

RESEARCH PROJECT

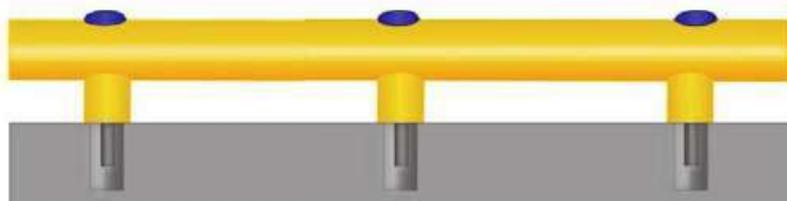
NUMERICAL-EXPERIMENTAL COMPARATIVE STUDY OF THE RESISTANCE OF POLYETHYLENE BOLLARDS AND CRASH BARRIERS.

PANEL **CHOK**

BOLLARDS



CRASH BARRIERS



Zaragoza, December 2014

MR LUIS FORCANO OBÓN, TENURED PROFESSOR AT THE UNIVERSITY OF ZARAGOZA, TECHNICAL AND INDUSTRIAL ENGINEER, MEMBER NO. 2483 AT THE OFFICIAL ASSOCIATION OF TECHNICAL AND INDUSTRIAL ENGINEERS OF ARAGÓN, WITH SPANISH NATIONAL ID CARD NO. 17142925-J AND DOMICILED IN ZARAGOZA, CALLE MARÍA ZAMBRANO, NO. 21, 50018 ZARAGOZA, SPAIN

HEREBY DECLARES:

That on the 18th day of September 2014, the company S.G. FREELANCE S.L., with VAT Reg. No. B-97470678, and registered offices at Lugar Urbanización la Bonaigua, 14 Bj Lugar, 46111 Rocafort (Valencia), SPAIN, commissioned me with a TECHNICAL REPORT on the ECONOMIC-STRUCTURAL SUITABILITY of the BOLLARDS and CRASH BARRIERS they manufacture, market and install at industrial buildings to prevent crashes, normally of industrial vehicles such as forklifts, pallet trucks, etc., while they are handling materials stored at these sites.

CONSIDERATIONS

S.G. FREELANCE S.L. is interested in having a report drawn up on the products described above in order to actually test the energy levels they withstand in the buildings where they are installed.

This report provides an evaluation of the resistance and deformation capacity both in respect of tests performed by an officially approved laboratory (ENSAYA, Laboratorio de Ensayos Técnicos S.A.) by static loading, and the theoretical evaluation of this resistance and deformation capacity, also with static loading, based on the characteristics of the materials used in manufacturing and provided by the manufacturers using the finite element method (FEM) modelling process.

The results obtained based on the above description are always lower than those obtained using tests and modelling with dynamic loads.



03

Panelchok es la empresa líder en la fabricación y comercialización de soluciones constructivas para la industria agroalimentaria.

Gracias a la experiencia de más de 40 años en el sector, hemos adquirido un compromiso de calidad que nos permite ofrecer los mejores productos para cada necesidad. Nuestros productos disponen de la tecnología más avanzada del mercado, donde operamos en tres divisiones:

- Revestimientos Sanitarios de paredes y techos con PVC.
- Protecciones de Polietileno para la industria alimentaria.
- Paneles Aislantes

La innovación, calidad, servicio y el compromiso con nuestros clientes son los valores que buscamos aplicar en todas nuestras actividades.

Han confiado en nosotros.

TESCO **consum** **ELPOZO** **MERCADONA**

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[Text for picture above:]

Panelchok is a leading company in the manufacture and marketing of building solutions for the food and agricultural industries.

Thanks to our experience of over 40 years in the trade, we have acquired a commitment to quality that permits us to offer the finest products for each particular need. Our products are made using advanced technology, and we have three basic divisions:

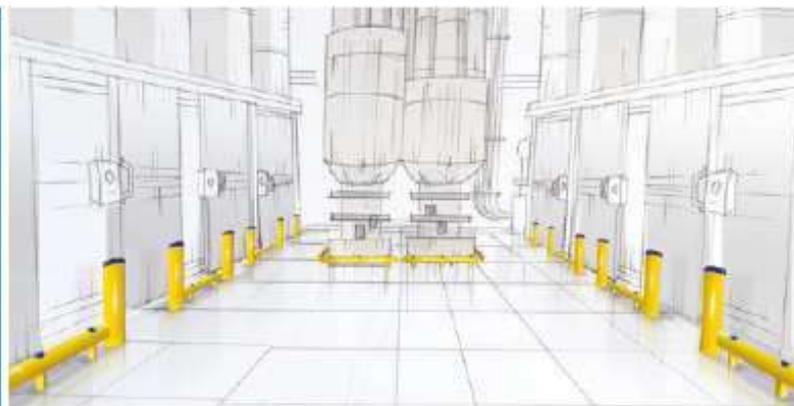
- Sanitary Surface Coverings for walls and ceilings in PVC.
- Polyethylene protection for the food and agricultural industries.
- Soundproofing panels.

Quality, service and commitment to our clients are the values we apply in all our activities. Clients having placed their trust in us: TESCO, Consum, El Pozo, Mercadona

Luis Forcano Obón.

Tenured Professor - University of Zaragoza
Technical and Industrial Engineer. Assoc. Member 2483.

PANELCHOK



CARACTERÍSTICAS:

- Nulo mantenimiento.
- Se puede nivelar.
- Polímero de alta densidad.
- Sin esquinas ni rincones.
- Resistente a ambientes altamente corrosivos.
- No se oxida.
- Alta resistencia a impactos.
- Gran viabilidad debido a su color.
- Absorción del impacto gracias a la flexibilidad.
- No proliferan hongos ni bacterias.

VENTAJAS:

- Protección eficaz sin rotura del suelo.
- En caso de curvarse o deteriorar se puede sustituir sin ninguna obra.
- Reducción de los costes de mantenimiento.
- Fácil montaje.
- Sin pintura debido a que es macizo.
- Un pieza sencilla.

