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Review paper

Notes on the tests and vibration properties of hospital elevated helipad structures

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Abstract: Helicopters of the Medical Air Rescue (LPR) help transport the patients to large hospitals quickly. The requirements for the space around the helipad and flight safety mean that more elevated helipads than ground helipads are built at hospitals located in proximity to the city centres. Elevated helipads can vary in design and location depending on the opportunities offered by the hospital buildings and their surroundings. The Vibroacoustic Laboratory of the Warsaw Institute of Aviation took measurements to determine the impact of a helicopter on a hospital elevated helipad during landing or taking off. Helicopter landings are neither frequent nor long, however, they can have a significant impact on a helipad structure, the hospital building itself and its patients, staff or equipment. The impact of the helicopter includes both the noise, vibrations transmitted by the helicopter chassis and air pulsations under the rotor (low-frequency ones). This paper discusses some methods used for measuring vibration properties of several elevated helipads and building recorded during the landing and take-off of the EC135 helicopter. The sample results of such tests are also presented. The tests discussed can be used to verify both the assumptions and calculations referring to helipads and to meet the requirements of the standards in the field of noise and vibrations.

Keywords: elevated helipads, vibration test, helicopter impact

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1. Introduction

Helicopter air transport makes it possible to provide quick medical assistance to people injured in accidents, disasters or those who are seriously ill. The operating conditions for the Polish Medical Air Rescue are stated in the Act of 8 September, 2006 on the State Medical Rescue [1] and the Regulation of the Minister of Health on hospital emergency departments in force from 1 July 2019 which also specifies the requirements for transport times and general conditions for the operation of hospital helipads.

The requirement that a patient should be transferred to hospital quickly determines the location of the landing area, which should be as close to the hospital as possible – such conditions are satisfied by the elevated helipads.

Aviation regulations govern the space requirements and organisation of a landing site (e.g. [3]). Elevated helipads may have different structures and may therefore be affected by the landing or taking off of a helicopter:

1. Figure 1 – free-standing helipads or helipads above a multi-storey garage: vibrations are not transmitted to the hospital building, but the noise remains an impact factor. However, their construction requires a significant financial investment.
2. Figure 2 – built on top of a building frame. The structure is typical of newly designed hospital buildings with an emergency department.
3. Figure 3 – placed on a rooftop of an existing building as a steel structure.

At present, there are 36 elevated helipads in Poland, 28 of which are located on buildings. Due to the efficiency of the Medical Air Rescue, one can expect an increase in the number of new helipads at hospitals located near the city centres.

Helipads on buildings can shorten the distance between the helicopter and the Hospital Emergency Department (SOR). Their disadvantages are: high construction cost, requirements for safe operation, high maintenance costs in winter and possible dangerous consequences in the event of an accident during a take-off or landing.

Depending on the construction capabilities and the structure of the building, a helipad located on the building may have:

- a concrete structure,
- a steel structure.

One of the characteristic features of concrete landing sites is a heavy plate placed on several or more concrete pillars that are an extension of the building structure and form a consistent structure with it (Figure 2). The top plate of the helipad, in which the heating system and pipes for draining water and fuel (from a potential leak) are installed, can be placed on an elastic-damping layer which provides vibro-insulation of the heliport. Such solutions are usually adopted when a new hospital is built.

Helipads designed for existing buildings are usually made of steel and have a truss structure (Figure 3) – lighter and supported by up to several dozen steel pillars. The deck plate consists of duralumin or composite panels with heating and drainage systems and pillars placed on the vibroinsulators. Such a design can be found on the oldest (still existing) hospital buildings.

A feature of a helipad design that is required today (e.g. by [2]) is the presence of an air gap – a space between the landing area and the supporting building which allows free-flow of air through the gap. The use of an air gap requires raising the deck plate and thus reducing the stiffness of the helideck support (bending pillars, in particular).

