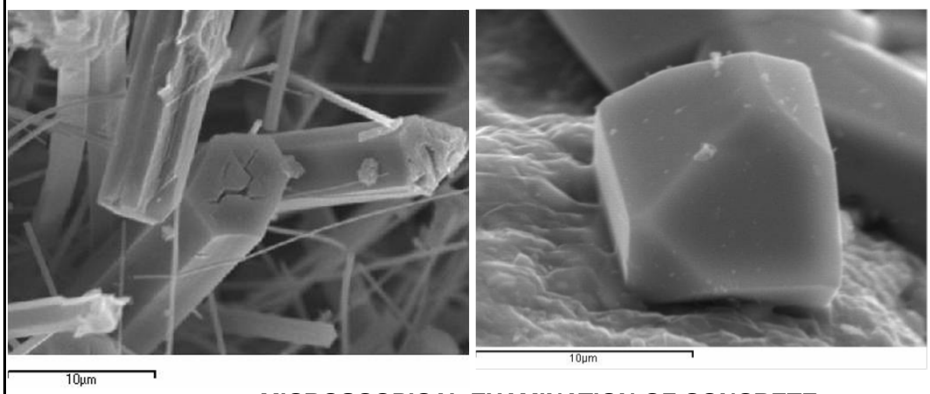



**MICROSCOPICAL EXAMINATION OF CONCRETE**

**António Santos Silva**
**ssilva@lnec.pt**



COURSE
Testing techniques for structures inspection 29th and 30th May 2012

# The need

Human beings have always searched tools that enhance your senses.
For example, vision is not as developed as in other animals.

LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL
Investing in our common future

**COURSE**
**Testing techniques for structures inspection** **29th and 30th May 2012**

# The need

Human beings have always searched tools that enhance your senses.
For example, vision is not as developed as in other animals.
Man has always tried see more
- far

LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL

Investing in our common future

European Union
European Regional Development Fund

**COURSE**
**Testing techniques for structures inspection** **29th and 30th May 2012**

# The need

Human beings have always searched tools that enhance your senses.
For example, vision is not as developed as in other animals.
Man has always tried see more
- far
- and more closely

LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL

Investing in our common future

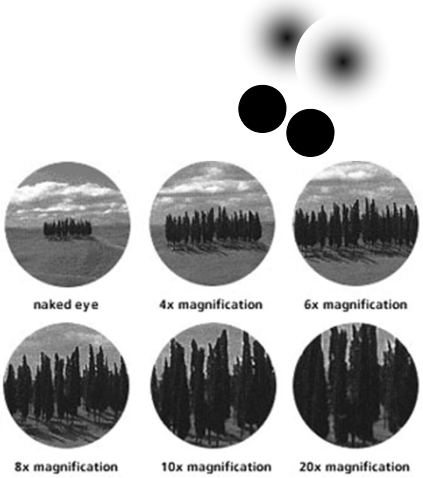
European Union
European Regional Development Fund

# which improves?

it depends on two properties:

**Resolution**, i.e., the ability to distinguish two objects in the nearby and
**Magnification**, i.e., how much the size of an object, apparently, increases.

These two properties are not completely independent because with the magnification increases the tendency to increase the resolution.



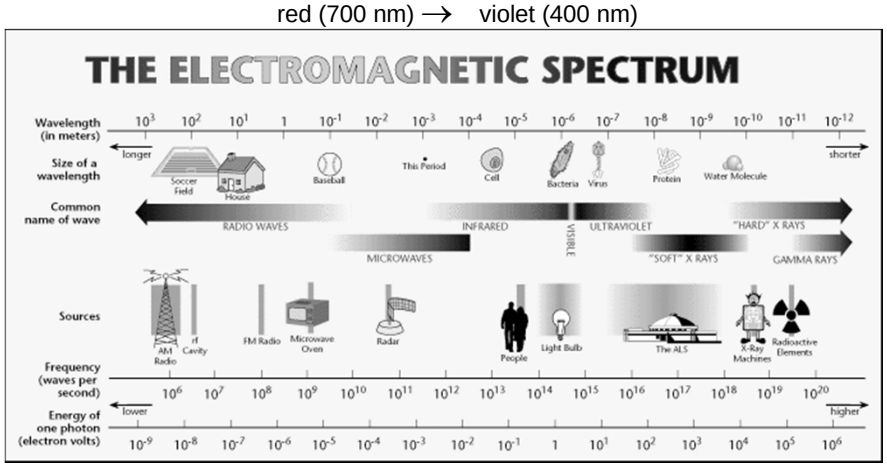



**COURSE**
**Testing techniques for structures inspection** **29th and 30th May 2012**

## What we see? … only on part

Electromagnetic spectrum

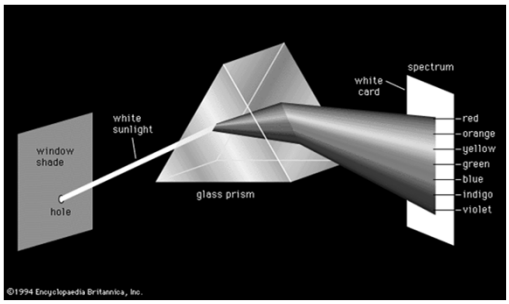
red (700 nm) → violet (400 nm)

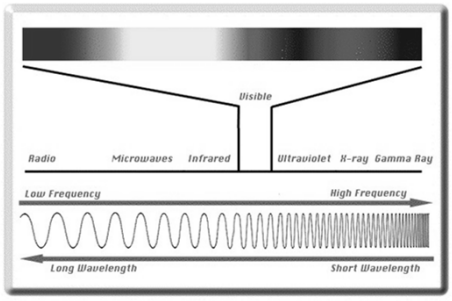



LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL
Investing in our common future

# The white light and the colour…

The white light consists of all wavelengths, of visible.
Thus, the colour is achieved by differential absorption wavelengths, for example, absorption of red and yellow makes objects blue, or absorption of blue and red make them yellow or green ...