PCK SEGURIDAD

Datos técnicos	Unidad	HNW-PE
Densidad ISO 1183	g/cm ³	0.95
Resistencia a la tracción DIN EN ISO 527	N/mm ²	29
Resistencia al alargamiento DIN EN ISO 527	%	18
Alargamiento de la rotura	%	300
Módulo E DIN EN ISO 527	MPa	890
Resistencia al impacto DIN EN ISO 179	KJ/m ²	Sin rotura
Resistencia al impacto en probeta DIN EN ISO 179	KJ/m ²	50
Dureza superficial DIN EN ISO 2009-1	N/mm ²	45
Dureza D ISO 868	shore	66
Espansión lineal coeficiente DIN 53752	K ⁻¹	19 · 10 ⁻⁵
Conductividad térmica DIN 52612	W/m·K	0.38
Rigidez dieléctrica VDE 0303:21	KV/mm	44
Resistencia superficial DIN IEC 167	Ohm	10 ¹¹
Rango de temperatura	°C	-100 hasta +90
Resistencia a los productos químicos	-	Alta resistencia a los ácidos, álcalis y disolventes.
Aceptable fisiológicamente	-	Si
Se blanda	-	Si
Refuerzo fibra de vidrio	-	-
Laqueado, impresión	-	-
Moldado en caliente	-	Posible

[text for image above]

CHARACTERISTICS:

No maintenance
Can be levelled
High density polymer
No corners
Resistant to highly aggressive atmospheres.
Non-rust
High impact resistance.
High visibility due to its colour
Absorption of impact due to high flexibility
Non-proliferation of fungi or bacteria

ADVANTAGES:

Efficient protection against floor breakage
In the event of bending or damage, replacement is simple, with no construction work
Reduction of maintenance costs
Easy assembly.
No painting, as the colour is in the solid body
Simple cleaning

Technical data	Unit	HMW-PE
Density ISO 1193	g/cm ³	0.95
Traction resistance DIN EN ISO 527	N/mm ²	28
Elongation resistance DIN EN ISO 527	%	+8
Elongation at break	%	300
Module-E DIN EN ISO 527	MPa	850
Impact resistance DIN EN ISO 179	KJ/m ²	No breakage
Impact resistance in test piece DIN EN ISO 179	KJ/m ²	50
Surface density DIN EN ISO 2039-1	N/mm ²	45
Hardness D ISO 868	Shore	66
Linear expansion ratio DIN 53752	K-1	1.8 10 ⁻⁴
Thermal conductivity DIN 52612	W/m-K	0.38
Dielectric strength VDE 0303-21	KV/mm	44
Surface resistance DIN IEC 167	Ohm	10 ¹⁴
Temperature range	°C	-100 to +80
Resistance to chemical attack	-	High resistance to acids, alkalis and solvents.
Physiologically acceptable	-	Yes
Welding	-	Yes
Glass fibre reinforcement	-	-
Lacquering, printing	-	-
Hot-moulding	-	Possible

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UNBREAKABLE HIGH DENSITY POLYETHYLENE

A material that is highly resistant with a performance better than stainless steel, and complying with standards for materials in contact with foods.

SPECIAL ROD

Special alloy to guarantee flexibility against impact and prevent rupture.

NEOPRENE

Special neoprene to seal the protection joint and avoid any filtration.

FLOOR PROTECTION

Special covering that insulates and protects the floor against impacts hitting the rod and avoiding rod breakage.

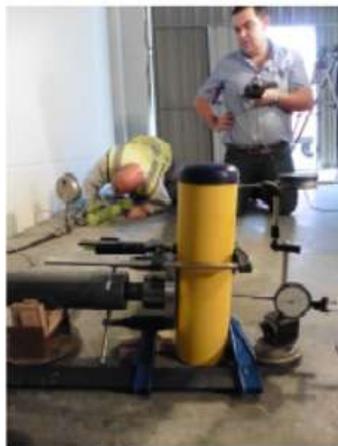
REPLACEABLE ANCHORING SYSTEM

Guarantees maximum fixing and resistance for the protection and if necessary facilitates rod replacement.

SOLID BODY

Manufactured in solid pieces to give maximum resistance. Note also there's no paint; pigment is in the material itself.

Test preparation:



Test performance:



Measurement:



Completion:



1st LOAD CONTINUOUS IN INTERVALS OF 50 kg UP TO 800, FROM 100 kg TO 2000 and FROM 500 TO 8000.

