The role of environmental monitoring in construction in the UK

Gary EVANS[1], Simon PERRY[2]

[1]Plowman Craven Ltd, London, United Kingdom
[2]Sigicom Ltd, Horsham, United Kingdom
Corresponding author: Gary Evans (gary.evans2020@outlook.com)

Abstract

The role of environmental monitoring in construction in the UK has become more and more important in the last 10 years. This is partly due to legislation related to planning and the advances in available technologies in power, communications, sensors and the use of visualisation platforms.

Whilst it is possible to purchase sensors to monitor environmental parameters such as noise, dust and vibration, there is at present no definitive best practice guidance available to the construction industry for the placement, use, setting of trigger levels and interpretation of these sensors. This has led to varying levels of quality as to how the sensors are deployed and the reasons that they are deployed on construction sites.

There are various standards that are used to define trigger levels in relation to the sensors. These include BS5228 Parts 1 and 2 and BS735. The interpretation of the data should also be considered in when a specification is produced. The specification and certification of the monitoring equipment requested can vary for example MCERTS for particulate monitors. The guidance provided by the standards does not require a baseline survey period as a prerequisite however many projects request this.

It is extremely important that sensors are deployed in the correct manner, so that the right sensor is used in in the way that it has been designed to be used however, it is also important that the monitoring remains proportionate to the project.

The authors will explore the current legislation, standards, guidance and provide an example of how best practice has been used. They will also explore the challenges that have been encountered due to the way that specifications have been generated based on the current available standards, ideas and beliefs related to environmental monitoring.

Keywords: Noise, Dust, Particulate, Vibration, Monitoring

1.0 Introduction

This paper explores the growing requirement for monitoring of environmental effects of construction alongside the more established structural and geotechnical monitoring. We will look at the legislative background alongside the mechanisms for enforcement and identify and explore the challenges and best practice.

The environmental impacts typically monitored in the UK comprise noise, vibration and particulates (from PM10 to dust deposition). Generally, we monitor the effects of these factors in terms of human response however, with regards to vibration it is also important to consider the risk of structural damage.

2.0 Why Monitor?

Construction activities by their nature can have negative impact upon the local environment for the duration of the works. This impact is most keenly felt by surrounding sensitive receptors such as residential properties and places of work, however, the requirement to continuously monitor the effects is relatively new, driven by advances in monitoring technology and subsequently requirements imposed on projects by Local Authorities (LA), third party asset owners such as rail, water, sewerage, gas, electricity or telecommunications and legally binding constraints such as Party Wall Agreements.

Standards and guidance should be reviewed on a frequent basis to ensure that changes in technologies in activities such as piling are captured and to keep up to date with changes in environmental monitoring techniques and equipment. The current British Standards are all over 12 years old and reference data from the

1980's. These may not be valid anymore. However, they are used as the basis for current assessments and specifications of environmental monitoring.

2.1 Noise

It is common practice that the noise limits are set either by the LA or on a project level for major infrastructure works. This practice has developed over time and been led by the following legislation and guidance.

Noise from construction activities was first introduced to the UK by the Wilson Committee presented to parliament in 1963 which went on to inform the Advisory Leaflet 72 (AL72) in 1968 which was subsequently revised in 1976 which proposed fixed noise limits based upon empirical evidence. The Control of Pollution Act 1974 provided legal mechanisms to control and manage noise from construction activities in Sections 60 and 61 (S60 and S61).

S60 provides the Local Authority with the necessary powers to impose noise limits and Best Practicable Means (BPM) upon construction activities if they are considered to be unacceptably noisy. In these situations a stop notice can be served requiring all works to stop until appropriate actions have been undertaken as stipulated.

