Trends in Development of Repair Mortars for Concrete in the Czech Republic

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Faculty of Civil Engineering

Institute of Technology of Building Materials and Components

Brno University of Technology
27.000 students

- Faculty of Civil Engineering (BUT FCE)
- Faculty of Architecture
- Faculty of Chemistry
- Faculty of Business and Management
- Faculty of Electrical Engineering and Communication
- Faculty of Information Technology
- Faculty of Mechanical Engineering
- Faculty of Fine Arts

BUT FCE BRNO

Faculty of Civil Engineering

Statistical data

University and faculty founded: 1899

Number of academic teachers: 300
Support staff : 130

Number of students: cca 5500
Number of graduates: cca 600 per year

STUDY PROGRAMMES AND SPECIALIZATIONS

Civil Engineering

E Economics and Management in the Industry

K Constructions and Traffic Structures

M Building Materials Engineering

S Building Constructions

V Water Management and Water Structures

Geodesy and Cartography

Up to now the standard period of study:

Bachelor	4 years with the academic degree	**Bc.**
Master	1,5 years with the academic degree	**Ing.**
Doctor	4 years with the academic degree	**Ph.D.**

Faculty of Civil Engineering

Brno UT

Institute (Department) of Technology of Building Materials and Components

Main research topics

- Development of new types of progressive buildings materials
- Utilization of selected types of waste materials
- Durability monitoring
  - in common and corrosive environment
  - investigation methods
- Development of technologies for repair works

Development of new types of progressive building materials

- Concrete
  - Self compacting concrete SCC, light, dense, RPC, recycled concrete
  - PC and PCC grouts and mortars concrete technology
- Soil stabilization
- Polymer materials
  - Coating systems, screeds, adhesiveness,
  - PC and PMM - grouts and mortars
- Binders
  - Cement, lime
  - Gypsum products
  - Anhydrite screeds, alfa gypsum, etc.
- Ceramic
  - Heat resistance ceramic, bricks, blocks, tiles etc.
- Insulation materials

Utilization of selected types of waste materials

- Fly ash
  - from fluid and classic combustion
  - concrete, SCC, cement, ceramic tiles, ceramic bricks…
- FGD-gypsum (energy gypsum)
  - production of alpha-gypsum
- Waste foundry sand
- Wood waste particles
  - thermal insulation
- Ferrous dust
- Dust and washings from aggregate production
- Concrete debris - recycled concrete production

Utilization of selected types of waste materials

- **Grinding and cutting waste**
  - **Mineral**
  - **Polymer**
- **Slag**
  - **Blast furnace slag**
  - **Steelwork slag for cement production,**
- **Mineral dust and washings**
  - **waste powder for concrete production esp. for SCC**
- **Utilization of wastes in ceramics**
  - **Organic waste**
  - **silicate waste**
- many more

Co-operation with praxis

- Accredited Testing Laboratory (ATL)
  - Independent accredited laboratory
  - Established 2003
  - Testing of quality of building materials
  - Accredited testing of more than 50 different properties
  - The laboratory is issuing officially accredited certificates for tests results
  - Testing for research and also business purposes
  - Large number of equipments

Development of Repair Mortars for Concrete

1. DURABILITY OF THE CONCRETE AND REINFORCED CONCRETE CONSTRUCTIONS

REASONS OF THE CONCRETE CONSTRUCTION DEFECTS AND FAILURES

- a) Chemical effects
- b) Physical effects
- c) Mechanical effects

1.1 Reasons of the concrete construction defects and failures

a) Chemical effects:

- Aggressive chemicals,
- **Alkali aggregate expanse**,
- Calcium expanse,
- Magnesium expanse,
- **Sulphate expanse,**
- **Chloride expanse**
- Microbiologic effects.

