

listen to that structure whistle blowing

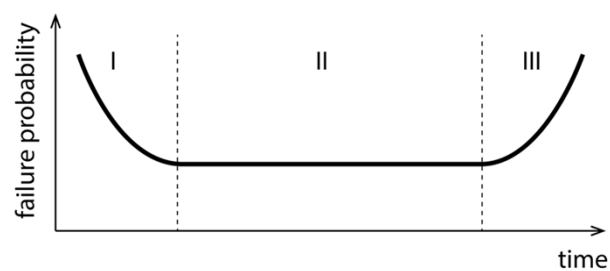
—measurement techniques on
concrete structures

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**As structural engineers, we
know enough about our
structures when we design
them.**

Not really

Situations that we are not so certain



- Existing structures
- New structures
- Load testing
- Scientific research

Measurement technology for concrete structures

- Ultra sonic measurement
 - Acoustic emission
 - Wave transfer properties related measurements
 - Coda Interferometry
- Stress measurement

Acoustic Emission

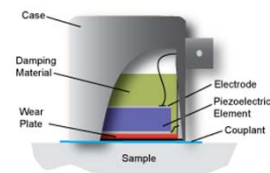
- **Acoustic emission** (AE) is the phenomenon of radiation of acoustic (elastic) waves in solids that occurs when a material undergoes irreversible changes in its internal structure.

–Wikipedia

- For concrete structures this is mainly related to cracks (video)

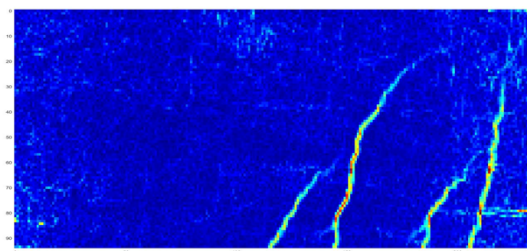
Basics of AE measurement

- AE sensors are typically piezoelectric sensors with elements made of special ceramic elements like lead zirconate titanate (PZT).
- dynamic displacement -> electrical signal
- Sample rate: 1-10 millions of samples per sec
- Response frequency: 1 kHz to 1 MHz



Indication of early damage

- Crack opening at early stage – warning for proof loading

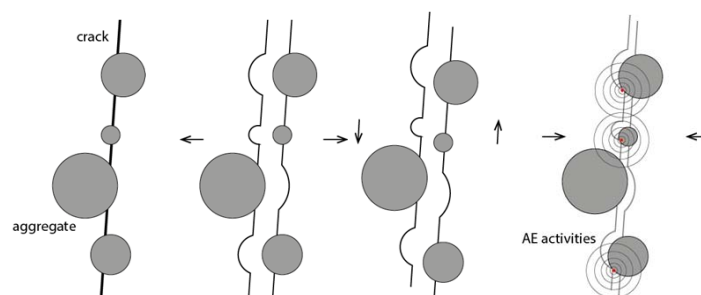


Stop criteria for shear



AE when crack closes

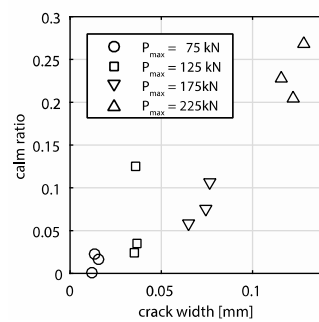
- When a crack closes it generates AE signals



AE when crack closes

- Crack closing – damage indication

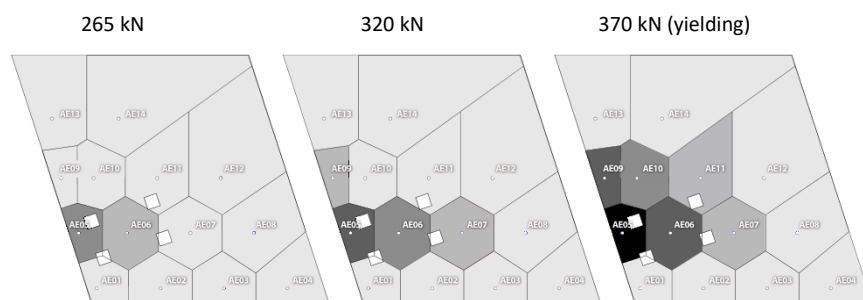
$$\text{Calm Ratio} = \frac{\text{the number of cumulative signal strength under unloading}}{\text{total signal strength during the whole cycle}}$$



Ruytenchildt bridge

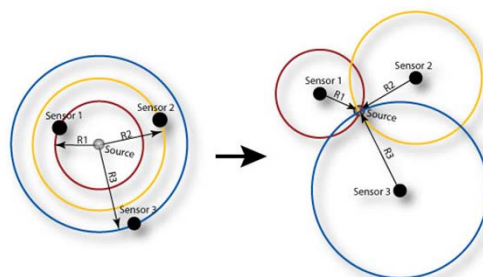
Damage indication with Acoustic Emission

- Measurement of Ruytenschildt bridge test



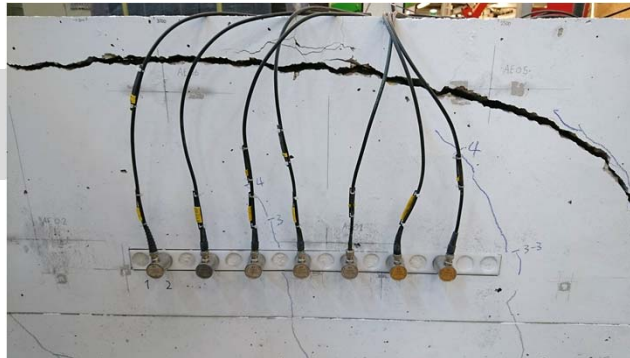
AE source location

- The basic wave propagation properties like wave speed and attenuation are needed.



