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Sciences Appliquées

Guidelines for concrete surface preparation: 10 years research and experience

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19-21 November 2018

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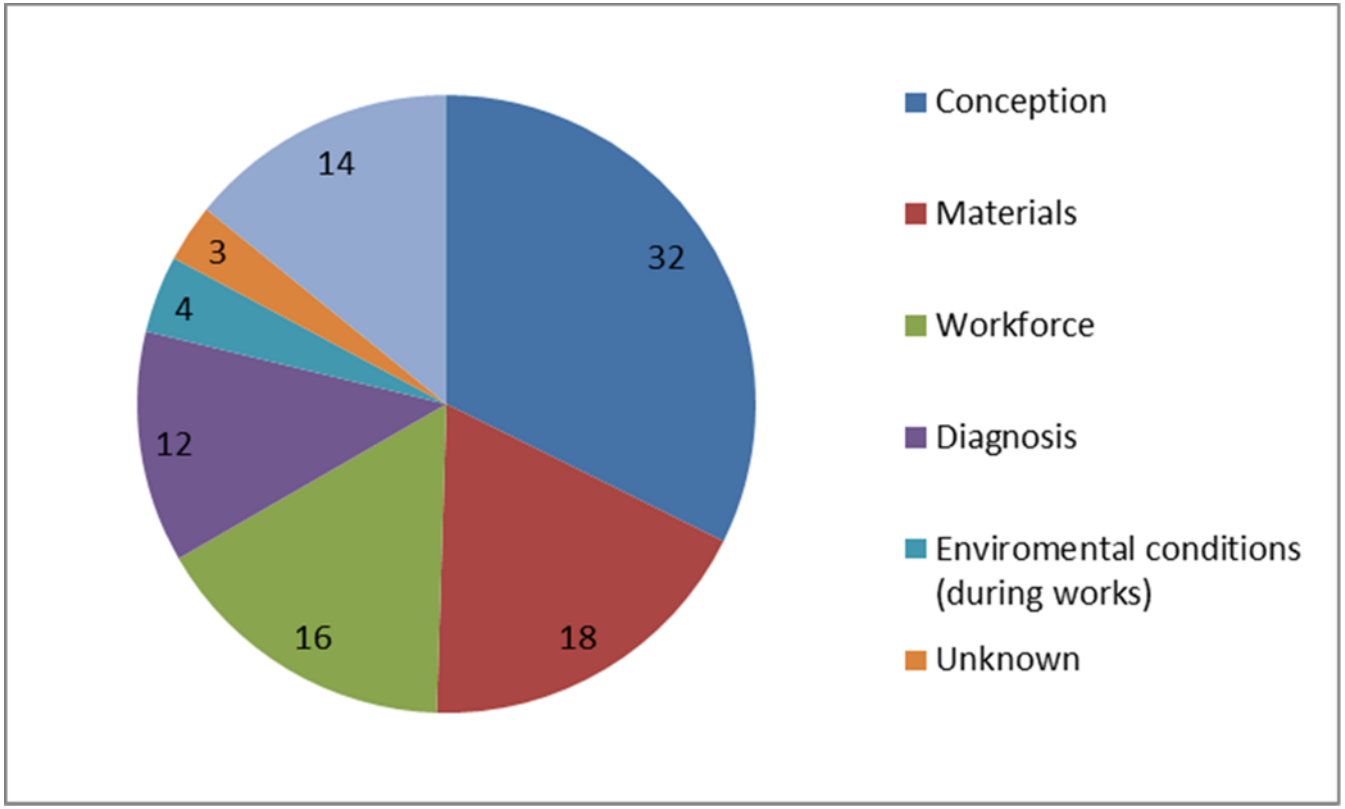
Is that repair?

Somewhere in the world …

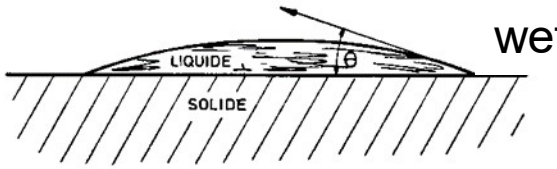
Causes of failure in repair (acc. Tilly, 2004)



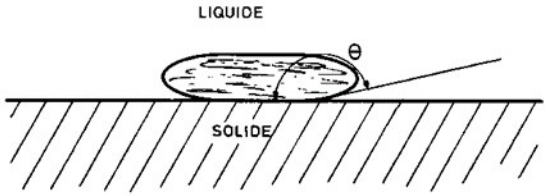
Based on *Réparation des ouvrages en béton armé – Partie 1 : pathologies et diagnostic.* L. Courard et B. Bissonnette. Techniques de l'ingénieur (novembre 2016)

Parameters affecting repair (acc. Silwerbrand, 2004)

- Among many parameters
  - Surface preparation
  - Absence of laitance
  - Cleanliness of the substrate
  - Compaction method
  - Curing of the new material

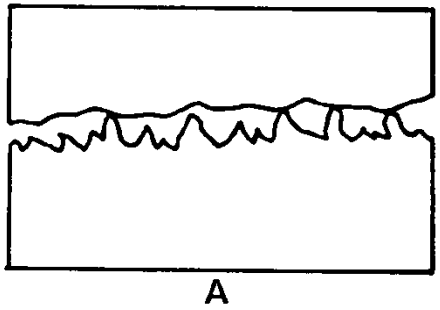


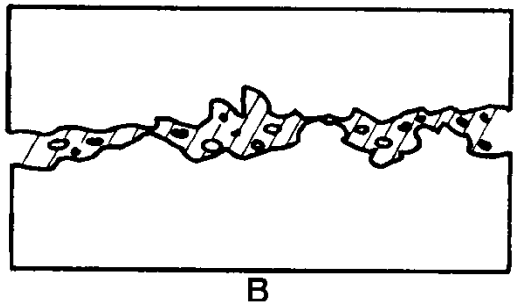
Good wetting?



Bad wetting!

Mechanical interlocking?





