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Surface treatment of construction materials

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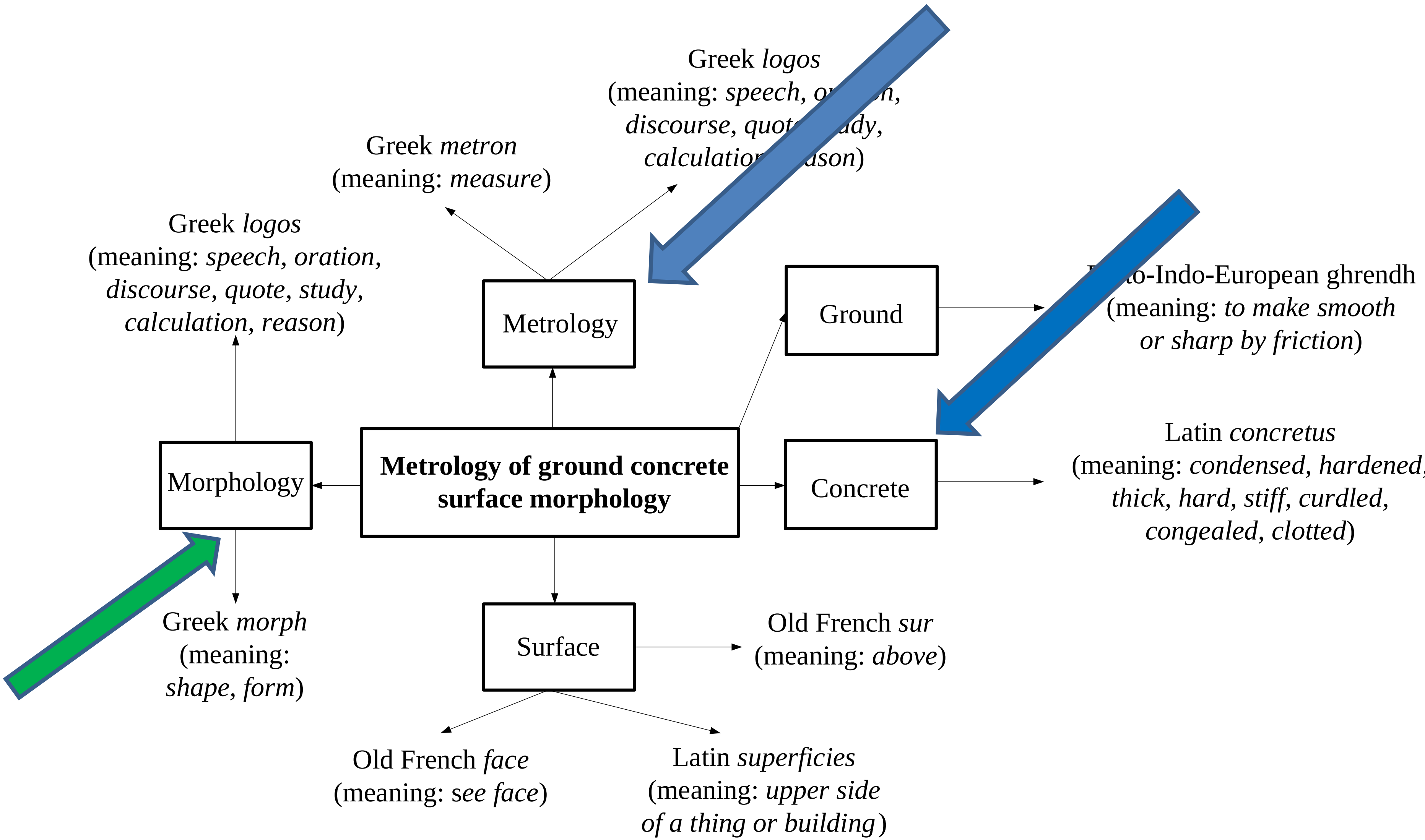
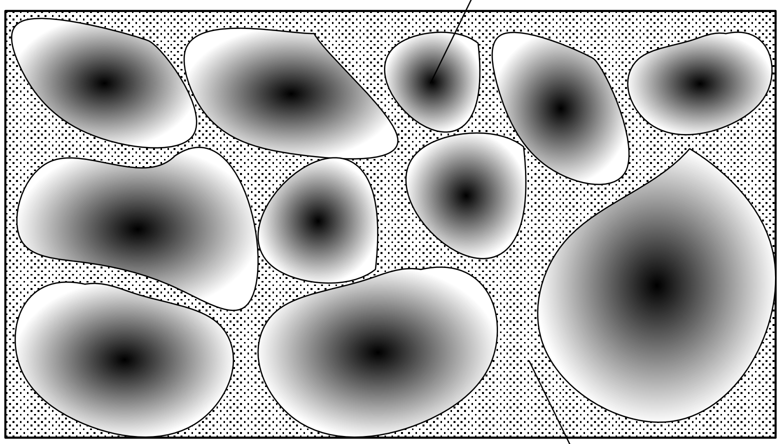
Areal morphogenesis of surface of concrete

Etymology of subject



Morphological specifity of mortar

Fresh mortar can generally be defined as a mixture of cement, sand and water.



It forms a heterogeneous material.

Coarse granular material is hard and brittle

Binder material is softer and less brittle

Diversity of mortar surfaces

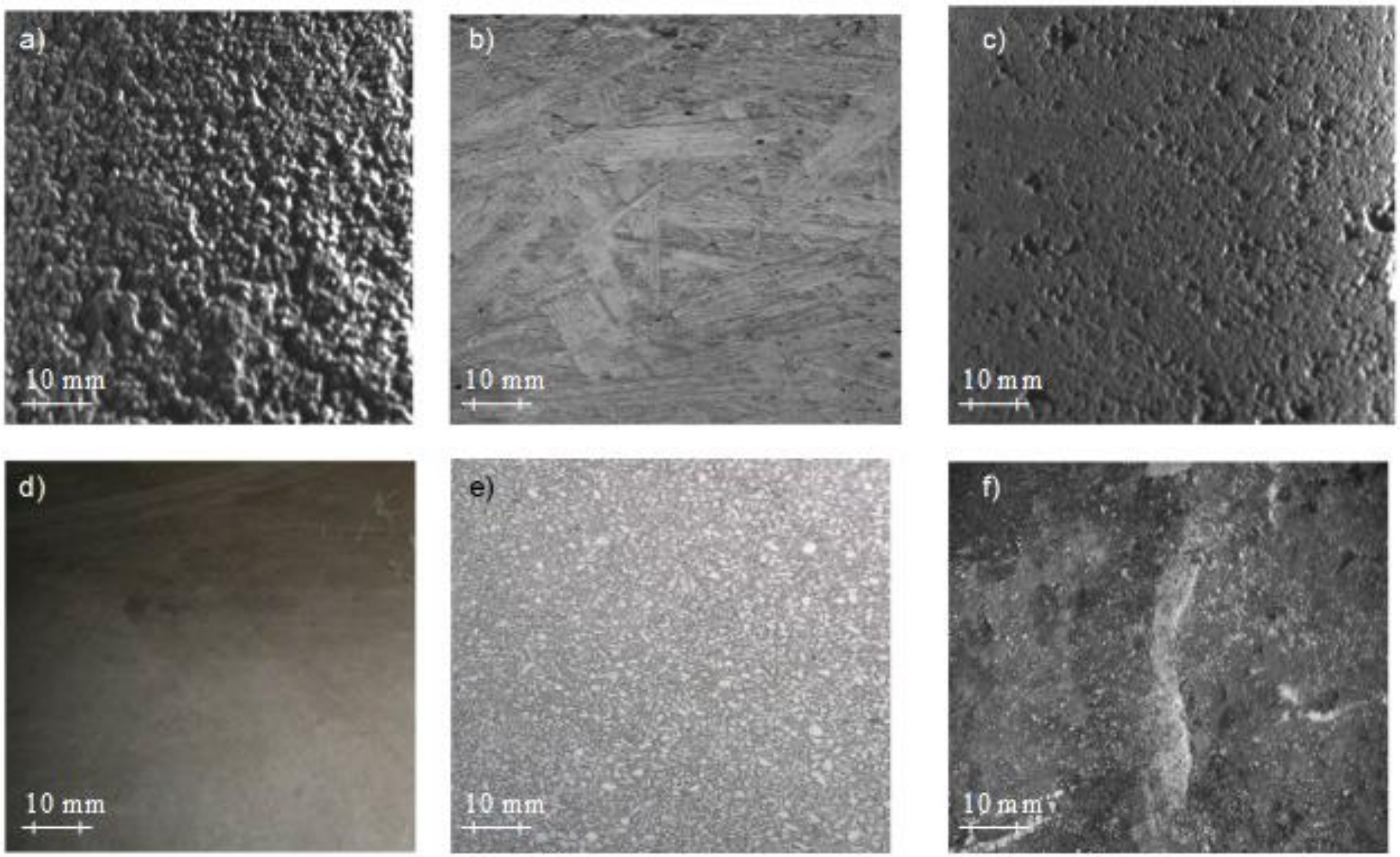


Fig. 3 Examples of concrete surfaces: a) as cast, b) raw concrete formwork, c) ground, d) architectural, e) polished, f) aged concrete

Newly executed elements


Industrial floors


Cement screeds

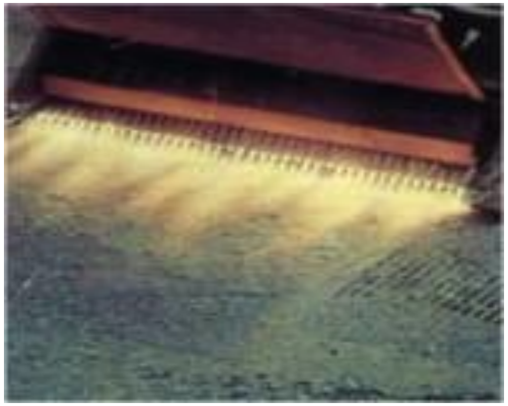

Floors in garage

Floors in garage

Diversity of surface treatment methods

Grinding

Milling



Sunbathing

Patch grabbing

Abrasive Water Jet

Blasting

The following fundamental questions arise:

•Why is the externally discernible cracking process in surface morphology, and therefore the serviceability of cement-based materials interesting?

