A Procedure for Verifying Pavix CCC100 Concrete Impregnation by Core Examination

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Introduction

The objective of this study is to devise a practical, low cost procedure for verifying concrete impregnation by means of cores extracted from a structure. In this, the central idea is to compare treated and untreated areas. For the purposes of testing, pairs of cores are extracted from both treated and untreated areas. The two approaches investigated are (i) petrographic examination and (ii) performance testing. A total of 12 pairs of cores were use in the study. The report concludes with a provisional procedure for the later, this involving use of a soluble fluorescent dye.

Concrete Impregnation

For the purposes of the study, three 500 mm x 500 mm x 200 mm concrete slabs where used, these corresponding to a mix design and procedure specified for testing impregnates [1]. Pavix CCC100 was applied uniformly at a dosage rate of 200 ml/m^2 to half of the 500 mm x 500 mm surface of each slab (in a real structure it would be appropriate to protect a small area from impregnation). In all, twelve pairs of cores were extracted from the treated and un-treated areas of these slabs.

Prior to impregnation, the slabs were air dried for a minimum of 48 hours and then blown down using compressed air. The later is a significant measure because it helps to ensure that surface pores are open and best able to absorb the impregnate. Ensuring that the concrete surface is dry reflects the well established fact that sorptivity decreases with increasing moisture content. Whilst not a recommended action, due to its unknown effect on the impregnant, penetration was previously tested by adding black, water based ink to a small sample of the impregnant and applying this to a trail area. This was then dry cut and the penetration depth detected as varying from 3.2 mm to 4.9 mm.

Following the proper application of the impregnate, the slabs were firstly air dried for 1 hour then kept surface wet for 4 hour by intermit spraying with distilled water. Cores where then cut from the slabs after 7 days room storage. The spraying and drying sequence was introduced to stimulate crystal growth in the curing of the impregnant. In the case of a real structure, curing would be achieved naturally by the action of rain. Ideally, cores would be extracted from the structure after a few hours of rain.

Approach to Verification

Two broad approaches to verification of impregnation work have been examined. One is to identify the presence of the impregnate in the near surface pores of the concrete and the other to detect its ‘water proofing’ property.

By the first method, the presence of the impregnate crystals is confirmed by petrographic examination. In these observations, the apparent size of the crystals and extent to which pores are filled, depends on the prevailing moisture environment. Quantification lacks obvious relevance because of the difference between the nature of the buried environment in the concrete core and the exposed environment of the petrographic surface.

The second approach is attractive because it tests an important performance requirement. In all cases, it is also considerably faster and cheaper to operate. A further point of comparison is that, unlike the first approach, its does not involve sophisticated equipment and highly skilled personnel.

The outcome of this study is a robust approach to verifying that impregnation is effective by confirming its water proofing performance. Within the construction site operation, a quality assurance regime would cover other considerations such as batch age, applied dosage rate and the possibility of fraudulent dilution.

Outcomes of Investigation

Core dimensions

Taking into account the maximum aggregate size in typical structural concrete and edge wastage arising in the core soaking process, a minimum core diameter of about 48 mm - 50 mm is required. With smaller diameter cores there is the risk that the useful observation area may be too small due to the presence of individual large stones near the surface and irrelevant penetration on the core perimeter. Whilst it would be attractive to extract a shallow 'button core', trial an error showed that the minimum achievable depth for a whole, undamaged core is in the 50 mm – 60 mm range. When extracting cores, it is important that the 'external surface end' is not damaged. A poor breaking out technique may render a core unsuitable for testing.

Core preparation

After surface cleaning cores with distilled water, cores surfaces were inspected using an illuminated crack gauge microscope. Two cores that had sustained cracks in the coring and extraction process were discarded.

In the case of old and degraded concrete, where micro-cracks, voids and other defects may be prevalent, it would be appropriate to attempt to seal the surface of the core cylinder with a light coating of silicone or similar material. In doing this, great care must be exercised to ensure that the 'external surface end' is not contaminated, perhaps avoiding a few millimetres of the cylinder at this end.

