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Effect of Curing Methods And Environment on Properties of Concrete

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Abstract

The paper presents the effect of three different curing methods i.e. water curing, sealed curing , air curing and curing periods on hardened properties of different concrete mixes(with and without flyash) at different regions in India (in varied conditions of temperature, humidity and wind). The results showed that the strength of water & sealed cured specimens are comparable. The behaviour of concrete with and without flyash against improper curing is similar. The relative values of Rapid Chloride Penetration Test (RCPT) are lowest for water cured samples. For a given design mix when range of temperature variation during curing period is high (15ºC), it results in compressive strength as low as 43%and when a humidity variation is high (40%), RCPT values are as high as 300%.

Keywords: curing, strength, temperature, humidity, concrete.

1. Introduction

Curing has a significant influence on the properties of hardened concrete, such as strength, permeability, abrasion resistance, and volume stability, resistance to freezing and thawing, and deicing chemical [1]. The hydration of cement virtually ceases when the relative humidity within capillaries drops below 80% [2]. The concrete specimens lose moisture through evaporation and become dry in absence of a proper curing. The evaporation decreases the relative humidity and thereby retards the hydration of cement.

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In severe cases, when hydration is eventually stopped, sufficient calcium silicate hydrate (CSH) cannot develop from the reaction of cement compounds and water. CSH is the major strength-providing reaction product of cement hydration. Without adequate CSH, the development of dense microstructure and refined pore structure is interrupted. A more continuous pore structure may be formed in cover concrete, since it is very sensitive to drying. The continuous pore structure formed may allow the ingress of deleterious agents [3], and thus would cause various durability problems. Moreover, the drying of concrete surfaces results in shrinkage cracks that may aggravate the durability problems.

2. Research significance

It is evident that an efficient curing is inevitable to prevent the moisture movement from concrete surface. The movement of water from the concrete soon after placing depends on the temperature and relative humidity of the ambient air and the wind velocity over the surface of the concrete. These are the major factors that decide the method and curing time of concrete. The temperature during curing also controls the rate of progress of the reaction of hydration and consequently affects the development of strength of concrete; hence the strength of concrete is a function of time interval and temperature [4].

Different methods adopted for curing is widely depending on the condition on the site and on the size, shape and position of the member/structure. Curing plays a significant role in the concrete with fly ash, as the rate of hydration, in-turn the rate of strength gain in such concrete is proportional to secondary hydration reaction hence delayed. This study presents the effect of different curing methods, period of curing and meteorological data on several hardened properties of concrete with and without fly ash.

3. Experimental investigation

3.1. Materials and mixes

Specimens were cast and tested at three different locations i.e. Tamilnadu (BHAVINI), Rajasthan (RAPP) and Maharashtra (TAPS) in India. Locally available crushed granite stone, crushed and river sand were used as coarse and fine aggregates respectively. Ordinary Portland cement has been used in all the projects. Fly ash conforming to the requirements of IS 3812 (Part 1): 2003 has been used in all projects. The sum of SiO_2, $Al2O_3$ and Fe_2O_3 is above 89%, and material retained on 45 micron is in the range of 10% to 20% at all the projects indicating that almost same quality of fly ash was available at all the project sites. Normal tap water was used for preparing concrete and also for curing purpose. Sulfonated naphthalene formaldehyde condensate based superplasticizer was used to achieve workability.

Mixes of grade M50 with 40% fly ash (525F40), grade M35 with 0 % (320F0) and 50% fly ash (420F50) was used for this study. The details of the mixes are given in Table 1. All the project sites used these proportions keeping the same quantity of cement, fly ash and water. The quantity of plasticizer and aggregate were adjusted for requisite grade of the mix.

TABLE1: MIX PROPORTION OF CONCRETE FOR CURING METHOD STUDIES

Sl. No.	Grade of Mix	Total binder (kg)	Cement (kg)	Fly ash (kg)	Water (kg)	Coarse Aggregate (kg)	Fine Aggregate (kg)	Admixture (%)
1	M50 (525F40)	525	315	210	153	1083	676	1.6
2	M35 (420F50)	420	210	210	147	1140	729	1.6
3	M35 (320F0)	320	320	0	144	1172	855	0.9

3.2. Preparation of specimens

Cube specimens of 150 mm size were cast for compressive strength test and cylinder specimens of 100 mm in diameter and 200 mm long for Rapid chloride penetration test (RCPT). The exposed surface was covered by plastic sheet and stored in the moulds for 24 hrs then de-moulded.

3.3. Curing methods

For water curing, specimens were immersed in curing tank up-to various ages as per schedule given in Table 2.The specimens were covered by plastic sheet for sealed curing, whereas, air curing was done under natural conditions. The sealed cured, air cured and water cured specimens after designated period of curing were stored in an open area covered at the top such that the specimens were not exposed to direct sun at any time of the day [5-12]. At all the sites, the metrological data such as wind data, humidity and temperature were recorded daily during the period of curing studies.

TABLE 2: TEST SCHEDULE FOR WATER AND SEALED CURED SPECIMENS FOR COMPRESSIVE STRENGTH

Days of testing→ curing↓	7	10	14	28	56
7	✓	✓	✓	✓	✓
10	-	✓	✓	✓	✓
14	-	-	✓	✓	✓
28	-	-	-	✓	✓

Figs. 1a-c, 2a-c & 3a-c show the maximum, minimum, day average ambient dry bulb temperature, relative humidity and wind speed for a) RAPP, b) TAPS, and c) BHAVINI site.

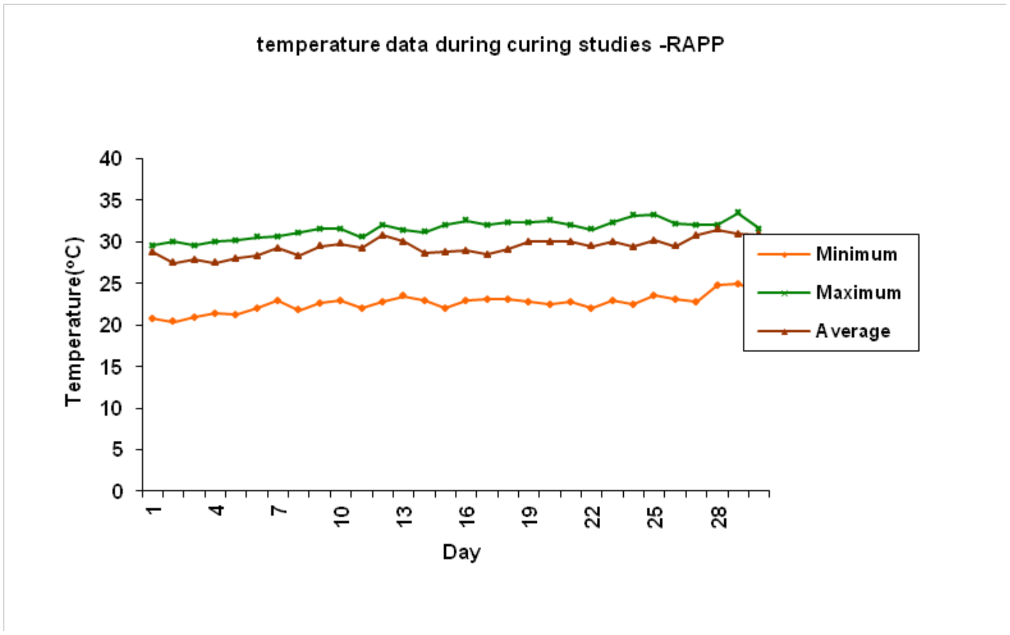

Figure 1a). Temperature data – RAPP.

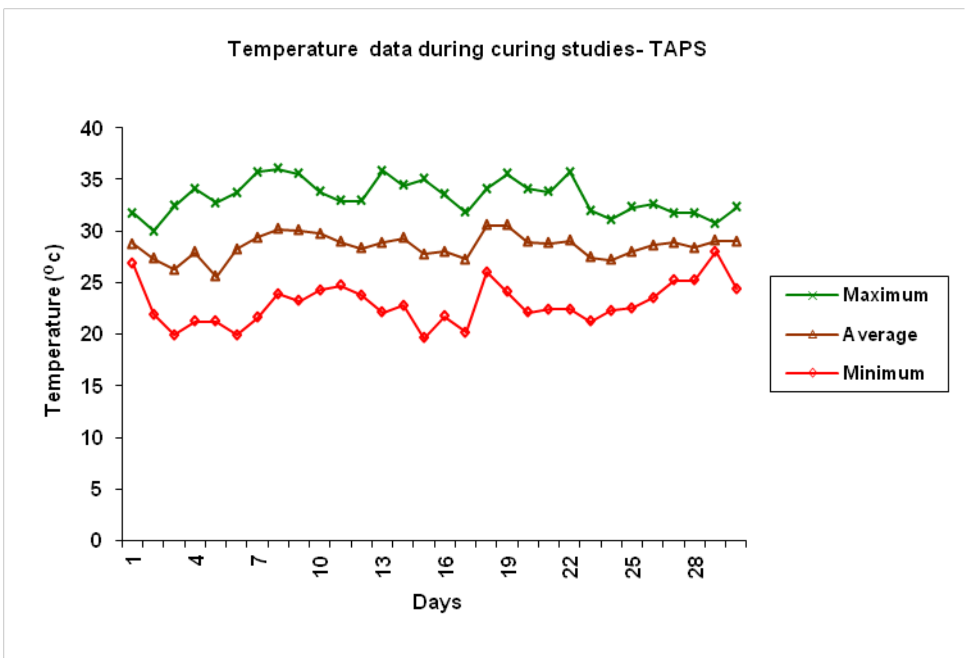

Figure 1b). Temperature data – TAPS.

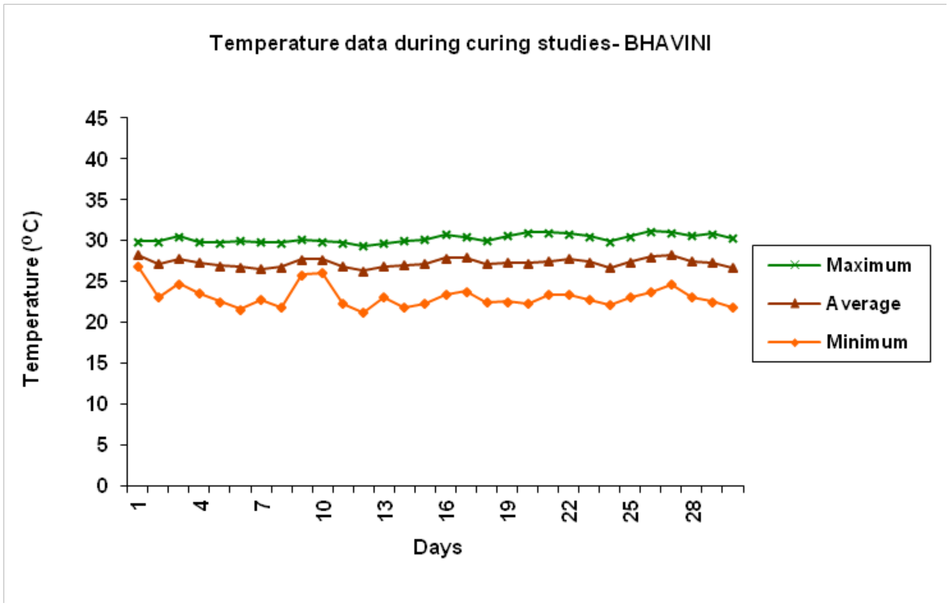

Figure 1c). Temperature data – BHAVINI.