S61 provides a mechanism for prior approval of works as an alternative to S60. Using this method, the contractor can apply to the LA for approval of their proposed method of works identifying the BPM to be applied, once approved as long as the agreed methods are used works can proceed uninterrupted. It is now common to include detailed noise predictions in S61 applications. Major projects in built up areas typically follow the S61 route. This legislation is still in force, there is no explicit requirement for monitoring, however, this is likely a reflection of the technology available at the time of writing. It is important to consult the LA before submitting a S61 application, for example the City of London (2019) "does not advise the use of Section 61 consents but it does support a system of prior agreement on similar lines, as this allows a much more flexible approach of greater benefit to the Contractor".

Further guidance on the management and control of noise arising from construction sites is provided in BS5228 - 1. This was first published in 1975 and has most recently been revised in 2009. This document provides guidance on the determination of BPM, different mitigation methods as well as three methods for setting noise thresholds; one based upon the absolute levels set out in AL72 and two based upon the pre-existing ambient noise levels.

2.2 Vibration

Vibration arising from construction impacts both the human receptors and surrounding sensitive structures. These are generally considered separately, however, it should be noted that the human response to vibration is in part linked to the perceived risk of structural damage.

BS7385 provides guidance on the level of vibration at which damage may occur in structures. It sets out the factors to be considered and provides two guidance lines for the onset of cosmetic damage, Line 1, for reinforced structures, a fixed limit of 50mm/s PPV (Peak Particle Velocity) and Line 2 for unreinforced structures, starts at 15mm/s PPV increasing to 50mm/s PPV at high frequencies to reflect the sensitivity of these structures to low frequency vibration.

The above limits do not describe the onset of human response to vibration, guidance for this is provided in two standards BS5228 – 2 which provides guidance on the likelihood of complaint in terms of PPV see Table 1 below, and more recently some major projects have begun to reference BS6472 - 1.

You can see from Table 1 that the levels at which complaints will begin to occur are significantly below the thresholds for possible cosmetic damage to buildings as such these levels typically form the basis of project vibration limits.

Vibration level	Effect
0.14 $mm \cdot s^{-1}$	Vibration might be just perceptible in the most sensitive situations for most vibration frequences associated with construction. At lower frequencies, people are less sensitive to vibration.
0.3 $mm \cdot s^{-1}$	Vibration might be just perceptible in residential environments.
1.0 $mm \cdot s^{-1}$	It is likely that vibration of this level in residential environments will cause complaint, but can be tolerated if prior warning and explanation has been given to residents.
10 $mm \cdot s^{-1}$	Vibration is likely to be intolerable for any more than a very brief exposure to this level.

Table 1. Guidance on effects of vibration levels from BS5228-2

Utility assets owners such as Thames Water and BT Openreach prescribe a PPV limit of 10mm/s to 15mm/s. Whilst, rail asset owners have a limit of only 5mm/s.

BS6472-1 considers vibration as a dose value, Vibration Dose Value (VDV). This measures the overall vibration dose received by the human receptor to vibration across a day (0700 – 2300) and a night time (2300 – 0700) period. This has been used when considering vibration from sources such as rail in the planning process, although, this is a good descriptor of human response across a day and night to vibration the practicality of monitoring this in occupied properties limits its application in practice.

2.3 Particulate Matter and Dust

2.3.1 Environmental Legislation

Dust that is generated as a result of construction works is considered a statutory nuisance under the Environmental Protection Act 1990 (EPA) if it is considered prejudicial to health or a nuisance. LAs are able to investigate a statutory nuisance if there has been a complaint by a member of the public and have the power to inspect areas to detect statutory nuisances, should they suspect that they may be present. Works that could cause dust must be undertaken in accordance with Section 79 of the EPA using BPM according to what is reasonably practicable.

Certain operations/processes and equipment that require a permit such as batching plants and crushing are also covered by The Pollution Prevention and Control Act 1999 and The Environmental Permitting (England and Wales) Regulations 2016.

2.3.2 Health & Safety Legislation

It is also worth noting that silica, wood and ‘general’ dust generated as a result of construction works using concrete, wood or limestone can he harmful to a site workers health. This is covered by The Control of Substances Hazardous to Health Regulations 2002 and the Occupational Exposure Limits (OEL) published by the Health & Safety Executive in EH40.

