Rheological properties of lime putty

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Lime plasters and stucco on historical buildings

Studied problems and influences

- freshly prepared lime putty
- matured lime putty
- mechanically activated lime putty
- the influence of freezing on the lime putty
- the influence of anorganic salts on quality of lime putty

Slaking process of lime

calcium oxide CaO – quicklime

(cubic formation, the crystallographic axis of CaO is a = 4,802.10^{-10} m)

↓ H_2O

calcium hydroxide $Ca(OH)_2$ – slaked lime

(hexagonal formation, the crystallographic axis of $Ca(OH)_2$ is a = 3.58.10^{-10} m and the height is c = 5,03.10^{-10} m)

⇓

enlarging of volume during slaking

$$CaO + H_2O \rightarrow Ca(OH)_2 + 65{,}2\ kJ.mol^{-1}$$

Structure of lime putty and its influence on quality of mortars

- lime putty is a macrocolloidal dispersion system
- $Ca(OH)_2$ = portlandit
- calcium crystals finer $\rightarrow$ more plastic and efficient mortar and more consistent
- the small particles = the greatest surface

Maturing of lime putty

- mortars for walls - lime putty formed by hydration slaking is possible to use immediately
- lime putty should be sufficiently matured - must be slaked additionally
- traditional methods of maturing suggest leaving the putty in hollows in the ground - inlaid with wood $\rightarrow$ the putty could gain its optimal final characteristics – mainly its consistent volume, efficiency and rheological qualities or plasticity
- particles of slaked lime incidentally forming agglomerates, that haven't yet been hydrated and slaked, CaO are converted to $Ca(OH)_2$ during a longer period - it has a constant volume
- time of hydrating - minimum length for "maturing" be no less than three weeks. It is a known fact that slaked lime used for significant buildings was dug into the ground for several years
- in general, it is assumed that the longer the lime putty has been cured, the higher the quality.
- nowadays, cured lime putty is suitable for paints, facades, stucco etc. and is available on our markets at specialised manufacturers or suppliers. They offer one-year old, three-year old, six-year old and older limes with corresponding prices.

The influence of freezing on the rheological properties of lime putty

- „lime putty can not freeze“

- a satisfactory objective explanation of the dangers of damage due to frost is still unknown

- possible explain - as in the cases of polymeric dispersions, that the freezing of the system causes a certain coagulation of slightly dispersed particles

↓

worsening of the rheological properties

„Blasting of plasters"

problem, which is caused by incomplete hydration of CaO

$$CaO + H_2O \rightarrow Ca(OH)_2 + 65{,}2\ kJ.mol^{-1}$$

- during this reaction, the particles are increasing significantly
- if there are remaining not slaked particles of calcium oxide, bigger than 0,6 mm remain, their hydration will additionally follow due to the air humidity
- during this process particles are increasing in volume = causes of damage of facades

The mechanical activation of lime putty

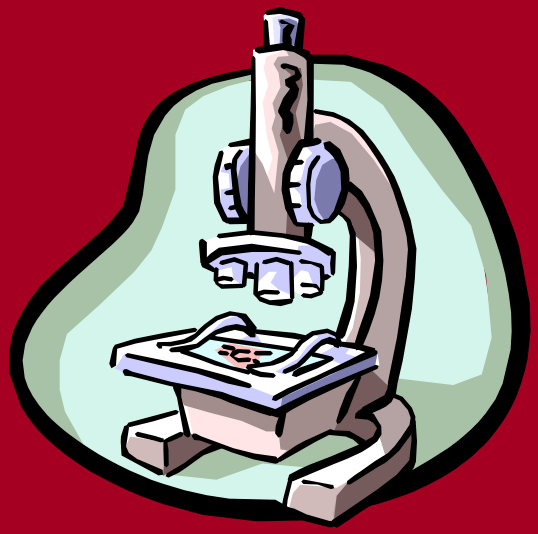
- the mechanical activation → plasticity of lime putty is increasing and quality of the putty is the same as the quallity of putty several years matured

