

Investigation of the Vibration Properties of Concrete Elevated Hospital Helipads

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Abstract

Elevated helipads at hospitals offer the possibility of rapid transport and assistance to persons injured in accidents or severely ill. Such helipads may have a diverse structure and location depending on the possibilities of the hospital environment, including the vicinity of other buildings. Vibroacoustics Laboratory of the Institute of Aviation performed the measurement of the vibration properties of several helipads of varying degrees of construction. These tests were intended to determine the vibration properties of the helipads as well as the building, as an attempt to assess the impact of the vibrations induced during a helicopter's landing and take-off on the construction of the helipad, the building and its equipment. This paper presents the tests and some results of the measurements made with a modal hammer, carried out on two new elevated helipads, built on the building's roofs and an estimation of the impact of the helicopter on its construction at the stage of design and construction of the helipad.

Keywords: elevated helipads, ground vibration tests, vibration measurements

1. Introduction

The air transport system for injured or severely ill people facilitates the provision of rapid and specialized medical assistance. The general conditions for the functioning of air transport for medical purposes are governed by the Act of 28.09.2006 on State Medical Rescue (Journal of Laws 191, item 1410) [1] and the health-related regulation of 3.11.2011 in the hospital emergency department (Journal of Laws 2019 item. 1213) [2]. The requirement to provide a short transport time determines the location of the landing fields as close to the hospital as possible. In addition, it is important to ensure the safe operation on the landing fields for 24 hrs under the acceptable weather conditions.

In Poland there are currently about 240 working hospital helipads and among them there are 31 elevated helipads: 25 on buildings (Figure 1) and 6 free-standing (Figure 2) – they all operate as 24 hrs ready.

Due to the requirements and the area of operation of the Medical Air Rescue (polish: LPR), the increase in the number of elevated helipads can be expected. Most of them will be built on hospital buildings. An example of a currently built helipad located on a building is the South Hospital in Warsaw is presented in Figure 1.

Two basic solutions for hospital landings are:

- ground helipads (requiring a lot of spaces),
- elevated helipads - most often used in built-up areas (near the city centre).



Figure 1. Elevated helipad (under construction) on South Hospital in Warsaw (10.2018)



Figure 2. Elevated free-standing helipad near hospital in Krakow [3]

Elevated helipads require relatively small area and allow to shorten the distance between the helicopter and the Hospital Emergency Department (polish: SOR). Their disadvantages are: high cost of construction, requirements for safe operation [4], high costs of winter maintenance and the possibility of dangerous effects in case of a helicopter accident during take-off or landing.

The placement of the helipad on the building makes the helicopters' taking-off and landing, which are important sources of vibrations and noise, directly impact the building. The impact of the helicopter on the closest environment during landing and shutdown of the drive and then start and take-off follows from:

- the noise of the engine/engines,
- the noise of rotor blades (endings),
- the noise of the tail propeller,
- pulsation of the blow from the blade,
- loads from "hard landing",
- the vibration of the main rotor transferred to the landing gear by the chassis.

Elevated helipads on the roofs of buildings depending on the executive capacity and the strength properties of the building can be built as:

- concrete construction - heavy, planted on several concrete poles,
- steel construction - light, on a trill structure (Figure 3).



Figure 3. The steel structure of the hospital helipads on Lindley Street in Warsaw

The steel-structure-based helipads typically have vibration isolation elements. Their construction (built-up with multiple components) is characterised by a slightly higher vibration damping factor. These are the reasons for a decision to study the real vibration properties of concrete helipads. Their design is part of the building's design

and vibrations from the helicopter can be more easily transmitted to lower floors, where operating rooms or vibration-sensitive medical equipment can be located.

The important and recommended feature of the helipads is an airgap - the space between the roof of the building and the landing plate. In the case of a strong wind an airgap stabilizes the airflow around the building and the landing area increasing safety and facilitating the execution of a landing and take-off of a helicopter. The purposes of the airgap are to raise the landing plate and to reduce the stiffness of the support of the landing plate (in particular: bending of the poles).

