Surfology Based Concrete Repair Engineering

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ABSTRACT

Research projects performed at the University of Liege and the Warsaw University of Technology have pointed out the importance of taking care about *surfology* of materials: if durability also means sustainability, we may then consider that optimization in material selection is essential for repair efficient. Surfology contributes to understand what will make the contact effective or not, and allow interactions of variable intensities between the materials. Different scales of observation – micro to macro - are needed to exactly represent what happens when materials are put into contact.

1. INTRODUCTION

This is a well-known assumption to declare that adhesion between overlays and concrete substrate is one of the most important factors that affects the reliability and durability of repair [1, 2]. A higher adhesion causes a higher tolerance to non-compatibility of properties of the both materials [3]. Adhesion depends on many phenomena taking place at interface zone [4]: bond-detrimental layers (including bleeding), wettability of concrete substrate by repair materials, secondary physical attraction forces induced in the system, roughness of surface (interlocking mechanism), moisture content in concrete substrate versus the repair system (e.g. cement concrete or polymer composite). The aim of a surface treatment of concrete is to remove any type of layer that causes the decrease of adhesion as well as to enlarge the area of contact surface by increasing surface roughness. Depending on local conditions of the specific building, surface roughness is obtained after sandblasting, milling, grinding, hydro-jetting or shot blasting; the technique and the energy chosen induce many different shapes and configurations. The effect of concrete surface roughness on the adhesion is not yet clear [5]. A few authors [6] conclude that surface roughness itself does not have significant influence; however, microcracks induced by surface treatment [7] will mainly contribute to the deterioration of the quality of the bond. The effect of a bond coat (PC or PCC type) is also under discussion [8]. Some authors have shown that a presence of bond coat can significantly increase adhesion [9].

This paper illustrates some aspects of surfology matter and parameters influencing binding quality, on the base of general considerations [10,11,12] and previous discussions.

2. SURFACE TREATMENT AND ROUGHNESS EVALUATION

2.1. Evaluation techniques and parameters

Different types of surface preparation techniques were investigated: scarifying (SC), high pressure water jetting (HPW) and polishing (PTW) [7]. The visual observation of the concrete surfaces indicates that the high pressure water jetting technique induces a particular texture characterized by large waves mostly parallel to the water flow while scarifying will generally induce some oriented macro-roughness (grooved surface).

After treatment, concrete surfaces present fractal topography. As for any fractal object, it is possible to break up this surface or this profile in a sum of under-profiles. Each under-profile can be differentiated in terms of wavelengths; there is however no limit or precise criterion to validate the choice of decomposition method (Fig.1).

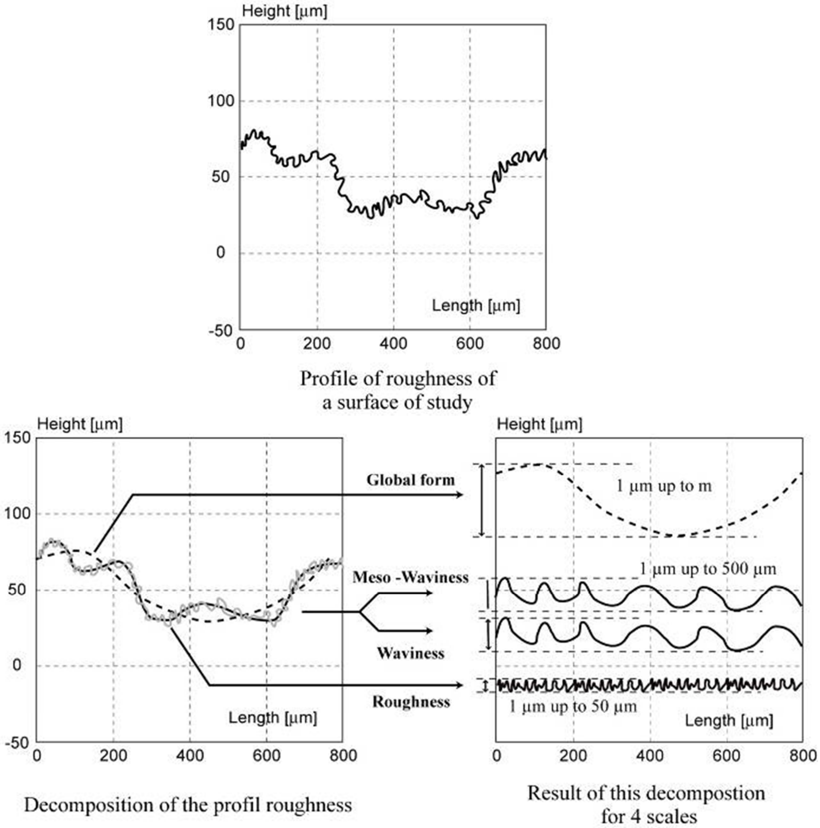


Figure 1. Scale effect on profile decomposition

The method with mechanical stylus [13] and high resolution reaches two scales of roughness named: roughness (R) and waviness (W). The optical method, with a resolution of 0.200-µm, makes possible to reach two higher scales named mesowaviness (M) and form (F).

