ERIES – VERDI User Group

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Ambient vibration and shake table tests carried out at LNEC on 2026-01-26/28 and 2026-02-24/26

Summary of the test sequence, data outputs and post-processing

Introduction

This document serves as a guide to use the data shared online in the BED portal regarding the experimental campaign of the ERIES-VERDI project, carried out at the National Laboratory for Civil Engineering (LNEC) in Lisbon, Portugal. The data shared includes specimen drawings, material characterization tests, instrumentation detailing, the test sequence data outputs and post-processing for ambient vibration test (AVT) and shake table test (ST). The folders are organised as follows:

- *Test_data*
  - *Drawings*
  - *Seismic_input*
- *Material_tests*
  - *Mortar_elasticity_modulus_ressonance_frequency*
  - *Mortar_elasticity_modulus_ultrasound*
  - *Mortar_flexural_compression_strength*
  - *Stones_compression_strength*
- *AVT_Results*
- *ST_Resullts*
- *Photos*
  - *0 Construction*
  - *1 Instrumentation*
  - *2 Ambient_Vibration_Tests*
  - *3 Shake_Table_Tests*
  - *4 post_shake_table_test_damage_assessment*
- *Videos_Shake_Table_Test*

Test specimen description

A 1:7 scale masonry tower, representative of a structural typology present in the centre and south of Italy, was built at the National Laboratory for Civil Engineering (LNEC) in Lisbon, Portugal. A detailed drawing with the tower geometry and different masonry layout patterns is presented in the folder *Drawings*, file "ERIES-VERDI_Tab2rev_v4.pdf".

The model presents two side walls to reproduce the surrounding aggregates, up to a height of 1.80m. The tower presents a cross section square geometry of 1.00 x 1.00 m^2, 0.20 m thick walls, and a total height of 6.30 m. Rectangular openings are distributed across all four façades, aligned at the same elevation on opposite sides and vertically offset between adjacent façades. The masonry was made of three leaves of rough shaped stones with average dimensions of 60-70 x 60-70 x 130-140 mm^3, mortar joints of about 3-4 mm, and regular horizontal courses.

The construction of the model lasted approximately 1.5 months, taking 13 days to reach up to the side walls total height and the remaining 28 days for the isolated tower above. On average, about 2.5 rows of the isolated tower cross section were built per day. Photos of the construction stages are inside the folder *Photos*.

Material characterization

The construction material was tested at LNEC and their results are in the folder *Material_tests*. The results include the stone's compressive strength, mortars' compressive and flexural strength, mortar's dynamic modulus of elasticity based on ultrasonic pulse velocity, and the mortar's dynamic modulus of elasticity by the frequency of resonance method.

Samples of mortar were collected by LNEC technicians during the construction of the tower and of the small specimens that were used in the characterization of the masonry joints (*wallettes*). A weak hydraulic-lime mortar (class M5) comparable with the overall masonry properties of historical buildings was adopted. However, to guarantee an adequate bonding between the concrete slab foundation and the specimen, a natural hydraulic lime mortar of higher capacity was used on the first three courses (class M15). A total of 8 mortar samples were collected: seven from the mortar used to build the tower (one of type M15, designated R1-M15, and the others of type M5, designated R2-M5 to R7-M5), and one from the *wallettes* (type M5, designated R8-M5). The M5 samples from the tower were gathered from the

following locations: two at the side walls level (one M15 and another M5) and the other seven along the tower's height (all M5), approximately one each tower's level.

Vertical and diagonal compression tests were carried out on masonry *wallettes*; however, results are not yet available up to this date.

Instrumentation

The instrumentation adopted for the ambient vibration and shake table tests is inside the folder *Test_data* in file "Instrumentation_plan.pdf". Besides the instrumentation used for the control of the shake table (3 translations and 3 accelerations), the file includes the description of the accelerometers added to the top surface of the shake table and to the specimen, followed by the instrumentation channels, and the signal convention of each instrumentation channel. Photos of the instrumentation are inside the folder *Photos*.

Ambient Vibration Tests

Ambient vibration tests were carried out before placing the tower on the shake table to characterise its dynamic behaviour, identifying the first and second modes of the structure, thus, enabling the selection of excitation frequencies for the shake table tests. The recorded signals were firstly pre-processed to remove filter initialisation artifacts (first three samples in each channel) and to remove artificial offset/trend (a high pass second order Butterworth forward-backward filter with cut-off of 0.1Hz was applied).

