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Investigation of Machine Induced Ground-Borne Noise in Calabar

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ABSTRACT

Electric generators of various masses were used to investigate the propagation of machine-ground borne noise in Calabar. The research therefore focuses on the measurement of the amplitudes of ground induced vibrationalwavesin the surrounding area. ABEM Vibraloc– a seismic measuring equipment was used for this study. Measurements consisted of vertical V, Longitudinal L, and Transverse T, amplitudes of vibrations. The results are presented in the form of graphs and Pearson correlation coefficients. The correlation between PPV of vibration and masses of different generators were obtained using a Microsoft Excel Statistical Software. A Pearson correlation result for PPV and masses of generator was obtained and the correlation coefficient is r = 0.83. This shows that there is a strong positive linear relationship between PPV and masses of generators. Results show that the amount of triggered PPV which arrived at a distant point of 6 meters from the source of vibration was between 0.03mm/s to 0.05mm/s. The value of PPV which arrived at the building foundationwas below the existing vibration criteria for the collapse of building structure for continuous vibration which has a threshold value of 2.50mm/s. Though the results show that machine induced vibration from electric generators may not result in building collapse, the figures are sufficient to cause damage to masonry and plaster, besides the harm it does to the underground ecosystem.

Key words: Ground-borne vibration, ground-borne noise, Machine Induced Vibration (MIV)

1. INTRODUCTION

Electric Motor generators constitute various forms of pollution hazard to the environment, ranging from the gaseous and particulate pollutants they emit to the noise they generate. They generate physical vibration while in operation, giving rise to both air and ground waves. Air waves produce sound while ground waves produce transmittable vibrations. When they are fixed to the ground for stability, they produce ground borne vibrations which aretransmittedthrough ground support systems to some points away from the source of vibration.

Both ground borne and air borne vibrations are unwanted signals and cantherefore be classified as noise. Ground-borne vibration is propagated in wave-form through the ground and can be transmitted into foundations of nearby structures and or destabilize soil ecosystems. Also, audible sound waves may be produced by resonance generated in walls and ceilings. This may cause damage to masonry and plaster of building structures, apart from the risk of building collapse. Historical buildings and delicate machinery in buildings near rail tracks are also adversely affected by this kind of vibration [1]. Transmission and communication facilities are not left out. Signal distortions and communication bridges are common forms of interferences.

Figure 1 shows the modes of transmission of vibrational waves from machines. We can see how vibrational signals are transmitted through air as audible sounds and through seismic waves to foundation of building structures.

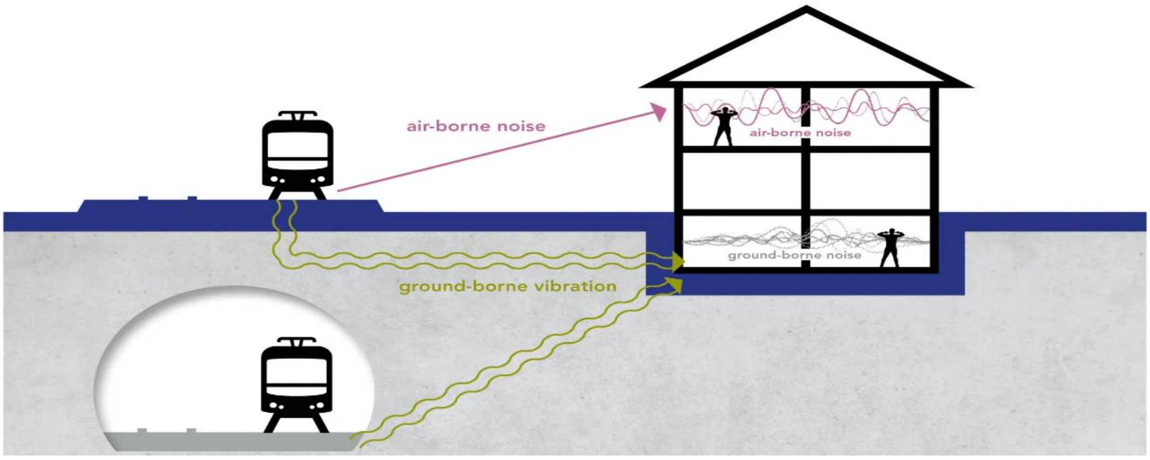

Fig. 1 Machine induced Vibration;Adapted from Lapinus [1] @ https://www.lapinus.com/applications/urban-acoustics/rockdelta/ground-borne-vibration/

Ground vibrations originating from heavy machinery and explosivescan cause more serious damage to slopes, structures, and underground workingswhich are in close proximity. It is important to monitor and predict ground vibration levels induced by blasting and to take measures to reduce their hazardous effects [2].

Three major elements can be identified in ground vibration, namely: the source, transmitter and the receiver. The source is a vibrating machine in this case. Vibration is produced in a machine as a result of an imbalance when the "rotor", an unbalance part of a machine is made to rotate around a "stator", the stationary part of the machine, in order to produce potential difference to power buildings. By so doing, vibration is generated from a source of the power supply. This form of Ground Borne Vibration (GBV) is known as Machine Induced Vibration (MIV).

