REPORT BIN 151

INVESTIGATION OF CONCRETE CORES
(Hong Kong Highways Department)
FOR RADCRETE PACIFIC

Report

by

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IN CONFIDENCE TO

RADCRETE PACIFIC PTY LTD

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North Ryde

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CSIRO BUILDING, CONSTRUCTION AND ENGINEERING

CSIRO
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Improving the Built Environment

Investigation of Concrete Cores (Hong Kong Highways Department) for Radcrete Pacific

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Executive Summary

This report present the findings obtained from an investigation of concrete cores as supplied by Radcrete Pacific Pty Ltd. The objectives of this investigation were a) determination of the penetration depth of Radcon Formula #7 in the cores; b) determination of water penetration characteristics of Radcon Formula #7 treated cores; c) determination of chloride profiles in the cores; and d) detection of evidence of alkali-aggregate reaction (AAR).

Three sets of three samples were provided for this investigation. Scanning Electron Microscopy (SEM) and Optical Microscopy (OM) were used in for determining depth of penetration of Radcon Formula #7 and AAR evidence. Water penetration characteristics were determined using water sorptivity test. Chloride profiles were determined by analysis of drilled powder obtained at different depths.

The important findings are:

1 The depth of Radcon Formula #7 is in the range of 14 – 17 mm;
2 Water soluble chloride level in the cores at depth of 25 mm is about 0.05% by weight of dry concrete or less;
3 The 24 hour water penetration into treated cores is about 5 mm or less. This is equal to or better than most 60 MPa untreated concrete cut surface;
4 No evidence of alkali-aggregate reaction found in the supplied cores.

1. Background

Three sets of concrete cores were supplied to the CSIRO – BCE by Radcrete Pacific Pty Ltd. Each set consists of three samples. The cores, 68 mm in diameter and approximately from 35 to 45 mm in high, were marked with No. 2, 3 and 4. The authors were informed that these cores were taken from a 27-years-old structure from three different areas, which had been treated with Radcon Formula #7 (April 1997). This structure is maintained/managed by Hong Kong Highways Department.

This report presents the findings obtained from an investigation into the characteristics of these concrete cores. This investigation was directed at examination of the effectiveness of Radcon Formula #7 treatment using in situ samples. The objectives included the followings:

- Determination of penetration of Radcon Formula #7;
- Determination of water penetration characteristics of treated concrete;
- Determination of chloride patterns in treated concrete; and
- Examination of treated concrete cores for alkali-aggregate reaction.

2. Experimental procedures

One core sample from each set was used for examination by Scanning Electron Microscopy and Optical Microscopy. Three types of specimens were prepared for this work. They were:

- Fractured surface specimens;
- Polished surface specimens (cast in resin); and
- Thin slice specimens

The concrete samples were microscopically examined from the exposed surface to about 30 – 40 mm depth. The objectives of this section of work were to determine the depth of penetration of Radcon Formula #7 and to find evidence of alkali-aggregate reaction (if any).

One core sample from each set was used for determination of chloride penetration pattern. This was achieved by analysing drilling powders obtained from different depths (2 mm increments) from exposed/treated surface. The drilling powder (of known weight) from each step was collected, leached with (measured fixed amount) distilled water and filtered to obtain filtrate. The filtrates were analysed for water soluble chloride content using spectrophotometric method. Calibration with solutions of known chloride contents and with ICP-AES technique were performed before the testing.

One core sample from each set was used for the determination of water penetration characteristics by water sorptivity test method. This consisted of coating the core circumference with epoxy and conditioning the coated core sample in standard laboratory environment (23oC, 50% RH) until no weight change was observed (> 7 days). The Radcon Formula #7 treated surface of the coated core was then exposed to water as shown in Figure 1. After designated time (1 day) of water exposure, the sample was split and the fractured surfaces sprinkled with Ritchie's powder (a mixture of methylene blue and glucose powder). The water penetration depth into the core can be determined by measuring the visible colour front (deep purple) on the fractured surface (See Figure 4). During this test, the weight change patterns of the coated cores were also recorded.

