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SHAKING TABLE TESTS OF A REINFORCED CONCRETE PRECAST BUILDING SYSTEM

RELATÓRIO 97/2006 – NESDE

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Trabalho realizado para o projecto:
PRECAST STRUCTURES EC8 – Seismic Behaviour
of Precast Concrete Structures with Respect to Eurocode 8

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1 INTRODUCTION

This report describes the first phase activity of the Portuguese group in the *Precast Structures EC8* research project. The Portuguese group is composed by *Laboratório Nacional de Engenharia Civil* (LNEC) and the *Civibral, S.A.* precast company.

In this phase, seismic tests were made in the LNEC's triaxial shaking table to a 2 stories RC precast structure, designed by *Civibral* using their usual practice. The same company supplied the precast elements and erected them directly on top of the shaking table. The rest of the tasks were performed by the LNEC staff.

This report presents the results and the analysis of the seismic behaviour of the tested specimen. The text is organized in 9 sections. After this introduction, the reference prototype and the idealized model are presented, followed by the instrumentation and test setup. Afterwards, is discussed the global behaviour of the structure and of the beam-column connections, followed by the test conclusions, acknowledgments and bibliography. To make the text more readable, the majority of the test data is presented in 14 annexes and only summaries of results are presented in the main text.

2 PROTOTYPE

2.1 General characteristics

The chosen prototype is a typical precast system from *Civibral* and it is used mainly for industrial buildings. The structure has 2 stories with 4.5m of height each and 10.5x12.0 m^2 in plan. In the longest direction there are 2 bays and only one in the other. All the columns have 0.45x0.45 m^2 of cross section. There are two types of beams: one is L shaped for receiving the loads from the slabs, with outside dimensions of 0.70x0.45 m^2; the other is a rectangular section of 0.70x0.30 m^2 and does not receive load directly from the slabs. The slabs are 2.0 m wide ribbed panels, which structurally works only in one direction. After the erection of the structure, a 5 cm thickness topping layer is concreted on top of the panels. The connections between elements are discussed in section 3 (Model). More detailed information about the prototype is presented in the Annex B drawings.

2.2 Prototype design

The prototype was designed by *Civibral* using their usual practice and considering the Portuguese codes [REAE 1986; REBAP 1983; RSA 1983]. The design report of the prototype is presented in the Annex A.

2.2.1 Loads

The dead loads were calculated using the usual specific weight of RC elements (25 kN/m^3). It was also considered a live load of 5 kN/m^2 on the floors ($\psi_0 = 0.7$; $\psi_1 = 0.6$; $\psi_2 = 0.4$). The earthquake load was obtained from the horizontal components of the semi-artificial *Tolmezzo* accelerograms (Figure 4-1), which were corrected to be compatible with the Eurocode 8, type B soil and 5% of damping [EC8 2003]. The amplitudes of the accelerograms were scaled for PGA=0.25g.

It was used the earthquake spatial combination of the Eurocode 8 [EC8 2003]:

$$\begin{cases} E_x + 0.3\,E_y \\ 0.3\,E_x + E_y \end{cases} \tag{2.1}$$

The combination of loads was calculated using the Portuguese code RSA [RSA 1983]:

$$\begin{cases} S_d = \sum_i \gamma_{g,i}\,G_{k,i} + \gamma_q \left(Q_{k,l} + \sum_{j=2}^{n} \psi_{0,j}\,Q_{k,j} \right) \\ S_d = \sum_i G_{k,i} + \gamma_q\,E_k + \sum_{j=2}^{n} \psi_{2,j}\,Q_{k,j} \end{cases}, \tag{2.2}$$

where:

- $G_{k,i}$ – is the effect of the dead loads;
- $Q_{k,l}$ – is the effect of the main live load used in each combination;
- $Q_{k,j}$ – is the effect of the other live loads considered;
- E_k – is the effect of the earthquake load;
- $\gamma_{g,i}$ – is the partial factor for the dead loads (1.35 for unfavourable effects and 1.0 for favourable);
- γ_q – is the partial factor for the live loads (1.5);
- ψ – is the combination factor.

For comparing the results presented in this report, with the results obtained using other structural codes, that do not apply a partial factor to the earthquake load (e.g. [EC8 2003]), the structure was design for PGA=0.375g, because the effects of the earthquake loads were amplified by a 1.5 scale factor (2.2).

The effects of the earthquake load were obtained from the elastic values reduced by a global behaviour factor of q=2.0.

2.2.2 Materials

The adopted materials are indicated in the Annex B drawings.

2.2.3 Method of analysis

A linear time-history analysis was computed in a commercial 3D finite element program, considering pinned connections between the columns and the beams and full restrained connections between the columns and the foundations.

For considering second order and time effects it was adopted the accidental eccentricity, the creep eccentricity and the second order eccentricity defined in RSA [RSA 1983].

2.2.4 Safety verifications

The safety verifications were made considering the ultimate limit states and serviceability limit states defined in the Portuguese codes.

3 MODEL

3.1 Similitude law

The model conception took in consideration the characteristics of the LNEC's triaxial shaking table (presented in Annex C), namely:

1. Dimensions of the shaking table platform ($4.60 \times 5.60 m^2$);
2. Payload capacity of the shaking table (40 tons).

It was chosen a geometric scale of 1/3 as indicated in equation (3.1). Adopting this geometric scale made possible to use in the scaled specimen the same materials of the prototype (3.2) and still not exceed the 40 tons payload capacity:

$$L_P / L_M = \lambda = 3, \qquad (3.1)$$

$$E_P / E_M = 1. \qquad (3.2)$$

In dynamic tests it is usual to adopt the Cauchy similitude and the Froude similitude simultaneously [Carvalho 1998], that can be expressed through the following relations:

$$Cauchy\ value = \frac{\rho v^2}{E}, \tag{3.3}$$

$$Froude\ value = \frac{v^2}{L g}, \tag{3.4}$$

leading to the additional relations:

$$\left(\frac{\rho v^2}{E}\right)_P = \left(\frac{\rho v^2}{E}\right)_M ; \tag{3.5}$$

$$\left(\frac{v^2}{L g}\right)_P = \left(\frac{v^2}{L g}\right)_M . \tag{3.6}$$

With the relations indicated in the equations (3.1), (3.2), (3.5) and (3.6), is possible to define all the relevant scale factors (see Table 3-1).

Parameter	Symbol	Scale Factor $(\ )_P/(\ )_M$
Length	L	$L_P/L_M = \lambda = 3$
Modulus of elasticity	E	$E_P/E_M = e = 1$
Specific mass	ρ	$\rho_P/\rho_M = \rho = \lambda^{-1} = 0.33333$
Area	A	$\lambda^2 = 9$
Volume	V	$\lambda^3 = 27$
Mass	m	$\lambda^2 = 9$
Displacement	d	$\lambda = 3$
Velocity	v	$\lambda^{1/2} = 1.73205$
Acceleration	a	1
Weight	w	$\lambda^2 = 9$
Force	F	$\lambda^2 = 9$
Moment	M	$\lambda^3 = 27$
Stress	σ	1
Strain	ε	1
Time	t	$\lambda^{1/2} = 1.73205$
Frequency	f	$\lambda^{-1/2} = 0.57735$

Table 3-1: Similitude law scale factors.

The major consequences of using this similitude law are:

- time "compression" of the test,

$$t_P/t_M = \sqrt{\lambda} = 1.73205 ; \tag{3.7}$$

- same accelerations on the model and on the reference prototype:

$$a_P/a_M = 1 ; \tag{3.8}$$

- the specific mass of the model should be λ times greater than the mass of the prototype:

$$\rho_P/\rho_M = \lambda^{-1} = 0.333(3)\,. \tag{3.9}$$

This last relation has an important consequence on the tests. Since we are using the same materials (initial criteria), it is required to use additional masses on the scaled specimen.

3.2 Additional masses calculations

3.2.1 Number of masses

In Figure 3-1 is presented a summary of the calculations made for determining the amount of additional masses to be added to the specimen.

Weight of the prototype after concreting: $W^P = 1784.25\,kN$;

Equivalent value for the model: $W^M = \dfrac{1784.25}{\lambda^2} = 198.25\,kN$;

Weight of the model after concreting (includes topping layer): $W^P = 157.55\,kN$;

Weight due to the reduced value of the live load: $W^{SC} = \psi_2 \times Q \times A_f \times nfloors = 56.00\,kN$;

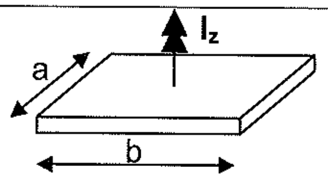
Weight to be added: $W^{MAS} = 198.25 - 157.55 + 56 = 96.7\,kN$;

= 8 masses of 6 kN in each floor.

Figure 3-1: Additional masses calculations.

3.2.2 Positioning criteria

The used criteria was to enforce that the additional masses should have the same translational inertia and polar moment of inertia, of a uniform mass thin shell with the same mass and with the dimensions of the slabs (see Figure 3-2)



$$I_z = \frac{1}{12} M (a^2 + b^2)$$

Figure 3-2: Additional masses positioning criteria.

The adopted distribution is presented on drawing nº9 in the Annex D and a detailed view of the fixing system in the Figure F-9.

3.3 General characteristics

The adopted model is directly a 1/3 scaled version of the prototype with differences only on the slabs, which are solid instead of ribbed because of construction difficulties. The thickness of the model's topping layer was chosen to match the flexure moment of inertia of the prototype. Rubber supports were used to simulate the non-continual contact points between the slabs and the L shaped beams.

There are two types of beam-column connections:

1. The first connects the columns and the L shaped beams (see Figure 3-3 and Figure 3-5a). During erection of the structure, the beams are supported by hollow box sections that are firmly connected inside the columns. On top of the beams there is a steel plate where a pre-stressed bolt connects it to the hollow box. The steel plate is also connected to the column using welded bolts. Before concreting the topping layer the voids are filled with a mortar through an inclined hole.

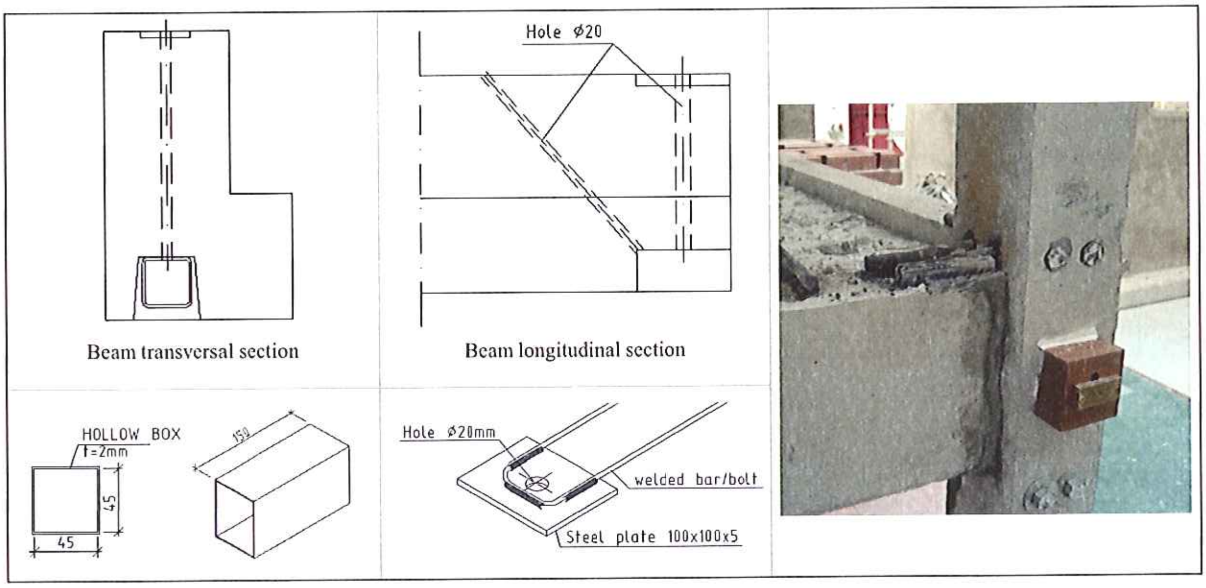


Figure 3-3: Beam-column connection type #1.

2. The second type of beam-column connection is similar to the first one (see Figure 3-4 and Figure 3-5b). The major difference consists in using an angle section instead of the hollow box referred above.

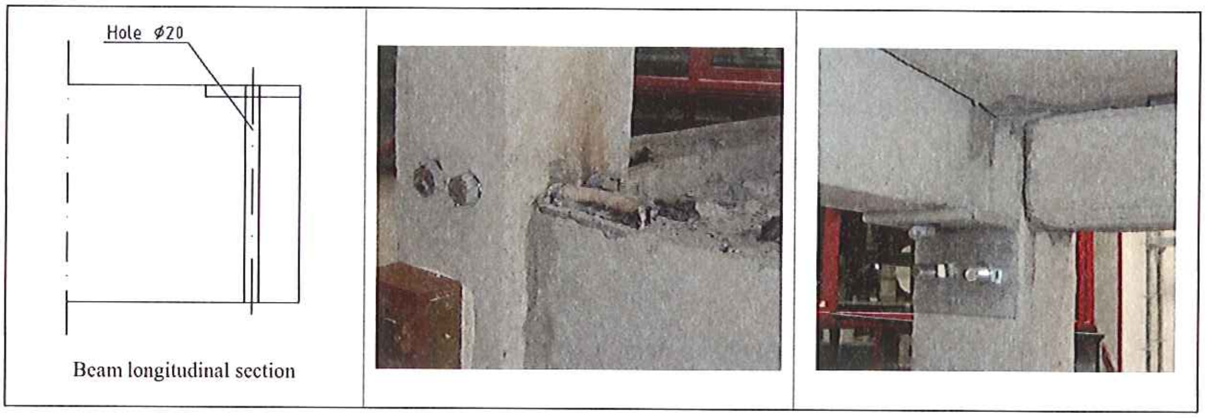


Figure 3-4: Beam-column connection type #2.

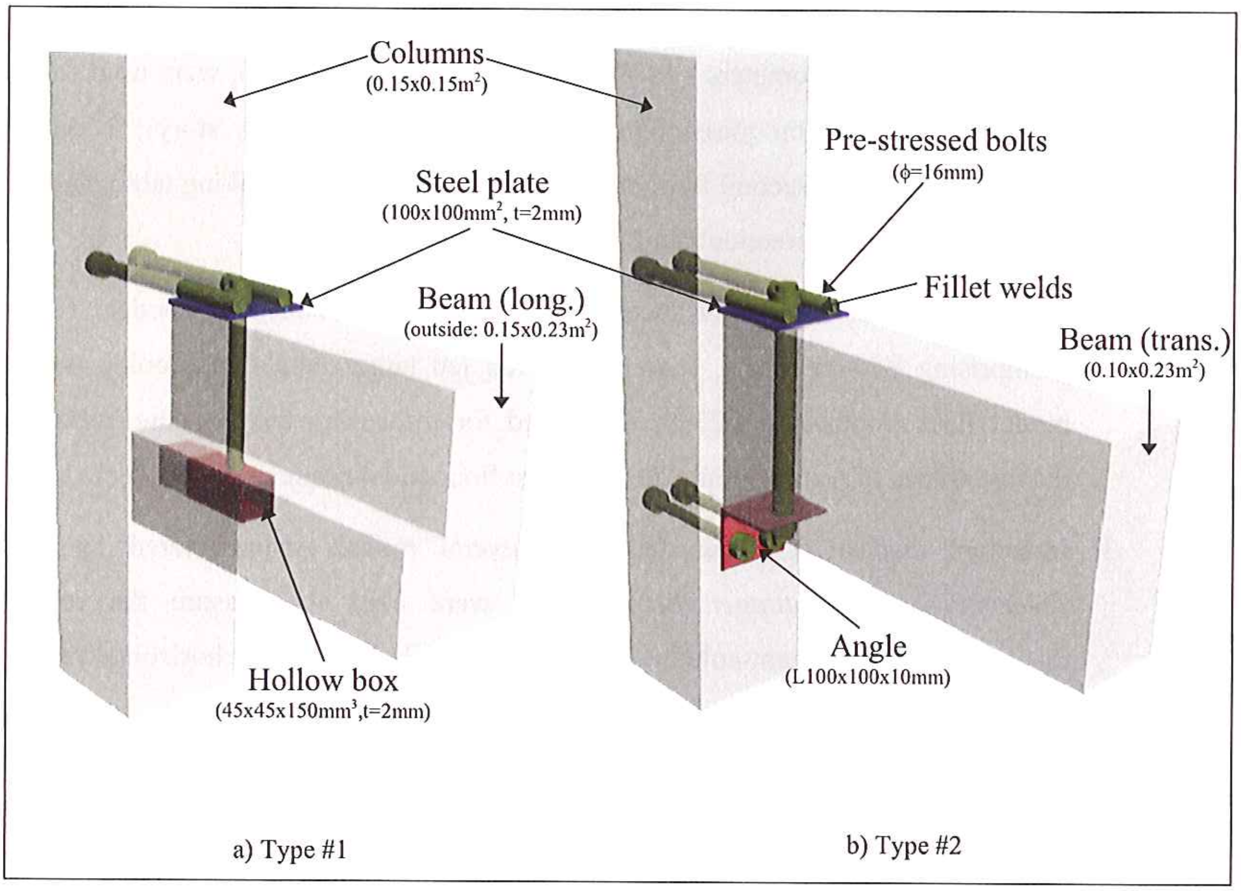


Figure 3-5: 3D visualization of the beam-column connections.

The columns and the footings were cast together in one monolithic element.

Detailed information of the model is available in the Annex D drawings and in the Figures F-1 to F-8.

3.4 Erection of the specimen

The specimen was erected directly on top of the shaking table by *Civibral's* specialized personal. The joint sealing operation and the concreting of the topping layer were made by the LNEC staff.

4 INSTRUMENTATION AND TEST SETUP

4.1 Instrumentation

The specimen was instrumented with the following type of sensors:

1. Piezoelectric accelerometers - *PCB Piezotronics*, model 337A26, were used for the horizontal acceleration measurements on 12 joints (6 in each story), 3 vertical accelerations on the second floor slabs and 4 accelerations in shaking table platform (2 in the horizontal direction and 2 in the vertical).
2. Optical displacement transducers – *Hamamatsu Photonics*, model C5949 (comprising F50 mm lens, sensor head and led target) and conditioning device, model PSH Controllers C2399, were used for measuring the absolute horizontal displacements of 6 slab points (2 on the first floor and 4 on the second floor).
3. Inductive displacement transducers – Several models manufactured by *RDP Electronics* and *Hottinger Baldwin M.*, were used to measure the relative displacements of 8 beam-column connections, 4 slab diagonals, 2 horizontal relative displacements and the horizontal displacements of the shaking table.

More information about the sensors technical specifications are available in the Annex E.

Photographic and video recording were also made during the tests. The photographs were taken using a digital camera and the video records were made using a tripod mounted camera.

4.2 Test setup

In the Annex E drawings is presented detailed information about the positioning of the sensors, channels lists and reports of the math channels calculations. A selection of photographs of the test setup is presented in the Annex F (Figures F10 to F16).

4.2.1 Earthquake input

The earthquake input used on the tests was the horizontal components of the *Tolmezzo* semi-artificial accelerogram, generated to be compatible with the EC8, soil B, 5% damping response spectra (see Figure 4-1). The *Acc X* component was the input in the transversal direction of the shaking table (E-W) and the *Acc Y* component in the longitudinal (N-S), as indicated in Figure 4-2.

The records were time scaled to cope with the similitude law (3.7), adapted to the shaking table, and transformed into displacement records.

4.2.2 Test programme

The test programme included two types of series:

1. The *Stage Series,* which are the main earthquake series. The first stage (Stage 00) was arround PGA=0.1g on both directions, followed by increasing intensity stages with the approximated pattern: $PGA^{Trans} \simeq PGA^{Long} \times 1.5$. At the end of the test there were 5 stages (Stage 00 – Stage 04).
2. The *Cat Series,* that precede every Stage Series, are low amplitude, broadband base signals with the objective of estimating the specimen's dynamic characteristics and their evolution during the test.

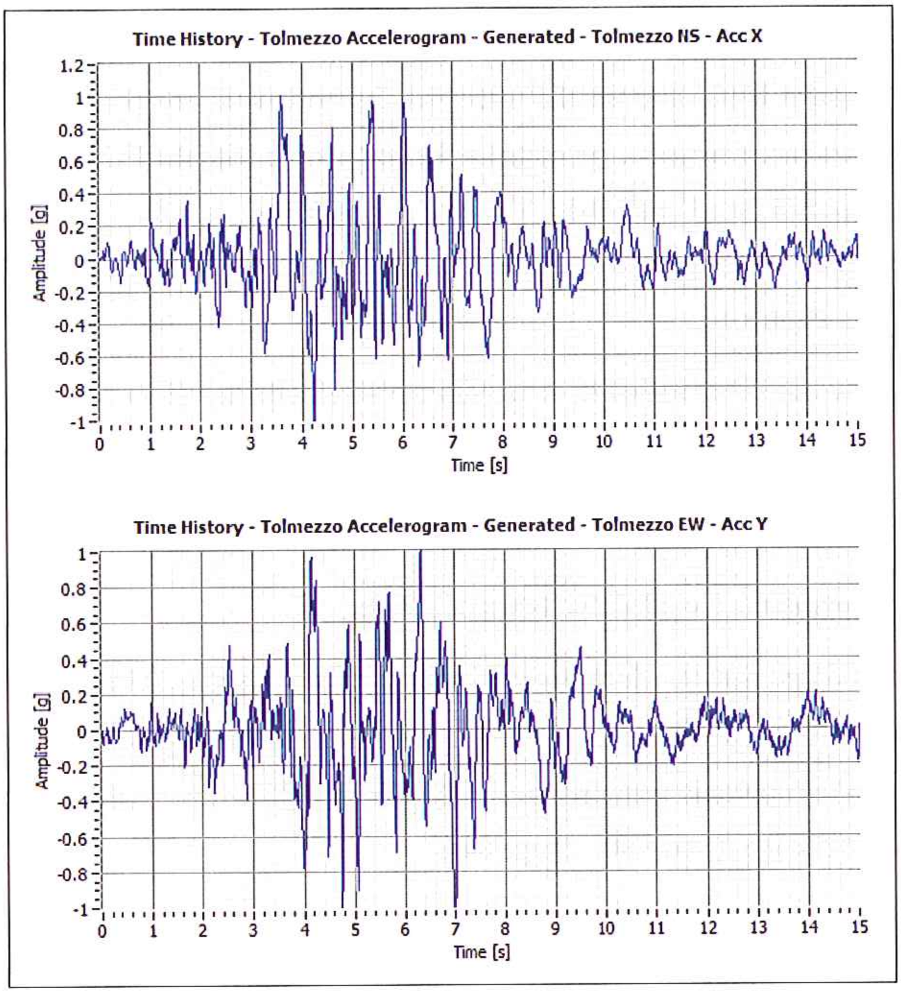


Figure 4-1: Semi-artificial *Tolmezzo* accelerogram.

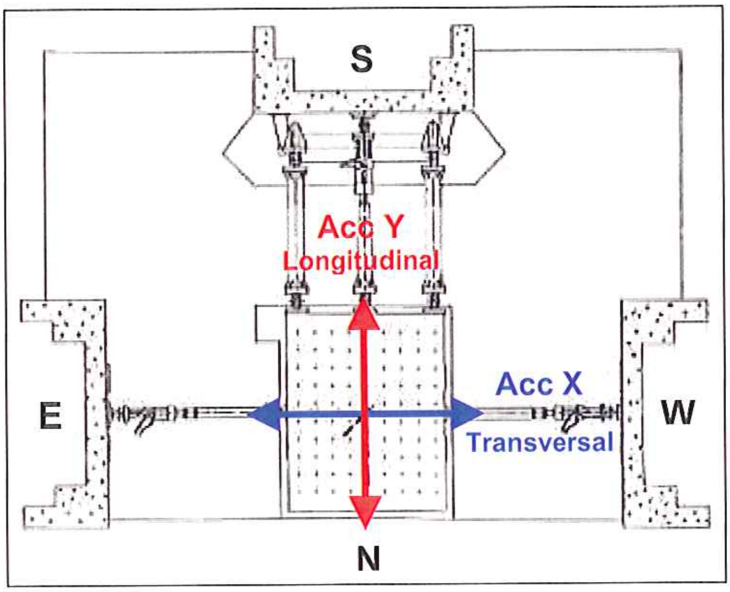


Figure 4-2: Earthquake components.

5 GLOBAL BEHAVIOUR ANALYSIS

5.1 Observed behaviour

During and after the test the following behaviour was observed:

- Beams and columns (away from the beam-column connections)

  Away from the connections, the beams sustained a very small amount of visible damage (see Figure F-18, F-19).

  The visible damage on the columns was also very small, even in high moment zones, probably due to cantilever design (see Figure F-20, F-33).

- Beam-column connections – Type #1

  In this type of connection medium to high damage was observed (see Figure F-18 to F-19 and F-29 to F-32).

  In many cases the concrete was crushed on the beams and on the columns (see Figure F-27, F-28).

- Beam-column connections – Type #2

  Severe damage was observed and there were visible crushed concrete in all cases (see Figure F-23, F-24).

  One large crack appeared on the bottom of the beams, through the vertical bolt hole (see Figure F-21, F-22).

- Cracking

  A small amount of cracks, not directly related with the beam-column connection mechanism, were observed and the opening of the cracks was small (see Figure F-31, F-32, F-34)

- Topping layer

  Near the columns and in the earlier stages of the tests, the topping layer was crushed and separated (see Figure F-35, F-36). In the rest of the areas only light damage was visible (small cracking).

5.2 Experimental modal frequencies

The modal frequencies were identified using frequency response functions estimations and the peak picking method. Only translational modes were identified because the torsion modes do not have enough amplitude. The lack of amplitude of the torsion modes is due to 2 main reasons: firstly, the structure is symmetric on both horizontal directions, leading to a very close center of mass (CM) and center of stiffness (CS), even after damage; secondly, the stimulus in the *Cat Series* is only of translational type, because the rotation d.o.f. are passively restrained in LNEC's triaxial shaking table.

The identified modal frequencies are presented numerically in Table 5-1 and graphically in Figure 5-1. The identified frequency response functions (FRF) peaks are presented in the Annex G.

Experimental Modal Frequencies (Model) [Hz]				
Series	1st Trans.	2nd Trans.	1st Long.	2nd Long.
Cat 00	2.9	9.0	3.2	14.3
Cat 01	2.3	7.7	2.9	12.6
Cat 02	2.0	6.6	2.7	11.5
Cat 03	1.4	5.5	2.4	9.6
Cat 04	1.2	4.9	1.9	8.4

Table 5-1: Experimental modal frequencies – Model.

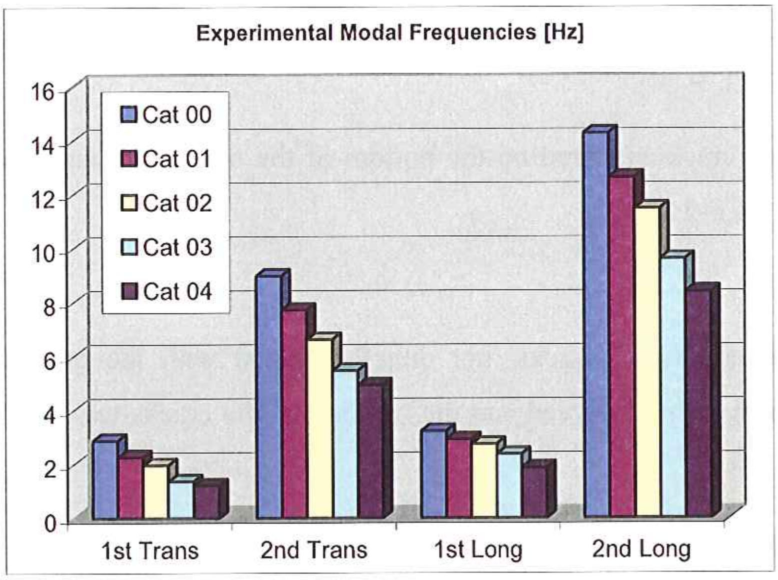


Figure 5-1: Experimental modal frequencies – Model.

A linear dynamic analytical model was used for validating the results of the experimental modal frequencies. These results are presented and compared with the experimental values in Table 5-2.

Modal Frequencies [Hz]	Linear Dynamic Model			Experimental				
	Model #1	Model #2	Model #3	Cat 00	Cat 01	Cat 02	Cat 03	Cat 04
First - Transversal	3.04	1.32	0.93	2.9	2.3	2.0	1.4	1.2
First - Longitudinal	4.01	1.32	0.93	3.2	2.9	2.7	2.4	1.9
First - Torsion	5.65	2.88	2.47	-	-	-	-	-
Second - Transversal	10.39	8.61	6.12	9.0	7.7	6.6	5.5	4.9
Second - Longitudinal	11.59	8.61	6.12	14.3	12.6	11.5	9.6	8.4
Second - Torsion	16.67	13.34	9.99	-	-	-	-	-
Beam-column connec.	Rigid	Pinned	Pinned	-	-	-	-	-
Cracking	No	No	50% stiff.	-	-	-	-	-

Table 5-2: Analytical and experimental modal frequencies.

For the first modes, the frequencies of the analytical model with rigid beam-column connections and with uncracked sections (model #1) are close to the initial experimental results (Cat 00). After all test stages, the results for the first modes are similar to the analytical model with pinned beam-column connections and 50% flexure stiffness reduction due to cracking (model #3). In the longitudinal directions the experimental frequencies are greater than expected, mainly due to less damage in the connections leading some rotational stiffness.

To obtain the equivalent modal frequencies in the prototype is necessary to apply the expression (3.7).

5.3 Earthquake scenario

A first analysis to the measured base accelerations gave the PGA values presented in Table 5-3 and in Figure 5-2.

PGA [g]	Trans.	Long.
Stage 00	0.09	0.10
Stage 01	0.27	0.18
Stage 02	0.45	0.29
Stage 03	0.89	0.72
Stage 04	1.26	1.18

Table 5-3: Measured peak ground accelerations.

An extensive list of ground motion parameters is presented in the Annex H.

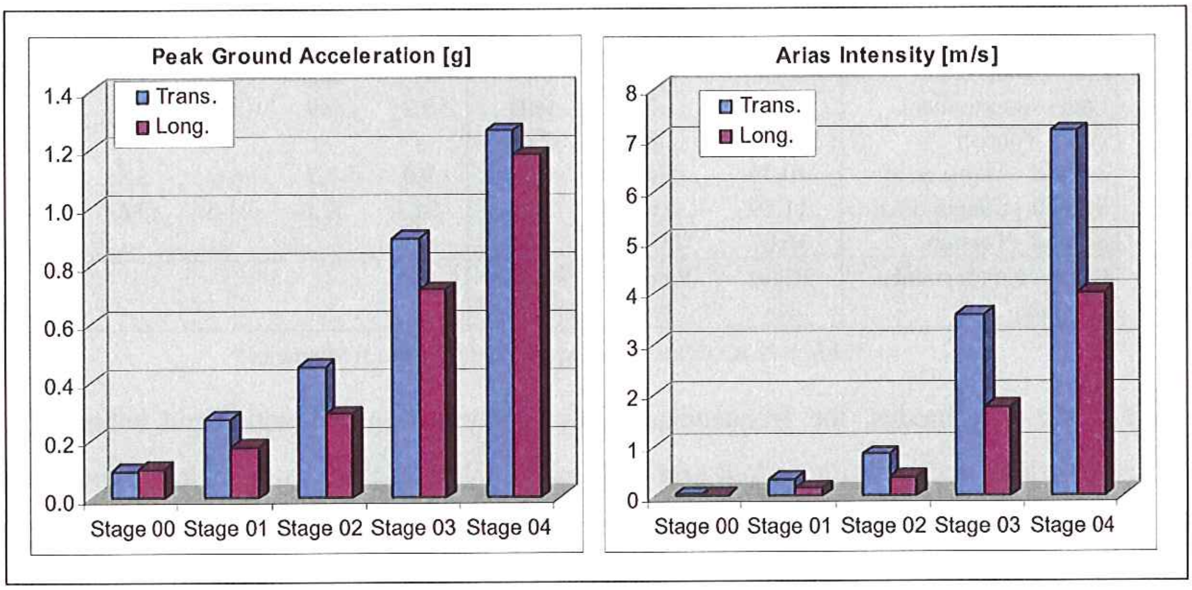


Figure 5-2: Measured PGA and Arias intensity.

Analysing the results more deeply is possible to conclude that the measured values of PGA were influenced by shaking table high frequency, narrow band acceleration peaks (away from the structure principal modal frequencies) and are not the best parameter to quantify the earthquake intensity (see Figure 5-3)

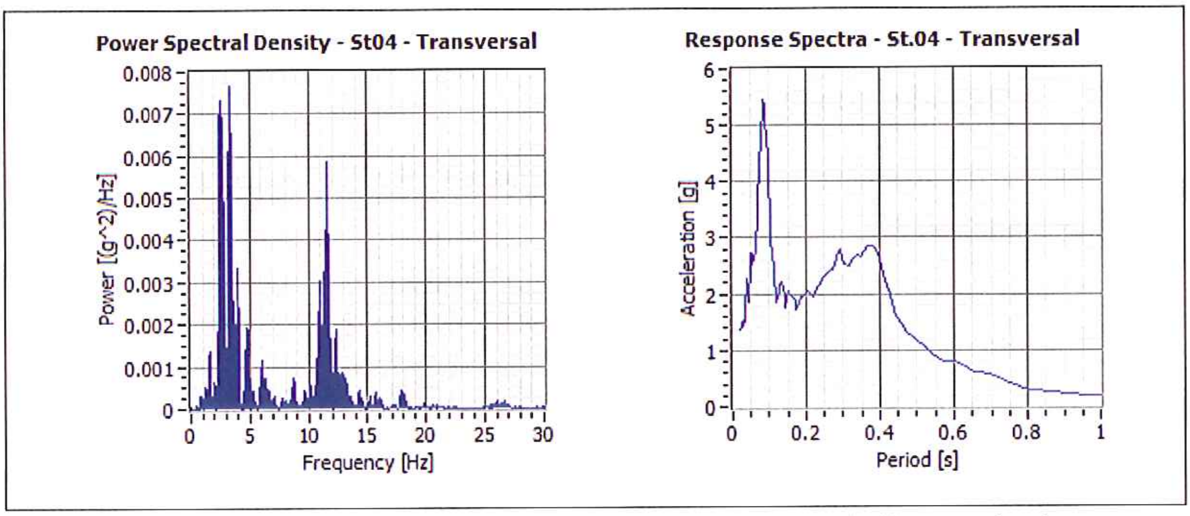


Figure 5-3: Power spectral density and elastic response spectra of typical base accelerations.

To reduce this effect on the PGA values it was used an energy related parameter, *Arias Intensity* (4.1) and the actual target accelerogram,

$$I_a = \frac{\pi}{2g} \int \left[a(t) \right]^2 dt \,. \tag{4.1}$$

The adopted procedure was to use a modified peak ground acceleration (PGA*), which the Arias intensity parameter of the *Tolmezzo* accelerogram corresponds to the same value on the measured series (see Figure 5-4).

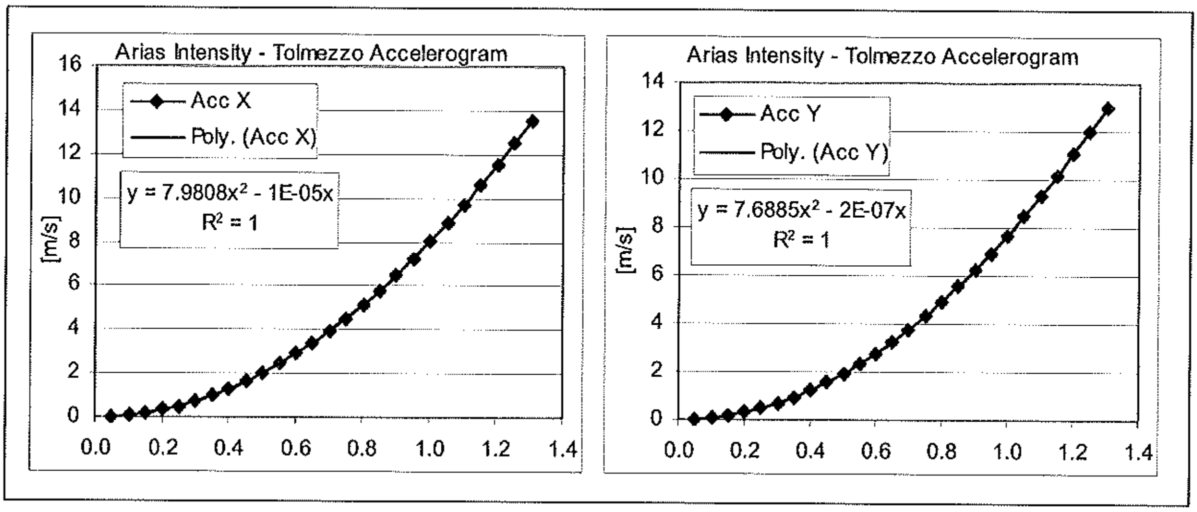


Figure 5-4: Discrete values of the Arias intensity parameter for different PGA values.

The results are presented in Table 5-4. These values revealed some reduction of the PGA values and good correspondence with the target in the response spectra diagrams (see Annex H). The values of the peak ground acceleration (PGA*) were adopted in this report.

PGA* [g]	Trans.	Long.
Stage 00	0.07	0.08
Stage 01	0.21	0.14
Stage 02	0.32	0.23
Stage 03	0.67	0.48
Stage 04	0.95	0.72

Table 5-4: Corrected peak ground accelerations.

Comparing the response spectra of the measured ground acceleration with the target values (see Annex H) revealed good correspondence in the transversal direction (although some differences in the plateau zone and in the higher periods) and only medium quality in longitudinal direction. The principal reason for this problem was due to different specimen-shaking table interaction that the one considered in the signal adaptation, which were performed long-time before and for another test programme.

5.4 Floor diaphragm

For monitoring the deformation of the floors and for testing the viability of considering them as rigid diaphragms, it was measured the deformations of 4 diagonals on the second story floor. Some technical reports indicate that the relative rotations in beam-column connections, typical of some precast structures, leads to beam elongation that can promote relative displacements between elements (see Figure 5-5).

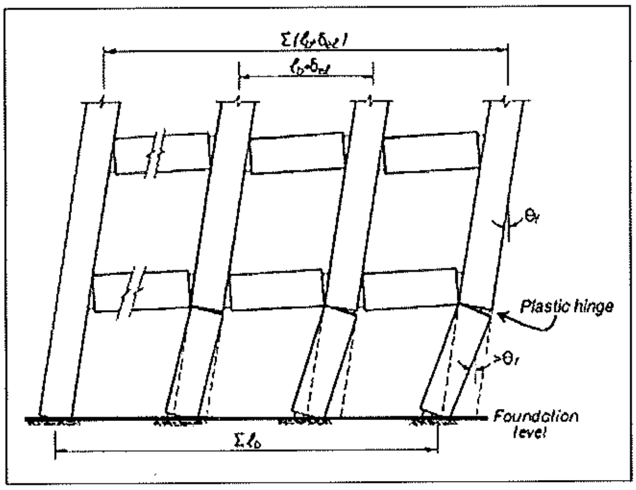


Figure 5-5: Effect of beam elongation (adapted from [FIB 2003]).

The results of the diagonals deformations are presented in Annex I and summarized in Table 5-5.

Deformation	Stage 00	Stage 01	Stage 02	Stage 03	Stage 04
Diagonal RD1	0.00%	0.00%	0.01%	0.04%	0.05%
Diagonal RD2	0.00%	0.00%	0.01%	0.06%	0.09%
Diagonal RD3	0.00%	0.00%	0.01%	0.02%	0.03%
Diagonal RD4	0.00%	0.00%	0.02%	0.07%	0.11%

Table 5-5: Maximum values of the diagonals deformations.

These values revealed very small deformations in the diagonals, less than 0.11% or 4.4 mm in 3.95 m diagonals, and part can be due to the transducers layout.

Taking also in consideration that some codes classify, for design proposes, a diaphragm as flexible when their deformation is more than twice the interstory drift of the associated floor [ICBO 1997], that in our case is about 3% (see section 5.6), so using this criteria the specimen's floors can be consider as rigid and it is feasible to use a 3 d.o.f. model for each.

5.5 Center of mass displacements

The center of mass accelerations, relative displacements and the polar diagrams presented in the Annex J were obtained using a 3 d.o.f. model (2 translations and 1 rotation about the vertical axis in each floor). The maximum values are summarized in Table 5-6 and in Figure 5-6.

Center of Mass	Units	Stage 00	Stage 01	Stage 02	Stage 03	Stage 04
1st Floor - Rel. Disp. - Trans.	[mm]	4.0	8.5	11.2	20.6	23.6
1st Floor - Rel. Disp. - Long.	[mm]	2.4	4.6	6.5	13.6	27.2
1st Floor - Rel. Rotation	[°]	0.02	0.02	0.04	0.06	0.08
2nd Floor - Rel. Disp. - Trans.	[mm]	6.6	16.5	24.1	47.1	59.0
2nd Floor - Rel. Disp. - Long.	[mm]	2.5	6.6	10.6	23.9	48.1
2nd Floor - Rel. Rotation	[°]	0.00	0.00	0.00	0.01	0.01

Table 5-6: Center of mass maximum relative displacements and rotations.

The displacements were higher in the transversal direction (see Figure 5-6) but in the last stage the longitudinal displacements increased more, probably due to the development of damage. As expected, the floors rotations are very small because of the biaxial symmetry of the structure.

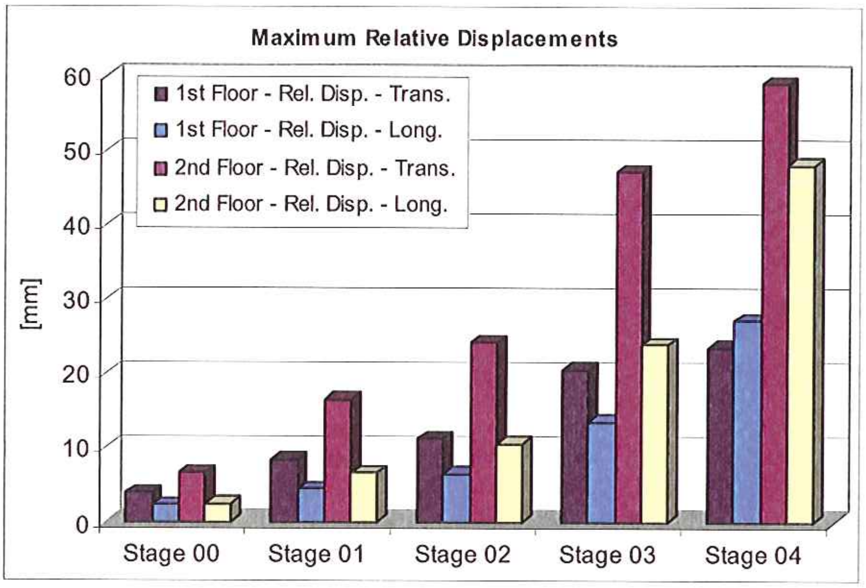


Figure 5-6: Center of mass maximum relative displacements.

5.6 Interstorey drifts

In Table 5-7 is presented the maximum values of the interstorey drifts obtained on the conner columns and on the center of mass of each storey. The time-histories are presented in the Annex K.

The maximum values of the center of mass interstorey drifts were about 0.3% in stage 00, 0.6% in stage 01, 0.9% in stage 02, 2.1% in stage 03 and 2.9% in stage 04. Some columns achieved higher values (e.g. 3.4% on the second floor NW column) as the CM values tends to be averaged due to incipient torsion.

Position		Stage 00		Stage 01		Stage 02		Stage 03		Stage 04	
		Trans.	Long.	Trans.	Long.	Trans.	Long.	Trans.	Long.	Trans.	Long.
Columns	1st F. NW	0.3%	0.2%	0.6%	0.3%	0.8%	0.5%	1.5%	1.0%	1.7%	1.9%
	1st F. SE	0.2%	0.1%	0.6%	0.2%	0.7%	0.4%	1.3%	0.9%	1.3%	1.9%
	1st F. NE	0.2%	0.1%	0.4%	0.1%	0.5%	0.2%	0.9%	0.6%	0.8%	0.6%
	1st F. SW	0.2%	0.1%	0.5%	0.1%	0.7%	0.2%	1.2%	0.5%	1.4%	0.8%
	2nd F. NW	0.3%	0.1%	0.8%	0.3%	1.2%	0.6%	2.7%	1.2%	3.4%	2.6%
	2nd F. SE	0.2%	0.2%	0.5%	0.2%	0.9%	0.3%	2.1%	0.9%	2.9%	1.4%
	2nd F. NE	0.2%	0.1%	0.6%	0.2%	1.0%	0.4%	2.1%	0.9%	2.7%	1.7%
	2nd F. SW	0.2%	0.2%	0.7%	0.3%	1.1%	0.5%	2.2%	1.1%	2.8%	2.6%
CM	1st F. CM	0.3%	0.2%	0.6%	0.3%	0.7%	0.4%	1.4%	0.9%	1.6%	1.8%
	2nd F. CM	0.2%	0.1%	0.6%	0.2%	0.9%	0.4%	2.1%	0.9%	2.9%	1.4%

Table 5-7: Maximum interstorey drifts.

The maximum values were achieved on the second floor, mainly because in the final test stages the columns behaved more as cantilevers then as part of a frame system. In the early stages, the maximum interstorey drifts were obtained on the first floor (frame effect).

The graphical representation of the center of mass interstorey drifts versus earthquake input (PGA*) presented in Figure 5-7, shows an almost linear relation with some slope increasing due to damage. The only visible exception is on stage 04, in the transversal direction, that seams to "regain stiffness". In this direction the damage of the structure shifted its dynamic behaviour to a frequency band with lower energy contents, so the large increase in the PGA* value is not representative of the real earthquake input (see section 5.7). Another explanation could be that the interstorey drift is near the maximum physical value, leading to a shape typical of a fragility curve.

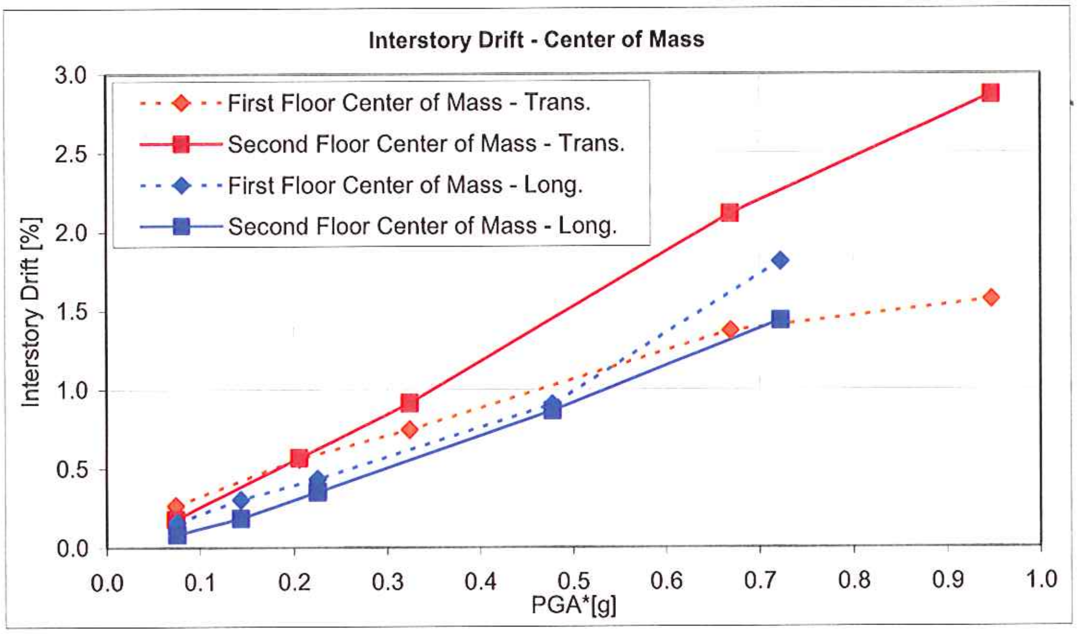


Figure 5-7: Center of mass interstorey drifts.

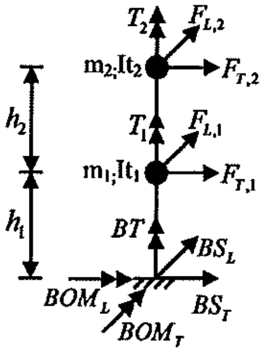
5.7 Global forces

For estimating the global forces developed on the specimen it was used a simplified model that assumes that the inertia forces are equal to the restoring forces (neglecting damping forces):

$$\begin{cases} \{F_i\}+\{F_d\}+\{F_k\}=0 \\ \{F_d\}\approx 0 \end{cases} \Rightarrow \{F_i\}\approx -\{F_k\}. \qquad (4.2)$$

This model gives only approximated values, with more accuracy when the velocities are small (viscous damping), but enables to compute forces and moments using only the measured cinematic values.

The inertia and torque forces (IF, IT), the story inertia and torque forces (SF, ST), the base shear (BS) and the base overturning moment (BOM) were computed as defined in Figure 5-8.



$$IF_{T,i} = m_i \; a_{T,i} \; ; \; IF_{L,i} = m_i \; a_{L,i} \; ; \; IT_i = It_i \; a_{Tor,i}$$

$$SF_{T,i} = \sum_{k=i}^{ns} IF_{T,k} \; ; \; SF_{L,i} = \sum_{k=i}^{ns} IF_{L,k} \; ; \; ST_i = \sum_{k=i}^{ns} IT_k$$

$$BS_T = \sum_{i=1}^{ns} IF_{T,i} \; ; \; BS_L = \sum_{i=1}^{ns} IF_{L,i} \; ; \; BT = \sum_{i=1}^{ns} IT_i$$

$$BOM_T = \sum_{i=1}^{ns} IF_{T,i} \, h_i \; ; \; BOM_L = \sum_{i=1}^{ns} IF_{L,i} \, h_i$$

ns – Number of storey		SF	– Story inertia force
m – Story mass		ST	– Story inertia torque
It – Story torsion inertia		BS	– Base shear
IF – Inertia force		BOM	– Base overturning moment
IT – Inertia torque			

Figure 5-8: Simplified global model.

The global forces time-histories are presented in the Annex L. The maximum values are summarized in Table 5-8.

	Units	Stage 00	Stage 01	Stage 02	Stage 03	Stage 04
Base Shear - Trans.	kN	35.7	60.8	61.8	78.0	76.7
Base Shear - Long.	kN	22.1	39.7	51.3	84.0	128.5
Base Torque	kN.m	0.03	0.10	0.19	0.42	0.54
Base Overt. Mom. - Trans.	kN.m	82.4	139.9	163.6	192.9	139.1
Base Overt. Mom. - Long.	kN.m	50.0	94.2	122.5	216.3	296.0

Table 5-8: Maximum values of the global forces.

The maximum values of base shear are initially higher in the transversal direction, but in the last 2 stages the values in the longitudinal direction increased significantly (see Figure 5-9). This behaviour is due to less earthquake input in the transversal direction in Stage 03 and 04, although the PGA values are always greater. These results are expected because of the changes in the dynamic characteristics of the structure to an input frequency band with lower energy contents (see Figure 5-10).

Very small values of the base torque were obtained.

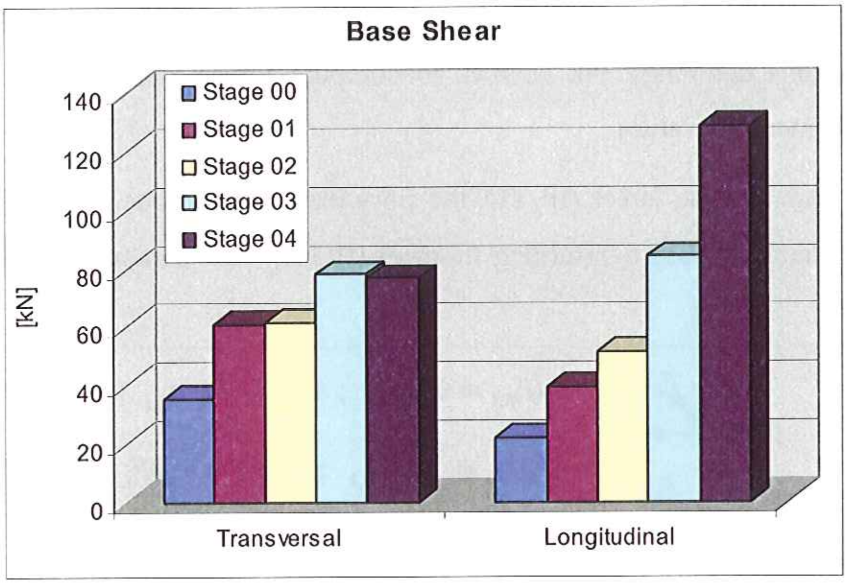


Figure 5-9: Base shear maximum values.

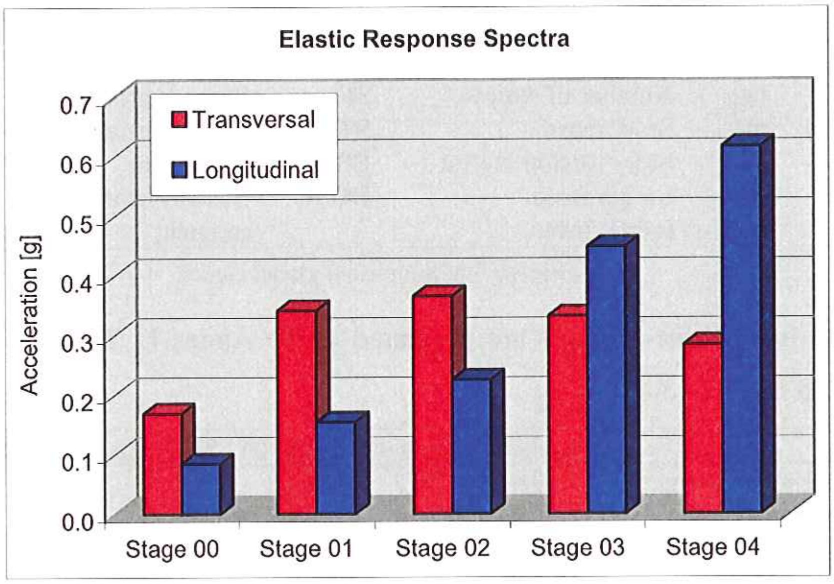


Figure 5-10: Elastic response spectra values for the fundamental modal frequency.

Taking in consideration that the specimen weighted 254 kN (see Figure 3-1) the values of the ratio of the maximum base shear vs. weight of the specimen are presented in Table 5-9. We conclude that the sum of the calculated inertia forces reached 31% of the specimen weight in the transversal direction and 51% in the longitudinal direction.

Stage 00	Stage 01	Stage 02	Stage 03	Stage 04
0.14	0.24	0.24	0.31	0.30
0.09	0.16	0.20	0.33	0.51

Table 5-9: Values of the maximum base shear vs. weight of the specimen ratio.

5.8 Histeresis loops

The simplified model used for the global forces (Figure 5-8) allows computing the global and the storey histeresis loops presented in the Annex M.

In the global histeresis loops (base shear vs. top relative displacement) is possible to observe the following behaviour:

- In Stage 00, the results are strongly influenced by high noise/signal ratio and have no physical meaning;
- In Stage 01 is possible to observe non-linear behaviour in the transversal direction, with some energy dissipation, and in the other direction an almost elastic response;
- In Stage 02, the global behaviour is similar to the previous stage, with increasing amplitude in the cycles, decreasing of the stiffness and some pinching effect in the transversal direction. In the other direction the non-linear behaviour is still not evident;
- In Stage 03, the stiffness of the structure in the transversal direction is very small and the diagrams exhibit the presence of higher mode contributions. On the longitudinal direction non-linear phenomena appears more visible;
- In Stage 04, the transversal direction shows only residual stiffness and in the longitudinal direction the diagram shows a highly non-linear behaviour with a clear pinching effect, due to the opening and closing of beam-column connections;

In the storey histeresis loops (interstorey shear vs interstorey drift), also presented in the Annex M, is possible to observe the same behaviour, confirming the results obtained in the global histeresis loops.

6 BEAM-COLUMN CONNECTIONS

As indicated in section 4.1, the displacements of 8 beam-column connections were measured using displacement transducers in the top and bottom faces of the beams (see drawing nº 2 of the Annex E). These displacements were also converted to global opening and relative rotation as indicated in the Annex N. In the same annex is also presented the time-histories of the displacements, with all stages joined in one diagram to allow a more clear view of the displacements' progression. The maximum values are presented in Table 6-1 and in Figure 6-1.

Joint	Top opening (max-final) [mm]		Bottom opening (max-final) [mm]		Global relative disp. (max-final) [mm]		Global relative rotation (max-final) [rad]		[°]	
Joint 3 - Trans.	5.0	2.3	5.9	2.4	4.8	2.4	0.018	0.000	1.0	0.0
Joint 9 - Trans.	2.5	1.2	8.4	5.3	4.8	3.3	0.036	0.021	2.1	1.2
Joint 3 - Long.	1.4	0.0	4.7	0.5	3.0	0.2	0.021	0.003	1.2	0.1
Joint 9 - Long.	0.6	0.4	3.6	0.4	1.7	0.0	0.022	0.005	1.3	0.3
Joint 2 - NE	0.5	0.0	0.5	0.2	0.3	0.1	0.004	0.001	0.2	0.0
Joint 2 - SE	0.4	0.0	0.7	0.1	0.3	0.1	0.005	0.001	0.3	0.0
Joint 8 - NE	0.9	0.0	0.7	0.3	0.4	0.2	0.006	0.001	0.3	0.1
Joint 8 - SE	0.9	0.0	0.5	0.2	0.3	0.1	0.007	0.001	0.4	0.1

Table 6-1: Beam-column connections maximum displacements and rotations.

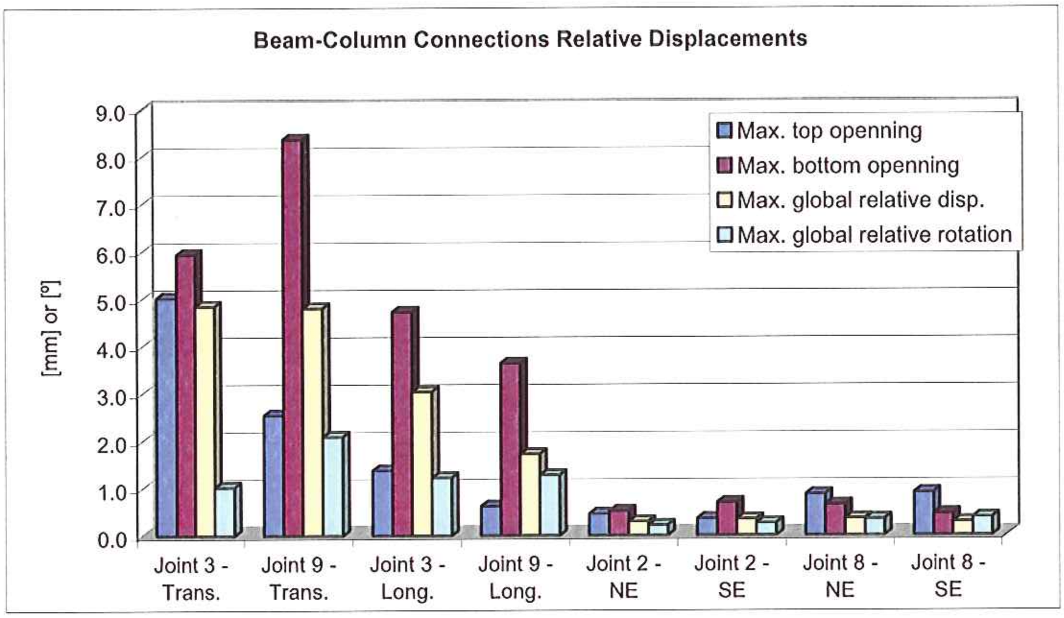


Figure 6-1: Beam-column connections maximum displacements and rotations.

For obtaining the equivalent displacements in the prototype the values should be multiply by 3 (scale factor), except for the rotations that are dimensionless.

Analysing the results is possible to observe that:

- Smaller displacements were measured in the connections of inner columns (joints 2 and 8, see Figure 6-1);
- The openings at the bottom of the beams (8.4 mm) were greater than at the top (5.0 mm);
- The maximum final opening is also in the bottom of the beams (5.3mm);
- The maximum global relative displacement was of 4.8 mm, with a permanent value of 3.3 mm at the end of the test;

- The maximum relative rotation was of 2.1°, with a permanent value of 1.2° at the end of the test;
- In the transversal direction the openings and relative displacements were larger (beam-column connection type #2).

7 CONCLUSIONS

The tested precast structure, designed by *Civibral* for PGA=0.375g using q=2.0, was subjected in the LNEC's triaxial shaking table to 5 earthquake motions with increasing intensity. The results of the tests made possible to establish the following conclusions:

1. Observed Behaviour:
   - The majority of the visible damage was concentrated on the beam-column connections;
   - Away from the connections the elements sustained very few damage;
   - The presence of torsion was very small (Center of Mass≈Center of Stiffness).

2. Global Behaviour:
   - The first modal frequencies were about 2.9 Hz (Trans.), 3.2 Hz (Long.) before the tests, and 1.2 Hz (Trans.), 1.9 Hz (Long.) after all stages, so the specimen suffered a very intense stiffness degradation (around 80% reduction in the transversal direction);
   - The slabs had enough axial stiffness to be considered as a rigid diaphragm in its plane;
   - The interstory drifts reached very high values (around 3% in the last stage) so the global collapse could by eminent;
   - The estimated base shear reached also very high values (more than 50% the weight of the specimen);
   - Although, higher values of PGA* were in the transversal direction, the first stages damaged heavily the structure in that direction, shifting the dynamic characteristics of the specimen to frequencies with lower energy contents;

- The global histeresis loops showed in Stages 01 and 02 an almost elastic response in the longitudinal direction and a clear non-linear behaviour in the transversal direction. In the following stages the non-linear behaviour appeared in the longitudinal direction and the transversal direction showed signs of residual stiffness.

3. Beam-column connections:

- On both connections types the bottom faces of the beams showed higher flexibility. The steel plate and bolts of the top face had a better response (higher stiffness and ductility);
- Comparatively, the type #2 connection had a worse performance (greater damage and higher stiffness degradation), although in that direction the stresses were higher due to structural configuration (only one bay);
- On type #2 connections the vertical bolt lost its contribution when a large crack appeared through the bolt hole (see Figure 4-c) leading to almost free bottom relative displacements;
- To understand the behaviour of these connections a more detailed study is required (i.e. cyclic tests).

4. Performance of the structure:

- In the less intense test stages the beam-column connections revealed non-negletable rotational stiffness and the overall behaviour was typical of a frame structure. At the final stages the overall behaviour has governed by cantilever columns (inverted pendulum response);
- The beam-column connections revealed enough ductility to sustain the earthquake input without collapsing;
- To design this structure for collapse prevention a conservative and real model is to consider the beam-column connections as pinned;
- The most probable collapse mechanisms identified were the local failure of the beam-column connections (in particular type #2 connections) and the global failure of the second floor columns (because of higher interstory drifts and the good response of the column's bases);

- Taking into consideration the performance of the structure presented in this paper, for the usual safety requirements (collapse prevention) it is expected that this structure should be able to receive a more intense seismic action that the one considered for design purposes (PGA=0.375g);
- To determine the safety margin against collapse prevention and damage limitation, further analysis should be carried out taking into account these results and the seismic hazard of the region where the structure will be constructed.

8 ACKNOWLEDGMENTS

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Annex B - PROTOTYPE DRAWINGS

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Annex L - GLOBAL FORCES

Annex M - GLOBAL HISTERESIS LOOPS

Annex N - BEAM-COLUMN CONNECTIONS

ANNEX A DESIGN REPORT FROM CIVIBRAL

MEMÓRIA DESCRITIVA

1. INTRODUÇÃO

Refere-se a presente memória descritiva ao dimensionamento de uma estrutura pré-fabricada tipo CIVIBRAL.

A solução adoptada consiste essencialmente na utilização de elementos pré-fabricados de betão armado e pré-esforçado, excepto as fundações que são realizadas *"in situ"*, a camada de solidarização das lajes e selagens pontuais.

Os elementos estruturais a utilizar fazem parte de um conjunto de soluções que se encontram optimizadas pela empresa de pré-fabricação CIVIBRAL e que foram objecto de estudos detalhados.

2. CONCEPÇÃO ESTRUTURAL

2.1. Tipo de estrutura

Adoptou-se uma solução pré-fabricada em betão armado e pré-esforçado do tipo CIVIBRAL. No que se refere às fundações e face às características da construção estas são directas, constituídas por sapatas isoladas.

Procurou-se adoptar recobrimentos das armaduras que conduzissem a uma boa durabilidade da estrutura, tendo-se adoptado como recobrimento 2.5cm para vigas e pilares e 5cm para sapatas.

Assim, a estrutura será constituída por pilares e vigas executadas em fábrica betão pré-esforçado solidarizadas entre si *"in-situ"*.

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Estruturalmente a estrutura apresenta ligações rotuladas entre as vigas dos pisos e os pilares, admitindo-se assim um funcionamento das vigas como bielas, que compatibilizam os deslocamentos dos pilares, mas sem qualquer transmissão de momentos. As ligações entre pilares e vigas são igualmente rotuladas. Inferiormente os pilares encontram-se perfeitamente encastrados em sapatas de fundação.

2.2. Ligações

A ligação pilar/sapata é realizada introduzindo a extremidade inferior do pilar numa cavidade existente na fundação. O preenchimento do espaço remanescente da cavidade é realizado com uma argamassa. A eficácia desta ligação é garantida pela resistência da argamassa de selagem, da sua aderência às superfícies do pilar e do comprimento do pilar embebido na fundação. É de notar que a resistência da referida argamassa deverá pelo menos ser igual à resistência mínima dos dois elementos a ligar.

3. CRITÉRIOS GERAIS DE SEGURANÇA E DE DIMENSIONAMENTO

3.1. Acções

A quantificação das acções foi efectuada a partir dos seus valores característicos, conforme descritos no R.S.A.;

3.1.1. Acções permanentes

As acções permanentes são aquelas que, assumem valores constantes ou com pequena variação em torno do seu valor médio, consistem nos pesos próprios dos elementos estruturais e não estruturais, os pesos dos equipamentos fixos, os impulsos das terras e os pré-esforços.

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Relativamente à estrutura em estudo as acções permanentes resultam do peso próprio da estrutura, revestimentos, efectuando-se a distinção entre cargas mobilizadas à data da aplicação do pré-esforço e as que apenas posteriormente irão ser aplicadas.

Assim teremos:

Piso:

- peso próprio dos elementos estruturais – 25.0 kN/m^3 (vigas, pilares, lajes...)
- camada de compressão – 5cm

3.1.2. **Acções variáveis**

As acções variáveis são aquelas que assumem valores com variação significativa em torno do seu valor médio durante a vida da estrutura. Consideram-se como acções variáveis, para o presente caso, as sobrecargas e a acção do sismo. Em seguida são apresentados os valores característicos de cada acção variável.

3.1.2.1. **Sobrecargas**

De acordo com o especificado, foram consideradas as seguintes sobrecargas uniformemente distribuídas:

- 5.0KN/m^2 nos pisos

Os valores reduzidos são obtidos através dos seguintes coeficientes:

- $\psi_0 = 0,7$; $\psi_1 = 0,6$; $\psi_2 = 0,4$

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3.1.2.2. Acção do sismo

Os acelerogramas utilizados foram os de Tolmezzo, corrigidos por forma a corresponderem ao espectro elástico de resposta do EC8 para solos do tipo 1, e do tipo B, escalados para PGA=1g.

De acordo com as zonas sísmicas e a intensidade da acção sísmica em território nacional, a estrutura foi dimensionada para 0.25g, que seria o equivalente a considerar de acordo com o RSA um coeficiente de sismicidade (α) igual a 0.85.

Os acelerogramas foram aplicados à estrutura nas direcções correspondentes, considerando uma análise incremental por passos (Time History Analysis). A análise foi do tipo linear e o "time history analysis" foi realizado através do método de sobreposição modal, considerando apenas os seis primeiros modos de vibração.

A combinação da acção sísmica horizontal em ambas as direcções, foi efectuada de acordo com o especificado no EC8:

$$Ex + 0.3Ey$$

$$0.3Ex + Ey$$

3.1.3. Combinação de acções

A verificação da segurança da estrutura é feita quer em relação aos diversos estados limites últimos, quer em relação aos estados limites de utilização (deformação e fendilhação), para as combinações de acções adequadas e definidas de acordo com o R.S.A. e o R.E.B.A.P..

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A dimensão dos elementos estruturais (lajes, vigas, pilares e fundações) assim como a quantidade e disposição das armaduras resistentes, são as necessárias para garantir a segurança aos esforços mais gravosos, quer em estado limite último, quer em estado limite de utilização.

A obtenção destes e quaisquer outros esforços nos elementos estruturais é feita com o recurso aos métodos de cálculo mais actuais e recorrendo à utilização de programas de cálculo automático. Estes métodos permitem a obtenção dos esforços para as combinações de acções consideradas, assim como o dimensionamento das armaduras (passivas e de pré-esforço) segundo as regras e os critérios definidos regulamentarmente.

A verificação aos estados limites foi feita em termos de esforços, com base na condição,

$$S_d \leq R_d$$

em que S_d e R_d designam respectivamente os valores de cálculo do esforço actuante e do esforço resistente.

Consideram-se as seguintes combinações fundamentais:

Em geral:

$$S_d = \Sigma\, \gamma_{gi} S_{Gik} + \gamma_q (S_{Q1k} + \Sigma\, \psi_{0j} S_{Qj\gamma})$$

em que

S_{Gik} – esforço resultante de uma acção permanente, tomada com o seu valor característico ;

S_{Q1k} – esforço resultante da acção variável considerada como acção de base da combinação, tomada com o seu valor característico (S_{Ek} no caso da acção sísmica) ;

S_{Qjk} – esforço resultante da acção variável distinta da acção de base, tomada com o seu valor característico;

γ_{gi} – coeficiente de segurança relativo às acções permanentes;

γ_q – coeficiente de segurança relativo às acções variáveis;

$\psi_{0j}\psi_{2j}$ – coeficiente ψ correspondente à acção variável de ordem j;

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Os coeficientes de segurança γ_{gi} e γ_q considerados, respectivamente para as acções permanentes e variáveis são os seguintes:

- peso próprio da estrutura $\gamma_{gi} = 1.35$ ou 1.0 (conforme mais desfavorável)
- restantes cargas permanentes $\gamma_{g2} = 1.35$ ou 1.0 (conforme mais desfavorável)
- acções variáveis $\gamma_q = 1.50$, para todas as acções variáveis

4. Materiais

Os materiais utilizados apresentam as características constantes do R.E.B.A.P. e R.E.A.E., nomeadamente em termos de valores característicos e de cálculo de tensões de rotura do betão à compressão referidos a provetes cilíndricos (respectivamente f_{ck} e f_{cd}) e valores de cálculo de tensões de cedência ou de tensões limite de proporcionalidade a 0,2% em tracção do aço das armaduras ordinárias (f_{syd}) ou valores característicos da tensão de rotura em tracção do aço das armaduras de pré-esforço (f_{puk}).

Os materiais mais utilizados apresentam os seguintes valores de tensões:

Betão armado e pré-esforçado:	Betão C35/45: $f_{ck} = 35$ Mpa $f_{cd} = 23.3$ MPa
Fundações:	Betão C20/25: $f_{ck} = 20$ Mpa $f_{cd} = 13.3$ MPa
Pilares, vigas de travação e enchimento:	Betão C25/30: $f_{ck} = 25$ Mpa $f_{cd} = 16.7$ MPa

Armaduras:

Armaduras passivas A500 NR: $f_{syd} = 435$ MPa

Armaduras de pré-esforço: $f_{puk} = 1860$ Mpa

Perfis e Chapas Metálicas: Fe360

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5. Processos de Cálculo

Relativamente aos elementos em betão armado pré-esforçado, procura-se estabelecer um compromisso entre os estados limites de utilização (deformação e fendilhação) e os estados limites últimos de resistência. São efectuadas as verificações de tensões para as diversas combinações de acções de serviço (quase permanentes, frequentes e raras) e é efectuada a verificação de segurança em relação ao estado limite último de resistência por comparação dos esforços solicitantes com os esforços resistentes.

O estudo dos pilares obedeceu a critérios de 1ª e 2ª ordem, uma vez que devido à sua altura e devido às ligações com os restantes elementos estruturais, o efeito de instabilidade por causa do fenómeno de encurvadura pode revelar-se importante.

Os efeitos de 2ª ordem foram contabilizados através das excentricidades adicionais, mais nomeadamente, a excentricidade acidental, a excentricidade de 2ª ordem e a excentricidade de fluência, tendo-se para o efeito respeitado todas as disposições regulamentares constantes nos artigos 61° a 64° do R.E.B.A.P..

No que diz respeito aos elementos metálicos, é efectuada a verificação de segurança em relação ao estado limite último de resistência sem plastificação, por comparação dos valores de cálculo das tensões actuantes com os valores de cálculo das tensões resistentes, conforme o estipulado no artigo 41° do R.E.A.E..

O cálculo dos diversos elementos estruturais é efectuado com o recurso a programas de cálculo automático.

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A título exemplificativo podem referir-se os seguintes:

- CÁLCULO DE ESTRUTURAS RETICULADAS PLANAS: Análise de elementos porticados, utilizado o programa global dos elementos estruturais principais (pilares e vigas).

- CÁLCULO DE VIGAS CONTÍNUAS: Análise de vigas contínuas com indicação de esforços e de armaduras.

- CÁLCULO DE MOMENTOS RESISTENTES: Estudo de secções de com uma determinada geometria (com eixo vertical de simetria), apresentando as características geométricas da secção e os esforços resistentes de cálculo.

6. Bibliografia

Da bibliografia utilizada para a execução do presente projecto destacam-se os seguintes elementos:

"RSA - Regulamento de Segurança e Acções para Estruturas de Edif. e Pontes"
"REBAP - Regulamento de Estruturas de Betão Armado e Pré-esforçado"
"EC2 – Eurocódigo 2 - Estruturas de Betão Armado e Pré-esforçado"
"PCI Design Handbook – Precast and Prestressed Concrete"
"Construções de Concreto, Volume 3" – Leonhardt
"EC8 – Eurocódigo 8 – Dimensionamento Sísmico de Estruturas"

Maia, 30 de Agosto de 2004

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ANEXOS

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Elementos de cálculo

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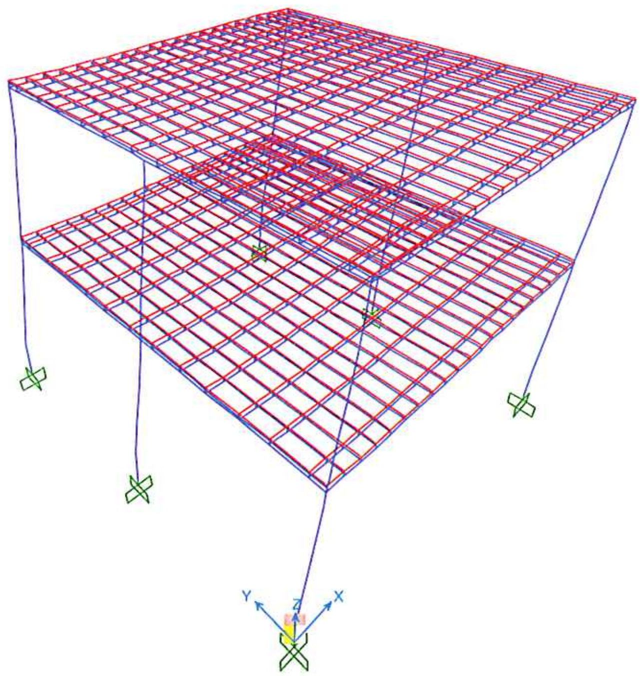
Períodos e frequências de vibração

OutputCase Text	StepType Text	StepNum Unitless	Period Sec	Frequency Cyc/sec	CircFreq rad/sec	Eigenvalue rad2/sec2
MODAL	Mode	1.000000	0.901381	1.1094E+00	6.9706E+00	4.8590E+01
MODAL	Mode	2.000000	0.837751	1.1937E+00	7.5001E+00	5.6251E+01
MODAL	Mode	3.000000	0.501775	1.9929E+00	1.2522E+01	1.5680E+02
MODAL	Mode	4.000000	0.274818	3.6388E+00	2.2863E+01	5.2272E+02
MODAL	Mode	5.000000	0.268081	3.7302E+00	2.3438E+01	5.4932E+02
MODAL	Mode	6.000000	0.259055	3.8602E+00	2.4254E+01	5.8827E+02

Modos de vibração

1º modo



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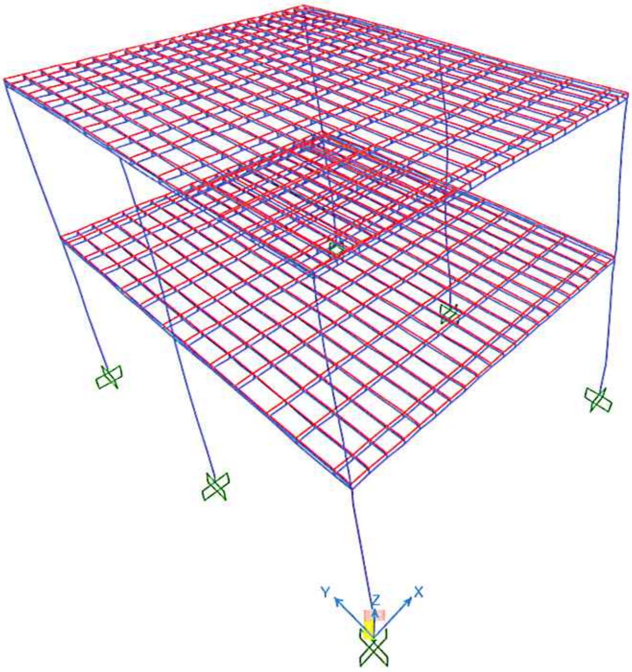
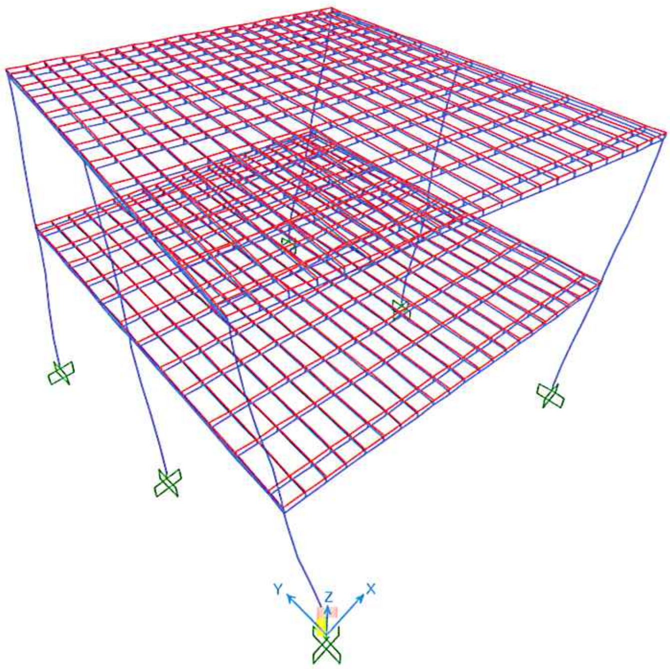
2º modo



3º modo



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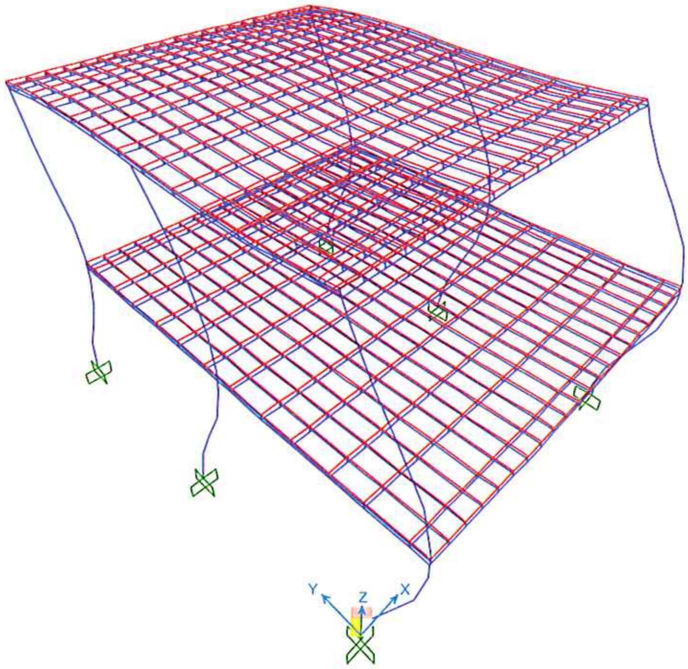
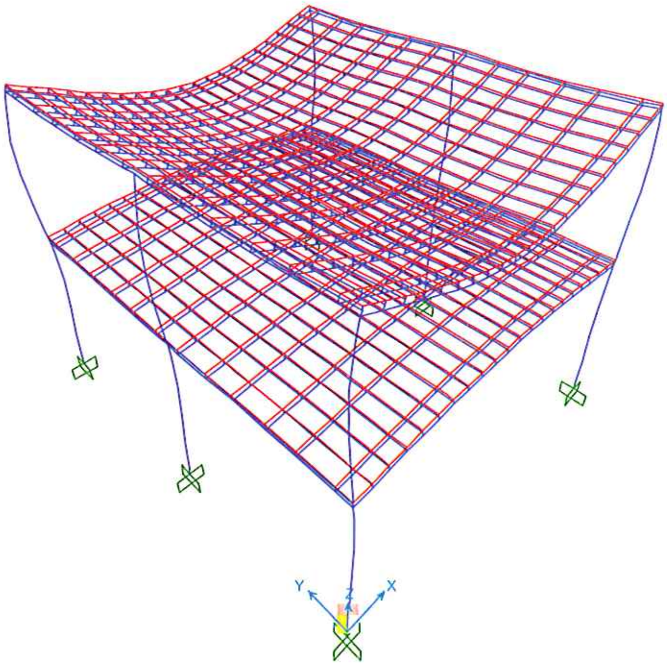
4º modo



5º modo



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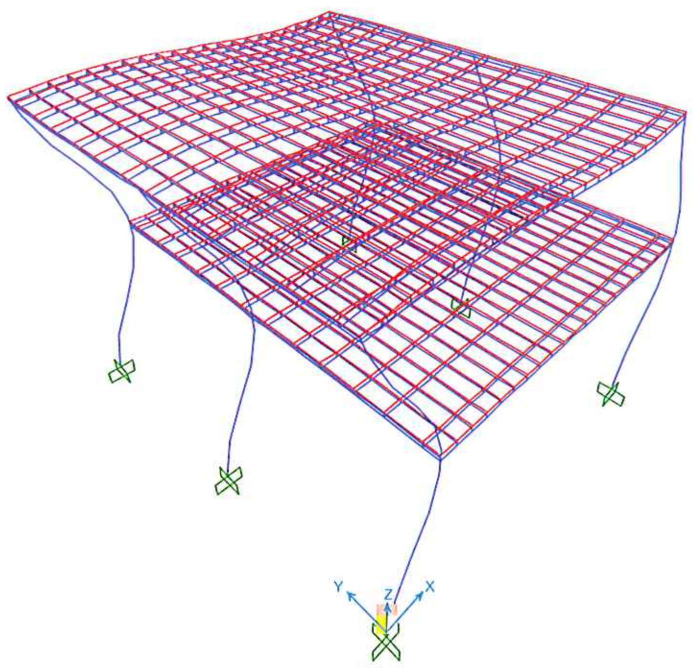
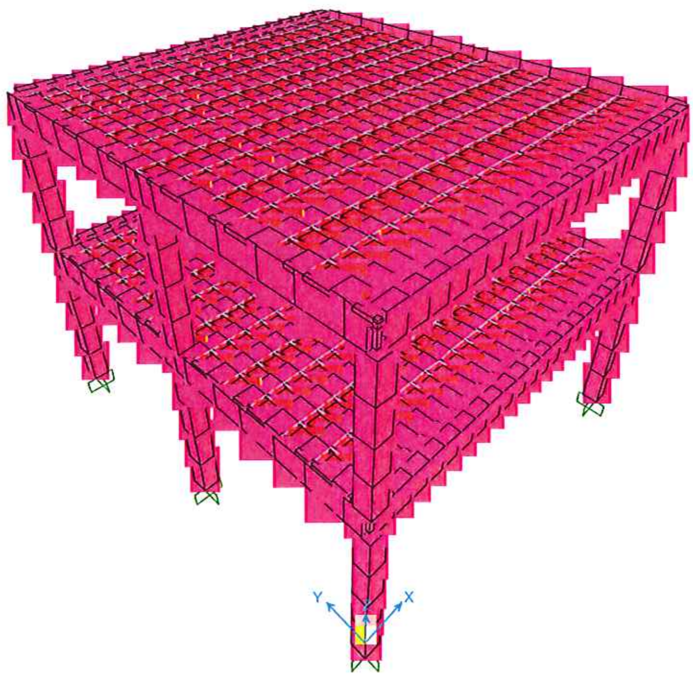
6º modo



Modelo estrutural



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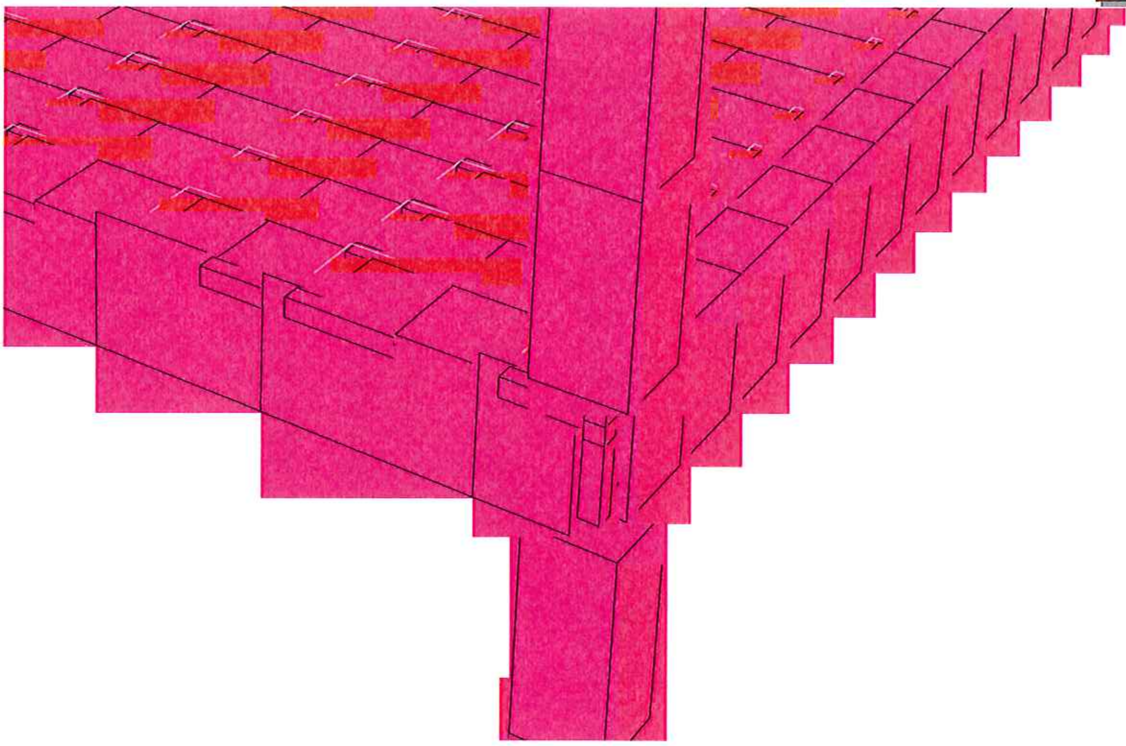

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Esforços de dimensionamento dos pilares (sem consideração de excentricidades)

Joint	OutputCase	CaseType	StepType	U1	U2	U3	R1	R2	R3
Text	Text	Text	Text	KN	KN	KN	KN-m	KN-m	KN-m
21	ELUx	Combination	Max	74.612	17.763	360.436	23.4297	181.8942	0.1972
21	ELUx	Combination	Min	-33.735	-7.133	271.409	-44.7480	-110.0419	-0.4785
21	ELUy	Combination	Max	34.194	48.745	415.632	99.6614	73.7657	1.0069
21	ELUy	Combination	Min	-0.829	-34.693	212.554	-128.4206	-20.0292	-1.2629
27	ELUx	Combination	Max	44.246	18.364	357.367	22.4413	135.4250	0.0355
27	ELUx	Combination	Min	-64.073	-6.827	268.001	-45.0805	-156.4637	-0.0751
27	ELUy	Combination	Max	4.079	49.796	413.784	97.7525	27.6569	0.1404
27	ELUy	Combination	Min	-31.433	-34.671	213.002	-128.2004	-66.8498	-0.1942
31	ELUx	Combination	Max	80.897	20.135	581.100	50.6492	191.1537	0.0094
31	ELUx	Combination	Min	-33.163	-24.876	466.056	-48.3884	-109.0657	-0.1919
31	ELUy	Combination	Max	37.231	74.568	571.914	162.8244	77.0724	0.2594
31	ELUy	Combination	Min	2.931	-75.889	471.783	-167.8540	-13.1213	-0.4584
35	ELUx	Combination	Max	43.981	19.300	575.451	48.8956	134.9890	0.1762
35	ELUx	Combination	Min	-70.082	-24.076	461.138	-46.5283	-165.2356	-0.0452
35	ELUy	Combination	Max	0.330	71.927	568.476	156.6773	20.9349	0.4499
35	ELUy	Combination	Min	-34.012	-73.087	471.576	-161.9761	-69.3335	-0.3346
39	ELUx	Combination	Max	75.116	10.821	362.045	31.4957	183.1080	0.3981
39	ELUx	Combination	Min	-34.137	-12.420	272.411	-34.1282	-110.9208	-0.2428
39	ELUy	Combination	Max	34.564	39.732	384.953	104.5304	74.5835	1.1904
39	ELUy	Combination	Min	-0.872	-38.001	248.704	-114.5246	-20.0287	-1.0060
43	ELUx	Combination	Max	44.803	10.680	358.384	31.5159	136.7172	0.1418
43	ELUx	Combination	Min	-64.487	-12.772	268.410	-33.3320	-157.3687	-0.1015
43	ELUy	Combination	Max	4.295	39.966	384.068	103.5092	28.2511	0.1917
43	ELUy	Combination	Min	-31.272	-38.525	247.204	-113.0507	-66.5266	-0.1773

Prémio IDICT "Prevenir Mais Viver Melhor no Trabalho" – 2003 - Menção Honrosa

Esforços de dimensionamento dos pilares (considerando excentricidades)

```
OBRA: Estrutura LNEC
PILAR: P1
.............................................................
bx = 0.45,    by = 0.45,     l = 4.64,     Recobrimento = 0.040  (m)
Dir. X: lo/i = 81.0  (NM)                 Dir. Y: lo/i = 81.0  (NM)
Comb. Sec.    ey     ex       Nsd       M'sdx     M'sdy      As    As(min)
             (cm)   (cm)      (kN)     (kN.m)    (kN.m)    (cm2)     (cm2)
  1   Inf   16.8   21.5    360.62     83.75    259.39     29.58    12.15
  1   Sup   16.8   21.5    360.53     83.73    259.37     29.58    12.15
  2   Inf   16.8   21.5    271.61     90.75    168.29     18.97    12.15
  2   Sup   16.8   21.5    271.51     90.73    168.27     18.97    12.15
  3   Inf   16.8   21.5    415.83    170.04    163.24     25.25    12.15
  3   Sup   16.8   21.5    415.73    170.03    163.22     25.25    12.15
  4   Inf   16.8   21.5    212.74    163.84     55.66     17.08    12.15
  4   Sup   16.8   21.5    212.65    163.82     55.64     17.08    12.15
-----------------------------------------------------------------
```

Prémio IDICT "Programa Trabalho Seguro" - 2002

IMP – ADM 010

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OBRA: Estrutura LNEC
PILAR: P1

bx = 0.45, by = 0.45, l = 4.64, Recobrimento = 0.040 {m}
Dir. X: lo/i = 81.0 (NM) Dir. Y: lo/i = 81.0 (NM)

Comb.	Sec.	ey (cm)	ex (cm)	Nsd (kN)	M'sdx (kN.m)	M'sdy (kN.m)	As (cm2)	As(min) (cm2)
1	Inf	17.1	21.5	362.24	92.87	260.86	30.50	12.15
1	Sup	17.1	21.5	362.15	92.85	260.84	30.50	12.15
2	Inf	17.1	21.5	272.61	80.56	169.59	18.40	12.15
2	Sup	17.1	21.5	272.51	80.54	169.57	18.40	12.15
3	Inf	17.1	21.5	385.14	170.78	157.78	25.08	12.15
3	Sup	17.1	21.5	385.05	170.76	157.76	25.08	12.15
4	Inf	17.1	21.5	248.88	157.51	63.50	16.06	12.15
4	Sup	17.1	21.5	248.79	157.49	63.48	16.06	12.15

OBRA: Estrutura LNEC
PILAR: P3

bx = 0.45, by = 0.45, l = 4.64, Recobrimento = 0.040 {m}
Dir. X: lo/i = 80.0 (NM) Dir. Y: lo/i = 80.0 (NM)

Comb.	Sec.	ey (cm)	ex (cm)	Nsd (kN)	M'sdx (kN.m)	M'sdy (kN.m)	As (cm2)	As(min) (cm2)
1	Inf	17.6	21.8	581.18	153.23	317.56	44.43	12.15
1	Sup	17.6	21.8	581.09	153.22	317.54	44.44	12.15
2	Inf	17.6	21.8	466.24	130.02	210.53	27.01	12.15
2	Sup	17.6	21.8	466.15	130.00	210.51	27.01	12.15
3	Inf	17.6	21.8	574.10	263.99	202.02	43.22	12.15
3	Sup	17.6	21.8	574.01	263.97	202.00	43.21	12.15
4	Inf	17.6	21.8	471.96	251.02	115.78	31.32	12.15
4	Sup	17.6	21.8	471.87	251.00	115.75	31.32	12.15

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Dimensionamento da laje TT e viga de apoio VL

Peças Pré-esforçadas

Titulo : Laje TT40 sob 5

Secção tipo : TT40x2.00

Resumo das análises efectuadas

i) Aplicação da pré-tensão "in situ".	Tracção:	Verifica
	Compressão:	Verifica
ii) Armazenamento e transporte.	Tracção:	Verifica
	Compressão:	Verifica
iii) Betonagem da laje "in situ".	Tracção:	
	Compressão:	
iv) Aplicação do pós-esforço "in situ".	Tracção:	
	Compressão:	
iv) Fase de utilização.	Descompressão (Comb.Q.P.):	Verifica
	Abertura de fendas (Comb.F.):	Verifica
	Compressão (Comb.Q.P.):	Verifica
	Compressão (Comb.Raras):	Verifica
v) Estado limite último.	Momentos (em x):	Verifica
	Esforço transverso máximo:	Verifica

Características dos materiais

Betão = C35/45 — fcd = 23300 kPa; fck = 35000 kPa; fctk = 2200 kPa; τ_1 = 900 kPa; τ_2 = 7000 kPa

Aço = A500 — fsyd = 435000 kPa; fpk = 1860 MPa

Betão transf. = C30/37 — fck.j = 30000 kPa; fctm.j = 2800 kPa

Acções consideradas

Vão = 10.50 m
l inf. inicio = 1.000 m
l inf. final = 1.000 m

Laje betonada "in situ"
Espessura no início = 0.00 m
Espessura no final = 0.00 m
Largura no início = 0.00 m
Largura no final = 0.00 m

Comprimento em consola
Esquerda = 1.00 m
Direita = 1.00 m

rcp = 2.00 KN/m²
Sob.(Momentos) = 5.00 KN/m² ψ_1 = 0.60 ψ_2 = 0.40
Sob.(Esf.transv.) = 5.00 KN/m²

	pp	Δ pp	rcp	Sob.
C.equiv. 1/2 Vão	2.83	0.00	2.00	5.00
Coef.E.L.Último	1.35	1.35	1.50	1.50

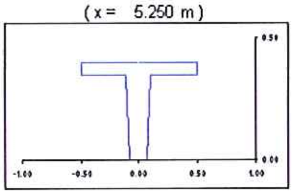
Sem peso próprio extra
Sem peso próprio da laje extra
Sem restante carga perm. extra
Sem sobrecarga extra

Pt

Características mecânicas da secção transversal

(x = 5.250 m)

	Fase 1	Fase 2
A =	0.1130 m²	0.1130 m²
I =	0.0017 m⁴	0.0017 m⁴
vi =	0.2689 m	0.2689 m
vs =	0.1311 m	0.1311 m
h =	0.4000 m	0.4000 m
bs =	0.1500 m	0.1500 m
bmáx =	1.0000 m	



Ambiente = Moderadamente agressivo

Pré-esforço

Pré-tensão (P1)

Nº de strands: 4
Diâmetro: 0.6"
$P_{1,útil}$ = 600 KN

Pós-tensão (P2)

	Nº	ø ["]	$P_{2,útil}$ [kN]
Alinhamento 1	0	0.6"	0
Alinhamento 2	0	0.6"	0
Alinhamento 3	0	0.6"	0

Estado limite último

Máximos fase de montagem		Máximos ELUltimo	
Msd =	52.6 kNm	Msd =	197 kNm
Vsd =	20.0 kN	Vsd =	75 kN

Valores na secção corrente (x=5.25m)

