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Division V

BEHAVIOR OF PRE-CAST ANCHORS IN REINFORCED CONCRETE UNDER DYNAMIC LOADINGS

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INTRODUCTION

In nuclear facilities, essential devices must be able to preserve their functions under extreme load cases. To ensure the well anchorage of the devices, their bases are preferentially pre-casted in the reinforced concrete structures.

To increase the protection of these devices against fast-dynamic accidental load cases such as airplane crashes, blasts or dropped loads, they are fixed as far as possible from the potential impact areas. However, even if they are not located inside the impact zone, they might be affected by transient loads, after they spread through the RC structure.

The purpose of this study is to estimate how the anchors system affects the signal transmitted from the structure to the anchored devices.

METHODOLOGY

For this study, a Finite element model of a pre-cast anchor system was built using LS-DYNA code.

The anchor system chosen for this study is composed of four pre-casted rods, fixed to a steel plate placed onto the concrete surface. A nut is welded at the end of each of the four rod.

Table 1: Part sizes

Rod diam	Rod length	Space btw rods	Nut diam	Nut thick.	Plate dim.	Plate thick.
20 mm	400 mm	140 mm	60 mm	10 mm	400X400mm	40 mm

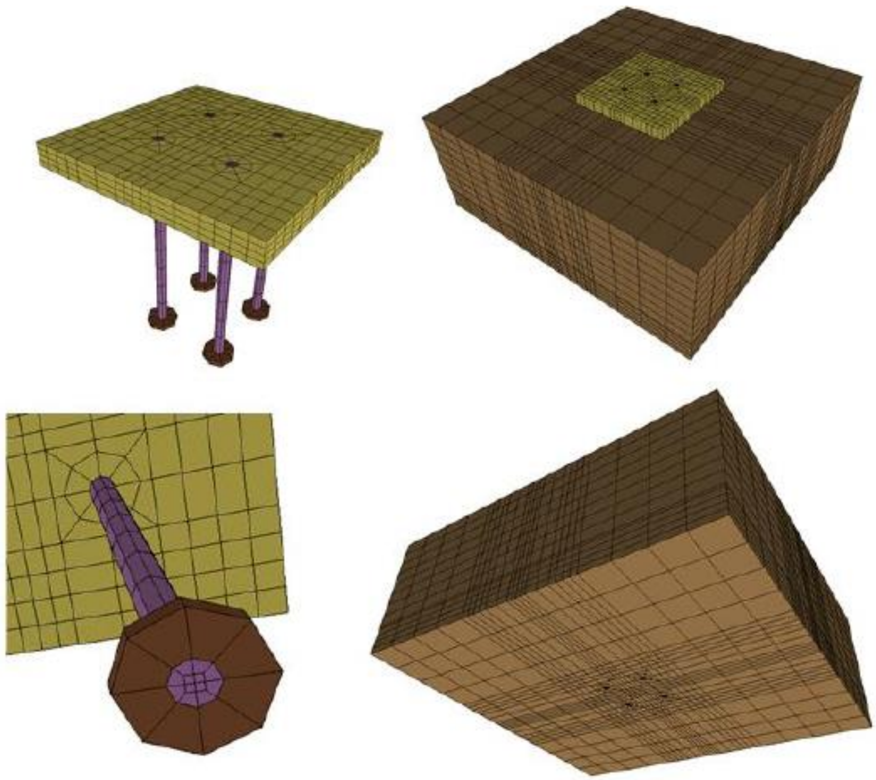


Figure 1. General views of the finite element model.

The model includes 10144 hexahedral fully integrated solid elements, distributed as follow:

Concrete embedment	Steel plate	Rods	Nuts
8272	1216	624	32

The following material properties have been used:

	Young modulus	Density	Poisson ratio
Steel	210 GPa	7800 kg/m^3	0.3
Concrete	30 GPa	2300 kg/m^3	0.2

Based on the results of [1], a time signal is applied at the boundary of the model, in order to represent the impact-induced effects of a fast dynamic loading (in this case a plane crash) after its propagation within the RC structure.