Context of the study

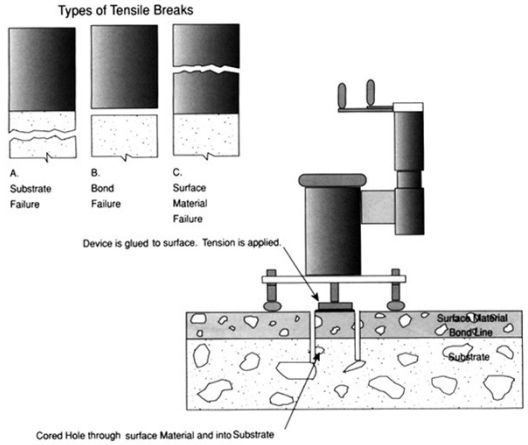
- Development of Specifications and Performance Criteria for Surface Preparation Based on Issues Related to Bond Strength
  - ACI Concrete Research Council
  - Study devoted to the most significant factors influencing bond in repairs (roughness, degree of saturation and carbonation of the substrate) and its field evaluation (type of loading, device misalignment).
  - Guideline-type recommendations for surface preparation prior to repair

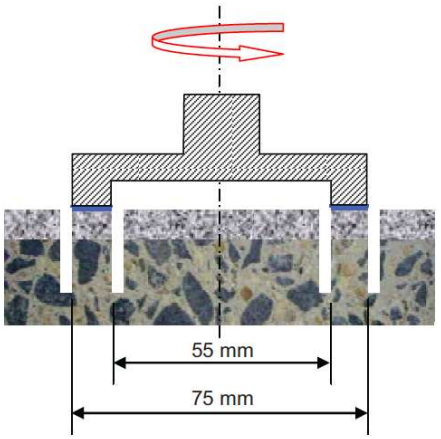
Objectives

- Guidelines - recommendations
- Concrete repair bond evaluation
  - To evaluate the effect of load misalignment upon tensile pull-off test results
  - To evaluate the correlation between tensile/shear bond strength and surface roughness
  - To evaluate the optimum moisture conditioning of a concrete substrate prior to repair
  - *To evaluate the effect of substrate carbonation upon repair bond strength*

General research program

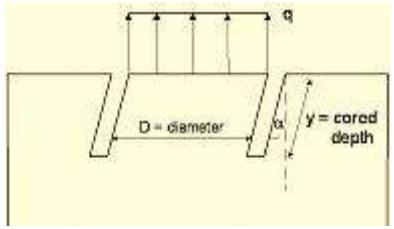
- Test specimens
  - Support slabs cast, conditioned, profiled and repaired
- Repaired slab testing
  - Pull-off testing for tensile bond strength (ASTM C1583; EN 1542:1999)
  - Torque testing for torsional (shear) bond strength



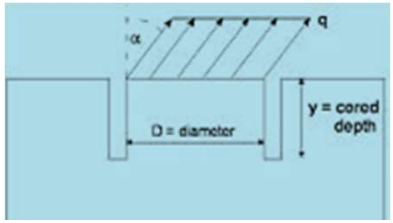


Methodology

- Influence of pull-off test misalignment
  - Test program
    - Series of 600×400×100 mm test slabs (6) prepared (SaB) with three different concrete mixtures (30 MPa; 40 MPa; 50 MPa)
    - Controlled coring misalignment
      - core inclination: 0°; 2°; 4°
      - coring depth: 15 mm; 30 mm



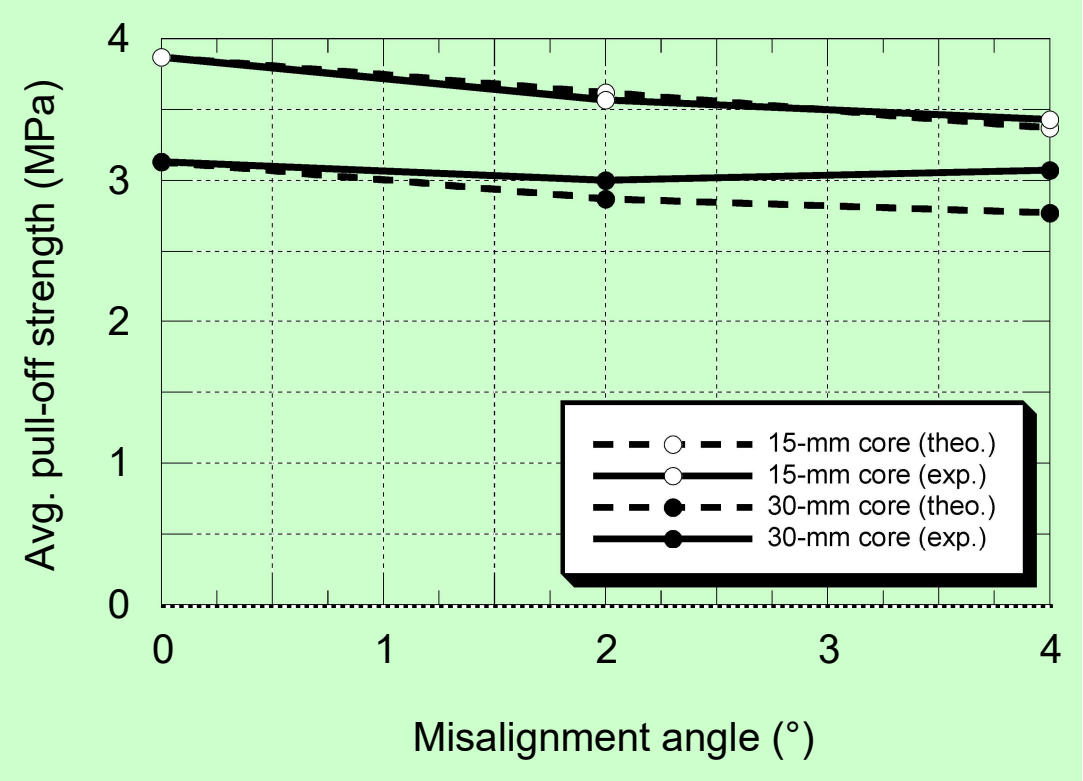
  - Complementary FEM analysis (elastic) analysis
    - Source of misalignment: coring vs. load
    - No significant difference

