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ACOUSTIC EMISSION METHODS IN STEEL BRIDGE DEGRADATION IDENTIFICATION AND MONITORING

Šorm F.*

Abstract: *Acoustic emission methods proved to be an effective diagnostic tool in many industrial sectors. The potential of this method in the field of steel bridge diagnostics is explored in this article. The goal is to find the most effective use of this method.*

Keywords: Steel bridges, diagnostics, acoustic emission.

1. Introduction

Many cases of steel bridge degradation (cracks, corrosion) are sources of acoustic emission signals. This gives an opportunity to use acoustic emission based methods for structure diagnostics. However, there is a problem with identification of the nature of acoustic emission source. There may be many sources of acoustic emission present in steel bridges, not all of them originating in degraded parts (like e.g. friction in joints). It is the goal of this research to define the conditions of acoustic emission use, which would make the interpretation of measured results more certain.

Analysis of real structure data was considered necessary. Degraded part of steel bridge deck has been therefore tested in ITAM laboratory as a first step of the research. Results and some initial conclusions derived from the experiment are discussed in this article.

2. Test method

The tested element (see Fig. 1) was a degraded steel orthotropic deck element from the bridge over the Labe river in Opatovice. The element consisted of a 1050 x 3040 mm upper plate with a non-slip profiled driven surface. Soffit of the plate was reinforced with 4 longitudinal U profiles, closed by vertical front plates at both ends. Lower edges of the front plates formed bearing surface of the element, which spanned simply supported between cross girders of the bridge.

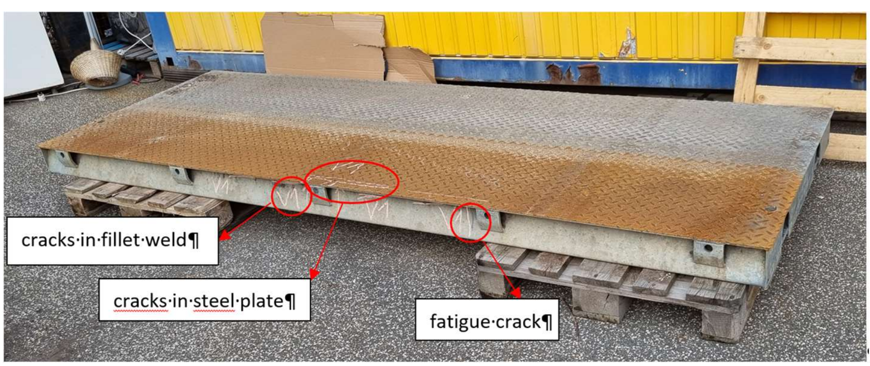

Fig. 1: Tested steel bridge deck element.

* Ing. Filip Šorm: Institute of Theoretical and Applied Mechanics, Prosecká 809/76; 140 00, Prague; CZ, sorm@itam.cas.cz

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The examination was carried out in the Institute of Theoretical and Applied Mechanics laboratory in Prague. Test method was designed in such a way, so that the laboratory action was analogous to the actual load on the element in the bridge deck.

The element oriented with the upper (driven) surface downwards was placed between two special test frames modeling the bearing of the element on the cross girders of the bridge (see Fig. 2). Pair of hydraulic jacks was placed under the worst degraded longitudinal stiffener in the least favorable position to represent critical action of rear axle wheels of a truck. The effect of tire elasticity was simulated by elastomeric profiles placed between the element and the hydraulic jacks. Magnitudes of applied forces were controlled by force sensors placed under the loading jacks. Acoustic emission measurement was focused on the area of the wall of the outermost longitudinal U-profile, where fatigue crack was formed (see Fig. 3).