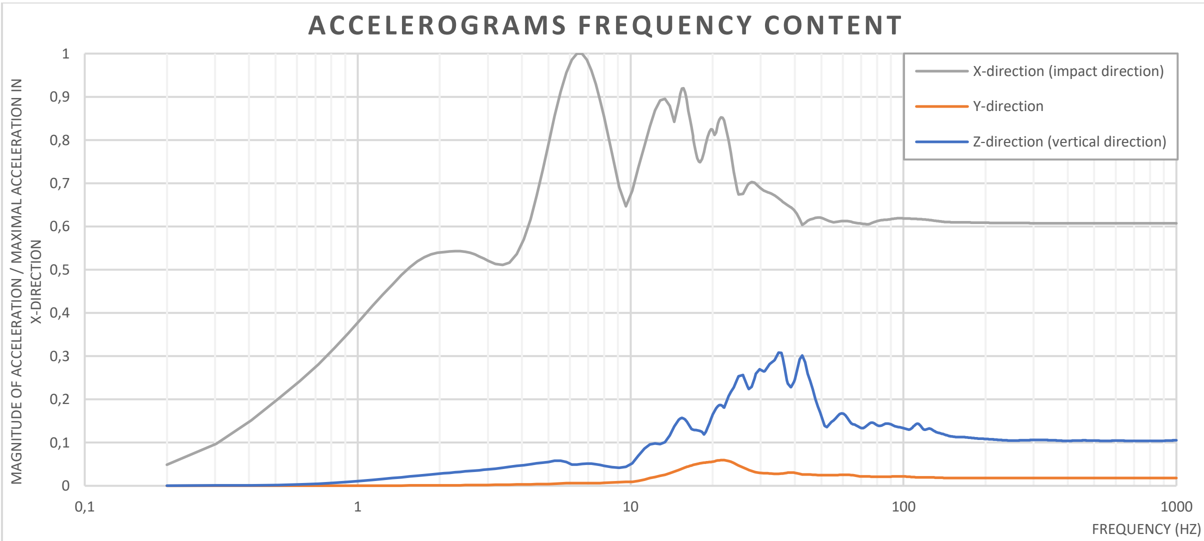


Figure 2: Fast Fourier Transform (FFT) of the three accelerograms applied at the boundary of the model (obtained from [1]).

The X axis matches the direction of the airplane, following the normal to the wall of the building. The anchor system is pre-casted in the floor located at level 2 of the building model of [1].

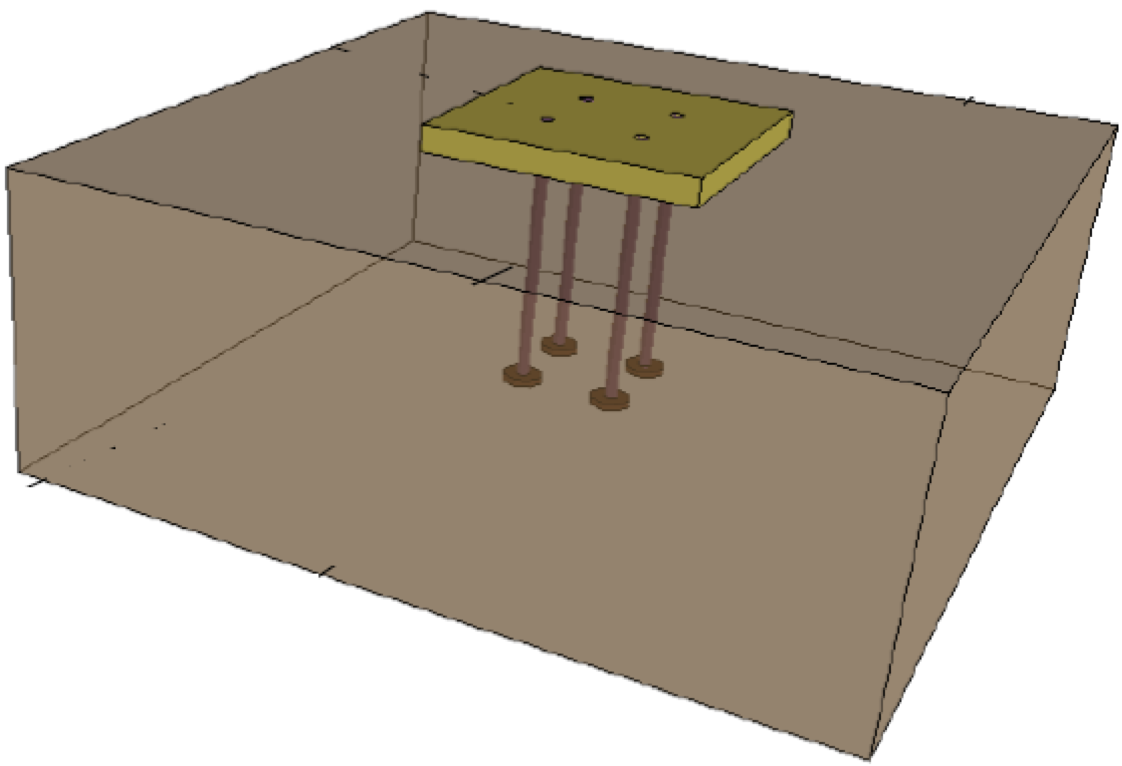


Figure 3: X (grey) Y (orange) and Z (blue) axis of the FEM analysis.

