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Acoustic Emission Monitoring during Static Modulus Elasticity Test of Concrete Specimen

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Abstract. Acoustic emission method is often used to detect a failure at a very early stage of damage long before a structure completely fails. The paper presents experiment focused on analysing acoustic emission signals captured during commonly used static modulus elasticity test of specimens of concrete. Quantitative acoustic emission techniques were used to measure micro fracture properties. For three different concrete mixtures typical acoustic emission patterns were identified in the acoustic emission records to further describe the under-the-stress behaviour and failure development. Although we are able to predict failure loads and damage patterns to some extent, we still do not have a good understanding of the relationships between micro structural phenomena and the corresponding effects on macroscopic behaviour. It logically follows that if we have a better understanding of the relationships between micro structural events and macroscopic behaviour, we will be in a better position to formulate predictive models for large-scale structural performance and reliability. An understanding of microstructure–performance relationships is the key to true understanding of material behaviours. Since we know that material microstructure influences its properties, and that cement-based materials of different microstructure have different failure properties and then the variations in micro fracture phenomena must be manifested in the acoustic emission response of the different specimens.

Introduction

Acoustic emission is an experimental tool well suited for monitoring fracture processes. It is a passive ultrasonic technique, where elastic waves generated in a material are detected [1]. Acoustic emission waves are generated by such dynamic mechanisms as cracking, delamination fretting, dislocation motion, transformation and so forth. Consequently it draws a great attention as a means of evaluating damages and defects in structures. Acoustic emission sources could be modelled by dynamic displacement motions [2]. In the case of cracking it is confirmed that acoustic emission waveforms can be synthesized by the dislocation model. The dislocation motions consist of crack kinematics and crack kinetics. Acoustic emission activity during the fracture process has been investigated in relation to Kaiser Effect. Under cyclic loading acoustic emission activity is low as sequential loading takes place up to the preload level. Estimation of previous stress level is under investigation, although the results are still marginal [3,4,5].

Fracture in a material takes place with the release of stored strain energy which is consumed by nucleating new external surfaces (cracks) and emitting elastic waves which are defined as acoustic emission waves. The elastic waves propagate inside a material and are detected by an acoustic emission sensor [6]. Except for contactless sensors, acoustic emission sensors are directly attached on the surface as shown in Fig. 1. Acoustic emission signals are detected as dynamic motions at the surface of a material are converted into electric signals [7]. Then signals are amplified and filtered. Final goal of monitoring acoustic emission phenomena is to provide beneficial information to prevent fatal fracture by correlating detected acoustic emission signals with growing fracture process or deterioration [8].

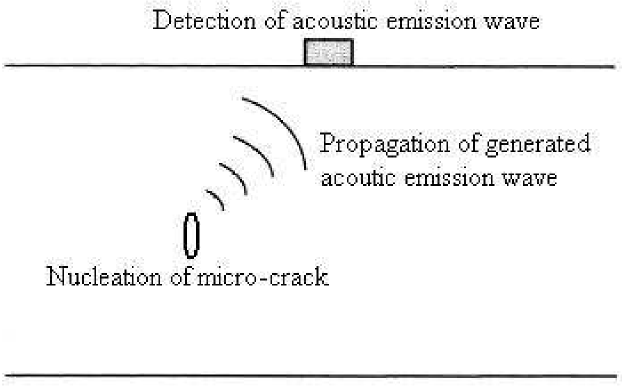

Figure 1: Detection of acoustic emission wave [8]

Modulus of elasticity is one of very important material parameter for concrete structures, that goes into series of static computing and is close to other physically-mechanic characteristic of concretes as creep, shrinkage, frost resistance, durability etc. Modulus of elasticity describes ability of concrete to yield under load. Modulus is determined by deformations which impend after known loading [9,10].

The higher the value of the modulus, the stiffer the material is. Thus, comparing a high performance concrete to a normal strength concrete, it is seen that the elastic modulus for high performance concrete will be higher, thereby making it a stiffer type of concrete. Stiffness is a desirable property for concrete to have because the deflection a structure may experience will be decreased. However, deformations, such as creep, increase in high strength concrete [11].