The file "TestSequence_VERDI.xlsx", inside the folder *Test_data*, summarizes the information about the ambient vibration tests (AVT) in tab "AmbientVibrationTests", and the unique name associated with each step to ease the manipulation of the output files. The output files, in ".xlsx" format, associated with the ambient vibration tests, which comprised 21 steps, are located inside the folder *AVT_Results*. Photos of the ambient vibration tests are inside the folder *Photos*.

Shake table tests

The output files associated with the shake table tests, which comprised 97 steps in between seismic tests, dynamic identification tests, ambient vibration tests and other operations performed on the shake table. A set of two ground motion records with increasing intensities

was applied to the shake table in both x and y directions. All data regarding the definition of the seismic input given to the shake table is shared inside the folder *Seismic_input*.

The ground motions were generated to match a code-compliant design elastic response spectrum (ERS) defined according to the Italian Standard for the seismic hazard at the "Sciri" tower coordinates in Perugia, as explained in the file "SCIRI_TOWER - Seismic_Input_Parameters.pdf". The target spectrum was calculated for the Damage Limit State, corresponding to a peak ground acceleration (PGA) of 0.094 g (50-year return period), using the Rexel software provided by ReLUIS. The target real scale ERS was interpolated for time history generation with 200 logarithmically spaced frequencies between 0.25Hz and 50Hz. Moreover, because the tested specimen was built at a 1:7 scale, the target ERS was scaled using the Cauchy similitude law, i.e., by dividing the period and multiplying the spectral accelerations by a factor of 7, but keeping the original sampling frequency. More details about the signal generation are presented in the file "ERIES-VERDI_signal_generation.pdf".

The file "TestSequence_VERDI.xlsx" summarizes the information about the full test sequence in tab "ShakeTableTestSequence", including the detailed description of each test stage, the unique identifier associated with each stage to ease the manipulation of the output files, the number of trials at each stage, as well as observations and comments, namely about the instrumentation of the model. Moreover, Table 1 shows the major steps of the experimental campaign.

The processed data for seismic tests (GMs) and dynamic identification tests (CAT), according to the test sequence, is presented inside the folder *ST_Results* in ".xlsx" format. For CAT tests only accelerations were recorded, while for GM tests all instrumentation was active. Each ".xlsx" file is named according to the corresponding identifier of each CAT and GM, indicated in column P (label "ACQ"). For each test stage, more than one trial may have been executed to achieve the target motion.

Table 1- Test campaign.

Sequence	Test
1	Pink noise X and Y
2	Ambient vibration tests
3	Pink noise X and Y
4	Filtered reduced scale seismic motion 50%
5	Pink noise X and Y
6	Filtered reduced scale seismic motion 100%
7	Pink noise X and Y
8	Filtered reduced scale seismic motion 125%
9	Pink noise X and Y
10	Filtered reduced scale seismic motion 150%
11	Pink noise X and Y
12	Filtered reduced scale seismic motion 175%
13	Pink noise X and Y
14	Filtered reduced scale seismic motion 200%
15	Pink noise X and Y
16	Filtered reduced scale seismic motion 225%
17	Pink noise X and Y
18	Ambient vibration tests
19	Pink noise X and Y
20	Unfiltered reduced scale seismic motion 25%
21	Unfiltered reduced scale seismic motion 50%
22	Unfiltered reduced scale seismic motion 75%
23	Unfiltered reduced scale seismic motion 100%
24	Unfiltered reduced scale seismic motion 125%
25	Pink noise X and Y

The raw data was processed differently depending on the type of test carried out on the shake table and type of measurement:

- Acceleration (in units of mg) in ambient vibration tests – remove filter initialisation artifacts (first three samples in each channel) and apply a high pass second order Butterworth forward-backward filter with cut-off of 0.1Hz to remove artificial offset/trend.

- Acceleration (in units of mg) in seismic tests and dynamic identification tests – remove initial offset (mean of the first 100 samples) and pad final samples from the shake table control system to match the number of samples in the data acquisition system.
- Displacement (in units of mm) in seismic tests and dynamic identification tests – no pre-processing required.
- Synthetic accelerations (in units of mg) in seismic tests – two additional acceleration channels (with suffix "_synth"), one for each direction of the specimen (and of the shake table), were synthesised using a crossover filter between displacements and accelerations of the shake table to be used to compute the test response spectra.

A separate folder was created with representative videos of the seismic tests, named *Videos_Shake_Table_Test*. Videos of the highest intensity tests were included. Photos taken during the shake table test and after for post-test damage assessment were added inside the folder *Photos*.

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