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Monitoring the Dynamic Impact of Autonomous Generators on a Historic Building in an Emergency Condition

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SUMMARY

Historical structures that remain in use or are subject to restoration may be exposed to repeated anthropogenic dynamic impacts, including those generated by autonomous power generators under conditions of limited power supply. Such impacts are particularly relevant for buildings in an unsatisfactory technical condition and located under complex interaction between the structures and the soil foundation. The dynamic response of a historical building in an emergency condition to the anthropogenic excitation produced by three autonomous generators located at distances of 14, 42, and 49 m from the monitoring point was investigated. The sequential shutdown of the generators was used as a field experiment to determine the parameters of damped vibrations. Similar damped oscillation frequencies of 37.49–37.75 Hz were identified for all three cases, while the intensity of the vibration response decreased with increasing distance from the excitation source, approaching an $A \sim 1/l$ relationship. For the two most intense excitation cases, the damping ratio was 0.422–0.446%, whereas the lower value of 0.195% obtained after the shutdown of the third generator is associated with the gradual nature of its shutdown. The obtained parameters can be used as baseline characteristics for further dynamic monitoring of the historical structure.

Keywords: Vibration-based monitoring; Historic structure; Diesel generator; Vibration damping; Logarithmic decrement; Spectral analysis.

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Introduction

The operation of a diesel or gasoline generator produces a periodic anthropogenic dynamic impact that propagates through the soil mass to the foundations of historical structures, the characteristics of which depend on the generator operating mode. For a building that already has defects and is in an emergency condition, even relatively low-amplitude repeated vibrations may be relevant for assessing its current dynamic state.

Non-destructive monitoring systems are increasingly used to assess the condition of structures, particularly those of historical significance (Gattulli et al., 2016; López-Castro et al., 2022; Cherevko et al., 2025). Accelerometers are among the most widely used sensor types in structural health monitoring (SHM), including capacitive, piezoelectric, force-balance, and microelectromechanical system (MEMS) devices (Gattulli et al., 2016; Morino-Gomez et al., 2017; Lopez-Castro et al., 2022; Kril et al., 2024). Some of these studies focused on the identification of modal parameters of buildings, including natural frequencies, damping ratios, and mode shapes, to improve finite element models of structures, while others focused on damage detection following hazardous natural or anthropogenic events (Hassani & Dackermann, 2023; Rossi & Bournas, 2023).

The aim of this study is to instrumentally assess the dynamic response of a historical building to periodic anthropogenic excitation associated with the operation and sequential shutdown of autonomous generators, and to determine the vibration parameters that should be considered when assessing the technical condition and planning the restoration of historical structures. To achieve this aim, the following tasks were addressed: analysis of the engineering-geological conditions of the study area; collection of data on the sources of anthropogenic excitation (generators); analysis of vibration records from the building during generator operation and shutdown; assessment of the damped vibrations after the sequential shutdown of the generators; and comparison of the response of the historical structure under different numbers of operating generators.

The study was conducted on the example of the historical structure of national significance, the Sikorsky Mansion (protection number 260087), located within the central historical area of Kyiv. Vibrometric observations were carried out during scheduled power outages in September 2024. Specialized seismometric equipment of the Institute of Geological Sciences of the National Academy of Sciences of Ukraine, acquired through a grant from the National Research Foundation of Ukraine (Project No. 2022.01/0209), was used for the measurements.

Method

Principle of the field experiment: the seismometric system was installed at a control point on the historical building; diesel generators located at different distances from the building served as sources of dynamic excitation; continuous recording was performed during the period of simultaneous generator operation and their sequential shutdown.

Data processing methodology included the following steps: trend extraction, filtering, time-domain analysis, spectral analysis, and frequency-domain analysis. Quantitative analysis of the local three-component response was performed using the ALE, ALN, and ALZ channels. The BLE channel was used for the general inspection of the records but was not included in the approximation of damping parameters. The signals were processed in digital converter units. The provisions of ISO 4866:2010 (International, 2010) concerning the determination of the structural vibration were taken into account.

The power spectral density was determined using the P.D. Welch, 1967 method with overlapping time windows. A short-time Fourier transform (STFT) was used to monitor changes in the frequency content over time. The generator shutdown time was identified not from an individual peak, but from a simultaneous and sustained decrease in energy across several harmonic bands. This criterion allowed us to distinguish the shutdown event from random disturbances (short-term impulses, human movement).