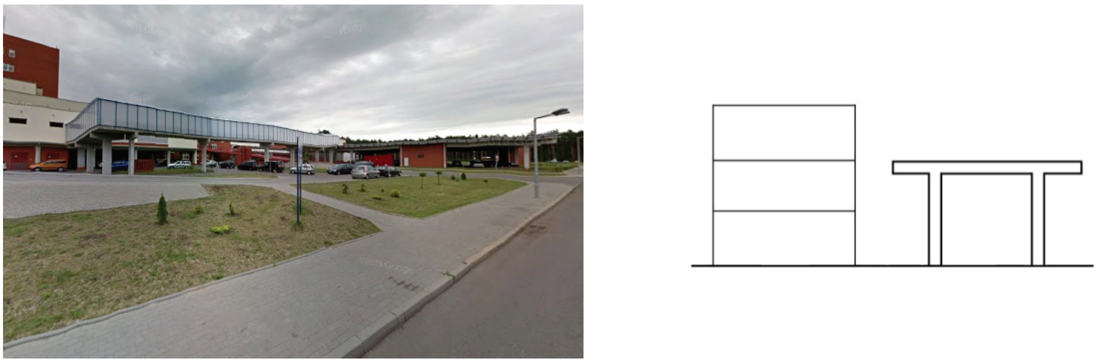

Fig. 1. Free-standing helipads: stand-alone and above a garage (e.g., hospital in Grudziądz) and a design scheme (photo: www.google.pl/maps)

Fig. 2. Helipad on top of a building frame (e.g., Warsaw South Hospital) and a design scheme

Fig. 3. Helipad on a rooftop of an existing building (e.g., hospital in Iława) and a design scheme

The impact of the helicopter on the helideck and the immediate surroundings during landing and switching off the engine and subsequent start-up and take-off is caused by:

- pulsations of the air downwash from the blades,
- the noise of the engine, blades and tail propeller,
- the impulse load due to “hard landing”,
- main rotor vibrations transmitted from the landing gear to the landing platform.

The main forces causing vibrations (transmitted by the air from under the main rotor and chassis) are vertical. The forces related to braking and making the rotor blades churn and transmitted by the chassis are horizontal or generate a moment relative to the vertical axis. Variable rotor speed and wind can cause resonant vibrations on the chassis of the helicopter. Such vibrations are more common in helicopters with three-hinged rotor hubs (e.g., Mi-2 or W-3 “Falcon” helicopters). As to EC-135 helicopters, the manufacturer developed procedures and tooling for the trimming and balancing of the main rotor blades and a tail fan to ensure that vibration is minimized over the entire rotor frequency range (and multiples thereof, which depends on the number of blades). Although these forces are small, the low dampening of the landing structure, however, can cause vibrations and transfer them to the building [4], [5].

The standard PN-B-02171_2017 [6] specifies the method of measurement and defines the recommended levels of vibrations on the floor of various rooms in buildings located in the area that might be affected by a motorway, railway tracks, a factory or a construction site. Control measurements should be carried out in the frequency range up to 100 Hz.

The author of this paper made preliminary measurements to assess the type and magnitude of the helicopter environmental impact, including the noise emitted [7].

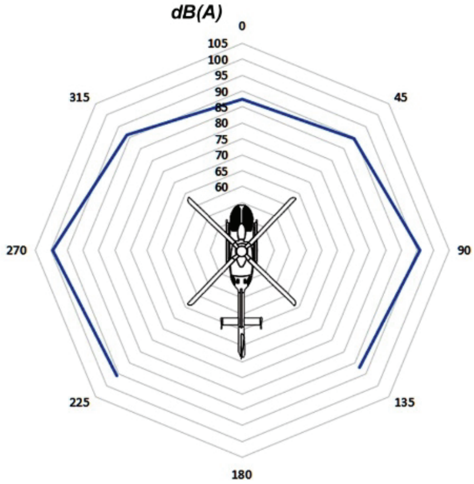

Fig. 4. Testing the noise sources of the landing helicopter and a directional diagram of the amount of noise emitted by the helicopter at the helipad

This article comments on research on vibration properties of the elevated helipads and the environmental impact of helicopters during their landings and take-offs.

2. The objects examined and the scope of measurement

Vibration studies were conducted by analysing a signal in the range up to about 150 Hz. coming from the sensors located on the helipad structure and inside the building. Noise measurements were carried out using microphones placed in selected areas of the helipad and rooms in the building.

The measurements of the vibrations of the elevated helipad were carried out in three successive stages:

- the determination of the basic forms of free vibrations of the helipad,
- the assessment of the transferability of vibrations from the helipad plate to the floor on the lower floors of the building,
- the measurement of the impact of the helicopter during its landing and take-off.