- the mechanical stimulation of particles that were not slaked → decreases their size hence increasing the reaction surface and the accessibility of water to the surface of CaO particles is improved → which makes it easier to hydrate them

- the mechanical aktivation proceeds approximately 15 minutes

Experimental methods

- measuring the viscosity of lime putty - rheoviscosimetre type cylinder-cylinder ("Searle" system) RHEOTEST RV
- optical microscopy
- electron microscopy



Measuring the viscosity of lime putty

- **rheoviscosimetre type cylinder-cylinder ("Searle" system) RHEOTEST RV**

  (producer Mechanik Prüfgeräte Medingen, Dresden)

$$\tau_r = \alpha \cdot Z$$

$$\eta = (\tau_r / D_r) \cdot 100 \quad [mPa.s]$$

τ_r ... shearing tension [Pa]

α ...value on displey of rheoviscosimeter [piece]

z ...constant of measuring sensors S1/S2/S3/H and range I/II,

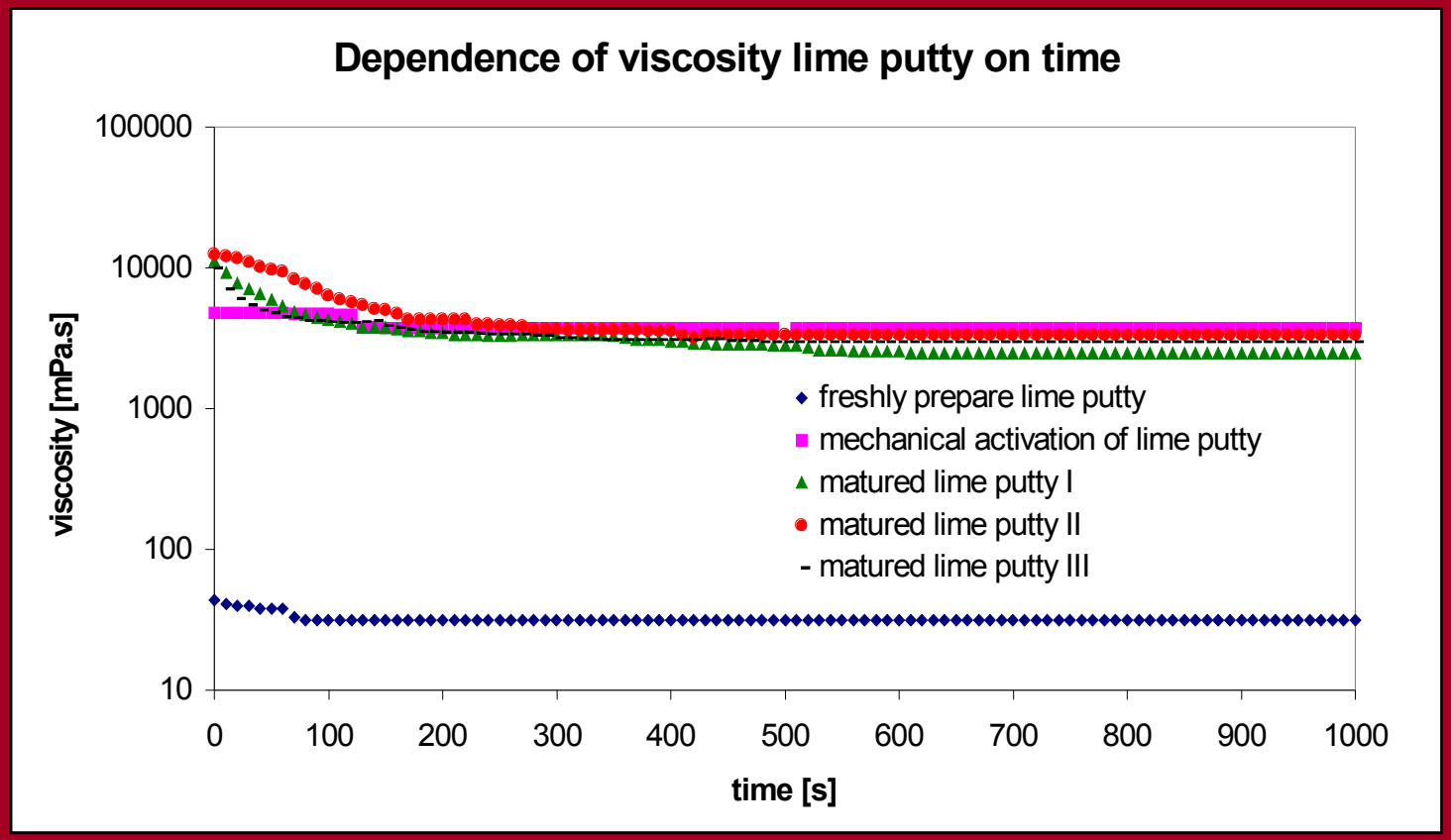
η ...dynamic viscosity [mPa.s]

