

CONSERVING CONCRETE HERITAGE AN EXPERTS MEETING TO IDENTIFY RESEARCH NEEDS TO ADVANCE THE FIELD

The Getty Conservation Institute

June 9-11, 2014
Los Angeles, CA

Concrete Surface Engineering for Cultural Heritage

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CONSERVING
MODERN
ARCHITECTURE

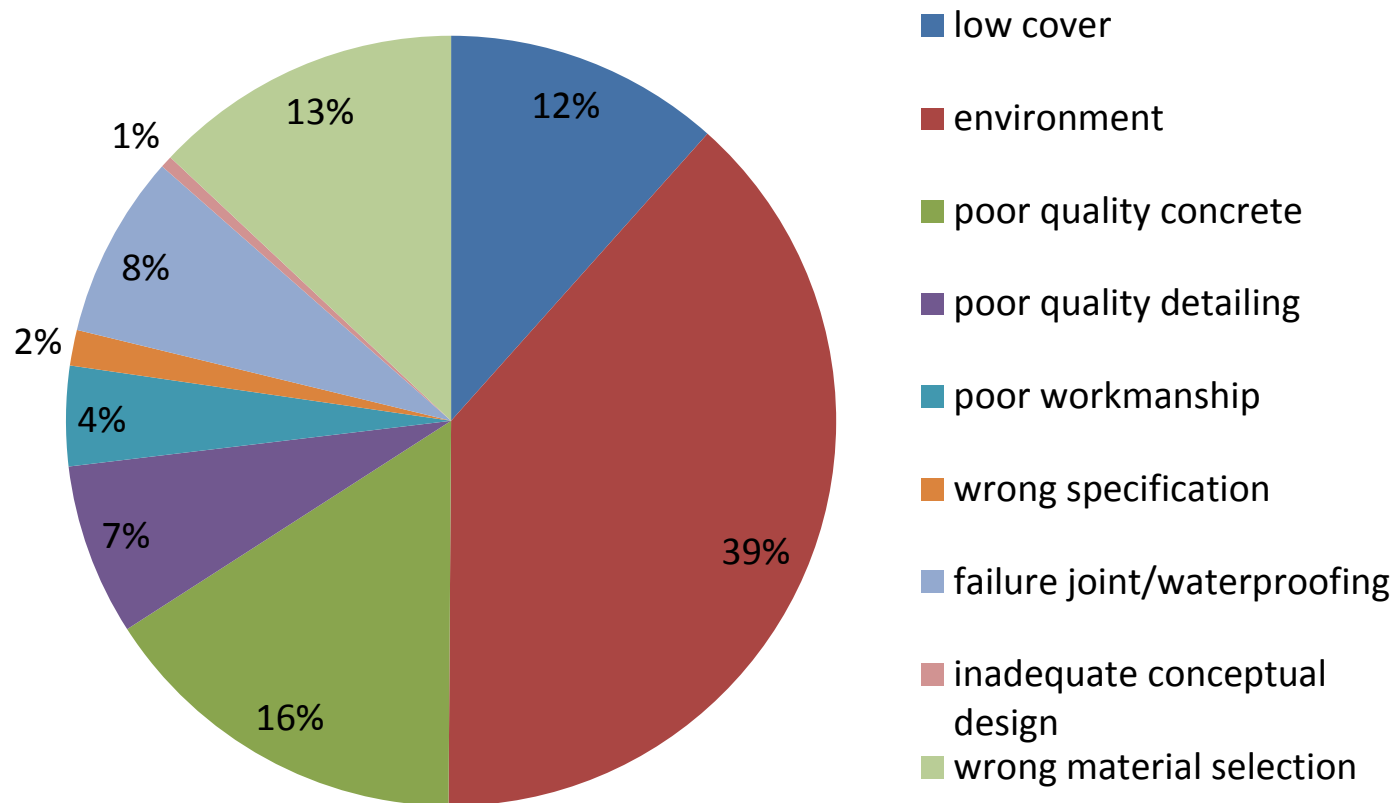


An initiative of
The Getty Conservation Institute

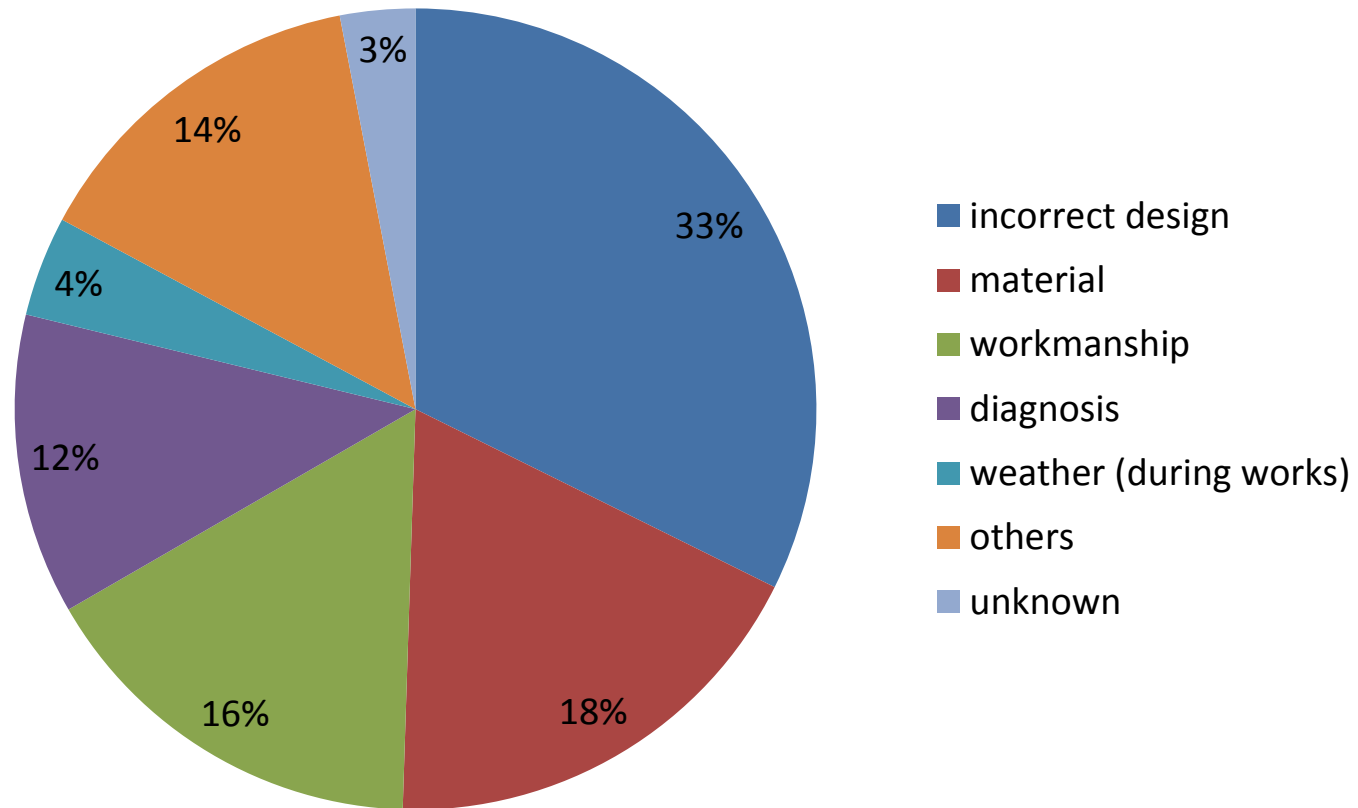
Situation of our infrastructure today



Factors contributing to the degradation of concrete structures (*BCA, 1997*)



Factors contributing to the failure of repair (*Tilly, 2004*)



Concrete churches in Liège county: pathologies



Saint-Hubert



Saint-Juliana



Saint-Georges



Saint-Francis of Sales



Corrosion
Cracking
Humidity



Saints Peter and Paul



Holy Heart and
Our Lady of
Lourdes



Saint-Martin



Saint-Virgin Maria



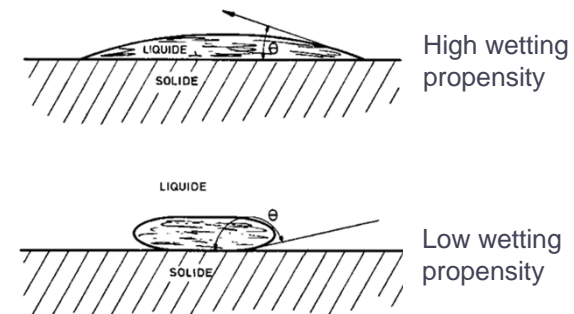
Saint-Vincent

Repair: how to select materials?

