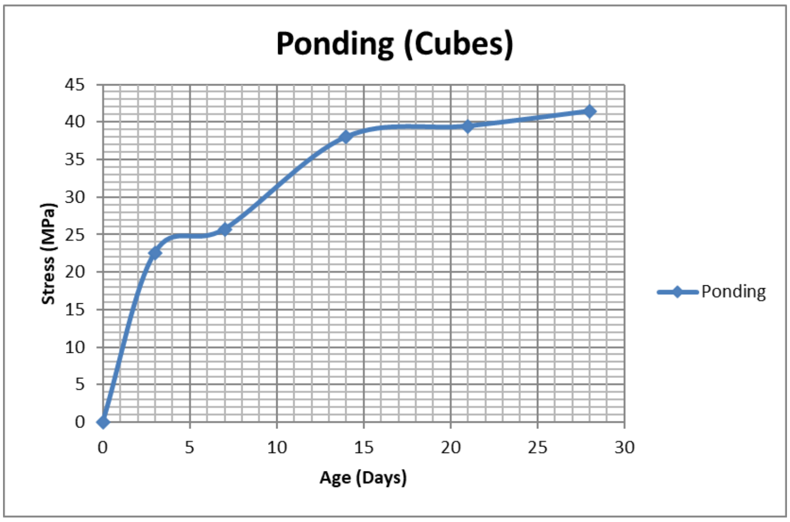

Figure 8 Compressive Strength for Ponding Cube Samples for curing duration of 28 days

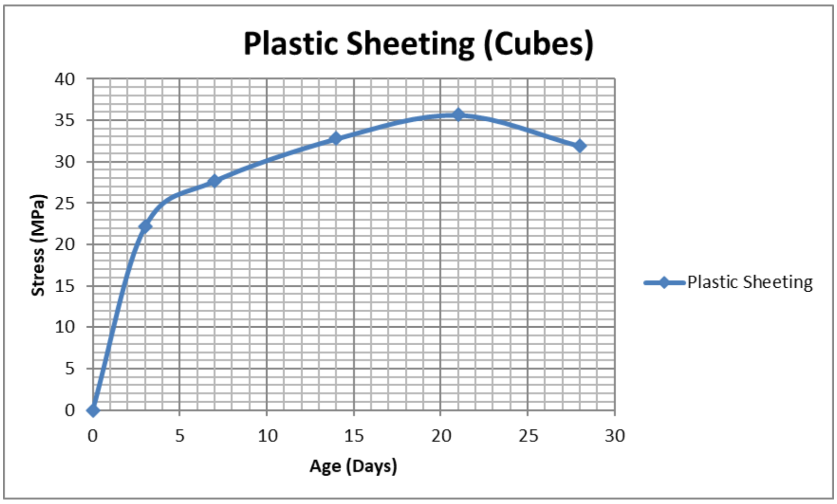

Figure 9 Compressive Strength for Plastic Sheeting Cube Samples for curing duration of 28 days

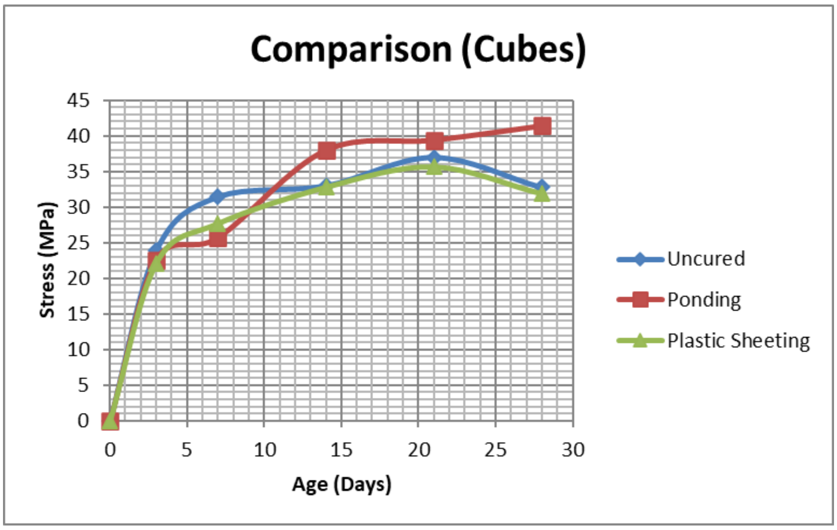

Figure 10 Comparison Graphs of Compressive Strengths for Cube Samples for curing duration of 28 days for different techniques

