Monte-Carlo simulation for moderate seismic zones using artificial accelerograms

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1 Keywords:

Monte-Carlo simulation, Seismic hazard, artificial accelerogram, mining, numerical approach,

Abstract

The present technical note deals with a new method to generate seismic accelerograms based on statistical characteristics and the classification of seismic waves. A short heterogeneous site-based analyse of these accelerograms is given with a seismic wave propagation code in 1D. After, a numerical simulation is done in order to obtain PGA using Newmark's implicit scheme, and finally, Monte-Carlo simulation is used to determinate failure's probability of structures localised in moderate seismic zones in hexagonal France.

2 Introduction

Starting from geological context, the theory of plate tectonics seems to justify seismic waves by existence of faults. The theory Of Reid confirms that on subduction zone, there is a big risk of earthquake. Indeed, The accumulation of shearing stress causes an instant release of energy, appeared on surface as earthquake. The figure 1 explain the process. The seismic hazard depends essentially on geological parameters that is called seismic site effect. Many researches prove that there are other parameters that can describe seismic wave such as Velocity, frequency and depth of soil. In this study, we will discuss a new method in order to generate seismic accelerograms according to statistical characteristics of different waves and simulation of Monte-Carlo for moderate seismic zones in France.

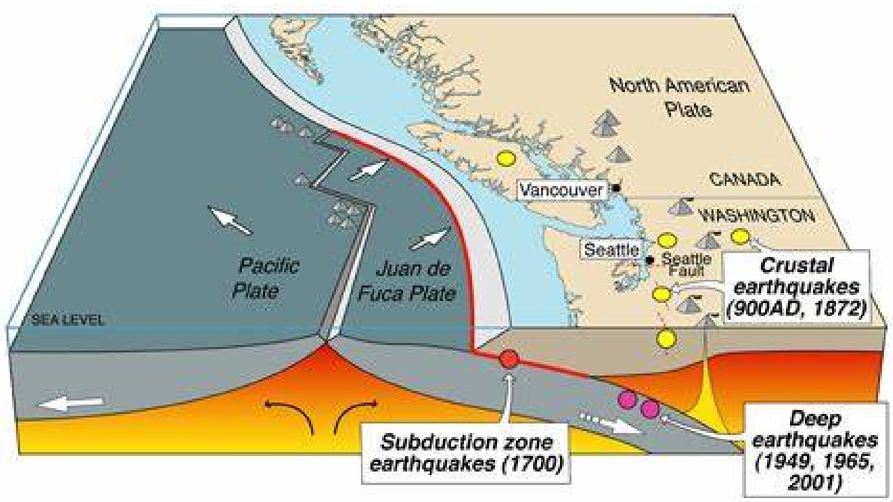

Figure 1: Example of suduction zone on pacific plate

3 A new method to generate artificial seismic accelerograms

3.1 Description of the principle of generation

The accelerograms are generated with classification of seismic waves of compression, shear and those of surface, and their statistical characteristics, average and standard deviation, using inverse Gaussian law. The signal is multiplied by an Gaussian envelope function. An example of artificial accelerogram is given on Figure 2, the elastic spectrum of displacement, velocity and acceleration are elaborated also in the figures 3, 4 and 5, using a coefficient of damping equal to 0.05.

