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Analysis and Design of Base Insulators Applied to the Helipad of the Hospital Structure

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Abstract: In catastrophic situations, rescue cannot be carried out via ground ambulances, which makes helicopters a very common solution to locate and transport patients to hospitals. However, due to the small areas in urban centers, hospitals choose to build landing areas on the rooftop, optimizing the space available. The main problem of this proposal is the transmissibility of vibration caused by the helicopter landing and takeoff, affecting employees, patients and equipment inside. In general, construction in hospitals, especially when they are still in operation, require simple, fast and effective solutions. For this, metallic structures and passive insulation are widely used in elevated hospital heliports. For passive isolation, some indicators are necessary for an efficient reduction, such as, applied loading, type of material and degree of transmissibility. For this study, analytical and numerical calculations are necessary, each of which is extremely important to assess whether the vibrations transmitted to the building will be negligible or whether it is necessary to add something for reduction.

Keywords: base isolation, elastomeric bearings, mechanical vibrations

1 Introduction

In 2018, Helibras, the Brazilian helicopter manufacturer, a subsidiary of Airbus Helicopters, made another H225M to the Brazilian Air Force, and in the same year, two more were made to the Brazilian Navy and the Armed Forces. The model above is the largest and heaviest helicopter currently in the national territory, as a result of the contract signed in 2008 with the Federal Government to supply 50 models to three Armed Forces. Despite the number of self-defense systems, the military version can carry up to 29 crew members or 11 stretchers, in addition to pilots, demonstrating its quality for searches and rescues in regions that are difficult to access.

For emergencies, such as natural disasters, air transport is essential, and helicopters are required to deliver patients to their destination as soon as possible. However, many hospitals do not have space to build specific areas for helicopters to land on the ground, adopting the assembly of elevated helipads on top of buildings. Despite being an interesting solution, the direct contact of the structure and the building causes a transmission of vibration during landing, causing discomfort to people inside and possibly a malfunction of precision equipment, making it necessary to use sound vibration isolators.

Base insulation is a technology classified as a passive protection method, working independently from any outside interference, showing itself as a valid, cheap, and effective alternative to problems involving vibration and noise. Generally, the insulation base can be defined as the insertion of appropriate rigidity elements, called insulators. These insulators are placed at the base of the supports of a structure in order to promote a region of horizontal discontinuity that allows to separate the vibration effect of the floor structure, thus reducing the efforts of the structural elements, preventing malfunction and structural damage to the floor.

This project aims to present a vibration absorber model for high helipad to the roof of a hospital in a large urban center, using computational analysis as the main tool for design.

2 Vibration in structures

According Filho (2008) in your book [7], each degree of freedom of the element has a free vibration movement similar to the mass-spring systems problem, therefore, in structural elements, the vibrations are harmonic, performing a simple harmonic movement. With stiffness $[K]$, mass $[M]$ and natural frequencies, vibration modes can be easily defined by:

$$det([K] - \omega^2[M]) = 0 \tag{1}$$

A way to define the transmissibility of a helicopter vibration to the helipad's floor is using a relation between system's natural frequency and forced vibration frequency. Smith, Bell, and Hackett in [12] recommend a simple association linking into a product of the rotation speed of the helicopter's rotor and the number of blades, with these, the excited frequency can be found. Figure 1 shows a helipad in a hospital structure, and an airbus H225M helicopter military model in profile view.