A series of parameters make it possible to break up a total wave into two waves. The determination of surface parameters (Table 1) is realised on the basis of the mean line as a reference line [14].

Table 1. Profile amplitude and statistic parameters

Parameter	***Definition***
X_t	total height of the profile
X_v	maximum depth of the profile (holes)
X_p	maximum height of the profile (peaks)
X_a	arithmetic mean of the deviation of the profile from the mean line
X_q	quadratic mean of the deviation of the profile from the mean line
S_k	skewness of surface height distribution
S_m	mean spacing between profile peaks at the mean line, measured over the assessment length

The optical technique is an interferometrical measurement method. The “moiré” phenomenon appears when two networks of light rays, made of equidistant lines - alternatively opaque and transparent -, are superimposed [15]. The technique of identification of relief is based on the deformation’s measurement of a parallel fringes pattern projected on a surface (Fig.2). Moreover, there is a relation between rise in the form and distance between each level line. The measurement accuracy [16] is directly related to the density of the fringes network and the capacity of differentiation of the network by the system of image analysis.

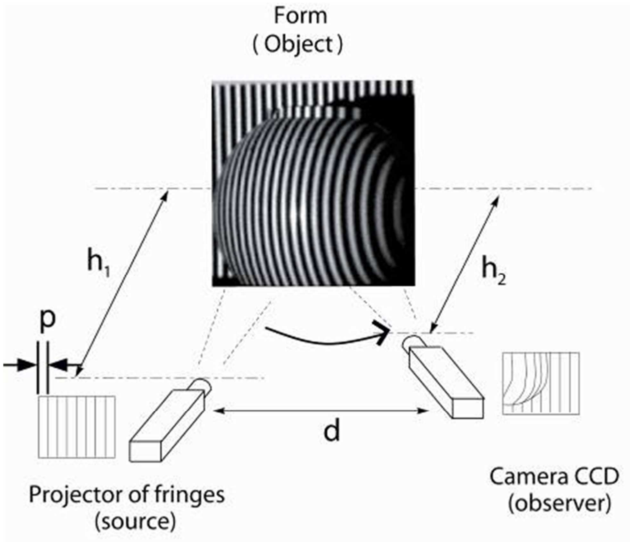


Figure 2. Principles of the Moiré projection technique

Because of the vertical resolution of the device, it is impossible, in this case, to separate roughness from waviness. A profile obtained through this approach will consequently give the description of meso-waviness and global form.

2.2. Results and comparison

A first evaluation by mechanical profilometry has been realized by means of a stylus with diamond sphere radius of 6 µm. The length of measurement was 8 mm and the filter used to separate roughness from the profile was fixed to 0.8 mm. Three profiles were registered on one sample of each kind of preparation; each profile on the sample was made in different directions. A second measurement was made with stylus of 79-mm long and a diamond of 1.5 mm radius, in order to point out waviness. The length of the measurement was enlarged to 30-mm or more. The filter was again chosen at 0.8-mm and the filter to separate shape from the profile was 16mm (two times the dimensions of the aggregates). Observation of the values of the roughness amplitude parameters (Table 2) clearly shows that R_a, R_q, R_t parameters are between 1.5 and 3 times smaller for the polished concrete profile than for water jetting and scarification, and that the values of amplitude and statistical roughness parameters are equal for water jetting and scarification.

Table 2. Waviness (W) and roughness (R) parameters for mechanical evaluation (µm)

Treatment	***Polishing***	***Water jetting***	***Scarification***
Wa	6	420	127
Wp	13	1003	346
Wq	9	501	158
Wv	47	923	445
Wt	60	1926	791
Ra	5	14	15
Rq	7	17	19
Rt	70	96	102
C_R	4	152	412
C_F	10	228	827
C_L	14	231	537

It is here confirmed that the surface treatment technique has no major influence on the micro-roughness ("high frequencies waves") of the profile. However, the differences are more effectives for waviness parameters (Fig. 3).