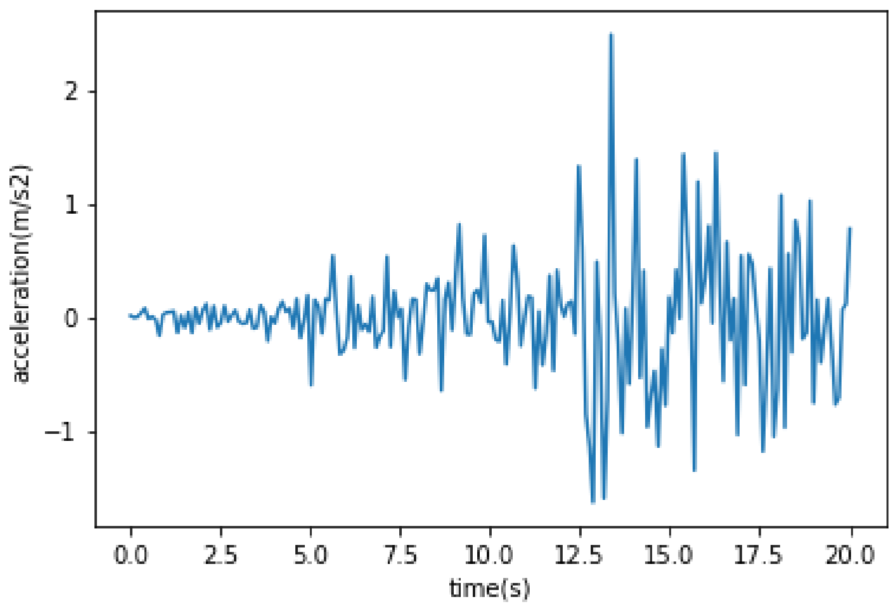

Figure 2: Example of artificial seismic accelorogram for a sample of 200 points, 20s as a time interval with following statistical characteristics: Wave Average Standard deviation P 0.00 0.15 S 0.01 0.34 Surface 0.01 1.10 Envelop 10 10

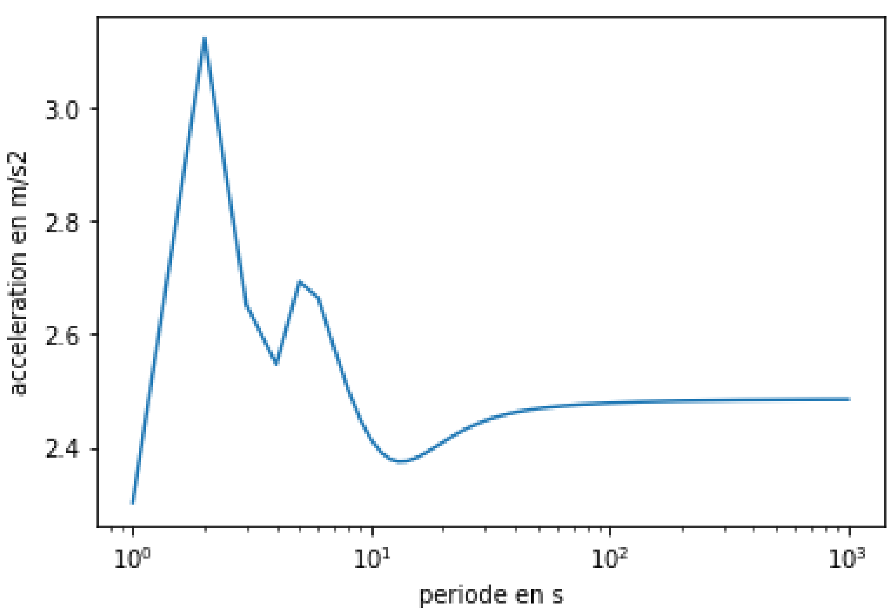

Figure 3: Acceleration spectrum, with D=0.05, using implicit scheme of temporal integration, beta=1/6 and gamma=1/2

