Performance evaluation of field curing methods using durability index tests

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3 authors:

Saarthak Surana
University of Cape Town

Radhakrishna Pillai
Indian Institute of Technology Madras

Manu Santhanam
Indian Institute of Technology Madras

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Saarthak Surana, Radhakrishna G. Pillai and Manu Santhanam

Curing plays a vital role in enhancing the impenetrability of cover concrete, which is essential to ensure the desired service life of a concrete structure. However, their performance in the field is most often evaluated by compressive strength instead of durability parameters. This paper presents an investigation of the suitability of durability index tests in evaluating the performance of various field curing methods. Five reinforced concrete slab specimens were cured in the field using the following curing methods: 7-day wet hessian, three types of curing compounds, and air curing. The field-cured concrete was tested at the age of 28 days using oxygen permeability index, water sorptivity index, rapid chloride migration test, and surface resistivity. In this study, durability index tests were able to differentiate between wet and air curing. The results of this study indicate that compressive strength as a standalone criterion is not adequate for assessing the performance of field curing methods.

Keywords: *Curing compounds; durability; field; concrete; strength*

1 INTRODUCTION

Curing encompasses any measures taken to facilitate the hydration of cement by preventing the loss of water from concrete or by providing additional water, if need be, while maintaining suitable temperature to achieve the desired rate of hydration [1], [2]. Curing methods can be broadly classified into (1) wet methods and (2) membrane methods. Wet methods involve supplying additional water (or moisture) to either the concrete surface directly or to the air in the immediate vicinity of the concrete surface. Membrane methods, on the other hand, restrict the loss of premixed water from the concrete by means of an impervious membrane laid over the concrete surface. Wet curing methods can be adopted in the form of ponding, sprinkling, wet blankets, or fogging, whereas plastic sheets, curing paper, and membrane-forming curing compounds constitute membrane methods [3]..

Construction industry, which consumes a large portion of potable water in the construction processes, needs to adopt more sustainable alternatives to reduce its water footprint. One such alternative is the use of curing compounds instead of conventional wet curing. Curing compounds are externally-applied liquid chemical compounds which form inert membrane on drying [4]. ASTM C309 (2011) specifies a water loss of not more than 0.55 kg/m^2 in 72 hours for curing compounds. Curing compounds find application particularly in situations that pose constraints to the use of conventional methods, such as wet curing, plastic sheets etc, in terms of either economy or feasibility. Some of the examples are large pavement slabs, high-rise buildings, and tunnel linings. Despite the fact that curing compounds present a potential to eliminate the need of additional water for curing, there has been very limited well documented attempts to study their performance.

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A report from the Minnesota Department of Transportation presents a review of the specifications followed for the selection and use of curing compounds and also describes important aspects of application of curing compounds on pavement surfaces by means of spraying [5]. Audenaert and Schutter (2002) conducted a round robin test to evaluate the evaporation efficiencies of curing compounds and showed that a linear relationship exist between 7-day evaporation efficiency and 28-day compressive strength[6]. In other studies, the efficiencies of curing compounds were evaluated in terms of their effect on the compressive strength of concrete [7]–[9].

The performance of curing methods, in general, has conventionally been assessed by their effect on the compressive strength of concrete[10]–[13]. However, the effect of curing is known to extend only up to a few centimetres from the surface, which constitutes the cover zone of the Reinforced Concrete (RC) [14]–[16].This implies that poor curing must have larger implications on the durability of concrete than on the strength. Consequently, the use of durability parameters would be a more rational approach in the performance evaluation of curing methods. Studies have shown that durability parameters demonstrate higher sensitivity to curing than compressive strength[17]–[19].

Durability parameters such as oxygen permeability and water sorptivityhave been shown to exhibit high sensitivity to changes in surface properties of concrete such as those resulting from deficient curing [20], [21]. Chloride diffusion coefficient as per Nord Test NT Build 492 [22] has also been found to be useful in studying the effects of curing [23]. However, large variability in results and limited sensitivity of durability tests in lab as well as field have also been reported [24], [25].

Table 1. Mixture proportion of concrete

Ingredient		Mass, (kg/m^3)
Water		187
Cement (OPC)		340
Coarse aggregate	20 mm	692
	10 mm	461
Fine aggregate (River sand)	4.75 mm	720

However, the majority of research on this subject focuses on curing under standard laboratory conditions—which are starkly different from the field conditions. Unique to the specific geographical location, exposure conditions at a site are characterized by diurnal as well as seasonal variations in the temperature, relative humidity, wind, sunlight, rainfall etc. All these factors need to be considered while selecting a curing method for a specific site. Thus, it is essential that the performance of curing methods be tested in the specific field conditions to establish a rational basis for their selection. To enable that, it is essential to identify test methods which can efficiently evaluate the effectiveness of a curing method in the field conditions. This study aims to contribute towards the same.

2 EXPERIMENTAL DETAILS

2.1 Slab specimens

An M35 grade ordinary Portland cement (OPC) concrete with a mixture proportion as per Table 1 was used in this study. The measured slump of the concrete was in the range of 40 to 90 mm. The relative influence of curing on the properties of concrete can increase as the surface-to-volume ratio of the specimen increases [26]. Therefore, relatively large specimens with close to practical surface-to-volume ratio were used in this study and smaller specimens were in-turn extracted from them for laboratory testing. Reinforced concrete slab specimens (1200 mm x 1200 mm x 200 mm) were cast in an outdoor location in the IIT Madras campus, Chennai, India. The slab specimens were doubly reinforced with 8-mm diameter bars, spaced 150 mm, centre-to-centre, in both the orthogonal directions (Figure 1).

Although the slab specimens were 1200 mm x 1200 mm in size, the test specimens were extracted from only the inner region (900 mm x 900 mm) of the slab specimens that excludes a strip of 150 mm from the edges of the slabs as shown in Figure 1.The outer 150 mm wide portion of the slab was excluded from testing or specimen extraction to avoid any possible variations in the properties of concrete arising due to the *edge effects*. The wall effect near the formed faces and the additional loss of water and heat to the atmosphere from the vertical edges constitute these edge effects. A total of five slab specimens were cast in situ, one for each type of curing method that was adopted in this study.