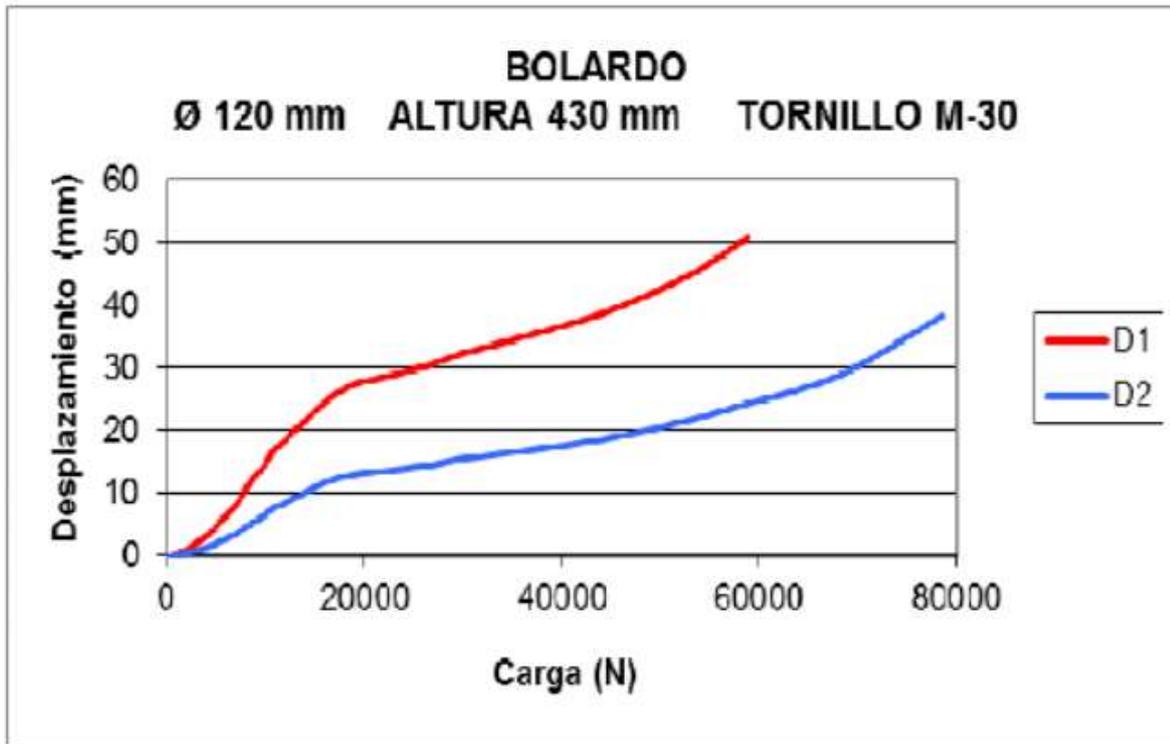
Load (kg)	Comparator readout (mm)		Observations	DEFORMATION (mm)	
	L1 upper	L2 lower		L1 upper	L2 lower
0	2.65	1.98			
50	2.76	2.03		0.09	0.05
120	3.11	2.21		0.44	0.23
150	3.34	2.30		0.67	0.32
200	3.70	2.45		1.03	0.47
250	4.13	2.63		1.46	0.65
300	4.60	2.83		1.93	0.85
350	5.15	3.05		2.48	1.07
400	5.70	3.27		3.03	1.29
450	6.40	3.55		3.73	1.57
500	7.15	3.87		4.48	1.89
550	8.23	4.32		5.56	2.34
600	8.85	4.58		6.18	2.60
650	9.75	4.95		7.08	2.97
700	10.54	5.33		7.87	3.35
750	11.59	5.78		8.92	3.80
800	12.83	6.35		10.16	4.37
900	15.30	7.49		12.63	5.51
1000	16.85	8.27		14.18	6.29
1100	19.49	9.56		16.82	7.58
1200	20.77	10.20		18.10	8.22
1300	22.41	11.07		19.74	9.09
1400	23.80	11.84		21.13	9.86
1500	25.34	12.71		22.67	10.73
1600	26.69	13.43		24.02	11.45
1700	28.14	14.05		25.47	12.07
Unloading at 10 min	0	15.05		12.38	6.77
	0	13.63		10.96	6.21

2nd LOAD CONSTANT INCREASE UP TO 1700 kg WITHOUT DEFORMATION READOUT.
INTERVALS OF 100 kg UP TO 2000, and FROM 500 TO 8000

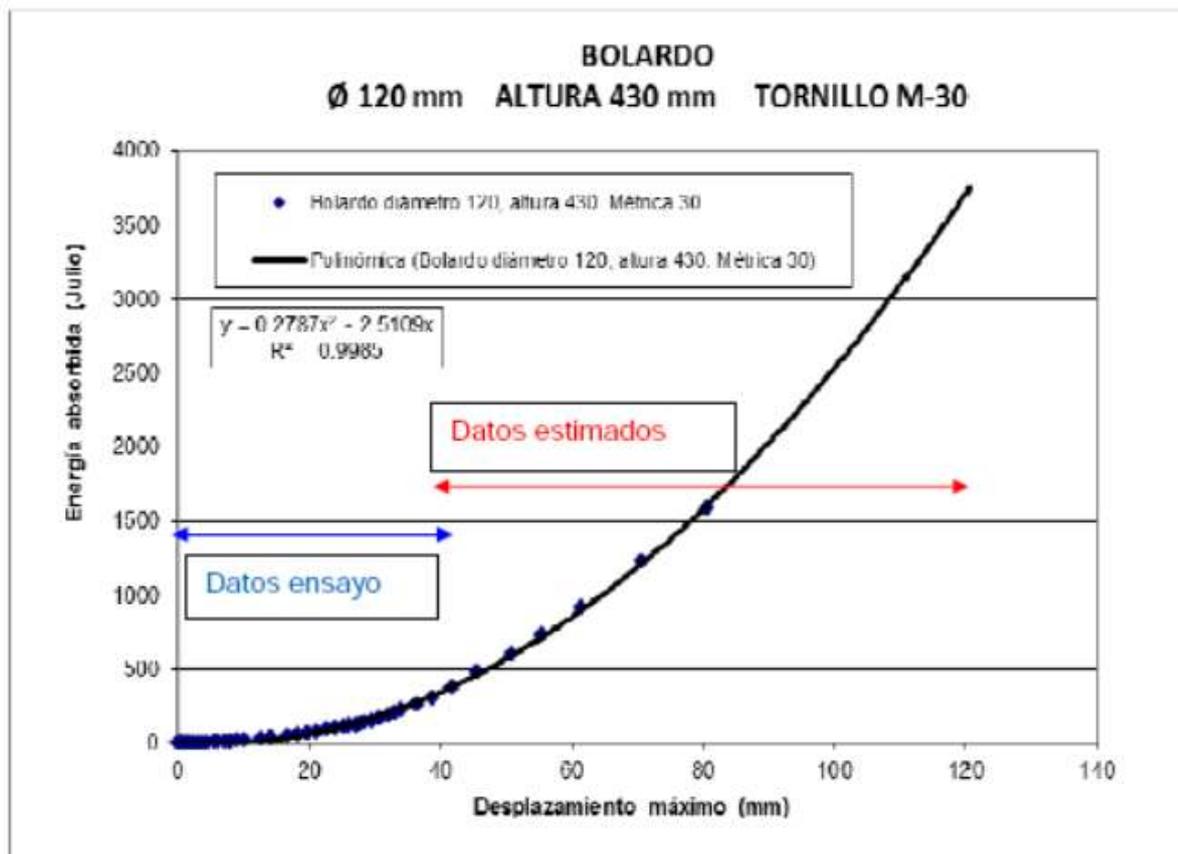
Load (kg)	Comparator readout (mm)		Observations	DEFORMATION (mm)	
	L1 upper	L2 lower		L1 upper	L2 lower
0	3.59	5.50			
1700	11.82	9.44		19.19	10.15
1800	12.63	9.84		20.00	10.55
1900	13.53	10.22		20.90	10.93
2000	14.03	10.45		21.40	11.16
2200	14.70	10.78		22.07	11.49
2500	15.88	11.34		23.25	12.05
2750	16.95	11.88		24.32	12.59
3000	18.39	12.69		25.76	13.40
3250	19.45	13.20		26.82	13.91
3500	20.47	13.71		27.84	14.42
4000	22.63	14.73		30.00	15.44
4500	25.02	15.94		32.39	16.65
5000	28.20	17.49		35.57	18.20
5500	32.03	19.40		39.40	20.11
6000	37.14	21.66		44.51	22.37
6500		23.70		0.00	24.41
7000		26.55		0.00	27.26
7500		30.90		0.00	31.61
8000		35.64		0.00	36.35