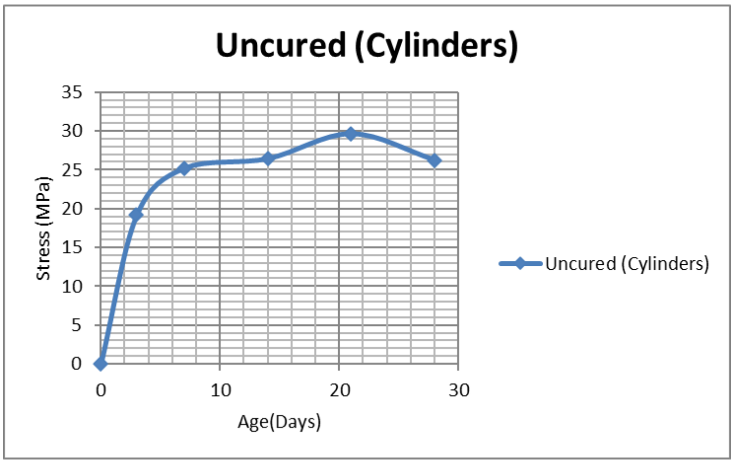

Figure 11 Compressive Strength for Uncured Cylinders Samples curing duration of 28 days

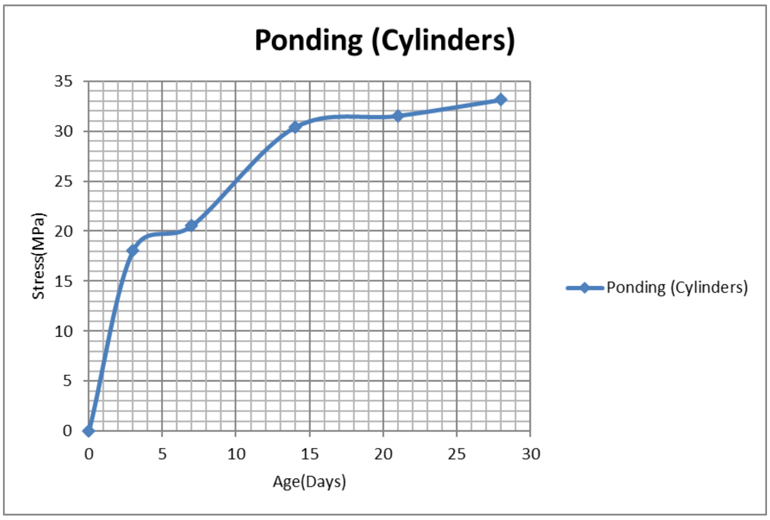

Figure 12 Compressive Strength for Ponding Cylinders Samples for curing duration of 28 days

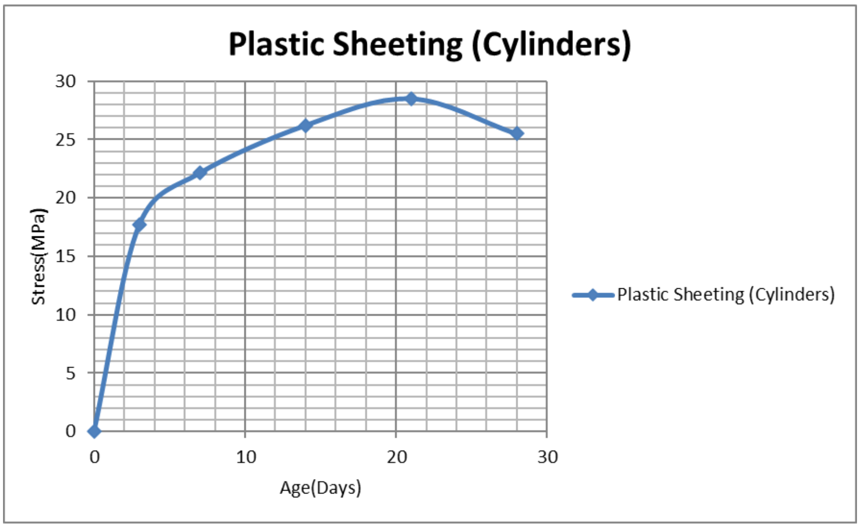

Figure 13 Compressive Strength for Uncured Cylinders Samples for curing duration of 28 days