The Transmitter is the medium which provides the path of propagation of the wave (vibration) energy. Good examples include soil and rock. Waves generated at the source are propagated outward through the ground. They are, however, attenuated in the soil over distance and by material damping effect [3].Loads generate waves, which propagate in the soil, eventually reaching the foundations of adjacent buildings and may cause them to vibrate as well. Equation 1 provides the relation for attenuation of waves in an elastic medium. The ground is often approximated to an elastic medium.

Mehdi and Bahrkamed,[4] present equation 1 for estimating the propagation attenuation of waves in a linear elastic medium.

$$v = v_0 \left(\frac{r}{r_0}\right)^{-n} . e^{-\alpha(r-r_0)} + v_a \qquad (1)$$

$where$

$v = Progationattenuationofwaveinalinearelasticmedium$

$v_0 = Particlevelocityatthesource$

$v_a = AmbientVibrationofthatlocation$

$r_0 = Thedistancefromthesourcetothereferencepointontheground$

$r = Thedistancefromthesourcetothereceiver$

$n = Thepowerofgeometricattenuation$ (Depends on the type of wave)

$\alpha = Thefactorformaterialdamping$ (Depends on the type of soil)

The receiver is a building, habitat or a human population where the wave energy seems to be affected or intersected.

During Ground vibration,energy,which is due to the dynamic loads produced as a result of the movement of the machine parts, is transferredor propagated along the ground from a source of vibration (generator) to a receiving end (buildings or habitat). This could be constituted nuisance to whole range of animal and plant habitats apart from the harm it does to buildings and human populations located close to the source. Incidences of building failures and collapses have become a major issue of concern all over the world and these are becoming common with devastating effects especially in developing countries including Nigeria. The inability of the building components to function effectively is described as building failure [5].Common causes of building collapse in Nigeria have been traced to factors such as ineffective enforcement of building codes by the relevant town planning authorities, lack of proper maintenance, lack of proper supervision, foundation failure e.t.c. [6].

Folagbade, [6] and Chinwokwu, [7] listed 42 cases of building collapse which occurred between 1980 and 1999 while Makinde, [8] discussed 54 cases of collapse which took place in Nigeria between 2000 and 2007.
Ezema, [9] recorded incidences of building collapse with about 173 people confirmed dead and 427 injured. From the survey, 6 were churches while others were plazas and uncompleted buildings. One of the buildings which collapsed was the Synagogue Church guest house in Ikotun, Lagos State, on September 12, 2014 killing about 115 people of various countries and injuring 131. Another noticeable incident was the collapse of the Reigners Bible Ministry Church located at KM1 Uyo, Akwa Ibom State, on December 10, 2016 during the church service which killed about 200 people [9].

2.MATERIALS AND METHODS

The major tools used in this work were generators of different sizes, a seismic meter and a measuring tape. The Seismic meter was an ABEM Vibraloc with three inbuilt geophones. The positive directions of the three inbuilt geophones (V, L and T) were defined on the front panel of the meterwhich makes it possible to align the equipment at the longitudinal direction of the wave motion while maintaining it horizontally on the plane level ground surface.
The distance from the source of vibration to the meter (receiver) was recorded using a measuring tape. Measurements were taken at increasing distances of 1m from the source of vibration.Corresponding PPV values were noted and recorded. This was repeated in steps of 1m until up to about 6m, being the average distance that outdoor electric generators were mounted from buildings. Generators produce continuous source of vibration which is seen to be injurious to structural facilities. Table of standard threshold values of PPV can found in Hindik, [10] & Ewona et al, [11].

Determination of the Peak Particle Velocity, PPV

The Peak Particle Velocity (PPV) were computed from the vibraloc readings of V_V (Vertical), V_L (Longitudinal), V_T (Transverse) velocities by applying equation 2 shown below. The Root Mean Square (RMS) values represent the average Peak Particle Velocity (PPV).

$$PPV = V_{VLT} = \sqrt{V_V^2 + V_L^2 + V_T^2} \quad (2)$$

3. RESULTS

The results are presented in the form of graphs and correlation coefficients.

