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COMBINED WHILE-DRILLING TECHNIQUES FOR THE ASSESSMENT OF THE FIRE DAMAGED CONCRETE COVER

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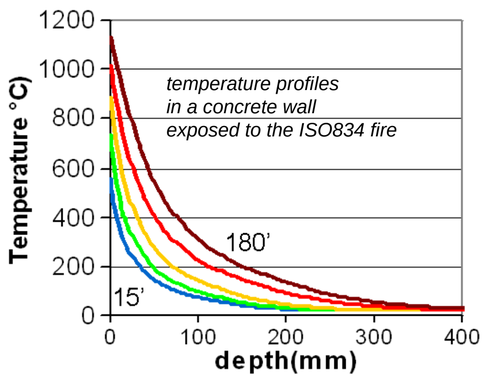
1) The assessment of fire damaged concrete

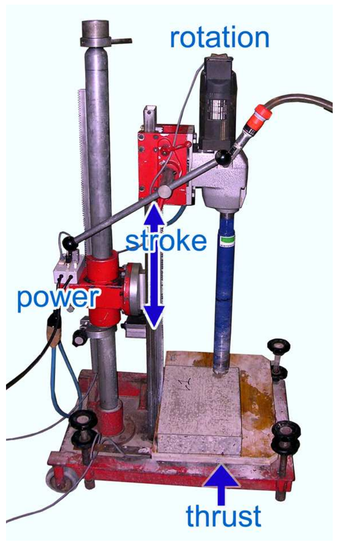
is quite a difficult task because of the steep temperature gradients undergone by the material (it is strongly layered)



2) Point-by-point analysis of cores

is a common approach to this problem

- Small scale mechanical testing
- Ultrasonic Pulse Velocity
- Dynamic Young's modulus
- Porosimetry
- Air permeability
- Micro-crack density analysis
- Weight increase of soaked samples
- Differential Thermal Analysis (DTA)
- Thermo-Gravimetric Analysis (TGA)
- Dilatometry (TMA)
- X-ray diffractometry
- Thermoluminescence
- Colorimetry
- Petrographic analysis
- Chemical analysis

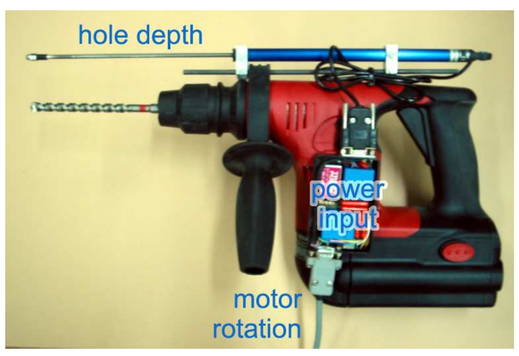


3) Core drilling as a way to scan the cover response

the drilling time (s/mm) under a constant thrust
is the most significant parameter to monitor

pros it is a sensitive technique *(~ Ultrasonic Pulse Velocity)*
the influence of the hard aggregate pebbles is smoothed
it can be combined with the analysis of the ensuing core

cons drilling a core is a demanding operation
possible detriment to the structure
the point-by point analysis of the core is time consuming



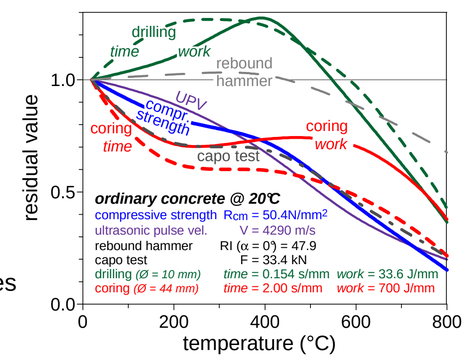
4) Damage detection via the hammer-drill resistance

the drilling work (J/mm) is the most significant parameter to monitor

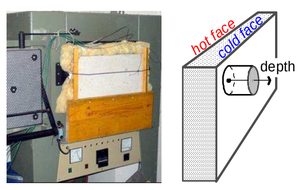
pros it is a very fast and easy technique *(one test in 10 seconds)*
no water or AC supply needed
little damage to the structure