D_r ...constant of measuring sensors S1/S2/S3/H and angular speed

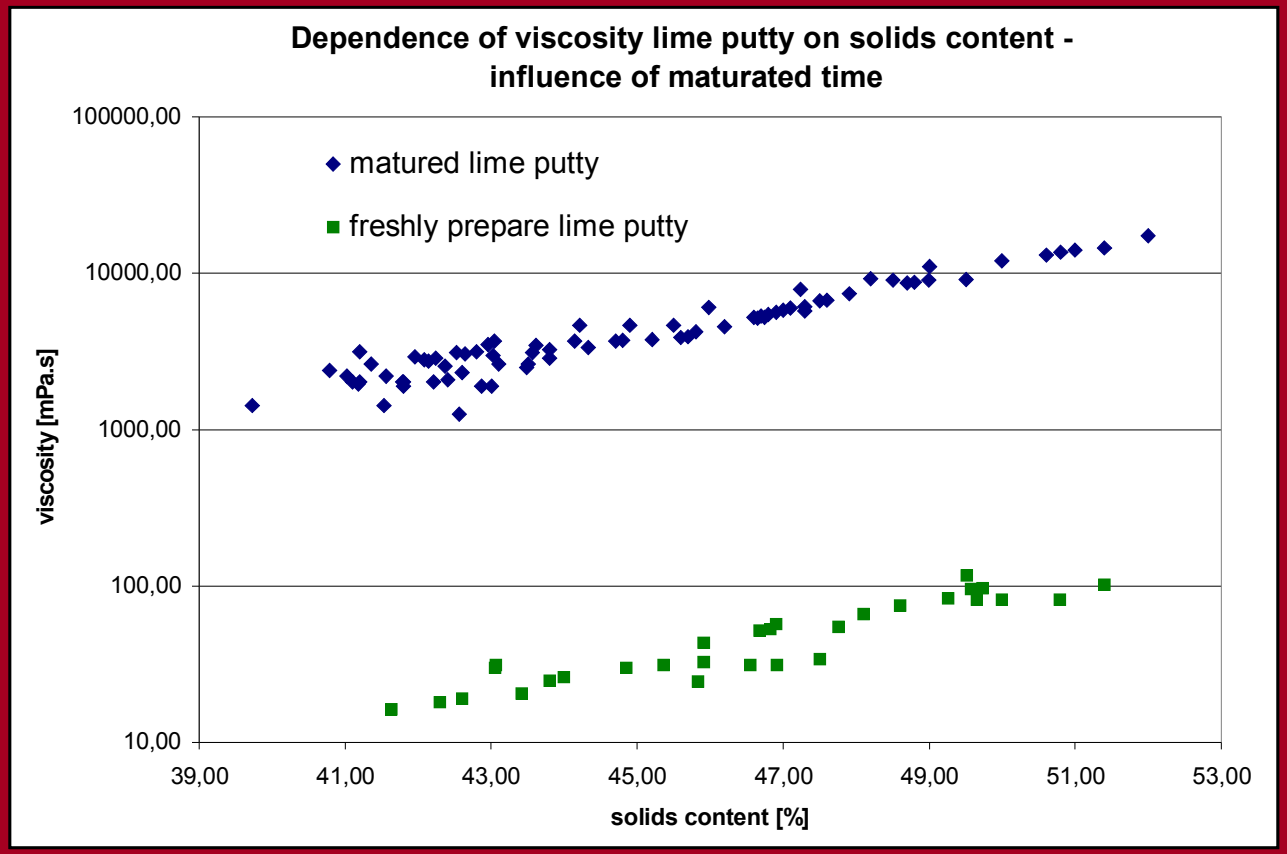
Summary of results

Type of lime putty	Number of samples	Solids content (%)	Viscosity of lime putty (mPa.s)
matured lime putty I (commercial product)	30	40-47	1427-3151
