INTEGRITY DIAGNOSTICS LTD.

Acoustic Emission for Inspection and On-Line Monitoring of Civil Infrastructure

Structures Fail without Warning!

A large number of structures fail every year without warning due to design errors, undetected or misevaluated flaws, low quality of construction materials and other reasons. Accurate, reliable assessment and monitoring of structures' condition is essential for minimizing risk of a catastrophic failure.

Different methods have been developed and applied during the recent decades for non-destructive evaluation of metal and reinforced concrete structures. Among these methods, **diagnostic acoustic emission** technology is unique as it not only detects flaws in metal and concrete but also used for on-line, real time monitoring of structural integrity under real operational conditions, evaluation of operational risk factors and detection of causes of flaw origination and development.

Since 1970s acoustic emission technology is widely applied for inspection of civil infrastructure over the world and has a proven experience in assessment of:

- Metal and reinforced concrete bridges.
- Tunnels.

- Industrial and civil buildings.
- Concrete structures after fire, earthquakes and other trauma events.
- Nuclear containment and structures subjected to radiation.
- Landslide activity.

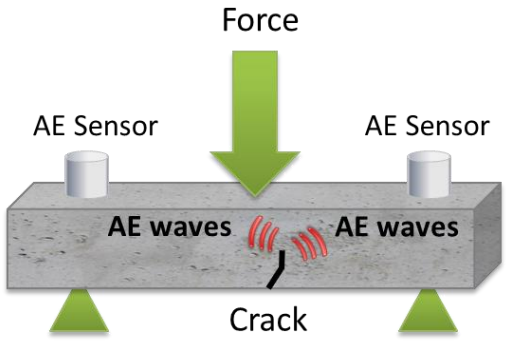
Cost Reduction with Increased Safety

Diagnostic Acoustic Emission brings significant value to customers both in terms of increased safety and cost reduction. Particularly, benefits of DAE inspections are:

- Global 100% inspection of a structure at competitive costs unlike other methods that are applied in selected locations.
- Shorter inspection times compared with other methods.
- No traffic interruption in most cases.
- Detection of developing flaws at early stages when repair is relatively inexpensive.
- Differentiation between developing and non-developing flaws that minimize need in maintenance actions.
- Detection of risk factors and reasons for damage occurrence in inspected structures that provide valuable information for predictive maintenance.
- On-line monitoring capabilities that reduce a risk of unexpected collapse in critical applications.
- Evaluation of repair effectiveness preventing ineffective consecutive repairs.

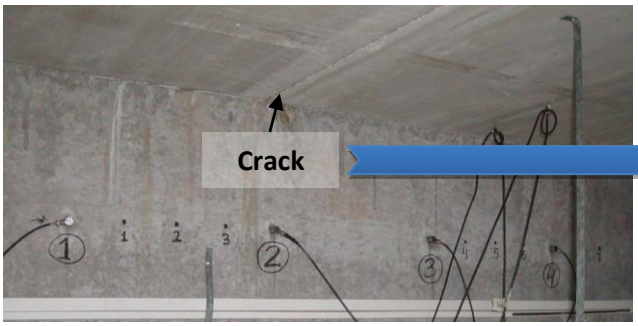
What is Acoustic Emission?

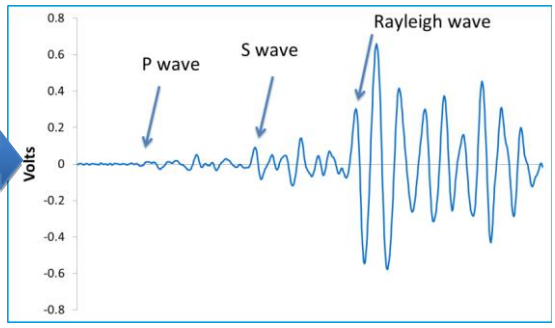
Acoustic emission is a phenomenon of sound and ultrasound (stress) wave radiation in materials that undergo deformation or fracture processes.



Crack propagation in loaded solid materials such as concrete, metal and composites results in a fast release of potential energy in form of stress waves with frequencies typically between 50 kHz and 2 MHz. These waves propagate along the structure for distances of several meters and are detected by piezoelectric sensors. Special analysis of detected AE waves is then performed to locate acoustic emission flaw sources, identify flaw type, evaluate rate of flaw propagation and it sensitivity to load/stress/operational changes.

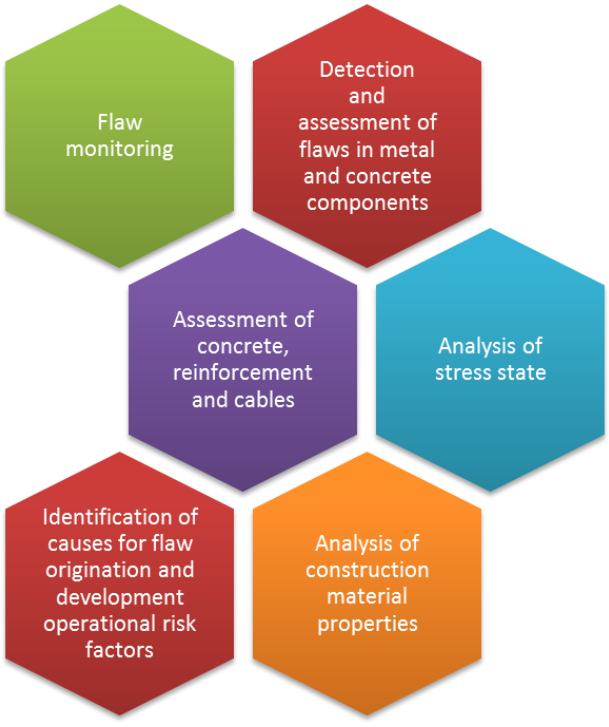
In addition to crack propagation, other sources of acoustic emission due to rebar corrosion, stress corrosion cracking, fatigue of metal components, wire rupture, concrete pore closure and micro-crack formation, aggregates fracture and de-bonding and other are readily detected and assessed by AE technology.