And subconsequently:

•How can the appropriate conditions for the application of surface hardeners be determined?

•When, how and for what purpose should a surface of cement mortar be machined to be correctly finished?

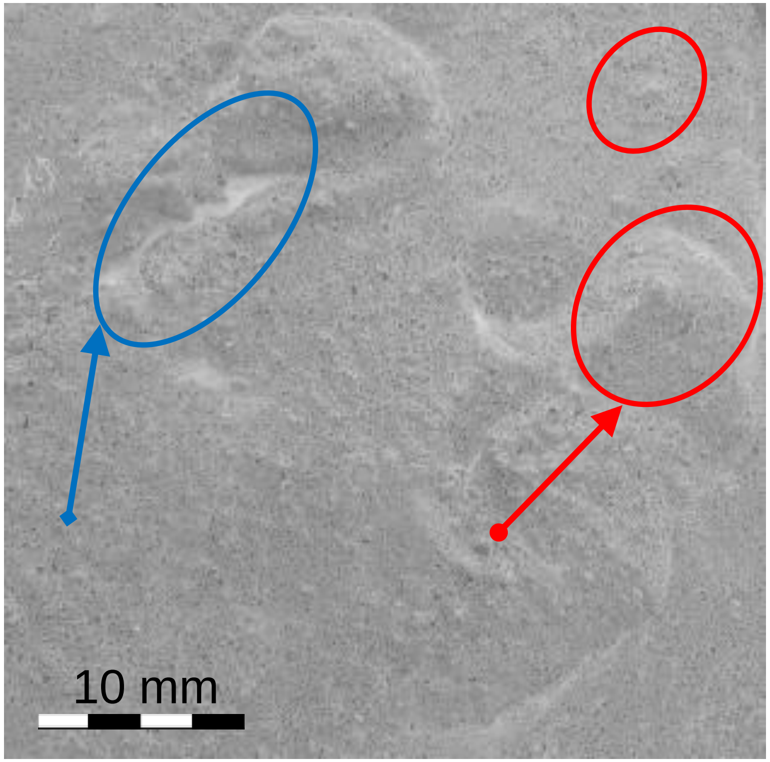
•What are the optimal conditions for the adhesion between a coating or paints and cement mortar?

1 800 s later

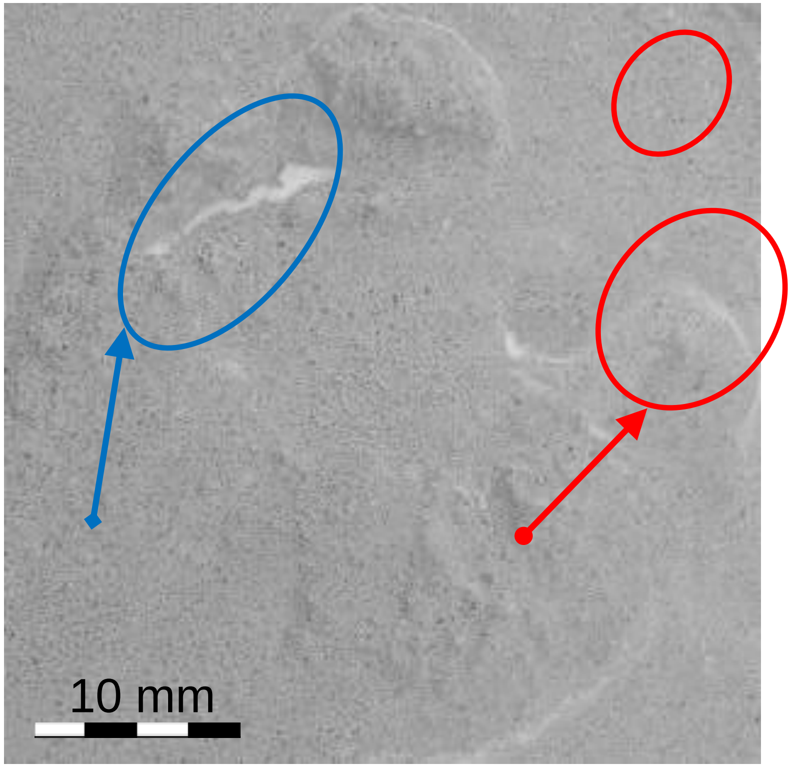
3 600 s later

Smartphone raw pictures of visual modifications in the morphology of cement mortar at early ages

Starting state



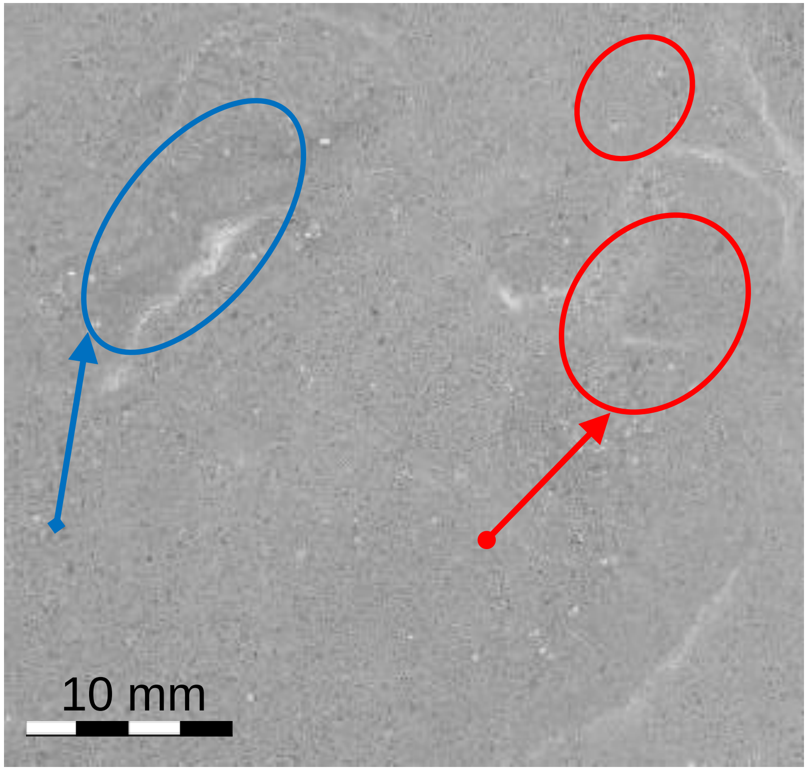
600 s later

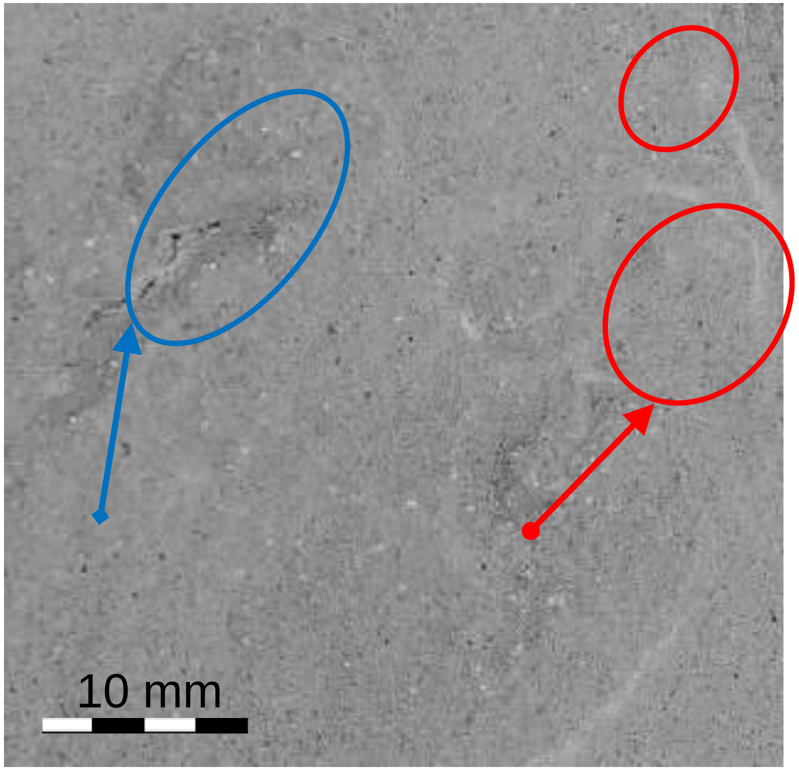


Smartphone raw pictures of visual modifications in the morphology of cement mortar at early ages

1 800 s later

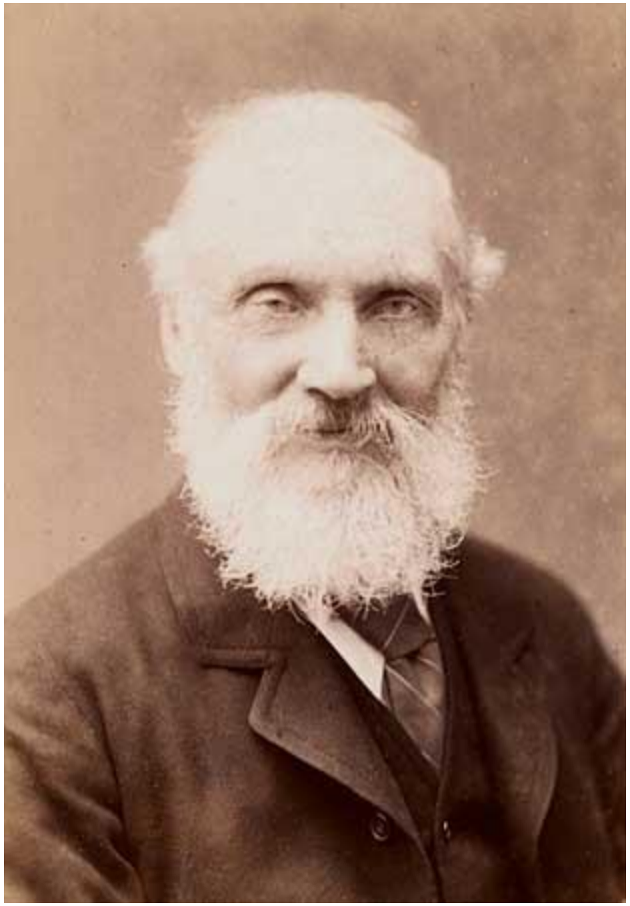
3 600 s later





Lord Kelvin (Sir William Thomson)
[Popular Lectures Vol. I, p. 73, "Electrical Units of Measurement", 1883-05-03]

„I often say that when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely in your thoughts advanced to the state of Science, whatever the matter may be"



Aims of the research:

- to reveal and measure the evident superficial morphological evolution,
- to discriminate its transitional phases during the solidification process of the surface of cement mortar at early ages.