matured lime putty II (commercial product)	30	40-48	1248-17293
matured lime putty III (commercial product)	30	41-45	1724-6124
freshly prepared lime putty	30	30-51	16-117
freshly prepared, mechanically activated lime putty	30	42-50	1946-7032

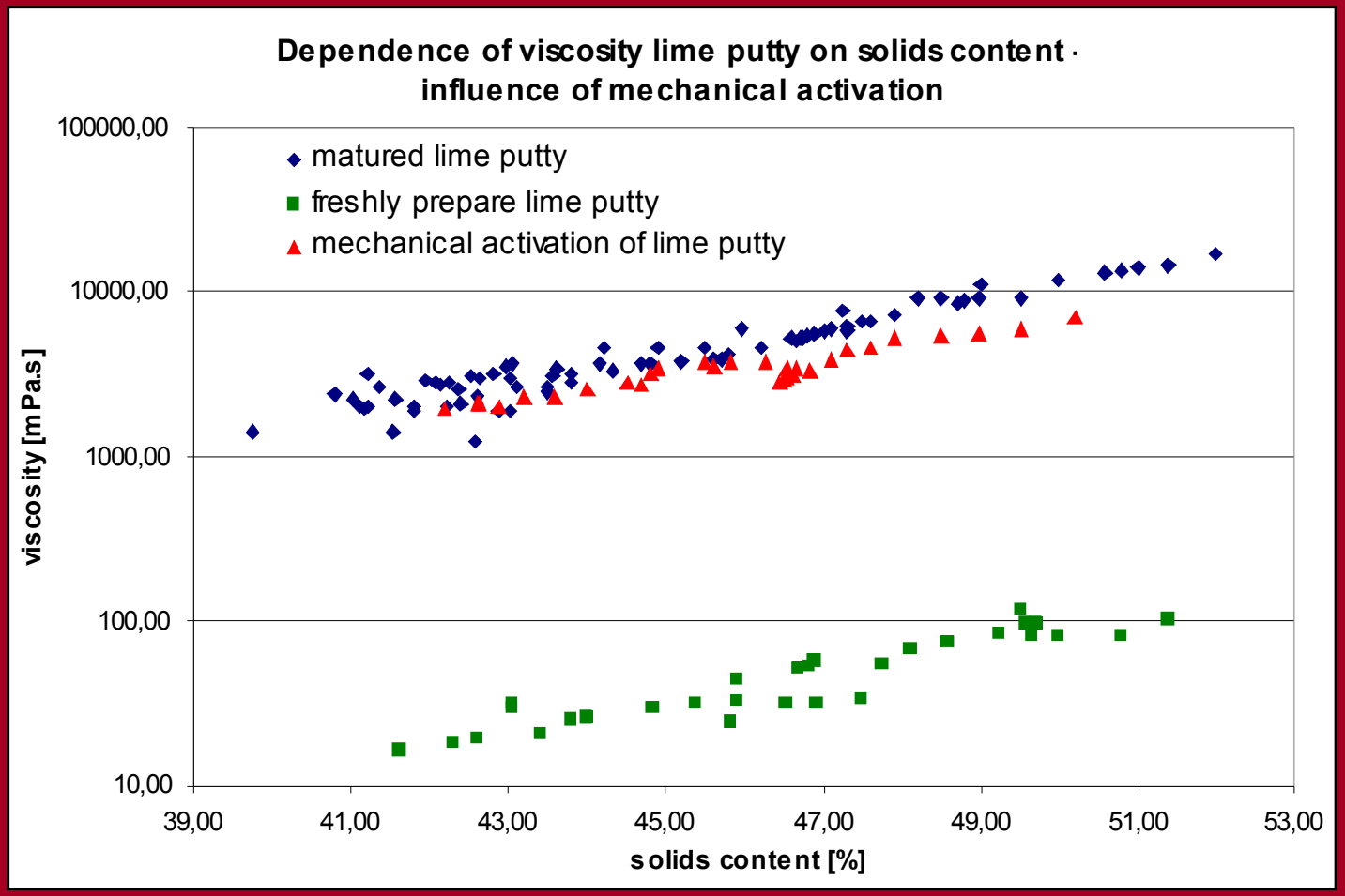
Dependence of viscosity lime putty on time



