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RESEARCH ON THE DEGRADATION OF CONSTRUCTION AND BUILDING MATERIALS WITH THE USE OF VIBRATION PROCESSES

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ABSTRACT

Existing civil engineering structures, especially masonry structures, are subjected to heavy loads of dynamic, significant reflected vibration in the generated processes. These vibrations can affect the condition of the works by reducing the safety of people working there, as they can reach the level of endangering the safety of the structure. The effect of vibration on the structure manifests itself mainly as an additional stress, which adds to the stress of static loads. In addition, there are often the effects of climate-related environments on fatigue, which dynamize the destruction of the object. Dynamic loads can cause devastating effects in buildings of various types of construction or lead to catastrophic destruction. This article presents a modern methodology for non-invasive testing of masonry structures using vibration processes. The possibility of using modal analysis methods to assess the state of destruction elements and masonry using the process of vibration and vibration measurement is shown. This is a new approach, using innovative research methods supported by information technologies to examine the suitability of building materials and the conditions for the construction of a diagnostic agent.

Keywords: modelling, mass, stiffness, damping, vibration signal, modal analysis, stability diagram, diagnostic agent

INTRODUCTION

Great inventions, rapid growth in production, and other achievements of recent years resulted in several unintended consequences that threaten humans, the environment in which people live and work, as well as buildings. For these reasons, environmental protection of life and work is the subject of scientific interest and practical business. Matter degradation processes in the environment necessitate the need for their evaluation and the search for new study methods (Stępniewski, Uhl & Staszewski, 2013).

The construction of new materials and new technologies and inspiring design solutions enable more efficient processes but are often accompanied by high dynamic loads. There is a need to improve methods for testing the dynamic characteristics of structures, particularly those solutions that are accompanied by high dynamic loads.

In the case of dynamic loads exceeding limits, there is a need to build a model, the analysis of which can accurately identify ways and means of reducing the excessive burden. The first step in the analysis is a dynamic system identification of the vector excitation forces

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acting directly on certain elements of the structure and moving to other components, in such a way that the latter are excited to vibrate by the impact of the adjacent element. Because it is "moving up", it takes place in a selective manner, as the elements of design are the filtering properties, and it is important to know these properties (Stępniewski, Uhl & Staszewski, 2013).

Recognising the need to improve methods for testing the quality of masonry building structures to assess their condition and assess the safety factors of walls (PN-B-03002, pts 3.1.3 and 4.6), this paper attempts to develop a methodology for testing the quality of selected materials and the destruction of building structures using the modal analysis method (Allemang & Phillips, 2004).

Occupying an important place in this regard is the frequently-used non-destructive testing of masonry in the laboratory, as well as studies directly on the structure using the sclerometer methods (fingerprint measurement method, the method of measuring the rebound), pulse methods (ultrasonic, hammering), radiological methods (radiographic, radiometric), electromagnetic methods (magnetic, dielectric) and special methods (e.g. electrical methods).

Both the mentioned dynamic research systems and experiments are performed on the real objects (Cempel, 1994).

New tools in this area of research relate to the possibility of using modal analysis methods, as well as modern mining and vibration processes, to assess the quality of construction and masonry, which form the basis of considerations of this work. In practical applications, they allow for a better understanding of the behaviour of complex structures in the process of optimising the design and evaluation of dangerous conditions (Cempel, 2003).

Modal analysis is widely used in studies of degradation status and fault location, in the modification of the dynamics of these structures, in the description and updates of the analytical model, and is used to monitor the vibration of structures in the aerospace and civil engineering fields (Żółtowski, 2014).

The study recognises the usefulness of modal analysis methods to evaluate the degradation in the quality of materials and structures, and proposes a research methodology for acquisition, processing and reasoning for the data obtained in the study on building degradation.

MATERIAL AND METHODS

Experiments that identify the failure state of the test masonry are the primary source of information, and from the measurements, the structure of the model can be determined. On the one hand, the quality of the experimental results obtained depends on the quality of the model, and on the other hand, the manner of experimentation determines the structure of the identified model.

Modal analysis experiments can be divided into the following steps:

1. Experimental plan:
   - selection of the type of vibration load on the test piece and the point of application,
   - selection of measuring points and vibration measuring devices,
   - selection of suitable measuring equipment,
   - selection of the system model (reduction in the number of degrees of freedom).
2. Calibration of the measuring path.
3. Record and process test results.

The purpose of this experiment is to perform a modal analysis of the motion of a masonry sample by energising and measuring the response to the blackout. Based on measurements of the vibration process, the properties of the examined masonry can be estimated. The general process for carrying out this work is shown in Figure 1.

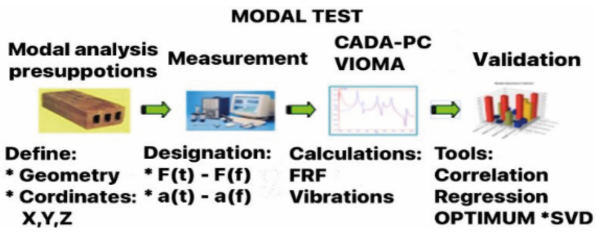


Fig. 1. The essence of the measurement channel using modal analysis

Source: own work.

The force conversion signal applied to the sample corresponds to the vibration signal, proportional to the failure state. The applied force and response signals are used to determine the function of the further FRF, the stability of the graph, as well as the oscillation frequency. Additionally, with these methods, the

vibration estimator can be used for other interesting cognitive processes, which can also be used for further research. The test results are processed by various algorithms for statistical analysis. From the point of view of experimental modal analysis, methods can be divided into:
– a method to force the movement of multiple actuators to excite a waveform,
– a method of forcing one or more points to move and measure the transfer function.

The first group of methods is to manually move the system to force the vibration according to the vibrating embodiment. This requires a complex control system of the actuator to obtain the proper phasing force. The second group is used to enforce any action based on the object type. The complete set of equipment for the modal analysis experiment consists of the following parts:
– dynamic and reaction force measurements,
– signal conditioning system (preprocessing),
– processing and collection of signals,
– forced signal generation system,
– vibration excitation.

For maintenance reasons, the simplest solution is to use a signal analyser, but the most modern solutions with the greatest potential are based on workstations and special interface measurements. The basic operation performed by all applicable devices measuring modal analysis is analogue to digital processing, which enables the use of digital signal processing techniques to determine the modal analysis required by the characteristics of estimators.

Modal studies do not consider the magnitude of motion in which the system responds. In fact, displacement measurements give better results in terms of accelerations in the low and high frequency ranges. It is generally accepted that velocity measurements are optimal for structural dynamics studies because the root mean square vibration velocity is, in a sense, a measure of the kinetic energy of the system's vibration. However, sensors for displacement and velocity measurement are relatively heavy and affect the behaviour of the test object, while acceleration sensors are much smaller and, therefore, have no effect on the motion of the system. Another advantage of accelerometers is that the velocity or displacement oscillations can be integrated to obtain another signal from the acceleration signal. The reverse operation consisting of differentiation can lead to large errors, especially at higher frequencies.