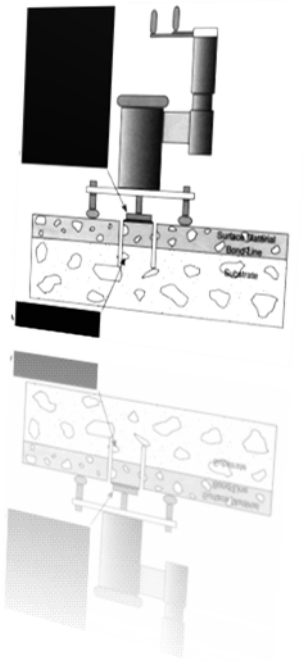


Effect of misalignment on pull-off test results: numerical and experimental assessments. L. Courard, B. Bissonnette, A. Garbacz, A. Vaysburd, K. von Fay, G. Moczulski, M. Morency. ACI Materials Journal, 111 (2), 2014, 153-162

Results and analysis

- Influence of testing misalignment
  - Pull-off testing (superficial strength)





Methodology

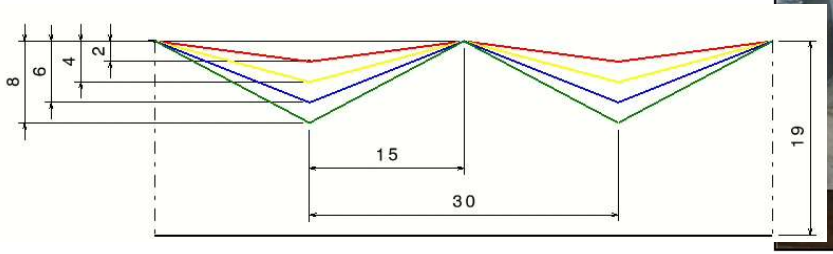
- Influence of surface preparation
  - Series of 650×1250×150 mm test slabs (15) prepared with two different concrete mixtures (25 MPa; 35 MPa)
    - Slabs overlaid with OPC concrete after moisture stabilization and surface preparation

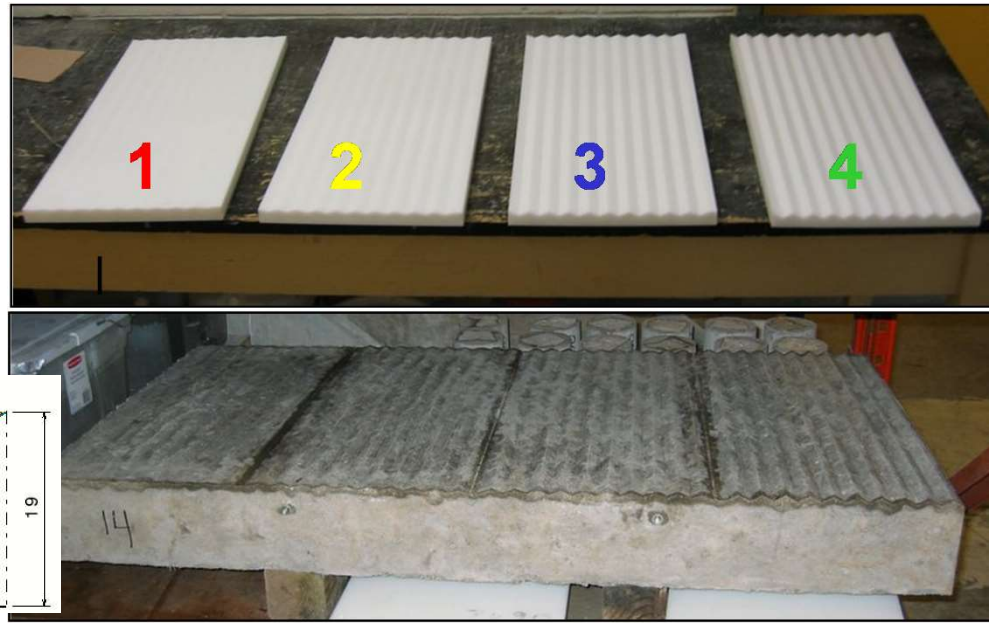
  - Investigated techniques
    - Sandblasting (SaB)
    - Shotblasting (ShB)
    - Scarifying (Sc)
    - High pressure water jetting 100-MPa (HJ)
    - Jackhammering 7-kg (JH)

Bissonnette, B., Courard, L., Garbacz, A. Concrete surface engineering. Modern Concrete Technology 18, CRC Press, Nov. 30, 2015, 272p. (ISBN-13: 978-1498704885)

Methodology

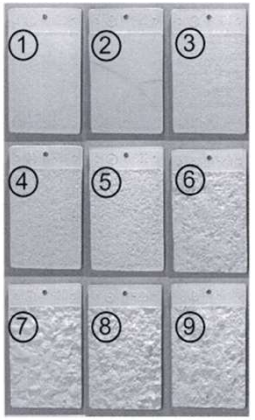
- Influence of surface preparation
  - Reference: artificially-profiled slab
    - No damage induced by the profiling operations
  - V-shape rippled acrylic dies installed at the bottom of the slab (l = 30 mm)
    - A = 2 mm
    - A = 4 mm
    - A = 6 mm
    - A = 8 mm

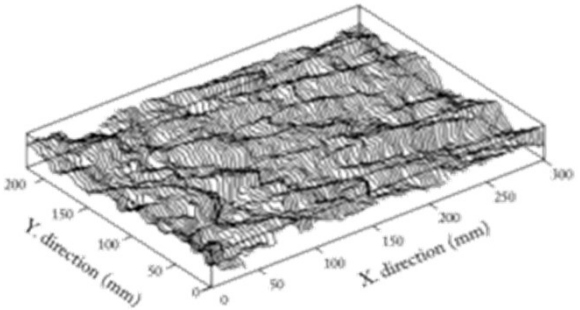




Methodology

- Influence of surface preparation
  - Roughness
    - CSP (concrete surface profile) index: 1 - 9 (ICRI Guideline No. 03732 / molded replicas)
    - Sand patch test (ASTM E965; EN 13036-1:2002)
    - Optical profilometry (Moiré-type)
  - Mechanical integrity
    - Pull-off experiments (superficial strength)
    - Schmidt hammer soundings