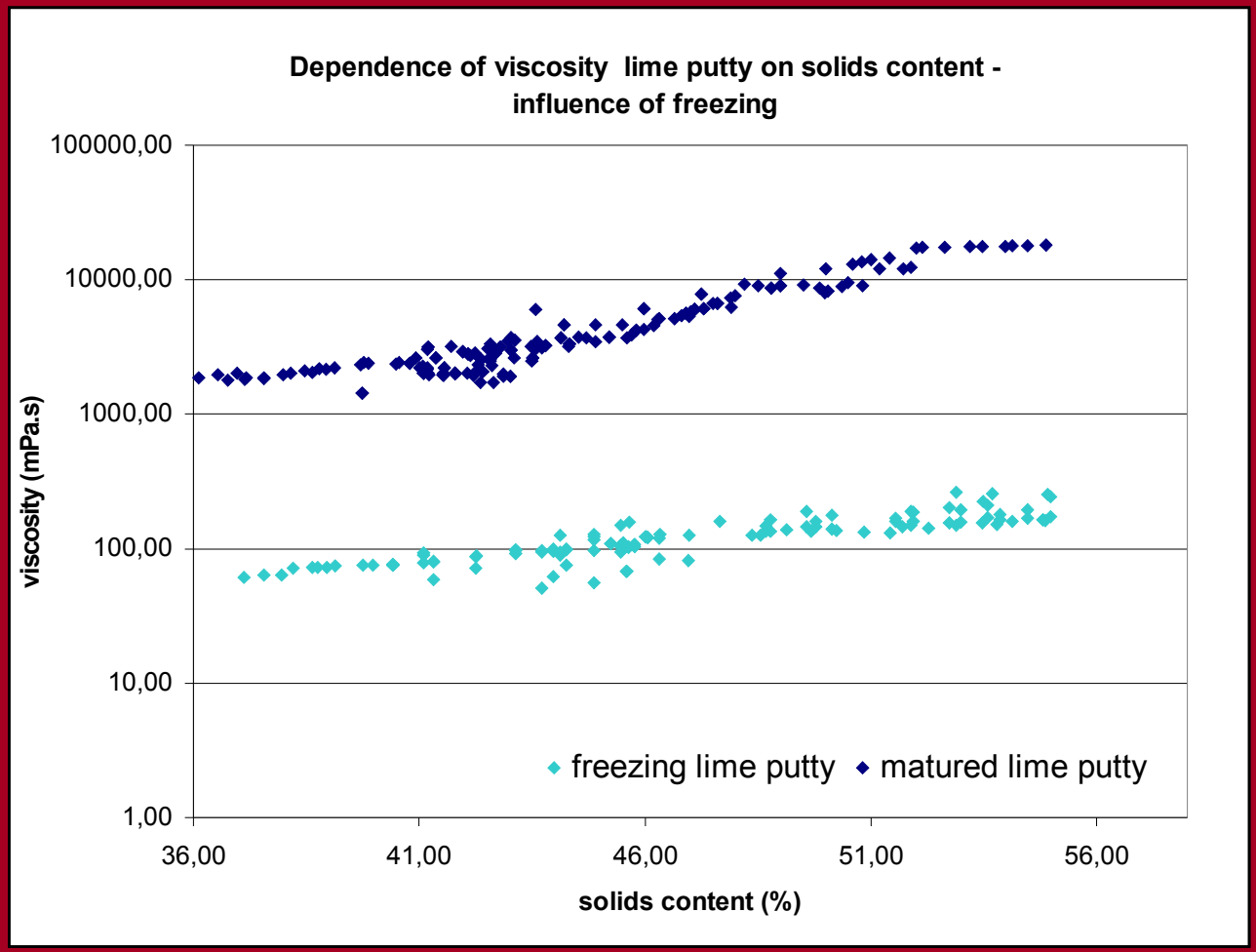
Dependence of viscosity lime putty on solids content influence of matured time