On those grounds, acceleration sensors are the most used transducers for studies of modal structure. Acceleration sensors built on the piezo-electric phenomena can be modelled as a system with one degree of freedom from suppression. The weight of this model is the seismic mass aggravating crystal piezoelectric material during movement. Due to the design of the sensors, it has a resonance, which reduces the frequency range in which they can be applied (Żółtowski & Żółtowski, 2014).

Measuring software

Registering of vibration signals (excitation and response) in tested masonry elements is quite complicated, but vital to determine the state of destruction (Żółtowski i Martinod, 2016).

Determination of modal parameters is done with the stabilisation diagram, which can be obtained directly from the numerical modal analysis (LMS) or using the least squares complex exponential method (LSCE). It has been implemented in the "VIOMA" used to carry out an initial operational modal analysis (Stępniewski et al., 2013). The program consists of the following modules:
– "Data" module – used for downloading, viewing, and simple measurement data processing,
– "Geometry" module – allows the building and visualisation of the object's geometry,
– "Analysis" module – implements modal analysis, including the LSCE method,
– "Visualisation" module – allows visualisation of analysis results.

Figure 2 shows an example of a stability diagram, where the stable poles were selected from the 39 for the following estimation of the normal modes. The data obtained as a result of the analysis can be represented graphically via the "Visualisation". Figure 3 shows samples with selected natural frequencies.

Measured waveforms generated by force and response of the measured samples, and the possibility of determining the modal parameters of the model in the study of masonry structures can be made by measuring equipment named LMSTEST.XPRESS LMS (Fig. 4).

The LMS software allows for the creation of a diagram of one stabilisation measurement (option "Selected function"), and it is possible to create a stabilisation diagram for all measurements (the "SUM"). The sample stabilisation diagram is shown in Figure 4,

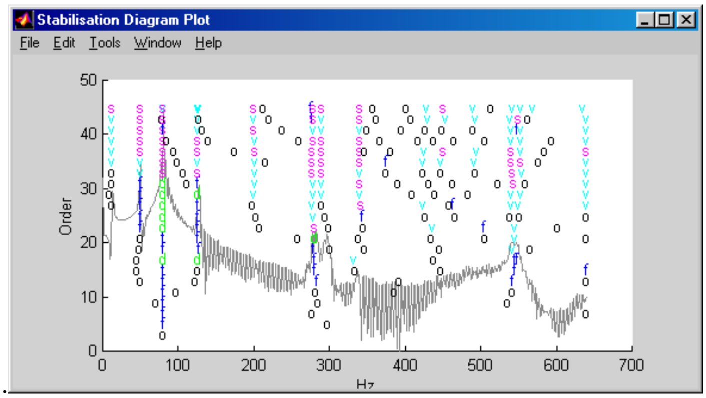


Fig. 2. Stability diagram and method for determining the poles: o – unstable pole, f – pole has a fixed frequency, v – pole has a fixed frequency and a modal vector, p – stable pole

Source: own work.

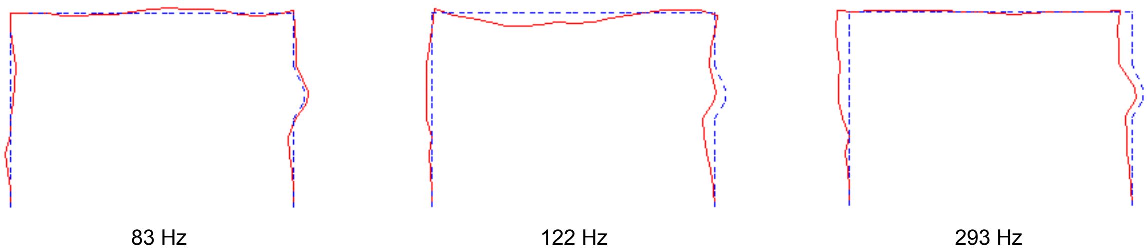


Fig. 3. Sample forms for the selected natural frequencies

Source: own work.

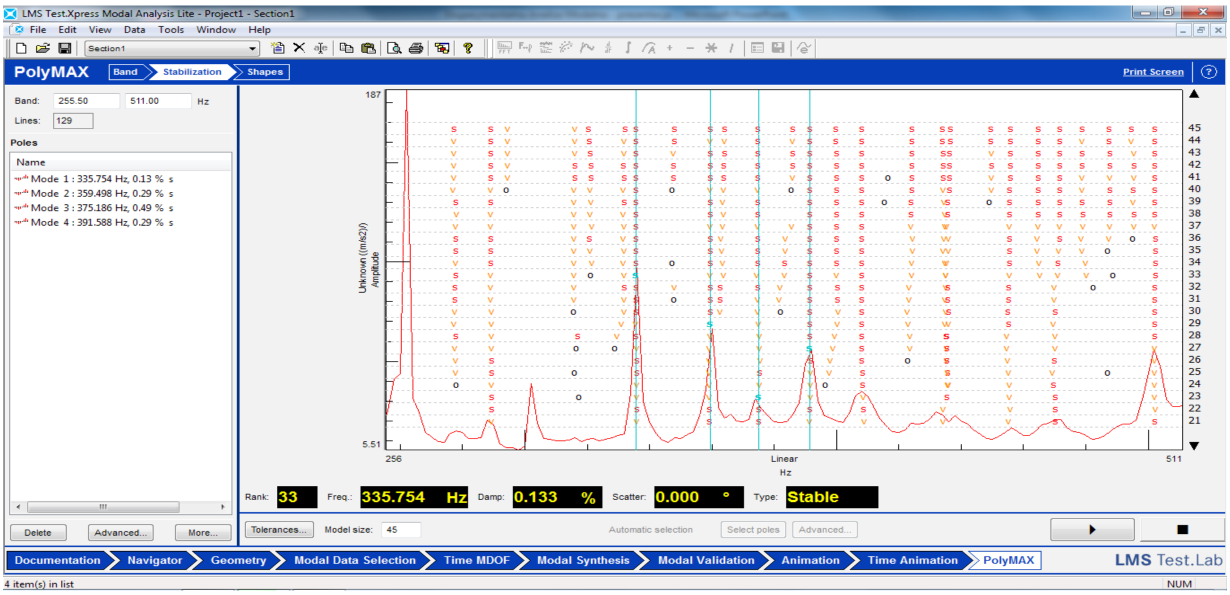


Fig. 4. The stabilisation diagram

Source: own work.

which introduces the polarity markings: S – stable, V – modal vector, and D – damping. The software option "Mode" is suitable for the visualisation of a geometric deformation model.

The software (accurate, durable and reliable) allows for the implementation of a variety of experiments, often in difficult and not very reproducible conditions.

Compilation of statistical results

Many measurement data processing capabilities resulting from vibration signals lead directly to the need for statistical analysis.

In practical applications, preconditioning obtained from the measured data is an important step in the data classification, affecting both the efficiency of distinguishing between states, the speed and ease of construction and the learning model of cause-effect as well as its subsequent generalisation (Wiliams, Crowley & Vold, 1985).

Analysing the experimental data is associated with the occurrence of various kinds of scales of measurement, which may be numerical or symbolic. Diagnostic information processing systems are characterised by the fact that the most frequently analysed features describing the objects should be characterised numerically.