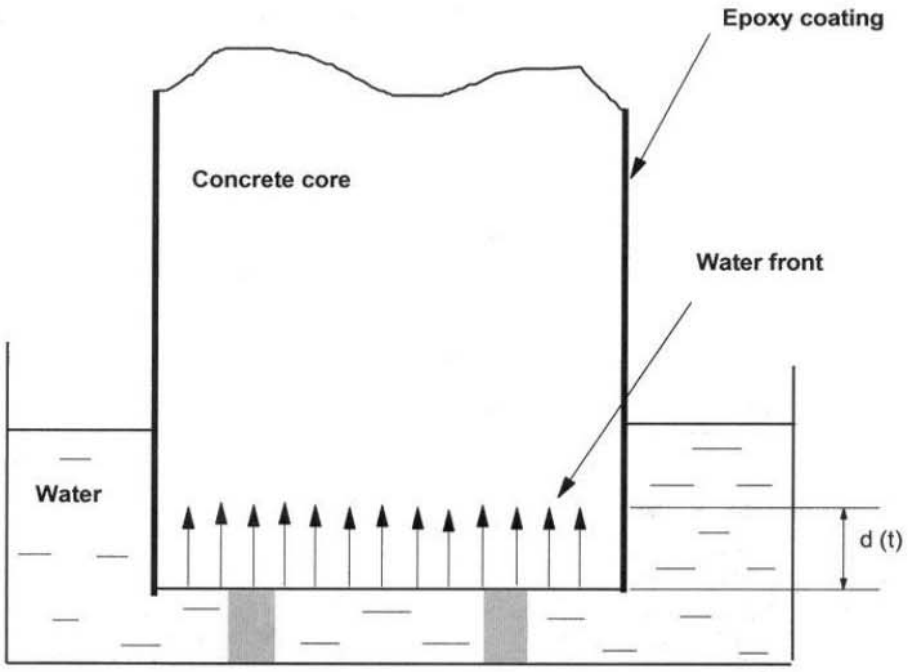

Figure 1. Schematic description of water penetration test

3. Results and discussion

3.1 Water penetration characteristics of Radcon Formula #7 treated concrete core

After 24 hour of partial immersion in water, the water penetration depth in the Radcon Formula #7 treated concrete cores were:

- Core No. 2 = 5 mm
- Core No. 3 = 3 mm
- Core No. 4 = 4 mm

These results denote that the treated cores have a very low water sorptivity characteristic. Figure 2 shows the comparison of the water penetration into treated cores and those observed in 32 MPa and 60 MPa grade concretes with different curing periods (cut surfaces).

Due to its low water sorptivity characteristic, it can be deduced that the Radcon Formula #7 treated surface can offer a better resistance to the ingress of harmful elements containing in liquid (eg. Chloride ions) than most 32 MPa grade concretes and at least an equal resistance to that shown by most 60 MPa grade concretes.

Figure 3 shows the pattern of water absorption (by weight) with time of treated cores. (It should be noted that there is a relationship between water penetration depth and absorbed water for unidirectional absorption (coated samples). If the sample were not coated, this is not applicable). A schematic pattern of water absorption of a concrete (cut surface) is also shown. The difference in the water absorption pattern suggests strongly that the treated surface act as a "membrane" against the ingress of water.