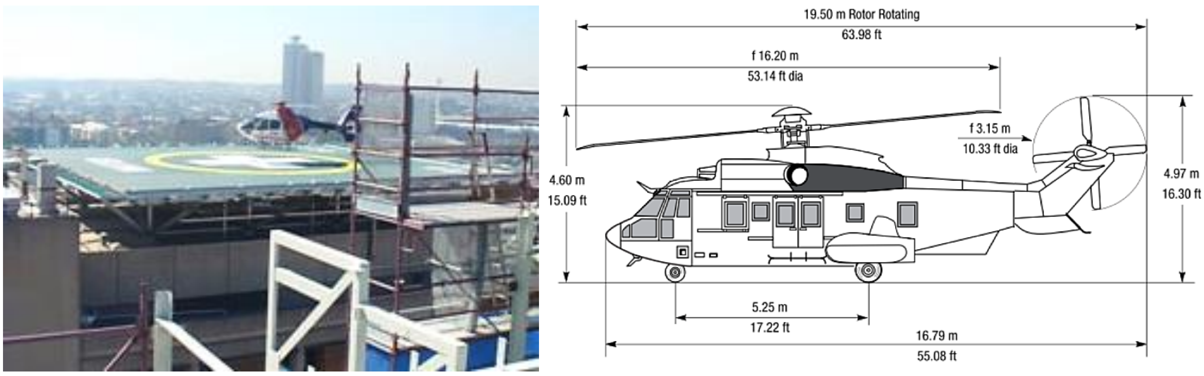

Figure 1. Mater Hospital's rooftop helipad (Aluminium Offshore, 2007) and H225M (Airbus Helicopter, 2016)

2.1 Simplification

For a shorter simulation processing time, Filho (2008) recommends in his book [7] that the structures can be simplified into geometries that represent the real characteristics, in addition, any element that is in the system, but that is not the object of study, be treated as a force or moment acting on the structure. This method is called model simplification.

2.2 Elastomeric insulators

Insulators are used to minimize negative effects of vibration by reducing the transmission of energy from one body to another and are generally inserted as a connection between the source of excitation absorbing energy, a common option for insulators are the compounds of elastomeric materials.

With a system with a degree of freedom represented by a set of masses, springs and dampers, an elastomeric insulation can be represented. Knowing this, the absorption performance of the system is defined by the rate of transmitted vibration, defined as transmissibility (T). Using a relationship between dynamic input and output, natural frequency of insulator (f_n), excitation frequency (f_d) and damping factor (ζ) the flow is defined as:

$$T = \sqrt{\frac{1+\left(2\frac{f_d}{f_n}.\zeta\right)^2}{\left(1-\frac{f_d{}^2}{f_n{}^2}\right)^2+\left(2\frac{f_d}{f_n}.\zeta\right)^2}} \tag{2}$$

Considering the damping factor as negligible, it can be reduced to:

$$T = \left| \frac{1}{1-\left(\frac{f_d}{f_n}\right)^2} \right| \tag{3}$$

To define the stiffness of the cylindrical insulation (K), the form factor (S), the dynamic module of the material (E), radius (r), and thickness (h) are required.

$$K = \frac{E(1+2S^2)\pi r^2}{h} \tag{4}$$

3 Structure meshing

The mesh generated in Ansys Workbench 2020 R1 was modeled using BEAM188 bar elements in profiles and SHELL181 shell elements on the floor. The medium-sized helipad structure uses SAE 1045 steel and ASTM A36 steel, while the floor uses concrete. The structure is shown in Figure 2.