The measurements of the third stage were carried out at two different helipads.

The test objects were four elevated rooftop helipads: two with concrete structure and two with steel structure.

3. The test procedure

A modal hammer (5.6 kg) and a sandbag (20 kg) were used as vibration inducers to determine the vibration properties of the helipad. The signal from the sensors was recorded and analysed using measurement equipment with LMS software.

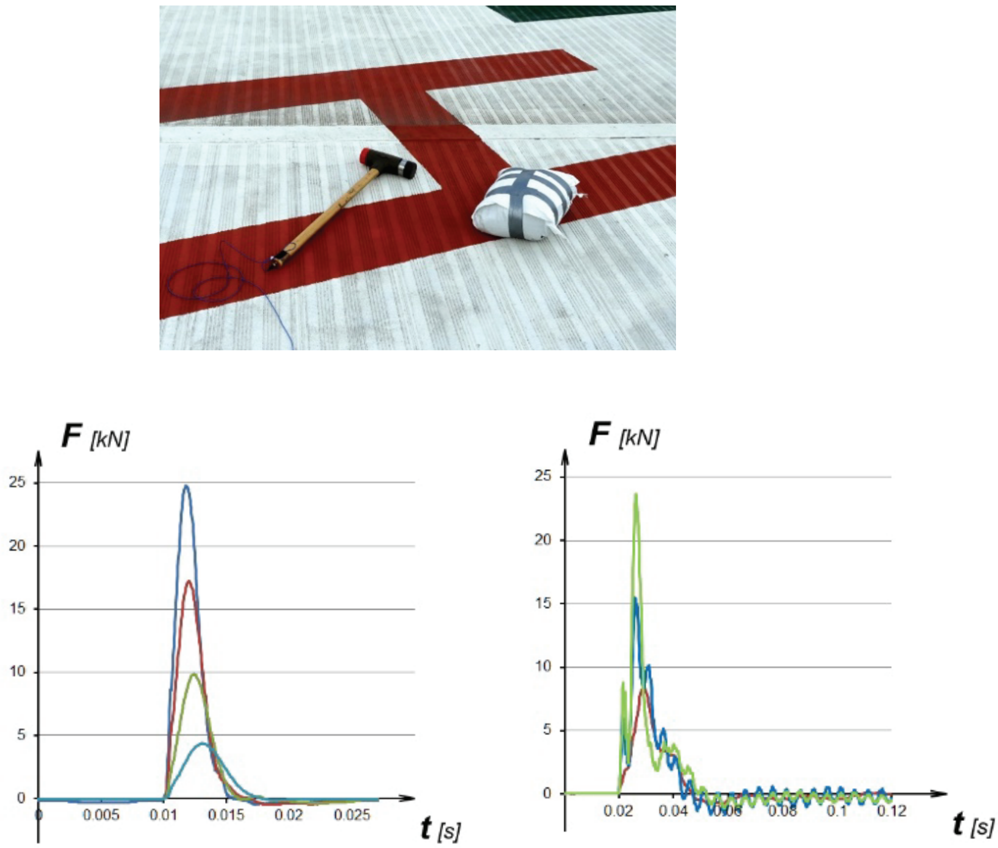

Fig. 5. Modal hammer (5.6 kg) and sandbag (20 kg) in the centre of the helipad plate. The graphs show the force patterns for four different hammer blows and dropping of the bag from three different heights

The studies of the free vibrations of the landing plate (including the pillars) after impulse excitation were designed to determine the basic vibration forms at the lowest frequencies. The sensors were placed under the helipad plate (in the middle of it and near its edges) and on the bases of the pillars at the roof level. One sensor was put on the floor below the roof, near the vertical axis of the landing site. Figure 6 shows two sample models for visualising vibration forms (the nodes show sensor numbers and the direction of operation). The model shown in Figure 6a has been used for concrete helipads, while the model in Figure 6b facilitating the determination of the vibrations of the plate on the pillars has been adopted for steel landing sites.