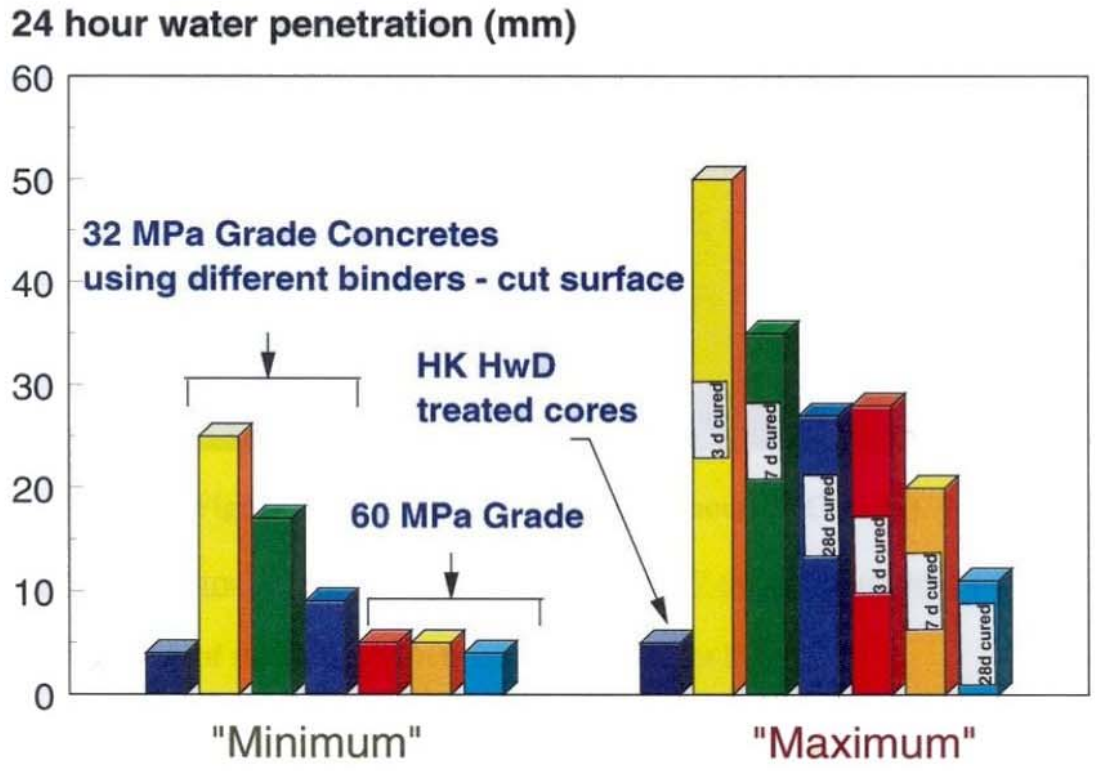

Figure 2. Water sorptivity characteristics of treated cores and other concretes

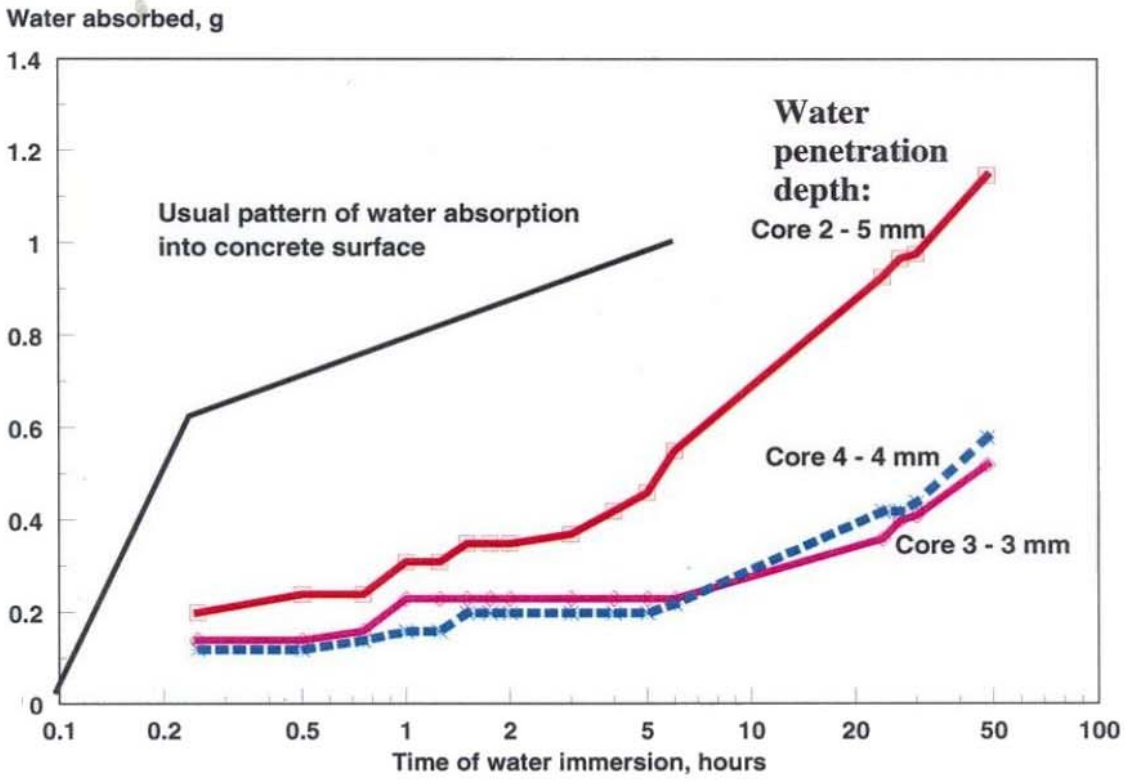

Figure 3. Water absorption patterns of treated cores

Figure 4. Water penetration after 24 hours in Core No. 4

3.2 Chloride penetration patterns in Radcon Formula #7 treated concrete cores

The chloride profiles of supplied concrete cores presented in Figure 5.

