Guidelines for concrete surface preparation: 10 years research and experience

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Is that repair?

Somewhere in the world …

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

Mechanical interlocking?

Good wetting?

Bad wetting!
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

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)

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)

![Bar chart showing avg. pull-off cohesion strength (MPa) for different concrete removal techniques and substrate strengths.](chart.png)
Results and analysis

- Evaluation of bond strength
  - Pull-off testing (tensile bond strength)
Results and analysis

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

![Graph showing bond strength vs. roughness half-amplitude](image)

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)

![Graph showing the relationship between average direct tension bond strength (MPa) and roughness half-amplitude (Ra mm).]

[Image of materials or samples with numbers 1, 2, 3, and 4.]
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)

Results and analysis

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

![Graph showing the relationship between saturation level and average pull-off bond strength. The graph plots saturation level in the substrate (%) on the x-axis and average pull-off bond strength (MPa) on the y-axis. Two lines represent dry slurry and wet slurry, with the wet slurry line showing higher bond strength at saturation levels below 90%.](image-url)
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
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