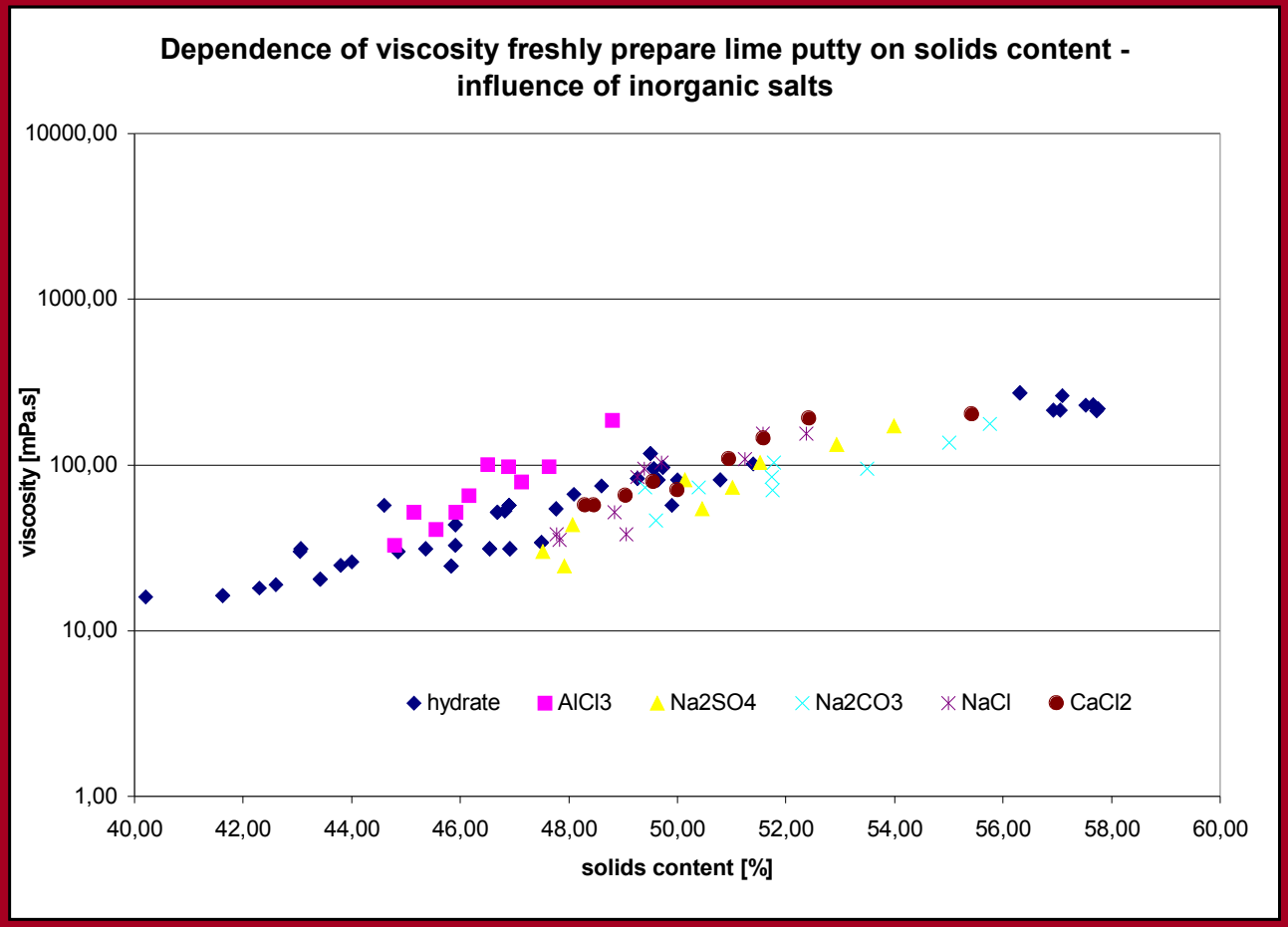
Dependence of viscosity lime putty on solids content influence of mechanical activation