The recently introduced standards PN-B-02170_2016 [5] and PN-B-02171_2017 [6] determine the method of measurement and recommended vibration levels on the floor of different rooms of buildings in the area of influence of e.g. railway tracks, factories or construction sites. Measurements should be carried out for a frequency range up to 100 Hz.

During the start-up and braking of the main rotor, vibrations generated by the blades can be transmitted to the ground. Variable rotor rotations and wind can cause helicopter's resonant vibrations on the chassis. This is usually the case for helicopters with three-axis articulated rotor heads (such measurements were made in IoA for the Mi-2 helicopter). In the case of EC-135 helicopters the procedures and the equipment for the torsional blade and balancing of the carrier rotor and the tail fan prepared by the manufacturer ensures that vibrations are minimized across the range of the rotating frequencies of the rotor (and multiples of the number of blades). These excitations are small, but the low damping of the structure can cause vibration of the helipad move to the building [7].

The authors of this paper have made preliminary measurements of the environmental impact of the EC-135 helicopter to estimate the type and magnitude of the impact of the helicopter on the environment [8]. This article provides examples of the measurement results of the vibration properties of concrete helipads on buildings and vibrations transmitted to the building.

2. Scope of research

The research of the vibration properties of the helipad and the upper part of the building is a way of estimating the frequencies and vibration levels that may occur during landing and take-off of a helicopter.

Measurements were made in two steps:

- determination of the shape of the free vibrations of the helipad,
- assessment of the transmission of vibrations from the landing plate to the floor of the stories under the helipad.

The investigations were carried out using sensor signal analysis after exciting the object with a pulse (a 5 kg modal hammer) in the range up to approx. 150 Hz. Figure 4 shows the modal hammer as well as a graph of the force's waveform for two different strokes – force impulses, from which it is apparent that the pulse time does not depend on the impact of force.

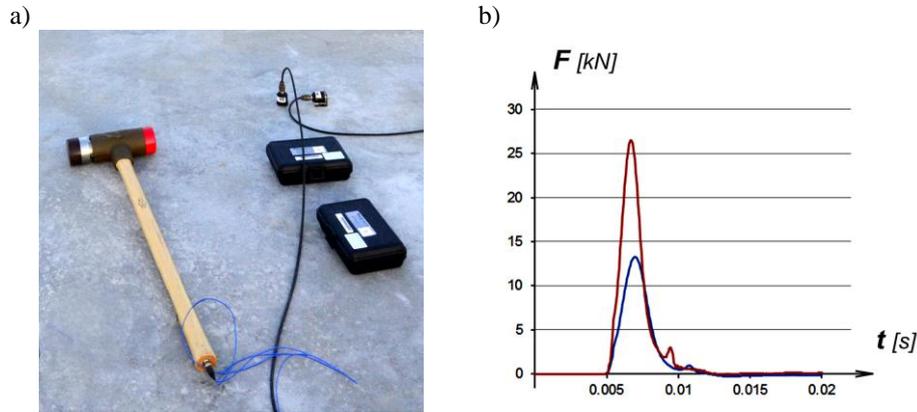


Figure 4. Modal hammer and sensors used in the measurements on the helipads (a) and an example of force pulse waveform for two different strokes (b)

In the case of a single construction (which is the concrete landing structure), this method of measurement produces sufficient and reliable results. The study used LMS measurement equipment and software.

3. Test results

The free vibration tests of helipads (including poles) were designed to determine the basic shapes with the lowest vibration frequencies. The sensors are located on the plate (in the centre and approx. 1 m from its edge), on the bases of the poles at the roof level and one sensor on the floor below the roof in the vertical axis of the helipad.

Figure 5 shows the model for visualizing the shape of vibrations: the displacements of the nodes correspond to the amplitude of the measured acceleration of vibration on the object. The measurement direction is given with the sensor numbers.

