

Passive driving of the waves induced by a helicopter land-crash

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ABSTRACT

Infrastructures for helicopter landing, the so called heliports, are becoming more and more common. From a safety point of view, this means a clustering of helicopter trajectories with an increase of accident occurrence at the site. The surrounding buildings are subjected to a spread of vibration waves. The goal of this contribution is to investigate policies for driving these waves far from where they could cause economical losses.

Keywords: *Helicopter, Heliport, Passive control, Soil structure interaction*

1 INTRODUCTION

Helicopters are the only flying machines designed for safe land crashing. Figures 1 gives an overview of some accidents recently occurred. For all of them, the pilots and passengers had injuries but not deaths were recorded. The web is full of accident reports covering civil as well as militar vehicles, of small as well as large size.

This is a unilateral way for approaching a problem where two bodies are engaged in their impact. On a side the flying machine, designed to crash in a proper manner to dissipate energy in view of preserving the carried lifes. On the other side the land, passive receptor of the helicopter impacting body. As a consequence of the impact in a land location, vibration waves progate all around reaching even far, likely sensible installations on the land surface which could result seriously damaged.

Helicopter are free to fly everywhere the engaged authority authorizes to do it. Therefore, given a location, the probability of land crashing at the site in a given reference time, which can be easily estimated, will generally be so low that no counteraction is economically justified within usual cost/benefit schemes. There is a single exception to this general result: heliports. They are sites where the landing is authorized and, hence, they are characterized by a clustering of potential trajectories. This is why the probability of occurrence of a land crash at the site could result so significant to oblige to study specific local solutions.

In some cases, the knowledge of the damping soil properties is sufficient to ensure that the wave propagation decay under an allowed value at an acceptable distance from the impact. But, when dealing with soil properties, ignorance and uncertainty are often predominant. Thus a form of passive defense must be introduced and the main idea is the construction of buried barriers which convey the vibration along the direction where the expected consequent losses are minimized.

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Implementations of buried barriers in vibration mitigation are mainly associated with the traffic induced vibration [1-3]. The FP7 research project RIVAS [4], which recently celebrated its closure conference, synthesized these aspects. The literature however also covers extensions to the protection from seismic [5], machine foundation [6] or blast [7] generated waves. The technology insight in this barrier area is quite broad and spans from passive [8] to active [9] solutions.

The question is now “how to design such a technological solution to the problem of vibration mitigation?”. At the design stage one has to rely on a numerical model able to simulate soil-structure interaction [10]. As usual in these cases, the size of the model is quite large and standard model order reduction (MOR) schemes [11] could be conveniently adopted. But buried barriers are better designed to behave in a nonlinear way, making the problem nonlinear. Since simple MOR techniques only hold for linear problems, more sophisticated schemes for the reduction of nonlinear problems are required.

Indeed an extension of standard MOR techniques to include cases with localized nonlinearities was recently introduced [12], with an application to the problem of falling helicopter impact. Such a problem is approached in this paper with focus on the consequence of the nonlinearity assumed for the protection barriers.



Figure 1 – Helicopter land crashes: clockwise from the top left, India 2012, UK 2015, Canada 2015, Fiji 2015.

2 THE PROBLEM

Heliports (or helipads, as they are also referred to) come with very different features as shown in Figure 2: isolated, built over a structure or inside an urban nucleus.



Figure 2 – Different features of heliports a) isolated in Russia; b) supported by a suitable structure in Turkey or c) within an urban nucleus in Canada.

In all cases, the accident occurrence involve an impact on the soil, which represents the transmission medium. In the surrounding buildings one can feel un-comfort due to the induced accelerations.

Thus the numerical model created within a finite element analysis (FEA) tool consists of a discretized soil block, an impact location and sites where the response has to be observed, see Figure 3 [12]. Moreover, buried barriers are introduced as passive ways to mitigate vibrations. The details are given in Figure 4.