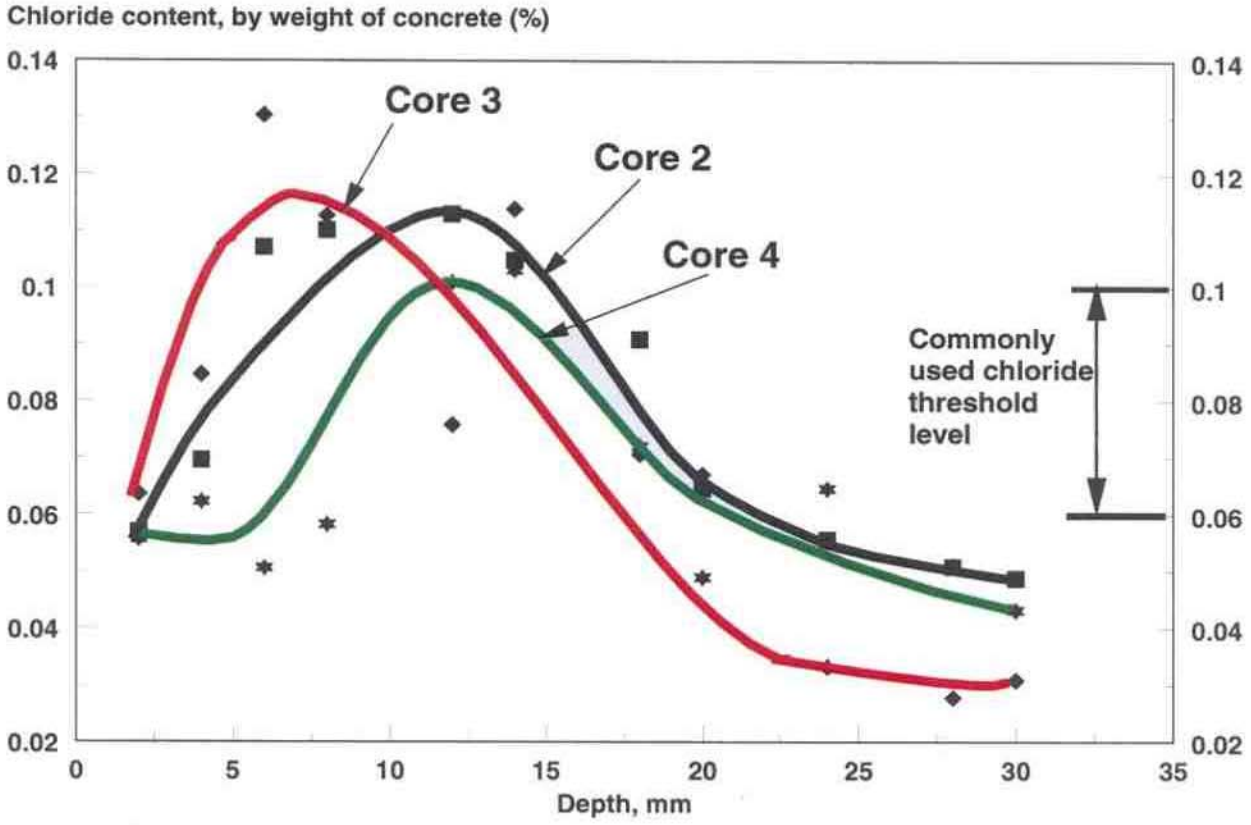

Figure 5. Chloride profiles of supplied concrete cores

The chloride patterns shown in Figure 5 denote that at a depth of 20 to 25 mm, the chloride contamination is in the range of 0.03 to 0.05% by weight of dry concrete. This range of chloride levels is well below the commonly used chloride threshold level for steel reinforcement corrosion. This implies that corrosion of steel reinforcement is not expected in this structure if the cover is 25 mm or more.