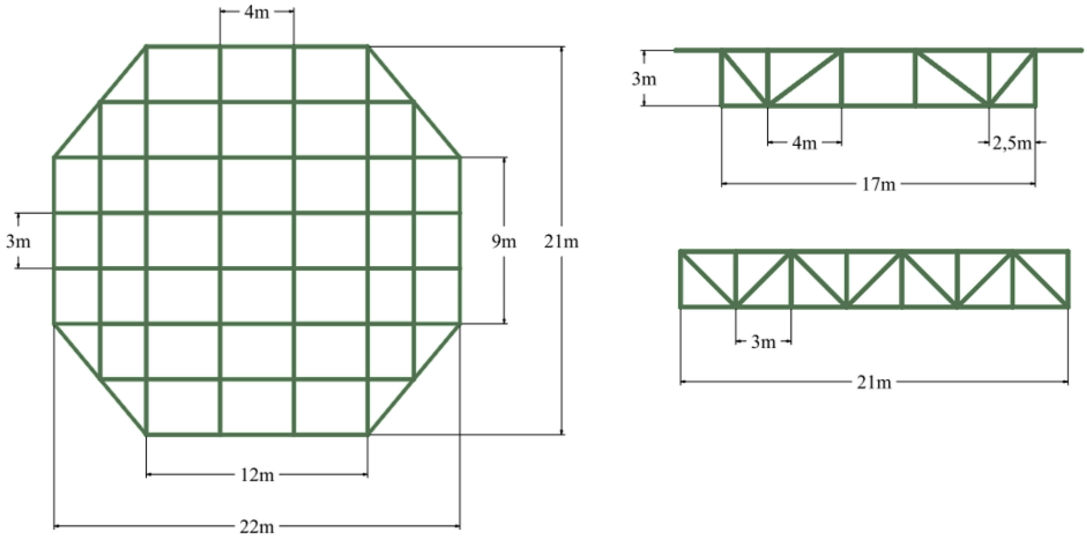

Figure 2. Rooftop helipad structure (Author, 2020)

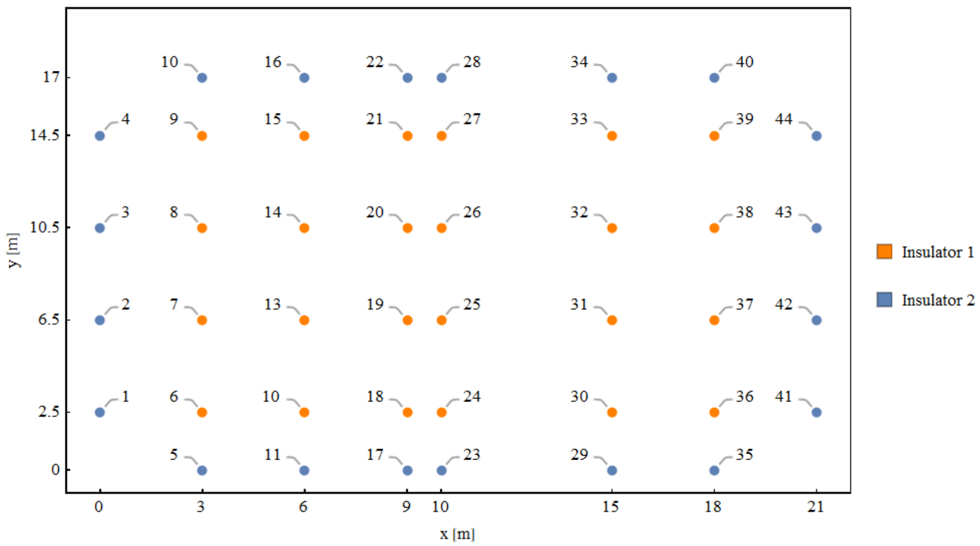

Figure 3. Insulators' position (Author, 2020)

The insulators are inserted at the 44 contact points of the structure with the hospital roof and subdivided into two different models.

The choice of only two isolation areas was not random and was made by observing the maximum support reaction values and also comparing with the helicopters most likely to land in the region with trained pilots. It is easy to see that with just two types of insulators, applied in zones, it is possible to dissipate the energy caused by the impact of landing and the effect of the vortex, when the helicopter's rotors are activated. The position of the insulators is shown in Figure 3.

3.1 Helicopter induced vibration

Smith, Bell and Hackett claim in their work [12] that helicopters cause vibration on the helipad for three main reasons: turbulence of the rotors, movements caused by rotors and the engine and, finally, the impact on landing. The greatest source of vibration and the most effective occurs before landing, with the vortex effect formed by the rotation of the blades, generating repeated efforts on the surface of the helipad at a specific forced frequency. This frequency can be defined linearly as a product between the rotor speed and the number of blades of the helicopter. Considering the Turbomeca Makila 2A rotors with reduced speed of 265 RPM and 5 blades in the helicopter, the excitation frequency is 22.083 Hz.

4 Results and discussions

Through the finite element model, it was possible to analyze support's reaction and with these results, define the necessary stiffness for the insulation to be satisfactory.