Montagem	Msd =	53 kNm	S.Inicial
	Mrd =	216 kNm	S.Inicial
E.L.Último	Msd =	197 kNm	S.Final
	Mrd =	216 kNm	S.Final

Armadura de tracção

As,inf = 0.00 cm²
As,sup = 0.30 cm²

y	0.05	0.35	0.00	0.00	0.00	0.00
As	0.00	1.01	0.00	0.00	0.00	0.00

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SEDE: Rua Cardosas – Apartado 4035 – 4471-906 MAIA - geral@civibral.pt Telf: 229 699 100 Fax: 229 699 199
DELEG.: Av. Engº Arantes Oliveira, 5 1ºB - 1990-221 LISBOA – lisboa@civibral.pt Telf: 218 471 061 Fax: 218 471 059

Peças Pré-esforçadas

Titulo : Viga VL sob 5

Secção tipo : VL (30+40)x(15+30)

Resumo das análises efectuadas

i) Aplicação da pré-tensão "in situ".	Tracção:	Verifica
	Compressão:	Verifica
ii) Armazenamento e transporte.	Tracção:	Verifica
	Compressão:	Verifica
iii) Betonagem da laje "in situ".	Tracção:	
	Compressão:	
iv) Aplicação do pós-esforço "in situ".	Tracção:	
	Compressão:	
iv) Fase de utilização.	Descompressão (Comb.Q.P.):	Verifica
	Abertura de fendas (Comb.F.):	Verifica
	Compressão (Comb.Q.P.):	Verifica
	Compressão (Comb.Raras):	Verifica
v) Estado limite último.	Momentos (em x):	Verifica
	Esforço transverso máximo:	Verifica

Características dos materiais

Betão = C35/45 — fcd = 23300 kPa; fck = 35000 kPa; fctk = 2200 kPa; τ_1 = 900 kPa; τ_2 = 7000 kPa

Aço = A500 — fsyd = 435000 kPa; fpk = 1860 MPa

Betão transf. = C30/37 — fck,j = 30000 kPa; fctm,j = 2800 kPa

Acções consideradas

Vão = 6.00 m
l inf. inicio = 5.250 m
l inf. final = 5.250 m

Laje betonada "in situ"
Espessura no início = 0.00 m
Espessura no final = 0.00 m
Largura no início = 0.00 m
Largura no final = 0.00 m

Comprimento em consola
Esquerda = 1.00 m
Direita = 1.00 m

rcp = 4.83 KN/m²
Sob.(Momentos) = 5.00 KN/m² ψ_1 = 0.60 ψ_2 = 0.40
Sob.(Esf.transv.) = 5.00 KN/m²

	pp	Δ pp	rcp	Sob.
C.equiv. 1/2 Vão	6.38	0.00	25.36	26.25
Coef.E.L.Último	1.35	1.35	1.50	1.50

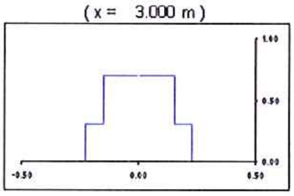
Sem peso próprio extra
Sem peso próprio da laje extra
Sem restante carga perm. extra
Sem sobrecarga extra

Pı

Características mecânicas da secção transversal

(x = 3.000 m)

	Fase 1	Fase 2
A =	0.2550 m²	0.2550 m²
I =	0.0104 m⁴	0.0104 m⁴
vi =	0.3147 m	0.3147 m
vs =	0.3853 m	0.3853 m
h =	0.7000 m	0.7000 m
bs =	0.3000 m	0.3000 m
bmáx =	0.4500 m	



Ambiente = Moderadamente agressivo

Pré-esforço

Pré-tensão (P1)
Nº de strands: 4
Diâmetro: 0.6"
$P_{1,útil}$ = 600 KN

Pós-tensão (P2)

	Nº	ø ["]	$P_{2,útil}$ [kN]
Alinhamento 1	0	0.6"	0
Alinhamento 2	0	0.6"	0
Alinhamento 3	0	0.6"	0

Estado limite último

Máximos fase de montagem: Msd = 38.7 kNm; Vsd = 25.8 kN
Máximos ELUltimo: Msd = 387 kNm; Vsd = 258 kN

Valores na secção corrente (x=3.00m)

Montagem	Msd =	39 kNm	S.Inicial
	Mrd =	569 kNm	S.Inicial
E.L.Último	Msd =	387 kNm	S.Final
	Mrd =	569 kNm	S.Final

Armadura de tracção

As,inf = 0.00 cm²
As,sup = 2.89 cm²

y	0.05	0.35	0.00	0.00	0.00	0.00
As	5.65	3.83	0.00	0.00	0.00	0.00

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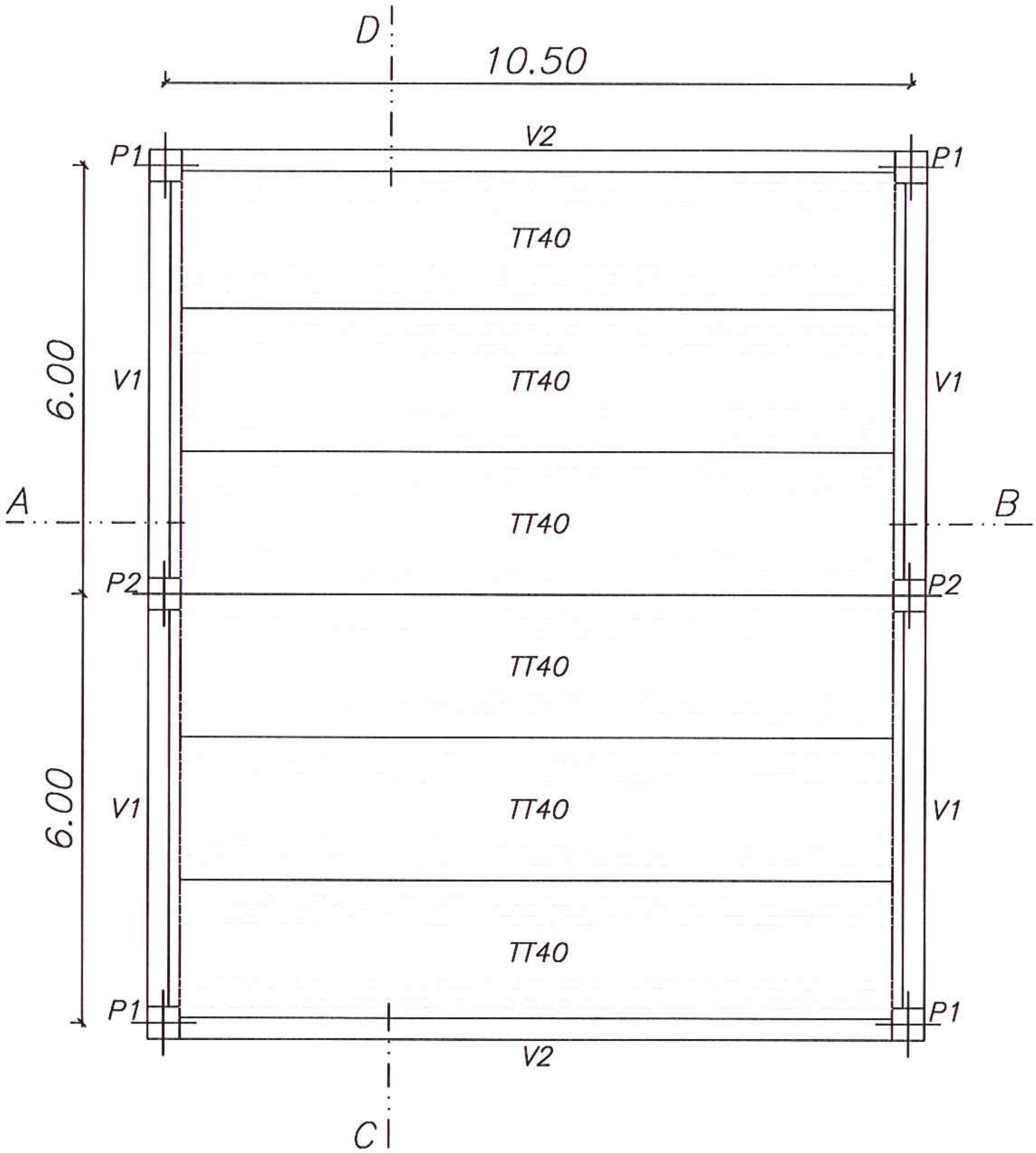
SEDE: Rua Cardosas – Apartado 4035 – 4471-906 MAIA - geral@civibral.pt Telf: 229 699 100 Fax: 229 699 199
DELEG.: Av. Engº Arantes Oliveira, 5 1ºB - 1990-221 LISBOA – lisboa@civibral.pt Telf: 218 471 061 Fax: 218 471 059

ANNEX B PROTOTYPE DRAWINGS

List of Drawings:

Plan View

Scale: 1/100



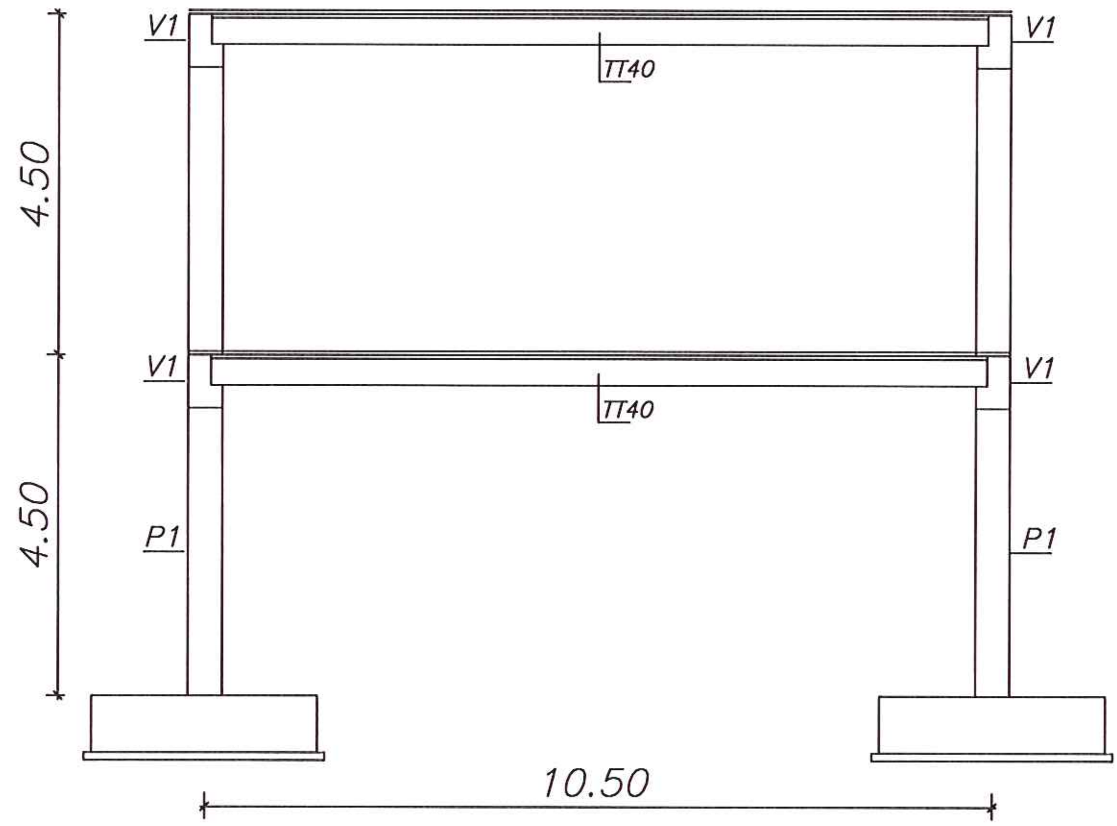
Dimensions in meters

This drawing is based on the Civibral S.A. system drawings

NATIONAL LABORATORY OF CIVIL ENGINEERING LNEC / NESDE	PRECAST STRUCTURES EC8	Dec 2005
Scale: 1:100 (except if indicated)	Prototype – Story Plan	Drawing Nº 1

Section A-B

Scale: 1/100



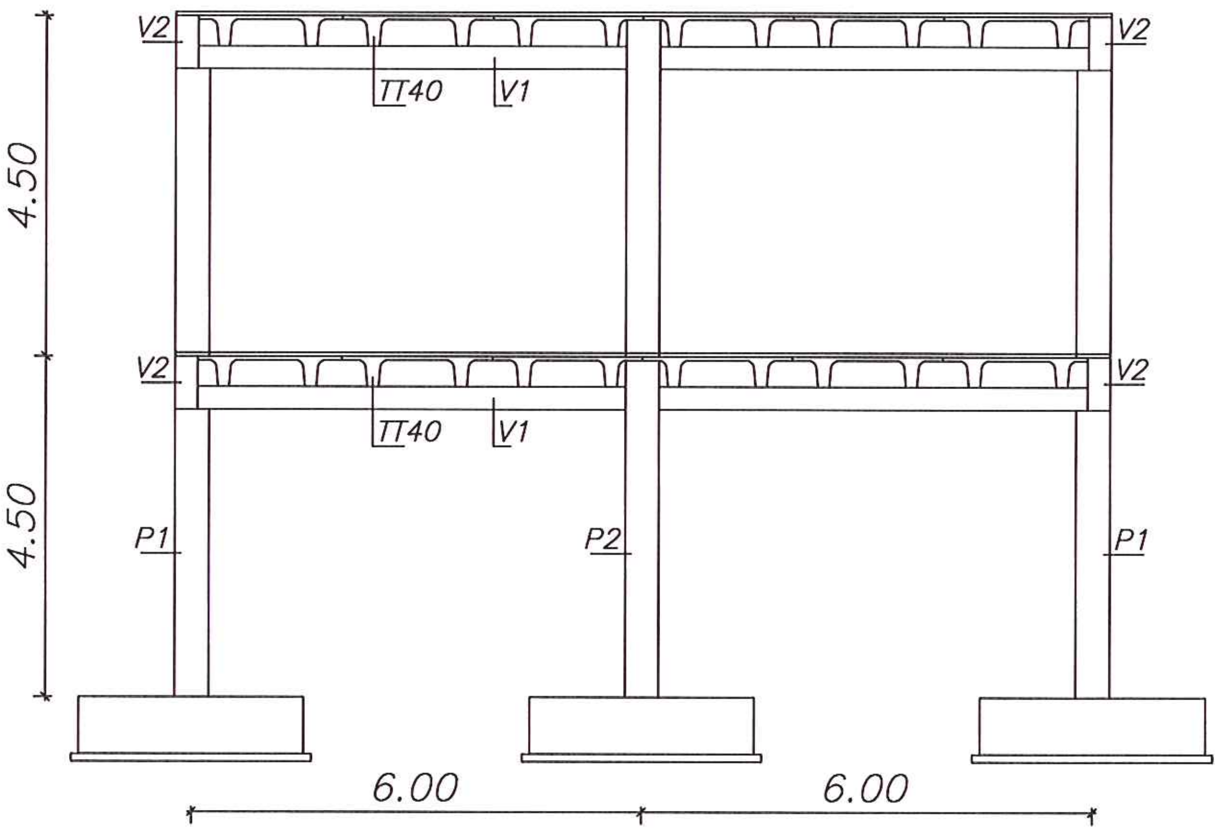
Dimensions in meters

This drawing is based on the Civibral S.A. system drawings

NATIONAL LABORATORY OF CIVIL ENGINEERING LNEC / NESDE	PRECAST STRUCTURES EC8	Dec 2005
Scale: 1:100 (except if indicated)	Prototype – Section A–B	Drawing Nº 2

Section C-D

Scale: 1/100



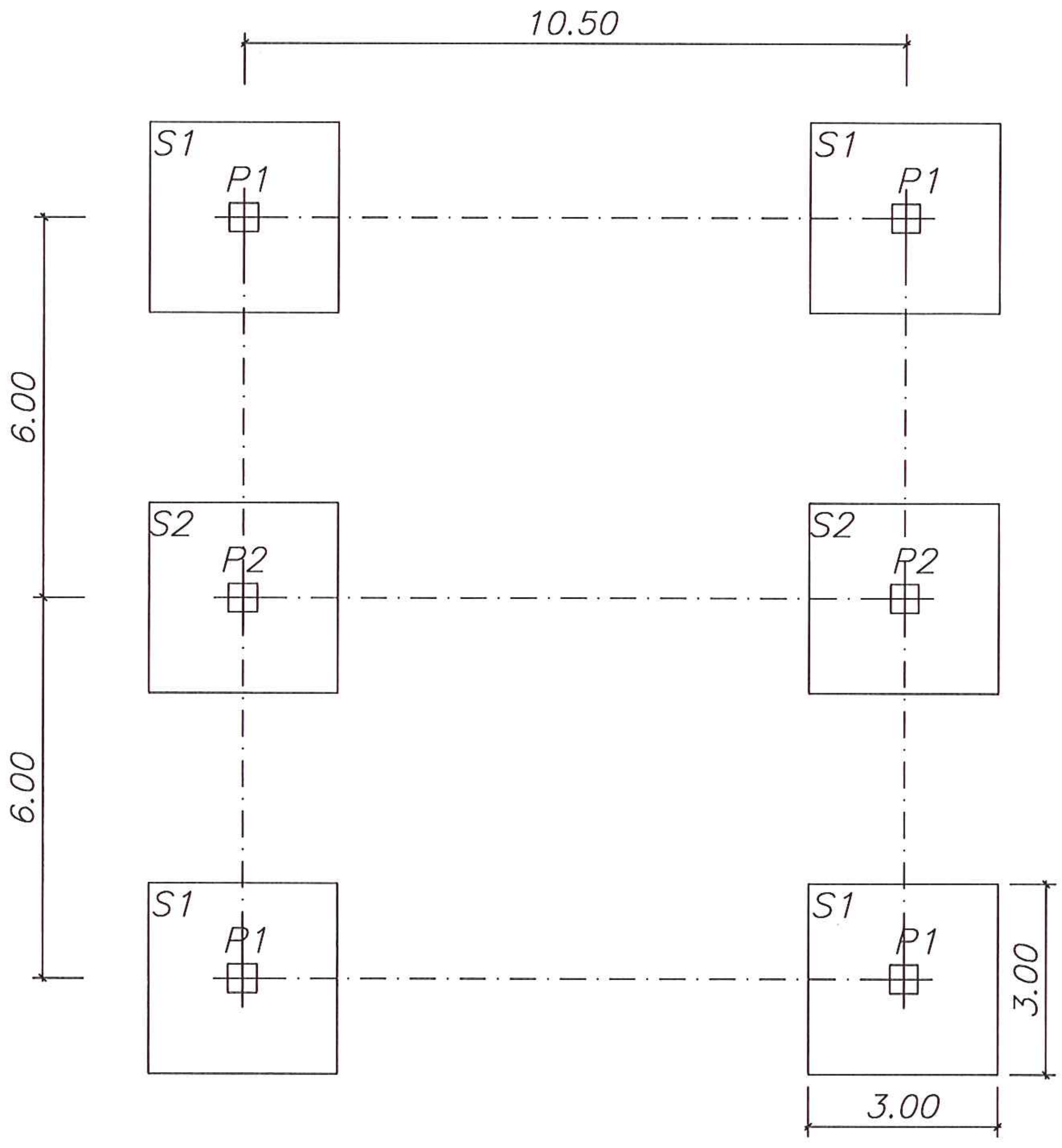
Dimensions in meters

This drawing is based on the Civibral S.A. system drawings

NATIONAL LABORATORY OF CIVIL ENGINEERING LNEC / NESDE	PRECAST STRUCTURES EC8	Dec 2005
Scale: 1:100 (except if indicated)	Prototype – Section C–D	*Drawing N°* *3*

Foundations Plan

Scale: 1/100



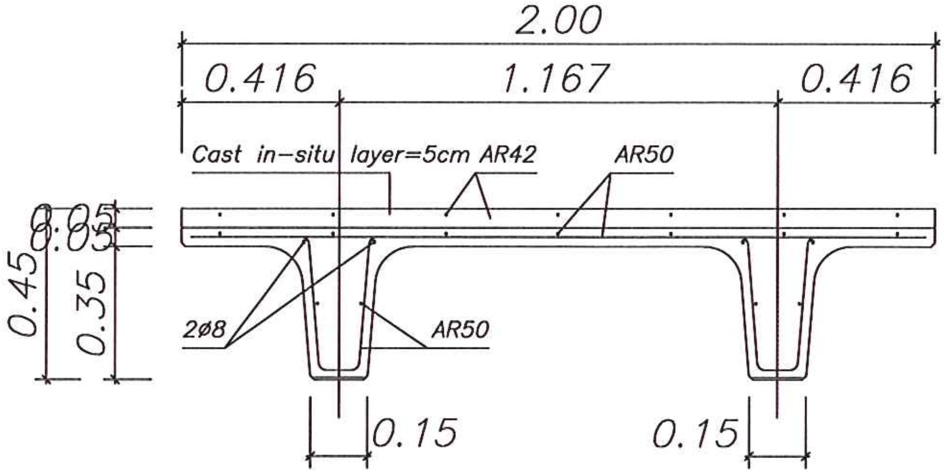
Dimensions in meters

This drawing is based on the Civibral S.A. system drawings

NATIONAL LABORATORY OF CIVIL ENGINEERING LNEC / NESDE	PRECAST STRUCTURES EC8	Dec 2005
Scale: 1:100 (except if indicated)	Prototype – Foundations Plan	Drawing Nº 4

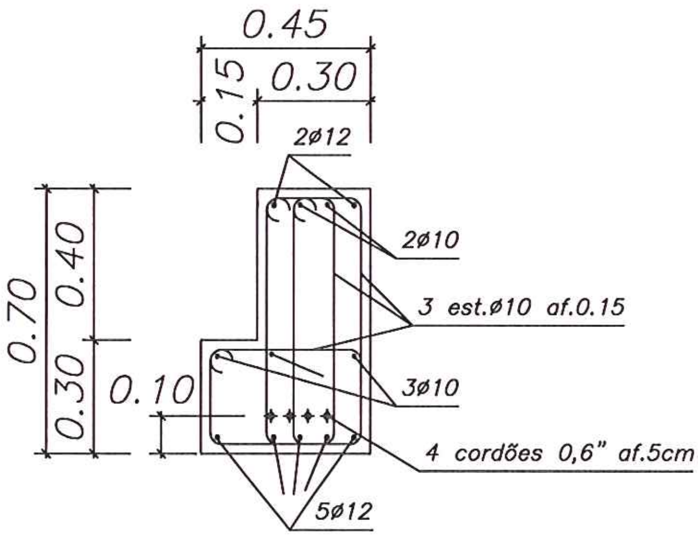
Slab TT40

Scale: 1/20



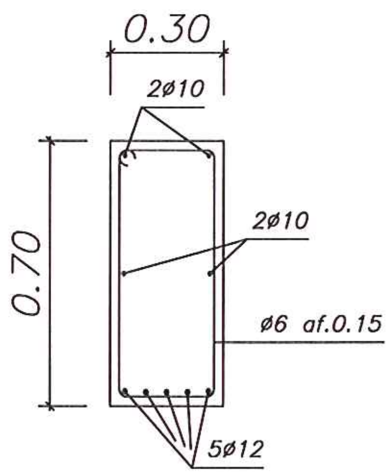
Beam V1

Scale: 1/20



Beam V2

Scale: 1/20



MATERIALS	
Concrete:	
Prestressed Elements	C35/45
Other Elements	C25/30
Steel:	
Reinforcing Steel	A500NR
Welded Mesh	A500EL
Prestressing Steel	FpuK=1860Mpa
Cover:	2.5cm

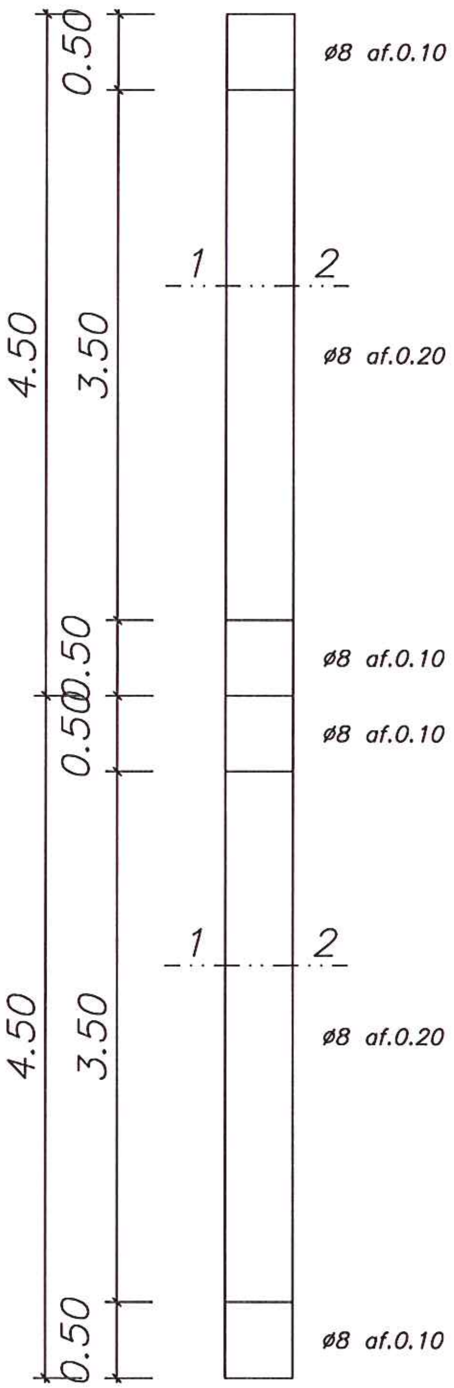
Dimensions in meters

This drawing is based on the Civibral S.A. system drawings

NATIONAL LABORATORY OF CIVIL ENGINEERING LNEC / NESDE	PRECAST STRUCTURES EC8	Dec 2005
Scale: 1:100 (except if indicated)	Prototype – Slab and Beams Details	Drawing Nº 5

Columns Stirups

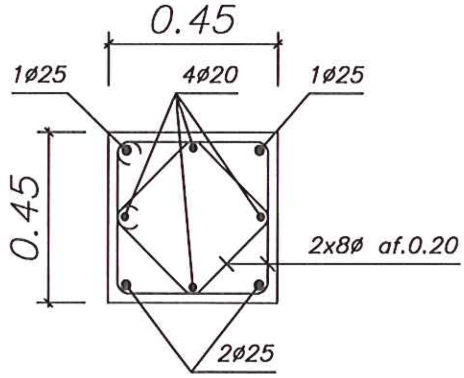
Scale: 1/50



Column P1

Section 1-2

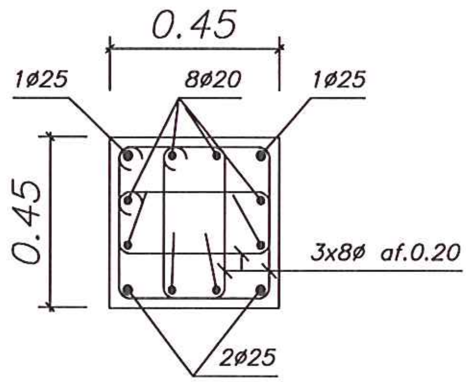
Scale: 1/20



Column P2

Section 1-2

Scale: 1/20



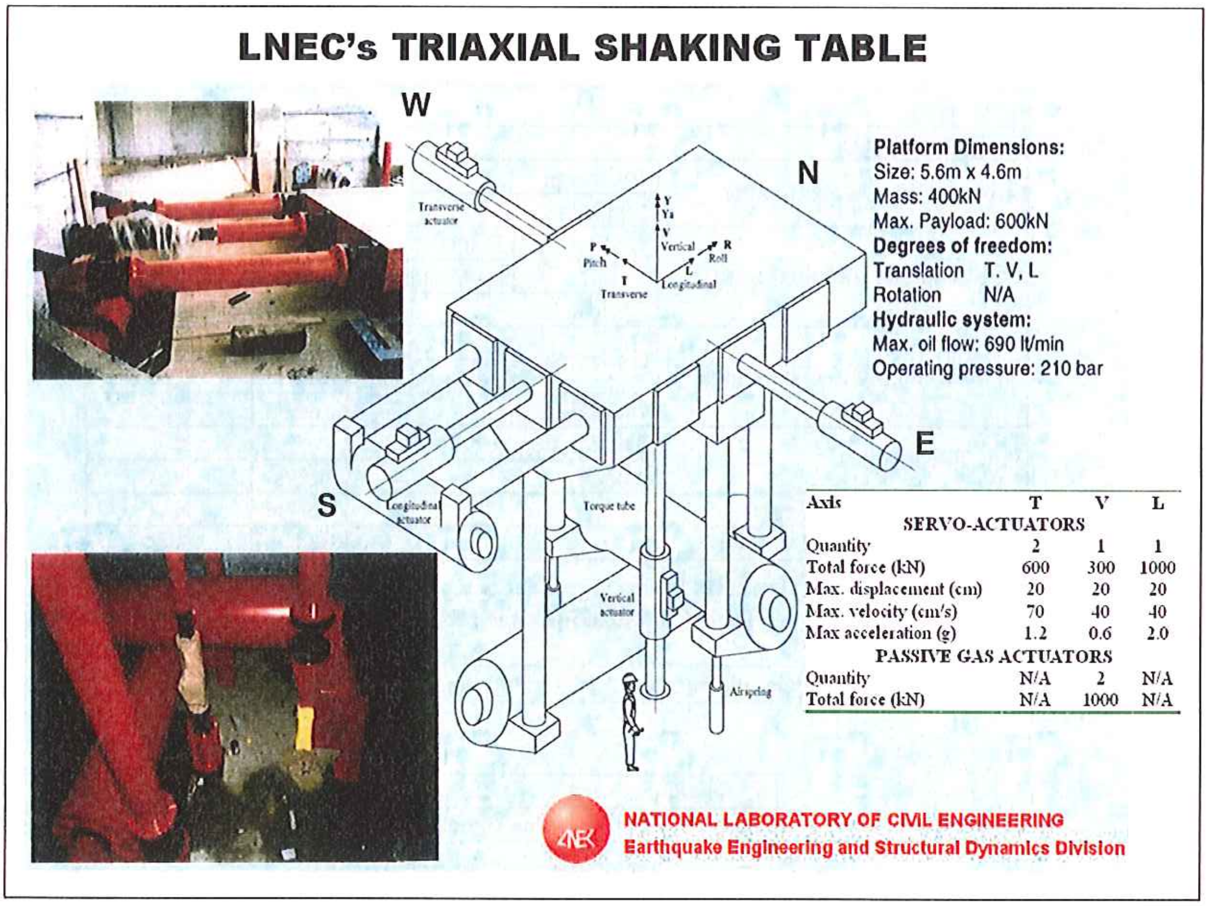
MATERIALS	
Concrete:	
Prestressed Elements	C35/45
Other Elements	C25/30
Steel:	
Reinforcing Steel	A500NR
Welded Mesh	A500EL
Prestressing Steel	FpuK=1860Mpa
Cover:	2.5cm

Dimensions in meters

This drawing is based on the Civibral S.A. system drawings

NATIONAL LABORATORY OF CIVIL ENGINEERING LNEC / NESDE	PRECAST STRUCTURES EC8	Dec 2005
Scale: 1:100 (except if indicated)	Prototype – Columns Details	Drawing N° 6

ANNEX C SHAKING TABLE CHARACTERISTICS



Full Name of the Shaking Table	MESA SÍSMICA TRIAXIAL DO LNEC
Abbreviated Name	LNEC-3G
Designer/Manufacturer	LNEC e INSTRON
Year of Installation	1995

Table C-1: General information

	Long. X	Lateral Y	Vertical Z	Pitch	Roll	Yaw
Multiaxial	Y	Y	Y	N/A	N/A	N/A

Table C-2: Type of Shaking Table

Size (m×m)	4,6 x 5,6
Weight (kN)	392
Material	Steel

Table C-3: Characteristics of the platform

Type of Actuation	Hydraulic
Electric Power (kW)	330
Flow Rate (kN)	690
Pressure (MPa)	20.7

Table C-4: Hydraulic System

	Manufacturer	Total Force (kN)	Number of units/axis
Longitudinal	INSTRON	1250	1
Lateral	INSTRON	750	2
Vertical	INSTRON	375	1

Table C-5: Actuators technical data

Frequency Range			Hz	0,1 – 40,0
Stroke (effective/maximum)	Horizontal		mm_{pp}	290/400
	Vertical		mm_{pp}	290/400
Max Velocity (nominal/limit)	Horizontal	Transversal	cm/s	70,1/121,5
		Longitudinal	cm/s	41,9/72,6
	Vertical		cm/s	42,4/73,5
Max Acceleration at bare table	Horizontal	Transversal	m/s^2	18,75
		Longitudinal	m/s^2	9,38
	Vertical		m/s^2	31,25
Yaw/Pitch/Roll	Rotation degrees		°	N/A
	Velocity		rad/s	N/A
Max Overturning Moment			kN×m	N/A
Max Specimen Dead Weight			kN	392
Max Compensated Dead Weight			kN	392

Table C-6: Shaking table performance

Type of Control	Mixed (Analogue/Digital)

Table C-7: Type of Control

Manufacturer	Instron
Type	Uni-Variable Units

Table C-8: Characteristics of the Analogue Part

Hardware	Computer	Instron 8580 Control Tower
	D/A Channels	8 ADC channels – 16 bit
	A/D Channels	
Software	Designer	Instron

Table C-9: Characteristics of the Digital Part

ANNEX D MODEL DRAWINGS

List of Drawings:

Drawing nº 1 – Model – Story Plan

Drawing nº 2 – Model – Section A-B

Drawing nº 3 – Model – Section C-D

Drawing nº 4 – Model – Foundations Plan

Drawing nº 5 – Model – Beam V1

Drawing nº 6 – Model – Beam V2

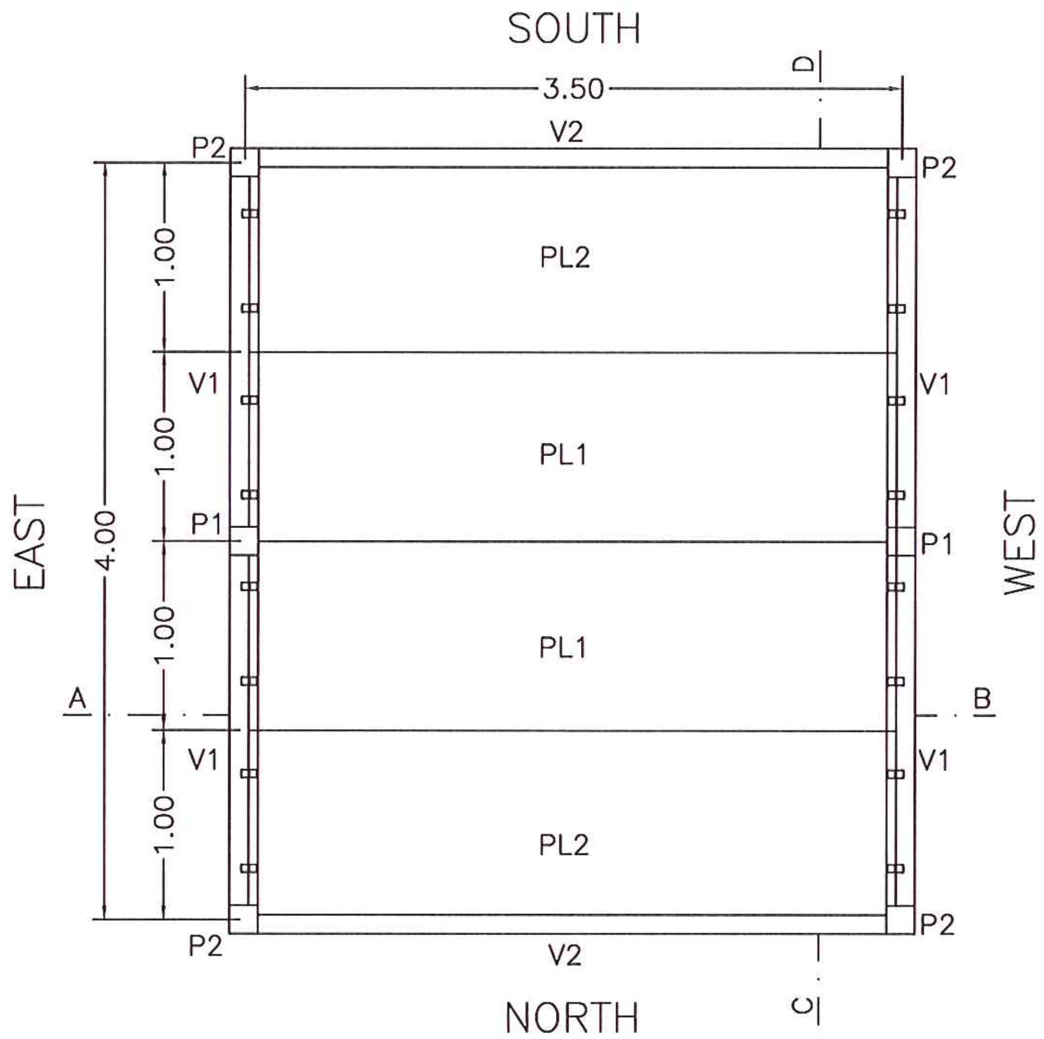
Drawing nº 7 – Model – Columns

Drawing nº 8 – Model – Slabs

Drawing nº 9 – Model – Position of the Additional Masses

Plan View

Scale: 1/40



Dimensions in meters

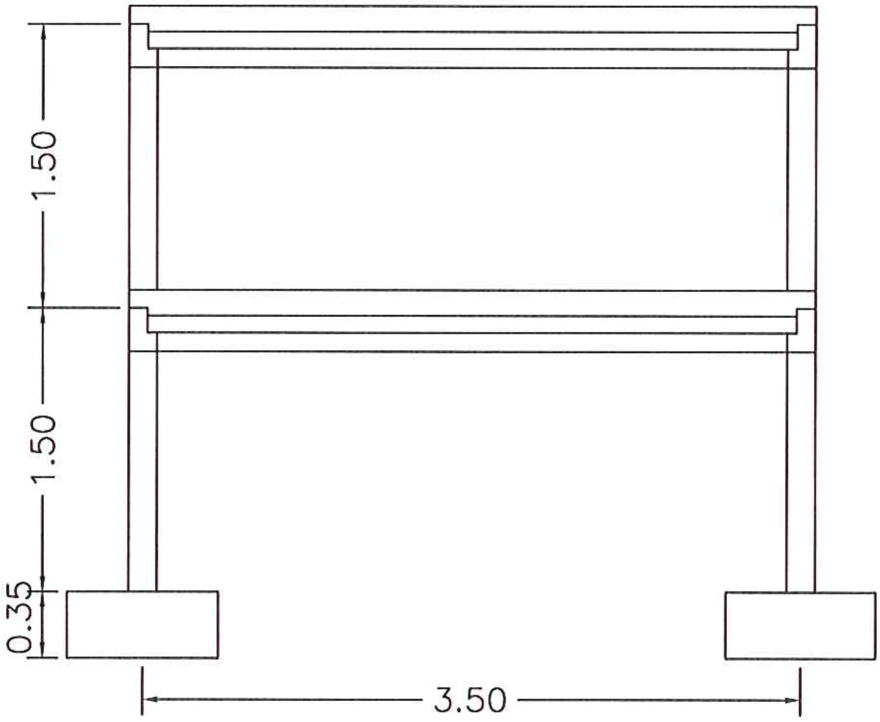
This drawing is based on the Civibral S.A. system drawings

NATIONAL LABORATORY OF CIVIL ENGINEERING LNEC / NESDE	PRECAST STRUCTURES EC8	Dec 2005
Scale: 1:100 (except if indicated)	Model – Story Plan	Drawing N° 1

Section A-B

North View

Scale: 1/40



Dimensions in meters

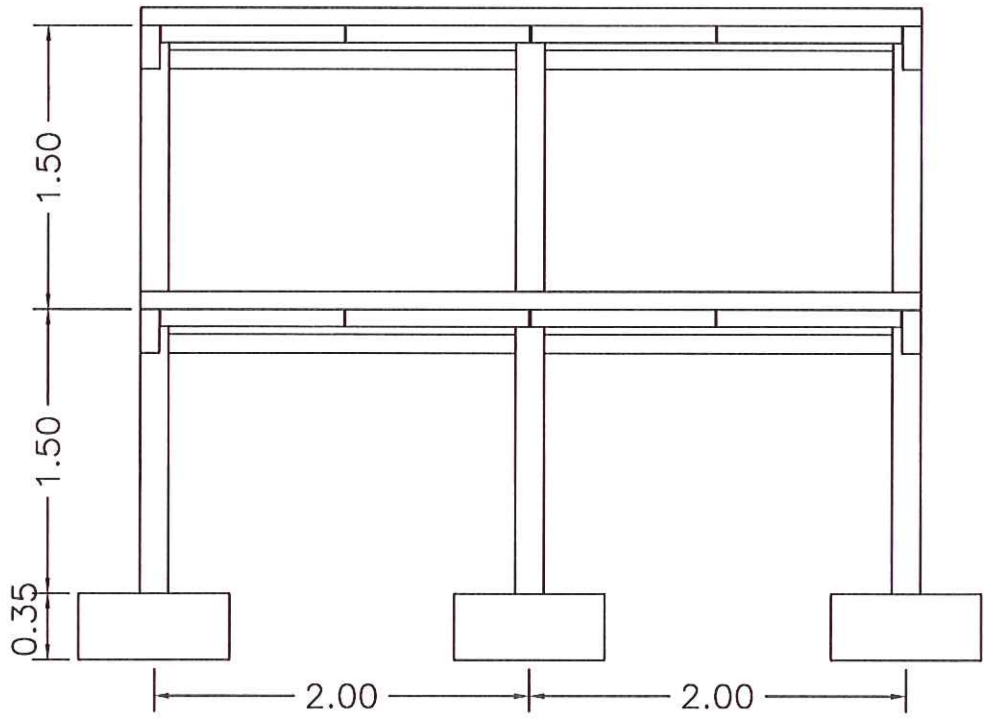
This drawing is based on the Civibral S.A. system drawings

NATIONAL LABORATORY OF CIVIL ENGINEERING LNEC / NESDE	PRECAST STRUCTURES EC8	Dec 2005
Scale: 1:100 (except if indicated)	Model – Section A–B	Drawing N° 2

Section C-D

East View

Scale: 1/40



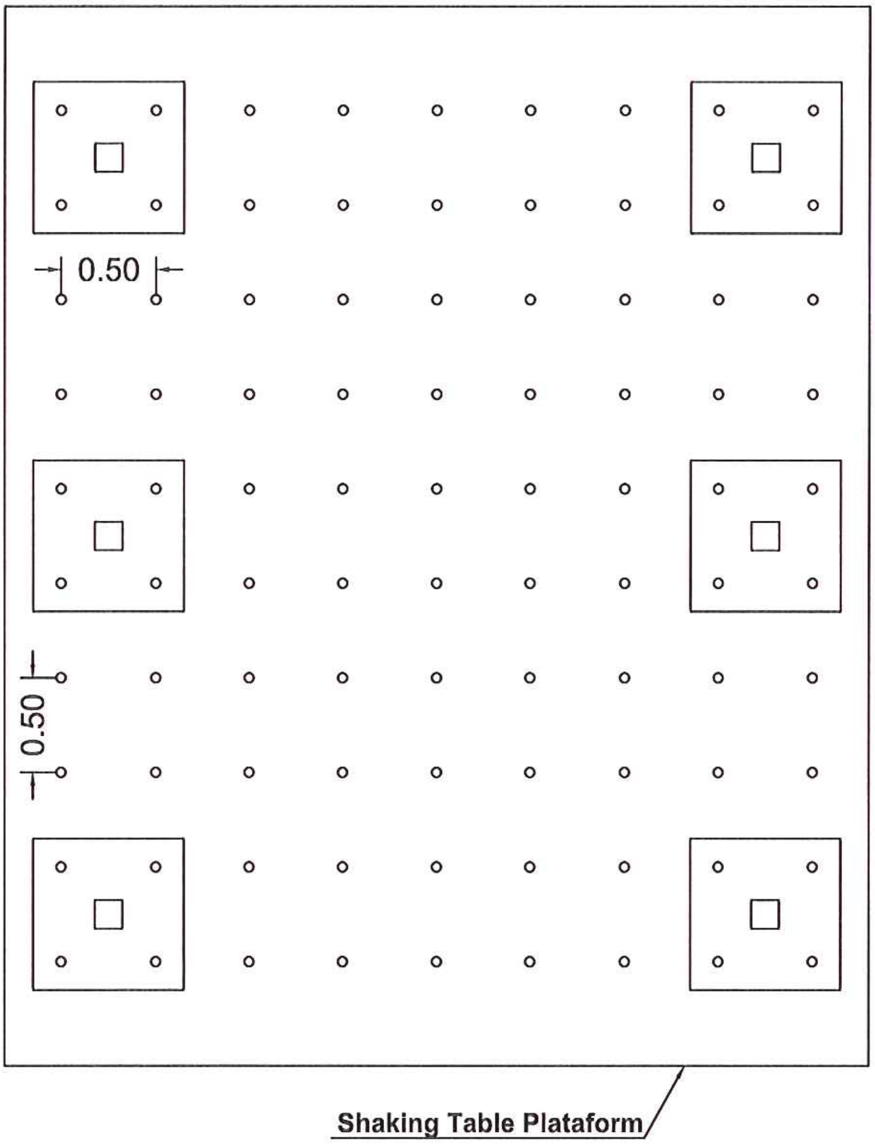
Dimensions in meters

This drawing is based on the Civibral S.A. system drawings

NATIONAL LABORATORY OF CIVIL ENGINEERING LNEC / NESDE	PRECAST STRUCTURES EC8	Dec 2005
Scale: 1:100 (except if indicated)	Model – Section C–D	Drawing N° 3

Foundations Plan

Scale: 1/40



Dimensions in meters

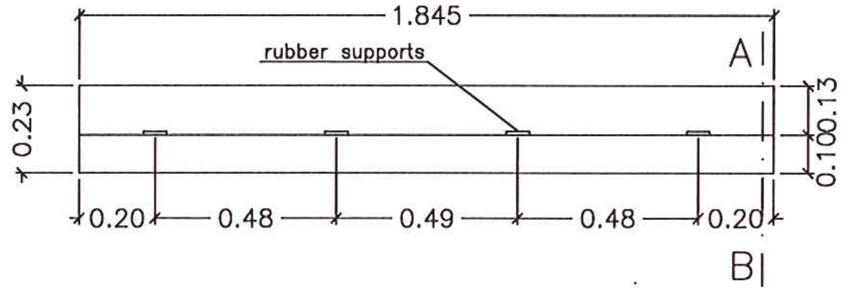
This drawing is based on the Civibral S.A. system drawings

NATIONAL LABORATORY OF CIVIL ENGINEERING LNEC / NESDE	PRECAST STRUCTURES EC8	Dec 2005
Scale: 1:100 (except if indicated)	Model – Foundations Plan	Drawing N° 4

Beam V1

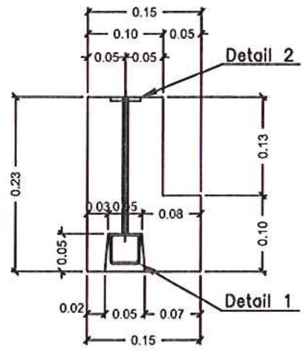
View

Scale: 1/20



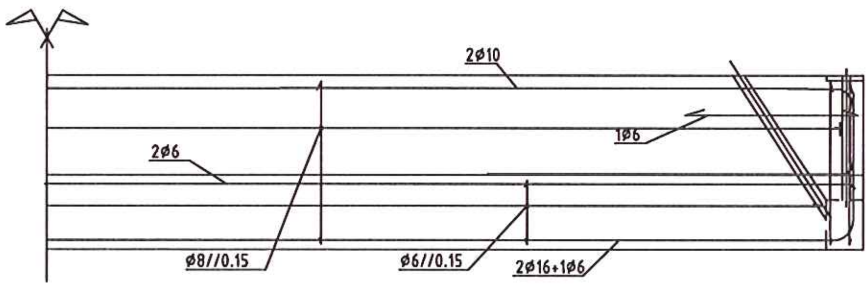
Section A-B

Scale: 1/10



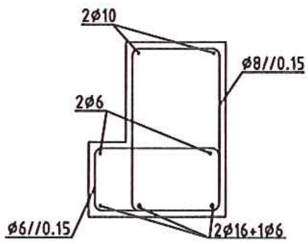
Details View

Scale: 1/10



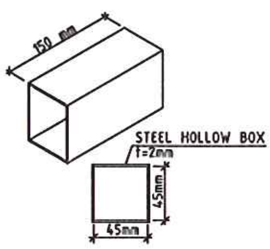
Details Section

Scale: 1/10



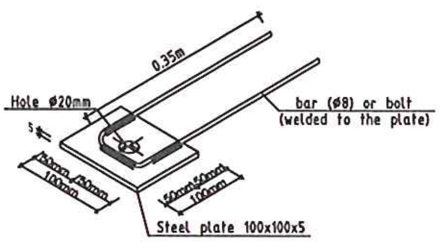
Detail 1

Scale: -



Detail 2

Scale: -



MATERIALS	
Concrete:	
Prestressed Elements	C35/45
Other Elements	C25/30
Steel:	
Reinforcing Steel	A500NR
Welded Mesh	A500EL
Prestressing Steel	FpuK=1860Mpa
Cover:	2.5cm

Dimensions in meters

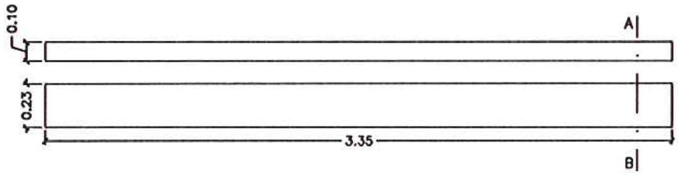
This drawing is based on the Civibral S.A. system drawings

NATIONAL LABORATORY OF CIVIL ENGINEERING LNEC / NESDE	PRECAST STRUCTURES EC8	Dec 2005
Scale: 1:100 (except if indicated)	Model – Beam V1	Drawing Nº 5

Beam V2

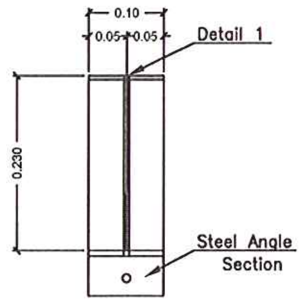
View

Scale: 1/40



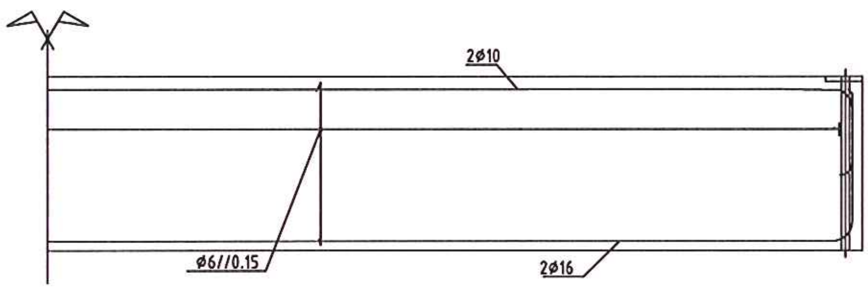
Section A-B

Scale: 1/10



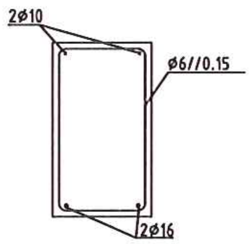
Details View

Scale: 1/10



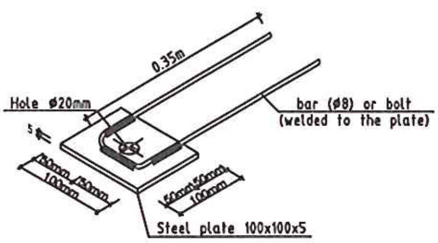
Details Section

Scale: 1/10



Detail 1

Scale: -



MATERIALS	
Concrete:	
Prestressed Elements	*C35/45*
Other Elements	*C25/30*
Steel:	
Reinforcing Steel	*A500NR*
Welded Mesh	*A500EL*
Prestressing Steel	*FpuK=1860Mpa*
Cover:	*2.5cm*

Dimensions in meters

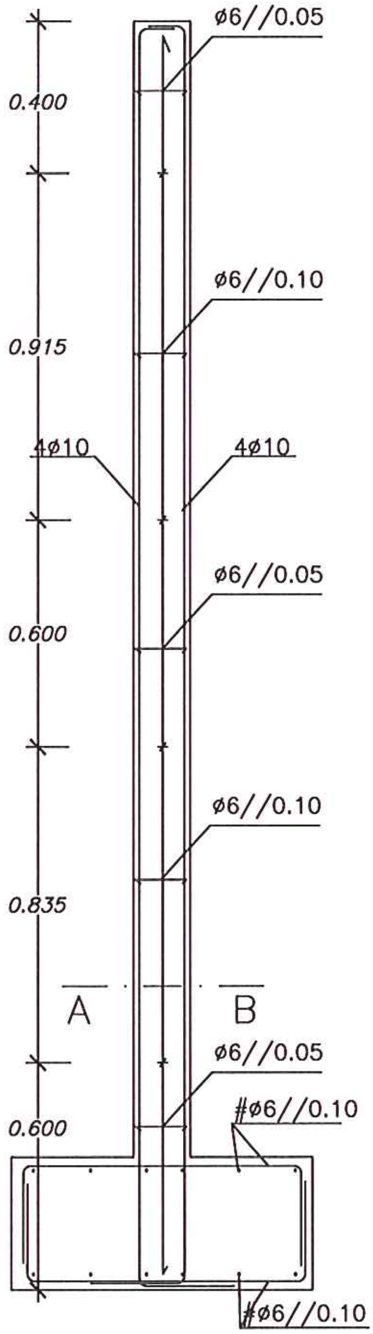
This drawing is based on the Civibral S.A. system drawings

NATIONAL LABORATORY OF CIVIL ENGINEERING LNEC / NESDE	PRECAST STRUCTURES EC8	Dec 2005
Scale: 1:100 (except if indicated)	Model – Beam V2	Drawing N° 6

Column P1

Details

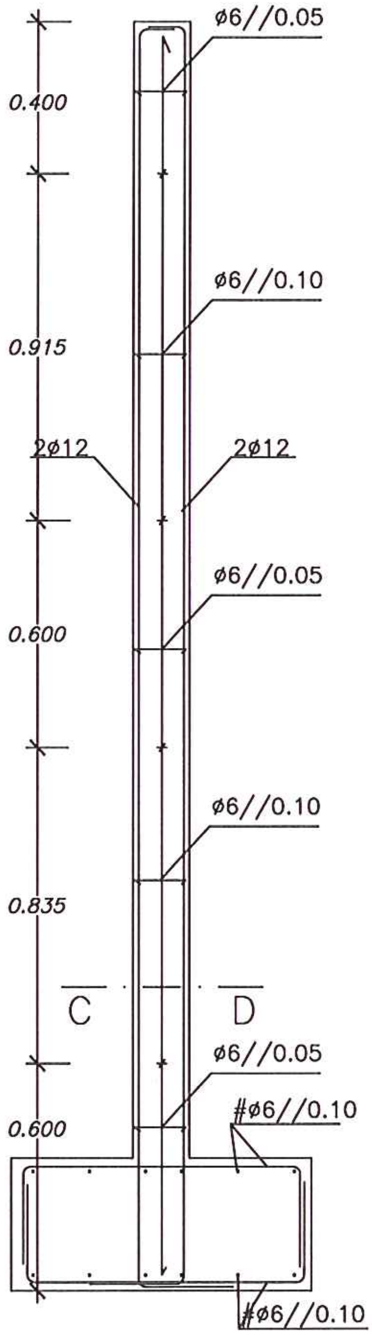
Scale: 1/20



Column P2

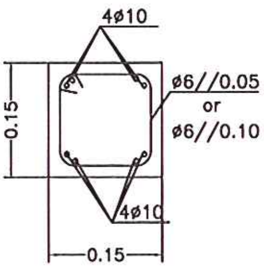
Details

Scale: 1/20



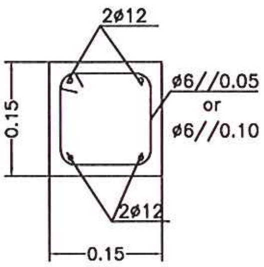
Section A-B

Scale: 1/10



Section C-D

Scale: 1/10

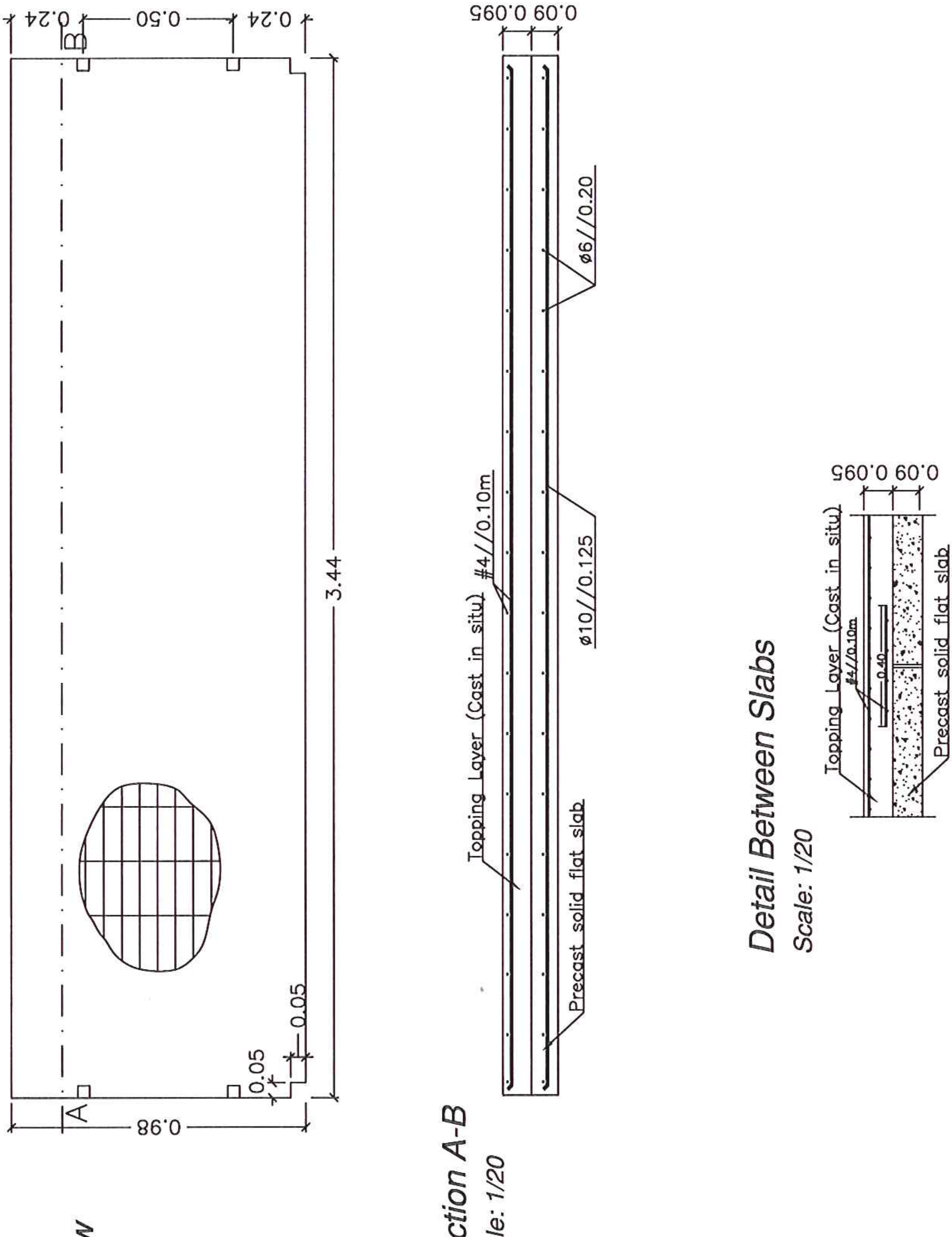


MATERIALS	
Concrete:	
Prestressed Elements	C35/45
Other Elements	C25/30
Steel:	
Reinforcing Steel	A500NR
Welded Mesh	A500EL
Prestressing Steel	FpuK=1860Mpa
Cover:	2.5cm

Dimensions in meters

This drawing is based on the Civibral S.A. system drawings

NATIONAL LABORATORY OF CIVIL ENGINEERING LNEC / NESDE	PRECAST STRUCTURES EC8	Dec 2005
Scale: 1:100 (except if indicated)	Model – Columns	Drawing Nº 7



Slab
Plan View
Scale: 1/20

Section A-B
Scale: 1/20

MATERIALS	
Concrete:	
Prestressed Elements	*C35/45*
Other Elements	*C25/30*
Steel:	
Reinforcing Steel	*A500NR*
Welded Mesh	*A500EL*
Prestressing Steel	*FpuK=1860Mpa*
Cover:	*2.5cm*

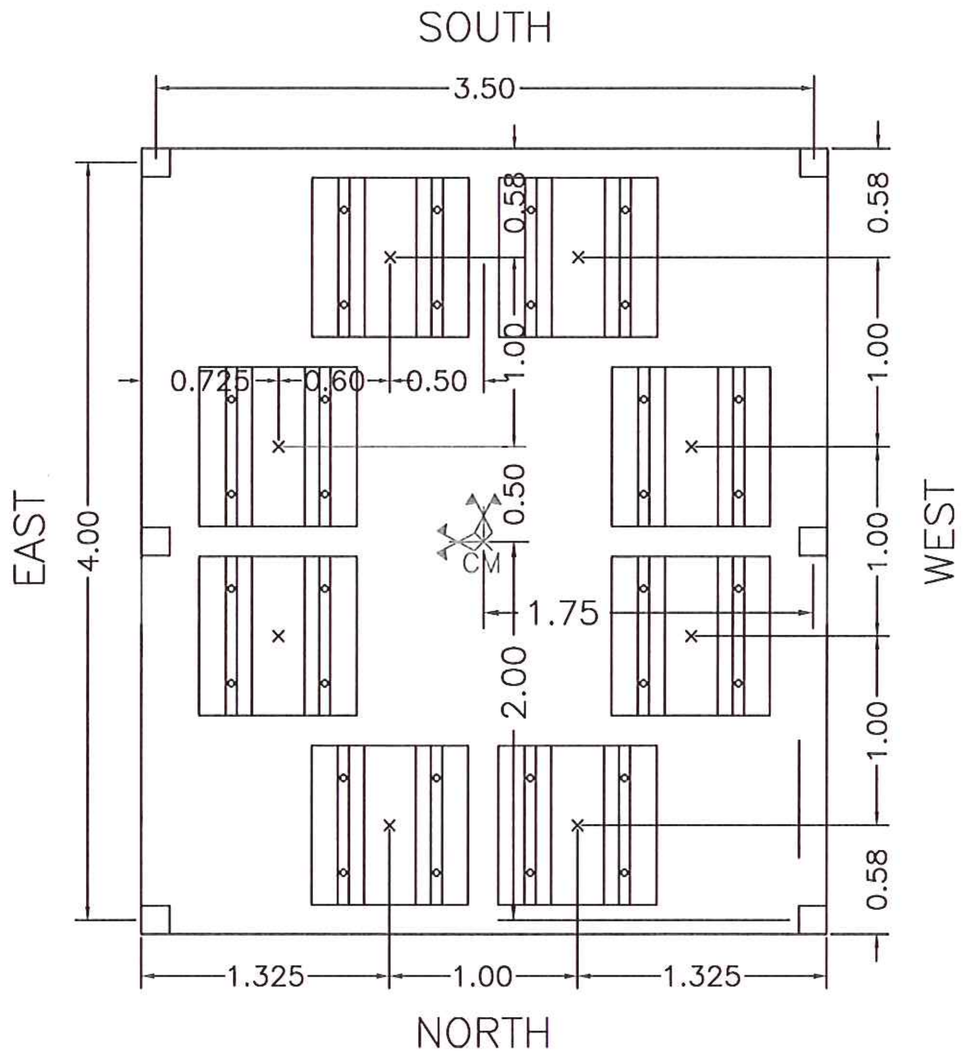
Dimensions in meters

This drawing is based on the Civibral S.A. system drawings

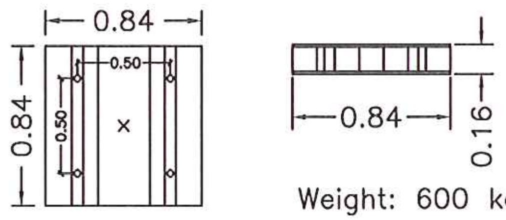
NATIONAL LABORATORY OF CIVIL ENGINEERING LNEC / NESDE	PRECAST STRUCTURES EC8	Dec 2005
Scale: 1:100 (except if indicated)	Model – Slabs	Drawing N° 8

Plan View

Scale: 1/40



DIMENSIONS OF THE MASSES



Weight: 600 kgf

Dimensions in meters

NATIONAL LABORATORY OF CIVIL ENGINEERING LNEC / NESDE	PRECAST STRUCTURES EC8	Dec 2005
Scale: 1:100 (except if indicated)	Model – Position of the Additional Masses	Drawing Nº 9

ANNEX E INSTRUMENTATION AND TEST SETUP

Table of Contents:

E.1 List of Channels

STAGE SERIES		
Nº	Name (ID-POS-TYPE-DIR)	Units
0	ST1-STNE-Acc-Trans	g
1	ST2-STNE-Acc-Long	g
2	ST3-STNW-Acc-Vert	g
3	ST4-STSE-Acc-Vert	g
4	ST5-ST-ADisp-Trans	mm
5	ST6-ST-ADisp-Long	mm
6	DA1-1FNW-ADisp-Trans	mm
7	DA1-1FNW-ADisp-Long	mm
8	DA2-1FSE-ADisp-Trans	mm
9	DA2-1FSE-ADisp-Long	mm
10	DA3-2FNE-ADisp-Trans	mm
11	DA3-2FNE-ADisp-Long	mm
12	DA4-2FNW-ADisp-Trans	mm
13	DA4-2FNW-ADisp-Long	mm
14	DA5-2FSE-ADisp-Trans	mm
15	DA5-2FSE-ADisp-Long	mm
16	DA6-2FSW-ADisp-Trans	mm
17	DA6-2FSW-ADisp-Long	mm
18	DR21-1FNE-RDisp-Trans	mm
19	DR22-1FNE-RDisp-Long	mm
20	DR23-1FSW-RDisp-Trans	mm
21	DR24-1FSW-RDisp-Long	mm
22	DR1-1FNE-RDisp	mm
23	DR2-1FNW-RDisp	mm
24	DR3-1FSE-RDisp	mm
25	DR4-1FSW-RDisp	mm
26	A1-2FNE-Acc-Trans	g
27	A2-2FNE-Acc-Long	g
28	A3-2FE-Acc-Trans	g
29	A4-2FE-Acc-Long	g
30	A5-2FSE-Acc-Trans	g
31	A6-2FSE-Acc-Long	g
32	A7-2FSW-Acc-Trans	g
33	A8-2FSW-Acc-Long	g
34	A9-2FW-Acc-Trans	g
35	A10-2FW-Acc-Long	g
36	A11-2FNW-Acc-Trans	g
37	A12-2FNW-Acc-Long	g
38	A13-1FNE-Acc-Trans	g
39	A14-1FNE-Acc-Long	g
40	A15-1FE-Acc-Trans	g
41	A16-1FE-Acc-Long	g
42	A17-1FSE-Acc-Trans	g
43	A18-1FSE-Acc-Long	g
44	A19-1FSW-Acc-Trans	g
45	A20-1FSW-Acc-Long	g

CAT SERIES		
Nº	Name (ID-POS-TYPE-DIR)	Units
0	ST1-STNE-Acc-Trans	g
1	ST2-STNE-Acc-Long	g
2	ST3-STNW-Acc-Vert	g
3	ST4-STSE-Acc-Vert	g
4	ST5-ST-ADisp-Trans	mm
5	ST6-ST-ADisp-Long	mm
6	A1-2FNE-Acc-Trans	g
7	A2-2FNE-Acc-Long	g
8	A3-2FE-Acc-Trans	g
9	A4-2FE-Acc-Long	g
10	A5-2FSE-Acc-Trans	g
11	A6-2FSE-Acc-Long	g
12	A7-2FSW-Acc-Trans	g
13	A8-2FSW-Acc-Long	g
14	A9-2FW-Acc-Trans	g
15	A10-2FW-Acc-Long	g
16	A11-2FNW-Acc-Trans	g
17	A12-2FNW-Acc-Long	g
18	A13-1FNE-Acc-Trans	g
19	A14-1FNE-Acc-Long	g
20	A15-1FE-Acc-Trans	g
21	A16-1FE-Acc-Long	g
22	A17-1FSE-Acc-Trans	g
23	A18-1FSE-Acc-Long	g
24	A19-1FSW-Acc-Trans	g
25	A20-1FSW-Acc-Long	g
26	A21-1FW-Acc-Trans	g
27	A22-1FW-Acc-Long	g
28	A23-1FNW-Acc-Trans	g
29	A24-1FNW-Acc-Long	g
30	A25-2FNN-Acc-Vert	g
31	A26-2FN-Acc-Vert	g
32	A27-2FC-Acc-Vert	g

46	A21-1FW-Acc-Trans	g
47	A22-1FW-Acc-Long	g
48	A23-1FNW-Acc-Trans	g
49	A24-1FNW-Acc-Long	g
50	A25-2FNN-Acc-Vert	g
51	A26-2FN-Acc-Vert	g
52	A27-2FC-Acc-Vert	g
53	DR5-1FNE-RDisp-BTrans	mm
54	DR6-1FNE-RDisp-TTrans	mm
55	DR7-2FNE-RDisp-BTrans	mm
56	DR8-2FNE-RDisp-TTrans	mm
57	DR9-1FNE-RDisp-BLong	mm
58	DR10-1FNE-RDisp-TLong	mm
59	DR11-2FNE-RDisp-BLong	mm
60	DR12-2FNE-RDisp-TLong	mm
61	DR13-1FE-RDisp-BLong	mm
62	DR14-1FE-RDisp-TLong	mm
63	DR15-2FE-RDisp-BLong	mm
64	DR16-2FE-RDisp-TLong	mm
65	DR17-1FE-RDisp-BLong	mm
66	DR18-1FE-RDisp-TLong	mm
67	DR19-2FE-RDisp-BLong	mm
68	DR20-2FE-RDisp-TLong	mm
69	MC DA1-1FNW-RDisp-Trans	mm
70	MC DA1-1FNW-RDisp-Long	mm
71	MC DA2-1FSE-RDisp-Trans	mm
72	MC DA2-1FSE-RDisp-Long	mm
73	MC DA3-2FNE-RDisp-Trans	mm
74	MC DA3-2FNE-RDisp-Long	mm
75	MC DA4-2FNW-RDisp-Trans	mm
76	MC DA4-2FNW-RDisp-Long	mm
77	MC DA5-2FSE-RDisp-Trans	mm
78	MC DA5-2FSE-RDisp-Long	mm
79	MC DA6-2FSW-RDisp-Trans	mm
80	MC DA6-2FSW-RDisp-Long	mm
81	MC DA7-1FNE-ADisp-Trans	mm
82	MC DA7-1FNE-ADisp-Long	mm
83	MC DA8-1FSW-ADisp-Trans	mm
84	MC DA8-1FSW-ADisp-Long	mm
85	MC DA7-1FNE-RDisp-Trans	mm
86	MC DA7-1FNE-RDisp-Long	mm
87	MC DA8-1FSW-RDisp-Trans	mm
88	MC DA8-1FSW-RDisp-Long	mm
89	MC RD1-2FNE-Elong-Diag	%
90	MC RD2-2FNW-Elong-Diag	%
91	MC RD3-2FSE-Elong-Diag	%
92	MC RD4-2FSW-Elong-Diag	%
93	MC ID1-1FNW-ID-Trans	%
94	MC ID1-1FNW-IDLong	%
95	MC ID2-1FSE-ID-Trans	%
96	MC ID2-1FSE-ID-Long	%
97	MC ID3-1FNE-ID-Trans	%

98	MC ID3-1FNE-ID-Long	%
99	MC ID4-1FSW-ID-Trans	%
100	MC ID4-1FSW-ID-Long	%
101	MC ID5-2FNE-ID-Trans	%
102	MC ID5-2FNE-ID-Long	%
103	MC ID6-2FNW-ID-Trans	%
104	MC ID6-2FNW-ID-Long	%
105	MC ID7-2FSE-ID-Trans	%
106	MC ID7-2FSE-ID-Long	%
107	MC ID8-2FSW-ID-Trans	%
108	MC ID8-2FSW-ID-Long	%
109	MC J3-1FNE-RDisp-Trans	mm
110	MC J3-1FNE-Rot-Trans	rad
111	MC J9-2FNE-RDisp-Trans	mm
112	MC J9-2FNE-Rot-Trans	rad
113	MC J3-1FNE-RDisp-Long	mm
114	MC J3-1FNE-Rot-Long	rad
115	MC J9-2FNE-RDisp-Long	mm
116	MC J9-2FNE-Rot-Long	rad
117	MC J2-1FEN-RDisp-Long	mm
118	MC J2-1FEN-Rot-Long	rad
119	MC J8-2FEN-RDisp-Long	mm
120	MC J8-2FEN-Rot-Long	rad
121	MC J2-1FES-RDisp-Long	mm
122	MC J2-1FES-Rot-Long	rad
123	MC J8-2FES-RDisp-Long	mm
124	MC J8-2FES-Rot-Long	rad
125	MC CM1-CM1F-RDisp-Trans	mm
126	MC CM2-CM1F-RDisp-Long	mm
127	MC CM3-CM1F-RDisp-Rot	rad
128	MC CM4-CM2F-RDisp-Trans	mm
129	MC CM5-CM2F-RDisp-Long	mm
130	MC CM6-CM2F-RDisp-Rot	rad
131	MC CM7-CM1F-ADisp-Trans	g
132	MC CM8-CM1F-ADisp-Long	g
133	MC CM9-CM1F-ADisp-Rot	rad/s^2
134	MC CM10-CM2F-ADisp-Trans	g
135	MC CM11-CM2F-ADisp-Long	g
136	MC CM12-CM2F-ADisp-Rot	rad/s^2
137	MC AAV1-CM1F-AccAvg-Trans	g
138	MC AAV2-CM1F-AccAvg-Long	g
139	MC AAV3-CM1F-RotAccAvg-Trans	rad/s^2
140	MC AAV3-CM1F-RotAccAvg-Long	rad/s^2
141	MC AAV3-CM1F-RotAccAvg-DirAvg	rad/s^2
142	MC AAV4-CM2F-AccAvg-Trans	g
143	MC AAV5-CM2F-AccAvg-Long	g
144	MC AAV6-CM2F-RotAccAvg-Trans	rad/s^2
145	MC AAV6-CM2F-RotAccAvg-Long	rad/s^2
146	MC AAV6-CM2F-RotAccAvg-DirAvg	rad/s^2
147	MC IF1-DOF1-X1	kN
148	MC IF2-DOF1-X2	kN
149	MC IF3-DOF1-Tor	kN.m

150	MC IF4-DOF2-X1	kN
151	MC IF5-DOF2-X2	kN
152	MC IF6-DOF2-Tor	kN.m
153	MC SF1-DOF1-X1	kN
154	MC SF2-DOF1-X2	kN
155	MC SF3-DOF1-Tor	kN.m
156	MC SF4-DOF2-X1	kN
157	MC SF5-DOF2-X2	kN
158	MC SF6-DOF2-Tor	kN.m
159	MC BS1-ST-X1	kN
160	MC BS2-ST-X2	kN
161	MC BT-ST-Tor	kN.m
162	MC BOM1-ST-X1	kN.m
163	MC BOM2-ST-X2	kN.m
164	MC ID9-1FCM-ID-Trans	%
165	MC ID9-1FCM-ID-Long	%
166	MC ID10-2FCM-ID-Trans	%
167	MC ID10-2FCM-ID-Long	%
168	MC CM13-CM2F-CM1F-RDisp-Trans	mm
169	MC CM14-CM2F-CM1F-RDisp-Long	mm

Name Conventions:

MC-Math Channel;

POS: ST-Base Shaking Table; 1F-First Floor; 2F-Second Floor; CM-Center of Mass; DOF-Degree of freedom; NW-Northwest etc

TYPE: Acc-Acceleration; ADisp-Absolute Displacement; RDisp-Relative Displacement; ID-Interstorey Drift; Rot-Rotation; Avg - Average; IF-Inertia Forces; SF-Storey Forces; BS-Base Shear BT-Base Torsion; BOM-Base Overturning Moment; EG-Energy

DIR: Trans=X1-Transversal direction; Long=X2-Longitudinal direction; Vert=Tor-Vertical direction

E.2 Sensors Technical Data

	Manufacture: PCB PIEZOTRONICS (www.pcb.com) Model: 337A26 Sensitivity: 100 mV/g Measurement range: ±50 g pk Broadband Resolution: 0.0001 g rms Frequency range: 0.5 to 5000 Hz

Table E-1: Piezoelectric accelerometers

	Manufacture: HAMAMATSU PHOTONICS (www.hamamatsu.com) Model: C5949 and C2399-00 Measurement points: 1 to 7 Spectral response: 700 to 1150 nm Sampling frequency: 300 Hz Position detection error: ±1% Error due to light: ±1%

Table E-2: Optical displacement transducers

	Manufacture: RDP ELECTRONICS (www.rdpe.com) Model: ACT2000, ACT4000 and ACT6000 Stroke: ±50mm (ACT2000);±100mm (ACT4000);±150mm (ACT6000) Sensitivity: 15 mV/V/mm (ACT6000) to 30 mV/V/mm (ACT2000) Energising supply: 5 Vrms, 5 kHz Linearity deviation: 0.08% (ACT2000) to 0.3% (ACT60000)
	Manufacture: HOTTINGER BALDWIN M. (www.hbm.com) Model: WA300 and WA500 Sensitivity: 80 mV/V Linearity deviation: ±0.1% to ±0.2% Frequency range: 5 to 65 Hz

Table E-3: Inductive displacement transducers

E.3 Math Channels Calculations

E.3.1 Relative Displacements

```
MATH CHANNELS REPORT
LNEC-SPA - Signal Processing and Analysis Program
File:   1-MC DA1_to_DA6-RDisp.bin

USED CHANNELS
        4 - ST5-ST-ADisp-Trans
        5 - ST6-ST-ADisp-Long
        6 - DA1-1FNW-ADisp-Trans
        7 - DA1-1FNW-ADisp-Long
        8 - DA2-1FSE-ADisp-Trans
        9 - DA2-1FSE-ADisp-Long
        10 - DA3-2FNE-ADisp-Trans
        11 - DA3-2FNE-ADisp-Long
        12 - DA4-2FNW-ADisp-Trans
        13 - DA4-2FNW-ADisp-Long
        14 - DA5-2FSE-ADisp-Trans
        15 - DA5-2FSE-ADisp-Long
        16 - DA6-2FSW-ADisp-Trans
        17 - DA6-2FSW-ADisp-Long

LEVEL 0 - Type: Operations between channels
        OPERATIONS
                0 - ID: Subtract channels (2nd ch - 1st ch); Channels n°: 4,6,; Parameters:
                1 - ID: Subtract channels (2nd ch - 1st ch); Channels n°: 5,7,; Parameters:
                2 - ID: Subtract channels (2nd ch - 1st ch); Channels n°: 4,8,; Parameters:
                3 - ID: Subtract channels (2nd ch - 1st ch); Channels n°: 5,9,; Parameters:
                4 - ID: Subtract channels (2nd ch - 1st ch); Channels n°: 4,10,; Parameters:
                5 - ID: Subtract channels (2nd ch - 1st ch); Channels n°: 5,11,; Parameters:
                6 - ID: Subtract channels (2nd ch - 1st ch); Channels n°: 4,12,; Parameters:
                7 - ID: Subtract channels (2nd ch - 1st ch); Channels n°: 5,13,; Parameters:
                8 - ID: Subtract channels (2nd ch - 1st ch); Channels n°: 4,14,; Parameters:
                9 - ID: Subtract channels (2nd ch - 1st ch); Channels n°: 5,15,; Parameters:
                10 - ID: Subtract channels (2nd ch - 1st ch); Channels n°: 4,16,;
Parameters:
                11 - ID: Subtract channels (2nd ch - 1st ch); Channels n°: 5,17,;
Parameters:
        CHANNELS OUT NAMES
                0 - MC DA1-1FNW-RDisp-Trans
                1 - MC DA1-1FNW-RDisp-Long
                2 - MC DA2-1FSE-RDisp-Trans
                3 - MC DA2-1FSE-RDisp-Long
                4 - MC DA3-2FNE-RDisp-Trans
                5 - MC DA3-2FNE-RDisp-Long
                6 - MC DA4-2FNW-RDisp-Trans
                7 - MC DA4-2FNW-RDisp-Long
                8 - MC DA5-2FSE-RDisp-Trans
                9 - MC DA5-2FSE-RDisp-Long
                10 - MC DA6-2FSW-RDisp-Trans
                11 - MC DA6-2FSW-RDisp-Long
        CHANNELS OUT UNITS
                mm
                mm
                mm
                mm
                mm
                mm
                mm
                mm
                mm
                mm
                mm
                mm
```

E.3.2 DA7 & DA8 Absolute and Relative Displacements

```
MATH CHANNELS REPORT
LNEC-SPA - Signal Processing and Analysis Program
File:   2-MC DA7_to_DA8-ADisp&RDisp.bin

USED CHANNELS
       4 - ST5-ST-ADisp-Trans
       5 - ST6-ST-ADisp-Long
       18 - DR21-1FNE-RDisp-Trans
       19 - DR22-1FNE-RDisp-Long
       20 - DR23-1FSW-RDisp-Trans
       21 - DR24-1FSW-RDisp-Long

LEVEL 0 - Type: Operations to individual channels
       OPERATIONS
              0 - ID: Add scalar; Channels n°: 18,; Parameters: 3.764070,
              1 - ID: Add scalar; Channels n°: 19,; Parameters: 2.432740,
              2 - ID: Add scalar; Channels n°: 20,; Parameters: 3.764070,
              3 - ID: Add scalar; Channels n°: 21,; Parameters: 2.432740,
              4 - ID: Unchanged; Channels n°: 4,; Parameters: 1.000000,
              5 - ID: Unchanged; Channels n°: 5,; Parameters: 1.000000,
       CHANNELS OUT NAMES
              0 - DR21-1FNE-RDisp-Trans(Add scalar)
              1 - DR22-1FNE-RDisp-Long(Add scalar)
              2 - DR23-1FSW-RDisp-Trans(Add scalar)
              3 - DR24-1FSW-RDisp-Long(Add scalar)
              4 - ST-BS-ADisp-Trans(Unchanged)
              5 - ST-BS-ADisp-Long(Unchanged)

LEVEL 1 - Type: Operations to individual channels
       OPERATIONS
              0 - ID: Multiply by scalar; Channels n°: 0,; Parameters: 0.929841,
              1 - ID: Multiply by scalar; Channels n°: 1,; Parameters: 0.822144,
              2 - ID: Multiply by scalar; Channels n°: 2,; Parameters: 0.929841,
              3 - ID: Multiply by scalar; Channels n°: 3,; Parameters: 0.822144,
              4 - ID: Multiply by scalar; Channels n°: 4,; Parameters: 1.000000,
              5 - ID: Multiply by scalar; Channels n°: 5,; Parameters: 1.000000,
       CHANNELS OUT NAMES
              0 - DR21-1FNE-RDisp-Trans(Add scalar)(Multiply by scalar)
              1 - DR22-1FNE-RDisp-Long(Add scalar)(Multiply by scalar)
              2 - DR23-1FSW-RDisp-Trans(Add scalar)(Multiply by scalar)
              3 - DR24-1FSW-RDisp-Long(Add scalar)(Multiply by scalar)
              4 - ST-BS-ADisp-Trans(Unchanged)(Multiply by scalar)
              5 - ST-BS-ADisp-Long(Unchanged)(Multiply by scalar)

LEVEL 2 - Type: Operations to individual channels
       OPERATIONS
              0 - ID: Subtract scalar (chan-scalar); Channels n°: 0,; Parameters:
3.500000,
              1 - ID: Subtract scalar (chan-scalar); Channels n°: 1,; Parameters:
2.000000,
              2 - ID: Subtract scalar (chan-scalar); Channels n°: 2,; Parameters:
3.500000,
              3 - ID: Subtract scalar (chan-scalar); Channels n°: 3,; Parameters:
2.000000,
              4 - ID: Multiply by scalar; Channels n°: 4,; Parameters: 1.000000,
              5 - ID: Multiply by scalar; Channels n°: 5,; Parameters: 1.000000,
       CHANNELS OUT NAMES
              0 - DR21-1FNE-RDisp-Trans(Add scalar)(Multiply by scalar)(Subtract scalar
(chan-scalar))
              1 - DR22-1FNE-RDisp-Long(Add scalar)(Multiply by scalar)(Subtract scalar
(chan-scalar))
              2 - DR23-1FSW-RDisp-Trans(Add scalar)(Multiply by scalar)(Subtract scalar
(chan-scalar))
              3 - DR24-1FSW-RDisp-Long(Add scalar)(Multiply by scalar)(Subtract scalar
(chan-scalar))
              4 - ST-BS-ADisp-Trans(Unchanged)(Multiply by scalar)(Multiply by scalar)
              5 - ST-BS-ADisp-Long(Unchanged)(Multiply by scalar)(Multiply by scalar)

LEVEL 3 - Type: Operations to individual channels
       OPERATIONS
              0 - ID: Unchanged; Channels n°: 0,; Parameters:
              1 - ID: Multiply by scalar; Channels n°: 1,; Parameters: -1.000000,
              2 - ID: Multiply by scalar; Channels n°: 2,; Parameters: -1.000000,
              3 - ID: Unchanged; Channels n°: 3,; Parameters:
```

```
            4 - ID: Unchanged; Channels n°: 4,; Parameters:
            5 - ID: Unchanged; Channels n°: 5,; Parameters:
      CHANNELS OUT NAMES
            0 - DR21-1FNE-RDisp-Trans(Add scalar)(Multiply by scalar)(Subtract scalar
(chan-scalar))(Unchanged)
            1 - DR22-1FNE-RDisp-Long(Add scalar)(Multiply by scalar)(Subtract scalar
(chan-scalar))(Multiply by scalar)
            2 - DR23-1FSW-RDisp-Trans(Add scalar)(Multiply by scalar)(Subtract scalar
(chan-scalar))(Multiply by scalar)
            3 - DR24-1FSW-RDisp-Long(Add scalar)(Multiply by scalar)(Subtract scalar
(chan-scalar))(Unchanged)
            4 - ST-BS-ADisp-Trans(Unchanged)(Multiply by scalar)(Multiply by
scalar)(Unchanged)
            5 - ST-BS-ADisp-Long(Unchanged)(Multiply by scalar)(Multiply by
scalar)(Unchanged)

LEVEL 4 - Type: Operations between channels
      OPERATIONS
            0 - ID: Unchanged; Channels n°: 0,4,; Parameters:
            1 - ID: Add channels; Channels n°: 1,5,; Parameters:
            2 - ID: Add channels; Channels n°: 2,4,; Parameters:
            3 - ID: Add channels; Channels n°: 3,5,; Parameters:
            4 - ID: Unchanged; Channels n°: 0,; Parameters:
            5 - ID: Unchanged; Channels n°: 1,; Parameters:
            6 - ID: Unchanged; Channels n°: 2,; Parameters:
            7 - ID: Unchanged; Channels n°: 3,; Parameters:
      CHANNELS OUT NAMES
            0 - DR21-1FNE-RDisp-Trans(Add scalar)(Multiply by scalar)(Subtract scalar
(chan-scalar))(Unchanged)(Unchanged)ST-BS-ADisp-Trans(Unchanged)(Multiply by
scalar)(Multiply by scalar)(Unchanged)
            1 - DR22-1FNE-RDisp-Long(Add scalar)(Multiply by scalar)(Subtract scalar
(chan-scalar))(Multiply by scalar)(Add channels)ST-BS-ADisp-Long(Unchanged)(Multiply by
scalar)(Multiply by scalar)(Unchanged)
            2 - DR23-1FSW-RDisp-Trans(Add scalar)(Multiply by scalar)(Subtract scalar
(chan-scalar))(Multiply by scalar)(Add channels)ST-BS-ADisp-Trans(Unchanged)(Multiply by
scalar)(Multiply by scalar)(Unchanged)
            3 - DR24-1FSW-RDisp-Long(Add scalar)(Multiply by scalar)(Subtract scalar
(chan-scalar))(Unchanged)(Add channels)ST-BS-ADisp-Long(Unchanged)(Multiply by
scalar)(Multiply by scalar)(Unchanged)
            4 - DR21-1FNE-RDisp-Trans(Add scalar)(Multiply by scalar)(Subtract scalar
(chan-scalar))(Unchanged)(Unchanged)
            5 - DR22-1FNE-RDisp-Long(Add scalar)(Multiply by scalar)(Subtract scalar
(chan-scalar))(Multiply by scalar)(Unchanged)
            6 - DR23-1FSW-RDisp-Trans(Add scalar)(Multiply by scalar)(Subtract scalar
(chan-scalar))(Multiply by scalar)(Unchanged)
            7 - DR24-1FSW-RDisp-Long(Add scalar)(Multiply by scalar)(Subtract scalar
(chan-scalar))(Unchanged)(Unchanged)

LEVEL 5 - Type: Operations to individual channels
      OPERATIONS
            0 - ID: Unchanged; Channels n°: 0,; Parameters:
            1 - ID: Unchanged; Channels n°: 1,; Parameters:
            2 - ID: Unchanged; Channels n°: 2,; Parameters:
            3 - ID: Unchanged; Channels n°: 3,; Parameters:
            4 - ID: Unchanged; Channels n°: 4,; Parameters:
            5 - ID: Unchanged; Channels n°: 5,; Parameters:
            6 - ID: Unchanged; Channels n°: 6,; Parameters:
            7 - ID: Unchanged; Channels n°: 7,; Parameters:
      CHANNELS OUT NAMES
            0 - MC DA7-1FNE-ADisp-Trans
            1 - MC DA7-1FNE-ADisp-Long
            2 - MC DA8-1FSW-ADisp-Trans
            3 - MC DA8-1FSW-ADisp-Long
            4 - MC DA7-1FNE-RDisp-Trans
            5 - MC DA7-1FNE-RDisp-Long
            6 - MC DA8-1FSW-RDisp-Trans
            7 - MC DA8-1FSW-RDisp-Long
      CHANNELS OUT UNITS
            mm
            mm
            mm
            mm
            mm
            mm
            mm
            mm
```

E.3.3 Rigid Diaphragm

```
MATH CHANNELS REPORT
LNEC-SPA - Signal Processing and Analysis Program
File:   3-MC RigidDiaphragm.bin

USED CHANNELS
        22 - DR1-1FNE-RDisp
        23 - DR2-1FNW-RDisp
        24 - DR3-1FSE-RDisp
        25 - DR4-1FSW-RDisp

LEVEL 0 - Type: Operations to individual channels
        OPERATIONS
                0 - ID: Divide by scalar (chan/scalar); Channels n°: 22,; Parameters:
3950.000000,
                1 - ID: Divide by scalar (chan/scalar); Channels n°: 23,; Parameters:
3950.000000,
                2 - ID: Divide by scalar (chan/scalar); Channels n°: 24,; Parameters:
3950.000000,
                3 - ID: Divide by scalar (chan/scalar); Channels n°: 25,; Parameters:
3950.000000,
        CHANNELS OUT NAMES
                0 - DR1-1FNE-RDisp(Divide by scalar (chan/scalar))
                1 - DR2-1FNW-RDisp(Divide by scalar (chan/scalar))
                2 - DR3-1FSE-RDisp(Divide by scalar (chan/scalar))
                3 - DR4-1FSW-RDisp(Divide by scalar (chan/scalar))

LEVEL 1 - Type: Operations to individual channels
        OPERATIONS
                0 - ID: Multiply by scalar; Channels n°: 0,; Parameters: 100.000000,
                1 - ID: Multiply by scalar; Channels n°: 1,; Parameters: 100.000000,
                2 - ID: Multiply by scalar; Channels n°: 2,; Parameters: 100.000000,
                3 - ID: Multiply by scalar; Channels n°: 3,; Parameters: 100.000000,
        CHANNELS OUT NAMES
                0 - MC RD1-2FNE-Elong-Diag
                1 - MC RD2-2FNW-Elong-Diag
                2 - MC RD3-2FSE-Elong-Diag
                3 - MC RD4-2FSW-Elong-Diag
        CHANNELS OUT UNITS
                %
                %
                %
                %
```

E.3.4 Interstorey Drift

```
MATH CHANNELS REPORT
LNEC-SPA - Signal Processing and Analysis Program
File:   4-MC Interstorey Drifts.bin

USED CHANNELS
        69 - MC DA1-1FNW-RDisp-Trans
        70 - MC DA1-1FNW-RDisp-Long
        71 - MC DA2-1FSE-RDisp-Trans
        72 - MC DA2-1FSE-RDisp-Long
        73 - MC DA3-2FNE-RDisp-Trans
        74 - MC DA3-2FNE-RDisp-Long
        75 - MC DA4-2FNW-RDisp-Trans
        76 - MC DA4-2FNW-RDisp-Long
        77 - MC DA5-2FSE-RDisp-Trans
        78 - MC DA5-2FSE-RDisp-Long
        79 - MC DA6-2FSW-RDisp-Trans
        80 - MC DA6-2FSW-RDisp-Long
        85 - MC DA7-1FNE-RDisp-Trans
        86 - MC DA7-1FNE-RDisp-Long
        87 - MC DA8-1FSW-RDisp-Trans
        88 - MC DA8-1FSW-RDisp-Long

LEVEL 0 - Type: Operations between channels
        OPERATIONS
                0 - ID: Unchanged; Channels n°: 69,; Parameters:
                1 - ID: Unchanged; Channels n°: 70,; Parameters:
                2 - ID: Unchanged; Channels n°: 71,; Parameters:
```

```
                3 - ID: Unchanged; Channels n°: 72,; Parameters:
                4 - ID: Unchanged; Channels n°: 85,; Parameters:
                5 - ID: Unchanged; Channels n°: 86,; Parameters:
                6 - ID: Unchanged; Channels n°: 87,; Parameters:
                7 - ID: Unchanged; Channels n°: 88,; Parameters:
                8 - ID: Subtract channels (1st ch - 2nd ch); Channels n°: 73,85,;
Parameters:
                9 - ID: Subtract channels (1st ch - 2nd ch); Channels n°: 74,86,;
Parameters:
                10 - ID: Subtract channels (2nd ch - 1st ch); Channels n°: 69,75,;
Parameters:
                11 - ID: Subtract channels (2nd ch - 1st ch); Channels n°: 70,76,;
Parameters:
                12 - ID: Subtract channels (2nd ch - 1st ch); Channels n°: 71,77,;
Parameters:
                13 - ID: Subtract channels (2nd ch - 1st ch); Channels n°: 72,78,;
Parameters:
                14 - ID: Subtract channels (1st ch - 2nd ch); Channels n°: 79,87,;
Parameters:
                15 - ID: Subtract channels (1st ch - 2nd ch); Channels n°: 80,88,;
Parameters:
        CHANNELS OUT NAMES
                0 - MC DA1-1FNW-RDisp-Trans(Unchanged)
                1 - MC DA1-1FNW-RDisp-Long(Unchanged)
                2 - MC DA2-1FSE-RDisp-Trans(Unchanged)
                3 - MC DA2-1FSE-RDisp-Long(Unchanged)
                4 - MC DA7-1FNE-RDisp-Trans(Unchanged)
                5 - MC DA7-1FNE-RDisp-Long(Unchanged)
                6 - MC DA8-1FSW-RDisp-Trans(Unchanged)
                7 - MC DA8-1FSW-RDisp-Long(Unchanged)
                8 - MC DA3-2FNE-RDisp-Trans(Subtract channels (1st ch - 2nd ch))MC DA7-1FNE-
RDisp-Trans
                9 - MC DA3-2FNE-RDisp-Long(Subtract channels (1st ch - 2nd ch))MC DA7-1FNE-
RDisp-Long
                10 - MC DA1-1FNW-RDisp-Trans(Subtract channels (2st ch - 1nd ch))MC DA4-
2FNW-RDisp-Trans
                11 - MC DA1-1FNW-RDisp-Long(Subtract channels (2st ch - 1nd ch))MC DA4-2FNW-
RDisp-Long
                12 - MC DA2-1FSE-RDisp-Trans(Subtract channels (2st ch - 1nd ch))MC DA5-
2FSE-RDisp-Trans
                13 - MC DA2-1FSE-RDisp-Long(Subtract channels (2st ch - 1nd ch))MC DA5-2FSE-
RDisp-Long
                14 - MC DA6-2FSW-RDisp-Trans(Subtract channels (1st ch - 2nd ch))MC DA8-
1FSW-RDisp-Trans
                15 - MC DA6-2FSW-RDisp-Long(Subtract channels (1st ch - 2nd ch))MC DA8-1FSW-
RDisp-Long

LEVEL 1 - Type: Operations to individual channels
        OPERATIONS
                0 - ID: Divide by scalar (chan/scalar); Channels n°: 0,; Parameters:
1500.000000,
                1 - ID: Divide by scalar (chan/scalar); Channels n°: 1,; Parameters:
1500.000000,
                2 - ID: Divide by scalar (chan/scalar); Channels n°: 2,; Parameters:
1500.000000,
                3 - ID: Divide by scalar (chan/scalar); Channels n°: 3,; Parameters:
1500.000000,
                4 - ID: Divide by scalar (chan/scalar); Channels n°: 4,; Parameters:
1500.000000,
                5 - ID: Divide by scalar (chan/scalar); Channels n°: 5,; Parameters:
1500.000000,
                6 - ID: Divide by scalar (chan/scalar); Channels n°: 6,; Parameters:
1500.000000,
                7 - ID: Divide by scalar (chan/scalar); Channels n°: 7,; Parameters:
1500.000000,
                8 - ID: Divide by scalar (chan/scalar); Channels n°: 8,; Parameters:
1500.000000,
                9 - ID: Divide by scalar (chan/scalar); Channels n°: 9,; Parameters:
1500.000000,
                10 - ID: Divide by scalar (chan/scalar); Channels n°: 10,; Parameters:
1500.000000,
                11 - ID: Divide by scalar (chan/scalar); Channels n°: 11,; Parameters:
1500.000000,
                12 - ID: Divide by scalar (chan/scalar); Channels n°: 12,; Parameters:
1500.000000,
                13 - ID: Divide by scalar (chan/scalar); Channels n°: 13,; Parameters:
1500.000000,
```

```
            14 - ID: Divide by scalar (chan/scalar); Channels n°: 14,; Parameters:
1500.000000,
            15 - ID: Divide by scalar (chan/scalar); Channels n°: 15,; Parameters:
1500.000000,
        CHANNELS OUT NAMES
            0 - MC ID1-1FNW-ID-Trans
            1 - MC ID1-1FNW-IDLong
            2 - MC ID2-1FSE-ID-Trans
            3 - MC ID2-1FSE-ID-Long
            4 - MC ID3-1FNE-ID-Trans
            5 - MC ID3-1FNE-ID-Long
            6 - MC ID4-1FSW-ID-Trans
            7 - MC ID4-1FSW-ID-Long
            8 - MC ID5-2FNE-ID-Trans
            9 - MC ID5-2FNE-ID-Long
            10 - MC ID6-2FNW-ID-Trans
            11 - MC ID6-2FNW-ID-Long
            12 - MC ID7-2FSE-ID-Trans
            13 - MC ID7-2FSE-ID-Long
            14 - MC ID8-2FSW-ID-Trans
            15 - MC ID8-2FSW-ID-Long

LEVEL 2 - Type: Operations to individual channels
        OPERATIONS
            0 - ID: Multiply by scalar; Channels n°: 0,; Parameters: 100.000000,
            1 - ID: Multiply by scalar; Channels n°: 1,; Parameters: 100.000000,
            2 - ID: Multiply by scalar; Channels n°: 2,; Parameters: 100.000000,
            3 - ID: Multiply by scalar; Channels n°: 3,; Parameters: 100.000000,
            4 - ID: Multiply by scalar; Channels n°: 4,; Parameters: 100.000000,
            5 - ID: Multiply by scalar; Channels n°: 5,; Parameters: 100.000000,
            6 - ID: Multiply by scalar; Channels n°: 6,; Parameters: 100.000000,
            7 - ID: Multiply by scalar; Channels n°: 7,; Parameters: 100.000000,
            8 - ID: Multiply by scalar; Channels n°: 8,; Parameters: 100.000000,
            9 - ID: Multiply by scalar; Channels n°: 9,; Parameters: 100.000000,
            10 - ID: Multiply by scalar; Channels n°: 10,; Parameters: 100.000000,
            11 - ID: Multiply by scalar; Channels n°: 11,; Parameters: 100.000000,
            12 - ID: Multiply by scalar; Channels n°: 12,; Parameters: 100.000000,
            13 - ID: Multiply by scalar; Channels n°: 13,; Parameters: 100.000000,
            14 - ID: Multiply by scalar; Channels n°: 14,; Parameters: 100.000000,
            15 - ID: Multiply by scalar; Channels n°: 15,; Parameters: 100.000000,
        CHANNELS OUT NAMES
            0 - MC ID1-1FNW-ID-Trans
            1 - MC ID1-1FNW-IDLong
            2 - MC ID2-1FSE-ID-Trans
            3 - MC ID2-1FSE-ID-Long
            4 - MC ID3-1FNE-ID-Trans
            5 - MC ID3-1FNE-ID-Long
            6 - MC ID4-1FSW-ID-Trans
            7 - MC ID4-1FSW-ID-Long
            8 - MC ID5-2FNE-ID-Trans
            9 - MC ID5-2FNE-ID-Long
            10 - MC ID6-2FNW-ID-Trans
            11 - MC ID6-2FNW-ID-Long
            12 - MC ID7-2FSE-ID-Trans
            13 - MC ID7-2FSE-ID-Long
            14 - MC ID8-2FSW-ID-Trans
            15 - MC ID8-2FSW-ID-Long
        CHANNELS OUT UNITS
            %
            %
            %
            %
            %
            %
            %
            %
            %
            %
            %
            %
            %
            %
            %
            %
```