PURPOSE

The signal obtained at the connection between the base plate and the equipment pole is then compared to the applied signal for three sets of parameters:

Set #0	Perfect adhesion between the concrete and the steel rods, rods welded to the plate (test case)
Set #1	Friction between the rods and the concrete (friction coeff.= 0.3), rods welded to the plate
Set #2	Perfect adhesion between the concrete and the steel rods, rods bolted to the plate with a 1mm mounting gap
Set #3	Perfect adhesion between the concrete and the steel rods, rods bolted to the plate with a 0.2mm mounting gap

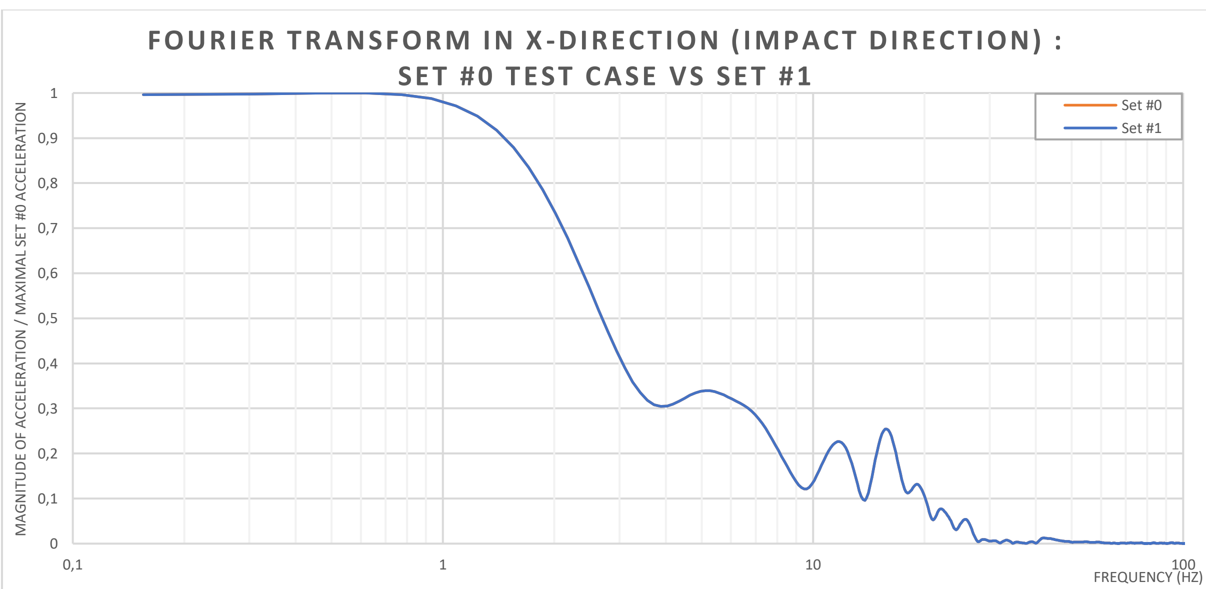
The purpose of this comparison is to highlight the impact of each of these non-linearities to the signal transmitted by the anchor system.