Unloading, and state of rods, grout and floor observed.

BOLLARD Ø 120 mm HEIGHT 430 mm BOLT M-30.



Displacement (mm) Load (N)



Bollard diameter 110 Height 430 mm Metric 30

Estimated data Test data

Energy absorbed (Joules)

Maximum displacement (mm)

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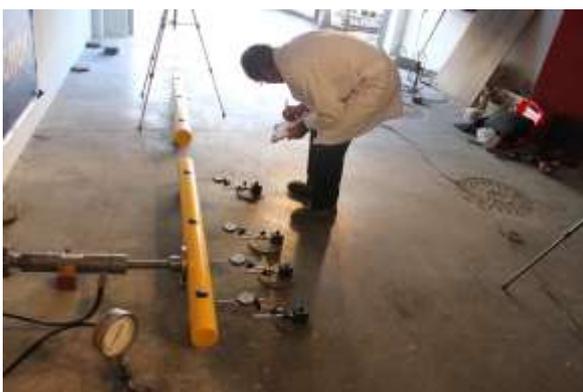
Tenured Professor - University of Zaragoza

Technical and Industrial Engineer. Assoc. Member 2483.

2.2. CRASH BARRIERS: Installation:



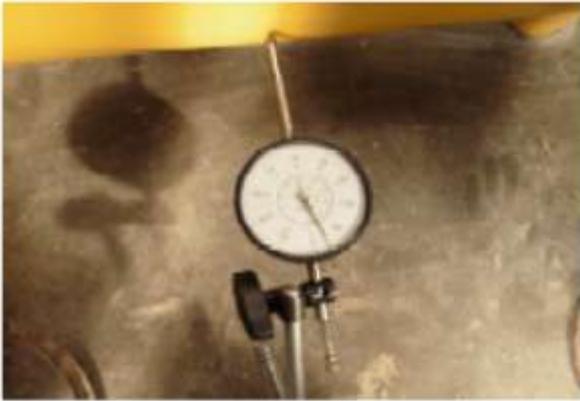
Preparation:



Performance



Measurement:

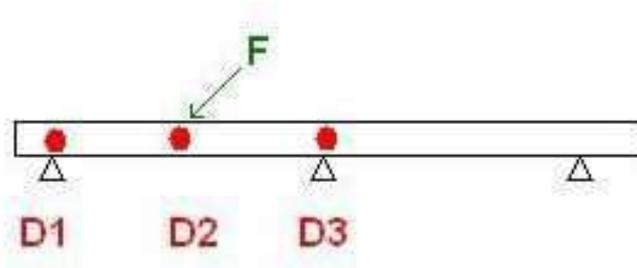


Completion:



2.2.1. CRASH BARRIER DIAMETER 100 mm. SINGLE BASE BOLT M-20. LOAD APPLIED BETWEEN SUPPORTS

2.2.1.	Diameter (mm)	Height (mm)	Ø Rod (mm)	Length (mm)	No. Anchorings	Base:
	100	150	20	1500	3	Single



Load applied between supports (D2)

Load (kg)	Comparator readout (mm)			Observations	Deformation (mm)		
	L1 left	L2 centre	L3 right		L1 left	L2 centre	L3 right
0	0.50	0.50	0.60				
100	0.70	0.85	0.71		0.2	0.35	0.11
200	0.88	1.33	0.84		0.38	0.83	0.24
300	1.06	1.81	1.00		0.56	1.31	0.4
400	1.27	2.36	1.18		0.77	1.86	0.58
500	1.53	3.01	1.40		1.03	2.51	0.8
600	1.90	3.85	1.69		1.4	3.35	1.09
700	2.20	4.67	1.98		1.7	4.17	1.38
800	2.65	5.51	2.28		2.15	5.01	1.68
900	3.06	6.42	2.62		2.56	5.92	2.02
1000	3.44	7.24	2.93		2.94	6.74	2.33
1100	3.96	8.35	3.34		3.46	7.85	2.74
Unloading at 10 min	0	1.68	2.83		1.18	2.33	0.78
	0	1.45	2.09		0.95	1.59	0.57

2nd load. Constant increase up to 1500 kg without deformation readout.

Load (kg)	Comparator readout (mm)			Observations	Deformation (mm)		
	L1 left	L2 centre	L3 right		L1 left	L2 centre	L3 right
0	0.50	0.50	0.60				
1500	4.94	11.88	5.69		4.34	11.39	5.09
2000	7.96	19.08	8.94		7.46	17.58	9.34
2500	12.63	26.52	13.58		12.13	27.61	12.98

Comparator 2 tared when maximum readout exceeded.