The modulus of elasticity of concrete is typically calculated from a compressive strength test of a concrete specimen. From these strength tests, stresses and strains are measured and plotted. The ratio between stresses versus strain on these diagrams is called the modulus of elasticity. Since concrete typically does not act in a linearly elastic manner, there exists no portion on the stress versus strain diagram where Hook's law may be applied to find the modulus of elasticity [12].

Factors Affecting Modulus of Elasticity of Concrete.

Specimens tested in dry condition show about 15% decreases in elastic modulus as compared to the wet specimens. This is explained by the fact that drying produces more micro-cracks in the transition zone, which affects the stress-strain behaviour of the concrete. This is opposite to its effects on compressive strength. The compressive strength is increased by about 15% when tested dry as compared with the wet specimens. Porosity of aggregate has the most effect on the elastic modulus of concrete. An aggregate with a low porosity has a high modulus of elasticity. The elastic modulus of concrete is affected by the volume fraction of the aggregate as well as the elastic modulus of the aggregate. The lower the porosity of the cement paste, the higher the elastic modulus of the cement paste. The higher the elastic modulus of cement paste, the higher the elastic modulus of the concrete. The void spaces and the micro-cracks in the transition play a major role in affecting the stress-strain behaviour of concrete. The transition zone characteristics affect the elastic modulus more than it affects the compressive strength of concrete [13].

Experiment Setup

The specimens of length, 400 mm, height, 100 mm, and width, 100 mm, were measured gradually. Four acoustic emission sensors were placed on the surface of both samples (see Fig. 2). Acoustic emission signals were taken by measuring equipment DAKEL XEDO with four acoustic emission sensors IDK-09. Acoustic emission events were measured during three stress cycles.

Figure 2: Photography of test setup

Experiment Results

The graph in Figure 3 shows the dependence of the number of overshoots and the forces on time, for samples with different value modulus of elasticity 26.5 GPa. The highest number of overshoots is at the beginning of loading. During next cycles, the numbers of overshoots are lower.