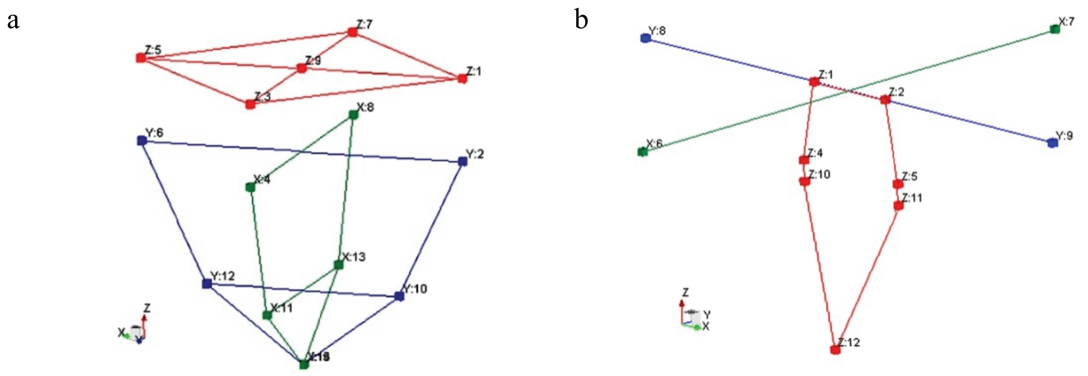

Fig. 6. The two models used to visualise the vibrations of the helipads;
a) concrete helipads, b) steel helipads

Figure 7 shows several drawings presenting the shapes of vibrations of the concrete helipad [8]. Such vibrations as the bending of the landing plate and the horizontal vibrations of the plate placed on the nine pillars can be seen in the figure mentioned above.