	2500	12.63	0.20	13.58		19.69	40.50	20.31
	3000	20.19	13.09	20.91	Rod bends	0	0	0
Unloading at 10 min	0		49.02			7.87	21.62	7.83
	0	8.37	27.40	8.43				

3rd load. Loaded up to breakage, constant increase in load up to 6500 kg.
Unloaded, and state of rods, and floor grout observed.

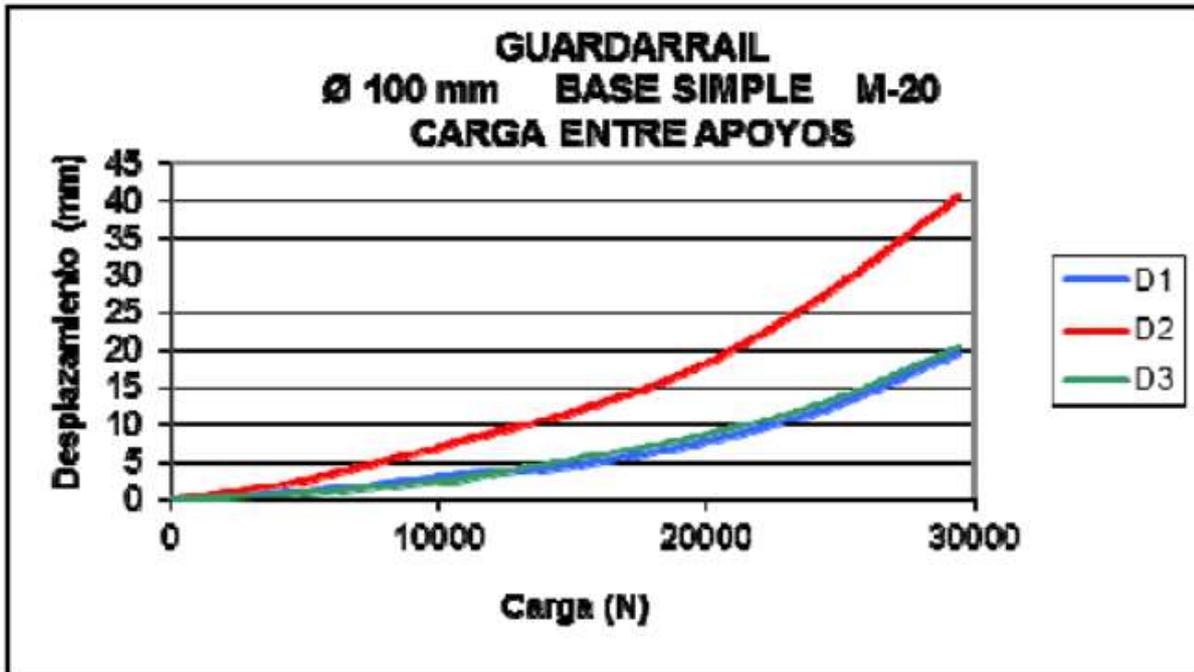
1st cycle

Load (kg)	DEFORMATION (mm)		
	L1 left	L2 centre	L3 right
0	0.5	0.5	0.6
100	0.20	0.35	0.11
200	0.38	0.83	0.24
300	0.56	1.31	0.40
400	0.77	1.86	0.58
500	1.03	2.51	0.80
600	1.40	3.35	1.09
700	1.70	4.17	1.38
800	2.15	5.01	1.68
900	2.56	5.92	2.02
1000	2.94	6.74	2.33
1100	3.46	7.85	2.74
Unloading 10 min		1.18	2.33
		0.95	1.59

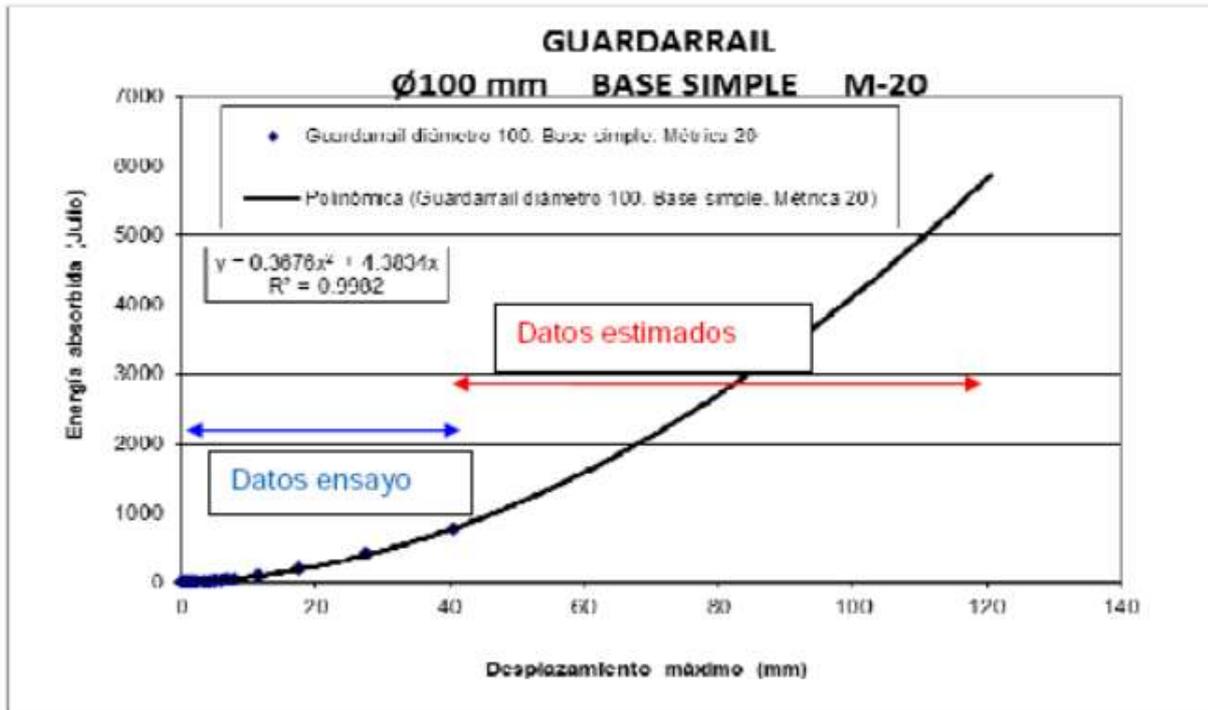
2nd cycle

	1500	4.34	11.38	5.09
	2000	7.46	17.58	8.34
	2500	12.13	27.61	12.98
	3000	19.69	40.50	20.31
	6500			
Unloading 10 min				
		7.87	21.62	7.83