Figure 5 suggests further that the Chloride concentration at the surface layer is very low (commonly in the range of 0.5 to 1% by weight of concrete). The "driving force" for chloride penetration, ie. concentration gradient, is expected to be less for Radcon Formula #7 treated surface concrete.

3.3 Radcon Formula #7 penetration depth and examination for Alkali-aggregate reaction products

Using Optical and Scanning Electron Microscopy, the depths of Radcon Formula #7 penetration in the supplied concrete cores, Nos. 2, 3 and 4 were found to be very similar. The depth of Radcon Formula #7 is defined as the depth in concrete at which reacted products of Radcon Formula #7 and cement hydrates can be found (calcium silicates containing some alkali). The depths of Radcon Formula #7 observed in different cores were in the range of 14 to 17 mm.

There was no observable evidence of alkali-aggregate reaction in the supplied cores. This observation was based on exhaustive examination of the cores by optical microscopy using thin slides samples and by Scanning Electron Microscopy using polished surfaced samples and fractured surface samples.

Some microstructures observed in the supplied cores are shown in the following Figures.

Figure 6. Typical aggregate-paste microstructure in region where Radcon Formula #7 can be found - dense microstructure at low magnification (polished surface sample)

The products of Radcon Formula #7 in these cores were mainly calcium silicates. The ratio of calcium-to-silica (as observed by EDAX microanalysis) of these products were observed to be higher at greater depth with some change in morphology (see Figure 10). In these cores, calcium hydroxide plate and columnar structures were observed at depth of about 10 mm and greater. This would explain the trend of change in Radcon Formula #7 product's morphology (due to the availability of calcium at greater depth). Near the surface, the availability of calcium would be limited due to conversion of calcium hydroxide to carbonate by carbonation process.

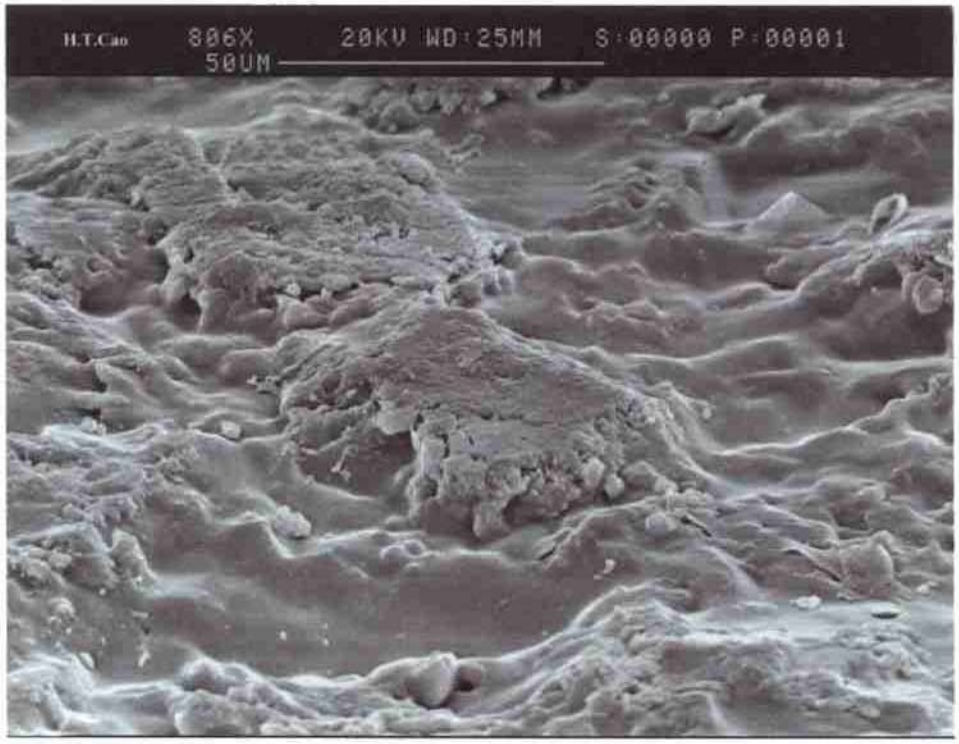

Figure 7. Dense amorphous "skin" formed on surface of treated concrete cores

Figure 8. Amorphous "glassy looking" very low calcium – silicate compound (product of Radcon Formula #7) found in the first few mm from treated surface