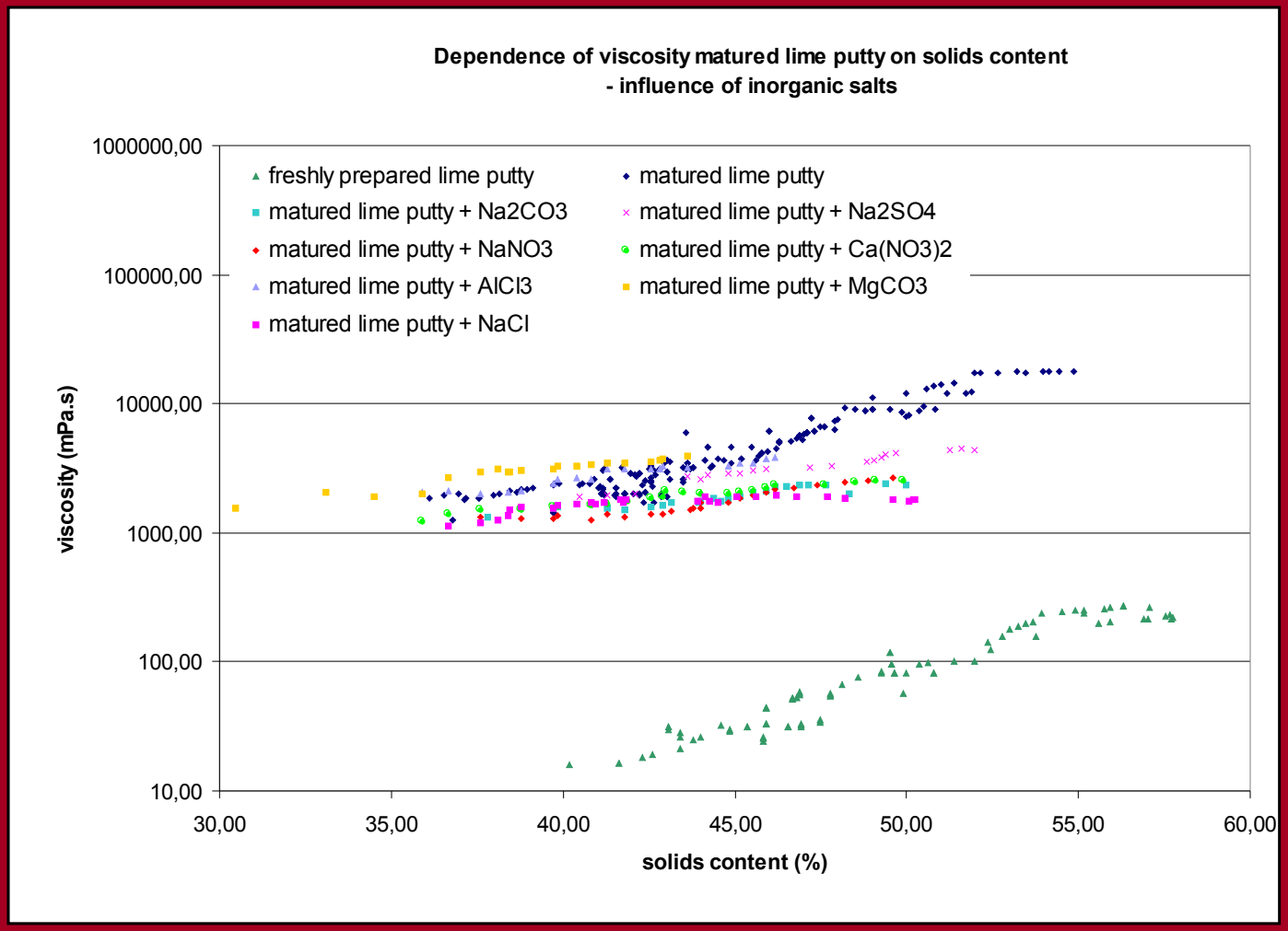
Dependence of viscosity lime putty on solids content influence of freezing