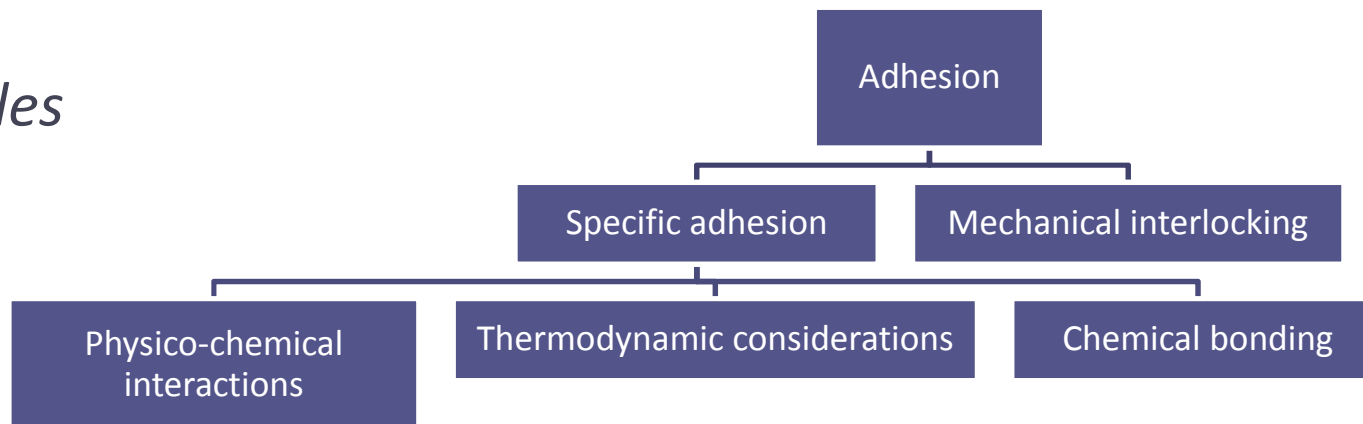
Condition 1 : spreading / wettability

Condition 2 : physico-chemical interaction

Condition 3 : mechanical interlocking



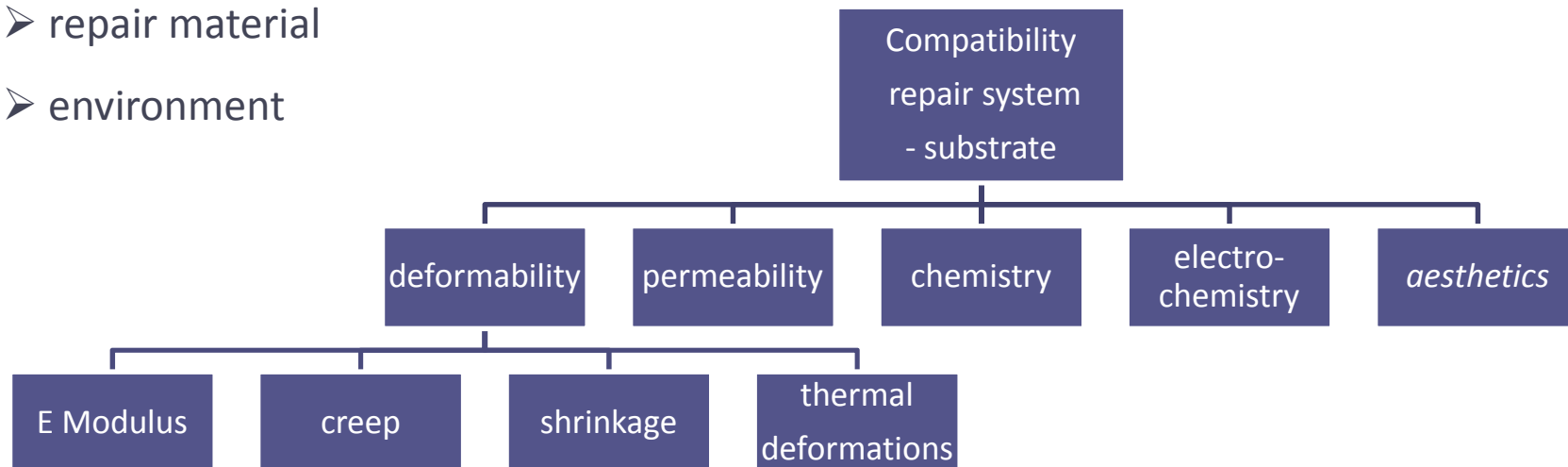
Principles



Repair: how to select materials?

Concept of compatibility for strong, long-lasting adhesion

- substrate
- repair material
- environment



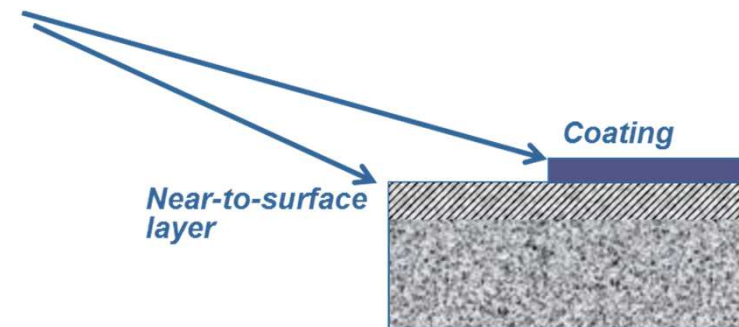
Concrete Surface Engineering

Definition

*Scientific and technological approaches addressing all surface-related considerations, notably those pertaining to **adhesion of a surface treatment** intended to improve the properties of the substrate, such as its resistance to corrosion and abrasion, or its aesthetic properties*