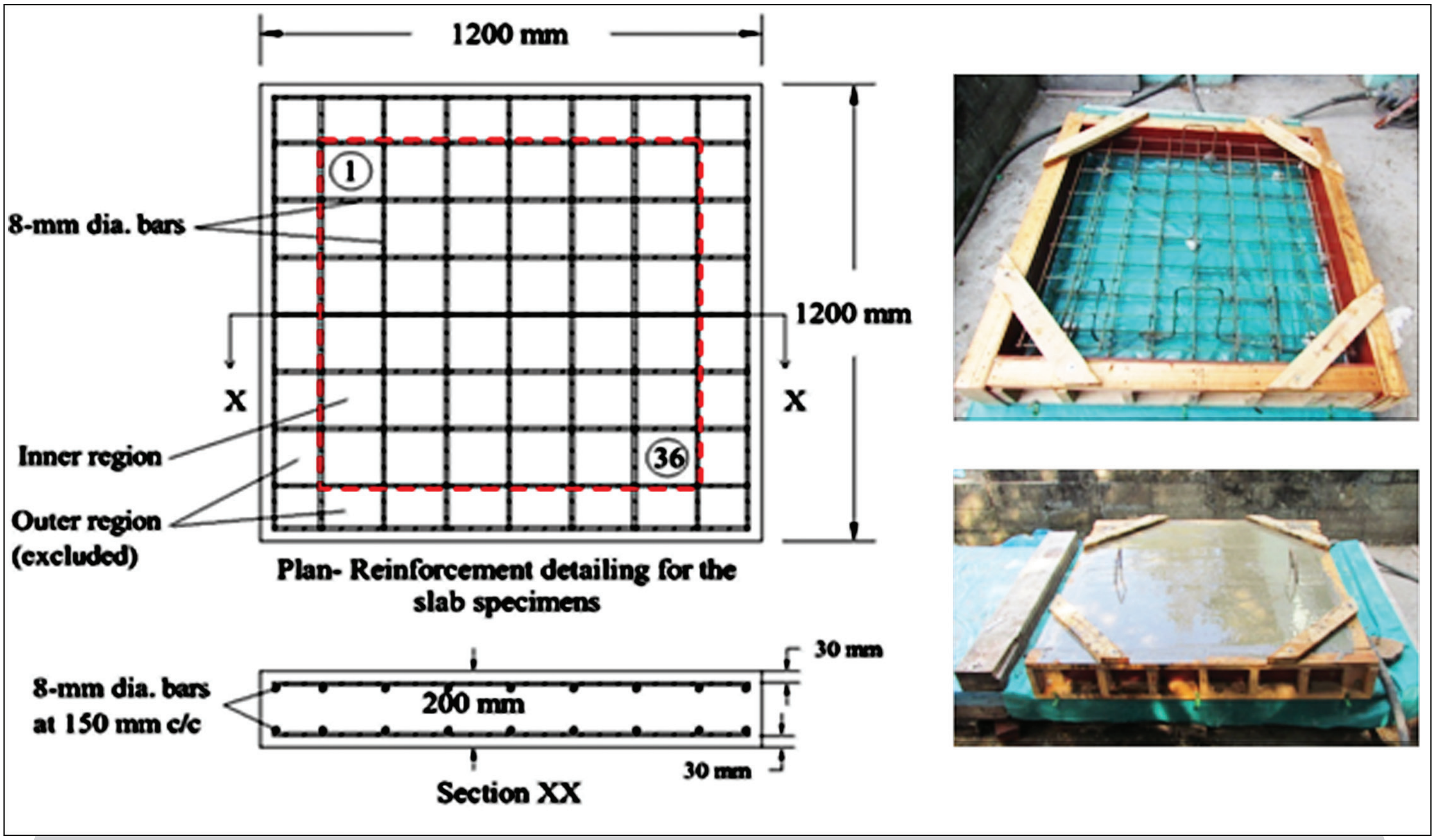


Figure 1. Reinforcement detailing and casting of the slab specimens

2.2 CURING

Five curing methods were used in this study as mentioned in Table 2. One slab specimen was cast for each curing method.

- Seven day wet hessian curing (7dH): The first slab was cured using two layers of wet hessian-cloth for 6 days after demoulding, i.e., until the age of 7 days, after which it was exposed to air. Hessian cloth was kept continuously wet by sprinkling water intermittently (Figure 2 (a)).

Table 2. Description of curing methods

Curing method	Description
7dH	Wet hessian-cloth until the age of 7 days, then in air
Air	Air curing
WX	Wax-emulsion-based CC
RS	Resin-solvent-based CC
RW	Resin-emulsion-based CC

- Air curing (Air): The second slab was left exposed to air after casting without any deliberate curing measures.
- Curing compounds (CC - WX, RS, and RW): The next three slabs were cured using three different curing compounds whose details are presented in Table 3:
- Wax-emulsion-based CC (WX)

Table 3. Details of curing compounds

Curing Compound	Generic Type	Classification as per ASTM C309	
		Based on Colour	Based on Composition
WX	Wax in Water (Wax Emulsion)	Type 2	Class A
RS	Acrylic Resin in Organic Solvent	Type 2	Class B
RW	Resin in Water (Resin Emulsion)	Type 2	Class B

Figure 2. Curing of slabs: (a) Wet hessian curing and (b) Curing compound

- Resin-solvent-based CC (RS)
- Resin-emulsion-based CC (RW)

The chosen curing compound was sprayed immediately after the disappearance of bleed water sheen from the concrete surface by using a compressed air assisted spraying gun (Figure 2 (b)). To ensure uniformity in the application rate, the whole area was divided into strips of 100 mm width. The height of the spray nozzle was also kept fixed at about 200 mm using a duly-supported horizontal bar. The time of traverse of the spray nozzle, from one end to the other end forming a strip, was adjusted in such a way as to maintain the rate of application throughout the strip. The rate of application was in the range of 5 to 6 m^2/L as recommended by the manufacturers and ASTM C309 (2011). An overlap of 2 to 3 cm was also maintained between each adjacent strip. Furthermore, standard laboratory specimens were also cast in the laboratory along with the slab specimens and were moist cured until the age of testing, i.e., 28 days (28d-Lab).

2.3 EXPOSURE CONDITIONS

All the five slab specimens were stored in an open space and thus, were exposed to the uncontrolled outdoor environment of Chennai. The monthly average temperature and precipitation data for Chennai during the period of exposure is plotted in Figure 3.

Due to the physical constraints involved in the casting and testing of such relatively large specimens, the specimens were cast in two phases: Phase-1 and Phase-2. Phase-1 comprised of slabs cured with wet hessian cloth curing

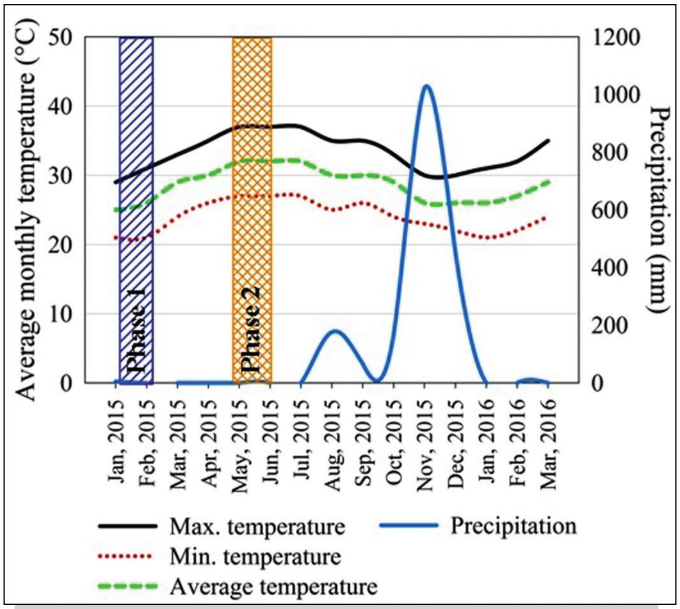


Figure 3. Average monthly temperature and precipitation data for the exposure period of the slab specimens [27]

and air curing, whereas Phase-2 consisted of the three slabs cured using curing compounds. The two hatched portions in Figure 3 approximately mark the two phases in which the slabs were cast.