In the case of classification models using the distance as a measure of similarity, it often happens that the various features are characterised by a physical state based on various physical quantities having different ranges of values, which can have different effects on the distance. Here, it is possible to apply several transformations, unifying the influence of individual characteristics on the distance value. The most common is the normalisation and standardisation.

Optimum

Optimisation techniques may be based on measurements of the distance from the ideal point measured to characterise the sensitivity to changes in symptoms. The distinction of damage is possible after symptoms of components projected on the respective axes x, y, and z (Fig. 5).

The presented algorithm allows the development of a statistical evaluation of diagnostic symptoms, resulting in a final ranking list of their sensitivity and usefulness. The next step of this procedure is (Żółtowski, Łukasiewicz & Kałaczyński, 2012):

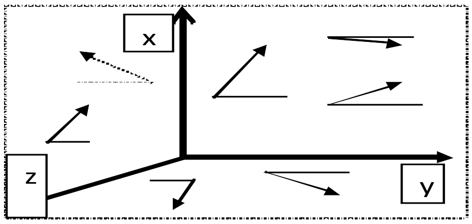


Fig. 5. Multidimensional observation space

Source: own work.

1. Creation of an observation matrix from the measured symptoms: $s_1, s_2, s_3, ..., s_m$.
2. Statistical evaluation of symptoms measured for different states by means of, for example:
   – variability of symptoms:

$$f_1 = \frac{S_j}{\vec{y}}, \tag{1}$$

where:
S_j – standard deviation,
$\vec{y}$ – the average;
   – assessment of symptom sensitivity to changes in:

$$w_1 = \frac{x_{i\max} - x_{i\min}}{\overline{x}_i}; \tag{2}$$

   – symptoms correlate with technical condition (correlation coefficient symptom – state):

$$r_{xy} = \frac{1}{n-1} \frac{\sum_{i=1}^{n}\left(x_i - x_{\text{avg}}\right)\left(y_i - y_{\text{avg}}\right)}{\sigma_x \sigma_y}.$$

$$f_2 = r(x, y). \tag{3}$$

3. When standardisation further maximises signal quality, measurement indicators obtain statistical characteristics of their sensitivity, which allows the determination of the coordinates of the ideal.
4. Determination of the distance measurement from the ideal point, according to:

$$L = \sqrt{(1 - f_1^*)^2 + (1 - f_2^*)^2}. \tag{4}$$

5. The sensitivity coefficients (weights) for each test signal are determined from the relationship:

$$w_i = \frac{1}{\frac{1}{L_i} \cdot \sum_{i=1}^{n} L_i}, \text{ where } \sum w_i = 1. \tag{5}$$

The algorithm can easily be implemented in MS Excel to give a qualitative ranking of the usefulness of the measured symptoms. Figure 6 shows the result of the described action procedures for sample data. The distance of each measurement point from the ideal point (1, 1) indicates the sensitivity of the evaluated measurement signal, and the points lying closest to (1, 1) are the best symptoms.

The quality of the model depends, however, on the number of measures considered, which indirectly, in the simplest regression models, can be assessed by the coefficient of determination (R^2).

Research methodology of masonry units

To test the usefulness of experimental modal analysis and assessment of the severity of the destruction of masonry and building materials using the vibration signal for selected representatives of the groups (EC6V):

- ceramic elements (EN 771-1) – solid brick, hollow brick, porotherm,
- elements of silicate (EN 771-2) – aerated concrete (suporex),
- concrete elements (EN 771-3) – cube (brick), concrete, concrete block.

Figure 7 shows a sample set of research material, before the destruction of the basic research.

The first bench testing was performed for unloaded masonry, with the release of test items for many degrees of freedom, which was obtained by suspending the items on an inextensible thread (Fig. 8).

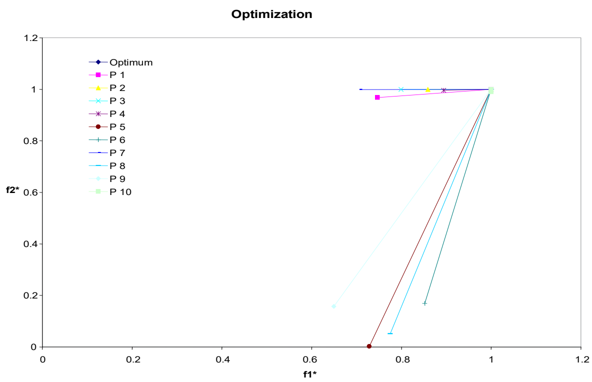


Fig. 6. The result of the ideal point method – OPTIMUM

Source: own work.

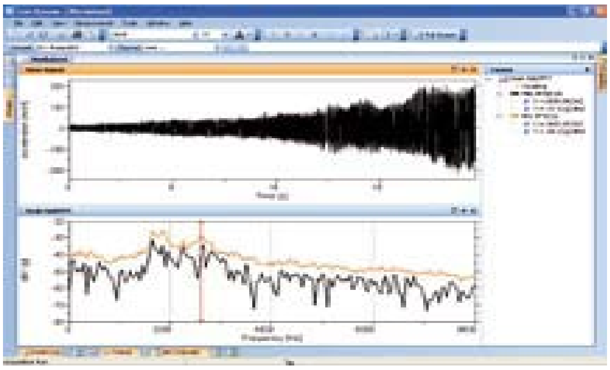


Fig. 7. Masonry and masonry segments adopted for testing

Source: own work.

Fig. 8. Attaching the sample, sensors, and test stand

Source: own work.

Measurements of vibration signal parameters (Fig. 9) were performed using a measuring package – the APB-200 processor that is part of CADA-PC software.

In practice, the study was carried out with no load and with a load testing machine (Fig. 10). Tested vibratory signals are dependent on the type of load of masonry, which results from the nature of the load curves obtained during a destructive test testing machine for each piece of masonry.

Fig. 9. Schematic structure of a measuring program

Source: own work.

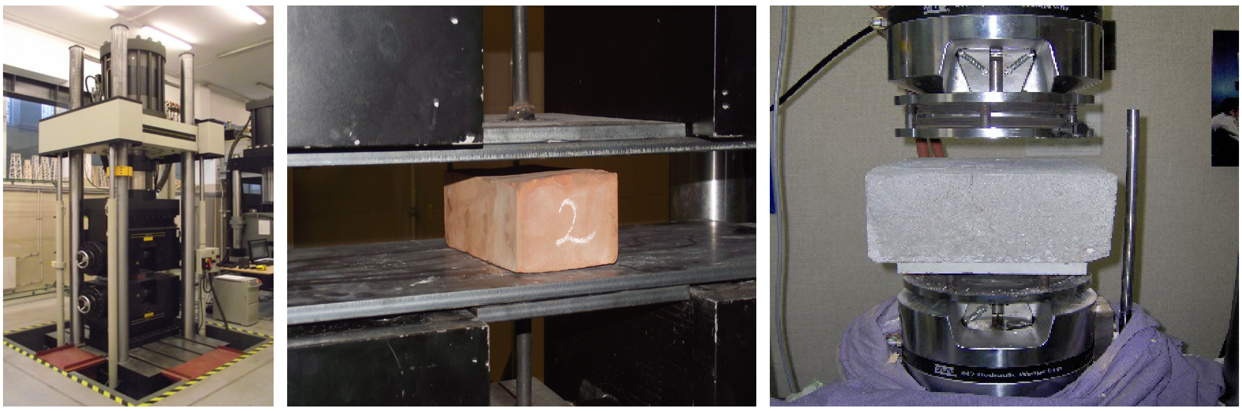


Fig. 10. Test under load testing machine

Source: own work.