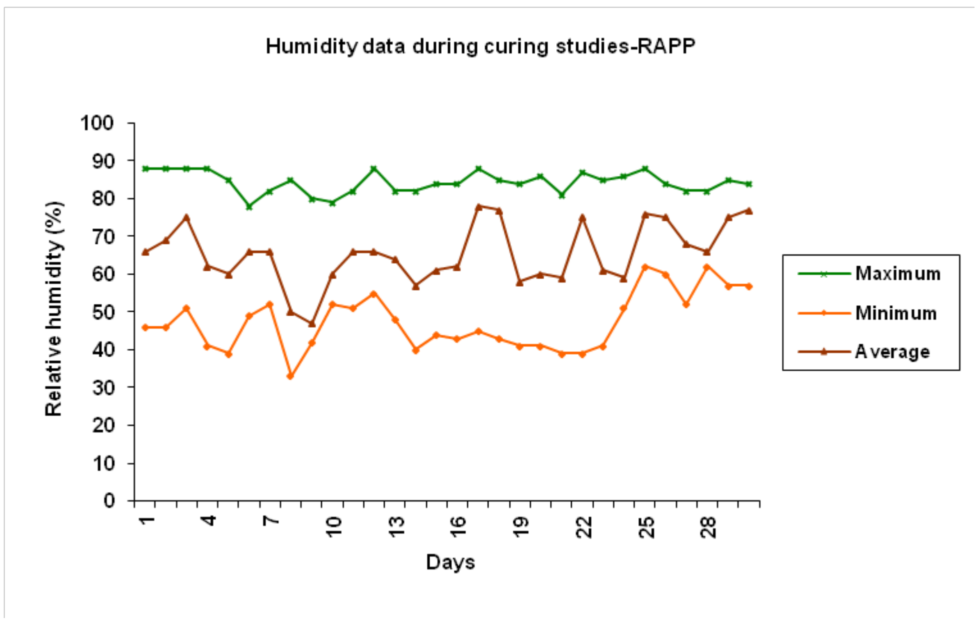

Figure 2a). Humidity data – RAPP.

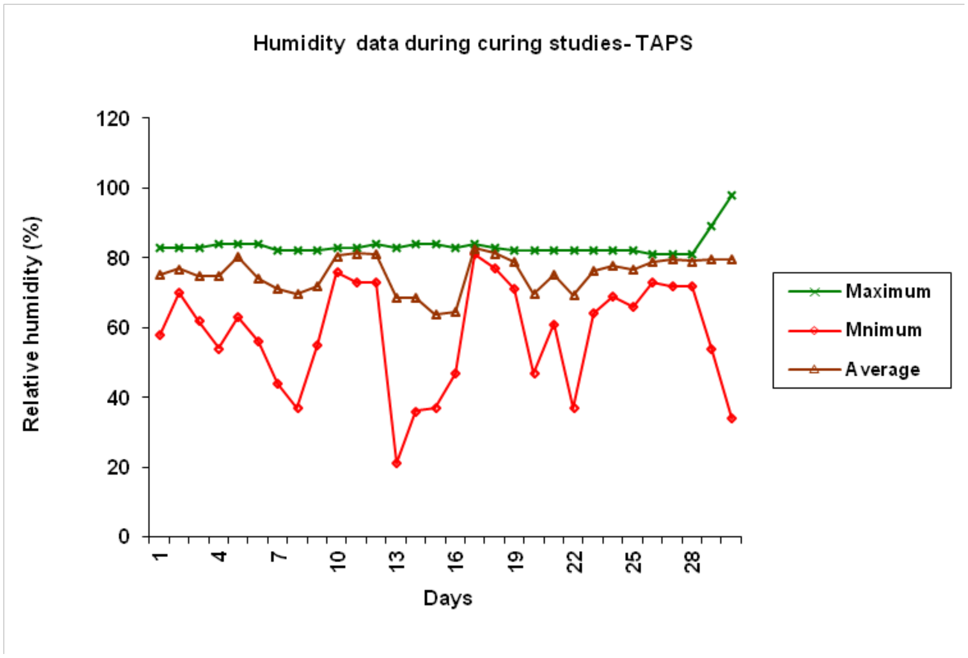

Figure 2b). Humidity data – TAPS.

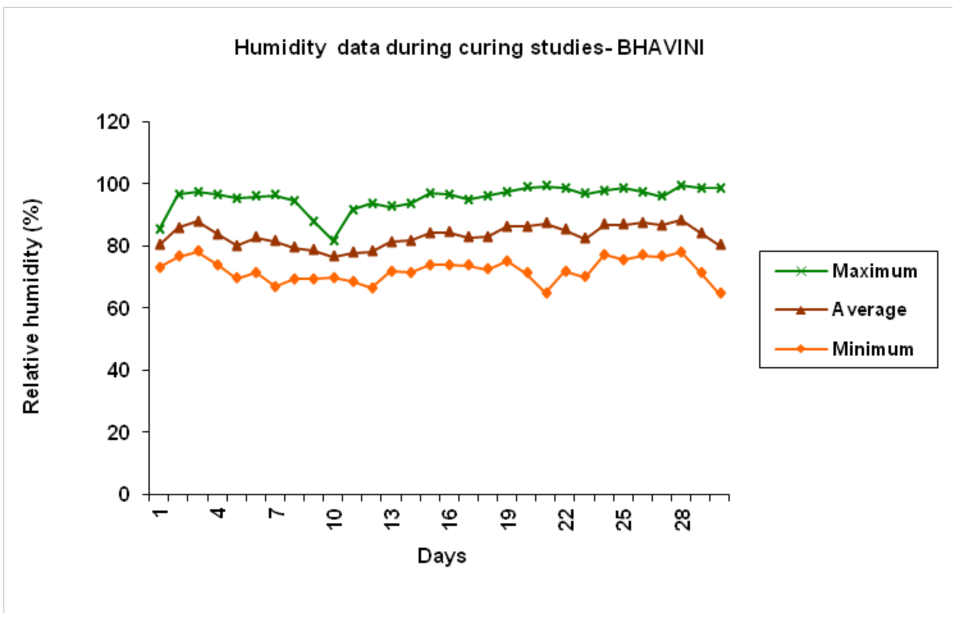

Figure 2c). Humidity data – BHAVINI.

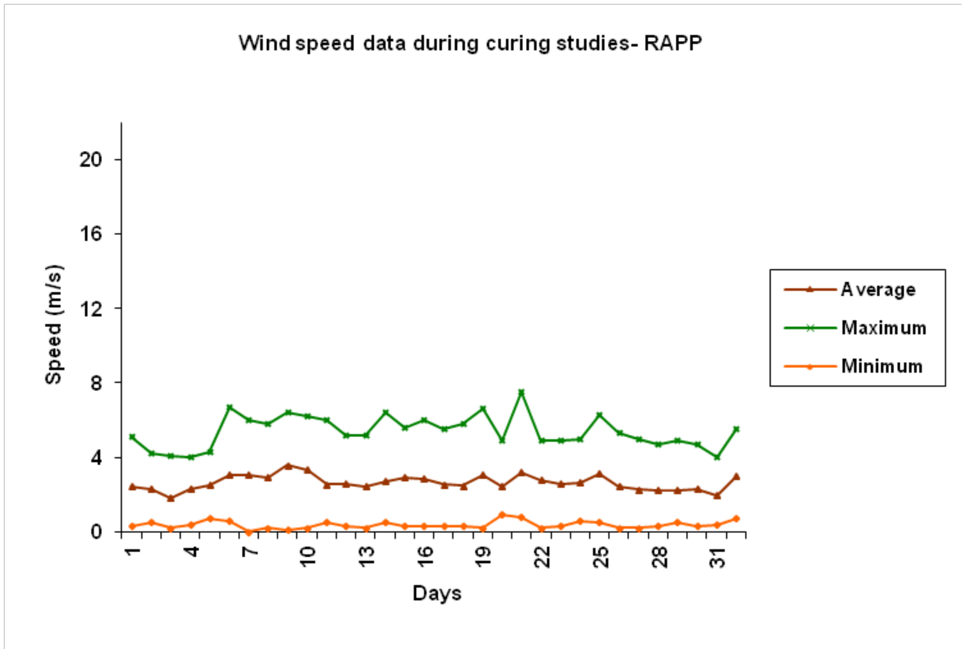

Figure 3a). Wind speed data – RAPP.

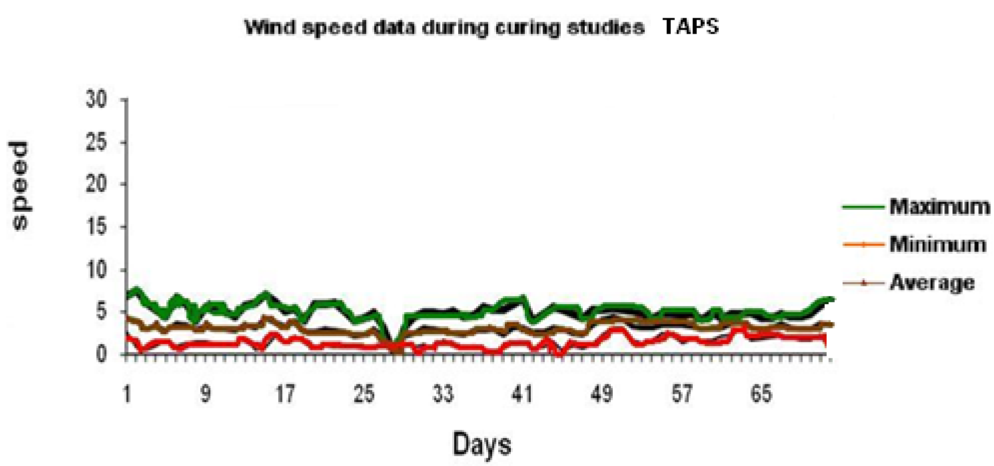

Figure 3b). Wind speed data – TAPS.

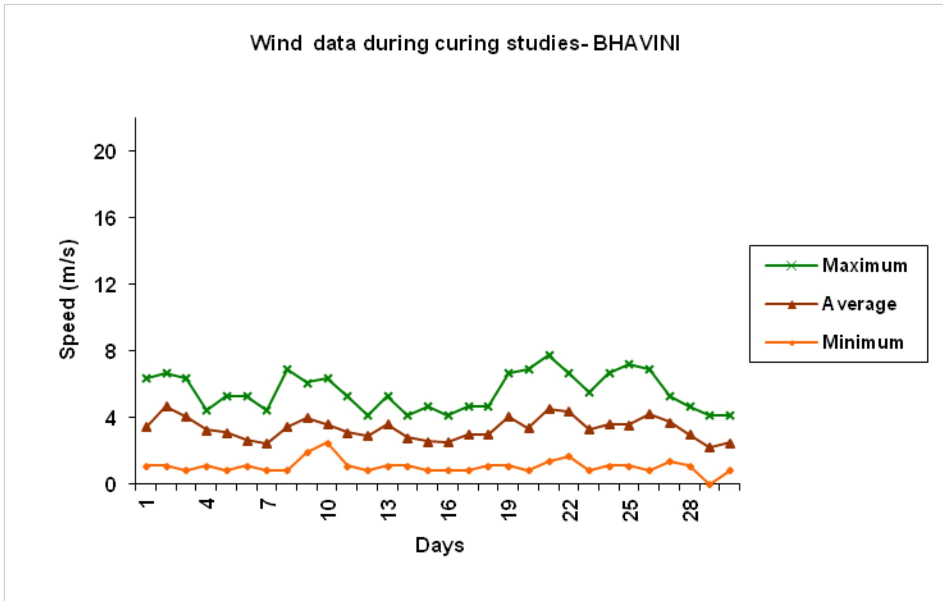

Figure 3c). Wind speed data – BHAVINI.

4. Results

4.1 Compressive strength

The cube compressive strength of water cured specimens and sealed cured specimens tested at different ages were compared with air cured specimens. Graphical presentation of the test data for 525F40 (M50), 420F50 (M35) and 320F0 (M35) concrete mix for different sites are given in Figs. 4a-f, 5a-f & 6a-f.

The compressive strength of sealed cured specimens were ±10 % in comparison with water cured specimens for all the ages of testing and duration of curing for all the sites, except for few isolated cases.

The compressive strength of water cured sample in general are 25 % to 30% higher than the air cured specimens, and in few cases it is either as high as 51.91% (Fig. 5e.) and as low as 7.07 % (Fig. 6a.). The highest difference for 28 days compressive strength between water and air cured concrete specimens are observed in case of TAPS for grade 320F0 (Fig. 5e).

