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Vibration-based health monitoring of lighting poles

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The health and integrity of lighting poles must be ensured as they are often installed at public places and as they must withstand severe conditions. Corrosive deterioration of lighting poles is dangerous and difficult to forecast due to their varying operating conditions of the poles. The Roch's study on structural stability of pole systems "Infrastrukturprojekt Straßenbeleuchtung 2000" (Infrastructure Project: Street Lighting 2000), which is representative on a Germany-wide scale, found that 3.3% of all poles pose a hazard [2]. To prevent pole collapse, the poles are regularly replaced, e.g. every 15 years. Such solution is expensive, workforce demanding and unreliable. Some poles are damaged sooner due to more sever conditions, but some poles may withstand much longer.

The corrosive damage of the pole occurs usually at the pole base, often under the surface. The corrosion on the top of the pole is less frequent. In any case, the damage is not apparent and localizable (Fig. 1).

Fig. 1. Damaged lighting poles

Due to the amazing number of lighting poles already installed, it is not feasible to regularly monitor and measure the pole conditions manually, esp. using complicated devices and tools. The automatic monitoring of pole health may enable engineers to concentrate maintenance effort only to damaged poles. Even though some specialized devices were proposed [1,2], their implementation into daily routine is quite limited and costly.

The paper deals with possibilities and feasibility of vibration based lighting pole monitoring. The modal properties of the structure are global values that aggregate all the local structure properties. The relation between pole deterioration and modal properties change is analysed.

The modal properties (eigen frequencies, modal damping and shapes) are studied as a tool for structural damage or structural change identification [3, 4, 5]. The published results and recommendations are quite broadly scattered. Either only a very small change of eigen frequency or damping is reported to be caused by quite significant structural damage of structure [3], or a quite large change of eigen frequency is used as the damage measure [4,5].

The lighting pole is of a specific construction. On one hand, it is quite simple welded beam with few moving parts or screw connections that often introduce nonlinearities. On the other hand, the poles are usually fixed into the ground using the sand bed. The sand is a material with excellent damping properties; however, the properties are related to the humidity of the sand. So the modal damping is not stationary and also the damping measurement has low accuracy; thus, damping cannot be used as a measure of the pole health. The pole eigen frequencies and shapes were initially analysed based on FEM modelling. The FEM model of healthy pole fixed into the frame and the pole destroyed (one third hole of the diameter) were compared. Eigen frequency change was very small for lower frequency range up to 40Hz (Δf cca 0.02-0.4 Hz). The change of eigen frequencies in higher frequency range (up to 250Hz) was more promising, although some differences were very small, some almost 3 Hz. But the pole deterioration cannot be judged based on observation of only one eigen frequency.

Fig. 2. Measurement setup for experimental modal analysis of lighting poles

The promising modelling results had to be verified experimentally. The two sets of existing, installed poles with same design, dimensions and arrangement, but quite different health, were selected. The complete experimental modal analyses were carried out for each pole in the investigated set. The first set was laboratory installation, fixed into the concrete bed, the second pole set consisted of regularly installed poles (same dimensions), i.e. in the sand bed. The excitation force was introduced by electromechanical shaker connected through load cell mounted on the pole in the height 3m. The pole response was measured by scanning laser vibrometer at several points on the pole (Fig. 2). The setup was same for all poles in the set.

The results in the form of frequency response functions (FRF) that were measured at the point 10 (see Fig. 2) are demonstrated in Fig. 4.

The concrete bed set has very low damping and eigen frequencies can be clearly visible. The frequency shift is almost negligible in the lower frequency range, but the frequency shift can be easily distinguished in higher frequency range. The regular set (sand bed poles) was heavily damped in all cases and some of pole eigen frequencies were not detectable due to high damping or position of measurement. But still, the higher frequency range of eigen frequencies exhibited a detectable frequency shift.

Pole health can be determined based on the pole vibration measurement. The complete experimental modal analyses requiring many measured transfer functions is not necessary.

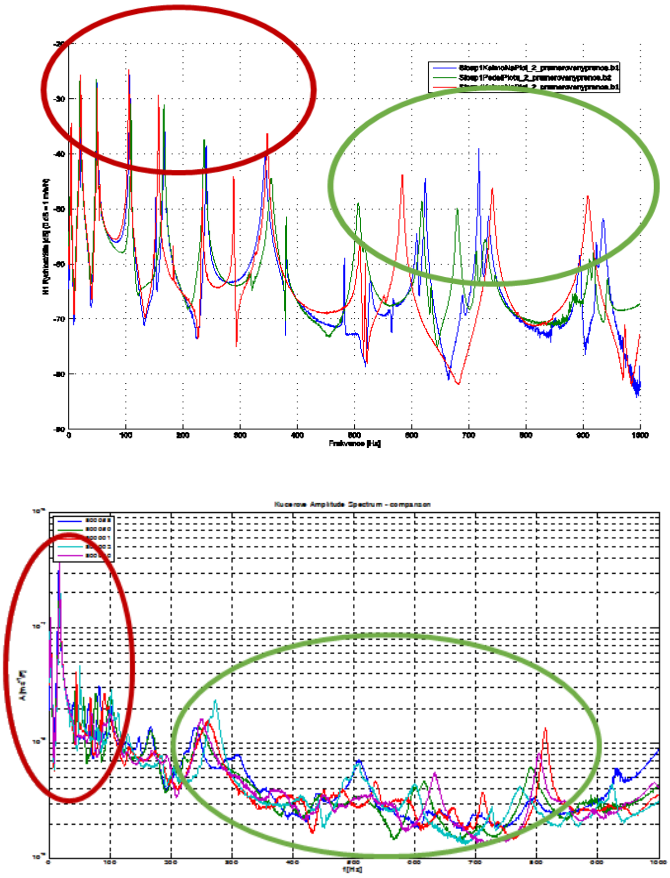

Fig. 3. Frequency transfer function of the lighting pole (a) in the concrete bed (b) in the sand bed

Many eigen frequencies, especially in higher frequency range must be taken into evaluation of the pole damage, which makes the evaluation more robust against the influence of soil, sand damping, pole damage location and the location of selected excitation and response measurement point. A single frequency, especially the first eigen frequency, does not provide us with solid information about structural damage of the pole.

The development of automatic pole inspection methods based on vibration measurement is thus feasible.

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