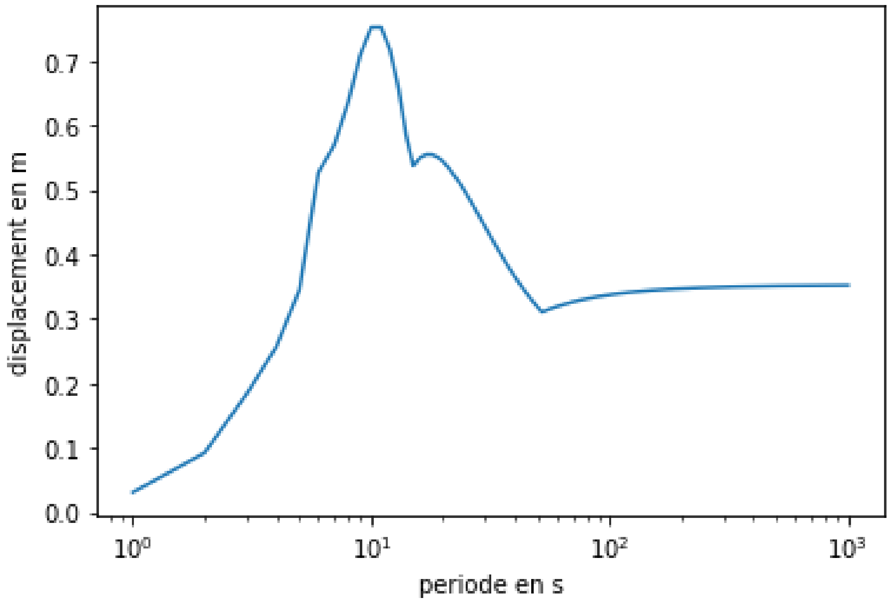

Figure 4: Displacement spectrum, with D=0.05, using implicit scheme of temporal integration, beta=1/6 and gamma=1/2

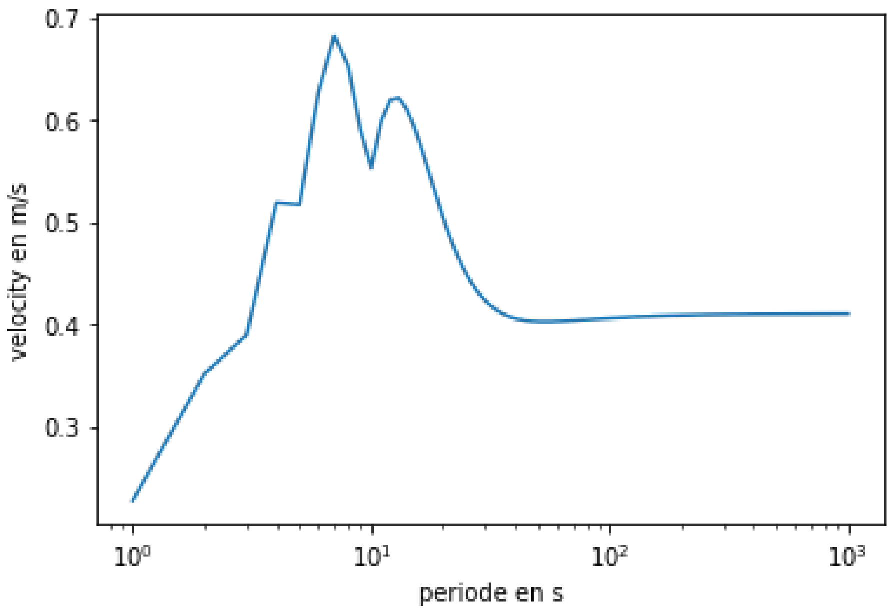

Figure 5: Velocity spectrum, with D=0.05, using implicit scheme of temporal integration, beta=1/6 and gamma=1/2

3.2 Propagation of seismic wave generated in heterogeneous soil media in 1D

The seismic site effects correspond to an amplification of the seismic waves in geological layers close to the earth's surface, there are two types of methods at this stage, either by sampling as much as possible and experimental method under cyclic load, either by geophysical methods of surface, seismic tomography is also a way to map the structure internal earth, namely the lithosphere, upper and lower mantle and therefore of derive the material parameters necessary to make digital fault models seismic. This method can be useful in order to fully understand the propagation of seismic waves at the focal point.

The propagation of seismic waves is done by a stochastic and random process in all directions from the seismic focus. The stochastic process consists on the propagation of waves in all directions and it is presented in figure 6, showing P and S waves propagating by refraction and reflection.