CRASH BARRIER Ø 100 mm. SINGLE BASE M-20.
LOAD BETWEEN SUPPORTS



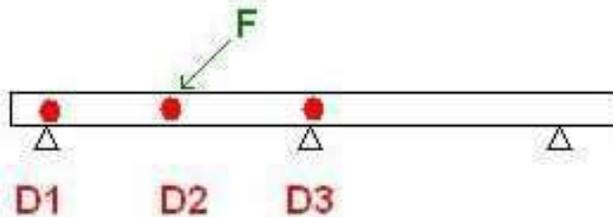
Displacement (mm) Load (N)



CRASH BARRIER Ø 100 mm. SINGLE BASE M-20
 Crash barrier diameter 100 Single base Metric 20
 Polynomial (crash barrier diameter 100 Single base Metric 20)
 Test data Estimated data
 Energy absorbed (joules)
 Maximum displacement (mm)

2.2.2. CRASH BARRIER DIAMETER 100 mm. REINFORCED BASE
BOLT M-30. LOAD APPLIED BETWEEN SUPPORTS

2.2.2.	Diameter (mm)	Height (mm)	Ø Rod (mm)	Length (mm)	No. Anchorings	Base:
	100	150	30	1500	3	reinforced



Load applied between supports (D2)

Load (kg)	Comparator readout (mm)			Observations	Deformation (mm)		
	L1 left	L2 centre	L3 right		L1 left	L2 centre	L3 right
0	0.55	4.08	0.16				
500	1.64	7.24	1.78		1.09	3.16	1.62
1000	3.18	10.75	3.79		2.63	6.67	3.63
1500	5.03	15.30	6.00		4.48	11.22	5.84
2000	6.95	19.60	7.24		6.4	15.52	7.08
2500	9.11	24.10	8.41		8.56	20.02	8.25
3000	11.15	29.35	9.76		10.6	25.27	9.6
3500	12.27	33.85	10.97		11.72	29.77	10.81
4000	13.48	39.70	12.49		12.93	35.62	12.33
4500	14.57	45.50	14.10		14.02	41.42	13.94

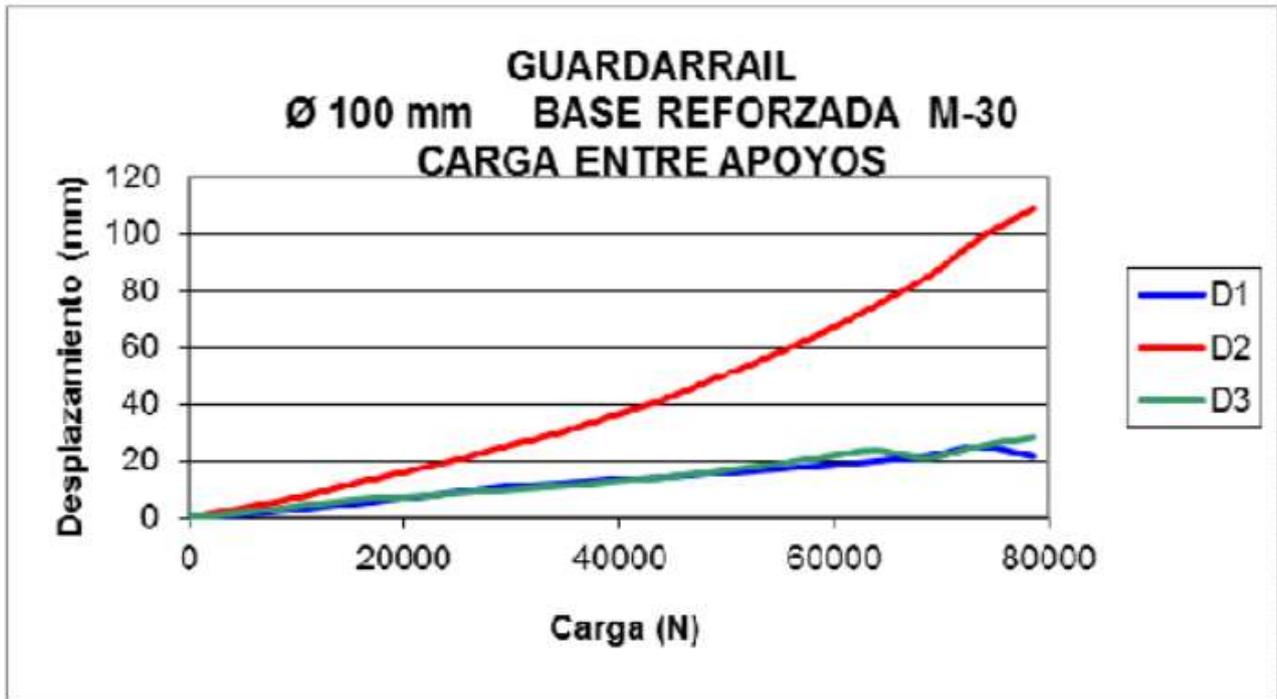
Comparator 2 tared when maximum readout exceeded.