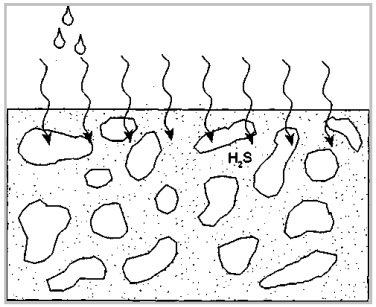


Fig.1: Microbiologic effects

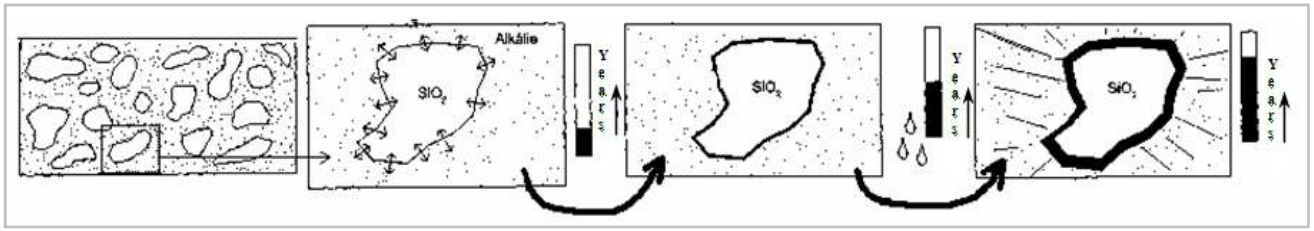


Fig.2: Alkali expanse

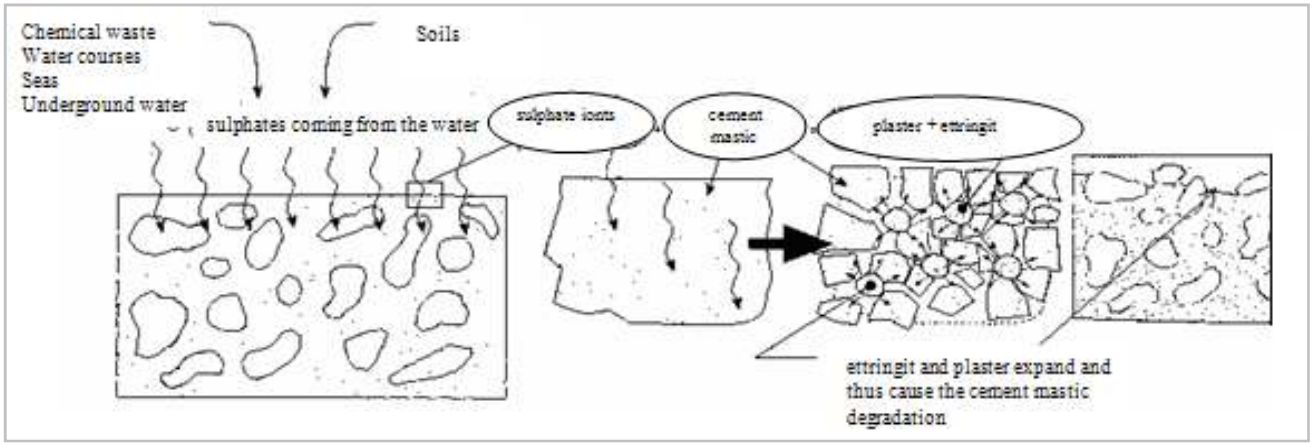


Fig.3: Sulphate expanse

1.1 Reasons of the concrete construction defects and failures

b) Physical effects:

- **Frost cycles**,
- **Temperature cycles**,
- Retraction,
- Erosion,
- Abrasiveness.

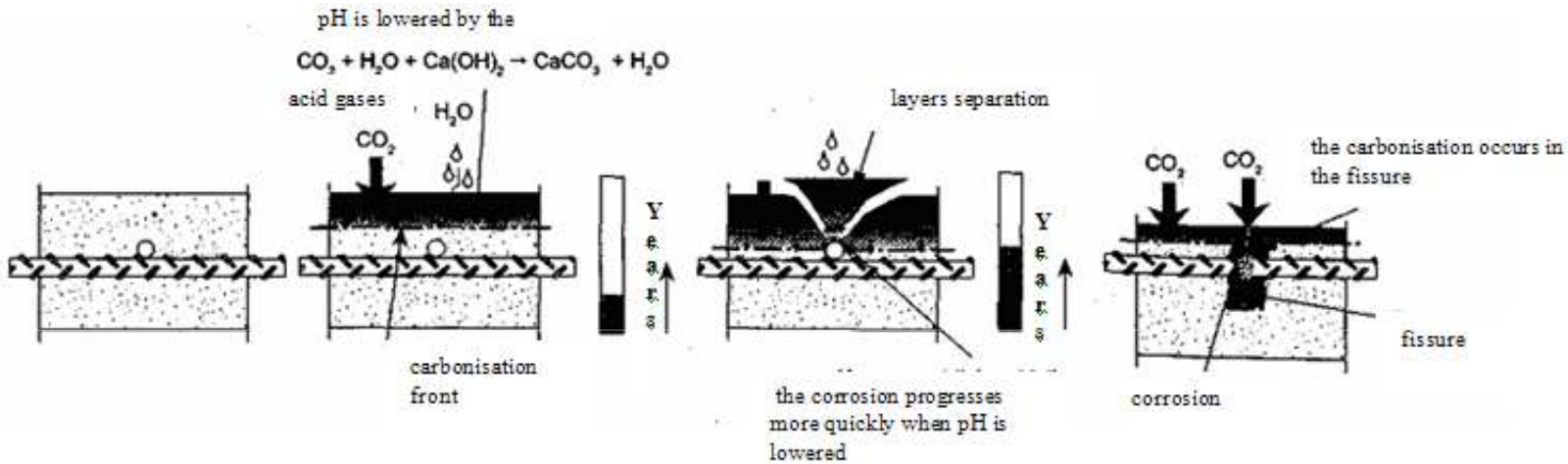
c) Mechanical effects

- Chock,
- Construction overload,
- Movement (settlement),
- Explosion or vibrations.