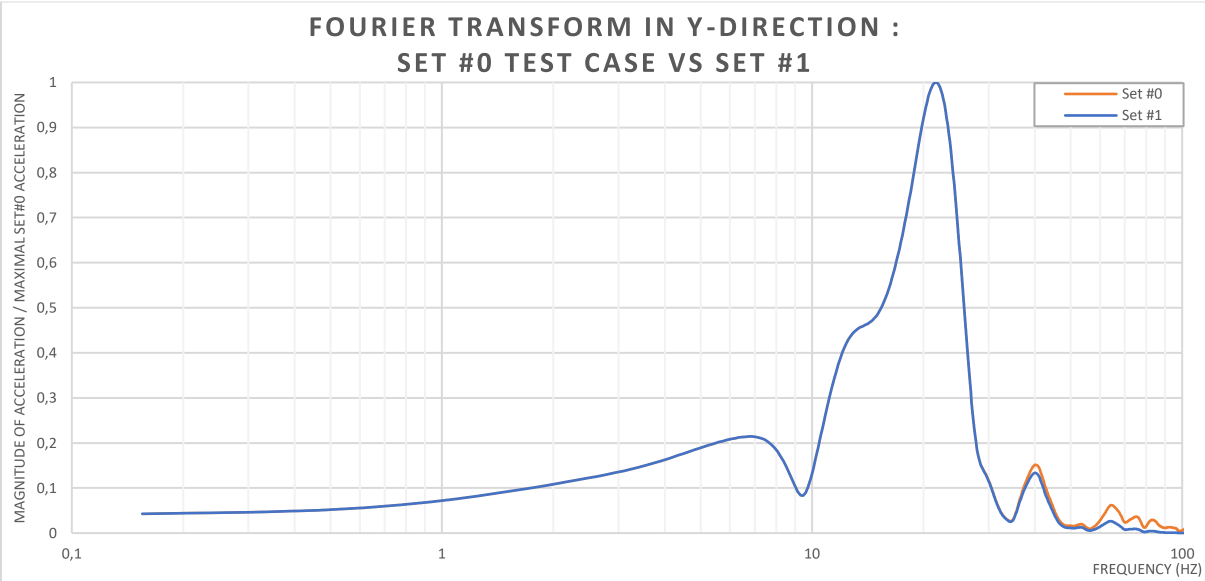
RESULTS

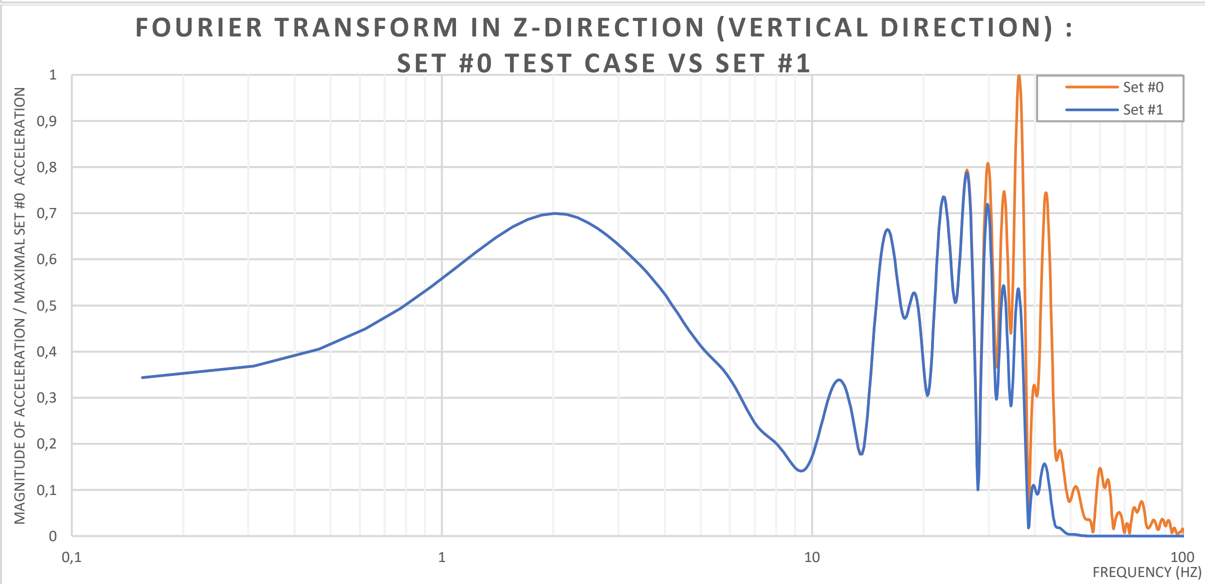
The following results are obtained on the top center of the steel plate. For each set of parameters, the FFT and the acceleration response spectra are given, and compared to the results of the test case. The acceleration values have been scaled by the maximum acceleration value of the test set.

Set #0 : This is the test set, and the resulting accelerations matches the applied signal

Set #1 Results :




FOURIER TRANSFORM IN Y-DIRECTION :
SET #0 TEST CASE VS SET #1
Set #0
Set #1
MAGNITUDE OF ACCELERATION / MAXIMAL SET#0 ACCELERATION
FREQUENCY (HZ)
0
0,1
0,2
0,3
0,4
0,5
0,6
0,7
0,8
0,9
1
0,1
1
10
100


FOURIER TRANSFORM IN Z-DIRECTION (VERTICAL DIRECTION) :
SET #0 TEST CASE VS SET #1
Set #0
Set #1
MAGNITUDE OF ACCELERATION / MAXIMAL SET #0 ACCELERATION
FREQUENCY (HZ)
0
0,1
0,2
0,3
0,4
0,5
0,6
0,7
0,8
0,9
1
0,1
1
10
100