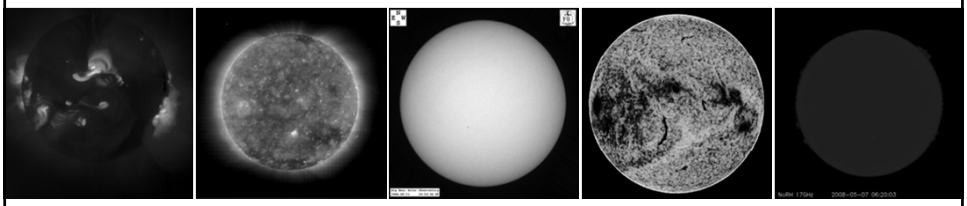



# The sun as example …

There is no light source as well known as the Sun … will be?

**COURSE**
**Testing techniques for structures inspection** **29th and 30th May 2012**

There is no light source as well known as the Sun … will be? ? ?



X-rays ultraviolet Visible Infrared Radio

LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL

Investing in our common future

European Union
European Regional Development Fund

**COURSE**
**Testing techniques for structures inspection** **29th and 30th May 2012**

# equipments …

LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL

Investing in our common future

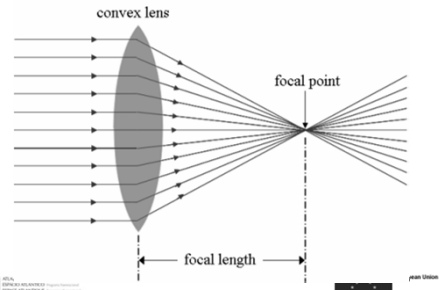
European Union
European Regional Development Fund

**COURSE**
**Testing techniques for structures inspection** **29th and 30th May 2012**

# magnifying glass …

A simple pocket magnifier lets you increase our ability to observe small objects.

Basically it is a convex lens, allowing a sharp image by adjusting the focal length.
The greater the curvature, higher magnification.




LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL

Investing in our common future

European Regional Development Fund

**COURSE**
**Testing techniques for structures**

# Stereomicroscope…

For higher magnifications need a binocular microscope or stereomicroscope.

Allowing an extended three-dimensional view of an object.

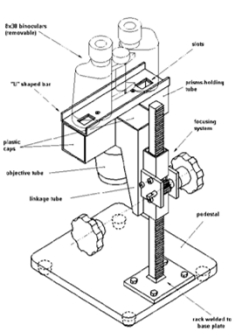


Figure 5 - Stereoscopic microscope (rear isometric view)

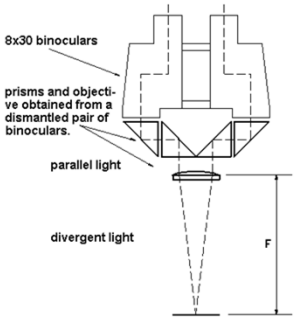
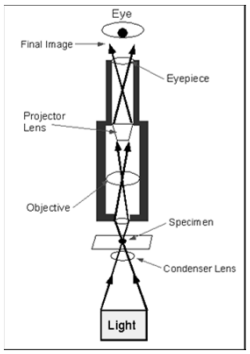


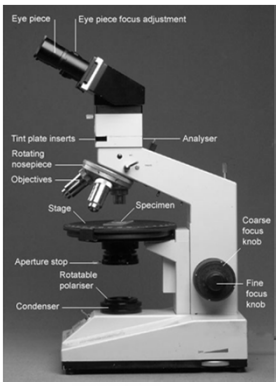

Figure 2
Optical schematic diagram of the common-objective stereoscopic microscope. The common objective is kept at the focal distance from the object. In this way, the light crossing the objective becomes parallel. The four prisms collect and space two optical paths. As the light is parallel, it can be seen by a pair of binoculars placed on the microscope.

LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL

# Optical microscope…

For higher magnifications we need samples prepared in a special way and observed under a microscope.

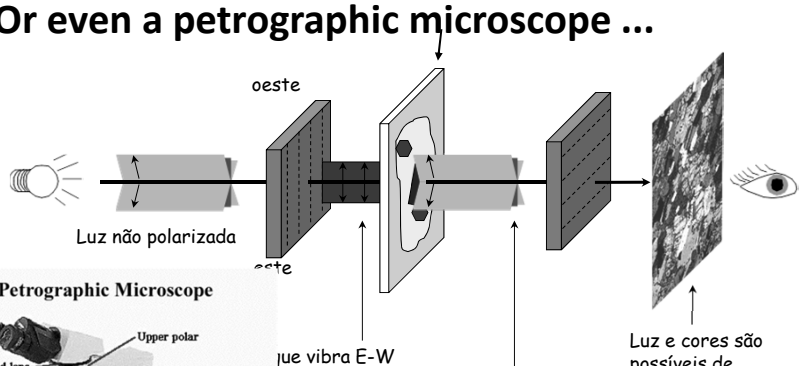


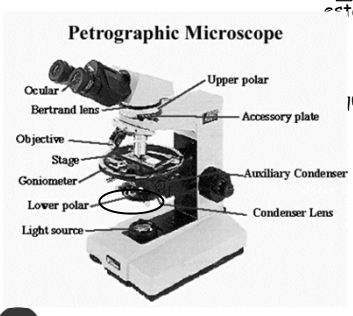








# Or even a petrographic microscope ...



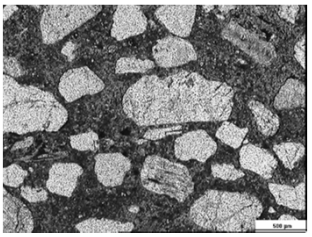



**COURSE**
**Testing techniques for structures inspection** **29th and 30th May 2012**

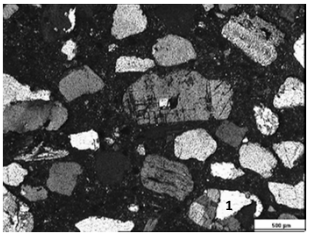
Minerals can be classified as **anisotropic** or as **isotropic**, depending on their light properties.

