Innovative testing solutions for safeguarding architectural heritage

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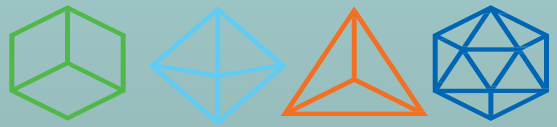


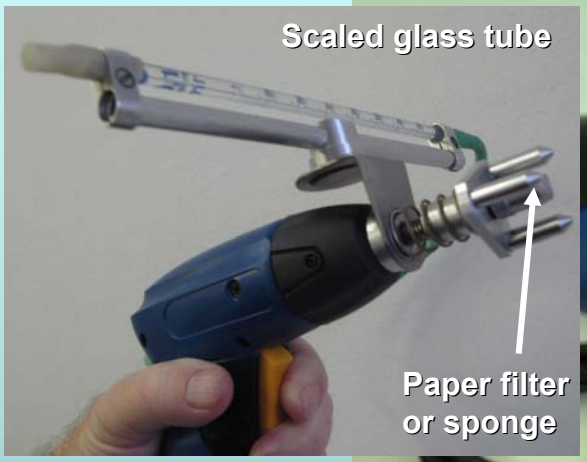
Acknowledgement to my research collaborators:
ing. Z. Slížková, Ph.D., ing. J. Valach, Ph.D., ing. D. Vavřík, Ph.D.
Ing. M. Kloiber, Ph.D., J. Lesák (MSc), ing. P. Zíma, ing. I. Jandejsek

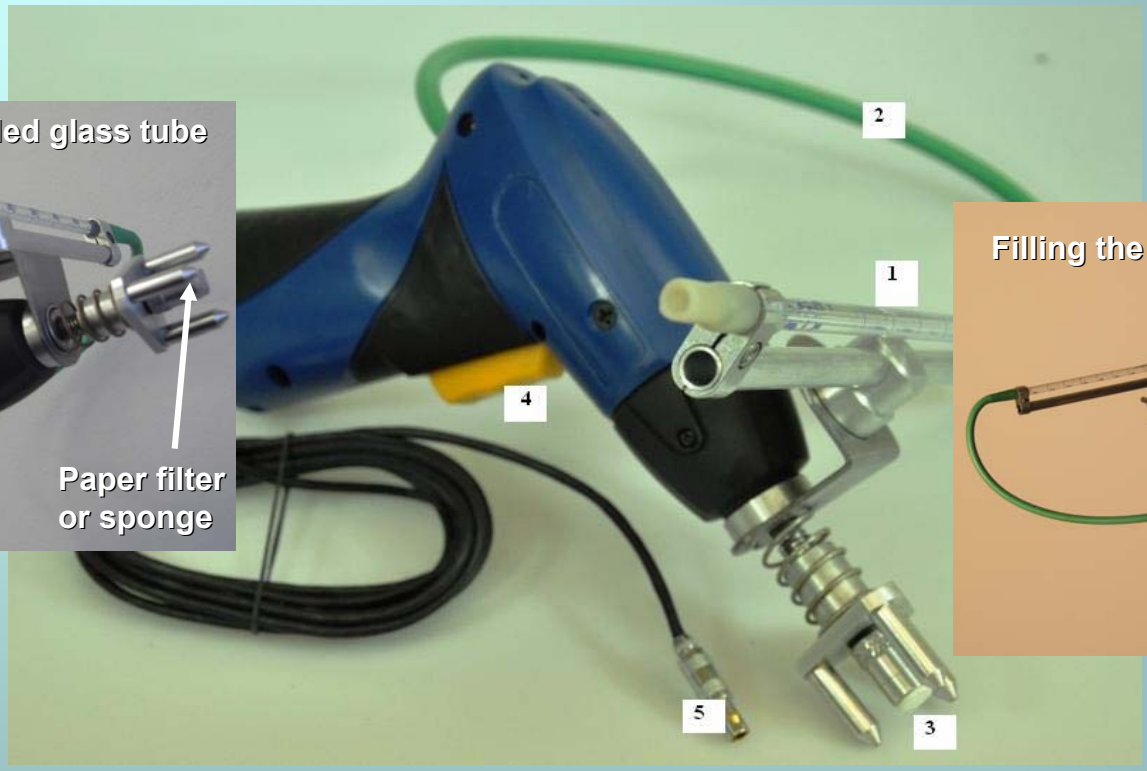
Water uptake *in situ* measurements

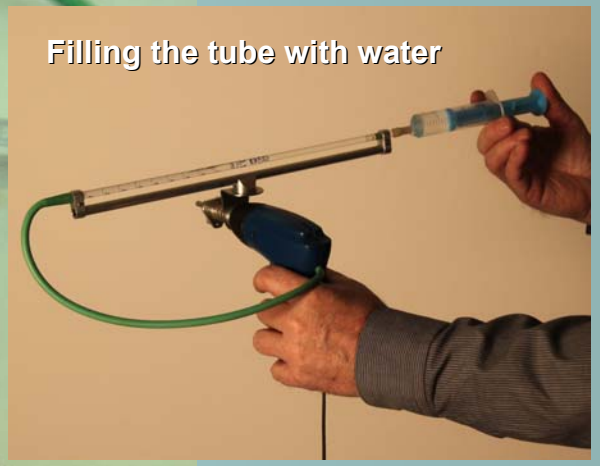
Water uptake **is measured in situ typically by means of the so called Karsten tube, which brings about many difficulties:**

- **problems with fixing a heavy glass tube on vertical surfaces,**
- **impossible measurements on inclined surfaces and ceilings,**
- **problems with sealing the contact ring area,**
- **a need for two operators – one who follows the water movement in the measurement tube together with stop-watch**
- **and another who records readings,**
- **soiling of surface with the sealing putty.**

Micro-tube for digitized water uptake measurement



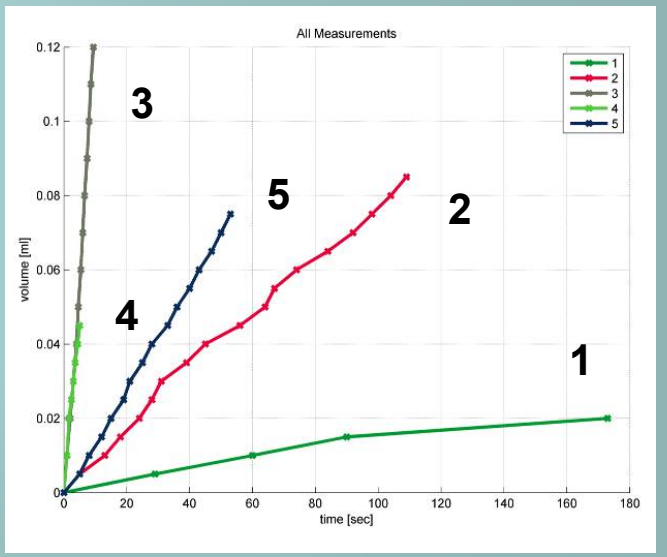


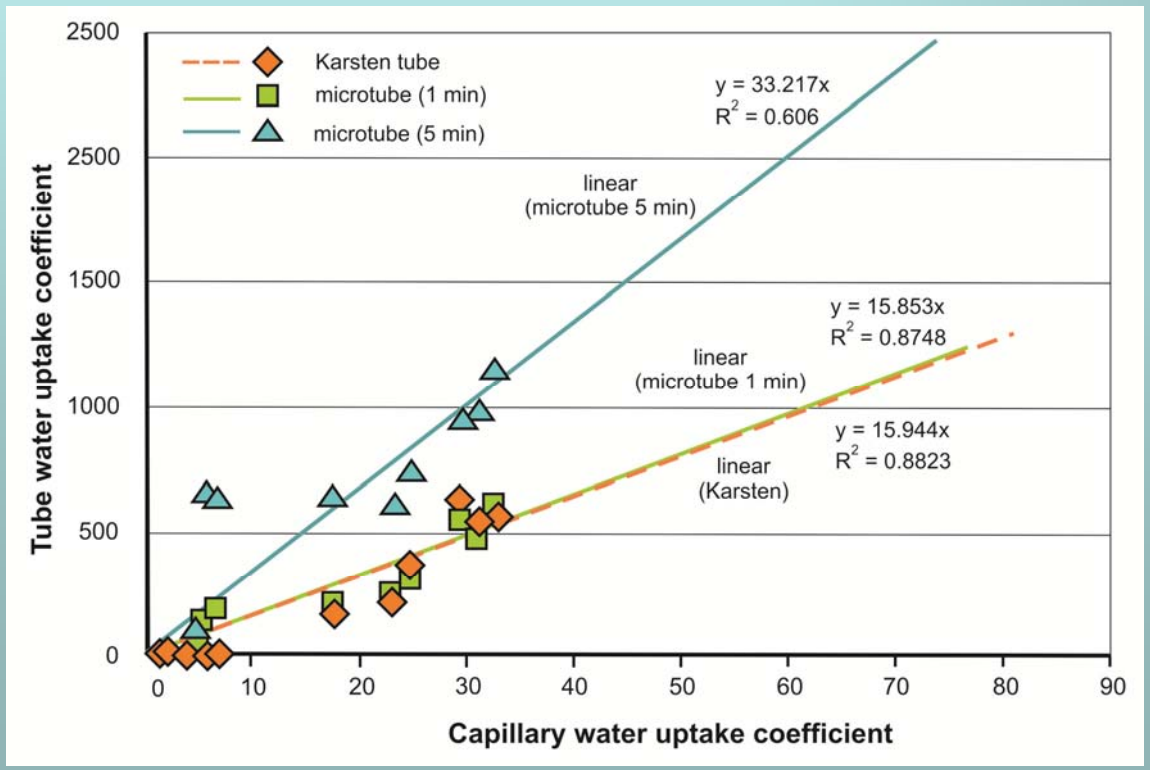


Mechanical part consists in 1 – scaled capillary tube in a tube holder adjustable in horizontal or vertical position (swivel connected), 2 – connecting plastic hose, 3 – outlet hinged head with a three point support, 4 – switch for manual recording data, 5 – connection cable to data storage unit