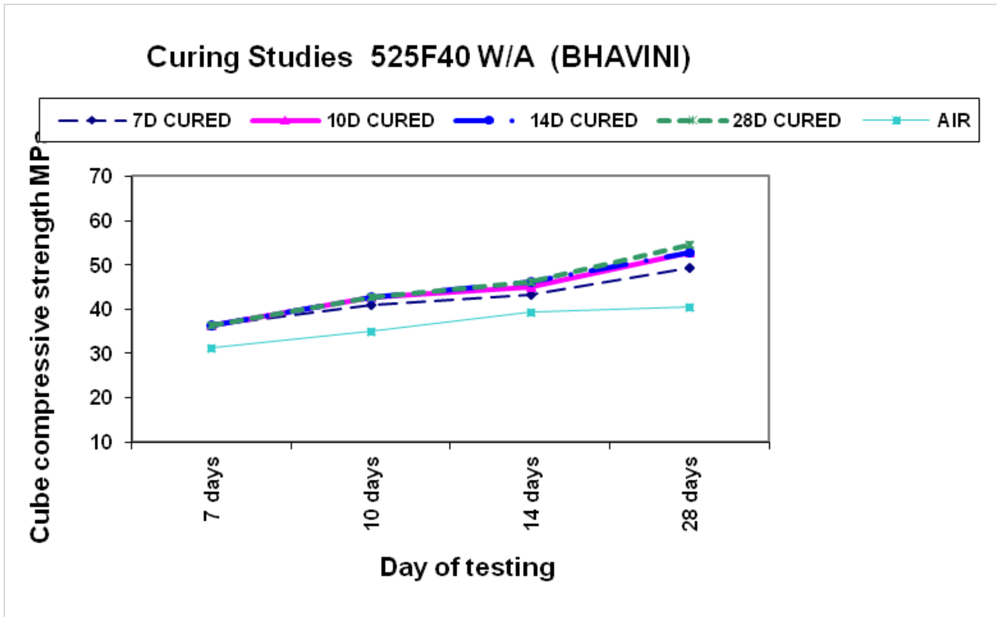

Figure 4a). Compressive strength of specimens water & air cured (W/A) (525F40) – BHAVINI.

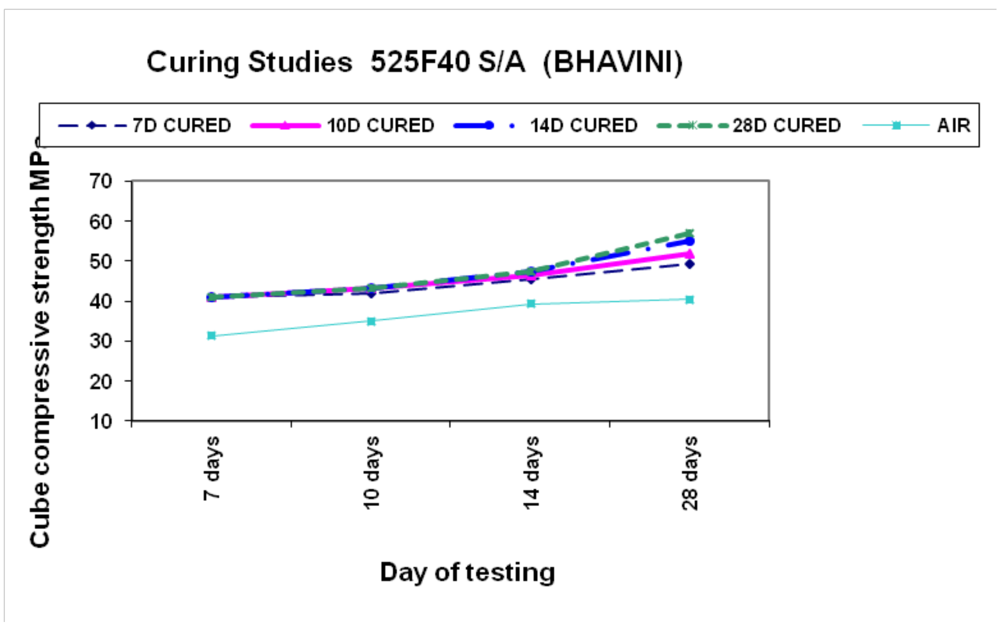

Figure 4b). Compressive strength of specimens sealed & air cured (S/A) (525F40) – BHAVINI.

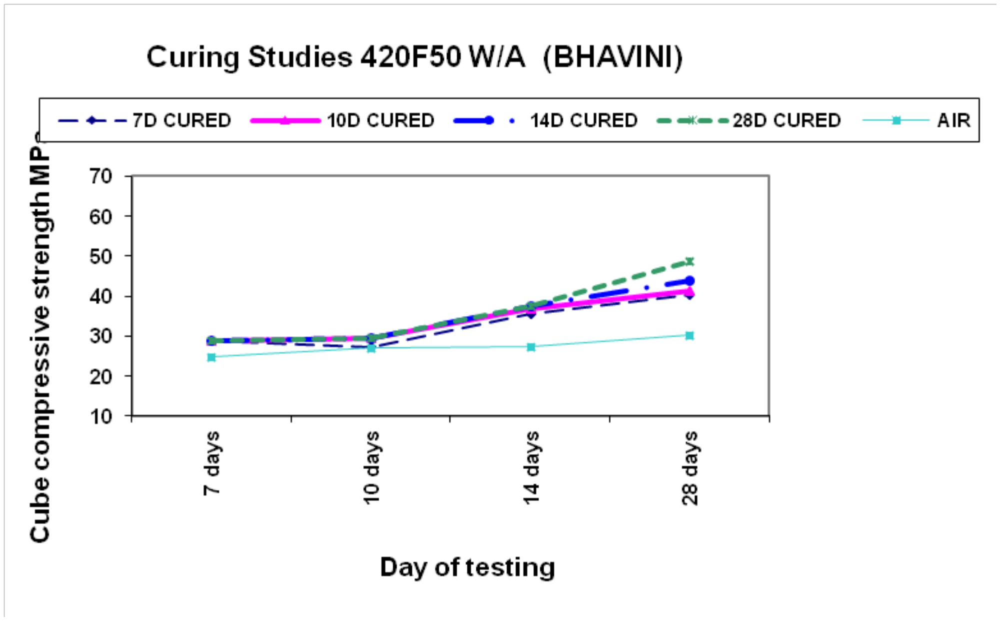

Figure 4c). Compressive strength of specimens water & air cured (W/A) (420F50) – BHAVINI.

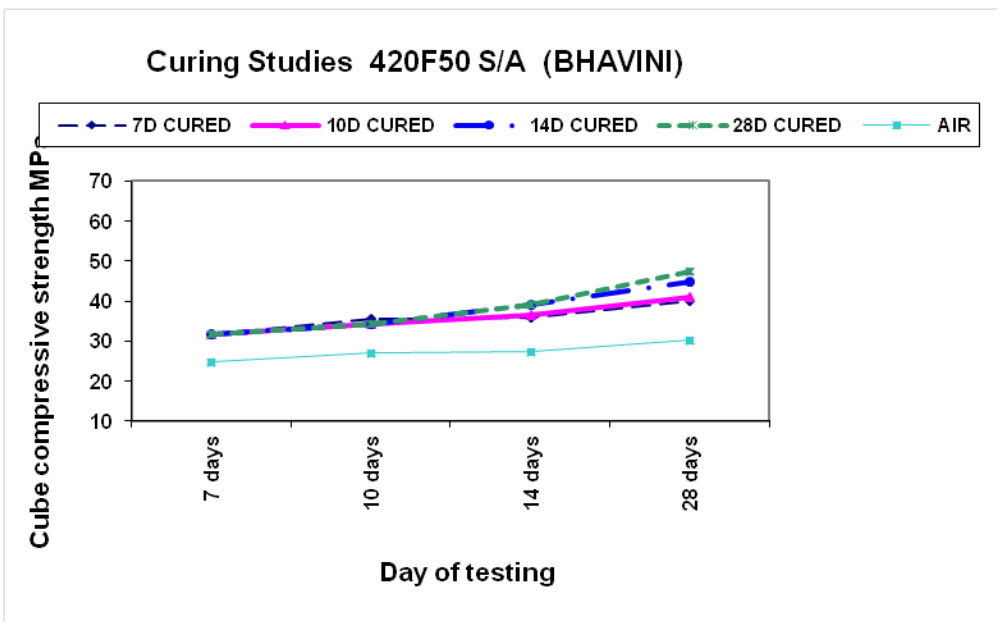

Figure 4d). Compressive strength of specimens sealed & air cured (S/A) (420F50) – BHAVINI.

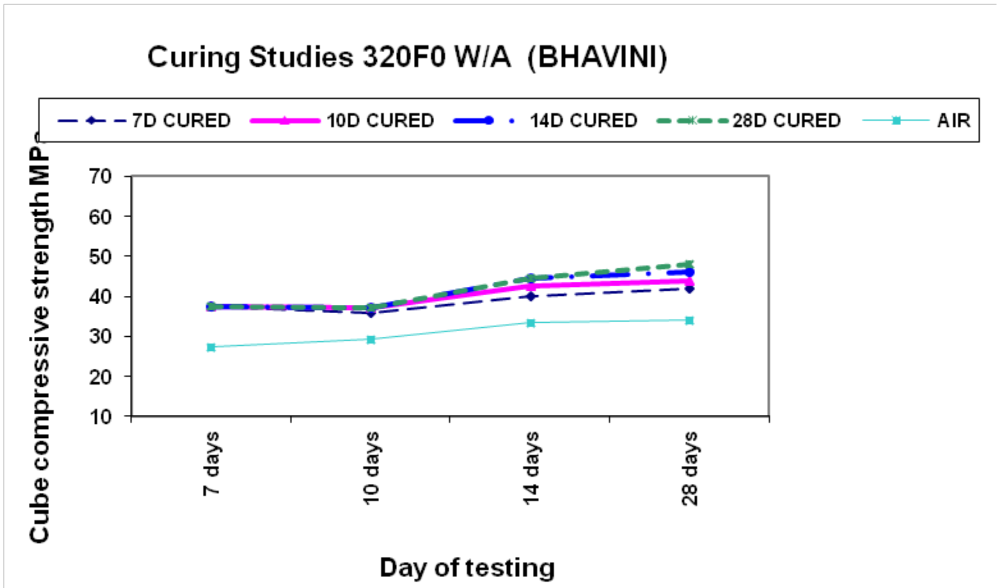

Figure 4e). Compressive strength of specimens water & air cured (W/A) (320F0) – BHAVINI.

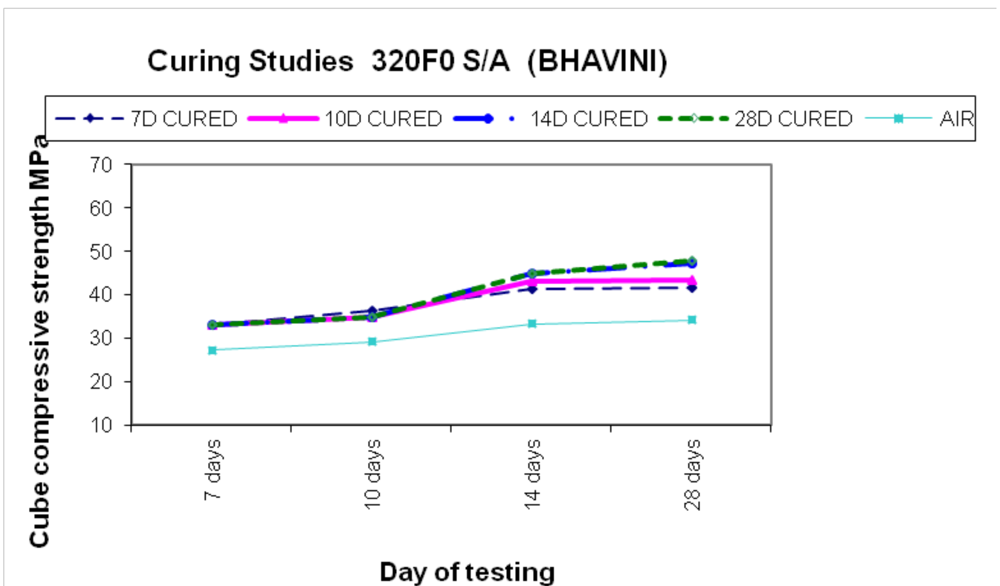

Figure 4f). Compressive strength of specimens sealed & air cured (S/A) (320F0) – BHAVINI.