4.1 Insulation system

Considering an environment with an average temperature between 25ºC and 30ºC and an average excitation frequency caused by impact, the materials that present good results and low cost are plastic materials, such as synthetic rubber. Among the different types of material, the synthetic rubber SL-60300 has the necessary strength, being possible to define the area and thickness necessary to reduce the transmissibility of the vibration for the building with the manufacturer's recommendations. Considering the recommended transmissibility for elevated helipads proposed by Smith, Bell, and Hackett in [12] of 5%, the transmissibility curve can be obtained with the helicopter's forced excitatory frequency and the natural frequency of the isolator. Figure 4 shows the transmissibility of movement for the two types of damping.

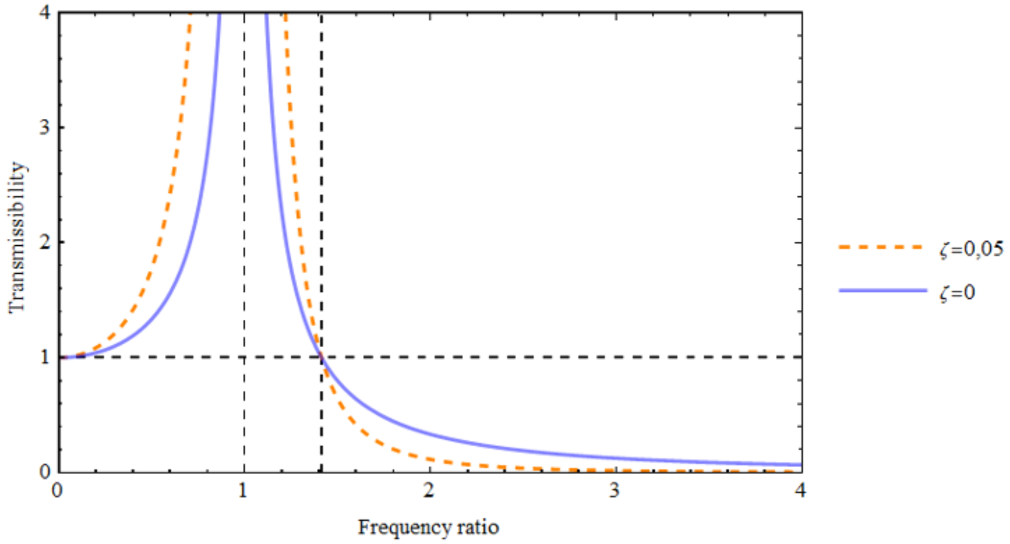

Figure 4. Insulator transmissibility (Author, 2020)

With that, we can extract an important consideration, since the intention is to generate an isolation to operate in a system outside the resonance range. The results using a rubber damping factor of 0.05 and those without considering the damping are very close, with this, the insulator can be dimensioned without considering the damping value, which simplifies the equation and facilitates obtaining results. With this, the rigidities of 8,592 kN/mm can be found for insulator 1 and 5,445 kN/mm for insulator 2.

With the results of stiffness, it is possible to define the main dimensions of the insulators. Frankovich recommends in his work [8] form factors from 0.5 to 1.0, this range allows to avoid instability in the support when subjected to loads. After several lightning tests, results between 50 mm and 60 mm demonstrated an efficient solution with small thicknesses.

In insulator 1, the necessary stiffness was 8,592 kN/mm, this result was not achieved using only one insulator, being necessary to either increase the radius or use a parallel association. However, the first proposal would not be interesting because the results have small thicknesses and good form factor results. In insulator 2, the required stiffness was 5.445 kN/mm, the result was achieved with a 50mm insulator. The Insulators thickness and stiffness are shown in Figure 5.