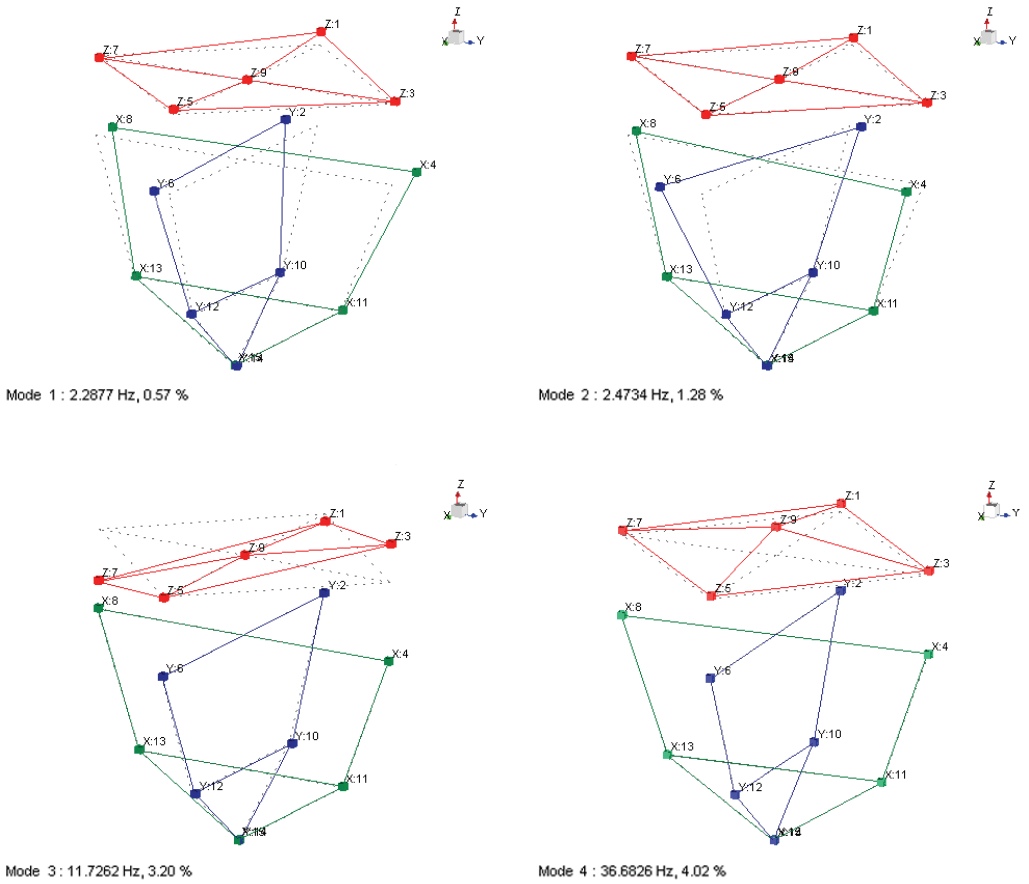

Fig. 7. Examples of typical vibrations shapes of concrete elevated helipad

The study of the modal vibrations of the helipad made it possible to assess the damping of the structure and to find out what the vibration frequency of the helideck is – this is important information for the designers but at the same time it verifies the assumptions and calculations made. The next step is to examine the transferability of vibrations from the helipad plate to the floor on the lower floors of the building. The tests were carried out using sensors measuring vertical vibrations. The sensors were placed in the centre of the landing plate and on the floor of the rooms on the lower floors of the building. Just as in the case of the free vibrations, a modal hammer and a sandbag, for reference, were used to excite vibrations. The goal was to measure the vibration magnitude and frequency in relation to excitation energy. Figure 8a shows a sample model used for visualising vibrations of concrete structures helipads – all sensors are in vertical (Z) direction. Sensor 1 was placed in the centre of the helipad plate whereas the remaining ones in the centre of the floor on the lower floors of the building. Figure 8b shows an example of a shape of free vibration after impulse excitation near the centre of the plate: the vibration amplitude at points 3 and 13 is greater than that at point 1.

a) b)

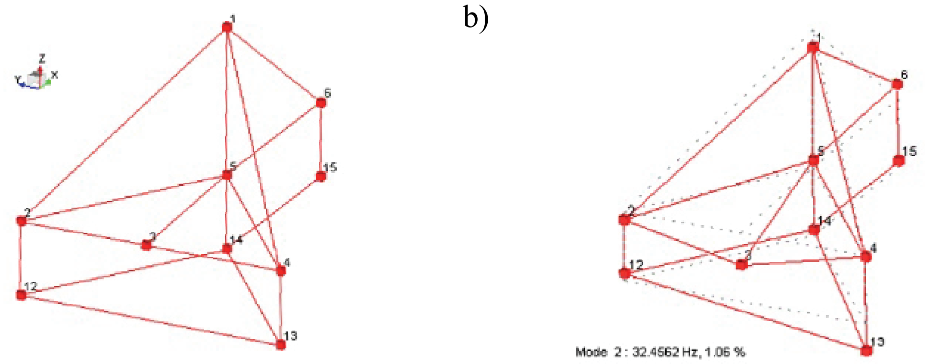

Fig. 8. Model for the visualisation and the evaluation of pulses transferred to the building (a) and an example of vibration shape measured after impulse excitation (b)

Measurements of vibration transmission from the helipad plate to the lower floors of the building were conducted in the hospital whose building was just being equipped. Courtesy of the hospital management, the measurements were conducted in the rooms almost ready for use.

Figure 9 shows examples of amplitude-frequency characteristics of a signal recorded by the sensors after impulse excitation (with a modal hammer) at the centre of the helideck. The sensor numbers and their position correspond to the model as in Figure 6b. In this case, a very small amplitude of the signal from sensors 10, 11 and 12 proves the effectiveness of the vibroinsulators mounted in the base of the posts.