E.3.5 Joints Displacements

```
MATH CHANNELS REPORT
LNEC-SPA - Signal Processing and Analysis Program
File:   5-MC JointsDisp&Rot.bin

USED CHANNELS
        53 - DR5-1FNE-RDisp-BTrans
        54 - DR6-1FNE-RDisp-TTrans
        55 - DR7-2FNE-RDisp-BTrans
        56 - DR8-2FNE-RDisp-TTrans
        57 - DR9-1FNE-RDisp-BLong
        58 - DR10-1FNE-RDisp-TLong
        59 - DR11-2FNE-RDisp-BLong
        60 - DR12-2FNE-RDisp-TLong
        61 - DR13-1FE-RDisp-BLong
        62 - DR14-1FE-RDisp-TLong
        63 - DR15-2FE-RDisp-BLong
        64 - DR16-2FE-RDisp-TLong
        65 - DR17-1FE-RDisp-BLong
        66 - DR18-1FE-RDisp-TLong
        67 - DR19-2FE-RDisp-BLong
        68 - DR20-2FE-RDisp-TLong

LEVEL 0 - Type: Operations between channels
        OPERATIONS
                0 - ID: Add channels; Channels n°: 53,54,; Parameters:
                1 - ID: Subtract channels (2nd ch - 1st ch); Channels n°: 53,54,;
Parameters:
                2 - ID: Add channels; Channels n°: 55,56,; Parameters:
                3 - ID: Subtract channels (2nd ch - 1st ch); Channels n°: 55,56,;
Parameters:
                4 - ID: Add channels; Channels n°: 57,58,; Parameters:
                5 - ID: Subtract channels (2nd ch - 1st ch); Channels n°: 57,58,;
Parameters:
                6 - ID: Add channels; Channels n°: 59,60,; Parameters:
                7 - ID: Subtract channels (2nd ch - 1st ch); Channels n°: 59,60,;
Parameters:
                8 - ID: Add channels; Channels n°: 61,62,; Parameters:
                9 - ID: Subtract channels (2nd ch - 1st ch); Channels n°: 61,62,;
Parameters:
                10 - ID: Add channels; Channels n°: 63,64,; Parameters:
                11 - ID: Subtract channels (2nd ch - 1st ch); Channels n°: 63,64,;
Parameters:
                12 - ID: Add channels; Channels n°: 65,66,; Parameters:
                13 - ID: Subtract channels (2nd ch - 1st ch); Channels n°: 65,66,;
Parameters:
                14 - ID: Add channels; Channels n°: 67,68,; Parameters:
                15 - ID: Subtract channels (2nd ch - 1st ch); Channels n°: 67,68,;
Parameters:
        CHANNELS OUT NAMES
                0 - DR5-1FNE-RDisp-BTrans(Add channels)DR6-1FNE-RDisp-TTrans
                1 - DR5-1FNE-RDisp-BTrans(Subtract channels (2nd ch - 1st ch))DR6-1FNE-
RDisp-TTrans
                2 - DR7-2FNE-RDisp-BTrans(Add channels)DR8-2FNE-RDisp-TTrans
                3 - DR7-2FNE-RDisp-BTrans(Subtract channels (2nd ch - 1st ch))DR8-2FNE-
RDisp-TTrans
                4 - DR9-1FNE-RDisp-BLong(Add channels)DR10-1FNE-RDisp-TLong
                5 - DR9-1FNE-RDisp-BLong(Subtract channels (2nd ch - 1st ch))DR10-1FNE-
RDisp-TLong
                6 - DR11-2FNE-RDisp-BLong(Add channels)DR12-2FNE-RDisp-TLong
                7 - DR11-2FNE-RDisp-BLong(Subtract channels (2nd ch - 1st ch))DR12-2FNE-
RDisp-TLong
                8 - DR13-1FE-RDisp-BLong(Add channels)DR14-1FE-RDisp-TLong
                9 - DR13-1FE-RDisp-BLong(Subtract channels (2nd ch - 1st ch))DR14-1FE-RDisp-
TLong
                10 - DR15-2FE-RDisp-BLong(Add channels)DR16-2FE-RDisp-TLong
                11 - DR15-2FE-RDisp-BLong(Subtract channels (2nd ch - 1st ch))DR16-2FE-
RDisp-TLong
                12 - DR17-1FE-RDisp-BLong(Add channels)DR18-1FE-RDisp-TLong
                13 - DR17-1FE-RDisp-BLong(Subtract channels (2nd ch - 1st ch))DR18-1FE-
RDisp-TLong
                14 - DR19-2FE-RDisp-BLong(Add channels)DR20-2FE-RDisp-TLong
                15 - DR19-2FE-RDisp-BLong(Subtract channels (2nd ch - 1st ch))DR20-2FE-
RDisp-TLong
```

```
LEVEL 1 - Type: Operations to individual channels
       OPERATIONS
              0 - ID: Divide by scalar (chan/scalar); Channels n°: 0,; Parameters:
2.000000,
              1 - ID: Divide by scalar (chan/scalar); Channels n°: 1,; Parameters:
190.000000,
              2 - ID: Divide by scalar (chan/scalar); Channels n°: 2,; Parameters:
2.000000,
              3 - ID: Divide by scalar (chan/scalar); Channels n°: 3,; Parameters:
195.000000,
              4 - ID: Divide by scalar (chan/scalar); Channels n°: 4,; Parameters:
2.000000,
              5 - ID: Divide by scalar (chan/scalar); Channels n°: 5,; Parameters:
158.000000,
              6 - ID: Divide by scalar (chan/scalar); Channels n°: 6,; Parameters:
2.000000,
              7 - ID: Divide by scalar (chan/scalar); Channels n°: 7,; Parameters:
173.000000,
              8 - ID: Divide by scalar (chan/scalar); Channels n°: 8,; Parameters:
2.000000,
              9 - ID: Divide by scalar (chan/scalar); Channels n°: 9,; Parameters:
206.000000,
              10 - ID: Divide by scalar (chan/scalar); Channels n°: 10,; Parameters:
2.000000,
              11 - ID: Divide by scalar (chan/scalar); Channels n°: 11,; Parameters:
189.000000,
              12 - ID: Divide by scalar (chan/scalar); Channels n°: 12,; Parameters:
2.000000,
              13 - ID: Divide by scalar (chan/scalar); Channels n°: 13,; Parameters:
217.000000,
              14 - ID: Divide by scalar (chan/scalar); Channels n°: 14,; Parameters:
2.000000,
              15 - ID: Divide by scalar (chan/scalar); Channels n°: 15,; Parameters:
187.000000,
       CHANNELS OUT NAMES
              0 - MC J3-1FNE-RDisp-Trans
              1 - MC J3-1FNE-Rot-Trans
              2 - MC J9-2FNE-RDisp-Trans
              3 - MC J9-2FNE-Rot-Trans
              4 - MC J3-1FNE-RDisp-Long
              5 - MC J3-1FNE-Rot-Long
              6 - MC J9-2FNE-RDisp-Long
              7 - MC J9-2FNE-Rot-Long
              8 - MC J2-1FEN-RDisp-Long
              9 - MC J2-1FEN-Rot-Long
              10 - MC J8-2FEN-RDisp-Long
              11 - MC J8-2FEN-Rot-Long
              12 - MC J2-1FES-RDisp-Long
              13 - MC J2-1FES-Rot-Long
              14 - MC J8-2FES-RDisp-Long
              15 - MC J8-2FES-Rot-Long

LEVEL 2 - Type: Operations to individual channels
       OPERATIONS
              0 - ID: Unchanged; Channels n°: 0,; Parameters:
              1 - ID: Apply atan (rad); Channels n°: 1,; Parameters:
              2 - ID: Unchanged; Channels n°: 2,; Parameters:
              3 - ID: Apply atan (rad); Channels n°: 3,; Parameters:
              4 - ID: Unchanged; Channels n°: 4,; Parameters:
              5 - ID: Apply atan (rad); Channels n°: 5,; Parameters:
              6 - ID: Unchanged; Channels n°: 6,; Parameters:
              7 - ID: Apply atan (rad); Channels n°: 7,; Parameters:
              8 - ID: Unchanged; Channels n°: 8,; Parameters:
              9 - ID: Apply atan (rad); Channels n°: 9,; Parameters:
              10 - ID: Unchanged; Channels n°: 10,; Parameters:
              11 - ID: Apply atan (rad); Channels n°: 11,; Parameters:
              12 - ID: Unchanged; Channels n°: 12,; Parameters:
              13 - ID: Apply atan (rad); Channels n°: 13,; Parameters:
              14 - ID: Unchanged; Channels n°: 14,; Parameters:
              15 - ID: Apply atan (rad); Channels n°: 15,; Parameters:
       CHANNELS OUT NAMES
              0 - MC J3-1FNE-RDisp-Trans
              1 - MC J3-1FNE-Rot-Trans
              2 - MC J9-2FNE-RDisp-Trans
              3 - MC J9-2FNE-Rot-Trans
              4 - MC J3-1FNE-RDisp-Long
              5 - MC J3-1FNE-Rot-Long
```

```
            6 - MC J9-2FNE-RDisp-Long
            7 - MC J9-2FNE-Rot-Long
            8 - MC J2-1FEN-RDisp-Long
            9 - MC J2-1FEN-Rot-Long
            10 - MC J8-2FEN-RDisp-Long
            11 - MC J8-2FEN-Rot-Long
            12 - MC J2-1FES-RDisp-Long
            13 - MC J2-1FES-Rot-Long
            14 - MC J8-2FES-RDisp-Long
            15 - MC J8-2FES-Rot-Long
        CHANNELS OUT UNITS
            mm
            rad
            mm
            rad
            mm
            rad
            mm
            rad
            mm
            rad
            mm
            rad
            mm
            rad
            mm
            rad
```

E.3.6 Center of Mass Relative Displacements

```
MATH CHANNELS REPORT
LNEC-SPA - Signal Processing and Analysis Program
File:  6-MC CMRDispRot.bin

USED CHANNELS
        69 - MC DA1-1FNW-RDisp-Trans
        70 - MC DA1-1FNW-RDisp-Long
        71 - MC DA2-1FSE-RDisp-Trans
        72 - MC DA2-1FSE-RDisp-Long
        73 - MC DA3-2FNE-RDisp-Trans
        74 - MC DA3-2FNE-RDisp-Long
        75 - MC DA4-2FNW-RDisp-Trans
        76 - MC DA4-2FNW-RDisp-Long
        77 - MC DA5-2FSE-RDisp-Trans
        78 - MC DA5-2FSE-RDisp-Long
        79 - MC DA6-2FSW-RDisp-Trans
        80 - MC DA6-2FSW-RDisp-Long
        85 - MC DA7-1FNE-RDisp-Trans
        86 - MC DA7-1FNE-RDisp-Long
        87 - MC DA8-1FSW-RDisp-Trans
        88 - MC DA8-1FSW-RDisp-Long

LEVEL 0 - Type: Operations between channels
        OPERATIONS
                0 - ID: Calculate Disp&Rot - Disp x1; Channels n°: 71,72,85,86,; Parameters:
0.000000,0.000000,4000.000000,0.000000,4000.000000,0.000000,0.000000,4000.000000,0.000000,0
.000000,0.000000,4000.000000,0.000000,0.000000,1750.000000,0.000000,4000.000000,0.000000,0.
000000,1750.000000,2000.000000,
                1 - ID: Calculate Disp&Rot - Disp x2; Channels n°: 71,72,85,86,; Parameters:
0.000000,0.000000,4000.000000,0.000000,4000.000000,0.000000,0.000000,4000.000000,0.000000,0
.000000,0.000000,4000.000000,0.000000,0.000000,1750.000000,0.000000,4000.000000,0.000000,0.
000000,1750.000000,2000.000000,
                2 - ID: Calculate Disp&Rot - Rot; Channels n°: 71,72,85,86,; Parameters:
0.000000,0.000000,4000.000000,0.000000,4000.000000,0.000000,0.000000,4000.000000,0.000000,0
.000000,0.000000,4000.000000,0.000000,0.000000,1750.000000,0.000000,4000.000000,0.000000,0.
000000,1750.000000,2000.000000,
                3 - ID: Calculate Disp&Rot - Disp x1; Channels n°: 85,86,87,88,; Parameters:
0.000000,0.000000,0.000000,0.000000,0.000000,3500.000000,0.000000,0.000000,3500.000000,4000
.000000,0.000000,0.000000,3500.000000,4000.000000,1750.000000,0.000000,0.000000,3500.000000
,4000.000000,1750.000000,2000.000000,
                4 - ID: Calculate Disp&Rot - Disp x2; Channels n°: 85,86,87,88,; Parameters:
0.000000,0.000000,0.000000,0.000000,0.000000,3500.000000,0.000000,0.000000,3500.000000,4000
.000000,0.000000,0.000000,3500.000000,4000.000000,1750.000000,0.000000,0.000000,3500.000000
,4000.000000,1750.000000,2000.000000,
```

5 - ID: Calculate Disp&Rot - Rot; Channels n°: 85,86,87,88,; Parameters:
0.000000,0.000000,0.000000,0.000000,0.000000,3500.000000,0.000000,0.000000,3500.000000,4000.000000,0.000000,0.000000,3500.000000,4000.000000,1750.000000,0.000000,0.000000,3500.000000,4000.000000,1750.000000,2000.000000,

6 - ID: Calculate Disp&Rot - Disp x1; Channels n°: 69,70,85,86,; Parameters:
3500.000000,3500.000000,0.000000,3500.000000,0.000000,0.000000,3500.000000,0.000000,0.000000,0.000000,3500.000000,0.000000,0.000000,1750.000000,3500.000000,0.000000,0.000000,0.000000,1750.000000,2000.000000,

7 - ID: Calculate Disp&Rot - Disp x2; Channels n°: 69,70,85,86,; Parameters:
3500.000000,3500.000000,0.000000,3500.000000,0.000000,0.000000,3500.000000,0.000000,0.000000,0.000000,3500.000000,0.000000,0.000000,0.000000,1750.000000,3500.000000,0.000000,0.000000,0.000000,1750.000000,2000.000000,

8 - ID: Calculate Disp&Rot - Rot; Channels n°: 69,70,85,86,; Parameters:
3500.000000,3500.000000,0.000000,3500.000000,0.000000,0.000000,3500.000000,0.000000,0.000000,0.000000,3500.000000,0.000000,0.000000,0.000000,1750.000000,3500.000000,0.000000,0.000000,0.000000,1750.000000,2000.000000,

9 - ID: Calculate Disp&Rot - Disp x1; Channels n°: 71,72,87,88,; Parameters:
0.000000,0.000000,4000.000000,0.000000,4000.000000,3500.000000,0.000000,4000.000000,3500.000000,4000.000000,0.000000,4000.000000,3500.000000,4000.000000,1750.000000,0.000000,4000.000000,3500.000000,4000.000000,1750.000000,2000.000000,

10 - ID: Calculate Disp&Rot - Disp x2; Channels n°: 71,72,87,88,;
Parameters:
0.000000,0.000000,4000.000000,0.000000,4000.000000,3500.000000,0.000000,4000.000000,3500.000000,4000.000000,0.000000,4000.000000,3500.000000,4000.000000,1750.000000,0.000000,4000.000000,3500.000000,4000.000000,1750.000000,2000.000000,

11 - ID: Calculate Disp&Rot - Rot; Channels n°: 71,72,87,88,; Parameters:
0.000000,0.000000,4000.000000,0.000000,4000.000000,3500.000000,0.000000,4000.000000,3500.000000,4000.000000,0.000000,4000.000000,3500.000000,4000.000000,1750.000000,0.000000,4000.000000,3500.000000,4000.000000,1750.000000,2000.000000,

12 - ID: Calculate Disp&Rot - Disp x1; Channels n°: 69,70,71,72,;
Parameters:
3500.000000,3500.000000,0.000000,3500.000000,0.000000,0.000000,3500.000000,0.000000,0.000000,4000.000000,3500.000000,0.000000,0.000000,4000.000000,1750.000000,3500.000000,0.000000,0.000000,4000.000000,1750.000000,2000.000000,

13 - ID: Calculate Disp&Rot - Disp x2; Channels n°: 69,70,71,72,;
Parameters:
3500.000000,3500.000000,0.000000,3500.000000,0.000000,0.000000,3500.000000,0.000000,0.000000,4000.000000,3500.000000,0.000000,0.000000,4000.000000,1750.000000,3500.000000,0.000000,0.000000,4000.000000,1750.000000,2000.000000,

14 - ID: Calculate Disp&Rot - Rot; Channels n°: 69,70,71,72,; Parameters:
3500.000000,3500.000000,0.000000,3500.000000,0.000000,0.000000,3500.000000,0.000000,0.000000,4000.000000,3500.000000,0.000000,0.000000,4000.000000,1750.000000,3500.000000,0.000000,0.000000,4000.000000,1750.000000,2000.000000,

15 - ID: Calculate Disp&Rot - Disp x1; Channels n°: 69,70,87,88,;
Parameters:
3500.000000,3500.000000,0.000000,3500.000000,0.000000,3500.000000,3500.000000,0.000000,3500.000000,4000.000000,3500.000000,0.000000,3500.000000,4000.000000,1750.000000,3500.000000,0.000000,3500.000000,4000.000000,1750.000000,2000.000000,

16 - ID: Calculate Disp&Rot - Disp x2; Channels n°: 69,70,87,88,;
Parameters:
3500.000000,3500.000000,0.000000,3500.000000,0.000000,3500.000000,3500.000000,0.000000,3500.000000,4000.000000,3500.000000,0.000000,3500.000000,4000.000000,1750.000000,3500.000000,0.000000,3500.000000,4000.000000,1750.000000,2000.000000,

17 - ID: Calculate Disp&Rot - Rot; Channels n°: 69,70,87,88,; Parameters:
3500.000000,3500.000000,0.000000,3500.000000,0.000000,3500.000000,3500.000000,0.000000,3500.000000,4000.000000,3500.000000,0.000000,3500.000000,4000.000000,1750.000000,3500.000000,0.000000,3500.000000,4000.000000,1750.000000,2000.000000,

18 - ID: Calculate Disp&Rot - Disp x1; Channels n°: 73,74,75,76,;
Parameters:
0.000000,0.000000,0.000000,0.000000,0.000000,3500.000000,0.000000,0.000000,3500.000000,0.000000,0.000000,0.000000,3500.000000,0.000000,1750.000000,0.000000,0.000000,3500.000000,0.000000,1750.000000,2000.000000,

19 - ID: Calculate Disp&Rot - Disp x2; Channels n°: 73,74,75,76,;
Parameters:
0.000000,0.000000,0.000000,0.000000,0.000000,3500.000000,0.000000,0.000000,3500.000000,0.000000,0.000000,0.000000,3500.000000,0.000000,1750.000000,0.000000,0.000000,3500.000000,0.000000,1750.000000,2000.000000,

20 - ID: Calculate Disp&Rot - Rot; Channels n°: 73,74,75,76,; Parameters:
0.000000,0.000000,0.000000,0.000000,0.000000,3500.000000,0.000000,0.000000,3500.000000,0.000000,0.000000,0.000000,3500.000000,0.000000,1750.000000,0.000000,0.000000,3500.000000,0.000000,1750.000000,2000.000000,

21 - ID: Calculate Disp&Rot - Disp x1; Channels n°: 73,74,77,78,;
Parameters:
0.000000,0.000000,0.000000,0.000000,0.000000,0.000000,0.000000,0.000000,0.000000,4000.000000,0.000000,0.000000,0.000000,4000.000000,1750.000000,0.000000,0.000000,0.000000,4000.000000,1750.000000,2000.000000,

22 - ID: Calculate Disp&Rot - Disp x2; Channels n°: 73,74,77,78,;
Parameters:
0.000000,0.000000,0.000000,0.000000,0.000000,0.000000,0.000000,0.000000,0.000000,4000.00000
0,0.000000,0.000000,0.000000,4000.000000,1750.000000,0.000000,0.000000,0.000000,4000.000000
,1750.000000,2000.000000,
23 - ID: Calculate Disp&Rot - Rot; Channels n°: 73,74,77,78,; Parameters:
0.000000,0.000000,0.000000,0.000000,0.000000,0.000000,0.000000,0.000000,0.000000,4000.00000
0,0.000000,0.000000,0.000000,4000.000000,1750.000000,0.000000,0.000000,0.000000,4000.000000
,1750.000000,2000.000000,
24 - ID: Calculate Disp&Rot - Disp x1; Channels n°: 73,74,79,80,;
Parameters:
0.000000,0.000000,0.000000,0.000000,0.000000,3500.000000,0.000000,0.000000,3500.000000,4000
.000000,0.000000,0.000000,3500.000000,4000.000000,1750.000000,0.000000,0.000000,3500.000000
,4000.000000,1750.000000,2000.000000,
25 - ID: Calculate Disp&Rot - Disp x2; Channels n°: 73,74,79,80,;
Parameters:
0.000000,0.000000,0.000000,0.000000,0.000000,3500.000000,0.000000,0.000000,3500.000000,4000
.000000,0.000000,0.000000,3500.000000,4000.000000,1750.000000,0.000000,0.000000,3500.000000
,4000.000000,1750.000000,2000.000000,
26 - ID: Calculate Disp&Rot - Rot; Channels n°: 73,74,79,80,; Parameters:
0.000000,0.000000,0.000000,0.000000,0.000000,3500.000000,0.000000,0.000000,3500.000000,4000
.000000,0.000000,0.000000,3500.000000,4000.000000,1750.000000,0.000000,0.000000,3500.000000
,4000.000000,1750.000000,2000.000000,
27 - ID: Calculate Disp&Rot - Disp x1; Channels n°: 75,76,77,78,;
Parameters:
3500.000000,3500.000000,0.000000,3500.000000,0.000000,0.000000,3500.000000,0.000000,0.00000
0,4000.000000,3500.000000,0.000000,0.000000,4000.000000,1750.000000,3500.000000,0.000000,0.
000000,4000.000000,1750.000000,2000.000000,
28 - ID: Calculate Disp&Rot - Disp x2; Channels n°: 75,76,77,78,;
Parameters:
3500.000000,3500.000000,0.000000,3500.000000,0.000000,0.000000,3500.000000,0.000000,0.00000
0,4000.000000,3500.000000,0.000000,0.000000,4000.000000,1750.000000,3500.000000,0.000000,0.
000000,4000.000000,1750.000000,2000.000000,
29 - ID: Calculate Disp&Rot - Rot; Channels n°: 75,76,77,78,; Parameters:
3500.000000,3500.000000,0.000000,3500.000000,0.000000,0.000000,3500.000000,0.000000,0.00000
0,4000.000000,3500.000000,0.000000,0.000000,4000.000000,1750.000000,3500.000000,0.000000,0.
000000,4000.000000,1750.000000,2000.000000,
30 - ID: Calculate Disp&Rot - Disp x1; Channels n°: 75,76,79,80,;
Parameters:
3500.000000,3500.000000,0.000000,3500.000000,0.000000,3500.000000,3500.000000,0.000000,3500
.000000,4000.000000,3500.000000,0.000000,3500.000000,4000.000000,1750.000000,3500.000000,0.
000000,3500.000000,4000.000000,1750.000000,2000.000000,
31 - ID: Calculate Disp&Rot - Disp x2; Channels n°: 75,76,79,80,;
Parameters:
3500.000000,3500.000000,0.000000,3500.000000,0.000000,3500.000000,3500.000000,0.000000,3500
.000000,4000.000000,3500.000000,0.000000,3500.000000,4000.000000,1750.000000,3500.000000,0.
000000,3500.000000,4000.000000,1750.000000,2000.000000,
32 - ID: Calculate Disp&Rot - Rot; Channels n°: 75,76,79,80,; Parameters:
3500.000000,3500.000000,0.000000,3500.000000,0.000000,3500.000000,3500.000000,0.000000,3500
.000000,4000.000000,3500.000000,0.000000,3500.000000,4000.000000,1750.000000,3500.000000,0.
000000,3500.000000,4000.000000,1750.000000,2000.000000,
33 - ID: Calculate Disp&Rot - Disp x1; Channels n°: 77,78,79,80,;
Parameters:
0.000000,0.000000,4000.000000,0.000000,4000.000000,3500.000000,0.000000,4000.000000,3500.00
0000,4000.000000,0.000000,4000.000000,3500.000000,4000.000000,1750.000000,0.000000,4000.000
000,3500.000000,4000.000000,1750.000000,2000.000000,
34 - ID: Calculate Disp&Rot - Disp x2; Channels n°: 77,78,79,80,;
Parameters:
0.000000,0.000000,4000.000000,0.000000,4000.000000,3500.000000,0.000000,4000.000000,3500.00
0000,4000.000000,0.000000,4000.000000,3500.000000,4000.000000,1750.000000,0.000000,4000.000
000,3500.000000,4000.000000,1750.000000,2000.000000,
35 - ID: Calculate Disp&Rot - Rot; Channels n°: 77,78,79,80,; Parameters:
0.000000,0.000000,4000.000000,0.000000,4000.000000,3500.000000,0.000000,4000.000000,3500.00
0000,4000.000000,0.000000,4000.000000,3500.000000,4000.000000,1750.000000,0.000000,4000.000
000,3500.000000,4000.000000,1750.000000,2000.000000,
CHANNELS OUT NAMES
0 - DA2 DA7 Calculate RDisp&Rot - Disp x1
1 - DA2 DA7 Calculate RDisp&Rot - Disp x2
2 - DA2 DA7 Calculate RDisp&Rot - Rot
3 - DA7 DA8 Calculate RDisp&Rot - Disp x1
4 - DA7 DA8 Calculate RDisp&Rot - Disp x2
5 - DA7 DA8 Calculate RDisp&Rot - Rot
6 - DA1 DA7 Calculate RDisp&Rot - Disp x1
7 - DA1 DA7 Calculate RDisp&Rot - Disp x2
8 - DA1 DA7 Calculate RDisp&Rot - Rot
9 - DA2 DA8 Calculate RDisp&Rot - Disp x1
10 - DA2 DA8 Calculate RDisp&Rot - Disp x2

```
            11 - DA2 DA8 Calculate RDisp&Rot - Rot
            12 - DA1 DA2 Calculate RDisp&Rot - Disp x1
            13 - DA1 DA2 Calculate RDisp&Rot - Disp x2
            14 - DA1 DA2 Calculate RDisp&Rot - Rot
            15 - DA1 DA8 Calculate RDisp&Rot - Disp x1
            16 - DA1 DA8 Calculate RDisp&Rot - Disp x2
            17 - DA1 DA8 Calculate RDisp&Rot - Rot
            18 - DA3 DA4 Calculate RDisp&Rot - Disp x1
            19 - DA3 DA4 Calculate RDisp&Rot - Disp x2
            20 - DA3 DA4 Calculate RDisp&Rot - Rot
            21 - DA3 DA5 Calculate RDisp&Rot - Disp x1
            22 - DA3 DA5 Calculate RDisp&Rot - Disp x2
            23 - DA3 DA5 Calculate RDisp&Rot - Rot
            24 - DA3 DA6 Calculate RDisp&Rot - Disp x1
            25 - DA3 DA6 Calculate RDisp&Rot - Disp x2
            26 - DA3 DA6 Calculate RDisp&Rot - Rot
            27 - DA4 DA5 Calculate RDisp&Rot - Disp x1
            28 - DA4 DA5 Calculate RDisp&Rot - Disp x2
            29 - DA4 DA5 Calculate RDisp&Rot - Rot
            30 - DA4 DA6 Calculate RDisp&Rot - Disp x1
            31 - DA4 DA6 Calculate RDisp&Rot - Disp x2
            32 - DA4 DA6 Calculate RDisp&Rot - Rot
            33 - DA5 DA6 Calculate RDisp&Rot - Disp x1
            34 - DA5 DA6 Calculate RDisp&Rot - Disp x2
            35 - DA5 DA6 Calculate RDisp&Rot - Rot

LEVEL 1 - Type: Operations between channels
      OPERATIONS
            0 - ID: Unchanged; Channels n°: 12,; Parameters:
            1 - ID: Unchanged; Channels n°: 13,; Parameters:
            2 - ID: Unchanged; Channels n°: 14,; Parameters:
            3 - ID: Average Channels; Channels n°: 18,21,24,27,30,33,; Parameters:
            4 - ID: Average Channels; Channels n°: 19,22,25,28,31,34,; Parameters:
            5 - ID: Average Channels; Channels n°: 20,23,26,29,32,35,; Parameters:
      CHANNELS OUT NAMES
            0 - MC CM1-CM1F-RDisp-Trans
            1 - MC CM2-CM1F-RDisp-Long
            2 - MC CM3-CM1F-RDisp-Rot
            3 - MC CM4-CM2F-RDisp-Trans
            4 - MC CM5-CM2F-RDisp-Long
            5 - MC CM6-CM2F-RDisp-Rot
      CHANNELS OUT UNITS
            mm
            mm
            rad
            mm
            mm
            rad
```

E.3.7 Center of Mass Absolute Displacements

```
MATH CHANNELS REPORT
LNEC-SPA - Signal Processing and Analysis Program
File:  7-MC CMADispRot.bin

USED CHANNELS
      6 - DA1-1FNW-ADisp-Trans
      7 - DA1-1FNW-ADisp-Long
      8 - DA2-1FSE-ADisp-Trans
      9 - DA2-1FSE-ADisp-Long
      10 - DA3-2FNE-ADisp-Trans
      11 - DA3-2FNE-ADisp-Long
      12 - DA4-2FNW-ADisp-Trans
      13 - DA4-2FNW-ADisp-Long
      14 - DA5-2FSE-ADisp-Trans
      15 - DA5-2FSE-ADisp-Long
      16 - DA6-2FSW-ADisp-Trans
      17 - DA6-2FSW-ADisp-Long
      81 - MC DA7-1FNE-ADisp-Trans
      82 - MC DA7-1FNE-ADisp-Long
      83 - MC DA8-1FSW-ADisp-Trans
      84 - MC DA8-1FSW-ADisp-Long
      85 - MC DA7-1FNE-RDisp-Trans

LEVEL 0 - Type: Operations between channels
      OPERATIONS
```

```
          0 - ID: Calculate Disp&Rot - Disp x1; Channels n°: 8,9,81,82,; Parameters:
0.000000,0.000000,4000.000000,0.000000,4000.000000,0.000000,0.000000,4000.000000,0.000000,0
.000000,0.000000,4000.000000,0.000000,0.000000,1750.000000,0.000000,4000.000000,0.000000,0.
000000,1750.000000,2000.000000,
          1 - ID: Calculate Disp&Rot - Disp x2; Channels n°: 8,9,81,82,; Parameters:
0.000000,0.000000,4000.000000,0.000000,4000.000000,0.000000,0.000000,4000.000000,0.000000,0
.000000,0.000000,4000.000000,0.000000,0.000000,1750.000000,0.000000,4000.000000,0.000000,0.
000000,1750.000000,2000.000000,
          2 - ID: Calculate Disp&Rot - Rot; Channels n°: 8,9,81,82,; Parameters:
0.000000,0.000000,4000.000000,0.000000,4000.000000,0.000000,0.000000,4000.000000,0.000000,0
.000000,0.000000,4000.000000,0.000000,0.000000,1750.000000,0.000000,4000.000000,0.000000,0.
000000,1750.000000,2000.000000,
          3 - ID: Calculate Disp&Rot - Disp x1; Channels n°: 81,82,83,84,; Parameters:
0.000000,0.000000,0.000000,0.000000,0.000000,3500.000000,0.000000,0.000000,3500.000000,4000
.000000,0.000000,0.000000,3500.000000,4000.000000,1750.000000,0.000000,0.000000,3500.000000
,4000.000000,1750.000000,2000.000000,
          4 - ID: Calculate Disp&Rot - Disp x2; Channels n°: 81,82,83,84,; Parameters:
0.000000,0.000000,0.000000,0.000000,0.000000,3500.000000,0.000000,0.000000,3500.000000,4000
.000000,0.000000,0.000000,3500.000000,4000.000000,1750.000000,0.000000,0.000000,3500.000000
,4000.000000,1750.000000,2000.000000,
          5 - ID: Calculate Disp&Rot - Rot; Channels n°: 81,82,83,84,; Parameters:
0.000000,0.000000,0.000000,0.000000,0.000000,3500.000000,0.000000,0.000000,3500.000000,4000
.000000,0.000000,0.000000,3500.000000,4000.000000,1750.000000,0.000000,0.000000,3500.000000
,4000.000000,1750.000000,2000.000000,
          6 - ID: Calculate Disp&Rot - Disp x1; Channels n°: 6,7,81,82,; Parameters:
3500.000000,3500.000000,0.000000,3500.000000,0.000000,0.000000,3500.000000,0.000000,0.00000
0,0.000000,3500.000000,0.000000,0.000000,0.000000,1750.000000,3500.000000,0.000000,0.000000
,0.000000,1750.000000,2000.000000,
          7 - ID: Calculate Disp&Rot - Disp x2; Channels n°: 6,7,81,82,; Parameters:
3500.000000,3500.000000,0.000000,3500.000000,0.000000,0.000000,3500.000000,0.000000,0.00000
0,0.000000,3500.000000,0.000000,0.000000,0.000000,1750.000000,3500.000000,0.000000,0.000000
,0.000000,1750.000000,2000.000000,
          8 - ID: Calculate Disp&Rot - Rot; Channels n°: 6,7,81,82,; Parameters:
3500.000000,3500.000000,0.000000,3500.000000,0.000000,0.000000,3500.000000,0.000000,0.00000
0,0.000000,3500.000000,0.000000,0.000000,0.000000,1750.000000,3500.000000,0.000000,0.000000
,0.000000,1750.000000,2000.000000,
          9 - ID: Calculate Disp&Rot - Disp x1; Channels n°: 8,9,83,84,; Parameters:
0.000000,0.000000,4000.000000,0.000000,4000.000000,3500.000000,0.000000,4000.000000,3500.00
0000,4000.000000,0.000000,4000.000000,3500.000000,4000.000000,1750.000000,0.000000,4000.000
000,3500.000000,4000.000000,1750.000000,2000.000000,
          10 - ID: Calculate Disp&Rot - Disp x2; Channels n°: 8,9,83,84,; Parameters:
0.000000,0.000000,4000.000000,0.000000,4000.000000,3500.000000,0.000000,4000.000000,3500.00
0000,4000.000000,0.000000,4000.000000,3500.000000,4000.000000,1750.000000,0.000000,4000.000
000,3500.000000,4000.000000,1750.000000,2000.000000,
          11 - ID: Calculate Disp&Rot - Rot; Channels n°: 8,9,83,84,; Parameters:
0.000000,0.000000,4000.000000,0.000000,4000.000000,3500.000000,0.000000,4000.000000,3500.00
0000,4000.000000,0.000000,4000.000000,3500.000000,4000.000000,1750.000000,0.000000,4000.000
000,3500.000000,4000.000000,1750.000000,2000.000000,
          12 - ID: Calculate Disp&Rot - Disp x1; Channels n°: 6,7,8,9,; Parameters:
3500.000000,3500.000000,0.000000,3500.000000,0.000000,0.000000,3500.000000,0.000000,0.00000
0,4000.000000,3500.000000,0.000000,0.000000,4000.000000,1750.000000,3500.000000,0.000000,0.
000000,4000.000000,1750.000000,2000.000000,
          13 - ID: Calculate Disp&Rot - Disp x2; Channels n°: 6,7,8,9,; Parameters:
3500.000000,3500.000000,0.000000,3500.000000,0.000000,0.000000,3500.000000,0.000000,0.00000
0,4000.000000,3500.000000,0.000000,0.000000,4000.000000,1750.000000,3500.000000,0.000000,0.
000000,4000.000000,1750.000000,2000.000000,
          14 - ID: Calculate Disp&Rot - Rot; Channels n°: 6,7,8,9,; Parameters:
3500.000000,3500.000000,0.000000,3500.000000,0.000000,0.000000,3500.000000,0.000000,0.00000
0,4000.000000,3500.000000,0.000000,0.000000,4000.000000,1750.000000,3500.000000,0.000000,0.
000000,4000.000000,1750.000000,2000.000000,
          15 - ID: Calculate Disp&Rot - Disp x1; Channels n°: 6,7,84,85,; Parameters:
3500.000000,3500.000000,0.000000,3500.000000,0.000000,3500.000000,3500.000000,0.000000,3500
.000000,4000.000000,3500.000000,0.000000,3500.000000,4000.000000,1750.000000,3500.000000,0.
000000,3500.000000,4000.000000,1750.000000,2000.000000,
          16 - ID: Calculate Disp&Rot - Disp x2; Channels n°: 6,7,84,85,; Parameters:
3500.000000,3500.000000,0.000000,3500.000000,0.000000,3500.000000,3500.000000,0.000000,3500
.000000,4000.000000,3500.000000,0.000000,3500.000000,4000.000000,1750.000000,3500.000000,0.
000000,3500.000000,4000.000000,1750.000000,2000.000000,
          17 - ID: Calculate Disp&Rot - Rot; Channels n°: 6,7,84,85,; Parameters:
3500.000000,3500.000000,0.000000,3500.000000,0.000000,3500.000000,3500.000000,0.000000,3500
.000000,4000.000000,3500.000000,0.000000,3500.000000,4000.000000,1750.000000,3500.000000,0.
000000,3500.000000,4000.000000,1750.000000,2000.000000,
          18 - ID: Calculate Disp&Rot - Disp x1; Channels n°: 10,11,12,13,;
Parameters:
0.000000,0.000000,0.000000,0.000000,0.000000,3500.000000,0.000000,0.000000,3500.000000,0.00
0000,0.000000,0.000000,3500.000000,0.000000,1750.000000,0.000000,0.000000,3500.000000,0.000
000,1750.000000,2000.000000,
```

19 - ID: Calculate Disp&Rot - Disp x2; Channels n°: 10,11,12,13,;
Parameters:
0.000000,0.000000,0.000000,0.000000,0.000000,3500.000000,0.000000,0.000000,3500.000000,0.00
0000,0.000000,0.000000,3500.000000,0.000000,1750.000000,0.000000,0.000000,3500.000000,0.000
000,1750.000000,2000.000000,
20 - ID: Calculate Disp&Rot - Rot; Channels n°: 10,11,12,13,; Parameters:
0.000000,0.000000,0.000000,0.000000,0.000000,3500.000000,0.000000,0.000000,3500.000000,0.00
0000,0.000000,0.000000,3500.000000,0.000000,1750.000000,0.000000,0.000000,3500.000000,0.000
000,1750.000000,2000.000000,
21 - ID: Calculate Disp&Rot - Disp x1; Channels n°: 10,11,14,15,;
Parameters:
0.000000,0.000000,0.000000,0.000000,0.000000,0.000000,0.000000,0.000000,0.000000,4000.00000
0,0.000000,0.000000,0.000000,4000.000000,1750.000000,0.000000,0.000000,0.000000,4000.000000
,1750.000000,2000.000000,
22 - ID: Calculate Disp&Rot - Disp x2; Channels n°: 10,11,14,15,;
Parameters:
0.000000,0.000000,0.000000,0.000000,0.000000,0.000000,0.000000,0.000000,0.000000,4000.00000
0,0.000000,0.000000,0.000000,4000.000000,1750.000000,0.000000,0.000000,0.000000,4000.000000
,1750.000000,2000.000000,
23 - ID: Calculate Disp&Rot - Rot; Channels n°: 10,11,14,15,; Parameters:
0.000000,0.000000,0.000000,0.000000,0.000000,0.000000,0.000000,0.000000,0.000000,4000.00000
0,0.000000,0.000000,0.000000,4000.000000,1750.000000,0.000000,0.000000,0.000000,4000.000000
,1750.000000,2000.000000,
24 - ID: Calculate Disp&Rot - Disp x1; Channels n°: 10,11,16,17,;
Parameters:
0.000000,0.000000,0.000000,0.000000,0.000000,3500.000000,0.000000,0.000000,3500.000000,4000
.000000,0.000000,0.000000,3500.000000,4000.000000,1750.000000,0.000000,0.000000,3500.000000
,4000.000000,1750.000000,2000.000000,
25 - ID: Calculate Disp&Rot - Disp x2; Channels n°: 10,11,16,17,;
Parameters:
0.000000,0.000000,0.000000,0.000000,0.000000,3500.000000,0.000000,0.000000,3500.000000,4000
.000000,0.000000,0.000000,3500.000000,4000.000000,1750.000000,0.000000,0.000000,3500.000000
,4000.000000,1750.000000,2000.000000,
26 - ID: Calculate Disp&Rot - Rot; Channels n°: 10,11,16,17,; Parameters:
0.000000,0.000000,0.000000,0.000000,0.000000,3500.000000,0.000000,0.000000,3500.000000,4000
.000000,0.000000,0.000000,3500.000000,4000.000000,1750.000000,0.000000,0.000000,3500.000000
,4000.000000,1750.000000,2000.000000,
27 - ID: Calculate Disp&Rot - Disp x1; Channels n°: 12,13,14,15,;
Parameters:
3500.000000,3500.000000,0.000000,3500.000000,0.000000,0.000000,3500.000000,0.000000,0.00000
0,4000.000000,3500.000000,0.000000,0.000000,4000.000000,1750.000000,3500.000000,0.000000,0.
000000,4000.000000,1750.000000,2000.000000,
28 - ID: Calculate Disp&Rot - Disp x2; Channels n°: 12,13,14,15,;
Parameters:
3500.000000,3500.000000,0.000000,3500.000000,0.000000,0.000000,3500.000000,0.000000,0.00000
0,4000.000000,3500.000000,0.000000,0.000000,4000.000000,1750.000000,3500.000000,0.000000,0.
000000,4000.000000,1750.000000,2000.000000,
29 - ID: Calculate Disp&Rot - Rot; Channels n°: 12,13,14,15,; Parameters:
3500.000000,3500.000000,0.000000,3500.000000,0.000000,0.000000,3500.000000,0.000000,0.00000
0,4000.000000,3500.000000,0.000000,0.000000,4000.000000,1750.000000,3500.000000,0.000000,0.
000000,4000.000000,1750.000000,2000.000000,
30 - ID: Calculate Disp&Rot - Disp x1; Channels n°: 12,13,16,17,;
Parameters:
3500.000000,3500.000000,0.000000,3500.000000,0.000000,3500.000000,3500.000000,0.000000,3500
.000000,4000.000000,3500.000000,0.000000,3500.000000,4000.000000,1750.000000,3500.000000,0.
000000,3500.000000,4000.000000,1750.000000,2000.000000,
31 - ID: Calculate Disp&Rot - Disp x2; Channels n°: 12,13,16,17,;
Parameters:
3500.000000,3500.000000,0.000000,3500.000000,0.000000,3500.000000,3500.000000,0.000000,3500
.000000,4000.000000,3500.000000,0.000000,3500.000000,4000.000000,1750.000000,3500.000000,0.
000000,3500.000000,4000.000000,1750.000000,2000.000000,
32 - ID: Calculate Disp&Rot - Rot; Channels n°: 12,13,16,17,; Parameters:
3500.000000,3500.000000,0.000000,3500.000000,0.000000,3500.000000,3500.000000,0.000000,3500
.000000,4000.000000,3500.000000,0.000000,3500.000000,4000.000000,1750.000000,3500.000000,0.
000000,3500.000000,4000.000000,1750.000000,2000.000000,
33 - ID: Calculate Disp&Rot - Disp x1; Channels n°: 14,15,16,17,;
Parameters:
0.000000,0.000000,4000.000000,0.000000,4000.000000,3500.000000,0.000000,4000.000000,3500.00
0000,4000.000000,0.000000,4000.000000,3500.000000,4000.000000,1750.000000,0.000000,4000.000
000,3500.000000,4000.000000,1750.000000,2000.000000,
34 - ID: Calculate Disp&Rot - Disp x2; Channels n°: 14,15,16,17,;
Parameters:
0.000000,0.000000,4000.000000,0.000000,4000.000000,3500.000000,0.000000,4000.000000,3500.00
0000,4000.000000,0.000000,4000.000000,3500.000000,4000.000000,1750.000000,0.000000,4000.000
000,3500.000000,4000.000000,1750.000000,2000.000000,
35 - ID: Calculate Disp&Rot - Rot; Channels n°: 14,15,16,17,; Parameters:
0.000000,0.000000,4000.000000,0.000000,4000.000000,3500.000000,0.000000,4000.000000,3500.00

```
0000,4000.000000,0.000000,4000.000000,3500.000000,4000.000000,1750.000000,0.000000,4000.000
000,3500.000000,4000.000000,1750.000000,2000.000000,
        CHANNELS OUT NAMES
                0 - DA2 DA7 Calculate ADisp&Rot - Disp x1
                1 - DA2 DA7 Calculate ADisp&Rot - Disp x2
                2 - DA2 DA7 Calculate ADisp&Rot - Rot
                3 - DA7 DA8 Calculate ADisp&Rot - Disp x1
                4 - DA7 DA8 Calculate ADisp&Rot - Disp x2
                5 - DA7 DA8 Calculate ADisp&Rot - Rot
                6 - DA1 DA7 Calculate ADisp&Rot - Disp x1
                7 - DA1 DA7 Calculate ADisp&Rot - Disp x2
                8 - DA1 DA7 Calculate ADisp&Rot - Rot
                9 - DA2 DA8 Calculate ADisp&Rot - Disp x1
                10 - DA2 DA8 Calculate ADisp&Rot - Disp x2
                11 - DA2 DA8 Calculate ADisp&Rot - Rot
                12 - DA1 DA2 Calculate ADisp&Rot - Disp x1
                13 - DA1 DA2 Calculate ADisp&Rot - Disp x2
                14 - DA1 DA2 Calculate ADisp&Rot - Rot
                15 - DA1 DA8 Calculate ADisp&Rot - Disp x1
                16 - DA1 DA8 Calculate ADisp&Rot - Disp x2
                17 - DA1 DA8 Calculate ADisp&Rot - Rot
                18 - DA3 DA4 Calculate ADisp&Rot - Disp x1
                19 - DA3 DA4 Calculate ADisp&Rot - Disp x2
                20 - DA3 DA4 Calculate ADisp&Rot - Rot
                21 - DA3 DA5 Calculate ADisp&Rot - Disp x1
                22 - DA3 DA5 Calculate ADisp&Rot - Disp x2
                23 - DA3 DA5 Calculate ADisp&Rot - Rot
                24 - DA3 DA6 Calculate ADisp&Rot - Disp x1
                25 - DA3 DA6 Calculate ADisp&Rot - Disp x2
                26 - DA3 DA6 Calculate ADisp&Rot - Rot
                27 - DA4 DA5 Calculate ADisp&Rot - Disp x1
                28 - DA4 DA5 Calculate ADisp&Rot - Disp x2
                29 - DA4 DA5 Calculate ADisp&Rot - Rot
                30 - DA4 DA6 Calculate ADisp&Rot - Disp x1
                31 - DA4 DA6 Calculate ADisp&Rot - Disp x2
                32 - DA4 DA6 Calculate ADisp&Rot - Rot
                33 - DA5 DA6 Calculate ADisp&Rot - Disp x1
                34 - DA5 DA6 Calculate ADisp&Rot - Disp x2
                35 - DA5 DA6 Calculate ADisp&Rot - Rot

LEVEL 1 - Type: Operations between channels
        OPERATIONS
                0 - ID: Unchanged; Channels n°: 12,; Parameters:
                1 - ID: Unchanged; Channels n°: 13,; Parameters:
                2 - ID: Unchanged; Channels n°: 14,; Parameters:
                3 - ID: Average Channels; Channels n°: 18,21,24,27,30,33,; Parameters:
                4 - ID: Average Channels; Channels n°: 19,22,25,28,31,34,; Parameters:
                5 - ID: Average Channels; Channels n°: 20,23,26,29,32,35,; Parameters:
        CHANNELS OUT NAMES
                0 - MC CM7-CM1F-ADisp-Trans
                1 - MC CM8-CM1F-ADisp-Long
                2 - MC CM9-CM1F-ADisp-Rot
                3 - MC CM10-CM2F-ADisp-Trans
                4 - MC CM11-CM2F-ADisp-Long
                5 - MC CM12-CM2F-ADisp-Rot
        CHANNELS OUT UNITS
                g
                g
                rad/s^2
                g
                g
                rad/s^2
```

E.3.8 Averaged Storey Accelerations

```
MATH CHANNELS REPORT
LNEC-SPA - Signal Processing and Analysis Program
File:   8-MC AccAvg Pisos.bin

USED CHANNELS
        26 - A1-2FNE-Acc-Trans
        27 - A2-2FNE-Acc-Long
        28 - A3-2FE-Acc-Trans
        29 - A4-2FE-Acc-Long
        30 - A5-2FSE-Acc-Trans
        31 - A6-2FSE-Acc-Long
```

```
        32 - A7-2FSW-Acc-Trans
        33 - A8-2FSW-Acc-Long
        34 - A9-2FW-Acc-Trans
        35 - A10-2FW-Acc-Long
        36 - A11-2FNW-Acc-Trans
        37 - A12-2FNW-Acc-Long
        38 - A13-1FNE-Acc-Trans
        39 - A14-1FNE-Acc-Long
        40 - A15-1FE-Acc-Trans
        41 - A16-1FE-Acc-Long
        42 - A17-1FSE-Acc-Trans
        43 - A18-1FSE-Acc-Long
        44 - A19-1FSW-Acc-Trans
        45 - A20-1FSW-Acc-Long
        46 - A21-1FW-Acc-Trans
        47 - A22-1FW-Acc-Long
        48 - A23-1FNW-Acc-Trans
        49 - A24-1FNW-Acc-Long

LEVEL 0 - Type: Operations between channels
        OPERATIONS
                0 - ID: Average Channels; Channels n°: 38,40,42,44,46,48,; Parameters:
                1 - ID: Average Channels; Channels n°: 39,41,43,45,47,49,; Parameters:
                2 - ID: Average Channels; Channels n°: 26,28,30,32,34,36,; Parameters:
                3 - ID: Average Channels; Channels n°: 27,29,31,33,35,37,; Parameters:
                4 - ID: Subtract channels (2nd ch - 1st ch); Channels n°: 38,42,;
Parameters:
                5 - ID: Subtract channels (1st ch - 2nd ch); Channels n°: 44,48,;
Parameters:
                6 - ID: Subtract channels (1st ch - 2nd ch); Channels n°: 39,49,;
Parameters:
                7 - ID: Subtract channels (1st ch - 2nd ch); Channels n°: 43,45,;
Parameters:
                8 - ID: Subtract channels (2nd ch - 1st ch); Channels n°: 26,30,;
Parameters:
                9 - ID: Subtract channels (1st ch - 2nd ch); Channels n°: 32,36,;
Parameters:
                10 - ID: Subtract channels (1st ch - 2nd ch); Channels n°: 27,37,;
Parameters:
                11 - ID: Subtract channels (2nd ch - 1st ch); Channels n°: 33,37,;
Parameters:
        CHANNELS OUT NAMES
                0 - MC AA1-1F-AccAvg-Trans
                1 - MC AA2-1F-AccAvg-Long
                2 - MC AA3-2F-AccAvg-Trans
                3 - MC AA4-2F-AccAvg-Long
                4 - A13-1FNE-Acc-Trans(Subtract channels (2nd ch - 1st ch))A17-1FSE-Acc-
Trans
                5 - A19-1FSW-Acc-Trans(Subtract channels (1st ch - 2nd ch))A23-1FNW-Acc-
Trans
                6 - A14-1FNE-Acc-Long(Subtract channels (1st ch - 2nd ch))A24-1FNW-Acc-Long
                7 - A18-1FSE-Acc-Long(Subtract channels (1st ch - 2nd ch))A20-1FSW-Acc-Long
                8 - A1-2FNE-Acc-Trans(Subtract channels (2nd ch - 1st ch))A5-2FSE-Acc-Trans
                9 - A7-2FSW-Acc-Trans(Subtract channels (1st ch - 2nd ch))A11-2FNW-Acc-Trans
                10 - A2-2FNE-Acc-Long(Subtract channels (1st ch - 2nd ch))A12-2FNW-Acc-Long
                11 - A8-2FSW-Acc-Long(Subtract channels (2nd ch - 1st ch))A12-2FNW-Acc-Long

LEVEL 1 - Type: Operations to individual channels
        OPERATIONS
                0 - ID: Unchanged; Channels n°: 0,; Parameters:
                1 - ID: Unchanged; Channels n°: 1,; Parameters:
                2 - ID: Unchanged; Channels n°: 2,; Parameters:
                3 - ID: Unchanged; Channels n°: 3,; Parameters:
                4 - ID: Divide by scalar (chan/scalar); Channels n°: 4,; Parameters:
4.000000,
                5 - ID: Divide by scalar (chan/scalar); Channels n°: 5,; Parameters:
4.000000,
                6 - ID: Divide by scalar (chan/scalar); Channels n°: 6,; Parameters:
4.000000,
                7 - ID: Divide by scalar (chan/scalar); Channels n°: 7,; Parameters:
4.000000,
                8 - ID: Divide by scalar (chan/scalar); Channels n°: 8,; Parameters:
3.500000,
                9 - ID: Divide by scalar (chan/scalar); Channels n°: 9,; Parameters:
3.500000,
                10 - ID: Divide by scalar (chan/scalar); Channels n°: 10,; Parameters:
3.500000,
```

```
            11 - ID: Divide by scalar (chan/scalar); Channels n°: 11,; Parameters:
3.500000,
        CHANNELS OUT NAMES
            0 - MC AA1-1F-AccAvg-Trans(Unchanged)
            1 - MC AA2-1F-AccAvg-Long(Unchanged)
            2 - MC AA3-2F-AccAvg-Trans(Unchanged)
            3 - MC AA4-2F-AccAvg-Long(Unchanged)
            4 - A13-1FNE-Acc-Trans(Subtract channels (2nd ch - 1st ch))A17-1FSE-Acc-
Trans(Divide by scalar (chan/scalar))
            5 - A19-1FSW-Acc-Trans(Subtract channels (1st ch - 2nd ch))A23-1FNW-Acc-
Trans(Divide by scalar (chan/scalar))
            6 - A14-1FNE-Acc-Long(Subtract channels (1st ch - 2nd ch))A24-1FNW-Acc-
Long(Divide by scalar (chan/scalar))
            7 - A18-1FSE-Acc-Long(Subtract channels (1st ch - 2nd ch))A20-1FSW-Acc-
Long(Divide by scalar (chan/scalar))
            8 - A1-2FNE-Acc-Trans(Subtract channels (2nd ch - 1st ch))A5-2FSE-Acc-
Trans(Divide by scalar (chan/scalar))
            9 - A7-2FSW-Acc-Trans(Subtract channels (1st ch - 2nd ch))A11-2FNW-Acc-
Trans(Divide by scalar (chan/scalar))
            10 - A2-2FNE-Acc-Long(Subtract channels (1st ch - 2nd ch))A12-2FNW-Acc-
Long(Divide by scalar (chan/scalar))
            11 - A8-2FSW-Acc-Long(Subtract channels (2nd ch - 1st ch))A12-2FNW-Acc-
Long(Divide by scalar (chan/scalar))

LEVEL 2 - Type: Operations between channels
        OPERATIONS
            0 - ID: Unchanged; Channels n°: 0,; Parameters:
            1 - ID: Unchanged; Channels n°: 1,; Parameters:
            2 - ID: Unchanged; Channels n°: 2,; Parameters:
            3 - ID: Unchanged; Channels n°: 3,; Parameters:
            4 - ID: Average Channels; Channels n°: 4,5,; Parameters:
            5 - ID: Average Channels; Channels n°: 6,7,; Parameters:
            6 - ID: Average Channels; Channels n°: 8,9,; Parameters:
            7 - ID: Average Channels; Channels n°: 10,11,; Parameters:
        CHANNELS OUT NAMES
            0 - MC AA1-1F-AccAvg-Trans(Unchanged)(Unchanged)
            1 - MC AA2-1F-AccAvg-Long(Unchanged)(Unchanged)
            2 - MC AA3-2F-AccAvg-Trans(Unchanged)(Unchanged)
            3 - MC AA4-2F-AccAvg-Long(Unchanged)(Unchanged)
            4 - A13-1FNE-Acc-Trans(Subtract channels (2nd ch - 1st ch))A17-1FSE-Acc-
Trans(Divide by scalar (chan/scalar))(Average Channels)A19-1FSW-Acc-Trans(Subtract channels
(1st ch - 2nd ch))A23-1FNW-Acc-Trans(Divide by scalar (chan/scalar))
            5 - A14-1FNE-Acc-Long(Subtract channels (1st ch - 2nd ch))A24-1FNW-Acc-
Long(Divide by scalar (chan/scalar))(Average Channels)A18-1FSE-Acc-Long(Subtract channels
(1st ch - 2nd ch))A20-1FSW-Acc-Long(Divide by scalar (chan/scalar))
            6 - A1-2FNE-Acc-Trans(Subtract channels (2nd ch - 1st ch))A5-2FSE-Acc-
Trans(Divide by scalar (chan/scalar))(Average Channels)A7-2FSW-Acc-Trans(Subtract channels
(1st ch - 2nd ch))A11-2FNW-Acc-Trans(Divide by scalar (chan/scalar))
            7 - A2-2FNE-Acc-Long(Subtract channels (1st ch - 2nd ch))A12-2FNW-Acc-
Long(Divide by scalar (chan/scalar))(Average Channels)A8-2FSW-Acc-Long(Subtract channels
(2nd ch - 1st ch))A12-2FNW-Acc-Long(Divide by scalar (chan/scalar))

LEVEL 3 - Type: Operations between channels
        OPERATIONS
            0 - ID: Unchanged; Channels n°: 0,; Parameters:
            1 - ID: Unchanged; Channels n°: 1,; Parameters:
            2 - ID: Unchanged; Channels n°: 4,; Parameters:
            3 - ID: Unchanged; Channels n°: 5,; Parameters:
            4 - ID: Unchanged; Channels n°: 2,; Parameters:
            5 - ID: Unchanged; Channels n°: 3,; Parameters:
            6 - ID: Unchanged; Channels n°: 6,; Parameters:
            7 - ID: Unchanged; Channels n°: 7,; Parameters:
        CHANNELS OUT NAMES
            0 - MC AA1-1F-AccAvg-Trans
            1 - MC AA2-1F-AccAvg-Long
            2 - MC AA3-1F-RotAccAvg-Trans
            3 - MC AA4-1F-RotAccAvg-Long
            4 - MC AA5-2F-AccAvg-Trans
            5 - MC AA6-2F-AccAvg-Long
            6 - MC AA7-2F-RotAccAvg-Trans
            7 - MC AA8-2F-RotAccAvg-Long

LEVEL 4 - Type: Operations between channels
        OPERATIONS
            0 - ID: Unchanged; Channels n°: 0,; Parameters:
            1 - ID: Unchanged; Channels n°: 1,; Parameters:
            2 - ID: Unchanged; Channels n°: 2,; Parameters:
```

```
            3 - ID: Unchanged; Channels n°: 3,; Parameters:
            4 - ID: Average Channels; Channels n°: 2,3,; Parameters:
            5 - ID: Unchanged; Channels n°: 4,; Parameters:
            6 - ID: Unchanged; Channels n°: 5,; Parameters:
            7 - ID: Unchanged; Channels n°: 6,; Parameters:
            8 - ID: Unchanged; Channels n°: 7,; Parameters:
            9 - ID: Average Channels; Channels n°: 6,7,; Parameters:
      CHANNELS OUT NAMES
            0 - MC AA1-1F-AccAvg-Trans
            1 - MC AA2-1F-AccAvg-Long
            2 - MC AA3-1F-RotAccAvg-Trans
            3 - MC AA3-1F-RotAccAvg-Long
            4 - MC AA3-1F-RotAccAvg-DirAvg
            5 - MC AA4-2F-AccAvg-Trans
            6 - MC AA5-2F-AccAvg-Long
            7 - MC AA6-2F-RotAccAvg-Trans
            8 - MC AA6-2F-RotAccAvg-Long
            9 - MC AA6-2F-RotAccAvg-DirAvg

LEVEL 5 - Type: Operations to individual channels
      OPERATIONS
            0 - ID: Unchanged; Channels n°: 0,; Parameters:
            1 - ID: Unchanged; Channels n°: 1,; Parameters:
            2 - ID: Divide by scalar (chan/scalar); Channels n°: 2,; Parameters:
9.806700,
            3 - ID: Divide by scalar (chan/scalar); Channels n°: 3,; Parameters:
9.806700,
            4 - ID: Divide by scalar (chan/scalar); Channels n°: 4,; Parameters:
9.806700,
            5 - ID: Unchanged; Channels n°: 5,; Parameters:
            6 - ID: Unchanged; Channels n°: 6,; Parameters:
            7 - ID: Divide by scalar (chan/scalar); Channels n°: 7,; Parameters:
9.806700,
            8 - ID: Divide by scalar (chan/scalar); Channels n°: 8,; Parameters:
9.806700,
            9 - ID: Divide by scalar (chan/scalar); Channels n°: 9,; Parameters:
9.806700,
      CHANNELS OUT NAMES
            0 - MC AAV1-CM1F-AccAvg-Trans
            1 - MCAAV2-CM1F-AccAvg-Long
            2 - MC AAV3-CM1F-RotAccAvg-Trans
            3 - MC AAV3-CM1F-RotAccAvg-Long
            4 - MC AAV3-CM1F-RotAccAvg-DirAvg
            5 - MC AAV4-CM2F-AccAvg-Trans
            6 - MC AAV5-CM2F-AccAvg-Long
            7 - MC AAV6-CM2F-RotAccAvg-Trans
            8 - MC AAV6-CM2F-RotAccAvg-Long
            9 - MC AAV6-CM2F-RotAccAvg-DirAvg
      CHANNELS OUT UNITS
            g
            g
            rad/s^2
            rad/s^2
            rad/s^2
            g
            g
            rad/s^2
            rad/s^2
            rad/s^2
```

E.3.9 Global Forces

```
MDOF GLOBAL BEHAVIOUR REPORT
LNEC-SPA - Signal Processing and Analysis Program
File:  9-MDOF-01.bin

DOF 0
      Height: 1.500000       Units: m
      Mass X1:       12.960000       Units: ton
      Mass X2:       12.960000       Units: ton
      Inertia Rot. X3:       33.000000       Units: ton.m^2
      Channel Acceleration X1:      137-MC AAV1-CM1F-AccAvg-Trans Units: g
      Channel Acceleration X2:      138-MCAAV2-CM1F-AccAvg-Long   Units: g
      Channel Acceleration X3:      139-MC AAV3-CM1F-RotAccAvg-Trans     Units: rad/s^2
      Channel Displacement X1:      125-MC CM1-CM1F-RDisp-Trans   Units: mm
      Channel Displacement X2:      126-MC CM2-CM1F-RDisp-Long    Units: mm
```

```
        Channel Displacement X3:      127-MC CM2-CM1F-RDisp-Long    Units: rad
        Output Units Forces:  kN
        Output Units Moments: kN.m

DOF 1
        Height: 3.000000       Units: m
        Mass X1:        12.960000      Units: ton
        Mass X2:        12.960000      Units: ton
        Inertia Rot. X3:       33.000000      Units: ton.m^2
        Channel Acceleration X1:      142-MC AAV4-CM2F-AccAvg-Trans Units: g
        Channel Acceleration X2:      143-MC AAV5-CM2F-AccAvg-Long Units: g
        Channel Acceleration X3:      144-MC AAV6-CM2F-RotAccAvg-Trans     Units: rad/s^2
        Channel Displacement X1:      128-MC CM4-CM2F-RDisp-Trans   Units: mm
        Channel Displacement X2:      129-MC CM5-CM2F-RDisp-Long    Units: mm
        Channel Displacement X3:      130-MC CM5-CM2F-RDisp-Long    Units: rad
        Output Units Forces:  kN
        Output Units Moments: kN.m

Output Channels:
        MC IF1-DOF1-X1 Units: kN
        MC IF2-DOF1-X2 Units: kN
        MC IF3-DOF1-Tor       Units: kN.m
        MC IF4-DOF2-X1 Units: kN
        MC IF5-DOF2-X2 Units: kN
        MC IF6-DOF2-Tor       Units: kN.m
        MC SF1-DOF1-X1 Units: kN
        MC SF2-DOF1-X2 Units: kN
        MC SF3-DOF1-Tor       Units: kN.m
        MC SF4-DOF2-X1 Units: kN
        MC SF5-DOF2-X2 Units: kN
        MC SF6-DOF2-Tor       Units: kN.m
        MC BS1-ST-X1   Units: kN
        MC BS2-ST-X2   Units: kN
        MC BT-ST-Tor   Units: kN.m
        MC BOM1-ST-X1  Units: kN.m
        MC BOM2-ST-X2  Units: kN.m
```

E.3.10 Center of Mass Interstorey Drifts

```
MATH CHANNELS REPORT
LNEC-SPA - Signal Processing and Analysis Program
File:  10-MC CM Interstorey Drifts.bin

USED CHANNELS
        125 - MC CM1-CM1F-RDisp-Trans
        126 - MC CM2-CM1F-RDisp-Long
        128 - MC CM4-CM2F-RDisp-Trans
        129 - MC CM5-CM2F-RDisp-Long

LEVEL 0 - Type: Operations between channels
        OPERATIONS
                0 - ID: Unchanged; Channels n°: 125,; Parameters:
                1 - ID: Unchanged; Channels n°: 126,; Parameters:
                2 - ID: Subtract channels (2nd ch - 1st ch); Channels n°: 125,128,;
Parameters:
                3 - ID: Subtract channels (2nd ch - 1st ch); Channels n°: 126,129,;
Parameters:
        CHANNELS OUT NAMES
                0 - MC CM1-CM1F-RDisp-Trans(Unchanged)
                1 - MC CM2-CM1F-RDisp-Long(Unchanged)
                2 - MC CM1-CM1F-RDisp-Trans(Subtract channels (2nd ch - 1st ch))MC CM4-CM2F-
RDisp-Trans
                3 - MC CM2-CM1F-RDisp-Long(Subtract channels (2nd ch - 1st ch))MC CM5-CM2F-
RDisp-Long

LEVEL 1 - Type: Operations to individual channels
        OPERATIONS
                0 - ID: Divide by scalar (chan/scalar); Channels n°: 0,; Parameters:
1500.000000,
                1 - ID: Divide by scalar (chan/scalar); Channels n°: 1,; Parameters:
1500.000000,
                2 - ID: Divide by scalar (chan/scalar); Channels n°: 2,; Parameters:
1500.000000,
                3 - ID: Divide by scalar (chan/scalar); Channels n°: 3,; Parameters:
1500.000000,
        CHANNELS OUT NAMES
```

```
            0 - MC CM1-CM1F-RDisp-Trans(Unchanged)(Divide by scalar (chan/scalar))
            1 - MC CM2-CM1F-RDisp-Long(Unchanged)(Divide by scalar (chan/scalar))
            2 - MC CM1-CM1F-RDisp-Trans(Subtract channels (2nd ch - 1st ch))MC CM4-CM2F-
RDisp-Trans(Divide by scalar (chan/scalar))
            3 - MC CM2-CM1F-RDisp-Long(Subtract channels (2nd ch - 1st ch))MC CM5-CM2F-
RDisp-Long(Divide by scalar (chan/scalar))

LEVEL 2 - Type: Operations to individual channels
      OPERATIONS
            0 - ID: Multiply by scalar; Channels n°: 0,; Parameters: 100.000000,
            1 - ID: Multiply by scalar; Channels n°: 1,; Parameters: 100.000000,
            2 - ID: Multiply by scalar; Channels n°: 2,; Parameters: 100.000000,
            3 - ID: Multiply by scalar; Channels n°: 3,; Parameters: 100.000000,
      CHANNELS OUT NAMES
            0 - MC ID9-1FCM-ID-Trans
            1 - MC ID9-1FCM-ID-Long
            2 - MC ID10-2FCM-ID-Trans
            3 - MC ID10-2FCM-ID-Long
      CHANNELS OUT UNITS
            Undefined
            Undefined
            Undefined
            Undefined
```

E.3.11 Center of Mass – Second Floor – Relative Displacements

```
MATH CHANNELS REPORT
LNEC-SPA - Signal Processing and Analysis Program
File:   11-MC CM2FRDisp.bin

USED CHANNELS
      125 - MC CM1-CM1F-RDisp-Trans
      126 - MC CM2-CM1F-RDisp-Long
      128 - MC CM4-CM2F-RDisp-Trans
      129 - MC CM5-CM2F-RDisp-Long

LEVEL 0 - Type: Operations between channels
      OPERATIONS
            0 - ID: Subtract channels (2nd ch - 1st ch); Channels n°: 125,128,;
Parameters:
            1 - ID: Subtract channels (2nd ch - 1st ch); Channels n°: 126,129,;
Parameters:
      CHANNELS OUT NAMES
            0 - MC CM13-CM2F-CM1F-RDisp-Trans
            1 - MC CM14-CM2F-CM1F-RDisp-Long
      CHANNELS OUT UNITS
            mm
            mm
```

E.3.12 Joints Displacements – All Stages

```
MATH CHANNELS REPORT
LNEC-SPA - Signal Processing and Analysis Program
File:   12-MC JointsDisp&RotAllStages.bin

USED CHANNELS
      0 - DR5-1FNE-RDisp-Btrans
      1 - DR6-1FNE-RDisp-TTrans
      2 - DR7-2FNE-RDisp-BTrans
      3 - DR8-2FNE-RDisp-TTrans
      4 - DR9-1FNE-RDisp-BLong
      5 - DR10-1FNE-RDisp-TLong
      6 - DR11-2FNE-RDisp-BLong
      7 - DR12-2FNE-RDisp-TLong
      8 - DR13-1FE-RDisp-BLong
      9 - DR14-1FE-RDisp-TLong
      10 - DR15-2FE-RDisp-BLong
      11 - DR16-2FE-RDisp-TLong
      12 - DR17-1FE-RDisp-BLong
      13 - DR18-1FE-RDisp-TLong
      14 - DR19-2FE-RDisp-BLong
      15 - DR20-2FE-RDisp-TLong

LEVEL 0 - Type: Operations between channels
```

```
        OPERATIONS
                0 - ID: Add channels; Channels n°: 0,1,; Parameters:
                1 - ID: Subtract channels (2nd ch - 1st ch); Channels n°: 0,1,; Parameters:
                2 - ID: Add channels; Channels n°: 2,3,; Parameters:
                3 - ID: Subtract channels (2nd ch - 1st ch); Channels n°: 2,3,; Parameters:
                4 - ID: Add channels; Channels n°: 4,5,; Parameters:
                5 - ID: Subtract channels (2nd ch - 1st ch); Channels n°: 4,5,; Parameters:
                6 - ID: Add channels; Channels n°: 6,7,; Parameters:
                7 - ID: Subtract channels (2nd ch - 1st ch); Channels n°: 6,7,; Parameters:
                8 - ID: Add channels; Channels n°: 8,9,; Parameters:
                9 - ID: Subtract channels (2nd ch - 1st ch); Channels n°: 8,9,; Parameters:
                10 - ID: Add channels; Channels n°: 10,11,; Parameters:
                11 - ID: Subtract channels (2nd ch - 1st ch); Channels n°: 10,11,;
Parameters:
                12 - ID: Add channels; Channels n°: 12,13,; Parameters:
                13 - ID: Subtract channels (2nd ch - 1st ch); Channels n°: 12,13,;
Parameters:
                14 - ID: Add channels; Channels n°: 14,15,; Parameters:
                15 - ID: Subtract channels (2nd ch - 1st ch); Channels n°: 14,15,;
Parameters:
        CHANNELS OUT NAMES
                0 - DR5-1FNE-RDisp-BTrans(Add channels)DR6-1FNE-RDisp-TTrans
                1 - DR5-1FNE-RDisp-BTrans(Subtract channels (2nd ch - 1st ch))DR6-1FNE-
RDisp-TTrans
                2 - DR7-2FNE-RDisp-BTrans(Add channels)DR8-2FNE-RDisp-TTrans
                3 - DR7-2FNE-RDisp-BTrans(Subtract channels (2nd ch - 1st ch))DR8-2FNE-
RDisp-TTrans
                4 - DR9-1FNE-RDisp-BLong(Add channels)DR10-1FNE-RDisp-TLong
                5 - DR9-1FNE-RDisp-BLong(Subtract channels (2nd ch - 1st ch))DR10-1FNE-
RDisp-TLong
                6 - DR11-2FNE-RDisp-BLong(Add channels)DR12-2FNE-RDisp-TLong
                7 - DR11-2FNE-RDisp-BLong(Subtract channels (2nd ch - 1st ch))DR12-2FNE-
RDisp-TLong
                8 - DR13-1FE-RDisp-BLong(Add channels)DR14-1FE-RDisp-TLong
                9 - DR13-1FE-RDisp-BLong(Subtract channels (2nd ch - 1st ch))DR14-1FE-RDisp-
TLong
                10 - DR15-2FE-RDisp-BLong(Add channels)DR16-2FE-RDisp-TLong
                11 - DR15-2FE-RDisp-BLong(Subtract channels (2nd ch - 1st ch))DR16-2FE-
RDisp-TLong
                12 - DR17-1FE-RDisp-BLong(Add channels)DR18-1FE-RDisp-TLong
                13 - DR17-1FE-RDisp-BLong(Subtract channels (2nd ch - 1st ch))DR18-1FE-
RDisp-TLong
                14 - DR19-2FE-RDisp-BLong(Add channels)DR20-2FE-RDisp-TLong
                15 - DR19-2FE-RDisp-BLong(Subtract channels (2nd ch - 1st ch))DR20-2FE-
RDisp-TLong

LEVEL 1 - Type: Operations to individual channels
        OPERATIONS
                0 - ID: Divide by scalar (chan/scalar); Channels n°: 0,; Parameters:
2.000000,
                1 - ID: Divide by scalar (chan/scalar); Channels n°: 1,; Parameters: -
190.000000,
                2 - ID: Divide by scalar (chan/scalar); Channels n°: 2,; Parameters:
2.000000,
                3 - ID: Divide by scalar (chan/scalar); Channels n°: 3,; Parameters: -
195.000000,
                4 - ID: Divide by scalar (chan/scalar); Channels n°: 4,; Parameters:
2.000000,
                5 - ID: Divide by scalar (chan/scalar); Channels n°: 5,; Parameters: -
158.000000,
                6 - ID: Divide by scalar (chan/scalar); Channels n°: 6,; Parameters:
2.000000,
                7 - ID: Divide by scalar (chan/scalar); Channels n°: 7,; Parameters: -
173.000000,
                8 - ID: Divide by scalar (chan/scalar); Channels n°: 8,; Parameters:
2.000000,
                9 - ID: Divide by scalar (chan/scalar); Channels n°: 9,; Parameters: -
206.000000,
                10 - ID: Divide by scalar (chan/scalar); Channels n°: 10,; Parameters:
2.000000,
                11 - ID: Divide by scalar (chan/scalar); Channels n°: 11,; Parameters: -
189.000000,
                12 - ID: Divide by scalar (chan/scalar); Channels n°: 12,; Parameters:
2.000000,
                13 - ID: Divide by scalar (chan/scalar); Channels n°: 13,; Parameters: -
217.000000,
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            14 - ID: Divide by scalar (chan/scalar); Channels n°: 14,; Parameters:
2.000000,
            15 - ID: Divide by scalar (chan/scalar); Channels n°: 15,; Parameters: -
187.000000,
        CHANNELS OUT NAMES
            0 - MC J3-1FNE-RDisp-Trans
            1 - MC J3-1FNE-Rot-Trans
            2 - MC J9-2FNE-RDisp-Trans
            3 - MC J9-2FNE-Rot-Trans
            4 - MC J3-1FNE-RDisp-Long
            5 - MC J3-1FNE-Rot-Long
            6 - MC J9-2FNE-RDisp-Long
            7 - MC J9-2FNE-Rot-Long
            8 - MC J2-1FEN-RDisp-Long
            9 - MC J2-1FEN-Rot-Long
            10 - MC J8-2FEN-RDisp-Long
            11 - MC J8-2FEN-Rot-Long
            12 - MC J2-1FES-RDisp-Long
            13 - MC J2-1FES-Rot-Long
            14 - MC J8-2FES-RDisp-Long
            15 - MC J8-2FES-Rot-Long

LEVEL 2 - Type: Operations to individual channels
        OPERATIONS
            0 - ID: Unchanged; Channels n°: 0,; Parameters:
            1 - ID: Apply atan (rad); Channels n°: 1,; Parameters:
            2 - ID: Unchanged; Channels n°: 2,; Parameters:
            3 - ID: Apply atan (rad); Channels n°: 3,; Parameters:
            4 - ID: Unchanged; Channels n°: 4,; Parameters:
            5 - ID: Apply atan (rad); Channels n°: 5,; Parameters:
            6 - ID: Unchanged; Channels n°: 6,; Parameters:
            7 - ID: Apply atan (rad); Channels n°: 7,; Parameters:
            8 - ID: Unchanged; Channels n°: 8,; Parameters:
            9 - ID: Apply atan (rad); Channels n°: 9,; Parameters:
            10 - ID: Unchanged; Channels n°: 10,; Parameters:
            11 - ID: Apply atan (rad); Channels n°: 11,; Parameters:
            12 - ID: Unchanged; Channels n°: 12,; Parameters:
            13 - ID: Apply atan (rad); Channels n°: 13,; Parameters:
            14 - ID: Unchanged; Channels n°: 14,; Parameters:
            15 - ID: Apply atan (rad); Channels n°: 15,; Parameters:
        CHANNELS OUT NAMES
            0 - MC J3-1FNE-RDisp-Trans
            1 - MC J3-1FNE-Rot-Trans
            2 - MC J9-2FNE-RDisp-Trans
            3 - MC J9-2FNE-Rot-Trans
            4 - MC J3-1FNE-RDisp-Long
            5 - MC J3-1FNE-Rot-Long
            6 - MC J9-2FNE-RDisp-Long
            7 - MC J9-2FNE-Rot-Long
            8 - MC J2-1FEN-RDisp-Long
            9 - MC J2-1FEN-Rot-Long
            10 - MC J8-2FEN-RDisp-Long
            11 - MC J8-2FEN-Rot-Long
            12 - MC J2-1FES-RDisp-Long
            13 - MC J2-1FES-Rot-Long
            14 - MC J8-2FES-RDisp-Long
            15 - MC J8-2FES-Rot-Long
        CHANNELS OUT UNITS
            mm
            rad
            mm
            rad
            mm
            rad
            mm
            rad
            mm
            rad
            mm
            rad
            mm
            rad
            mm
            rad
```

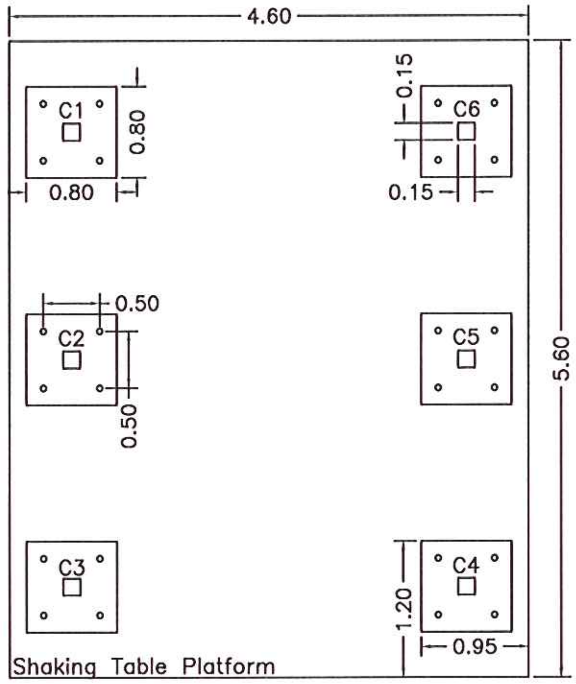
E.4 Drawings

List of Drawings:

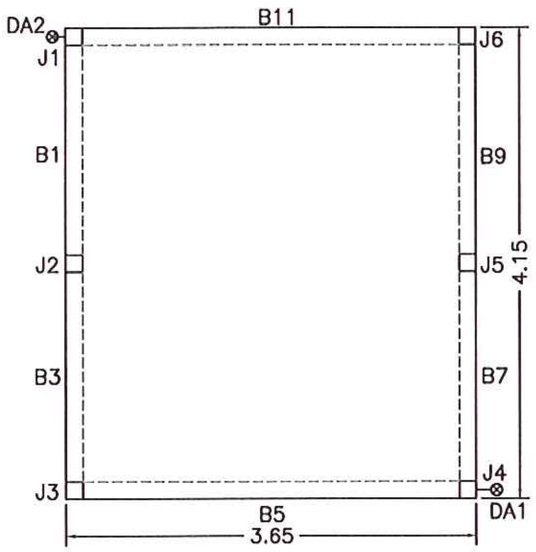
Test Setup

Plans

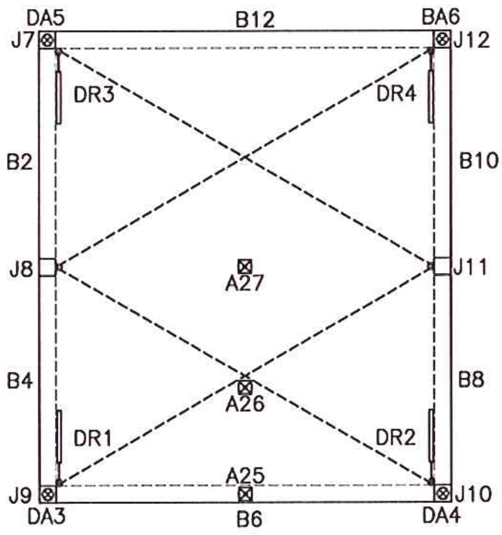
Scale: -



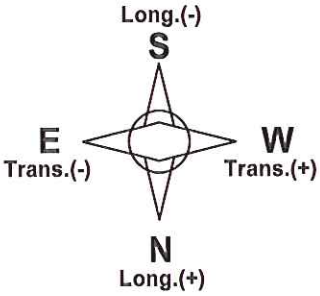
BASE LEVEL



FIRST FLOOR



SECOND FLOOR



LEGEND	
◯ ⊗	Optical displacement transducers (lens/target led)
	Accelerometers (Arrows represents directions measured)
	LVDT displacement transducers

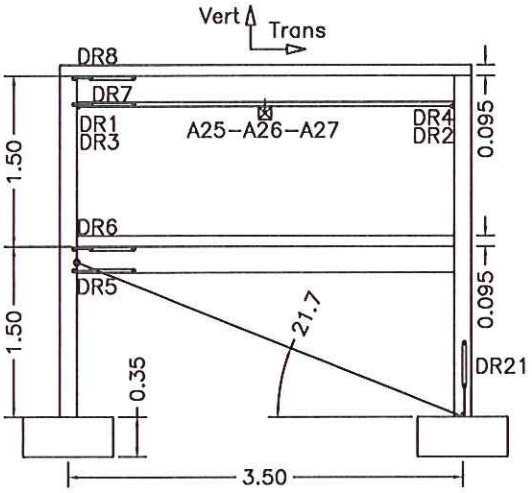
Dimensions in meters

NATIONAL LABORATORY OF CIVIL ENGINEERING LNEC / NESDE	PRECAST STRUCTURES EC8	Dec 2005
Scale: 1:100 (except if indicated)	Test Setup – Plans	Drawing Nº 1

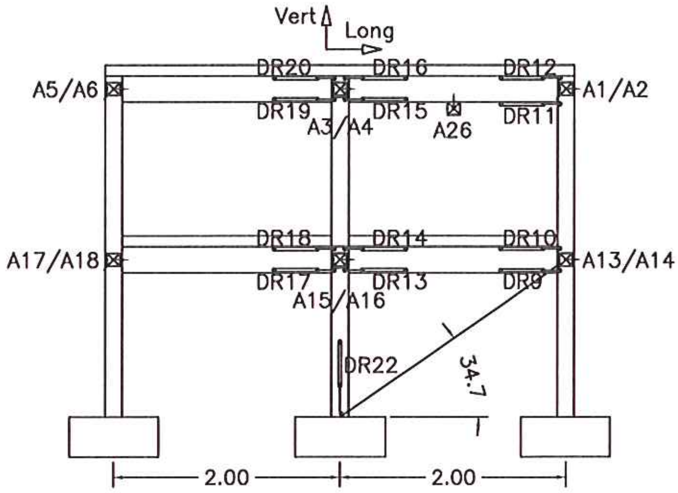
Test Setup

Views

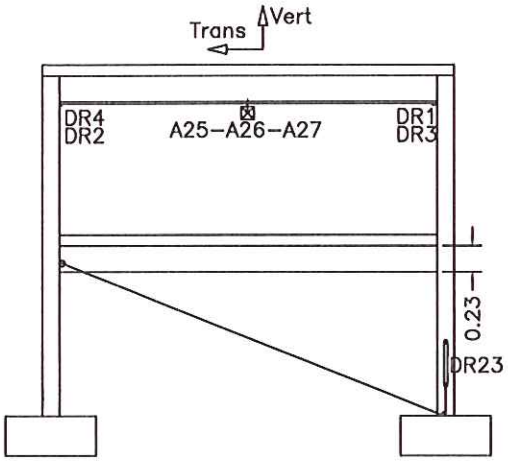
Scale: -



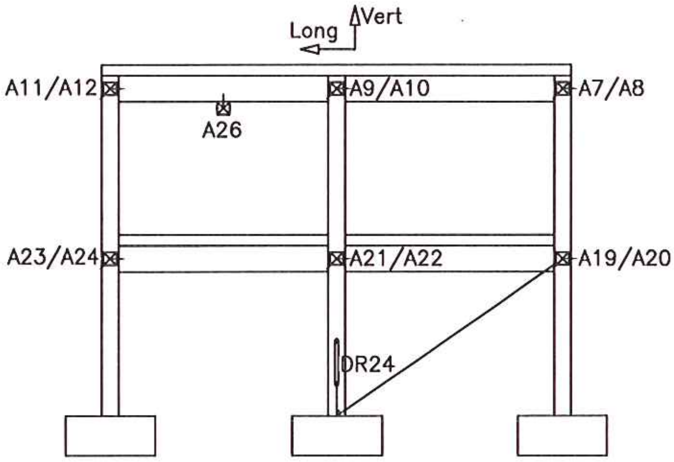
NORTH VIEW



EAST VIEW



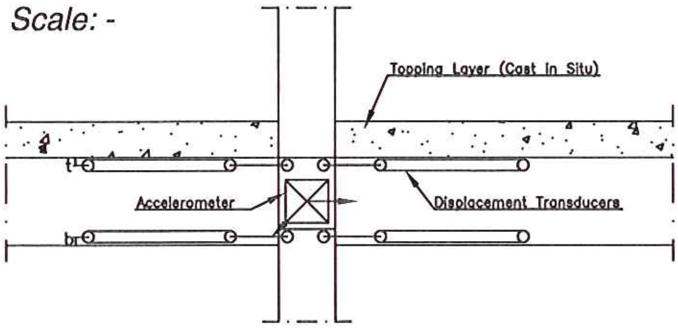
SOUTH VIEW



WEST VIEW

Detail

Scale: -



LEGEND	
◯ ⊗	Optical displacement transducers (lens/target led)
⊠	Accelerometers (Arrows represents directions measured)
▭—o	LVDT displacement transducers

Dimensions in meters

NATIONAL LABORATORY OF CIVIL ENGINEERING LNEC / NESDE	PRECAST STRUCTURES EC8	Dec 2005
Scale: 1:100 (except if indicated)	Test Setup – Views	Drawing N° 2

ANNEX F PHOTOGRAPHIC REPORT

In this annex is presented a selection of photographs taken before, during and after the test. On the figure's captions there is an identifier label to be matched with the positions indicated on the test setup drawings.

List of Figures:

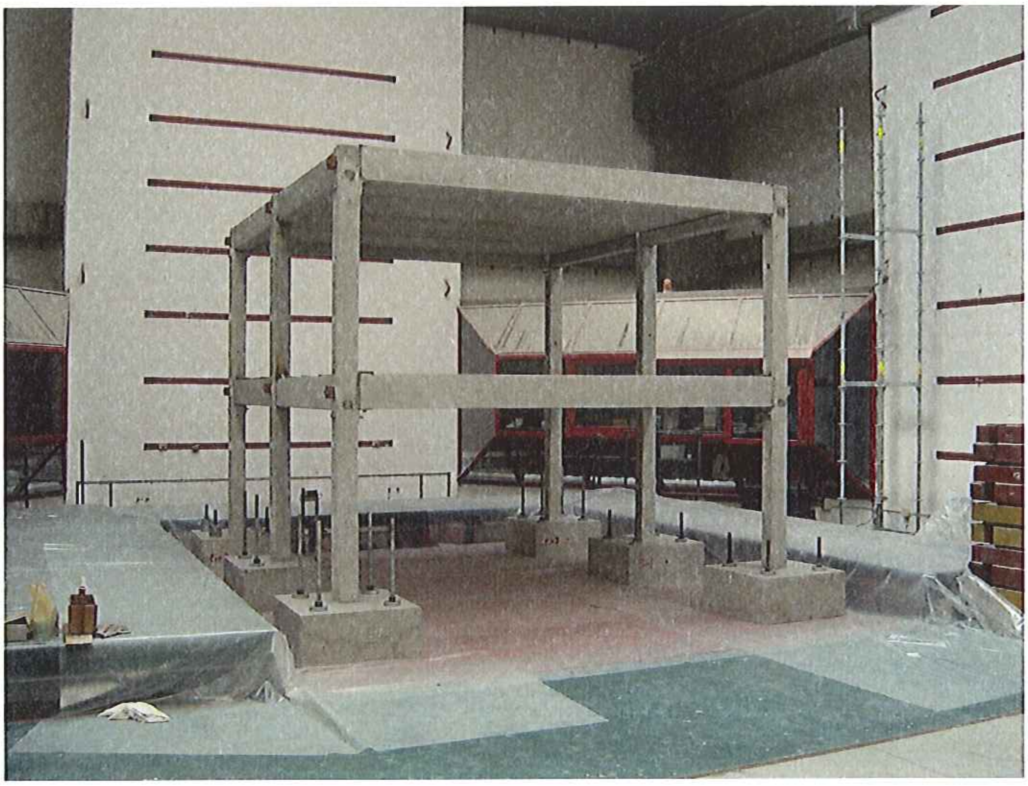


Figure F-1: General view of the model after erection.

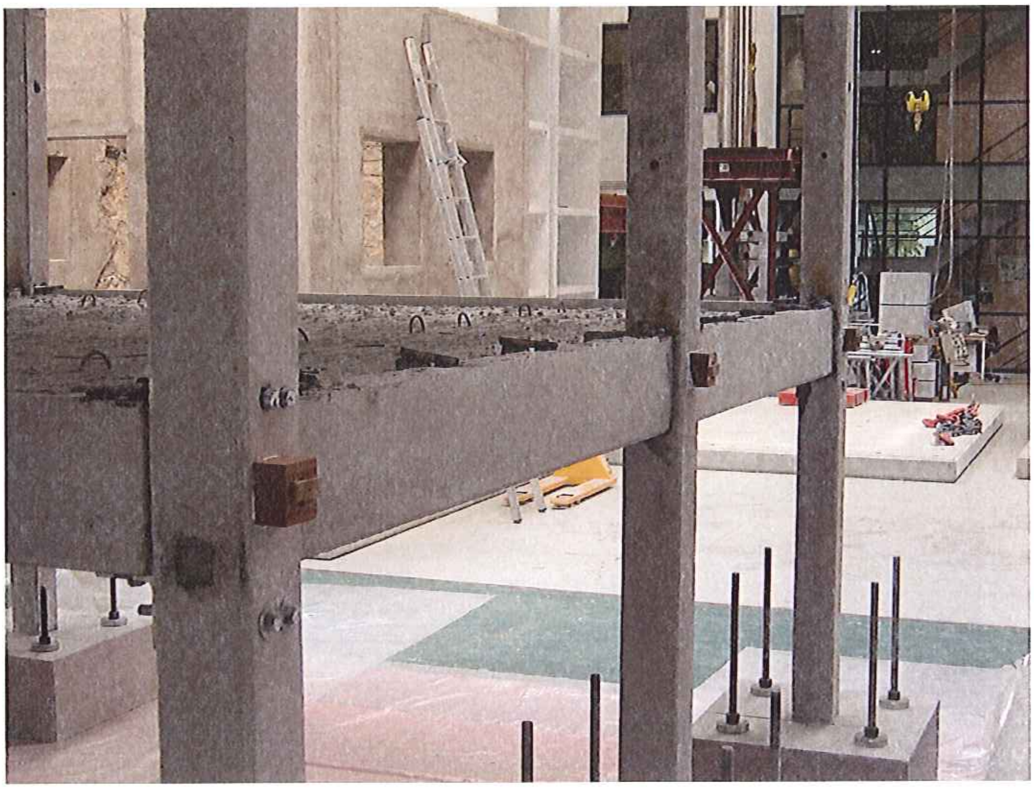


Figure F-2: General view – Longitudinal direction

Figure F-3: Detail of the beam-column connections (J3-Long.)

Figure F-4: Detail of the beam-column connections (J2-Long.)

Figure F-5: Detail of the beam-column connections (J6-Trans.)