The innovated micro-tube method enables

- easy operation
- fast operation
- easy storage of data and further elaboration
- measurement on arbitrarily inclined surfaces
- considerate application (no soiling)
- measurement on highly curved surfaces
- measurement in a dense array of points





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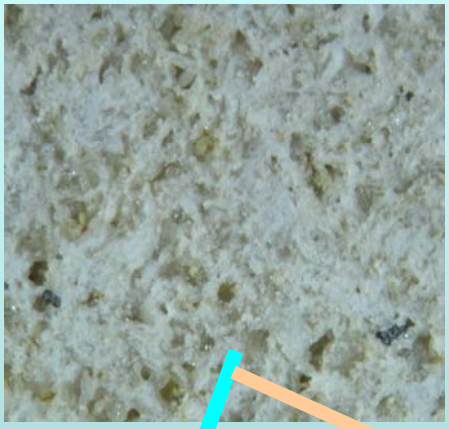
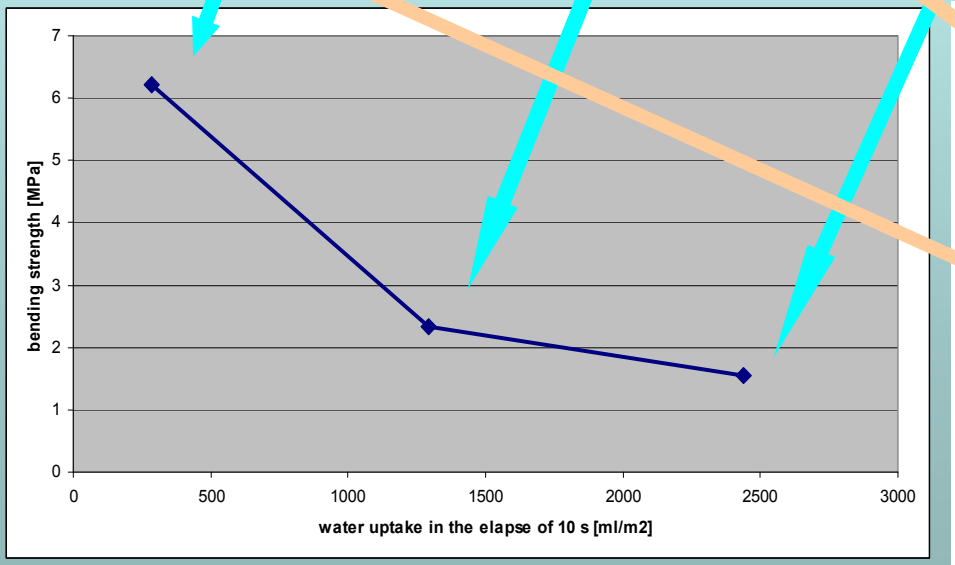
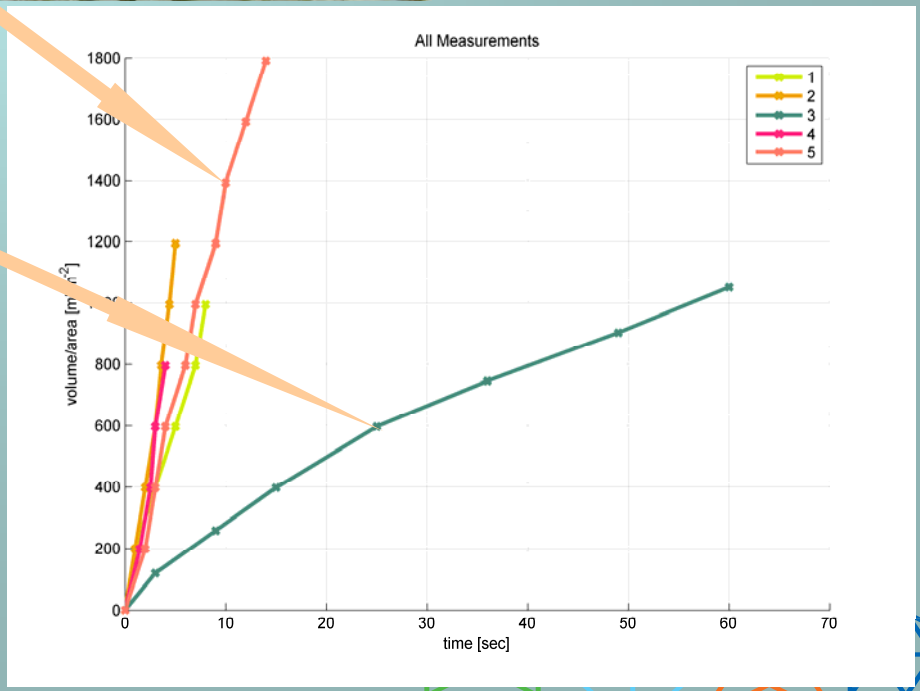
Correlation of micro-tube water uptake and bending strength of detritic limestone with various porosity



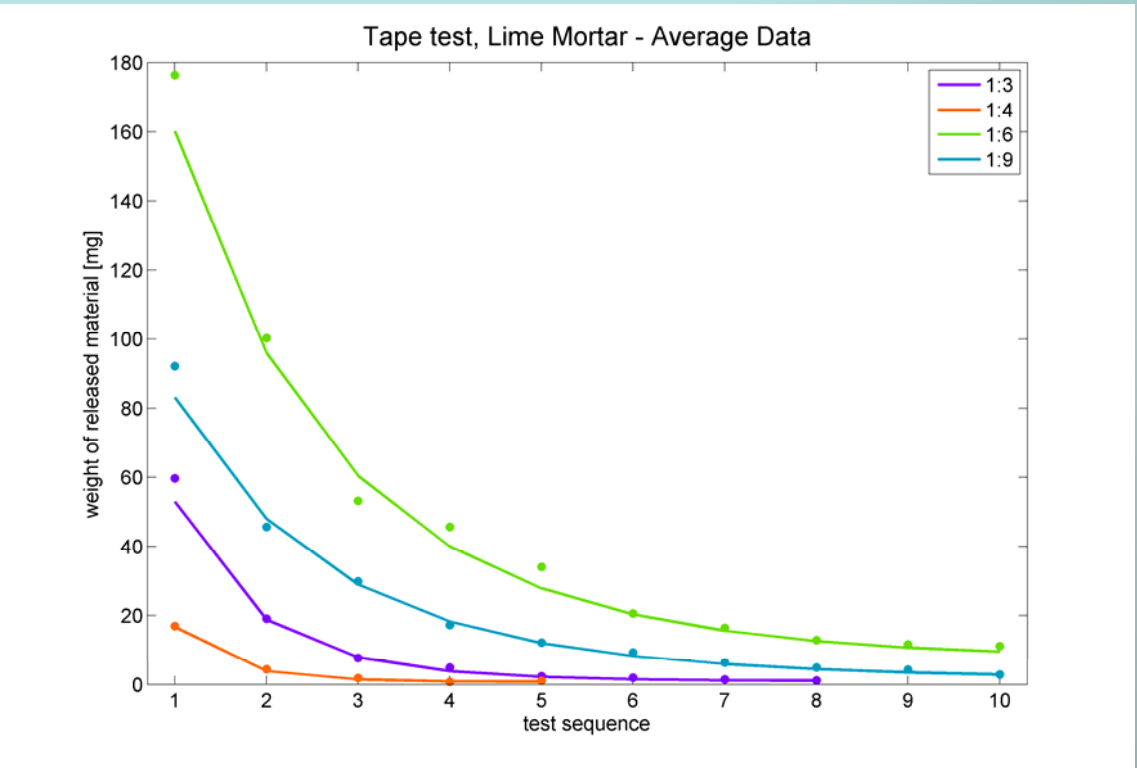


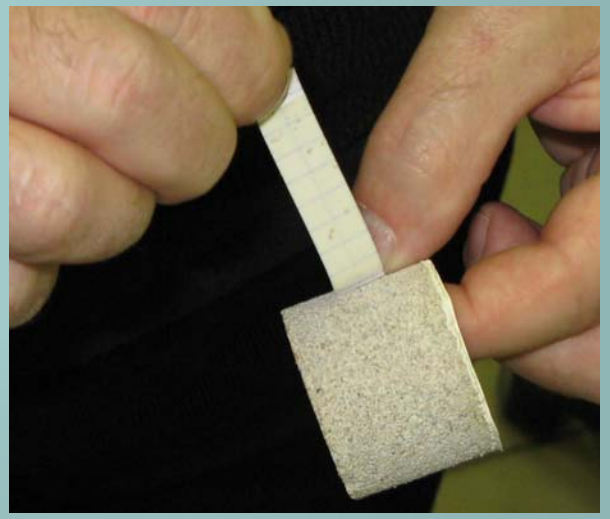


Peeling („Scotch tape“) testing

The main doubts about the method lay in the fact that the loosen particles on the tested surface do not represent the „near surface“ cohesion characteristics of the tested material.