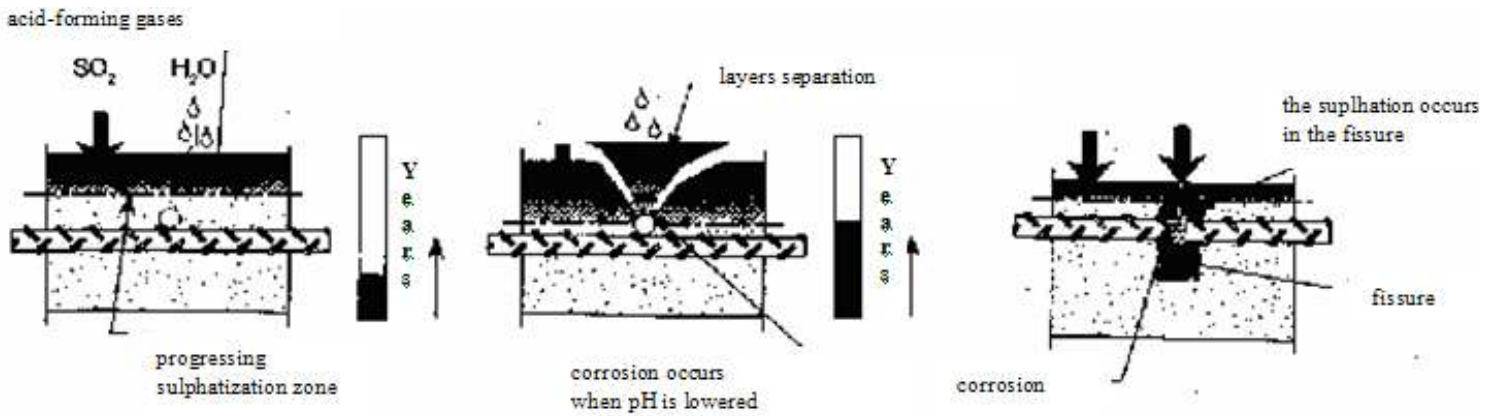
Fig. 4: Advanced stage of the reinforced concrete construction degradation.