Dependence of viscosity freshly prepared lime putty on solids content influence of inorganic salts

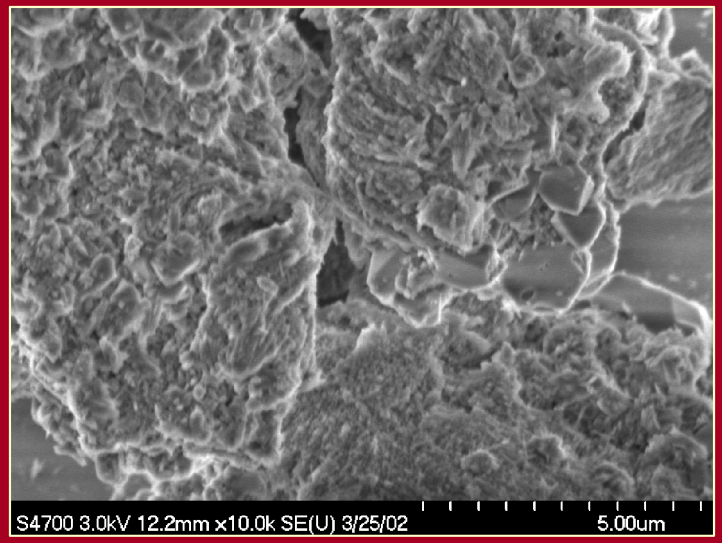


Dependence of viscosity matured lime putty on solids content influence of inorganic salts

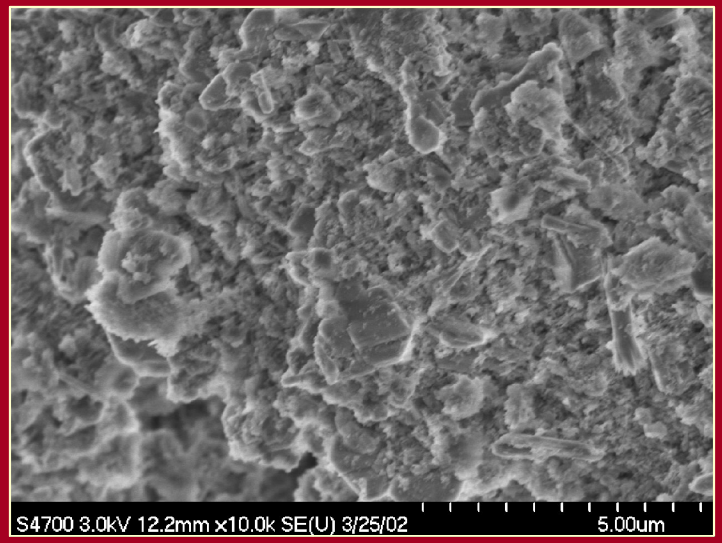


Electron microscopy

- freshly prepared lime putty



- matured lime putty



Conclusions

- the matured lime putty has during measuring the highest viscosity
- the freshly prepared lime putty has the viscosity very low - till about two levels
- the freshly prepared lime putty and mechanically activated in mixer has rheological properties the same as the lime putty several years matured
- lime putty should not freeze
- in practice - we can evaluated influence of maturing and activation on rheological properties of lime putty and determine methodology useful for appreciation quality of lime putty = the measurement of lime putty's viscosity on a rheoviscosimetre
- to control the material's quality precisely prior to application → which could help prevent the usage of inadequate materials on historical buildings and monuments

Future

- to prepare mortars
- to study influences of lime putty quality on quality of mortars and plsters

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I thank you for your attention.