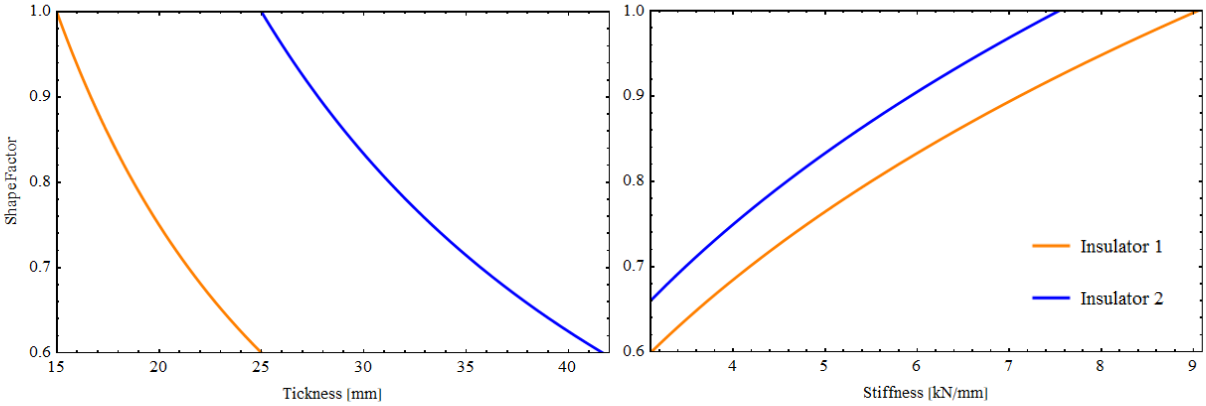

Figure 5. Insulator’s thickness and stiffness (Author, 2020)

It is noticeable that the greater the form factor, the required thickness decreases and the rigidity increases, thus exemplifying the behavior of rubber when subjected to compression caused by impacts or vibrations, showing that the greater the height, the greater the instability and the lower stiffness. Type one and two insulators are shown in Figure 6.

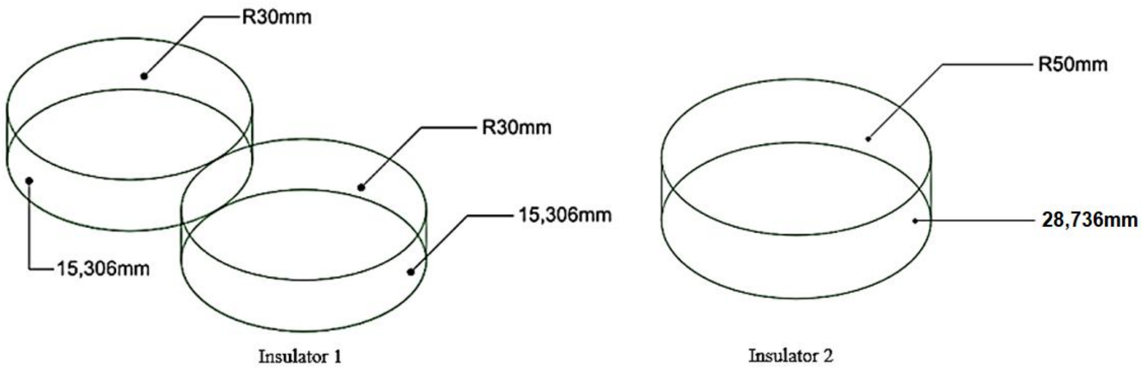

Figure 6. Geometry (Author, 2020)

4.2 Modal shape

Two modal analyzes were performed, one with fixed support condition and another adding spring elements with equivalent stiffness and spring size in the connection, partially allowing the movement around the Y axis. Among the vibration modes, the results in excitation range of 22,083 Hz were compared, explaining the difference between the natural frequency and vibration modes with and without isolation.

Measuring the insulators’ efficiency only with frequency values does not show significant results. Observing the 3 first results, it is possible to see in a simple way that the mass participation in the vertical axis is reduced, changing the way that the helipad’s structure behaves despite being in a similar frequency range. The vibration modes of the structure are seen and compared in Figure 7 and Figure 8.