If we repeat the peeling on the same place we observe a decrease of the released material and thus we see an apparent consolidation effect, which is false.





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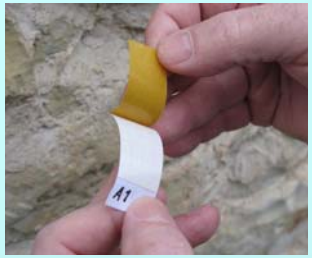
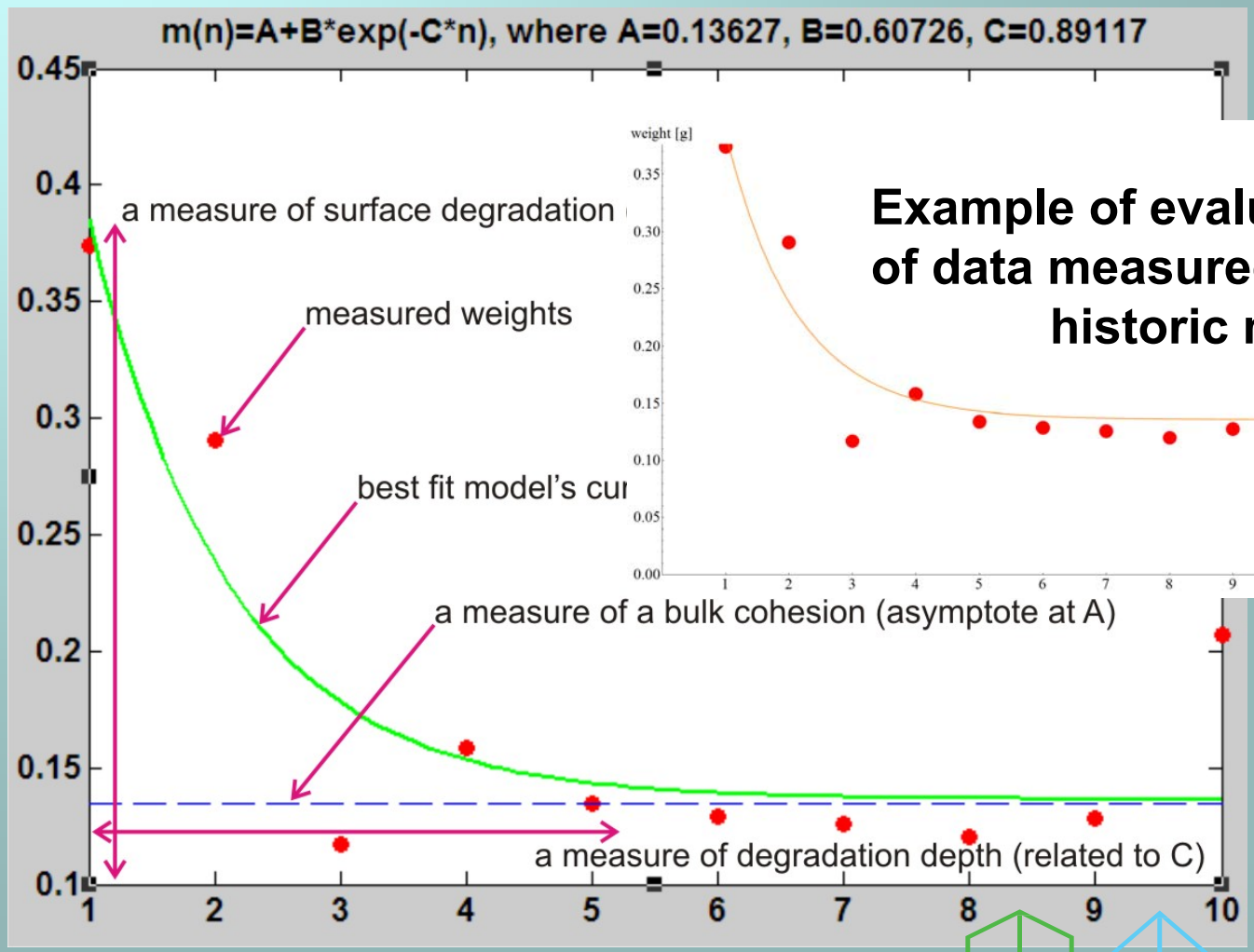




Measurement and evaluation of data

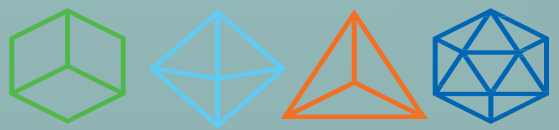
If the data converge to some positive value a nonlinear approximation model is adopted $m(n) = A + B * e^{-C*n}$



Example of evaluation of data measured on a historic mortar

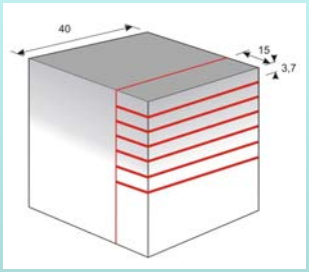
Conclusion to the peeling testing

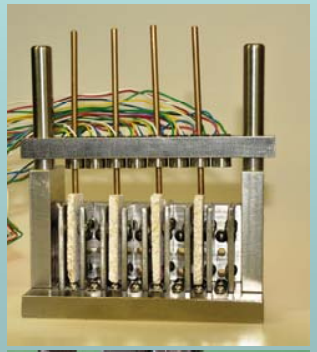
- **The method is on one side quite sensitive to surface condition, on the other side one measurement does not give data for reproducible measurement of quantitative material (mechanical) characteristics describing state of material under the very near surface layer.**
- **It seems that the change of released amounts of material from the surface which had been repeatedly touched in any manner - by repeated peeling testing, by application of consolidation treatment, by cleaning – may make the peeling material characterization after any treatment not objective, uncertain and not reproducible.**
- **After repeated peeling the amount of released material starts to be almost constant.**
- **The amount of detached material mostly correlates with the bending strength of the tested mortars or stone.**
- **The method is well applicable for relative assessment of material cohesion characteristics.**

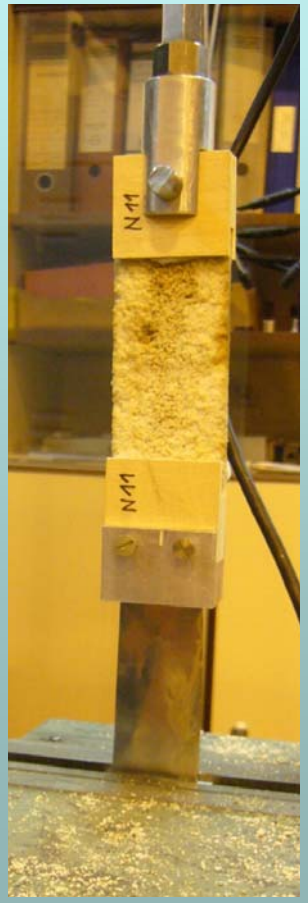


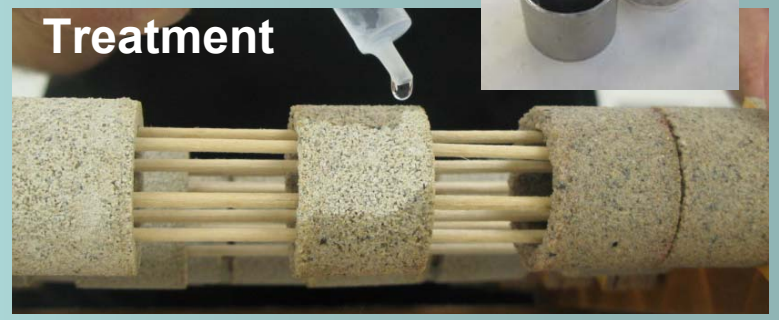
Testing of consolidation effects

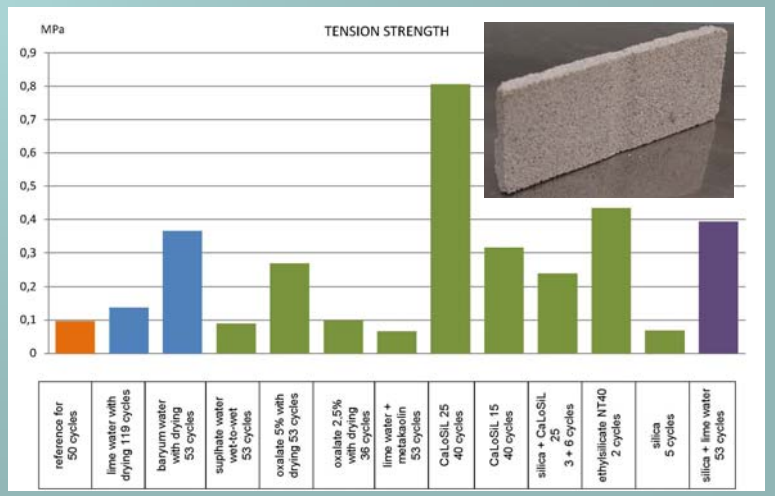
Effect of impregnation of stone along the depth profile has been traditionally tested on thin slices which enable determination of bending strength, modulus of elasticity, dilation coefficients and vapour permeability. For mortars, special thin-walled test specimens are used.



