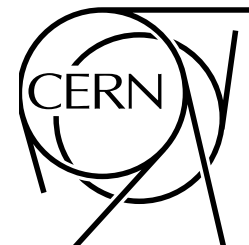


LBNF – Testing and results from Coimbra of the Module 0 LBNF cryostat components

Dimitar MLADENOV - CERN EP/NU

LBNF/DUNE interface meeting

CERN, 21-23 August 2018



LBNF – Test Connections

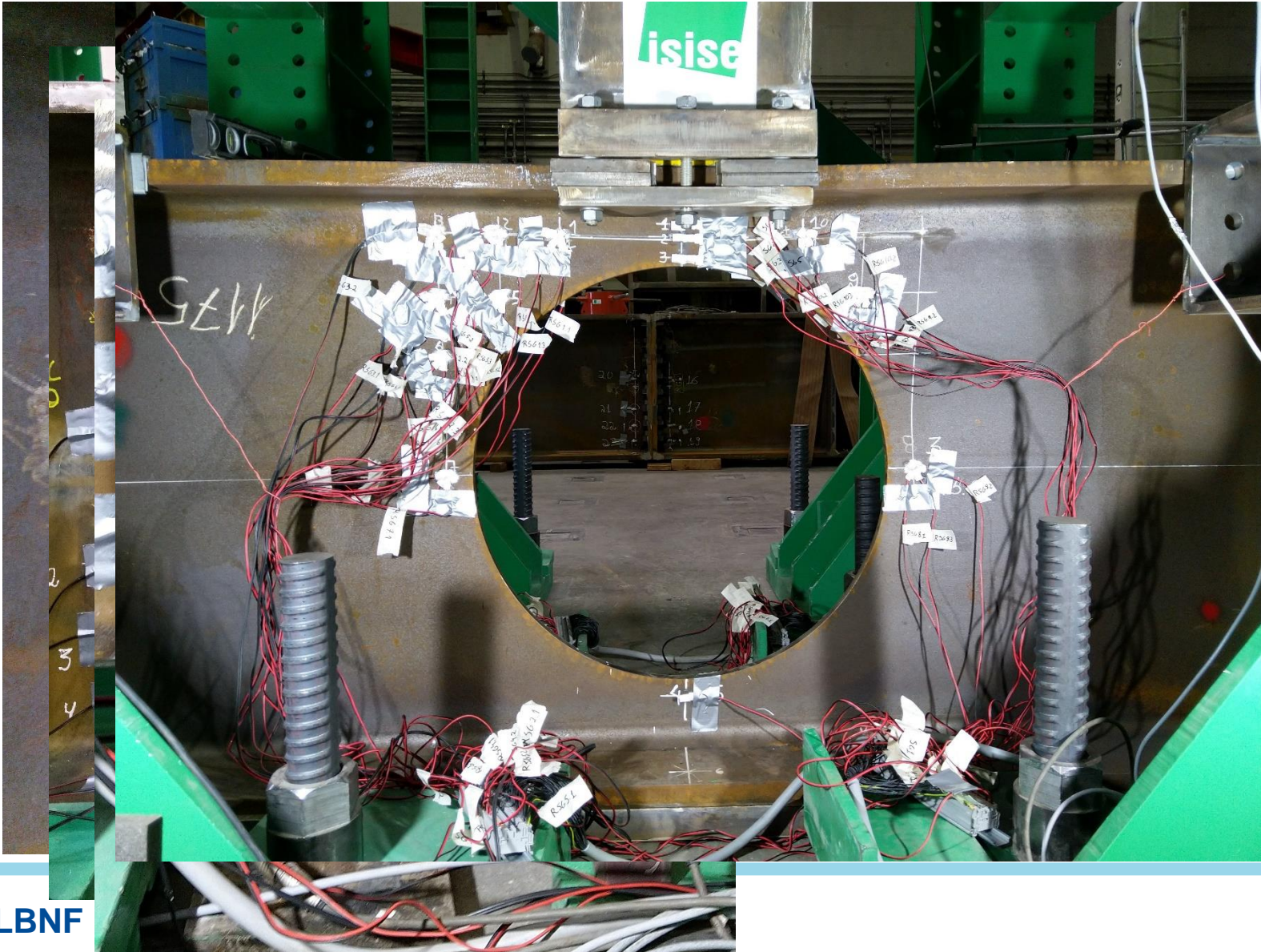


LBNF – Test Connections



A large industrial hall with a yellow overhead crane and green structural beams. A group of people are gathered around a computer monitor displaying a red arrow, with others standing and talking. The floor is concrete and the walls are white.