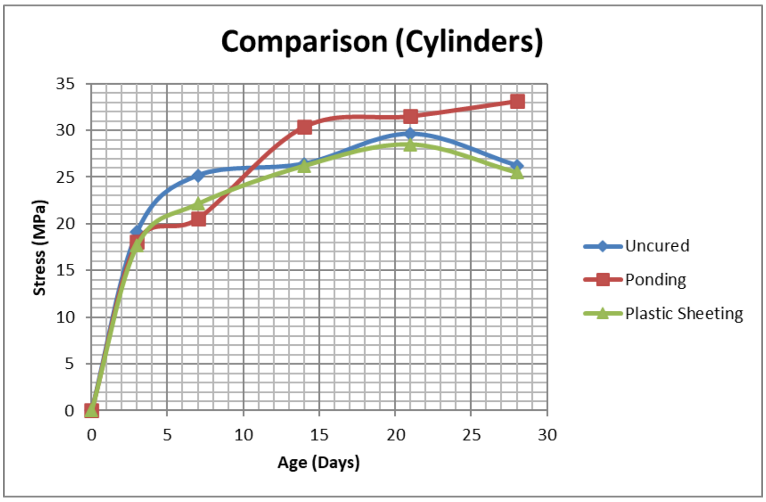

Figure 14 Comparison Graphs of Compressive Strengths for Cylinder Samples for curing duration of 28 days for different techniques

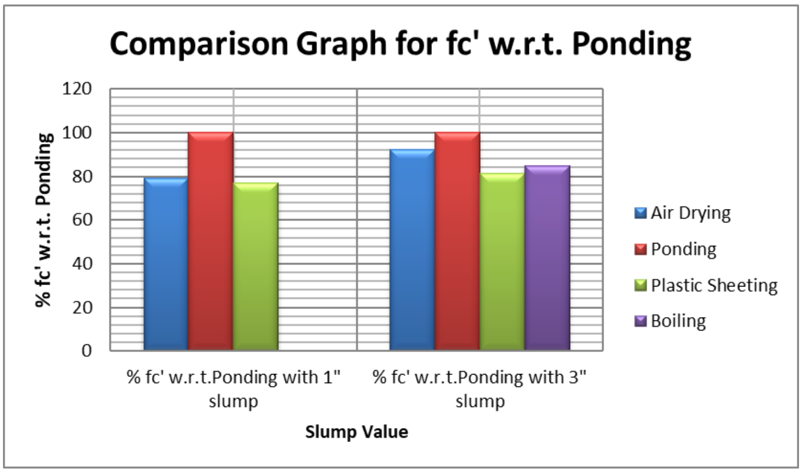

Figure 15 Comparison graph showing percentage compressive strength (fc') w.r.t Ponding technique for different slump values

3.2. Observations

It can be observed from the above experimental results that;

- The compressive strength (fc') of the samples by "Ponding Technique" being tested in saturated surface dry condition is higher than the other two techniques tested in dry state. (Uncured and Plastic Sheeting)
- Relative to ponding the uncured samples are giving less but appreciable strength. The reason for this behavior is the temperature and humidity in the days of sampling and testing. The cubes were exposed in the open air for the evaporation of water content but it didn't happen to the extent of our expectations because of cold and foggy climate.
- The Plastic sheeting technique yielded the least strength as compared to the Ponding and Uncured technique with the same concrete mix. The difference of the uncured and sheeting sample results do not vary much because both of the techniques were sampled and tested in winters. So it didn't make much difference whether we kept out samples exposed or covered. The strength that these samples achieved was solely because of that hydration water which was added at the time of concrete mix.
- Another important thing we noticed is that except in ponding, in both the other techniques (air-drying and plastic sheeting), a drop in compressive strength after 21 days was observed. A thing which can be inferred from this is that the concrete requirement of water was fulfilled up to 21 days and later on when this requirement was not fulfilled, there occurred a deficit in the compressive strength of concrete.
- From the tables as well as from the graphs, it can be seen that the early strength of uncured samples was even more than the ponding-cured samples. Now there might be two reasons behind this:

- Since the tests were performed under surface dry condition, the major thing that contributed towards the failure of the specimen earlier is the pore water pressure. When stress is applied onto a specimen, the pore water pressure also exerts force to rupture the specimen, and ultimately it fails.
- One thing that may occur, specifically related to salt ion related durability of concrete, is that unhydrated cement may remove moisture from the pore system. This removal of moisture could inhibit the transport of salts within concrete, therefore increasing the amount of time required for chlorides to attack rebar or for salts to build up and cause crystallization damage. However, this effect would be confined to a specific amount of time and moisture; once the cement becomes hydrated enough, this effect would cease to operate.