Dye selection

A number of different water soluble dye types were investigated for penetration and visibility. All dye types where tested to varying concentrations, with ash-less filter paper filtering before commencing the soaking procedure.

Whilst it was originally hoped that a commonly used vegetable dye might be appropriate, this did not prove to be so. The conclusion is that sodium fluorescein (yellow fluorescence) and sulphordamine B (red flourescnce) are both suitable for the application. A pre-filtered concentration of about 1gm of dye per 10 litres of distilled water was found to give satisfactory results with both dyes.

Appropriate personal protective equipment must be worn when handling dyes, particularly in powder form. It is noted that purchasers may have to meet special conditions before a supplier is prepared to supply dyes of the type recommended.

Dying procedure

Individual Petri dishes were used to soak the 'external surface end' of each core. Three number 2.5 mm thick spacers were positioned in each dish to support the perimeter of the core face. After placing a core, its dish was kept filled with dye to the point of overflowing, thus maintaining an effective soaking depth of about 10 mm. All cores were soaked continuously for 4 days and then air dried for 48 hours.

Arrangement for dye soaking of cores

Typical core button

Yellow dye stain on core

Specimen preparation

After drying, the dyed cores were sectioned in two stages. Firstly, the cores was cut through by dry sawing to give a button of 15 mm to 20 mm thickness. In the second stage, this button was sectioned using a 100 mm diameter wet diamond saw. Diamond sawing took more than 30 minutes per section, the reason for reducing the specimen to a button in the first stage. Additionally grinding and polishing each specimen was abandoned because this was time consuming and found not to significantly contribute to the quality of visual verification. A propriety lubricant, commonly used in gem stone cutting, was used with the diamond saw. The figure below shows the cutting sequence. Use of appropriate PPE is clearly necessary in the preparation of specimens.

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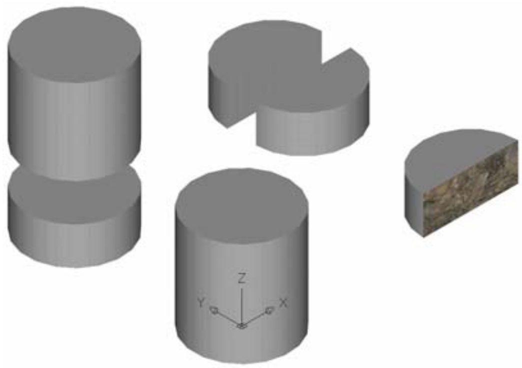
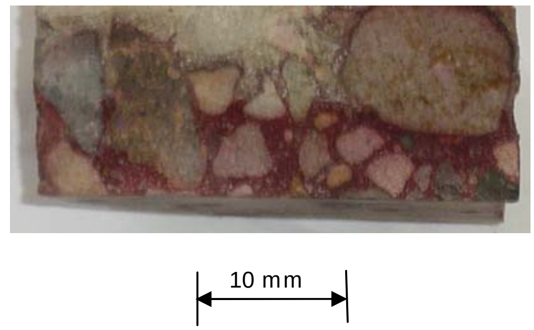


Core sectioning sequence

Typical untreated core



Section showing red dye penetration

UV Illumination

Ultraviolet light is electromagnetic radiation in the part of the spectrum between visible light and x-rays, in the 180 nm – 400 nm region. It is too short to be sensed by the human eye. The selected dyes, fluorescein sodium and sulforhodamine B have phosphors that emit radiation when illuminated by UV light. This phenomenon, which is known as fluorescence, is visible to the human eye.

Unfortunately, UV black light sources tend to be expensive. For this reason, a number of light sources were investigated to determine a good compromise between performance and cost. The conclusion is that a low cost, battery powered, double wavelength source is satisfactory. The selected device gives 315 nm on the long wavelength side or 280 nm on the short wavelength side. Investigation of the combinations of dye type and UV wavelength led to a preference for the yellow sodium dye illuminated using the shorter wavelength option. Of the two factors, wavelength selection has a greater influence than dye type. A darkened location is necessary for viewing fluorescence with the human eye.