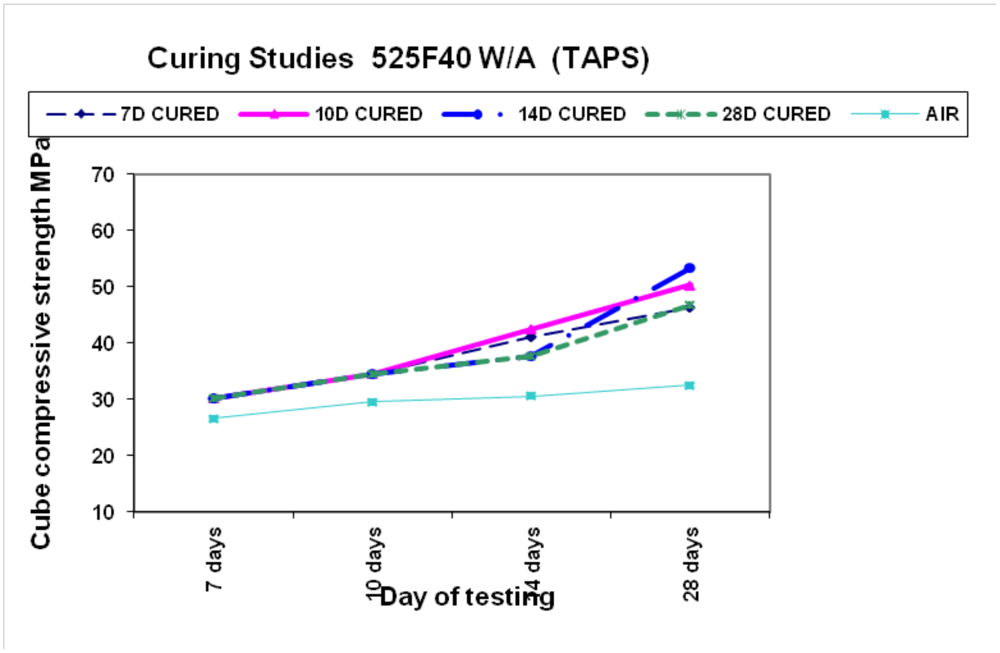

Figure 5a). Compressive strength of specimens water & air cured (W/A) (525F40) – TAPS.

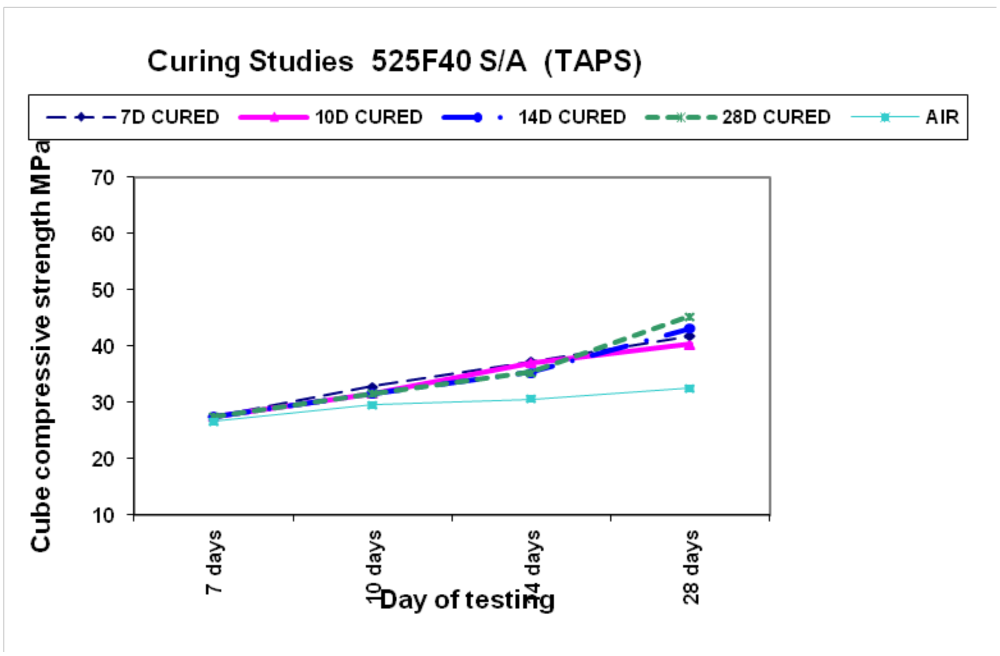

Figure 5b). Compressive strength of specimens sealed & air cured (S/A) (525F40) – TAPS.

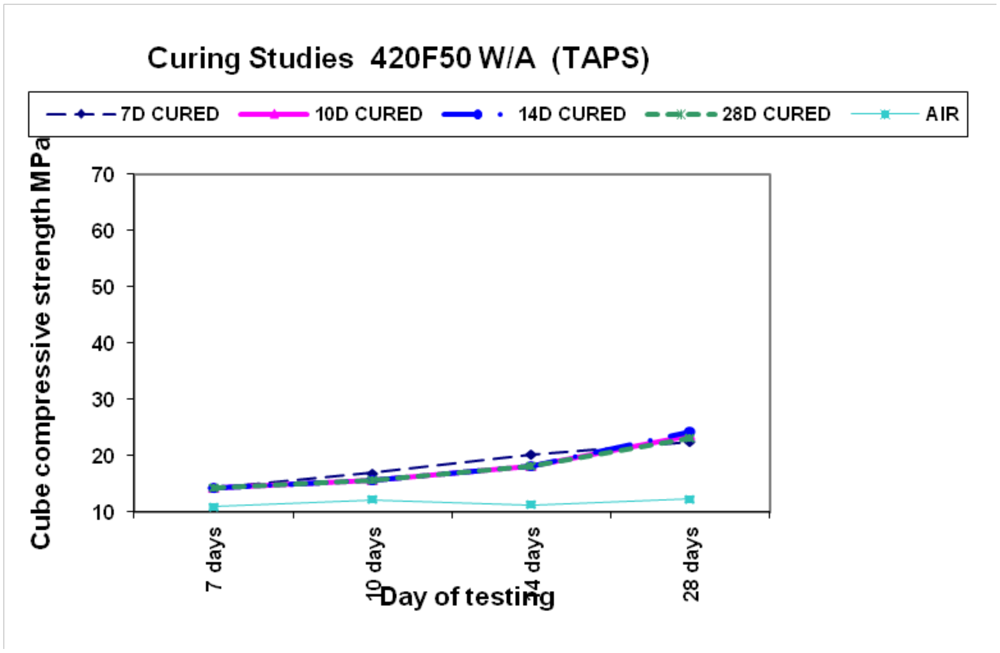

Figure 5c). Compressive strength of specimens water & air cured (W/A) (420F50) – TAPS.

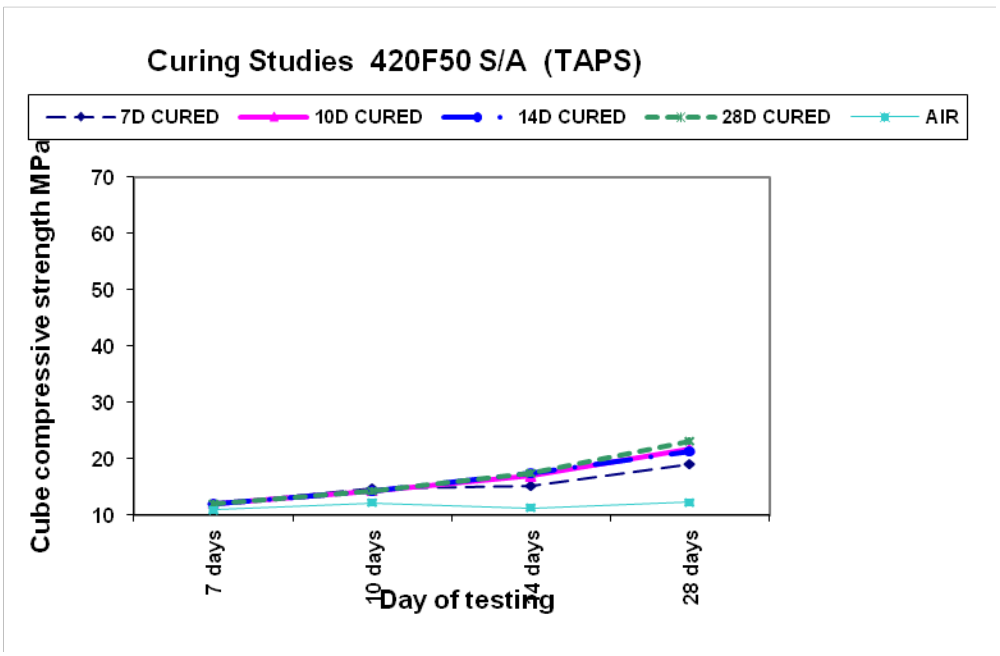

Figure 5d). Compressive strength of specimens sealed & air cured (S/A) (420F50) – TAPS.

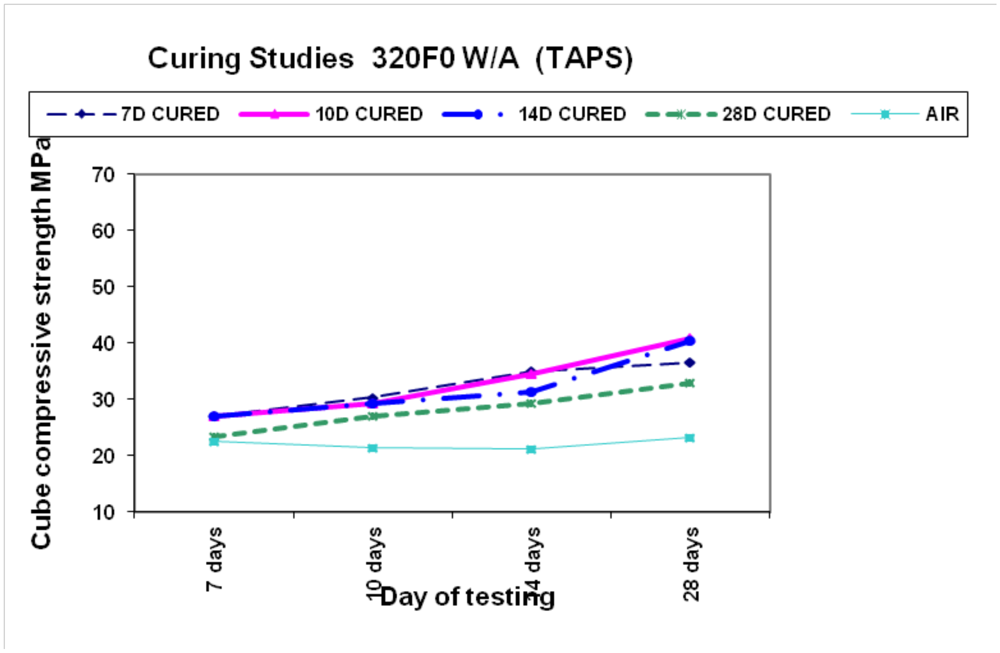

Figure 5e). Compressive strength of specimens water & air cured (W/A) (320F0) – TAPS.