It can be observed from Figure 3 that there was a difference in temperature of about 7 °C between the exposure periods (28 days) of the slabs cast in Phase-1 and Phase-2 (shown as the two shaded vertical bands in Figure 3). However, the temperature presented here represents only the temperature of the ambient air, not of the concrete itself. Phase-2 was during the summer which is characterised by increased amount and intensity of the directly incident solar radiation. Considering that, the actual magnitude of the difference between the internal temperatures of the concrete slabs in Phase-1 and Phase-2 could have been well beyond 10 °C. Also, there was no significant precipitation during the 28 days exposure period of any slab. However, large amounts of precipitation were received later in the months of November and December, shown as the higher of the two blue peaks in Figure 3.

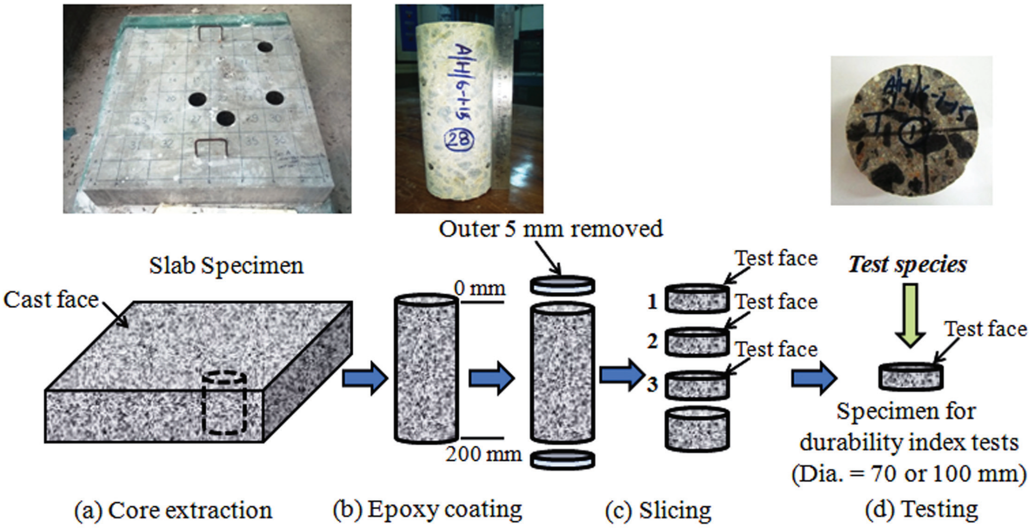
2.4 Testing

2.4.1 Compressive strength

Cylindrical cores of size 100 mm (diameter) x 200 mm (length) were used for the compressive strength test. The cores were extracted from the slab specimens at the age of 7 days, 28 days, and between 299 and 425 days. The cores were capped at the ends with sulphur mortar and were saturated with water for 48 hours as per IS 516 (1959) before conducting the test. Therefore, the age at the time of testing also includes the duration of specimen saturation. Four specimens were tested for each compressive strength result.

2.4.2 Durability index (DI) tests

Four tests were used in this category: Porosity, Oxygen Permeability Index (OPI), Water Sorptivity Index (WSI) and Rapid Chloride Migration Test (RCMT). The Porosity, OPI, and WSI test were conducted as per the South African Concrete Durability Index Testing Manual [29] and RCMT as per Nordic standard NT Build 492[22]. Cylindrical slices of diameter 70 mm and thickness 30 mm were used for porosity, OPI, and WSI tests.Slices of diameter 100 mm and thickness 50 mm were used for RCMT.



(a) Core extraction (b) Epoxy coating (c) Slicing (d) Testing

Note: 1 – outer slice; 2 and 3 – inner slices

Figure 4. Preparation of specimens for durability index tests

The procedure of specimen preparation is described in Figure 4. First, cores were extracted from the slab specimens. Then, the lateral surfaces of these cores were sealed with epoxy coating. The outer layer of thickness 5 mm was then removed from both the sides of the cores. Then, slices of 30 mm or 50 mm were cut from the cores.

As the objective of this study is to evaluate the effect of curing on the durability characteristics of concrete, it is essential that the concrete that is tested belongs to the near-surface region, which is most affected by curing. Therefore, the concrete slices were extracted from the depth of 5 mm to 35 mm (and from 5 mm to 55 mm for RCMT) from the surface of the slab specimens, mentioned as the outer slice in Figure 4. Nevertheless, to evaluate the effect of curing on concrete with increasing depth from the surface, specimens were also extracted from region beyond the first 35 mm (or 55 mm for RCMT), mentioned as the inner slices in Figure 4. The tests were performed such that the penetration of the test species (oxygen, water, or chloride ions) were from the surface of the slice that was nearest to the exposed surface of the slab as shown in Figure 4. Each result for the field-cured concrete is an average of test observations on four slices which were extracted from different four different cores. However, in the case of lab-cured concrete, each result is an average of test observations on three slices which were extracted from one core.

2.4.3 Surface resistivity and surface moisture measurement

7- and 28-daysurface resistivity of the slab specimens was measured using Wenner Four Probe method. Surface moisture content was also measured with surface resistivity using a portable moisture meter to facilitate valid interpretation of surface resistivity results.

3 RESULTS AND DISCUSSIONS

3.1 Compressive strength

The results are presented in terms of equivalent cube strength at the age of testing in Table 4. The type of curing method does not seem to influence compressive strength during the age of 9 to 12 days significantly. However, curing compound RS led to the highest strength in this age range surpassing even the concrete that was cured with 7-day wet-hessian curing (7dH). On the other hand, none of the curing compounds resulted in a significant improvement in compressive strength over that of air-cured concrete during the age of 31 to 38 days. The air-cured concrete (Air) exhibited 20 % lower compressive strength than 7-day wet-hessian-cured concrete, although the scatter in the data was very large. From these results, all the three curing compounds seem to be ineffective.