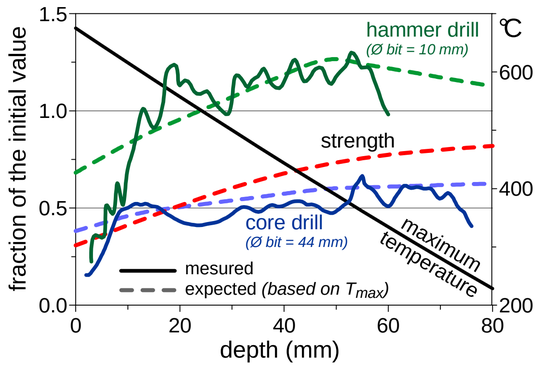
cons only a marked damage can be detected *(strength decay = 30-50%)*
sensitive to the hard aggregate pebbles *(more tests to be averaged)*
no undisturbed concrete samples are provided for laboratory analyses

sensitivity to a uniform thermal damage



detection of gradients in a concrete panel heated on one side

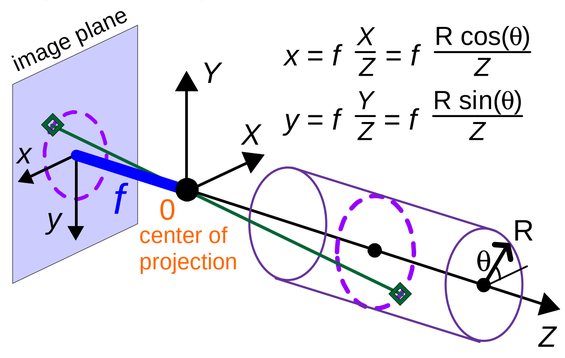




5) Combining the drilling resistance with other material analyses:

in the absence of an undisturbed concrete sample, the analyses can be performed on the remaining hole and on the concrete dust collected while drilling

5.1) Visual Inspection and colorimetric analysis of the drilled hole

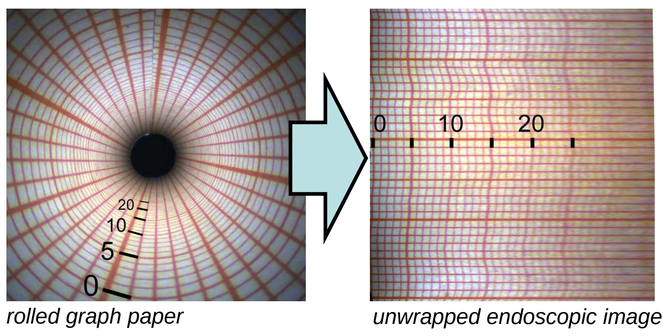


$$x = f\,\frac{X}{Z} = f\,\frac{R\cos(\theta)}{Z}$$

$$y = f\,\frac{Y}{Z} = f\,\frac{R\sin(\theta)}{Z}$$

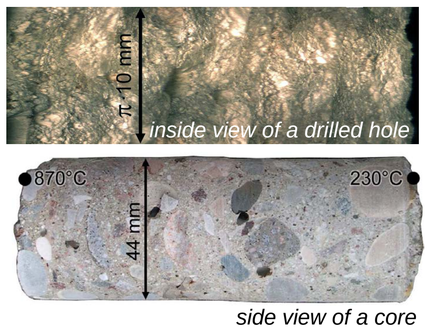
pinhole-model of the endoscopic image projection

a) unwrapping of the drilled hole endoscopic images



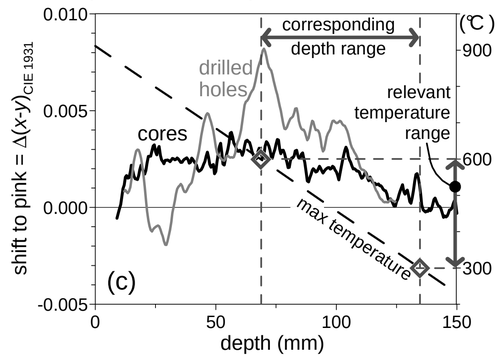
rolled graph paper *unwrapped endoscopic image*