1.2 Concrete reinforcement corrosion causes

a) Concrete carbonation

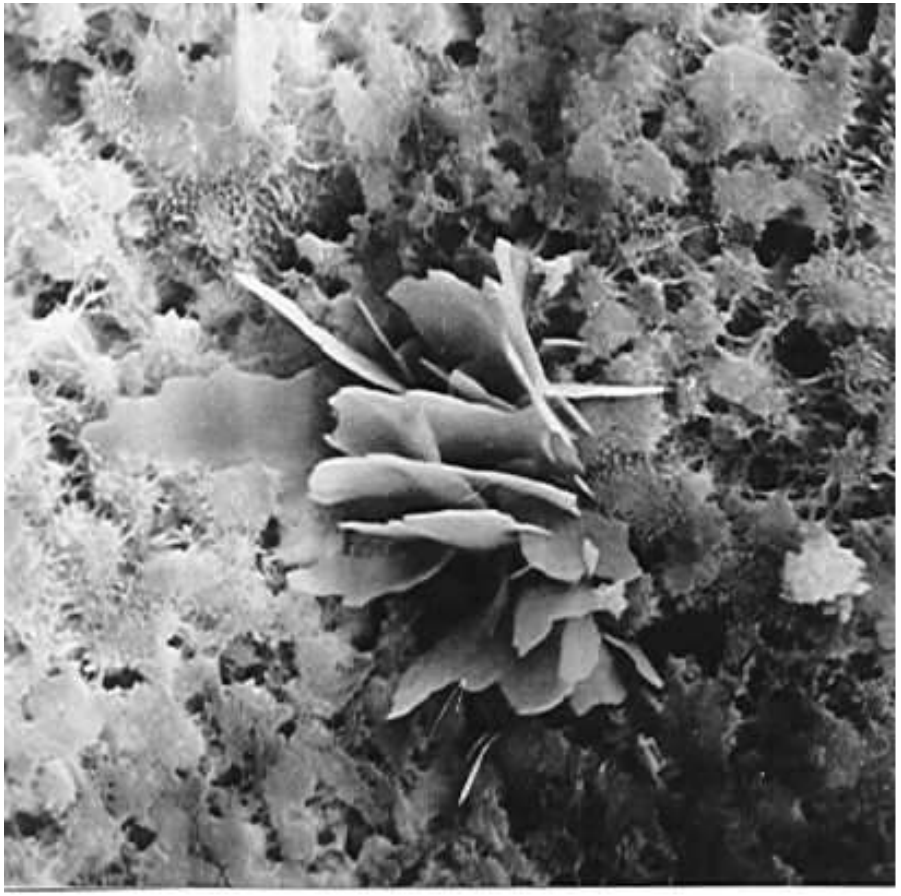


b) Concrete sulphation



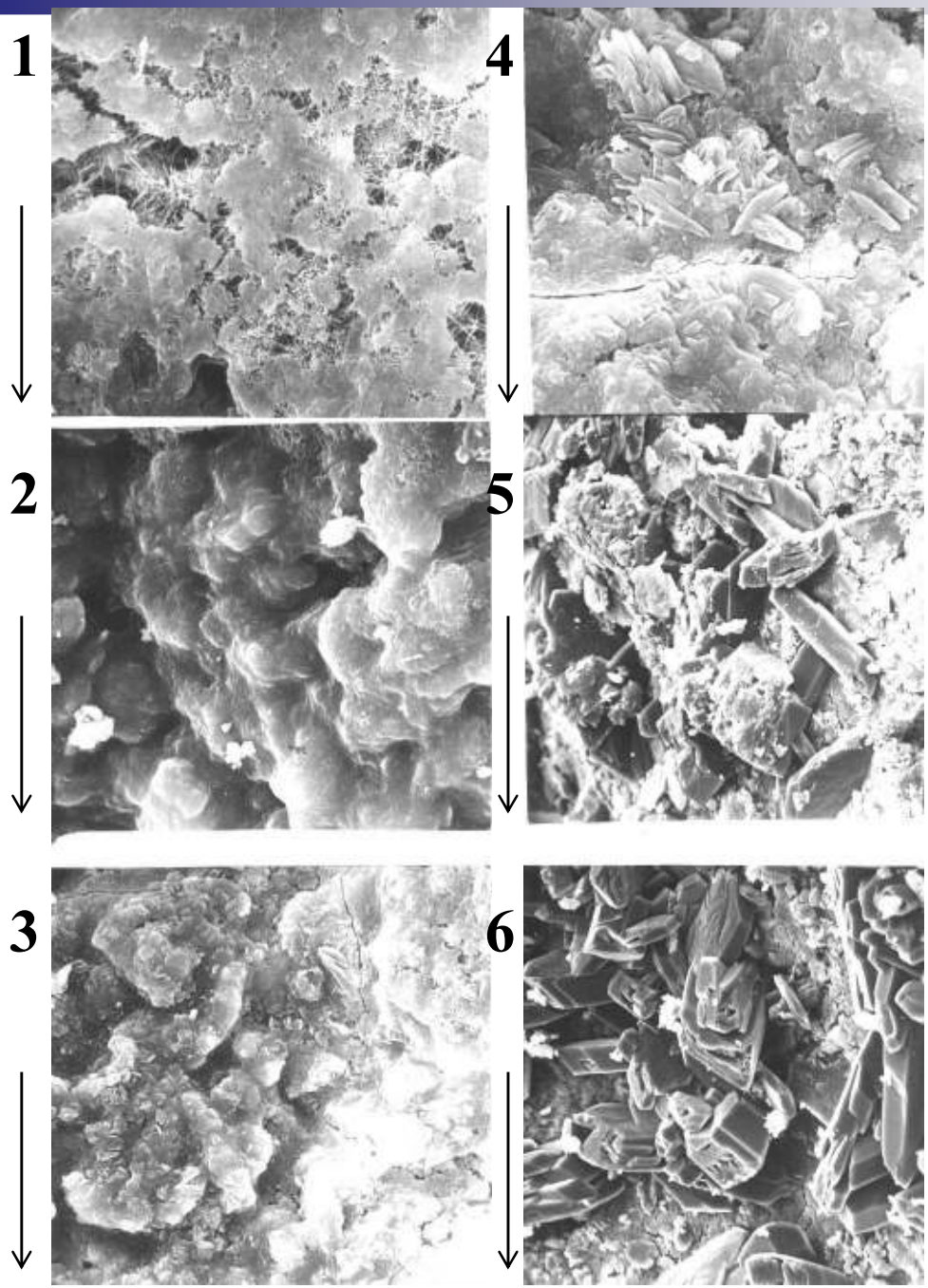
Aragonite clear prismatic crystals in cement stone microstructure.

Enlarged 2700 x.



Well developed kidney-shaped calcite crystals in the concrete. Furthermore a gel structure of cement stone is clear.

Enlarged 2200 x.



Mechanism of sulphation illustrated via picture of scanning electron microscope of the same enlargement (2.200x).