RESULTS AND DISCUSSION

The results of destructive testing of selected masonry on the machine Instron 8502 are shown in Figure 11, and they were the basis for determining the load of test materials and masonry.

Deliberately, tensile test results are summarised in Figure 11, and they are in the range of:

- for items marked as 2, 4, 5 – load testing: 25 kN, 50 kN, 75 kN,
- for items marked as 1, 3, 6 – load testing: 50 kN, 100 kN, 150 kN.

In further studies, each element of walled compounds was tested between the types of measures (indicated above 3, and no load) and the vibration signal generated. Experiments carried out to verify the suit-

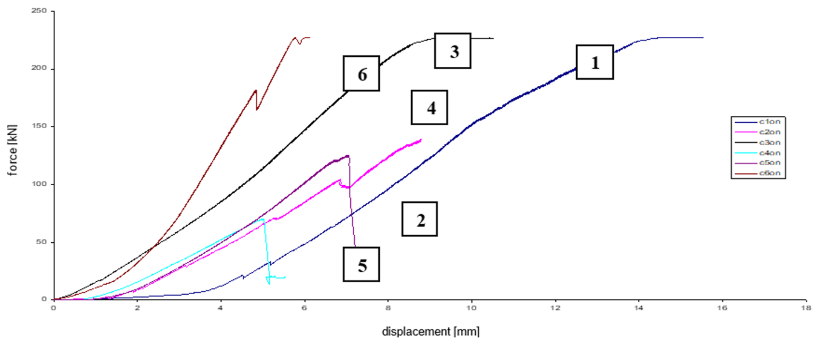


Fig. 11. Time passes to the destruction of the load curves for the tested masonry units: 1 – solid brick; 2 – hollow brick; 3 – concrete blocks; 4 – suporex; 5 – porotherm; 6 – concrete block

Source: own work.

and Y for different loads of studied masonry form the basis for further processing. From the raw data presented in MS Excel sheets using the software GENERATE symptoms, made in MATLAB for the purposes of this research, generated 12 representative measurements of the state for each tested masonry elements.

Graphical presentation of the data in the MS Excel tables presented in the form of amplitude characteristics in the X and Y axes are shown in Figure 12.

In Figures 13–15, power waveforms are shown in the form of modal hammer force and the corresponding amplitude of vibration acceleration for the tested masonry materials with different loads F_1, F_2 and F_3. It is worth noting that the first group of materials – solid brick, concrete brick, and concrete block, are loaded at the time of testing forces: 50 kN, 100 kN and 150 kN. The second group materials – hollow brick, porotherm and suporex forces during the tests: 25 kN, 50 kN and 75 kN.

Timing and response force, shown in Figures 13–15, do not allow for any reasonable inference, but illustrate the data used in further analyses.

ability of the FRF measurement of vibration and other estimators to assess changes in the destruction of some masonry gave almost 3,500 different measurements of vibration (vibration estimators studied 12 × 6 × 2 masonry directions of load measurements × 4 equal to 576 measurement values; and a further 576 measurements × 6 sets of masonry equal to 3,456 vibration signal measurements). Exemplification earned on this data research methodology is the next big data group and underwent the same procedure processing.

Archived timing and strength of vibration acceleration force (1,024 samples) measured along the X

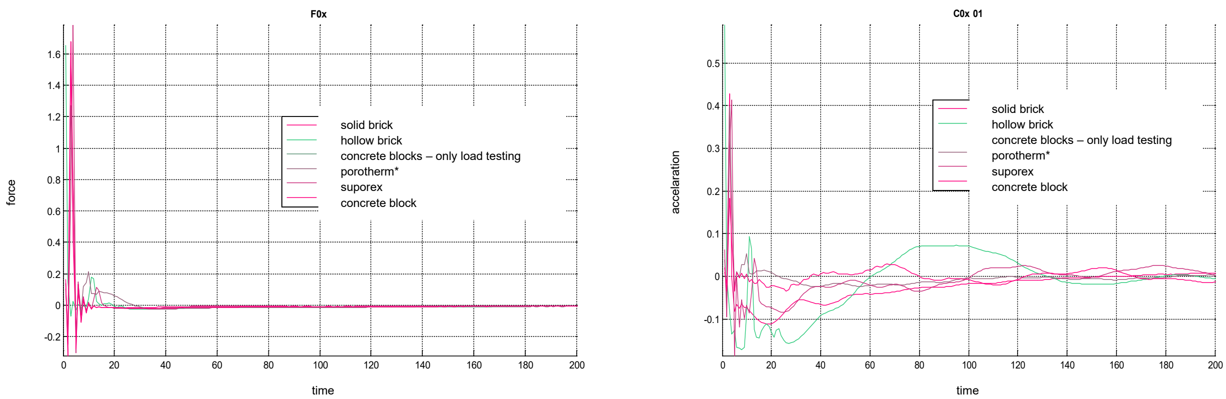


Fig. 12. Force and amplitude of the vibration acceleration along the X-axis for the test of six masonry elements without the F_{0X} load

Source: own work.

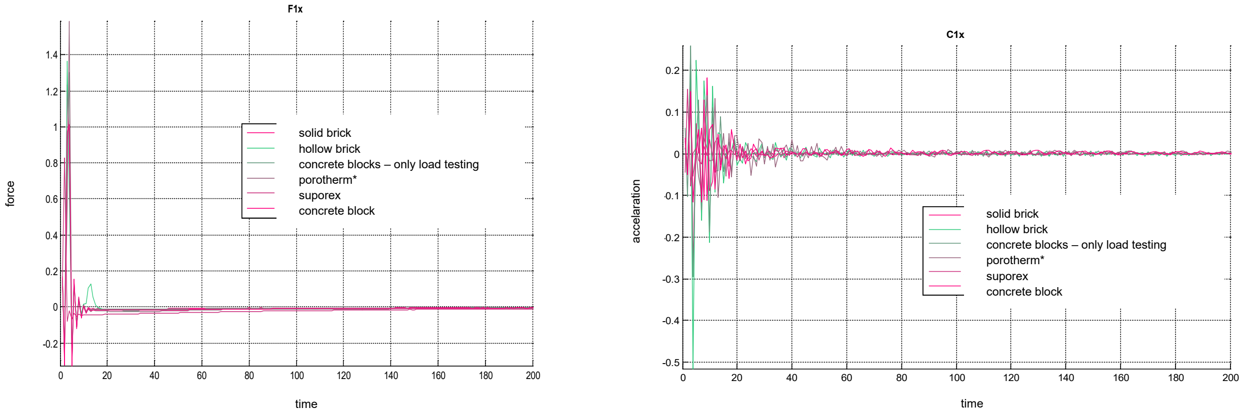


Fig. 13. Force and amplitude of the vibration acceleration for the test of six masonry elements with the F_{1X} load

Source: own work.