2.3.3 Guidance Documents

Most LAs such as the different boroughs in London have produced guidance documents for the monitoring and control of dust and particulate matter. These documents are usually based on guidance from bodies including the Institute of Air Quality Management (IAQM) and the Greater London Authority (GLA).

IAQM (2014) also distinguishes between demolition, earthworks, construction and track out and provides example definitions on whether a site is considered to be large, medium or small based on total building volume, type of construction material used or activities onsite, height of demolition or number of vehicles leaving site. It is suggested it is likely that demolition and earthworks create the highest dust emissions magnitude followed by construction and then track out. However, an assessment needs to be made to quantify the level of risk and measures required (including monitoring). Some LA guidance such as Westminster County Council (2022) categorise sites as Level 1, 2 or 3 based on the number of new residential (100 to 10) or commercial units based on floor space in square metres (10,000 to 1000).

2.3.4 Monitoring Certification Scheme for equipment (MCERTS)

MCERTS is the Environment Agency's Monitoring Certification Scheme. Pollutants covered include particulate matter (PM10 and PM2.5), nitrogen monoxide (NO), carbon monoxide (CO), nitrogen dioxide (NO2), ozone (O3), sulphur dioxide (SO2), benzene and benzene-like VOCs.

Some LAs specify that particulate monitoring equipment should meet MCERTS. If your works produce potentially harmful emissions and you are an environmental permit holder it is mandatory to use equipment that complies with MCERTS. For construction monitoring Indicative Ambient Particulate Monitors (IAPM) are used compared to alternative systems due to cost and availability. They can be certified to comply with the MCERTS Performance Standards for Indicative Ambient Particulate Monitors, over a certain range for example: PM10 0 to 100µg/m^3. It should be noted that indicative monitors provide measurement data with the uncertainty defined as +/- 50%.

To maintain the validity of the data from the monitors they must be calibrated offsite at an approved supplier's facility at least every twelve months or when the instrument is moved to a different site. This calibration is over a two-week period. They should also be maintained as per the manufacturer's recommendations. Onsite maintenance includes flow and filter checks, with possible changing of filters every 3 months or more frequently (Fuller *et al*, 2017).

A list of monitors that comply with MCERTS can be found at the certifying bodies (CSA Group Testing UK Ltd) website, see the following link: https://www.csagroup.org/en-gb/services/mcerts/.

The UK has a national air quality monitoring network for compliance with the European Union Air Quality Directive, IAPM cannot be used as a substitute for continuous ambient air quality monitoring systems (CAMs). Air quality monitoring will not be addressed in this paper, due to the brevity of the paper but it should be examined in relation to construction works and environmental monitoring to see if it is relevant.

3.0 Implementation

3.1 Challenges

Continuous environmental monitoring of construction activities has traditionally had many challenges to overcome to ensure robust, reliable data sets. These challenges are summarised below:

3.1.1 Communication

The benefits of continuous monitoring are most obvious when access to the data captured is available remotely. This has become possible with the advent and incorporation of both mobile connectivity and more recently cloud-based databases.

2G started in 1993 in the UK. 3G was launched in 2003, this allowed more data/larger packs of data to be sent via a modem than the earlier 2G system. In the early 2000s modem technology became advanced and affordable enough for remote access to monitoring stations to become available in products such as Instantel's Blastmate III. With data roaming sim packages enabling near complete coverage of the UK connectivity is no longer a significant issue for most locations.

In the 2010s companies started to offer online software to visualise data from remote monitors and this linked to advances in sensors. Systems such as Sigicom's INFRA Net and Instantel's Insta Link enabled automated upload of sensor data to the Cloud removing the need for communication between the user and the sensor each time data was required.

3.1.2 Location

The location of the instruments must also be considered. Normally units are placed on site hoardings a site can change over time due to the phase of the works, for example, during demolition, piling, excavation, substructure, superstructure and finally fit out stage. They also need to be accessible for installation, maintenance or repair if they become damaged. Projects depending on their size can run from months -if it's a decreet phase of works such as demolition- to 2-5 years if it is for the whole duration of the project.