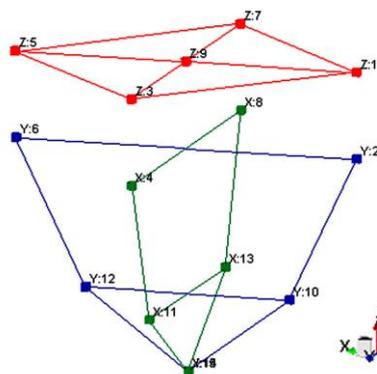


Figure 5. Model for visualizing the vibration shape of the tested helipad

The basic measured vibration figures, short description of the shape, frequency and damping coefficients in the range up to 100 Hz are summarized in Table 1. Figure 6 illustrates some examples of the measured shapes of vibrations.

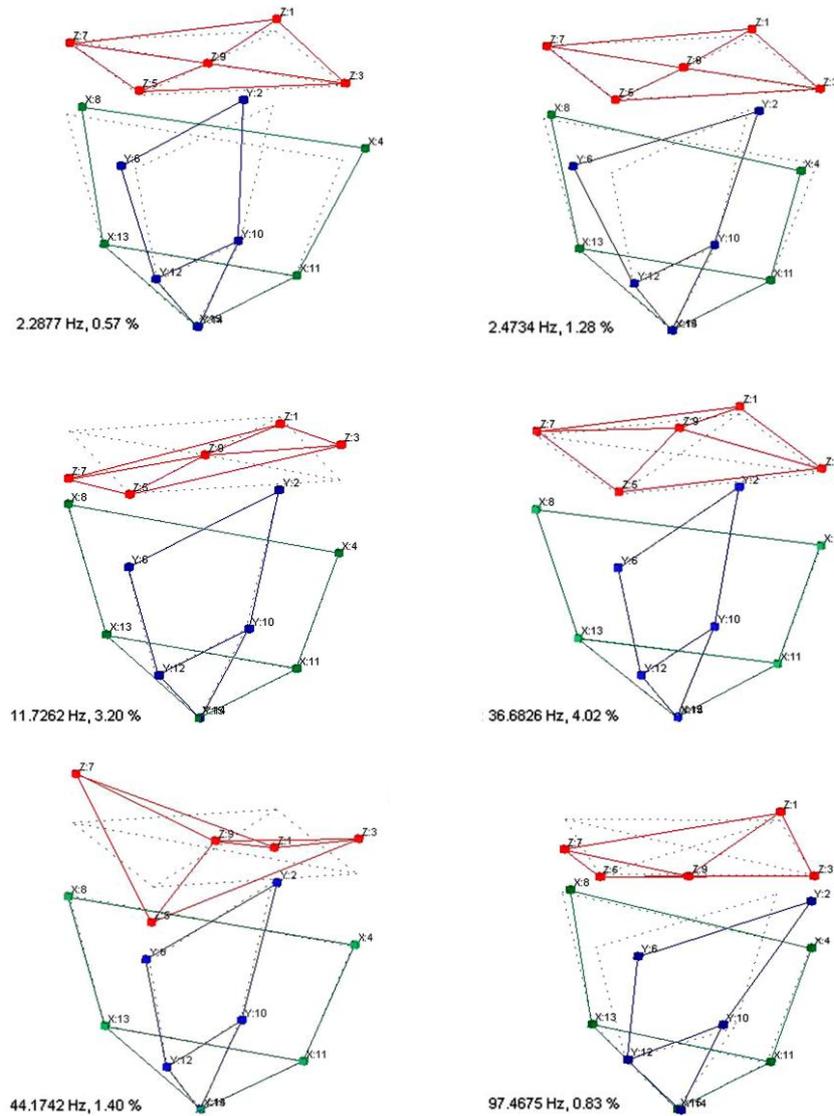


Figure 6. Examples of the shapes of the measured helipad vibrations

Table 1. Overview of the form of helipad and building vibrations

No.	Shape of vibration	f [Hz]	Damping coeff.
1	Poles bending in directions X i Y	2.28	0.57%
2	Torsion around the Z axis (vertical)	2.47	1.28%
3	Swinging the plate round X axis	11.73	3.20%
4	Vertical vibration the middle of the plate	36.68	4.02%
5	Plate bending in X and Y axis	44.17	1.40%
6	Vertical displacement of the plate	70.55	2.05%
7	Poles bending in direction X	94.74	0.95%
8	Poles bending in direction Y	97.47	0.83%