- Under pure uniaxial compressive loading, the failure cracks generated should be approximately parallel to the direction of applied loading along the length with very a few cracks formed at an angle to the applied loading. But practically the failure cracks were not formed all along the length of the cube or cylinder. This is because end platen effects cause the compression testing system to produce a complicated system of stresses. It is evident that cubes or cylinders experience lateral expansion as a result of the poison effect. The lateral expansion of steel plates is not as great as that of concrete [22]. As a result, there is a difference in the lateral expansion tendency between the steel platens and the faces of the concrete cube, which causes tangential forces to be generated between the end surfaces of the concrete specimen and the nearby steel platens of the machine. The amount of platen constraint on the concrete section is determined by the amount of friction created at the concrete-steel interfaces and by how far the cubes are from their end surfaces. Due to the cubes' imperfectly smooth faces and the lack of any oil on the platens, haphazard breaking was seen.

3.3. Comparison

- The compressive strength of the samples by Ponding technique increases gradually with the age because the sample stays in the pond continuously and the hydration process goes on continuously.
- Whereas in case of other two techniques, the compressive strength of the samples increases swiftly in early days and because of this abrupt gain, the samples get weakly structured and more porous causing their breaking strength reduced than the ultimate strength.
- The SSD (saturated surface dry) sample has pore water pressure in it while dry sample is free of it. So the later shows more strength than expected (observed in case of uncured and ponding comparison).

Table 3 Test Performance Results with 3'' Slump

Test Performance with 3'' Slump					
Technique	**Age**	**Stresses (MPa)**			
	Days	Cubes	% strength gain of fc' w.r.t. ponding	Cylinders	% strength gain of fc' w.r.t. ponding
Ponding	0	0	0	0	0
	7	17.94	55.3874	14.352	55.3875
	28	32.39	100	25.912	100
Plastic Sheeting	0	0	0	0	0
	7	15.94	49.2127	12.752	49.2127
	28	26.41	81.5375	21.128	81.5375
Uncured	0	0	0	0	0
	28	29.9	92.3124	23.92	92.3124
Accelerated Curing (Boiling)	Age	Stresses (MPa)			
	Days	Cubes		Cylinders	
Ra	28 Hours	11.83	84.9027	9.464	91.1161
Predicted fc' = 8.09+1.64Ra	0	0		0	
	28	27.5		23.61	

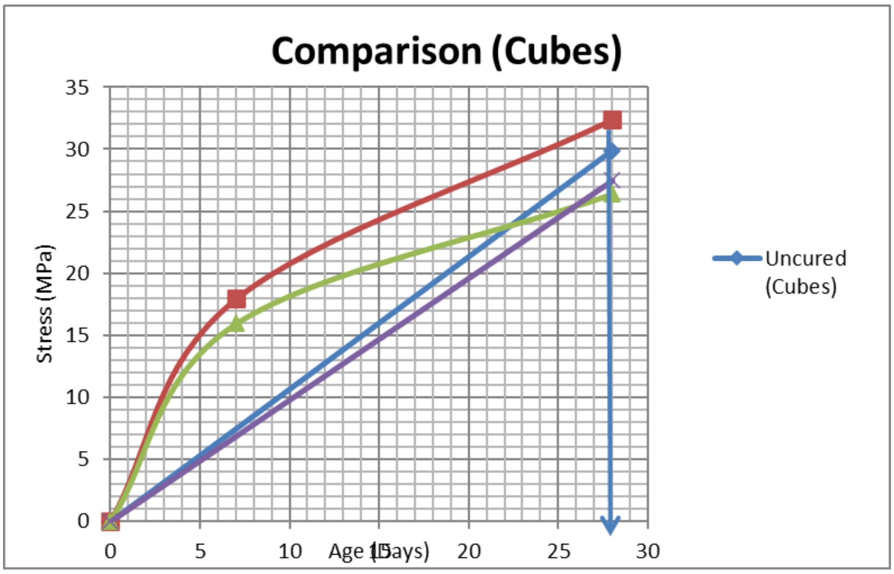

Figure 16 Comparison Graphs of Compressive Strengths for Cube Samples by air-dried, ponding, plastic-sheeting and accelerated curing