When illuminated, the UV light source appears almost black and thus the un-initiated user may mistakenly consider it to be un-harmful. The reverse it true to the extent that unprotected eyes and skin can be easily burnt by shortwave ultraviolet light rays. Wearing of UV blocking eyewear is highly recommended.

Visual Assessment

The pairs of untreated and impregnated sections were examined in a darken room using the short-wavelength option of the adopted light source. In all cases the visual effect of impregnation was decisive.

Untreated specimens consistently showed dye penetration to the cylinder sides and the 'external surface end'. This tended to populate regions of cement past, porous aggregate particles and define individual aggregate boundaries. The depth of penetration was found to vary considerable in the range of 2.4 mm to 7.5 mm for all specimens.

Treated specimens consistently showed very little (< 1.0 mm) penetration over their central 30 mm region. This was accompanied by 2.1 mm to 6.8 mm penetration at the cylinder edges.

Whilst depth measurements were made as part of the study, this appears to be unnecessary for the purposes of comparing penetration with or without impregnation.

Verification Procedure

The following chart sets out a suggested procedure for impregnation verification. Dye penetration in untreated concrete will depend largely on its quality. Strong, dense concrete will tend to show substantially less dye penetration than old, deteriorated concrete. With experience of use it may be possible to fine tune the suggested criteria, which is provisionally set as a maximum of 1.0 mm dye penetration in impregnated concrete with a minimum of 4.0 mm additional penetration in the same but untreated concrete.

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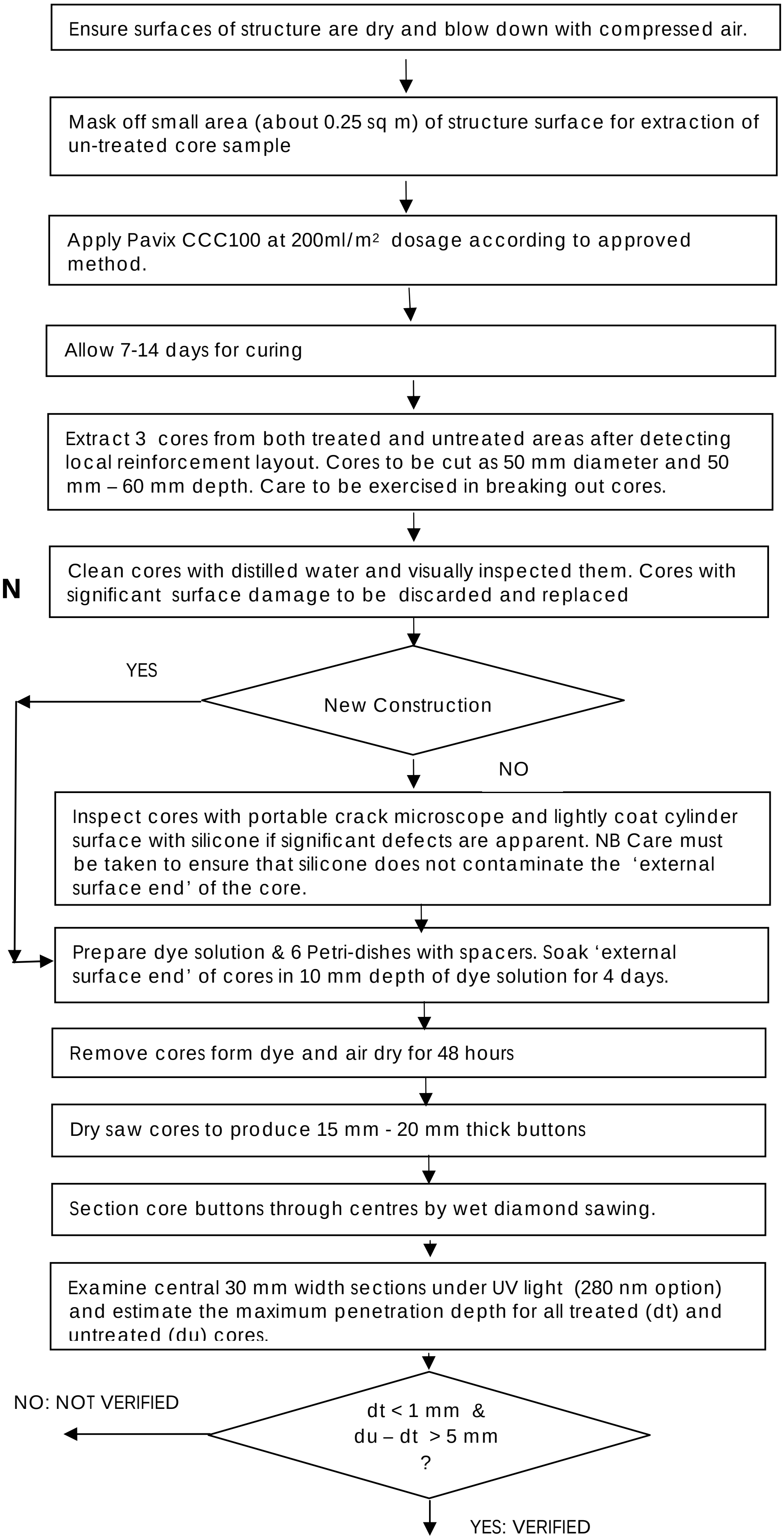
SUGGESTED VERIFICATION PROCEDURE