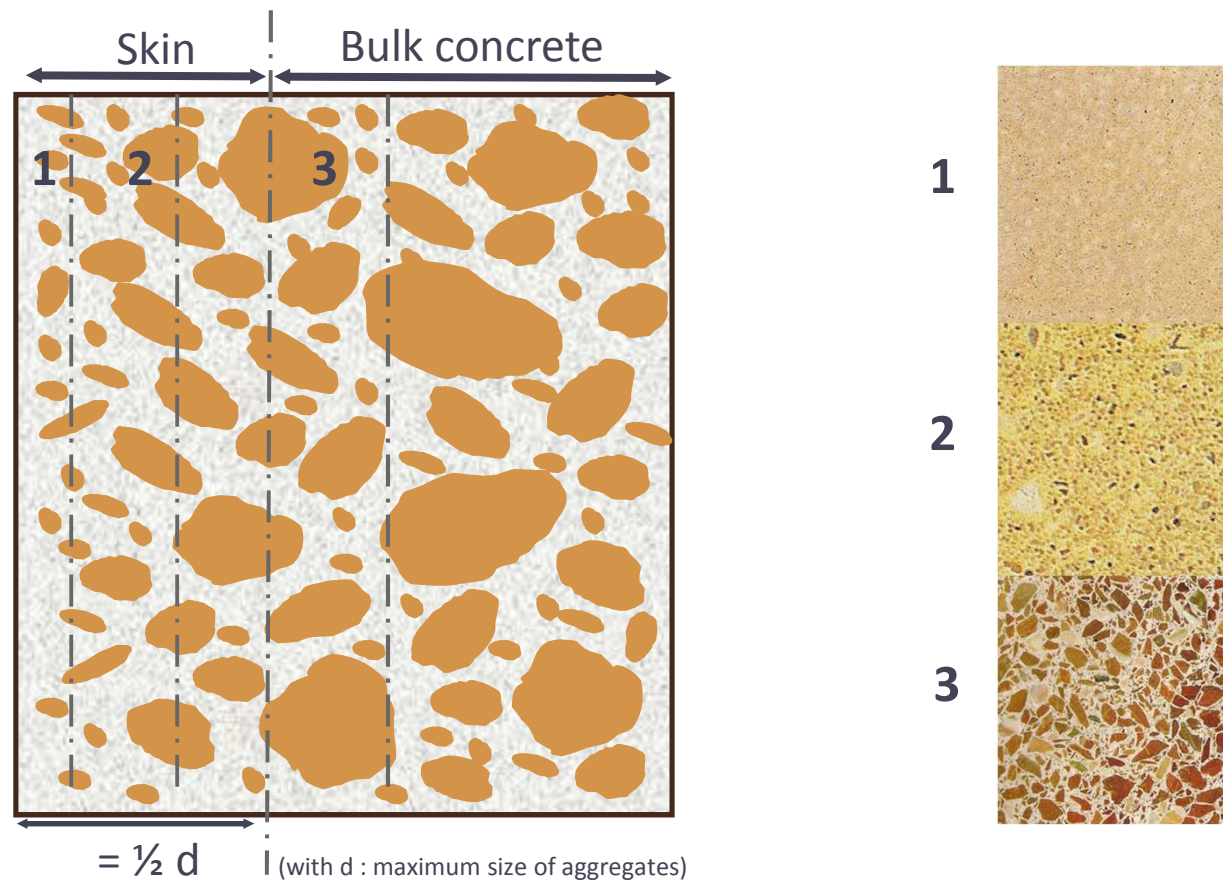
Surface engineering covers all phenomena involved in the preparation of the substrate near-to-surface layer and adherence of a surface treatment in given conditions

Example: hydrophobic treatment



Concrete Surface Engineering

What is surface concrete, of what is it made ?

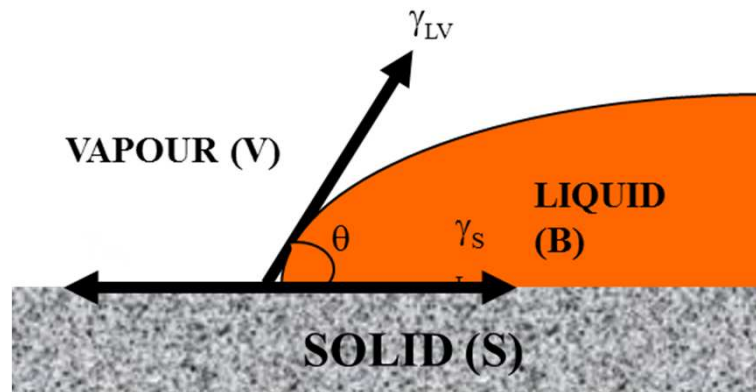


(Influence of the reuse of OSB and marine plywood formworks on concrete facing color. L. Courard, M. Martin, C. Goffinet, N. Migeotte, J. Piérard and V. Polet. Materials and structures 45(9), 2012, 1331-1343)

Concrete Surface Engineering

What is the effect of water at the interface?