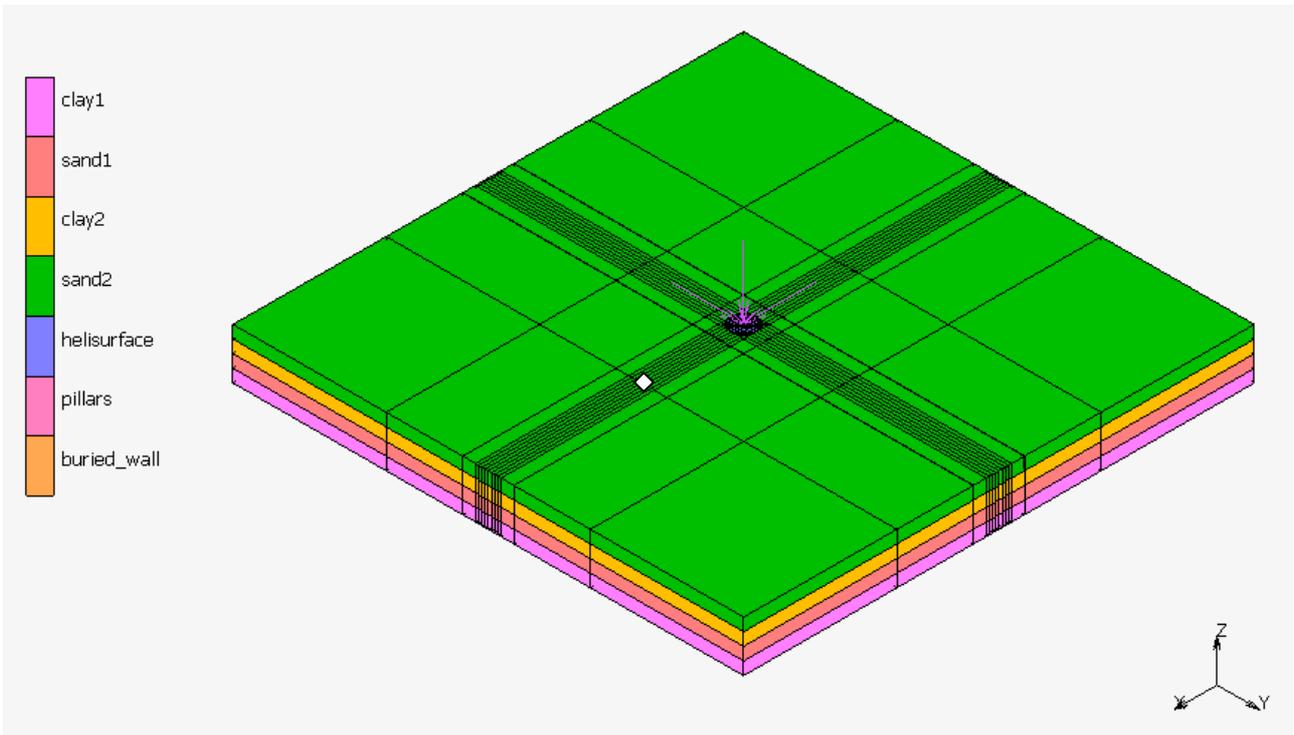


Figure 3 – The soil block object of a dynamic transient analysis, with the arrows denoting the impact location and the diamond the site where the response is observed.