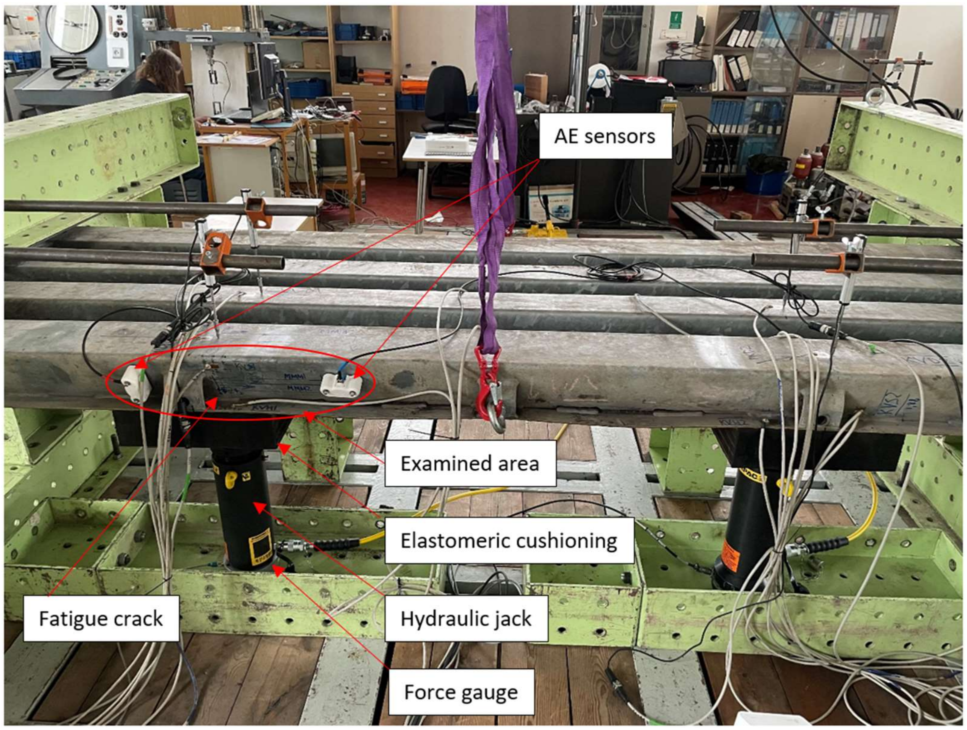

Fig. 2: Arrangement of tested element.

Load on the element was increased gradually. The forces in jacks reached in successive steps 0 - 40 - 50 - 60 - 70 - 75 kN. The final load level (75 kN) exceeded the most onerous load that could occur on the bridge (max. 67 kN per truck wheel). Such overloading was designed to force propagation of existing fatigue crack (Fig. 3). Acoustic emission signals emitted at the tip of propagating crack would then be recorded and analysed.

Acoustic emission signals were recorded by 2 piezoelectric sensors PK15I, attached to the element using magnetic holders. Location of the sensors can be seen in Fig. 2.

Recorded acoustic emission signals were analysed using Micro-SHM station controlled by the AEwin program supplied by the Physical Acoustics Company (USA).

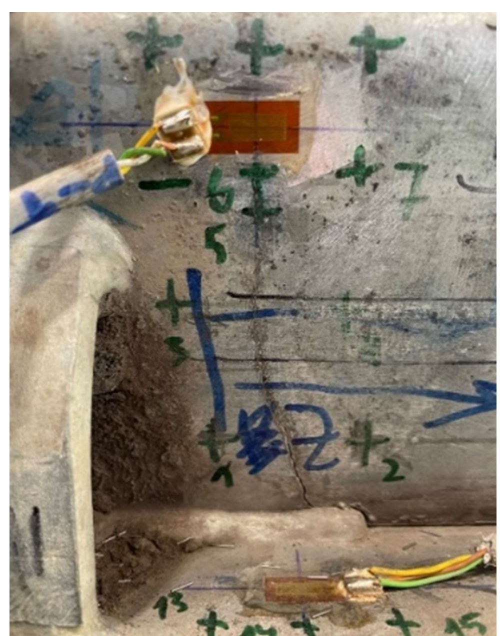

Fig. 3: Fatigue crack.

3. Results

3.1. Identification of sources of acoustic emission (AE events)

Acoustic emission signals (AE signal) have a form of mechanical waves propagating through material from its source. They originate in continuum if energy is suddenly released during so called AE events (e.g. crack propagation, corrosion processes, etc.). These waves cause voltage signals in piezoelectric sensors which can be recorded and then processed (see Fig. 4 for an example of typical AE signal record).

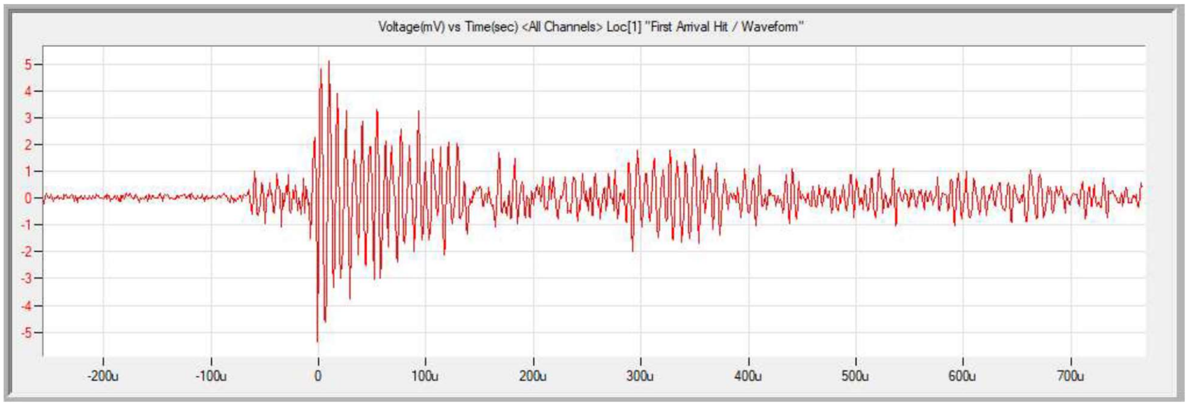

Fig. 4: Typical record of acoustic emission signal.