LBNF – Test Connections

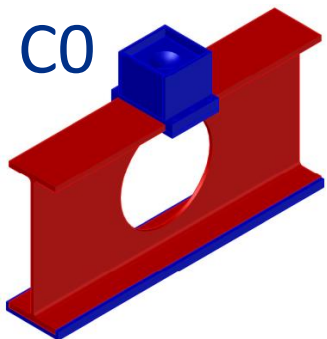


LBNF

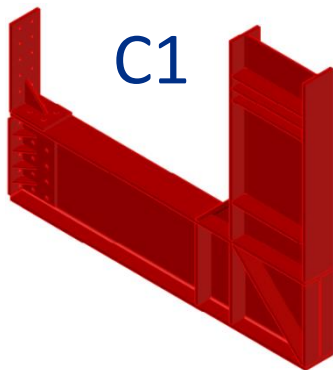
CERN NP

LBNF – Coimbra - Connections

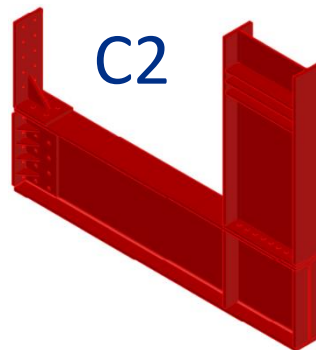
C0



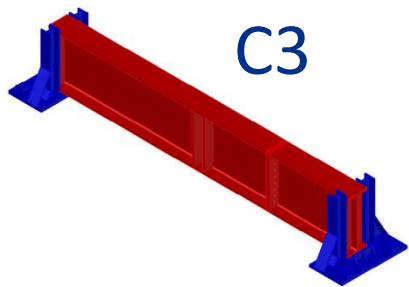
C1



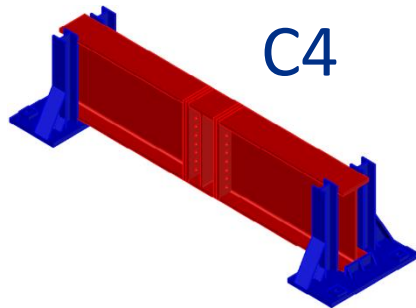
C2



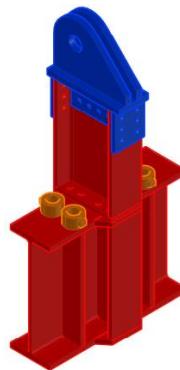
C3



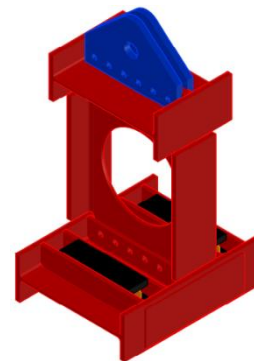
C4



C5



C6



Coimbra – Preliminary Reports



PRELIMINARY REPORT – LONG-BASELINE NEUTRINO FACILITY (LBNF) STEEL JOINTS – C0 STEEL SPECIMEN

Preliminary report on the C0 test – Draft_v1

CERN – EUROPEAN
ORGANIZATION FOR NUCLEAR
RESEARCH



Experimental results



Date:
27/07/2018

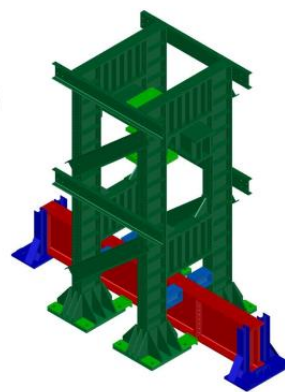
PRELIMINARY REPORT – LONG-BASELINE NEUTRINO FACILITY (LBNF) STEEL JOINTS – C3 STEEL JOINT

Preliminary report on the C3 test – Draft_v2

CERN – EUROPEAN
ORGANIZATION FOR NUCLEAR
RESEARCH



Experimental results



Date:
27/07/2018

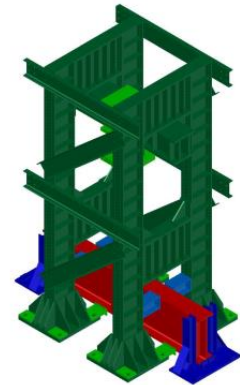
PRELIMINARY REPORT – LONG-BASELINE NEUTRINO FACILITY (LBNF) STEEL JOINTS – C4 STEEL JOINT

Preliminary report on the C4 test – Draft_v1

CERN – EUROPEAN
ORGANIZATION FOR
NUCLEAR RESEARCH

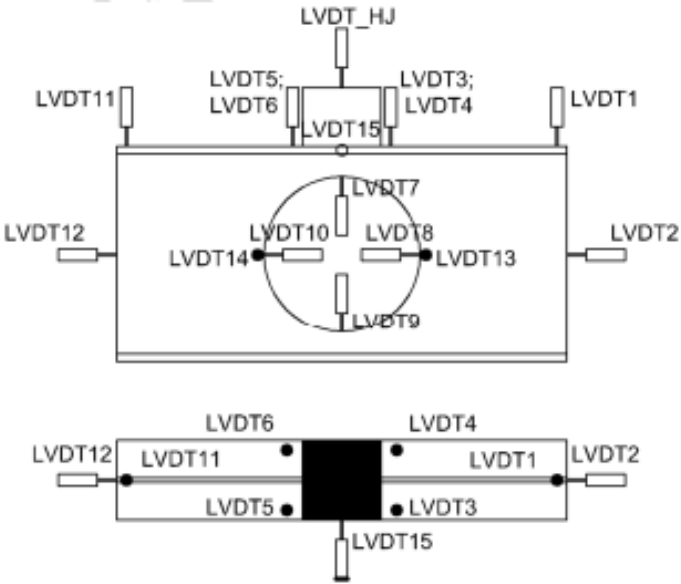
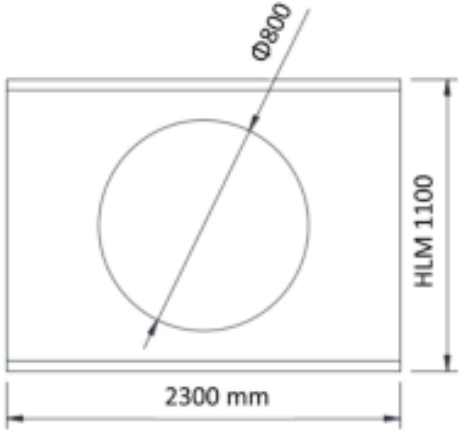