$$\gamma_{SV} = \gamma_{SB} + \gamma_{BV} \cdot \cos \theta$$

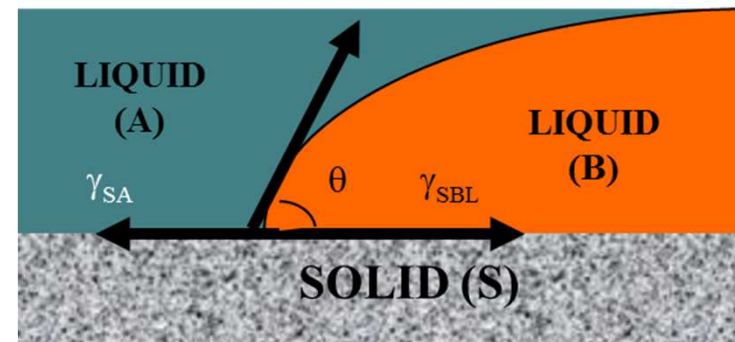


Equilibrium : the difference between tensions of adhesion is inferior to interfacial tension

No equilibrium : liquid B will expulse liquid A

$$\gamma_{SA} = \gamma_{SB} + \gamma_{AB} \cdot \cos \theta$$

$$\begin{cases} \gamma_S = \gamma_{SA} + \gamma_A \cdot \cos \theta_A \\ \gamma_S = \gamma_{SB} + \gamma_B \cdot \cos \theta_B \end{cases}$$



$$\gamma_B \cdot \cos \theta_B - \gamma_A \cdot \cos \theta_A < \gamma_{AB}$$



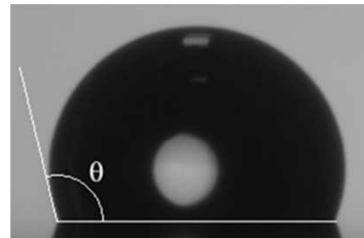
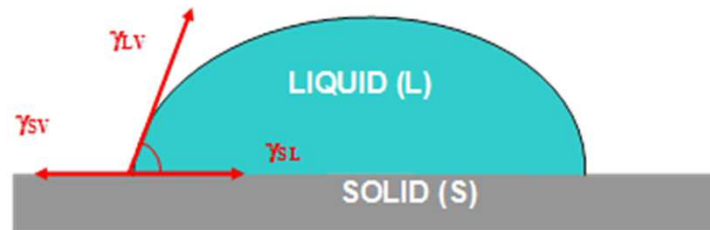
$$\gamma_B \cdot \cos \theta_B - \gamma_A \cdot \cos \theta_A > \gamma_{AB}$$



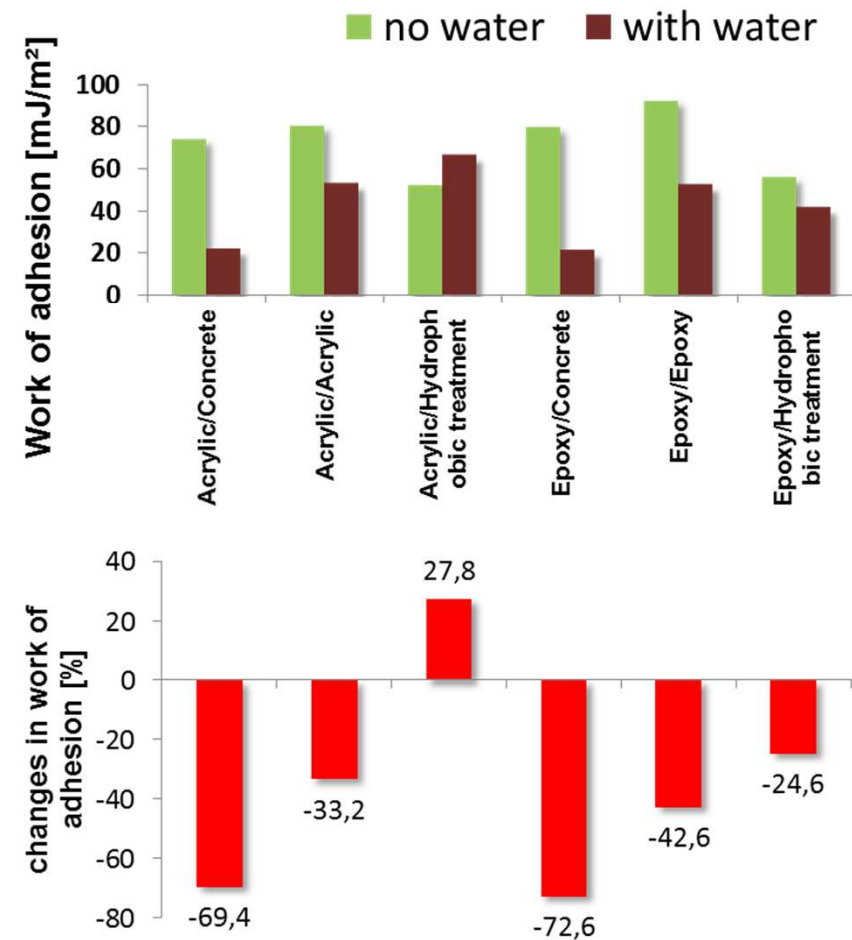
the liquid with the higher tension of adhesion will expulse the other one from the surface