Areal morphogenetic transitions of cement mortar at early ages have never been measured, quantified or investigated in detail. The morphologies were analyzed at different in-between stages.

2. Experimental strategy

Materials

The ingredients used to prepare the mortar were:

•276 kg/m^3 of type CEM I 42.5 R cement,

•138 l/m^3 of water and 1599 kg/m^3 of sand as the aggregate in the mortar.

The water-cement ratio was equal to 0.5.

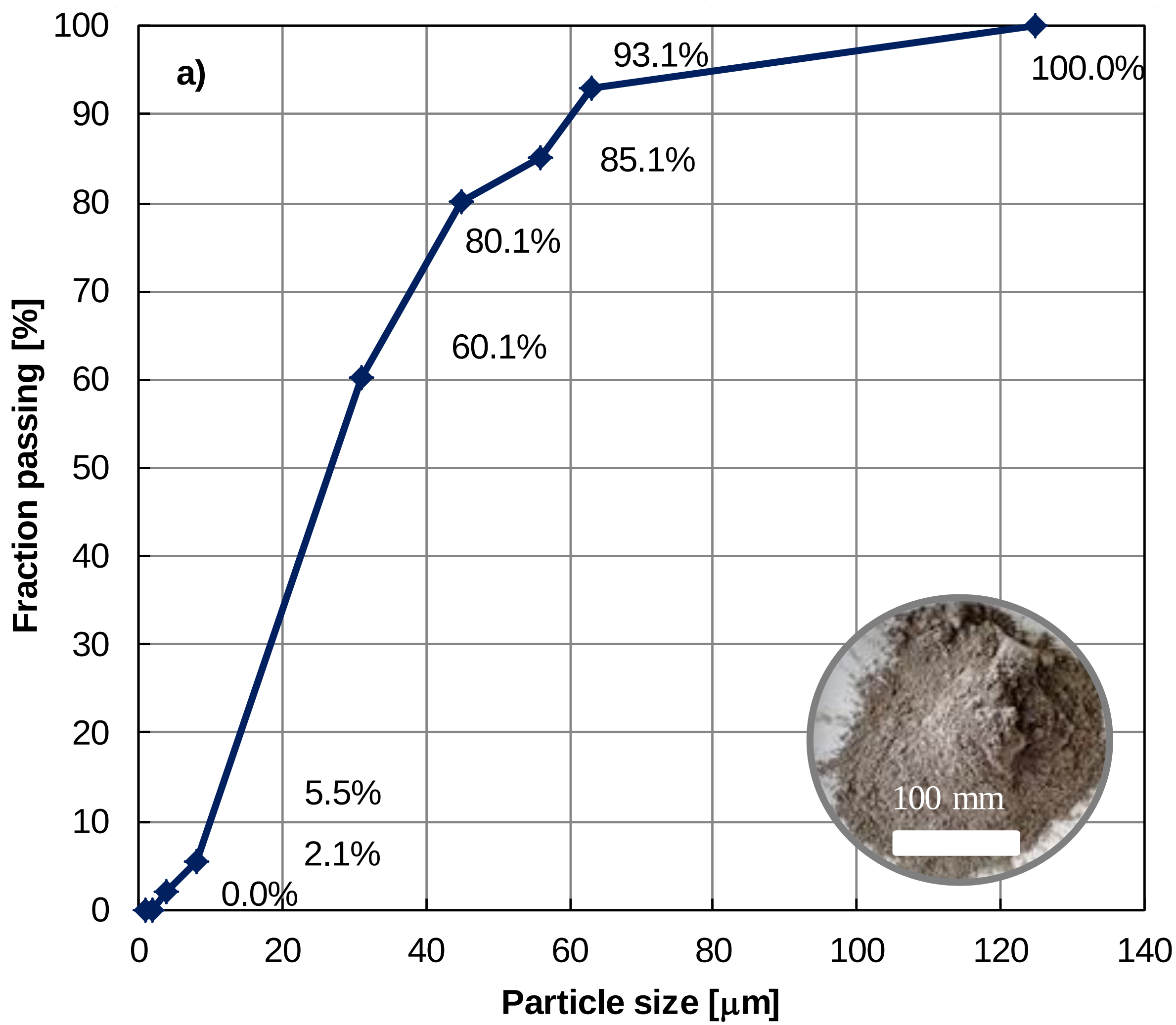
For this water-cement ratio, the consistency of the mortar will be liquid.

Thus, the expected changes of surface morphology can be well seen.

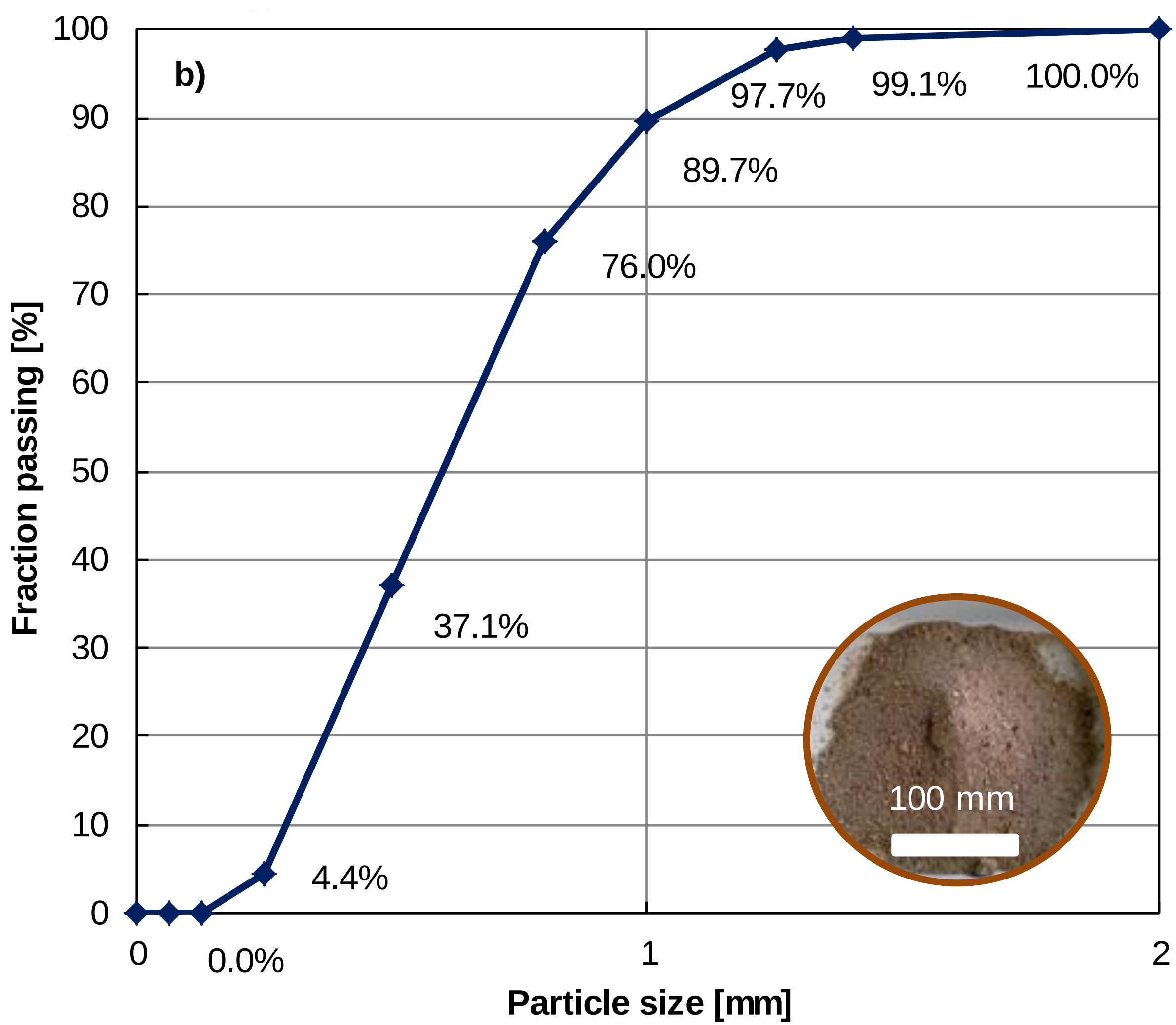
Selected mechanical, physical and chemical properties of cement CEM I 42.5R

Properties:	**CEM I 42.5R**
Start of the setting process	11 580 s
Compressive strength after 2 days	31.6 MPa
Compressive strength after 28 days	55.5 MPa
Surface area	4 170 cm^2/g
SO_3	3.31 %
Cl	0.037 %
Loss on calcination	2.91 %
Content of insoluble residue	0.74

Granular analysis (sieve method) of cement type CEM I 42.5 R



Granular analysis (sieve method) of water washed river sand



Mixing procedure

The mixing procedure based on EN 480-1 was adopted:

- The mixer was wiped inside with a damp cloth,
- Then, the dry components (sand and cement) were introduced to the mixer.
- The mixing was finished after 2 minutes (until they were homogenous).
- After that, the water was slowly added to the mix.
- The mixing of the mortar took about 3 minutes.