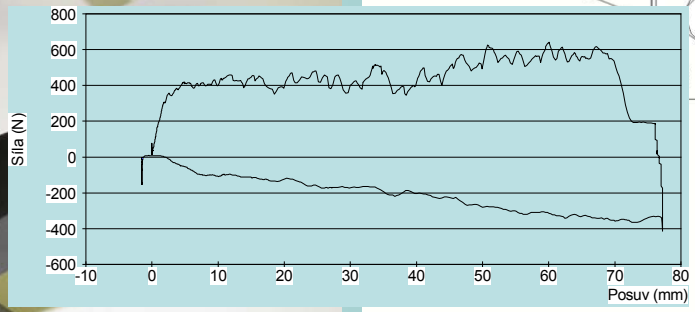


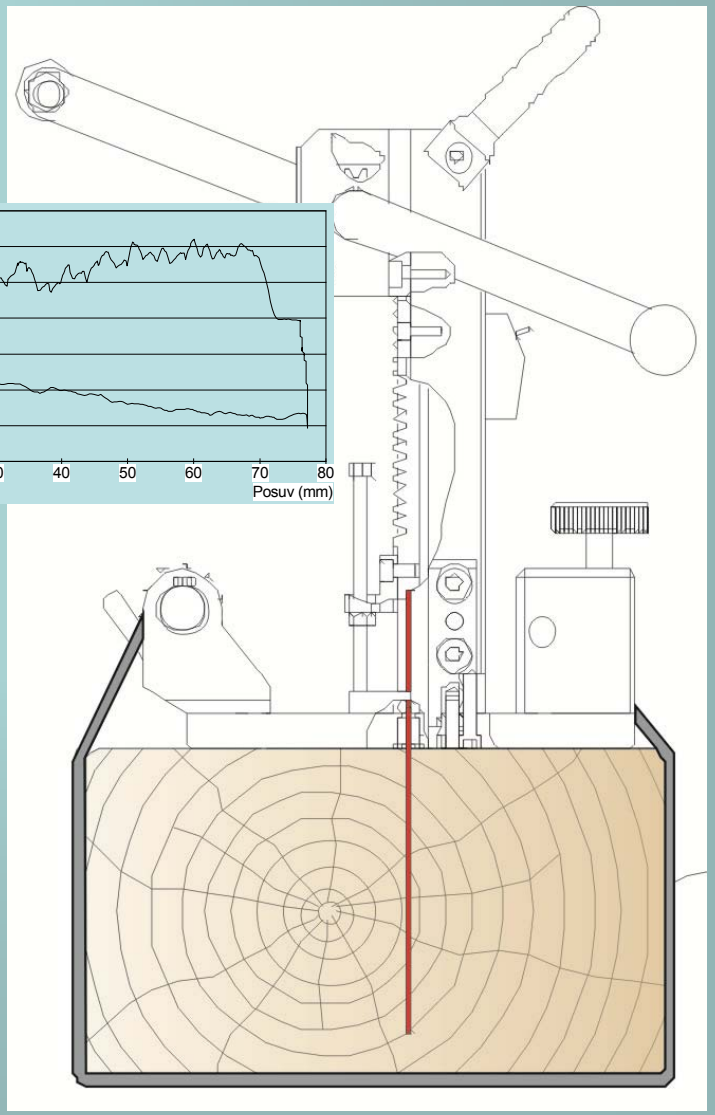




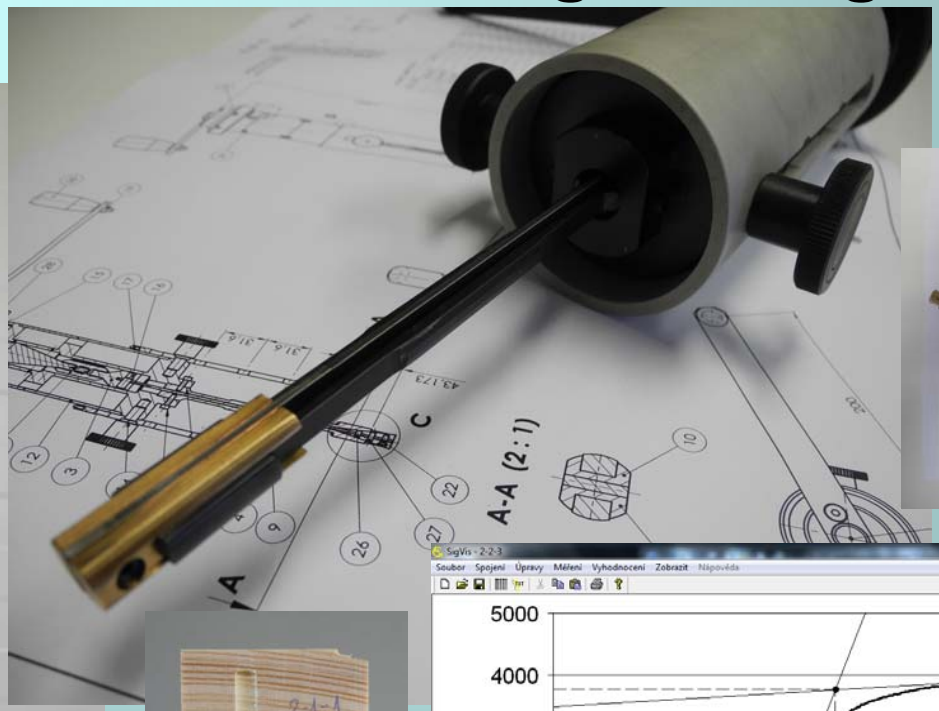


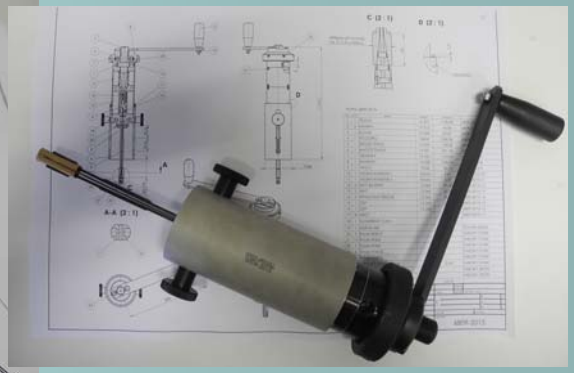
Testing of wood – driven rod & screw pulling