Isotropic minerals show the same velocity of light in all directions, while anisotropic minerals show the velocity of light varying in different orientations.

Anisotropic minerals show different colors when viewed under crossed polarizers. The colors seen are called interference colors, which can be used to help identify the minerals. Quartz, for example, appears as white when viewed under plane polarized light (N//), and will be white or some shade of gray when viewed under crossed polarizers (NX).



N//

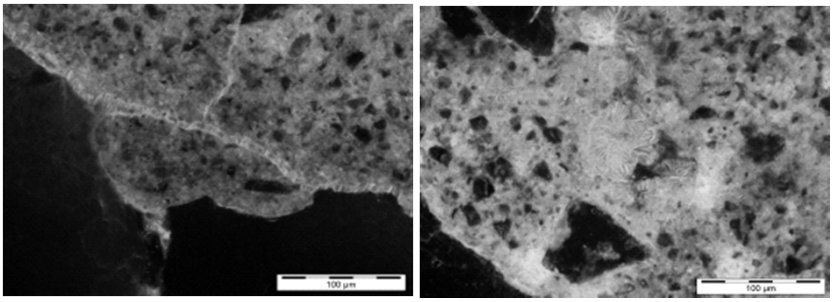


NX



**COURSE**
**Testing techniques for structures inspection** **29th and 30th May 2012**

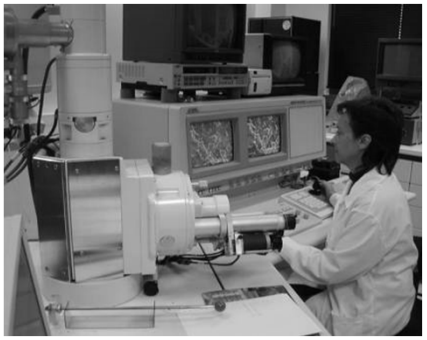
Another technique that can be attached to a petrographic microscope is the fluorescence microscopy. This technique consists of exciting the specimen to fluoresce by absorption of ultraviolet light and observing the resulting fluorescence. In cement-based materials the specimens must be previously stained with a fluorescent dye during the epoxy impregnation.

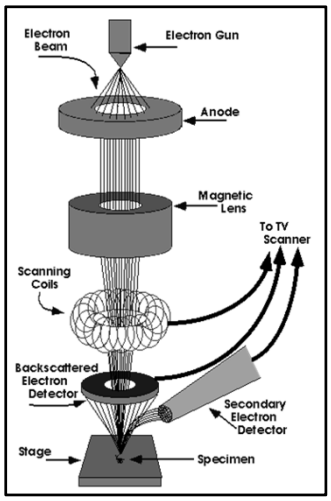


LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL
Investing in our common future
European Union
European Regional Development Fund

# Scanning electron microscope (SEM)

- in scanning electron microscopy a accelerated beam of electrons is focused on the sample to be analysed
- magnification to 300,000 X

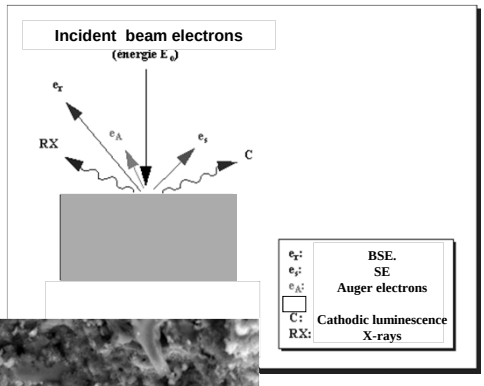


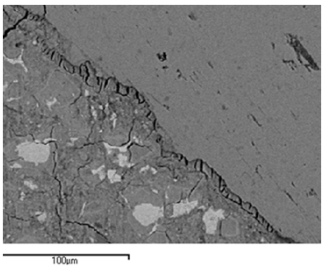


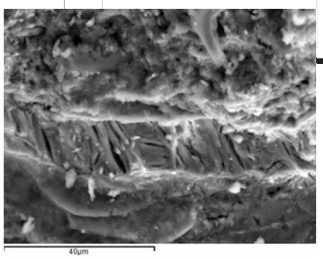



**COURSE**
**Testing techniques for structures inspection** 29th and 30th May 2012

the impact of the beam electrons causes the emission of signals from the sample:
secondary electrons (SEI) and backscattered electrons (BSE) are collected by detectors, which transmits these signals to a monitor screen.



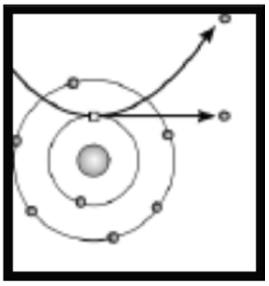




LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL
Investing in our common future

**Analysis of secondary electrons:**

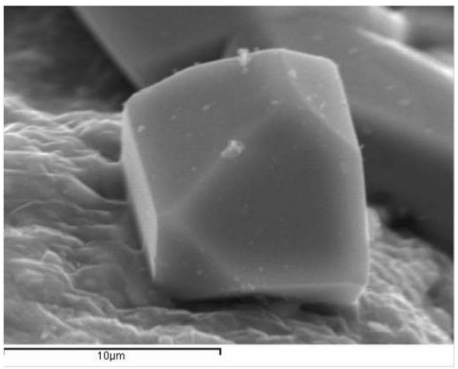
- Triggered by the shock of the beam electrons with atoms in the sample, a primary electron may transfer part of its energy to an electron just "on" (lower electron binding energy) leading to their ionization.
- It is called the electron secondary electron emitted in this process.
- These electrons have generally a low-energy (~ 50 eV), and therefore comes close vicinity of the point of impact of the electron beam and a depth not exceeding a few tens of nanometers.