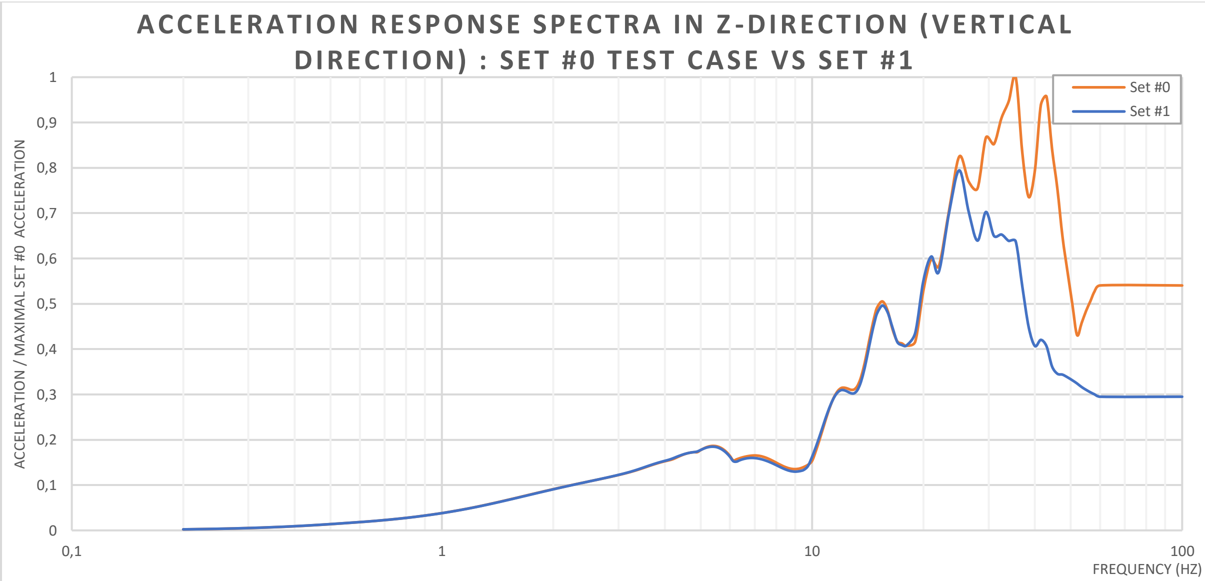
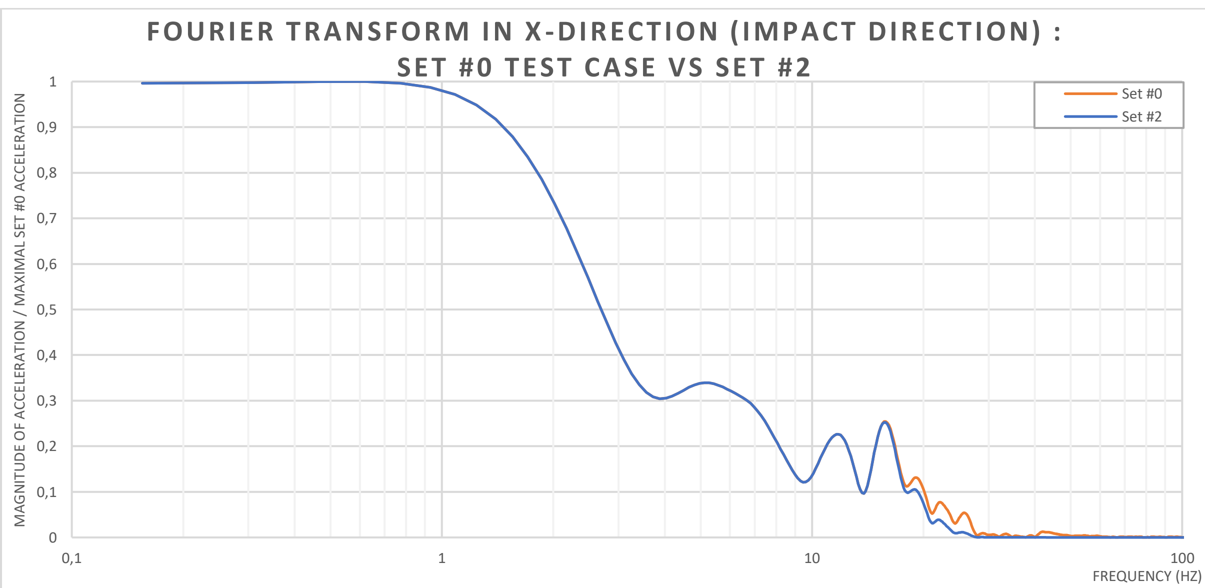


Figure 4: Set #1 acceleration results (frequency content in X, Y and Z directions and response spectra in Z direction).

These results show that when the signal is applied to the anchor devices, the rods almost do not slide in horizontal directions (we only see a slight attenuation of it on the Y-axis for high frequencies). However, in the vertical direction, they show a significant decrease of accelerations for high frequencies on the response acceleration spectra.

Set#2 Results:



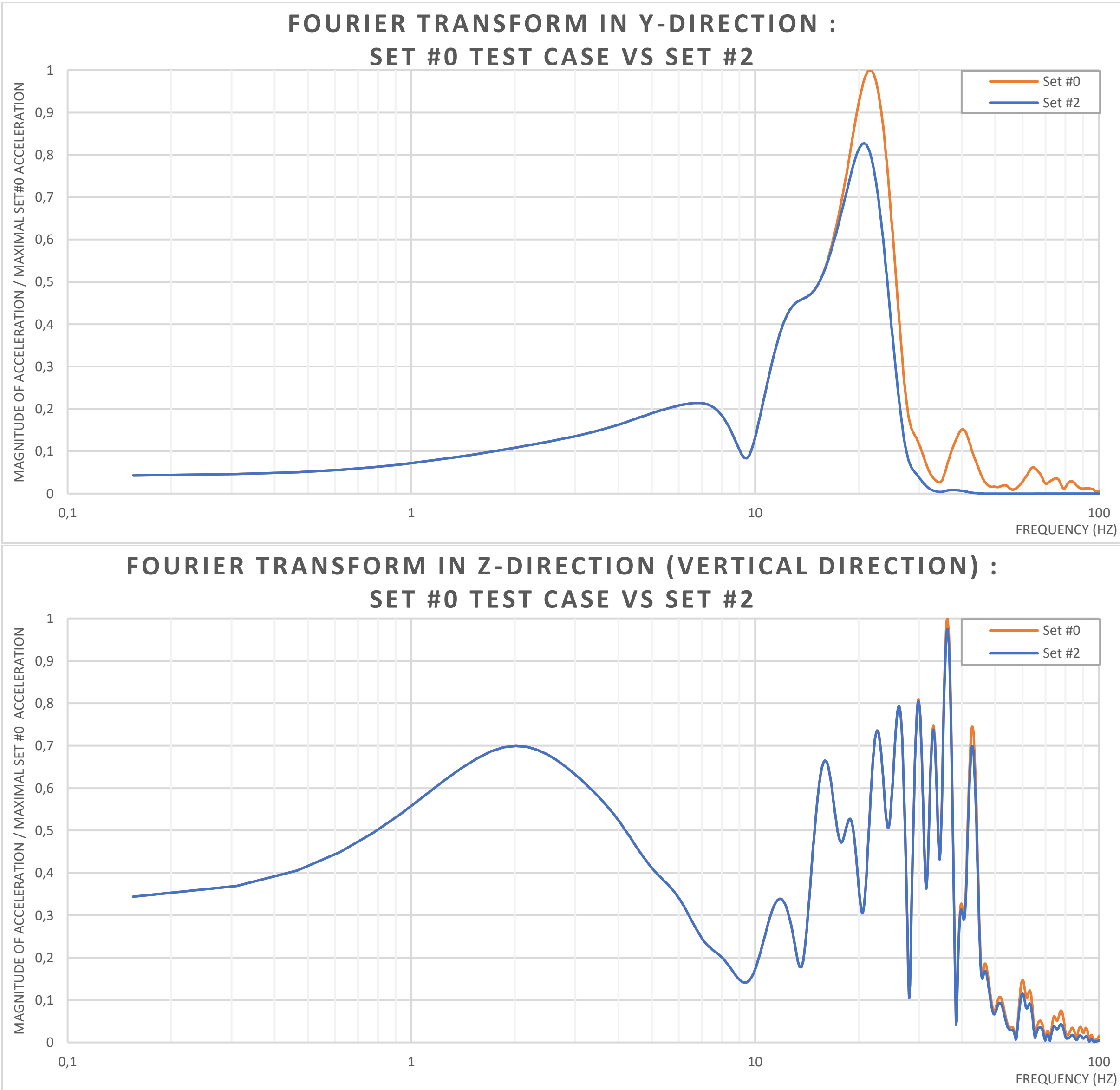


Figure 5: Set #2 acceleration results (frequency content in X, Y and Z directions).

In this case, acceleration values are mainly affected on horizontal directions for high frequencies. The