Experimental results

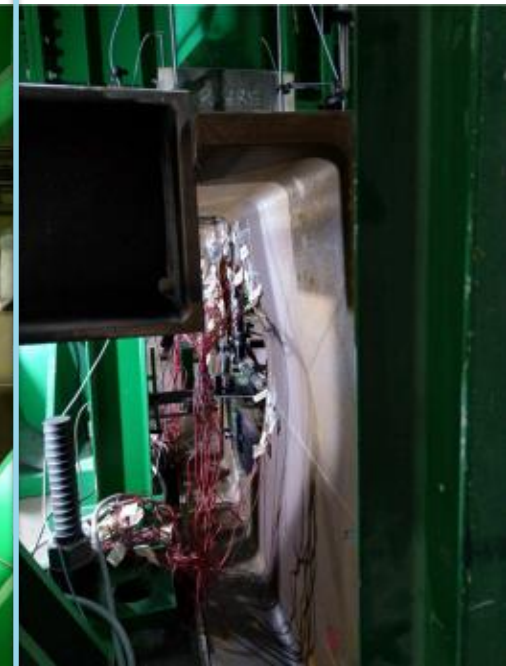


Date:
27/07/2018

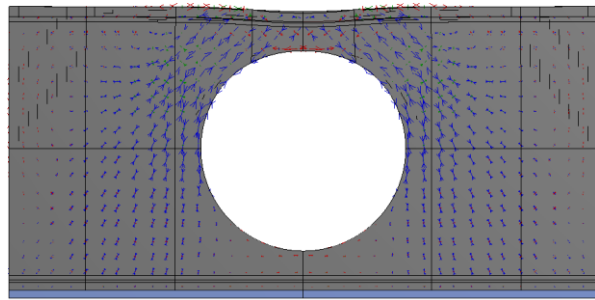
Coimbra – C0 - Setup



Coimbra – C0 - Setup



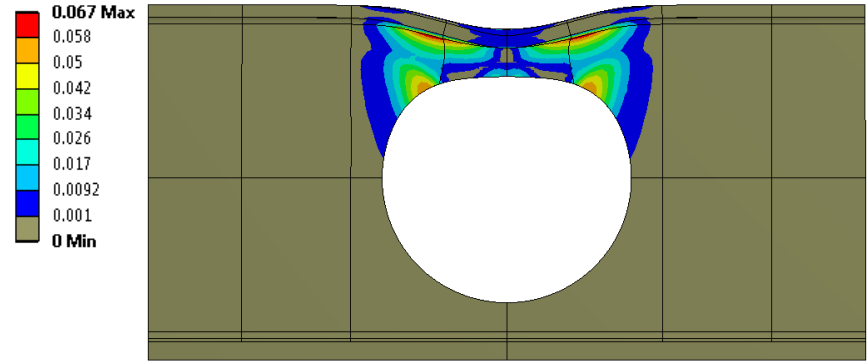
Coimbra – C0 - FEM



Principal stress vectors

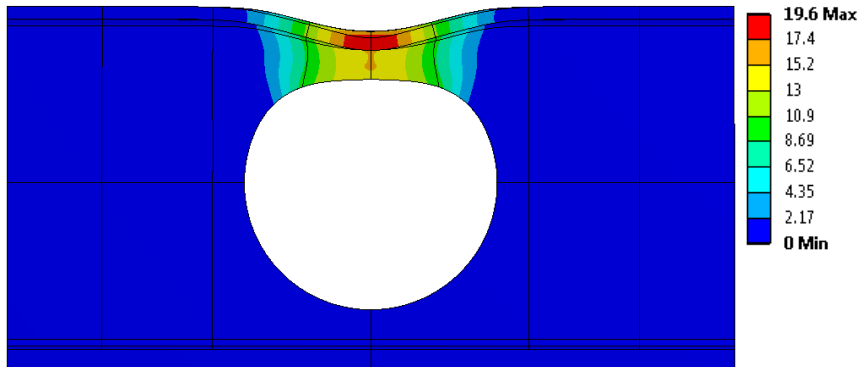
Maximum Principal
Middle Principal
Minimum Principal

Plastic strain [m/m]
@ F = 3600 kN



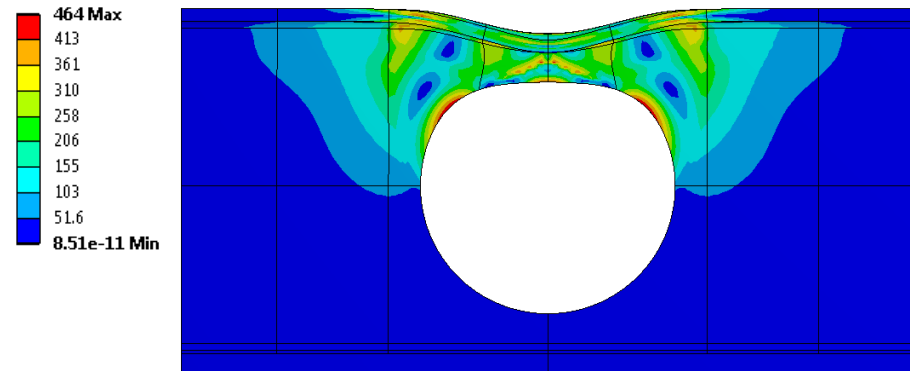
Deformations magnified 5x

Total deformation [mm]
@ F = 3600 kN



Deformations magnified 5x

Equivalent stress [MPa]
@ F = 3600 kN



Deformations magnified 5x

Coimbra – C0 - Correlation

All FEA curves overlap.
FEA results reasonably the average of both sides of flange.

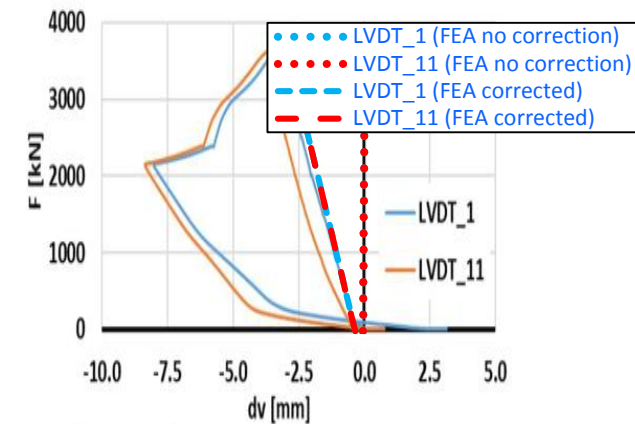
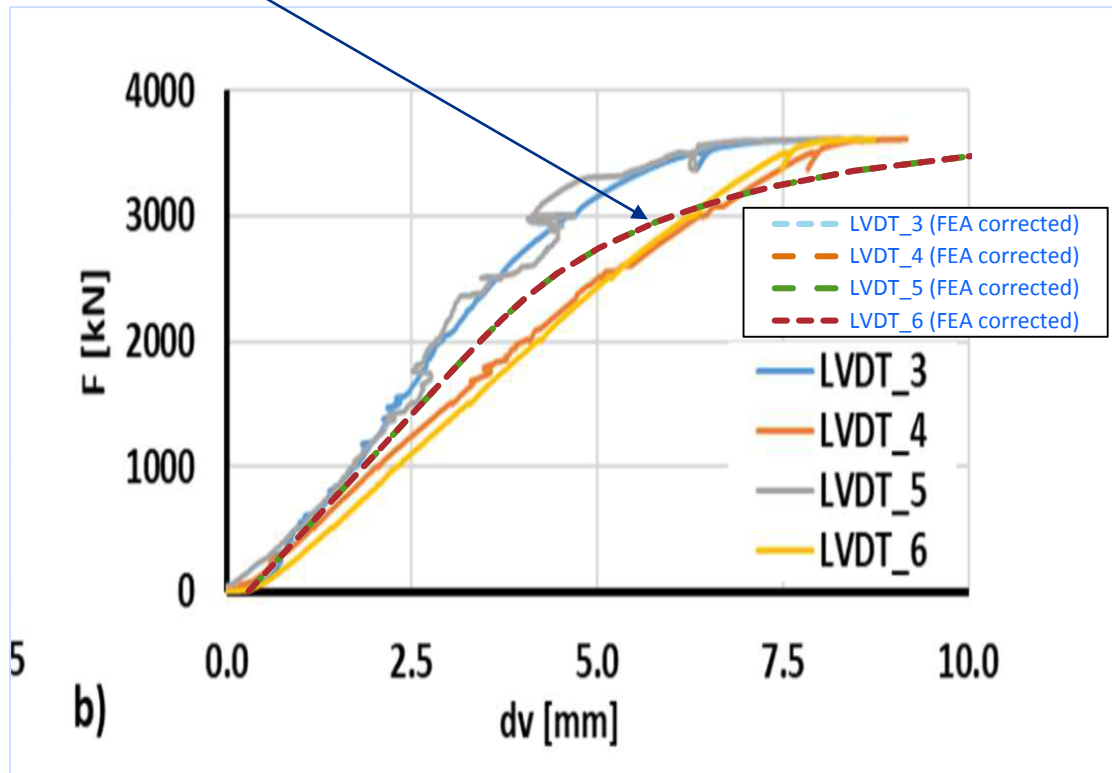
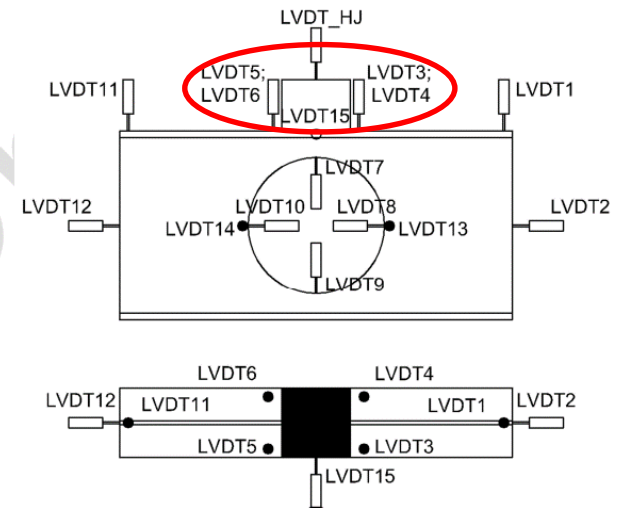