Concrete Surface Engineering

Effect of water at the interface



$$W_{a_{SL}} = \gamma_{LV} (1 + \cos \theta)$$



(Hygro-thermal application conditions and adhesion. L. Courard, A. Darimont, R. Degeimbre and J. Wiertz. Fifth International Colloquium Industrial Floors '03, (Ed. P. Seidler, Technische Akademie Esslingen), Ostfildern/Stuttgart, Germany (21-23 January 2003), 137-142)

Concrete Surface Engineering

What are the effects of surface texture (roughness)?

Devices for the measurement of surface texture



Mechanical profiling

Measured area : $200 \times 200 \text{ mm}^2$

Stylus shape: truncated cone

Stylus diameter: 1 mm

Measurement pitch: 1 mm



Atos I 3D Digitizer

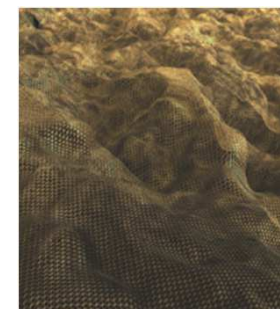
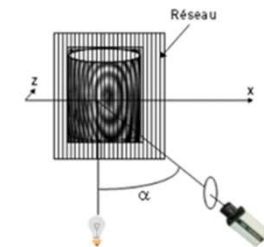
Fringe patterns

Measured area (range):

$120 \times 100 - 1000 \times 800 \text{ mm}^2$

Spatial resolution: 0.04 - 1 mm

Mathematical
treatment

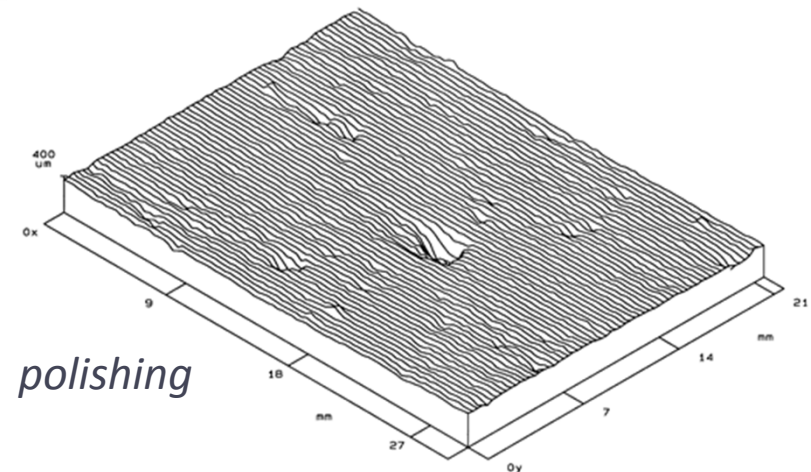
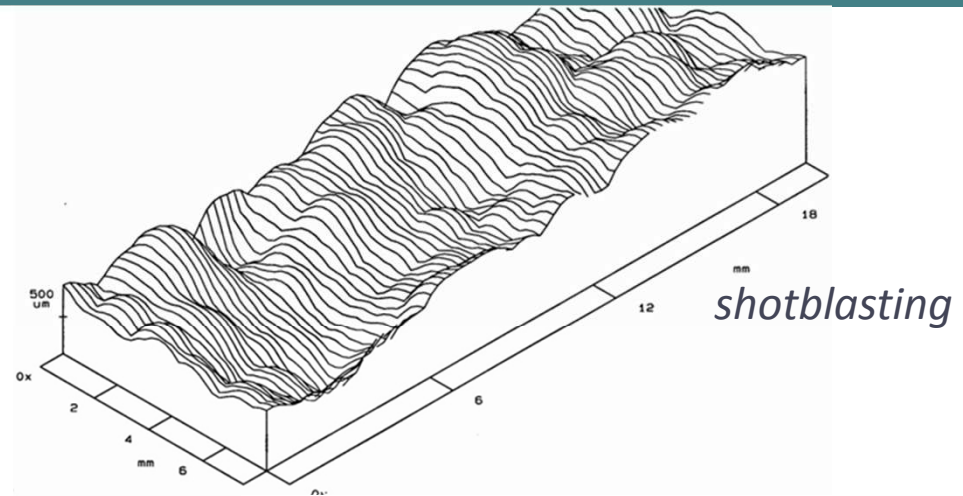
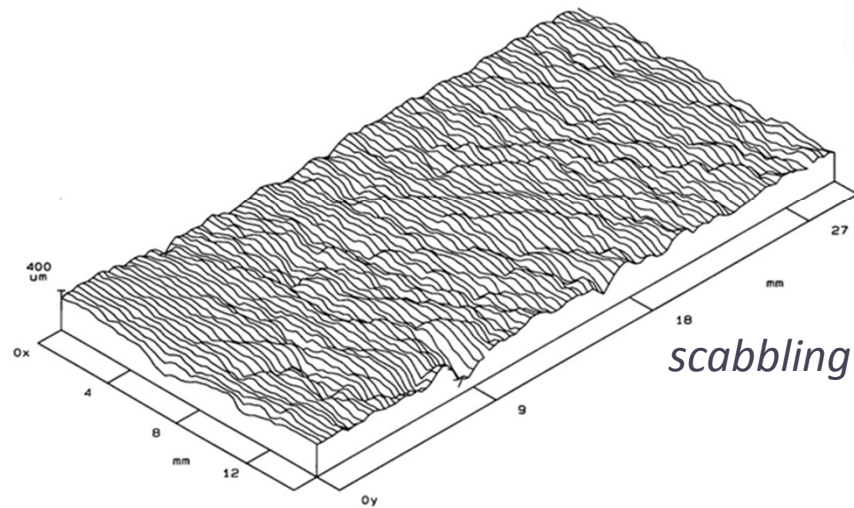