Diagnostic Acoustic Emission Technology for Inspection of Infrastructure

Diagnostic Acoustic Emission is an advanced AE method that was developed since 1970s specifically for assessment of different civil and industrial structures. Development of DAE technology included a wide scale research of acoustic emission characteristics of typical fracture processes developing in different metal and concrete components. A large number of tests were performed on construction materials with different types of flaws. Kilometers of bridges and tunnels and many buildings were experimentally inspected before the DAE has been developed into matured and experience proven technology.



Today, Diagnostic Acoustic Emission has capabilities necessary to answer on the following practical questions:

1. Are the structure and it components stable?
2. Are there flaws in the inspected structure and where?
3. What types of flaws are developing: cracks in concrete and metal, corrosion of reinforcement, fatigue, etc.?
4. How fast these flaws develop?

5. Are these flaws sensitive to load changes?
6. Is the structure non-uniformly or over- loaded?
7. Is there reduction in cable pre-stressing?
8. Is the concrete of low quality?
9. Was repair effective and have flaws stop to propagate?
10. Is there a change in the condition of a structure since the last inspection?

Acoustic Emission Standardization

Acoustic Emission one of the standard non-destructive test methods with several dozens of standards, procedures and test methods issued by various international organizations such as ASTM, ASME, ISO, EN, GOST, NDIS, RILEM and others.

Here some of the relevant standards, codes and documents:

1. NDIS 2421 (2000), *Recommended Practice for In-Situ Monitoring of Concrete Structures by Acoustic Emission*, Japanese Society for Non-Destructive Inspection.
2. JCMS-III B5706 (2003) Monitoring method for active cracks in concrete by acoustic emission, Federation of Construction Materials Industries, Japan.
3. Recommendation of RILEM TC 212-ACD: Acoustic emission and related NDE techniques for crack detection and damage evaluation in concrete. *Test method for classification of active cracks in concrete structures by acoustic emission*, 2010.
4. Recommendation of RILEM TC 212-ACD: Acoustic emission and related NDE techniques for crack detection and damage evaluation in concrete. *Test method for damage qualification of reinforced concrete beams by acoustic emission*, 2010.
5. Recommendation of RILEM TC 212-ACD: Acoustic emission and related NDE techniques for crack detection and damage evaluation in concrete. *Measurement method for acoustic emission signals in concrete*, 2010.
6. GOST (1991) *Concrete. Acoustic Emission method for strength characteristics determination*, State Standard of Soviet Union, State Committee on Construction, USSR.
7. European Norms (2009) EN1330-9 nondestructive testing-terminology-part 9: terms used in AE testing.
8. EN 13554 Nondestructive testing-acoustic emission-general principles.
9. ASTM E569, Standard Practice for Acoustic Emission Monitoring of Structures during Controlled Stimulation.
10. ASTM E1316, Standard definitions of terms relating to AE.
11. ASTM E650, Standard guide for mounting piezoelectric AE sensors.
12. ASTM E750, Standard practice for characterizing AE instrumentation.

DAE vs. Alternatives

Several methods for non-destructive testing of metal and reinforced concrete structures were developed in recent decades including radiography, ground penetrating radar, ultrasonics, thermography and other. Each of these methods have several advantages and capable to detect various types of structural flaws. However, unlike Diagnostic Acoustic Emission, these method are applied locally, in statistical locations, cannot be used to monitor flaw development or evaluate causes of flaw origination and propagation. Also, once a flaw detected by alternative methods, there will be always a question if this flaw is actively developing and how severe it is. DAE is capable to provide an answer on both questions and is used for evaluation of overall structural stability.

DAE Unique Technological Advantages

- Examination of 100% of structure.
- Detection and assessment of flaws in steel and concrete without limitation of flaw orientation, component thickness or material.
- Evaluation of flaw propagation rate.
- Differentiating between developing and non-developing flaws.
- Quantitative long-term monitoring of flaws.
- Continuous 24/7 monitoring capabilities.
- Detection of overstressed and non-uniformly loaded components.
- Detection of components with low quality concrete and reduction in pressed levels.
- Evaluation of overall structural stability.
- Evaluation of repair effectiveness.

DAE Experience

Diagnostic acoustic emission method has been used for inspection of over 100 kilometers of bridges and tunnels in Europe and Israel. Many building after trauma such as fire, earthquakes, landslides were assessed and monitoring using this technology. Results of research and practical inspections were published in a large number of scientific and technical papers (see Publications below). Several patents were issued on unique methodologies for infrastructure assessment.

European bridges inspected by the Diagnostic Acoustic Emission Technology