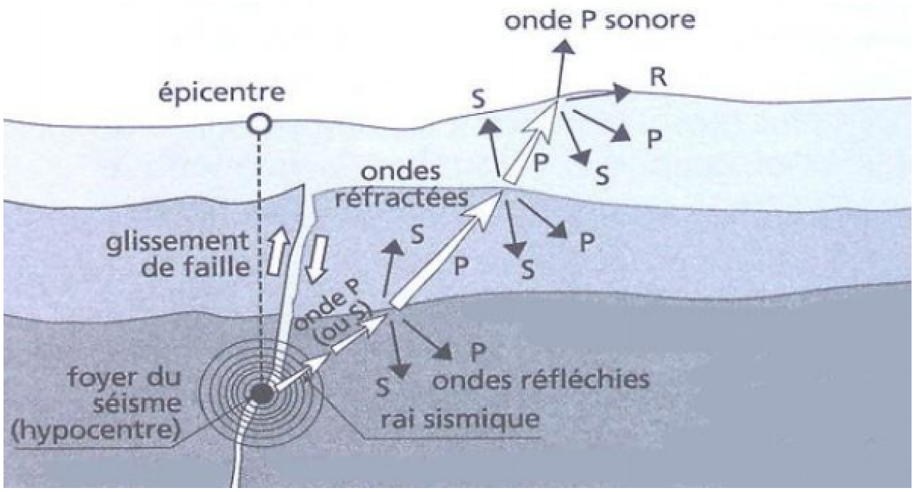

Figure 6: Principle of propagation of volume waves by reflexion and refraction

First of all, we generate a seismic signal at the surface as demonstrated on a figure 7 with statistical characteristics and we fix the velocity diagram with depth, figure 8

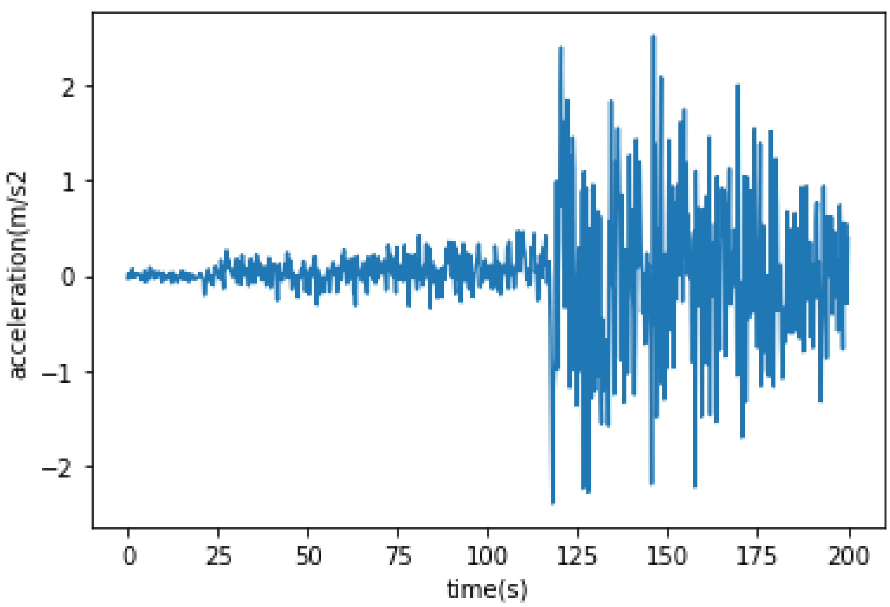

Figure 7: Example of artificial seismic accelorogram for a sample of 750 points, 200s as a time interval with following statistical characteristics: Wave Average Standard deviation P 0.00 0.1 S 0.08 0.154 Surface 0.01 1.20 Envelop 100 100