Mixing procedure

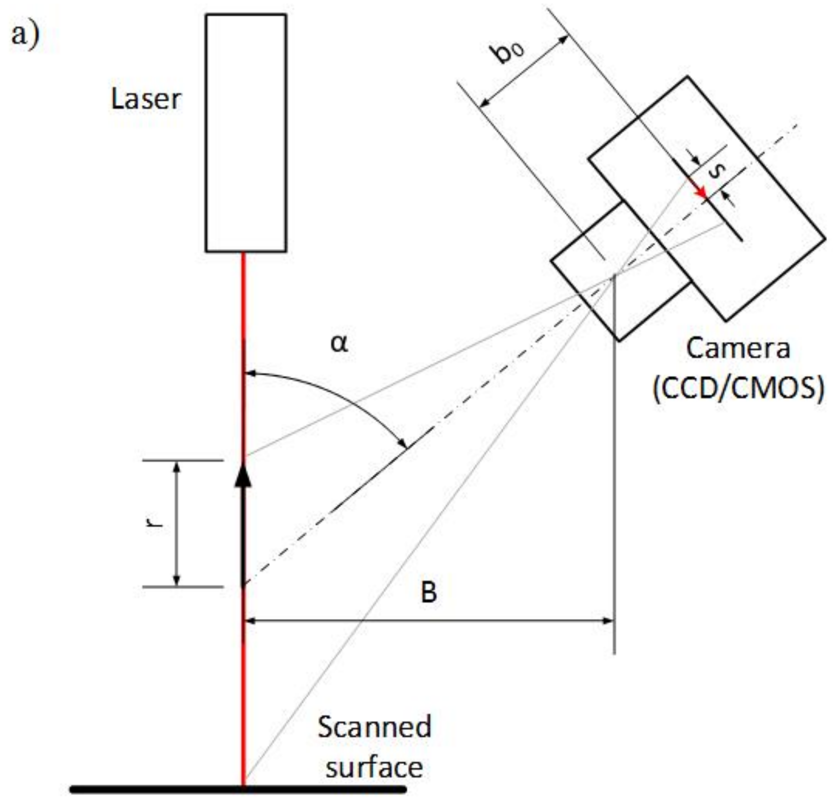
The prepared mixture was then poured into a 150x150x40 mm oiled mould.

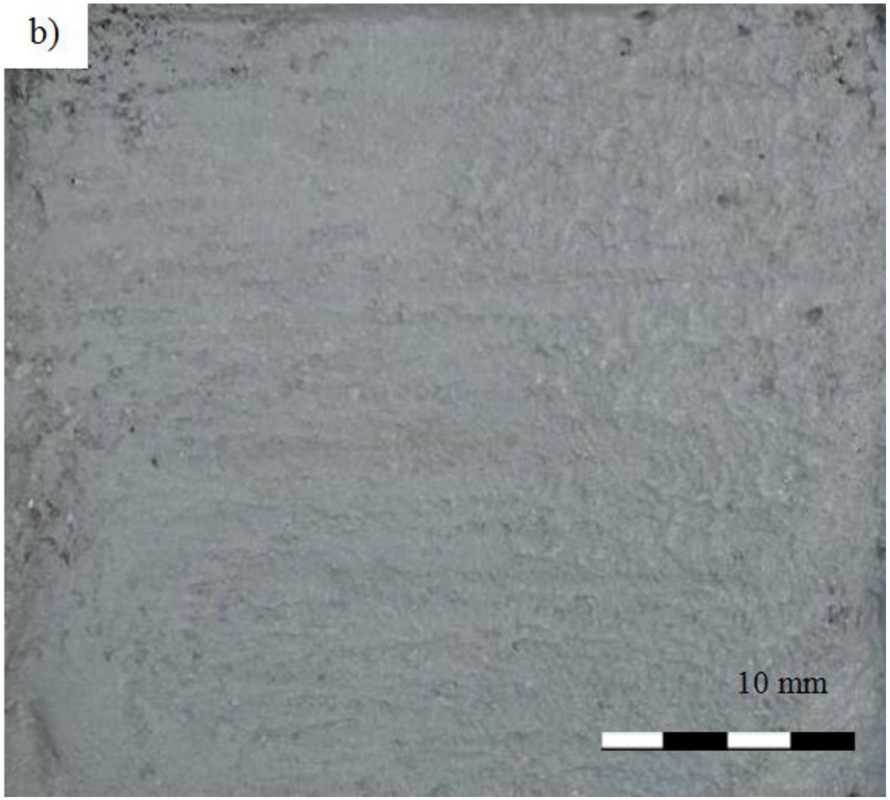
In order to see the changes on the surface, the mix was not specially vibrated.

Moreover, the surface of the cement mortar was not specially treated.

It was patch grabbed and left after concreting to obtain an appropriate flat surface for a metrological investigation.

Testing procedure





View of: a) scheme of the 3D LASER scanning technique, b) optical view of the fragment of the analyzed surface.

Test set up

The maximum performance of the IVC camera was equal to 5 000 profiles/s.

A red diode LASER (wavelength $\lambda = 658$nm) was also used.

A microcontroller for image segmentation was applied and the triangulation angle (σ) was equal to 53º.

The lateral and vertical resolution was equal to 0.01 mm.

The uncertainty did not exceed 0.01 mm.

Test set up

The calibration was performed by the calibration matrix and a south-shape target was used for this purpose.

Longitudinal scanning was done automatically and a linear guide integrated with an incremental encoder was used for this purpose.

The morphology of the surface of the cement mortar within an area of 50 x 50 mm was measured.

Using the above mentioned test settings, the single measurement took less than 60 s.

Results processing

The results of each measurement were obtained in the form of a cloud of points.

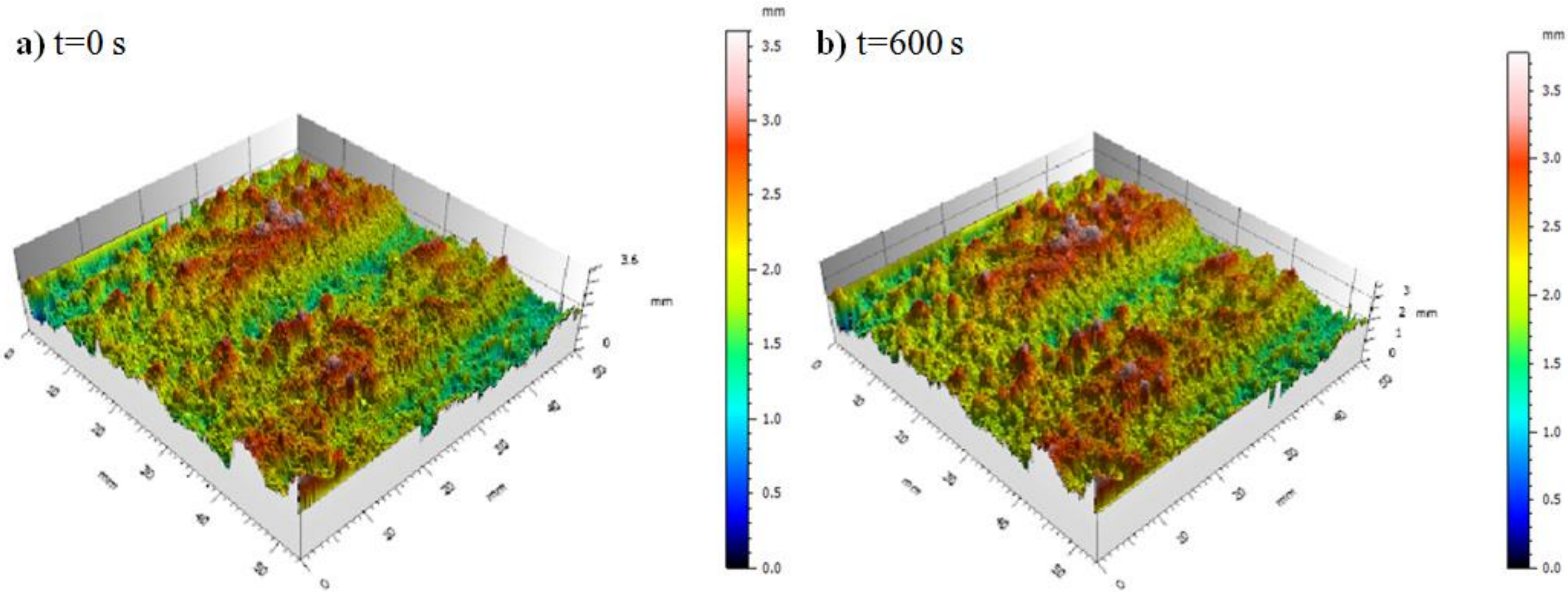
After finishing the measurements, the test results were sent via the Ethernet interface to a computer, saved in “*.csv” and converted to “*sur” format.

Before further processing, the data was levelled.