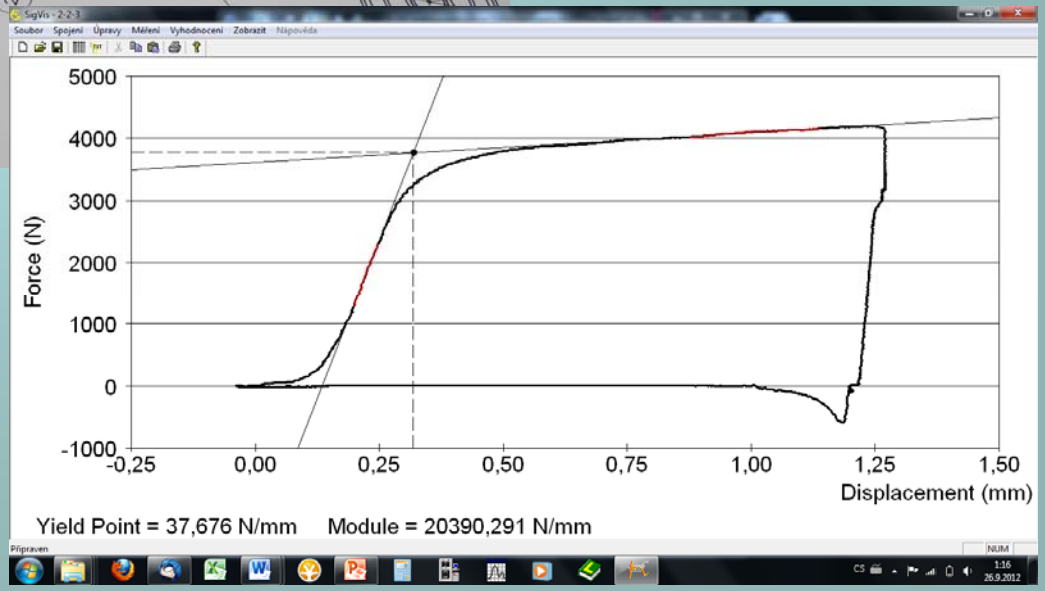




Testing of wood – strength along depth profile





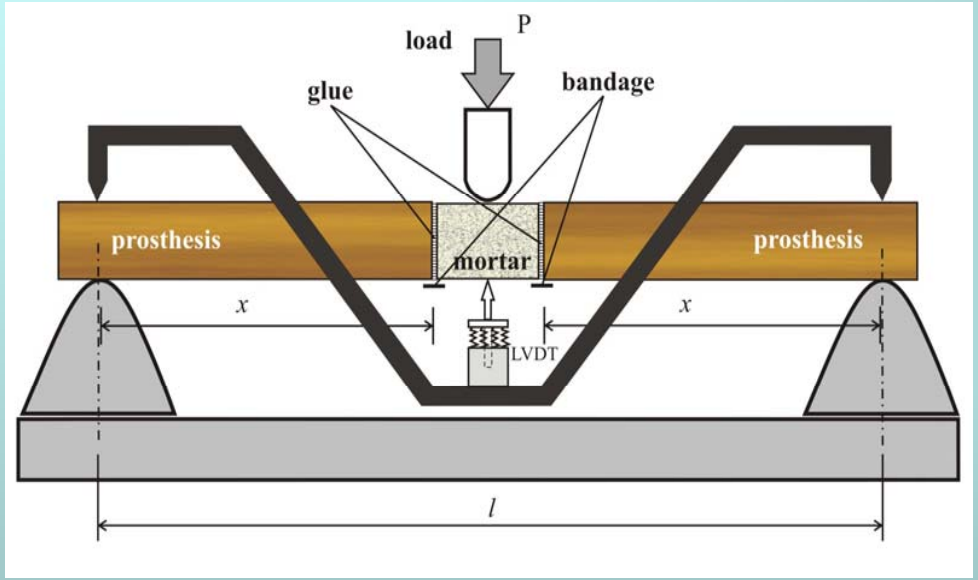


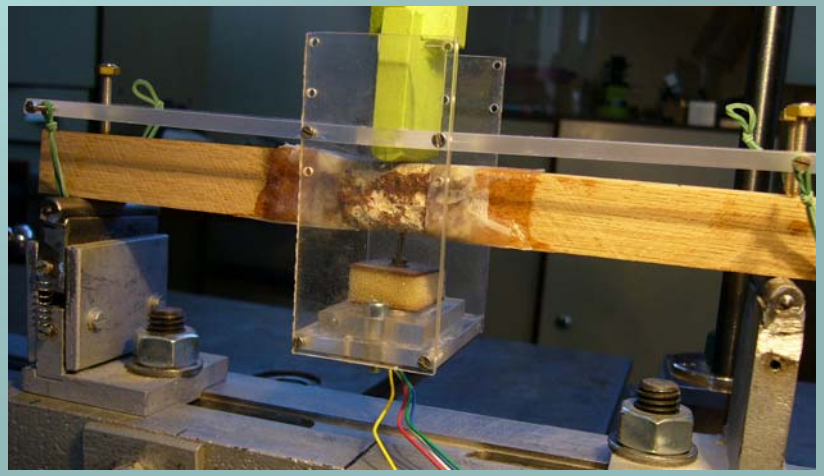
Testing of historic mortars - motivation

Specimens for testing ancient mortars of historic buildings are typically very flat - extracted from masonry bedding joints or from floors – & available in a small bulk

Testing of historic mortars

Non-standard specimen small sample testing of bending strength and Young modulus of elasticity

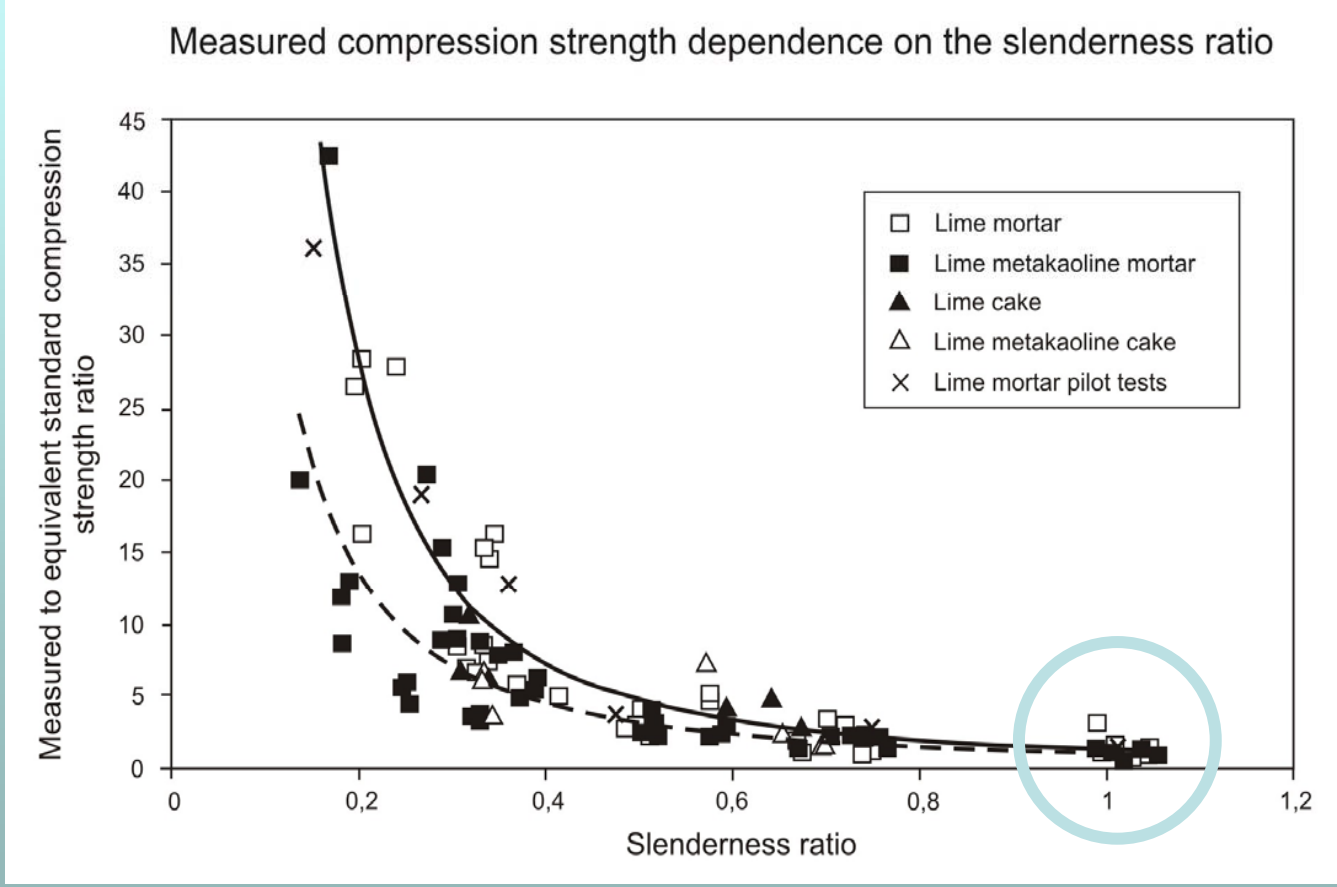


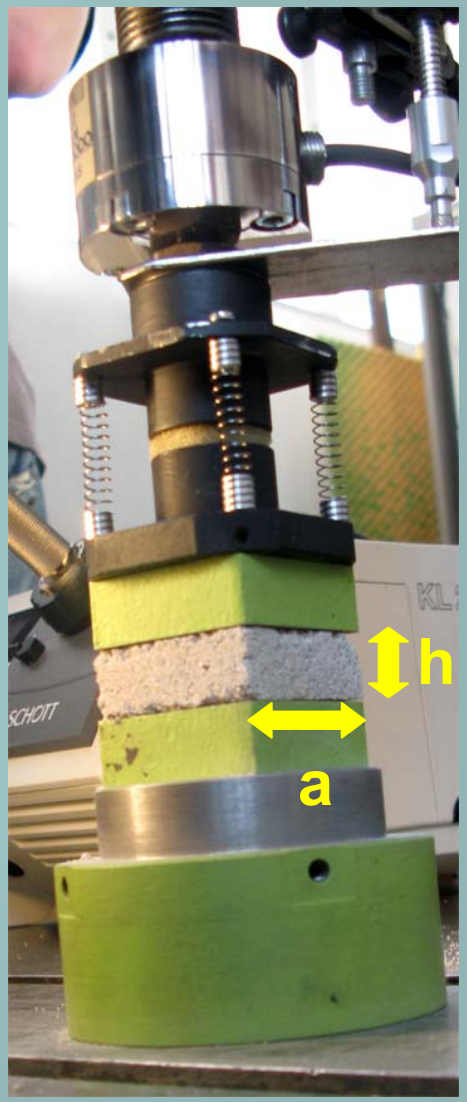


$$E = P (l - x) E J ((l - x)^2 + 6 (l - x) x + 12x^2) / 8 (6 y J E_1 J_1 - P J x^3)$$