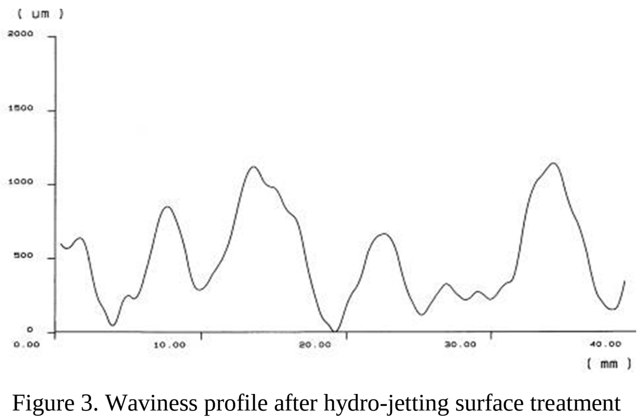
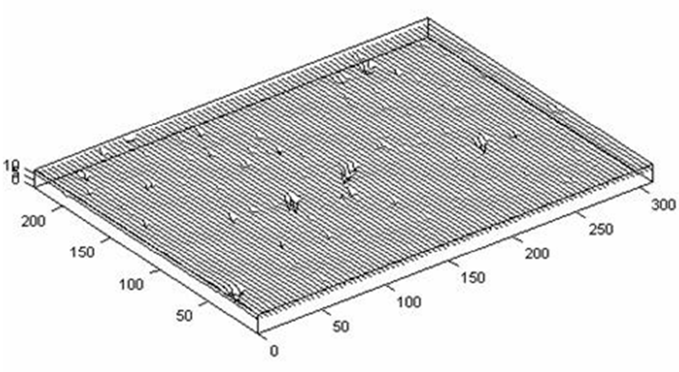
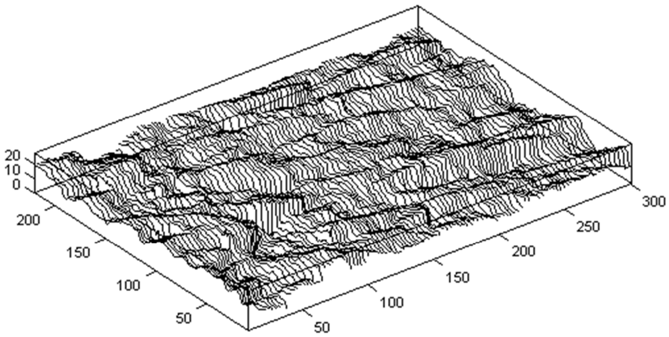


Figure 3. Waviness profile after hydro-jetting surface treatment

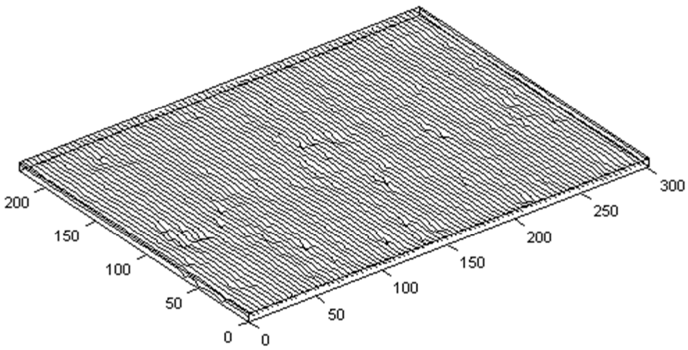
As the same way to mechanical evaluation, optometric topography evaluations have been realized. Fig. 4 presents the statements of the optical measurements. At this scale, water jetting technique seems to induce the largest "roughness". Polishing and scarification are quite similar.



(a) *polishing*



(b) *hydro jetting*



(c) *scarification*

Figure 4. Meso-waviness profiles (mm)

It is probably due to the bubble effect at the surface which gives roughness aspect. Observation of the values of the roughness amplitude parameters (Table 3) clearly shows that M_a parameter is 20 times more important for hydro jetting than for scarification and polishing. At this scale, the other treatments induce smooth surface. Polishing gives the less rough surface. The major part of apparent roughness of polishing surface comes from the bubble.

Table 3. Global form (F) and meso-waviness (M) parameters.for opto-metric evaluation (mm)

Treatment	***Polishing***	***Water jetting***	***Scarification***
Fa	0.137	0.358	0.326
Ft	4.1	10.8	12.6
F Sm	129	85.3	102.3
Ma	0.169	2.85	0.315
Mt	19.7	27.8	10.2
M Sm	15.3	36.5	22.5
C_R	0.30	4.65	0.41
C_F	0.29	5.76	0.55
C_L	0.35	5.71	0.81

3. CONCLUSIONS

The following conclusions may be reached from the present investigations. For mechanical analysis technique, one may consider that:

- stylus: because of the shape of the stylus, it is impossible to make measurements on very rough surfaces prepared by hydro-jetting for example;
- air bubbles: some of the air bubbles in concrete are so large that the stylus falls and the measurement is interrupted. That means that the selection of the zone to be investigated is very important;
- dimensions: this measurement is very high time consuming and it is the reason why the surface of investigation is limited. Moreover, this system is not usable on site.

Considering the use of opto-morphometry technique for the concrete surface roughness characterization, it is important to point out that:

- all the amplitude and statistic parameters are higher for hydro-jetting than for scabbling and polishing at the end which is the equivalent of aggressiveness of treatment. Decreasing values are obtained for scabbling and polishing, respectively;
- for each profile, there are more high peaks than deep valleys. The highest asymmetry is present for scabbling profile;
- opto-morphometric technique allows to analyze large surface areas (1000cm², with horizontal resolution of 500µm and vertical resolution of 300µm).

But it remains that the filtration process has a major influence on results and profiles; it should be clearly discussed, as well as the accuracy that is needed for roughness profile representation, with regards to adhesion.

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