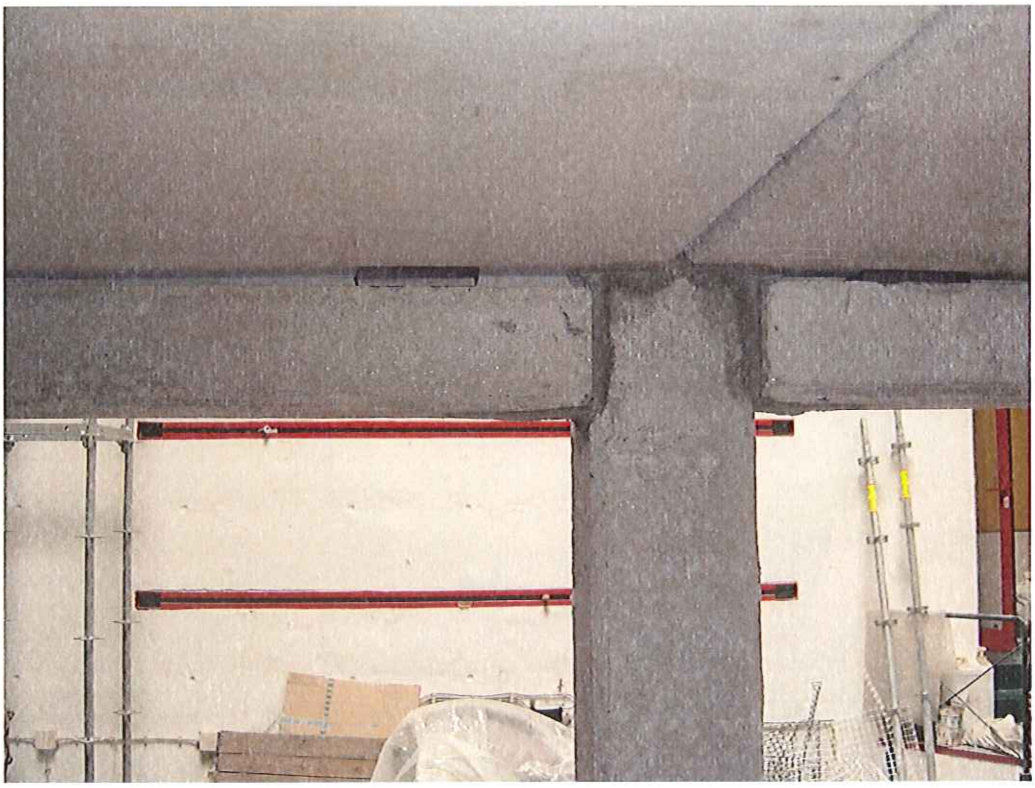


Figure F-6: Detail of the contact points between the slabs and the longitudinal beams

Figure F-7: Detail of the joint sealing operation (J7-Long.)

Figure F-8: General view of the first floor slab after concreting the topping layer

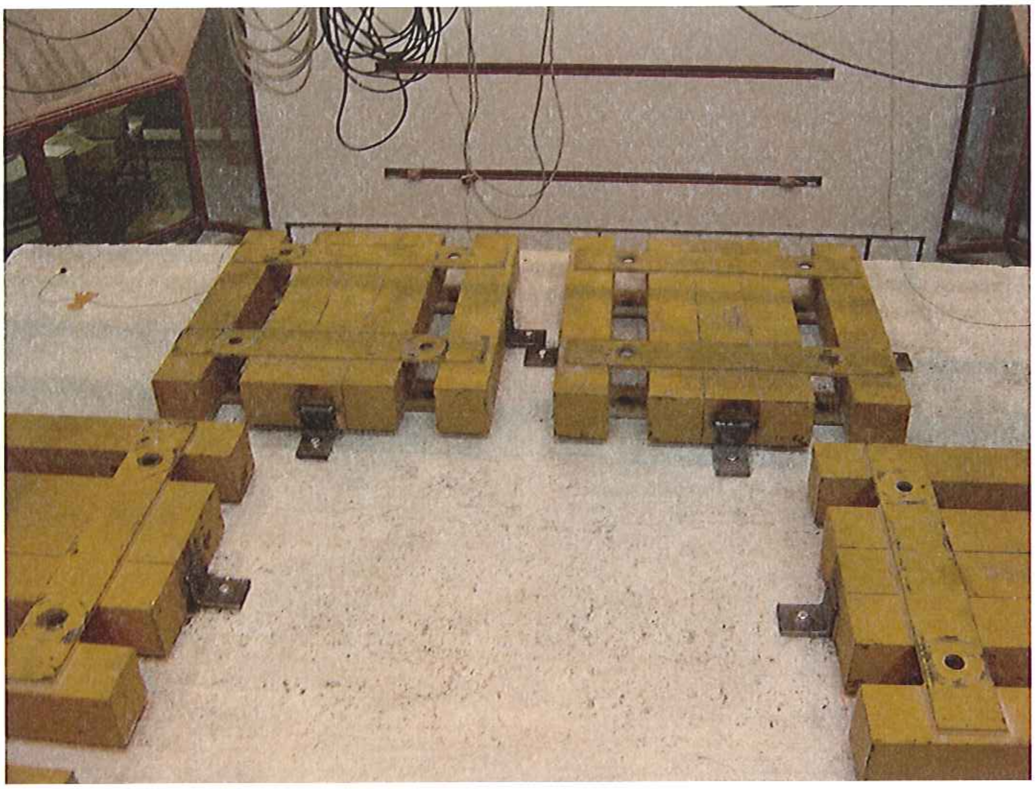


Figure F-9: Detail of the additional masses and the fixing system

Figure F-10: General view of the model before the test

Figure F-11: General view of the test setup (NE View)

Figure F-12: General view of the test setup (SW View)

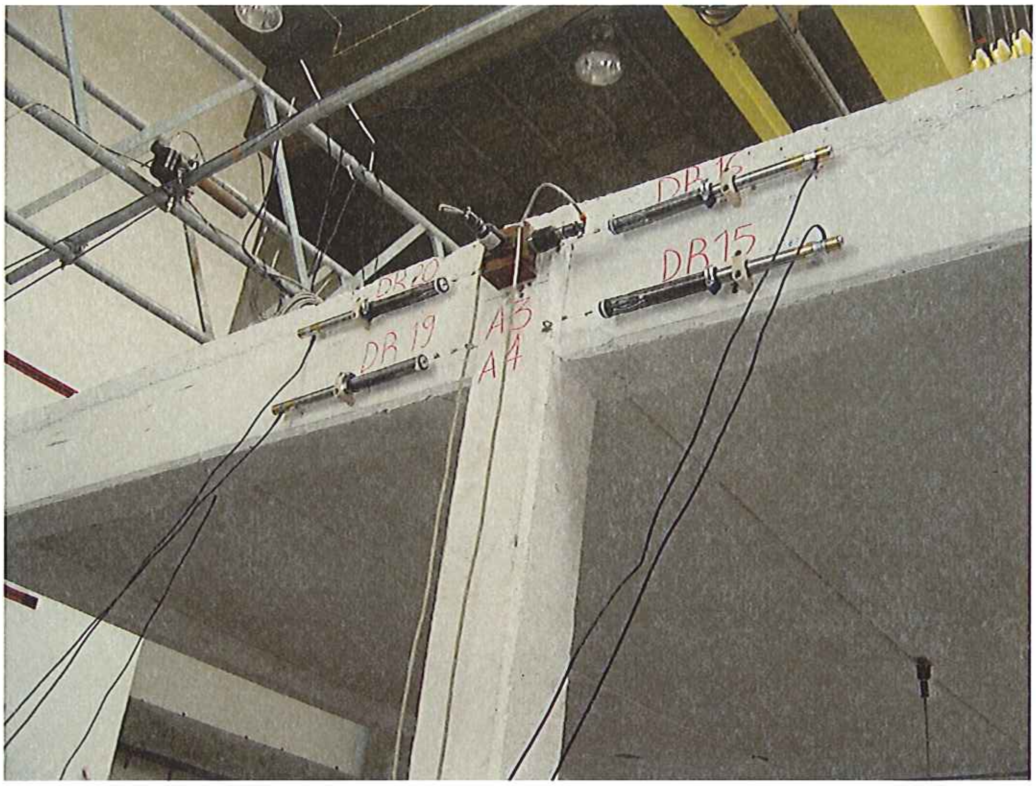


Figure F-13: Detail of the accelerometers and displacement transducers at the joints (J8-Long.)

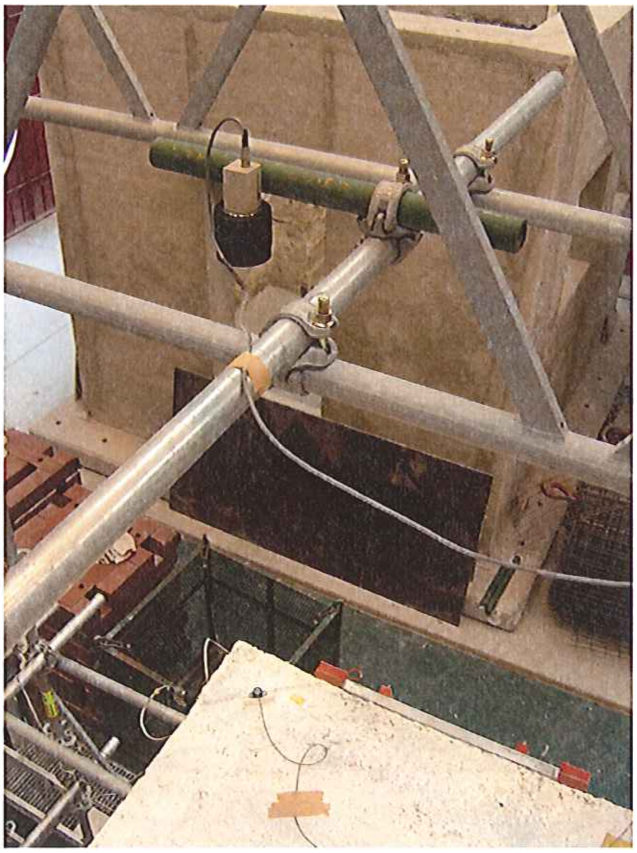


Figure F-14: Detail of the optical displacement transducers (J10)

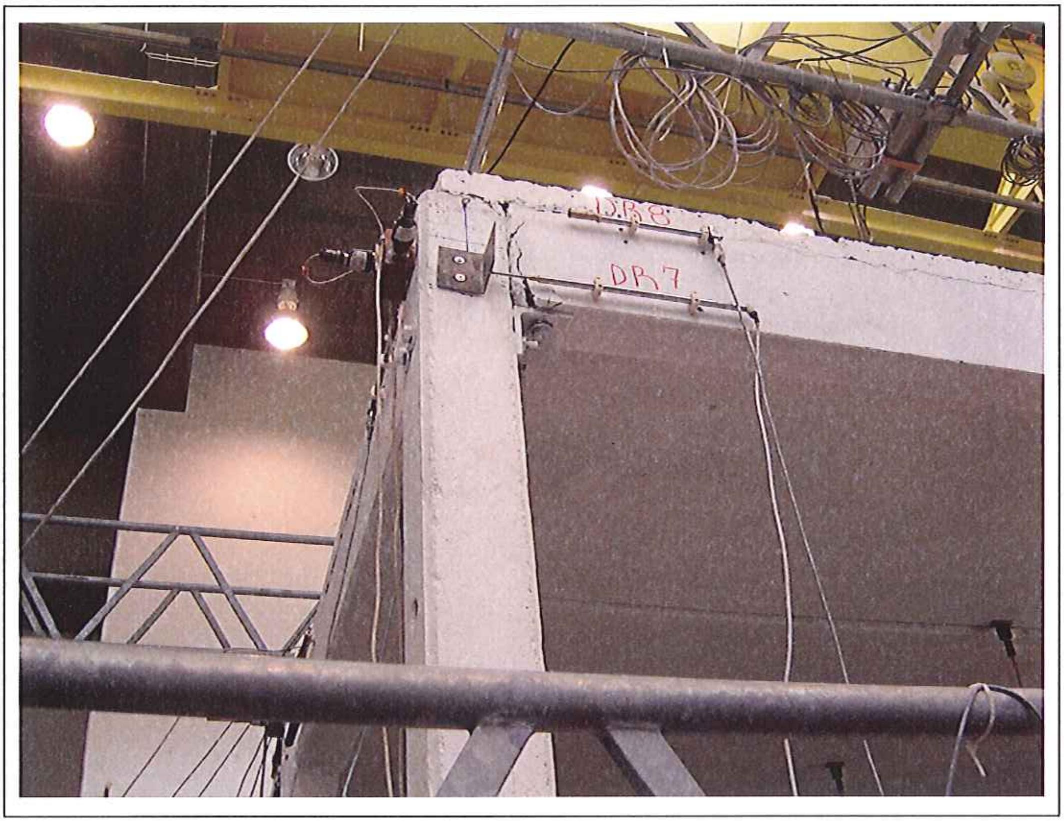


Figure F-15: Detail of the test setup (J9 - Trans.)

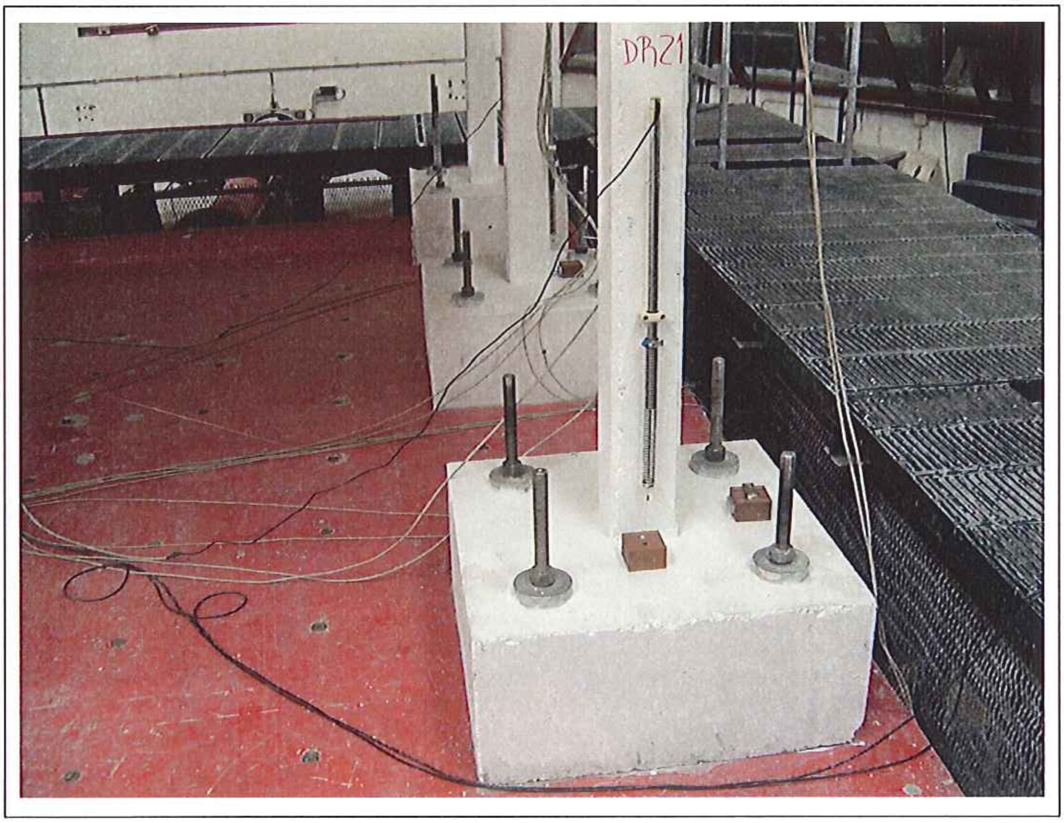


Figure F-16: Detail of the inductive displacement transducers (C4)

Figure F-17: Detail of the beam-column connection after stage 02 (J6-Trans.)

Figure F-18: Detail of the beam-column connection after stage 02 (J11-Long.)

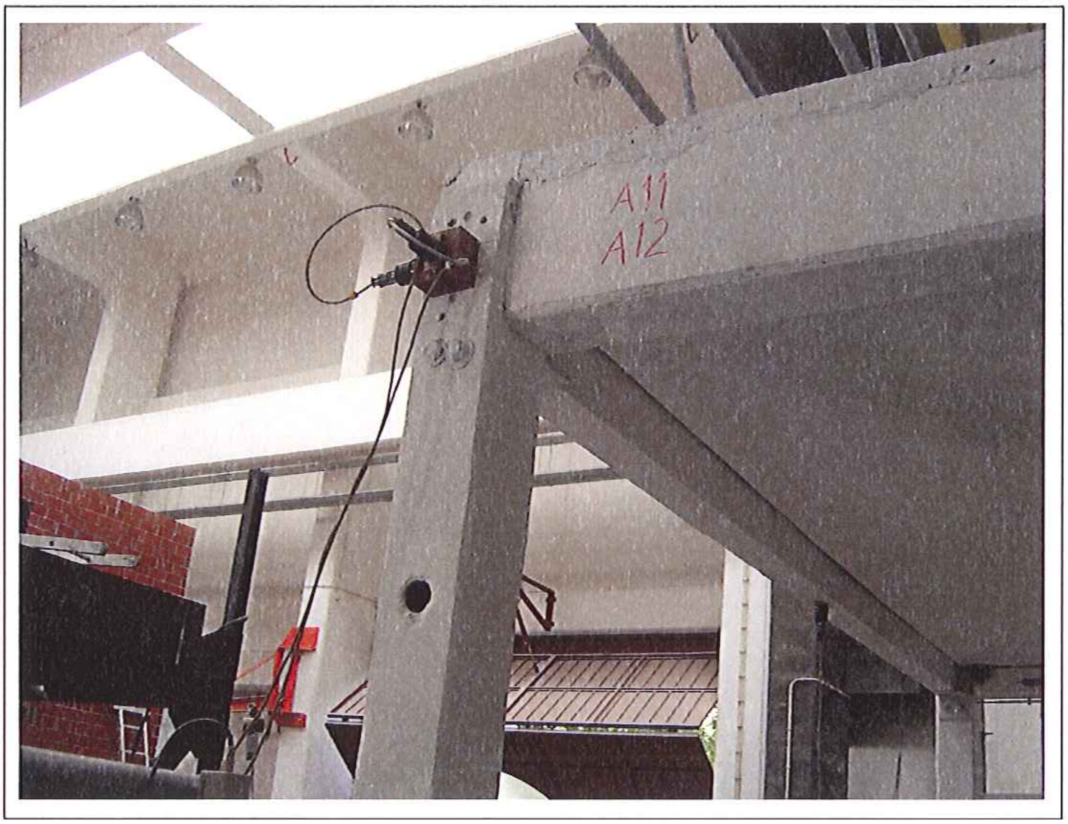


Figure F-19: Detail of the beam-column connection after stage 02 (J10-Long.)

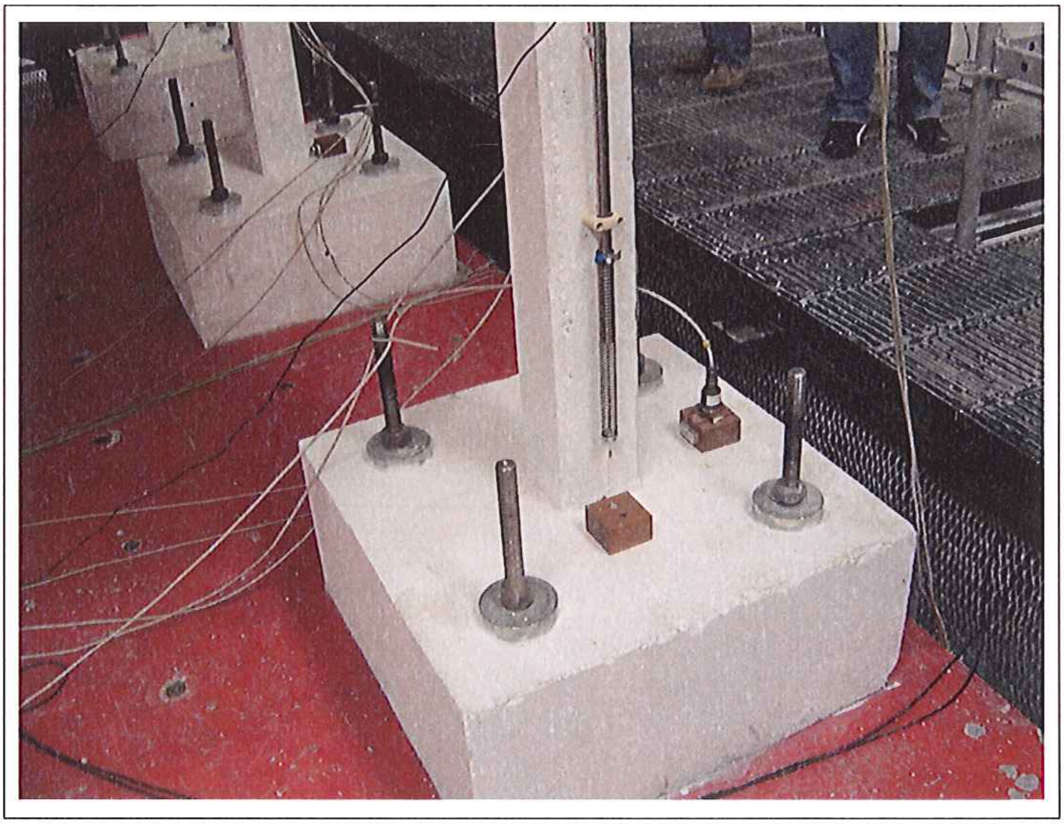


Figure F-20: Detail of the base of the column C4 after stage 02

Figure F-21: Detail of the beam-column connection after the test (J9-Trans.)

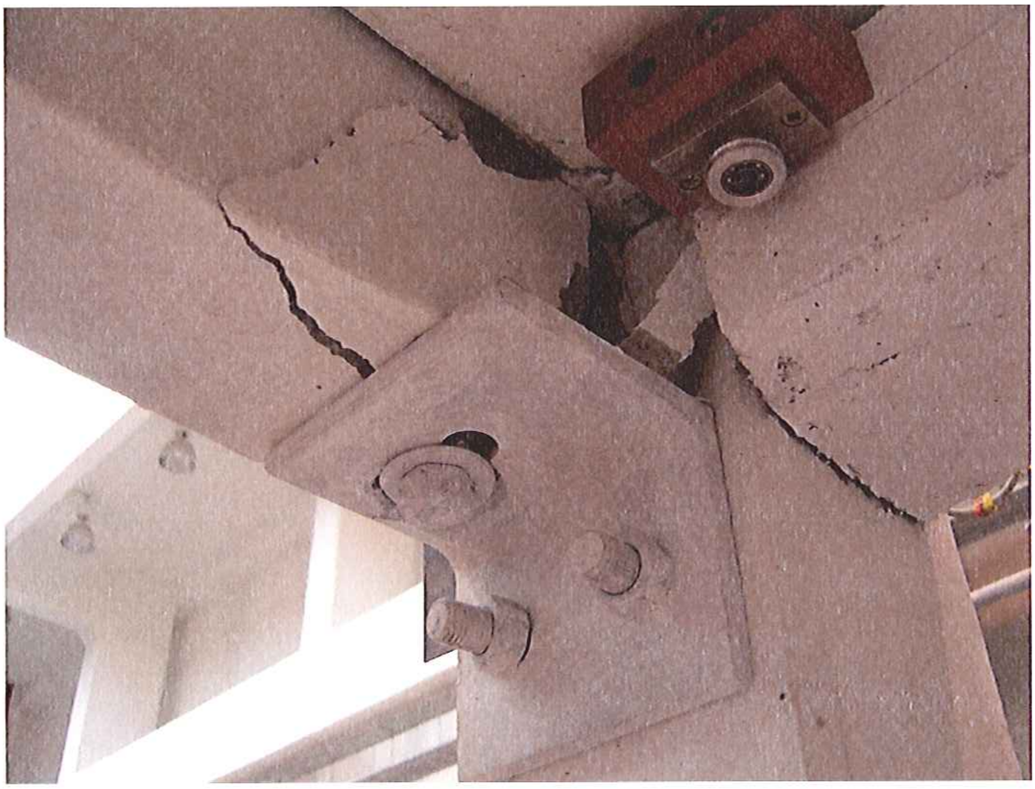


Figure F-22: Detail of the beam-column connection's inner part after the test (J9-Trans.)

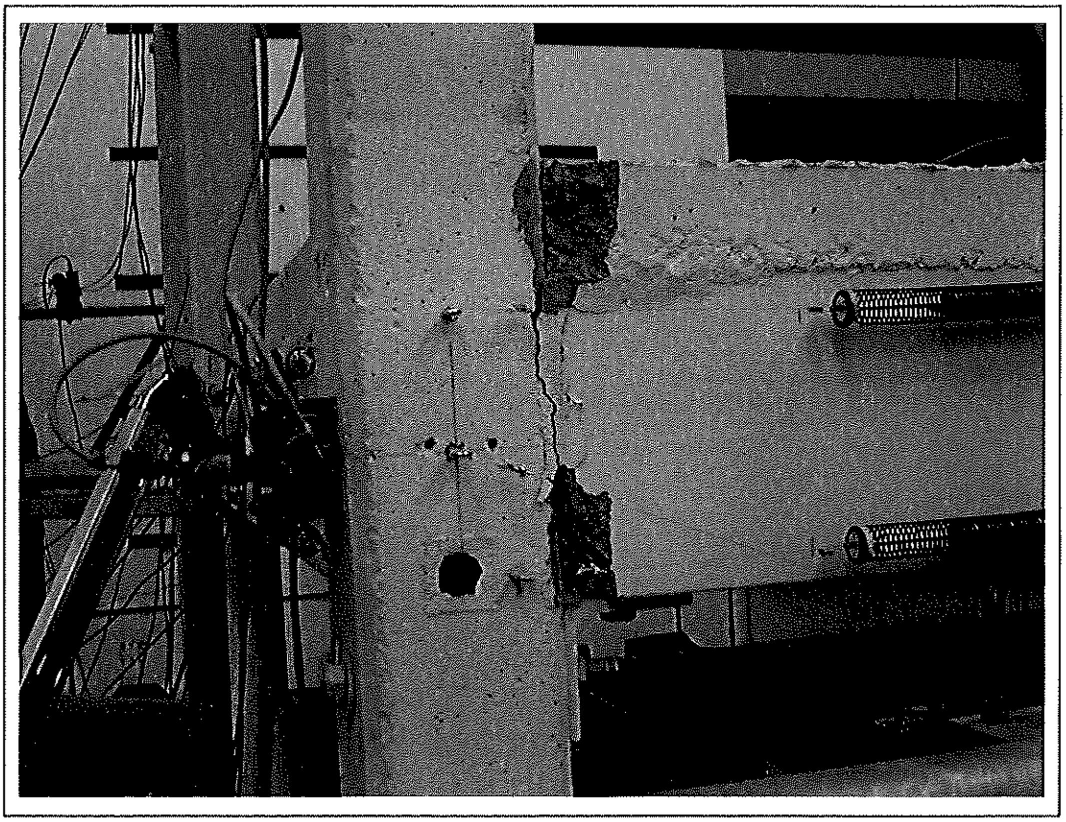


Figure F-23: Detail of the beam-column connection after the test (J3-Trans.)

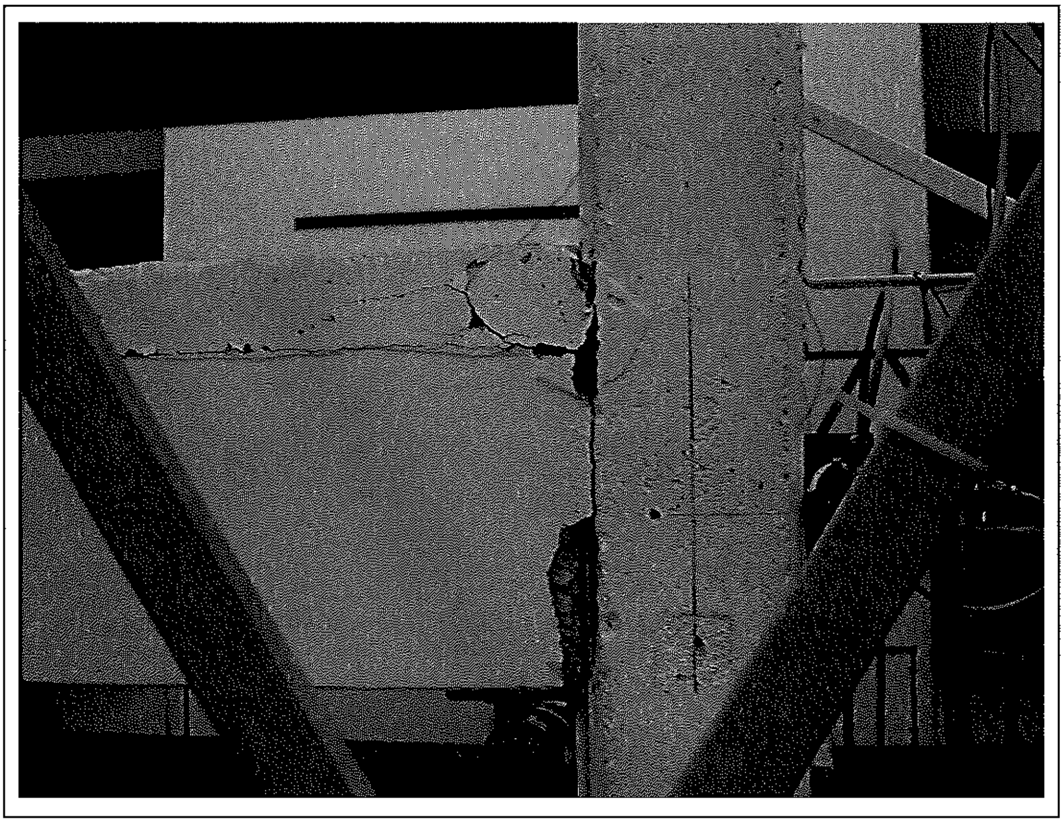


Figure F-24: Detail of the beam-column connection after the test (J4-Trans.)

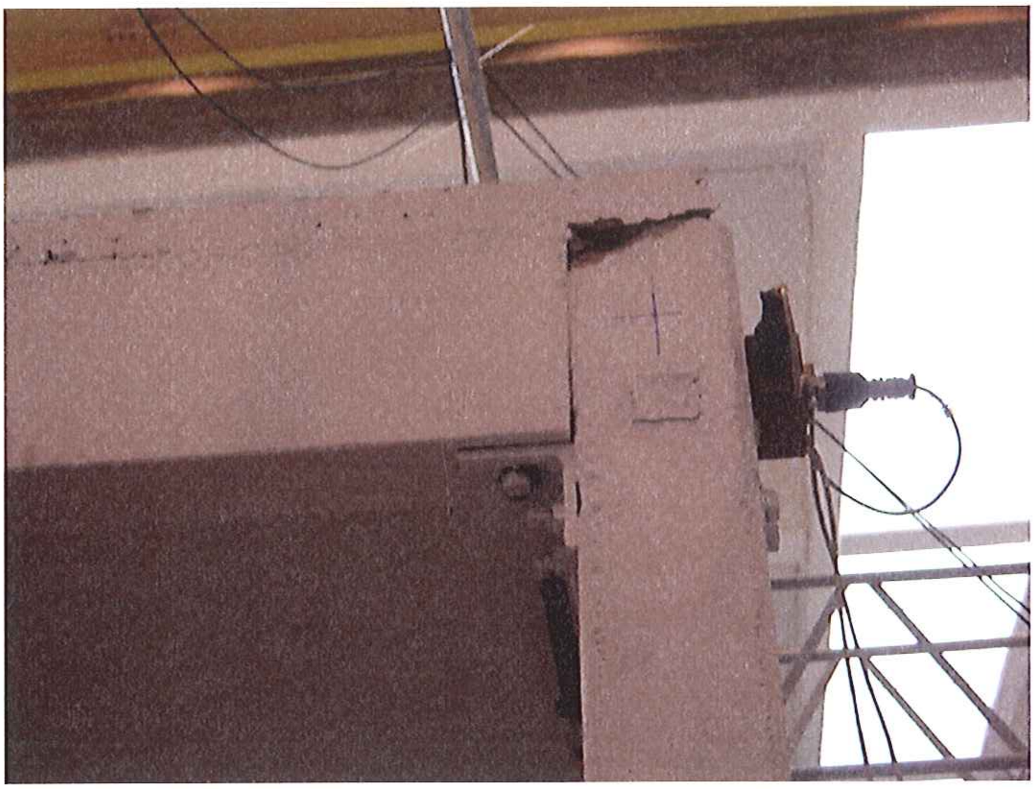


Figure F-25: Detail of the beam-column connection after the test (J7-Trans.)

Figure F-26: Detail of the beam-column connection after the test (J1-Trans.)

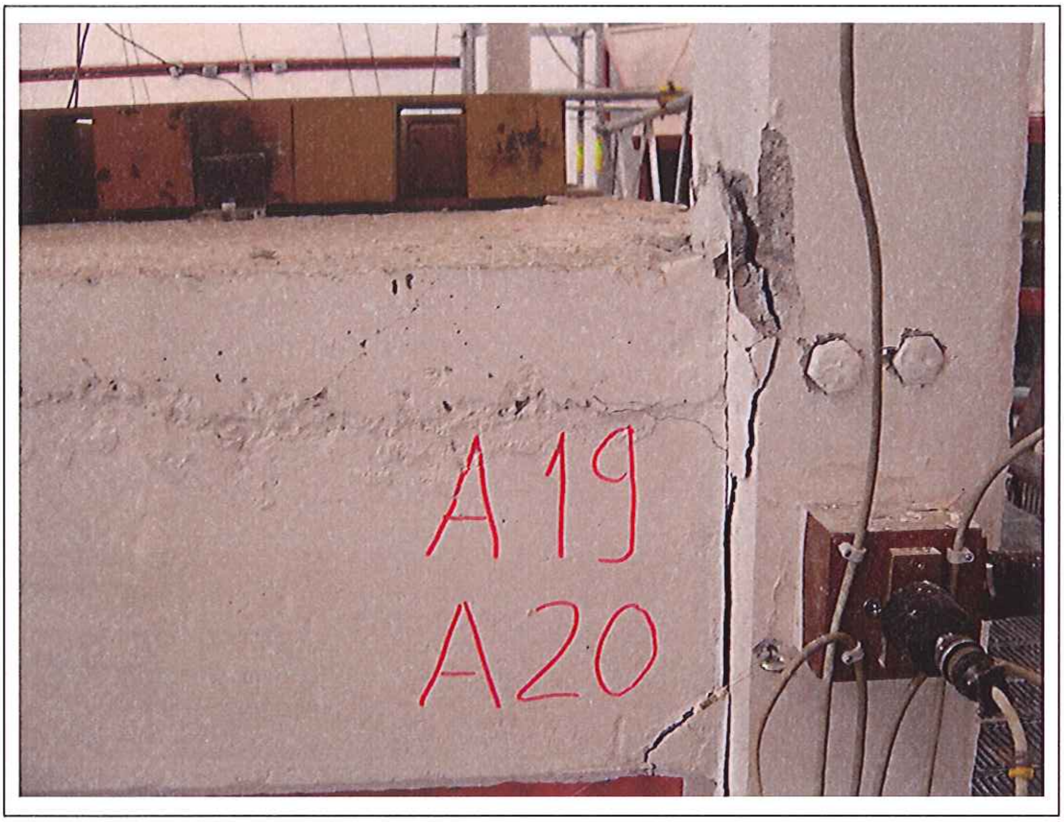


Figure F-27: Detail of the beam-column connection after the test (J6-Long.)

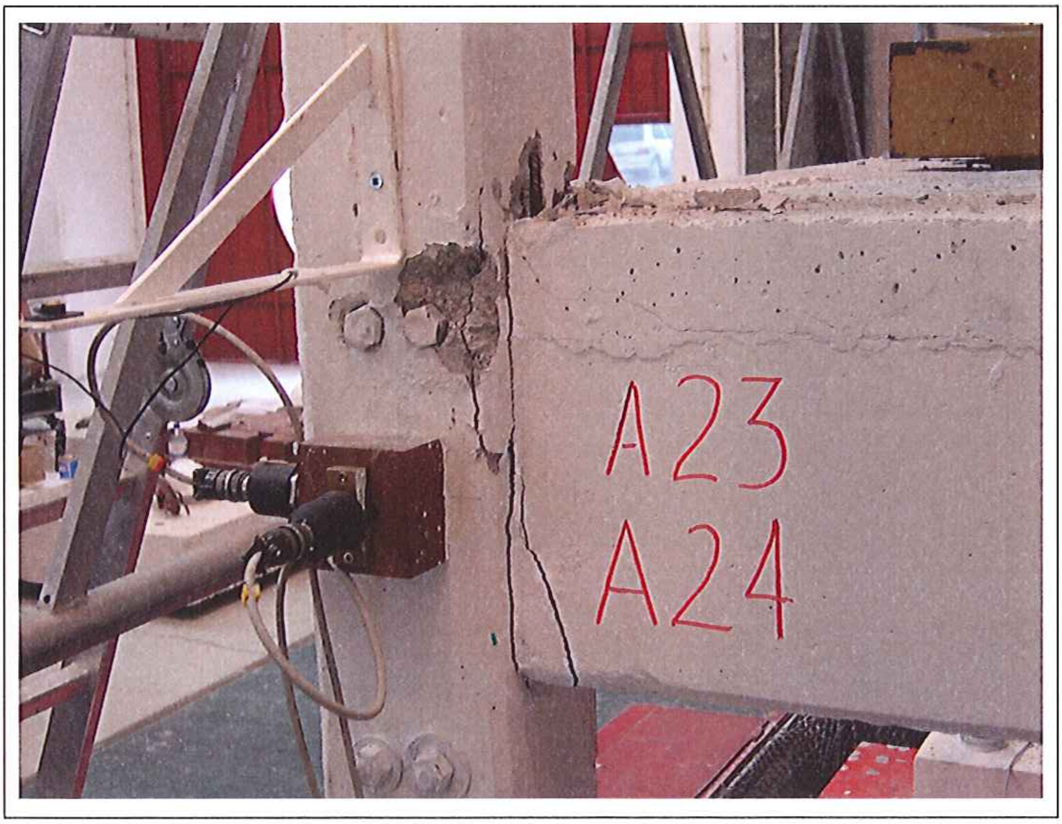


Figure F-28: Detail of the beam-column connection after the test (J10-Long.)

Figure F-29: Detail of the beam-column connection after the test (J1-Long.)

Figure F-30: Detail of the beam-column connection after the test (J8-Long.)

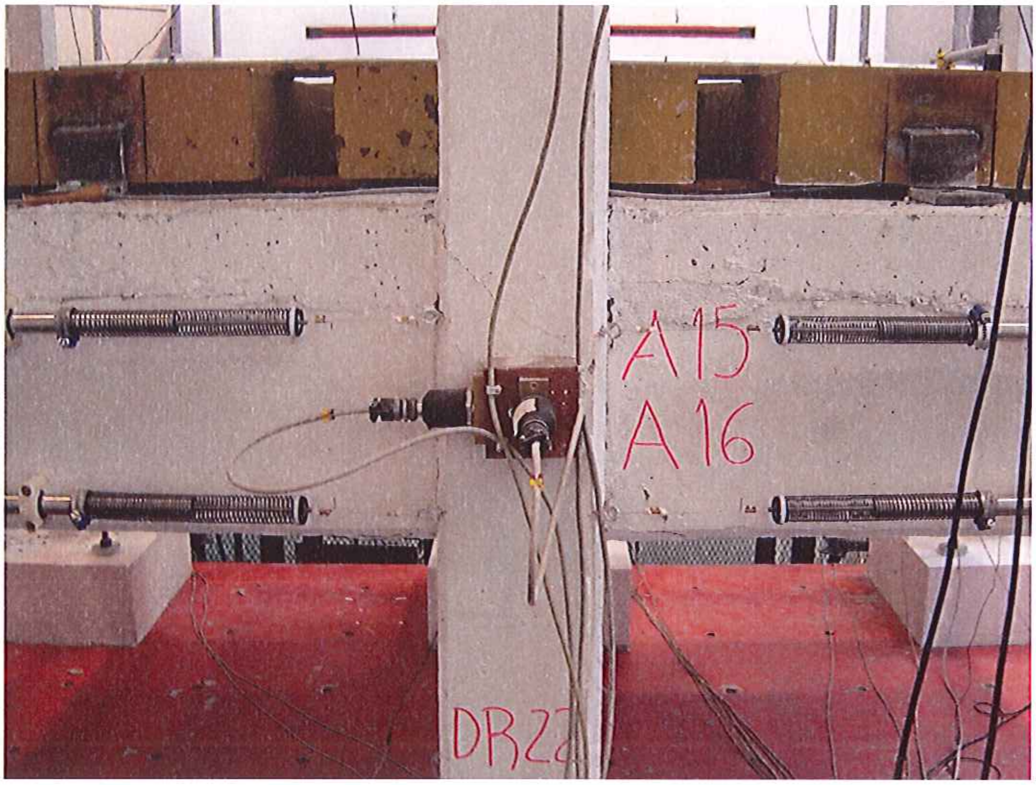


Figure F-31: Detail of the beam-column connection after the test (J2-Long.)

Figure F-32: Detail of the beam-column connection after the test (J5-Long.)

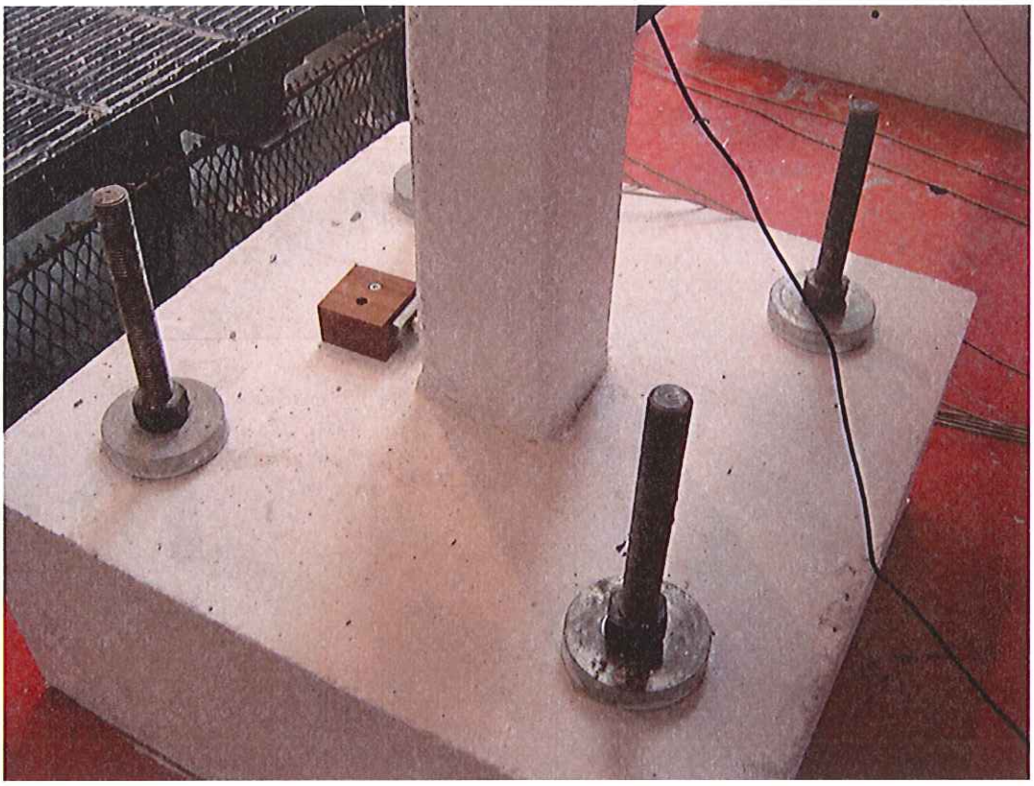


Figure F-33: Detail of the base of the column C3 after the test

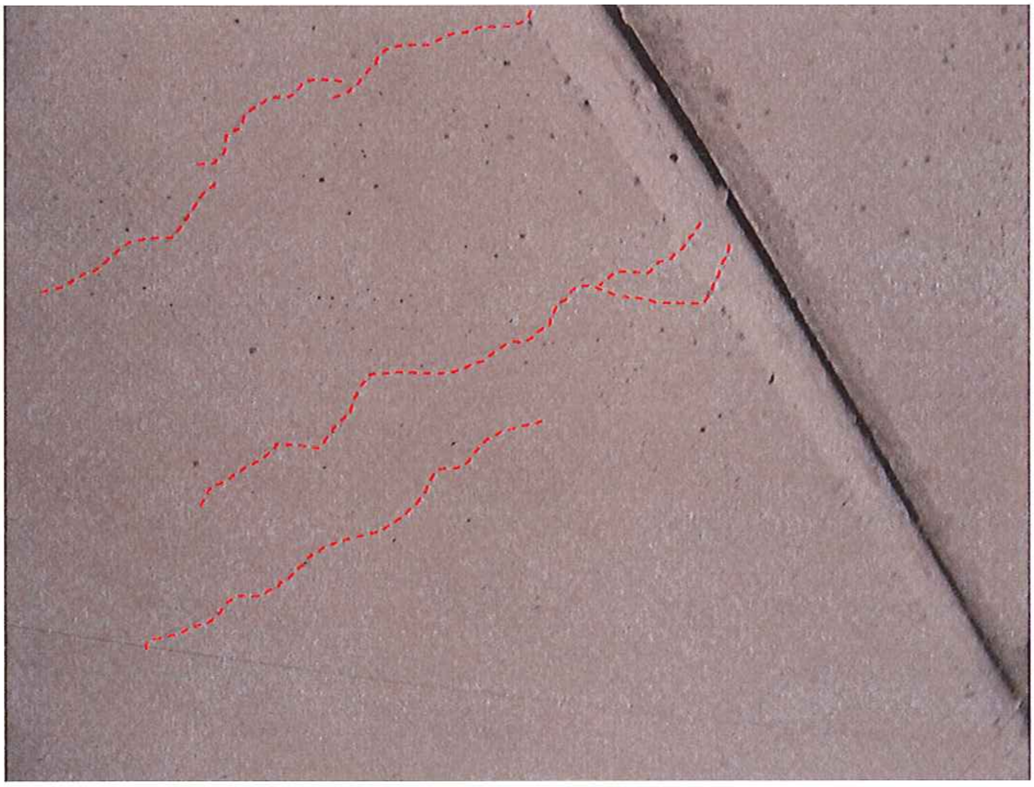


Figure F-34: Detail of cracking (bottom of the 2nd floor slab)

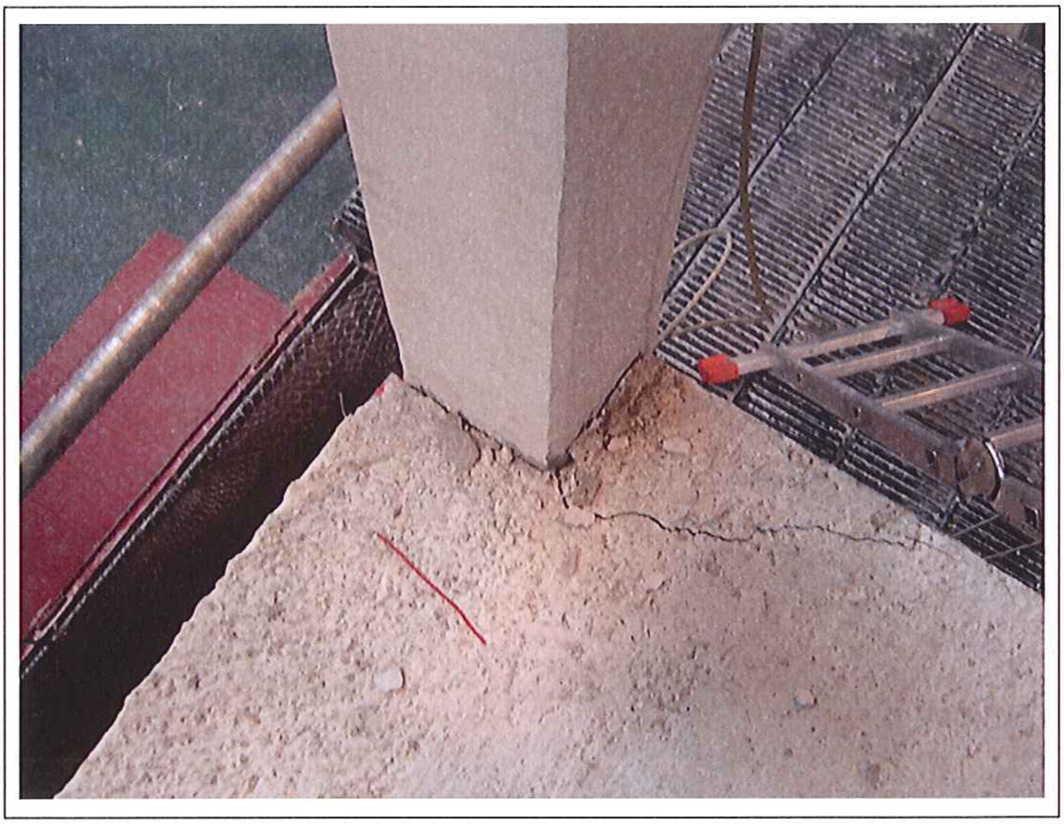


Figure F-35: Detail of cracking on the topping layer (J3)

Figure F-36: Detail of cracking on the topping layer (J1)

ANNEX G EXPERIMENTAL MODAL FREQUENCIES

List of Figures:

G.1 Cat 00

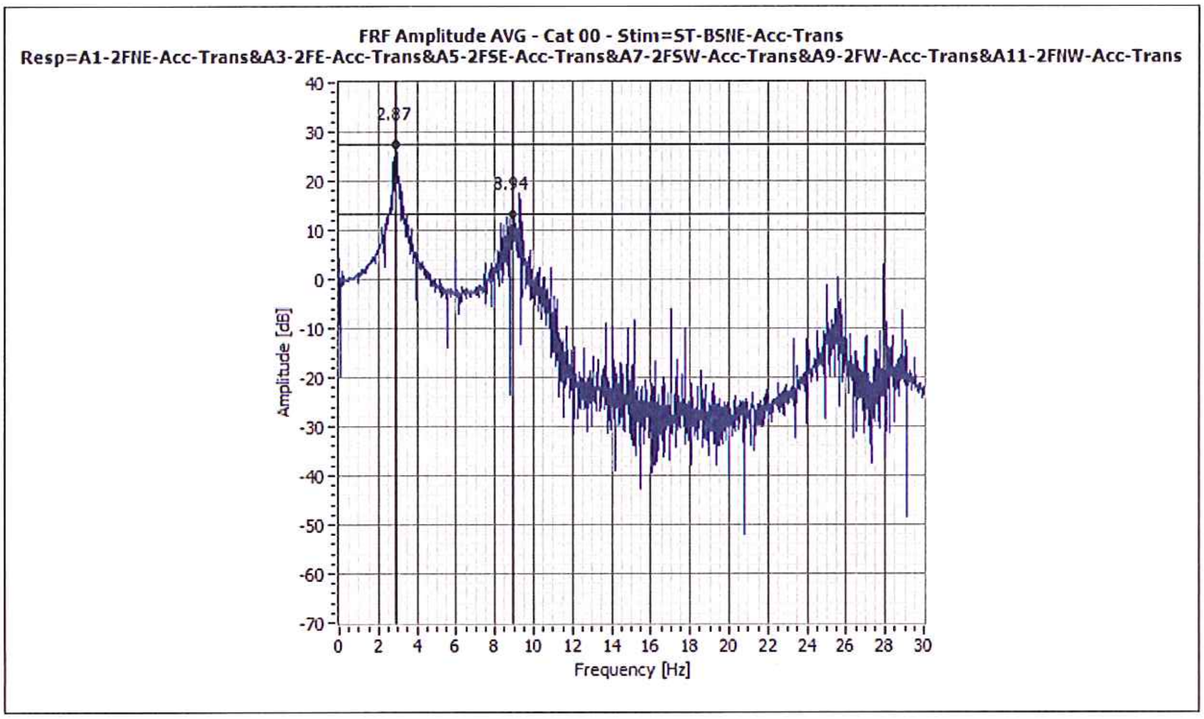


Figure G-1: FRF peak picking – Stage 00 – Transversal (2nd Floor)

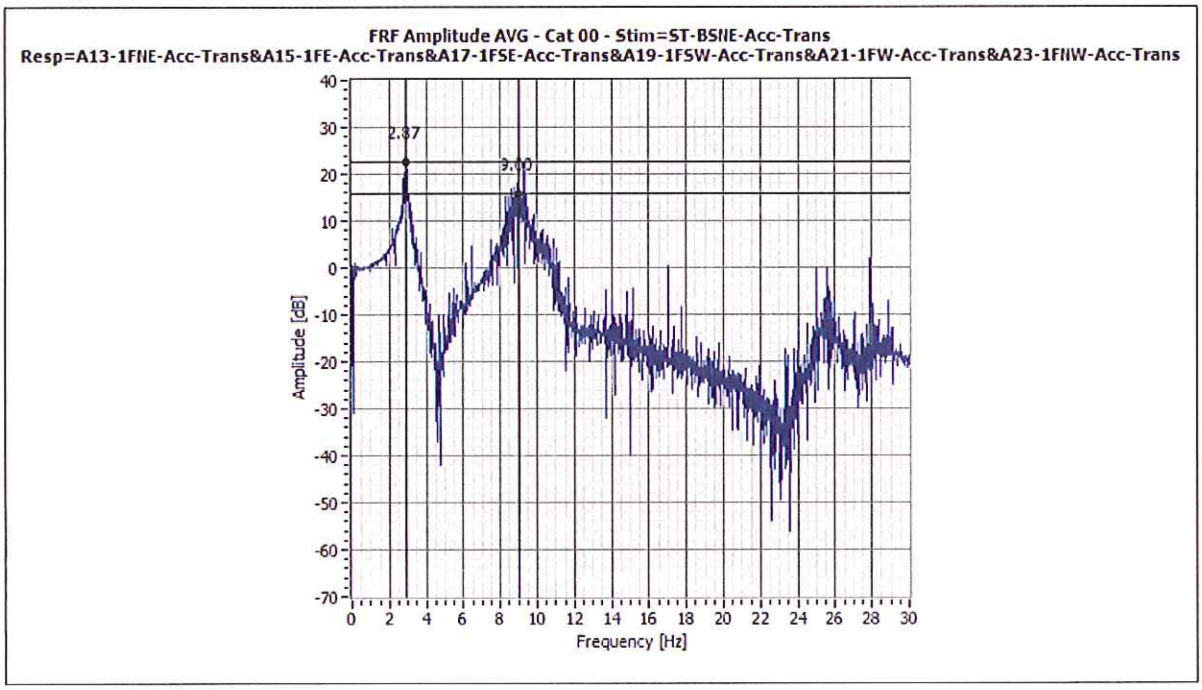


Figure G-2: FRF peak picking – Stage 00 – Transversal (1st Floor)

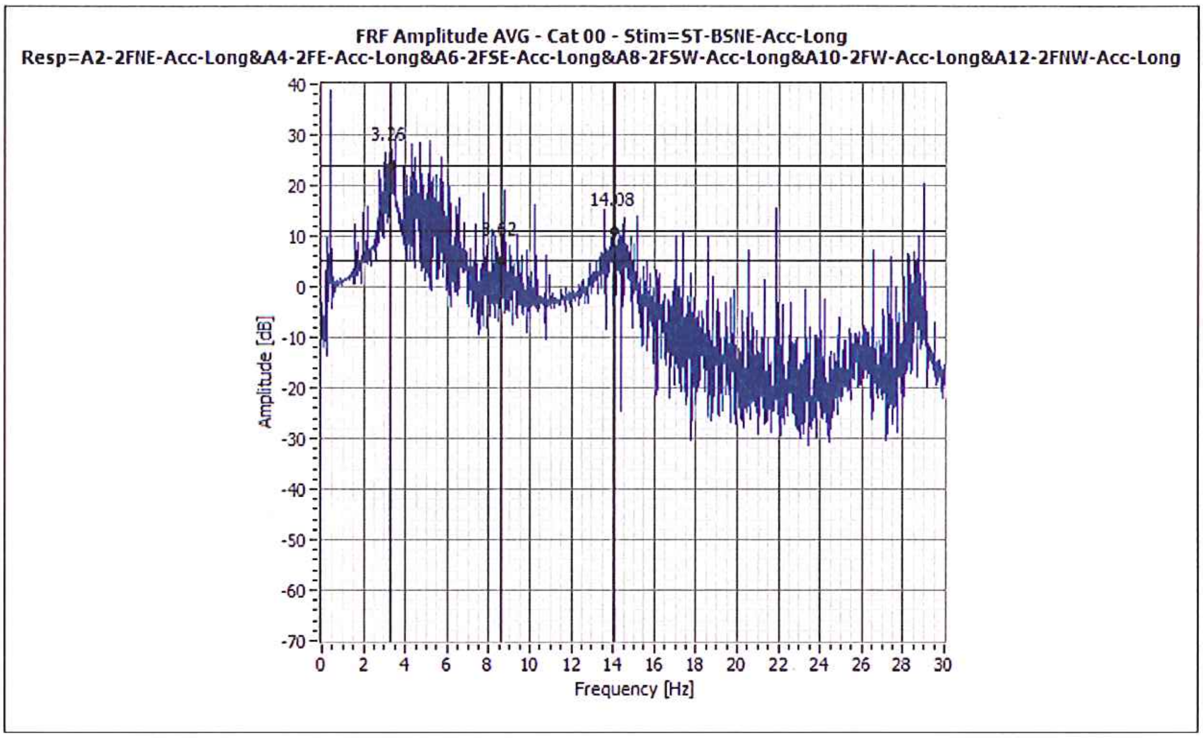


Figure G-3: FRF peak picking – Stage 00 – Longitudinal (2nd Floor)

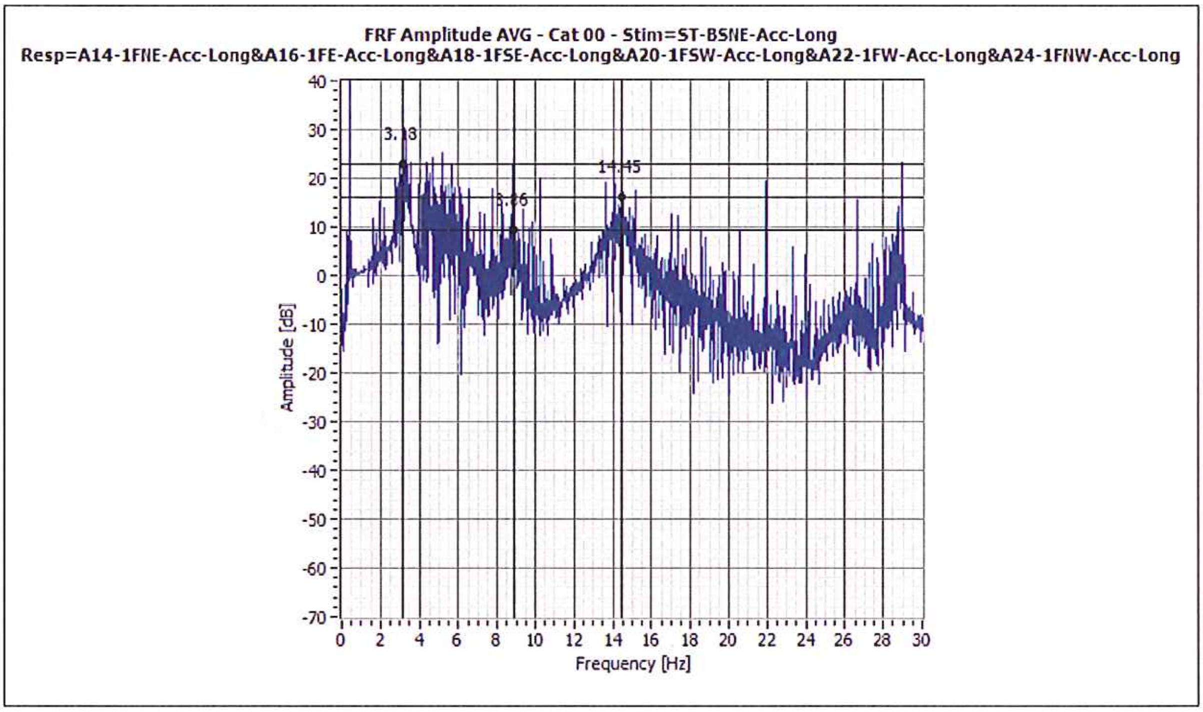


Figure G-4: FRF peak picking – Stage 00 – Longitudinal (1st Floor)

G.2 Cat 01

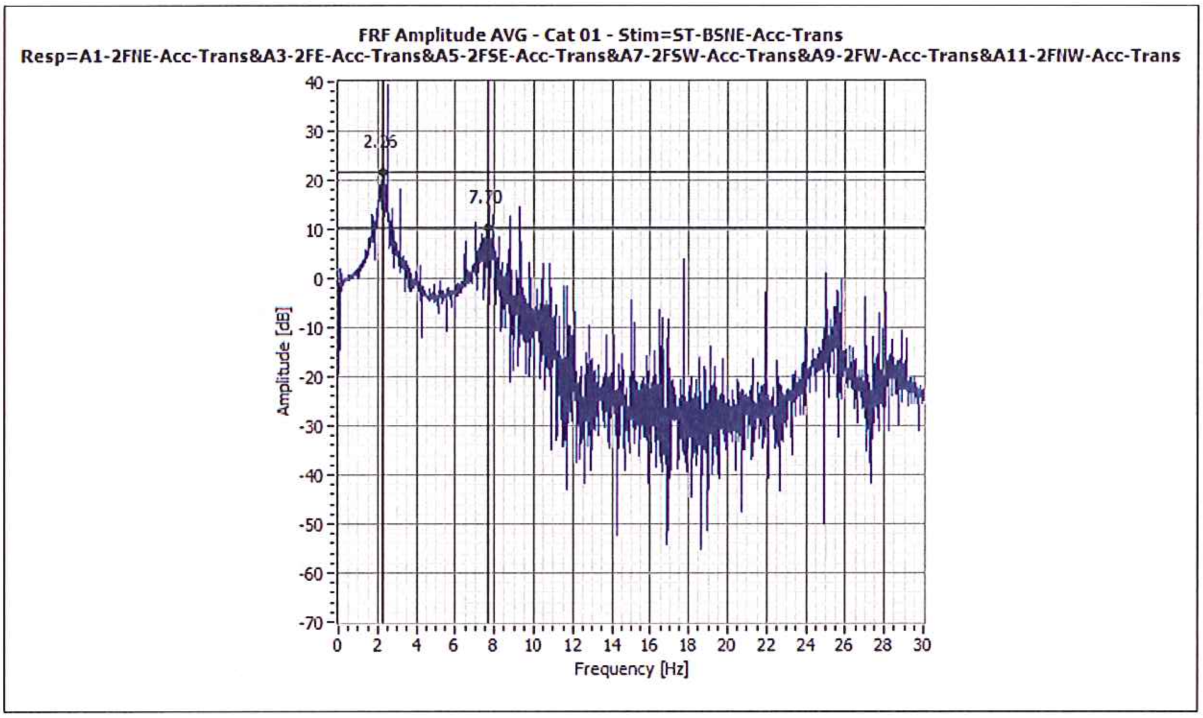


Figure G-5: FRF peak picking – Stage 01 – Transversal (2nd Floor)

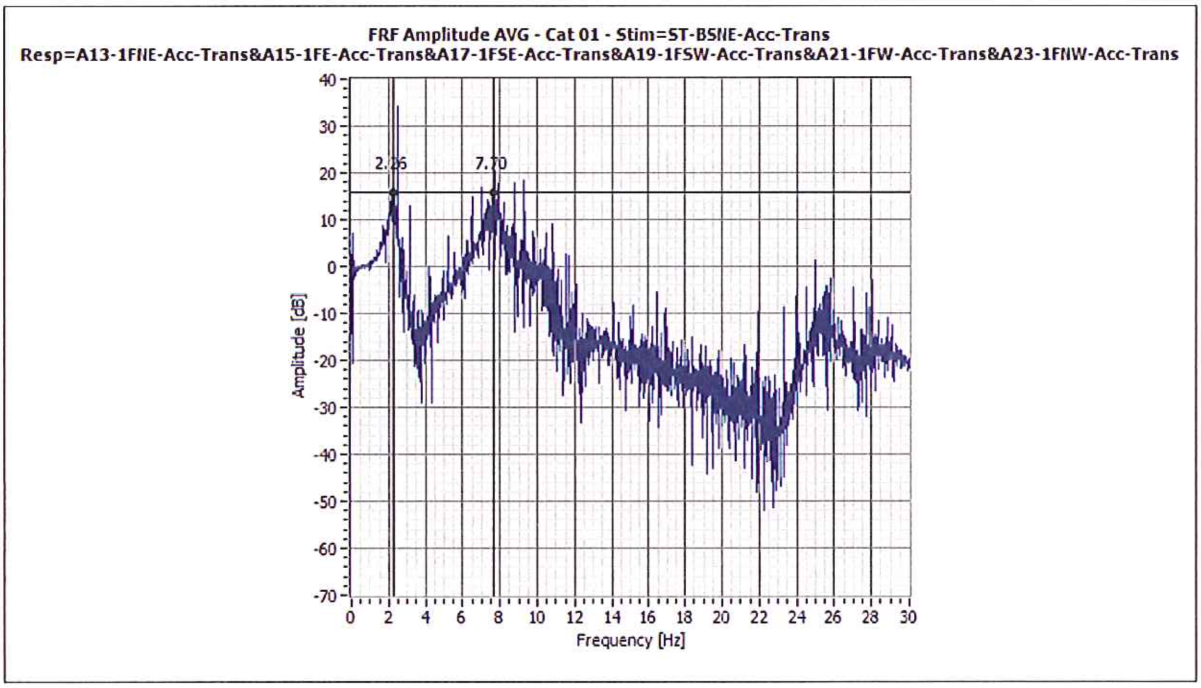


Figure G-6: FRF peak picking – Stage 01 – Transversal (1st Floor)

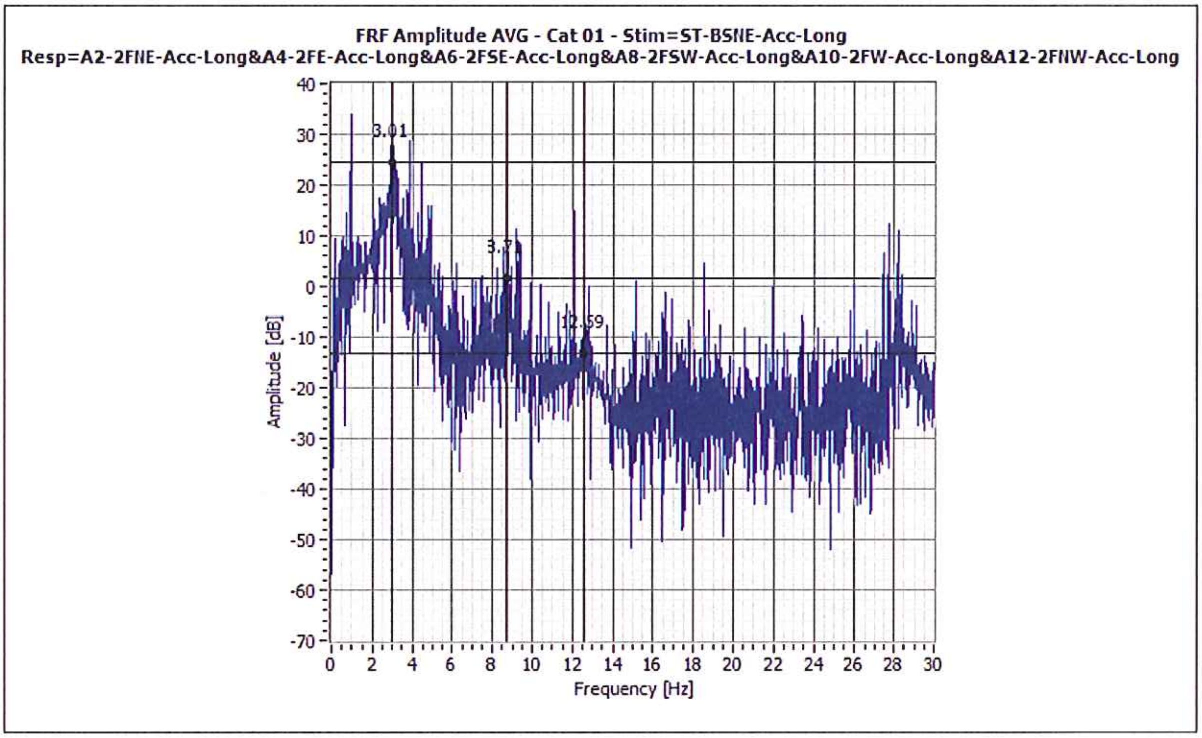


Figure G-7: FRF peak picking – Stage 01 – Longitudinal (2nd Floor)

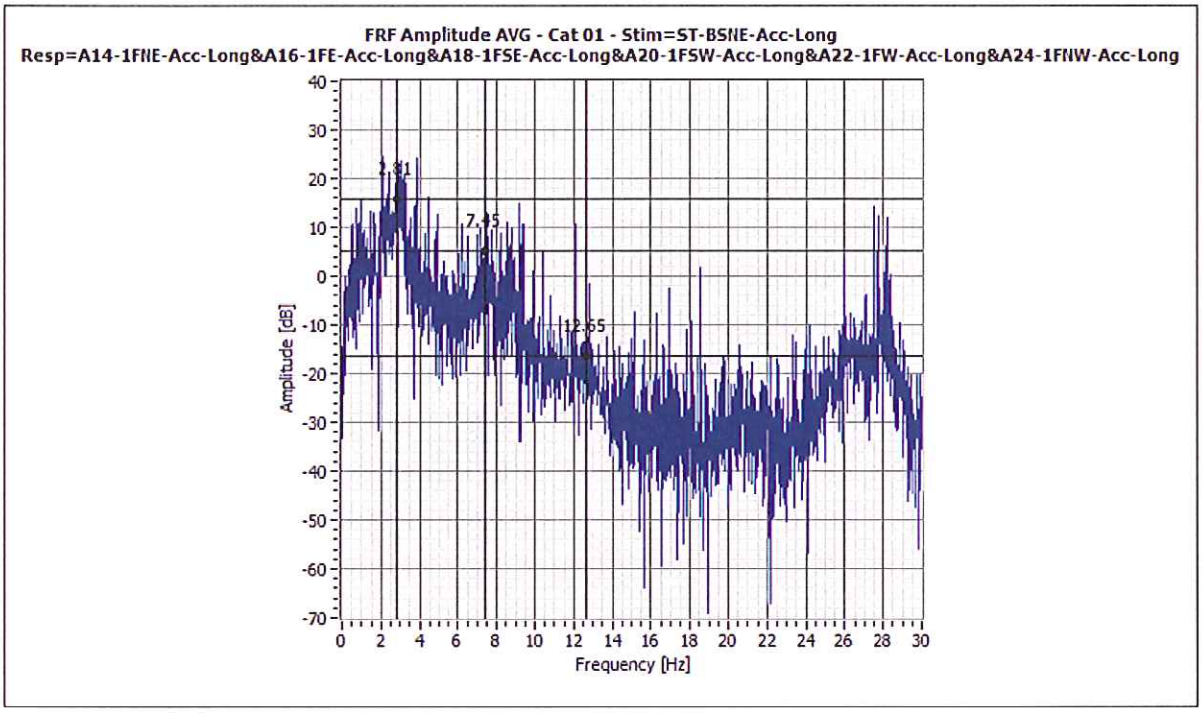


Figure G-8: FRF peak picking – Stage 01 – Longitudinal (1st Floor)

G.3 Cat 02

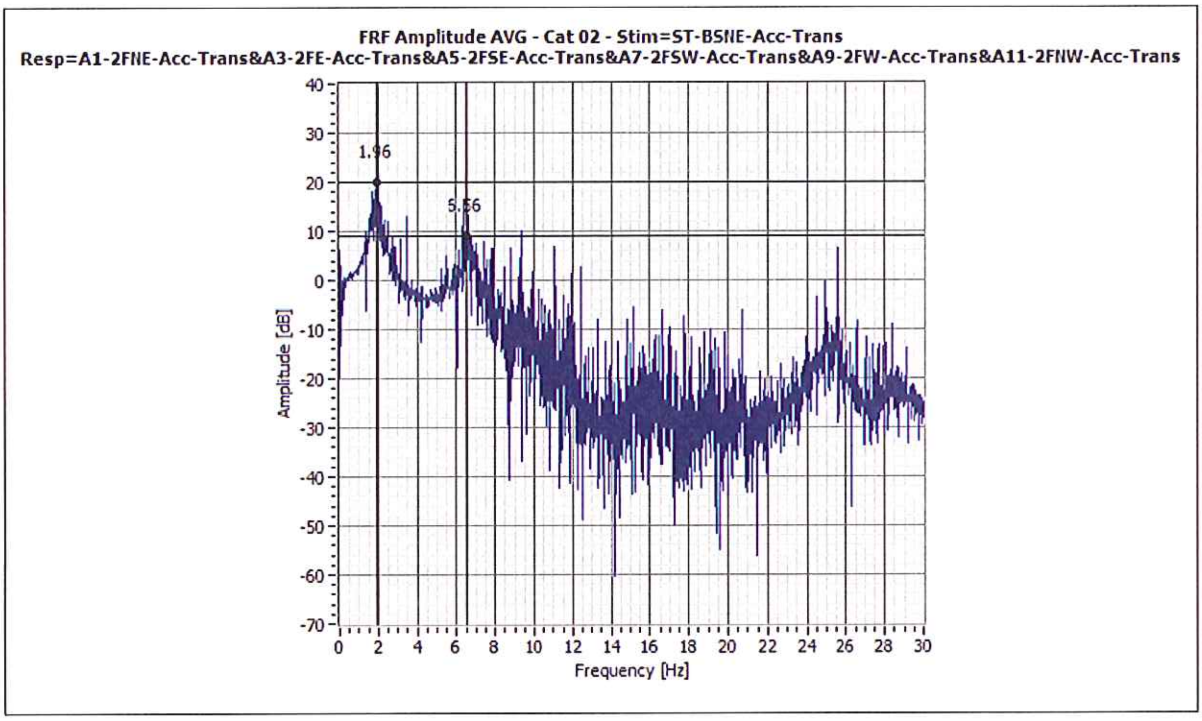


Figure G-9: FRF peak picking – Stage 02 – Transversal (2nd Floor)

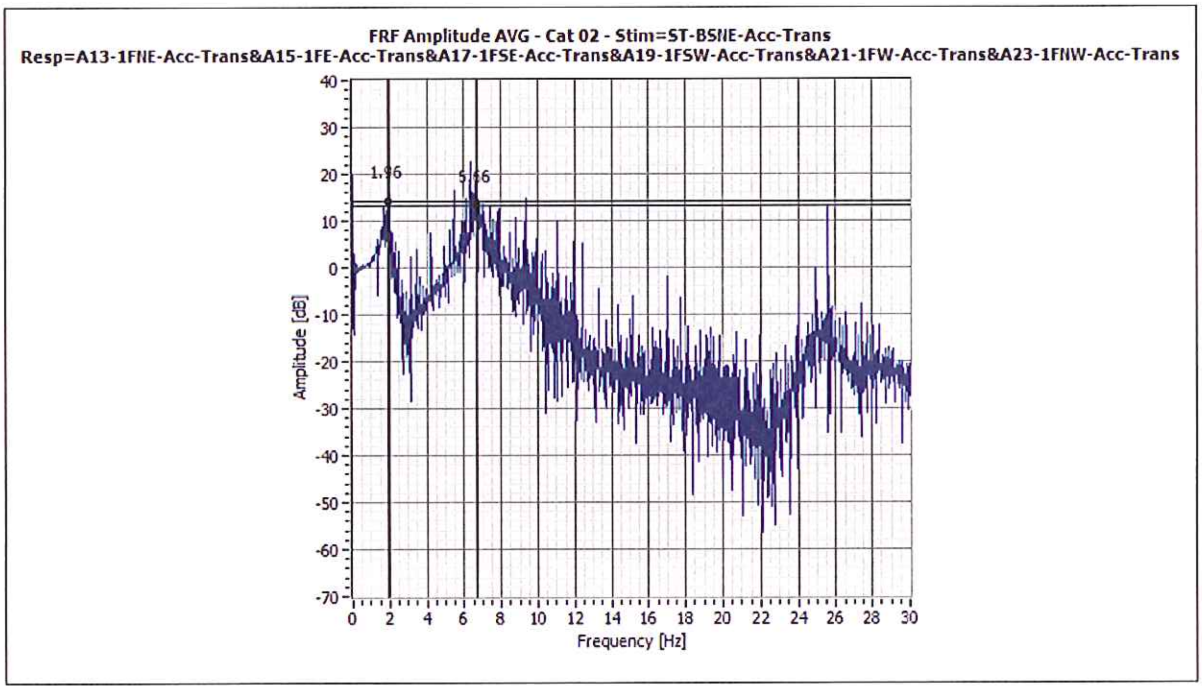


Figure G-10: FRF peak picking – Stage 02 – Transversal (1st Floor)

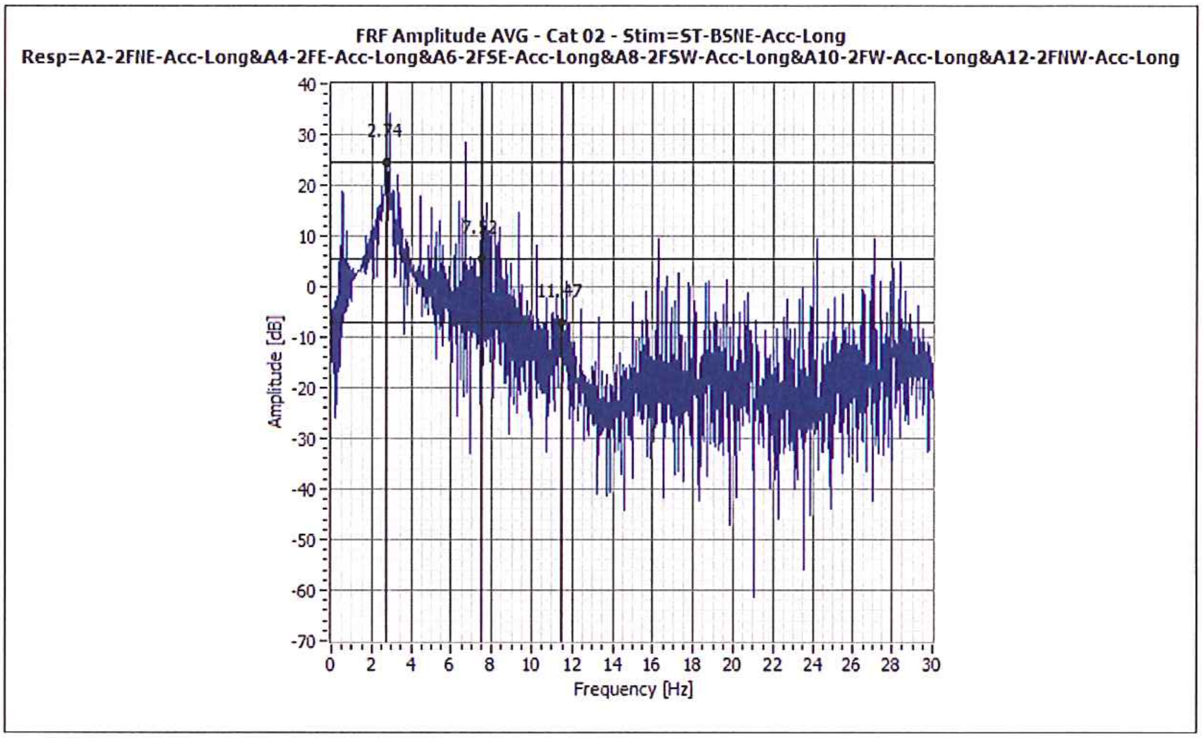


Figure G-11: FRF peak picking – Stage 02 – Longitudinal (2nd Floor)

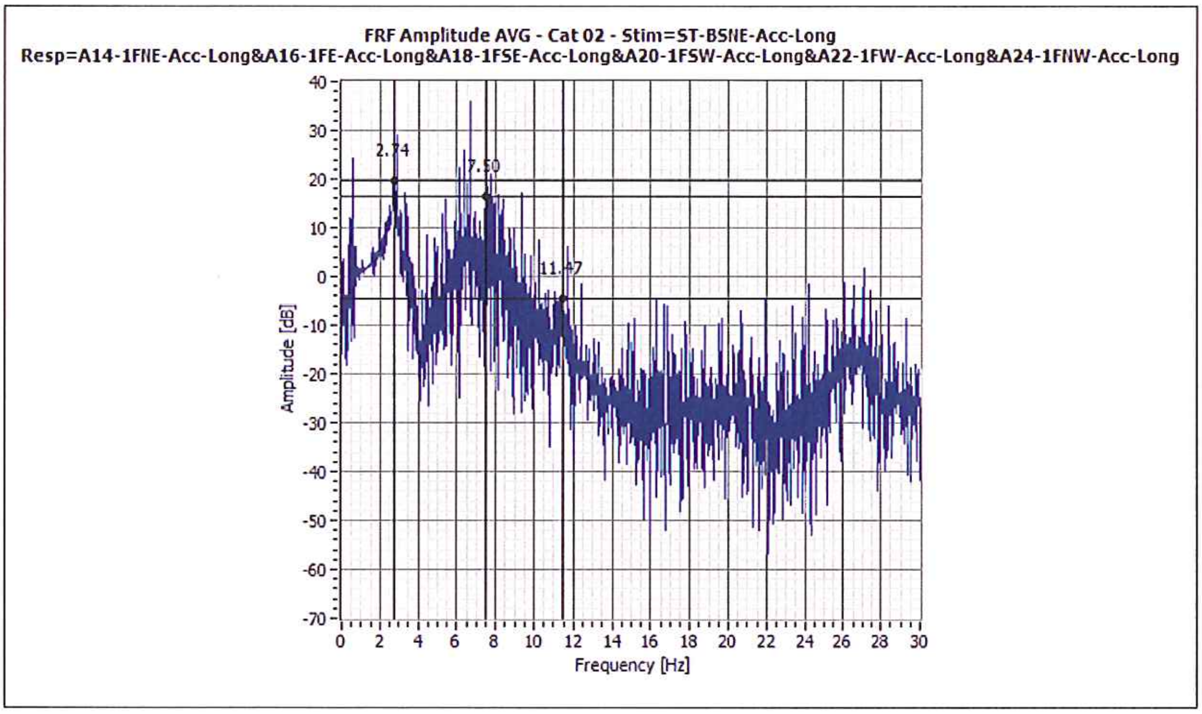


Figure G-12: FRF peak picking – Stage 02 – Longitudinal (1st Floor)

G.4 Cat 03

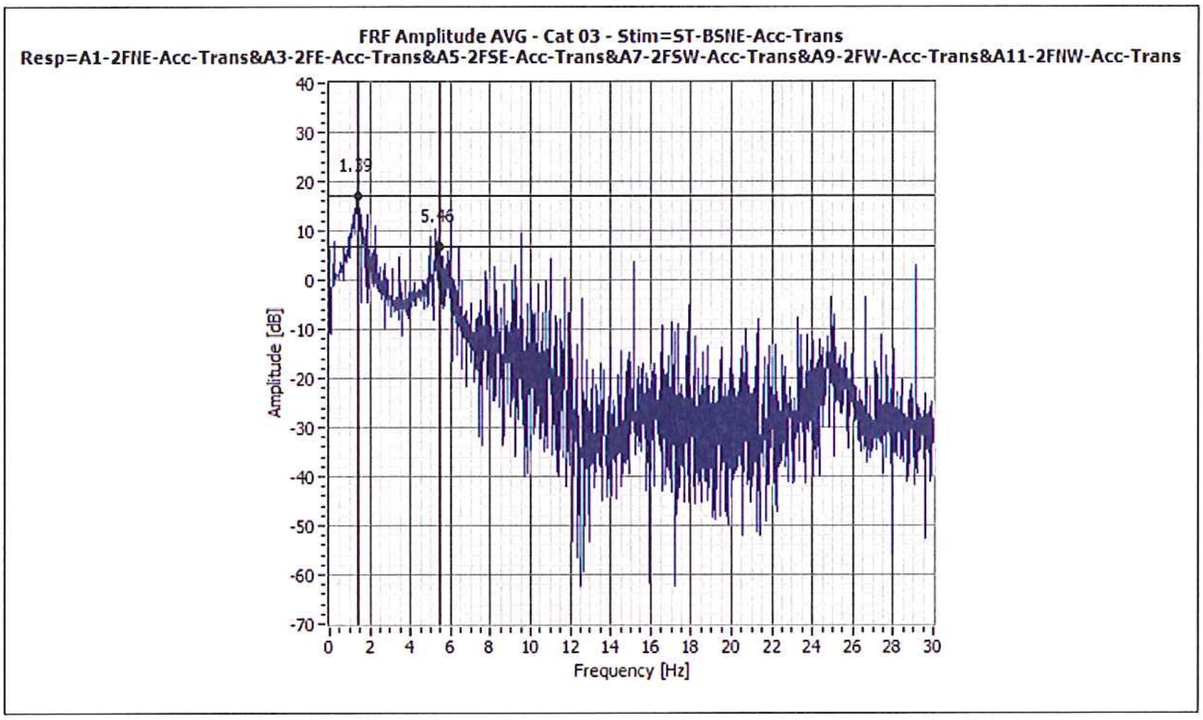


Figure G-13: FRF peak picking – Stage 03 – Transversal (2nd Floor)

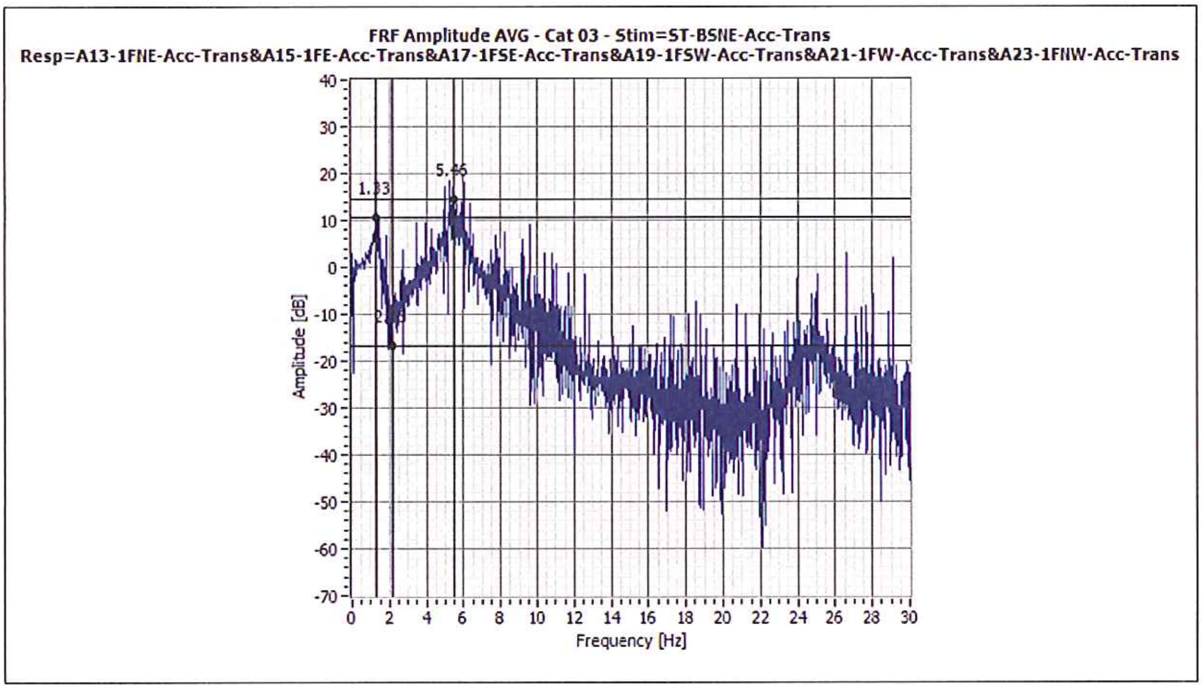


Figure G-14: FRF peak picking – Stage 03 – Transversal (1st Floor)

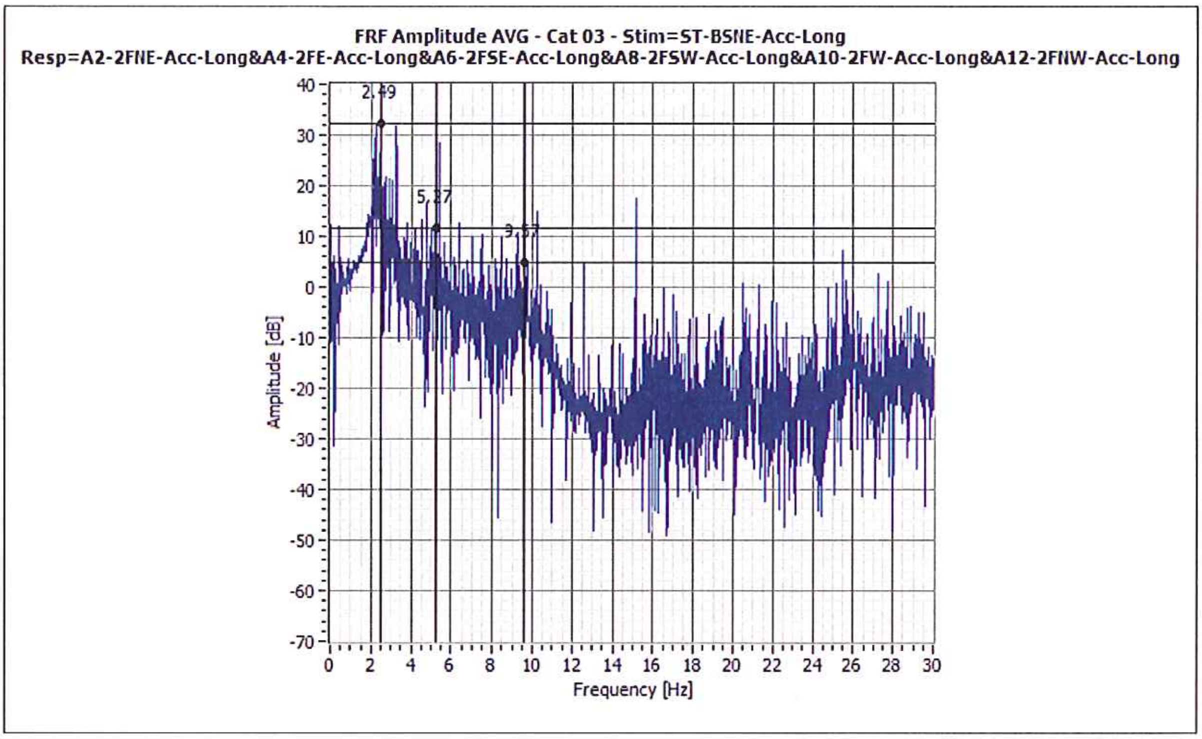


Figure G-15: FRF peak picking – Stage 03 – Longitudinal (2nd Floor)

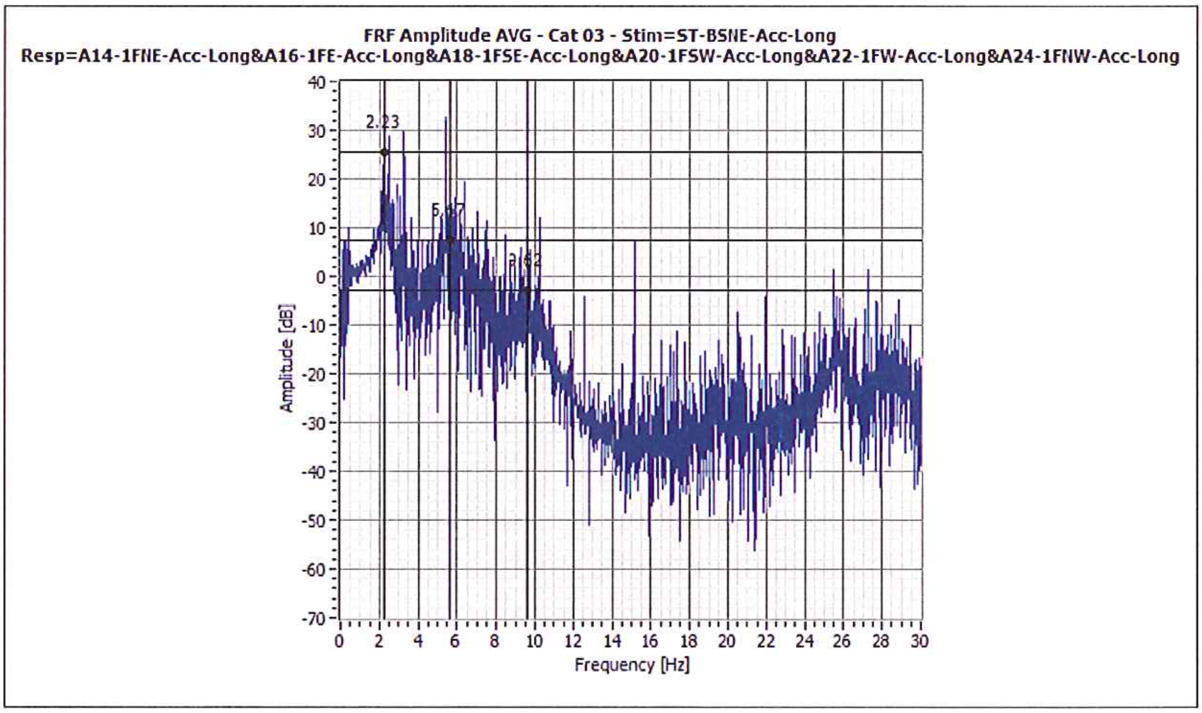


Figure G-16: FRF peak picking – Stage 03 – Longitudinal (1st Floor)

G.5 Cat 04

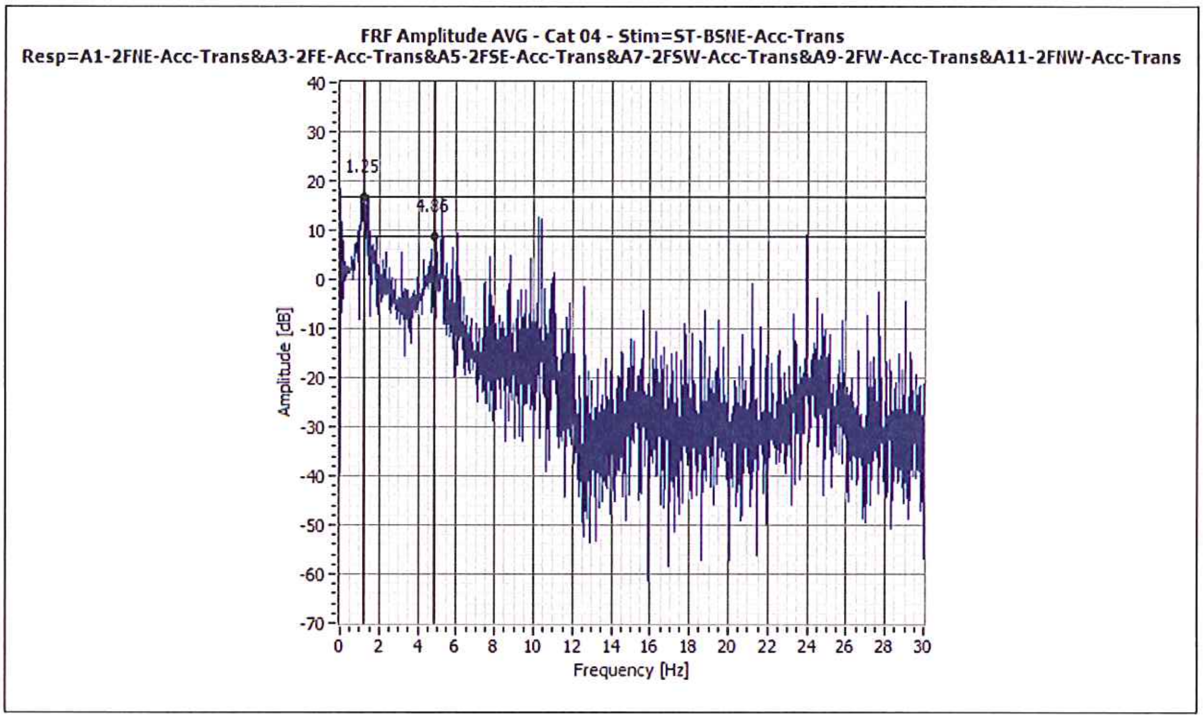


Figure G-17: FRF peak picking – Stage 04 – Transversal (2nd Floor)

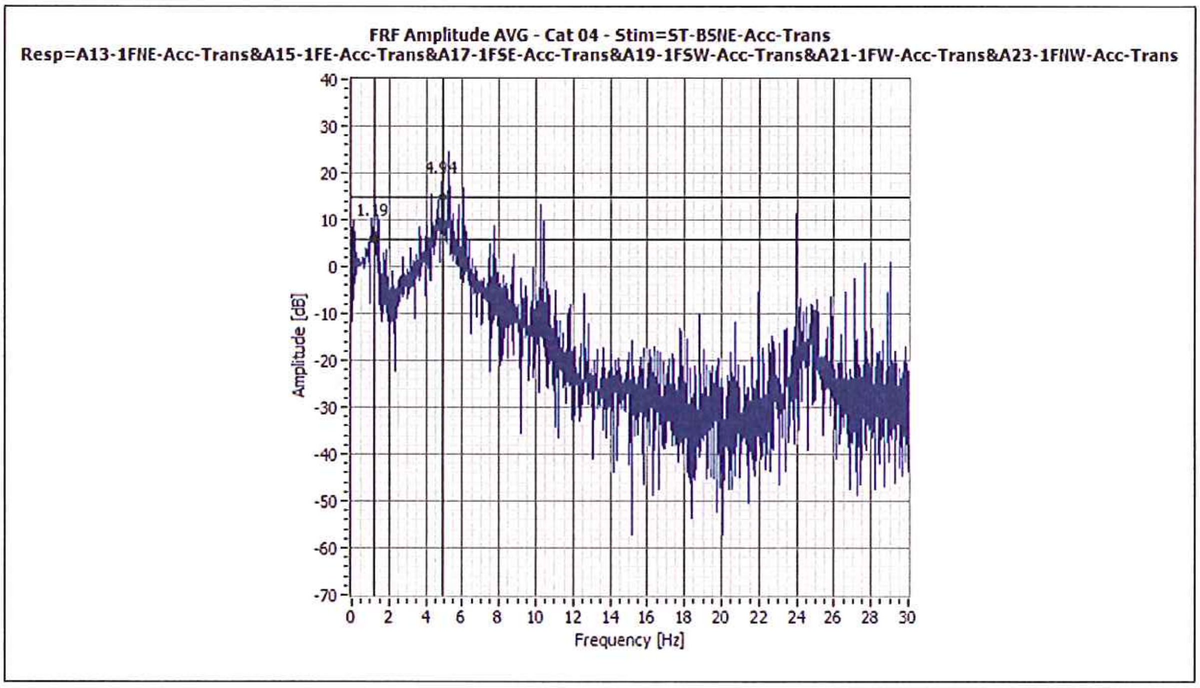


Figure G-18: FRF peak picking – Stage 04 – Transversal (1st Floor)