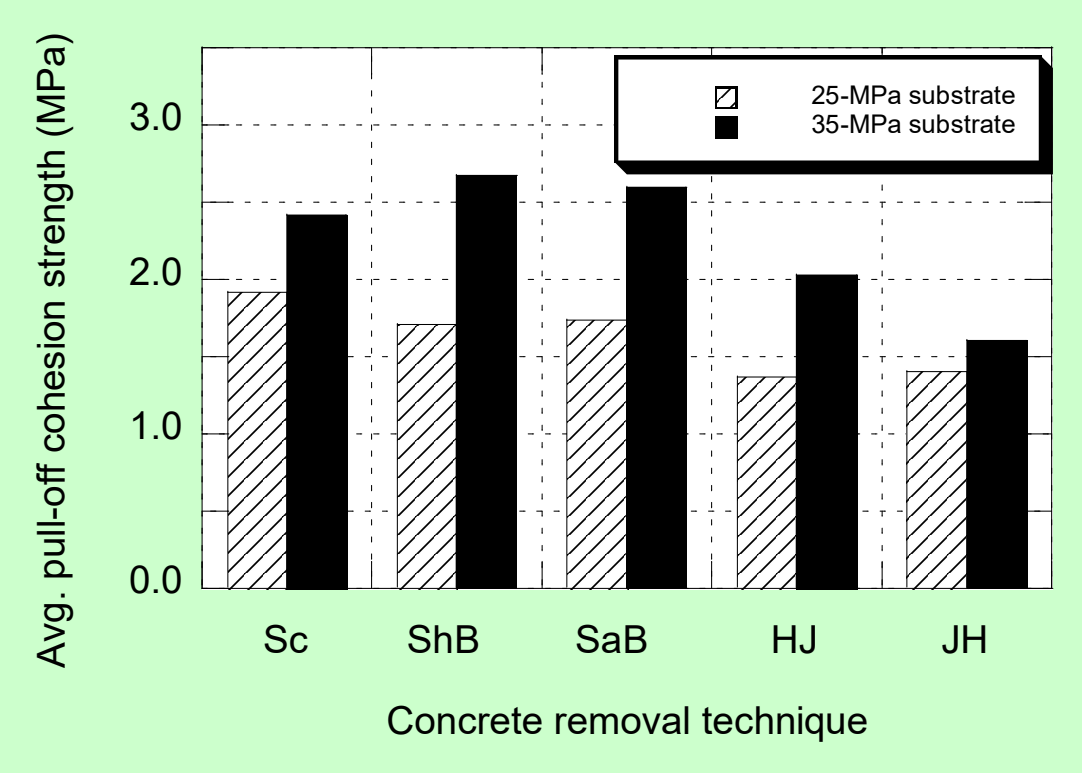


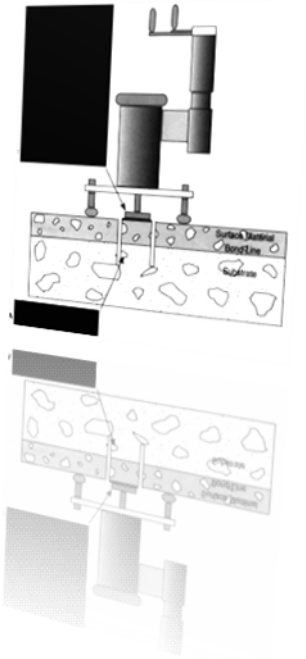


Evaluation of the mechanical integrity of a concrete surface by means of combined destructive methods. L. Courard, B. Bissonnette, A.M. Vaysburd, A. Garbacz. 5th International Conference on Concrete Repair, Queen's University, Belfast, 1-3 September 2014, 787-790.

Results and analysis

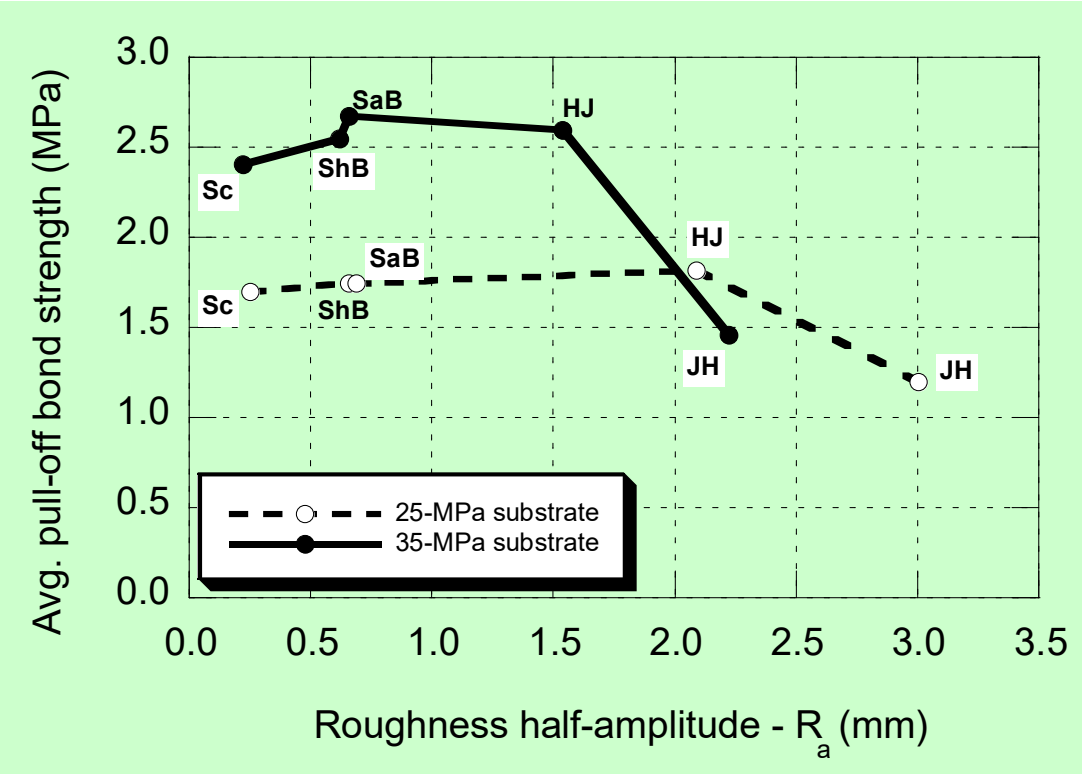
- Influence of surface preparation : integrity
  - Pull-off testing (superficial strength)