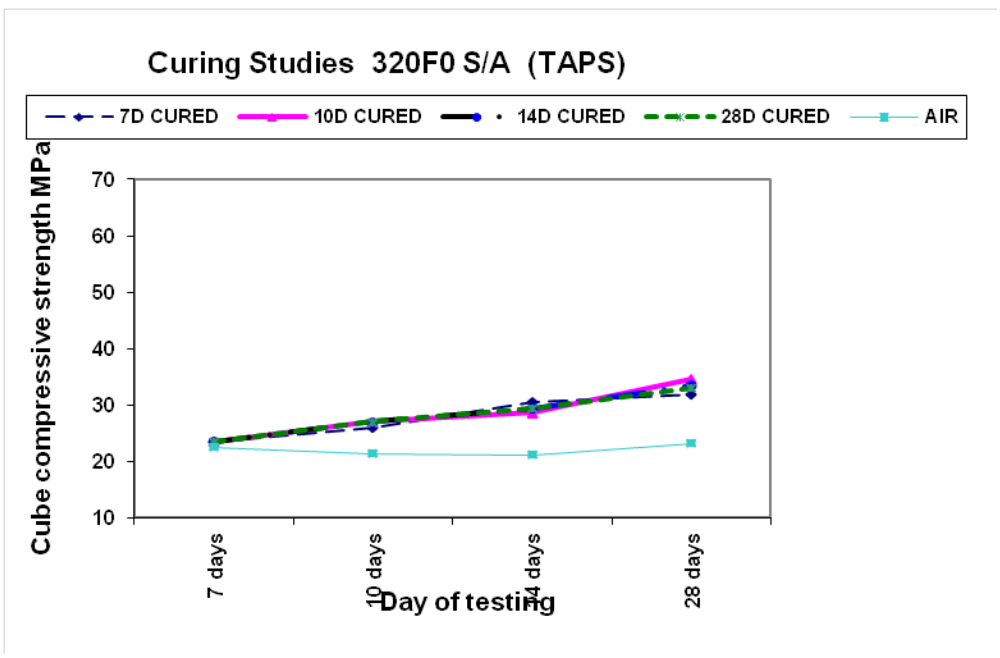

Figure 5f). Compressive strength of specimens sealed & air cured (S/A) (320F0) – TAPS.

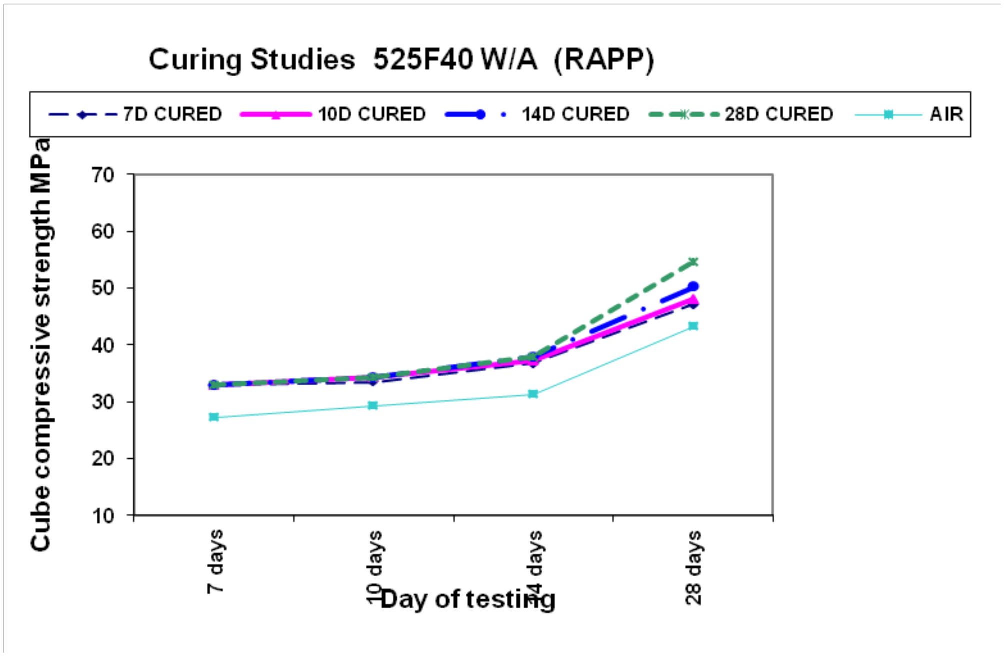

Figure 6a). Compressive strength of specimens water & air cured (W/A) (525F40) – RAPP.

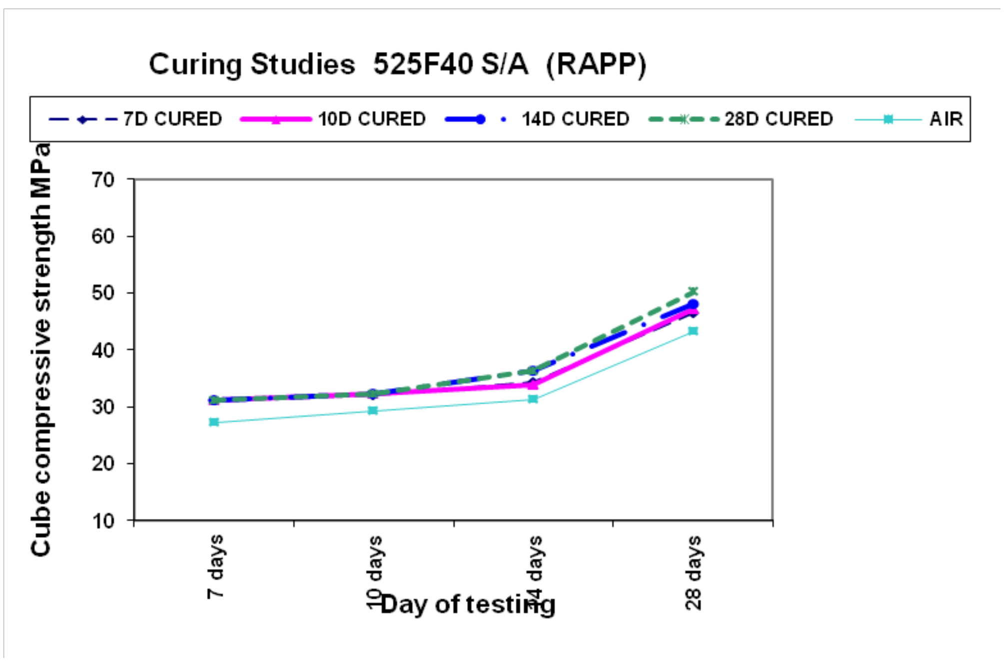

Figure 6b). Compressive strength of specimens sealed & air cured (S/A) (525F40) – RAPP.

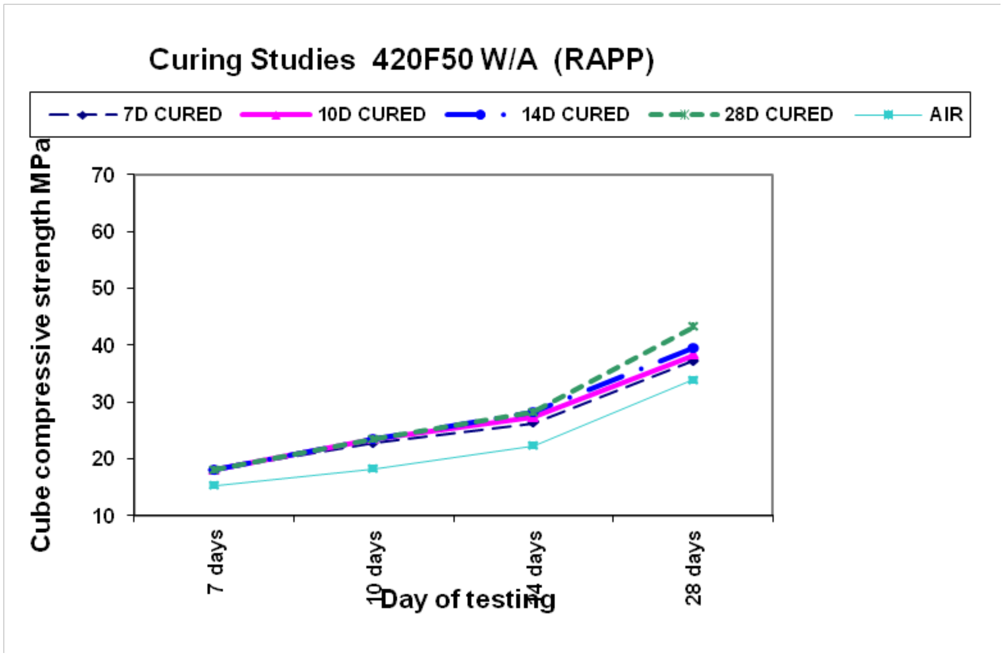

Figure 6c). Compressive strength of specimens water & air cured (W/A) (420F50) – RAPP.

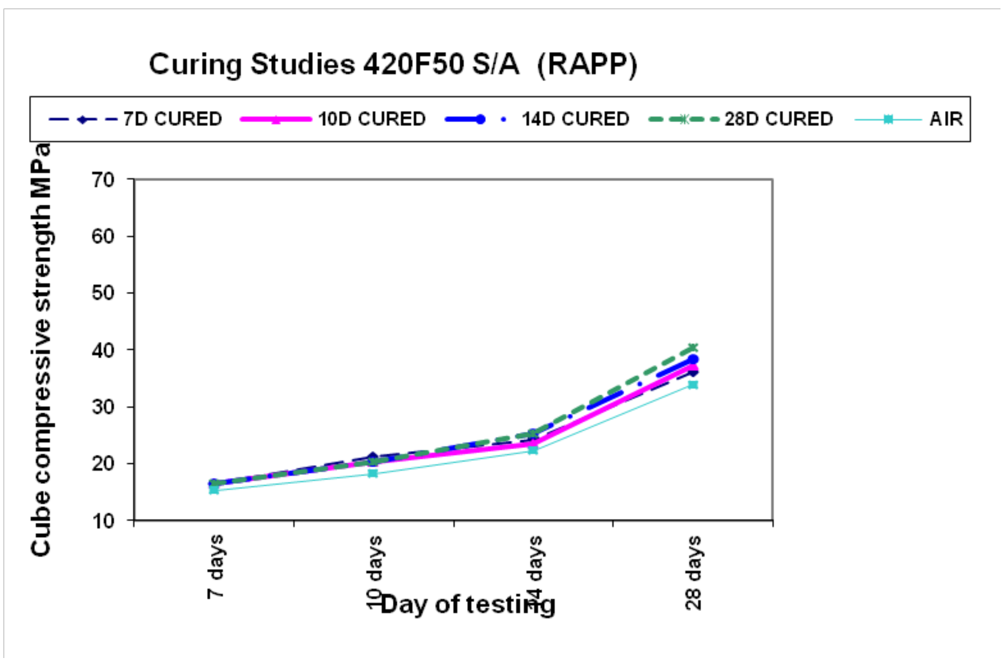

Figure 6d). Compressive strength of specimens sealed & air cured (S/A) (420F50) – RAPP.

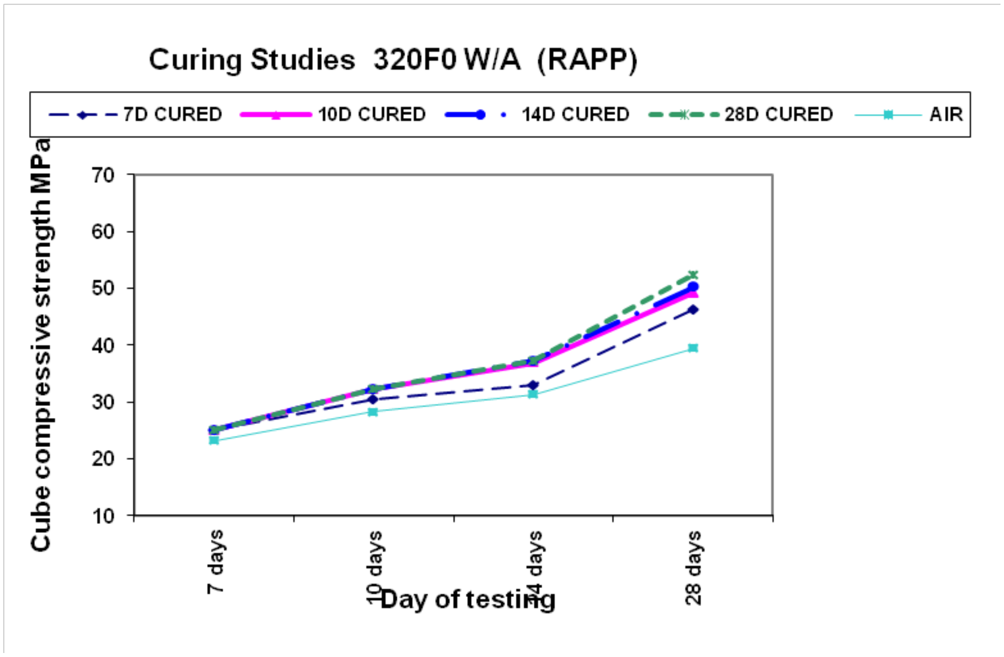

Figure 6e). Compressive strength of specimens water & air cured (W/A) (320F0) – RAPP.