Figure 7. Applied force vs vertical deformation at the specimen ends.



Coimbra – C0 - Correlation

FEA is in reasonably good agreement with tests

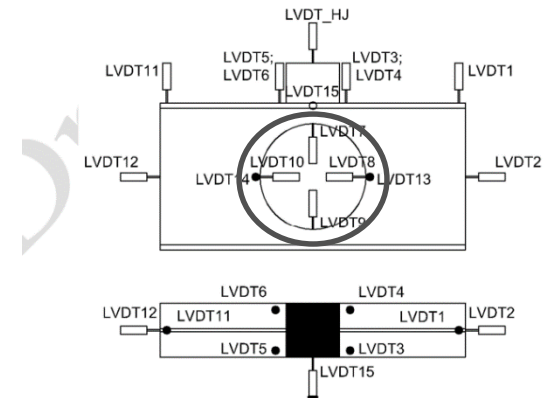
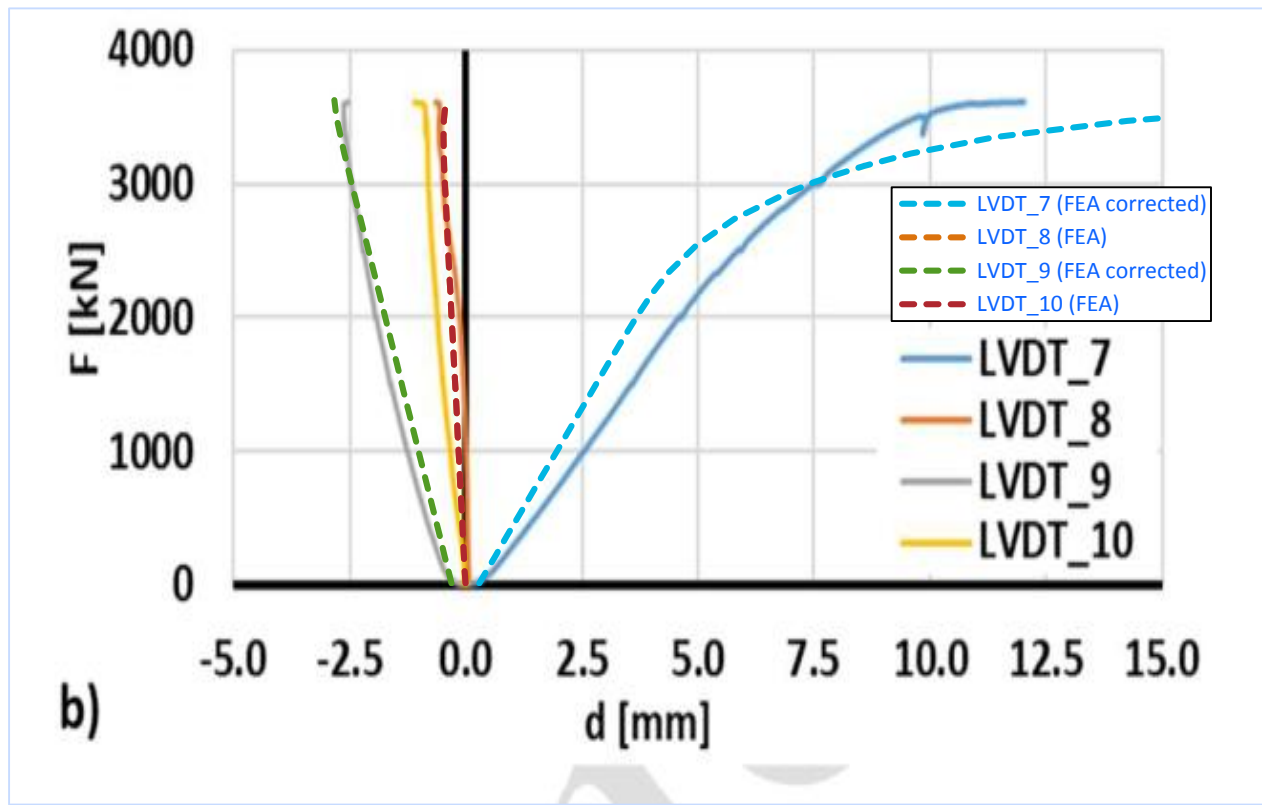


Figure 3. Instrumentation used in the C0 specimen. a) Lateral view. b) Top view.