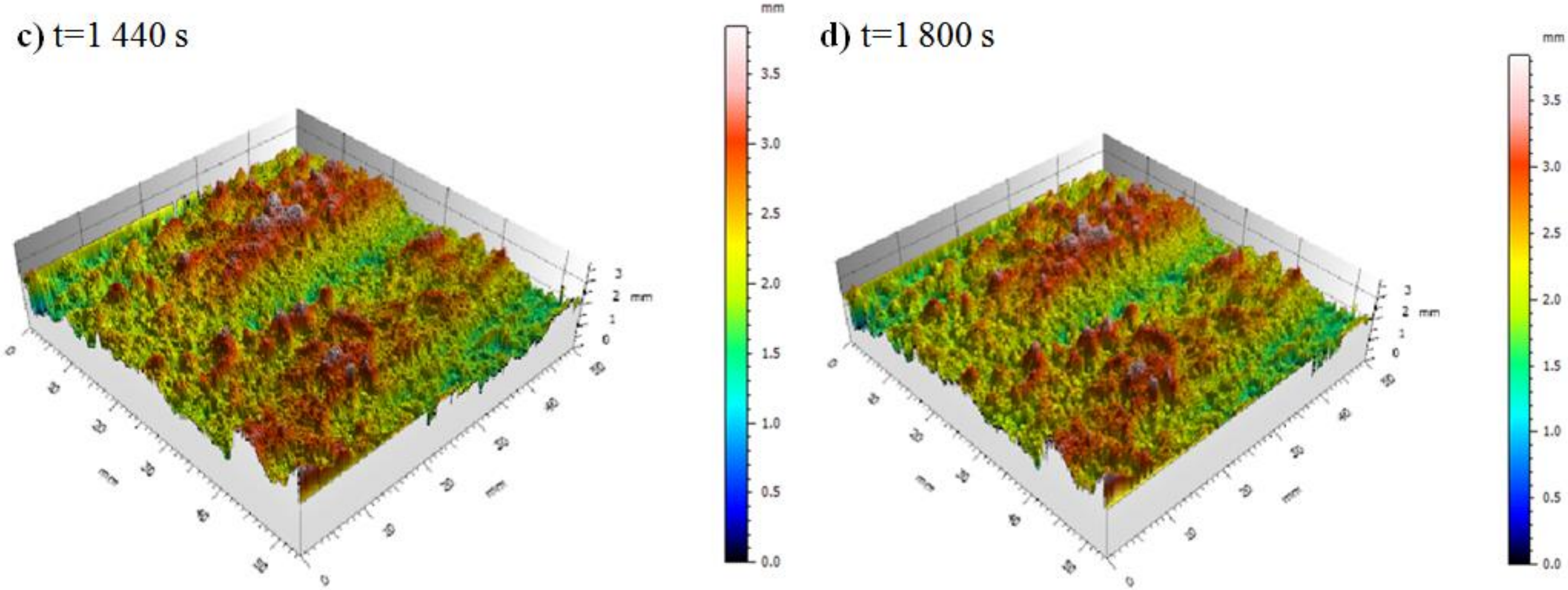
Data filtering was avoided in this analysis. Finally, the data was analyzed in MountainsMap® Premium 7.2 using Digital Surf software in accordance with ISO 25178.

3. Selected results and discussion

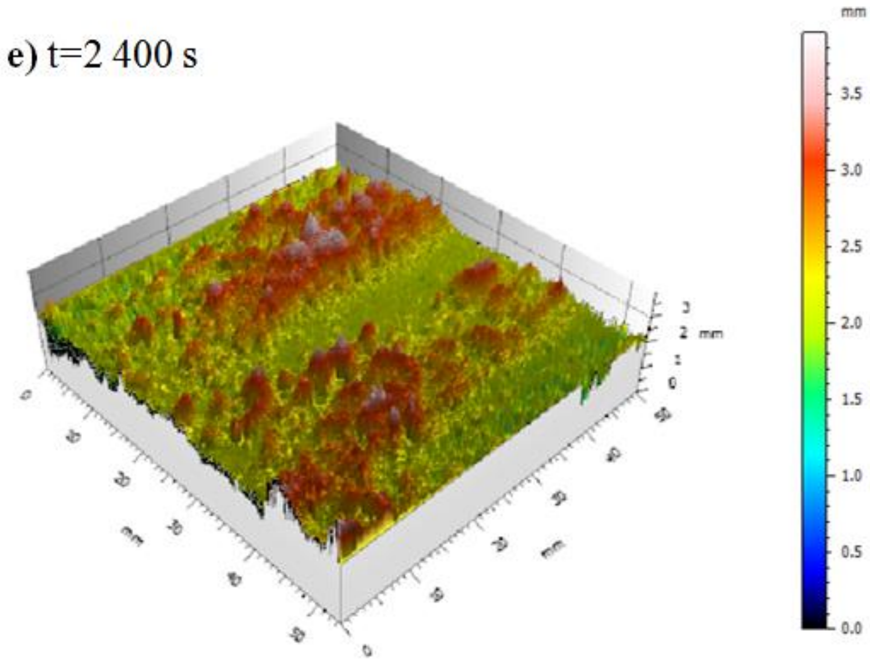
3D isometric pertinent visualizations versus the time of the cement mortar transitional surface morphology stages

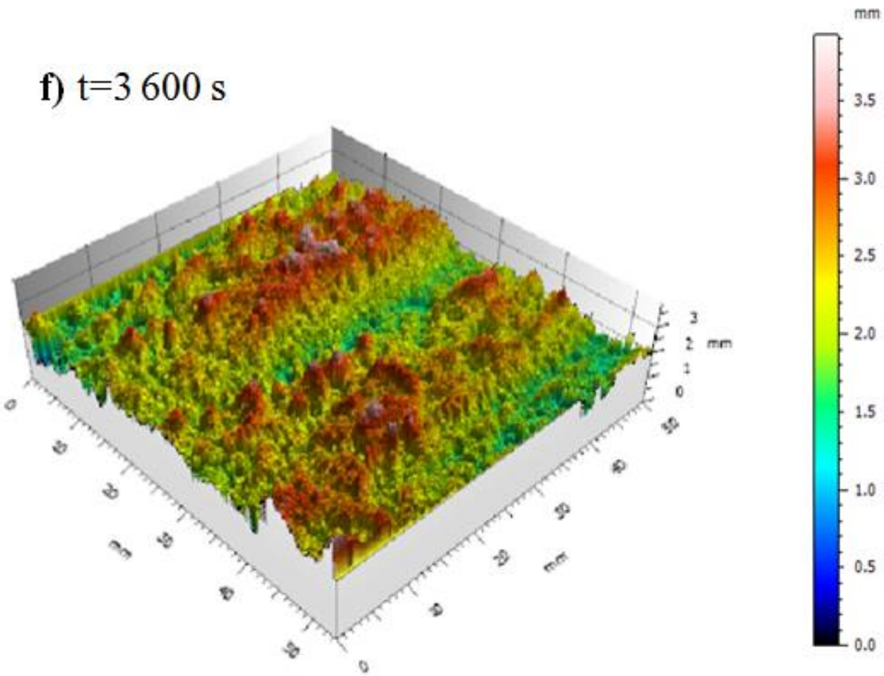


3D isometric pertinent visualizations versus the time of the cement mortar transitional surface morphology stages

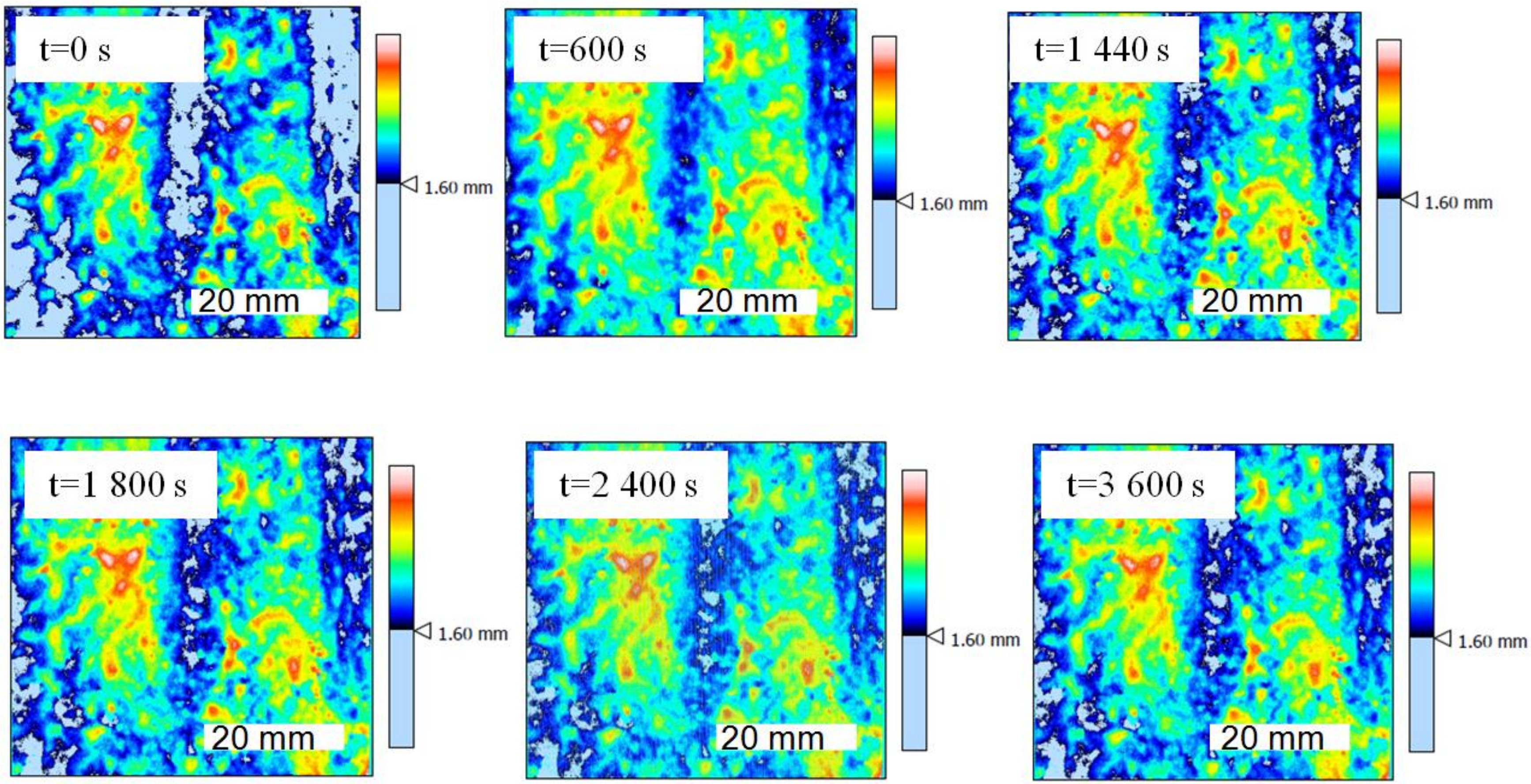


3D isometric pertinent visualizations versus the time of the cement mortar transitional surface morphology stages