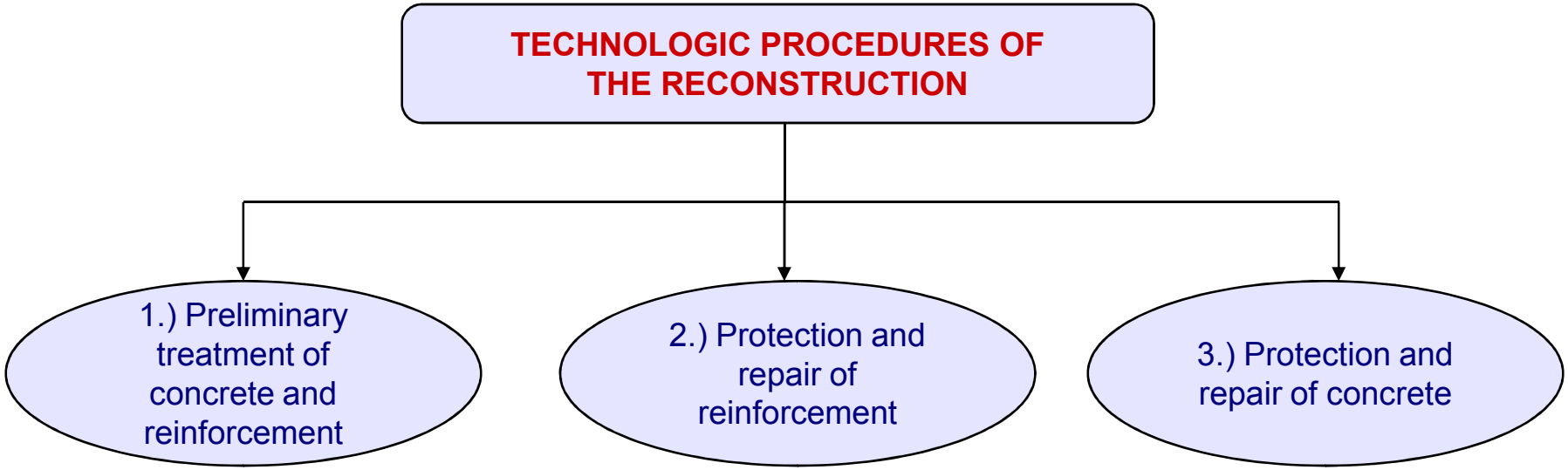
Damaged cooling tower before the reconstruction