3.1.3 Power

Availability of a permanent power supply may be required, although some systems can run on batteries for a limited time of a few days to weeks or months depending on the sensor type. Alternatively, an off-grid supply using solar panels and wind turbines may be employed if the site conditions and weather allow.

3.1.4 Longevity

Equipment used for monitoring must be fit for purpose and robust to be employed on construction sites during all weather conditions for example geophones for monitoring vibrations. Newer equipment should be tested thoroughly and compared to existing equipment for acceptance.

3.2 Best Practice

To realise the benefits of environmental monitoring beyond simply satisfying a project requirement it is essential that you understand the purpose of the monitoring through the identification of who or what you are protecting and against what impact; this is no different to any other form of monitoring such as geotechnical or structural.

Once you understand the above you will need to determine the optimum location for the sensors to provide you with the data required. These aspects vary based on the site circumstances but also the parameter you are measuring. It must be possible for the sensors to be securely mounted to either a structure or the floor.

To maximise the benefits of environmental monitoring a site visit should be undertaken to plan the works. This will look at the locations for siting the equipment, receptors and availability of power or potential for other sources such as solar or wind turbine and security of the site from vandalism or theft of equipment.

Noise: measured to ensure that the function of the receptor (typically residential or commercial) is not compromised by excessive noise. The ideal monitoring location is in free field conditions representative of the point of entry to the building, such as a window. This is often not practical due to access constraints, permissions from the building owner and access to power.

Commonly noise monitors are located on the site hoarding, as shown below in Figure 1, or on lampposts where access and power are more readily available. Where this is the case it is possible to correct the measurement data based on the position of both the noise source and the receptor relative to the monitoring location, however, this is not necessarily simple for construction where the noise sources are highly mobile rather than static. There is also a risk for large complex noise sources, such as piling rigs that when in close proximity to the sensor you may not be adequately measuring the noise emissions of all sources.

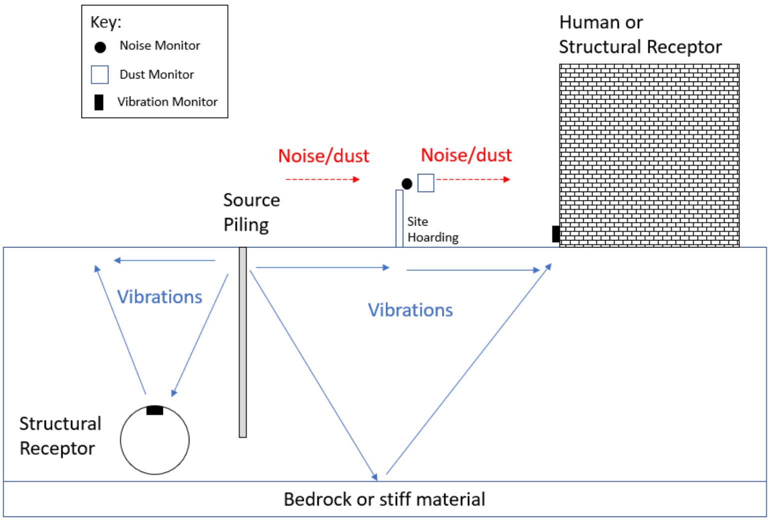

Figure 1. Illustration of typical source and receptor locations and associated monitoring

Vibration: normally measured to manage the risk of both human response and structural damage. Vibration should be measured at the point of interest, which is either a location representative of the building foundations/structure in question or at the point within the building where the occupant(s) may be exposed to vibration. The prediction of vibration propagation from one location to another is difficult and relies on knowledge of the underlying ground conditions and details of the structural makeup of the buildings in question, this is rarely available. Modelling of vibration propagation is complex and costly. For these reasons monitoring vibration at an intermediary location is not recommended as there is a real risk the vibration levels at the receiver are above those predicted, which could lead to significant issues should structural damage occur or you are questioned in a legal setting regarding human nuisance. Other cases include utilities as a receptor, these again have their own challenges especially when the receptor is below ground level. Where the sensor cannot be affixed to the utility you should site it below ground ensuring the siting and coupling are representative of the vibration received by the sensitive asset. The authors support a pre-construction condition survey of structures before works commence to note any existing defects such as cracks.