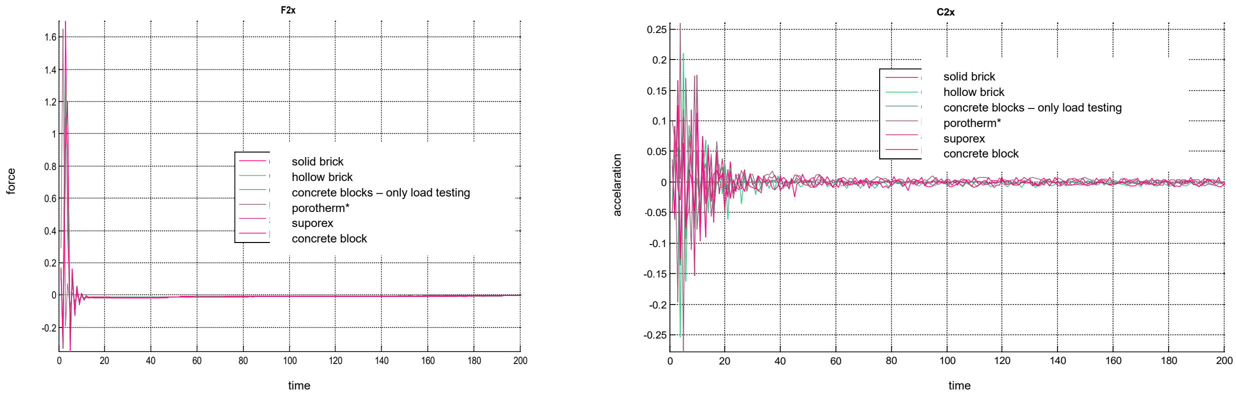


Fig. 14. Force and amplitude of the vibration acceleration for the test of six masonry elements with the F_{2X} load

Source: own work.

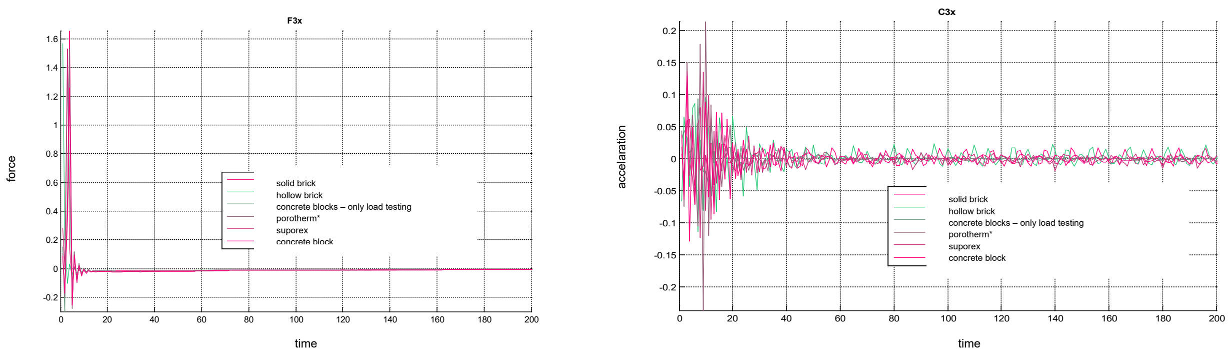


Fig. 15. Force and amplitude of the vibration acceleration for the test of six masonry elements with the F_{3X} load

Source: own work.

Figures 14 to 16 show the measure of destruction state for full brick that has been tested with no load and fixed earlier in the strength tests with three load values for only the original signal strength X. Force and acceleration amplitude of response function FRF was converted to spectral domain (frequency). Figure 16 shows the waveforms and their spectra for excitation force and the response to research full brick in the X direction.

The ratio of power spectrum amplitude and spectrum force vibration acceleration determines the function of the FRF (real and imaginary). Inversion of the FRF is a widely known transmittance function (real and imaginary). Changes in these measures on the frequency scale are shown in Figure 17.

Indicated earlier measurement – coherence function, with a good examination of the similarity between two signals in the frequency domain, and the cross-correlation function, with similar properties, but are defined in the time domain, are shown in Figure 18.

Figure 19 shows the waveform of an effective overall amplitude vibration and stability diagram obtained from the VIOMA program and characteristic eigenfrequencies of studied masonry elements.

The same measurements were obtained in studies of the workload for different values of all the tested masonry – the numerical values of measurement signals for each masonry with different levels of power load, and the input data for the development of statistical results. To distinguish the best measures for the

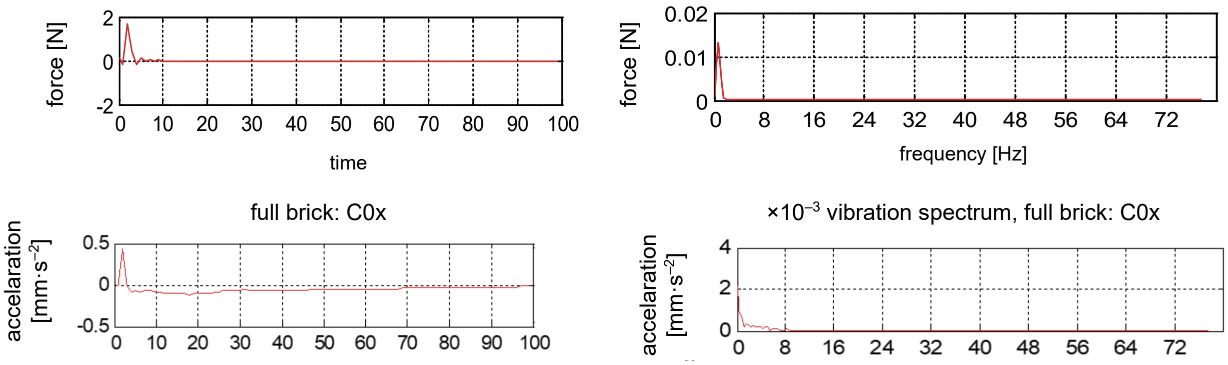


Fig. 16. Timing and power spectrum for the acceleration force and amplitude of the test response with no load

Source: own work.