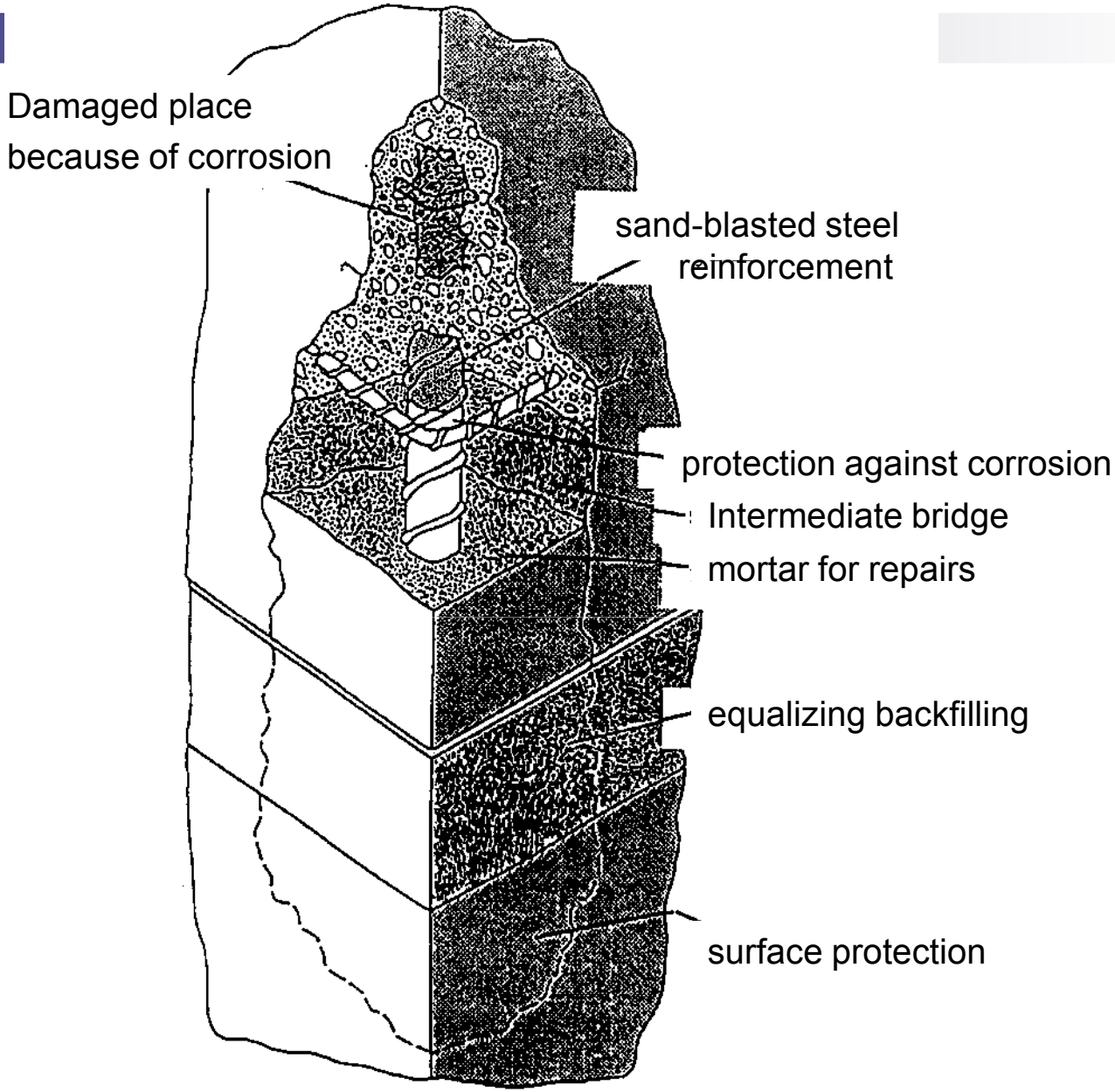
2. PROCESS OF THE CONCRETE AND REINFORCED CONCRETE CONSTRUCTION RECONSTRUCTION

The main goal of the concrete protection and repair:

- Slow down the corrosion processes,
- Renew original dimensions of the concrete elements and renew required aesthetic appearance,
- Prolong durability.

➡ Technologic procedures of the reconstruction can be divided into three basic stages:





Technological principle of reparation of degenerated steel concrete construction.

Problems in testing and developing polymer modified cement mortars (PMCM)

At the Institute of Building Materials and Components we perform:

- Tests of the properties of industrially produced PM mortars and the preparation for certification.

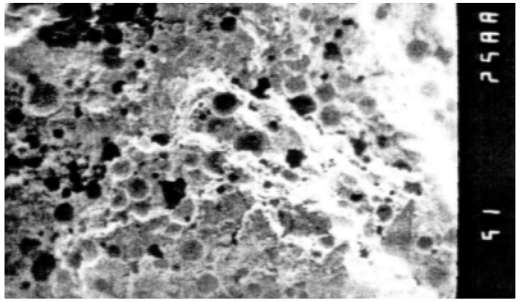
- Co-operation with common material producers (Sika, BASF, MC Bauchemie, MAPEI, STO, Stomix (CZ), Betosan (CZ) etc.)

- Development of PC and PM mortar formulations,

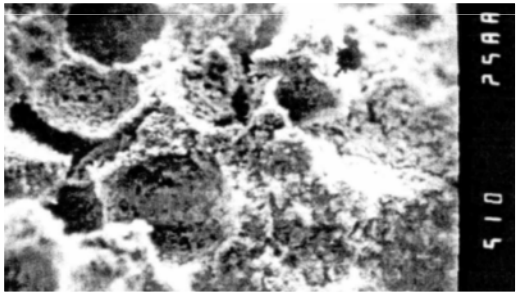
  - Mortars suitable for exposure to extreme conditions (chemically aggressive environment, high temperatures etc.)

  - Testing of alternative ingredients for production of PM materials (mortars suitable for repairing concrete structures, grouting etc. Components of industrial waste (fly-ash etc.) are used as alternative ingredients.

Examples of structural analysis of PM mortar using REM



Structural analysis of mortar modified with power-station fly-ash, mortar age 90 days, Enlarged 560 x.