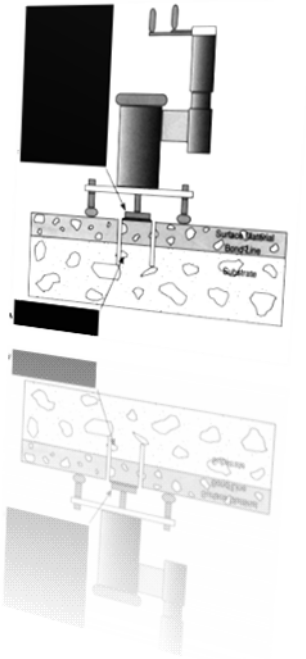




Results and analysis

- Evaluation of bond strength
  - Pull-off testing (tensile bond strength)





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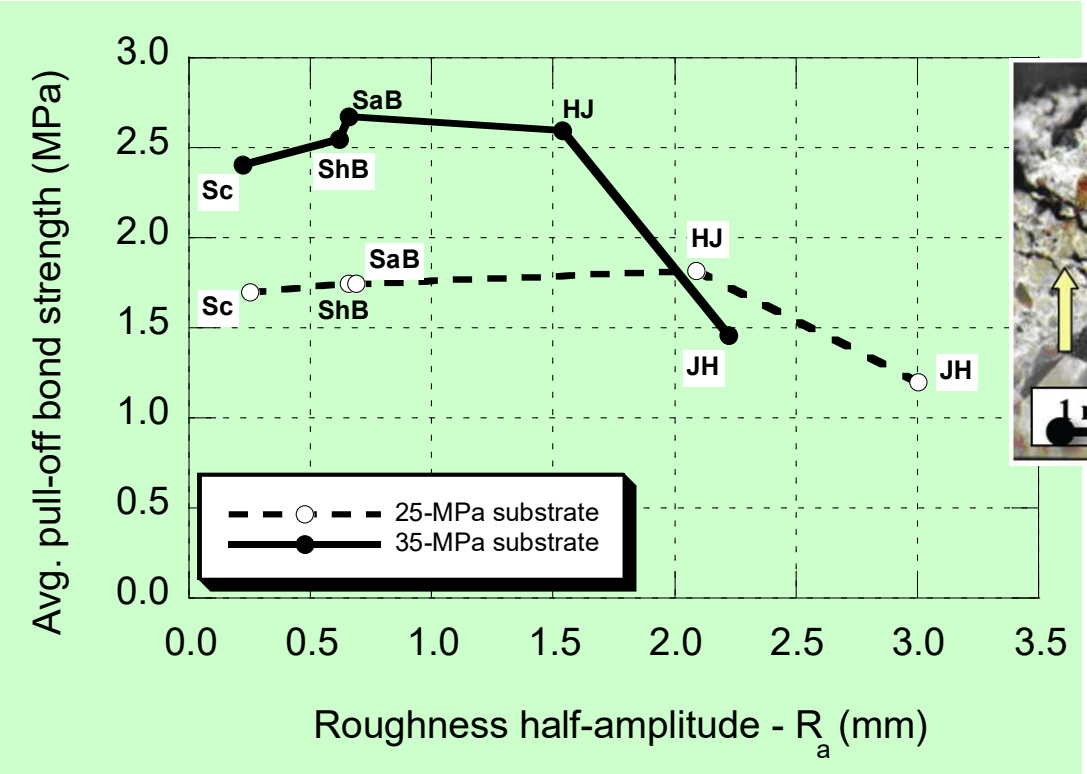
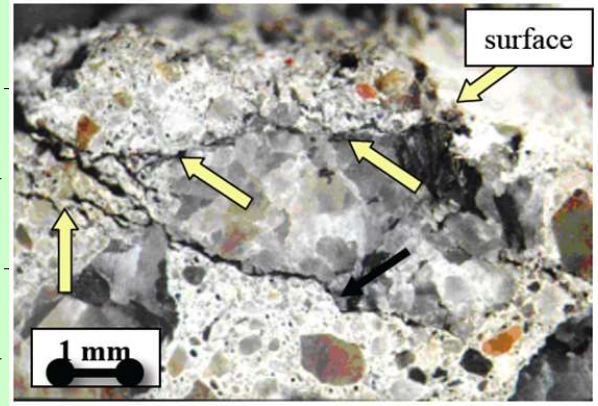
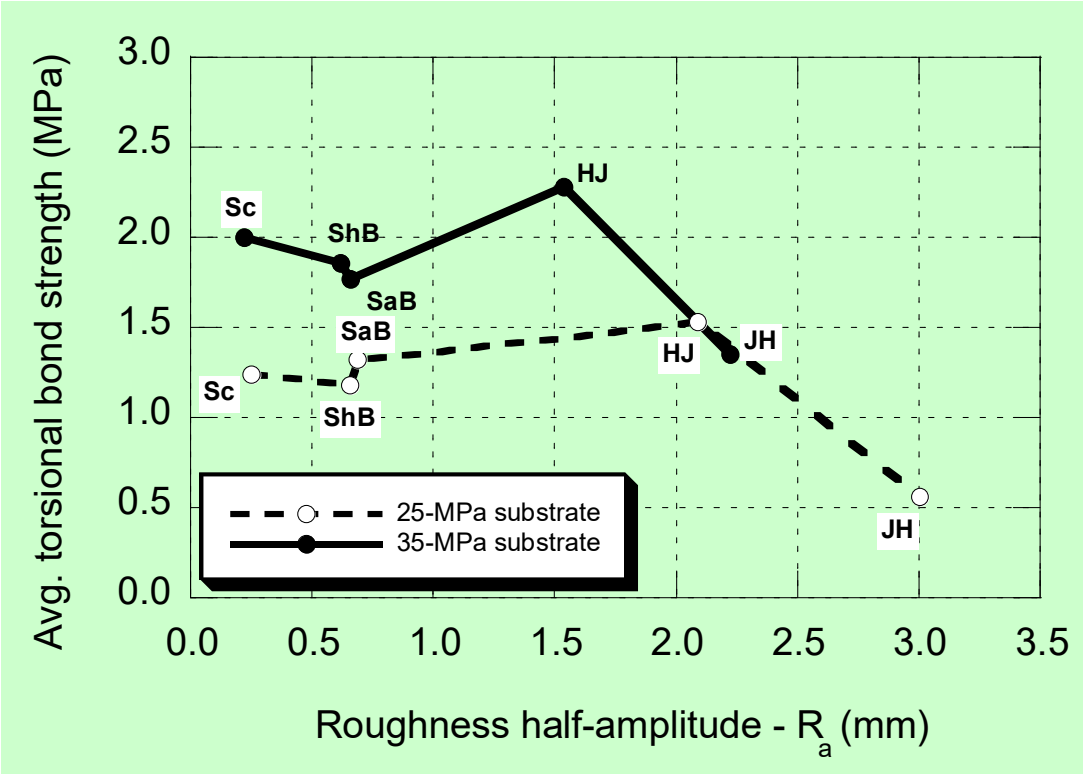