For damping assessment, the signal was band-pass filtered within the 37.0–38.2 Hz frequency range. The initial 0.25 s interval following generator shutdown was excluded to reduce the influence of the switching impulse. The subsequent 3 s segment was fitted using the model:

$$x(t) = Ae^{(-\beta t)} \cos(2\pi f_d t + \varphi) + C \tag{1}$$

where A is the initial amplitude, β is the exponential decay rate, f_d is the damped oscillation frequency, φ – the initial phase, and C is the residual displacement. These parameters were determined using the least-squares method separately for the two horizontal components. The logarithmic decrement δ and damping ratio ζ were calculated using the following expressions:

$$\delta = \frac{\beta}{f_d}, \qquad \zeta = \frac{\delta}{\sqrt{4\pi^2+\delta^2}}. \tag{2}$$

The consistency of the results was assessed based on the similarity of the frequency, logarithmic decrement, and damping ratio independently obtained from the two horizontal components. This cross-check reduces the influence of random disturbances and the selection of an individual channel. The filter parameters and duration of the fitting interval were kept identical for the ALE and ALN components, in accordance with the principles of damping estimation from full-scale time-domain records (Brincker & Ventura, 2015; Chen et al., 2021; Stollwitzer et al., 2025; Savchuk, 2026).

Results

The Sikorsky Mansion is located within the central historical area of Kyiv, on a gentle slope with an elevation difference of 30–32 m, within the Kyiv loess plateau (Starokyivska mountain). The absolute elevations of the building site are 191–192 m (Figure 1a). The Sikorsky Mansion is a three-story brick building with wooden floors and a basement. The building has strip foundations made of rubble concrete, which are built on loess-like sandy loams and loams. The building is in an emergency condition and requires restoration.

a) b)

Figure 1. *General scheme of the experimental site and generators (a), equipment placement (b): 1 – buildings and structures; 2 – isohypses, m; 3 – streets; 4 – sandy loams and loess-like loams (e,dvP$_{III}$); 5 – alluvial-diluvial deposits, sands, sandy loams (adP$_{III}$ud-bz)*

A three-component vibrometric sensor was installed near the center of the facade wall, while the accelerometer was placed on the windowsill (Figure 1b). The sources of forced structural excitation were a GENPOWER DMG GNT-71 diesel generator (G1), located at a distance of 14.0 m, and two diesel generators, Aksa APD135A (G2) and Aksa APD110BD (G3), located at distances of 49.0 and 42.0 m, respectively. Analysis of the records showed that the sequential shutdown of the generators was accompanied by pronounced changes in the vibration signal and frequency spectrum (Figure 2).

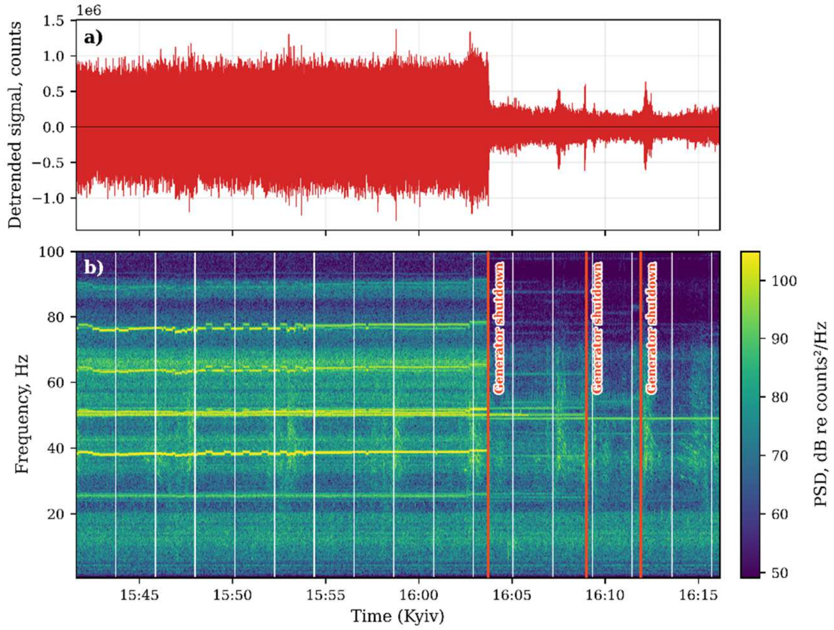

Figure 2. *Time-domain and time–frequency representation of the ALN-channel vibration record during the shutdown of generators G1, G3 and G2: a – detrended signal; b – spectrogram showing the generator shutdown and subsequent decay of vibration*

Parameters of damped vibrations were determined for each transient process after the sequential shutdown of the three generators (Table 1). The damped oscillation frequency varied only within the range of 37.49–37.75 Hz in all three cases, indicating its relative stability under changing anthropogenic excitation conditions. In contrast, the intensity of the structural response and the damping parameters depended on the excitation source and the nature of its shutdown.