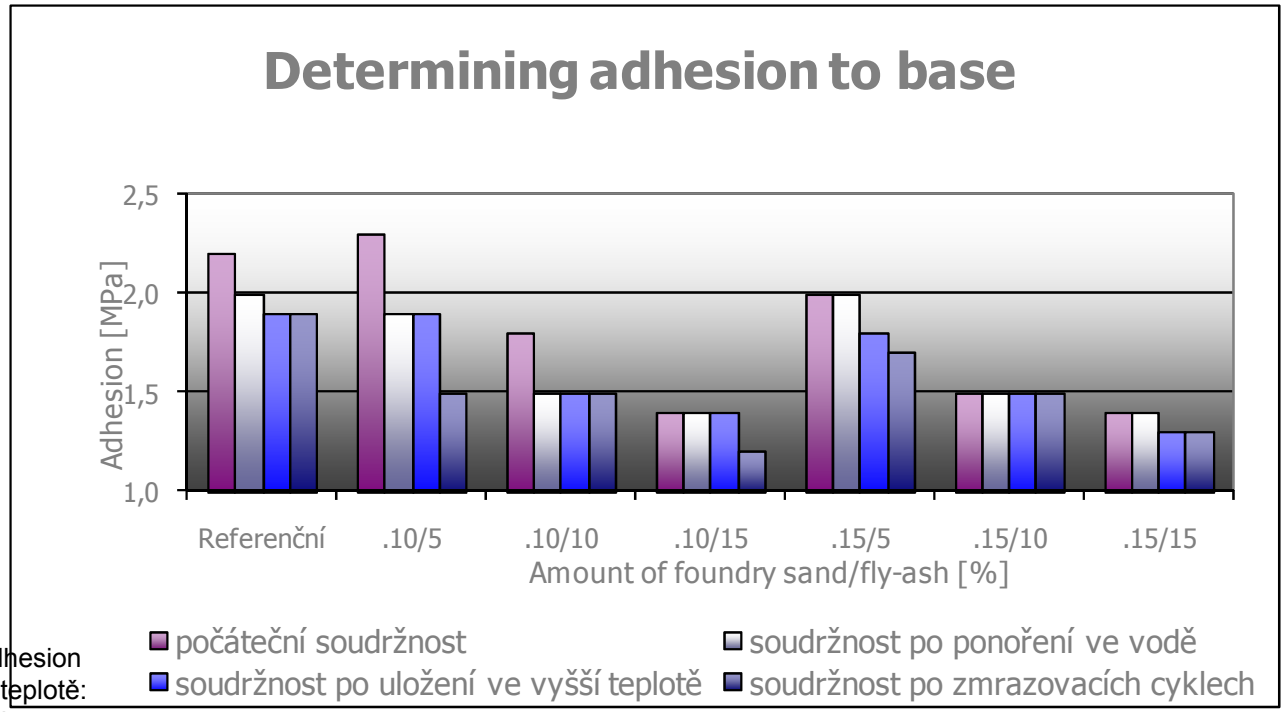


Fine porous structure of PX mortar containing power-station fly-ash, mortar age 90 days, Enlarged 1200 x.

Detail of pore, hexagonal portlandite crystals are clearly visible, age 90 days, mortar age 90 days, Enlarged 1200 x.

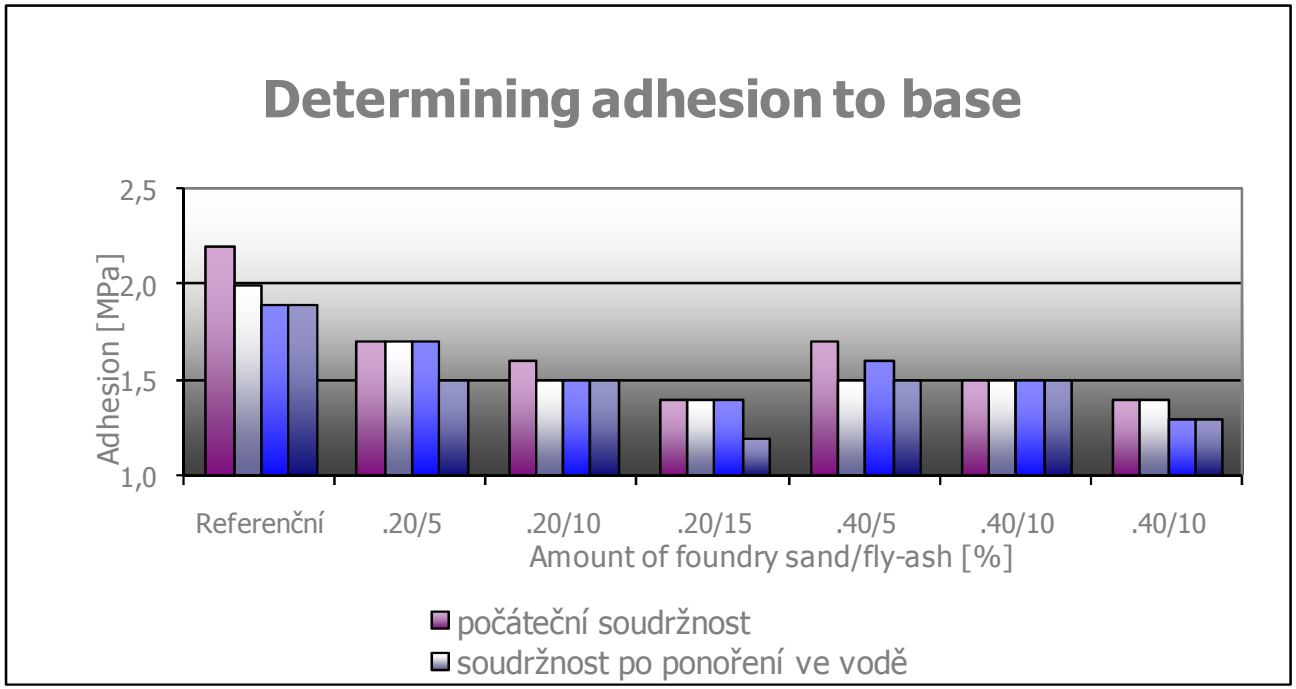
Example of testing PM mortars based on waste products – mortars developed for repairing reinforced concrete structures

- replacement of filling and bonding system,
- waste – fly-ash (bonding agent substitution), foundry sand filler substitution,
- testing adhesion to surface under various exposure conditions (frost, submersion in water etc.)