NB: Rebar detection recommended to avoid coring damage to rebars.



Conclusions

The study provides a flow chart approach to verifying concrete impregnation using Pavix CCC100. A simple dyeing and sectioning procedure has been worked out using 50 mm diameter shallow cores. Both untreated and impregnated cores are used.

On the basis that the dye and impregnant solutions are similarly absorbed, the untreated cores are useful because they indicate the probable impregnation depth. As the dye is water based, it also gives an impression of how vulnerable untreated concrete would be to the destructive action of frost, for example. The occurrence of limited dye penetration in the central region of impregnated cores confirms that the impregnant has water-proofed their 'external surface end'.

Using a low cost UV light source, the comparative extent of dye penetration in untreated and impregnated cores is found. This is distinct to the extent that actual measurement is arguably redundant. However, based on measurements taken in the study, verification criteria is suggested. This could be fine tuned in the future using data accumulated in the impregnation of new and rehabilitated structures.

In extracting cores, it is important that identification marks are not written on the exposed face (treated face) because this may locally affect absorption of the impregnant.

References

D.A.Chamberlain, TEST REPORT ESRC/2003/CP/01 PAVIX CCC100: Impregnation of Reinforced and Pre-stressed Concrete Highway Structures, Structures Research Centre, School of Engineering & Mathematical Sciences, City University, Oct 2003

Equipment Suppliers

Light Source (£20): UVSL-14P Mini-UV Lamp,
UVP Ltd., Unit 1, Trinity Hall Estate, Nuffield Road, Cambridge, CB4 1TG.
Tel: +44(0)1223-420022.
Email: info@uvp.co.uk

Concrete Saw (£200): Makita 2414NB Abrasive Cut-off Saw
Machine Mart Ltd, 211 Lower Parliament Street, Nottingham, NG1 1GN.
Tel: 0845 450 1800
Email: technical@machinemart.co.uk

Diamond Saw(£120): 4" Faceters Trim
Manchester Minerals Ltd., Georges Road, Stockport, SK4 1DP.
Tel:+44(0)1614770435.
Email: gemcraft@btconnect.com

Dyes (£30): Sulforhodamine B & Sodium Fluorescein Dyes
Sigma-Aldrich Co Ltd., The Old Brickyard, New Road, Gillingham, SP8 4XT.
Tel: +44(0)1747 833000.
Email: uktechsv@eurnotes.sial.com