Figure 9. Relatively high calcium – silicate compound (product of Radcon Formula #7) found in at depth about 10 mm in the core (ratio of Calcium to silica ~ 1 : 1)

Figure 10. Mixture of calcium – silicate compounds (product of Radcon Formula #7) with varying calcium contents. (Yellow – very low Ca, high Na and K; Red – Medium Ca; Blue – High Ca (~ 1.5 to 1 Ca/Si ratio); White – calcium hydroxide)

Some micrographs obtained during the examination of the thin slide samples by optical microscopy are shown in Figures 11 to 16. As noted previously, there was no evidence of AAR.

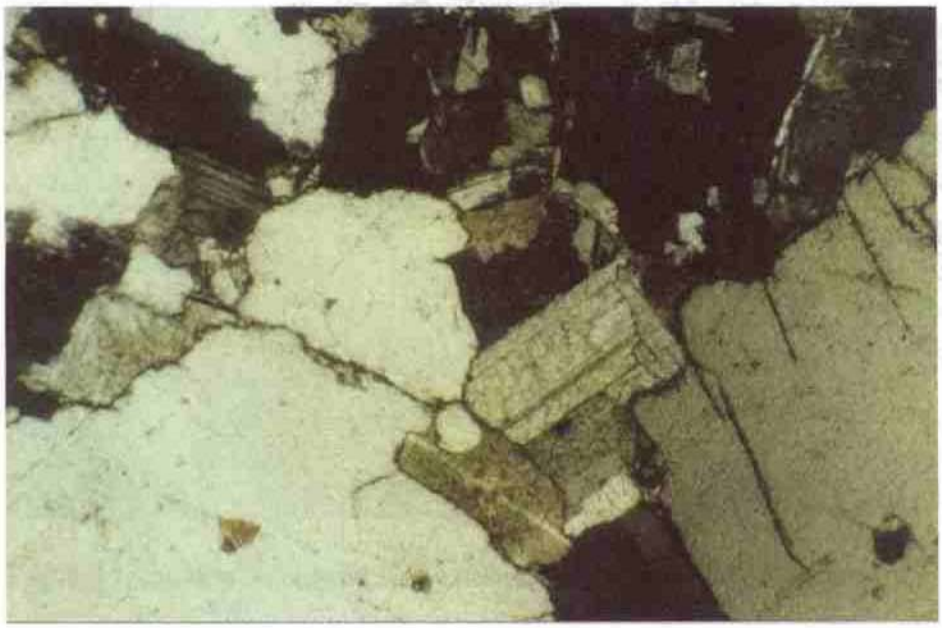

Figure 11. Typical thin slide micrograph of concrete core No2 showing no evidence of AAR.

Figure 12. Typical thin slide micrograph of concrete core No3 showing no evidence of AAR.

Figure 13. Typical thin slide micrograph of concrete core No4 showing no evidence of AAR.

Figure 14. Some thin slide micrograph of concrete core treated with Radcon Formula #7