In terms of percentage increase in the compressive strength at this age (31-38 days), the slab that was cured with 7-day wet-hessian gained 26 % strength with respect to strength at 9-12 days whereas all the other slabs exhibited a maximum gain of only 13 % in this period. However, in the long term (that is, 301-427 days), air-cured slab registered a strength gain of 49 % with respect to its strength at 31-38 days when all the other slabs gained strength in the range of 31-37 % including wet-hessian-cured slab. The high strength gain in OPC concrete after 28 days can be attributed to the excessive amount of precipitation received in the months of November and December, 2015 (see Figure 3, this excessive rainfall occurred during the Chennai floods, 2015 have been believed to be unprecedented in about 100 years and thus

Table 4. Equivalent cube compressive strength (f_{cube})

Curing method	Age (days)	f_{cube}	
		Average	Std. dev.
7dH	12	29.2	0.9
	36	36.7	3.3
	426	48.3	3.2
AC	9	28.6	2.5
	38	31.3	8.7
	427	46.7	5.6
WX	10	27.5	2.7
	31	31.2	0.9
	325	41.3	3.0
RS	9	32.8	1.4
	31	29.6	7.5
	321	38.7	1.1
RW	9	29.4	1.1
	31	32.3	1.2
	301	44.1	4.0

was a rare event).Also, the degree of hydration achieved within the first 28 days in the field using practical curing methods cannot be at par with the degree of hydration of laboratory-cured concrete. Therefore, such high gain of strength can be expected after 28 days.

Overall, inthe long term, air-cured concrete (cast during Phase-1) exhibited similar compressive strength as 7-day wet-hessian-cured concrete. Also, the concretes that were cured using curing compounds exhibited lower compressive strengths than even the air-cured concrete. Also, the slab that was cured using curing compound RS, which showed the highest strength during the age of 9 to 12 days, yielded the lowest strength in the long term. From these trends, it is apparent that in this study the concretes that were cured with curing compounds exhibit higher early strength and lower long-term strength than wet-cured concrete. This is typical of concrete exposed to high curing temperatures, which is also the case with these concretes (they were cast in Phase-2). In short, air-cured specimen exhibited strength similar to wet-hessian-cured specimen after a spell of heavy precipitation. However, curing compounds—which are seemingly ineffective—resulted in lower strengths than that of air-cured specimen. Hence, the specimens that were cured with curing compounds do not seem to have benefited by the precipitation as much as air-cured specimens. Such an enhancement in the properties of concrete due to beneficial environmental factors has been reported in the literature [30].

It should be noted here that from the compressive strength results (up to the age of 31-38 days), curing compounds seem to be ineffective in water retention. Owing to their ineffectiveness during the early period, they cannot be expected to prevent the ingress of water into the concrete during the precipitation. Thus, the concrete slabs that were cured with curing compounds are also expected to show long-term strength gain. However, this is contrary to what is seen in the long-term results. Hence, it seems that curing temperature could have a more significant influence on the long-term compressive strength than the curing method itself. Interestingly, all the concretes, irrespective of the adopted curing method, cleared the acceptance criteria of IS 456 (2000) by achieving a mean strength that is equal to or greater than 0.85 f_{ck}.

3.2 Durability indices of the near-surface concrete at 28 days

Durability Index (DI) test results of outer slices (i.e., from near-surface region) are presented in this section.

3.2.1 Total water-penetrable porosity

As shown in Figure 5, 28-day porosity of lab-cured specimens lies in the range of 10.5 to 11 %, whereas porosity of field-cured specimens falls in the range of 6.5 to 7.5 % and 8 to 10 % for the specimens that were cast in Phase-1 and Phase-2, respectively. The lab-cured concrete, despite being wet-cured for 28 days, yielded the highest porosity. This could have been due to the fact that lab-cured concrete was from a entirely separate batch of concrete. Also, there is no significant difference between the porosities of 7-day wet-hessian-cured concrete (7dH) and air-cured concrete (Air) even though the difference between the quality of curing that was adopted for them was drastically different. Further, despite the fact that curing compounds are expected to help in retaining water in the concrete to enhance cement hydration and consequently, reduce the capillary porosity, concrete specimens that were cured with curing compounds (WX, RS, and RW) yielded 1-3 % higher porosities than air-cured concrete; at the age of 28 days.

Overall, these trends suggest that factors other than curing could also have influenced the results. In the case of Phase-2 slabs, higher early temperature as compared to Phase-1 slabs could have reduced the bleeding by accelerating the setting process. The reduction in bleed water could result in higher amount of water left remaining in the slabs compared to Phase-1 slabs. The higher water content of Phase-2 slabs in turn could have lead to higher porosity than Phase-1 slabs at 28 days. Moreover, an increase in the ambient temperature during hydration itself leads to an increase in the total porosity at the same degree of hydration [31].

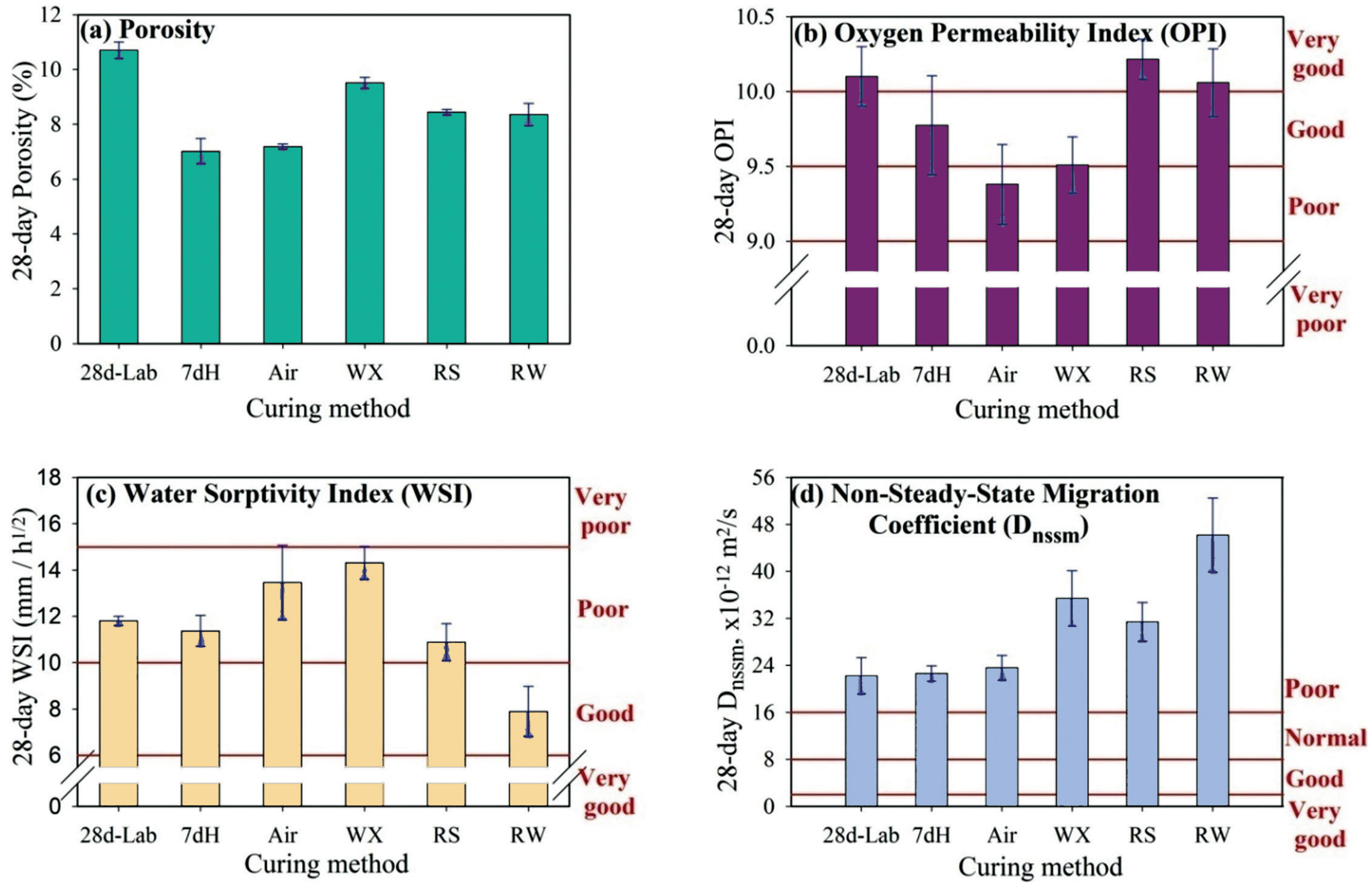
3.2.2 Oxygen Permeability Index (OPI - log scale)