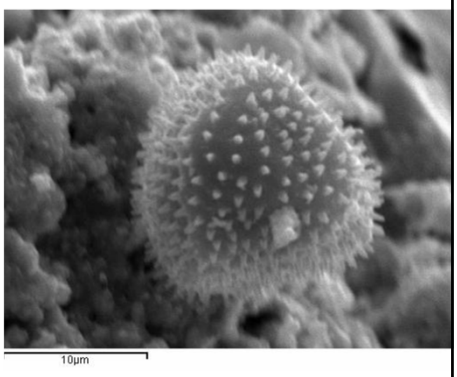




COURSE
Testing techniques for structures inspection 29th and 30th May 2012

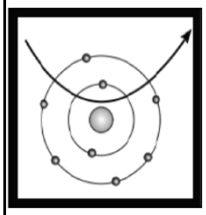
The image obtained by detection of SE has a strong topographic contrast, resembling an image obtained by direct visual observation or with a magnifying glass.




LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL
Investing in our common future

## Analysis of backscattered electrons:



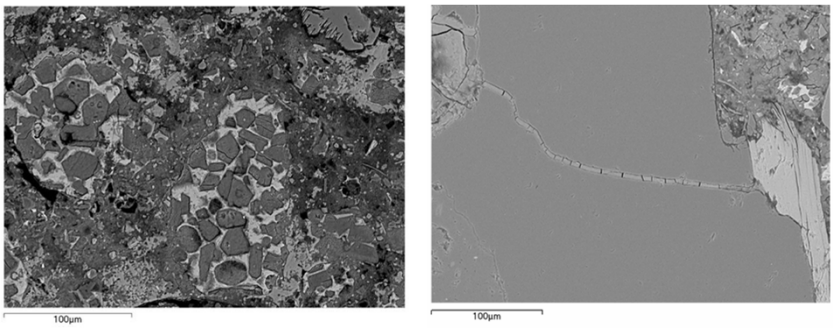
• BSE are the electrons emerging from the sample surface with high energy (close to the energy of primary electrons).

• These electrons are sensitive to atomic number. The heavier atoms emit more BSE than lighter atoms: Areas formed by heavier atoms will be brighter than areas consisting of lighter atoms.



COURSE
Testing techniques for structures inspection 29th and 30th May 2012

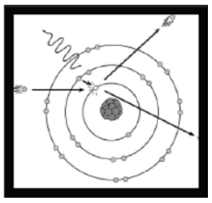
BSE images makes it possible to easily detect problems of inhomogeneity in the sample, due to presence of contrast.



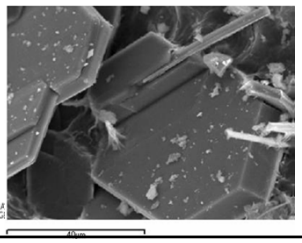

LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL
Investing in our common future
European Union
European Regional Development Fund

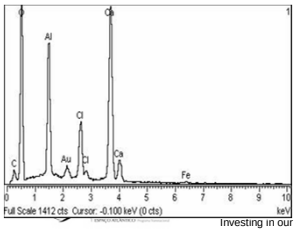
## X-ray analysis:

- The electron beam causes, in each constituent of the sample expulsion of the K-shell electron. Electron layer L and M will then take the places left vacant K-shell, with emission of energy: X-rays, which are characteristic of each element.



- Analytical technique extremely useful and widely used.





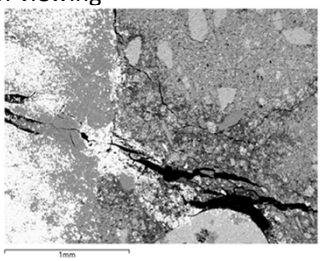


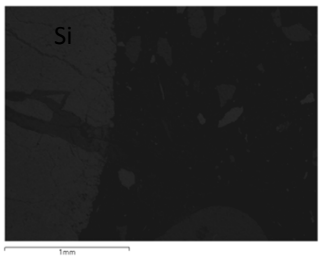

COURSE
Testing techniques for structures inspection 29th and 30th May 2012

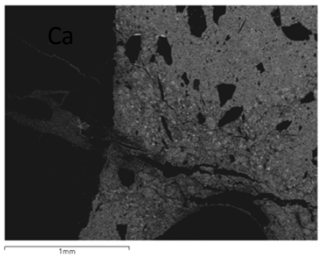
## Scanning electron microscopy

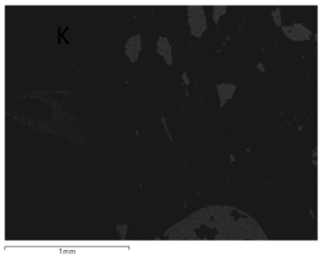
Another way of viewing

X-ray maps






Investing in our common future

**COURSE**
**Testing techniques for structures inspection** **29th and 30th May 2012**

# applications …

## in concrete

LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL

Investing in our common future

European Union
European Regional Development Fund

**COURSE**
**Testing techniques for structures inspection** **29th and 30th May 2012**

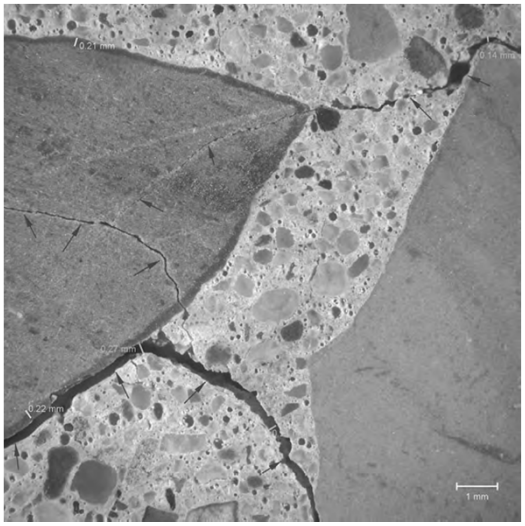
Examination of the concrete core surface, being perceptible the aggregate distribution, and the presence of voids, pores and deposits in the paste.

LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL

Investing in our common future

European Union
European Regional Development Fund

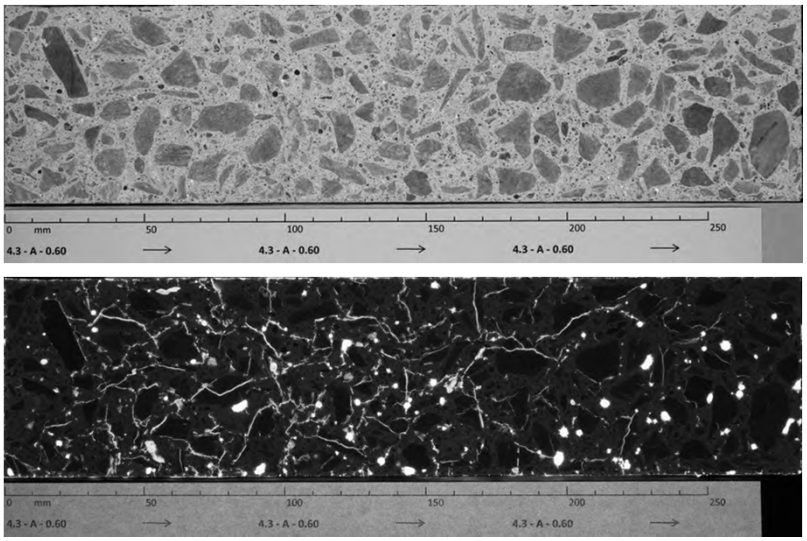
**COURSE**
**Testing techniques for structures inspection** **29th and 30th May 2012**




Reflected light photomicrographs of polished surface showing cracking and aggregate debonding associated with ACR. Red arrows indicate cracks and microcracks, green bars measure width of cracks and yellow bars measure width of reaction rim [Rothstein et al, 14th ICAAR]



**COURSE**
**Testing techniques for structures inspection** **29th and 30th May 2012**



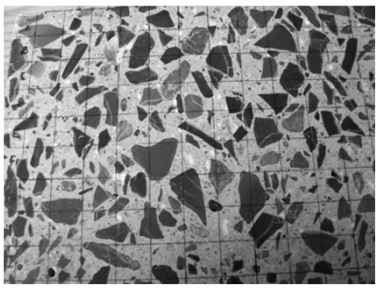

normal light

UV-light

[Lindgård et al, 14th ICAAR]

LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL
Investing in our common future

**COURSE**
**Testing techniques for structures inspection** **29th and 30th May 2012**



The Damage Rating Index (DRI) is a petrographic method that was developed by Grattan-Bellew and Dunbar in 1992 and 1995 to evaluate the extent of damage in concrete caused primarily by ASR.

TABLE 1: Factors applied to the total numbers of each type of defect.

| Damage feature counted | Factor applied |
|---|---|
| Coarse aggregate (CA) with cracks | 0.25 |
| Coarse aggregate (CA) with cracks & gel | 2.0 |
| Coarse aggregate (CA) with open crack | 3.0 |
| Coarse aggregate (CA) debonded | 3.0 |
| Coarse aggregate (CA) with reaction rim | 0.5 |
| Cement paste (P) with cracks | 2.0 |
| Cement paste (P) with cracks & gel | 4.0 |
| Air Void with gel | 0.5 |

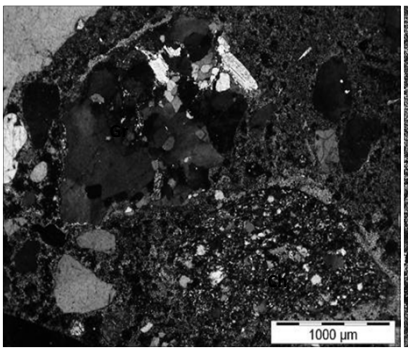
LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL

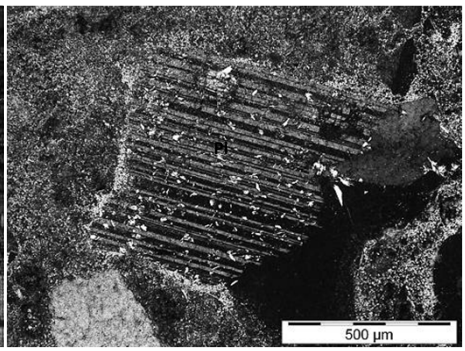
Investing in our common future

European Union
European Regional Development Fund

**COURSE**
**Testing techniques for structures inspection** **29th and 30th May 2012**

Examination of concrete thin sections under the petrographic microscope enables the description of concrete constituents:
-coarse and fine aggregates
- cementitious constituents (e.g. cement clinker, portlandite, ettringite, supplementary cementing materials (e.g. fly ashes and slags).
- reaction products.