Testing of historic mortars

Non-standard specimen small sample testing of compression strength





$$f_c = f_e\,(h/a)^{1,91}\ (h \le a,\ a = 40\ mm)$$

Digital image correlation - compression - modulus of elasticity

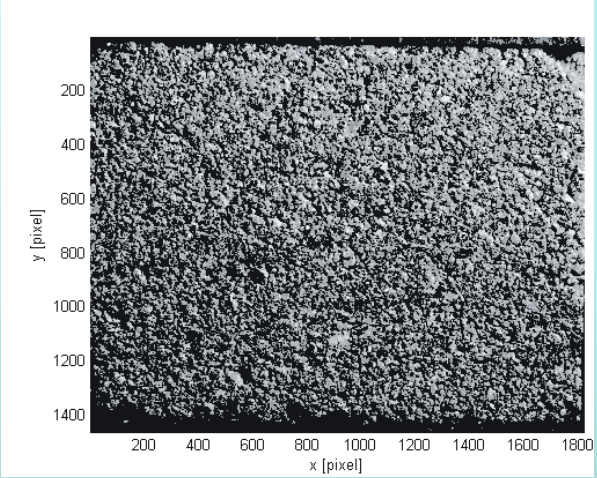
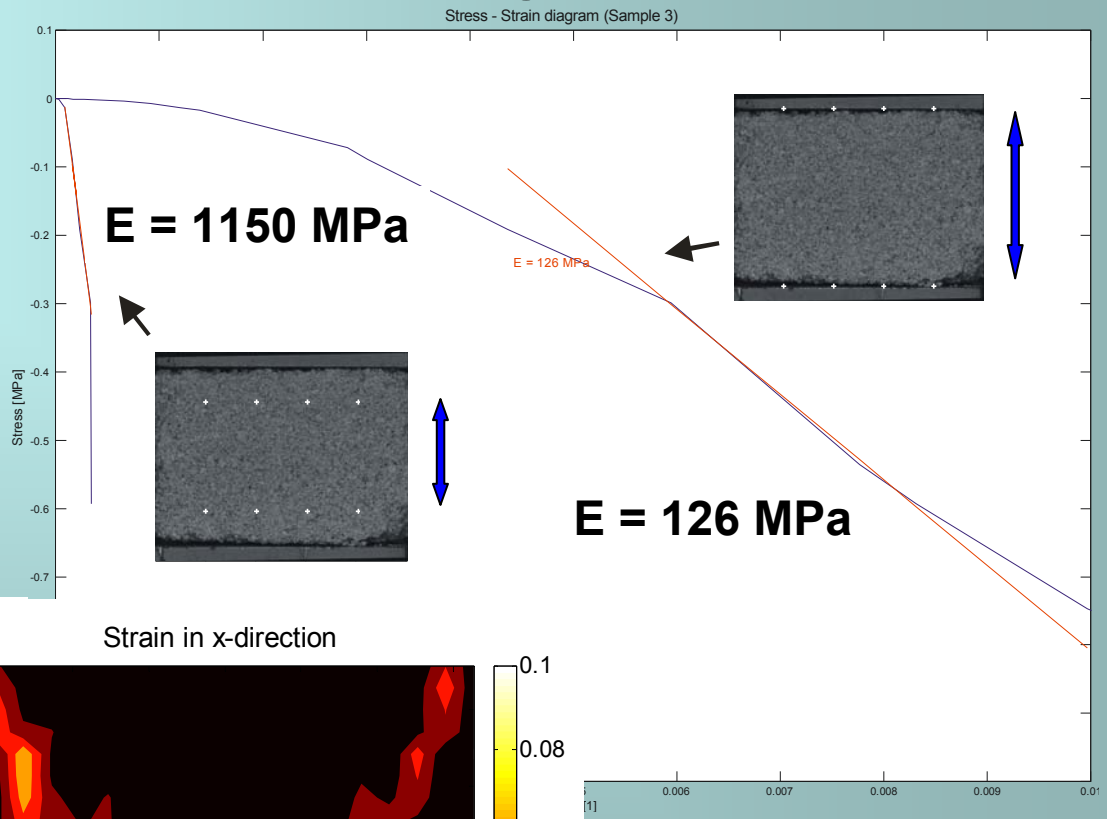
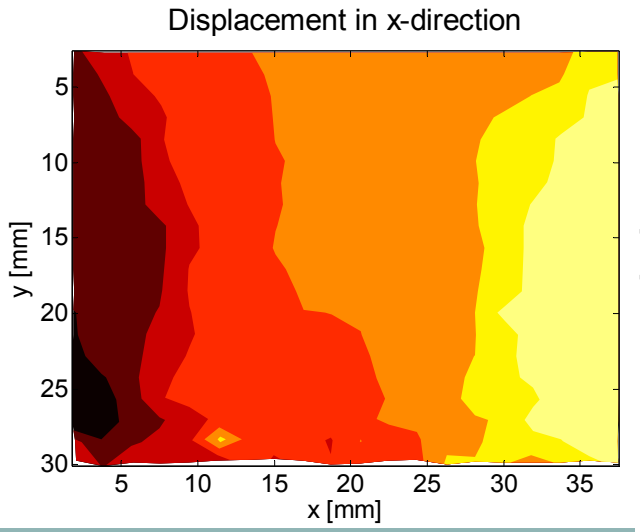
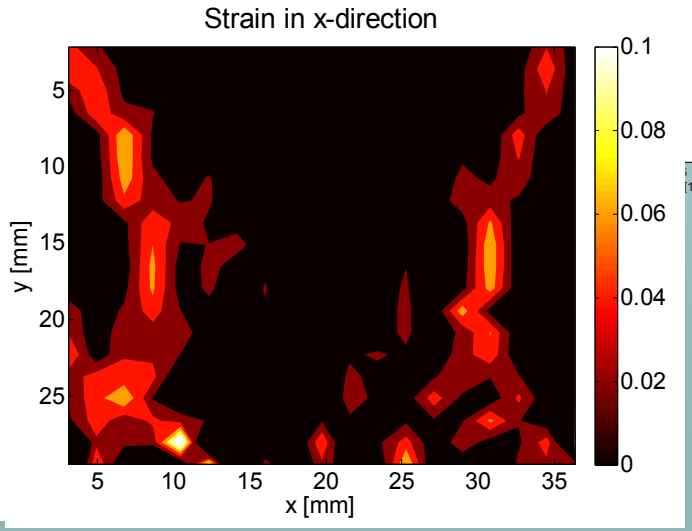


Image After Filtering & Noise reduction

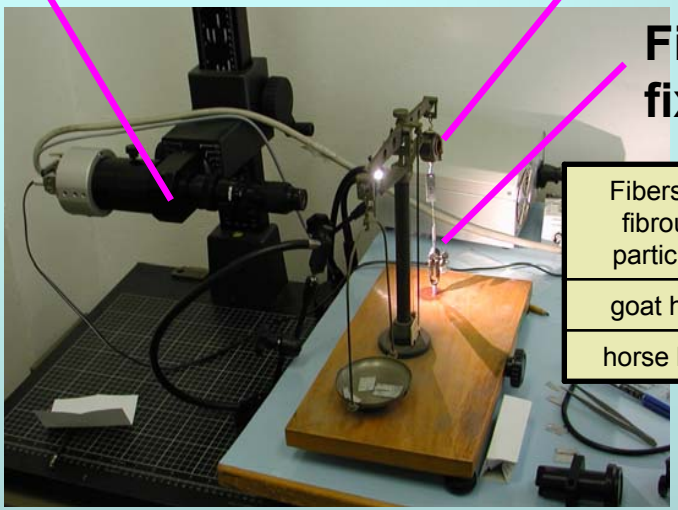






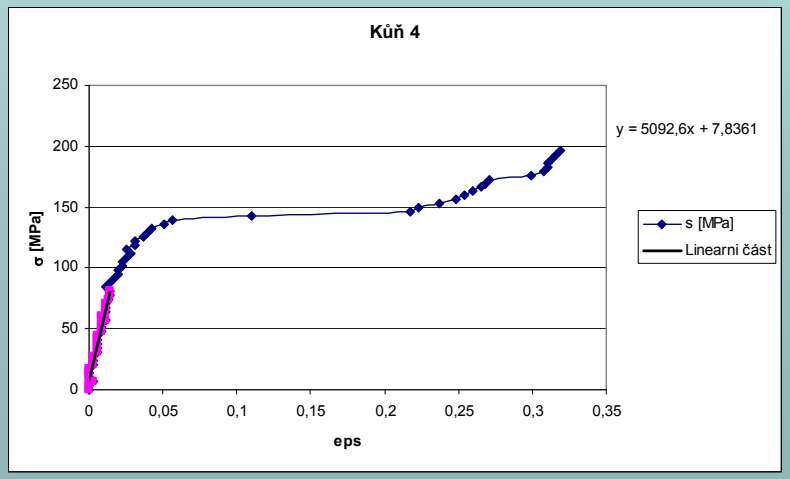
Digital image correlation – natural fibres

Microscopic camera **Laboratory balance converted into a test frame**

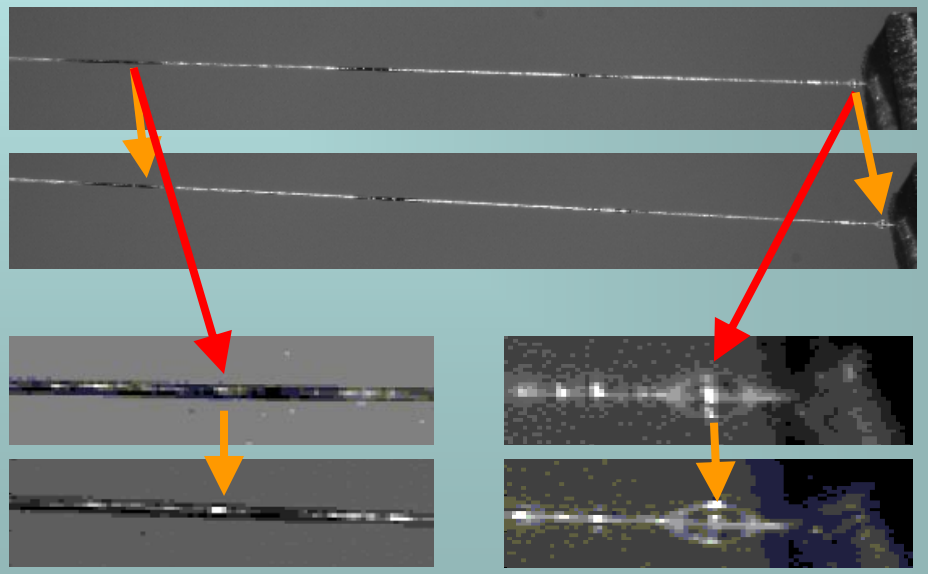


Fibre specimen glued between two metal sheet end fixtures and provided with two contrast marks