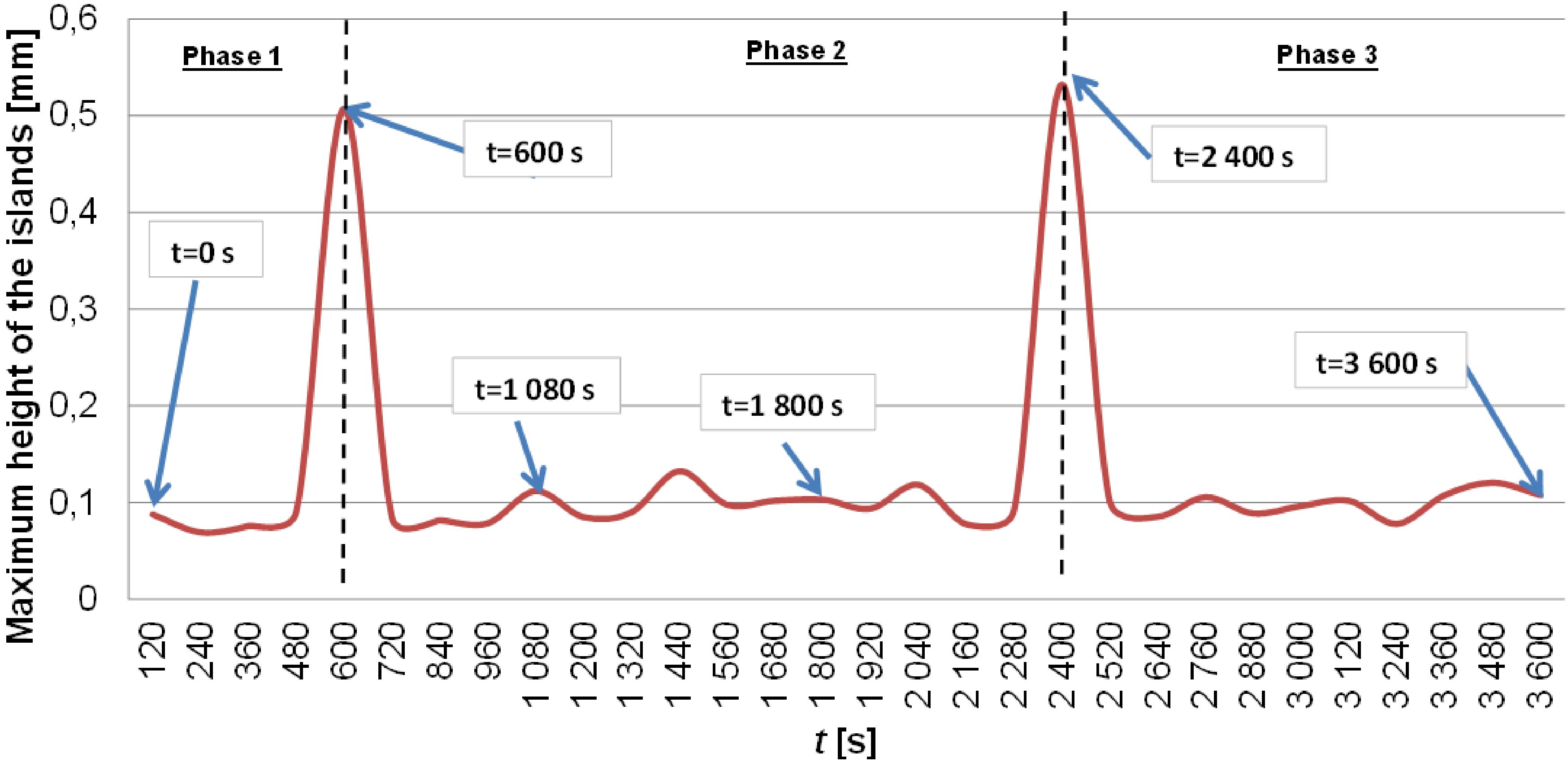


Kinetics of the visualizations of the 3D islands in surface morphology kinetics at early ages of mortar surface structure morphogenesis*



*threshold 1.60 mm over the lowest point of the surface

Kinetics of the visualizations of the 3D islands in surface morphology kinetics at early ages of mortar surface structure morphogenesis*



Based on the analysis, it can be observed that:

- The process can be divided into two transitions and three transitional phases,
- Phase 1 starts immediately after mixing. It takes until t = 600 s,
- At the transition between phase 1 and 2 the maximum height of the islands increases from 0.1 mm to 0.5 mm,
- The second transition is visible at 2 400 s.

There is a need to study this directionality phenomena in the morphogenesis of lateral transitions.

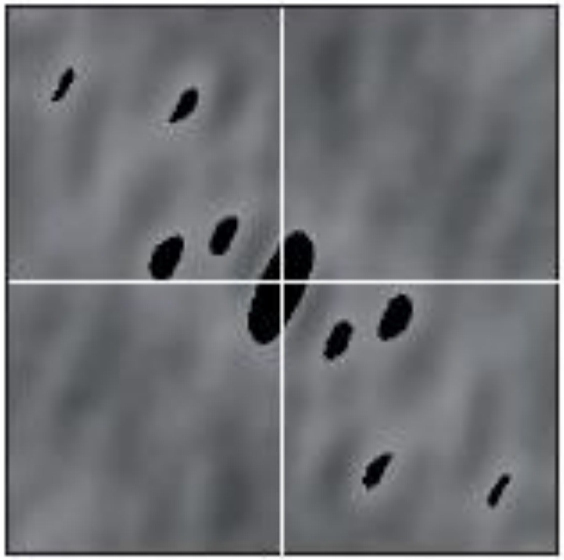
Procedure to calculate *Str*

The degree of isotropy was measured and evaluated according to ISO 25178 using the texture-aspect ratio of surface morphology (*Str*):

$$Str = \frac{R\min}{R\max}$$

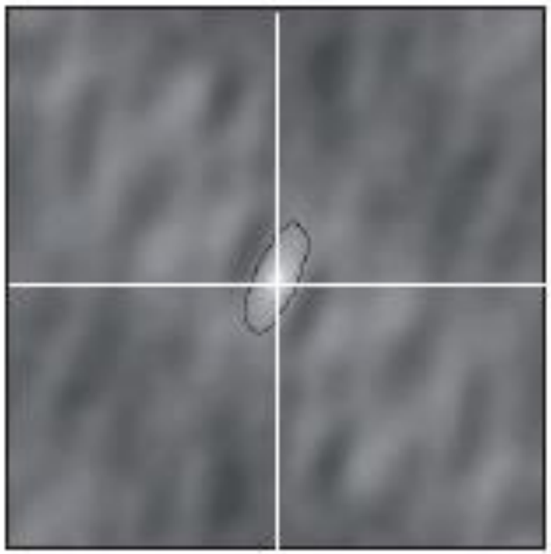
Procedure to calculate *Str* according to ISO 25178

a) Autocorrelation function of the surface

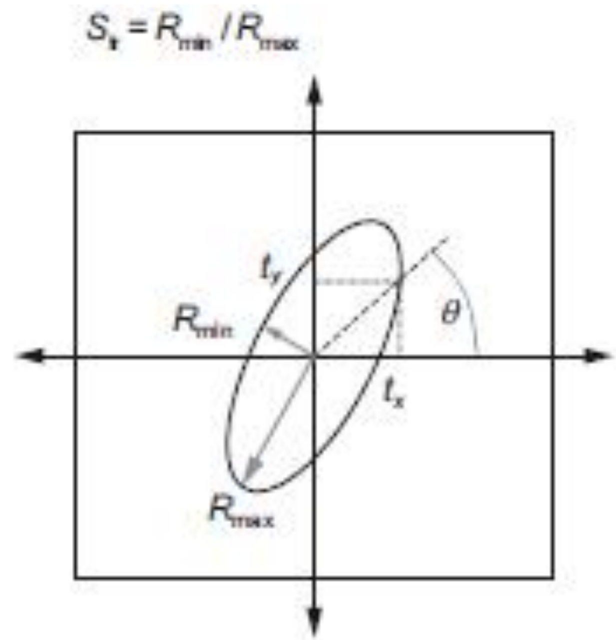


b) Threshold autocorrelation at s (the black spots are above the threshold)

Procedure to calculate *Str* according to ISO 25178



c) Threshold boundary of the central threshold portion



d) Polar coordinates leading to the autocorrelation lengths in different directions

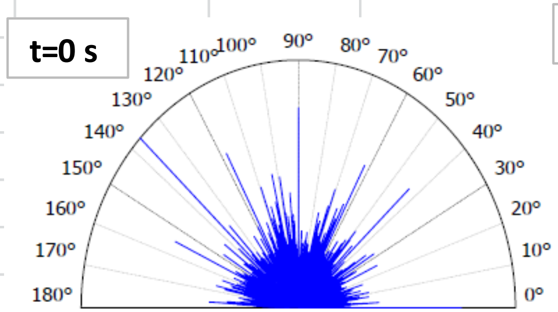
Facts about *Str*:

- The morphology of isotropic surfaces is characterized by *Str* values closer to 1.

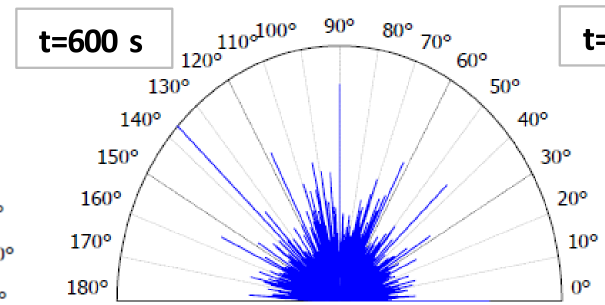
- Anisotropic topography, which is perfectly monodirectionally oriented, obtaines *Str* values closer to 0.

- A perfect isotropic surface of cement mortar probably does not exist.