Coimbra – C0 - Correlation

- The test specimen was observed to buckle at $F \approx 3.6$ MN.
- A non-linear buckling simulation with initial defect is performed to study the buckling behavior

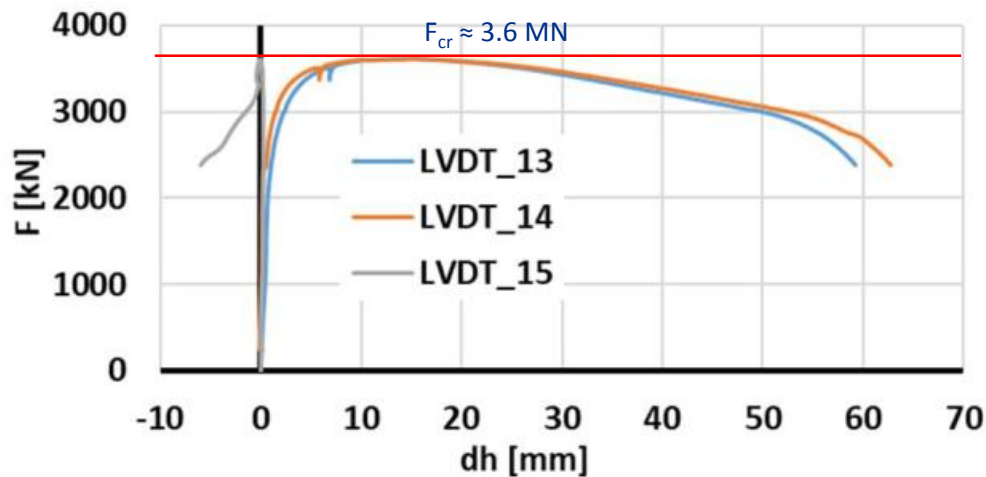
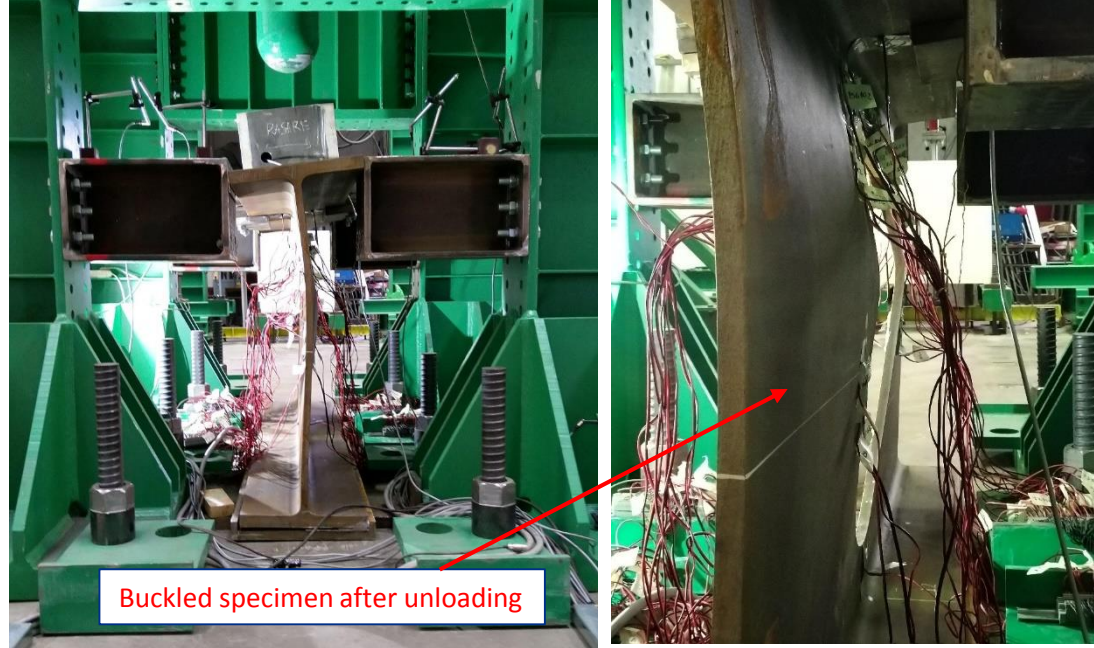
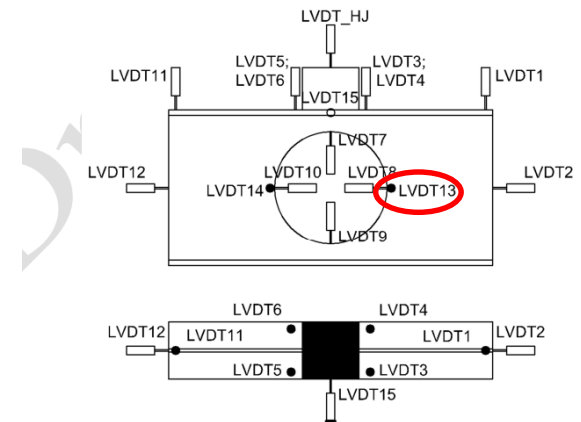
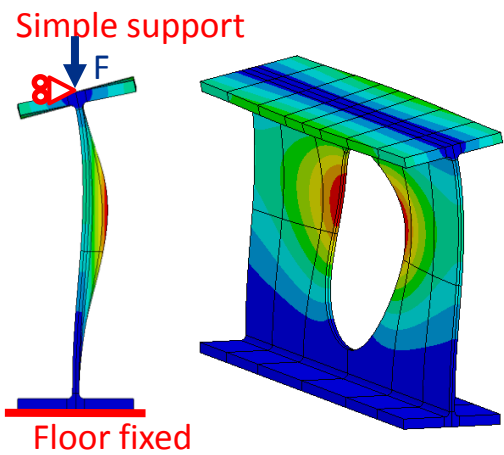


Figure 8. Applied force vs horizontal displacements.

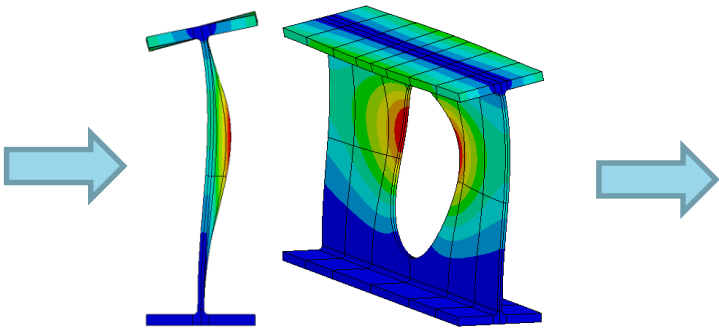


Coimbra – C0 - Correlation

Step 1:
Linear buckling simulation to obtain 1st buckling mode

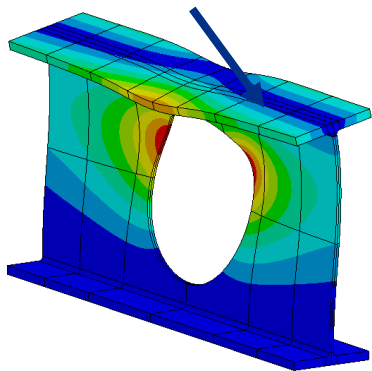


Step 2:
1st buckling mode is used as initial imperfect geometry (according to C.5 (2) of EN 1993-1-5). Mode shape is scaled to achieve 3 mm concavity of the web.