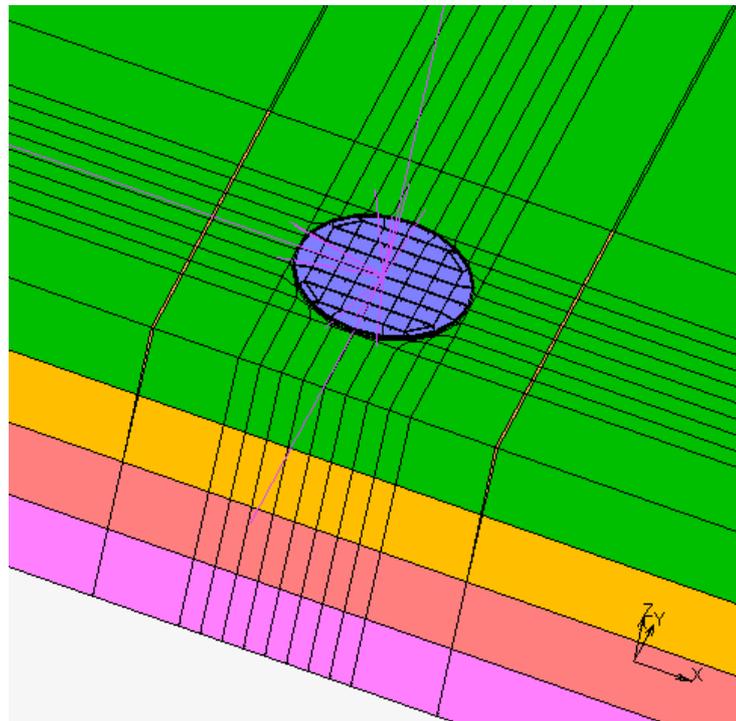


Figure 4 – Detail of the buried barrier location. They develop along direction y.

3 THE NATURE OF THE WALLS

References [12] and [13] studied some specific quadratic relationship for the stiffness associated with the buried barriers. The performance of two cubic relationships for the buried barriers stiffness are investigated in this paper. The first scheme (I) shows a rubber-like relation, while the second line (II) has a faster hardening (Figure 5). The relevant parameters are given in Table 1.

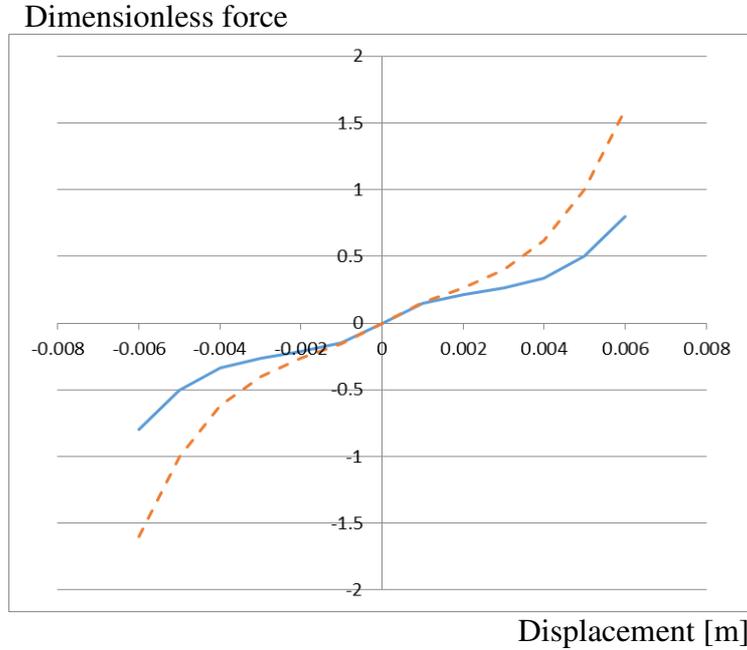


Figure 5 – The two cubic relationships associated with the stiffness adopted for the buried barriers. The solid line (I) shows a rubber-like relation, while the dashed line (II) shows a faster hardening. The relevant parameters are given in Table 1.

The reduced-order model discussed in [12] is used to estimate the acceleration response in the location marked as a diamond in Figure 3.