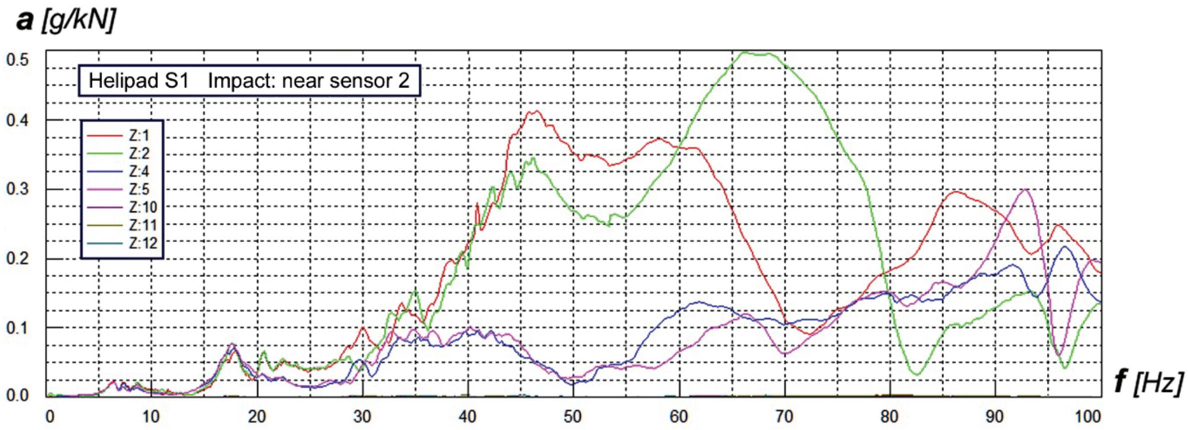

Fig. 9. Amplitude-frequency characteristics of a signal from the sensors placed on the helipad, vibroinsulators and on the floor of hospital room under the helipad

Part of the investigation into vibration transmission involves measuring the effectiveness of the vibroinsulators that are mounted at the bases of the helipad pillars (Figure 10). [9], [10].

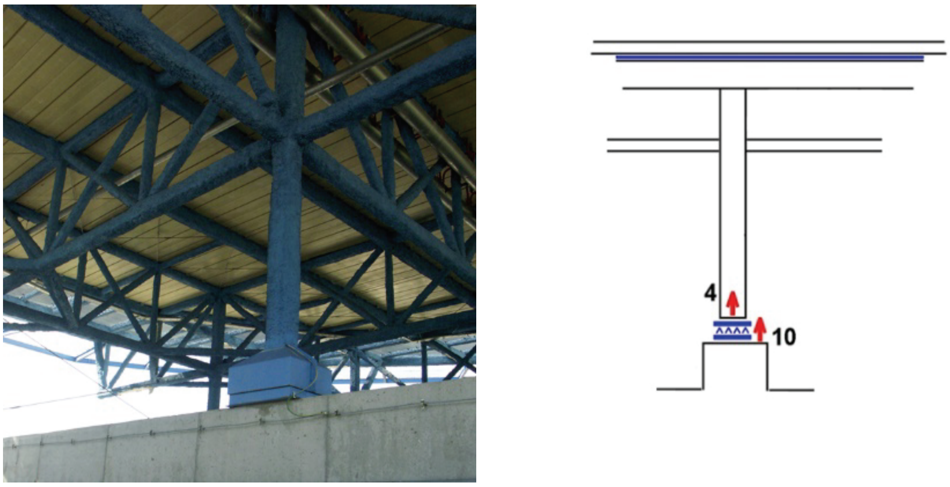

Fig. 10. Vibroinsulator and the position of the sensors at the base of the pillar

Figure 11 shows sample graphs of the signals recorded by the sensors during the helicopter landing on the helipad: the time elapsed between the helicopter's approach to the helipad and the rotor stopping. The landing skid of the helicopter touched the helipad surface in 78. second of the recorded signal. The graphs illustrate the difference between the signals recorded on both sides of the insulator at the base of the central pillar. The effectiveness of the vibroinsulator has been proved by a tenfold reduction in the vibration levels.

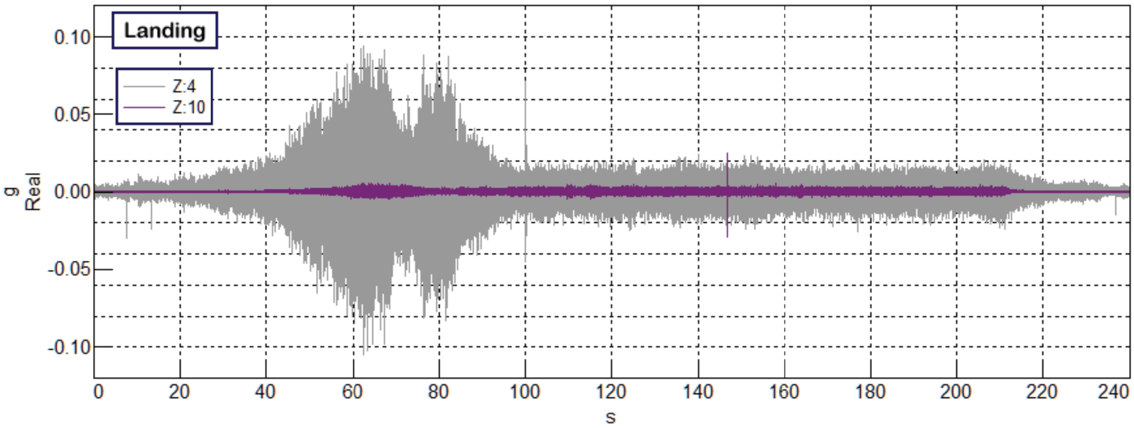

Fig. 11. Graphs of the signals recorded by the sensors placed on both sides of the vibroinsulator during the helicopter landing on the elevated helipad