Mode shape [mm]
(multiply by 3x to obtain initial defect)

Step 3:
Static structural with the initial defect. Point of buckling is evaluated.

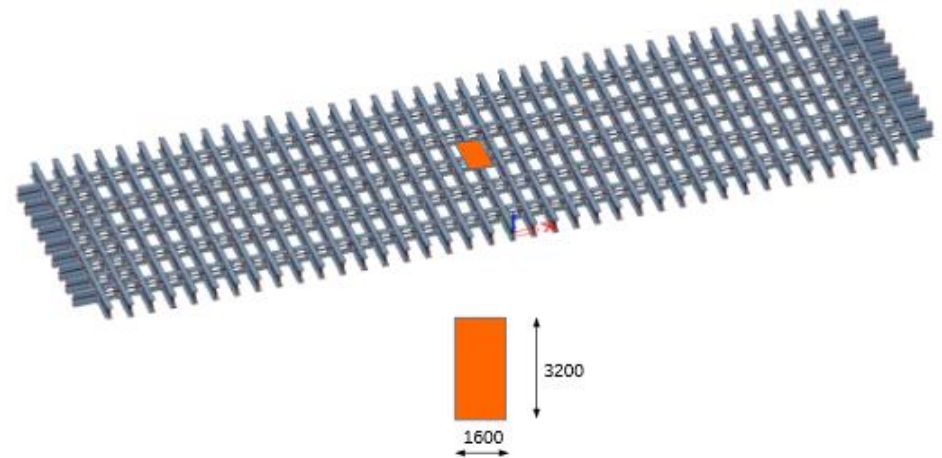


Critical load = 1 MN + 2.89 × 1 MN = 3.89 MN
Linear buckling simulation → **Not conservative!**

Normes / Standards / Normen	EN 10034: 1993 ⁴⁾	EN 10024: 1995	ASTM A 6/A 6M - 14	ASTM A 6/A 6M - 14	GOST 26020-83		STO ASCHIM 20-93		JIS G 3192: 2008 JIS A 5526: 2005	
Concavité de la dalle					hs120	1,0	hs120	1,0	b<400	2
Concavity of web					120<h<380	1,5	120<h<380	1,5	400<b<600	2,5
Konkavität des Stegs					380<h<680	2,0	380<h<680	2,0	b>600	3
					h>680	3,0	h>680	3,0		

Coimbra – C0 - Correlation

- The stability of the floor beams under transversal compression has been studied in EDMS 1769365 v.5 “Local stability checks of the LBNF vessel (interface with the floor)”
- A transversal compression resistance of 6476.8 kN was calculated for a section of **unperforated** beam.
- A maximum design load of 1576 kN was calculated over an area of 1600 mm × 3200 mm (pressure of 308.5 kN/m²). As a conservative assumption, this can be assumed as a point load on the specimen.
- The worst case load is then 44% of the maximum load reached in tests. (1576 kN/3600 kN = 0.44)
- The worst case load would be 54% of the critical load obtained from non-linear buckling simulations. (1576 kN/2900 kN = 0.54)



From EDMS 1769365 v.5

Figure 2.6: Influence area to estimate the point load on the stiffened vertical plates.

Coimbra – C0 - Conclusions

- Maximum compressive load of 3600 kN is reached in tests, after which the specimen buckles.
- The FEA results agree well with the tests. Buckling behavior or rotation of the specimen top flange and web is not captured in simulations with perfect geometry. The test specimen is stronger than the FE model.
- A critical buckling load of 2.9 MN is obtained from non-linear buckling simulations. A geometrical imperfection corresponding to the first 1st buckling mode shape was assumed, scaled to achieve a 3 mm concavity in the beam web (as max possible manufacturing defect)
- A better fit with the test data was achieved by a non-linear buckling simulation with 1 mm web concavity. A critical load of 3.0 MN was achieved.
- The non-linear buckling simulations are based on initial defects from the 1st buckling mode shape, which may not represent the real test specimen.
- Complete results to be reported when material data & strain gauge results are available from University of Coimbra.