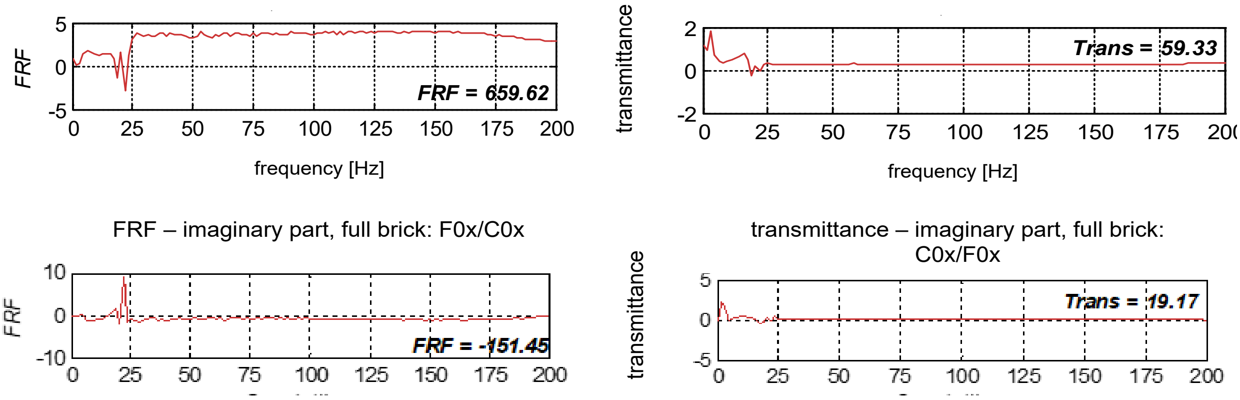


Fig. 17. The FRF variation waveforms and $H(f)$ (real and imaginary parts) of the test without load

Source: own work.

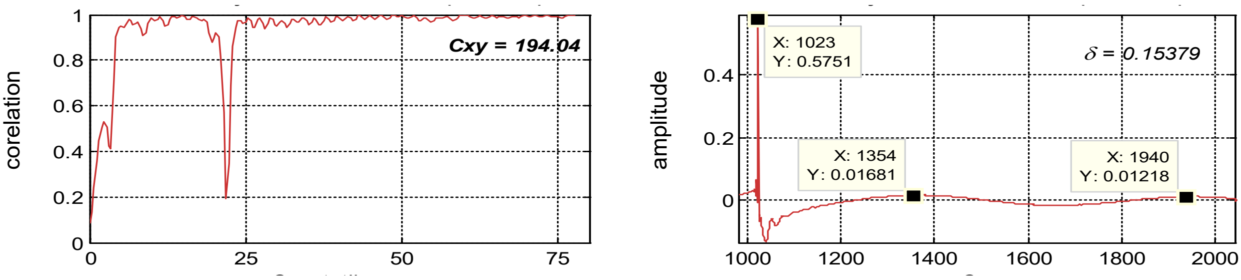


Fig. 18. The waveforms of the coherence function and cross-correlation function

Source: own work.

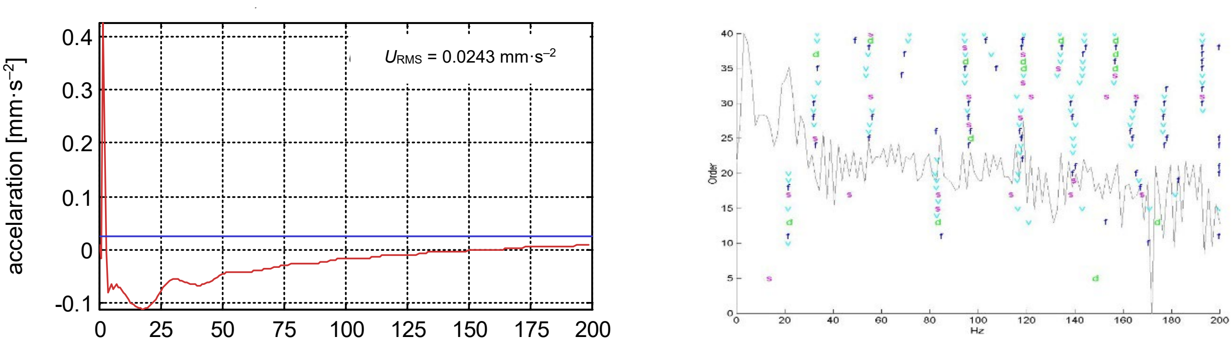


Fig. 19. Waveform amplitude and vibration acceleration effective stabilisation diagram with characteristic vibration frequencies

Source: own work.

destruction of the state of the tested masonry results were subjected to statistical evaluation first by the OPTIMUM method. Figure 20 illustrates cumulative sensitivity results of the measurement of destruction symptoms separately for the X-axis and the Y-axis.

Measures located closest to the ideal point of destruction best reflect the behaviour of masonry investigated under increasing load. A careful analysis measures the distance from the ideal point shown in the graphic display of all analyses treated individually as

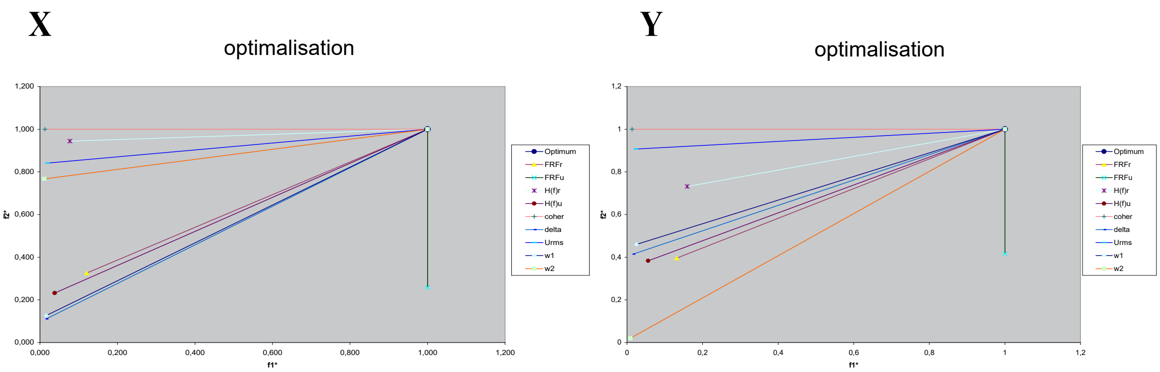


Fig. 20. Collective results of the sensitivity of the destruction of masonry elements

Source: own work.

a result of the two criteria (1 and 2) and permits the following ranking of the sensitivity of the tested measures:

- the direction of the axis X: FRF_u, $H(f)_r$, FRF_r, U_{RMS}, *coher*, ω_2, $H(f)_u$, ω_1, δ,
- the direction of the axis Y: FRF_u, $H(f)_r$, FRF_r, $H(f)_u$, U_{RMS}, *coher*, ω_1, δ, ω_2.

The tested destruction of masonry elements differs slightly in sensitivity factors and distance at each stage of the procedure, which makes conclusions difficult, although it allows preliminary confirmation of good properties in the following ranking:

FRFr FRFu H(f)r H(f)u URMS coher ω2 ω1 δ

Quantitative studies of the compounds described above and measurements of the state of the reflected load destruction applied were carried out using linear regression tests (simple and multiple).

Figure 21 shows the test results of multiple linear regressions, binding on all the relevant mathematical formulas, for study of destruction in masonry structures (full brick and suporex) depending on the load.

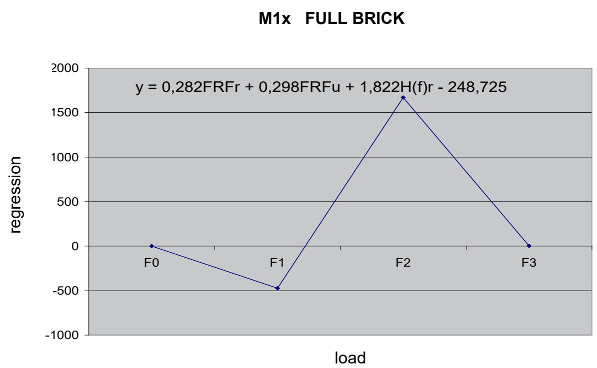
coefficient (R^2), also known as the coefficient of determination, the host value in the range [0, 1]. Its value is given in the regression figures, where the higher the value, the better the correlation – a better fit to the regression results.