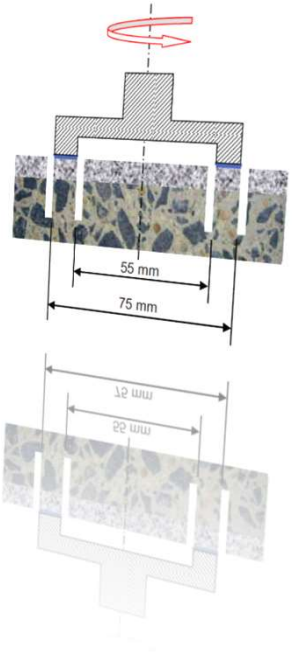


Bissonnette, B., Courard, L., Vaysburd A. and Bélair, N. (2006) Concrete Removal Techniques: influence on Residual Cracking and Bond Strength. Concrete International 28(12), 49-55.

Results and analysis

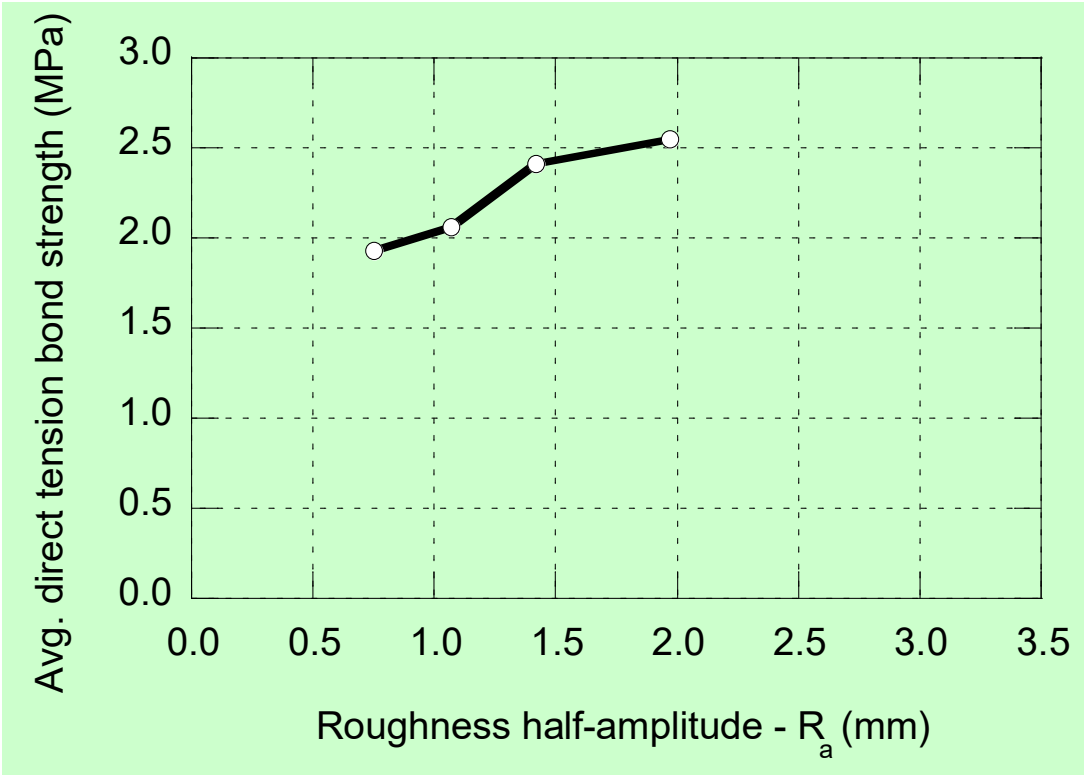
- Evaluation of bond strength
  - Torque testing (torsional/shear bond strength)

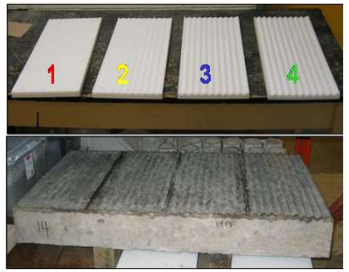




Results and analysis

- Evaluation of bond strength
  - Pull-off testing (tensile bond strength)