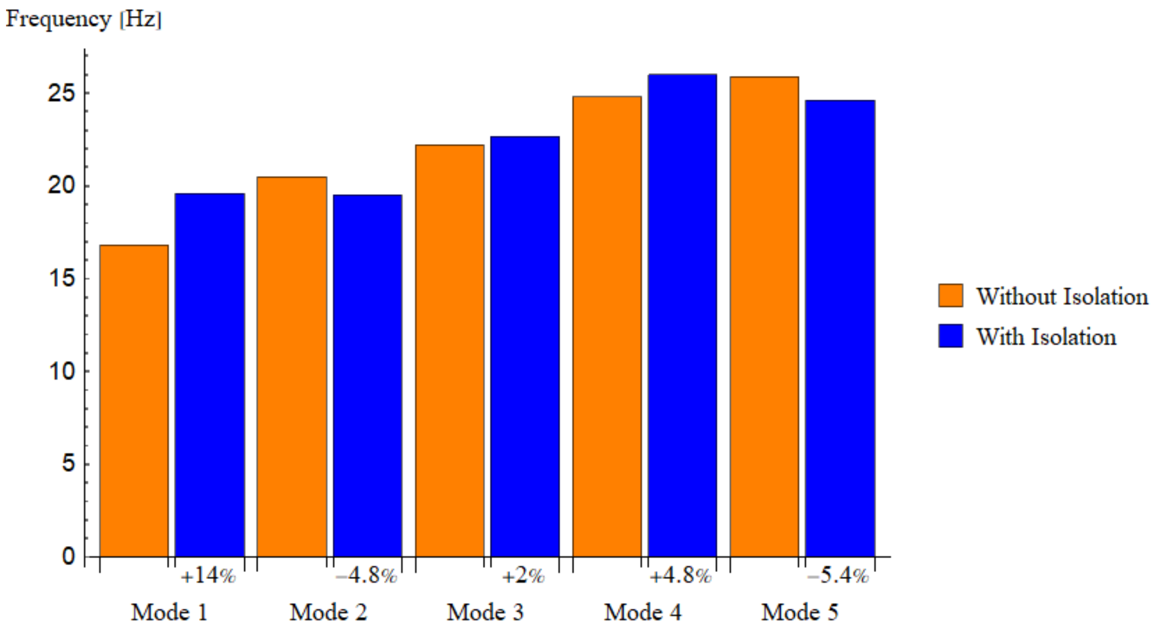

Figure 7. Vibration Mode (Author, 2020)