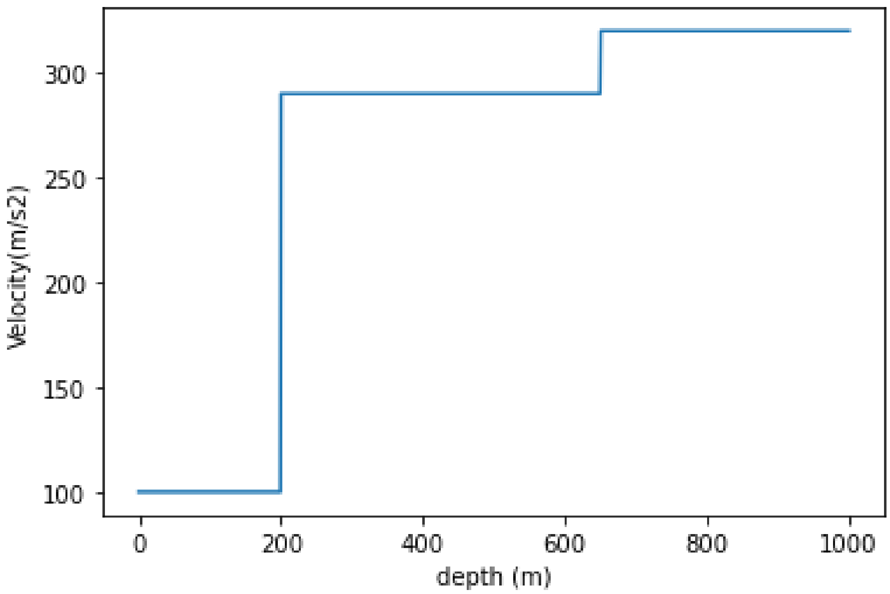

Figure 7: Velocity diagram to depth of 1000m:

The result of integration of 1D propagation wave equation is presented on the figure 8:

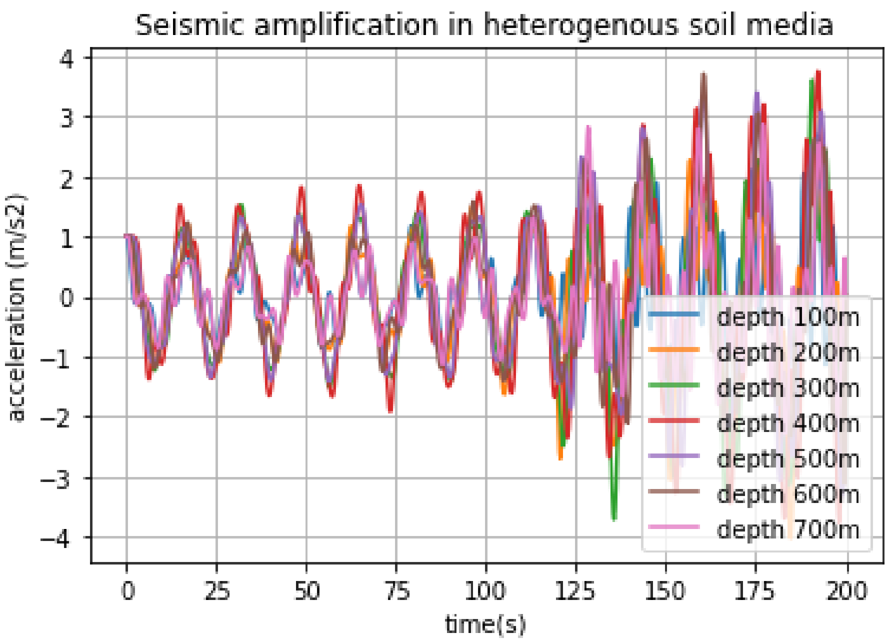

Figure 8: Propagation of generated wave until the depth of 700m

4 Monte-Carlo simulation for moderate seismic zones

4.1 General contexte

Seismic hazard is the possibility, for a given site, of being exposed to earthquakes or simply ground movement of given characteristics (generally expressed by parameters such as acceleration, intensity, response spectrum ...). The seismic hazard can be evaluated by a deterministic method or probabilistic; in the first case, the characteristics are that of a real event, possibly accompanied by a safety margin (historically known strong earthquake, for example).

In the probabilistic approach, all the data allowing the estimation of the hazard are examined in a statistical framework, and the hazard is then expressed as a probability of exceeding a fixed level. In the case of a probabilistic approach, the fixed level (probability of fault admissible by the client) depends essentially on the nature of the building. We can start from high-risk buildings such as nuclear power plants to low-risk buildings such as non-flammable product depots or waste reception centers. Note that there are two types of seismic hazards:

- Regional hazard: mainly depends on the rock outcropping in the seismic sources and it allows seismotectonic zoning, like the case of France indicated in figure 9, assimilating that we have an earthquake and a response spectrum at any point in the area. - Local hazard: depends essentially on the type of soil where the seismic waves and which takes the site effect into account.