Figure 5 (b) shows 28-day OPI of concrete specimens that were cured under various curing regimes. As the OPI is defined as the negative logarithm of the coefficient of permeability, increase in OPI represents a reduction in the oxygen permeability of concrete. In other words, the higher the OPI, the better the concrete quality is.

The OPI results do not seem to follow the trends seen in the porosity results. Despite having the highest total porosity, the 28-day lab-cured concrete yielded a better OPI than 7dH, Air, and WX curing methods. The 7-day wet-hessian-cured concrete shows superior OPI over the air-cured concrete, although not a significant improvement, yet 7 days of wet curing seem to elevate the concrete from *poor* to *good* concrete [20], [32] with respect to durability. However, the OPI values of concretes that were cured with the curing compounds RS and RW surprisingly exceeded that of the 7-day wet-hessian-cured concrete. Overall, OPI appears to be sensitive enough to show a distinction between wet curing and air curing.

3.2.3 Water Sorptivity Index (WSI)

28-day WSI results are presented in Figure 5 (c). Note that the higher the WSI, the lower the quality of concrete is. WSI, like OPI, exhibits a visible distinction between wet curing and air curing. However, subtle differences do exist between the trends of WSI and OPI. Contrary to the case of OPI, 28-day lab curing results in a similar WSI as 7-day wet-hessian curing, and not superior. Also, the curing compounds RS and RW lead to superior WSI over other curing methods; however, RW results in a better WSI than RS, contrary to the trend shown by them in OPI.



(*Note: Dnssm values for the case of air curing and curing compounds have not been corrected for chloride penetration through the entire depth of the specimens and thus could be higher than the values provided here)

Figure 5. 28-day durability index values of field-cured concrete

3.2.4 Non-steady-state migration coefficient (D_{nssm}) for chloride penetration

Rapid chloride migration test results,shown in Figure 5 (d), bear a clear contrast with the trends observed in OPI and WSI tests. The results suggested no improvement of D_{nssm} with wet curing—both lab and field. This is in contradiction with the findings of another study that demonstrated higher sensitivity of migration tests over OPI and WSI tests to curing in lab and field[25]. Furthermore, the values of 28-day D_{nssm} for concretes that were cured with curing compoundswere found to be inferior to that of concretes that were cured with 7-day wet-hessian curing. These results also suggest that although the concrete could achieve adequate compressive strength by 28 days regardless of curing, it could not attain satisfactorychloride-penetration resistance [32]even in the laboratory.

However, it is essential to note here that, in the case of air curing and curing compounds, the chlorides penetrated through the entire depth of the specimens in the course of testing. In such cases, D_{nssm} was computed using the average depth of the specimen. Also, as the exact time for the chlorides to reach the other end is unknown, the entire duration of the test is used in the calculation, instead. This can result in a less conservative value of the migration coefficient. Possibly, for this reason, the difference between the values of migration coefficient for wet-cured concrete and air-cured concrete appears to be smaller than expected.