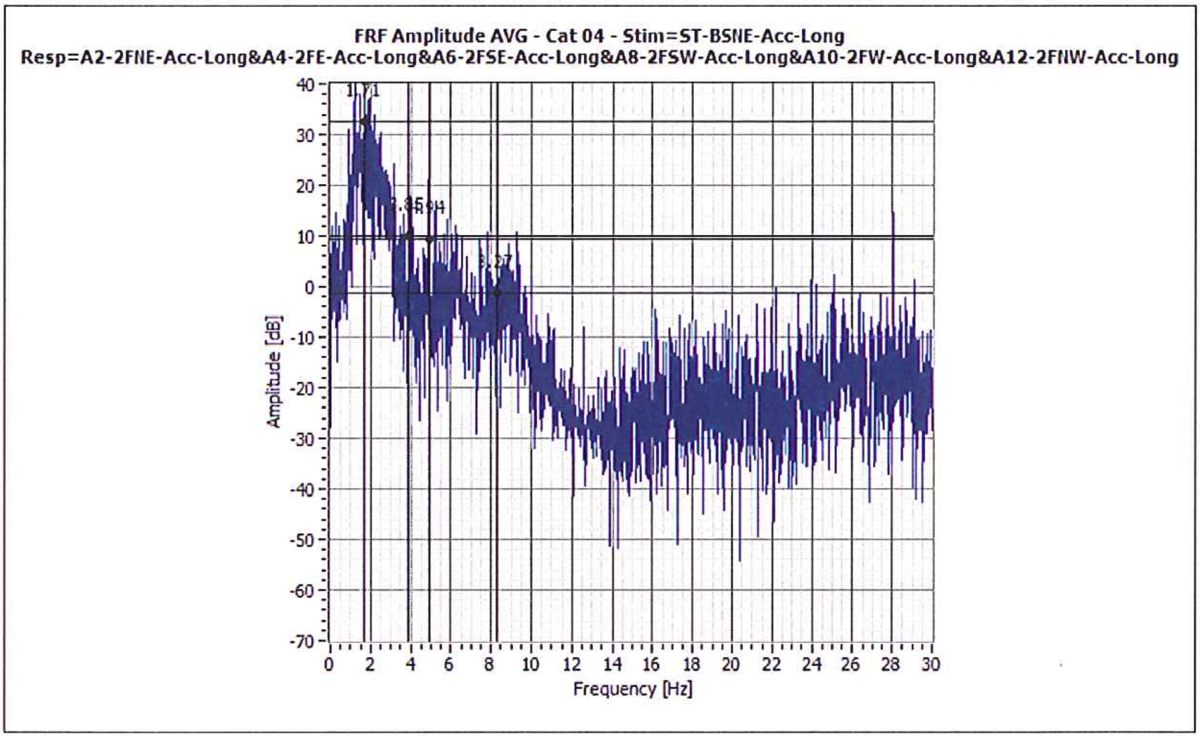


Figure G-19: FRF peak picking – Stage 04 – Longitudinal (2nd Floor)

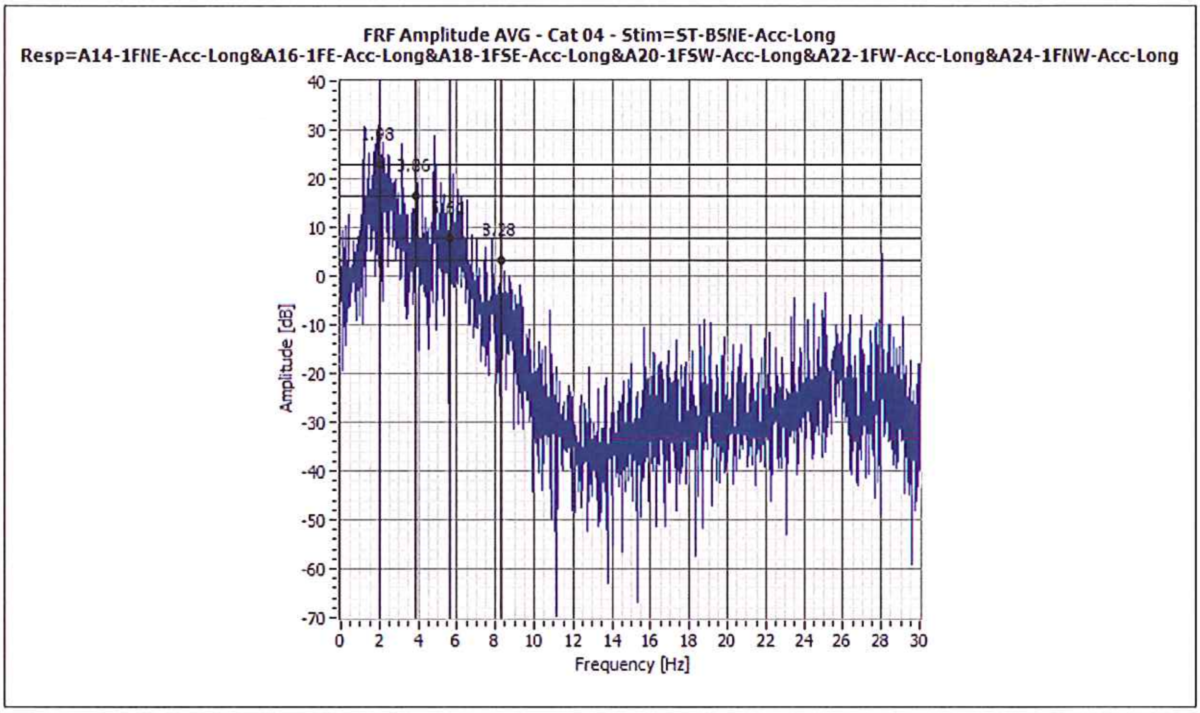


Figure G-20: FRF peak picking – Stage 04 – Longitudinal (1st Floor)

ANNEX H EARTHQUAKE SCENARIO

List of Figures:

H.1 Time Histories

H.1.1 Stage 00

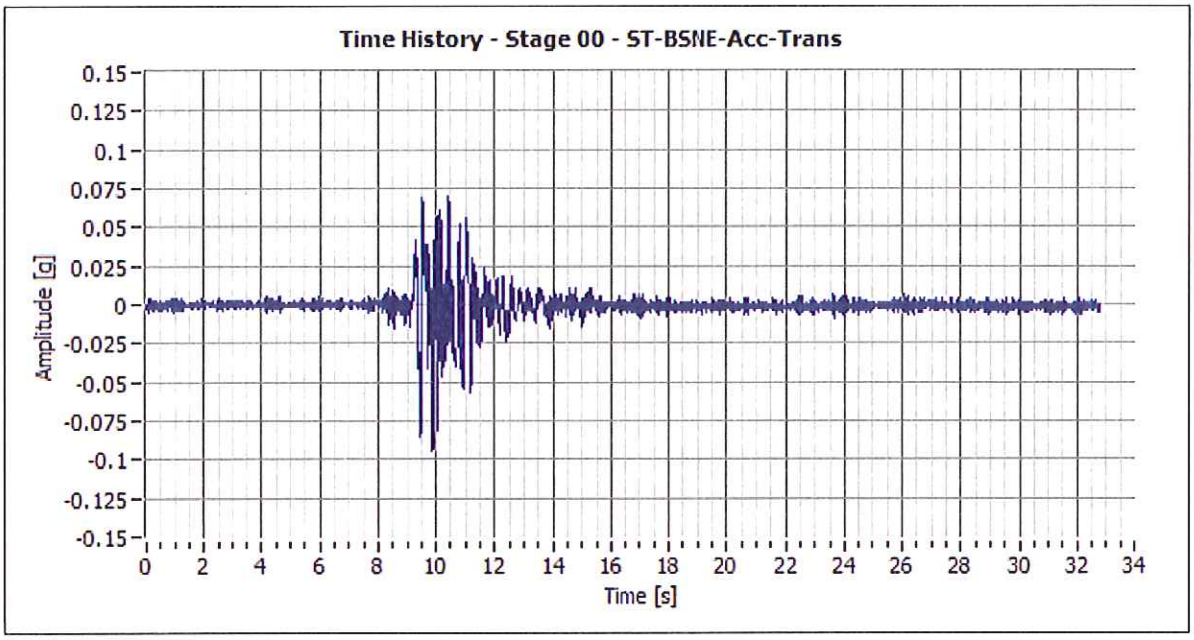


Figure H-1: Time History – Base Accelerations – Stage 00 – Transversal direction

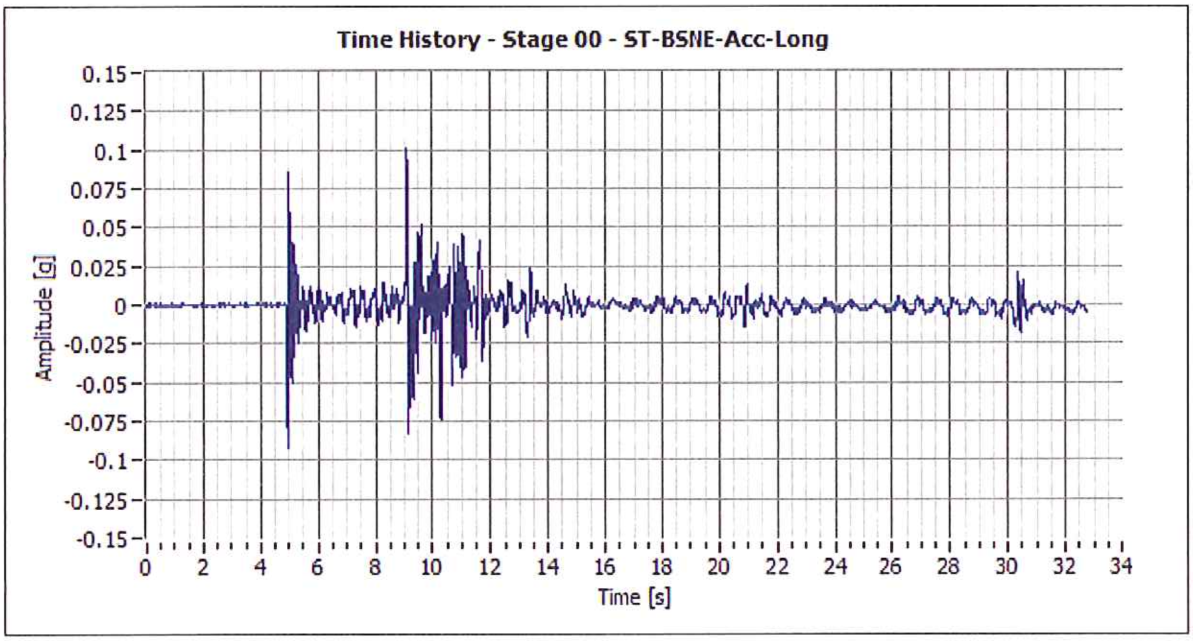


Figure H-2: Time History – Base Accelerations – Stage 00 – Longitudinal direction

H.1.2 Stage 01

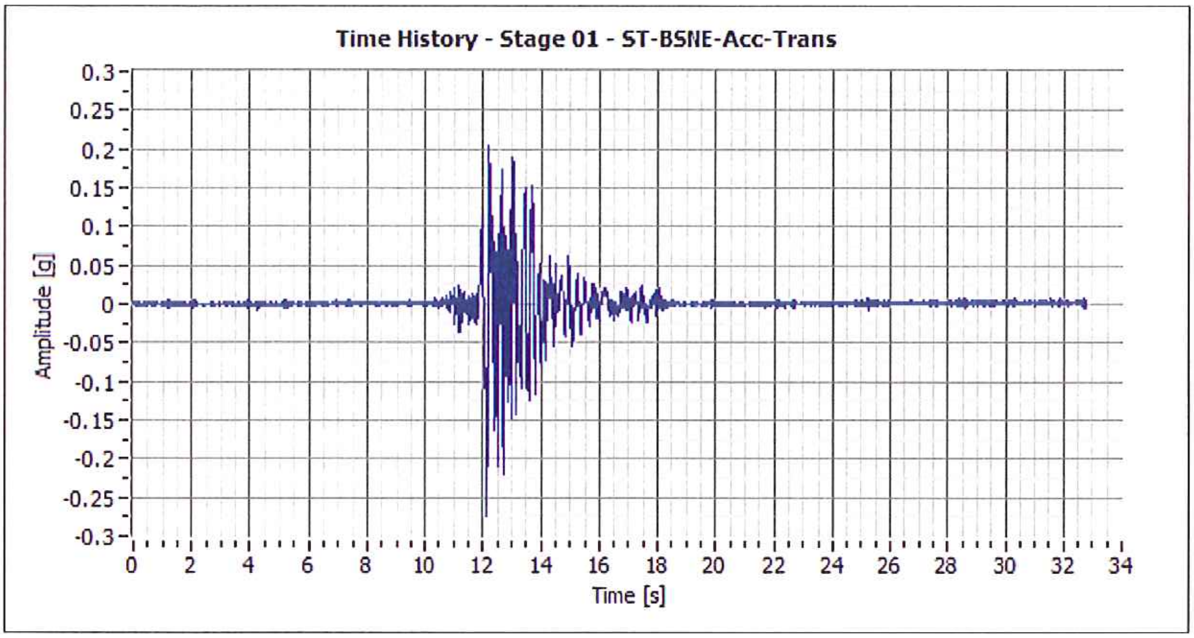


Figure H-3: Time History – Base Accelerations – Stage 01 – Transversal direction

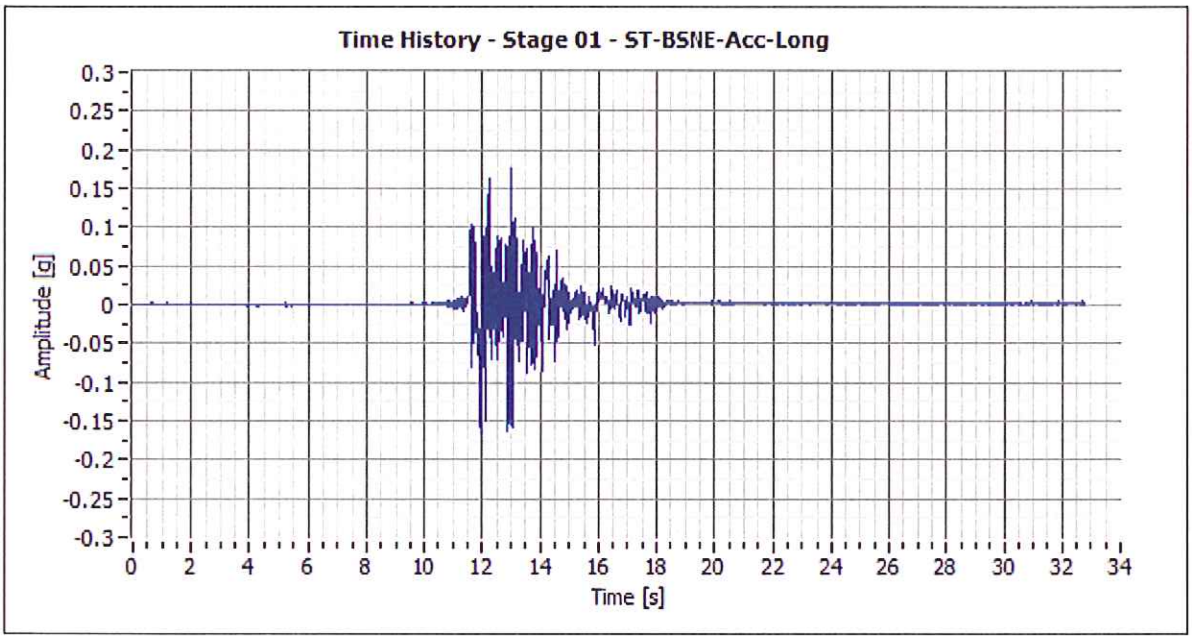


Figure H-4: Time History – Base Accelerations – Stage 01 – Longitudinal direction

H.1.3 Stage 02

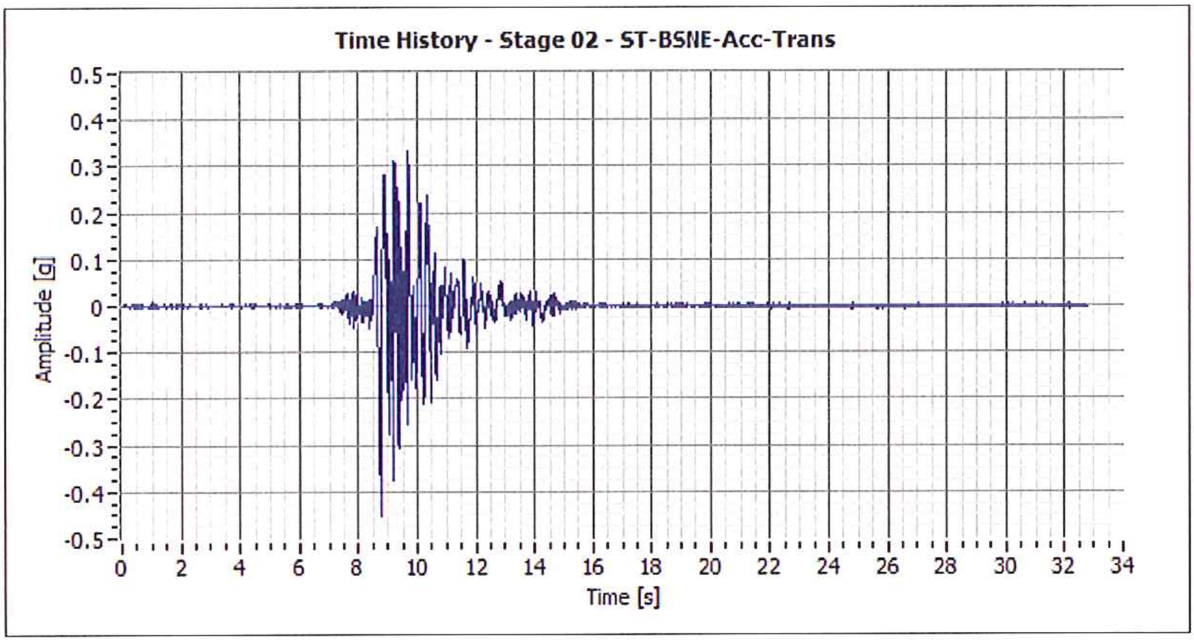


Figure H-5: Time History – Base Accelerations – Stage 02 – Transversal direction

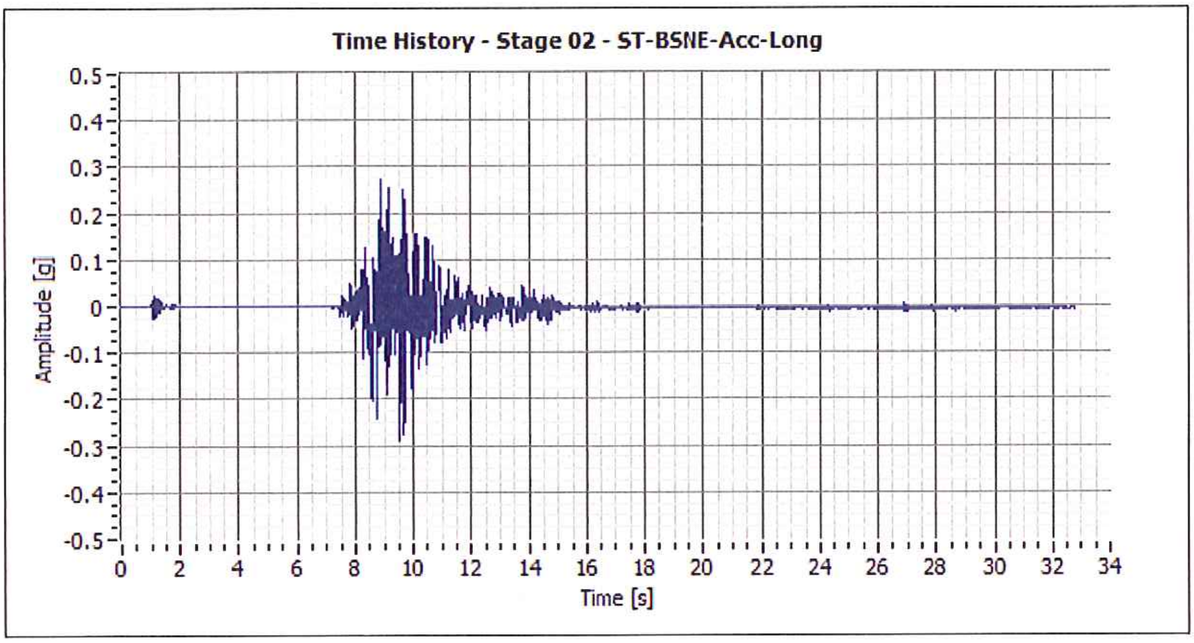


Figure H-6: Time History – Base Accelerations – Stage 02 – Longitudinal direction

H.1.4 Stage 03

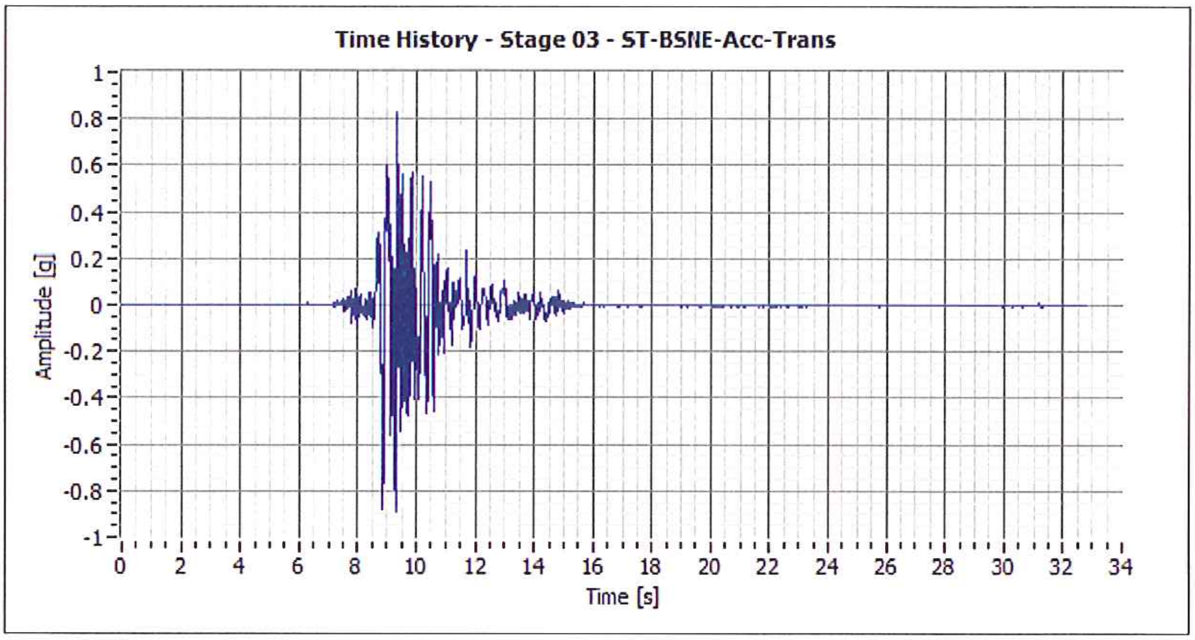


Figure H-7: Time History – Base Accelerations – Stage 03 – Transversal direction

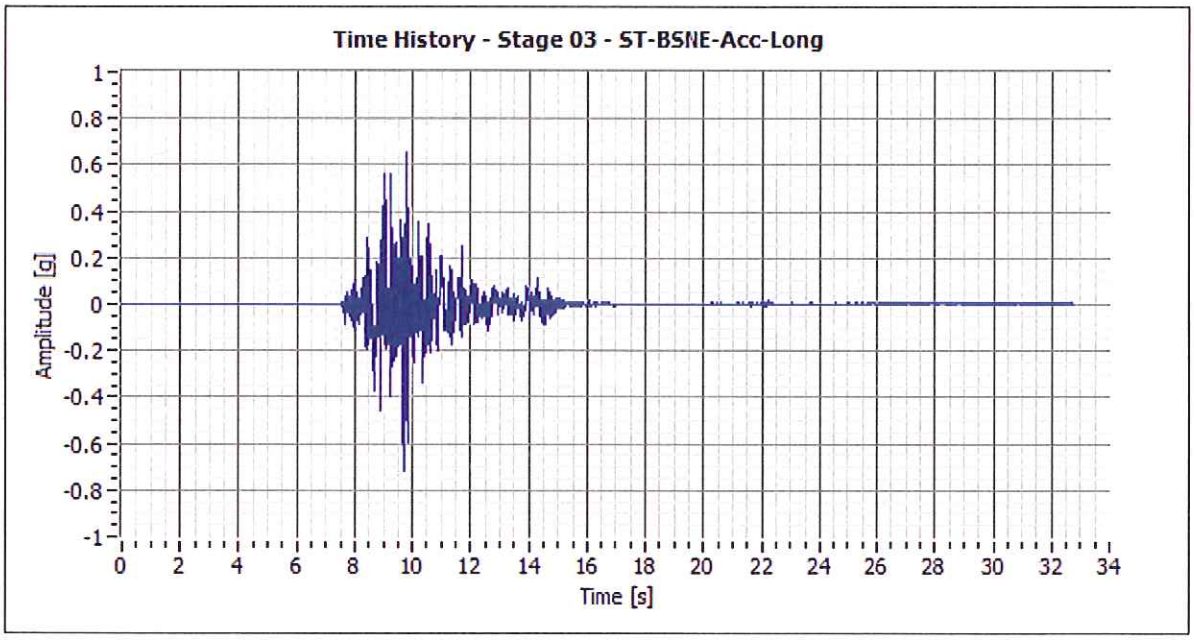


Figure H-8: Time History – Base Accelerations – Stage 03 – Longitudinal direction

H.1.5 Stage 04

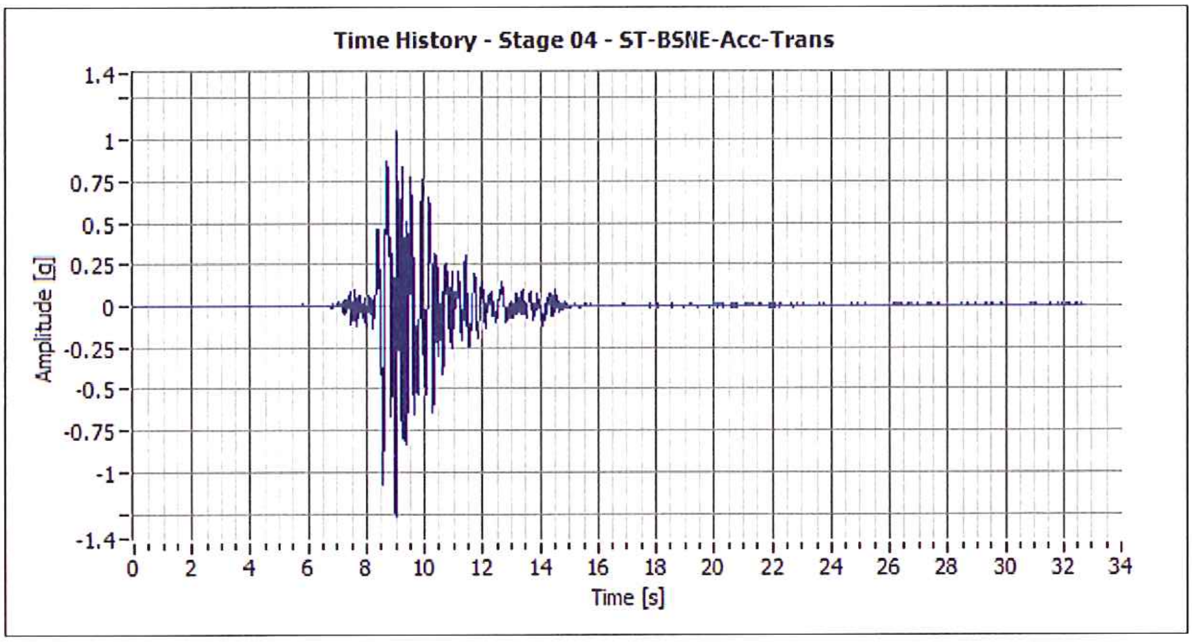


Figure H-9: Time History – Base Accelerations – Stage 04 – Transversal direction

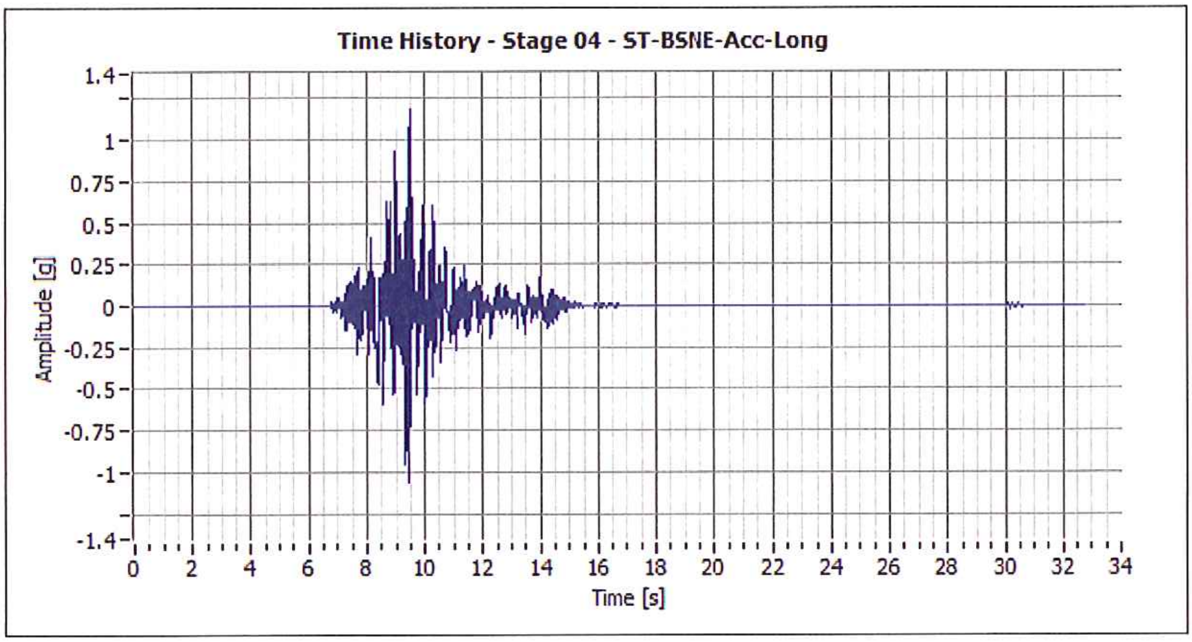


Figure H-10: Time History – Base Accelerations – Stage 04 – Longitudinal direction

H.2 Ground Motion Parameters

Ground Motion Parametes	Units	Stage 00		Stage 01		Stage 02	
		Trans.	Long.	Trans.	Long.	Trans.	Long.
Peak Ground Acceleration	g	0.095	0.101	0.275	0.176	0.453	0.289
Peak Ground Velocity	cm/s	4.593	4.322	12.893	8.305	19.604	11.750
Peak Ground Displacement	mm	3.174	3.442	8.600	8.826	13.595	14.198
Peak Velocity and Acceleration Ratio	s	0.049	0.044	0.048	0.048	0.044	0.041
Arias Intensity (Ia)	m/s	0.042	0.031	0.336	0.157	0.837	0.380
A95 Parameter	g	0.069	0.074	0.190	0.138	0.311	0.220
t05 (5% of Ia)	s	2.00	1.69	2.07	1.72	2.12	1.86
t95 (95% of Ia)	s	4.86	5.32	4.32	4.61	4.32	4.86
Significant Duration (t95-t05)	s	2.86	3.63	2.25	2.89	2.20	2.99
Characteristic Intensity	-	0.0069	0.0056	0.0331	0.0187	0.0656	0.0363
Predominant Period	s	0.082	0.082	0.082	0.091	0.082	0.091
Mean Period	s	0.215	0.194	0.232	0.172	0.231	0.167
Sustained Max Acceleraion	g	0.081	0.074	0.210	0.164	0.333	0.274
Sustained Max Velocity	cm/s	2.526	2.933	8.160	6.030	12.500	9.091
Acceleration Spectrum Intensity*	g	0.047	0.043	0.137	0.082	0.219	0.111
Velocity Spec. Int. (a.k. Housner Int.)*	cm/s	6.618	6.609	18.510	15.467	28.615	22.594

* adapted to the model time scale

Figure H-11: Ground motion parameters

Ground Motion Parametes	Units	Stage 03		Stage 04	
		Trans.	Long.	Trans.	Long.
Peak Ground Acceleration	g	0.892	0.717	1.262	1.178
Peak Ground Velocity	cm/s	34.703	22.106	48.431	30.350
Peak Ground Displacement	mm	28.077	28.756	41.560	42.819
Peak Velocity and Acceleration Ratio	s	0.040	0.031	0.039	0.026
Arias Intensity (Ia)	m/s	3.566	1.753	7.167	4.008
A95 Parameter	g	0.672	0.518	0.866	0.828
t05 (5% of Ia)	s	2.12	1.88	1.81	1.47
t95 (95% of Ia)	s	4.32	4.93	4.21	4.64
Significant Duration (t95-t05)	s	2.20	3.05	2.40	3.17
Characteristic Intensity	-	0.1945	0.1142	0.3284	0.2124
Predominant Period	s	0.082	0.091	0.082	0.091
Mean Period	s	0.223	0.161	0.228	0.161
Sustained Max Acceleraion	g	0.829	0.606	1.054	0.955
Sustained Max Velocity	cm/s	23.261	18.230	32.454	24.160
Acceleration Spectrum Intensity*	g	0.429	0.250	0.582	0.370
Velocity Spec. Int. (a.k. Housner Int.)*	cm/s	55.108	46.039	80.260	68.492

* adapted to the model time scale

Figure H-12: Ground motion parameters (cont.)

Where:

- Peak ground acceleration (PGA):

$$PGA = \max\left|a(t)\right|. \qquad (H.1)$$

- Peak ground velocity (PGV):

$$PGV = \max\left|v(t)\right| \qquad (H.2)$$

- Peak ground displacement (PGD):

$$PGD = \max\left|d(t)\right| \qquad (H.3)$$

- Peak velocity and acceleration ratio $\left(v_{max}/a_{max}\right)$

$$v_{max}/a_{max} = \frac{\max\left|v(t)\right|}{\max\left|a(t)\right|} \qquad (H.4)$$

- Arias Intensity $\left(I_a\right)$

$$I_a = \frac{\pi}{2g}\int\left[a(t)\right]^2 dt \qquad (H.5)$$

- A95 parameter (A95)

  Is the maximum value of acceleration that corresponds to 95% of the Arias intensity value.

- t05 parameter (t05):

  Is the time where 5% of the Arias intensity is reached.

- t95 parameter (t95):

  Is the time where 95% of the Arias intensity is reached.

- Significant duration (SD):

$$SD = t_{95} - t_{05} \qquad (H.6)$$

- Characteristic intensity $\left(I_c\right)$:

$$I_c = \left(a_{rms}\right)^{\frac{3}{2}}.\sqrt{t_{tot}}, \quad a_{rms} = \sqrt{\frac{1}{t_{tot}}\int\left[a(t)\right]^2 dt}. \qquad (H.7)$$

- Predominant period (Tp)

  Is the period where is reached the maximum spectral accelerations in an acceleration response spectra $(\xi = 5\%)$

- Mean period (Tm):

$$T_m = \frac{\sum C_i^2 / f_i}{\sum C_i^2}, \tag{H.8}$$

  Where: C_i are the Fourier amplitudes at f_i frequencies between 0.25 and 20 Hz.

- Sustained maximum acceleration (SMA)

  Is the third maximum acceleration measured.

- Sustained maximum Velocity (SMV)

  Is the third maximum velocity measured.

- Acceleration Spectrum Intensity (ASI)

$$ASI = \int_{0.1}^{0.5} S_a(\xi = 5\%, T)\, dT. \tag{H.9}$$

- Velocity Spectrum Intensity, also known as Housner Intensity (VSI)

$$VSI = \int_{0.1}^{2.5} S_v(\xi = 5\%, T)\, dT. \tag{H.10}$$

H.3 Reponse Spectra

H.3.1 Stage 00

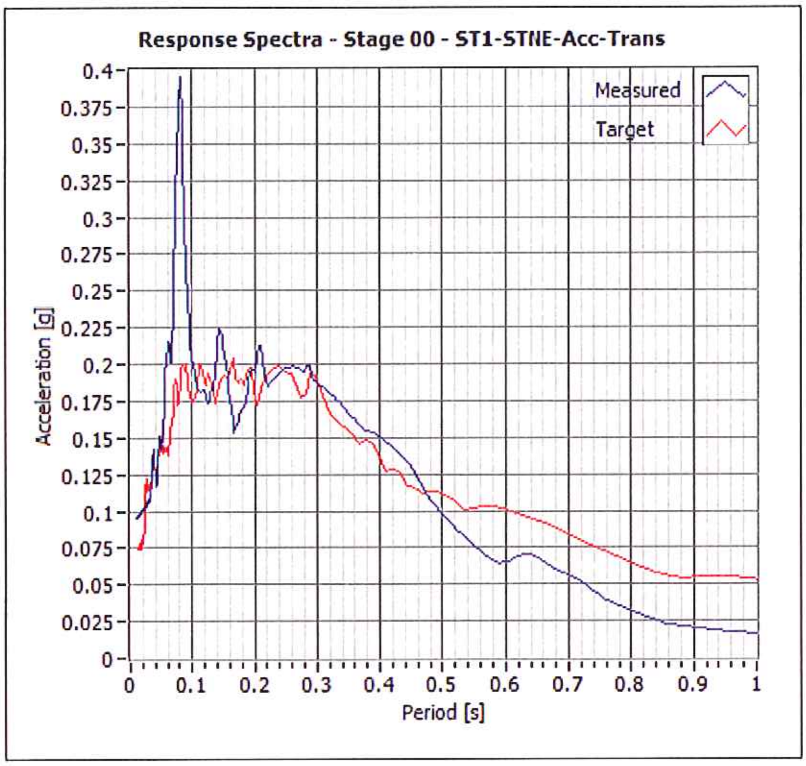


Figure H-13: Response Spectra – Base Accelerations – Stage 00 – Transversal direction

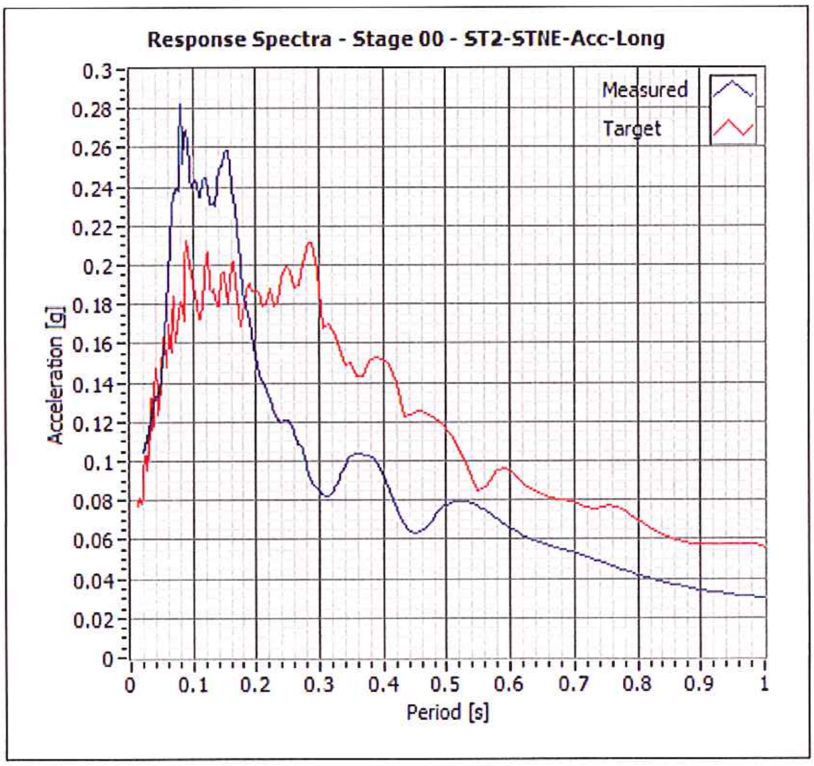


Figure H-14: Response Spectra – Base Accelerations – Stage 00 – Longitudinal direction

H.3.2 Stage 01

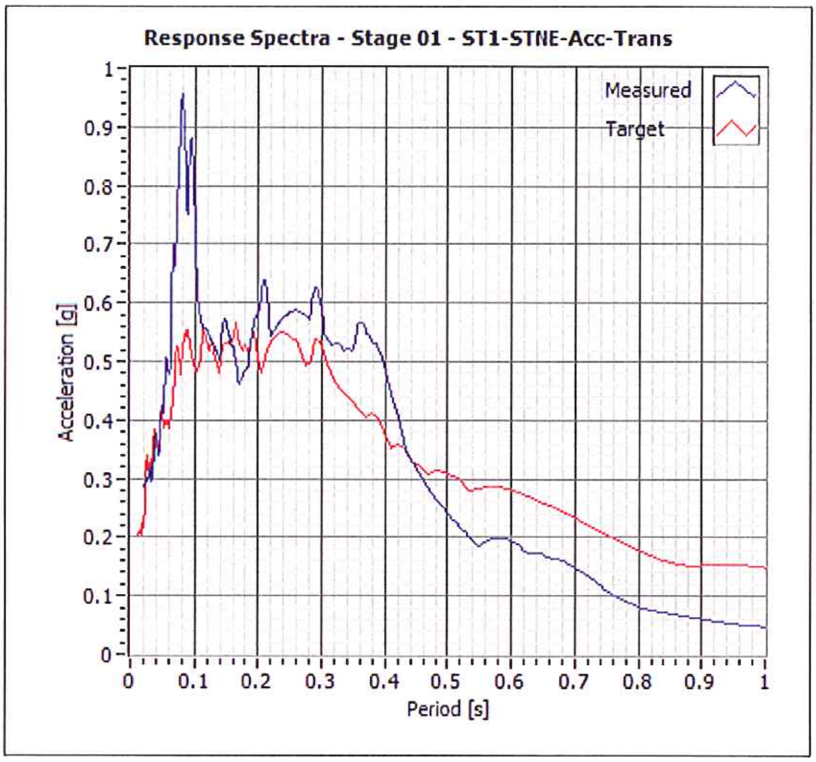


Figure H-15: Response Spectra – Base Accelerations – Stage 01 – Transversal direction

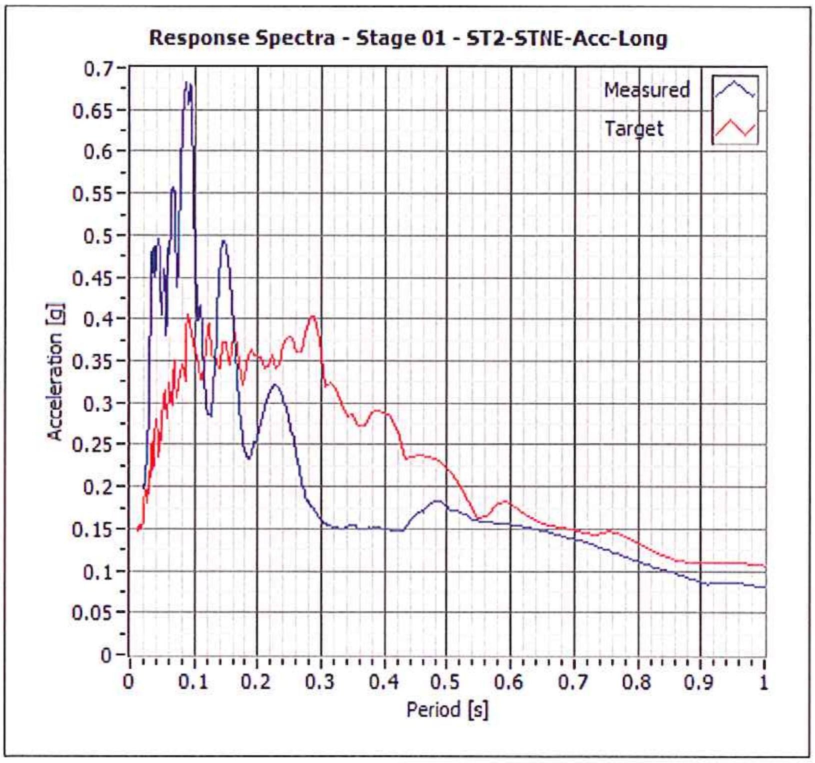


Figure H-16: Response Spectra – Base Accelerations – Stage 01 – Longitudinal direction

H.3.3 Stage 02

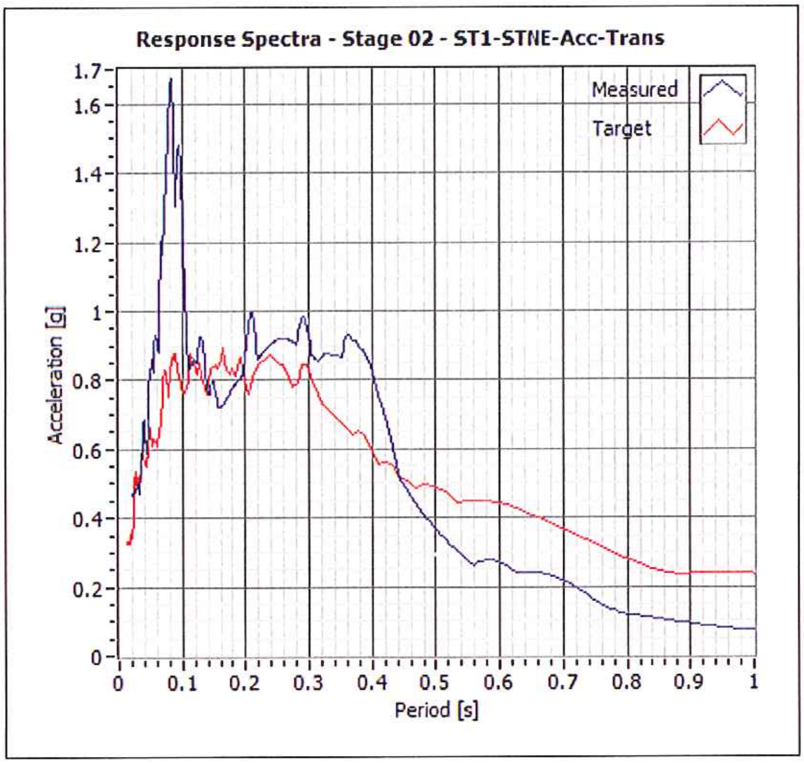


Figure H-17: Response Spectra – Base Accelerations – Stage 02 – Transversal direction

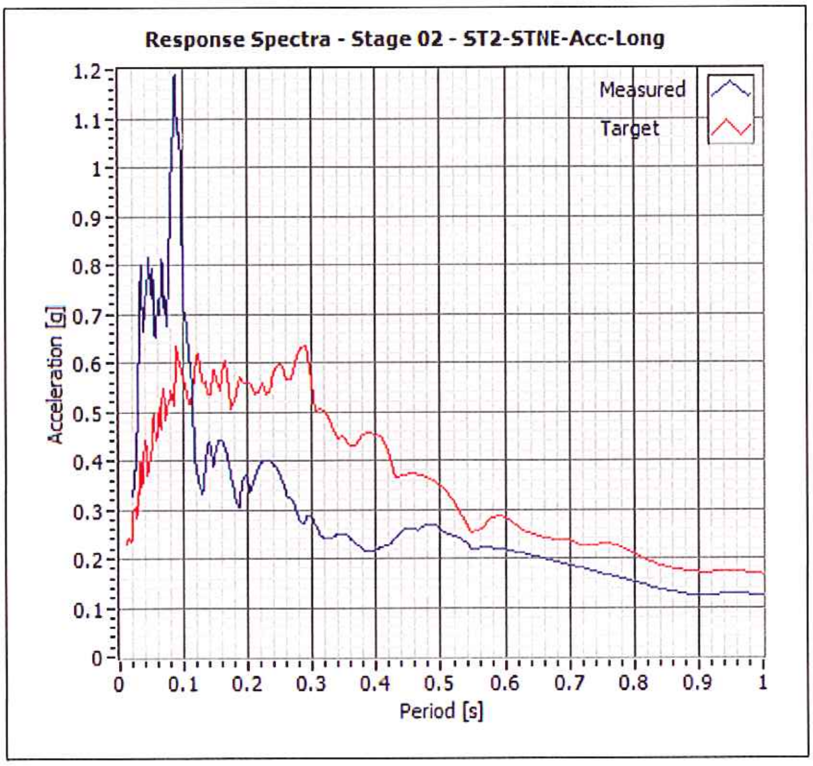


Figure H-18: Response Spectra – Base Accelerations – Stage 02 – Longitudinal direction

H.3.4 Stage 03

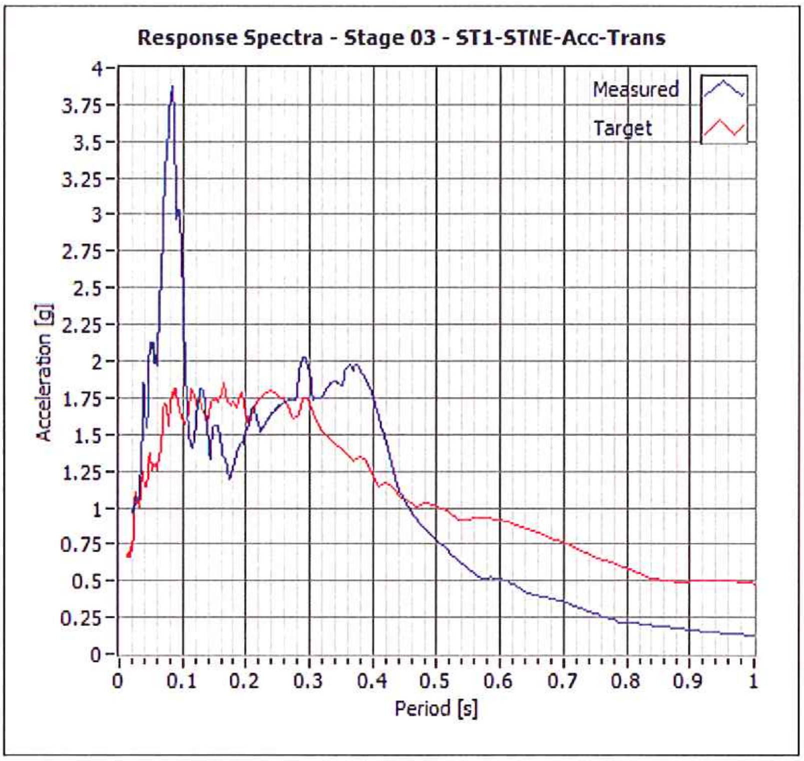


Figure H-19: Response Spectra – Base Accelerations – Stage 03 – Transversal direction

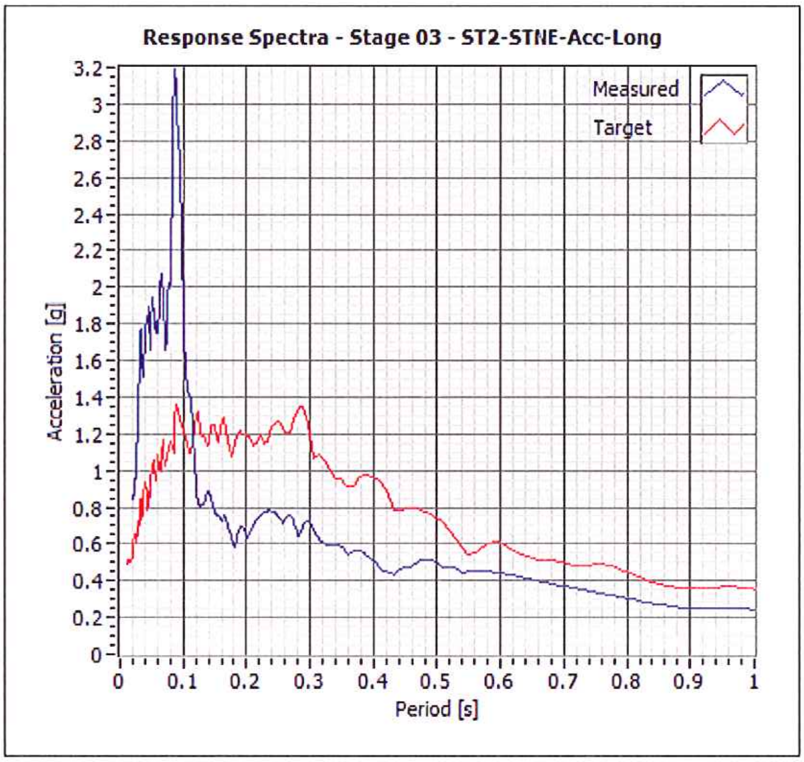


Figure H-20: Response Spectra – Base Accelerations – Stage 03 – Longitudinal direction

H.3.5 Stage 04

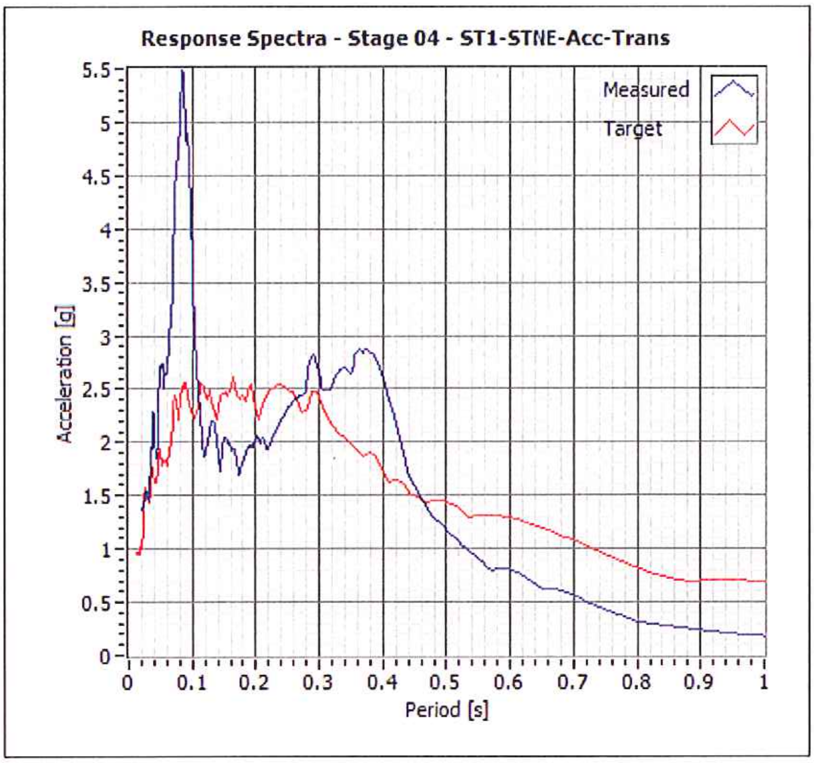


Figure H-21: Response Spectra – Base Accelerations – Stage 04 – Transversal direction

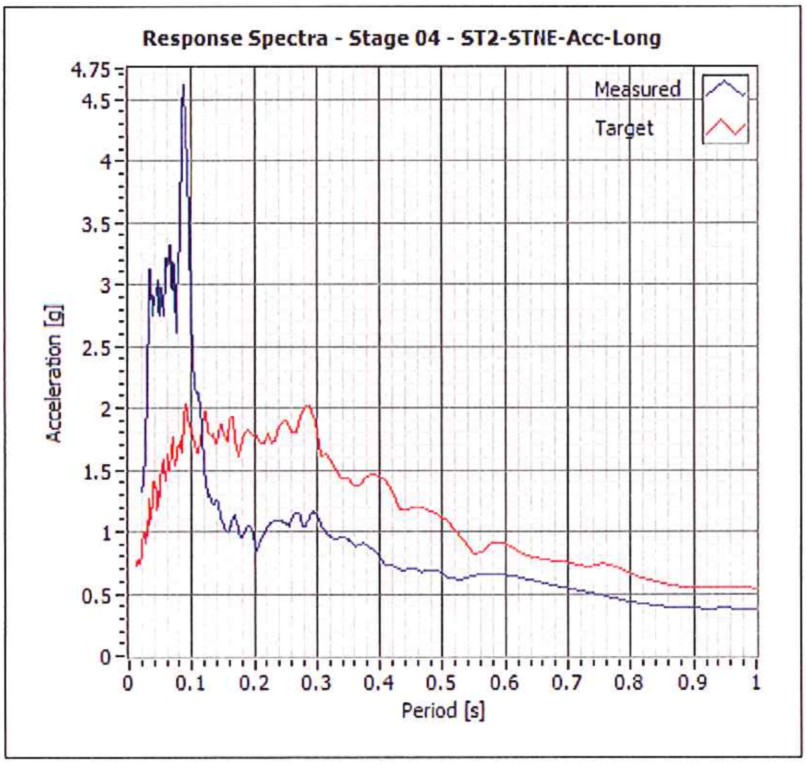


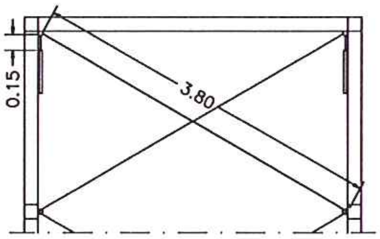
Figure H-22: Response Spectra – Base Accelerations – Stage 04 – Longitudinal direction

ANNEX I FLOOR DIAPHRAGM

In this annex is presented the time histories of the diagonals RD1, RD2, RD3, RD4 deformations.

List of Figures:

I.1 Math channels



$$\Delta d[\%] = \frac{Ch[mm]}{3950[mm]}.100$$

Figure I-1: Math channels calculation scheme

I.2 Stage 00

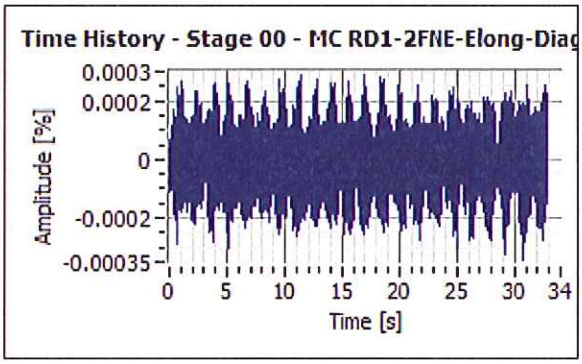


Figure I-2: Time History – RD1 – Diagonal deformation – Stage 00

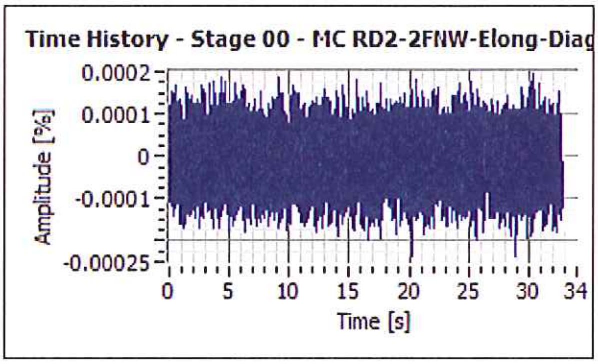


Figure I-3: Time History – RD2 – Diagonal deformation – Stage 00

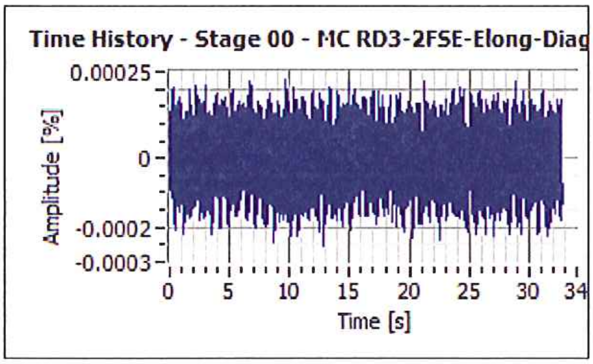


Figure I-4: Time History – RD3 – Diagonal deformation – Stage 00

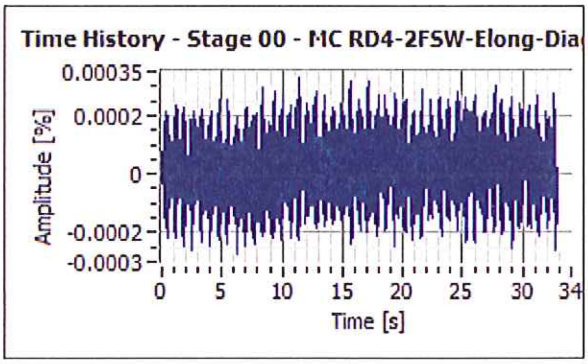


Figure I-5: Time History – RD4 – Diagonal deformation – Stage 00

I.3 Stage 01

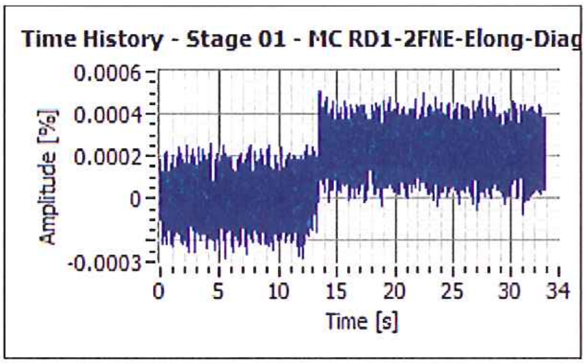


Figure I-6: Time History – RD1 – Diagonal deformation – Stage 01

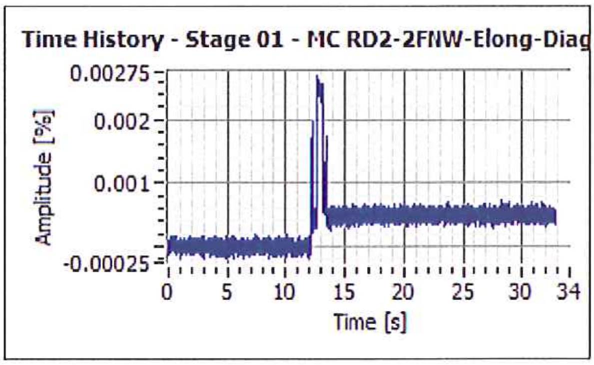


Figure I-7: Time History – RD2 – Diagonal deformation – Stage 01

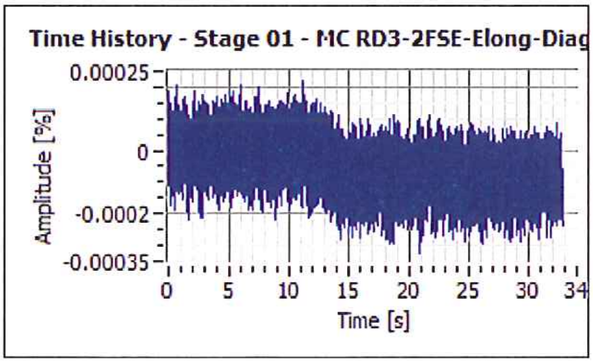


Figure I-8: Time History – RD3 – Diagonal deformation – Stage 01

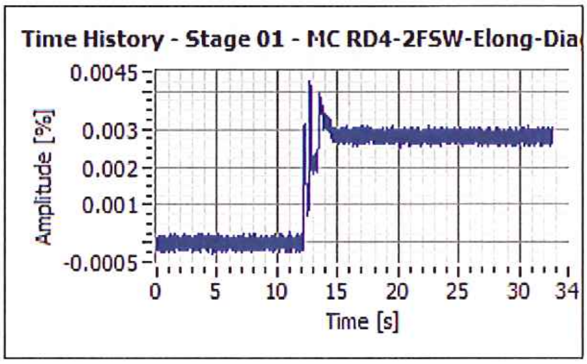


Figure I-9: Time History – RD4 – Diagonal deformation – Stage 01

I.4 Stage 02

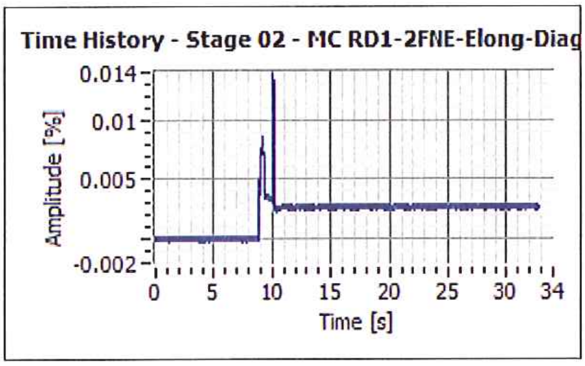


Figure I-10: Time History – RD1 – Diagonal deformation – Stage 02

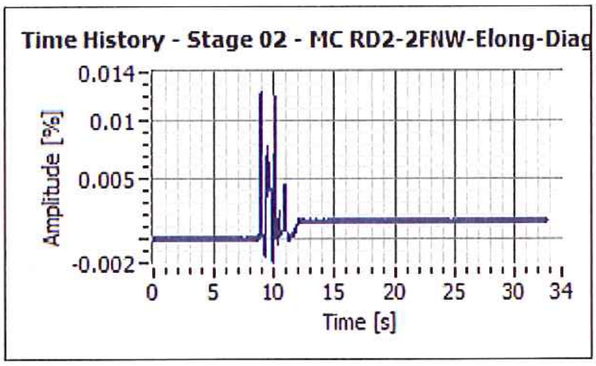


Figure I-11: Time History – RD2 – Diagonal deformation – Stage 02

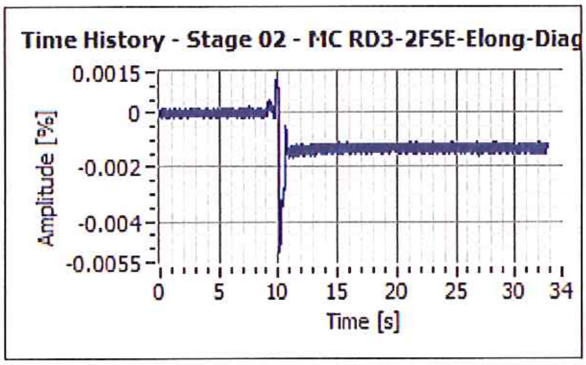


Figure I-12: Time History – RD3 – Diagonal deformation – Stage 02

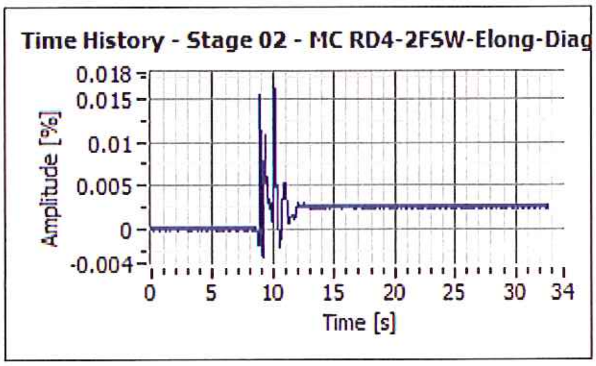


Figure I-13: Time History – RD4 – Diagonal deformation – Stage 02

I.5 Stage 03

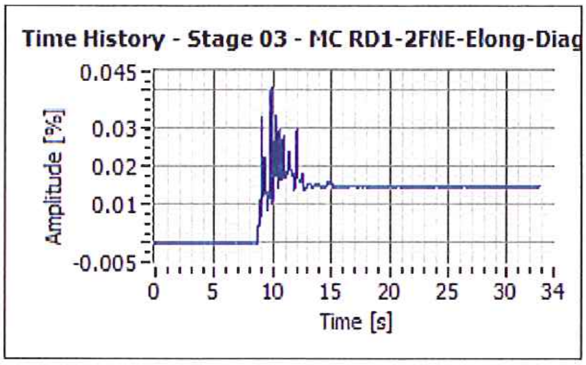


Figure I-14: Time History – RD1 – Diagonal deformation – Stage 03

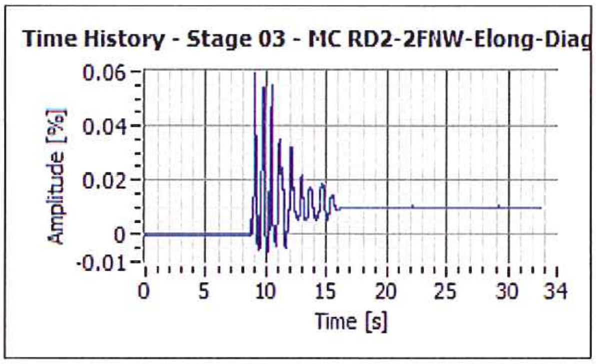


Figure I-15: Time History – RD2 – Diagonal deformation – Stage 03

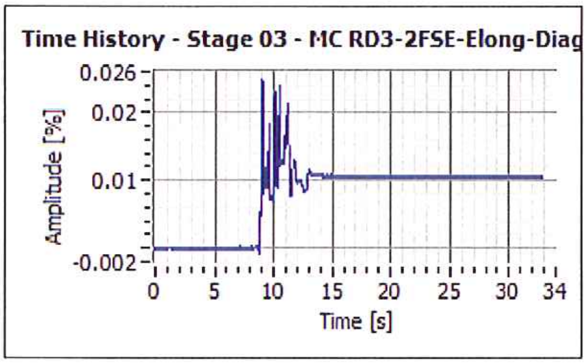


Figure I-16: Time History – RD3 – Diagonal deformation – Stage 03

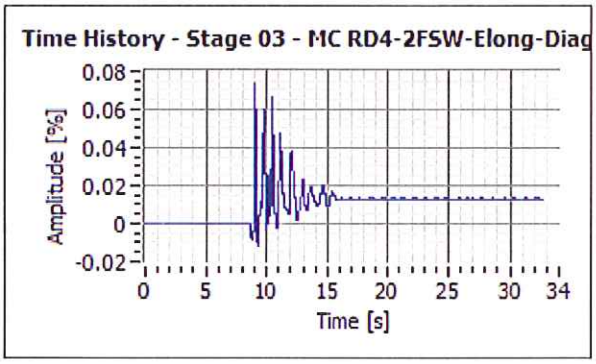


Figure I-17: Time History – RD4 – Diagonal deformation – Stage 03

I.6 Stage 04

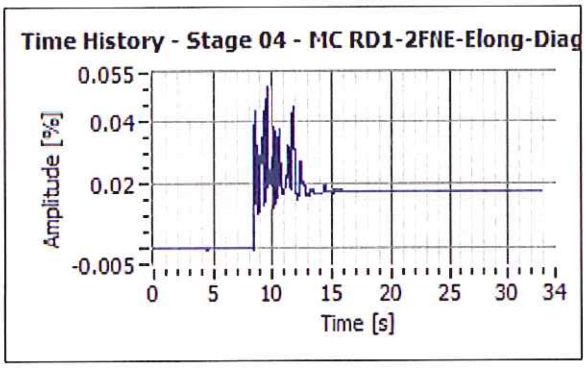


Figure I-18: Time History – RD1 – Diagonal deformation – Stage 04

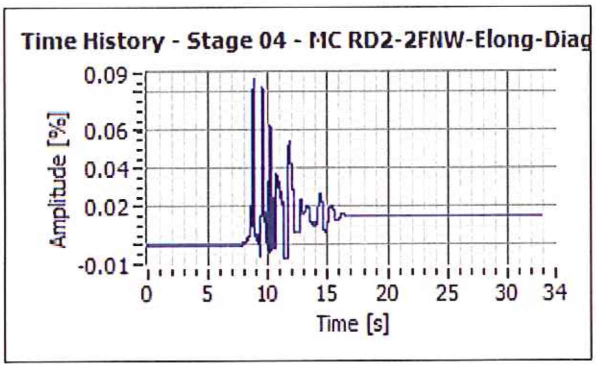


Figure I-19: Time History – RD2 – Diagonal deformation – Stage 04

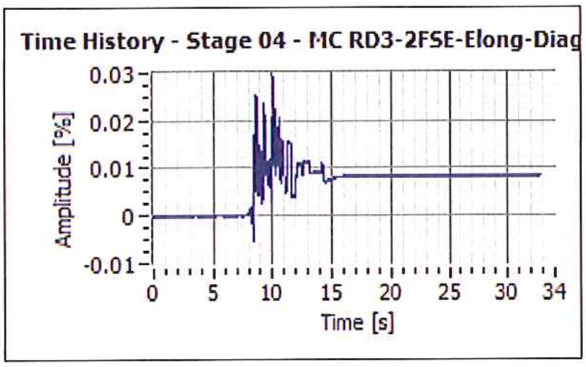


Figure I-20: Time History – RD3 – Diagonal deformation – Stage 04

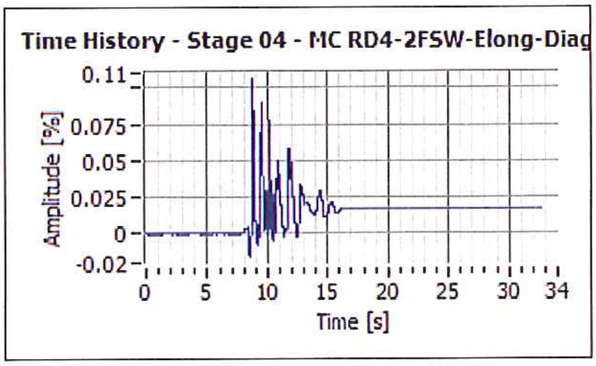


Figure I-21: Time History – RD4 – Diagonal deformation – Stage 04

ANNEX J CENTER OF MASS MOTIONS

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J.1.1 Stage 00

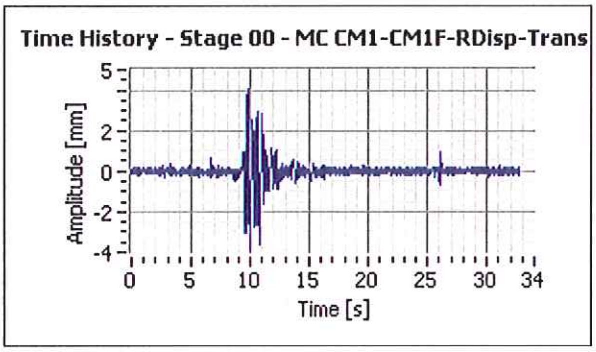

Figure J-1: Time History –1st Floor Center of Mass Relative Displacement –Trans. – Stage 00

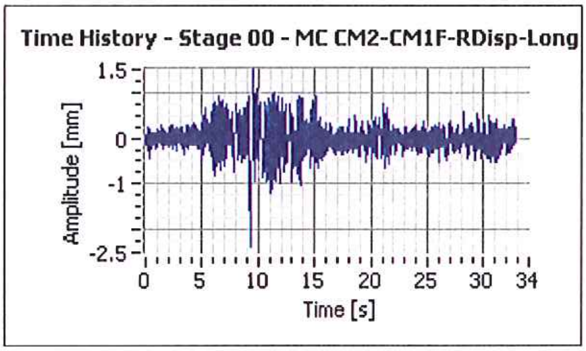

Figure J-2: Time History – 1st Floor Center of Mass Relative Displacement –Long. – Stage 00

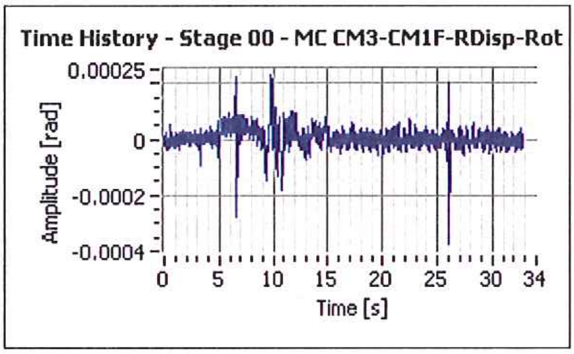

Figure J-3: Time History – 1st Floor Center of Mass Relative Rotation – Stage 00

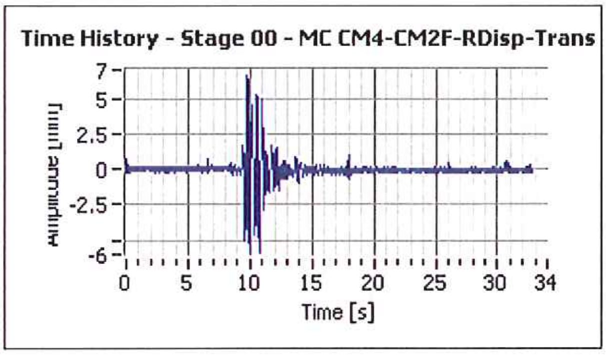

Figure J-4: Time History – 2nd Floor Center of Mass Relative Displacement –Trans. – Stage 00

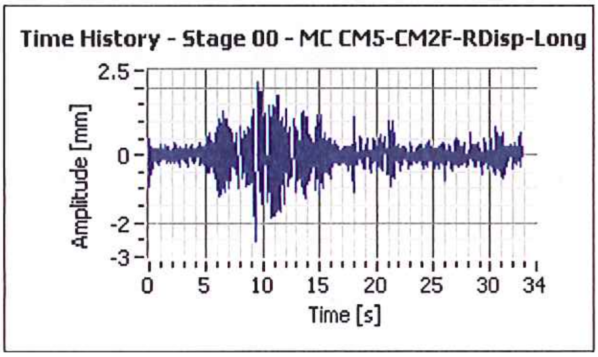

Figure J-5: Time History – 2nd Floor Center of Mass Relative Displacement –Long. – Stage 00

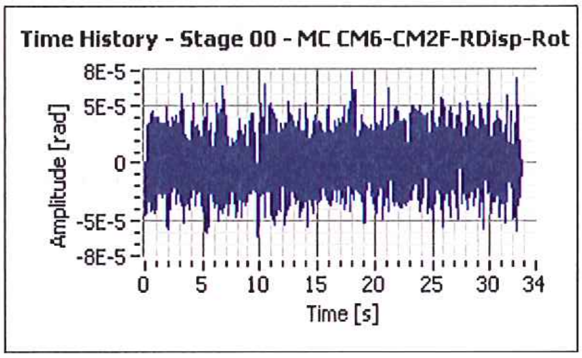

Figure J-6: Time History – 2nd Floor Center of Mass Relative Rotation – Stage 00

J.1.2 Stage 01

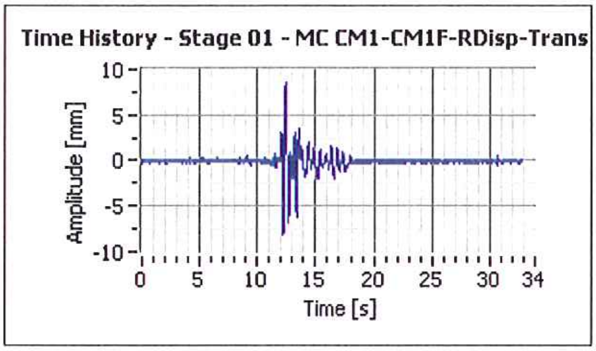

Figure J-7: Time History –1st Floor Center of Mass Relative Displacement –Trans. – Stage 01

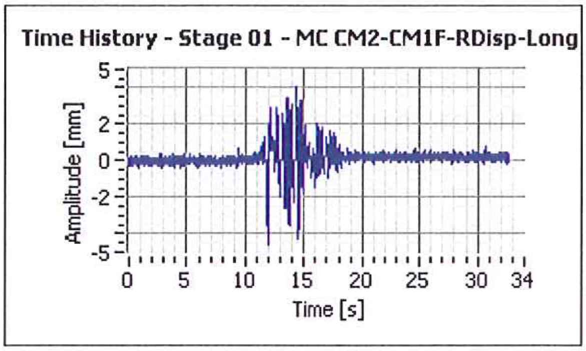

Figure J-8: Time History – 1st Floor Center of Mass Relative Displacement –Long. – Stage 01

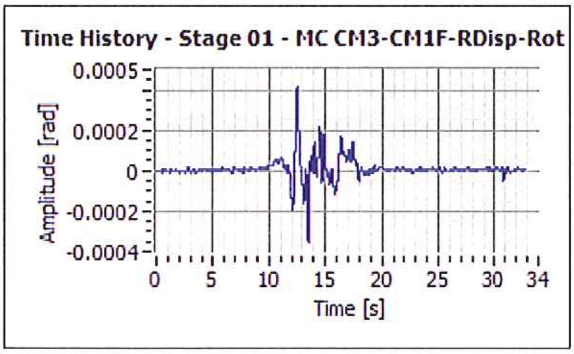

Figure J-9: Time History – 1st Floor Center of Mass Relative Rotation – Stage 01

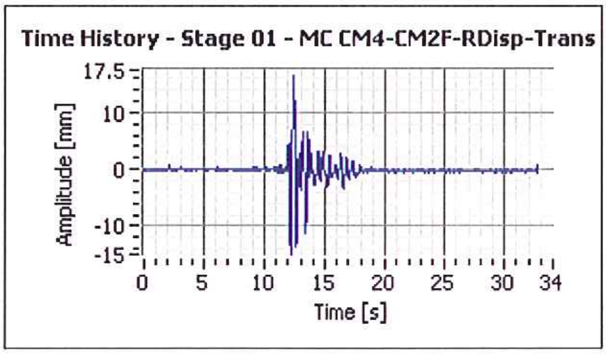

Figure J-10: Time History – 2nd Floor Center of Mass Relative Displacement –Trans. – Stage 01

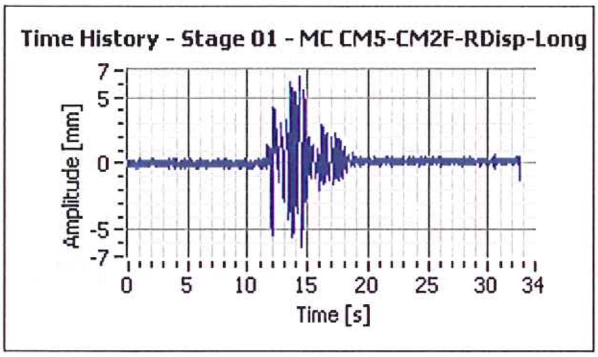

Figure J-11: Time History – 2nd Floor Center of Mass Relative Displacement –Long. – Stage 01

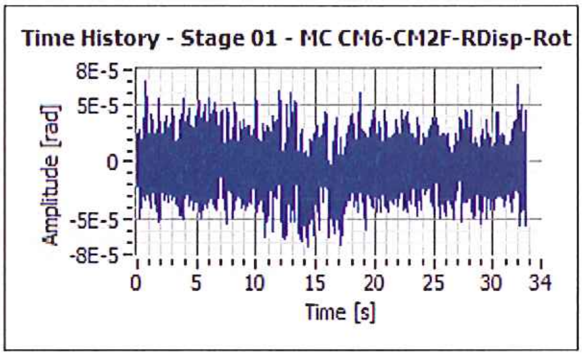

Figure J-12: Time History – 2nd Floor Center of Mass Relative Rotation – Stage 01

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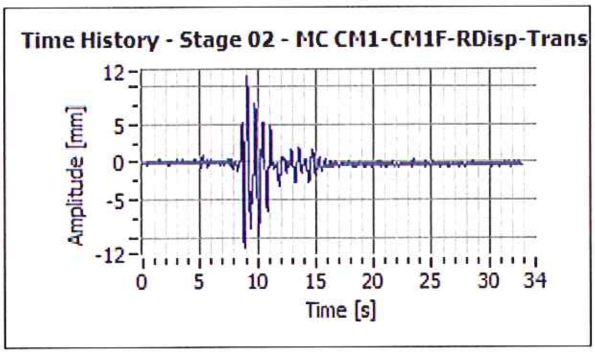


Figure J-13: Time History – 1st Floor Center of Mass Relative Displacement –Trans. – Stage 02

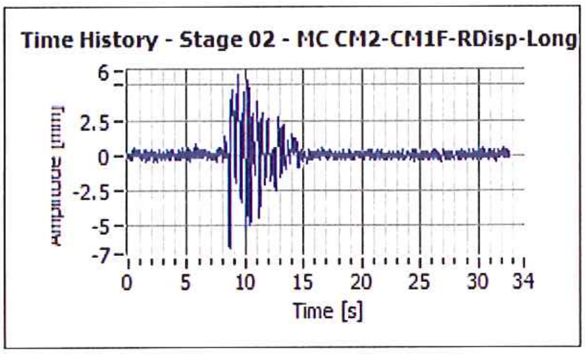
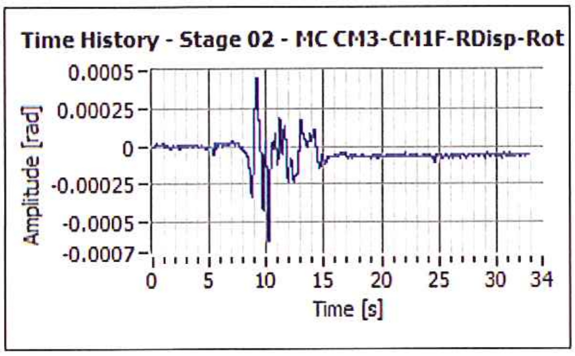


Figure J-14: Time History – 1st Floor Center of Mass Relative Displacement –Long. – Stage 02



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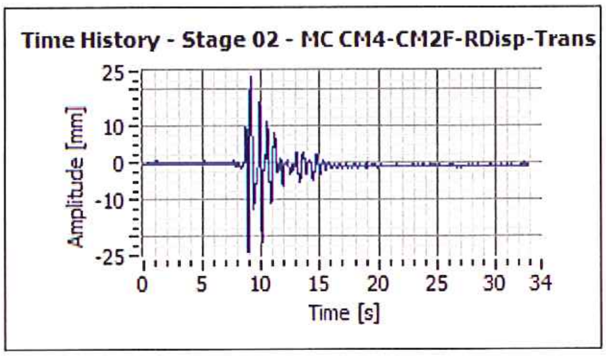

Figure J-16: Time History – 2nd Floor Center of Mass Relative Displacement –Trans. – Stage 02

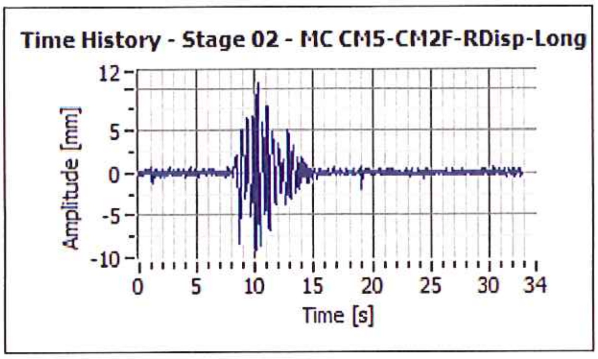

Figure J-17: Time History – 2nd Floor Center of Mass Relative Displacement –Long. – Stage 02

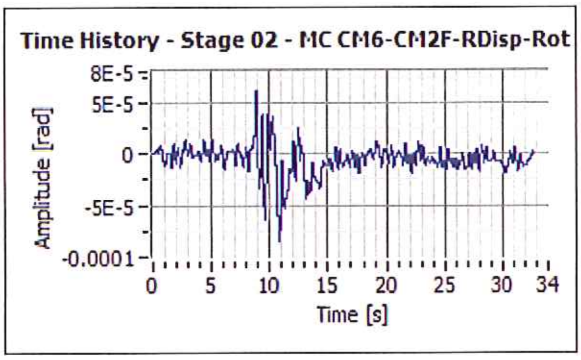

Figure J-18: Time History – 2nd Floor Center of Mass Relative Rotation – Stage 02

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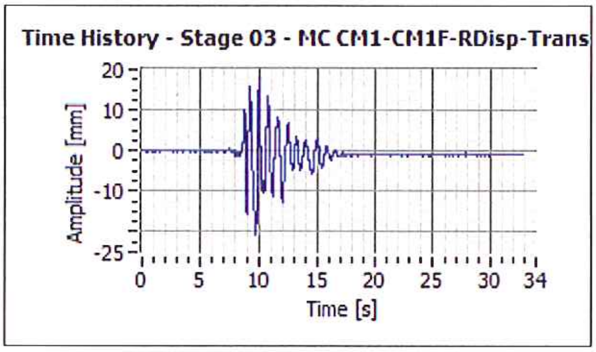
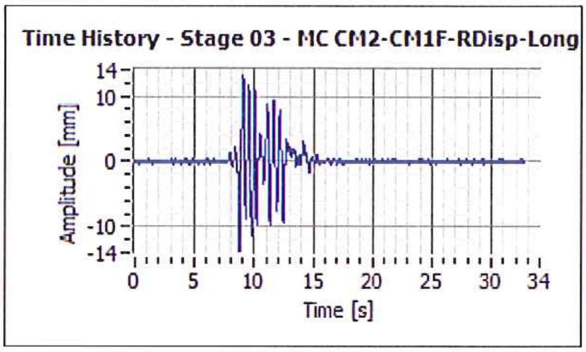


Figure J-19: Time History – 1st Floor Center of Mass Relative Displacement –Trans. – Stage 03



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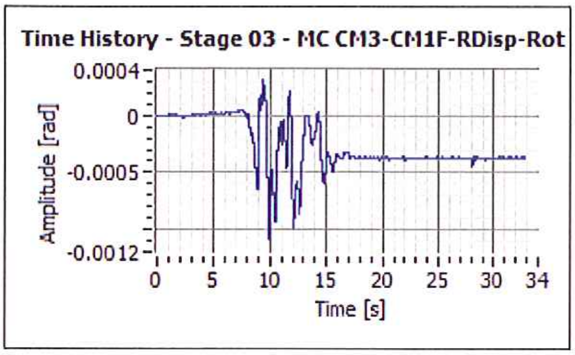


Figure J-21: Time History – 1st Floor Center of Mass Relative Rotation – Stage 03

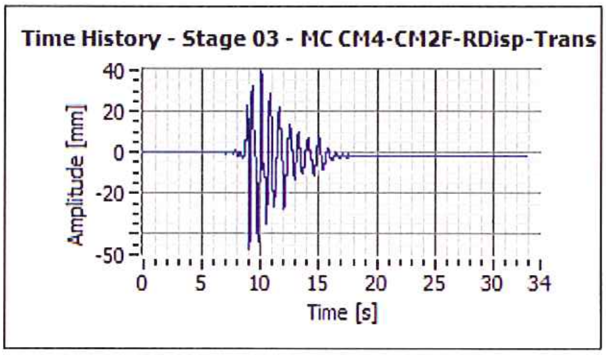


Figure J-22: Time History – 2nd Floor Center of Mass Relative Displacement –Trans. – Stage 03

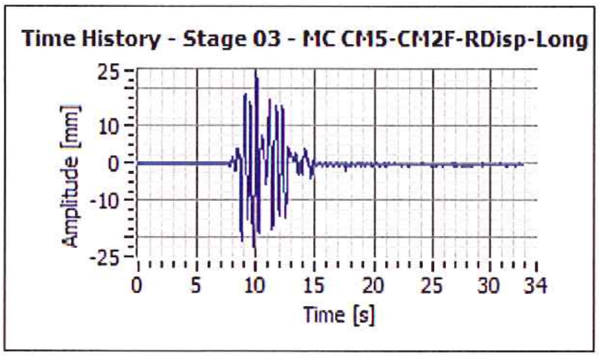


Figure J-23: Time History – 2nd Floor Center of Mass Relative Displacement –Long. – Stage 03

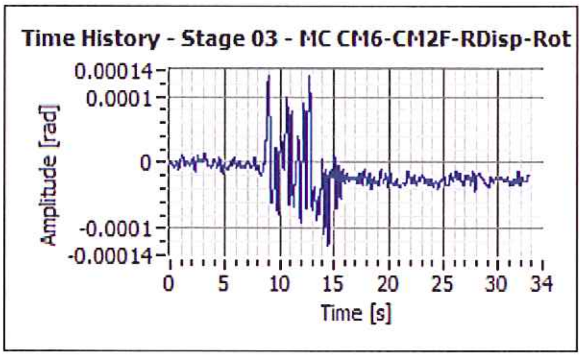


Figure J-24: Time History – 2nd Floor Center of Mass Relative Rotation – Stage 03

J.1.5 Stage 04

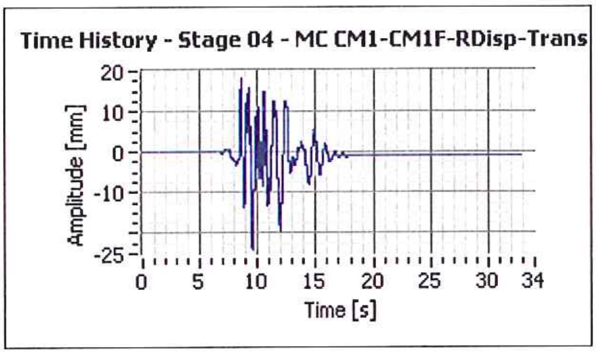


Figure J-25: Time History – 1st Floor Center of Mass Relative Displacement –Trans. – Stage 04

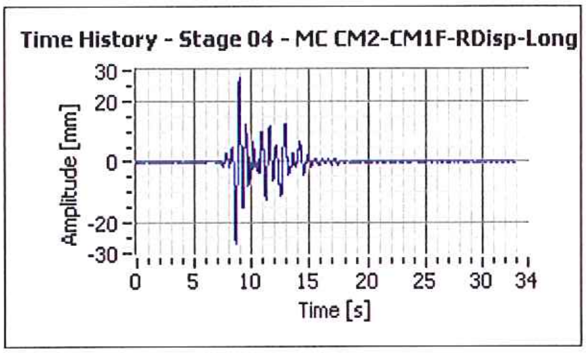


Figure J-26: Time History – 1st Floor Center of Mass Relative Displacement –Long. – Stage 04

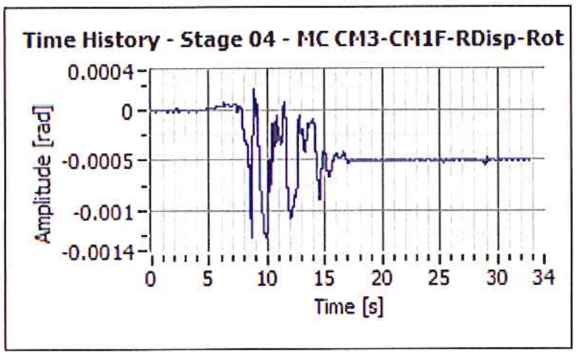


Figure J-27: Time History – 1st Floor Center of Mass Relative Rotation – Stage 04

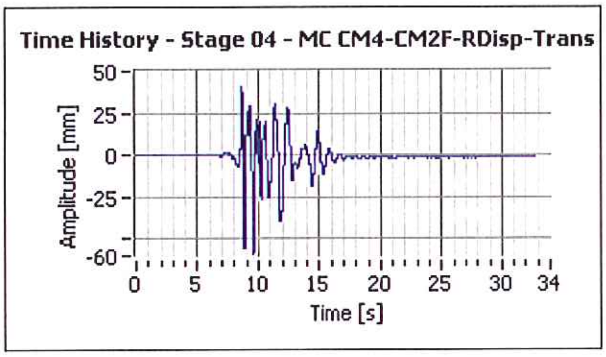


Figure J-28: Time History – 2nd Floor Center of Mass Relative Displacement –Trans. – Stage 04

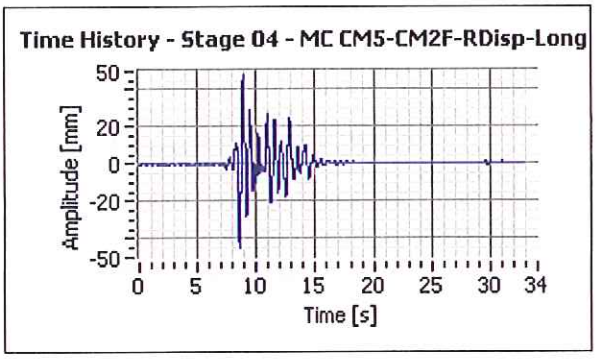


Figure J-29: Time History – 2nd Floor Center of Mass Relative Displacement –Long. – Stage 04

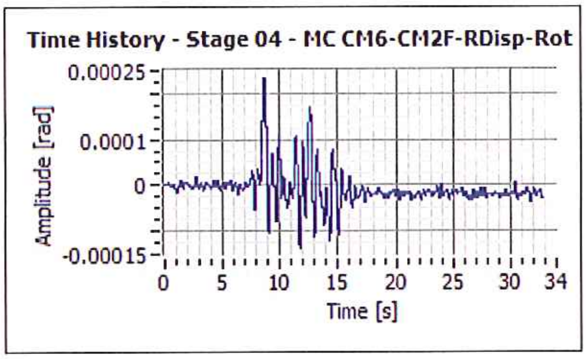


Figure J-30: Time History – 2nd Floor Center of Mass Relative Rotation – Stage 04