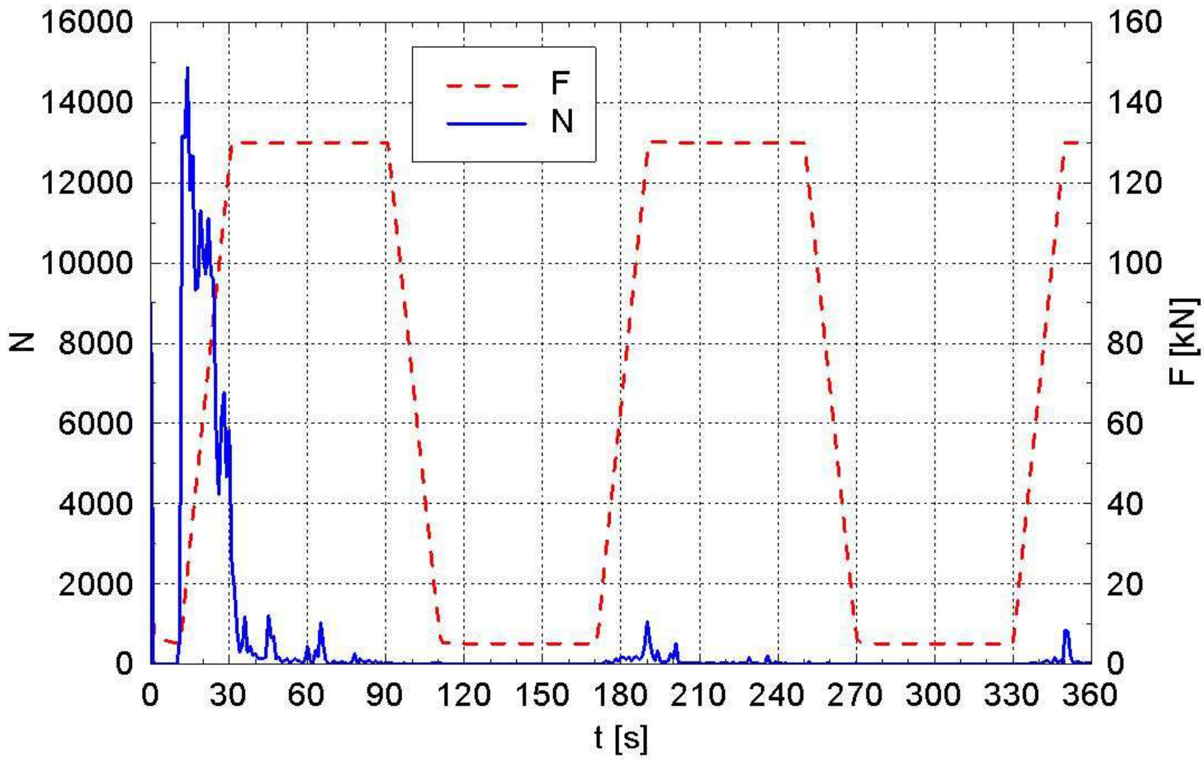

Figure 3: Dependence of the number of overshoots and the forces on time (for sample with E_c = 26.5 GPa)

The graph in Figure 4 shows the dependence of the number of overshoots and forces on time for samples with different value modulus of elasticity 35.7 GPa. The highest number of overshoot is at the beginning of loading, but now is the maximal values are about 5500 numbers of overshoot threshold levels. During next cycles the numbers of overshoots are lower.

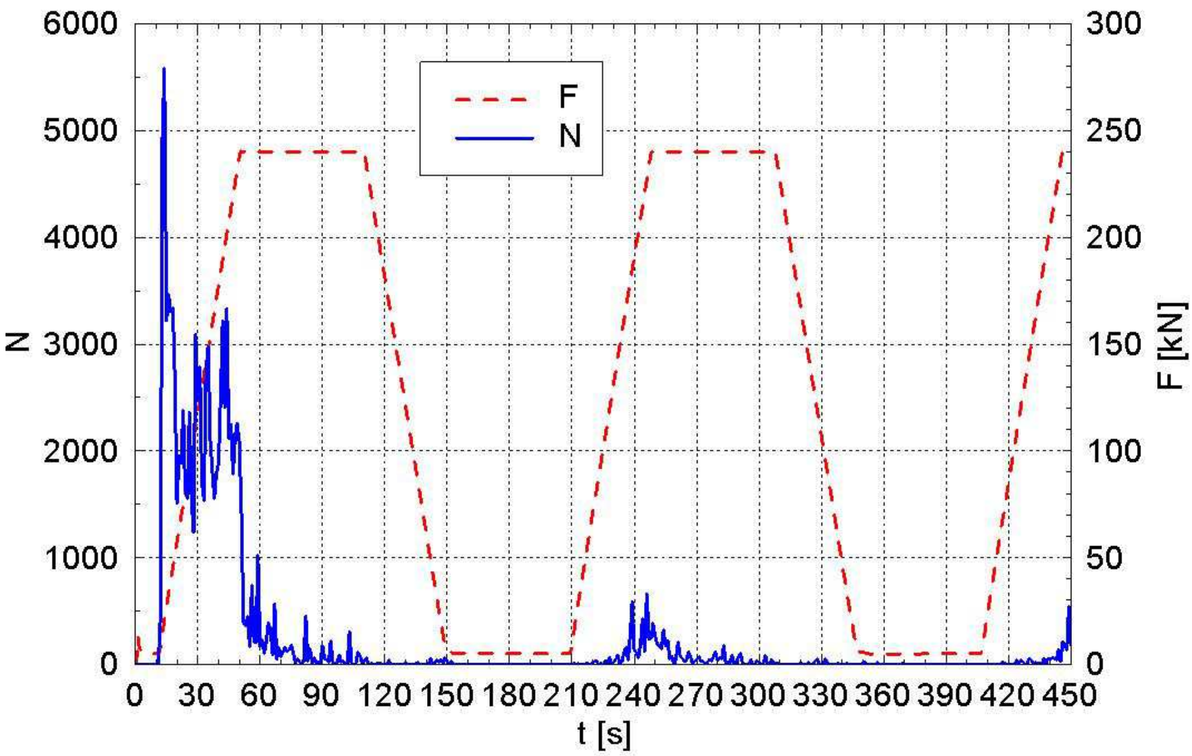

Figure 4: Dependence of the number of overshoots and the forces on time (for sample with E_c = 35.7 GPa)