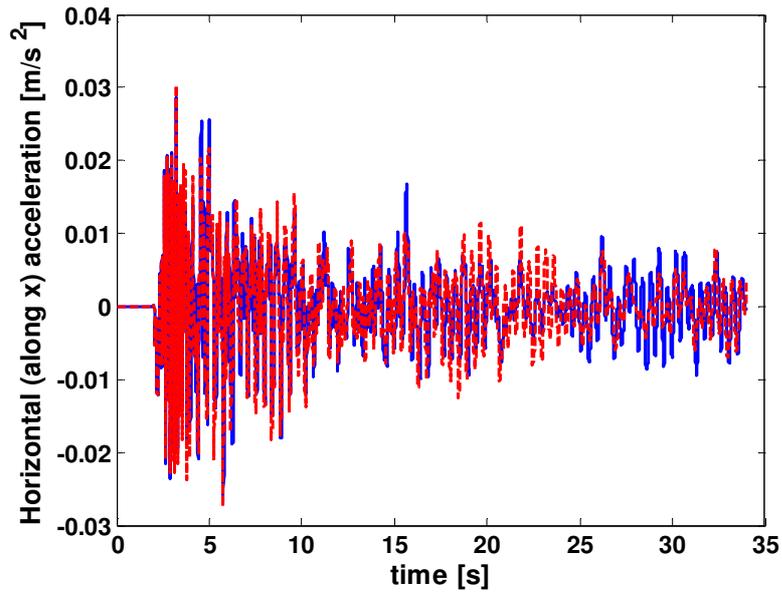
Table 1: Parameters of the cubic relationship in Figure 5.

Parameter	Solid line (I)	Dashed line (II)
constant	0	0
linear term factor	1	1
quadratic term factor	-1.6	-1.4
cubic term factor	1.1	1.4

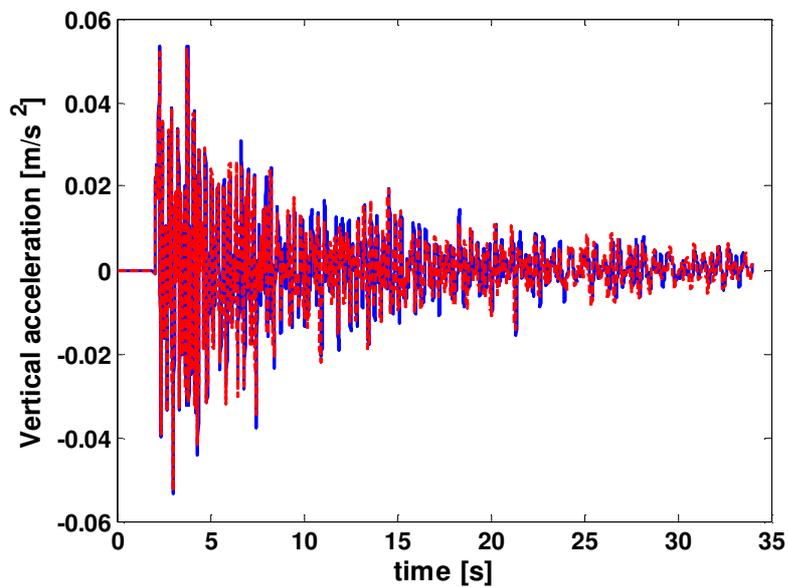
4 COMPARING THE WALLS PERFORMANCE

The acceleration time histories observed at the location marked by a diamond in Figure 3 were estimated for the two different design situations characterized by relationship I and II, respectively, for the stiffness of the buried walls.

They are plotted and compared each with the other in Figure 6. While the vertical acceleration is quite similar, in term of horizontal acceleration the adoption of line II is less effective at the beginning of the time history, while the response for line I shows delayed peaks.



a)



b)

Figure 6 – Comparison of the acceleration response estimated in the location marked by a diamond in Figure 3: a) horizontal (along x) acceleration; b) vertical acceleration. Option I is represented by a solid line; option II by a dashed line.

5 CONCLUSION

A model-order reduction approach for linear systems, but incorporating regions of limited extension made by nonlinear material, was proposed in [12]. It is applied to the design of a buried walls solution for mitigating the vibration propagating from the site where a helicopter land-crash has occurred.

The timely aspect of this study is that there is a ferment in the area of passive vibration mitigation achieved by the introductions of walls more and more sophisticated. In particular, the response, observed when cubic stiffness relationships are adopted for the buried walls, is investigated in this paper.

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