J.2 Center of Mass Accelerations

J.2.1 Stage 00

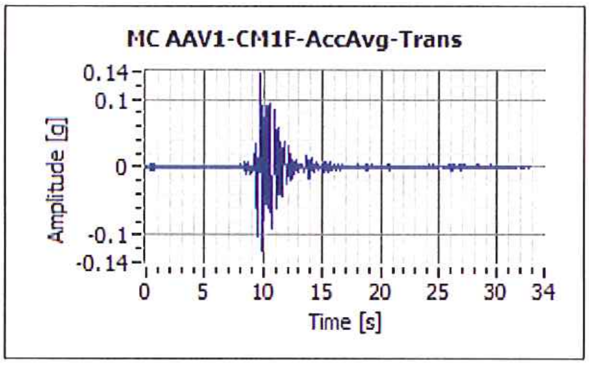


Figure J-31: Time History – 1st Floor Center of Mass Accelerations –Trans. – Stage 00

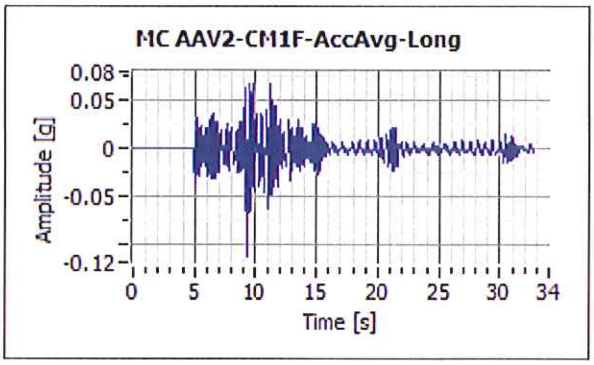


Figure J-32: Time History – 1st Floor Center of Mass Accelerations –Long. – Stage 00

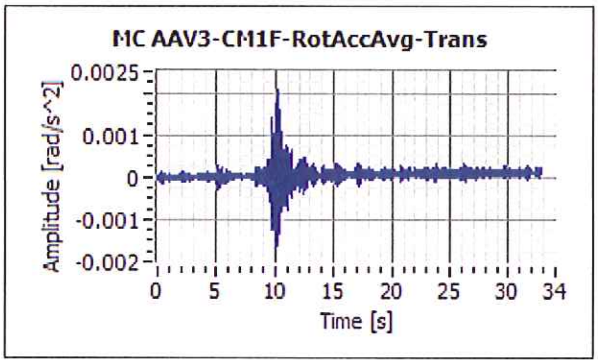


Figure J-33: Time History – 1st Floor Center of Mass Rotational Acceleration – Stage 00

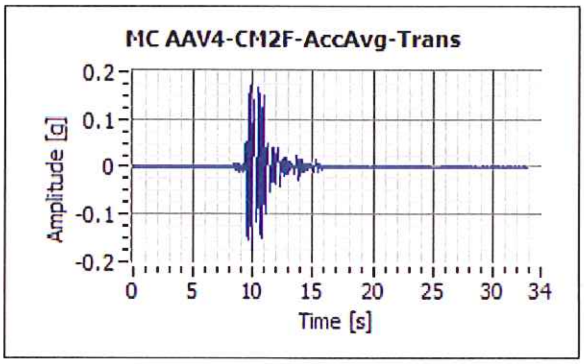


Figure J-34: Time History – 2nd Floor Center of Mass Accelerations –Trans. – Stage 00

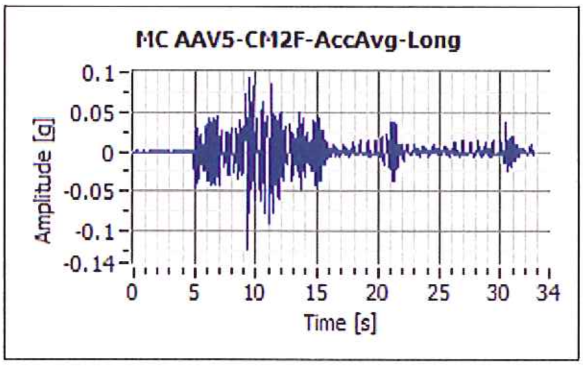


Figure J-35: Time History – 2nd Floor Center of Mass Accelerations –Long. – Stage 00

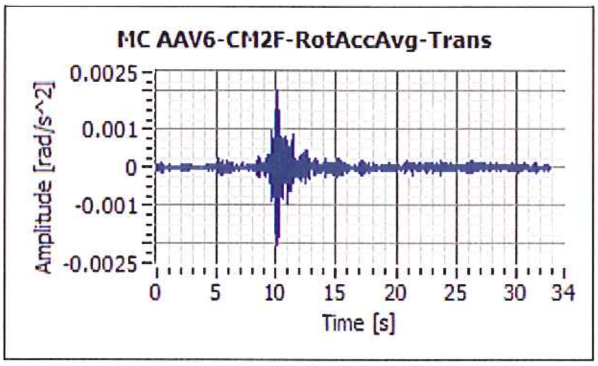


Figure J-36: Time History – 2nd Floor Center of Mass Rotational Acceleration – Stage 00

J.2.2 Stage 01

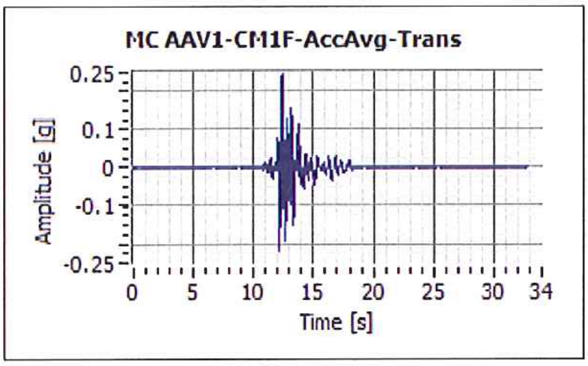


Figure J-37: Time History – 1st Floor Center of Mass Accelerations –Trans. – Stage 01

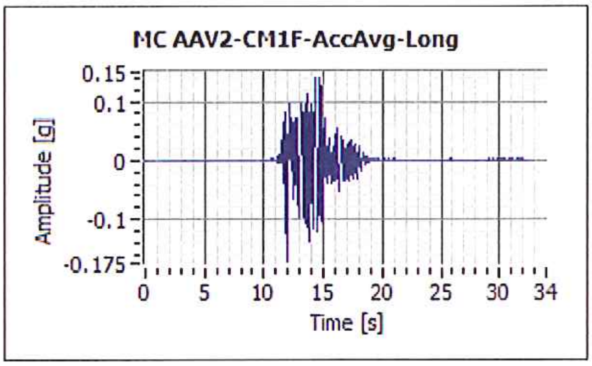
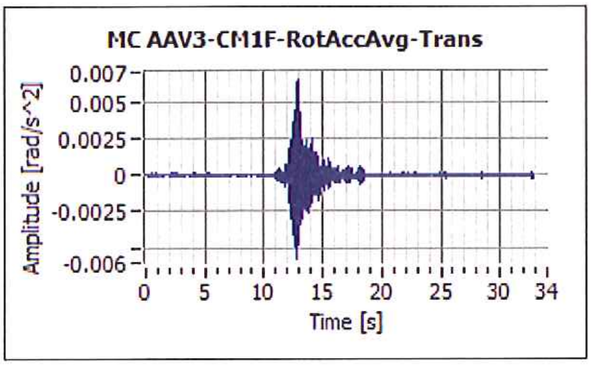


Figure J-38: Time History – 1st Floor Center of Mass Accelerations –Long. – Stage 01



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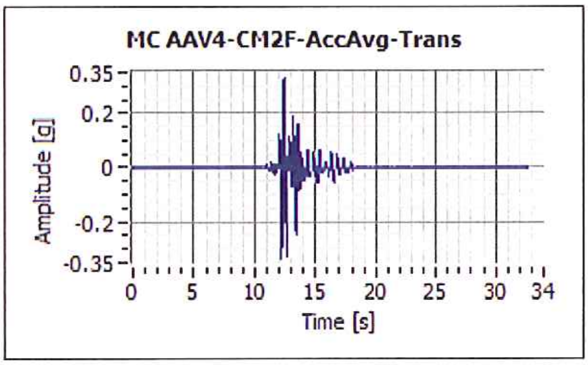

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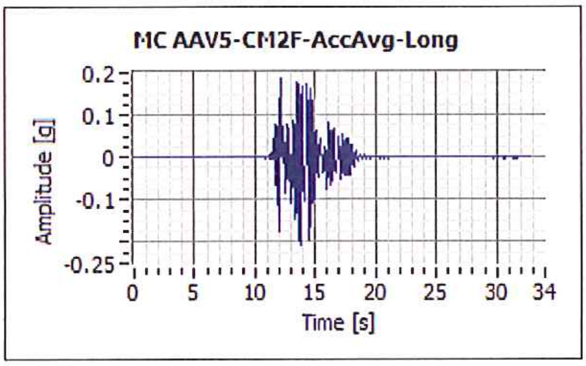

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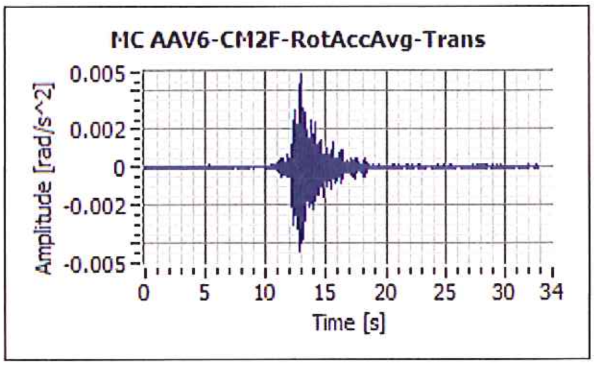

Figure J-42: Time History – 2nd Floor Center of Mass Rotational Acceleration – Stage 01

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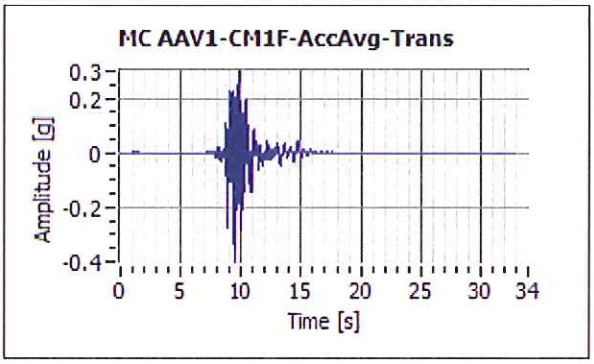


Figure J-43: Time History – 1st Floor Center of Mass Accelerations –Trans. – Stage 02

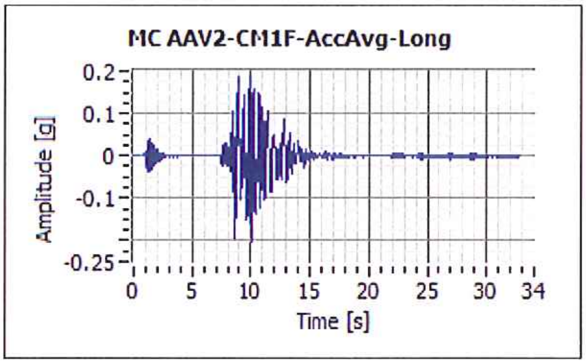


Figure J-44: Time History – 1st Floor Center of Mass Accelerations –Long. – Stage 02

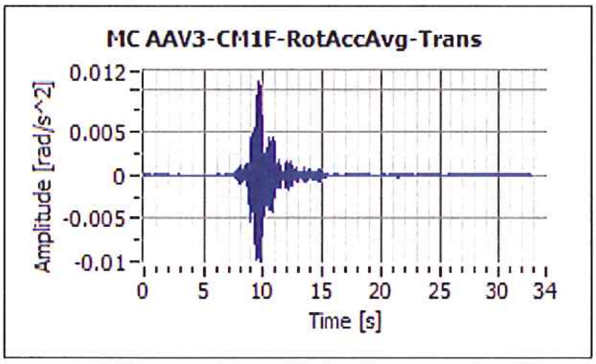
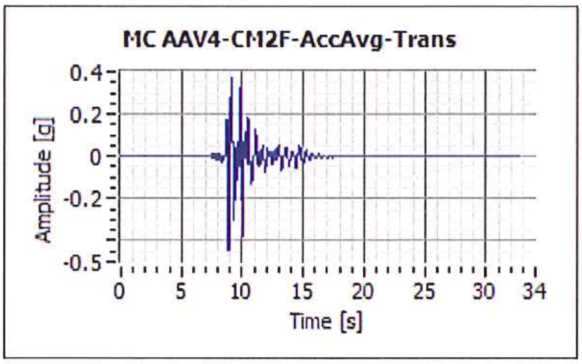


Figure J-45: Time History – 1st Floor Center of Mass Rotational Acceleration – Stage 02



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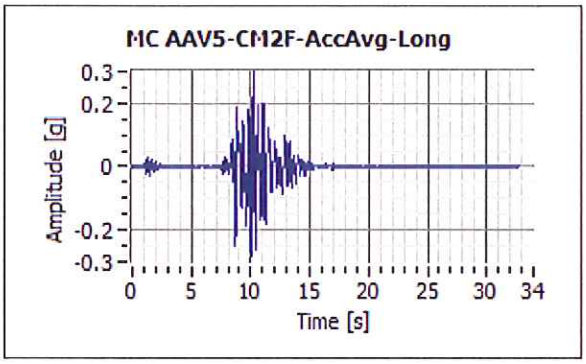

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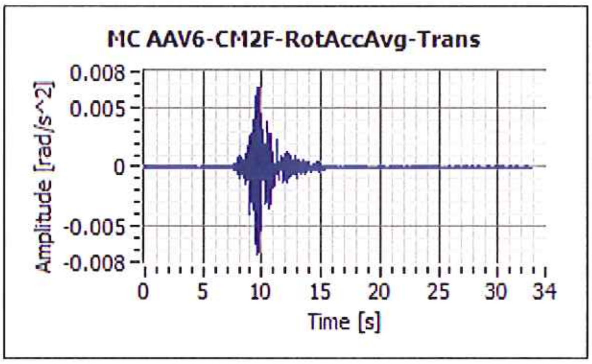

Figure J-48: Time History – 2nd Floor Center of Mass Rotational Acceleration – Stage 02

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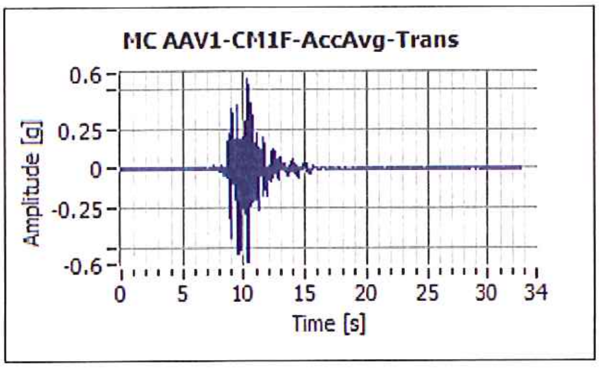


Figure J-49: Time History – 1st Floor Center of Mass Accelerations –Trans. – Stage 03

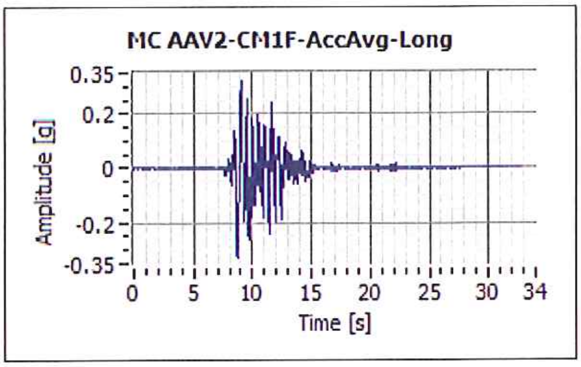


Figure J-50: Time History – 1st Floor Center of Mass Accelerations –Long. – Stage 03

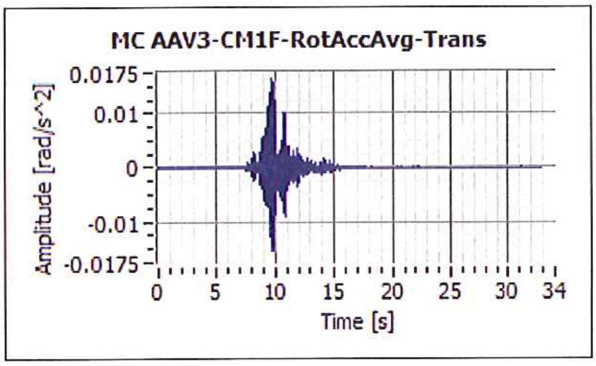


Figure J-51: Time History – 1st Floor Center of Mass Rotational Acceleration – Stage 03

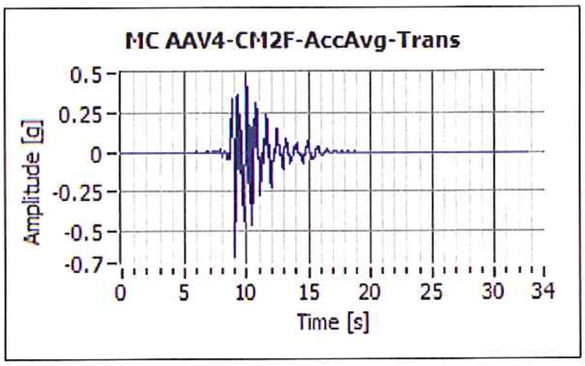


Figure J-52: Time History – 2nd Floor Center of Mass Accelerations –Trans. – Stage 03

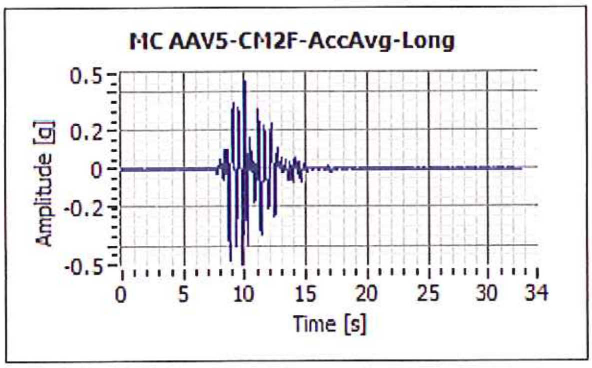


Figure J-53: Time History – 2nd Floor Center of Mass Accelerations –Long. – Stage 03

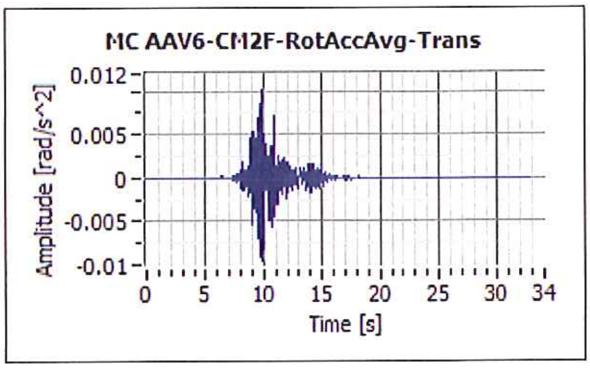


Figure J-54: Time History – 2nd Floor Center of Mass Rotational Acceleration – Stage 03

J.2.5 Stage 04

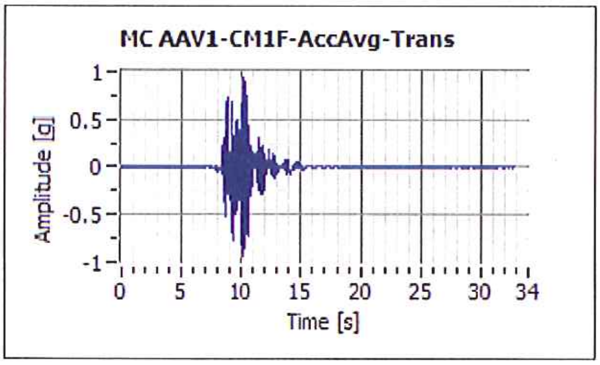


Figure J-55: Time History – 1st Floor Center of Mass Accelerations –Trans. – Stage 04

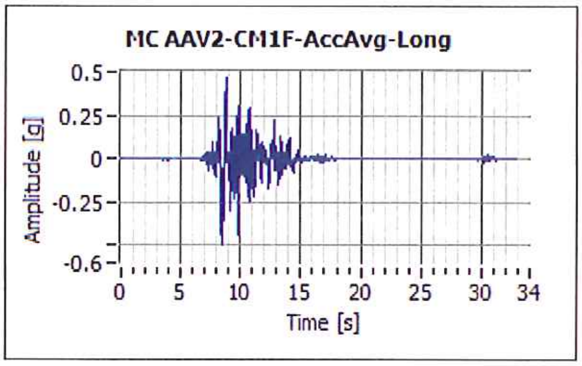


Figure J-56: Time History – 1st Floor Center of Mass Accelerations –Long. – Stage 04

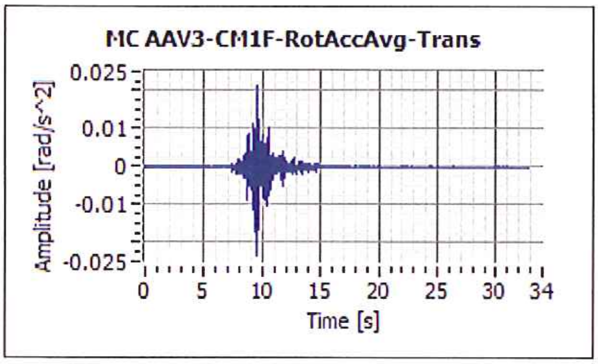


Figure J-57: Time History – 1st Floor Center of Mass Rotational Acceleration – Stage 04

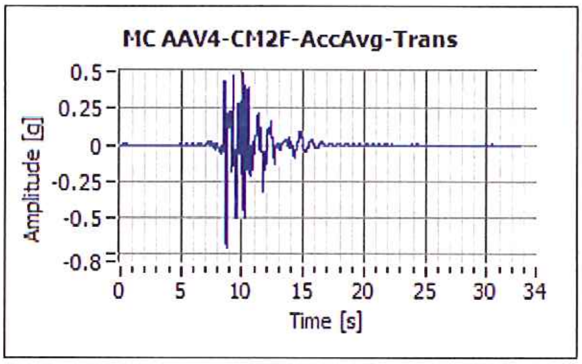


Figure J-58: Time History – 2nd Floor Center of Mass Accelerations –Trans. – Stage 04

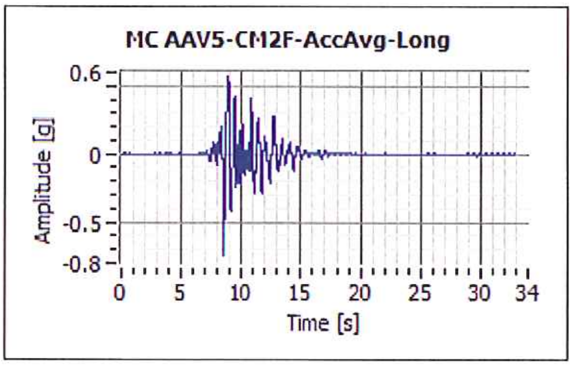


Figure J-59: Time History – 2nd Floor Center of Mass Accelerations –Long. – Stage 04

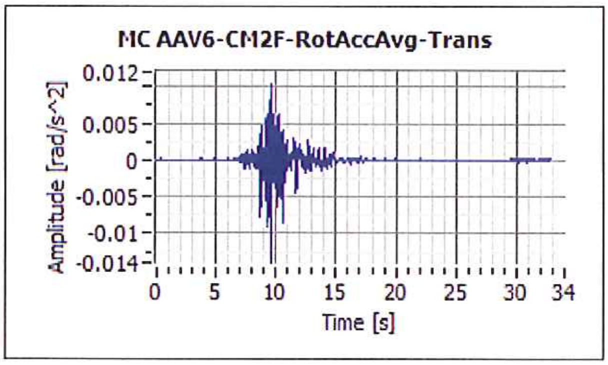


Figure J-60: Time History – 2nd Floor Center of Mass Rotational Acceleration – Stage 04

J.3 Center of Mass Polar Diagrams

J.3.1 Stage 00

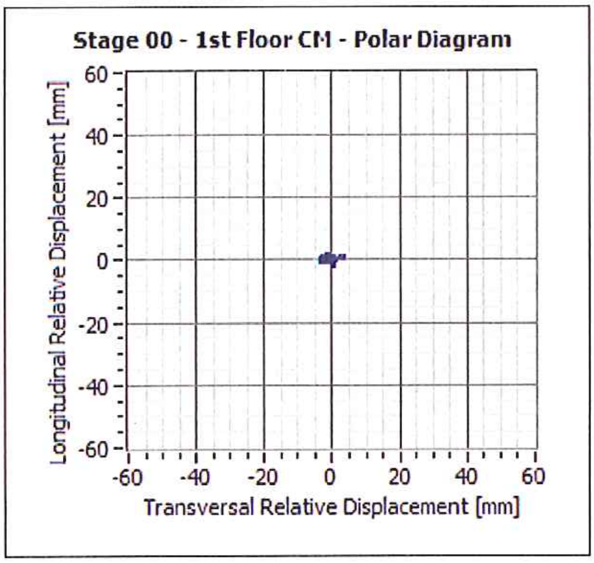


Figure J-61: Time History –1st Floor Center of Mass Polar Diagram – Stage 00

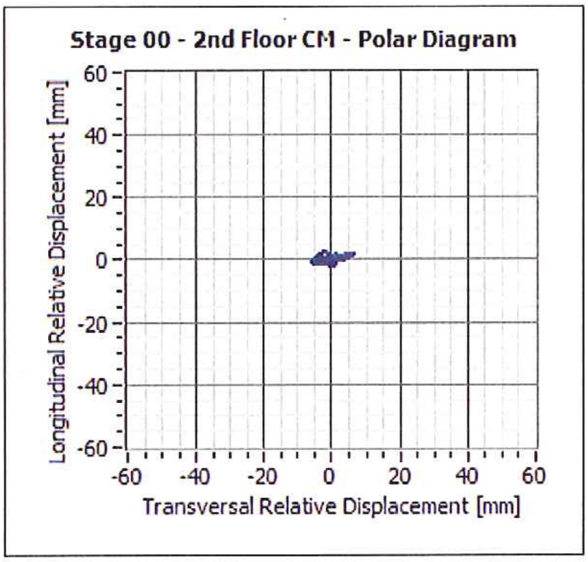


Figure J-62: Time History –2nd Floor Center of Mass Polar Diagram – Stage 00

J.3.2 Stage 01

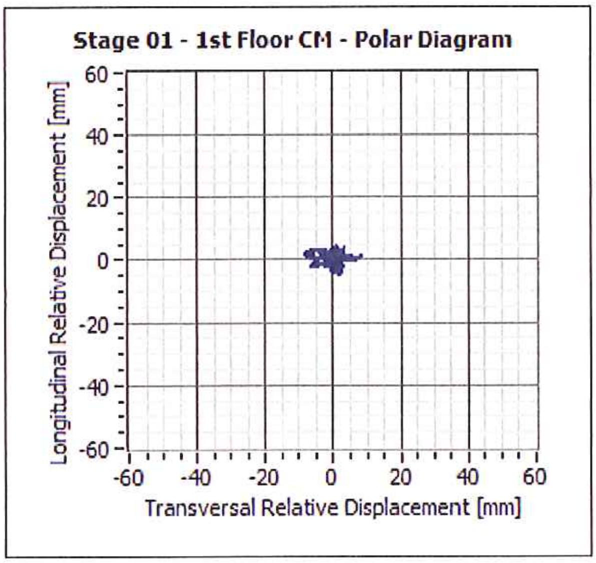


Figure J-63: Time History –1st Floor Center of Mass Polar Diagram – Stage 01

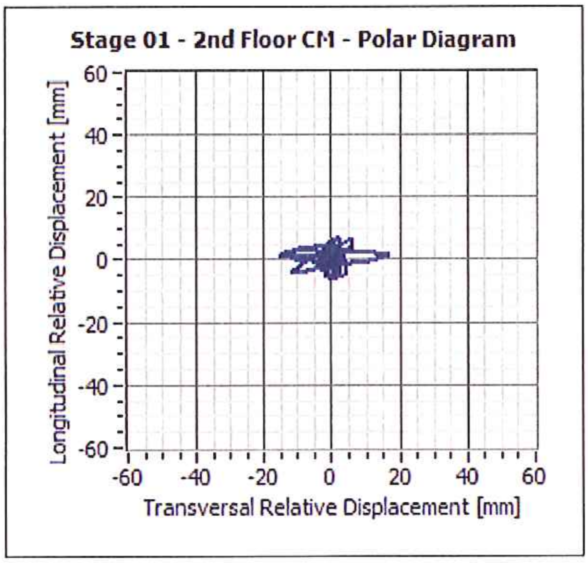


Figure J-64: Time History –2nd Floor Center of Mass Polar Diagram – Stage 01

J.3.3 Stage 02

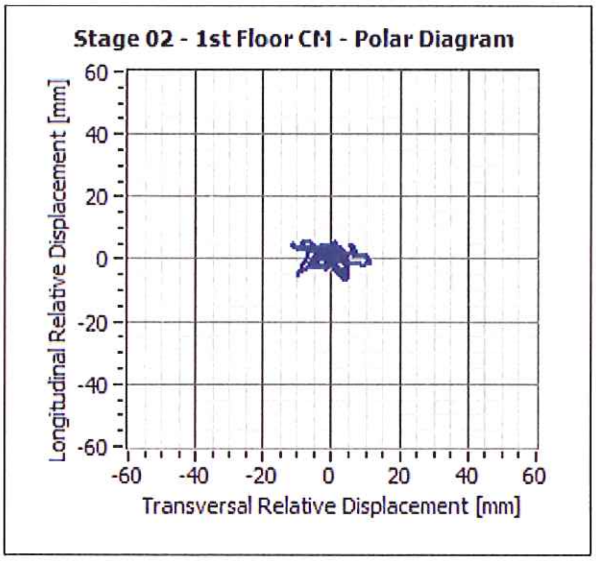


Figure J-65: Time History –1st Floor Center of Mass Polar Diagram – Stage 02

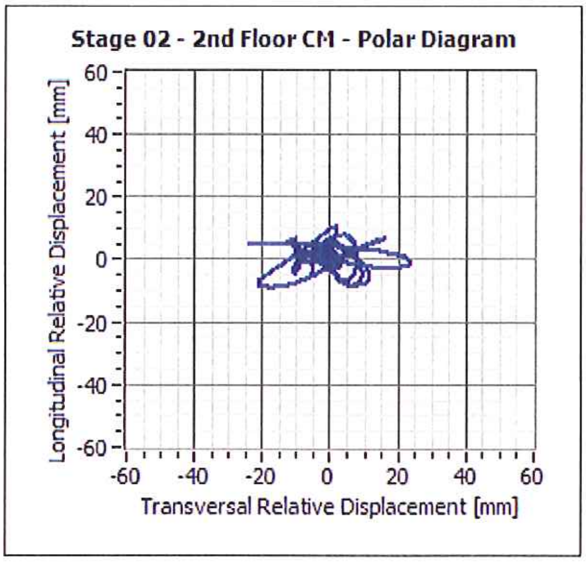


Figure J-66: Time History –2nd Floor Center of Mass Polar Diagram – Stage 02

J.3.4 Stage 03

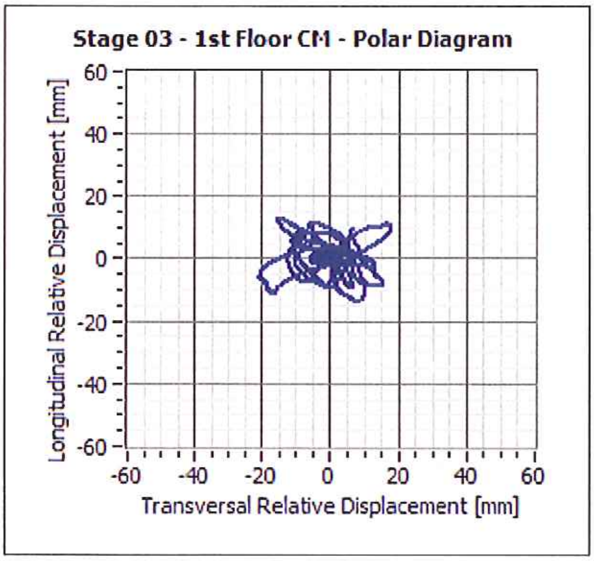


Figure J-67: Time History –1st Floor Center of Mass Polar Diagram – Stage 03

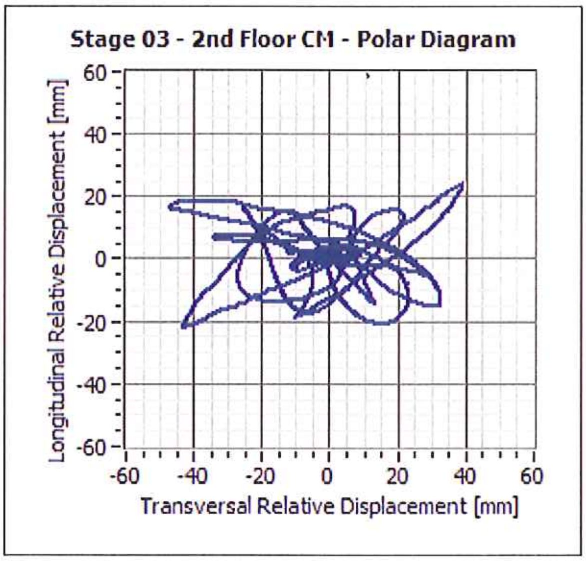


Figure J-68: Time History –2nd Floor Center of Mass Polar Diagram – Stage 03

J.3.5 Stage 04

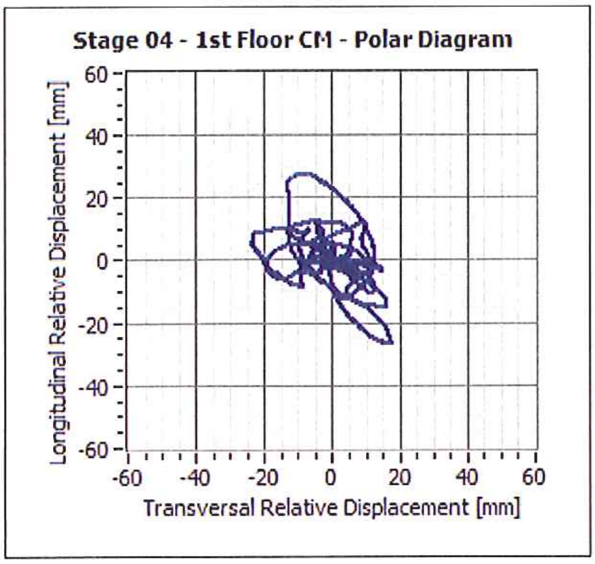


Figure J-69: Time History – 1st Floor Center of Mass Polar Diagram – Stage 04

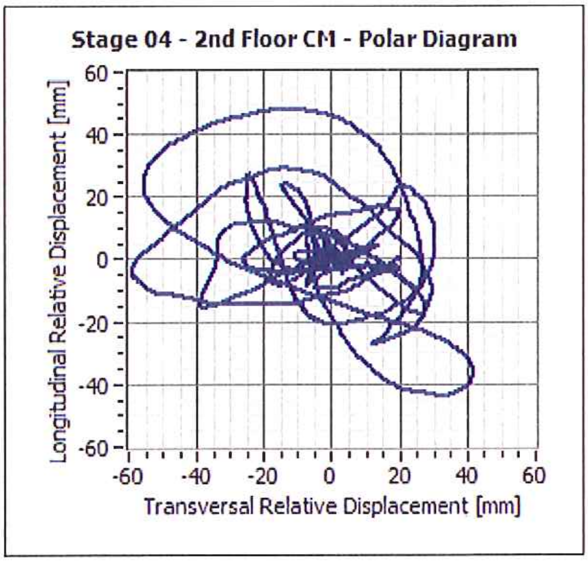


Figure J-70: Time History – 2nd Floor Center of Mass Polar Diagram – Stage 04

ANNEX K INTERSTOREY DRIFT

In this annex is presented the interstory drifts time histories of the 8 conner columns and of the center of mass of each floor.

Position			Label
Columns	First floor	NW	ID1
	First floor	SE	ID2
	First floor	NE	ID3
	First floor	SW	ID4
	Second floor	NE	ID5
	Second floor	NW	ID6
	Second floor	SE	ID7
	Second floor	SW	ID8
CM	First floor	CM	ID9
	Second floor	CM	ID10

Table K-1: Label identification

List of Figures:

K.1 Stage 00

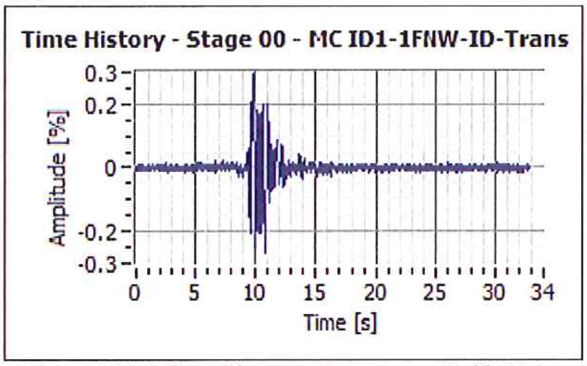


Figure K-1: Time History – Interstorey Drift ID1 – Stage 00 – Transversal direction

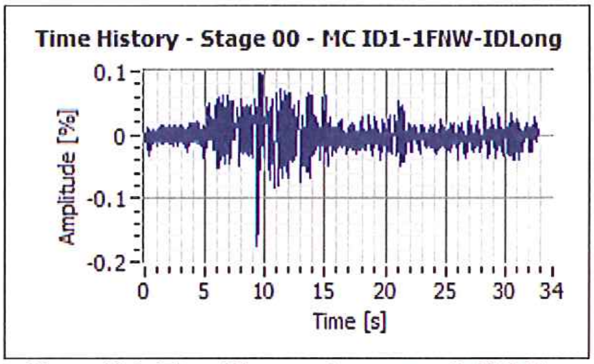


Figure K-2: Time History – Interstorey Drift ID1 – Stage 00 – Longitudinal direction

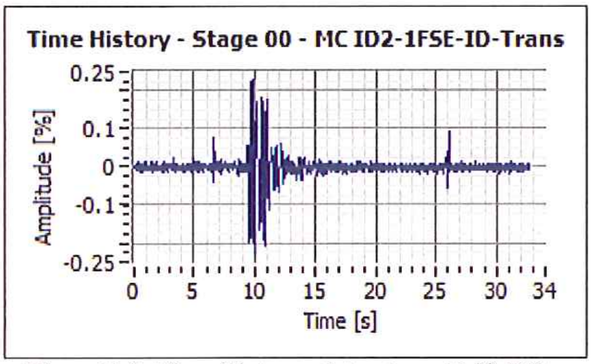


Figure K-3: Time History – Interstorey Drift ID2 – Stage 00 – Transversal direction

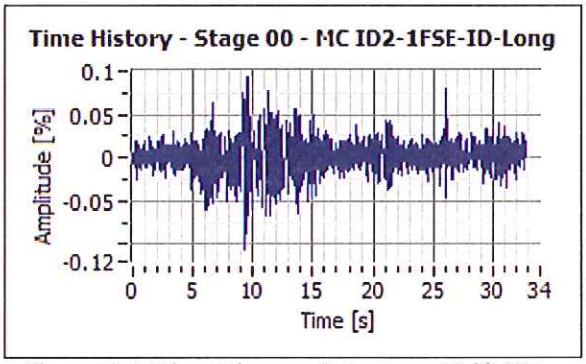


Figure K-4: Time History – Interstorey Drift ID2 – Stage 00 – Longitudinal direction

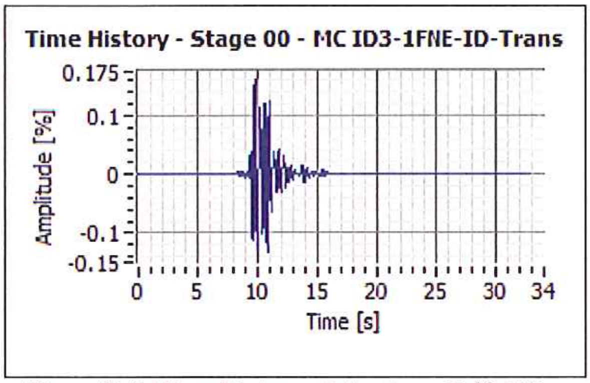


Figure K-5: Time History – Interstorey Drift ID3 – Stage 00 – Transversal direction

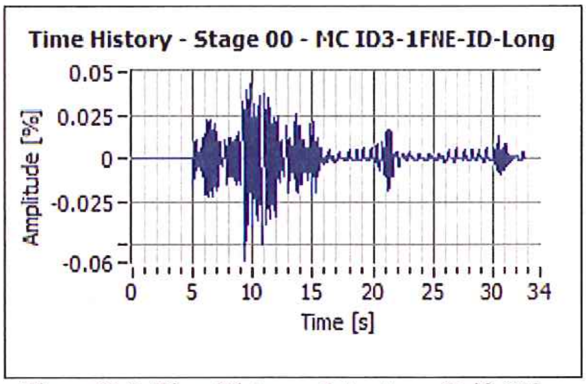


Figure K-6: Time History – Interstorey Drift ID3 – Stage 00 – Longitudinal direction

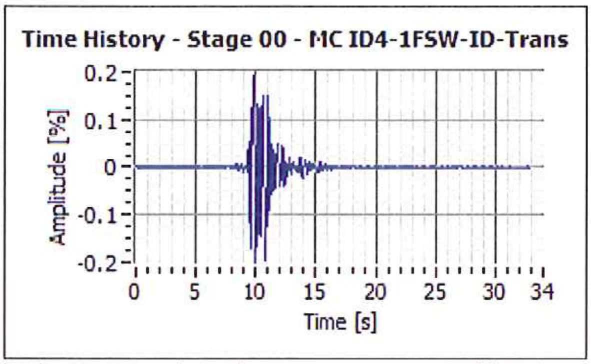


Figure K-7: Time History – Interstorey Drift ID4 – Stage 00 – Transversal direction

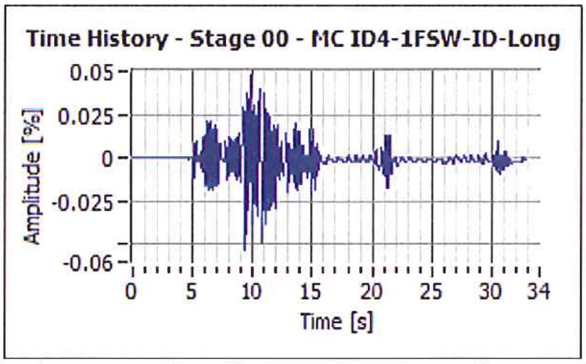


Figure K-8: Time History – Interstorey Drift ID4 – Stage 00 – Longitudinal direction

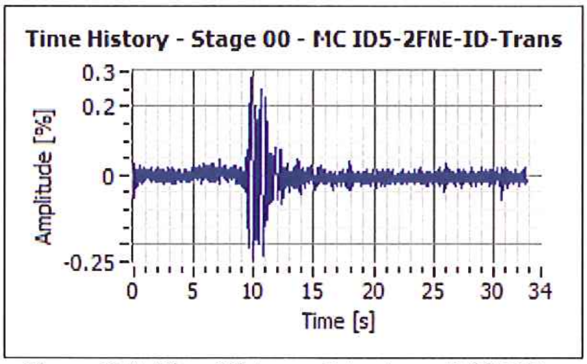


Figure K-9: Time History – Interstorey Drift ID5 – Stage 00 – Transversal direction

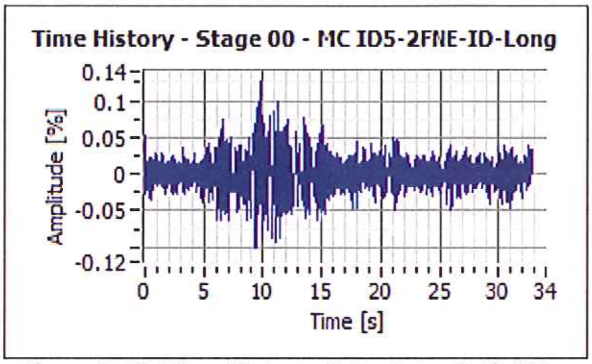


Figure K-10: Time History – Interstorey Drift ID5 – Stage 00 – Longitudinal direction

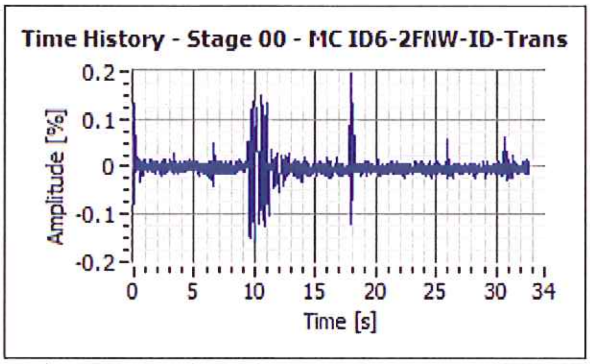


Figure K-11: Time History – Interstorey Drift ID6 – Stage 00 – Transversal direction

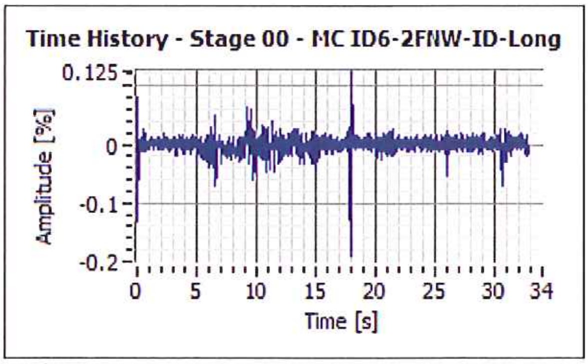


Figure K-12: Time History – Interstorey Drift ID6 – Stage 00 – Longitudinal direction

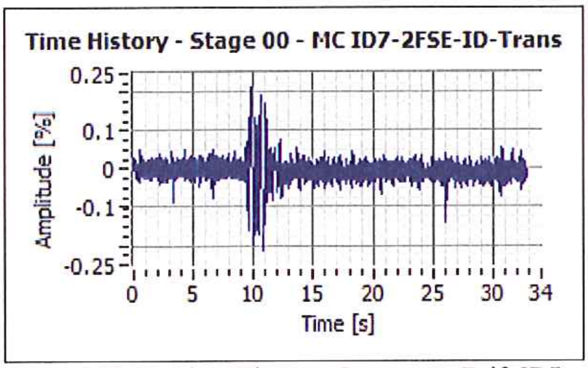


Figure K-13: Time History – Interstorey Drift ID7 – Stage 00 – Transversal direction

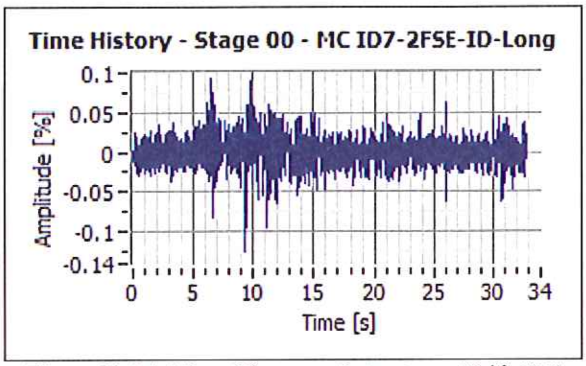


Figure K-14: Time History – Interstorey Drift ID7 – Stage 00 – Longitudinal direction

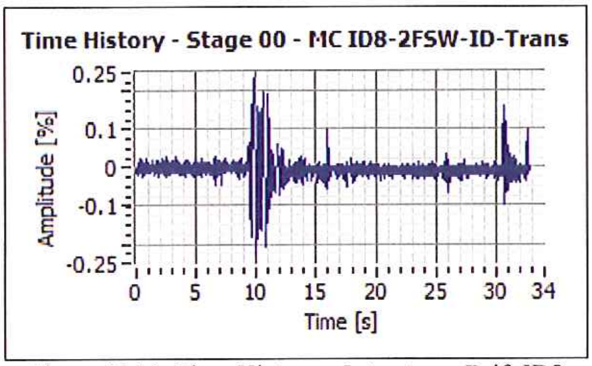


Figure K-15: Time History – Interstorey Drift ID8 – Stage 00 – Transversal direction

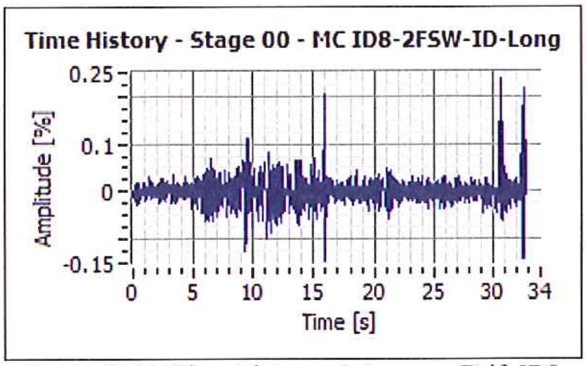


Figure K-16: Time History – Interstorey Drift ID8 – Stage 00 – Longitudinal direction

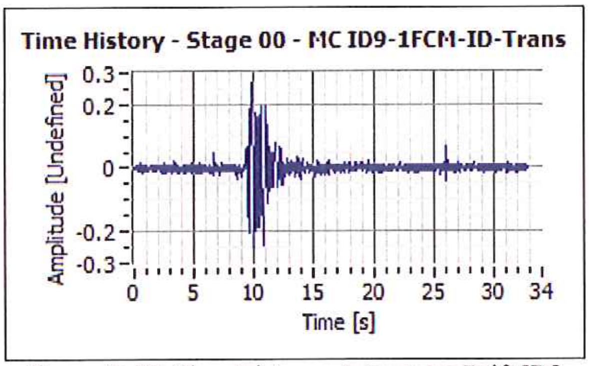


Figure K-17: Time History – Interstorey Drift ID9 – Stage 00 – Transversal direction

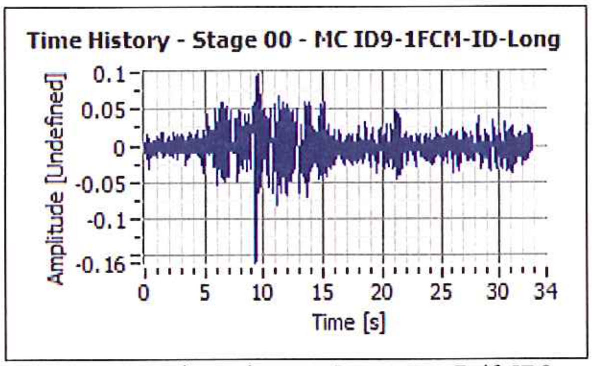


Figure K-18: Time History – Interstorey Drift ID9 – Stage 00 – Longitudinal direction

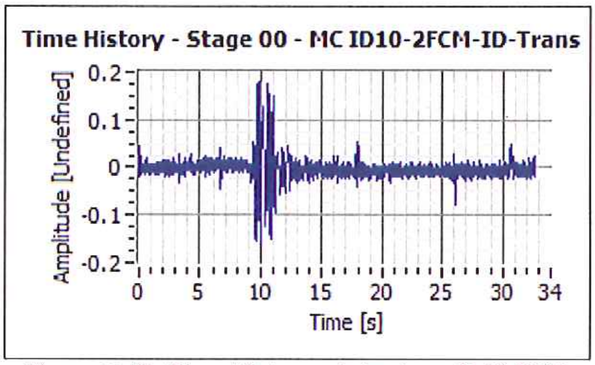


Figure K-19: Time History – Interstorey Drift ID10 – Stage 00 – Transversal direction

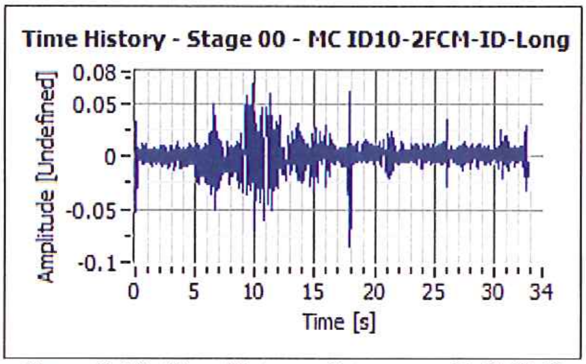


Figure K-20: Time History – Interstorey Drift ID10 – Stage 00 – Longitudinal direction

K.2 Stage 01

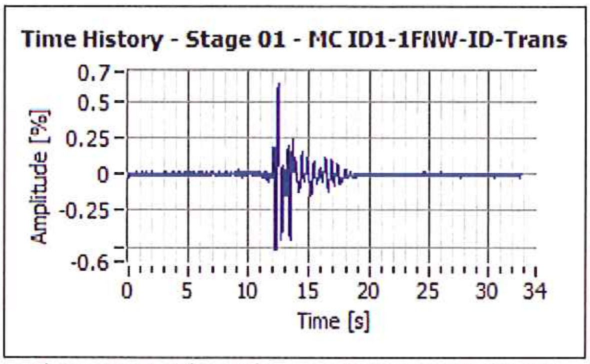


Figure K-21: Time History – Interstorey Drift ID1 – Stage 01 – Transversal direction

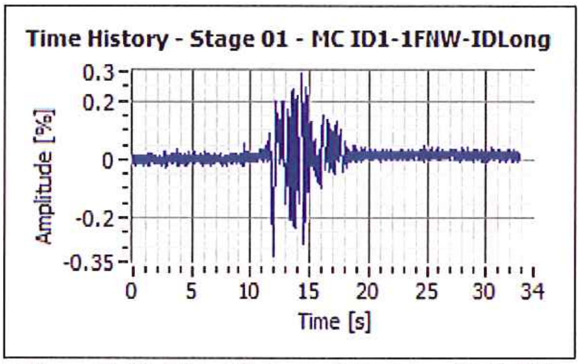


Figure K-22: Time History – Interstorey Drift ID1 – Stage 01 – Longitudinal direction

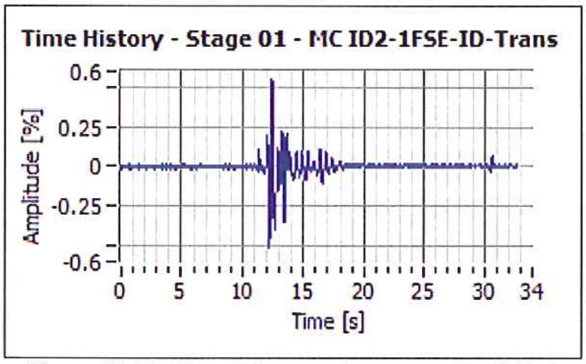


Figure K-23: Time History – Interstorey Drift ID2 – Stage 01 – Transversal direction

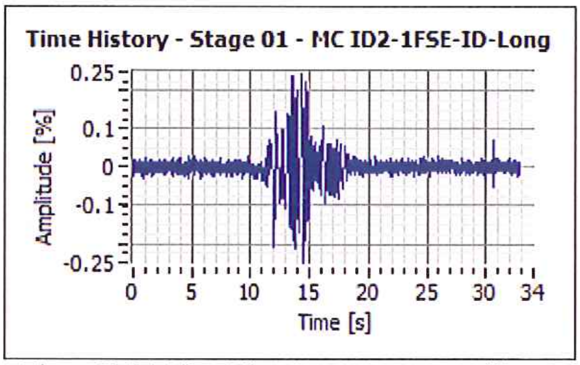


Figure K-24: Time History – Interstorey Drift ID2 – Stage 01 – Longitudinal direction

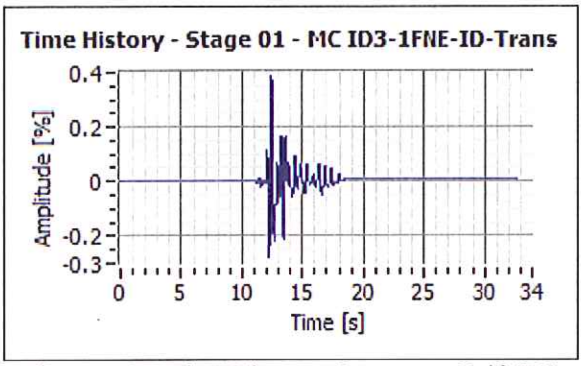


Figure K-25: Time History – Interstorey Drift ID3 – Stage 01 – Transversal direction

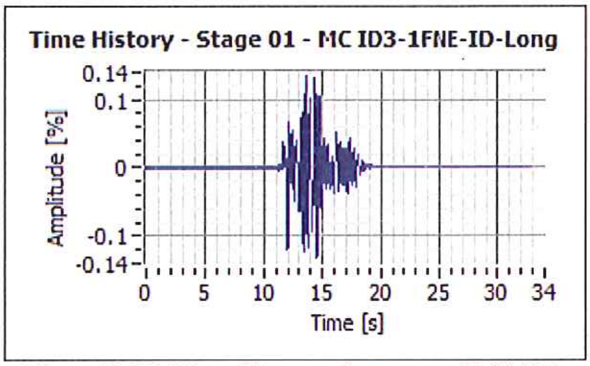


Figure K-26: Time History – Interstorey Drift ID3 – Stage 01 – Longitudinal direction

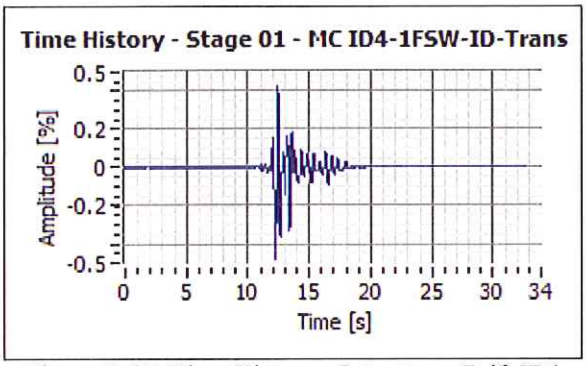


Figure K-27: Time History – Interstorey Drift ID4 – Stage 01 – Transversal direction

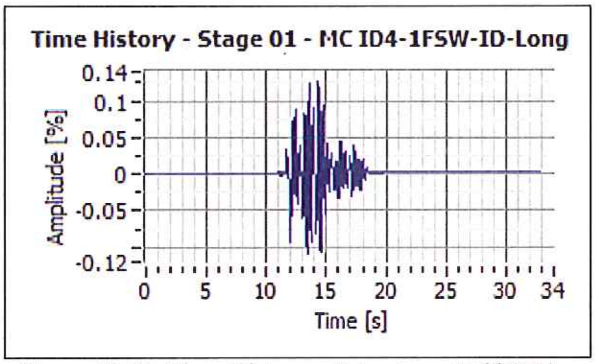


Figure K-28: Time History – Interstorey Drift ID4 – Stage 01 – Longitudinal direction

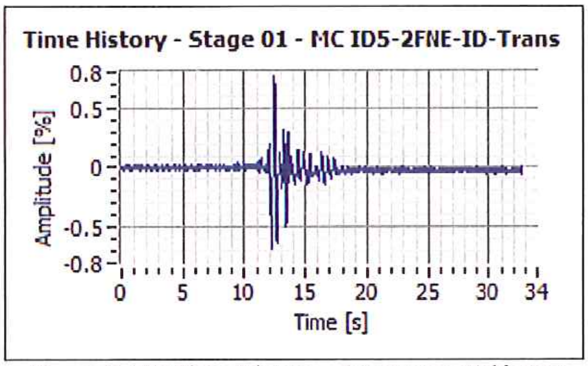


Figure K-29: Time History – Interstorey Drift ID5 – Stage 01 – Transversal direction

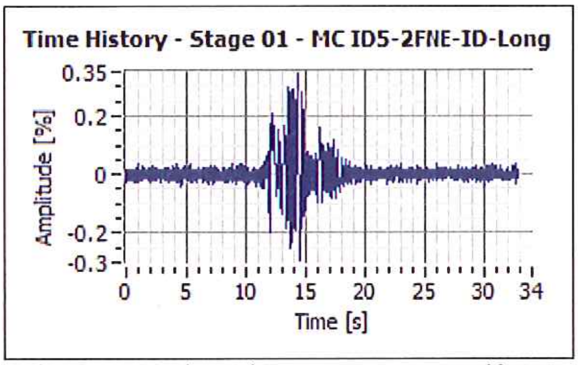


Figure K-30: Time History – Interstorey Drift ID5 – Stage 01 – Longitudinal direction

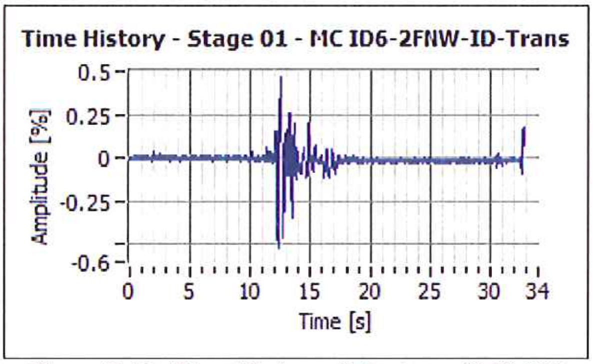


Figure K-31: Time History – Interstorey Drift ID6 – Stage 01 – Transversal direction

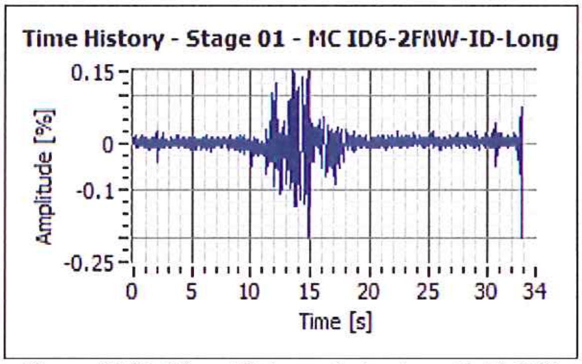


Figure K-32: Time History – Interstorey Drift ID6 – Stage 01 – Longitudinal direction

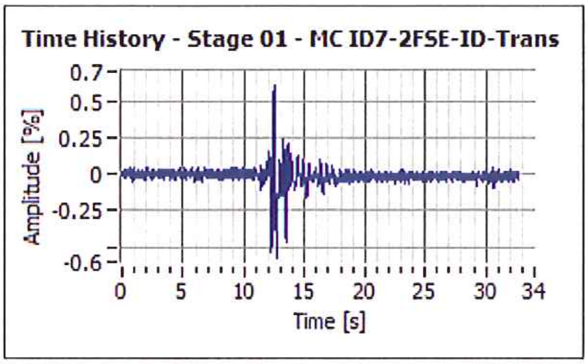


Figure K-33: Time History – Interstorey Drift ID7 – Stage 01 – Transversal direction

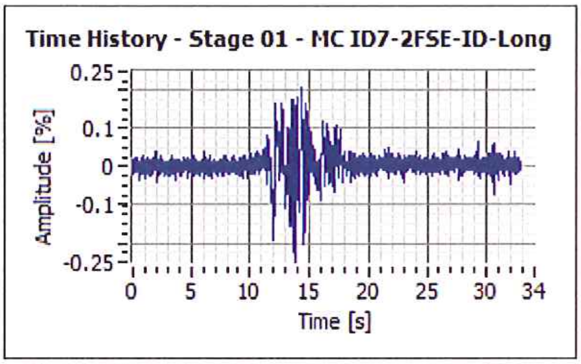


Figure K-34: Time History – Interstorey Drift ID7 – Stage 01 – Longitudinal direction

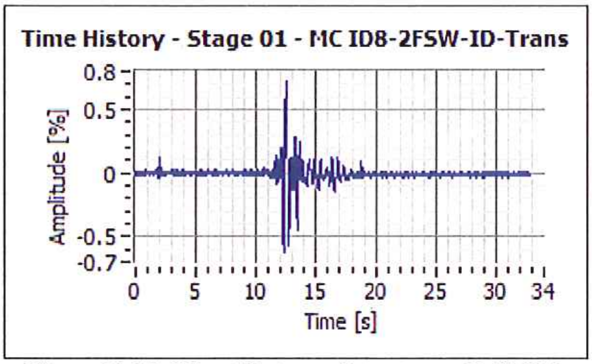


Figure K-35: Time History – Interstorey Drift ID8 – Stage 01 – Transversal direction

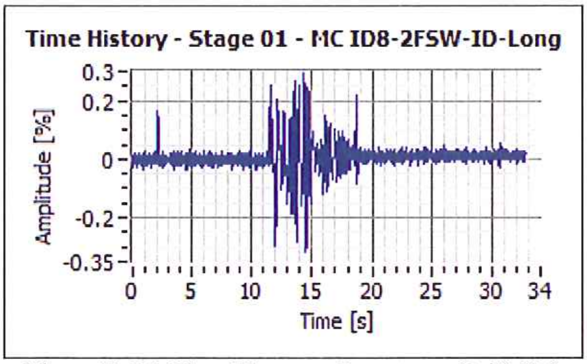


Figure K-36: Time History – Interstorey Drift ID8 – Stage 01 – Longitudinal direction

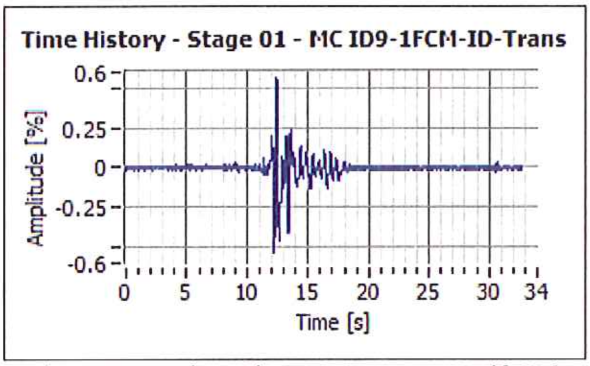


Figure K-37: Time History – Interstorey Drift ID9 – Stage 01 – Transversal direction

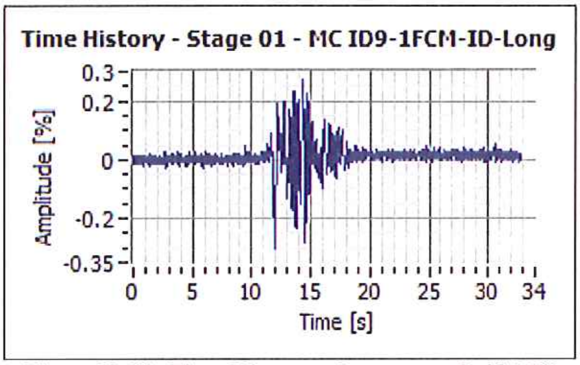


Figure K-38: Time History – Interstorey Drift ID9 – Stage 01 – Longitudinal direction

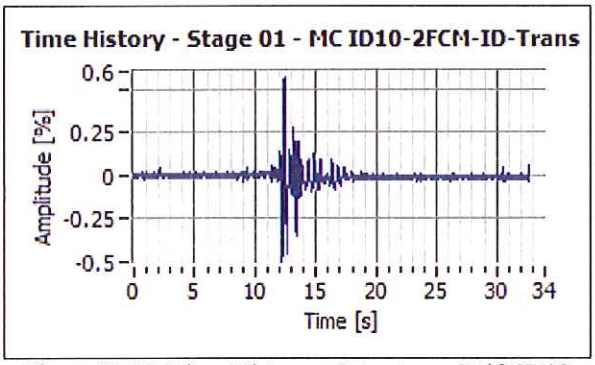


Figure K-39: Time History – Interstorey Drift ID10 – Stage 01 – Transversal direction

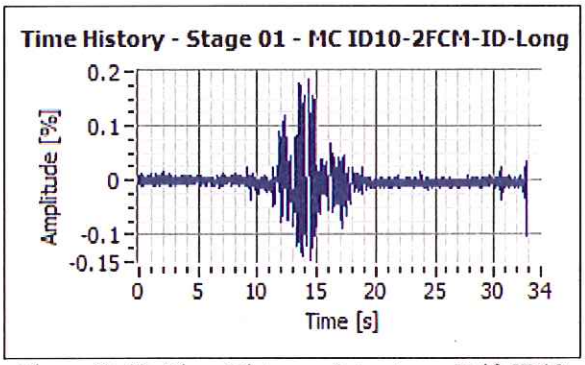


Figure K-40: Time History – Interstorey Drift ID10 – Stage 01 – Longitudinal direction

K.3 Stage 02

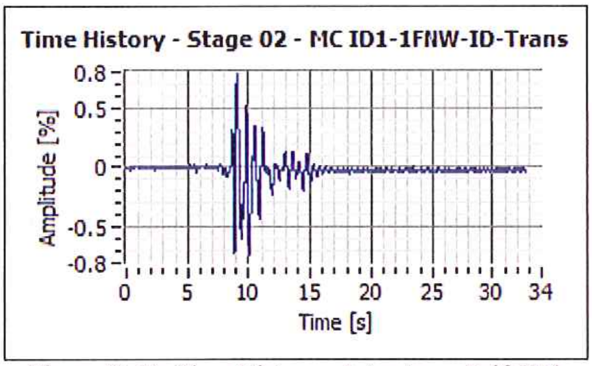


Figure K-41: Time History – Interstorey Drift ID1 – Stage 02 – Transversal direction

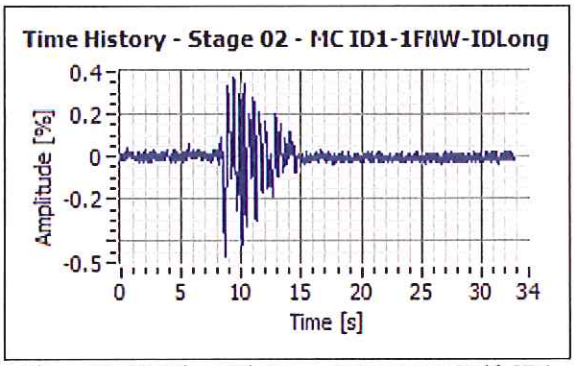


Figure K-42: Time History – Interstorey Drift ID1 – Stage 02 – Longitudinal direction

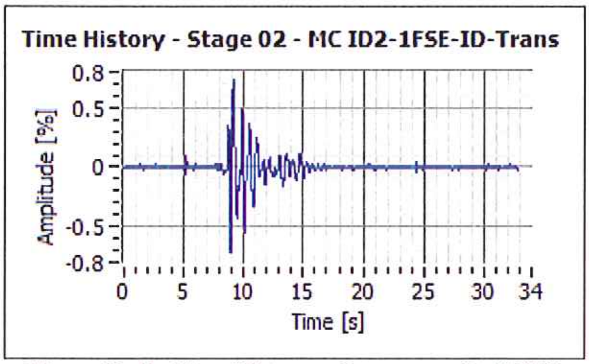


Figure K-43: Time History – Interstorey Drift ID2 – Stage 02 – Transversal direction

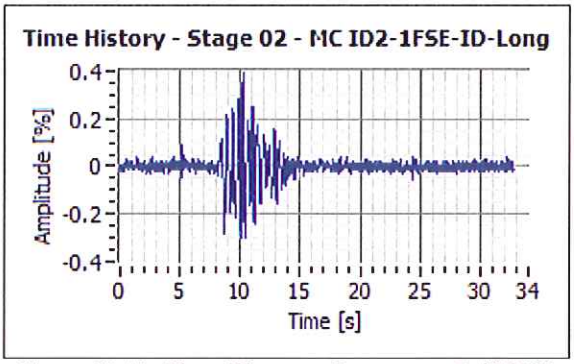


Figure K-44: Time History – Interstorey Drift ID2 – Stage 02 – Longitudinal direction

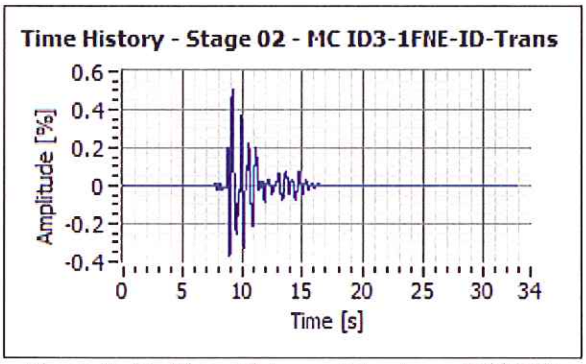


Figure K-45: Time History – Interstorey Drift ID3 – Stage 02 – Transversal direction

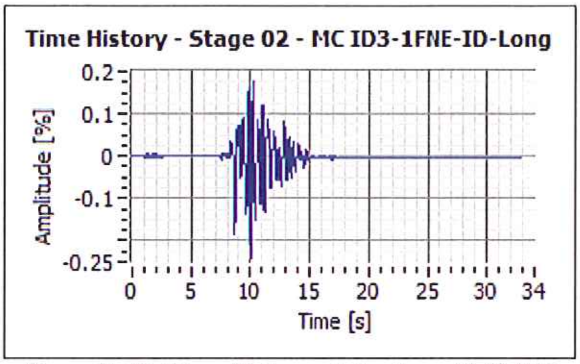


Figure K-46: Time History – Interstorey Drift ID3 – Stage 02 – Longitudinal direction

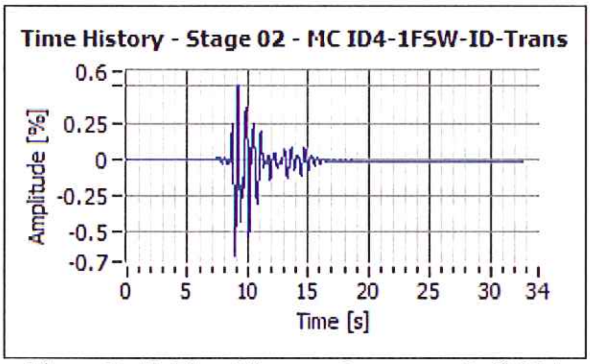


Figure K-47: Time History – Interstorey Drift ID4 – Stage 02 – Transversal direction

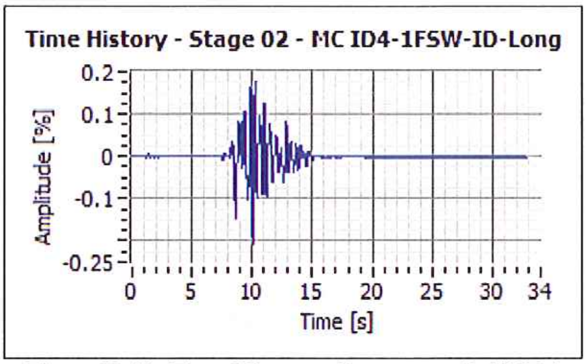


Figure K-48: Time History – Interstorey Drift ID4 – Stage 02 – Longitudinal direction

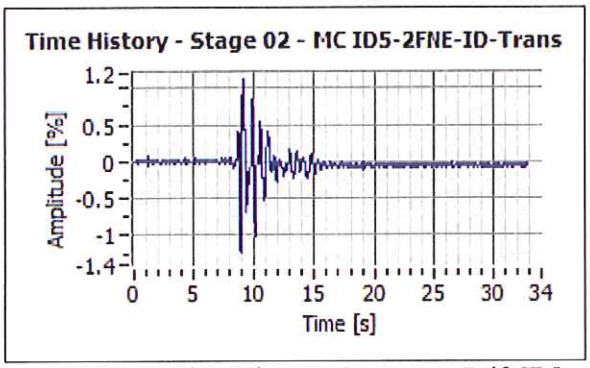


Figure K-49: Time History – Interstorey Drift ID5 – Stage 02 – Transversal direction

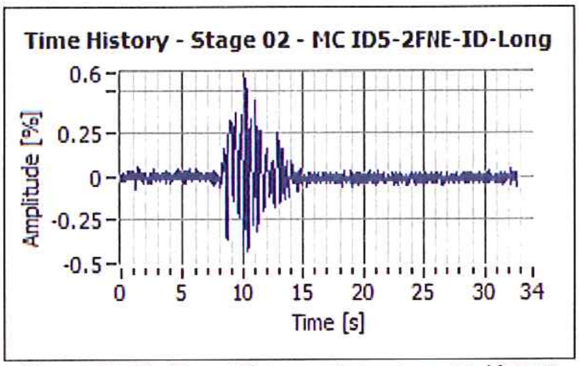
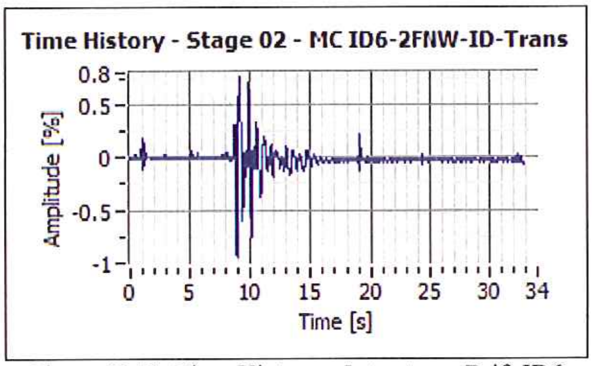


Figure K-50: Time History – Interstorey Drift ID5 – Stage 02 – Longitudinal direction



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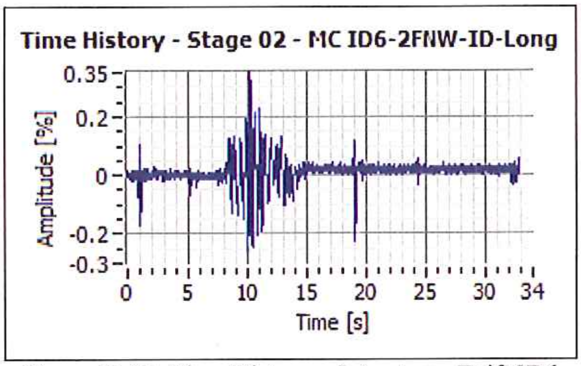
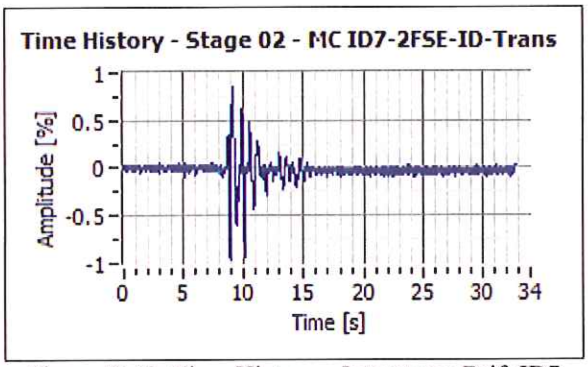


Figure K-52: Time History – Interstorey Drift ID6 – Stage 02 – Transversal direction



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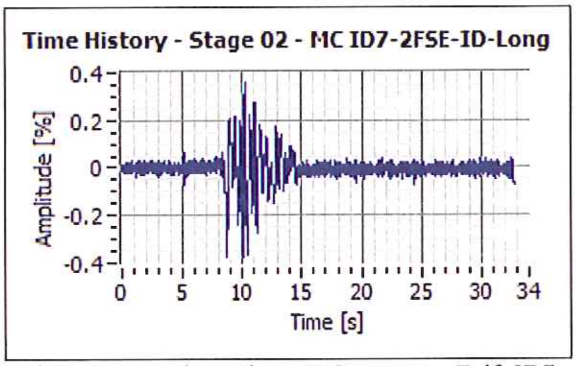

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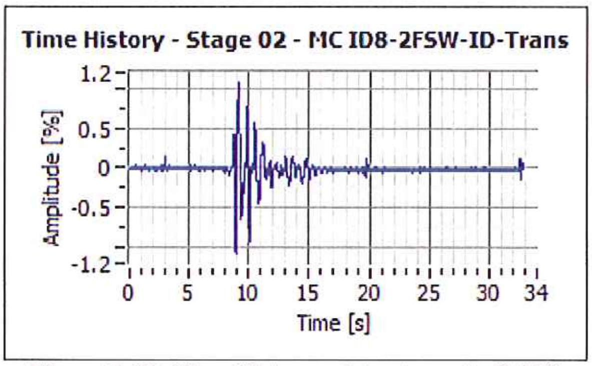

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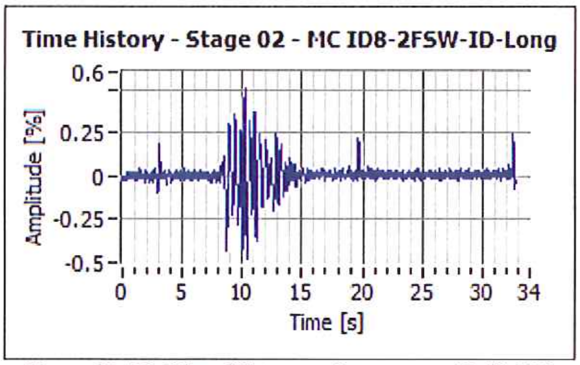
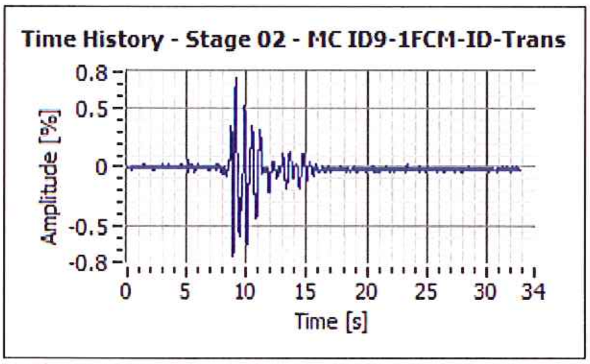


Figure K-56: Time History – Interstorey Drift ID8 – Stage 02 – Longitudinal direction



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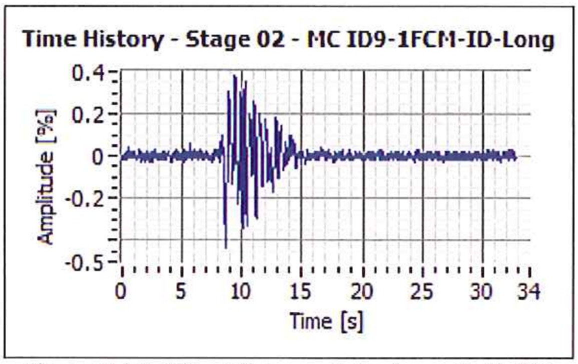

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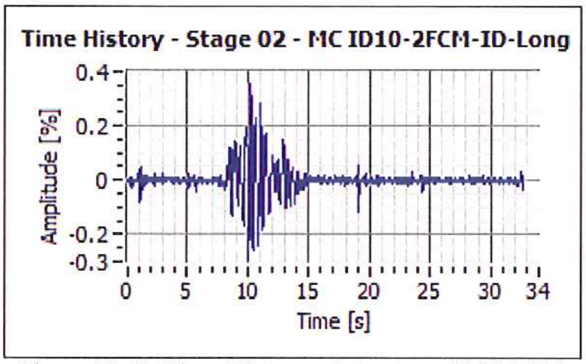

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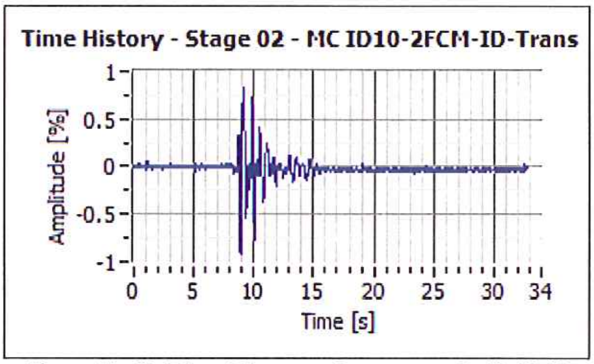

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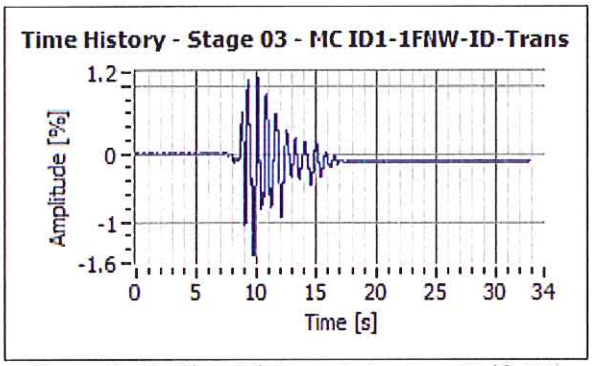

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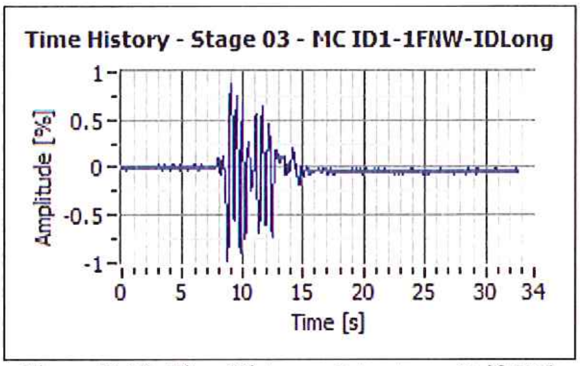
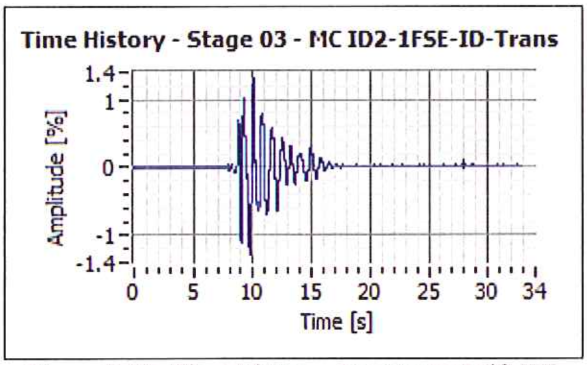


Figure K-62: Time History – Interstorey Drift ID1 – Stage 03 – Longitudinal direction



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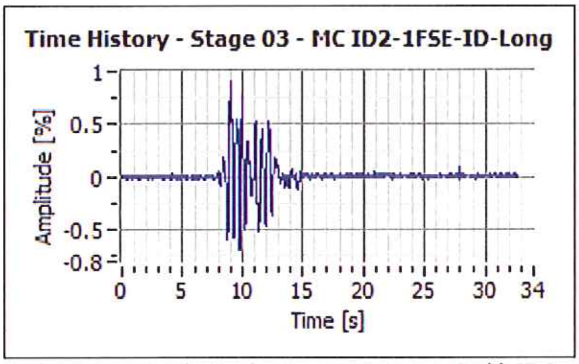

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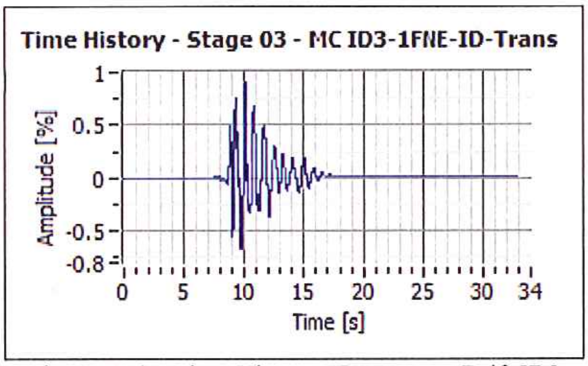

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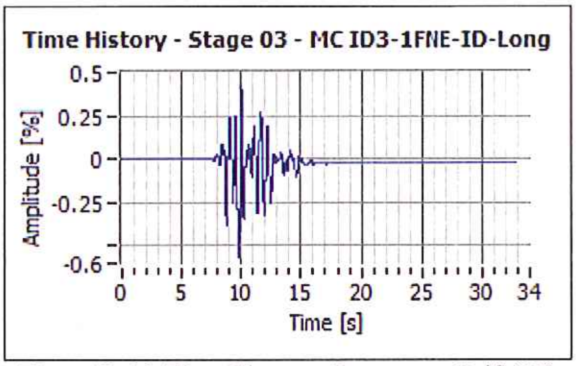

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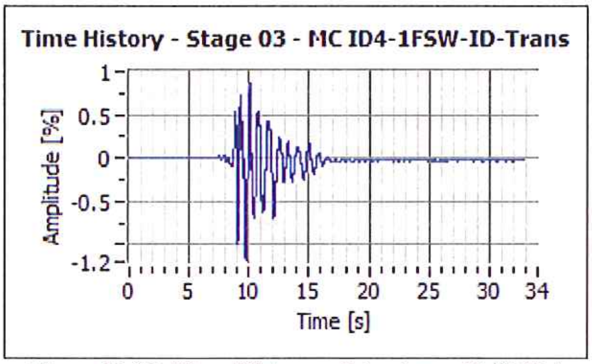

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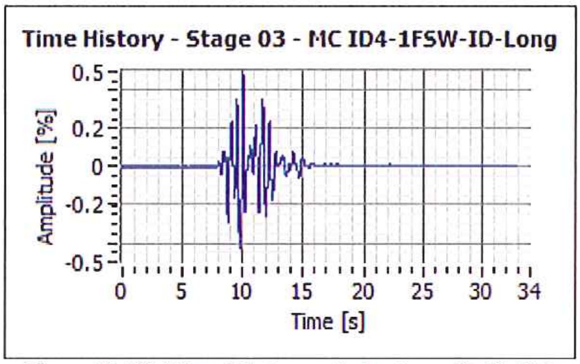

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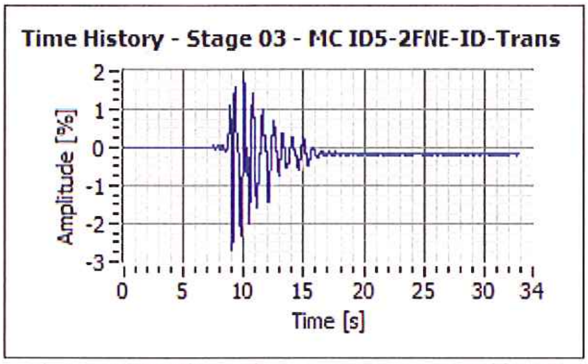

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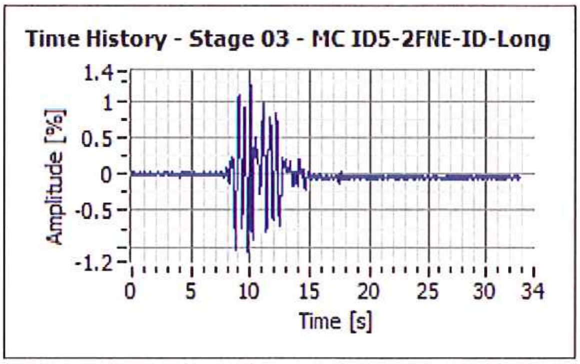

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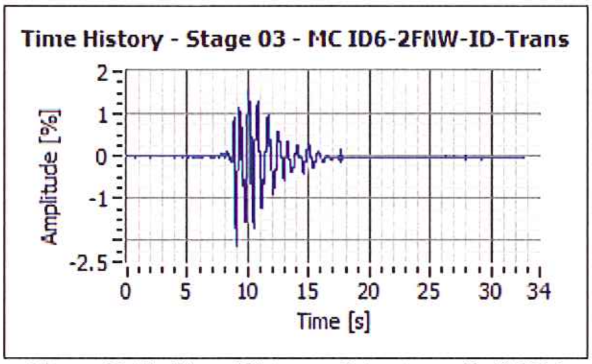

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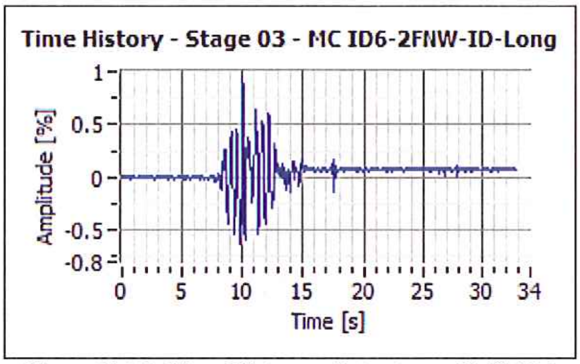

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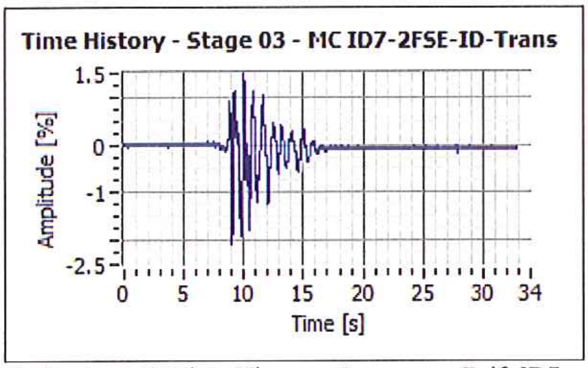

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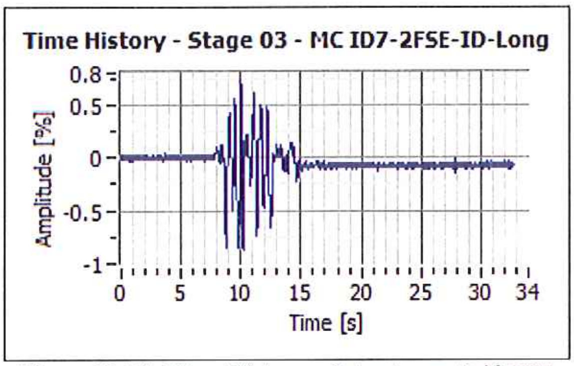

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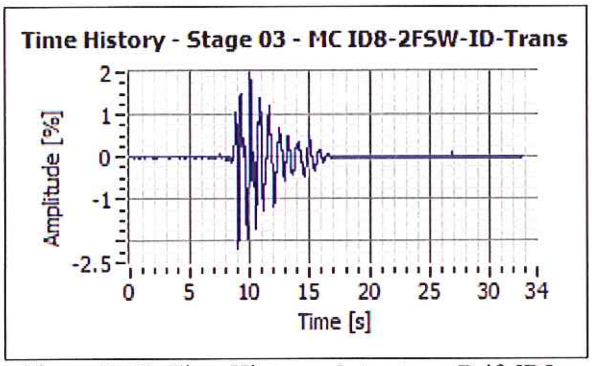

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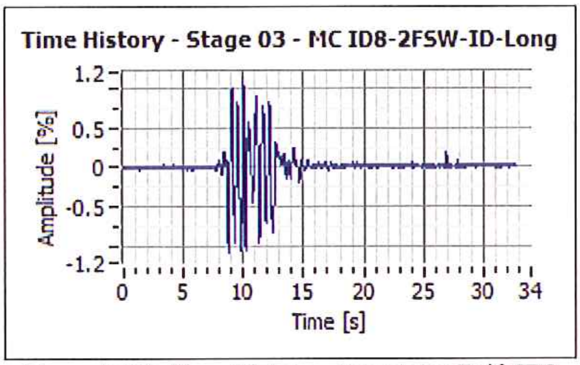

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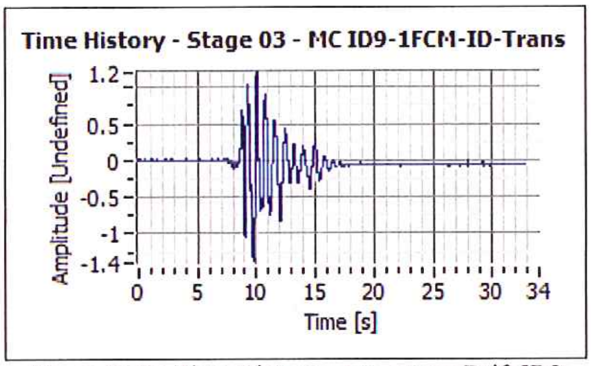

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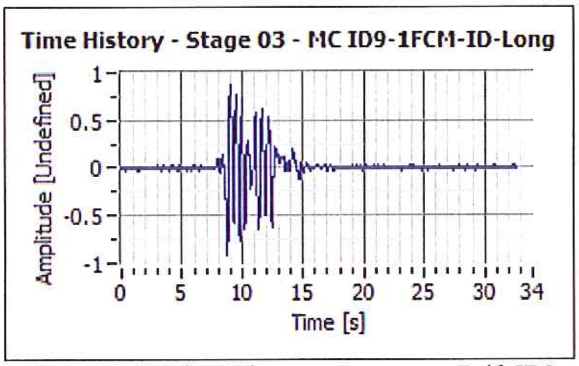

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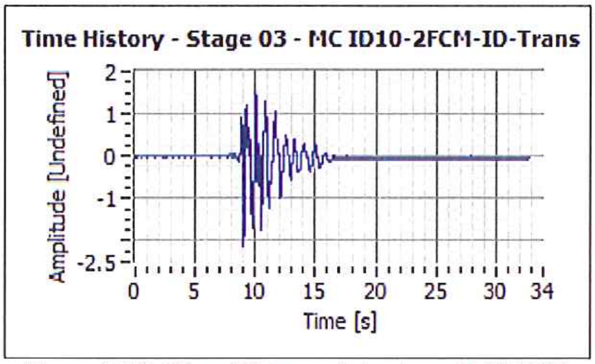

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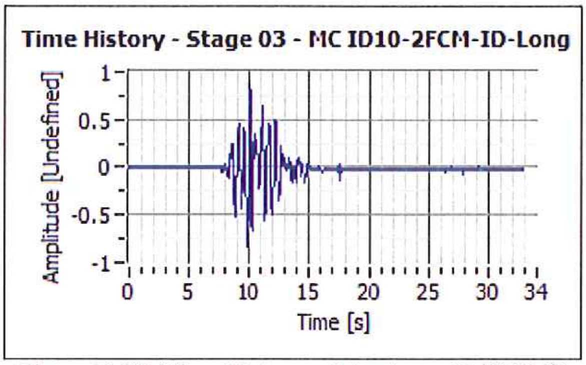