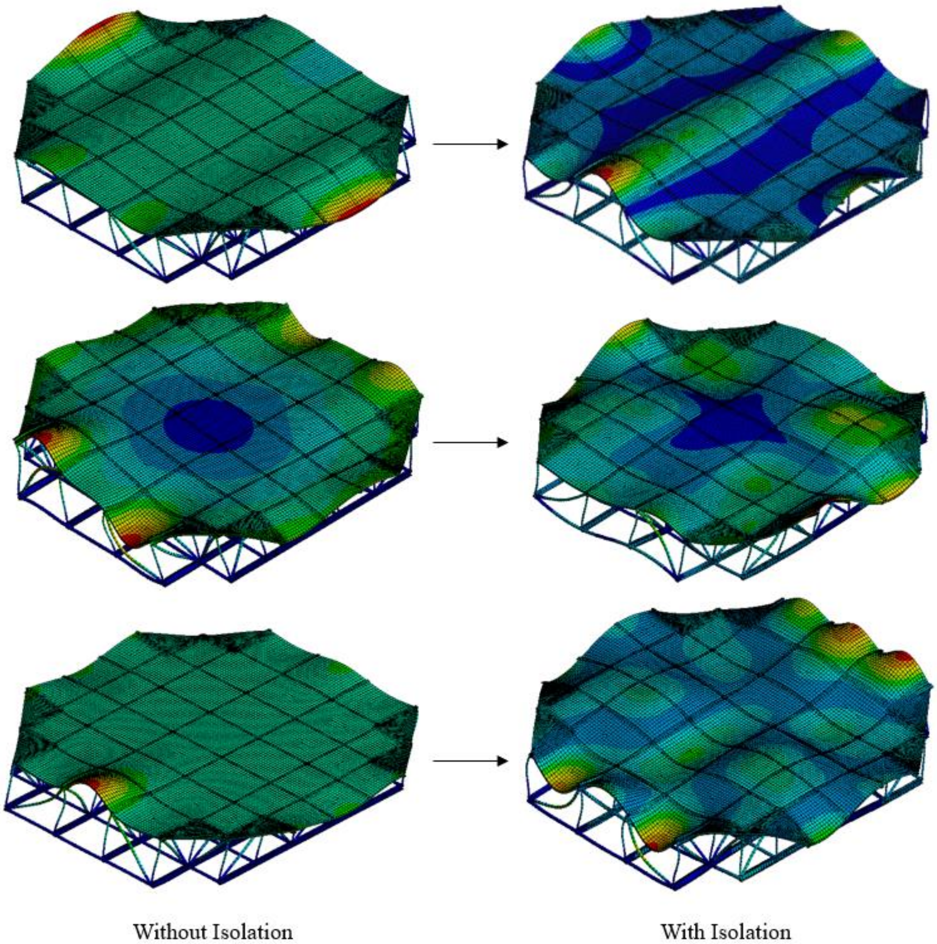

Figure 8. Comparation between vibration modes (Author, 2020)

5 Conclusions

After the structure modeling and simulation, it was clear how modal analysis can cooperate for a dynamic behavior solution. The greatest feature of computational simulation is the easy way of evaluating precise results when the software operator has knowledge about structure behavior, avoiding some errors. When a structure is modeling in computer, it is practical to use simplified models that allow to describe the real structure and behavior with less information, optimizing the time of calculation.

The application of mass points in the model was considerable in order to obtain the results to use in the insulator's project, therefore, the disregard of beam superposition effects, nonlinear characteristics and insertion of extrapolated load points representing the helicopter landing make the solution possibly oversized. Despite this, all design considerations follow manufacturers standards, articles and project recommendations, enabling their construction and application.

Even though it is possible to define an insulator for each support, the option to choose only two models applied in different regions was decided taking into account the ease of purchase and construction of the complete structure, avoiding possible errors in production and assembly. In the end, it can be said that the two insulators are in accordance with the recommendations of manufacturers of these accessories, therefore, despite the lack of dynamic results in the analysis, the insulation will present good functioning. After all these steps, it can be said that the two insulators are in accordance with the recommendations and, despite the lack of real dynamic data in the analysis, the isolation will work well.

References

[1] AEARO TECHNOLOGIES LLC. Isoloss SL Materials. Avaliable in: <https://earglobal.com/media/18644/mss52_sl_5web.pdf> Acess in: May 15, 2020.

[2] AIRBUS HELICOPTERS. Military Helicopter H225M Technical Data, 2016. Avaliable in: < http://www.airbushelicopters.ru/website/docs_wsw/RUB_26/tile_118/215C1-L1-16- 100-01E.pdf> Acesso em: November 13, 2019.

[3] ALUMINION OFFSHORE. Enhanced Safety Helideck. Avaliable in: <www.hospitalhelipads.com/enhanced-safety-helideck-for-brisbane-hospital/>. Acess in: November 13, 2019.

[4] BALACHANDRAN, B. MAGRAB, E. B. Vibrações Mecânicas. 2ª ed. São Paulo-SP: Cengage Learning, 2011.

[5] BITTENCOURT, M. L. Análise Computacional de Estruturas. 1a ed. Campinas - SP: Editora Unicamp, 2014.

[6] CAMPILHO, R. D. S. G. Método de Elementos Finitos: Ferramentas para Análise Estrutural. 1ª ed. Lisboa-Portugal: Editora Publindústria, 2012.

[7] FILHO, A. A. Elementos Finitos, A Base da Tecnologia CAE: Análise Dinâmica. 2a ed. São Paulo-SP: Editora Saraiva, 2017.

[8] FRANKOVICH, D. The Basics of Vibration Isolation Using Elastomeric Materials. 2002.

[9] INMAN, D. J. Vibrações Mecânicas. 4ª ed. Rio de Janeiro-RJ: Elsevier Editora, 2018.

[10] OLIVEIRA, H. P. Análise da Estrutura Suporte do Heliponto de uma Unidade AutoElevatória. Universidade Federal do Rio de Janeiro-UFRJ, Rio de Janeiro-RJ, 2013.

[11] PEREIRA, L. F. M. Concepção e dimensionamento de um Heliporto Elevado para operação do EH-101 "Merlin". Universidade Técnica de Lisboa IFI, Lisboa-Portual, 2008.

[12] SMITH, A.; BELL, A.; HACKETT, D. Trade-offs in Helipad Sitting & Design. 2017.