The following is a summary table (Table 1) of the frequency of vibrations generated for the measurement of the various states of degradation of the existing brick structure.

Table 1. Summary of natural frequencies for the different states of degradation of the structure

Extortion	Fit wall element	1 crack	2 cracks
No force	71,388 Hz	39,999 Hz	29,831 Hz
No force	81,699 Hz	40,806 Hz	39,207 Hz
With force	43,526 Hz	41,271 Hz	70,844 Hz
With force	81,699 Hz	147,588 Hz	110,296 Hz

Source: own work.



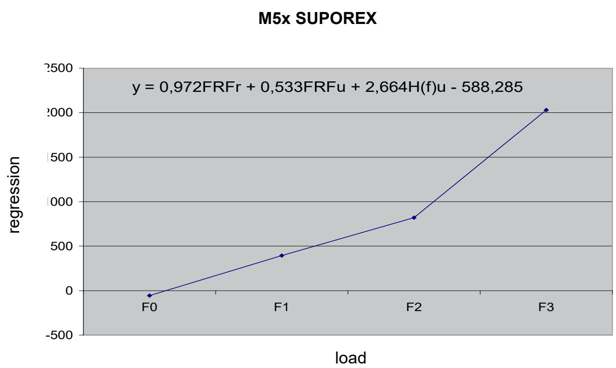


Fig. 21. Multiple regression results for all measures and examined loads

Source: own work.

The entire procedure consisted in determining the good state of damage to the tested masonry elements and establishing a cause-and-effect relationship between the condition and the destruction of the components. Approximation error of studied measurement functions was determined as multivariate correlation

Qualitative results without damaging the brick wall and damaged walls conducted by operational modal analysis (ODE) are presented in Figure 22.

A comprehensive of natural frequencies of studied states of brick wall degradation using experimental and operational modal analysis are shown in Table 2.

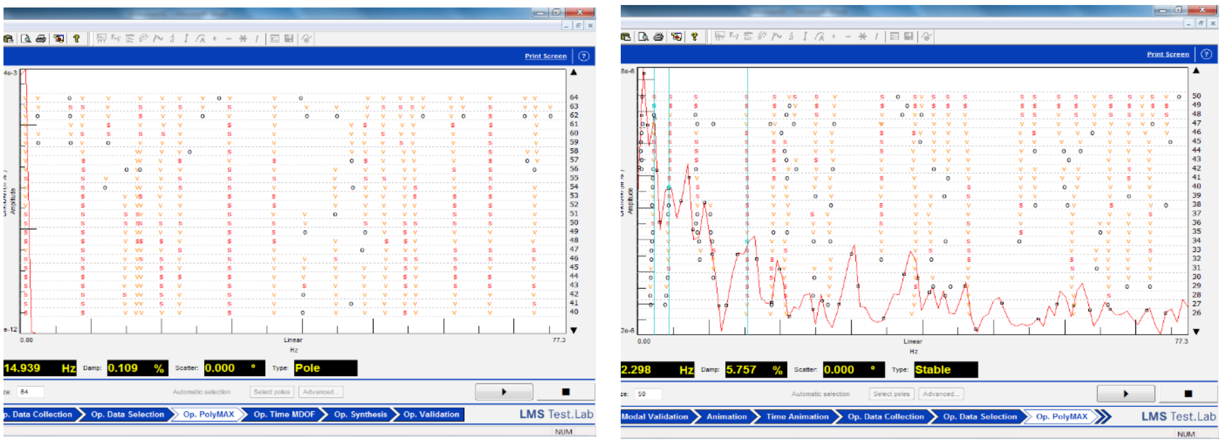


Fig. 22. Stability diagram for the fittest and damaged brickwork (OAM)

Source: own work.

Table 2. Summary of the test frequency of oscillations of a brick wall

Extortion	Fit element	Defective element
Force EAM	865.612 Hz	1 025.81 Hz 1 060.85 Hz 1 112.47 Hz
No force OAM	0.77 Hz	2.28 Hz 4.44 Hz 15.41 Hz
Force OAM	0.80 HZ	0.77 Hz 14.04 Hz

Source: own work.

When assessing the adequacy of the modal analysis method for diagnosing the degradation of masonry structures, it can be considered appropriate for these purposes, even without analysing the results obtained.

Cause-and-effect modelling

Many measures of state acquired in experiments requires the reduction of over measurement, which is possible with the use of the OPTIMUM procedure (statistical evaluation of separate measures):

$$\begin{gathered} y = -2.68w1 - 0.54\,row1 - 0.49x1 + 2.02w2 + \\ + 0.35row2 + 2.26\mathrm{x}2 - 0.07H(f) + 0.06H(f)L + \\ + 0.16g2xy - 92.39ARMS(t) + 12.99bkurt + \\ + 239.69Cs - 200.58I - 44.37 \end{gathered}$$

An optimised set of symptoms is the basis of constructing cause-and-effect, most often regressive, multidimensional models (Fig. 23). The wellness of the model is evaluated with the help of the determination coefficient (R^2), and the number of component symptoms determines its accuracy (Fig. 24).

For the purposes of this study, results were processed in the OPTIMUM method, and we were able to build a destruction regression model. This approach allowed the differentiation of measurement values for various degradations of the tested materials. It confirmed the effectiveness of the adopted method.

Information processing system diagnostic agent

The ability to quickly identify damage in the diagnosis of elements affecting the operation of the technical facilities was the basis for the creation of the program SIBI (identification research information system). This program is an attempt to implement the software for:

- the acquisition process of vibration,
- the processing of vibration processes,
- examining the interaction of vibration processes,
- symptoms susceptibility testing,
- statistical inference,
- visualisation of analysis results.

The menu of these programs is shown in Figure 25. Figure 26 presents the general idea of an agent system for a critical system in diagnostic observation and information flow in a future diagnostic.