The patterns of the signals indicate that the vibrations of the helipad are caused not only by the helicopter chassis but also by the airflow under the main rotor (turbulence, low frequency noise) [11]. The final verification of the vibration level in the building can only be carried out during the take-off and landing of the helicopter, but such actions involve a temporary disruption to the operation of the hospital. Taking the measurements involves a special helicopter landing and placing the sensors in the areas (rooms) that require asepsis (e.g. operating rooms) or the rooms with specialised testing equipment.

Finally, emergencies such as, for example, a helicopter hitting the helipad plate or turbulence-induced vibrations due to strong winds [12], pose a separate threat to the helipad, the building, the patients and the hospital staff.

4. Conclusions

All things considered, the following conclusions can be drawn based on the tests and findings discussed above:

1. The measurements that were carried out made it possible to obtain information on the actual vibration properties of the elevated helipads at rooftop level of various designs.
2. Checking the effectiveness of the vibroinsulators as it can significantly reduce the transmission of vibrations to the lower floors of the building is an important part of the measurement.

3. The actual force patterns related to the impact of the helicopter on the helipad under various conditions are not known, which makes the design of vibroinsulation difficult. The test results indicate that the vibration properties can be measured and verified by analysing the response to impulse excitation with a modal hammer of an appropriate size or with a sandbag.
4. The analysis of the signal sent by multiple sensors during the operational landing and take-off of the helicopter is the final verification of the impact of the helicopter on the helipad structural design and the hospital building.
5. In some cases, it would be advisable to monitor vibrations in selected parts of the building – the short landing or take-off time of the helicopter is not burdensome but the vibrations caused by pulses produced by a "hard landing" or gusts of wind may temporarily yet significantly exceed the permissible vibration levels.
6. Measurements of the impact of a landing helicopter on the hospital building, staff and patients (including equipment) should be mandatory in order to assess potential hazards.

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Uwagi o badaniach i właściwościach drganiowych konstrukcji szpitalnych lądowisk wyniesionych

Słowa kluczowe: lądowiska wyniesione, badania drgań, oddziaływanie śmigłowca

Streszczenie:

Śmigłowce Lotniczego Pogotowia Ratunkowego (LPR) umożliwiają szybki transport pacjentów do dużych szpitali. Wymagania dotyczące przestrzeni wokół lądowiska dla śmigłowców jak i bezpieczeństwo wykonywania lotów powodują, że przy szpitalach położonych w pobliżu centrów miast buduje się więcej lądowisk wyniesionych niż naziemnych. Lądowiska wyniesione dla śmigłowców mogą różnić się konstrukcją i lokalizacją w zależności od możliwości jakie stwarzają budynki szpitalne i ich otoczenie.

Laboratorium Wibroakustyki Instytutu Lotnictwa wykonało pomiary w celu określenia oddziaływania śmigłowca podczas lądowania lub startu na przyszpitalne lądowisko wyniesione. Lądowania śmigłowców nie są ani częste, ani nie trwają długo, jednak mogą mieć znaczący wpływ na konstrukcję lądowiska, budynek szpitala oraz jego pacjentów, personel a także wyposażenie. Oddziaływanie śmigłowca obejmuje zarówno hałas, drgania przenoszone przez podwozie śmigłowca, jak i pulsacje powietrza pod wirnikiem (o niskiej częstotliwości).

W artykule przedstawiono wybrane metody pomiaru właściwości drganiowych kilku lądowisk wyniesionych oraz oddziaływania na budynki zarejestrowane podczas lądowania i startu śmigłowca EC135. Przedstawiono również przykładowe wyniki takich badań. Omówione badania mogą służyć do weryfikacji zarówno założeń, jak i obliczeń konstrukcji lądowisk dla śmigłowców jak i spełnienia wymagań norm. w zakresie hałasu i drgań.

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