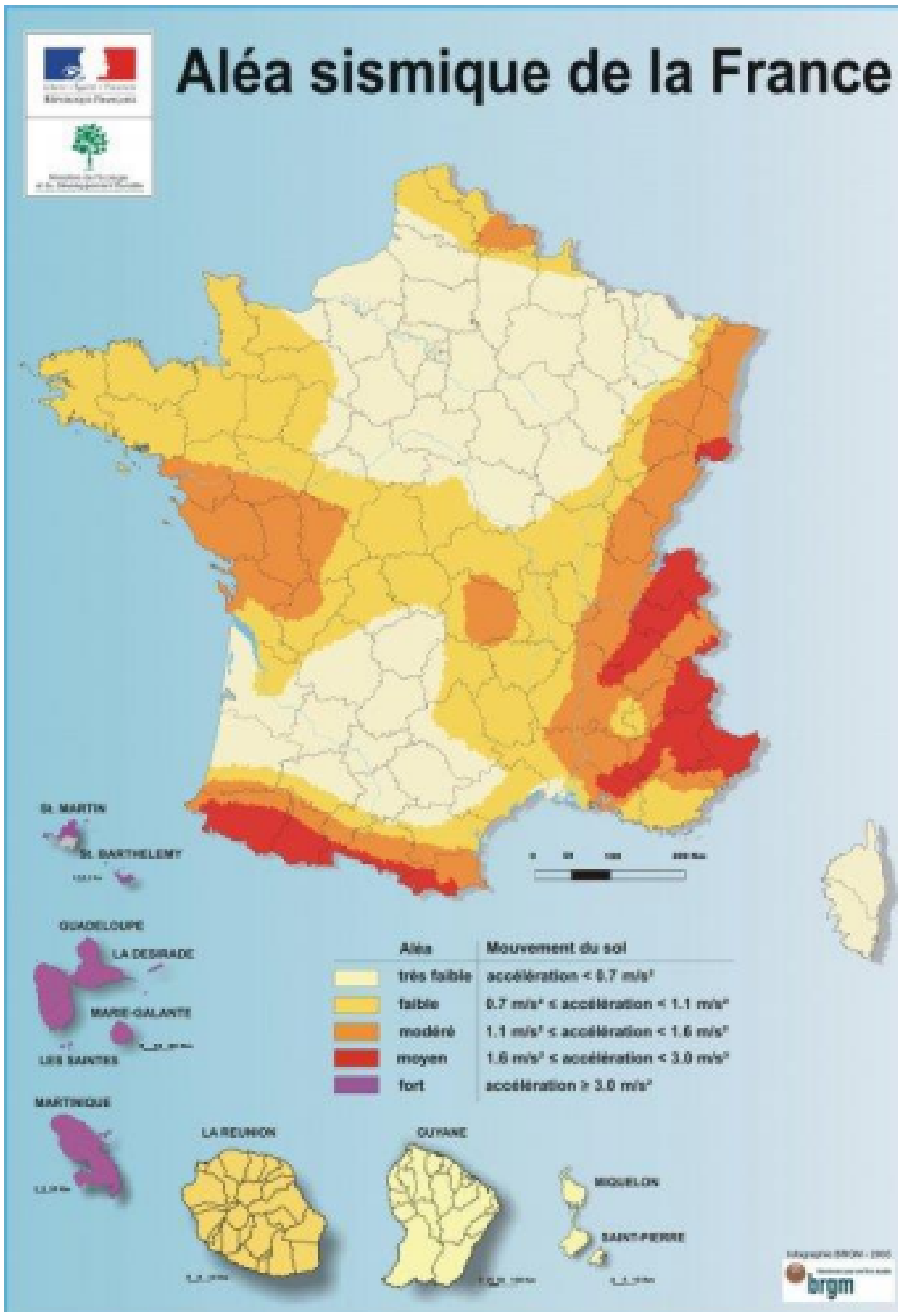

Figure 9: Regional seismic hazard in France Source: https://www.georisques.gouv.fr/