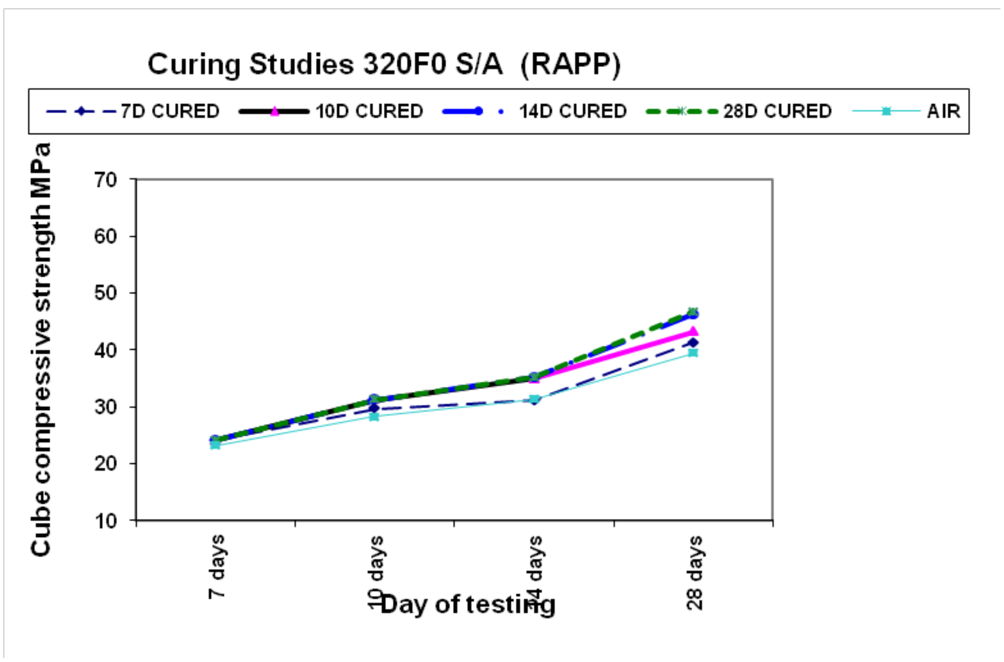

Figure 6f). Compressive strength of specimens sealed & air cured (S/A) (320F0) – RAPP.

In the case of concrete with fly ash the compressive strength keeps increasing with longer duration of curing. According to [1] "When strength is the essential performance criterion, it is common to maintain curing measures until a minimum of 70% of the specified 28-day strength *fc*, has been achieved .When the structure's performance requires that the in-place strength or other concrete property reaches 100% of the specified value, curing should be extended until tests prove that the specified property has been reached.". Fig. 7a) shows result of RAPP grade 320F0.The characteristic strength at 28 days required for this mix is 35 N/mm^2 and it is attained even with seven days of curing. Also 70% of characteristic strength (f_c) i.e. 24.5 N/mm^2 at 7th day is achieved with 7 days curing, as shown clearly. Whereas the concrete mix with fly ash, i.e. RAPP grade 420F50 (Fig.7c) and RAPP grade 525F40 (Fig.7e),cured for seven days , when tested at seven days shows compressive strength of only 18.0 N/mm^2 and 32.55 N/mm^2 respectively against required 24.5 N/mm^2&35 N/mm^2 .

From Figs.7a-f, it is observed that the required strength is achieved by specimens with fly ash, when water cured for 14 days. This fact is evident in results of all sites. Hence fly ash concrete requires a water curing period of at least 14 days. With sealed curing more periods has to be recommended as seen from Figs. 7a-f.

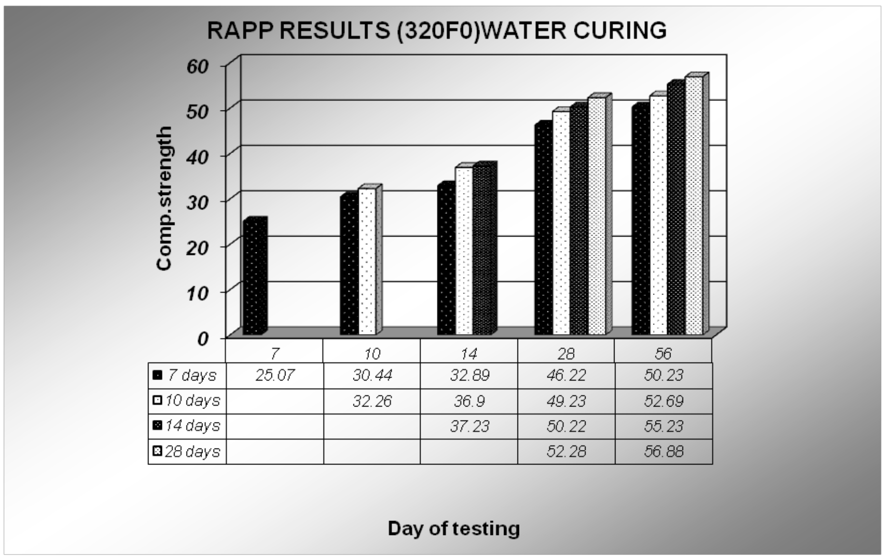

Figure 7a). Compressive strength water cured for different periods- RAPP (320F0).

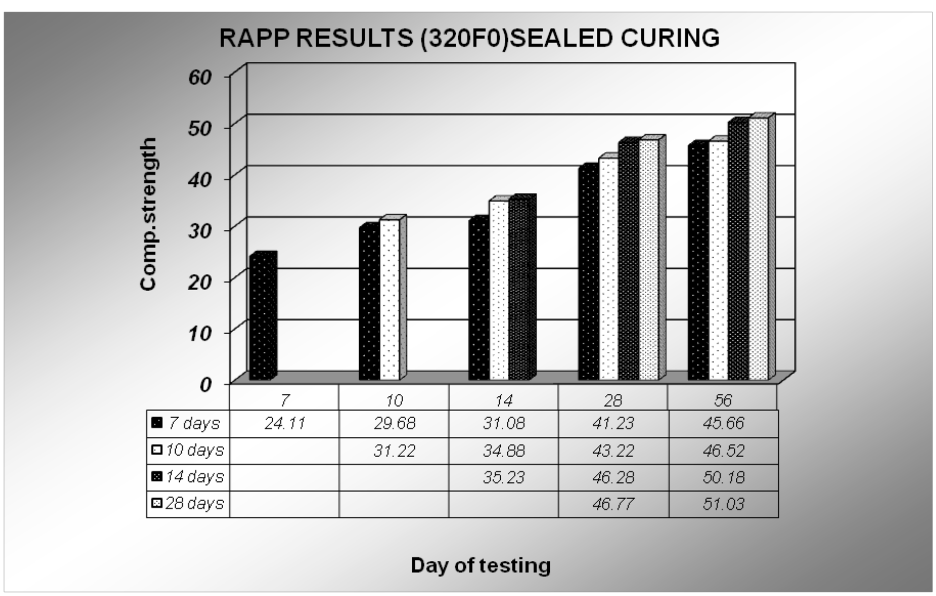

Figure 7b). Compressive strength sealed cured for different periods- RAPP (320F0).

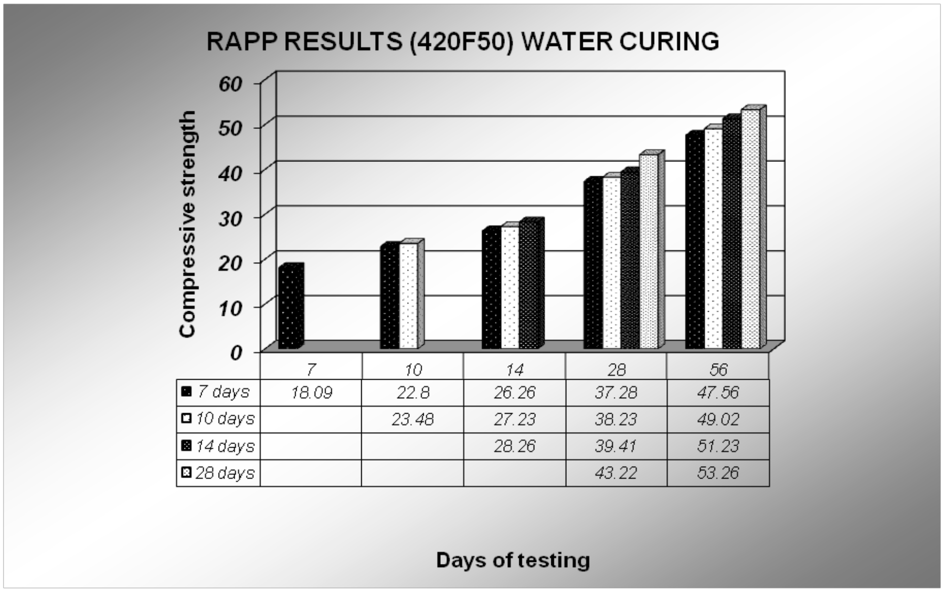

Figure 7c). Compressive strength water cured for different periods- RAPP (420F50).

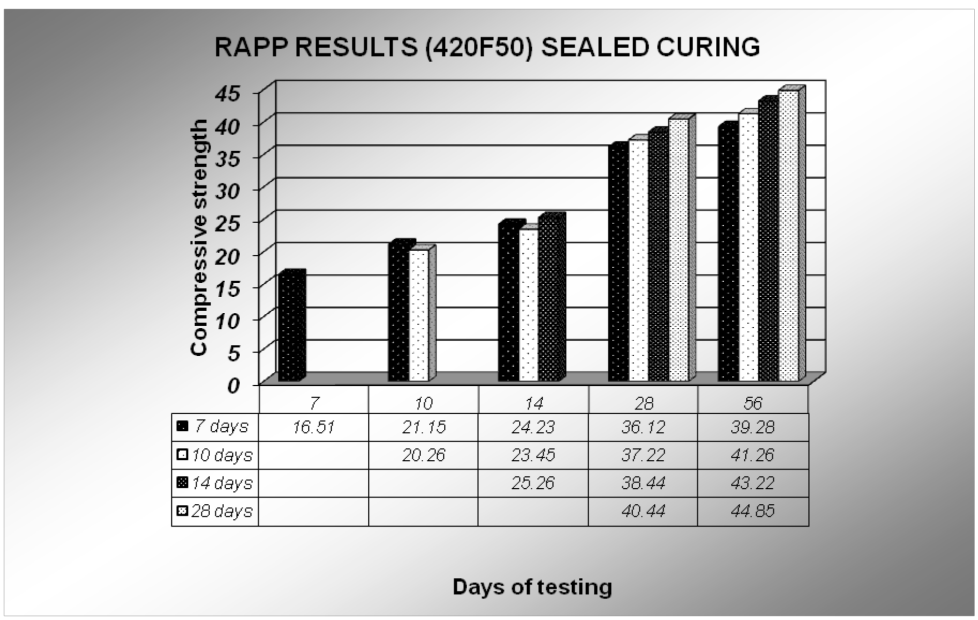

Figure 7d). Compressive strength sealed cured for different periods- RAPP (420F50).