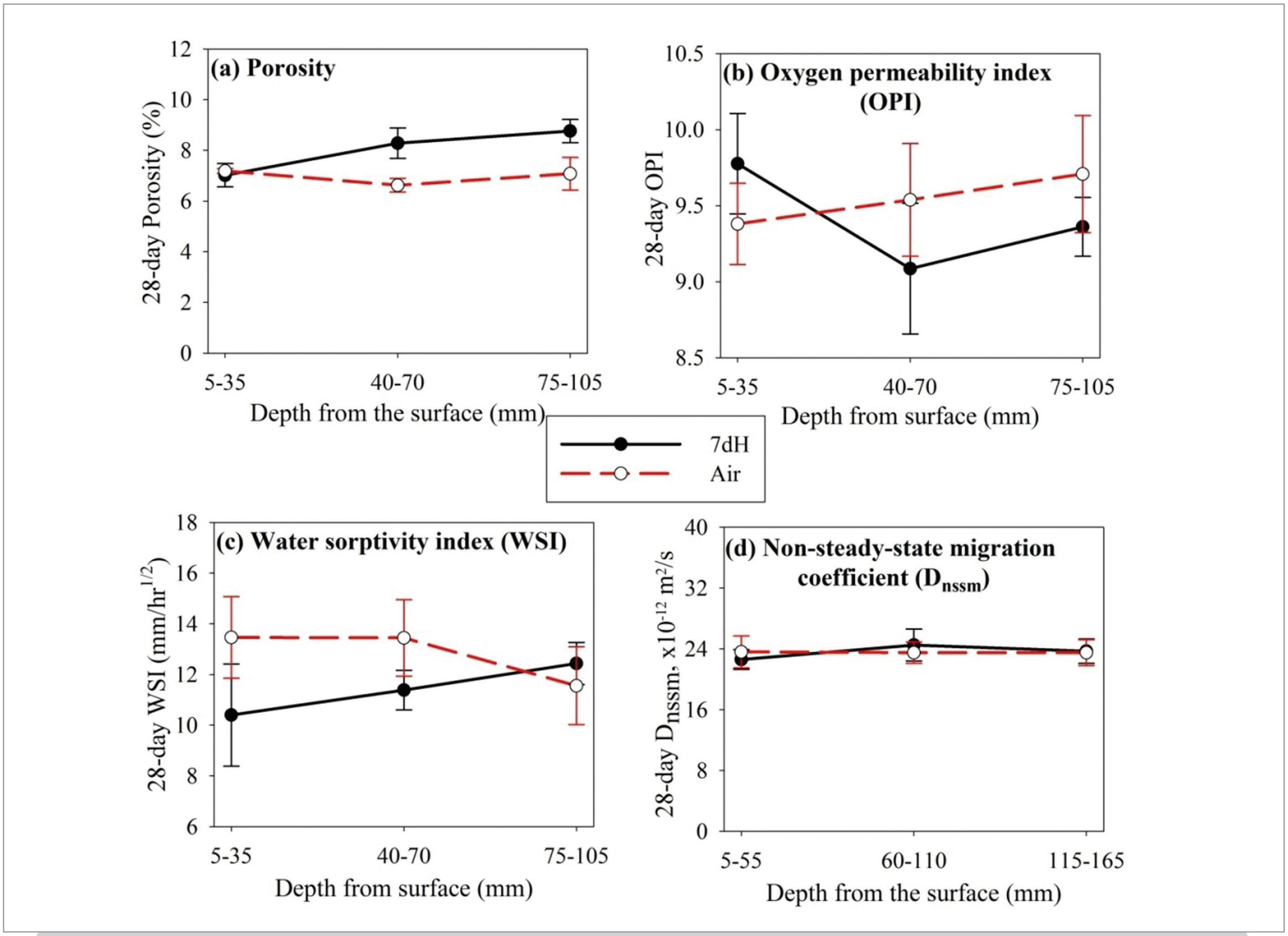


Figure 6. Variation of durability index values of 7-day wet-hessian-cured and air-cured concrete with depth from the surface

3.3 Durability characteristics of concrete with increasing depth from the surface

In the absence of proper curing, concrete loses its mix water to the surrounding air from the exposed surface during the early age of hydration. The severity of water loss varies with the depth from the surface, the surface being the most severely affected region. This difference in the availability of water at different depths can result in differences in the degree of hydration achieved. Consequently, the pore structure of concrete is also expected to vary with the depth. Therefore, it is relevant to investigate and compare the extent to which curing influences the properties of concrete in the near-surface region and in the inner region, respectively. For this reason, specimens from different depths were extracted from the wet-hessian-cured slab and air-cured slab, and durability tests were performed on them.

In such a case, it is expected that the gradient of durability index values for air-cured specimens will be found steeper than that for 7-day wet-hessian-cured specimens, with the 7-day wet-hessian-cured specimens achieving superior durability index values than the air-cured specimens. However, test results shown in Figure 6 do not follow this expected trend. In fact, the large scatter in the individual results as compared to the slight change in the index values due to curing renders any emerging trend unreliable.

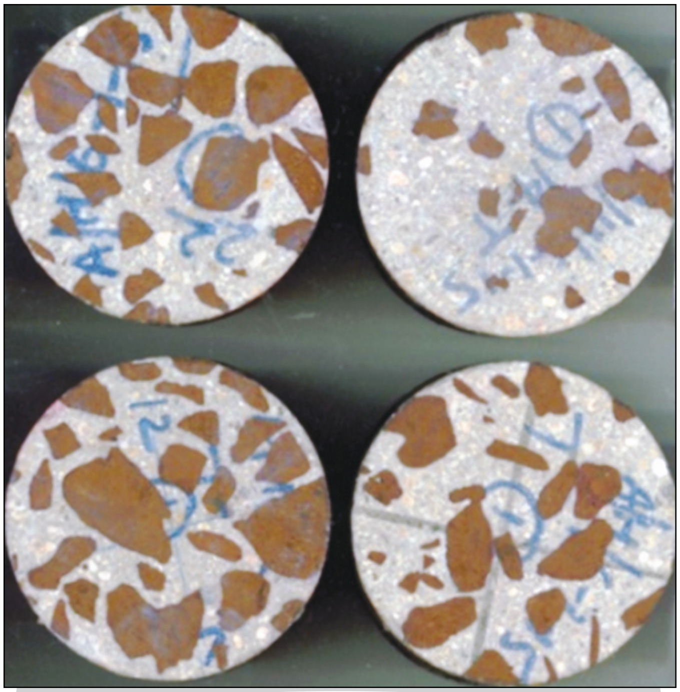


Figure 7. Image of 70-mm diametersorptivity specimens (7dH) showing the differences in the amount of coarse aggregates present on their test surfaces

From the visual inspection of the test specimens, it was observed that the amount of coarse aggregates present in the test specimens varied significantly (see Figure 7) and hence, could have led to the observed behaviour. So, to substantiate this possibility, the percentage area of mortar available on the surface of each specimen was computed using Image Analysis technique. Coarse aggregates visible on the surface of the specimens were coloured using a colour marker to enhance the contrast between the coarse aggregates and the mortar regions.

Then, the test faces of all the specimens were scanned using a document scanning machine and those images were analysed using the software Image Pro Premier 9.1®. Figure 8 shows a typical image that was used in the analysis and the different areas demarcated by the software. The percentage area of mortar with respect to the total area of the specimen was then computed with the help of this data for all the specimens.

OPI and WSI results are plotted against the percentage area of mortar present on the surface of the specimens in Figure 9. It can be observed from these figures that none of the results appear to bear any correlation with the percentage area of mortar. Therefore, the possibility that the relative amount of coarse aggregates present in the specimens influenced the durability index results over and above other factors cannot be substantiated through

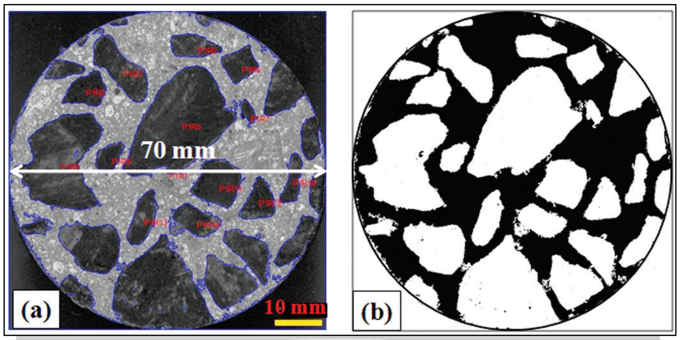


Figure 8. Image analysis of a 70-mm diameter specimen (used for OPI/sorptivity test) (a) a typical image that was used for the analysis and (b) different regions demarcated in the image by a software