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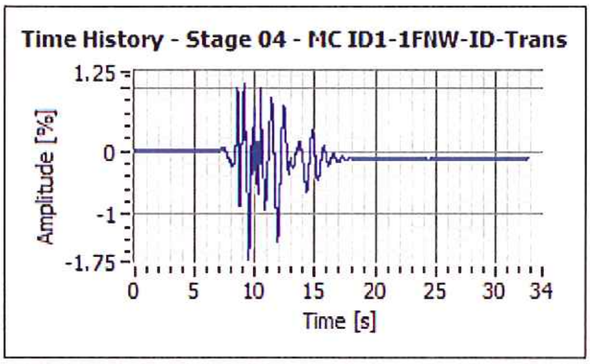
K.5 Stage 04



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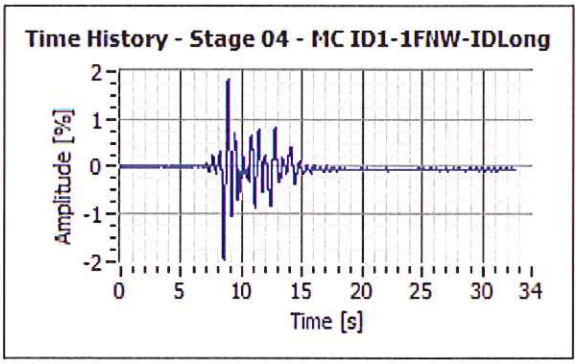

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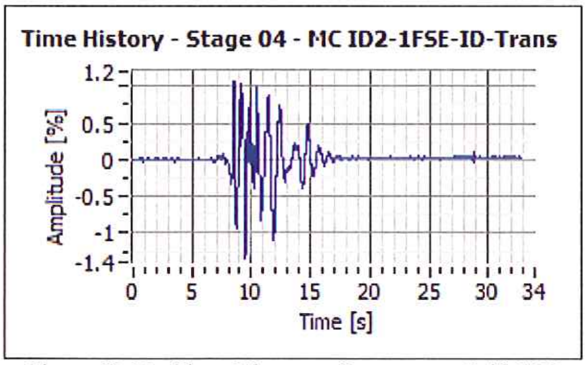

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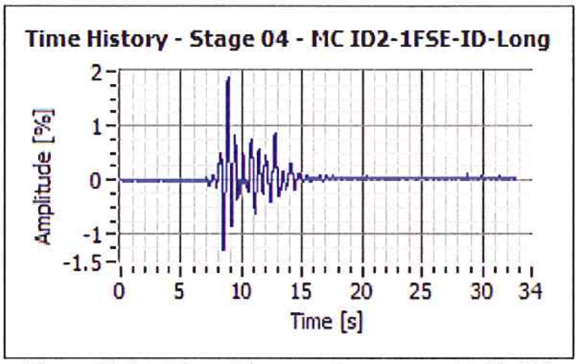

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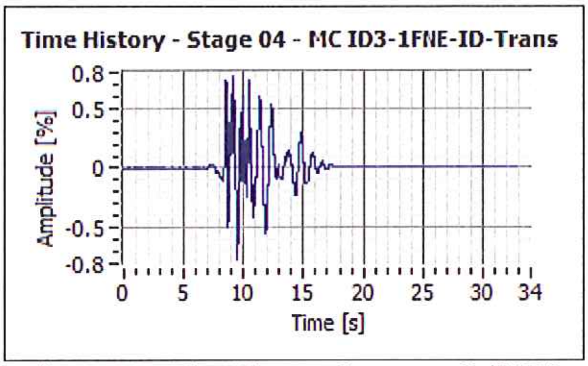

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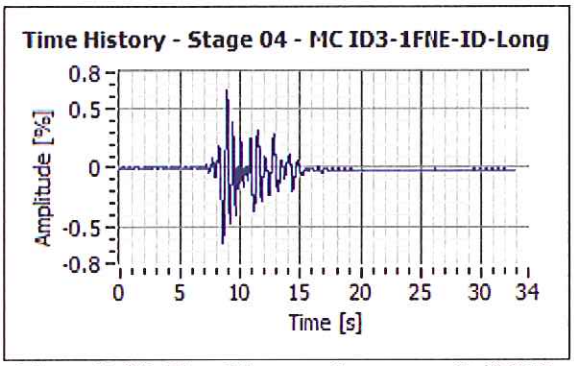

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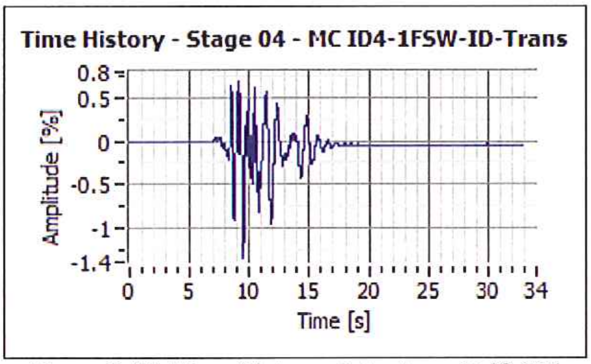

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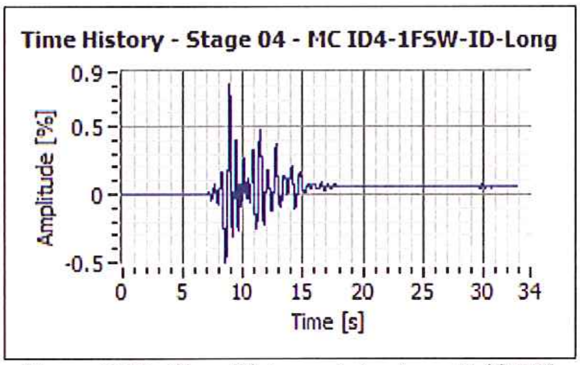

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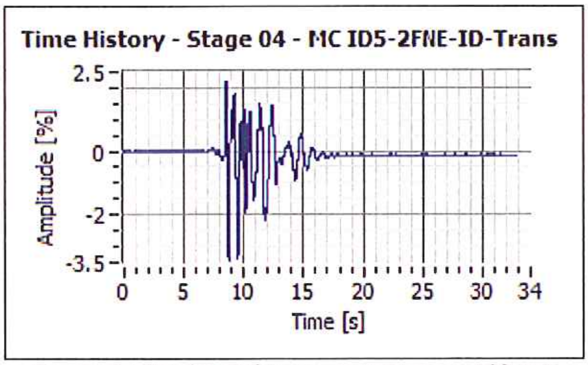

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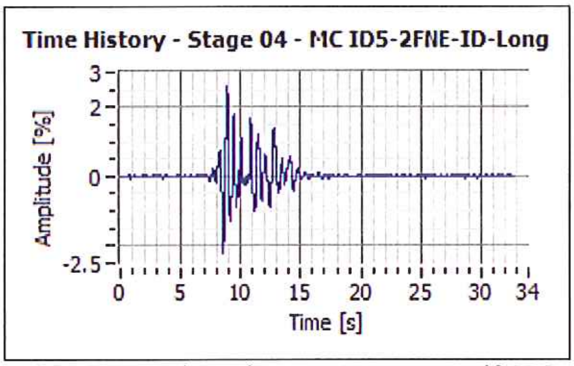
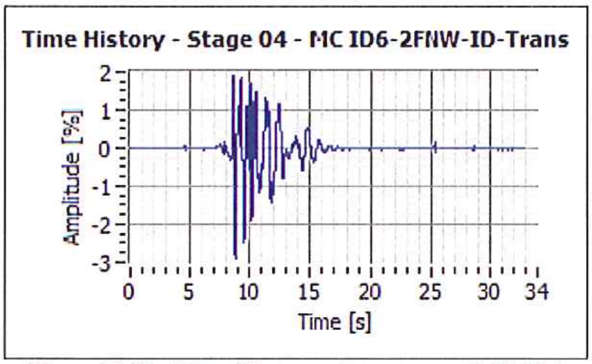


Figure K-90: Time History – Interstorey Drift ID5 – Stage 04 – Longitudinal direction



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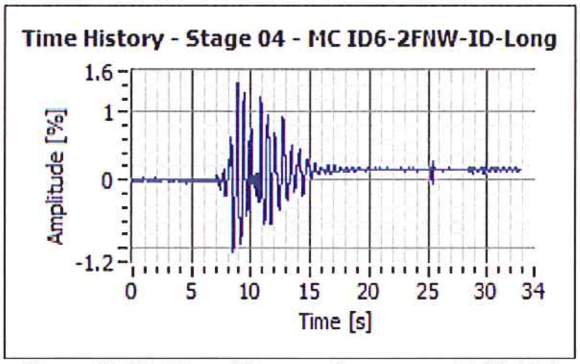

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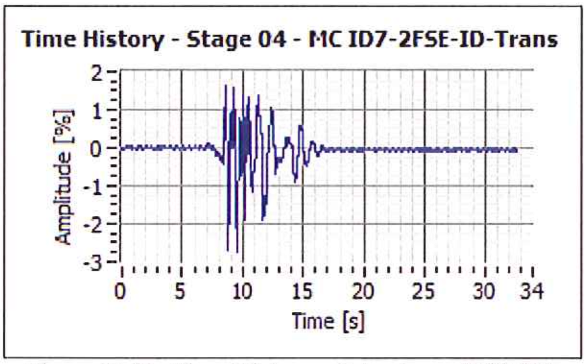

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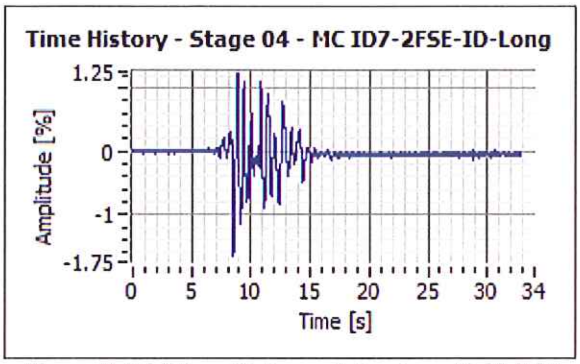

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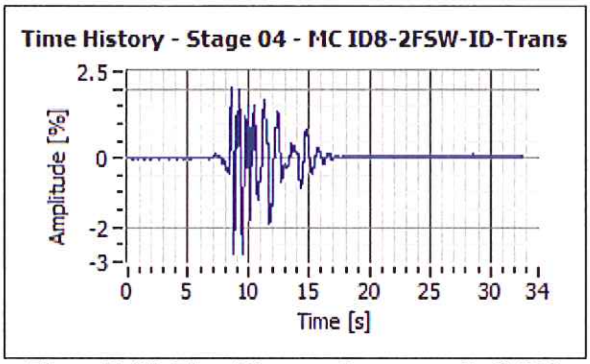

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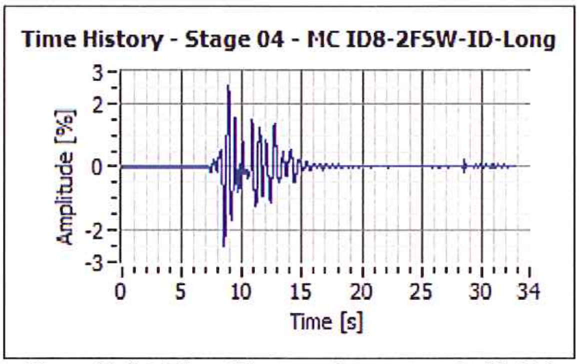

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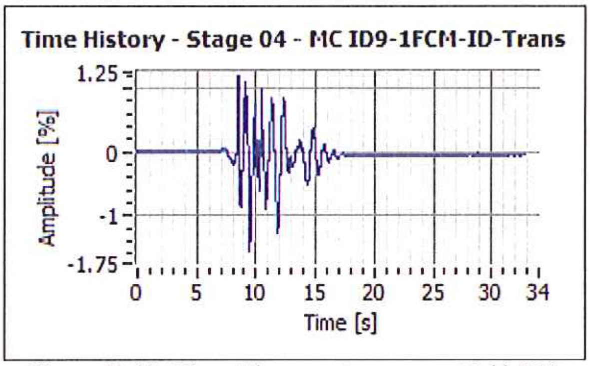

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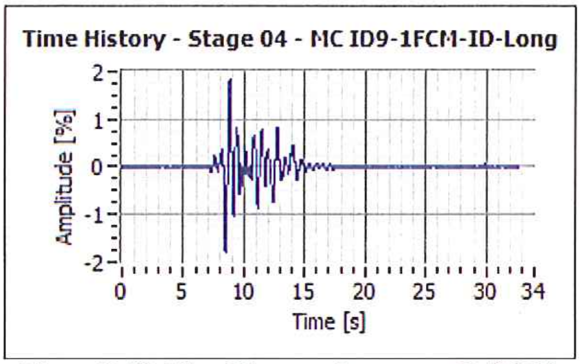

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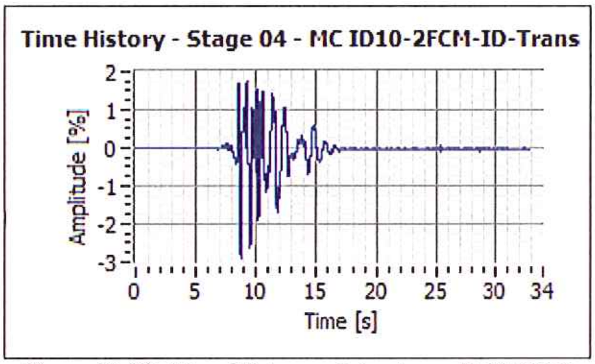

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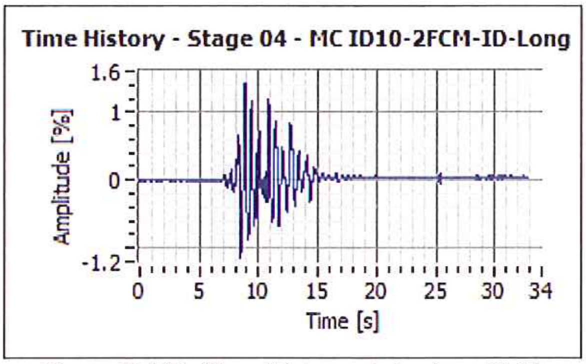

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ANNEX L GLOBAL FORCES

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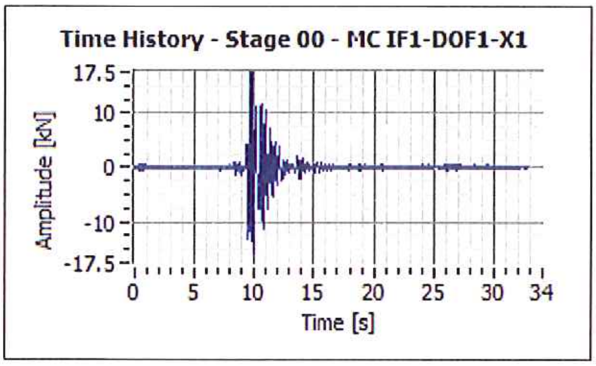

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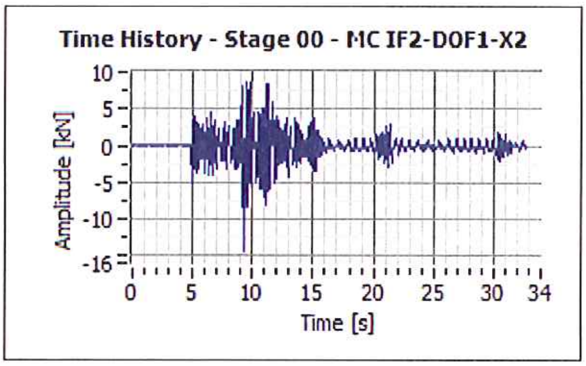

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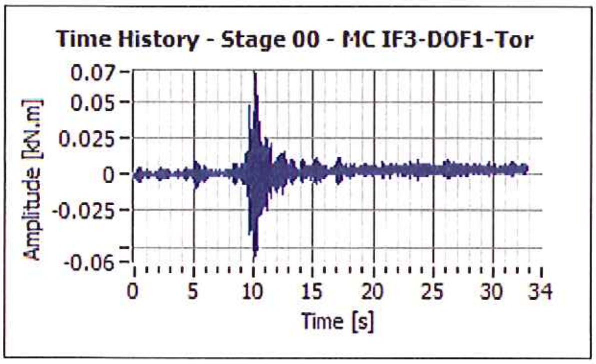

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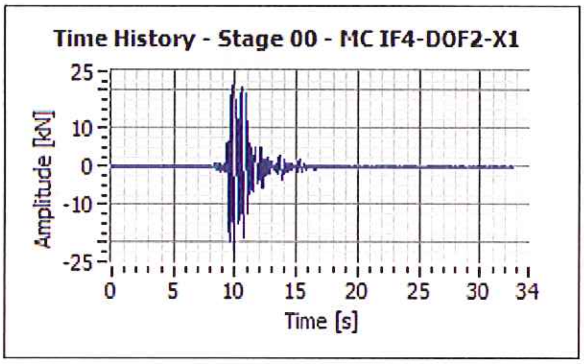

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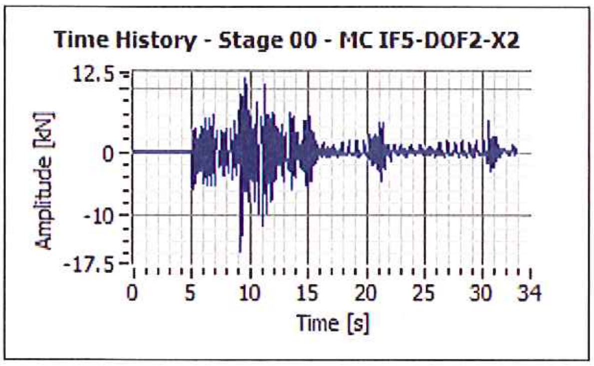

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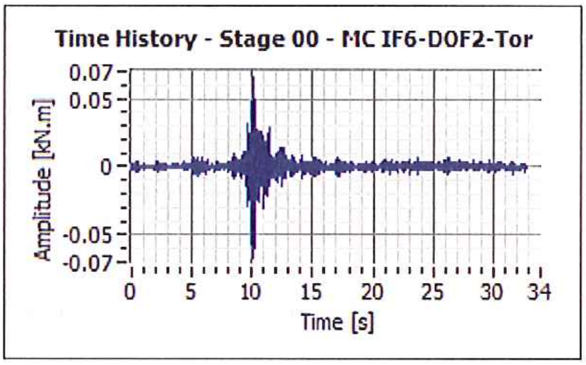

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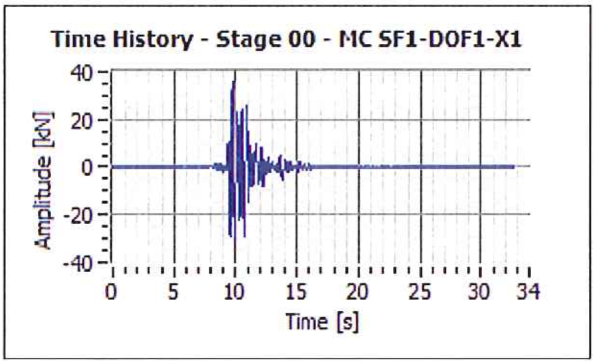

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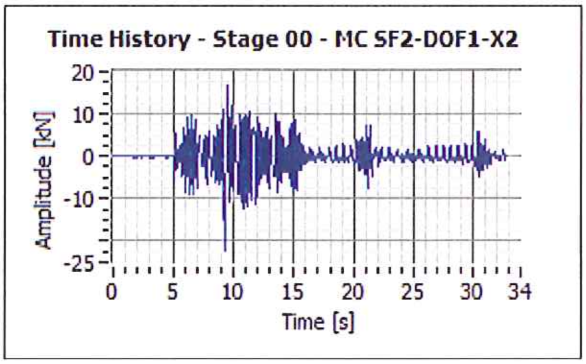

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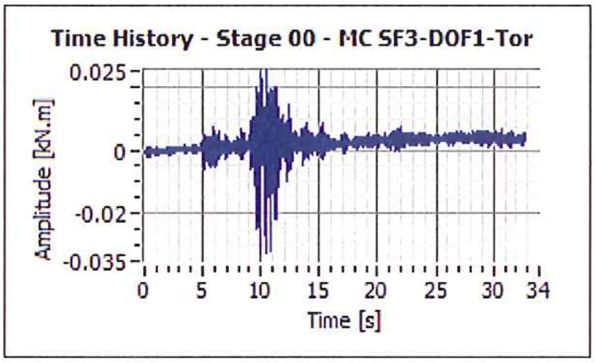

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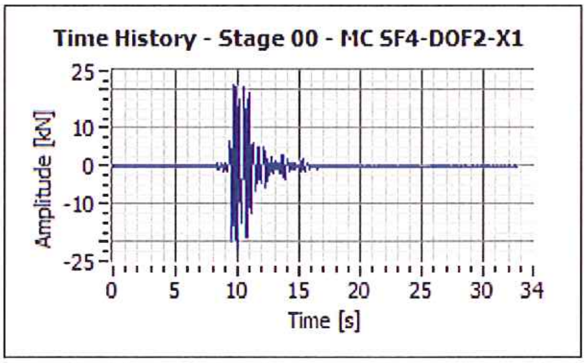

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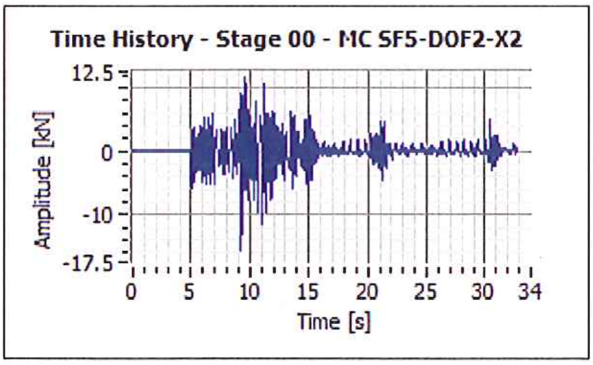


Figure L-11: Time History –Story Force DOF2 – Longitudinal Direction – Stage 00

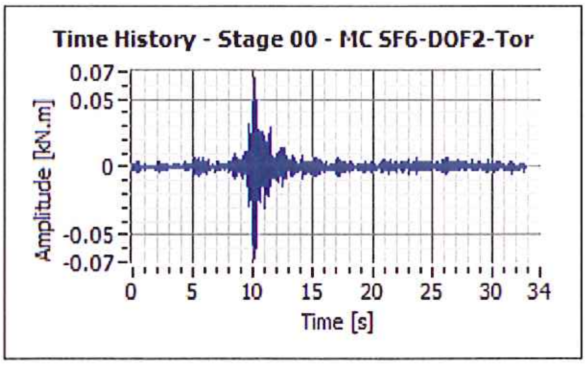


Figure L-12: Time History –Story Torque DOF1 – Stage 00

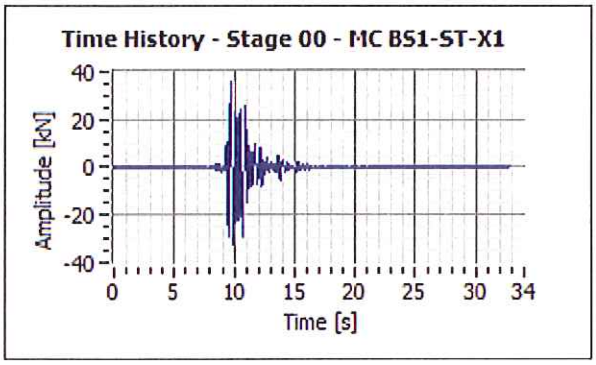


Figure L-13: Time History –Base Shear – Transversal Direction – Stage 00

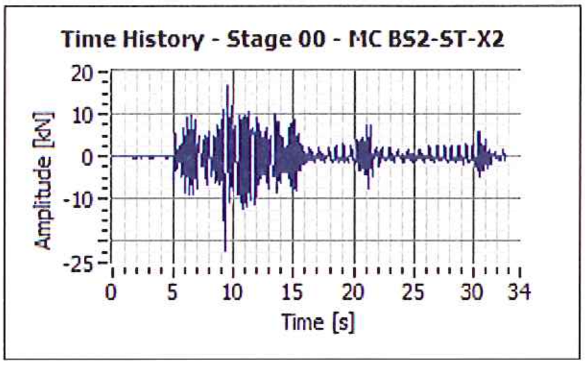


Figure L-14: Time History –Base Shear – Longitudinal Direction – Stage 00

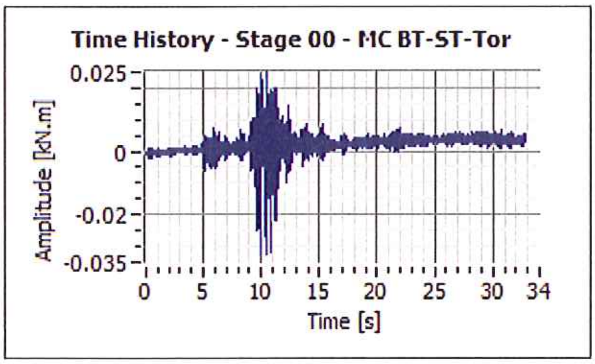


Figure L-15: Time History –Base Torque – Stage 00

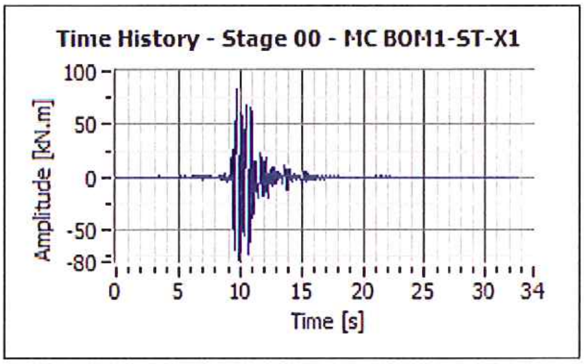


Figure L-16: Time History –Base Overturning Moment –Transversal Direction – Stage 00

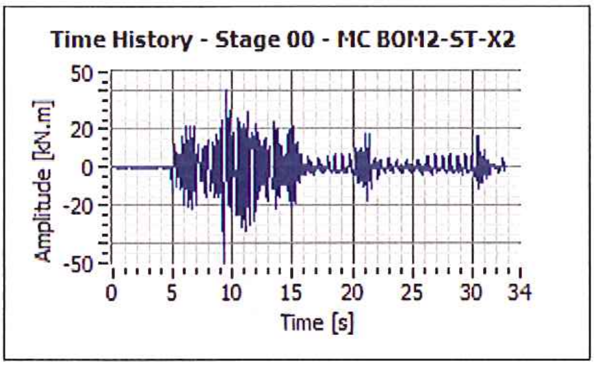


Figure L-17: Time History –Base Overturning Moment –Longitudinal Direction – Stage 00

L.2 Stage 01

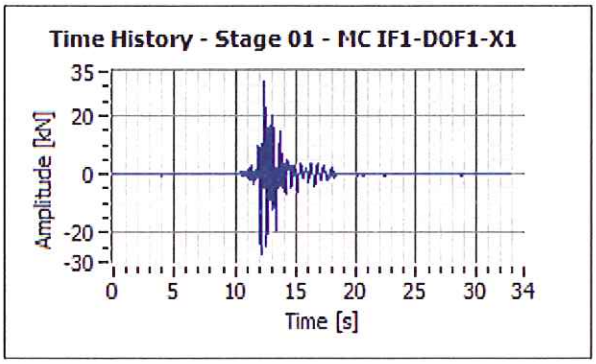


Figure L-18: Time History –Inertia Force DOF1 – Transversal Direction – Stage 01

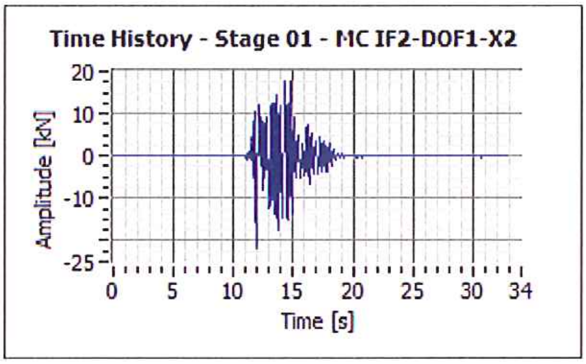


Figure L-19: Time History –Inertia Force DOF1 – Longitudinal Direction – Stage 01

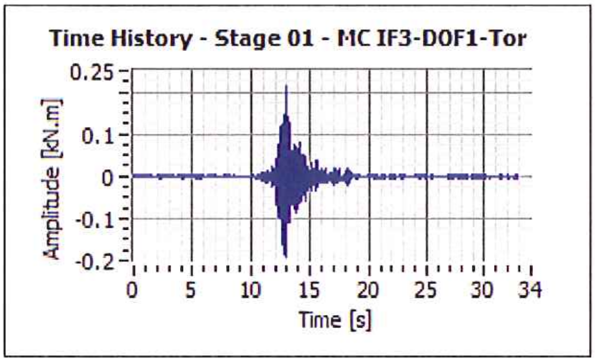


Figure L-20: Time History –Inertia Torque DOF1 – Stage 01

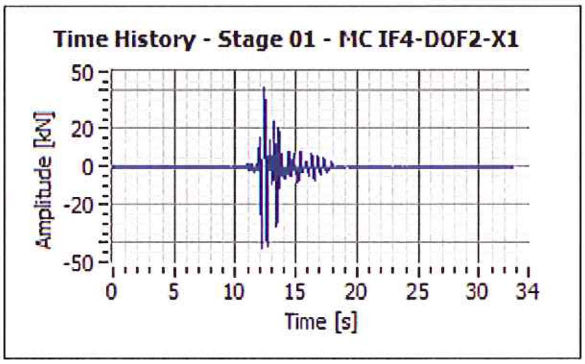


Figure L-21: Time History –Inertia Force DOF2 – Transversal Direction – Stage 01

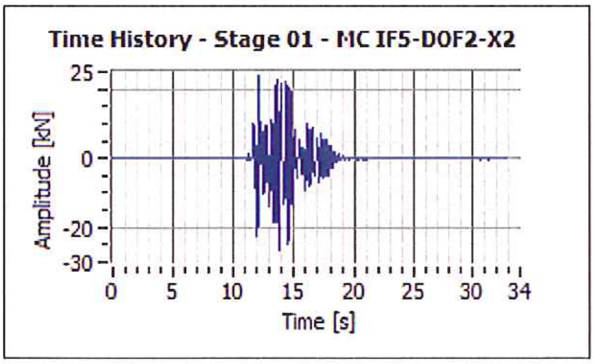


Figure L-22: Time History –Inertia Force DOF2 – Longitudinal Direction – Stage 01

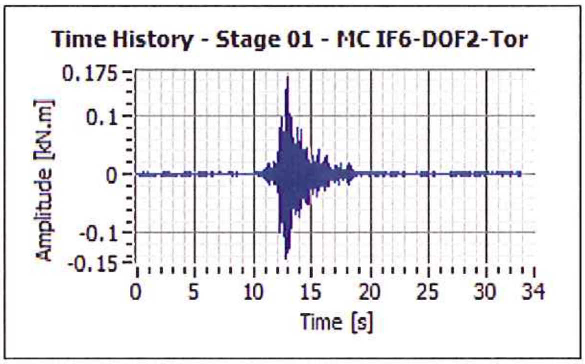


Figure L-23: Time History –Inertia Torque DOF2 – Stage 01

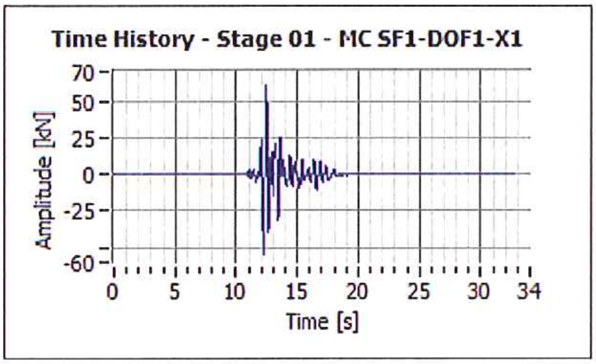


Figure L-24: Time History –Story Force DOF1 – Transversal Direction – Stage 01

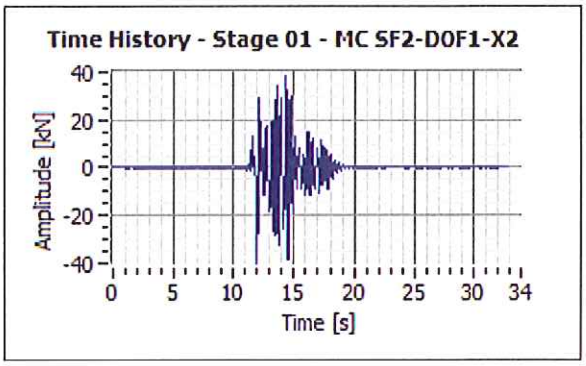


Figure L-25: Time History –Story Force DOF1 – Longitudinal Direction – Stage 01

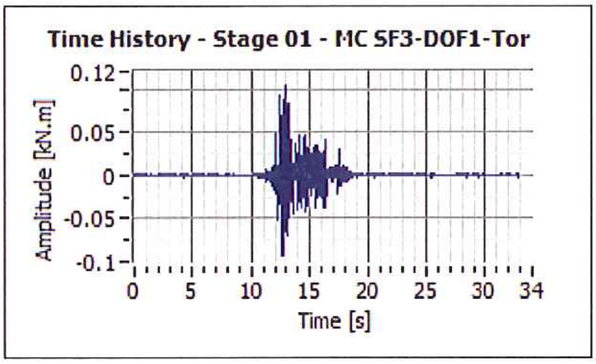


Figure L-26: Time History –Story Torque DOF1 – Stage 01

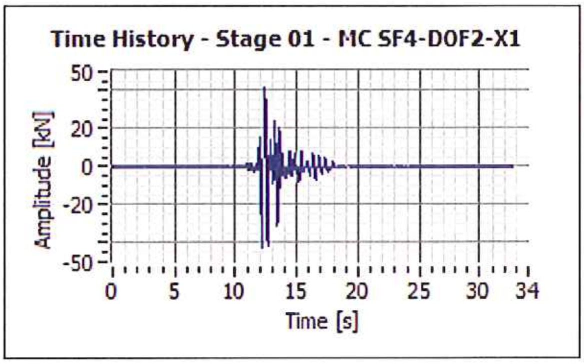


Figure L-27: Time History –Story Force DOF2 – Transversal Direction – Stage 01

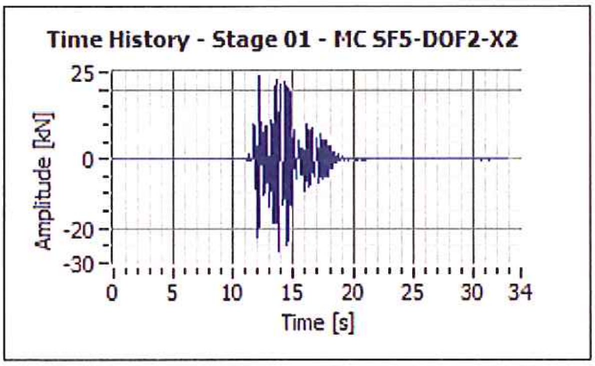


Figure L-28: Time History –Story Force DOF2 – Longitudinal Direction – Stage 01

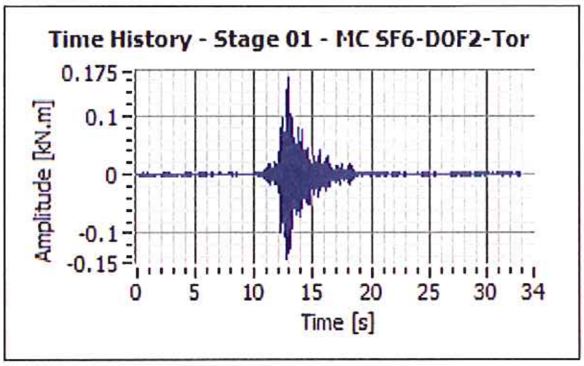


Figure L-29: Time History –Story Torque DOF1 – Stage 01

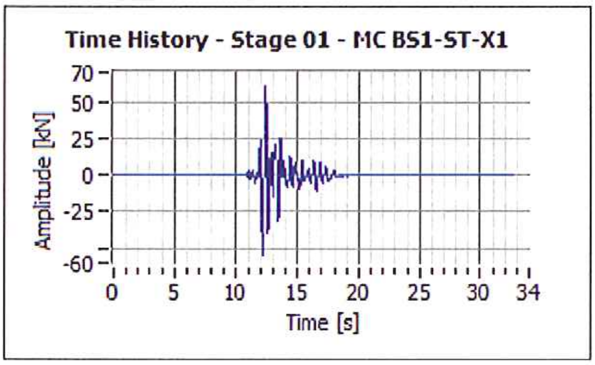


Figure L-30: Time History –Base Shear – Transversal Direction – Stage 01

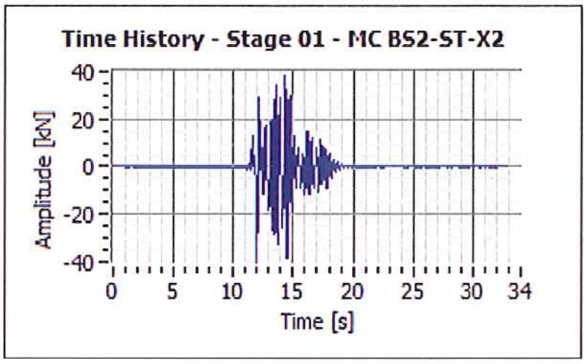


Figure L-31: Time History –Base Shear – Longitudinal Direction – Stage 01

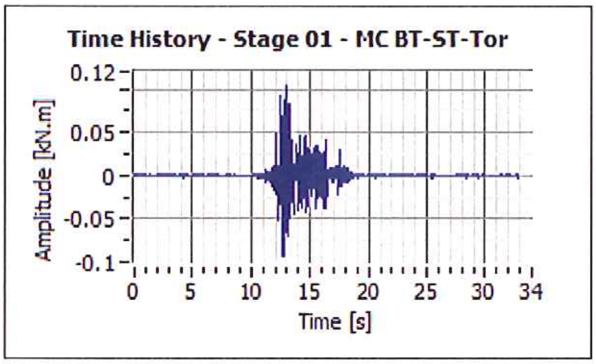


Figure L-32: Time History –Base Torque – Stage 01

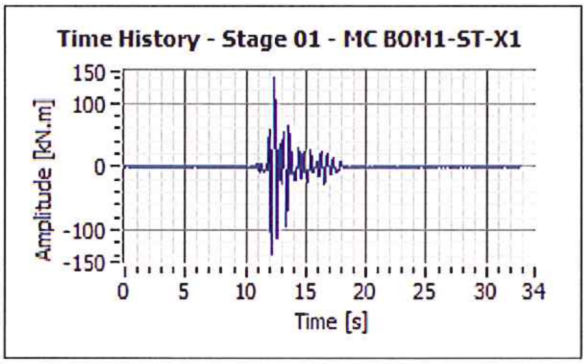


Figure L-33: Time History –Base Overturning Moment –Transversal Direction – Stage 01

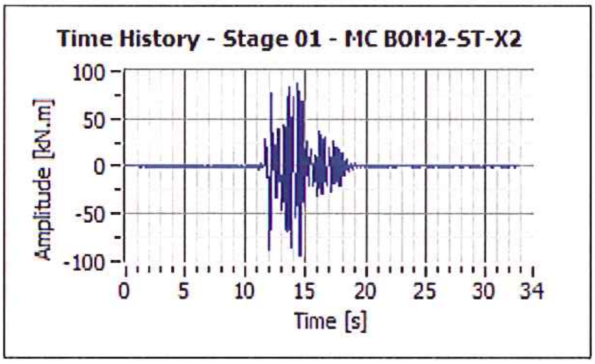


Figure L-34: Time History –Base Overturning Moment –Longitudinal Direction – Stage 01

L.3 Stage 02

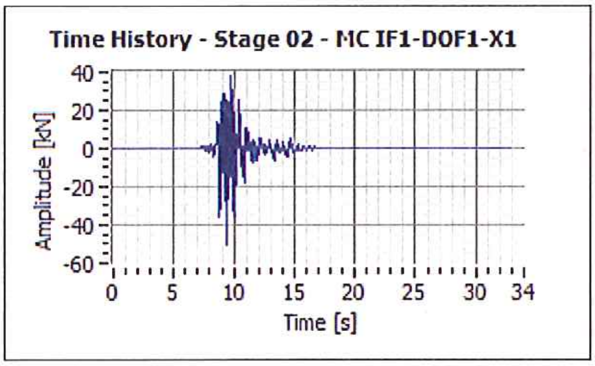


Figure L-35: Time History –Inertia Force DOF1 – Transversal Direction – Stage 02

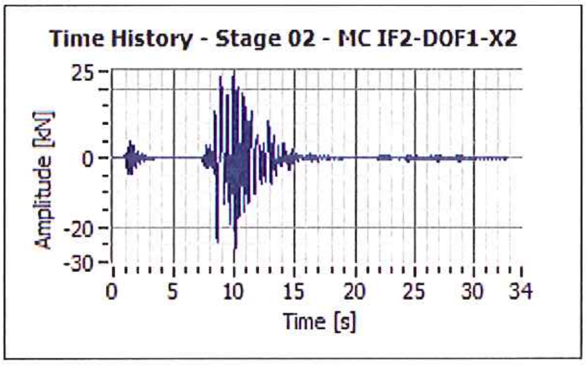


Figure L-36: Time History –Inertia Force DOF1 – Longitudinal Direction – Stage 02

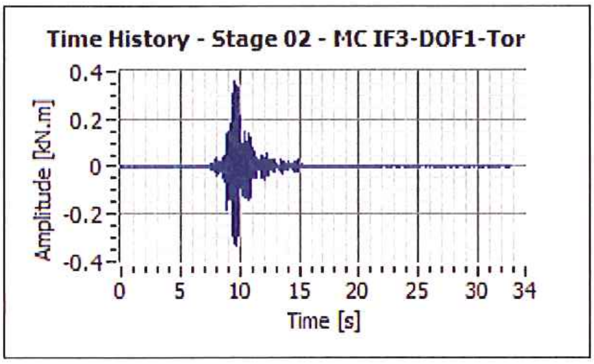


Figure L-37: Time History –Inertia Torque DOF1 – Stage 02

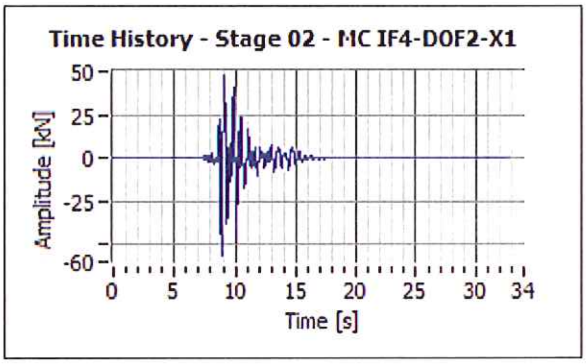


Figure L-38: Time History –Inertia Force DOF2 – Transversal Direction – Stage 02

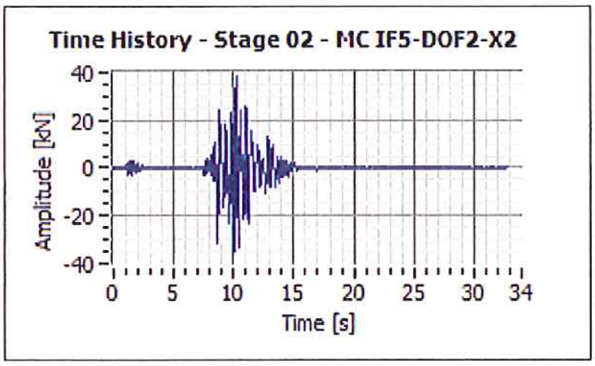


Figure L-39: Time History –Inertia Force DOF2 – Longitudinal Direction – Stage 02

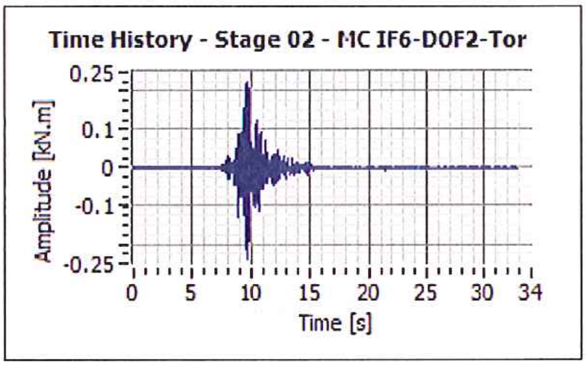


Figure L-40: Time History –Inertia Torque DOF2 – Stage 02

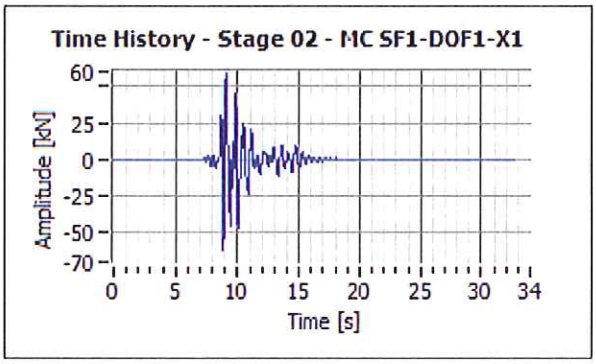


Figure L-41: Time History –Story Force DOF1 – Transversal Direction – Stage 02

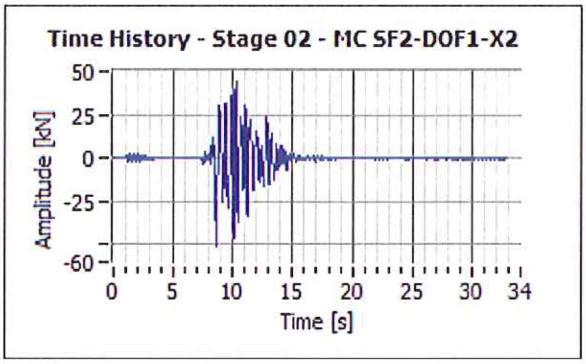


Figure L-42: Time History –Story Force DOF1 – Longitudinal Direction – Stage 02

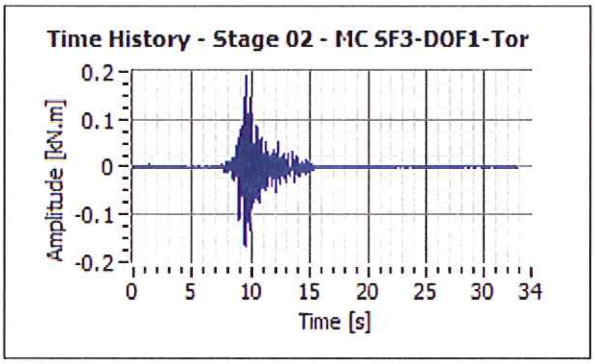


Figure L-43: Time History –Story Torque DOF1 – Stage 02

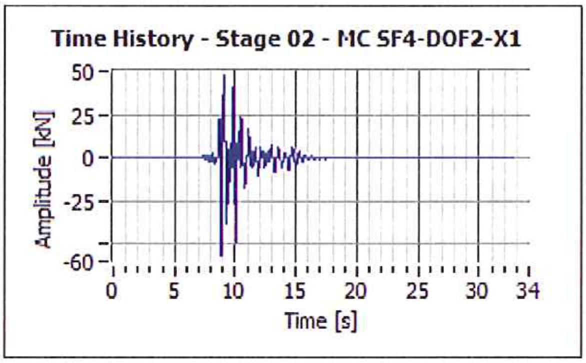


Figure L-44: Time History –Story Force DOF2 – Transversal Direction – Stage 02

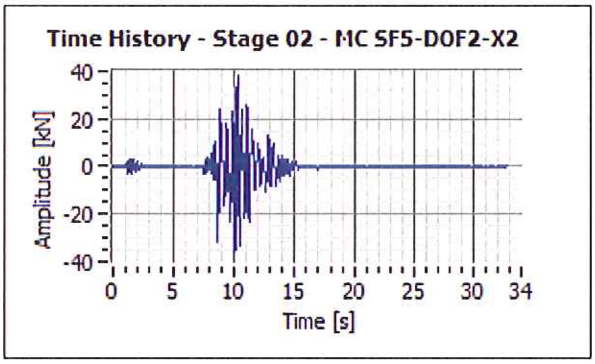


Figure L-45: Time History –Story Force DOF2 – Longitudinal Direction – Stage 02

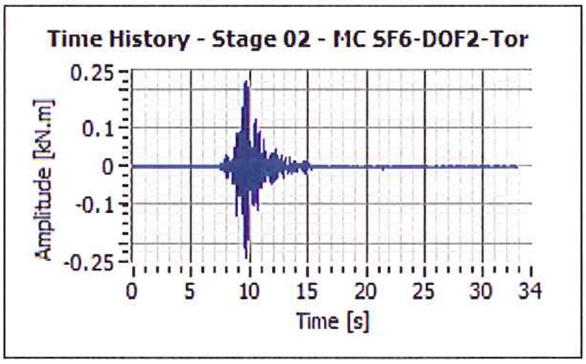


Figure L-46: Time History –Story Torque DOF1 – Stage 02

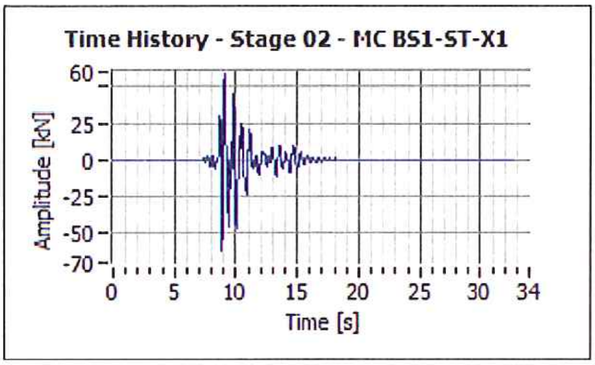


Figure L-47: Time History –Base Shear – Transversal Direction – Stage 02

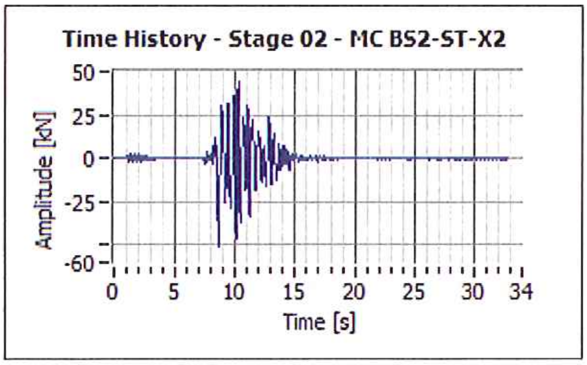


Figure L-48: Time History –Base Shear – Longitudinal Direction – Stage 02

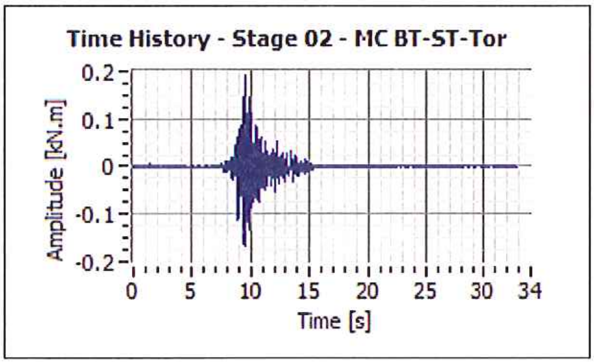


Figure L-49: Time History –Base Torque – Stage 02

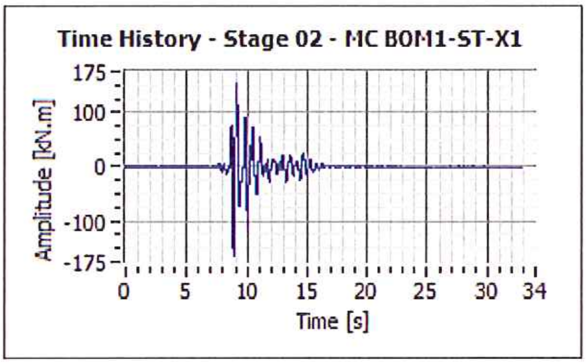


Figure L-50: Time History –Base Overturning Moment –Transversal Direction – Stage 02

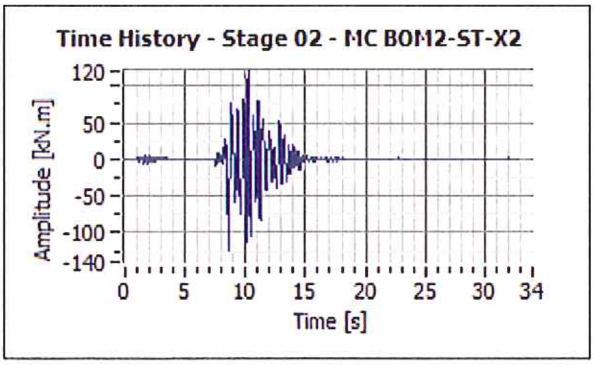


Figure L-51: Time History –Base Overturning Moment –Longitudinal Direction – Stage 02

L.4 Stage 03

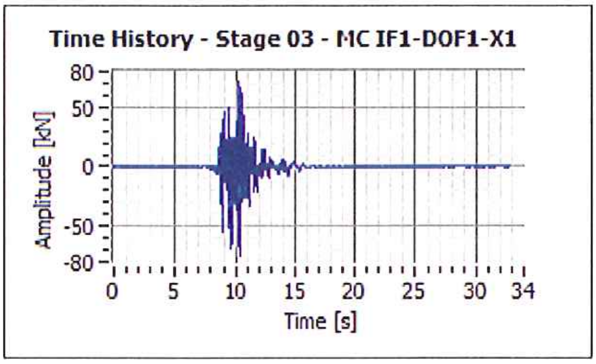


Figure L-52: Time History –Inertia Force DOF1 – Transversal Direction – Stage 03

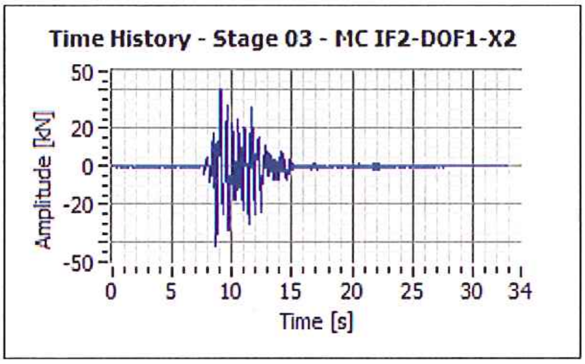


Figure L-53: Time History –Inertia Force DOF1 – Longitudinal Direction – Stage 03

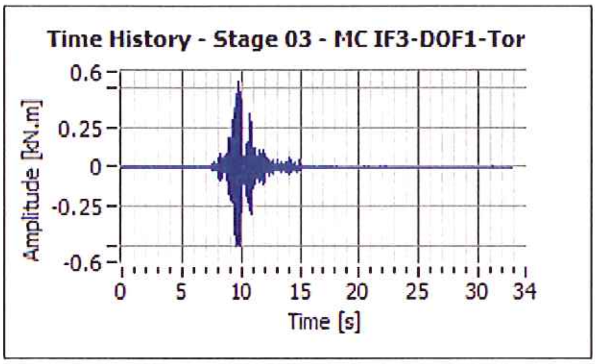


Figure L-54: Time History –Inertia Torque DOF1 – Stage 03

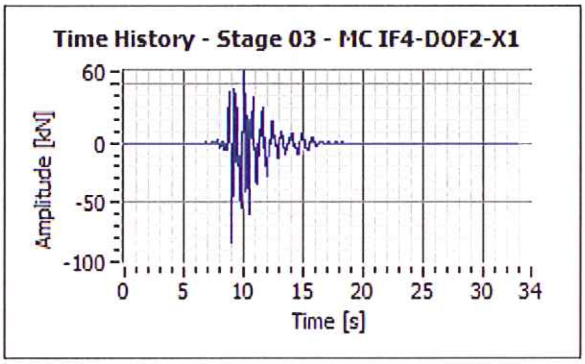


Figure L-55: Time History –Inertia Force DOF2 – Transversal Direction – Stage 03

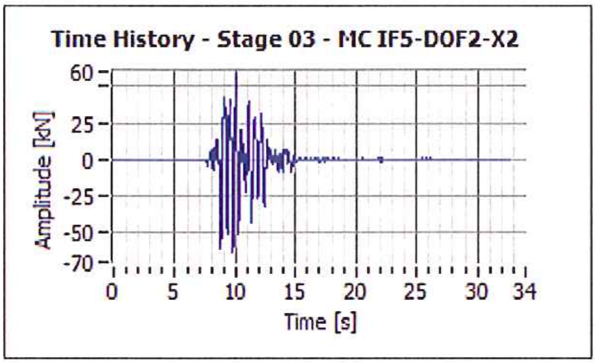


Figure L-56: Time History –Inertia Force DOF2 – Longitudinal Direction – Stage 03

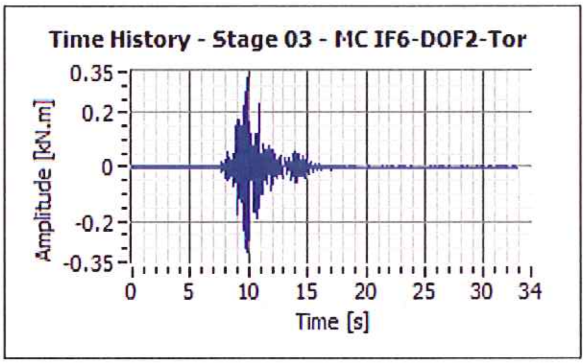


Figure L-57: Time History –Inertia Torque DOF2 – Stage 03

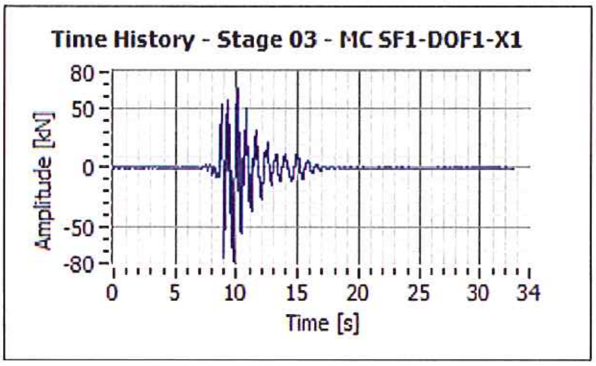


Figure L-58: Time History –Story Force DOF1 – Transversal Direction – Stage 03

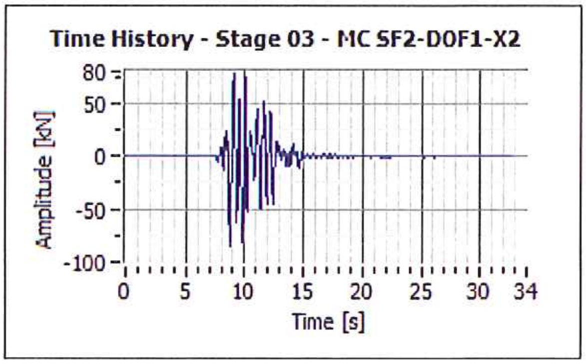


Figure L-59: Time History –Story Force DOF1 – Longitudinal Direction – Stage 03

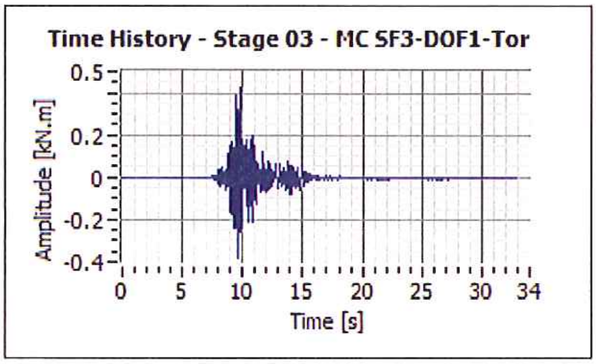


Figure L-60: Time History –Story Torque DOF1 – Stage 03

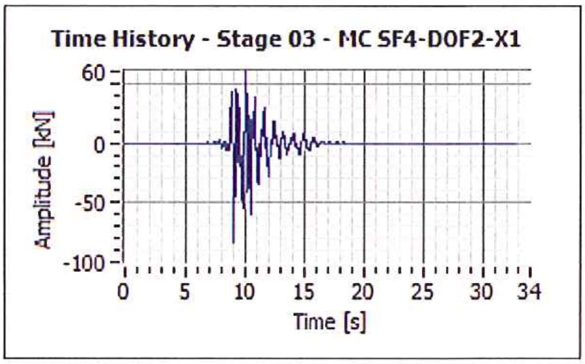


Figure L-61: Time History –Story Force DOF2 – Transversal Direction – Stage 03

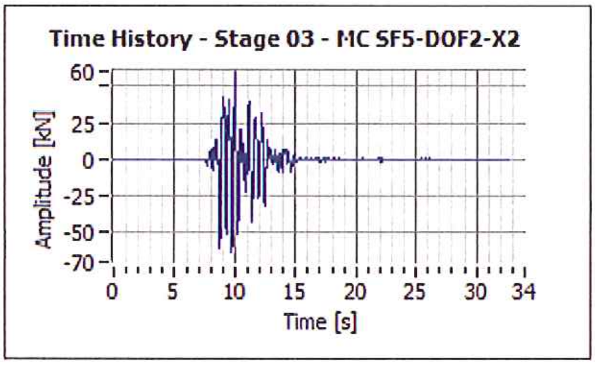


Figure L-62: Time History –Story Force DOF2 – Longitudinal Direction – Stage 03

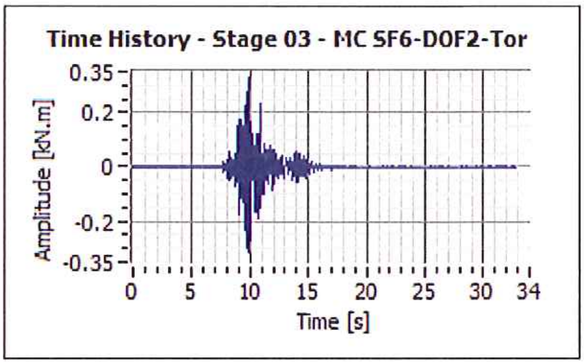


Figure L-63: Time History –Story Torque DOF1 – Stage 03

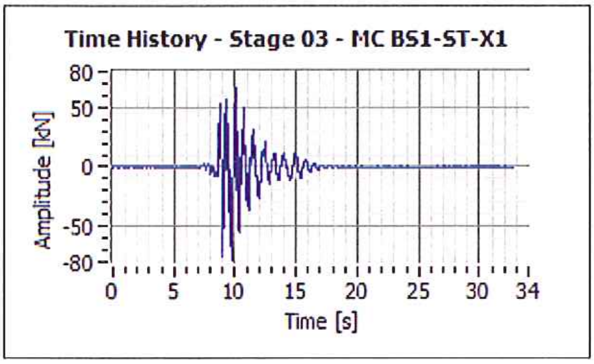


Figure L-64: Time History –Base Shear – Transversal Direction – Stage 03

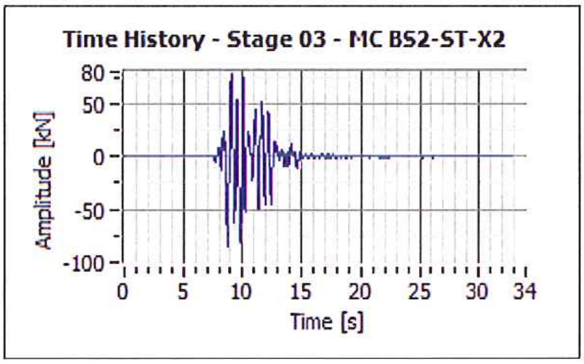


Figure L-65: Time History –Base Shear – Longitudinal Direction – Stage 03

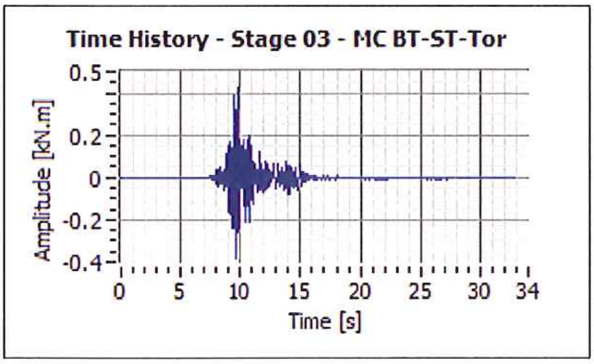


Figure L-66: Time History –Base Torque – Stage 03

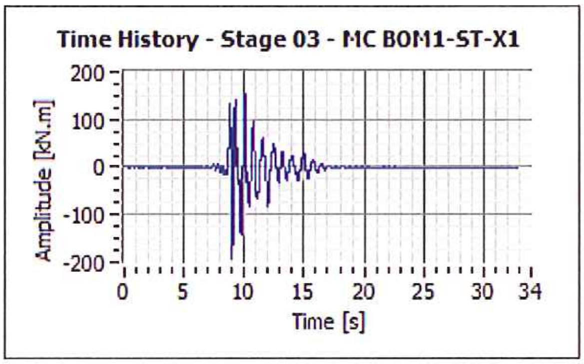


Figure L-67: Time History –Base Overturning Moment –Transversal Direction – Stage 03

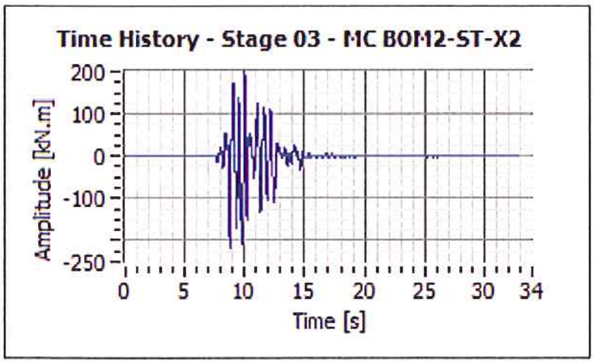


Figure L-68: Time History –Base Overturning Moment –Longitudinal Direction – Stage 03

L.5 Stage 04

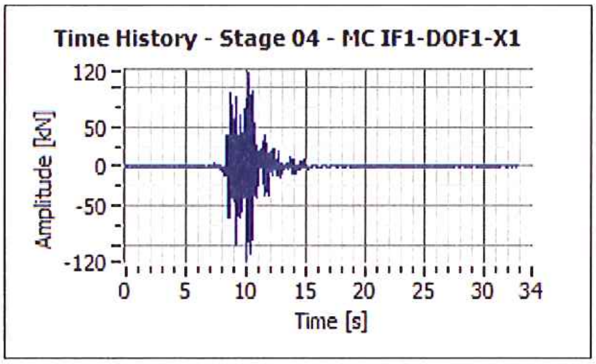


Figure L-69: Time History –Inertia Force DOF1 – Transversal Direction – Stage 04

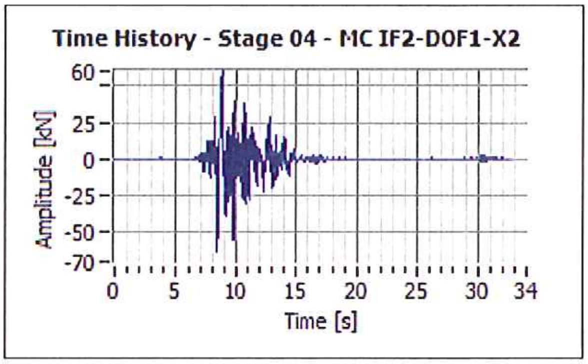


Figure L-70: Time History –Inertia Force DOF1 – Longitudinal Direction – Stage 04

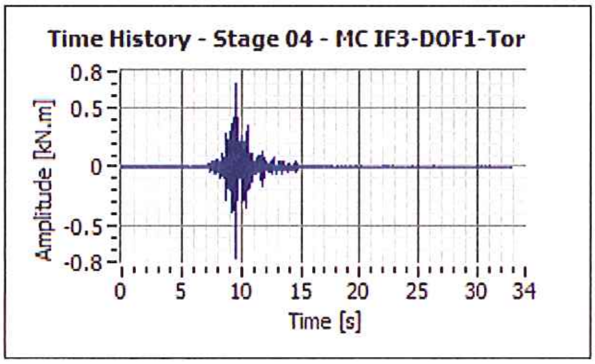


Figure L-71: Time History –Inertia Torque DOF1 – Stage 04

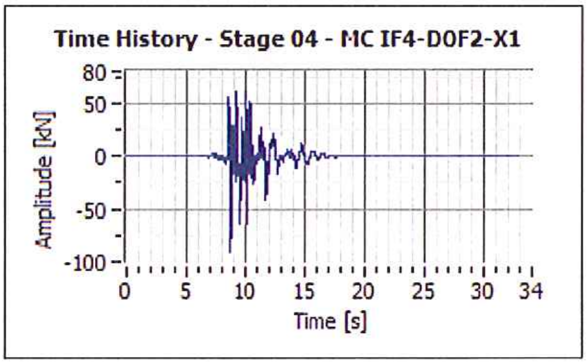


Figure L-72: Time History –Inertia Force DOF2 – Transversal Direction – Stage 04

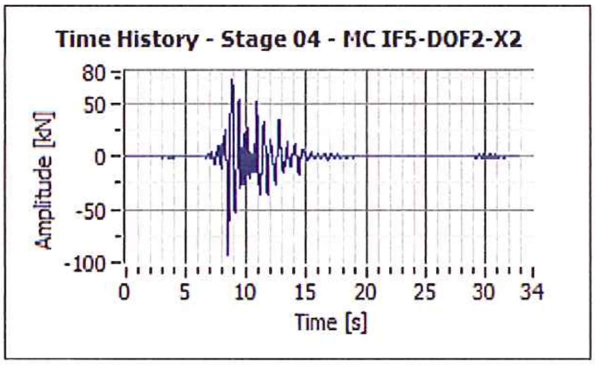


Figure L-73: Time History –Inertia Force DOF2 – Longitudinal Direction – Stage 04

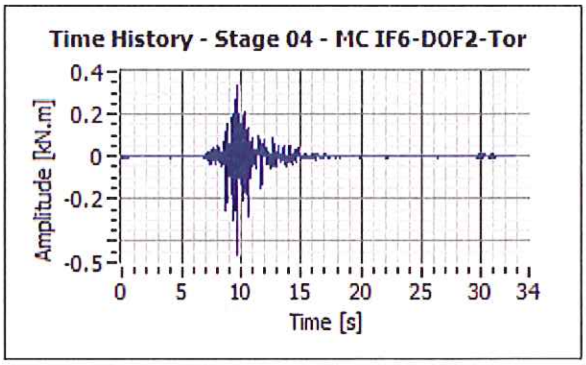


Figure L-74: Time History –Inertia Torque DOF2 – Stage 04

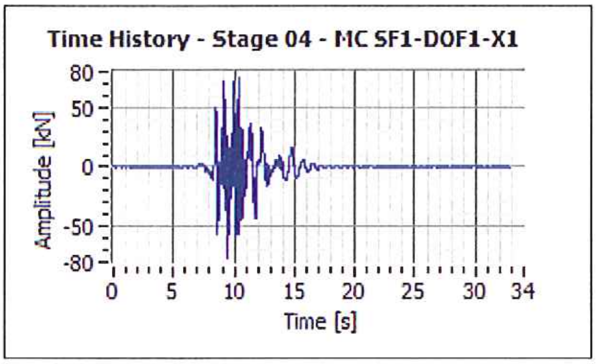


Figure L-75: Time History –Story Force DOF1 – Transversal Direction – Stage 04

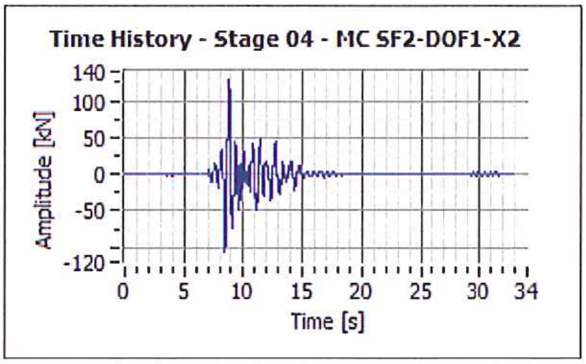


Figure L-76: Time History –Story Force DOF1 – Longitudinal Direction – Stage 04

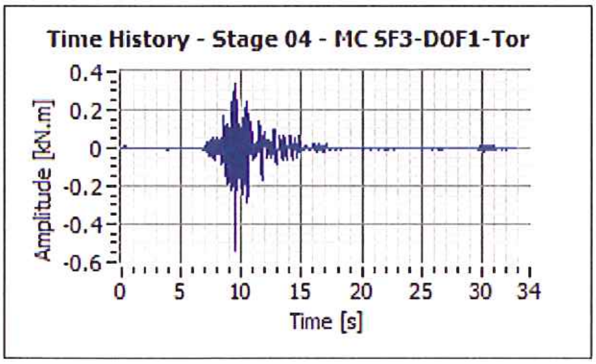


Figure L-77: Time History –Story Torque DOF1 – Stage 04

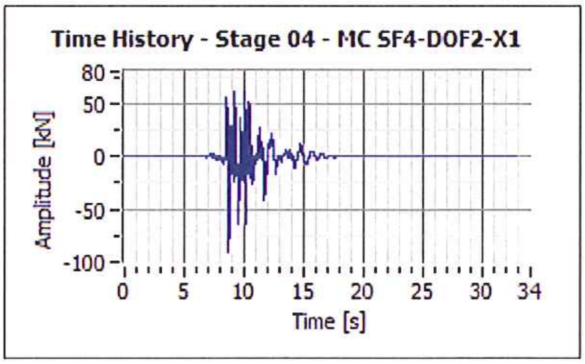


Figure L-78: Time History –Story Force DOF2 – Transversal Direction – Stage 04

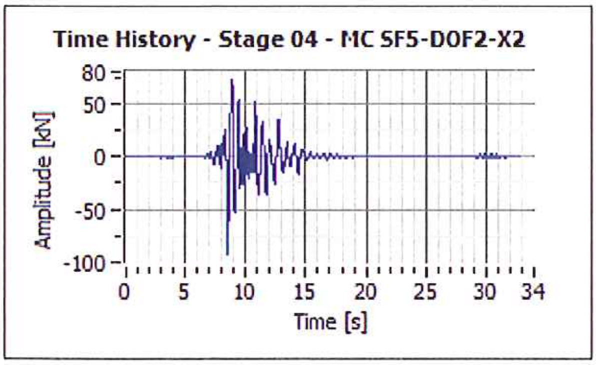


Figure L-79: Time History –Story Force DOF2 – Longitudinal Direction – Stage 04

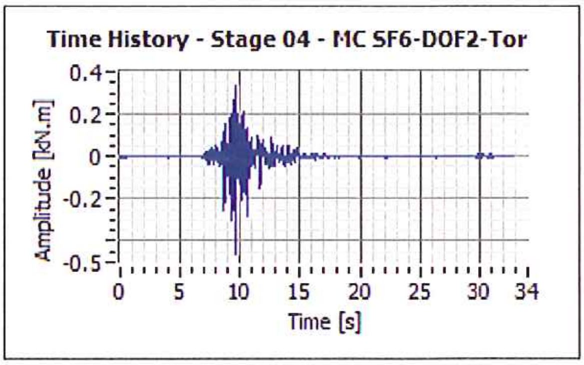


Figure L-80: Time History –Story Torque DOF1 – Stage 04

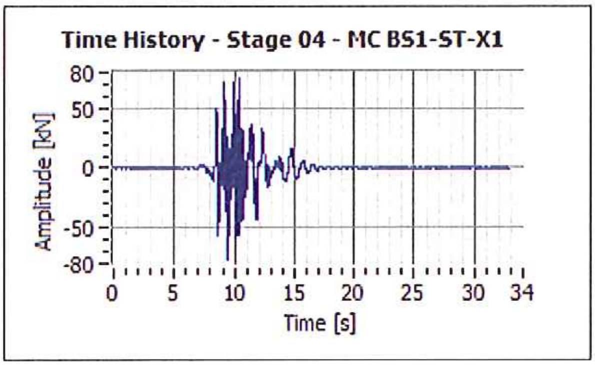
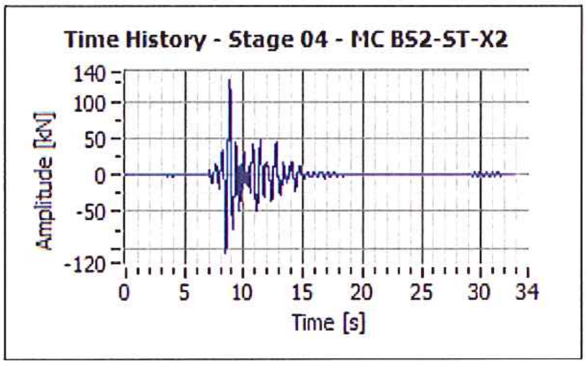


Figure L-81: Time History –Base Shear – Transversal Direction – Stage 04



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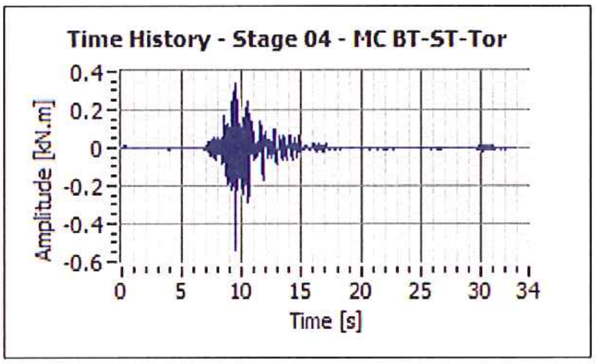

Figure L-83: Time History –Base Torque – Stage 04

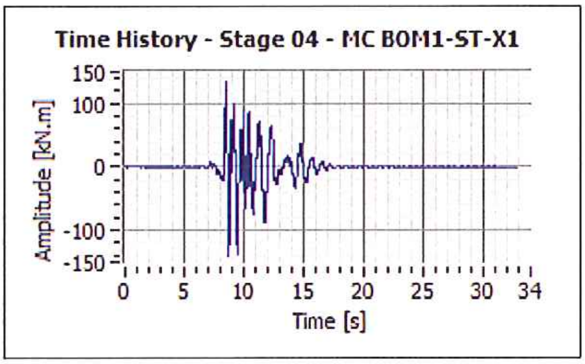

Figure L-84: Time History –Base Overturning Moment –Transversal Direction – Stage 04

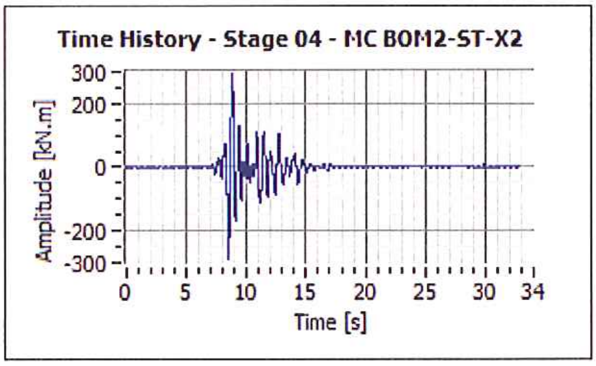

Figure L-85: Time History –Base Overturning Moment –Longitudinal Direction – Stage 04

ANNEX M HISTERESIS LOOPS

List of Figures:

M.1 Global Histeresis Loops

M.1.1 Stage 00

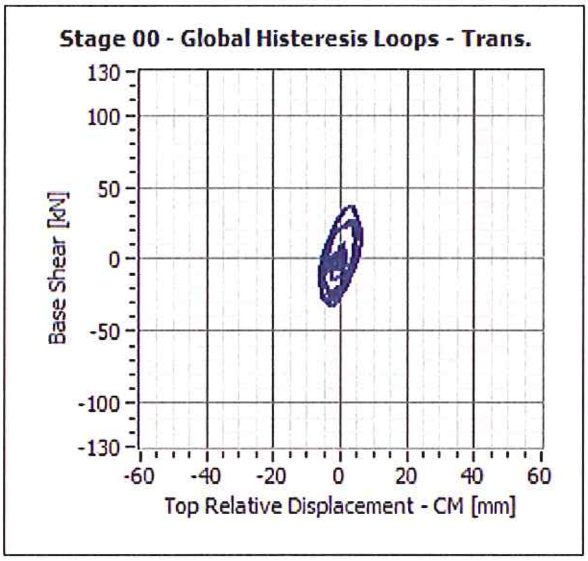

Figure M-1: Global Histeresis Loops – Transversal Direction – Stage 00

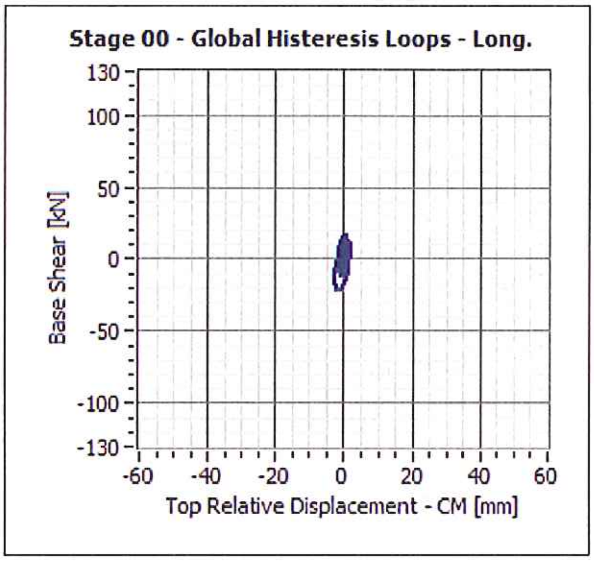

Figure M-2: Global Histeresis Loops – Longitudinal Direction – Stage 00

M.1.2 Stage 01

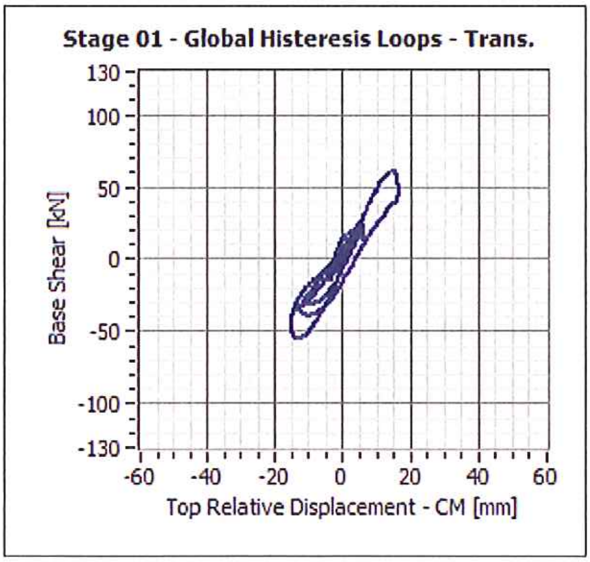

Figure M-3: Global Histeresis Loops – Transversal Direction – Stage 01

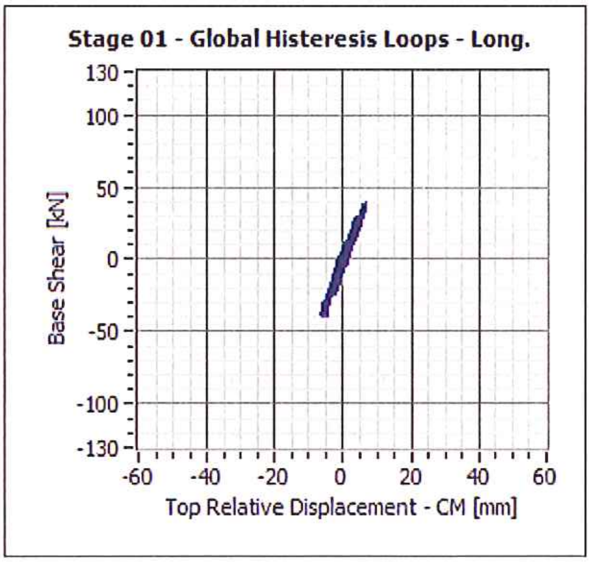

Figure M-4: Global Histeresis Loops – Longitudinal Direction – Stage 01

M.1.3 Stage 02

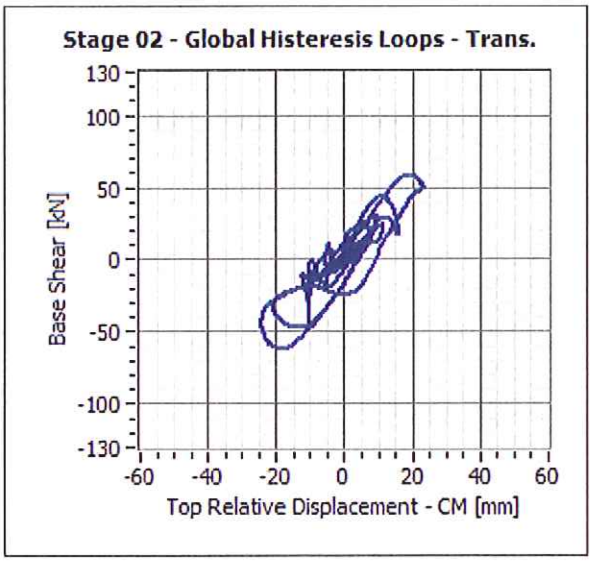

Figure M-5: Global Histeresis Loops – Transversal Direction – Stage 02

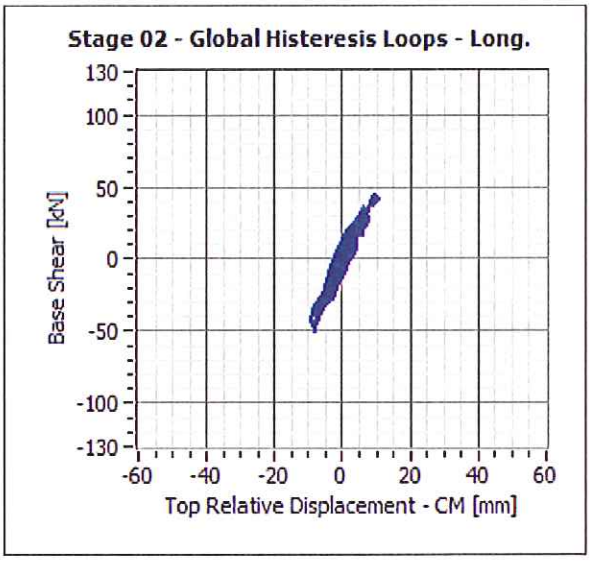

Figure M-6: Global Histeresis Loops – Longitudinal Direction – Stage 02

M.1.4 Stage 03

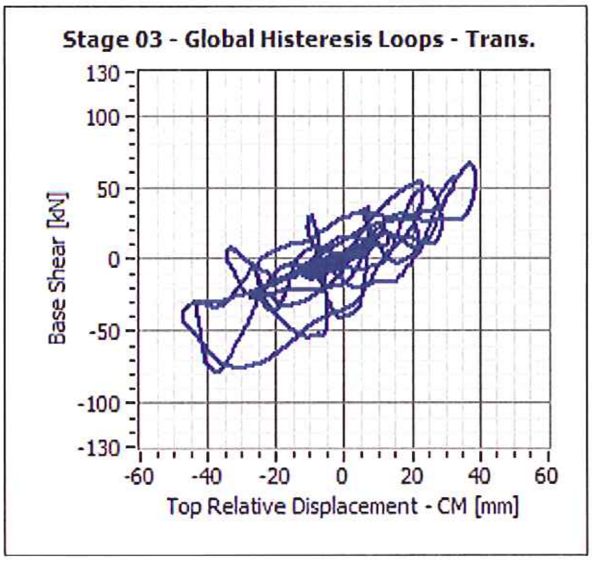

Figure M-7: Global Histeresis Loops – Transversal Direction – Stage 03

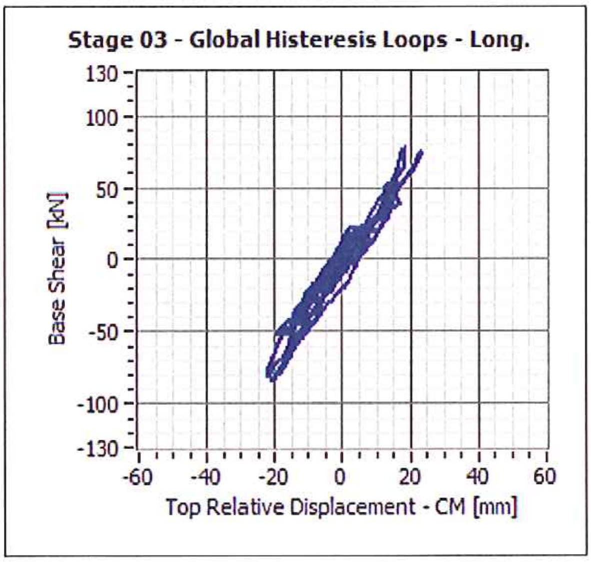

Figure M-8: Global Histeresis Loops – Longitudinal Direction – Stage 03

M.1.5 Stage 04

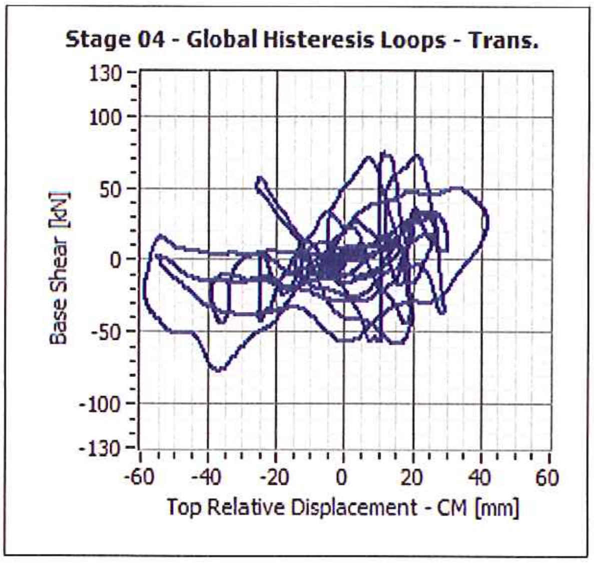

Figure M-9: Global Histeresis Loops – Transversal Direction – Stage 04

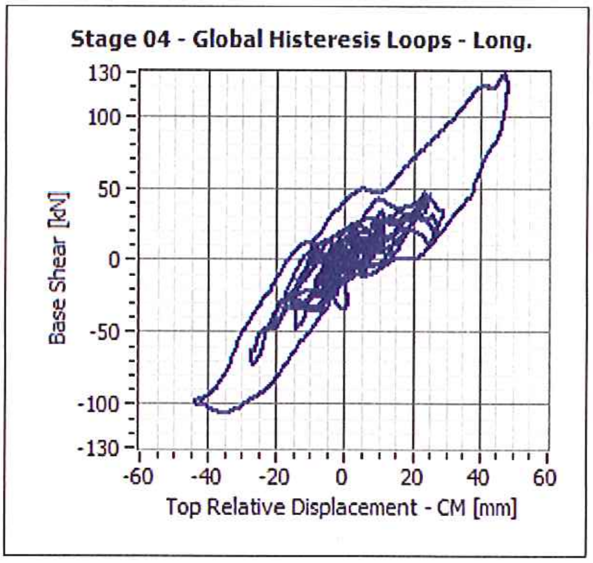

Figure M-10: Global Histeresis Loops – Longitudinal Direction – Stage 04

M.2 Storey Histeresis Loops

M.2.1 Stage 00

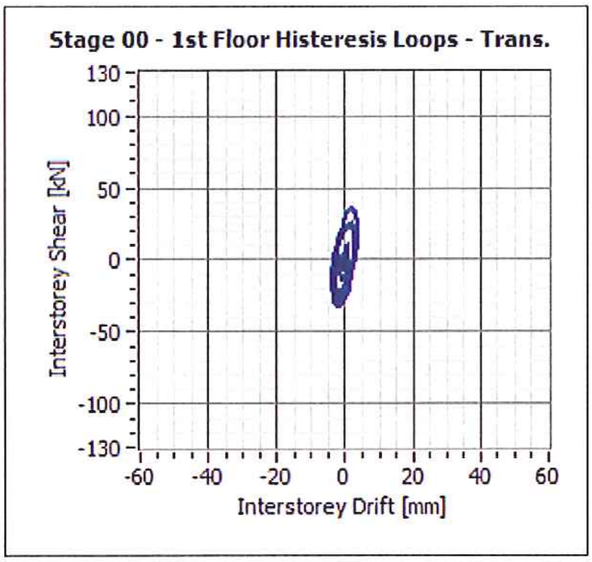

Figure M-11: Storey Histeresis Loops – 1st Floor – Transversal Direction – Stage 00

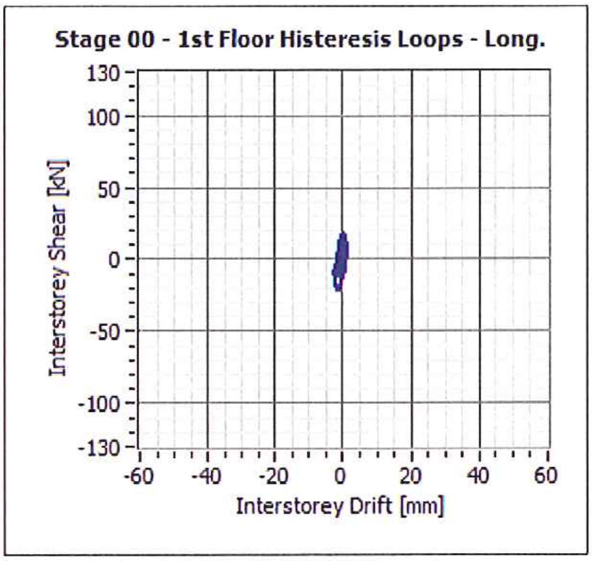

Figure M-12: Storey Histeresis Loops – 1st Floor – Longitudinal Direction – Stage 00

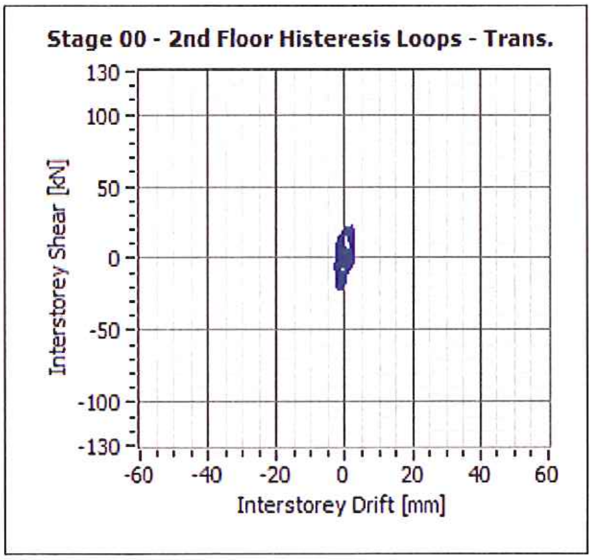

Figure M-13: Storey Histeresis Loops – 2nd Floor – Transversal Direction – Stage 00

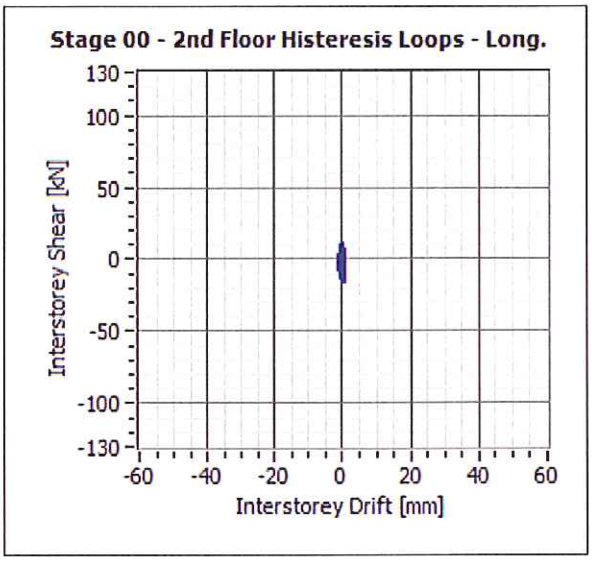

Figure M-14: Storey Histeresis Loops – 2nd Floor – Longitudinal Direction – Stage 00

M.2.2 Stage 01

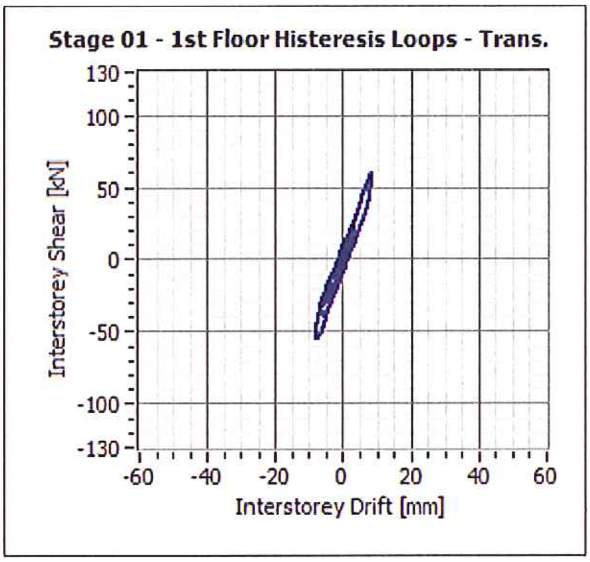

Figure M-15: Storey Histeresis Loops – 1st Floor – Transversal Direction – Stage 01