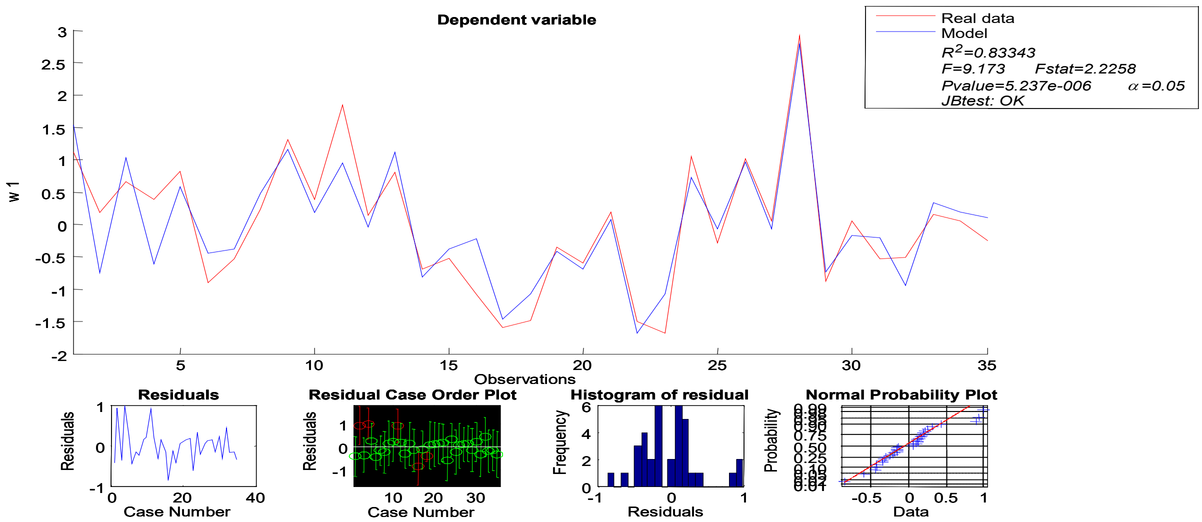


Fig. 23. Regressive determination model

Source: own work.

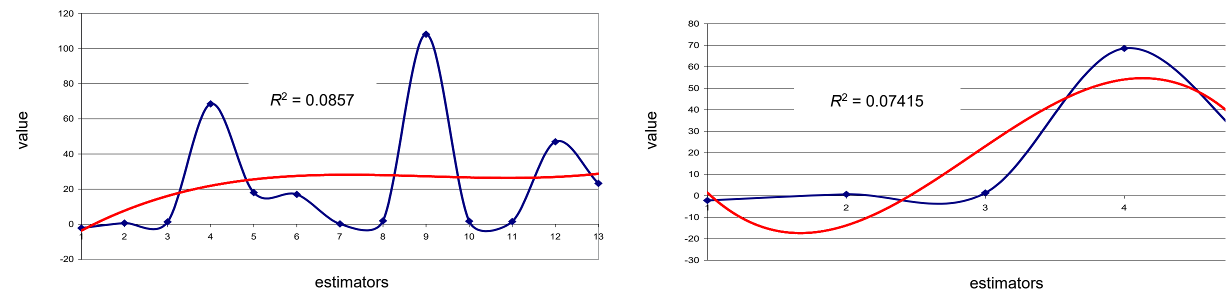


Fig. 24. Number of measures versus accuracy of the model

Source: own work.

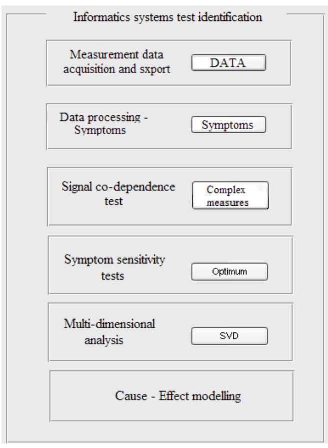


Fig. 25. The main window of the SIBI program

Source: own work.

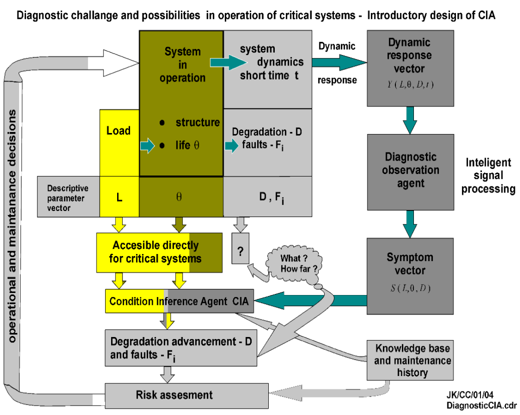


Fig. 26. The information flow and processing in an operating and intelligent monitoring system

Source: own work.

CONCLUSIONS

Methods of identification in the research on building construction (including construction materials) are utility methods to estimate changes in the operating structure. Modal analysis of the varieties for its realisation is increasingly being used by civil engineers, and the modal model accurately reflects the destruction of objects.

Searching for mapping models with models of modal vibration, bench research, and studies on real objects allows for assessing the similarity of the models and the relevance and effectiveness of decision methods. The search for methods of non-destructive testing of materials and structures indicates the possibility of using modal analysis in the assessment of their degradation, as shown in this study.

These studies have been developed or were adapted from MATLAB and practically implemented the following programs: visualisation research results in MS Excel, determination of the vibration process in GENERATE symptoms (correlation and regression testing), and susceptibility testing in OPTIMUM.

The results point to the fact that it is possible to distinguish the status of the degradation properties of brick, which has an impact on the ability to assess the risks and their mechanical properties.

It is, therefore, possible to determine the risks of building structures based on the study of natural frequencies and their characters, using operational modal analysis.

Authors' contributions

Conceptualisation: L.C. and B.Ż.; methodology: B.Ż.; validation: L.C. and M.C.; formal analysis: B.Ż. and L.C.; investigation: L.C.; resources: L.C.; data curation: B.Ż.; writing – original draft preparation: B.Ż.; writing – review and editing: M.Ż. and M.C.; visualisation: B.Ż.; supervision: B.Ż. and M.K.; project administration: M.Ż.; funding acquisition: M.Ż. and M.K.

All authors have read and agreed to the published version of the manuscript.

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BADANIA DEGRADACJI KONSTRUKCJI I MATERIAŁÓW BUDOWLANYCH Z WYKORZYSTANIEM PROCESÓW WIBRACYJNYCH

STRESZCZENIE

Istniejące konstrukcje inżynierskie, a zwłaszcza konstrukcje murowe, poddawane są dużym obciążeniom dynamicznym, dobrze odbijanym drganiom w tworzących się procesach. Drgania te mają wpływ na stan robót na placu budowy, gdyż mogą osiągnąć poziom zagrażający stabilności konstrukcji, co zmniejsza bezpieczeństwo osób tam pracujących. Wpływ drgań na konstrukcję objawia się głównie dodatkowymi naprężeniami w przekroju, które zwiększają naprężenia obciążeń statycznych. Ponadto często dochodzi do zmęczenia materiału (skutek oddziaływania klimatu związanego z otoczeniem), co dynamizuje destrukcję obiektu. Obciążenia dynamiczne mogą prowadzić do destrukcji i powodować niszczycielskie skutki w budynkach o różnej konstrukcji lub prowadzić do katastrofalnych zniszczeń. W artykule przedstawiono nowoczesną metodykę nieinwazyjnego badania konstrukcji murowych z wykorzystaniem procesów wibracyjnych. Pokazano również możliwości wykorzystania metod analizy modalnej do oceny stanu zniszczenia elementów i murów z wykorzystaniem procesu drgań i pomiaru drgań. Jest to diagnostyczne podejście wykorzystujące innowacyjne metody badawcze, wsparte technologiami informatycznymi, do badania przydatności materiałów budowlanych i warunków budowy.

Słowa kluczowe: modelowanie, masa, sztywność, tłumienie, sygnał drganiowy, analiza modalna, wykres stateczności, dedykowany system diagnostyczny