Concrete Surface Engineering

Texture (roughness / waviness)

vs.

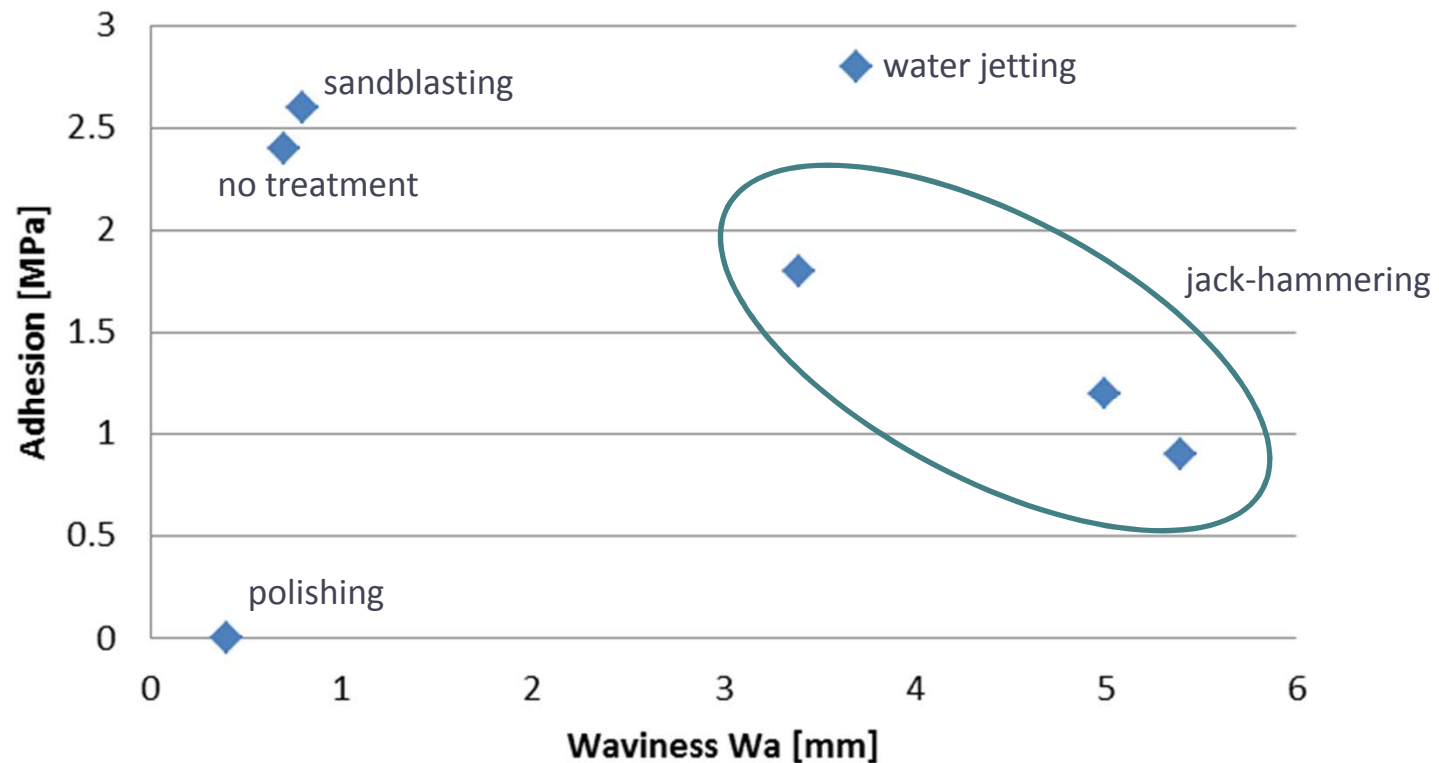
Surface preparation technique



(Surface analysis of mineral substrates for repair works: roughness evaluation by profilometry and surfometry analysis. L. Courard and M. Nélis. Mag. Concrete Res., 55(4) (August 2003), 355-366)