acceleration response spectra is plotted below, for the horizontal Y-axis, which is perpendicular to the direction of the plane crash:

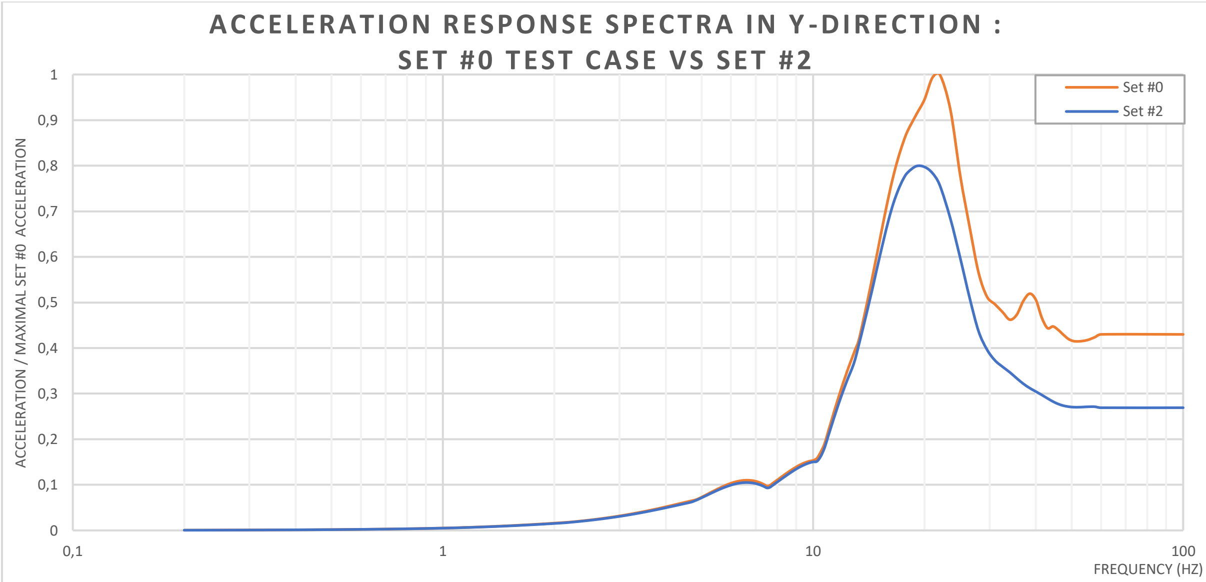
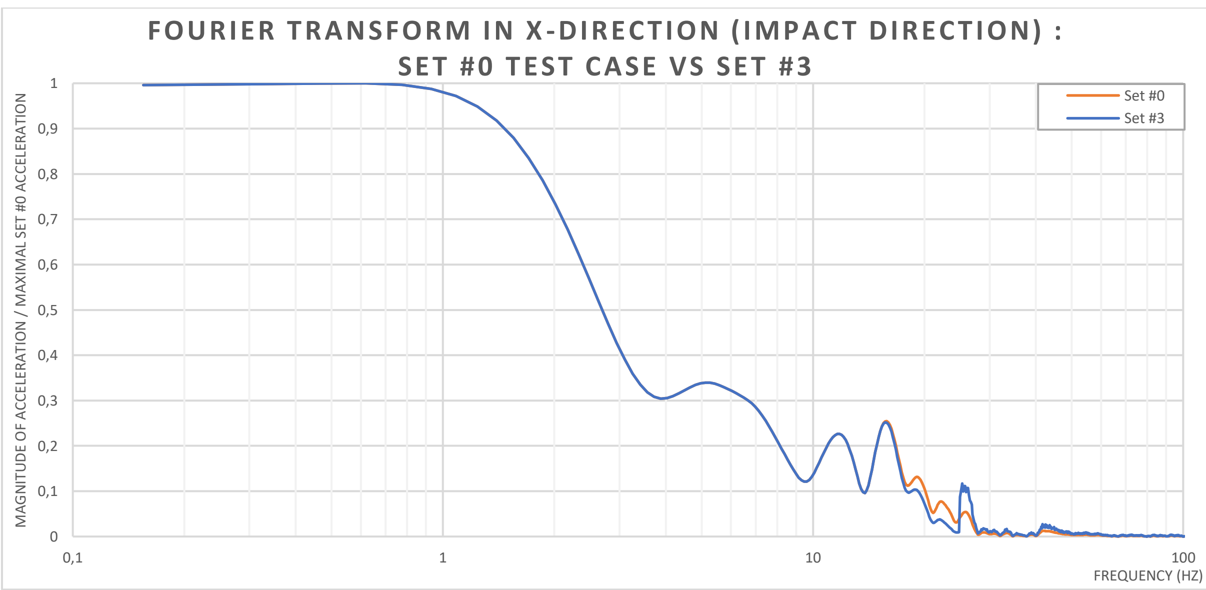