Measurements of the transmission of the vibrations from the helipad to the lower stories of the building were carried out at the hospital in Lublin. The building was in the process of equipping and at the courtesy of the Hospital Directorate the measurements were carried out for rooms in almost ready-to-use state, however the landing area was not yet completed.

The sensors have been located on the floor in the rooms under the helipad landing area on the two highest stories of the 5-story building: in the vertical axis of the landing area and in the middle of three adjacent rooms. Figure 7 shows the arrangement of the sensors as a model to visualize the amplitude of vibration at the measuring points. Sensor No. 1. is placed in the center of the landing plate, sensors No. 2 - 6 on the 4th floor, and sensors No. 12 - 15 on the 3rd floor. All sensors measured acceleration of vibrations in the vertical direction.

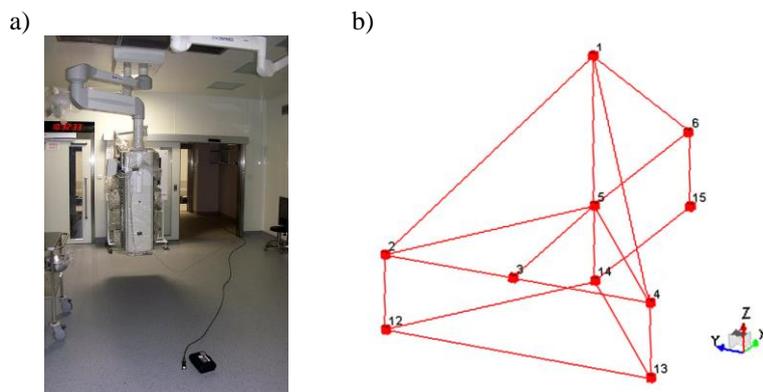


Figure 7. Sensor No 4. on the floor of operating theatre (a) and the arrangement of sensors - model visualizing the position and amplitude of vibration transmitted from helipad (b)

Figure 8 shows amplitude-frequency characteristics obtained on the basis of signal from the sensors after impulse excitation in the centre of the helipad.