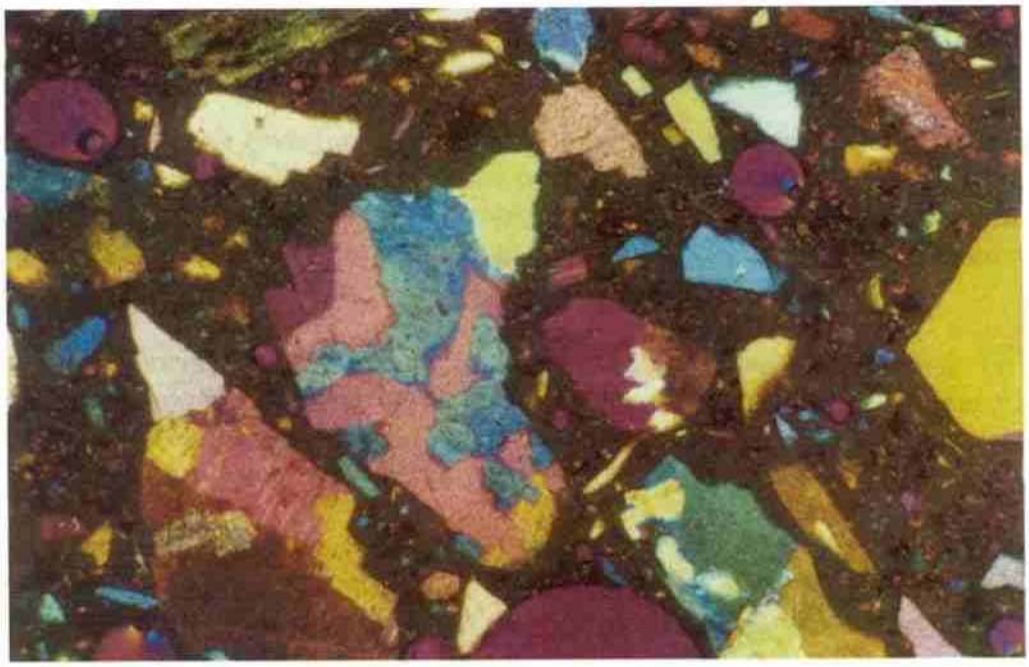

Figure 15. Some thin slide micrograph of concrete core treated with Radcon Formula #7

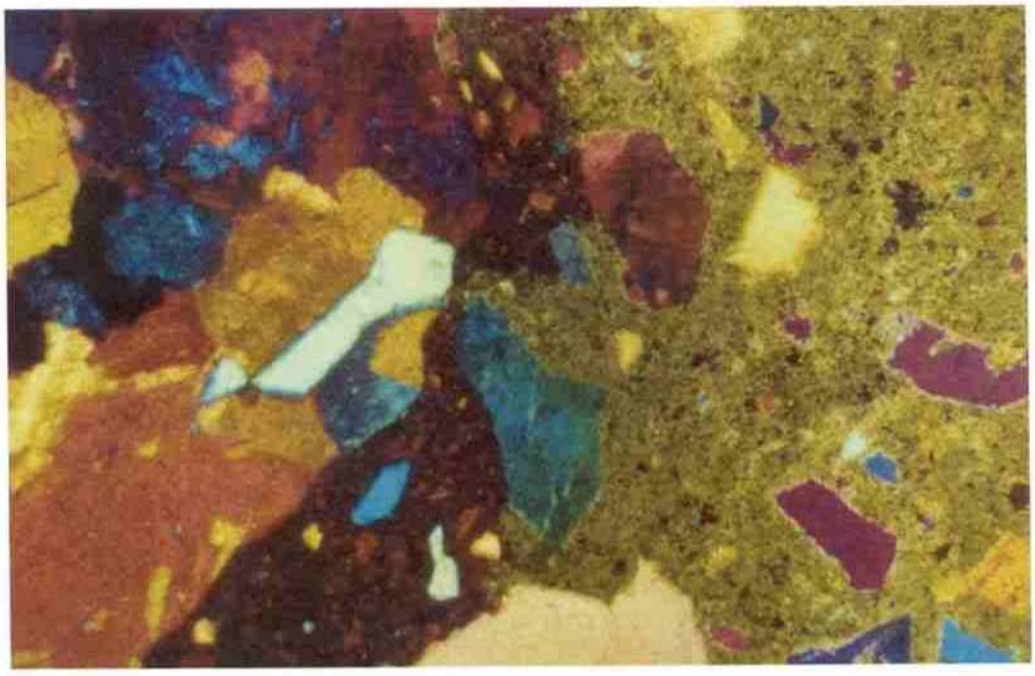

Figure 16. Some thin slide micrograph of concrete core treated with Radcon Formula #7

4. General discussion and conclusions

The results obtained in this investigation denote that the Radcon Formula #7 treatment is an effective method of improving concrete surface in situ. The most striking result is the very low water sorptivity characteristic of the treated concrete core samples. The treated cores show water sorptivity characteristics similar to or better than those shown by 60 MPa grade concretes. This can be translated to better resistance to the ingress of chloride ions.

There were some chloride contamination found in these cores. This would mostly be the "left-over" chloride contamination prior to application of Radcon Formula #7. With the relatively shallow existing chloride profile and particularly with low water penetration characteristics, further chloride contamination is expected to be very slow.

The depth of penetration of Radcon Formula #7 is about 14 –17 mm. In these regions, calcium silicates with varying calcium content forms resulting in dense microstructures of pastes and paste/aggregate interface. No evidence of alkali-aggregate reaction was observed in these cores.