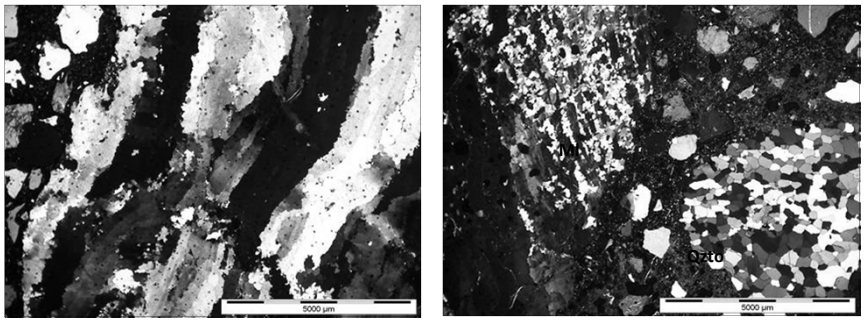

LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL

Investing in our common future

European Union
European Regional Development Fund

**COURSE**
**Testing techniques for structures inspection** **29th and 30th May 2012**

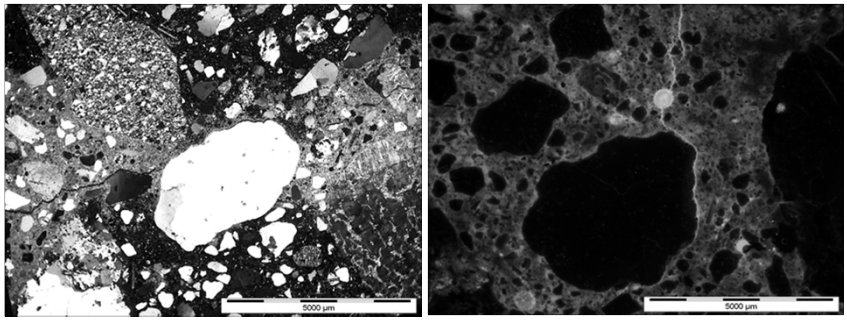
Examination of concrete thin sections under the petrographic microscope enables the description of concrete constituents:
-coarse and fine aggregates
- cementitious constituents (e.g. cement clinker, portlandite, ettringite, supplementary cementing materials (e.g. fly ashes and slags).
- reaction products.






**COURSE**
**Testing techniques for structures inspection** **29th and 30th May 2012**

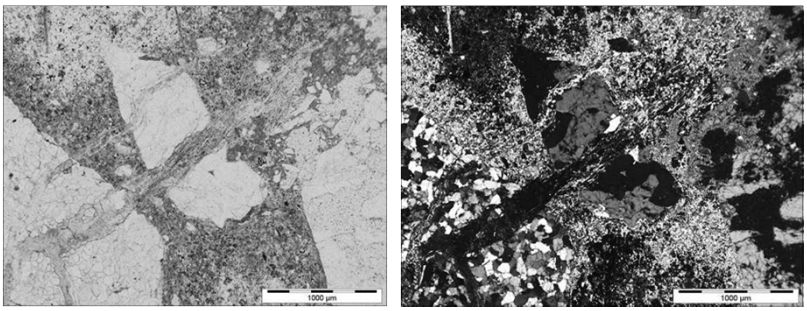
Examination of concrete thin sections under the petrographic microscope enables the description of concrete constituents:
-coarse and fine aggregates
- cementitious constituents (e.g. cement clinker, portlandite, ettringite, supplementary cementing materials (e.g. fly ashes and slags).
- reaction products.




LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL
Investing in our common future

**COURSE**
**Testing techniques for structures inspection** **29th and 30th May 2012**

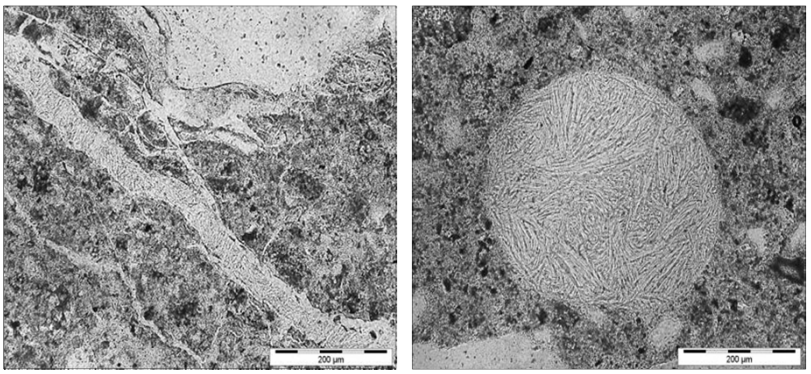
Examination of concrete thin sections under the petrographic microscope enables the description of concrete constituents:
-coarse and fine aggregates
- cementitious constituents (e.g. cement clinker, portlandite, ettringite, supplementary cementing materials (e.g. fly ashes and slags).
- reaction products.






**COURSE**
**Testing techniques for structures inspection** **29th and 30th May 2012**

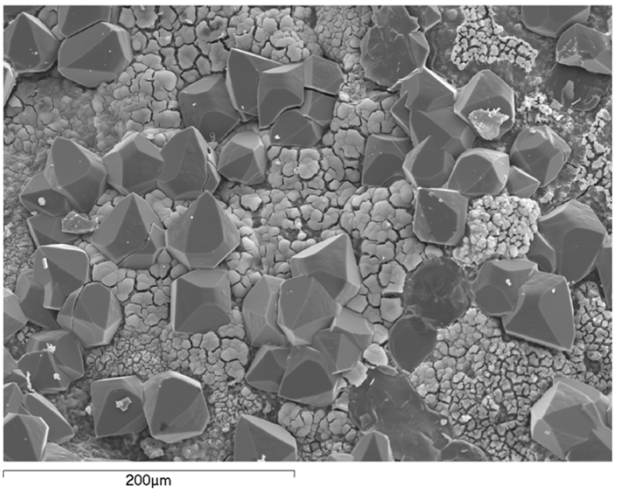
Examination of concrete thin sections under the petrographic microscope enables the description of concrete constituents:
-coarse and fine aggregates
- cementitious constituents (e.g. cement clinker, portlandite, ettringite, supplementary cementing materials (e.g. fly ashes and slags).
- reaction products.




LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL
Investing in our common future

**COURSE**
**Testing techniques for structures inspection** **29th and 30th May 2012**

Examination of concrete at SEM enables the observation of textures with high resolution, which means that closely spaced features can be examined at a high magnification.

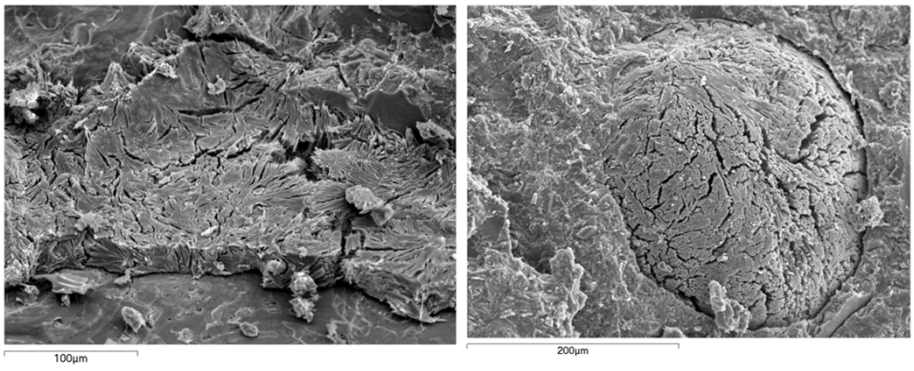



carbonation



**COURSE**
**Testing techniques for structures inspection** **29th and 30th May 2012**

Examination of concrete at SEM enables the observation of textures with high resolution, which means that closely spaced features can be examined at a high magnification.

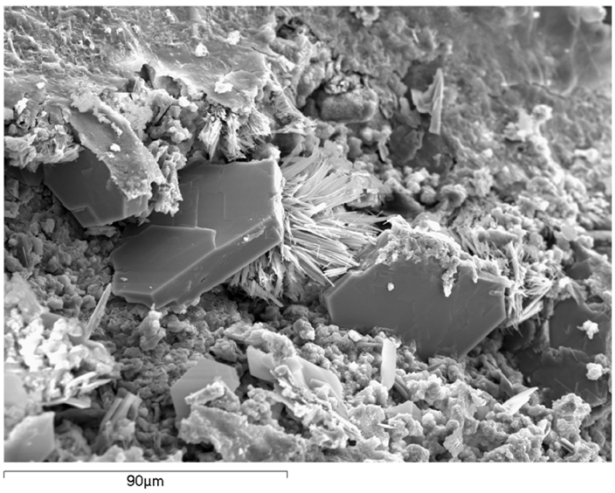



DEF

LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL
Investing in our common future
European Union
European Regional Development Fund

**COURSE**
**Testing techniques for structures inspection** **29th and 30th May 2012**

Examination of concrete at SEM enables the observation of textures with high resolution, which means that closely spaced features can be examined at a high magnification.




portlandite

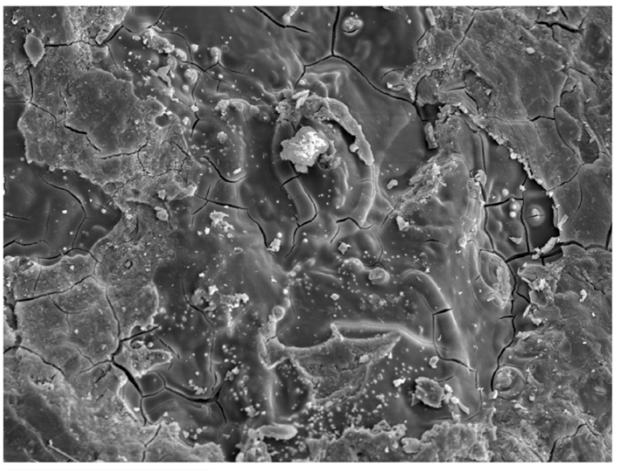
LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL

Investing in our common future

European Union
European Regional Development Fund

**COURSE**
**Testing techniques for structures inspection** **29th and 30th May 2012**

Examination of concrete at SEM enables the observation of textures with high resolution, which means that closely spaced features can be examined at a high magnification.




ASR

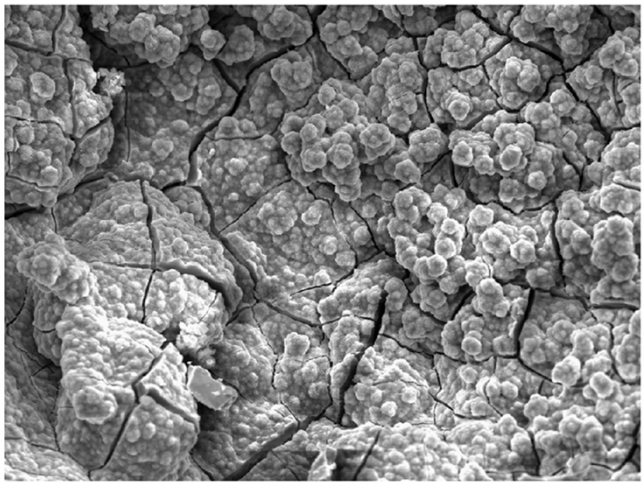
LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL

Investing in our common future

European Union
European Regional Development Fund

**COURSE**
**Testing techniques for structures inspection** **29th and 30th May 2012**

Examination of concrete at SEM enables the observation of textures with high resolution, which means that closely spaced features can be examined at a high magnification.