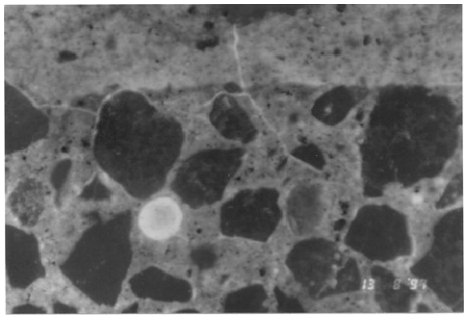


Methodology

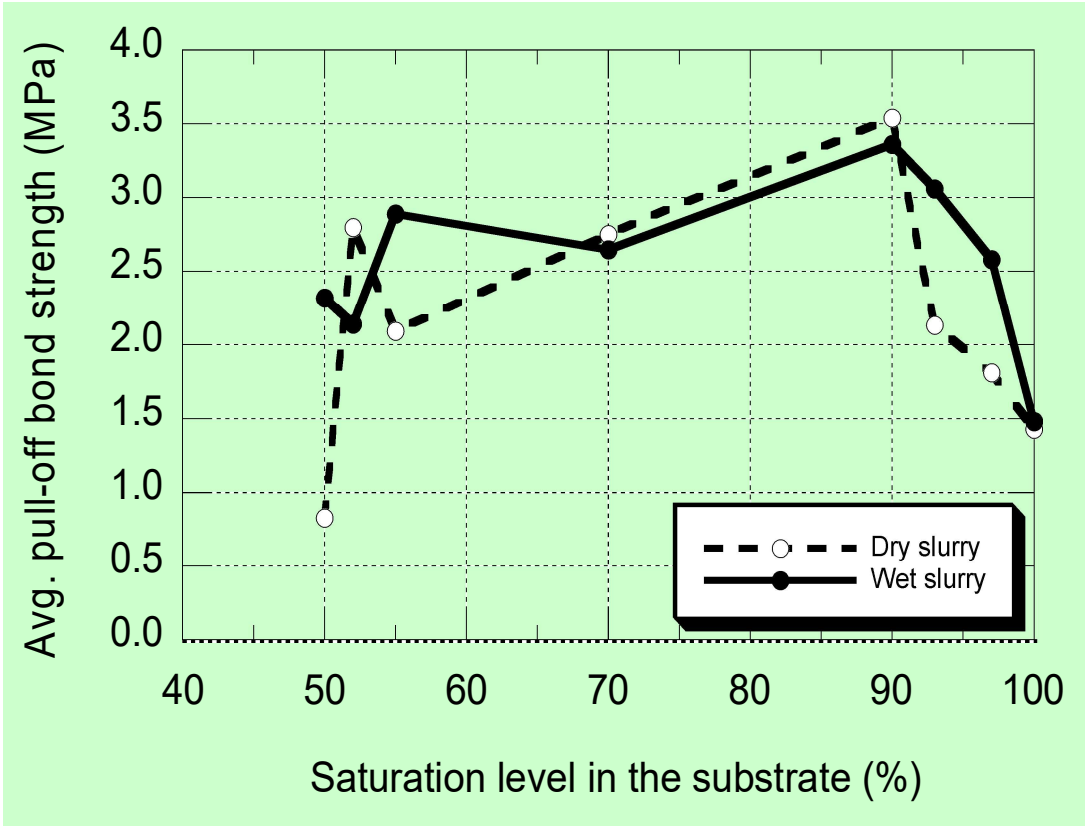
- Influence of substrate moisture content
  - Series of test slabs prepared with three different concrete mixtures (30 MPa; 40 MPa; 50 MPa)
    - Various conditioning regimes to yield moisture levels covering the range from 30 to 100 % RH
    - Test slabs overlaid with OPC concrete (SB) after moisture conditioning
    - Optimum moisture content of the concrete substrate for repair bond
  - Test methods for evaluating the moisture content (indirect methods)
    - Initial Surface Absorption test (ISAT)
    - Modified version of the Capillary Suction test (MCST)

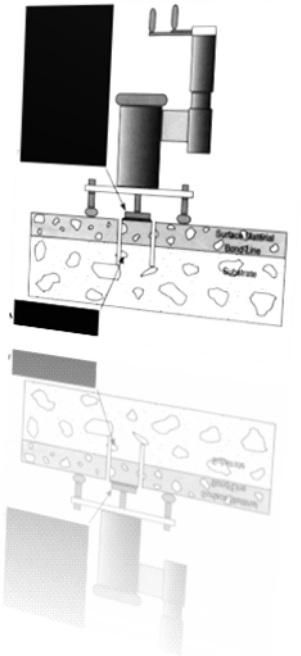
Courard, L., and Lenaers, J.F. (2009) Evaluation of Saturation and Microcracking of the Superficial Zone of Concrete: New Developments, Proceedings of the ICCRRR08 International Congress on Concrete Repair, Reinforcement and Retrofitting (Eds. Alexander et al.), Taylor & Francis Group, London, Cape Town, 977-82.

Results and analysis



- Influence of moisture content (PCC mortars)
  - Pull-off testing (tensile bond strength)





Conclusions

- **Pull-off testing** is a convenient and useful test method
  - Evaluation of both the mechanical integrity of the concrete surface (prior to repair) and the repair bond strength
  - Reliable and practical QC tool
- The potential bias due to testing **misalignment**, below the average naked-eye detection capability, was evaluated to reach up to approximately 15 %
  - For QC testing, the bias can only affect the pull-off strength evaluation on the conservative side