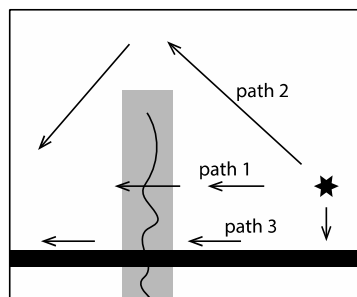
Wave transfer properties

- Wave velocity
- Wave attenuation



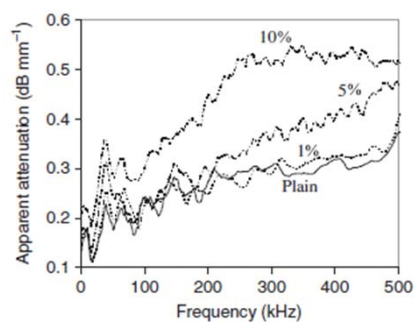
Wave velocity

- Crack has no effect on wave velocity?
- Crack band theory?
- Alternative paths?



Wave amplitude

- In all situations the amplitude attenuates
- When path 1 works, the attenuation reflects the crack opening

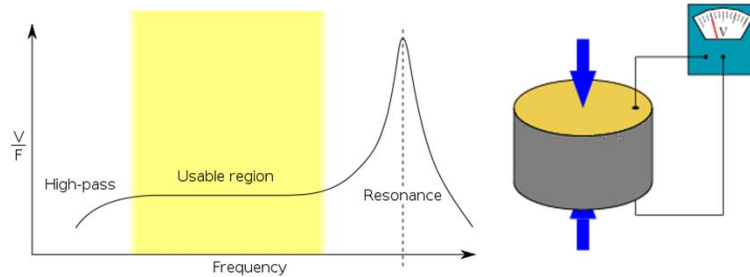


It would be nice if one can generate/measure AE wave manually at any location inside concrete structures.

Smart aggregate

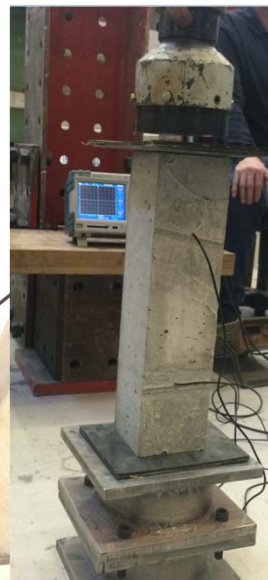
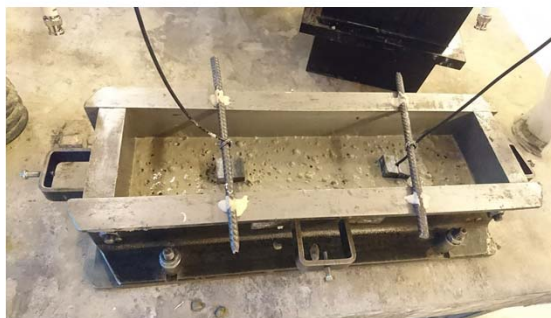
- Piezoelectric effect

$$C_{xx} = d_{xx}F_x$$



Smart aggregate

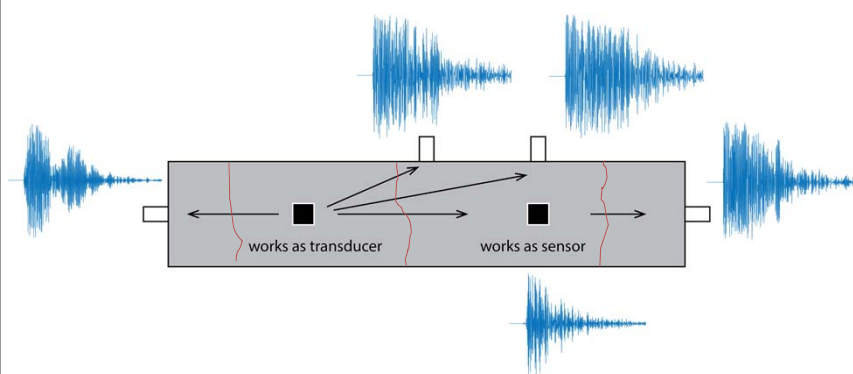
- Stress measurement (dynamic)



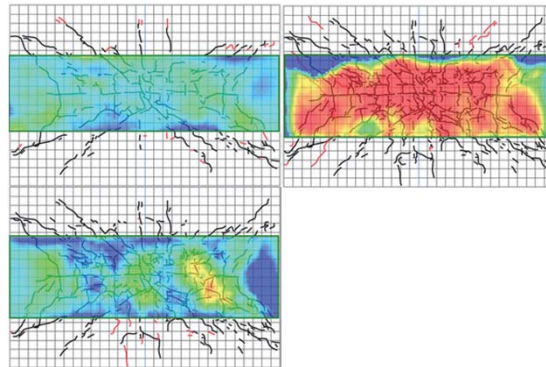
Proof tests



Proof tests



CT scan of a concrete structure



Summary

- AE measurement for early cracking activities (proof loading)
- AE measurement as damage indication
- Smart aggregate as monitor inside the structure
- Smart aggregate as active signal source for structure health monitoring
- And more...