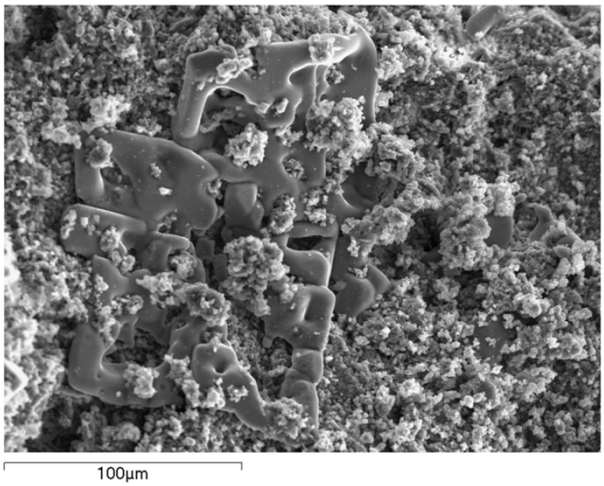



ASR



**COURSE**
**Testing techniques for structures inspection** **29th and 30th May 2012**

Examination of concrete at SEM enables the observation of textures with high resolution, which means that closely spaced features can be examined at a high magnification.

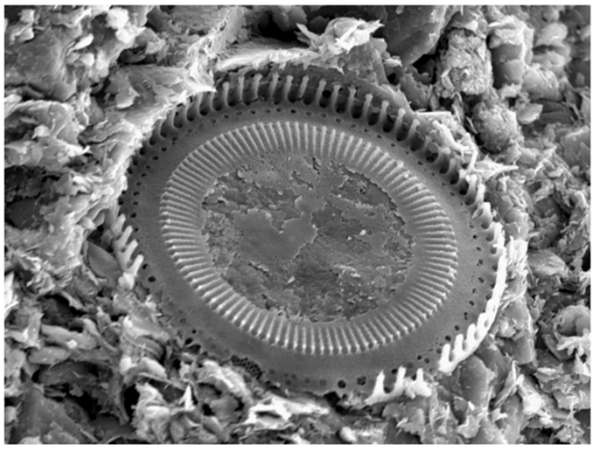



NaCl

LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL
Investing in our common future
European Union
European Regional Development Fund

**COURSE**
**Testing techniques for structures inspection** **29th and 30th May 2012**

Examination of concrete at SEM enables the observation of textures with high resolution, which means that closely spaced features can be examined at a high magnification.

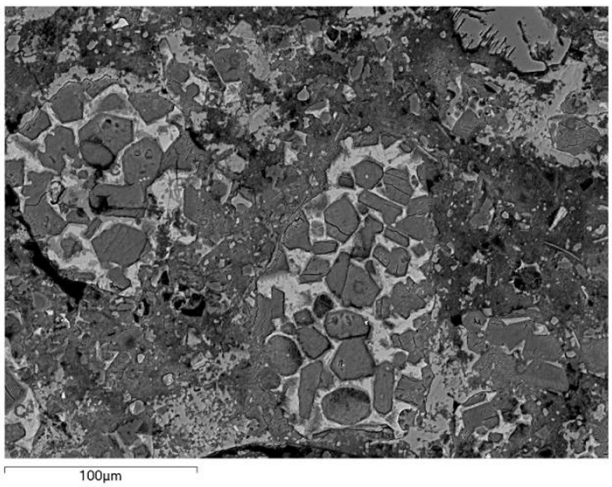



Biological colonization



**COURSE**
**Testing techniques for structures inspection** **29th and 30th May 2012**

Examination of concrete at SEM enables the observation of textures with high resolution, which means that closely spaced features can be examined at a high magnification.

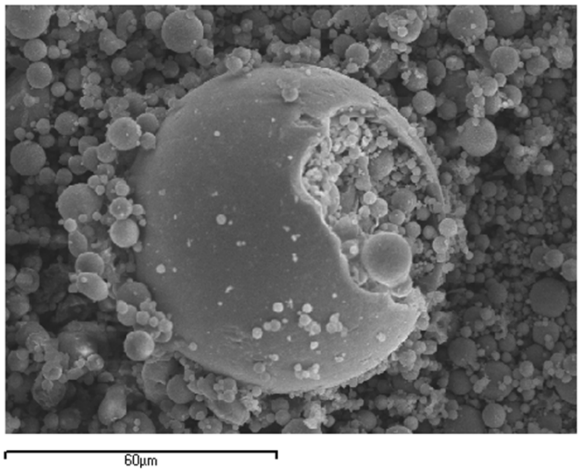



clinker

LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL
Investing in our common future

**COURSE**
**Testing techniques for structures inspection** **29th and 30th May 2012**

Examination of concrete at SEM enables the observation of textures with high resolution, which means that closely spaced features can be examined at a high magnification.



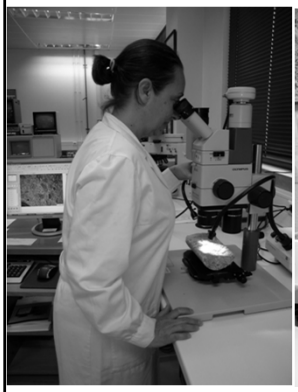

Fly ash

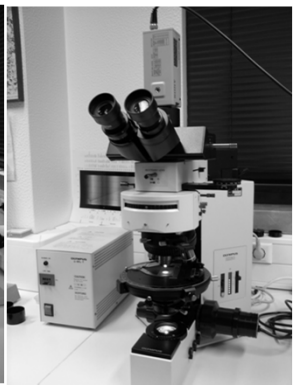
LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL

Investing in our common future

**COURSE**
**Testing techniques for structures inspection** **29th and 30th May 2012**

More afternoon, … practical session





LABORATÓRIO NACIONAL DE ENGENHARIA CIVIL

Investing in our common future