A large number of signals was recorded during the experiment. The first step of the analysis was therefore identification and removal of unwanted signals (noises).

In particular, all too short signals (EMI) were excluded, as well as signals that were not recorded approximately simultaneously on both sensors and thus could not originate inside the examined area.

Every pair of signals recorded (nearly) simultaneously indicated release of energy (AE event) inside the monitored area. These events could indicate energy release from strained material at the tip of progressing fatigue crack.

If pair of signals was recorded simultaneously on both sensors, only the first recorded signal (first arrival hit) was selected for further evaluation. The sensor which recorded this hit was obviously closer to the source of the acoustic emission (event) than the other one. The first arrival hit was thus less affected by attenuation and was therefore taken as the representative of the recorded AE event.

The numbers of recorded AE events (first arrival hits) are given in Tab. 1.

AE Event	**Individual loading levels [kN]**					**Load increase total**	**Load relieve total**
Load interval	(0-40)	(40-50)	(50-60)	(60-70)	(70-75)	(0-75 kN)	(75-0 kN)
AE Events #	**160**	**5**	**29**	**35**	**13**	**242**	**110**

Tab. 1: Number of identified AE Events.

Tab. 1 shows, the sources of acoustic emission (AE events) emerged in the examined area during all phases of the experiment. The crack clearly does not propagate at low levels of load or during load relieve. It means, there have to be also other sources of acoustic emission in addition to the sought-after AE events originating in propagating crack. Most likely, these were sources of acoustic emission signals arising as a result of friction between the elastomer profile and the strained element.

The next task was therefore to identify AE signals (first arrival hits) which could possibly come from the propagating crack. Parameters of the individual AE signals were analyses and characteristics identifying them as the right signals coming from the crack were searched for.

3.2. Analysis of AE signals

Analyses was based on an assumption that different signal parameters could signal different origins of the signal. The amplitude and the energy of recorded AE signals were examined.

Results of the AE signal amplitude analysis are summarized in Tab. 2.

Amplitude [μV]	**Individual loading levels [kN]**					**Load increase total**	**Load relieve total**
Load interval	(0-40)	(40-50)	(50-60)	(60-70)	(70-75)	(0-75 kN)	(75-0 kN)
Average value	50	47	50	50	52	**50**	**51**
Average deviation	7	3	7	6	10	**7**	**6**
Max. value	74	54	64	62	72	**74**	**74**
Min. value	35	42	36	37	35	**35**	**35**

Tab. 2: Amplitude analysis results.

The comparison of maxima and minima shows that signals with a significantly different amplitude were not recorded at the highest levels of loading. It is clear from the last two columns in Tab. 2., that the amplitudes of signals recorded during both loading and unloading are similar and therefore probably originate from the same source. This source cannot be a progressing crack as the crack does not progress during load relieve.

This result was interpreted in a following way: no fatigue crack developed during the experiment, all recorded AE signals have their origin in friction between the tested element and the elastomer profile.

The energy analysis of the measured signals led to the similar conclusions.

4. Conclusions

Although the experiment took place in laboratory conditions, the interpretation of results had to be based on an assumptions and carried some uncertainty about the AE source origin (the AE signals from progressing crack were assumed to be different from signals originating in friction which may or may not be true). Such uncertainty only increases if the measurements are carried out on real world structures, where many sources of acoustic emission could be present.

The acoustic emission methods need to be combined with other diagnostic methods to make reliable identification of detected sources of acoustic emission possible. In our case the conclusion of crack stability should have been confirmed by e.g. simple crack-gauge monitor.

The experiment rather disappointingly demonstrated fact, that the degradation of the element may not be discovered by acoustic emission based methods. Only progressing degradation produces AE signals which could be registered.

As the progressing degradation should be avoided on operated bridges, rather than for defects identification, these methods seem to be suitable for long-term monitoring of already identified defects that cannot be removed operatively and whose further development could threaten the safety of the structure.

If applied in such a way, the methods have an ability to monitor entire areas of the structure, detecting and locating activity of AE sources in real time.

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