Fibers or fibrous particles	Abb rev	Nominal length (mm)	Equivalent diameter (μm)	**Tensile strength (MPa)**	**Modulus of elasticity (GPa)**	Elongation at failure (%)	Moisture (%)
goat hair	Ko	50	30-100	**110-230**	**6.2-7.7**	2-29	negligible
horse hair	Ku	50	50-140	**110-200**	**3.9-5.1**	4.5-32	negligible



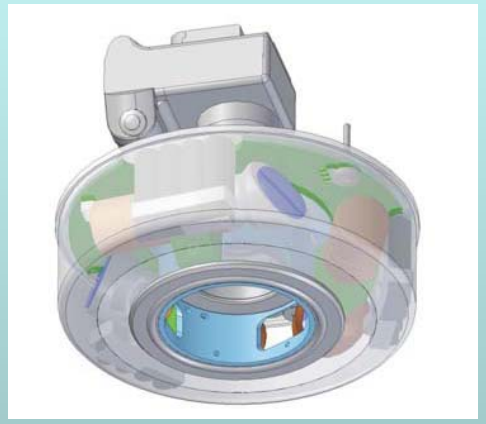
Horse hair stress / strain diagram

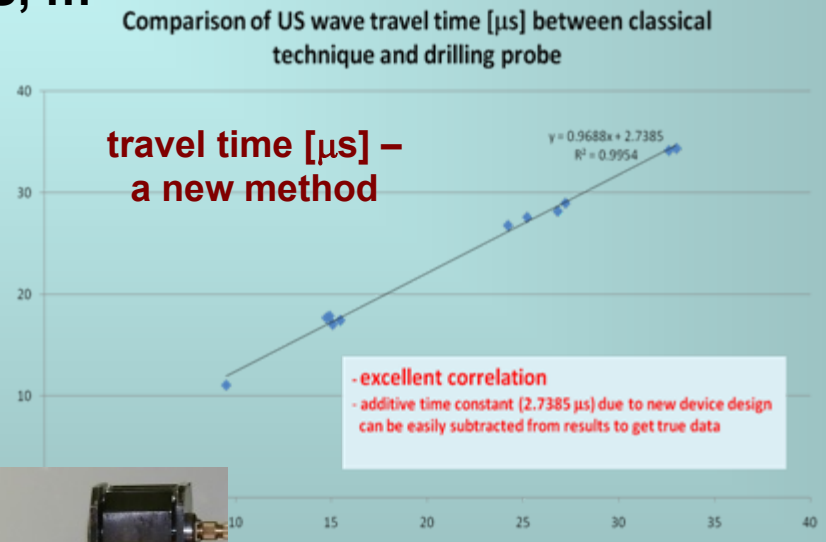


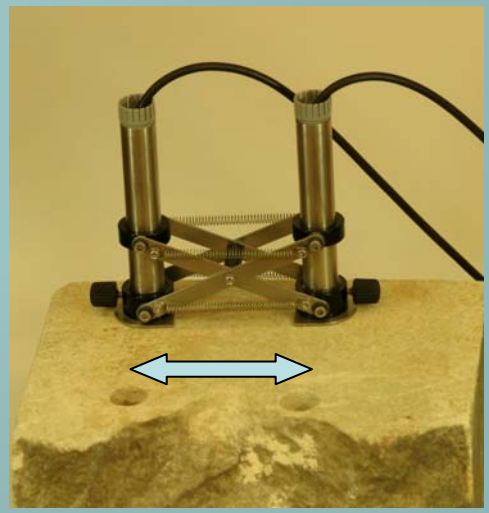
Evolution of fibre visual appearance

Other newly developed methods

- microdrilling – TERSIS - new version (GEOTRON Rolf Krompholz)
- ultrasonic device for measurement along depth profile (GEOTRON Rolf Krompholz)
- splitting tester, CPS, …



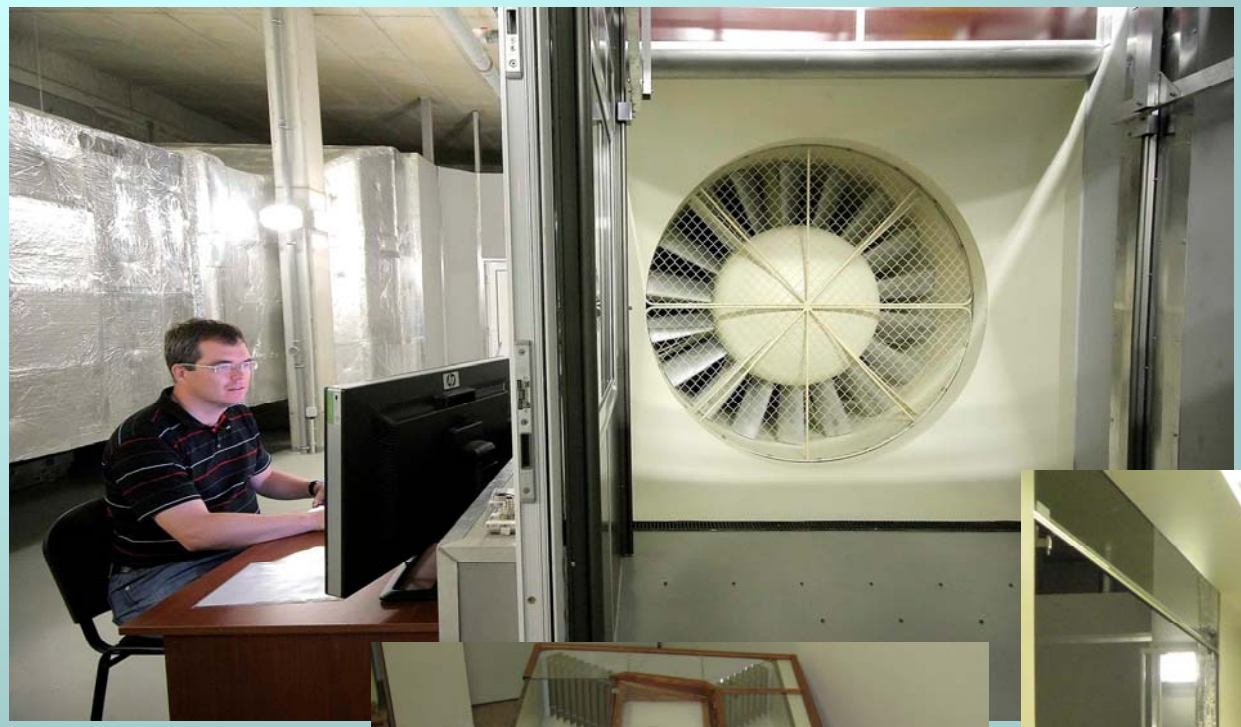


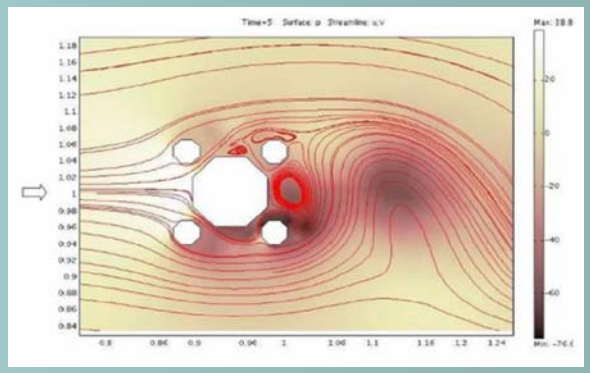


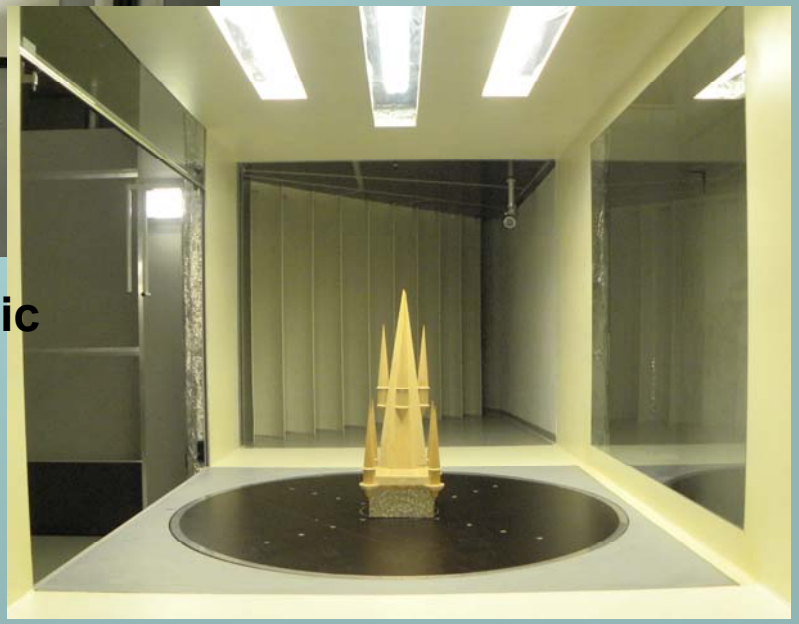
New research infrastructure for cultural heritage interdisciplinary research with climatic wind tunnel, x-ray and neutron radiography lab, mobile laboratory for emergency situations, corrosion stations, monitoring networks, databases on material and structural data in a World Heritage City of Telč, Czech Republic