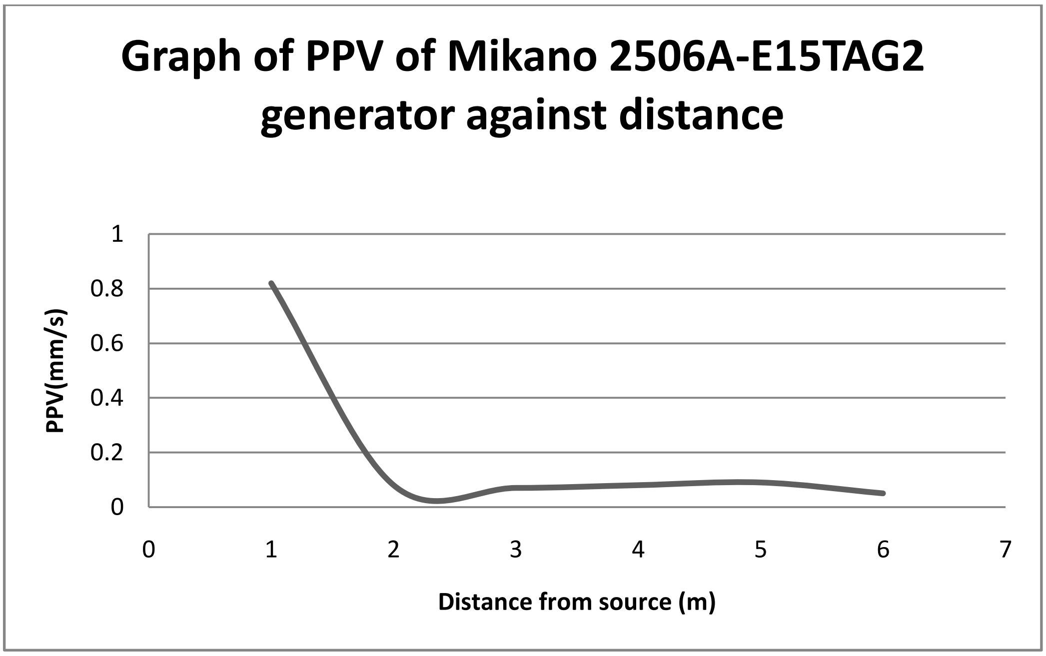

Fig. 2 Attenuation PPV triggeredvibration of Mikano 250generator with distance

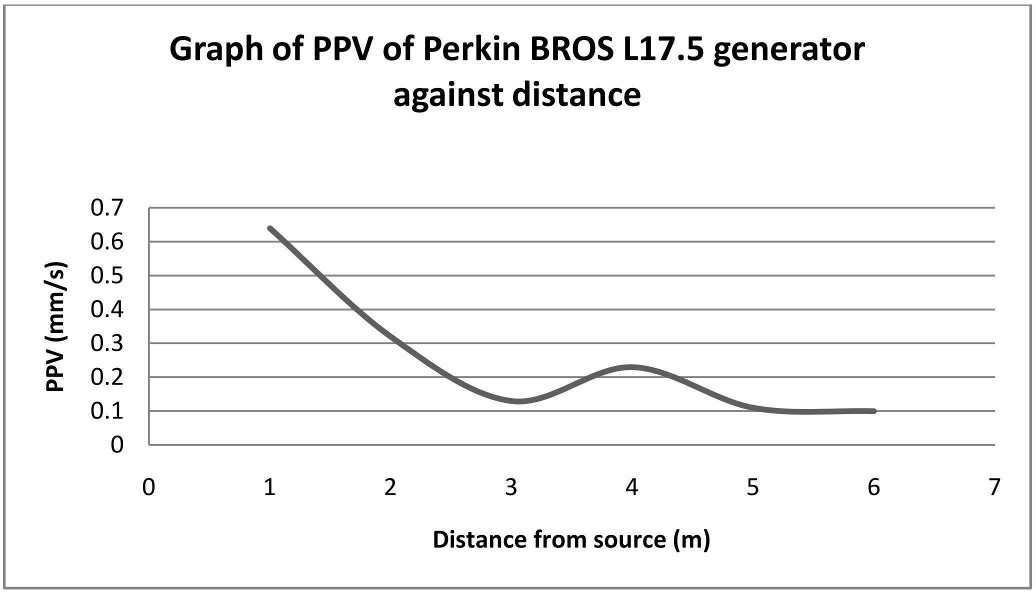

Fig. 3 Attenuation of PPV triggered vibration of Perkin l17.5 generator with distance

4.1. Discussionof Results

Figure 2 and 3 show the relationship between Peak Particle Velocity at various distances from the source of vibration. The seismic detector was placed at 1meterinterval from the vibrating source and up to a distance ofabout 6m away.The exponential decay showing the attenuation and the sharp decrease in PPV due to damping as a result of ground resistance is observable in the figures above. This clearly agrees with the works of other authors cited in this paper.

We also observe a steeper slope in figure 2 as against figure 3. This difference is as a result of the fact that the earlier generators are fastened to the ground and housed in a building. The steep decrease is as a result of the rate of absorption of the vibrational energy by the floor and the walls of the structures housing the generators.It clearlyshows how the vibrational energy is attenuated in an elastic medium.The results of this work therefore justify the theory of exponential decay provided in equation 1. The ground is estimatedto act as an elastic medium [8].

The PPV values in this work were found to lie in the range of 0.03 – 0.05 mm/s which is within the tolerable limit for building structures where 2.50mm/s is the threshold value for historical structures.

4.2. Conclusion

The result of this research shows that the PPV values lie between 0.03 and 0.05mm/s. Solidrock from the different vibration criteria which stipulate a maximum PPV value between 2.00-12.50 mm/s for historic buildings and structures within the location are not at risk.

Acknowledgement

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