b) colorimetric analysis of digital images



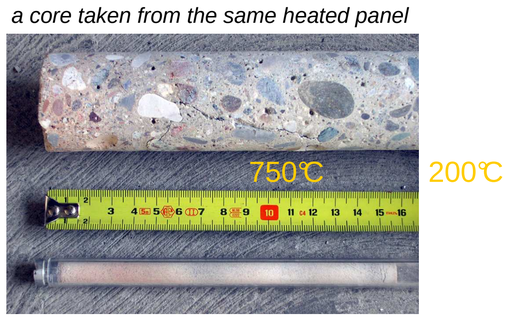
side view of a core

c) discoloration profiles



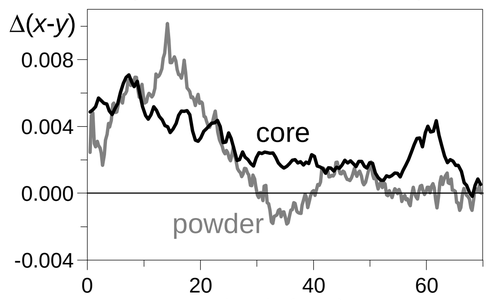
5.2) Colorimetric analysis of the powder

a core taken from the same heated panel



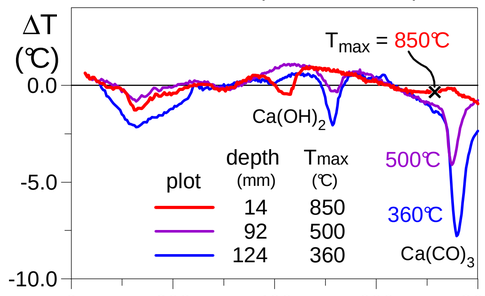
the powder sample in a transparent test tube

comparison between the two samples



5.3) Differential Thermal Analysis on the powder

DTA at different depth in a heated panel



6) General conclusions

The traditional approach based on the analysis of the drilled cores can take advantage at no extra cost of a proper monitoring of the drilling operations (*elapsed time per unit depth under a constant exerted thrust).*

The hammer drilling resistance is a fast and viable technique, with the limitation of a poor sensitivity to low levels of damage ($T_{max} \leq 500℃$).

Combining the drilling resistance with other material analyses is an interesting option to offset this limitation.
Though an undisturbed concrete sample is not available in this case, the remaining hole and the collected concrete powder can be the object of these further investigations.

7) Conclusions on the hole inspection and dust analysis

The colorimetric analysis of the drilled hole and the concrete powder leads to discoloration profiles that are comparable with cores.

The impracticality of neglecting the coarse aggregate in the analysis and the smaller size of the material sample are the reasons for the larger dispersion of the results.

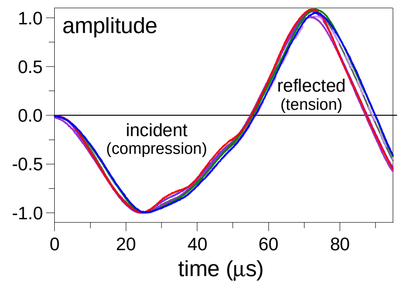
Though less rigorous compared to the normal laboratory practice, the Differential Thermal Analysis on the drilling powder is definitely far less demanding and maintains the ability to detect the main changes in the response of a concrete sample surviving a fire.

A systematic study on the reliability of these methods is necessary in order to factually merge different test results in the assessment of the fire damaged concrete cover.

8) Future developments

Colour measurement directly in the drilled hole
(optic fibres, special probes, etc)

Improvement of the sensitivity to low damage levels of the hammer-drilling technique by monitoring other parameters
(e.g. propagation of elastic waves during the drilling process)



strain waves in the drill bit