4.2 Statistical description of the seismic signal sample

With a sample of hundred seismic signal, we have an average PGA equal to 1.43 m/s2 with a standard deviation equal to 0.322, the sample of all PGA is presented on figure 10:

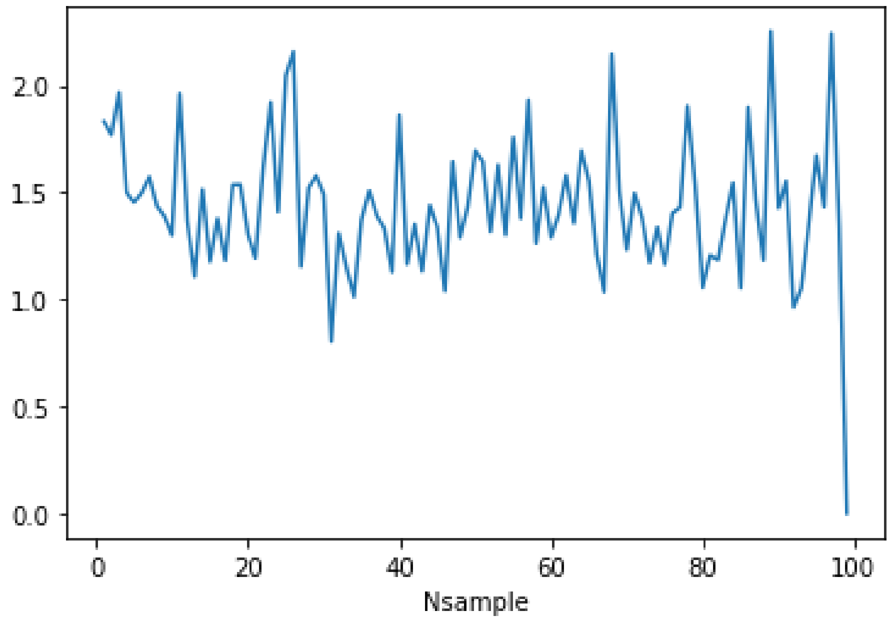

Figure 10: PGA of all sample of artificial seismic waves

We note that with average PGA=1,43m/s2 we are indeed in moderate seismic zones.

The simulation of Monte-carlo expressed by exceeding the value of 1.6 m/s2 fixed by Eurocode 8, give a probability of failure equal to 0.22 with co-variance equal to 0.18 and average's interval of confidence for 0.05 between 1.32m/s2 and 1.54m/s2.

The study of sampling give a certain stabilisation of co-variance, the figure 11 shows this with the augmentation of sample's number, also the figure 12 and 13 shows that with average of PGA and interval of confidence for 0.05 probability.