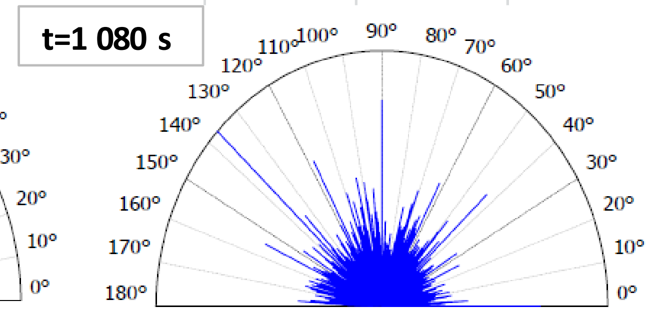
Kinetics of directionality in the morphogenesis of cement mortar surface isotropy changes at early ages



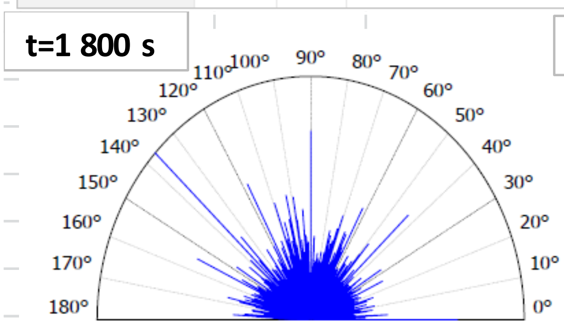
Parameters	Value	Unit
Isotropy	24.3	%
First Direction	137	°
Second Direction	90.0	°
Third Direction	0.183	°



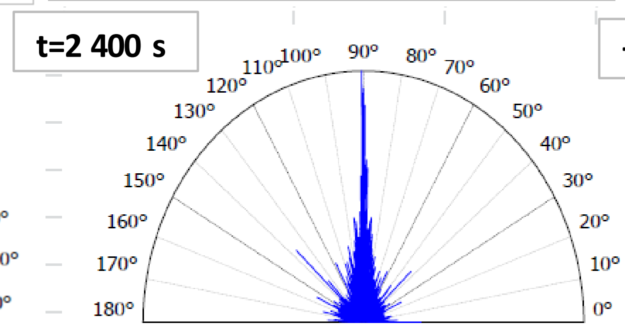
Parameters	Value	Unit
Isotropy	26.1	%
First Direction	137	°
Second Direction	90.0	°
Third Direction	0.200	°



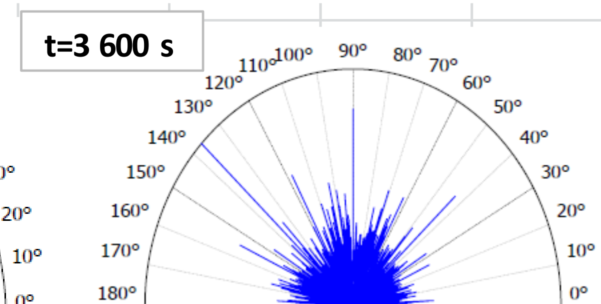
Parameters	Value	Unit
Isotropy	25.6	%
First Direction	137	°
Second Direction	90.0	°
Third Direction	0.173	°



Parameters	Value	Unit
Isotropy	26.4	%
First Direction	137	°
Second Direction	90.0	°
Third Direction	0.198	°

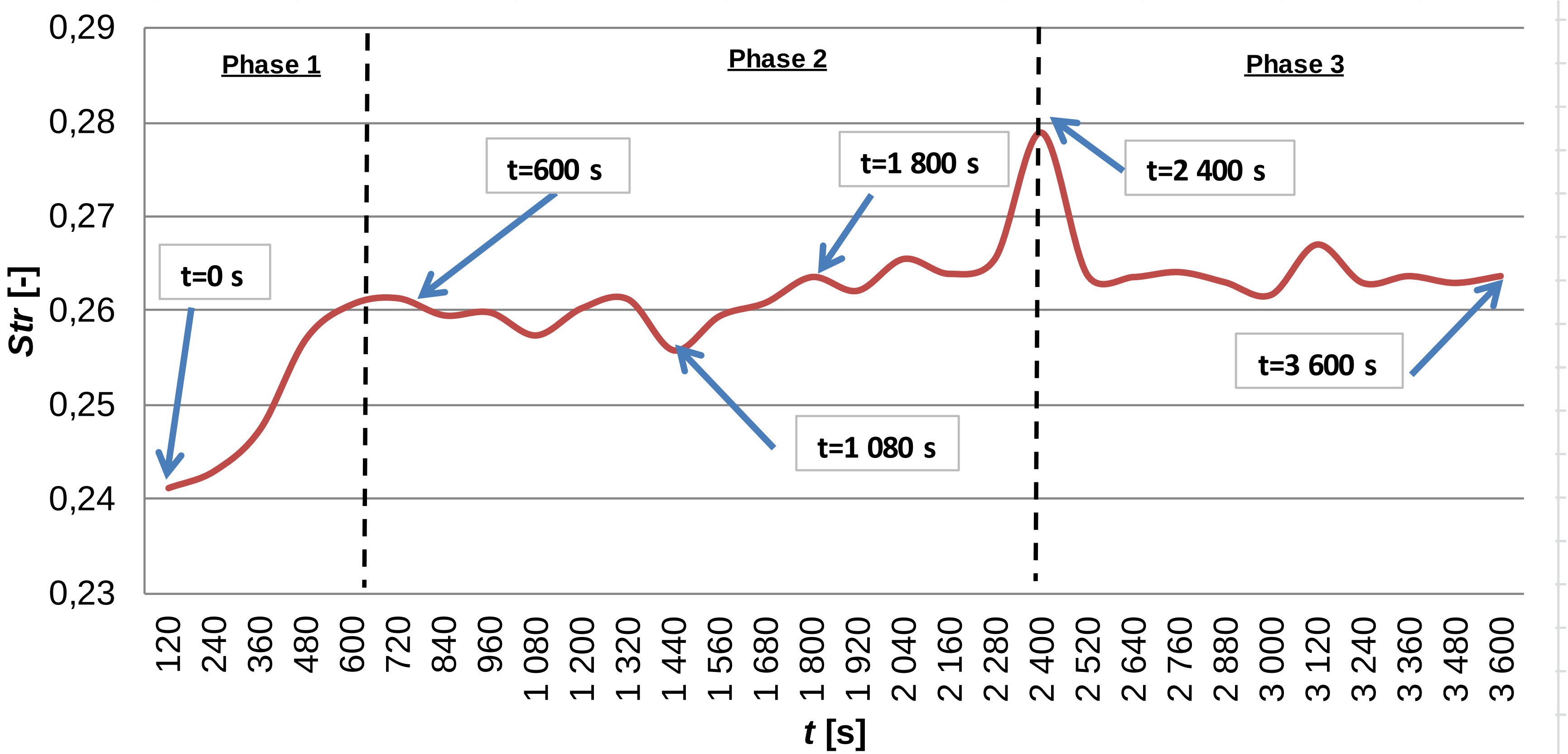


Parameters	Value	Unit
Isotropy	27.9	%
First Direction	90.5	°
Second Direction	96.0	°
Third Direction	137	°



Parameters	Value	Unit
Isotropy	26.3	%
First Direction	137	°
Second Direction	90.0	°
Third Direction	0.199	°

Kinetics of directionality in the morphogenesis of cement mortar surface isotropy changes at early ages



Based on the analysis, it can be observed that:

- The analysis confirms that the superficial morphological evolution process of mortar surface isotropy can be divided into three phases,
- During Phase 1, morphological isotropy increases from Str=0.24 to Str =0.26,
- In the second phase (Phase 2), which takes between 720 and 2 400 s, the surface morphology is still moving,

Based on the analysis, it can be observed that:

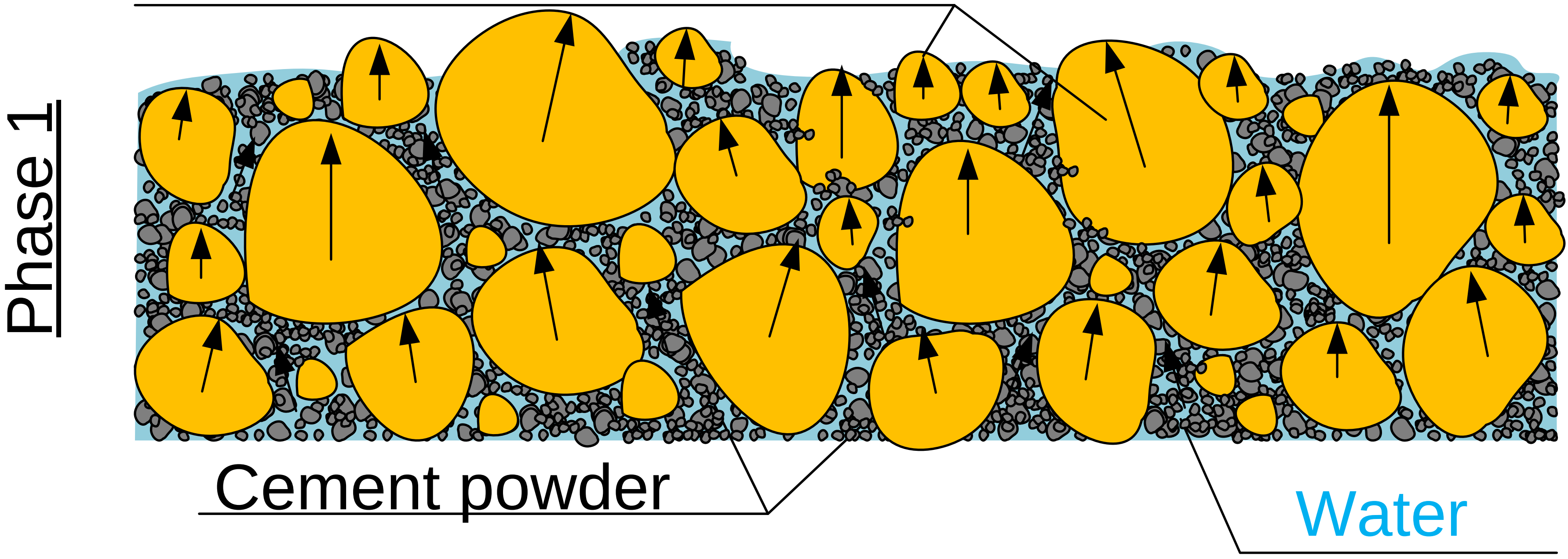
- After approximately 2 400 s from the start of the measurements (at which the Str=0.28), a steady hydration begins during the solidification stage and the superficial morphology of the surface of the cement mortar is steadying (Phase 3).