Table 1. *Mean dynamic characteristics of damped vibrations based on the horizontal ALE and ALN components after generator shutdown*

Generator	***Distance, m***	***Frequency, Hz***	***Decrement δ***	***Damping ratio ζ, %***
G1	*14.0*	*37.4*	*0.0252*	*0.401*
G3	*42.0*	*37.83*	*0.0282*	*0.449*
G2	*49.0*	*37.52*	*0.0135*	*0.216*

According to the spectral data, increasing the distance from the excitation source resulted in a substantial reduction in its contribution to the vibration background: for G3 (42.0 m), the response was approximately seven times weaker, while for G2 (49.0 m) it was approximately 31 times weaker than that produced by the nearest generator, G1 (14.0 m). The attenuation trend was close to the $A \sim 1/l$ relationship. For the two most intense transient processes (G1 and G3), the damping ratios were similar, amounting to 0.422% and 0.446%, respectively, whereas the value obtained after the shutdown of G2 was 0.195%. The lower value for G2 may be associated with the gradual nature of its shutdown, which resulted in a longer-lasting decay of the vibrations.

Conclusions

For the first time, an instrumental assessment of the dynamic response of a historical building in an unsatisfactory technical condition to repeated anthropogenic excitation from an autonomous power supply source was conducted under conditions of scheduled power outages. The sequential shutdown of generators was used as the field experiment to distinguish between the contributions of forced excitation and the subsequent damped structural response. The obtained parameters can be used to establish a baseline dynamic state of the historical structure and to further monitor changes in its dynamic characteristics.

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References

López-Castro, B. Haro-Baez, A.G. Arcos-Aviles, D. Barreno-Riera, M. Landázuri-Avilés, B.A. (2022). Systematic Review of Structural Health Monitoring Systems to Strengthen Post-Earthquake Assessment Procedures. *Sensors*, 22, 9206. https://doi.org/10.3390/s22239206.

Gattulli V, Lepidi M, Potenza F (2016) Dynamic testing and health monitoring of historic and modern civil structures in Italy. *Struct Monit Maint* 3:71–90. doi:10.12989/smm201631071.

Cherevko, I., Kril, T., Mostovyy, V., & Shcherbyna, S. (2025). Structural health monitoring of heritage buildings under military actions study. *International Journal of Conservation Science*, 16(4), 1755–1774. https://doi.org/10.36868/IJCS.2025.04.09

Moreno-Gomez, A., Perez-Ramirez, C.A., Dominguez-Gonzalez, A. et al. (2018) Sensors Used in Structural Health Monitoring. *Arch Computat Methods Eng*., 25, 901–918 https://doi.org/10.1007/s11831-017-9217-4.

Kril, T., Cherevko, I., Shcherbyna, S., & Chalyi, O. (2024). Modern risk assessment of the influences of natural and military man-made factors on the state of the historical buildings of the Kyiv-Pechersk Lavra. *Geofizicheskiy Zhurnal*, *46*(5). https://doi.org/10.24028/gj.v46i5.309056

Stollwitzer, A., Bettinelli, L., Loidl, S., et al. (2025). Novel evaluation methods for data-based determination of damping factors in the frequency and time domains with application on railway bridges. *Railway Engineering Science*, 33, 522–552. https://doi.org/10.1007/s40534-024-00373-1

Savchuk, D. (2026). Dynamic monitoring of building structures: Spectral-temporal methods. *Tekhnika budivnytstva*, (44), 38–47. DOI: https://doi.org/10.32347/tb.2026-44.0704

International Organization for Standardization. (2010). ISO 4866:2010. Mechanical vibration and shock – Guidelines for the measurement of vibrations and evaluation of their effects on structures.

Hassani, S., & Dackermann, U. (2023). A systematic review of advanced sensor technologies for non-destructive testing and structural health monitoring. *Sensors*, 23(4), 2204. https://doi.org/10.3390/s23042204

Rossi, M., & Bournas, D. A. (2023). Structural health monitoring and management of cultural heritage structures: A state-of-the-art review. *Applied Sciences*, 13(11), 6450. https://doi.org/10.3390/app13116450

Chen, W., Jin, M., Huang, J., Chen, Y. et al. (2021). A method to distinguish harmonic frequencies and remove the harmonic effect in operational modal analysis of rotating structures. *Mechanical Systems and Signal Processing*, 161, 107928. https://doi.org/10.1016/j.ymssp.2021.107928

Brincker, R., & Ventura, C. E. (2015). Introduction to Operational Modal Analysis. Wiley. https://doi.org/10.1002/9781118535141