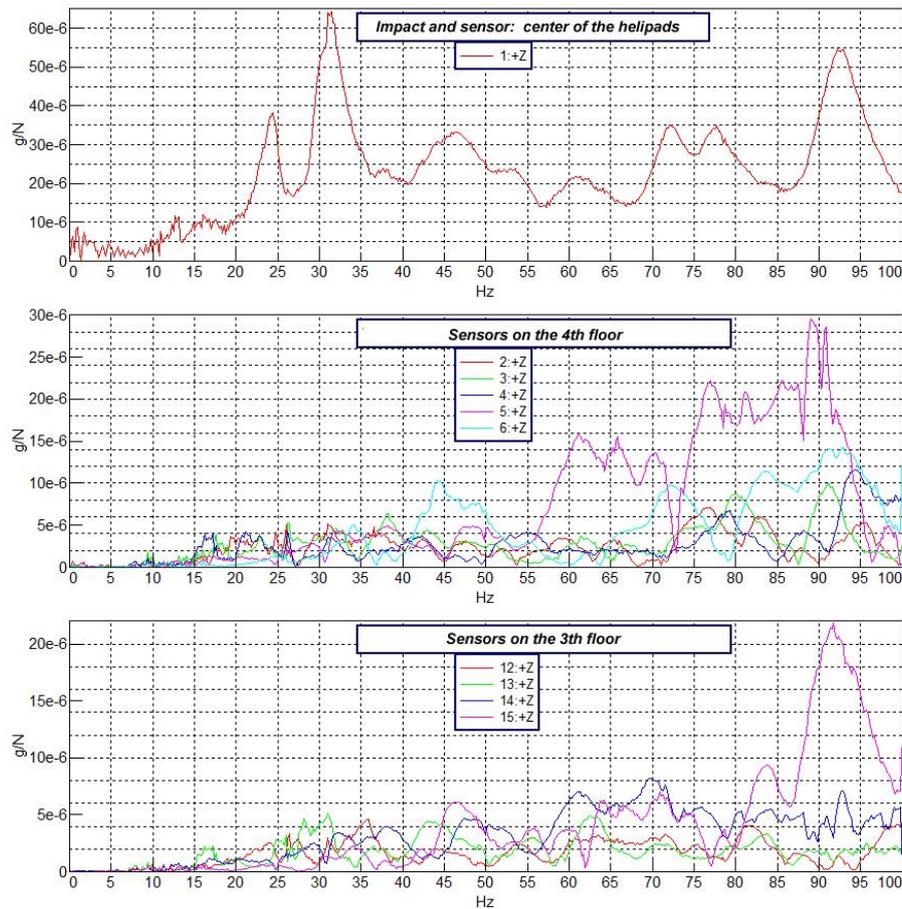


Figure 8. Frequency-amplitude characteristics from sensors

Based on the graphs, it can be concluded that a small part of the vibrations is transmit from the helipad to the lower story's. On floors there are vibrations of different frequencies which are damped and do not show the nature of individual resonances.

During the tests [8], a typical landing of EC-135 helicopter was recorded. The landing took place "at the tip of the left skid", which makes it usually gentle and thus does not cause dynamic (impact) loading of the landing pad.

In difficult weather conditions a "hard landing" is possible. The point effect of a force pulse which occurs during the hard landing is simulated by a modal hammer impact on the helipad well enough. In this way, without the involvement of the

helicopter and its crew, it is possible to measure the vibration of the landing pad and the building structure excited as a result of the force impulse.

The final verification of the vibration level in the building can only be carried out during helicopter's take-off and landing operations, however, their practical implementation is associated with a temporary disruption of the hospital's operation - they require a special helicopter landing and placing sensors in places (rooms) that require aseptic or special access e.g. operating rooms or rooms with specialized testing equipment.

A separate threat to the building, patients and hospital staff are emergency conditions, such as: helicopter impact on the helipad or turbulence from the rotor and wind in the event of an unusual landing or take-off.

4. Conclusions

As a result of the measurements, information about the dynamic properties of the helipad was obtained, i.e. the frequencies and forms of free vibrations were determined using the method of the force excitation with a modal hammer.

The impact of a helicopter on the environment may not be burdensome if the flights taking place no more than once a day. However the involvement of helicopters in the field of transport of sick and injured people will increase.

Compliance with the standards and recommendations should be planned in advance, but adequate data is needed to assess the impact of helicopters as well as a preliminary verification of vibration properties is needed in order to introduce any changes in the construction of the helipad.

Based on the measurements carried out, no significant transmission of vibrations (excited by a modal hammer) through the landing pad structure to the building floors was found, which indicates the extent to which vibrations are dampened by the building structure and its equipment.

The main rotor is the main source of vibrations excited by the helicopter. The EC-135 helicopters used by the Air Ambulance Service can be a source of vibrations with a nominal rotor operating frequency of about 6.5 - 6.8 Hz (depending on the version) and a multiple of the number of blades ± 1 . During starting and braking of the helicopter's rotor due to the changing frequency of excitation, there may be short-term excitations of vibrations resulting from passing through individual resonance frequencies of the structure (from 0 to 34 Hz). The engine starts for approx. 1 minute, and it brakes for approx. 1.5 minutes, therefore the resonance passages are fast.

The final verification of the impact of the helicopter on the construction of the helipad and the hospital building would be conducted by an analysis of the signal from many sensors during the landing and take-off of the helicopter.

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