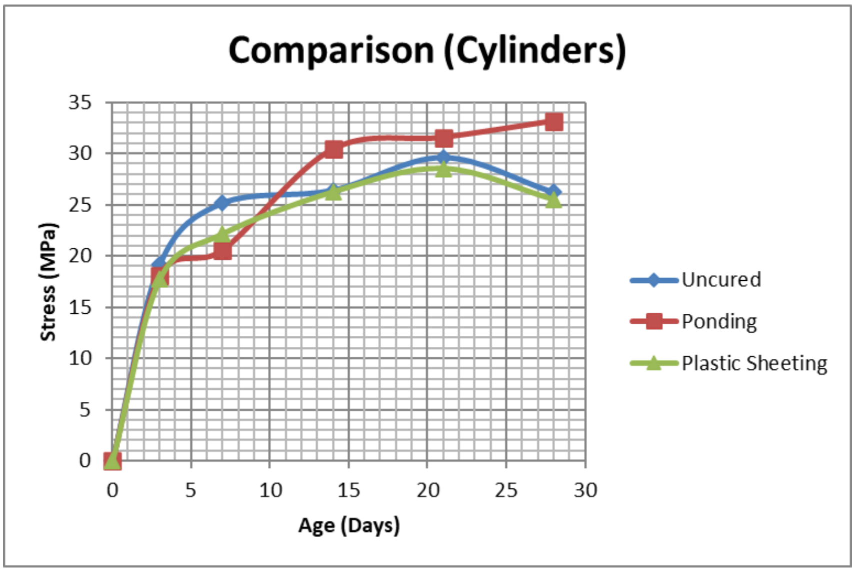

Figure 17 Comparison Graphs of Compressive Strengths for Cylinder Samples by air-dried, ponding, plastic-sheeting and accelerated curing

3.4. Observations

It can be observed from the above experimental results that;

- For concrete mix design the approximate compressive strength of concrete can be determined by accelerated curing which in our case is boiling.
- In boiling technique, the 43% of fc' was achieved in 28 hours. The predicted fc' in this testing is 85% of the fc' obtained by ponding curing of the same batch samples.
- For smaller cubes, since the probability of bleeding and hence the formation of weak spots is less, they should exhibit more strength owing to the Specimen Effect of concrete, while in our case, the strength was less. This was due to the reason that the slump value in the smaller cube specimen was taken more than the larger ones. Even then, the smaller cubes exhibited appreciable strength.

3.5. Comparison

In this case the behavior of concrete properties is same as discussed in previous section.

- The code specifications for sheeting of cubes were not followed strictly. 0.02 inches sheet that was locally available in the market was used for the purpose while the code suggests it to be 0.04 inches.
- Temperature and humidity during the batching storing and curing procedure were the parameters, uncontrolled.
- True slump was achieved in each case.
- The water quality was not ensured. The water to be used should not have more amounts of dissolved salts than drinking water. And the water should be replaced after 2 days on regular basis.
- Different ages of concrete testing due to the shortage of moulds in lab were skipped.
- For accelerated curing, the code (IS 9013-1978) was deviated.
  - The 90% humidity (as mentioned in the code) was not achieved.
  - The samples were to be boiled along with their moulds which wasn't followed.
  - The temperature of the boiling water was to be maintained at 100°C.
  - After the boiling, the specimens were to be cooled at 27°C in an immersing tank for two hours.
- Lack of lab facilities was the main reason for all these short comings.

4. Conclusions and Recommendations

The concrete curing is one of the most important areas in any concrete structure. It provides the basic line of defense against the applied by achieving the required compressive strength of concrete. The understanding of physical properties of concrete has a great influence on the durable design. This study was conducted in order to evaluate the effect of different curing techniques on concrete strength. Different types of techniques were applied on the samples of same concrete mix to see their performance. To do this, concrete cubes and cylinders were casted and tested at different ages. Out of all the curing techniques, ponding yields the best results. Ponding can also easily be handled on field. On field we can easily do ponding for slabs, rigid pavements while for line elements jute bags are preferred. The limitation of ponding is that the water can leak out of the pond if the proper sand boundaries are not made. Uncured concrete can be used in hilly areas where the humidity is more and the temperature is less. In plain areas uncured concrete would generate a poor outcome. Uncured concrete is less dense and more porous. Plastic sheeting cannot be preferred on field as it is time consuming and preferable results cannot be achieved by this method. With same design mix and curing techniques but with different slump values we observed a drastic change in compressive strength of concrete. Still ponding gave us the most desirable results. High temperature results in immediate crack formation, low fc' and high early strength because of the rapid escape of hydration water. Accelerated curing (boiling) is not feasible on field that's why we do this technique in lab and use its result for the concrete mix design to get instant compressive strength. In our case the result of compressive strength by formula suggested by code for this concrete, comes out near to that of ponding, and so we can say this method is reliable for lab use only to get instant results. Our boiling technique experimentation was a complete success.

Compliance with ethical standards

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Disclosure of conflict of interest

There is no conflict of interests to declare from anyone of authors.

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