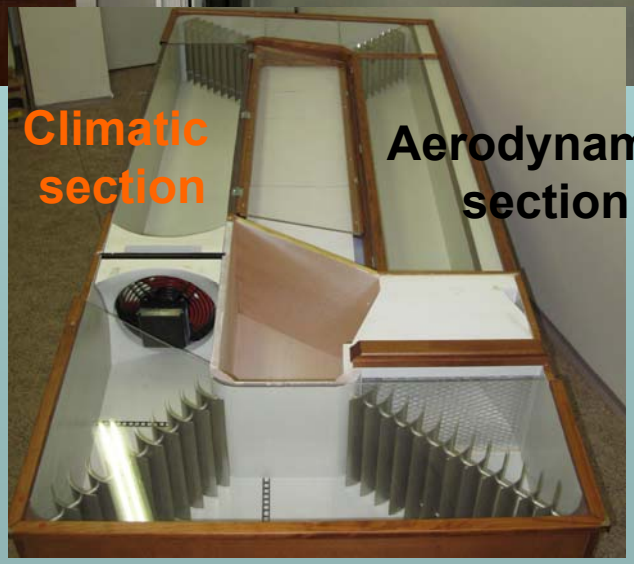
MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY
EVROPSKÁ UNIE
EVROPSKÝ FOND PRO REGIONÁLNÍ ROZVOJ
INVESTICE DO VAŠÍ BUDOUCNOSTI
2007-13
OP Výzkum a vývoj pro inovace

CET – climatic wind tunnel





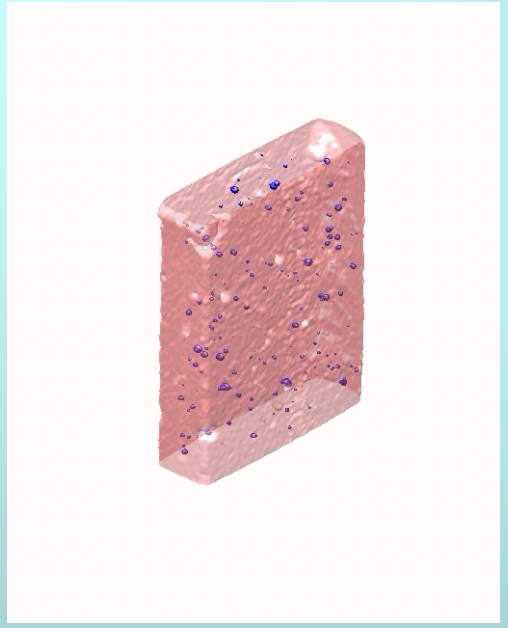


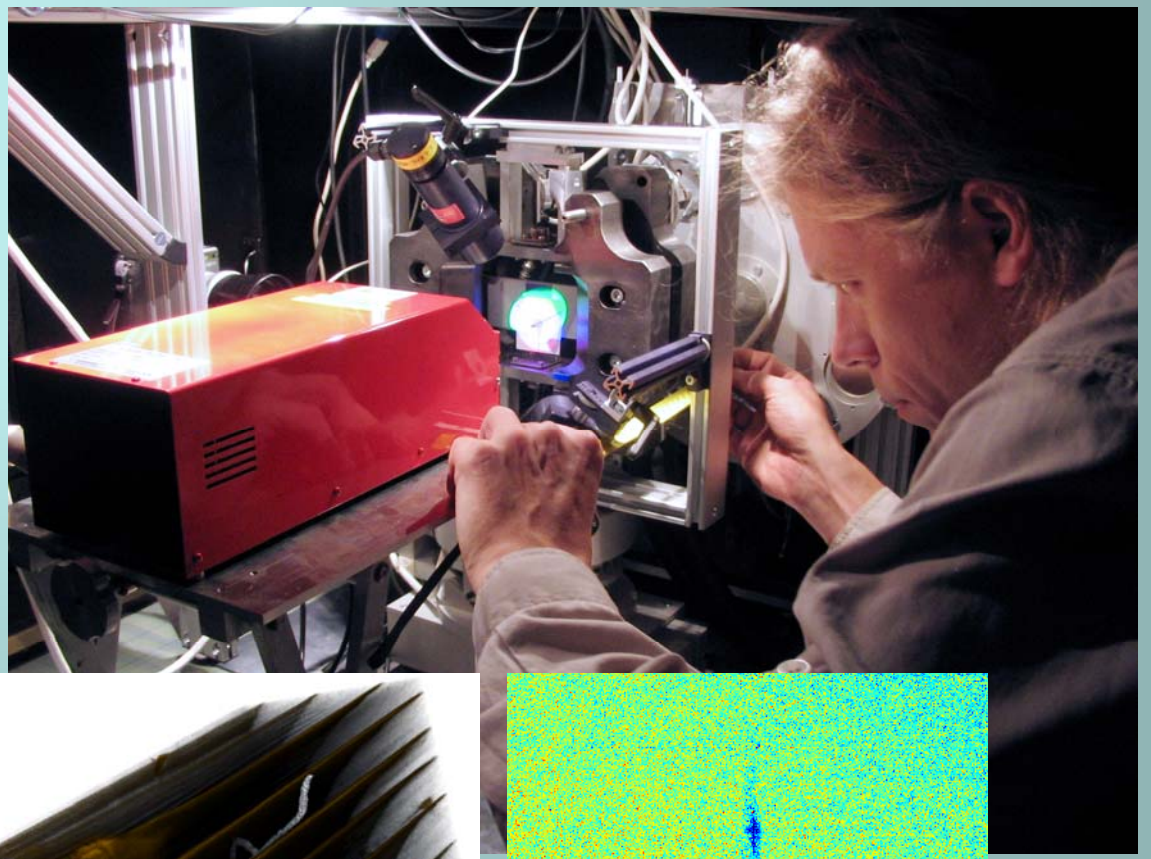


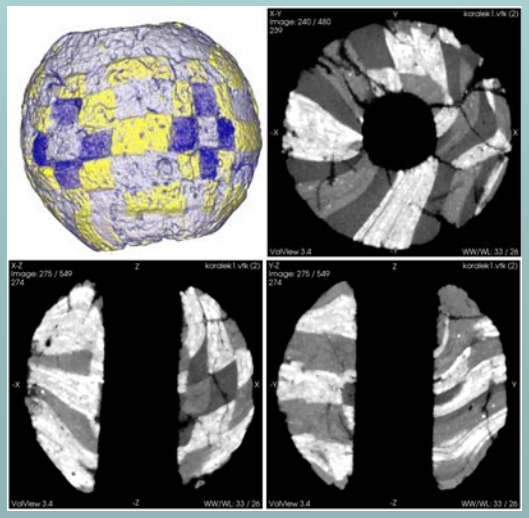
Climatic section

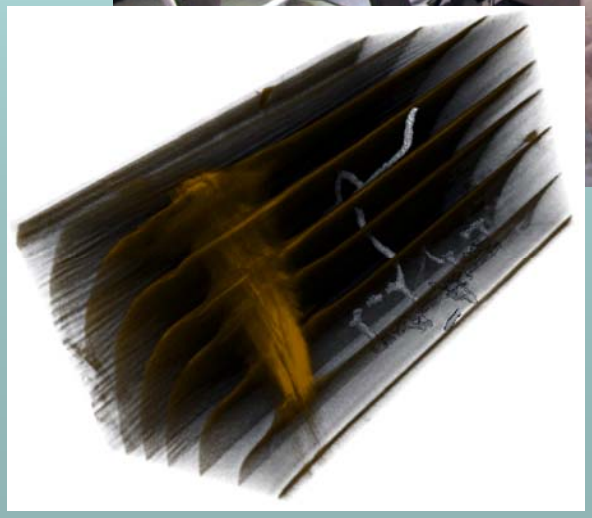
Aerodynamic section

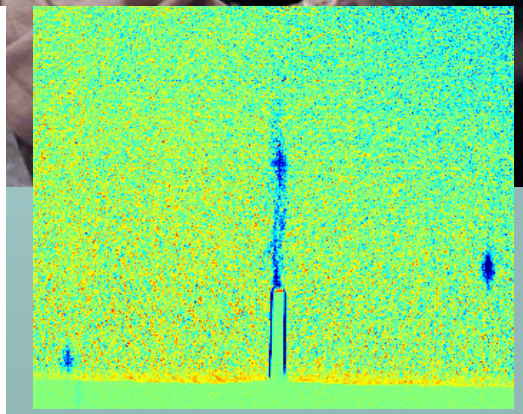
CET – X-ray micro tomography












Thank you for your attention
Nanolime consolidation effect