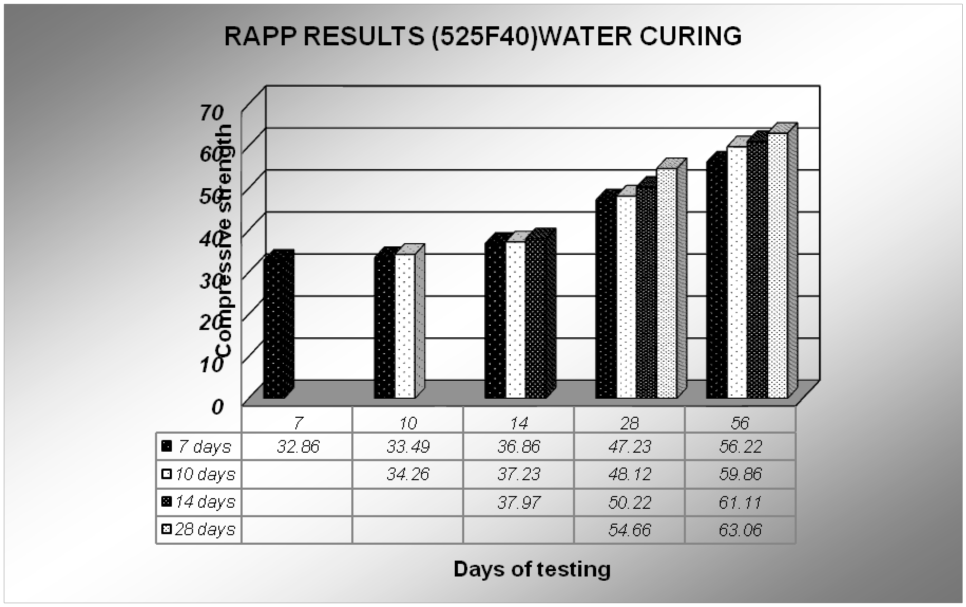

Figure 7e). Compressive strength water cured for different periods- RAPP (525F40).

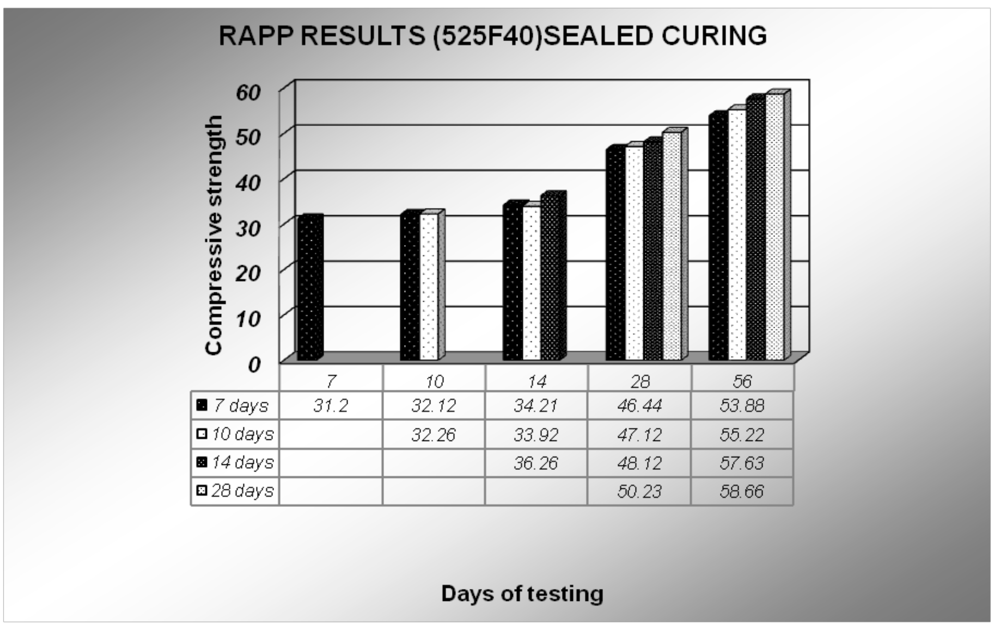

Figure 7f). Compressive strength sealed cured for different periods- RAPP (525F40).

The 56 days strength of fly ash concrete is generally 10% to 15% higher than the 28 days strength for all durations of curing in case of water cured specimens as observed from Figs.8a-f.

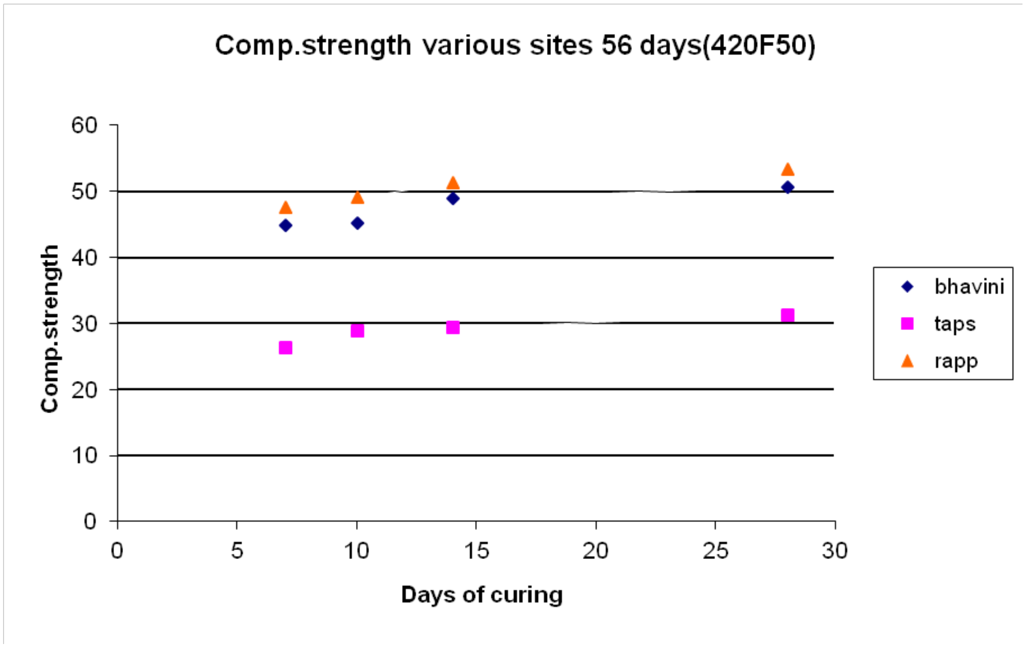

Figure 8a). Compressive strength water cured specimens (420F50) for different sites and curing periods.

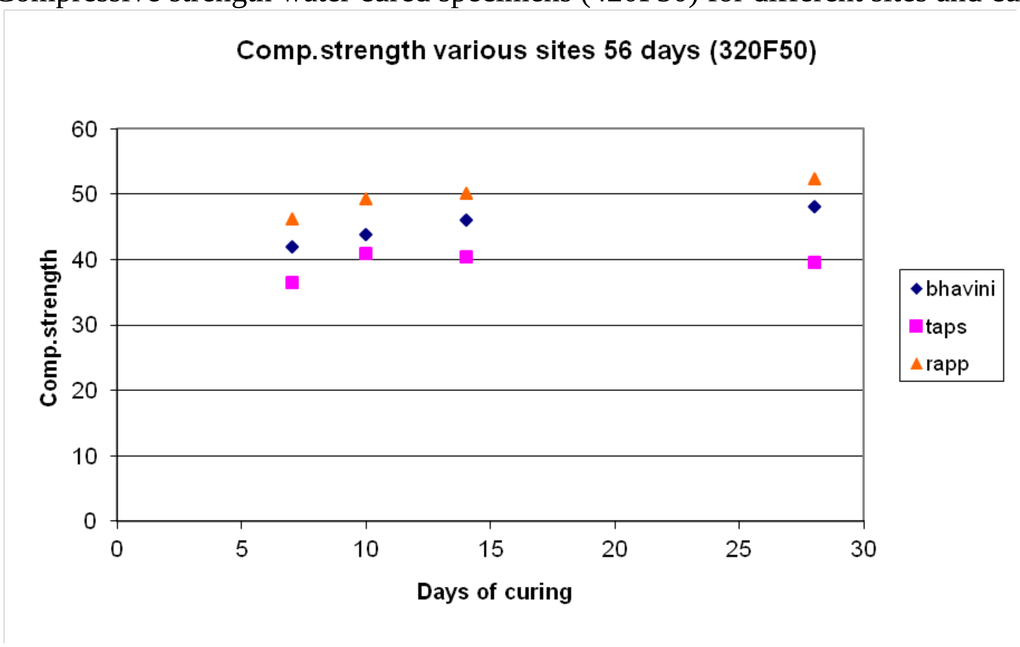

Figure 8b). Compressive strength water cured specimens (320F0) for different sites and curing periods.

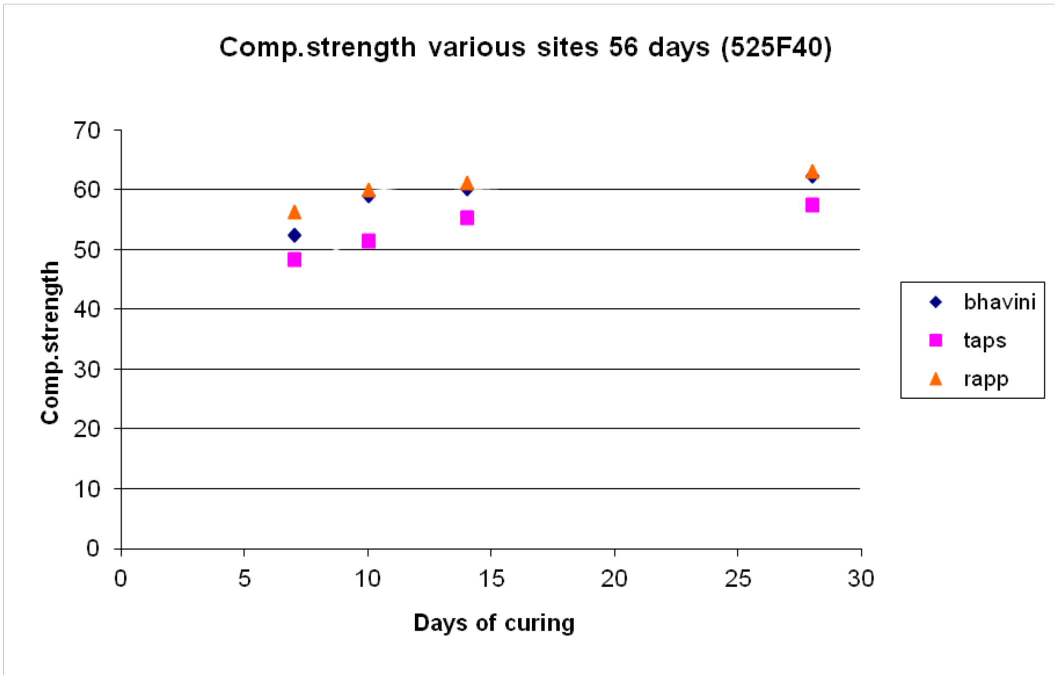

Figure 8 c). Compressive strength water cured specimens (525F40) for different sites and curing periods.

Figs. 8a-c graphically represents the comparison of compressive strength of water cured specimens at various sites. It is observed that, for the same mix proportions, TAPS specimens were consistently showing less compressive strength than other two sites. In the case of TAPS 420F50, the variation is as low as 43% (Fig. 8a).The temperature variation at TAPS site is between 20- 35° C, whereas at RAPP and BHAVINI it is 24-30°C (Figs.1a-c). Hence it is concluded that high variation in temperature during curing period affects the compressive strength of the concrete.

4.2 Rapid chloride penetration test

Generally water cured specimens are found to have lower Rapid chloride penetration test (RCPT)(ASTM –C 1202-97) value compared to sealed cured specimens (Figs. 9a-f).Though the relative trend is found to exist for RCPT behavior between water cured and sealed cured specimens, there is *significant* difference noticed in absolute values in all three sites. Especially RAPP, RCPT values were found to be highest and BHAVINI these are found to be lowest (Figs. 9a-f) though their strength for the same age was found to be comparable (Figs. 8a-c). The humidity variation at RAPP site is between 40%-80% (Figs. 2a-c), whereas at TAPS and BHAVINI it is 60%-90%. Figs. 9a-f explains that for the same mix RAPP specimens were consistently showing more RCPT values than other two sites.