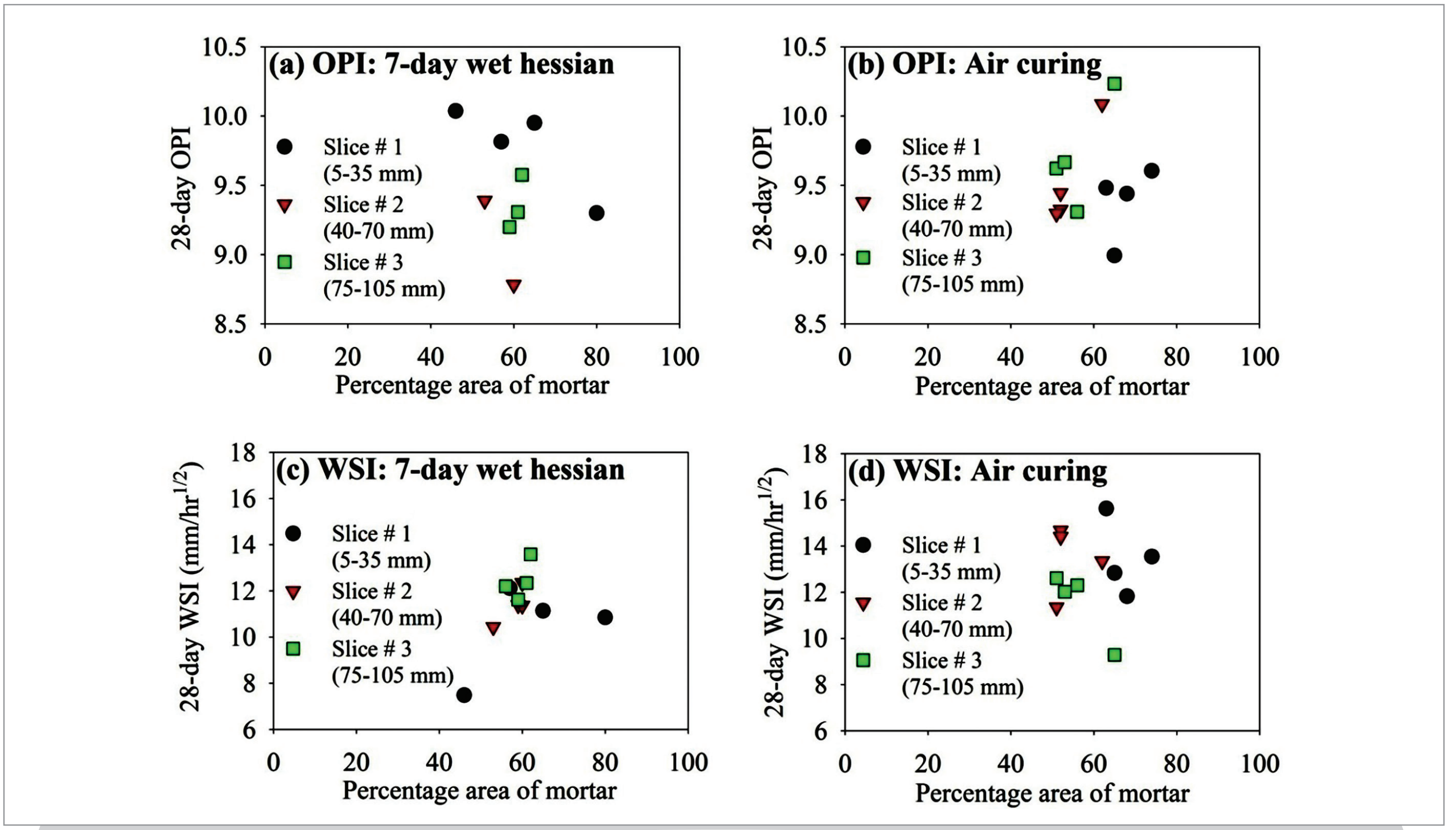


Figure 9. Effect of percentage area of mortar on OPI and WSIof 7-day wet-hessian-cured and air-cured concrete

these results. An increase in the overall variability of concrete in the field possibly can lead to such results.

3.4 Surface resistivity and moisture content

Figures 10 and 11 illustrate the relationship between surface resistivity and surface moisture content of the concrete specimens that were cured using different curing methods in the field, at the age of 7 days and 28 days. For each case, measurements were taken at 26 to 36 locations on the slab specimens. At each location, two measurements were taken in diagonally opposite directions. The average of these two measurements at each location is shown in the form of coloured markers, whereas the average values for each slab are shown in the inset graph in Figure 11 with filled and unfilled markers representing the age of 7 days and 28 days respectively. It is clear from Figure 11 that both surface resistivity and surface moisture results exhibit excessively large amount of scatter. Consequently, neither the influence of curing nor the influence of surface moisture on the surface resistivity could be detected from this data.

4 CONCLUSIONS

In this study, compressive strength, porosity, oxygen permeability index, water sorptivity index,non-steady-state migration coefficient, and surface resistivity were used to evaluate the performance of various field curing methods. The following can be observed from the results of this study.

- At the age of 28 days, compressive strength demonstrated variations according to the adopted curing method although with only minor changes. However, these variations were over shadowed by the large scatter involved in some of the results. Also, regardless of the adopted curing method, concrete in this study cleared the acceptance criterion for compressive strength.However, despite satisfactory strength achievement, concrete could not achieve satisfactory durability performance in some cases.
- OPI, WSI, and RCMT results also showed large scatter that, in some cases,even exceedsthe effect ofcuring methods on the results.