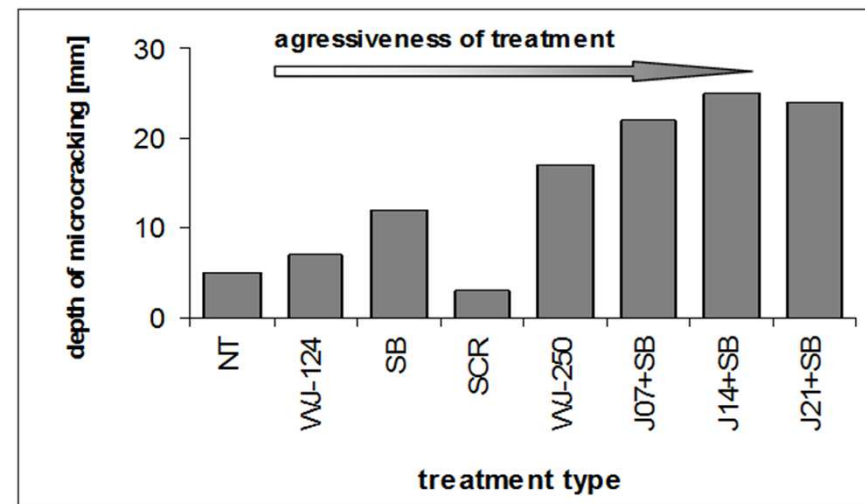
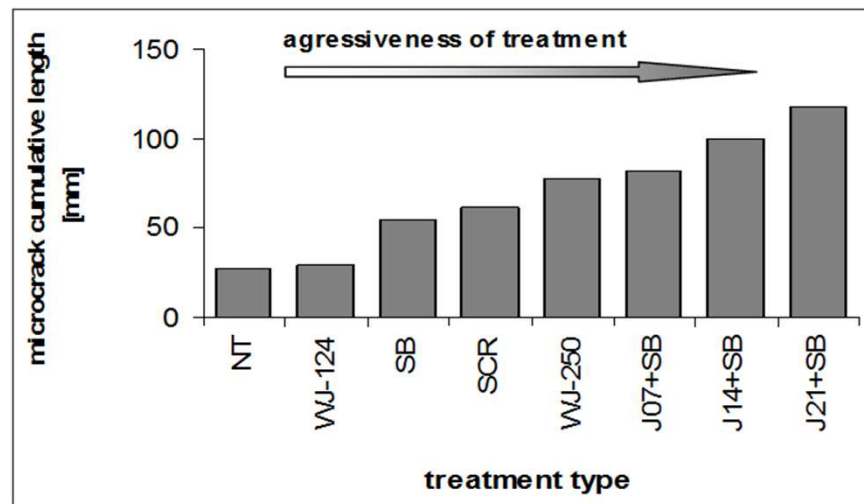
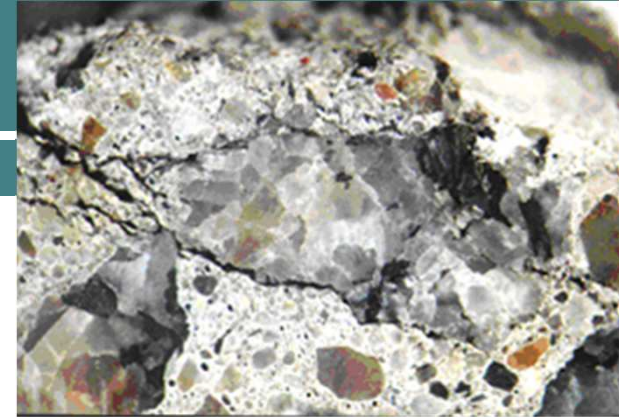
Concrete Surface Engineering

Roughness vs. adhesion



Concrete Surface Engineering

Roughness vs. microcracking



NT – no treatment; WJ – water jetting – pressure 124 psi/250MPa; SB – sandblasting; SCR – scabbling; J+SB – jack hammering of weight 7,14,21 kg + sandblasting

Concrete Surface Engineering

Degradation of historical concrete buildings and monuments

Causes quality of concrete → evaluation?

insufficient concrete cover → evaluation?

freeze-thaw cycles

Effects corrosion of steel reinforcement by carbonation

disintegration

Needs resistance to carbonation

aesthetics requirements

water repellency

(+ *compatibility issues*)