Coimbra – C3 - Setup



Coimbra – C3 - Setup



Coimbra – C3 - Setup

Test results from EDMS 2009829 v.1

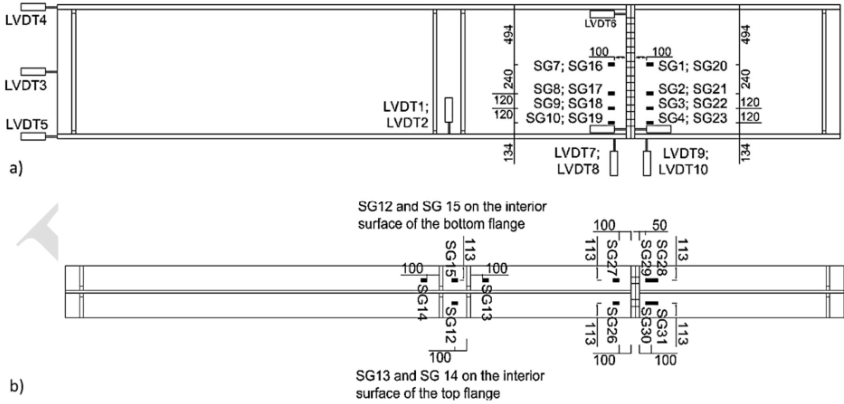
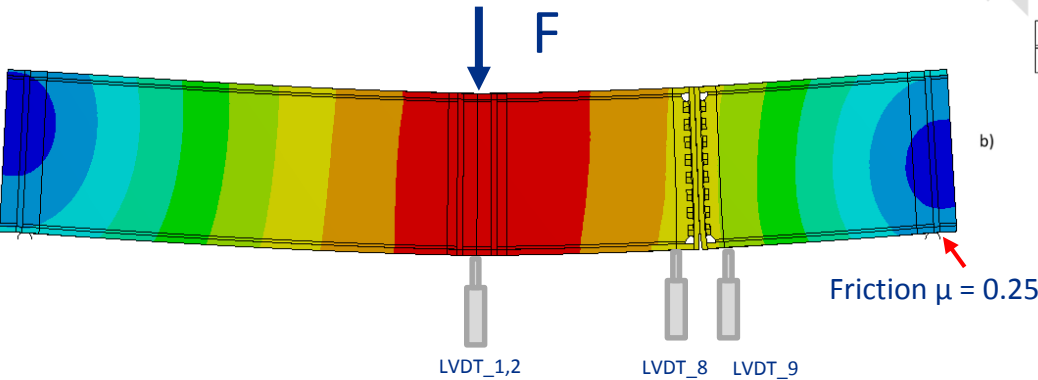
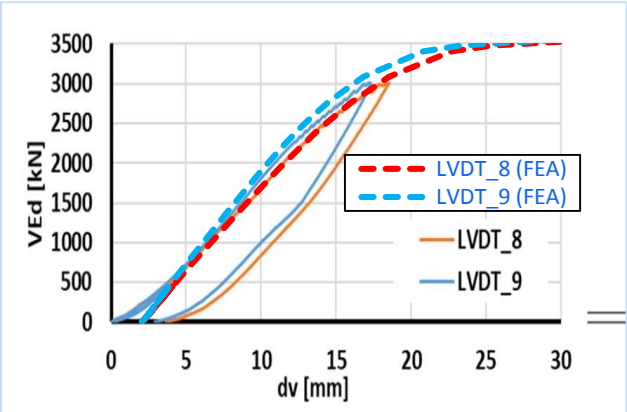
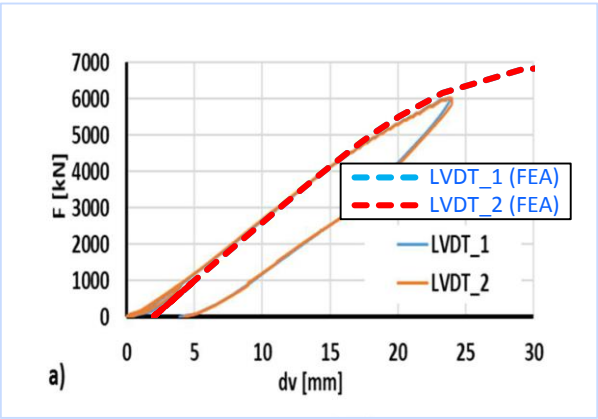


Figure 3. Instrumentation used in the C3 specimen. a) Lateral view. b) Top view.

FEA and test results are in good agreement

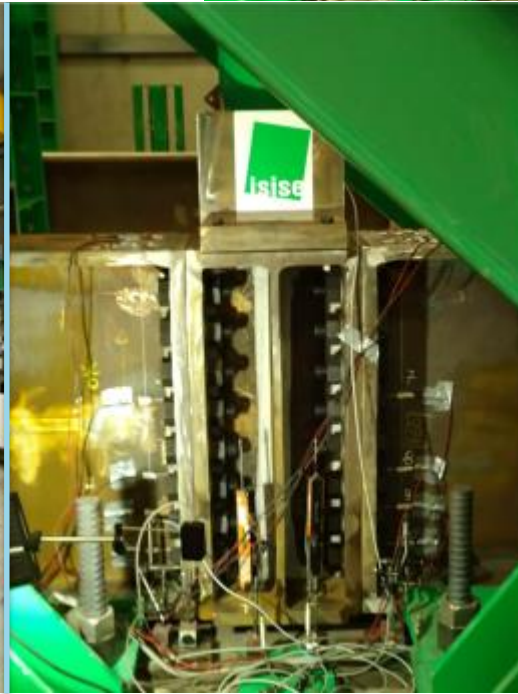
Initial displacement of 2 mm added to correct the initial embedding



LBNF – C3 - Conclusions

- Frictional coefficient of 0.25 used on the floor. Very good agreement achieved with friction coefficient between 0 (simply supported) and 0.25.
- FEA and test results of the vertical LVDTs are in good agreement.
- Complete results to be reported when material data & strain gauge results are available.

Coimbra – C4 - Setup



LBNF – C4 – Fem & Correlations

Test results from EDMS 2009829 v.1

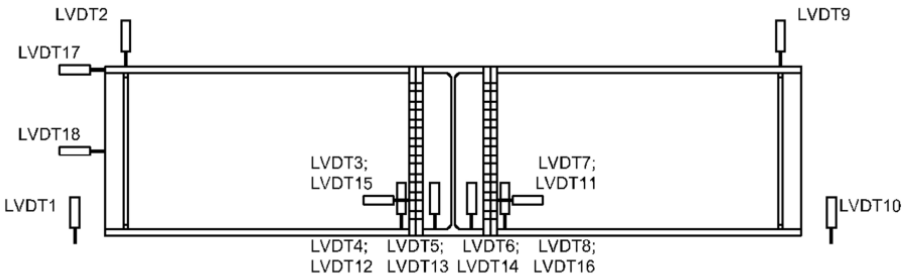
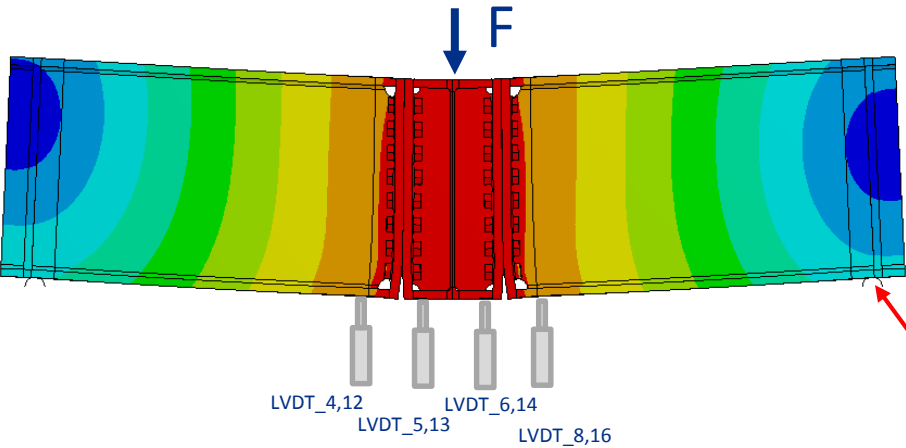
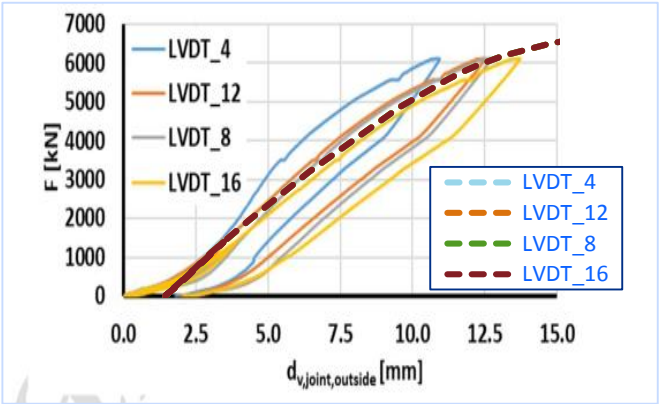
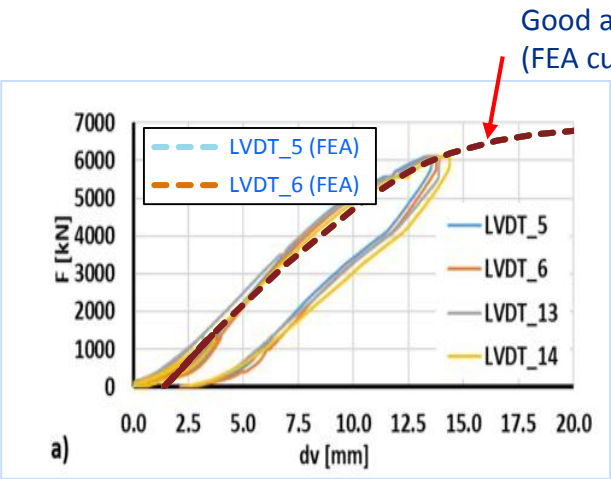