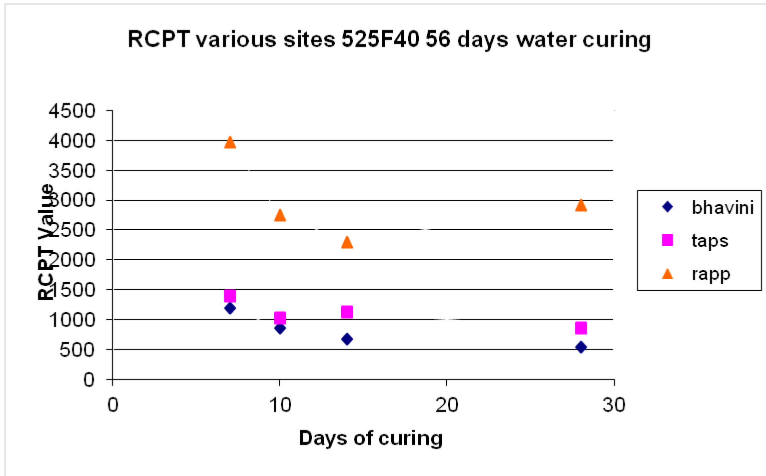

Figure 9a). RCPT water cured for specimens (525F40) different sites and curing periods.

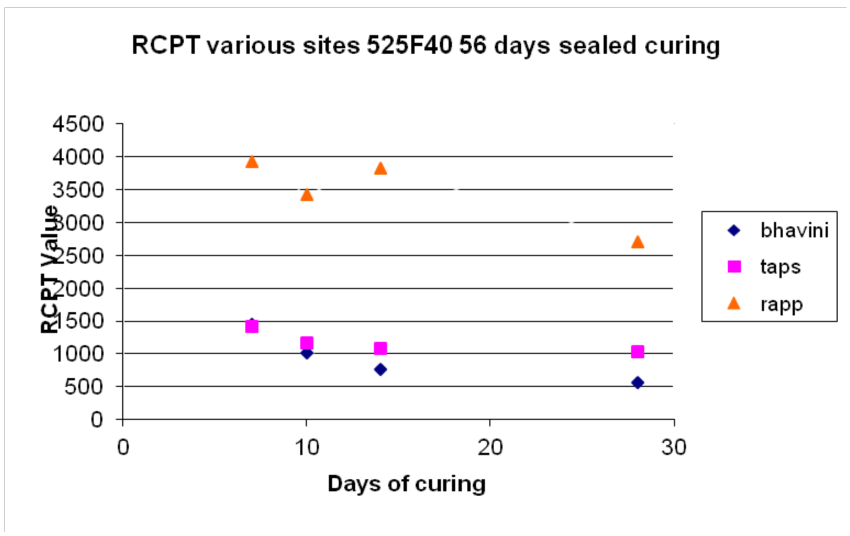

Figure 9b). RCPT sealed cured for specimens (525F40) different sites and curing periods.

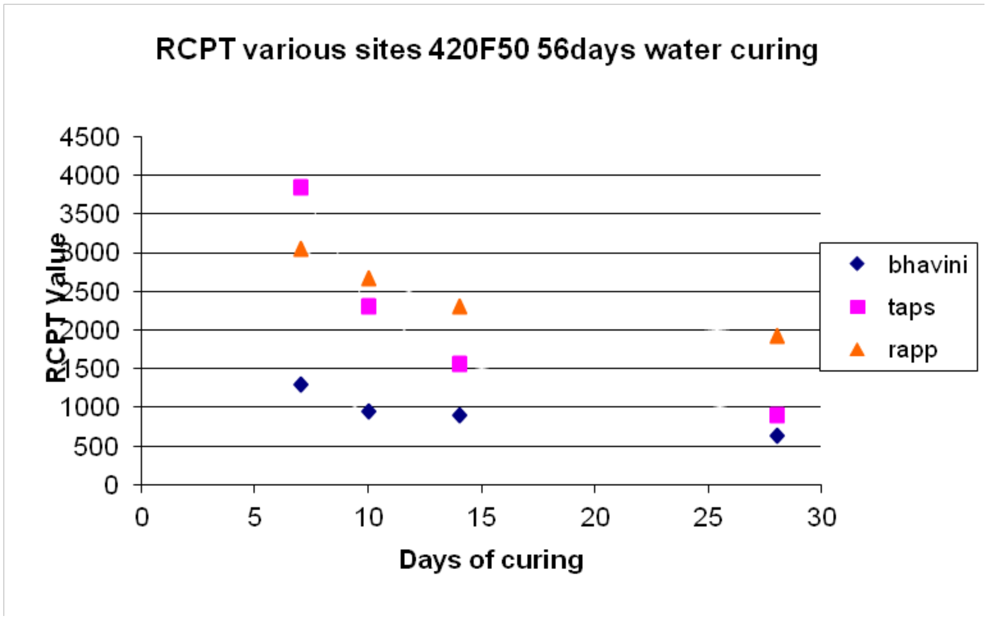

Figure 9c). RCPT water cured for specimens (420F50) different sites and curing periods.

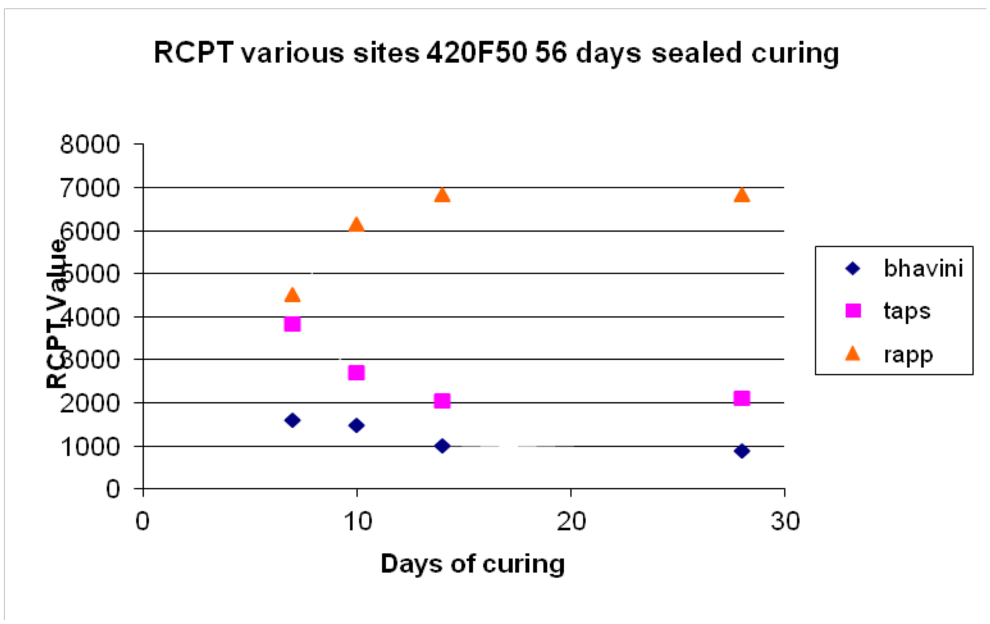

Figure 9d). RCPT sealed cured for specimens (420F50) different sites and curing periods.

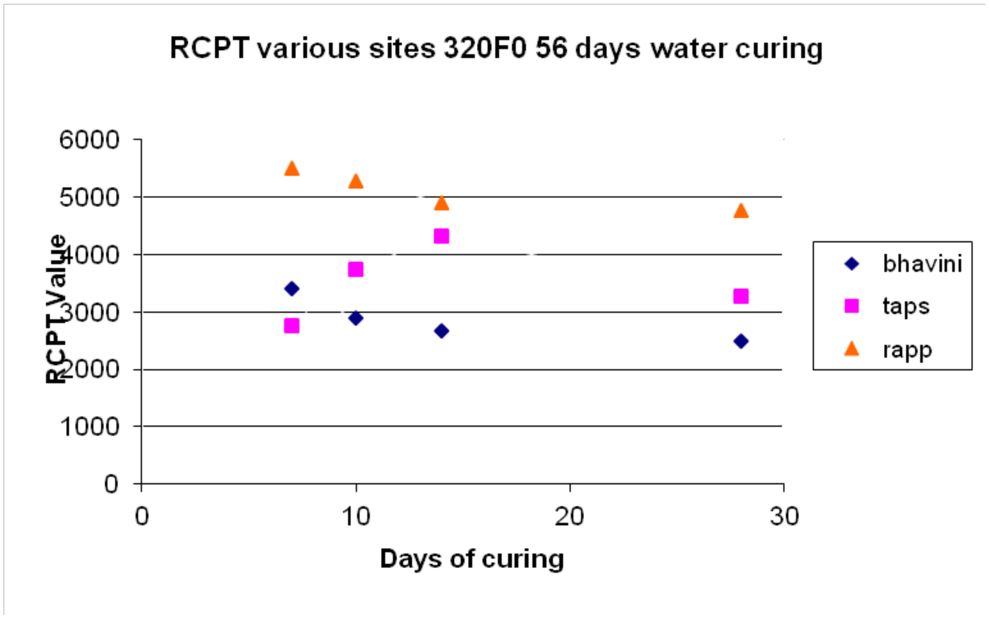

Figure 9e). RCPT water cured for specimens (320F0) different sites and curing periods.

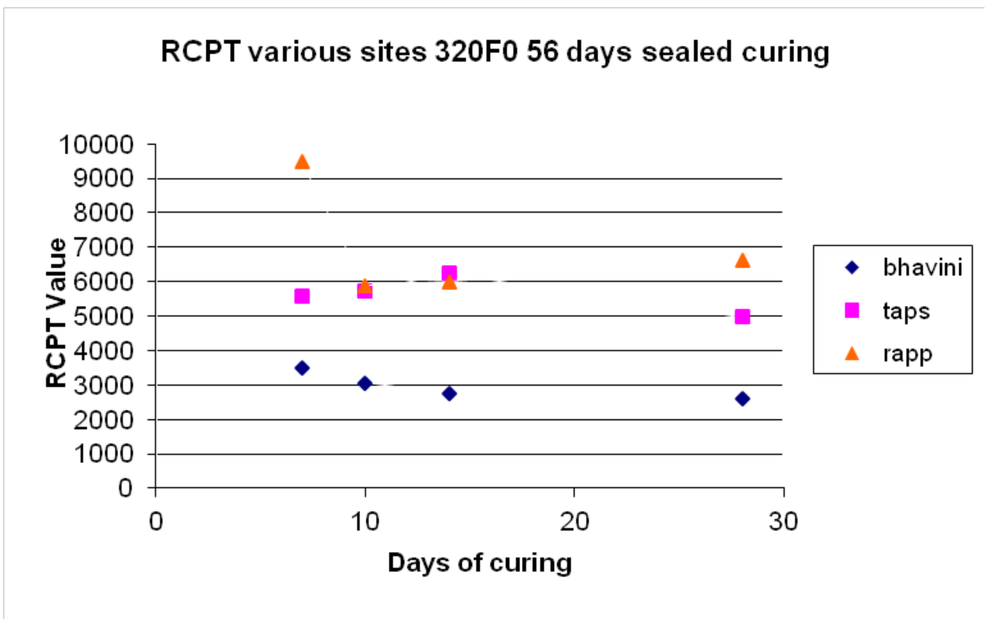

Figure 9f). RCPT sealed cured for specimens (320F0) different sites and curing periods.

The RCPT values for sealed and water cured specimens vary as high 300% to 100% in RAPP (Figs. 9e-f). The RCPT values are showing very complex behavior which may be due to variation in humidity.

5. Conclusion

The behavior of concrete against improper curing is similar for concrete with and without fly ash. The strength of water and sealed cured specimens are comparable when range of variation in temperature, humidity and wind is very less. The strength of water cured specimens is 25% to 30%

higher compared to the air cured specimens for all ages of curing. The 56 days strength of fly ash concrete is generally 10% to 15% higher than the 28 days strength for all durations of curing in case of water cured specimens. Minimum curing period required for structures with fly ash concrete is14 days with water curing. For a given design mix when range of temperature variation during curing period is high, effect is seen in compressive strength and when a humidity variation is high, effect is seen in RCPT values.

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