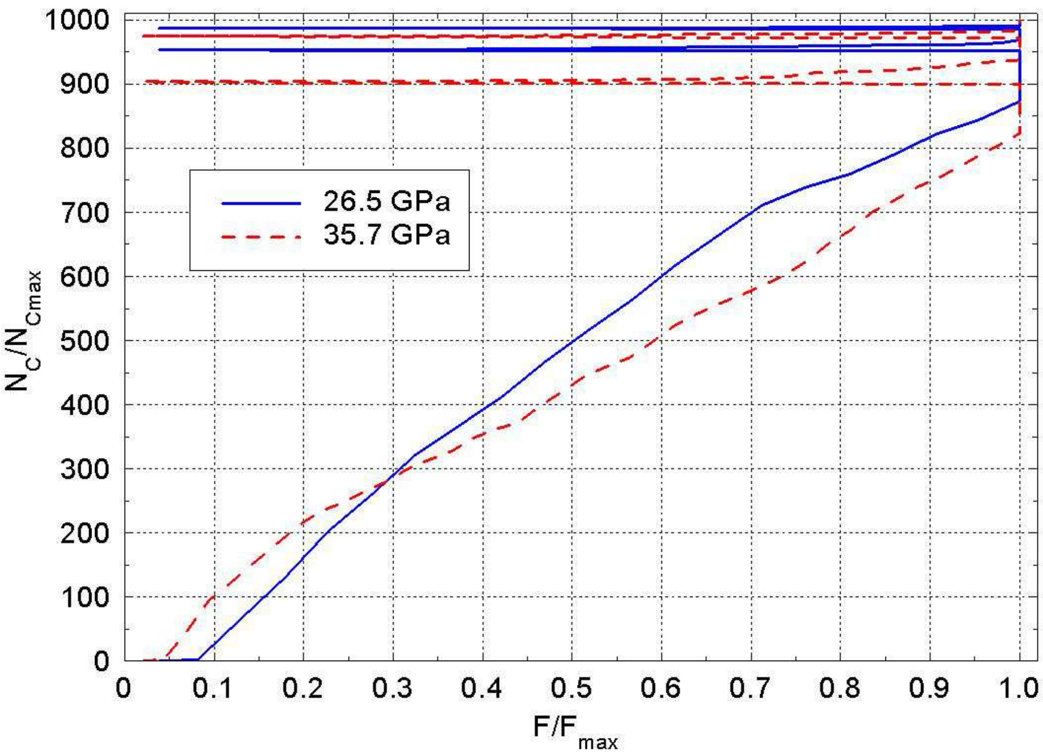

Figure 5: Dependence of the relative cumulative number of overshoots to relative force

The graph in Figure 5 shows the cumulative relative number of overshoots on relative force of the both samples. The graph shows that the sample with a lower modulus of elasticity (solid line) shows a larger increase of acoustic emission events than the sample with a higher modulus of elasticity (dashed line).

The samples were also monitored by other mechanical and non-destructive methods. The results are shown in Table 1. Each of these samples is a representative of a set of objects (the first group includes samples T1, T4, T6 and the second group includes samples T2, T3, T5). Samples that were shown in the detailed view of the results of the acoustic emission are highlighted in Table 1.

Table 1: Results of mechanical and non-destructive testing

Measurement	Weight	Maximal force	Compressive strength	Bulk density	Modulus of elasticity
Sample	[kg]	[kN]	[MPa]	[kg/m^3]	[GPa]
T1	9.56	394	39	2379	26.6
T4	**9.45**	**382**	**38**	**2370**	**26.5**
T6	9.46	407	41	2371	27.0
T2	9.61	744	74	2393	34.8
T3	9.62	731	73	2401	34.6
T5	**9.71**	**612**	**61**	**2414**	**35.7**

Conclusion

Acoustic emission prove to be as a powerful tool for determining the rise of micro-cracks in the under the stress concrete. It can be assumed that a great number of acoustic emission events is caused by higher numbers of micro-cracks in the concrete specimen. The number of micro cracks in concrete affects resulting mechanical properties of concrete. The amount of generated micro-cracks corresponds with the size of the modulus of elasticity of concrete specimens. The sample with a lower modulus of elasticity showed a higher activity of acoustic emission, and thus generation of micro-cracks, than a sample with a higher modulus of elasticity.

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