It has to be pointed out that in this presentation, focus was placed on morphology changes and that the chemical behavior of the surface of cement mortar was not treated.

4. Proposal of a dynamic mechanism

Proposal of a dynamic mechanism of morphogenetic transition

Sand grains intend to go out due to the densification and water influence



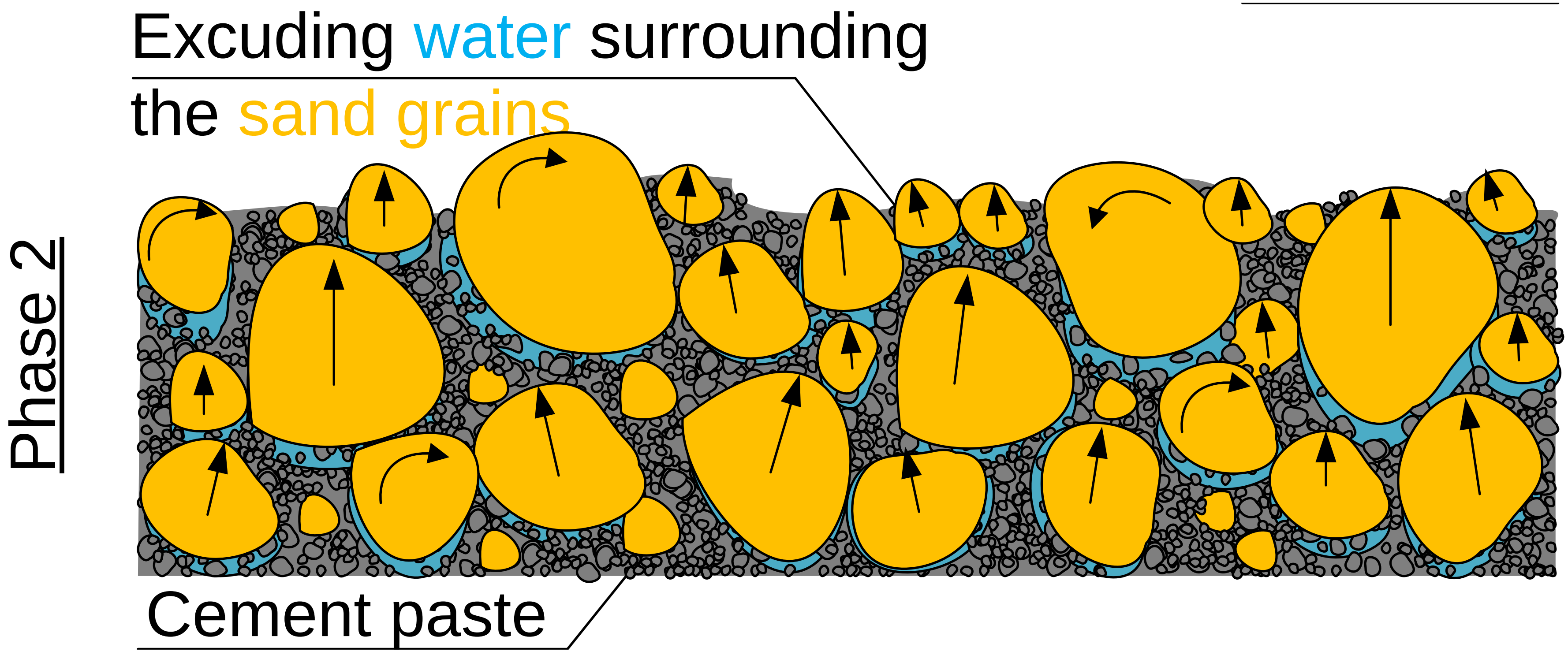
Main facts related to the Phase 1

The first phase starts immediately after mixing and takes until t = 600 s.

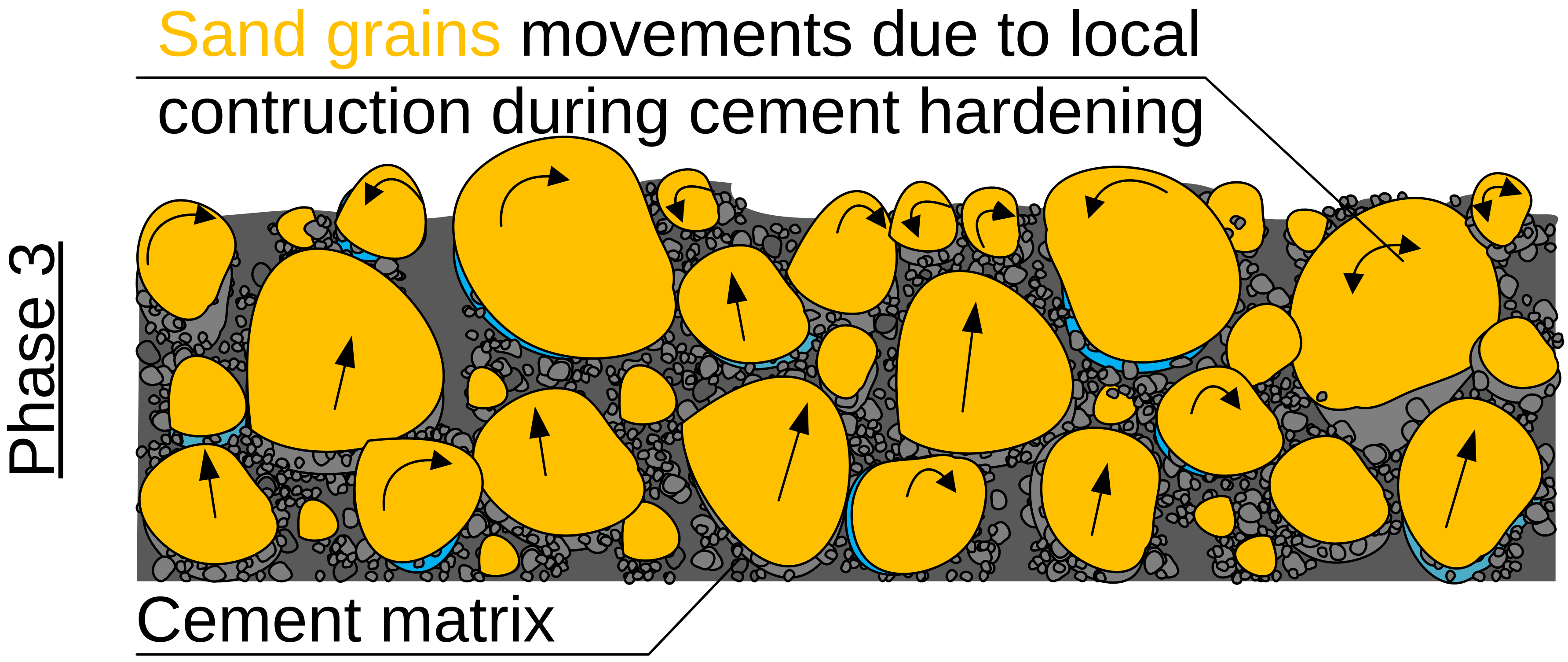
Coupling of liquid flow exudation from the mortar cement mixture and the surface behavior of gravel occurs by means of the tangential stress boundary condition during densification of the cement and sand.

This mechanism probably operates at the first transition.

Proposal of a dynamic mechanism of morphogenetic transition



Proposal of a dynamic mechanism of morphogenetic transition



Main facts related to the Phases 2 and 3

The second transition is visible at the time of 2 400 s.

The second morphological transition is probably due to the progressing of cement densification that accompanies the gravitation flow and also the expulsion of heaps and gravels that is accompanied by the second increase of the altitudes of “isles”.

5. Conclusions and perspectives

Conclusions

The most important results from the point of view of surface morphology are:

•The surface of a heterogeneous mortar cement to transition from boundary friction (lubrication) regime to elasto-hydrodynamic lubrication and/or heap and masse as an untidy collection of things oiled up haphazardly. Therefore, the amplitudes of “isles” are increased,

Conclusions

- Coupling of liquid flow exudation from mortar cement mixture and the surface behavior of gravel occurs by means of the tangential stress boundary condition during densification of cement and sand.

This mechanism probably operates at first transition,

Conclusions

- Second morphological transition is probably due to progressing of cement densification accompanying gravitation flow and expulsion of heaps and gravels accompanied of second increased of “isles” altitudes,
- The lateral or horizontal coincidence of transitional evolutions in terms of morphologically oriented surface changes are also depicted,

Conclusions

- Methods of measuring these temporary behaviors are available and show the results of the impact of surface rheology [41] on morphology mortar cement transitions,
- The observed transitions are irreversible in a three phasic mixture.

Conclusions

The most important results from the point of view of the modelling process are:

•The proposal of a model of a dynamic mechanism of morphogenetic transition with regards to surface rheology, internal stresses, mixing, water exudation film formation, physical chemistry and the roughness of concerned surfaces. This hypothetical model has to be developed and optimized,

Conclusions

- The monitoring of solidification for the predictive modeling of surface morphology, or the self-tuning adaptive control of the process should be explored further.

Tasks to be performed for the next class

1. Describe main 3 methods that may be used to treat the surface of 3 materials used your research,
2. Search for scientific articles in Scopus using combintion of selected 3 Methods and 3 materials,
3. Describe the content of 3 most cited articles related to surface treatment based on your Scopus search.