Figure 6: Set #2 acceleration results (response spectra in Y direction).

In this case, the non-linearity also results in a reduction of the acceleration for high frequencies.

<u>Set#3 Results :</u>



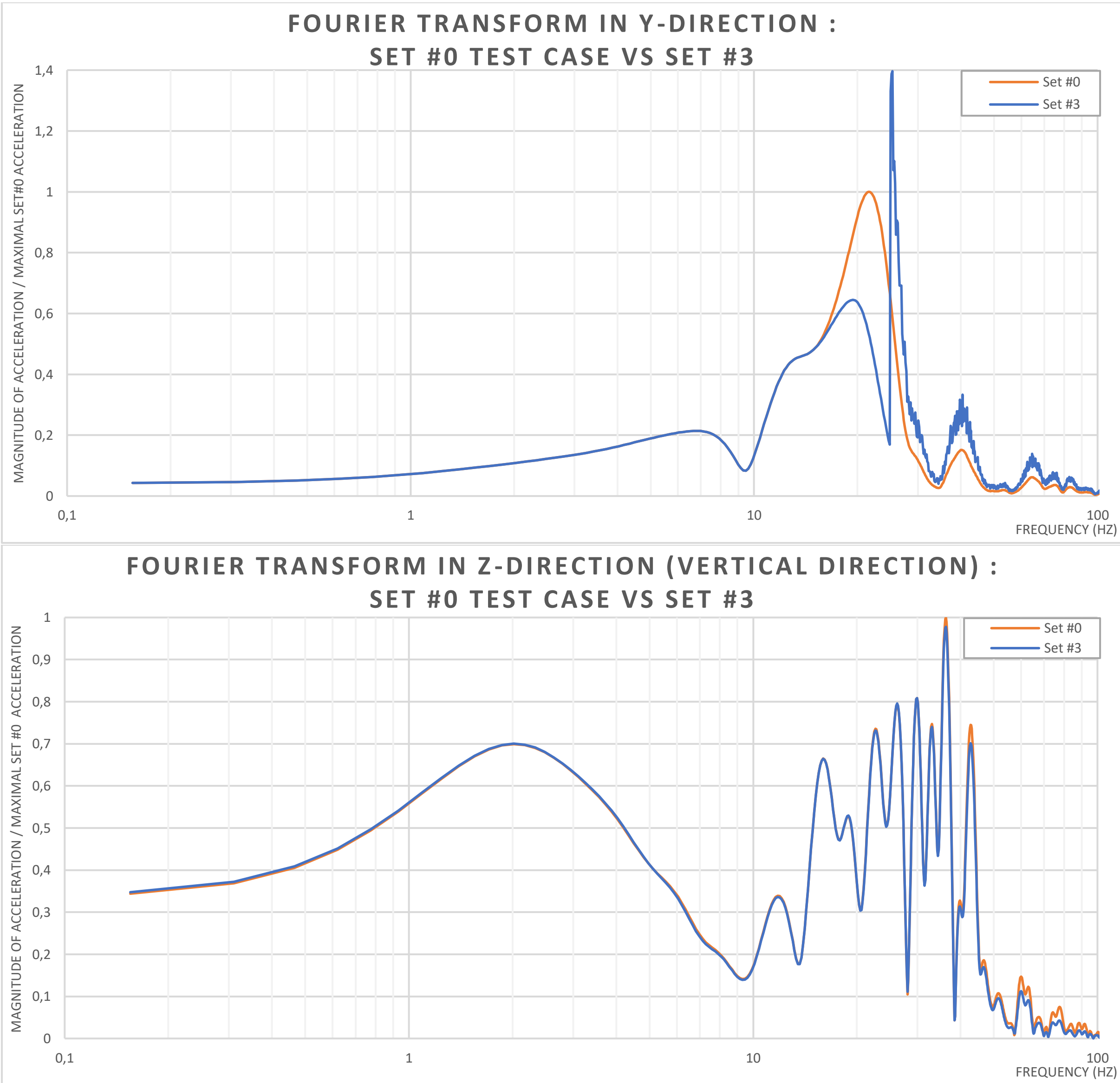


Figure 7: Set #3 acceleration results (frequency content in X, Y and Z directions).

As for set #2, acceleration values are mainly impacted on horizontal directions for high frequencies. The acceleration response spectra is plotted below for the Y-axis:

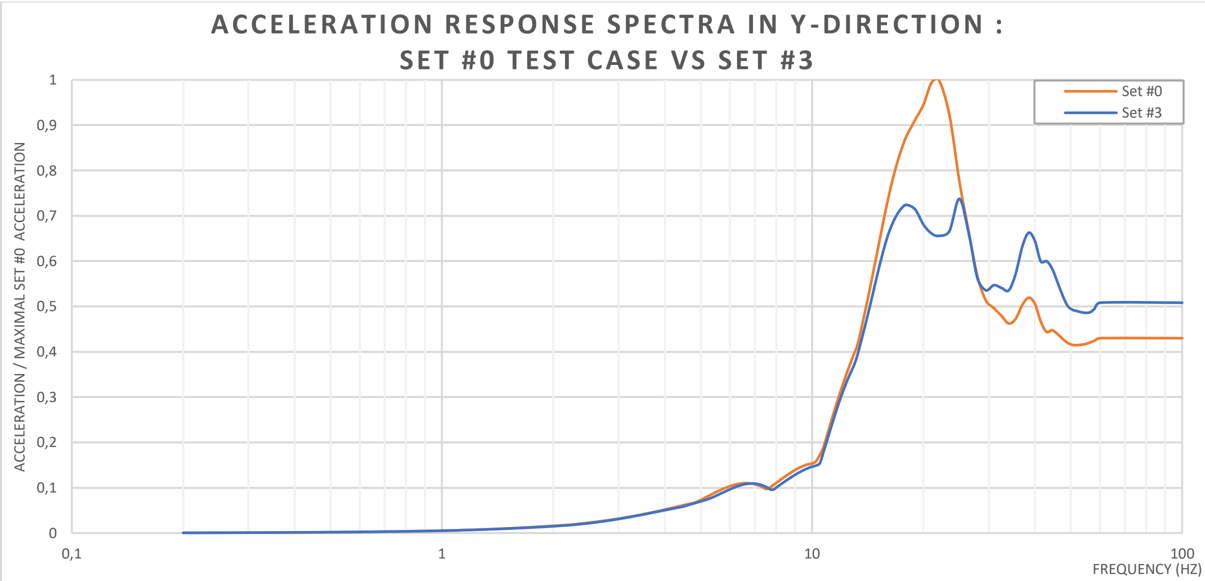


Figure 8: Set #3 acceleration results (response spectra in Y direction).

Unlike set #2, here the gap size is short regarding the displacement values induced by the plane crash. This results in higher acceleration values for high frequencies, due to the shocks between the rods and the plate. This effect can affect the design of the equipment connected to the anchor system.

CONCLUSION

For this set of tests, the sliding of the rods and the existence of gaps between the rods and the base plate of in-slabs pre-casted anchors subjected to fast dynamic loads show significant effects

- A sliding of the rods will result in permanent displacements, but if they are acceptable, they can help to reduce the vertical acceleration transmitted to the anchored equipment.
- Set#2 shows that a 1 mm gap between the rod heads and the steel plate will result in permanent displacements in horizontal directions. If they are acceptable they can help to reduce the horizontal acceleration transmitted to the equipment.
- Set#3 shows that a 0.2 mm gap, might, induce amplifications of horizontal acceleration for some frequencies due to the impacts of the rod heads on the base plate.

Those effects should be taken into account for the design of the anchor itself, and of the equipment connected on it.

REFERENCES

[1] Hervé G. and al. (2013). Optimizing the analysis of airplane crash induced spectra by means of generic airplane methodology, SMiRT-22, San Francisco, August 18-23.