Referenční: reference
Počáteční soudržnost¨: initial adhesion
Soudržnost po zložení ve vyšší teplotě:
Adhesion under exposure to higher temperature
Soudržnost po ponoření ve vodě:
Adhesion after immersion in water
Soudržnost po zmrazovacích cyklech:
Adhesion after frost cycle

Replacement of bonding agent and filler with 20 and 40% foundry sand



Evaluation:

- initial adhesion falls with increasing proportion of foundry sand and fly-ash
- highest adhesion demonstrated by mix with 20% replacement, lower for 40% replacement
- highest adhesion demonstrated by mixes initial adhesion
- lowest adhesion demonstrated by mixes after frost cycle
- lowest value demonstrated by mix with 20% replacement foundry sand and 15% fly-ash

2. PROCESS OF THE CONCRETE AND REINFORCED CONCRETE CONSTRUCTION RECONSTRUCTION

Fig. 5 and 6: Degraded outside shell of the chimney before the reconstruction.

Fig. 7: Outside chimney shell during the reconstruction - the reinforcement after the anticorrosion coating application.

Fig. 8: Outside chimney shell after the reconstruction.

2. PROCESS OF THE CONCRETE AND REINFORCED CONCRETE CONSTRUCTION RECONSTRUCTION

Fig. 9: Outside shell of the cooling tower before the reconstruction.

Fig. 10: Outside shell of the cooling tower after the reconstruction.

Fig. 11: Reinforced concrete double pole before the reconstruction – after the preparation (rusty concrete is removed and cleansed, the rusty reinforcement layer is removed).

Fig. 12: Reinforced concrete double pole after the reconstruction – after the anticorrosion coat and repair mortar application.

3. DEFECTS AND FAILURES OF THE PERFORMED RECONSTRUCTIONS

Main problems of repair materials:

- Problems and failures of the anticorrosive reinforcement protection,
- Problems and failures of the adhesive bridge,
- Problems and failures of the repair materials,
- Problems and failures of the surface protective systems (Figures 13 – 18)
- Problems and failures of the special materials for water proof provision,
- Problems of injections and filling materials.

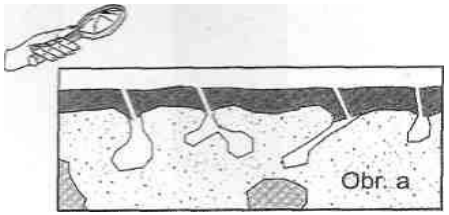


Fig.13: Craters and fissures

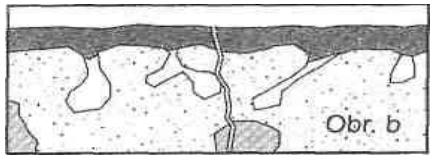


Fig.14: Origin of the consequential fissures

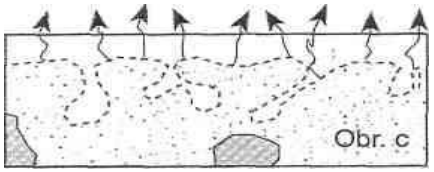


Fig.15: Surface protection losses

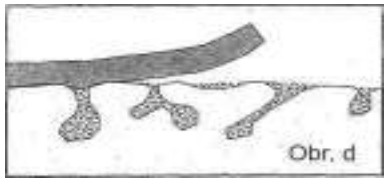


Fig. 16:Coherence rupture

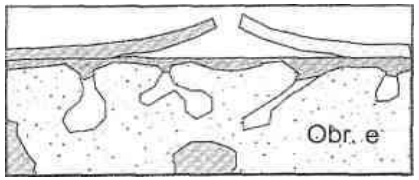


Fig. 17: Rupture of the coherence between the layers

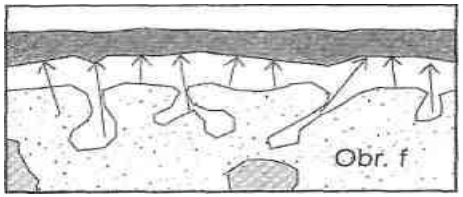


Fig.18: Coherence rupture due to the humidity closed under the coating

Reconstruction defects in practice

Cooling tower - 2 months after reconstruction:

Fig. 19 and 20: Wrong realization of the outside shell of the cooling tower reconstruction .

Cause of reconstruction failure:

- Fig. 19 - No treatment of the corroded reinforcement before the reconstruction
- Fig. 20 - The insufficient treatment of the repair mortar after its application

Reconstruction defects in practice

Cooling tower – 13 years after reconstruction:

Fig. 21 and 22: Outside shell of the cooling tower approx. 13 years after the reconstruction

Cause of reconstruction failure:

- Fig. 21 - missing protection paint ⇨ the peeling concrete surface and the corroded reinforcement detection
- Fig. 22 - water leaking in the shell ⇨ the leaches and salt efflorescence

Reconstruction defects in practice

Cooling tower – 13 years after reconstruction:

Fig. 23 and 24: Inside shell of the cooling tower approx. 13 years after the reconstruction.

⇨ the peeling surface, corroded reinforcement, salt efflorescence and presence of the unwelcome algae.

Thank you for your attention.