A new approach to test outdoor luminaires based on wind induced vibrations

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Abstract. Luminaires for outdoor use are subjected to mechanical vibrations, mainly due to wind, that can generate stress conditions on the devices and affect their reliability performance. The effects of such vibrations on the luminaires can impact both the fixing systems and the device’s components; in the last case, such effects can be divided into electrical type failures (LED control gear failure, electronic components failure, etc.) and optical type failures (breakage or detachment of the optics placed on the LED). Starting from the study of international standards concerning vibration tests for luminaires, and from scientific literature, several laboratory tests have been performed to verify the behaviour of equipment subjected to wind induced vibrations. After that, a new test profile applicable to luminaires for outdoor use has been proposed. In order to establish properly wind induced vibration levels and optimize luminaires testing costs.

1. Introduction

Luminaires for outdoor use, in particular luminaires for road and street lighting and floodlights, are subjected to several environmental stress that can generate fatigue conditions on the device and affect their reliability performance. Typical examples of environmental factors are temperature, rain, humidity, solar radiation, vibrations, etc., or a combination of these. In particular, fatigue effects caused by vibration are the main cause of mechanical failures in outdoor lighting equipment [1]. Concerning vibrations, all the mechanical stress related to the luminaire’s final installation should be taken into account in areas such as tunnels, bridges, roadways or overpasses, where wind and traffic are the most common sources of vibrations applied to the supporting structures of the luminaires and therefore, indirectly, to the devices themselves.

Vibration resistance of outdoor luminaires is described in the international standard IEC 60598-1 where it is specified that luminaires construction should be resistant against the effects of vibration that are likely to occur in service, in particular with regard to street lighting and floodlights [2]. Furthermore, the Standard requires that fixed connections between different parts of luminaires shall be made in such a way that they do not work loose by vibration as it may occur in normal use. International Standards IEC 60598-2-3 (safety requirements for luminaires for road and street lighting)
and IEC 60598-2-5 (safety requirements for floodlight) [3-4] assert that the luminaire clamps shall be appropriate to the weight of the luminaire and, at the same time, they have to avoid the dislodgement of any part of the luminaire or external part by vibration, either in service or during maintenance. Although the criticality of vibrations of an outdoor device is recognized, no test profile is described or suggested in the above mentioned standards and the study of the vibration profile that gives confidence of luminaire safety over product lifetime is therefore assigned to the “good engineering practice” [2]. Even if the standardization of a specific vibration test method is difficult to apply (due to differences in luminaire design, methods of mounting, application conditions, etc.) the manufacturers require a test profile suitable to verify the mechanical resistance of luminaires and the maintenance of installation fixings.

2. A proposal for a new vibration test profile
Based on the existing International Standards [2-6] and scientific literature [7-10], a new vibration test profile related to the wind induced vibrations for luminaires is proposed. The new test profile considers sine-wave vibrations on the bandwidth [2.5 ÷ 40] Hz with sweep rate of 1 oct/min; a resonance search performed at diminished amplitude vibration (0.5 g) shall be carried out and an endurance test based on the method almost fixed frequency described above shall be applied considering an acceleration of 1 g. The cumulative test time is 2 hours with the vibration level equal to 1 g. If no critical frequencies are found, the procedure “Endurance by sweeping” is applied [11]: the frequency swept over the full frequency range for 2 hours at a sweep rate of 1 oct/min and amplitude of 1 g. The test shall be performed in all three directions, with the articulated arm (if any), set in the most onerous position from the mechanical point of view. The acceptance conditions are based on shape of transmissibility graph obtained before and after endurance tests and according to the following checks [2]:

1) retention of components to their fixings within the luminaire;
2) no abrasions/damage to wiring or component insulation;
3) maintenance of electrical connections;
4) maintenance of mechanical connections;
5) maintenance of installation fixings;
6) maintenance of creepage and clearance distances;
7) no movement or “set” as per wind load testing (IEC 60598-2-3 and IEC 60598-2-5);
8) no lamp breakage;
9) lamp to remain in position;
10) early signs of fatigue that may be propagated to cause a safety failure;
11) no parts to become detached from the luminaire.

The new test profile differs from those described in the above mentioned Standards mainly for the acceleration control strategy: in the standard [5] the 3 g required acceleration is monitored on the luminaire’s centre of mass. The proposed test profile monitors the acceleration on the support of the luminaire and a second accelerometer on luminaire’s centre of mass is placed to identify the critical frequencies; in this way the luminaire will be tested applying the 1 g test acceleration multiplied for the resonance amplitude value. In this way it is possible to simulate the wind induced vibrations to which a luminaire can be subjected in its final application. Furthermore, the proposed test profile has a predetermined duration that does not depend on the resonance frequency (number of cycles at each resonance frequency); this approach allows luminaire’s manufacturers to optimize the test time and, consequently, the test costs.
3. Experimental validation of procedure

The new test profile has been validated with 95 trials on luminaires for road and street lighting according to the following steps:

3.1. Vibration response investigation

The aim of the test is to identify any critical frequencies of luminaires under test.
- Frequency range: 2.5 Hz to 62 Hz
- Sweep rate: 1 oct/min
- Vibration amplitude: 0.5 g
- Number of tested axes: 3 (x-axis, y-axis and z-axis)

The criteria to identify critical frequency are the following:
- Q factor > 5
- Amplitude value (AV) > 2 (g)/(g)

The vibration at frequencies lower than about 2 Hz have not been considered because they are usually not harmful to the pole or luminaires [12]. The test has been performed equipping the luminaire with two accelerometers, one located on the support of the device (test fixture) and one on top of the device, matching the axis of centre of mass. The first one (control accelerometer) has been used to drive the shaker according to test profile. The second one (monitor accelerometer), has been used to monitor the acceleration of the luminaire during the test (see Figure 1). The ratio between signals read from accelerometers has been plotted and the transmissibility graph has been obtained (see Figure 2).

| Frequency (Hz) | Amplitude value (g)/(g) | Q Factor |
|---------------|-------------------------|---------|
| 12.2 Hz       | 17.91                   | 21.52   |

Figure 1. Luminaire during test (z-axis)

Figure 2. Example of transmissibility graph.

3.2. Endurance test

An endurance test, applying an acceleration of 1 g, has been performed at each critical frequency previously identified (a frequency at a time) using the method almost fixed frequency, sweeping over a restricted frequency range between 0.8 and 1.2 time the critical frequency [11].

3.3. Resonance check after testing

In order to verify a change of critical frequencies or shape of transmissibility graph, tests according to the subsection 3.1 have been repeated.
3.4. Visual check after testing

The last step is intended to verify the presence of mechanical breakage of luminaire and its components, or luminaire’s movement from its support.

From the experimental activity it has been found that 92% of the critical frequencies are lower or equal to 40 Hz. Moreover, no mechanical breakage occurred at frequencies exceeding 40 Hz.

The mean value of transmissibility checked during tests is 4.5 (g)/(g), but peaks equal to 12 (g)/(g) have been recorded.

4. Conclusions

In this paper, a preliminary analysis of Standards and scientific literature concerning luminaires vibration tests has been carried out. Based on this analysis, laboratory tests have been carried out to verify the effects of wind induced vibrations on luminaires for outdoor use.

This experimental validation was carried out on luminaires for road and street lighting and a new test profile has been proposed. The laboratory testing activity has proven the validity of the proposed approach. Experimental results have created the basis for luminaires manufacturer’s internal testing procedures, allowing them to identify possible weaknesses in the design process of the devices that optimize a dynamic analysis of wind effects on the luminaries and, at the same time, reduce test time and therefore their costs.

5. References

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