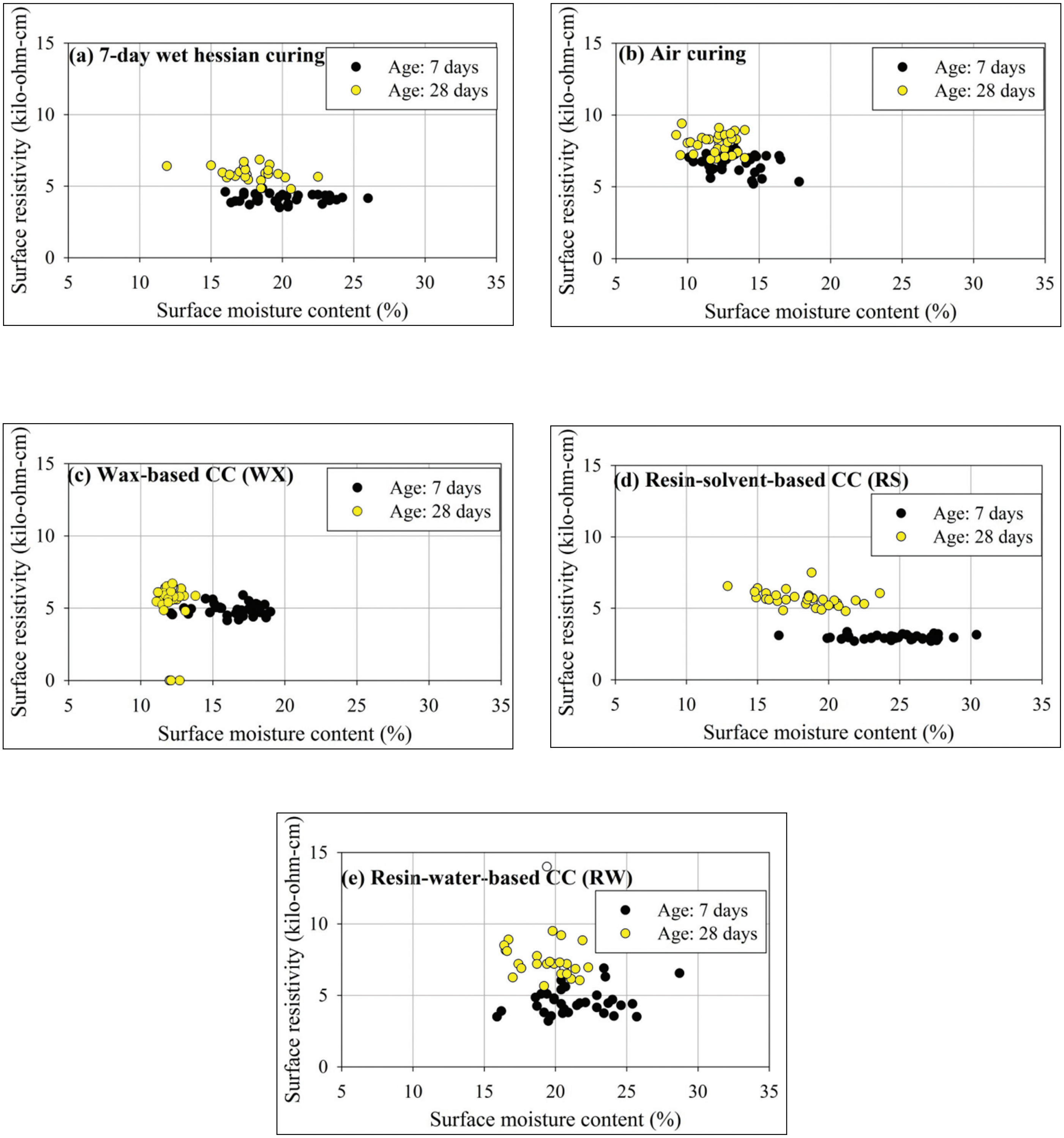


Figure 10. The relationship of surface resistivity with surface moisture content for field-cured concretes at the age of 7 and 28 days

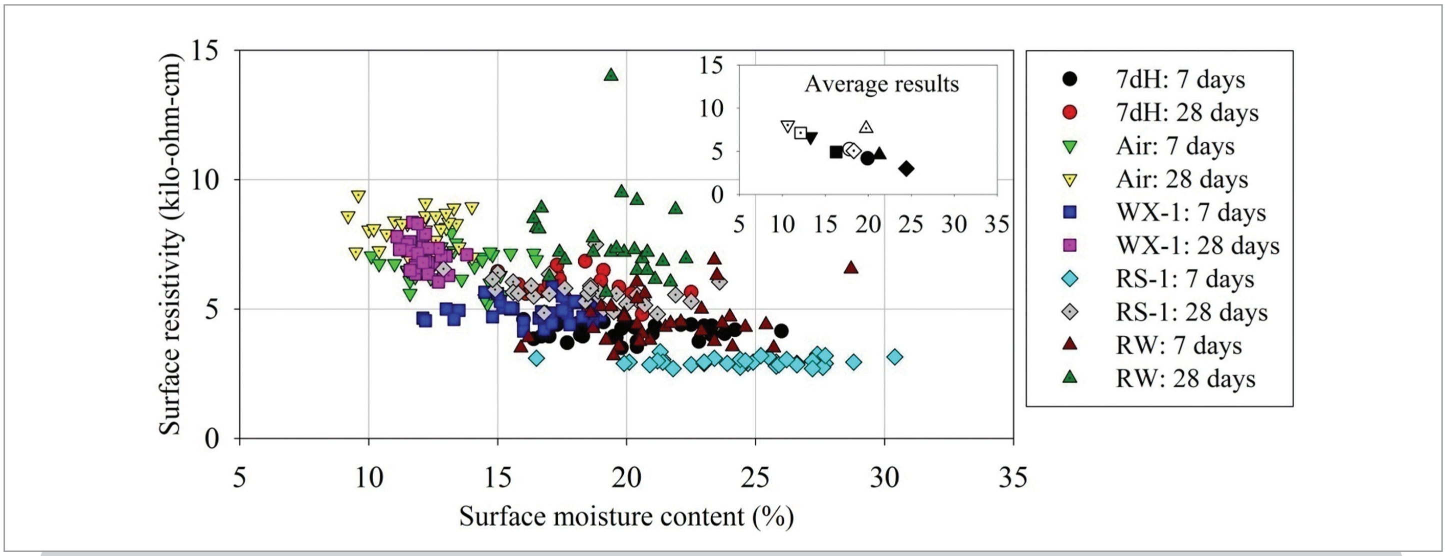


Figure 11. The relationship of surface resistivity with surface moisture content forall the field-cured concretes

- Although constrained by large scatter, OPI and WSI were still able to distinguish between wet curing and air curing.
- Surface resistivity results were not found to be sensitive enough to detect difference between the effects of different curing methods.

These observations suggest that further studies are required on different types of concrete and under different field conditions to validate these observations and take measures to improve the sensitivity of adopted test methods. Even amidst these shortcomings, it is clear that the use of the acceptance criteria that is based on compressive strength alone as a performance test for curing can severely undermine the importance of proper curing in achieving durability of concrete structures.

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Saarthak Surana holds a BE in Civil Engineering from MBM Engineering College, Jodhpur; pursuing his MS in the Department of Civil Engineering, Indian Institute of Technology Madras, Chennai. His research interests include concrete durability, microstructure, and non-destructive testing.

Dr. Radhakrishna G. Pillai holds a PhD Civil Engineering from Texas A&M University, USA. He is an Assistant Professor at IIT Madras, Chennai. His research interests include corrosion mechanisms, durability, service life estimation, and repair of concrete structures.

Prof. Manu Santhanam holds a PhD in Civil Engineering from Purdue University, USA. He is a Professor at IIT Madras, Chennai. He also has some industrial experience in a construction chemicals company and his research interests include special concretes, cement chemistry, durability and non-destructive evaluation.