4500	14.57	2.30	14.10				
5000	15.91	9.90	16.33		15.36	49.02	16.17
5500	17.26	17.70	18.76		16.71	56.82	18.6
6000	18.69	25.95	21.45		18.14	65.07	21.29
6500	20.35	35.30	23.96		19.8	74.42	23.8
7000	22.36	45.70	21.44		21.81	84.82	21.28

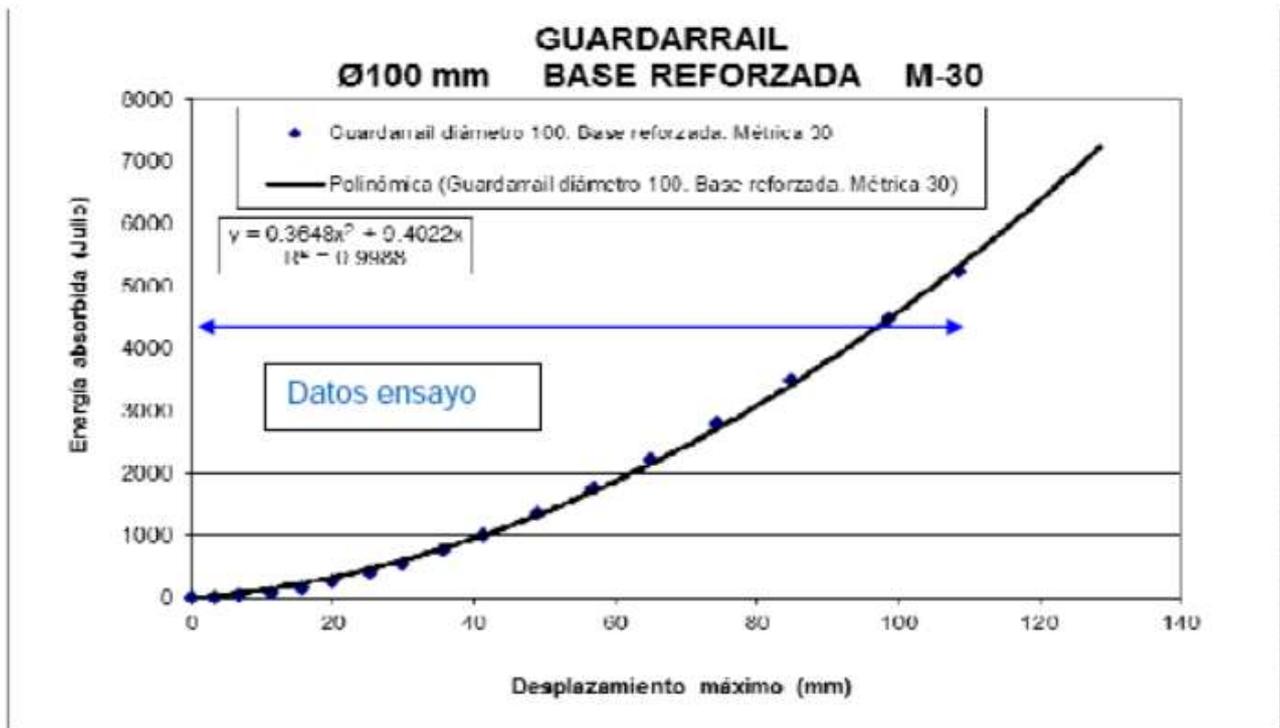
Comparator 1-2-3 tared when maximum readout exceeded.

7000	0.27	2.10	0.95				
7500	3.37	15.85	5.01		24.91	98.57	25.34
8000	5.93	25.95	8.05		21.81	108.67	28.38

CRASH BARRIER Ø 100 mm. REINFORCED BASE M-30.
LOAD BETWEEN SUPPORTS



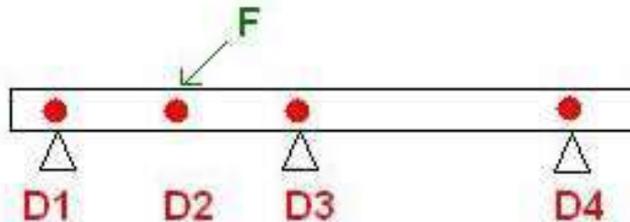
Displacement (mm) Load (N)



Test data

2.2.3. CRASH BARRIER DIAMETER 120 mm. SINGLE BASE BOLT M-20. LOAD APPLIED BETWEEN SUPPORTS

2.2.3.	Diameter (mm)	Height (mm)	Ø Rod (mm)	Length (mm)	No. Anchorings	Base:
	120	150	20	1500	3	single



Load applied between supports (D2)

Load (kg)	Comparator readout (mm)				Observ.	Deformation (mm)			
	L1 left	L2 centre	L3 right	L4 exterior		L1 left	L2 centre	L3 right	L4 exterior
0	2.90	4.26	3.91	3.04					
100	3.41	5.38	4.59	3.14		0.51	1.12	0.68	0.10
200	3.89	6.30	5.15	3.23		0.99	2.04	1.24	0.19
400	4.76	7.75	6.11	3.39		1.86	3.49	2.2	0.35
600	5.19	8.50	6.59	3.47		2.29	4.24	2.68	0.43
1000	6.06	9.85	7.49	3.64		3.16	5.59	3.58	0.60
1250	6.02	10.02	7.78	3.75		3.12	5.76	3.87	0.71
Unloading at 10 min	0	4.75	5.72	5.15	3.22	1.85	1.46	1.24	0.18
	0	3.62	5.49	5.00	3.21	0.72	1.23	1.09	0.17