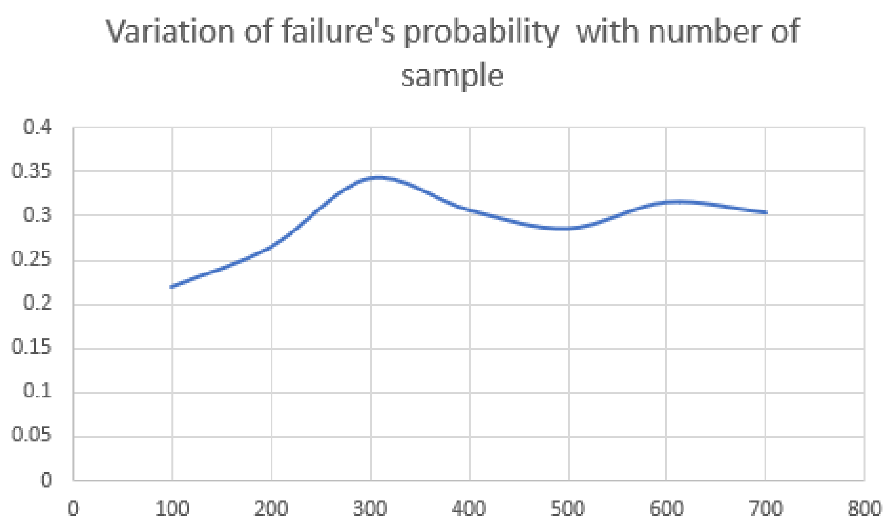

Figure 8: Variation of failure's probability with number of sample

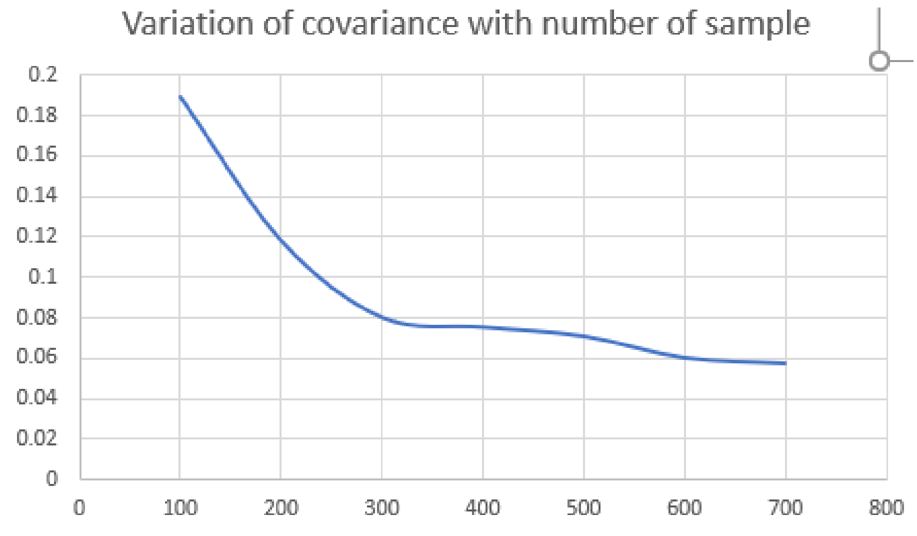

Figure 8: Variation of covariance with number of sample

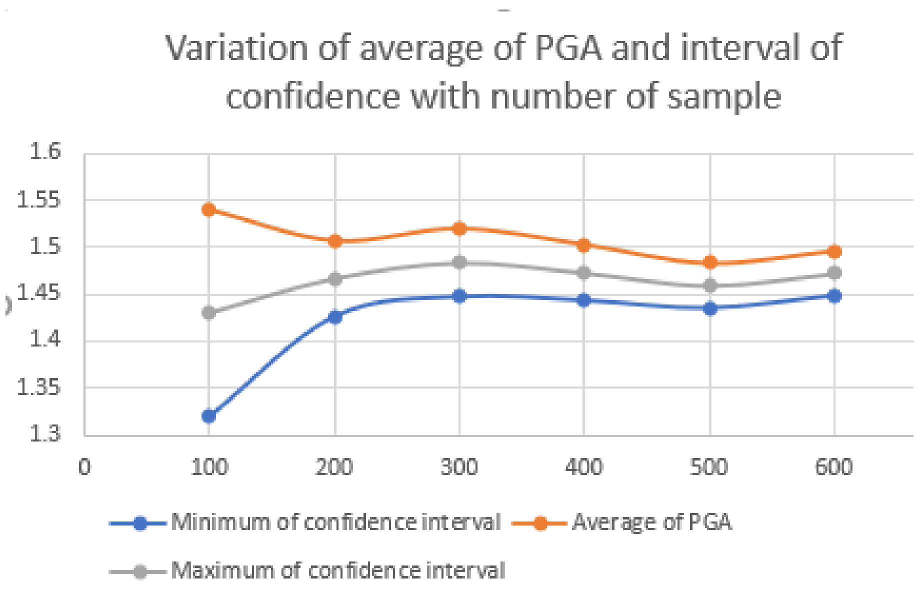

Figure 8: Variation of average of PGA and interval of confidence with number of sample

5 Conclusion

As a conclusion we note that on moderate seismic zones, we have an important failure probability according to the sample of seismic waves generated with a certain statistical characteristics and decomposition. This value should be considered with the coefficient of co-variance also fixed, for 700 seismic scenarios, at 0.05. The study maybe generalized for other seismic characteristics depending on strong motion referred in certain region, specially those presenting a high risk.

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