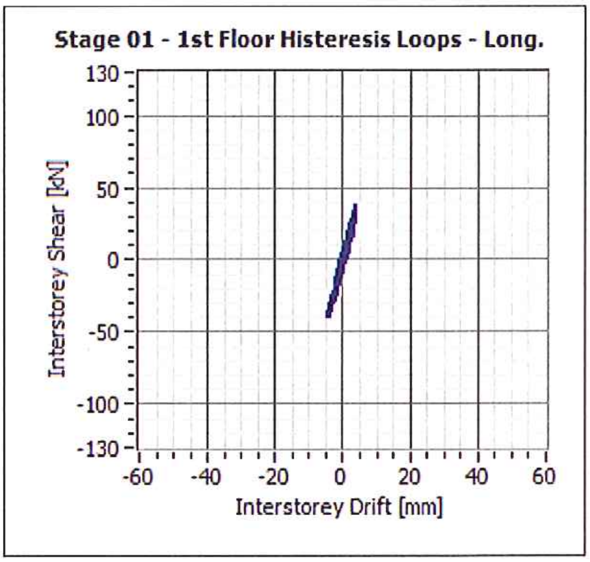

Figure M-16: Storey Histeresis Loops – 1st Floor – Longitudinal Direction – Stage 01

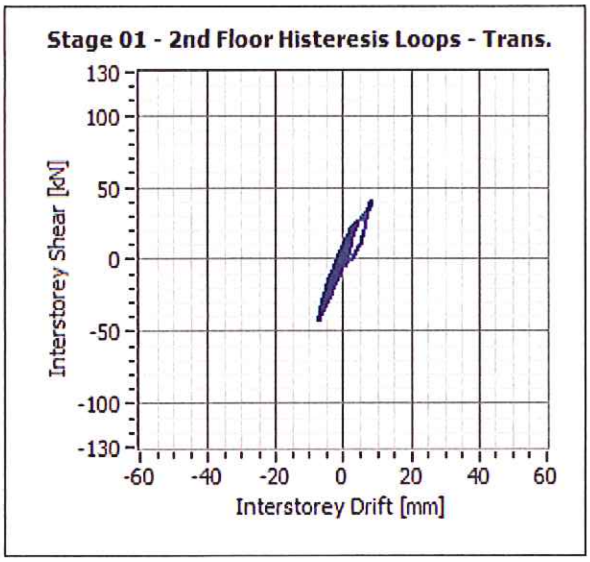

Figure M-17: Storey Histeresis Loops – 2nd Floor – Transversal Direction – Stage 01

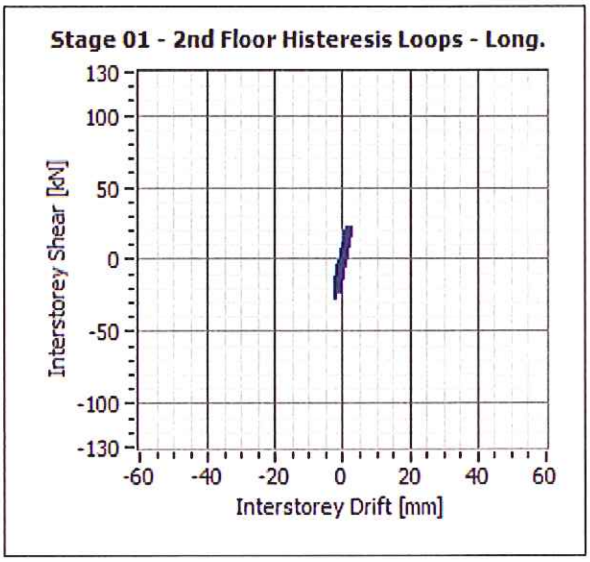

Figure M-18: Storey Histeresis Loops – 2nd Floor – Longitudinal Direction – Stage 01

M.2.3 Stage 02

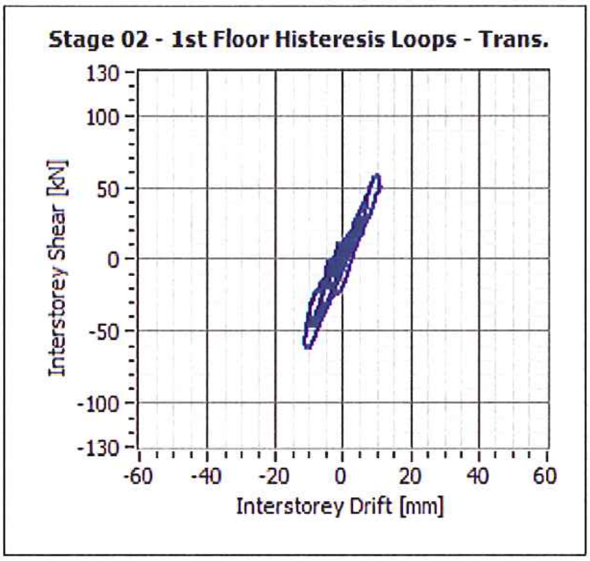

Figure M-19: Storey Histeresis Loops – 1st Floor – Transversal Direction – Stage 02

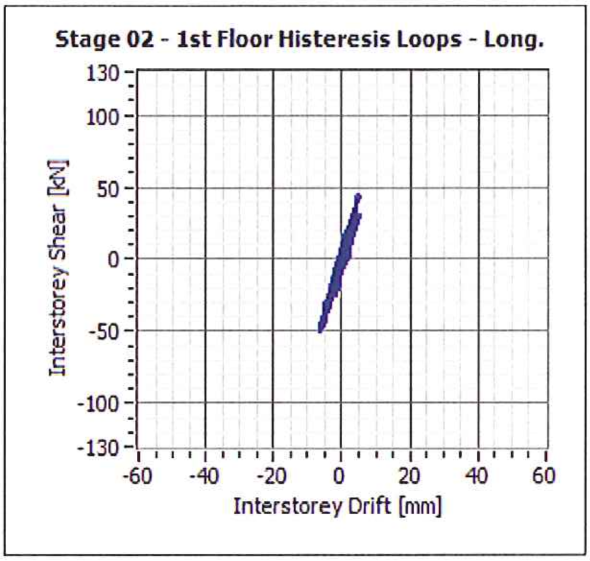

Figure M-20: Storey Histeresis Loops – 1st Floor – Longitudinal Direction – Stage 02

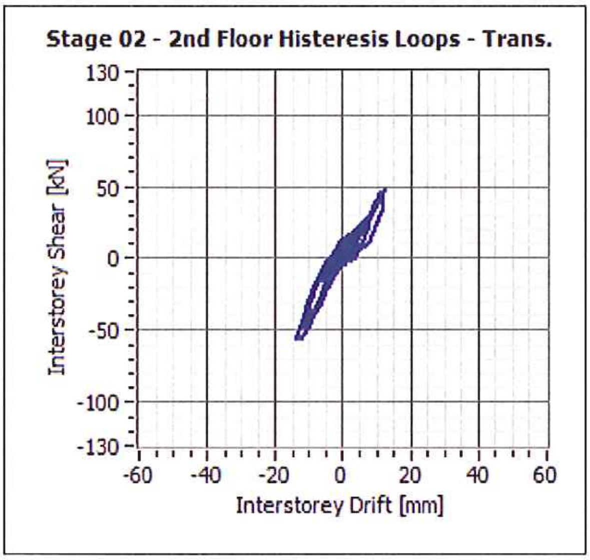

Figure M-21: Storey Histeresis Loops – 2nd Floor – Transversal Direction – Stage 02

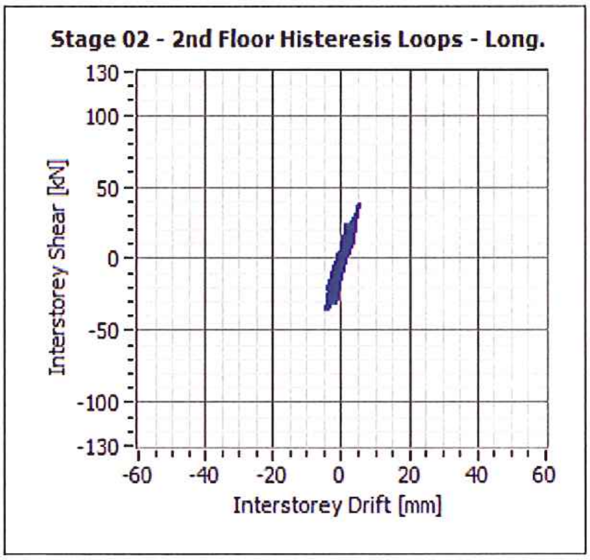

Figure M-22: Storey Histeresis Loops – 2nd Floor – Longitudinal Direction – Stage 02

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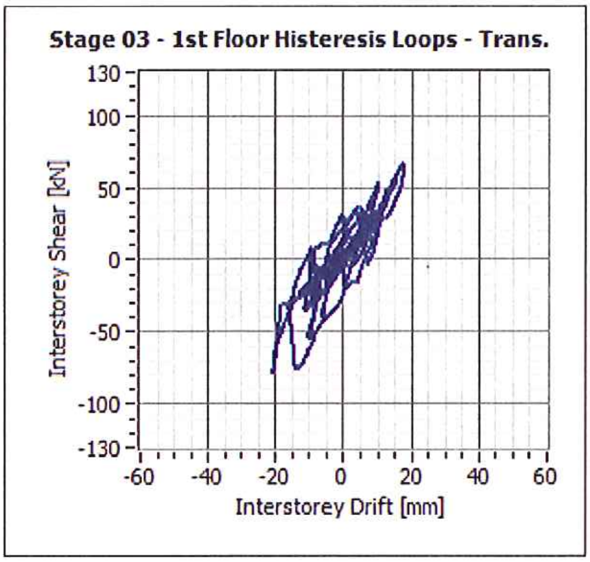


Figure M-23: Storey Histeresis Loops – 1st Floor – Transversal Direction – Stage 03

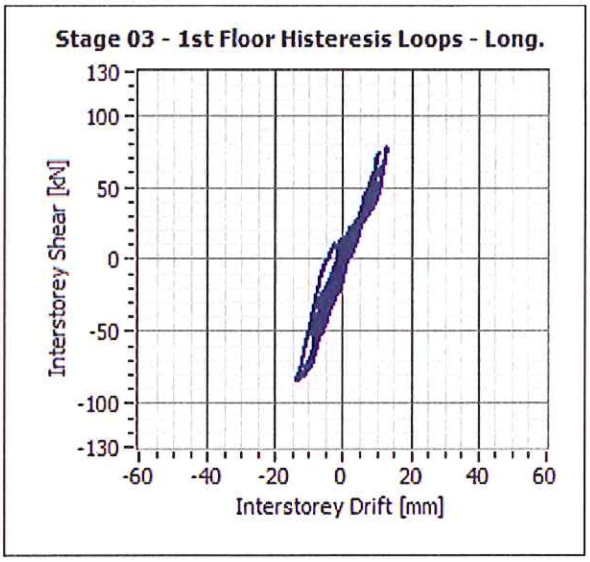


Figure M-24: Storey Histeresis Loops – 1st Floor – Longitudinal Direction – Stage 03

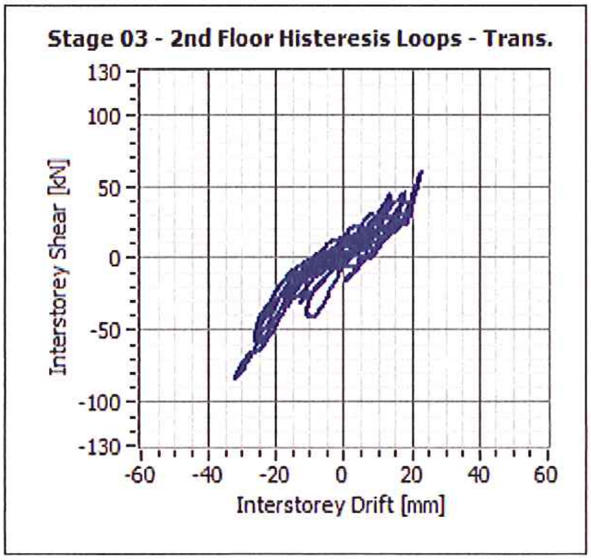


Figure M-25: Storey Histeresis Loops – 2nd Floor – Transversal Direction – Stage 03

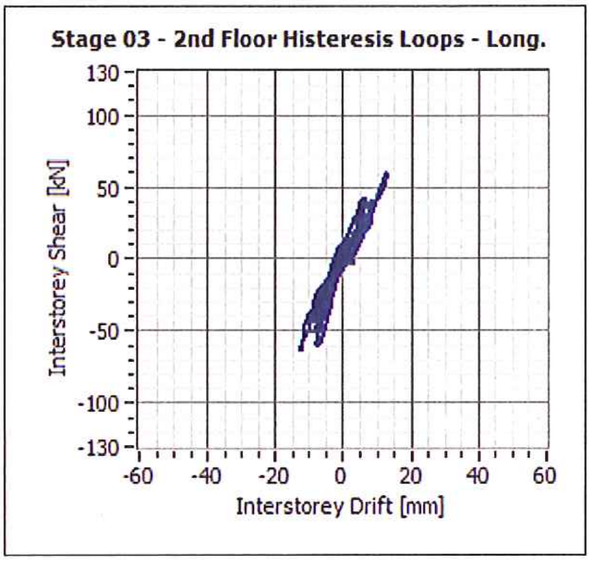


Figure M-26: Storey Histeresis Loops – 2nd Floor – Longitudinal Direction – Stage 03

M.2.5 Stage 04

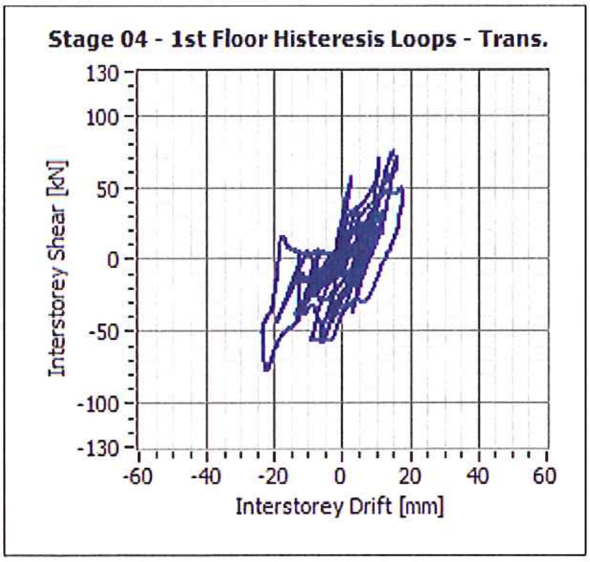


Figure M-27: Storey Histeresis Loops – 1st Floor – Transversal Direction – Stage 04

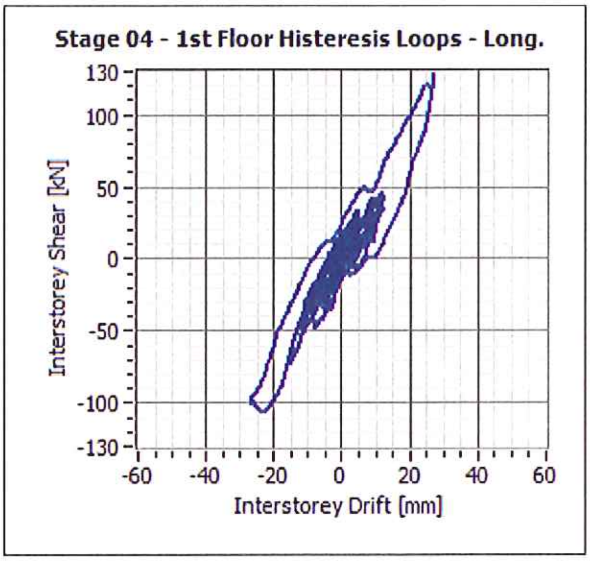


Figure M-28: Storey Histeresis Loops – 1st Floor – Longitudinal Direction – Stage 04

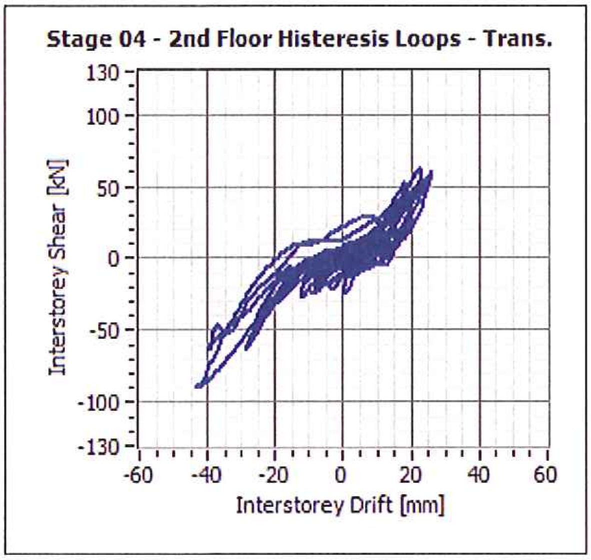


Figure M-29: Storey Histeresis Loops – 2nd Floor – Transversal Direction – Stage 04

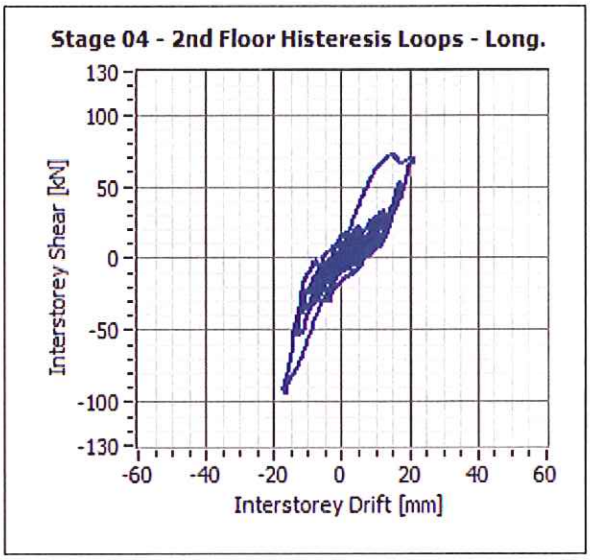
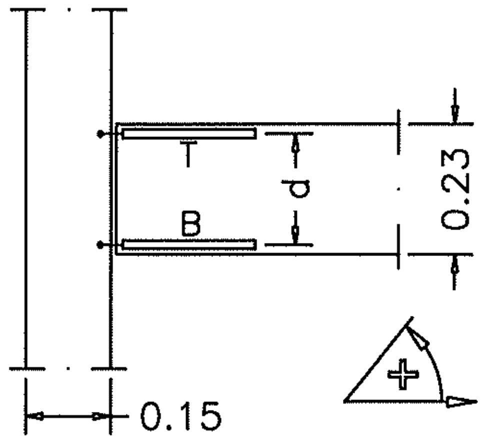


Figure M-30: Storey Histeresis Loops – 2nd Floor – Longitudinal Direction – Stage 04

ANNEX N BEAM-COLUMN CONNECTIONS

List of Figures:

N.1 Math channels



$$RDisp = \frac{T+B}{2}$$

$$Rot = \text{atan}\left(\frac{B-T}{d}\right)$$

Note:

1. In all relative displacements the positive sign means opening of the joint;
2. In all relative rotations the positive sign means closure at the top and opening at the bottom.

Figure N-1: Math channels calculation scheme

N.2 Joint 3 – Transversal Direction

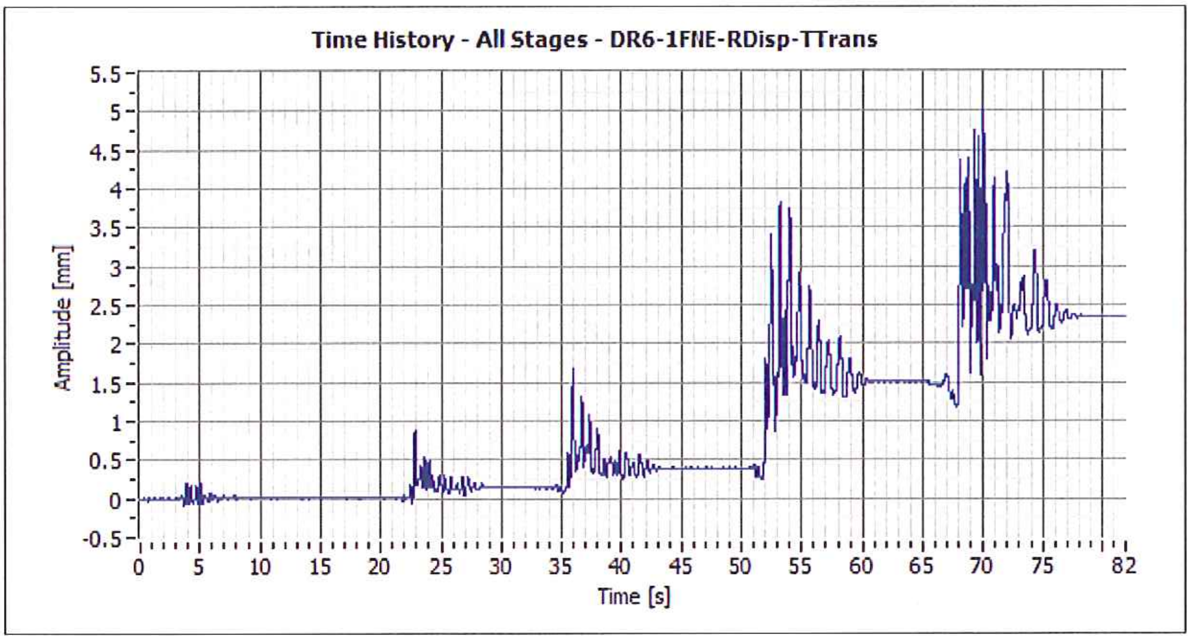


Figure N-2: Time History – Top Relative Displacement – Joint 3 Transversal

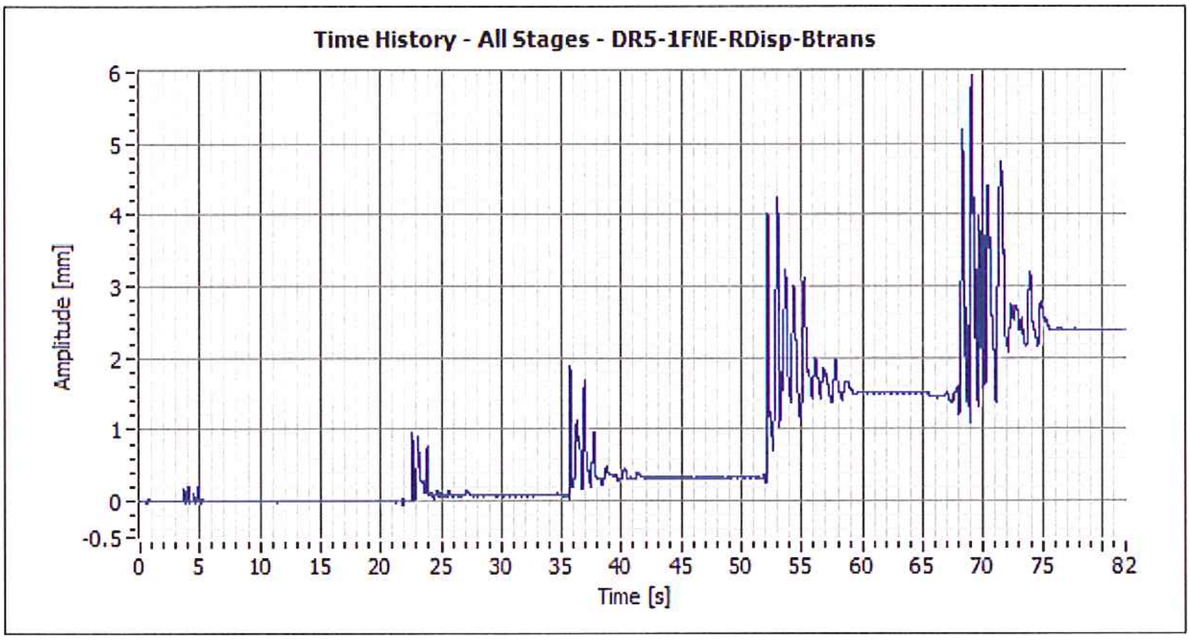


Figure N-3: Time History – Bottom Relative Displacement – Joint 3 Transversal

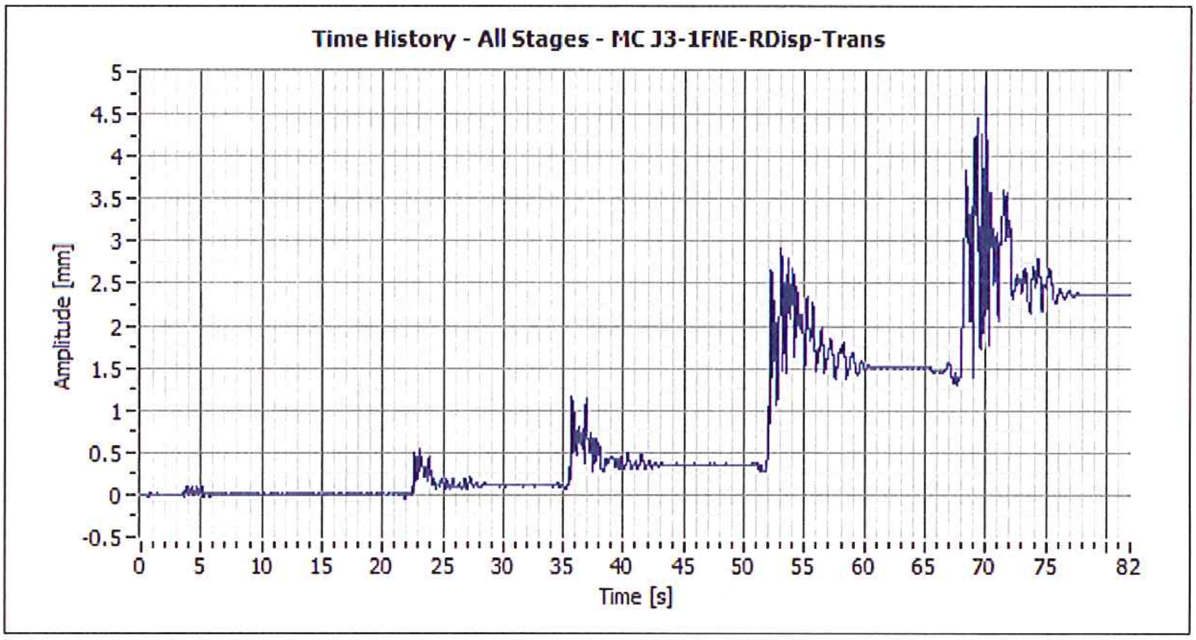


Figure N-4: Time History – Global Relative Displacement – Joint 3 Transversal

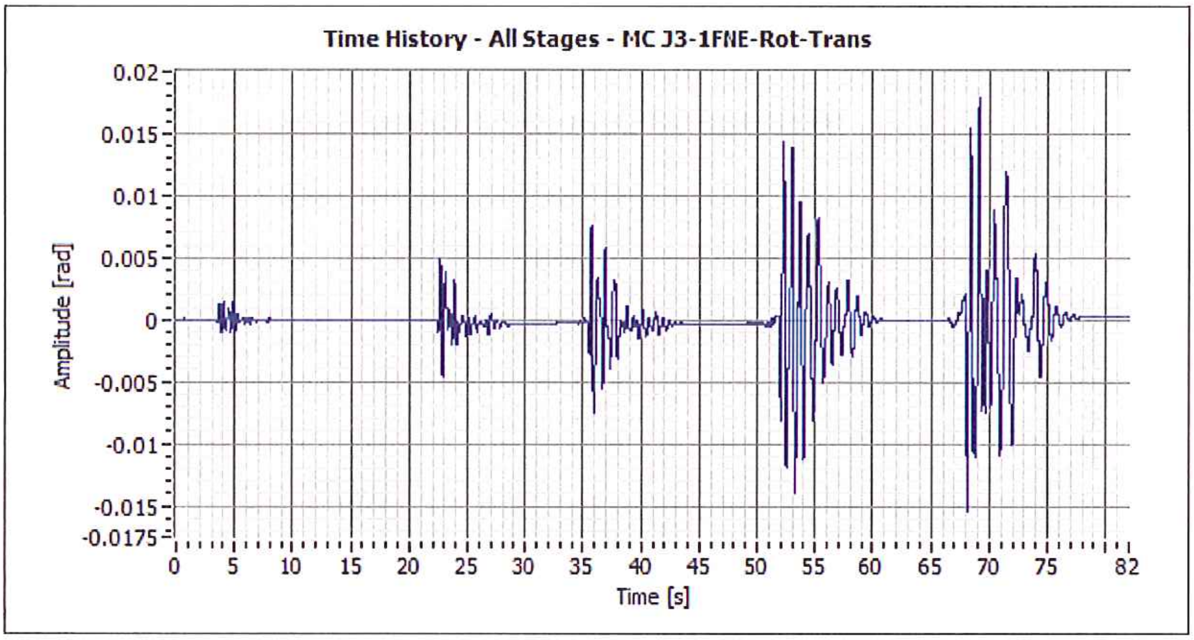


Figure N-5: Time History – Global Relative Rotation – Joint 3 Transversal

N.3 Joint 9 – Transversal Direction

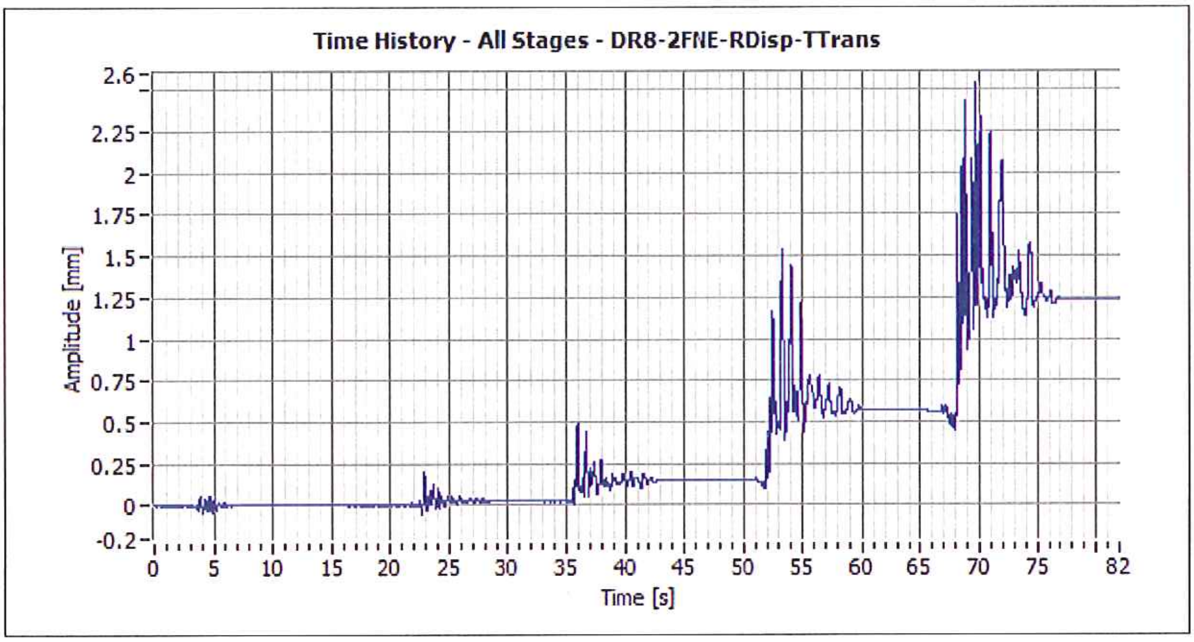


Figure N-6: Time History – Top Relative Displacement – Joint 8 Transversal

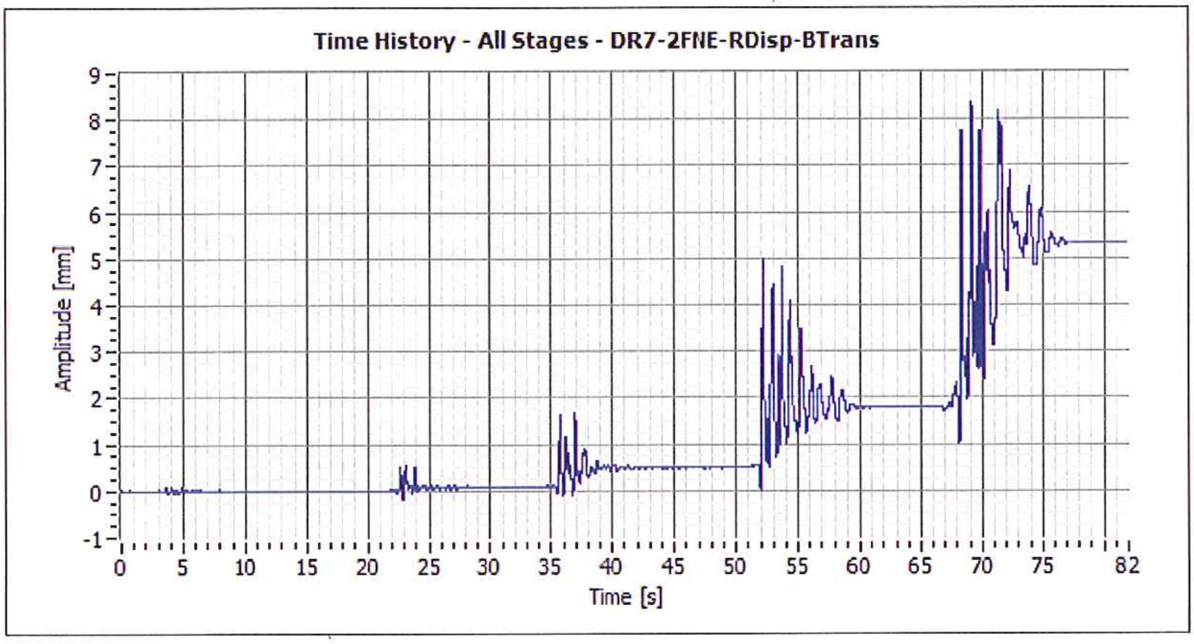


Figure N-7: Time History – Bottom Relative Displacement – Joint 3 Transversal

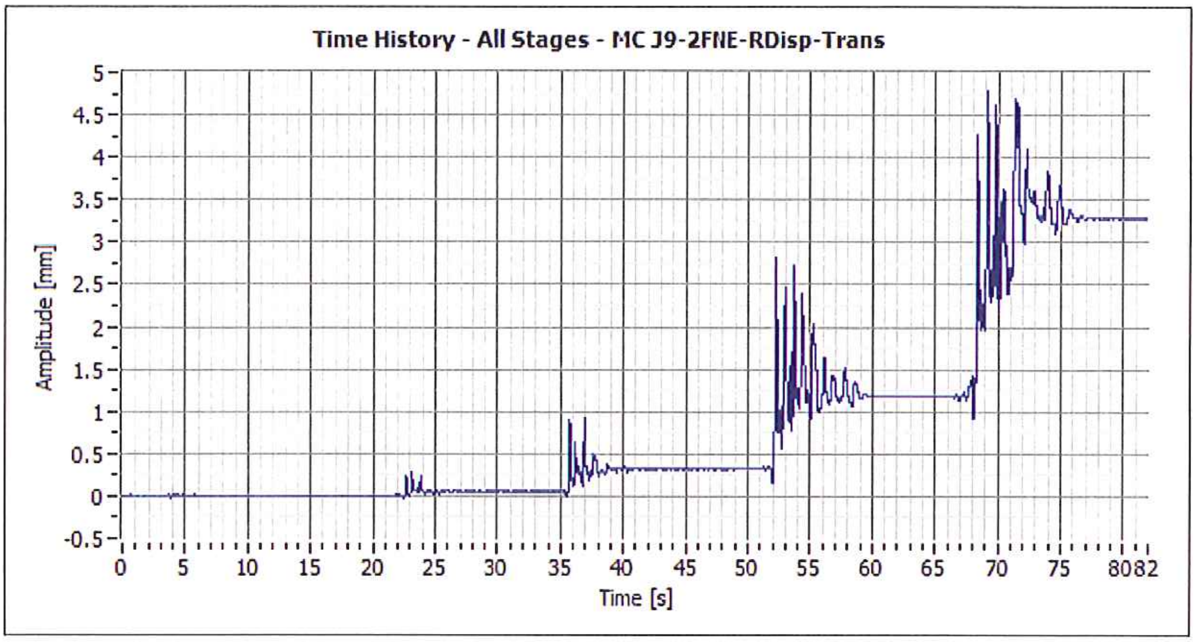


Figure N-8: Time History – Global Relative Displacement – Joint 9 Transversal

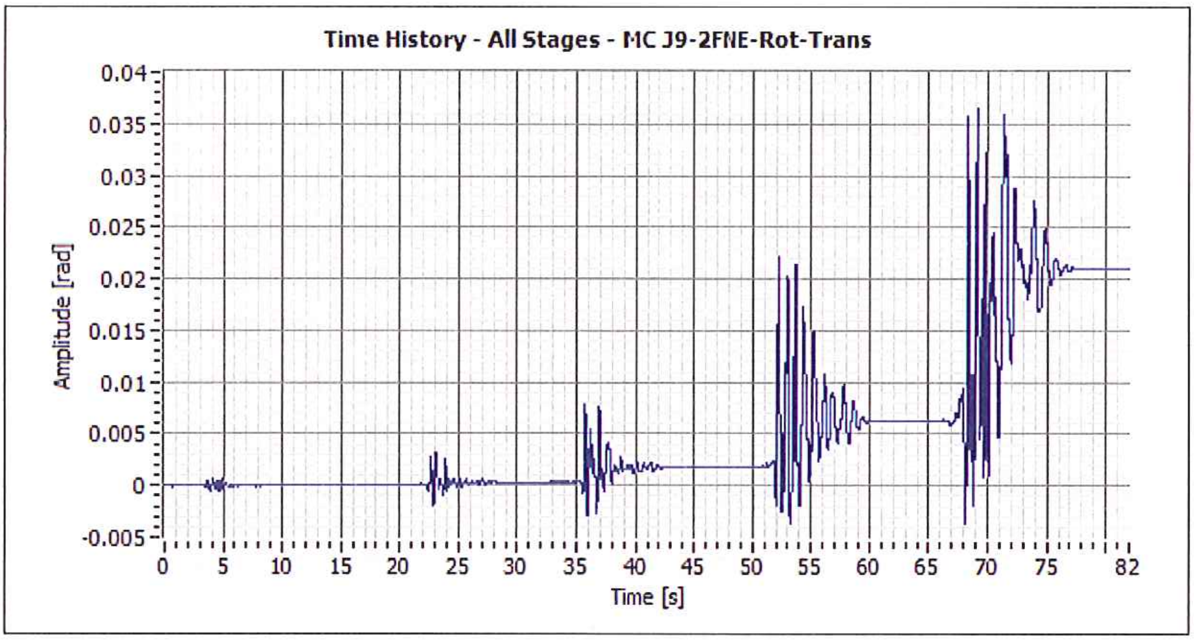


Figure N-9: Time History – Global Relative Rotation – Joint 9 Transversal

N.4 Joint 3 – Longitudinal Direction

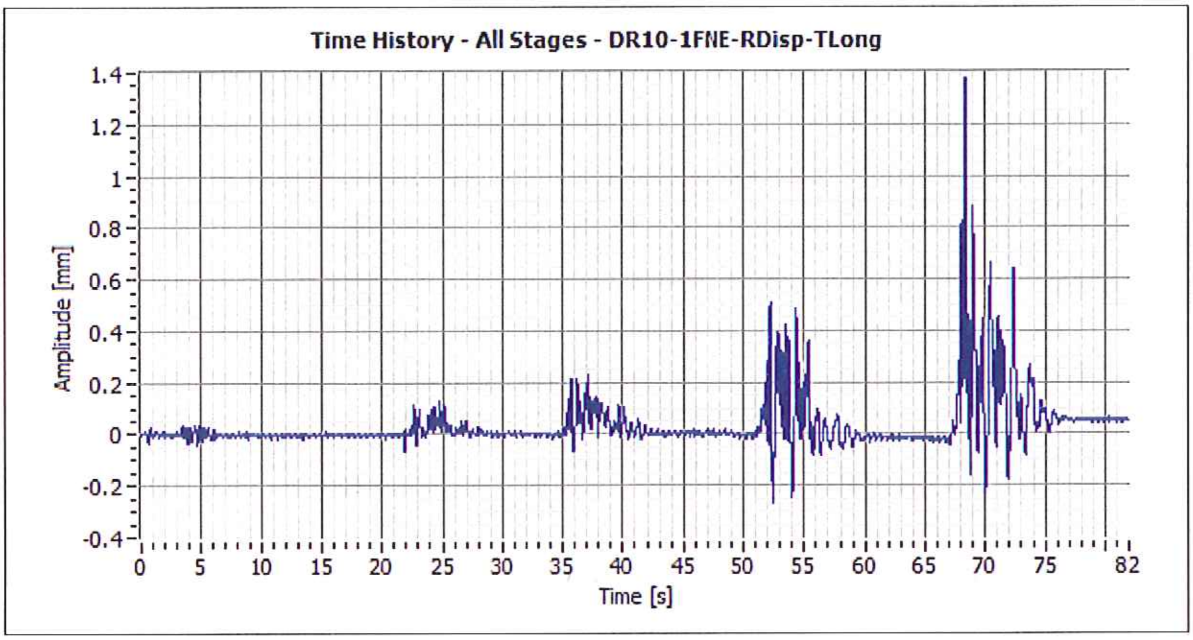


Figure N-10: Time History – Top Relative Displacement – Joint 3 Longitudinal

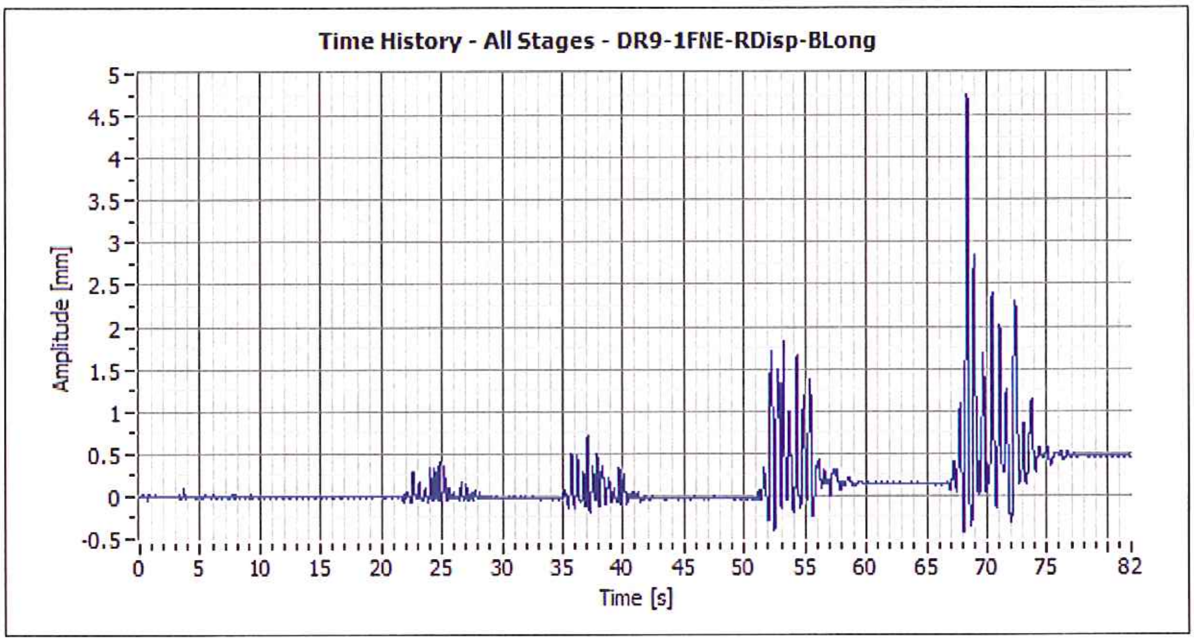


Figure N-11: Time History – Bottom Relative Displacement – Joint 3 Longitudinal

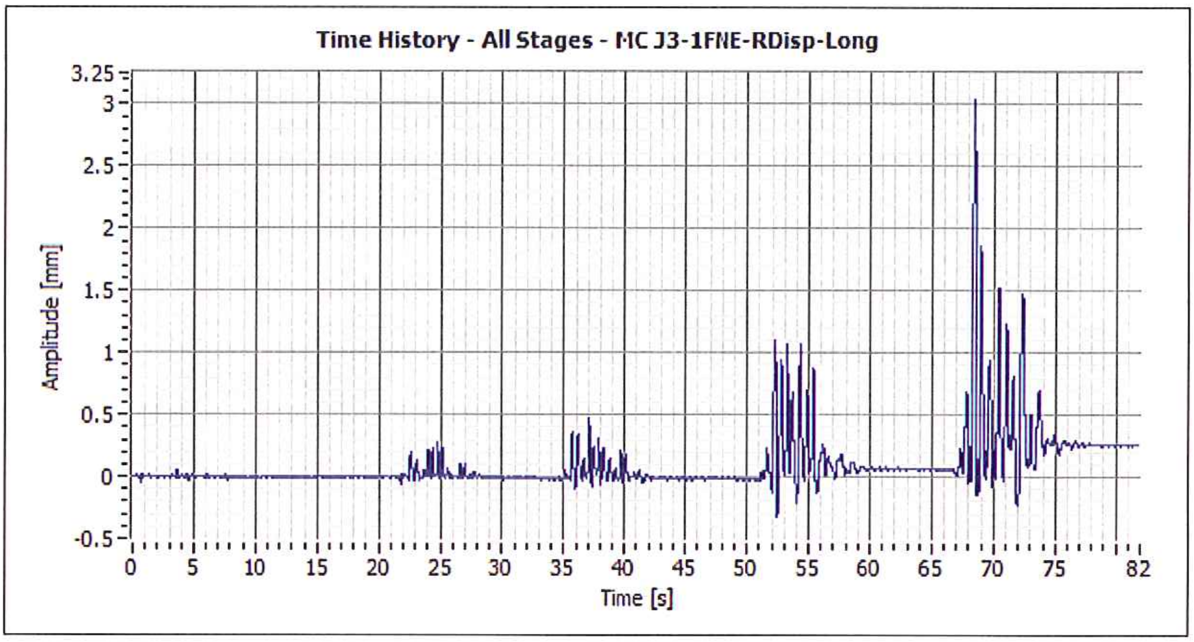


Figure N-12: Time History – Global Relative Displacement – Joint 3 Longitudinal

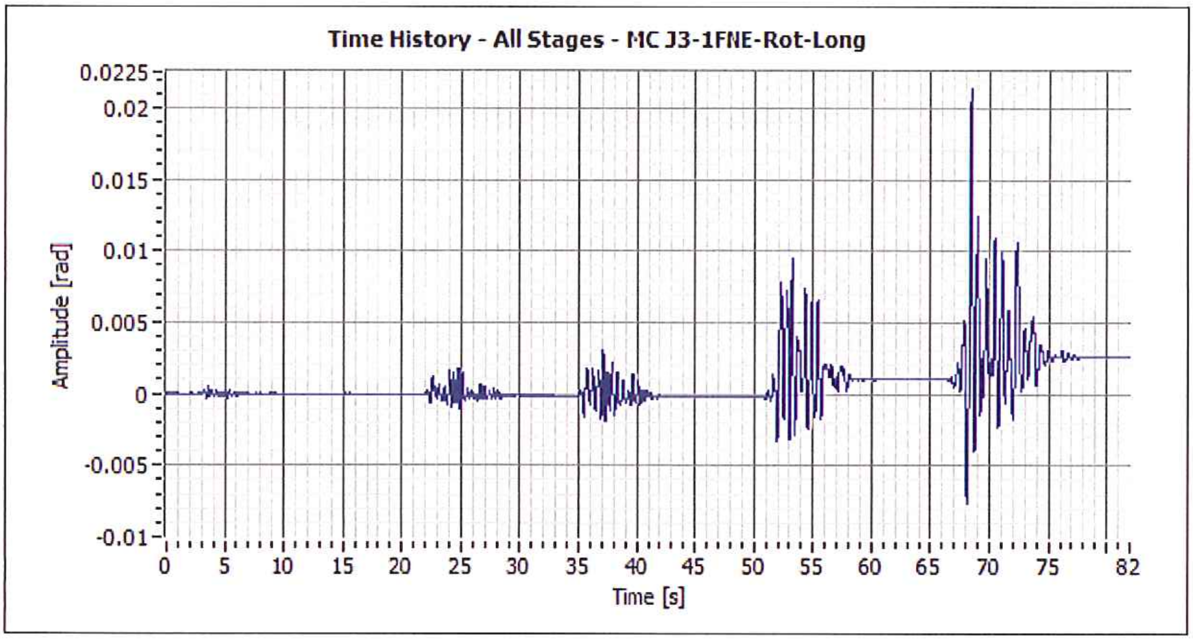


Figure N-13: Time History – Global Relative Rotation – Joint 3 Longitudinal

N.5 Joint 9 – Longitudinal Direction

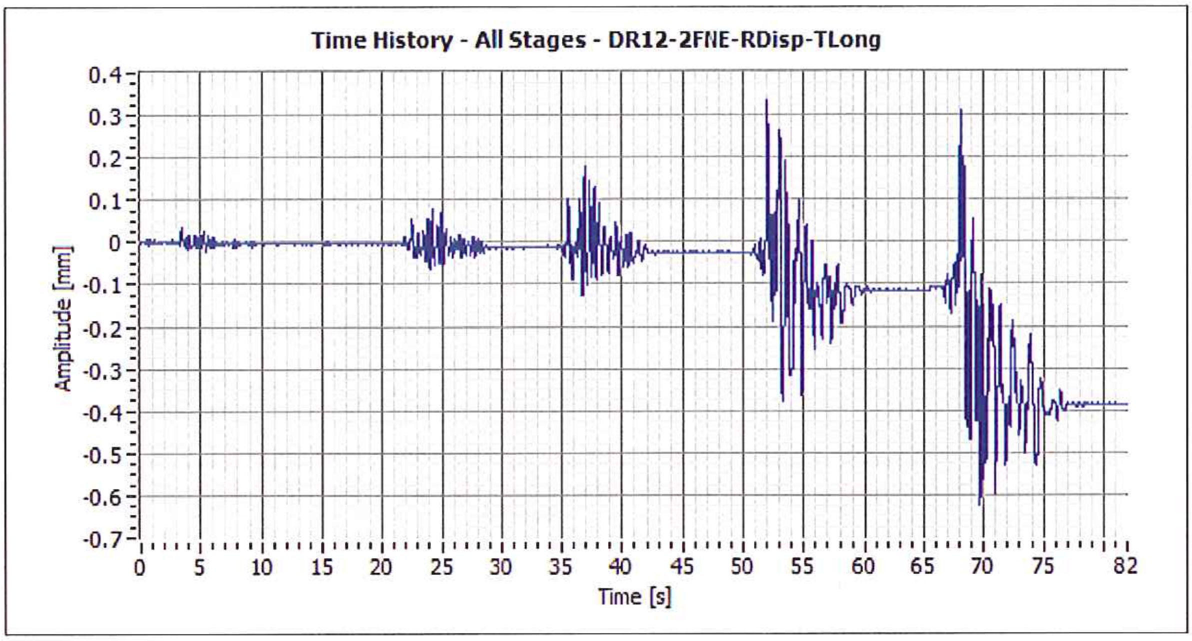


Figure N-14: Time History – Top Relative Displacement – Joint 9 Longitudinal

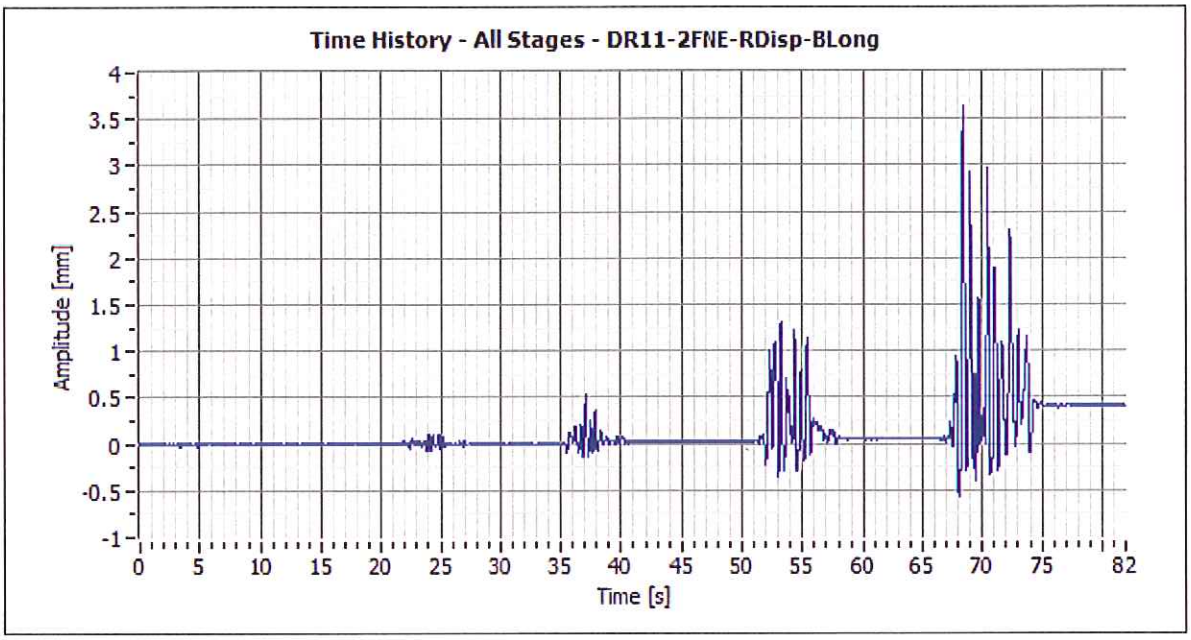


Figure N-15: Time History – Bottom Relative Displacement – Joint 9 Longitudinal

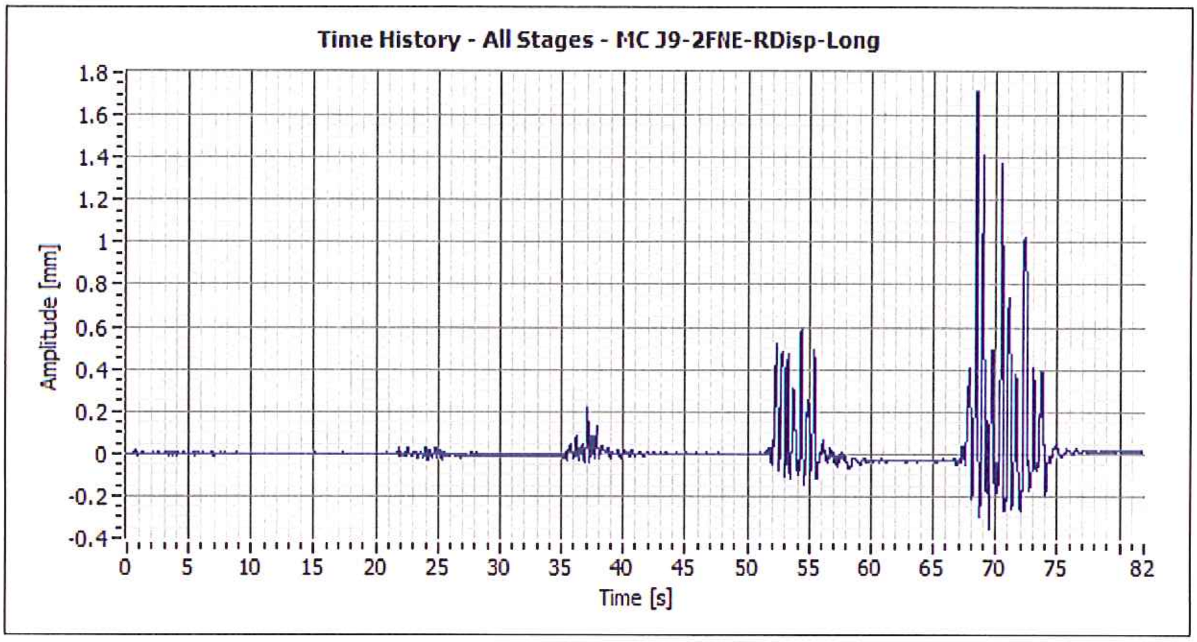


Figure N-16: Time History – Global Relative Displacement – Joint 9 Longitudinal

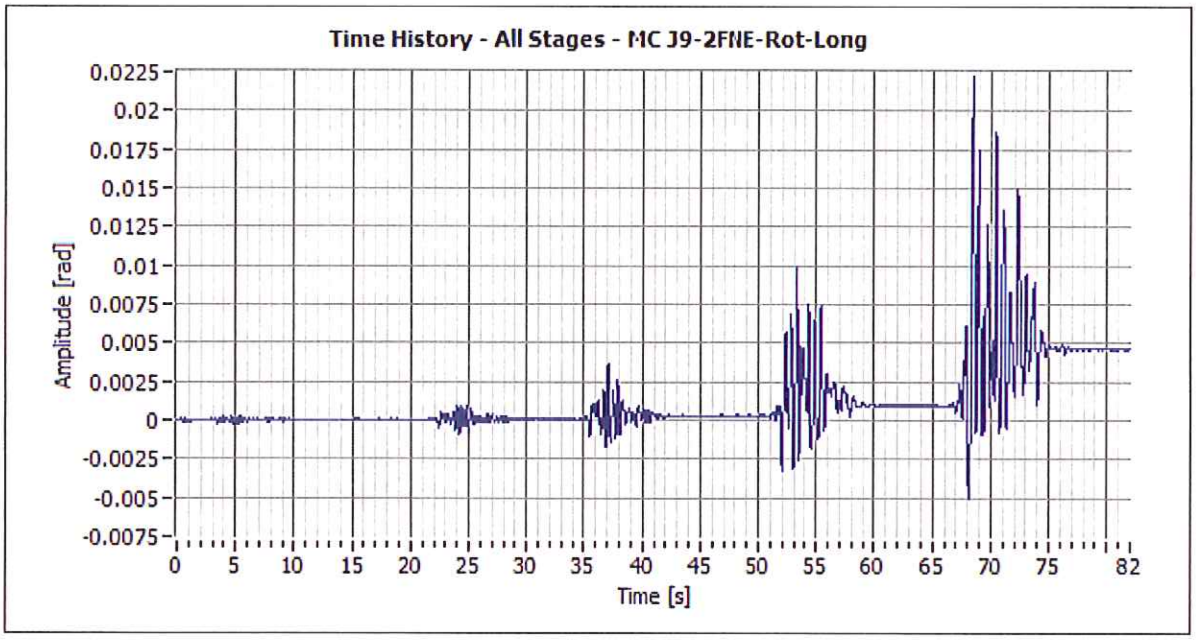


Figure N-17: Time History – Global Relative Rotation – Joint 9 Longitudinal

N.6 Joint 2

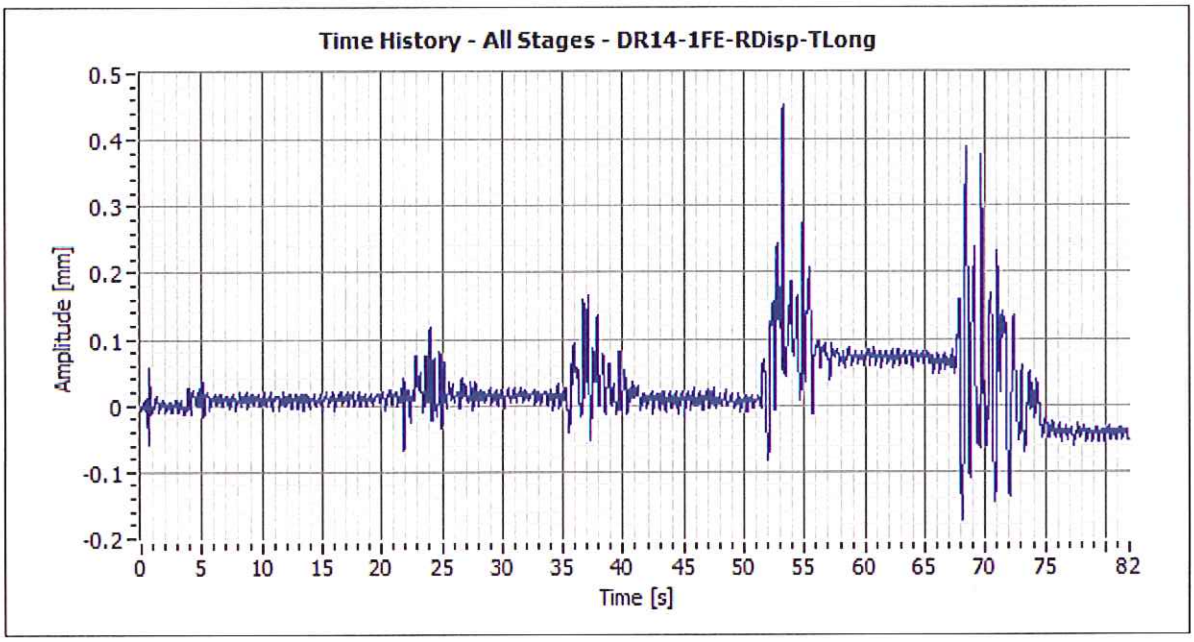


Figure N-18: Time History – Top Relative Displacement – Joint 2 NE

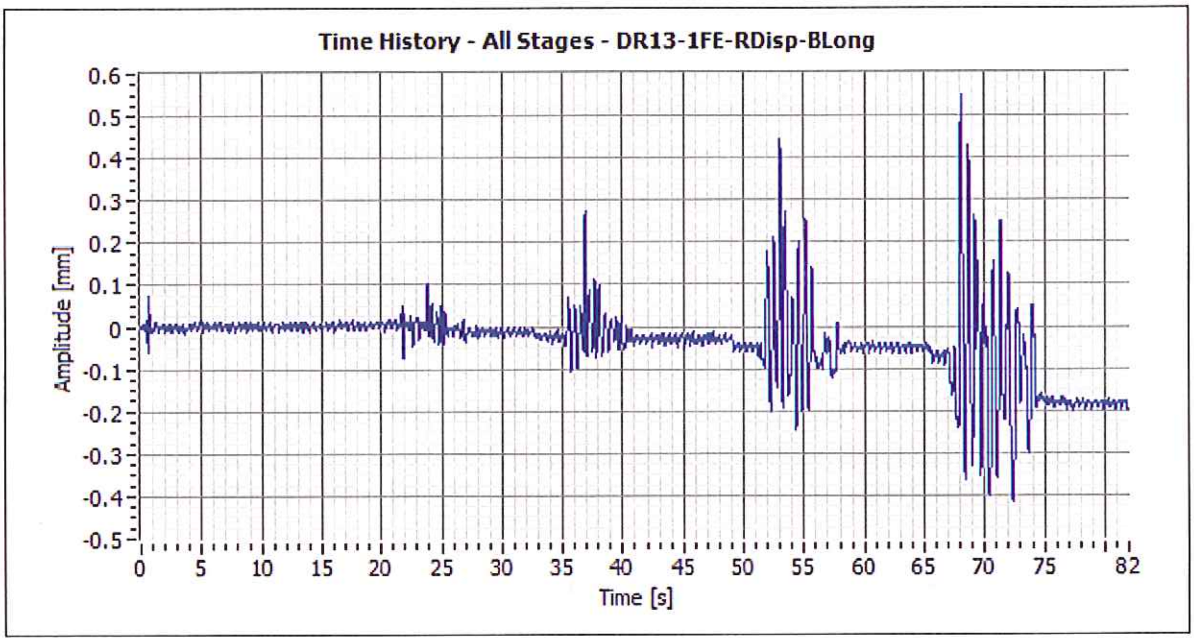


Figure N-19: Time History – Bottom Relative Displacement – Joint 2 NE

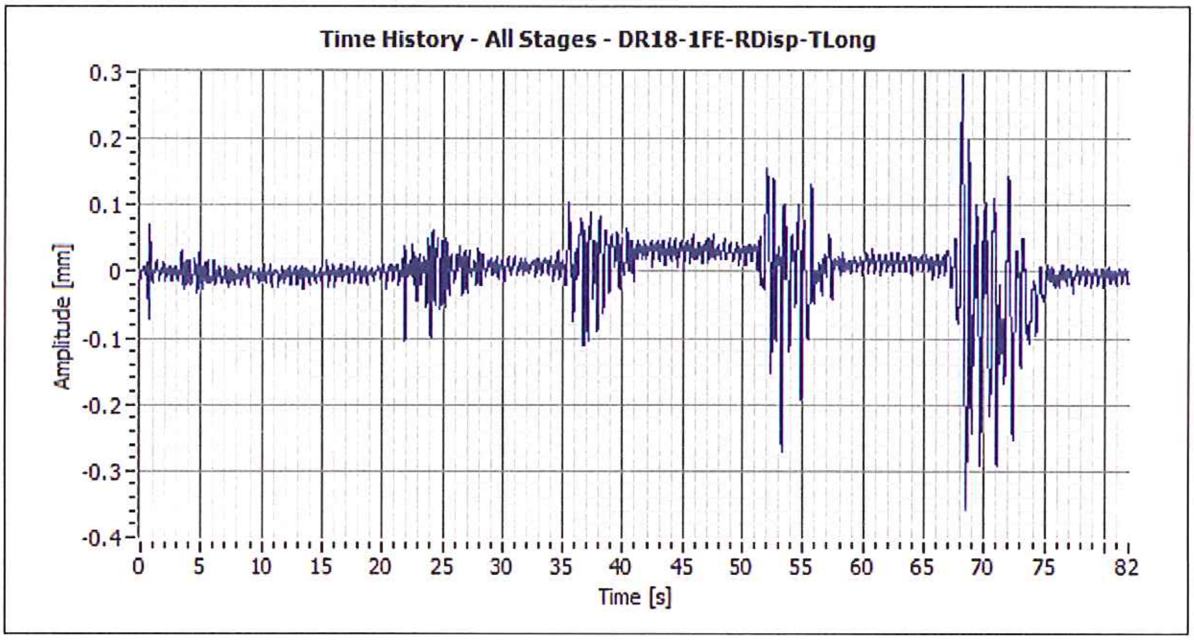


Figure N-20: Time History – Top Relative Displacement – Joint 2 SE

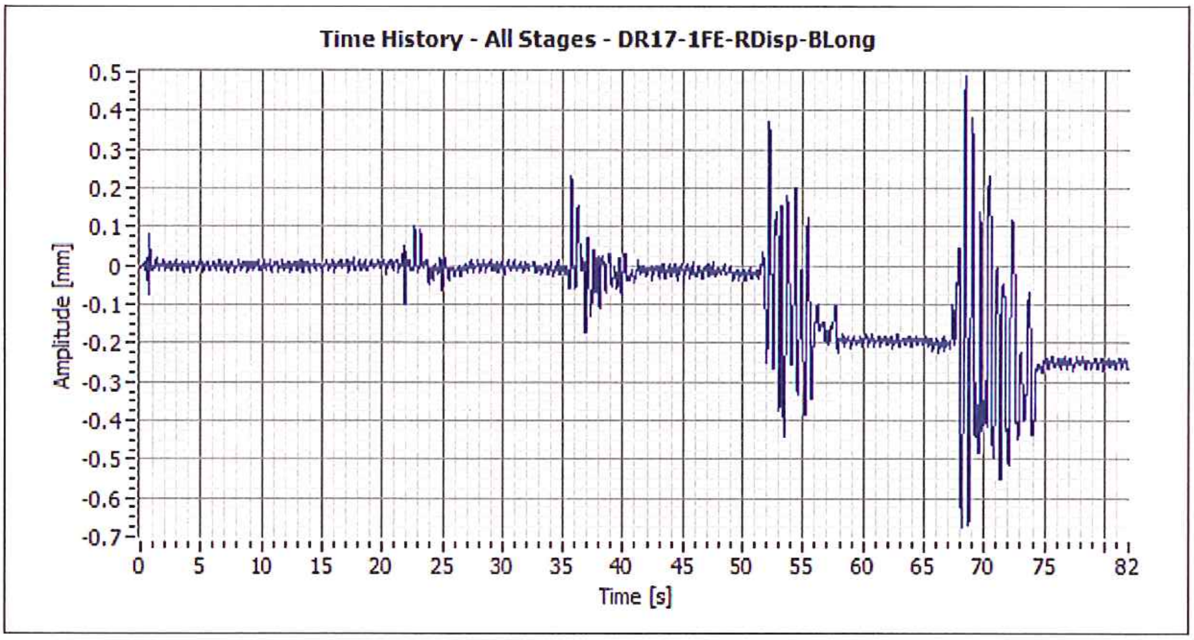


Figure N-21: Time History – Bottom Relative Displacement – Joint 2 SE

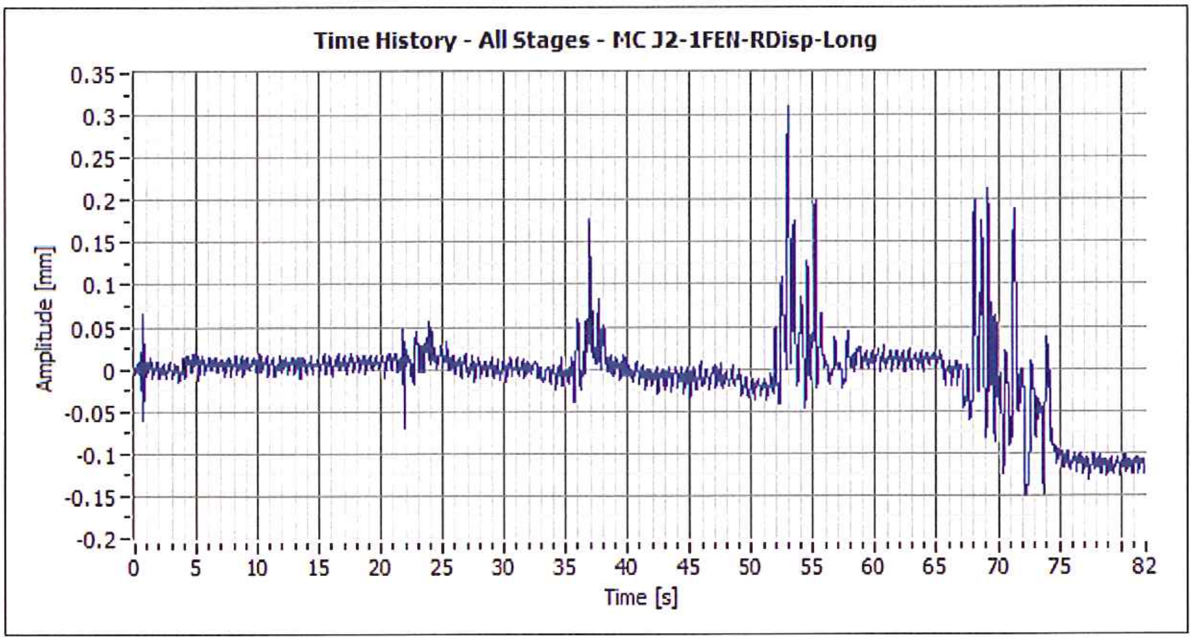


Figure N-22: Time History – Global Relative Displacement – Joint 2 NE

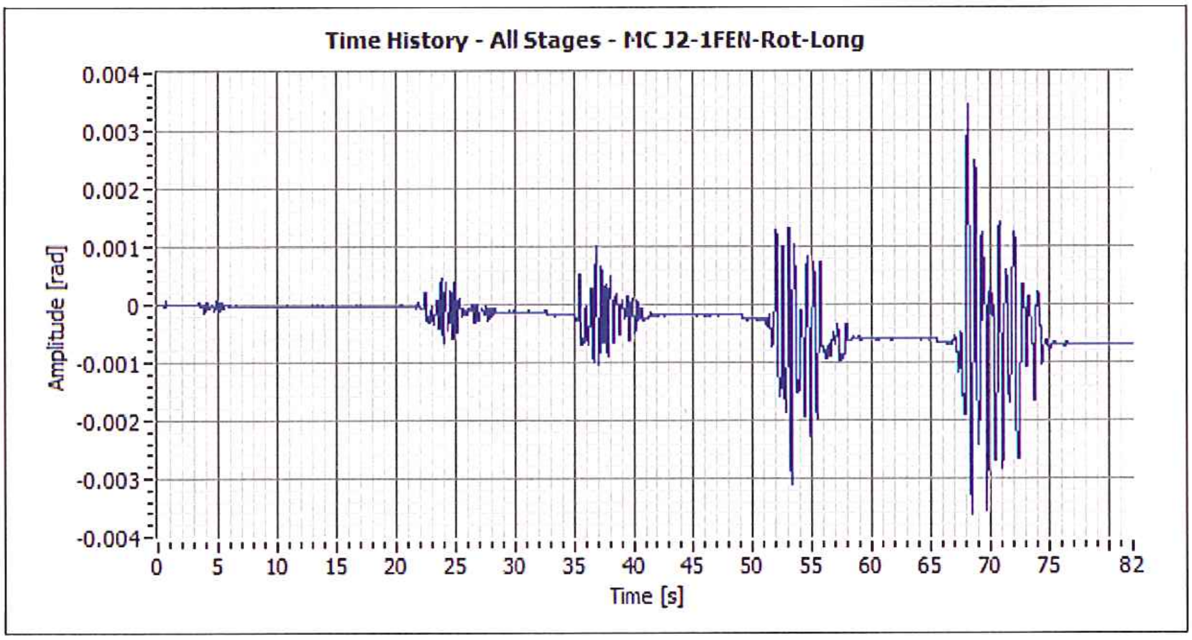


Figure N-23: Time History – Global Relative Rotation – Joint 2 NE

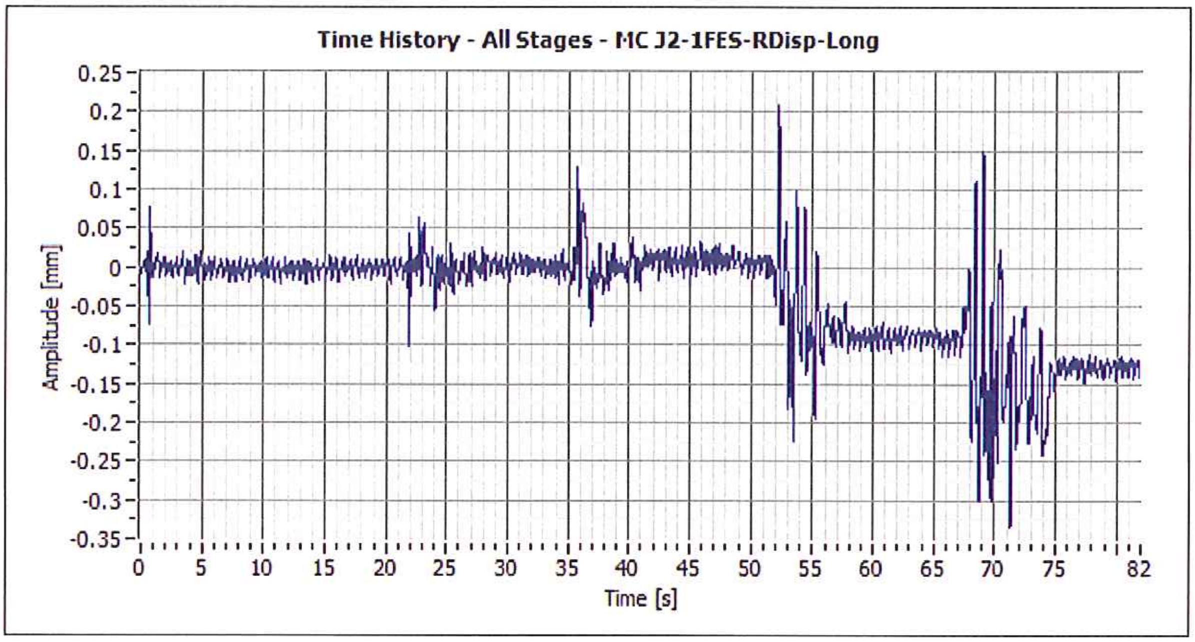


Figure N-24: Time History – Global Relative Displacement – Joint 2 SE

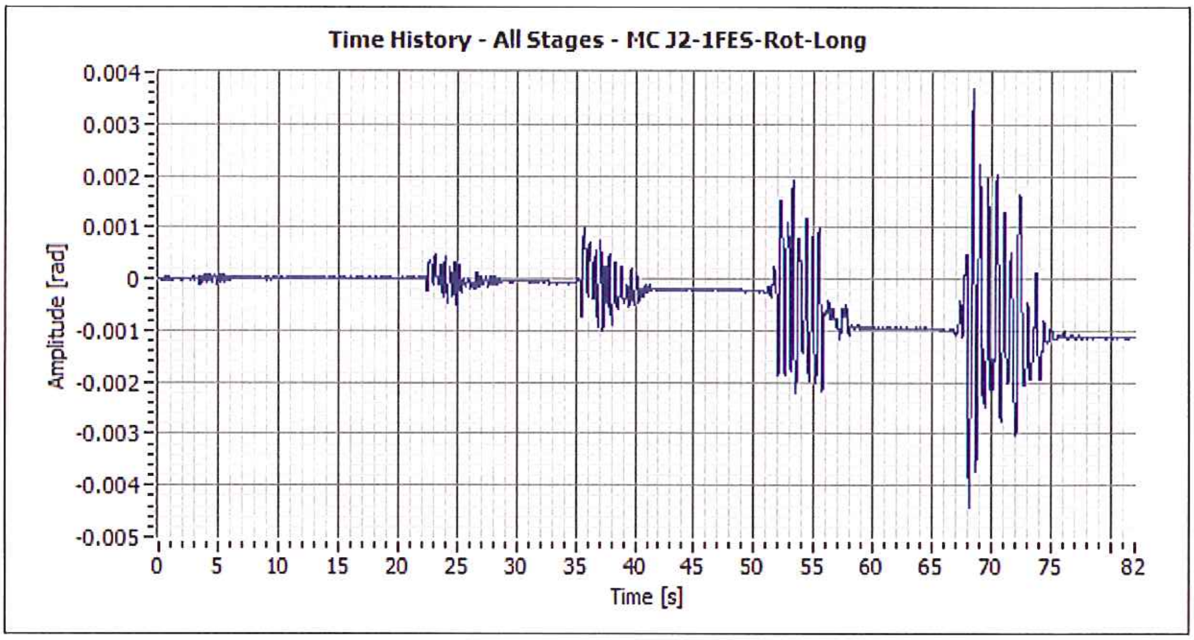


Figure N-25: Time History – Global Relative Rotation – Joint 2 SE

N.7 Joint 8

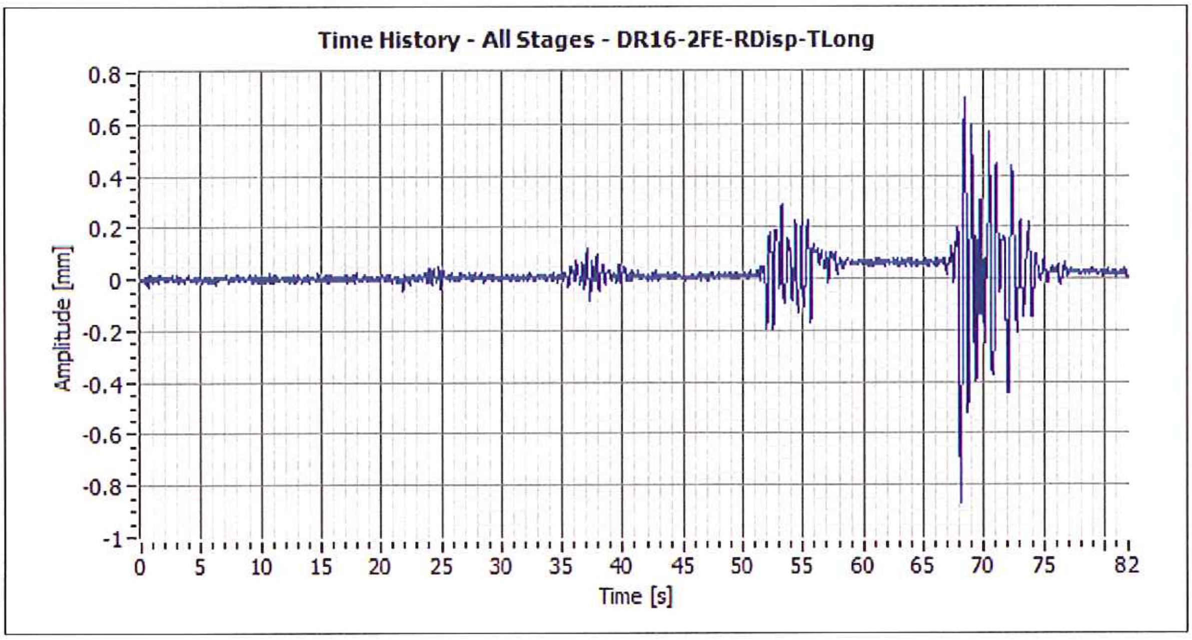


Figure N-26: Time History – Top Relative Displacement – Joint 8 NE

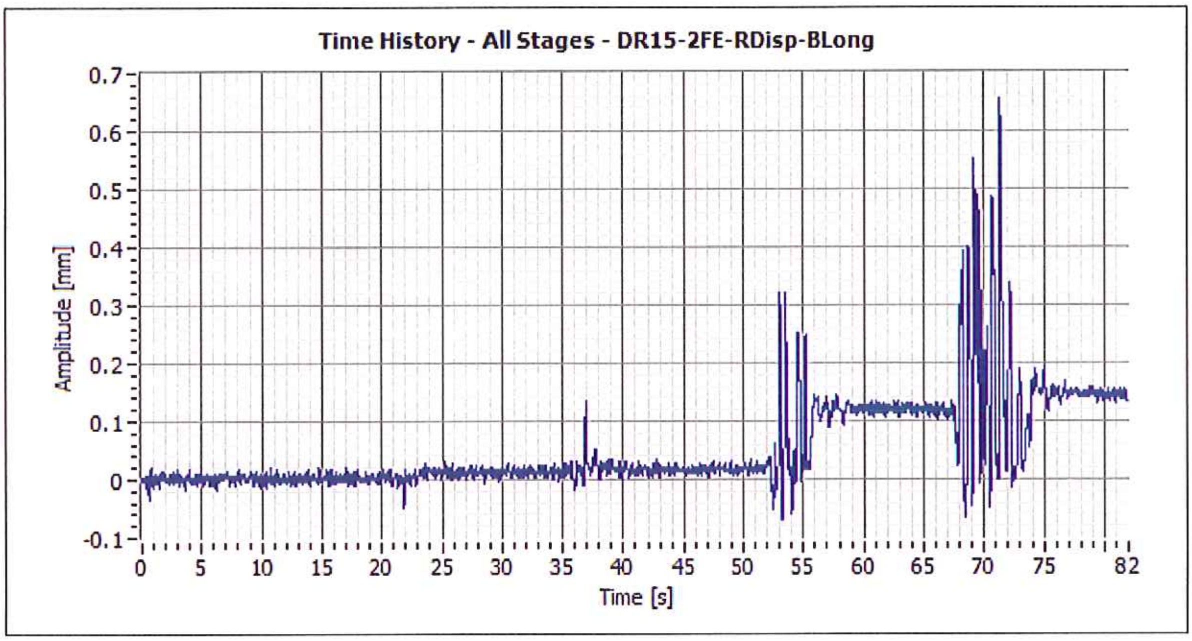


Figure N-27: Time History – Bottom Relative Displacement – Joint 8 NE

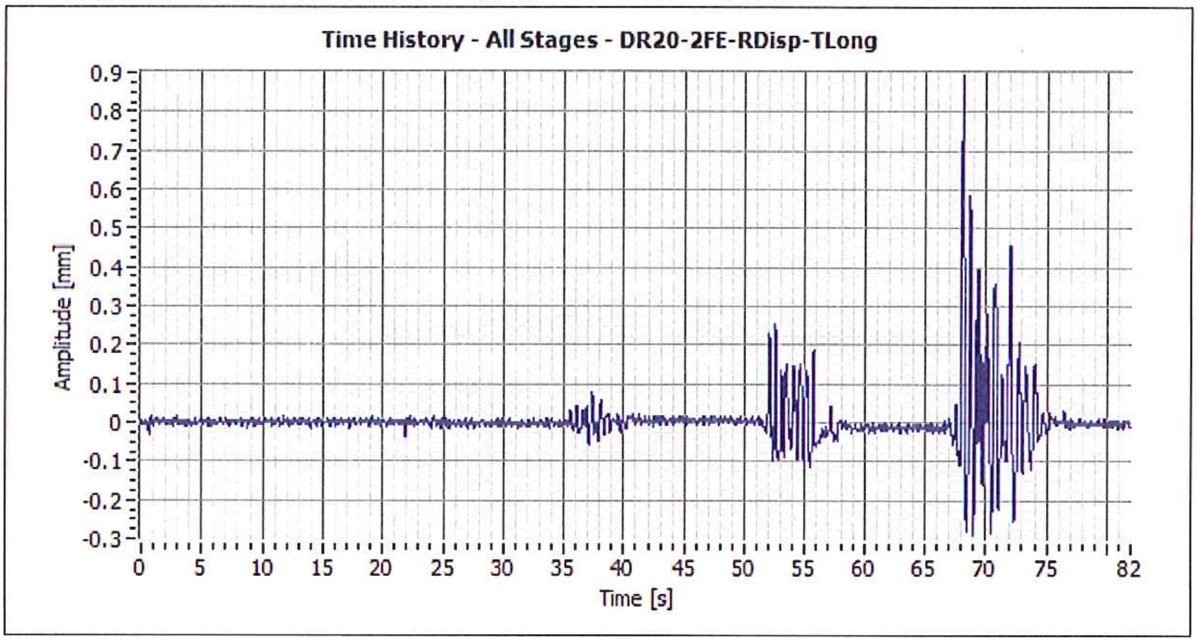


Figure N-28: Time History – Top Relative Displacement – Joint 8 SE

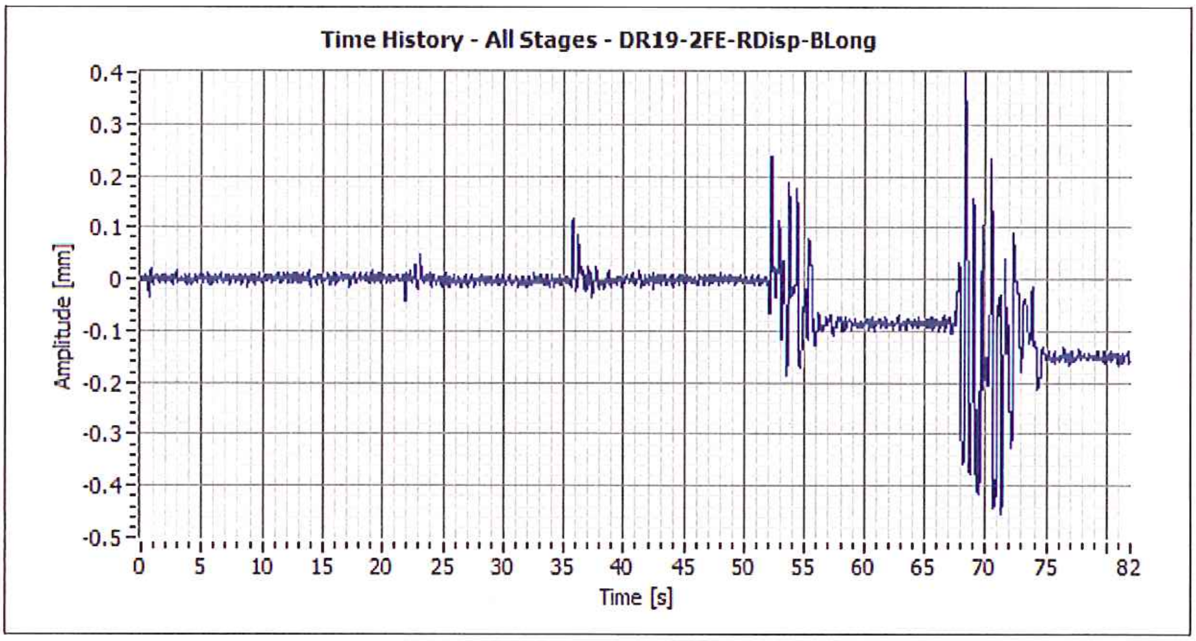


Figure N-29: Time History – Bottom Relative Displacement – Joint 8 SE

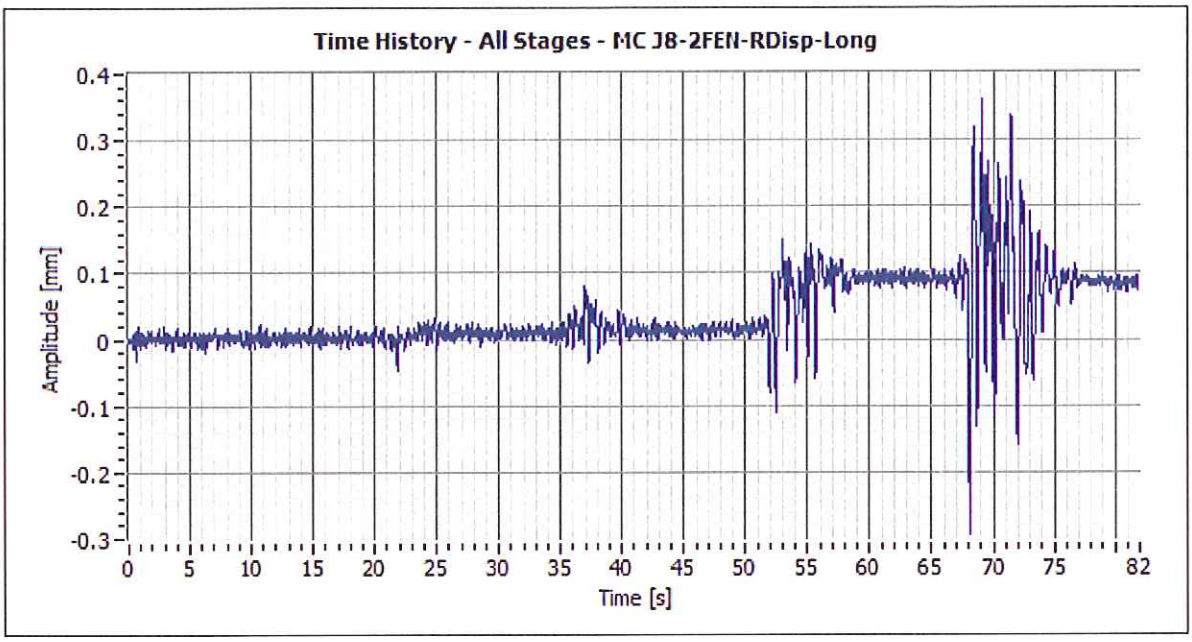


Figure N-30: Time History – Global Relative Displacement – Joint 8 NE

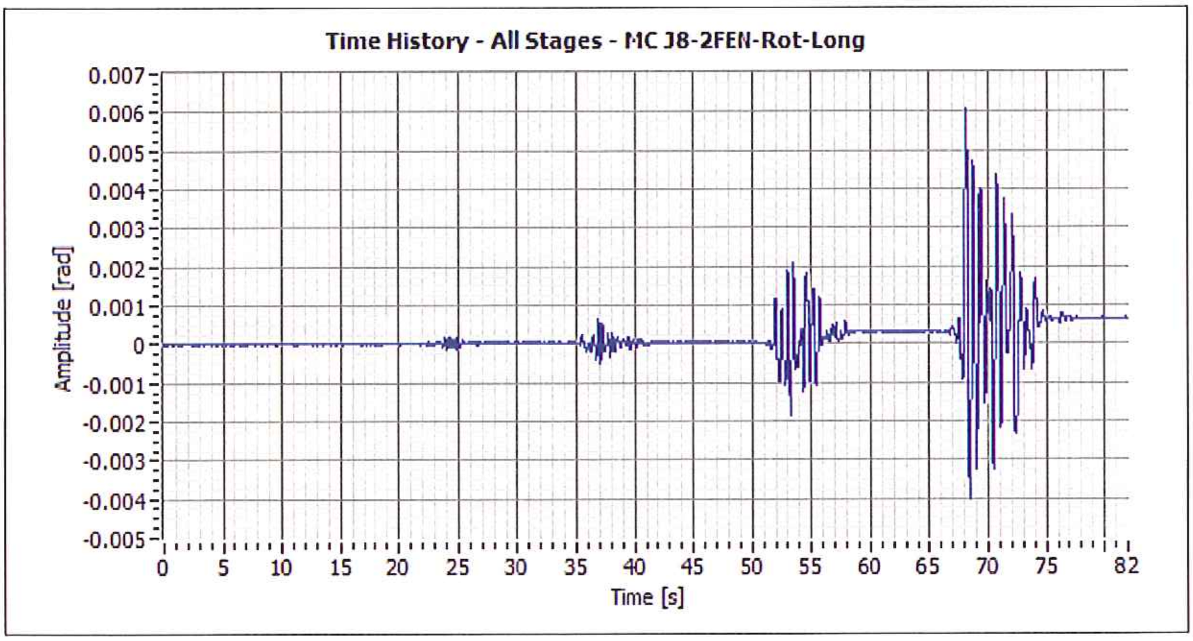


Figure N-31: Time History – Global Relative Rotation – Joint 8 NE

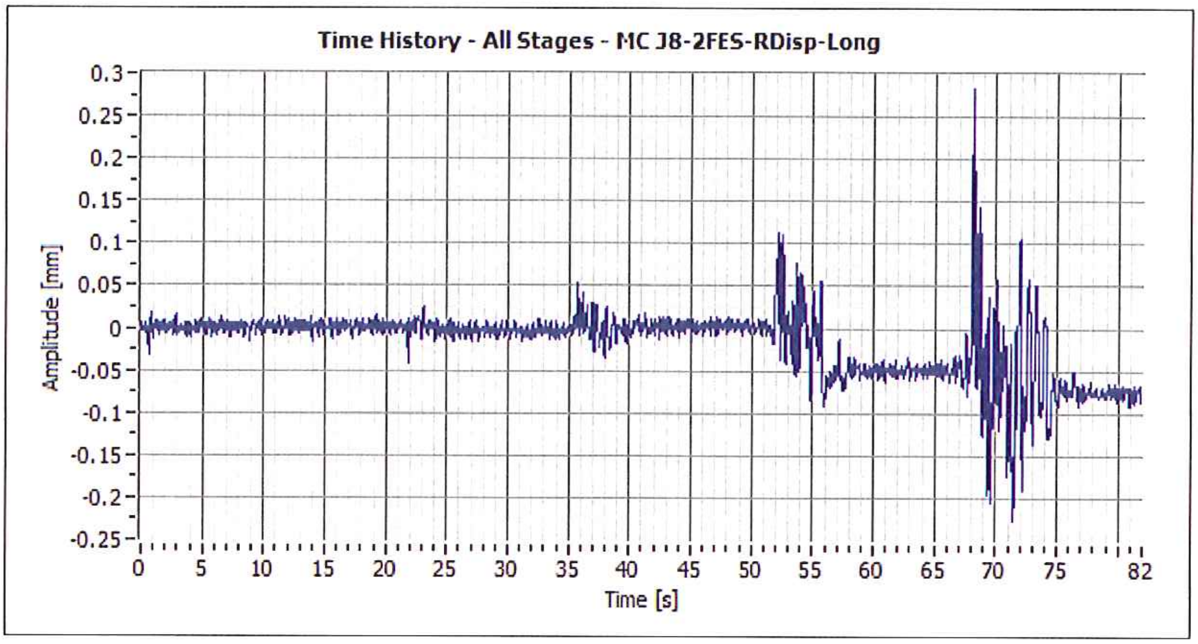


Figure N-32: Time History – Global Relative Displacement – Joint 8 SE

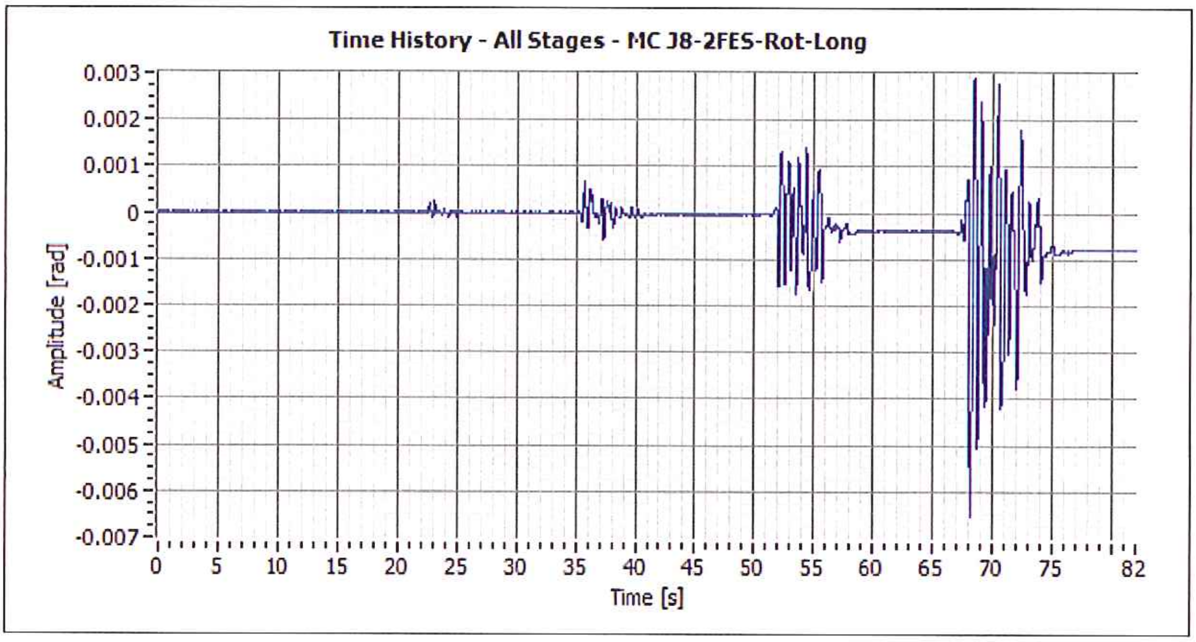


Figure N-33: Time History – Global Relative Displacement – Joint 8 SE

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