Conclusions

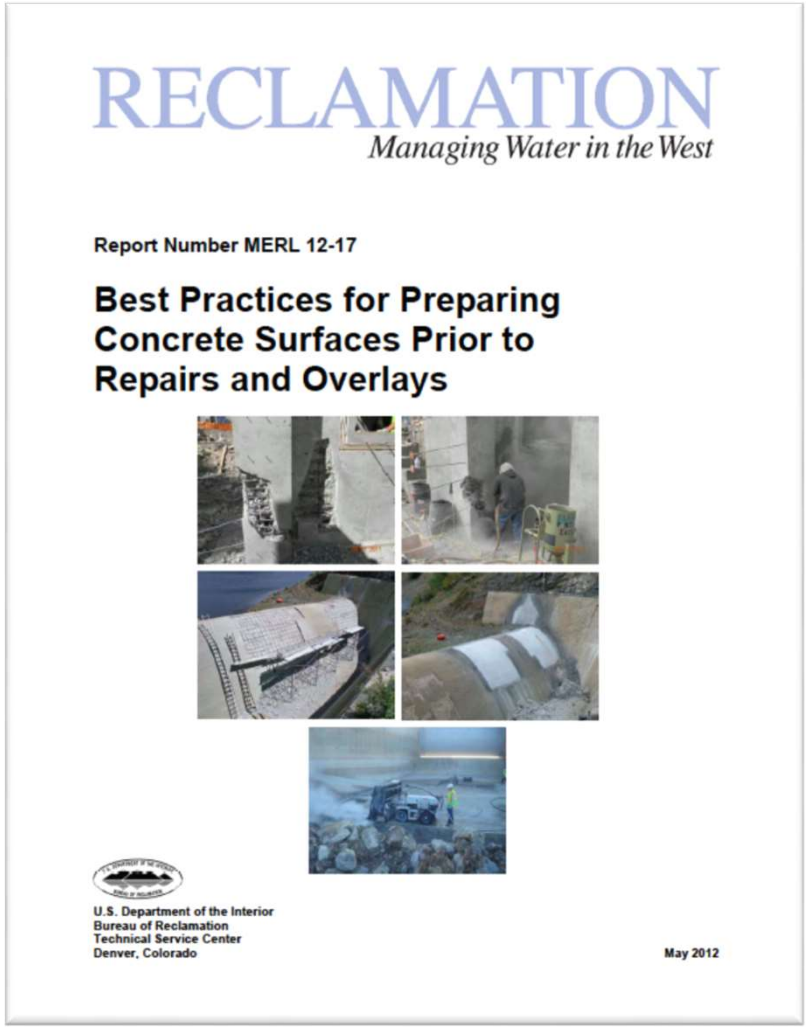
- Bond strength of concrete repairs depends on a number of parameters
  - In the absence of substrate-induced damage, tensile bond strength increases with the substrate **roughness**
  - Still, the most important parameter apparently remains the **mechanical integrity** of the substrate
  - In that regard, it must be stressed that the use of impacting methods such as **jack hammering** leaves significant damage at the surface, which can easily outweigh the benefits of an increased surface roughness

Conclusions

- The results obtained in the present study show that **optimum moisture saturation levels** for repair bond strength would lie somewhere between 55 to 90 % RH

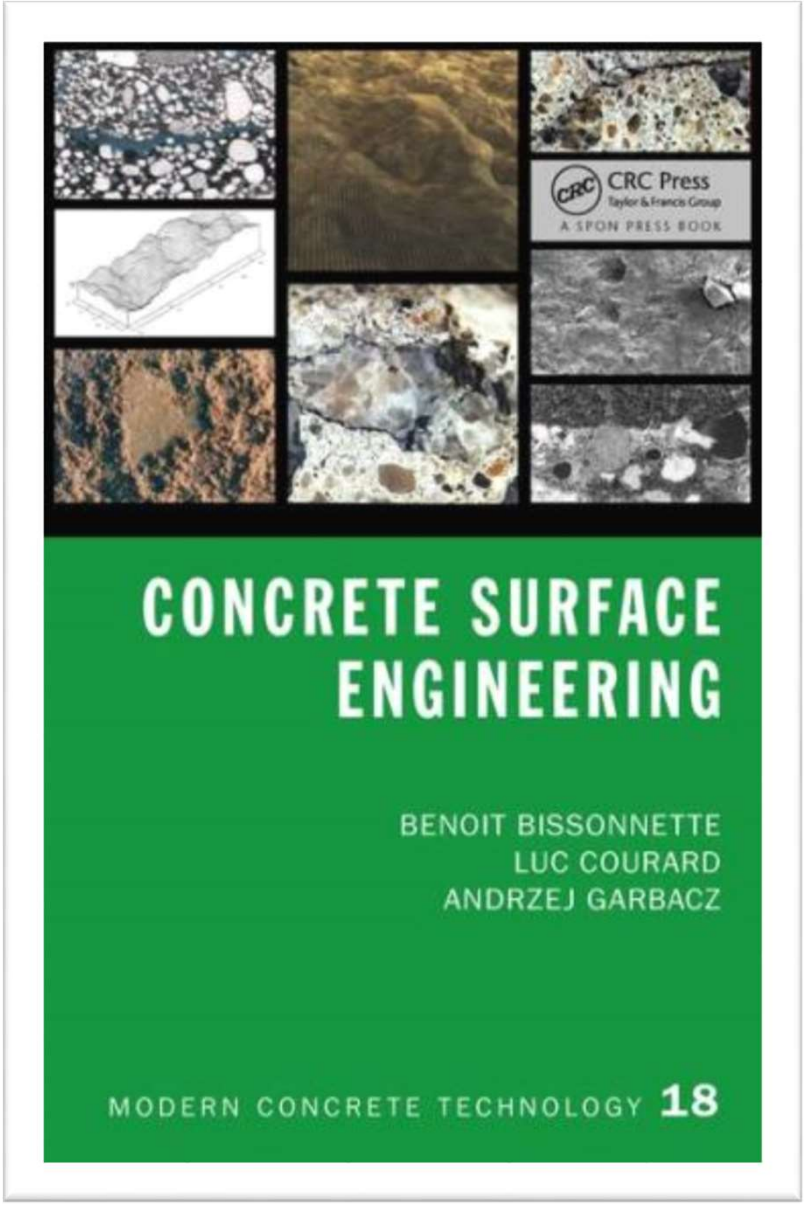
Conclusions

- A guideline was recently published by the U.S. Bureau of Reclamation
- Final Report ST-2017-2886 -1
- www.usbr.gov/research/projects



Conclusions

- Concrete Surface Engineering, CRC Press



Acknowledgements

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