Particulates and dust: GLA (2014) and IAQM (2014) guidance state site boundary monitoring at a minimum of two locations (upwind and downwind of the prevailing conditions) should be undertaken. This enables an assessment to be made as to whether particulates originate from a site or another source. Particulate monitors should be located with an unobstructed view of the sky which typically rules out façade locations and beneath trees and vegetation. This allows good air flow to the sensor. Data should be validated during non-construction periods to look for drift in sensors. This can be undertaken where multiple sensors are employed such as on weekends during the early hours of the morning. GLA (2014) advises the use of passive monitoring for dust deposition such as glass slides or sticky pads in conjunction with the automated monitoring system, as these methods are accurate measures for nuisance dust.

Baseline monitoring: It is highly recommended that you undertake baseline monitoring for both noise and vibration. There is some ambiguity in terms of the period and value of baseline monitoring before works are undertaken when it comes to particulates. These can be influenced by programme, access, power and cost restraints. Fuller *et al*, (2017) state that is not really required for particulate/dust due to the high variability across a year caused by variations in the weather. Data is available from other sources such as continuous ambient air quality monitoring systems to provide an indication of levels. This enables seasonal variations to be examined retrospectively.

The authors support a baseline so that the monitors that are installed can be checked to ensure that they are functioning properly, it also allows for checks of the defined trigger levels against the ambient conditions before the works commence; this can identify if project or contractual trigger thresholds are reasonable based on the ambient conditions. For noise the ambient noise level is often used to establish the trigger threshold; as an example ambient noise was measured in a large construction project in the UK close to a busy main road. It was found that the ambient noise was higher than the noise thresholds for construction, which allowed for the trigger levels to be uplifted by 5 decibels (dB) from 75 to 80dB. This ensured that the noise emissions from the site could remain proportionate to the ambient noise climate.

Monitoring stations are generally static locations and tend not to change. We advocate that additional mobile units are also employed where works take place in areas that are not representative of the data from the static units and are of a short duration. Most monitoring stations can work for a matter of days to weeks using their internal battery supply only. On construction sites sources of noise from plant such as piling rigs and excavators tend not to be static, they can move towards or away from a receptor. The use of mobile monitoring stations was used to great effect on a large construction project in the UK to provide additional assurance to member of the public. By fixing them to their properties for a short duration.

5.0 Conclusions

The requirements to control the effects of construction activities on the local environment are not new but have been part of UK legislation since the 1960's. Technological developments and the wide implementation of mobile communication and cloud storage technologies have made it simple and cost effective to undertake continuous remote monitoring of construction sites.

Current standards and guidance should be reviewed regularly to ensure they are fit for purpose at regular intervals. Some standards may now be out of date in relation to what could be considered the application of Best Practical Means based on current construction technologies and monitoring equipment.

You should consult the local county council's guidance documents because they vary as demonstrated in London between councils and with industry guidance.

A monitoring plan should be produced covering the location of the noise, vibration and dust sensors. This should be based on current best practice. This plan should detail the locations of the units for the whole project including piling, excavation and superstructure and not just the demolition phase. The sensors should be installed at a location representative of the receptor, if this is not possible you must assess the relationship between the monitoring location and the receptor and allow for any necessary corrections and limitations.

It is important to have a baseline before undertaking readings the duration of which can vary up to 3 months or more. This will then inform the trigger levels that have been set for the works.

It is important to maintain the equipment as per the manufacturer's instructions and adhere to any calibrations in order for the MCERTS to be valid and for the results to be reliable.

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