Figure 3. Instrumentation used in the C3 specimen. Lateral view.

FEA and test results are in fairly good agreement

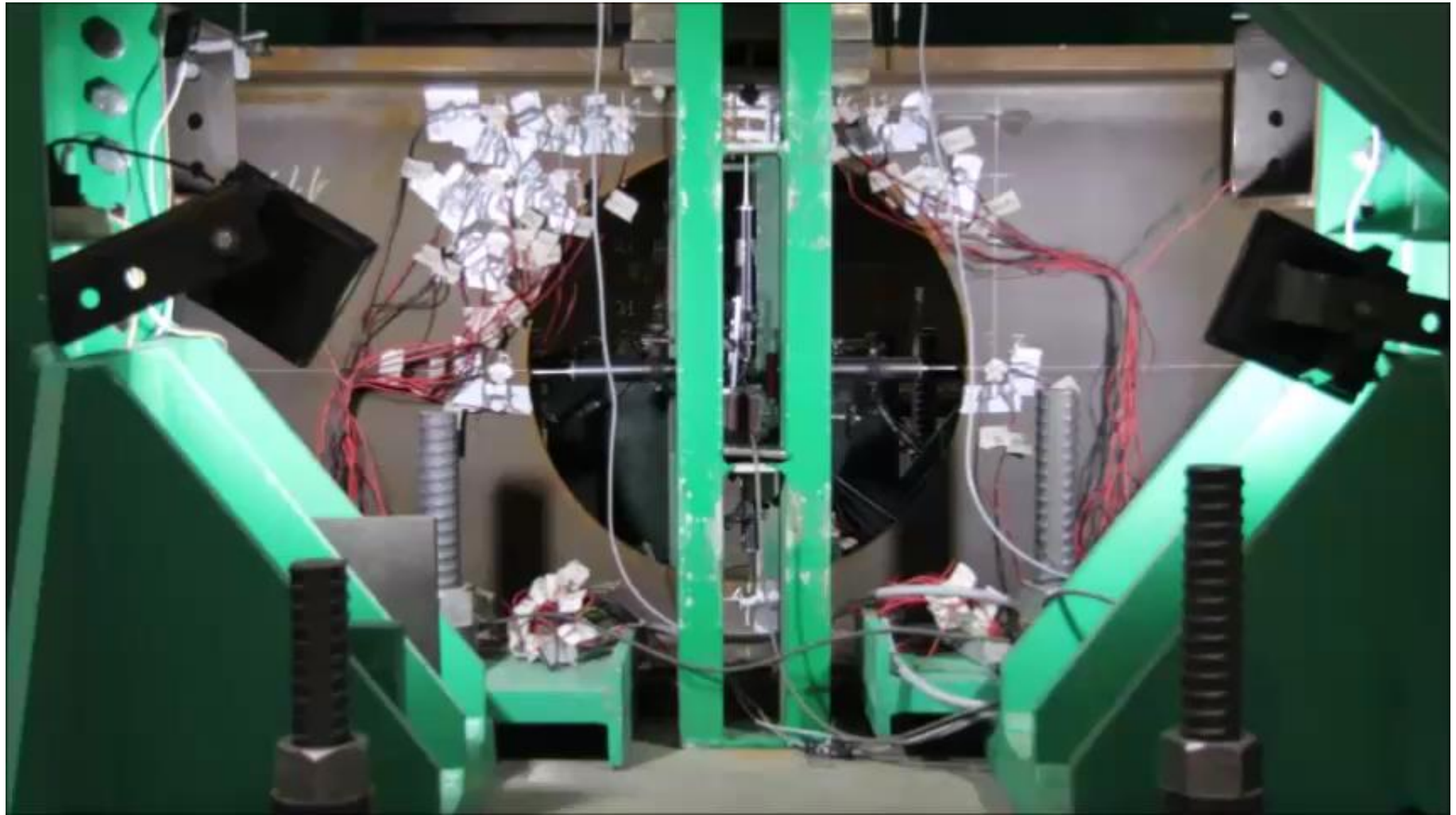
Initial displacement of 1.4 mm added to correct the initial embedding



LBNF – C4 - Conclusions

- Frictional coefficient of 0.25 used on the floor. Reasonably good agreement achieved with friction coefficient between 0 (simply supported) and 0.25.
- FEA and test results of the vertical LVDTs are in good agreement
- Complete results to be reported when material data & strain gauge results are available

LBNF – C0 - Timelaps



LBNF – COIMBRA - Schedule

- Three -> done
- Four to go

Activity	September				October				
	Week 1	Week 2	Week 3	Week 4	Week 1	Week 2	Week 3	Week 4	Week 5
Experimental test C2									
Positioning									
Instrumentation									
Pretest									
Test									
Disassembly									
Experimental test C1									
Positioning									
Instrumentation									
Pretest									
Test									
Disassembly									
Experimental test C5									
Positioning									
Instrumentation									
Pretest									
Test									
Disassembly									
Experimental test C6									
Positioning									
Instrumentation									
Pretest									
Test									
Disassembly									