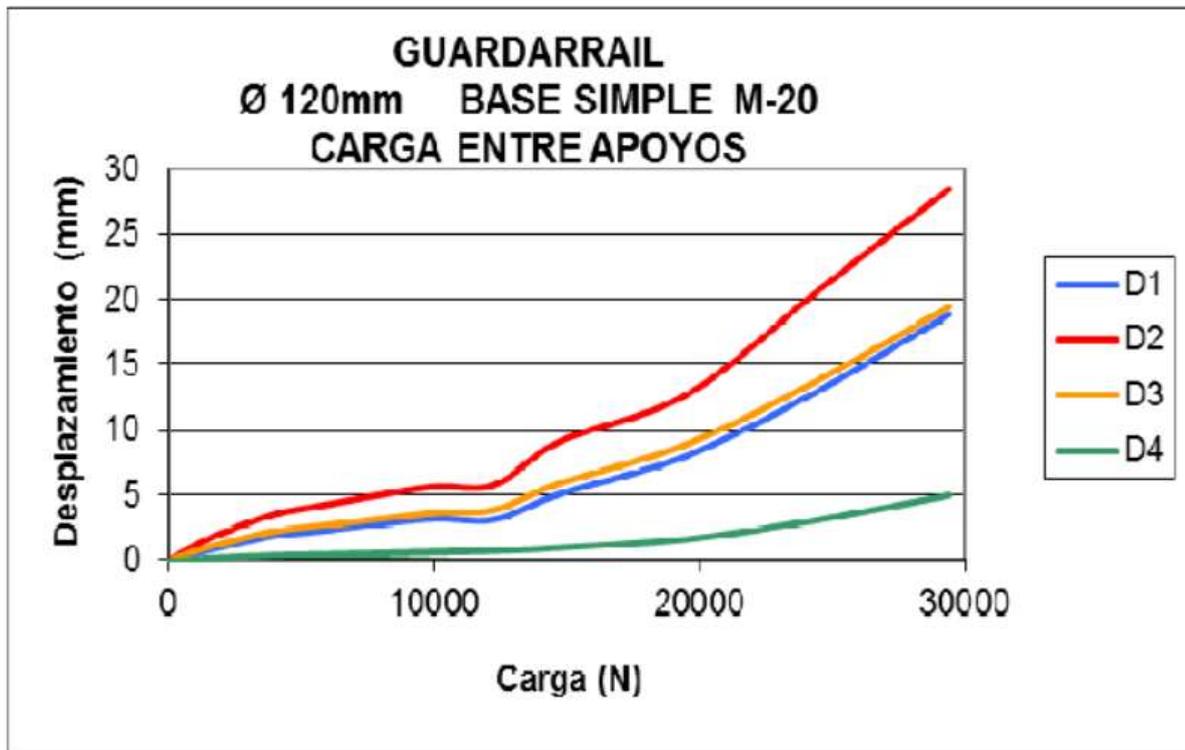
2nd load. Constant increase up to 1500 kg without deformation readout.

0	2.90	4.26	3.91	3.04		5.05	9.08	5.88	0.95
1500	7.95	13.34	9.79	3.99		8.08	12.79	8.97	1.63
2000	10.98	17.05	12.88	4.67		13.03	20.74	13.85	3.11
2500	15.93	25.00	17.76	6.15		18.85	28.49	19.46	4.98
3000	21.75	32.75	23.37	8.02		0.00	0.00	0.00	0.00
3500									
Unloading 10 min		12.50	15.89	12.91	5.91	9.60	11.63	9.00	2.87

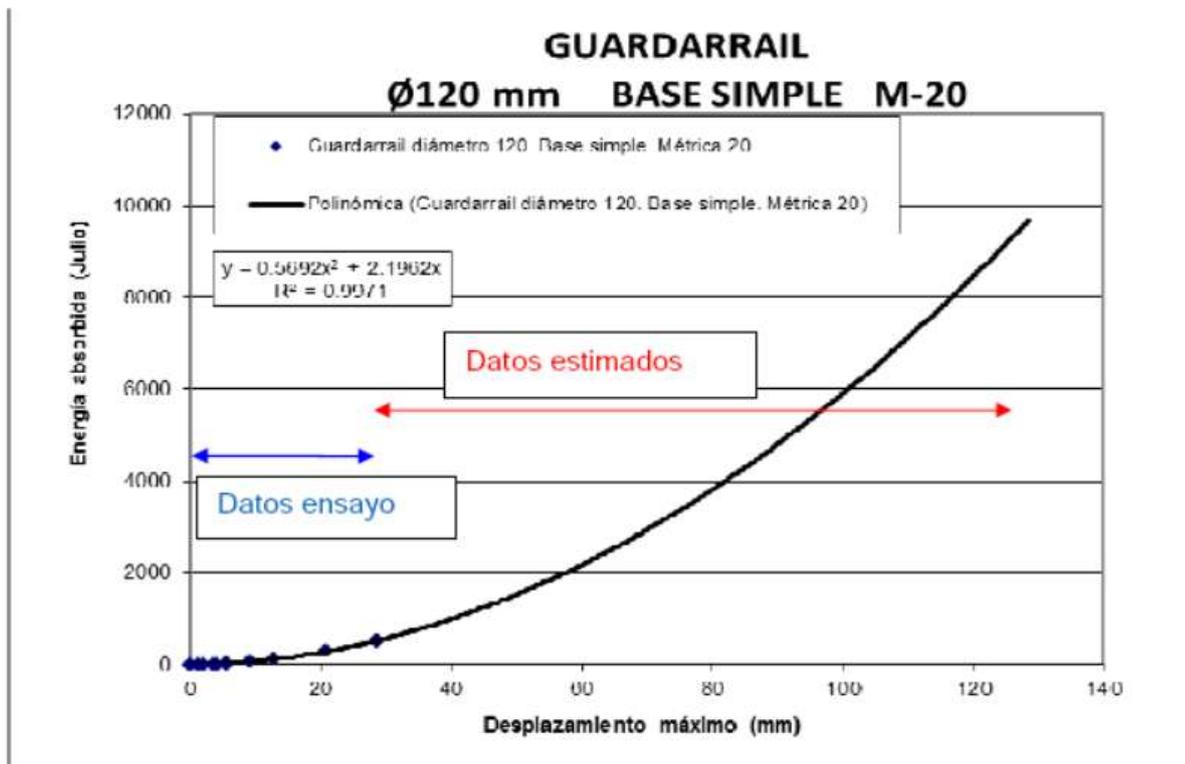
3rd load.

Loaded up to breakage, constant increase in load up to 5500 kg.
Test halted because hydraulic jack cannot load more.
Unloaded, and state of rods, and floor grout observed.

CRASH BARRIER Ø 120 mm. SINGLE BASE M-20. LOAD BETWEEN SUPPORTS



Displacement (mm) Load (N)

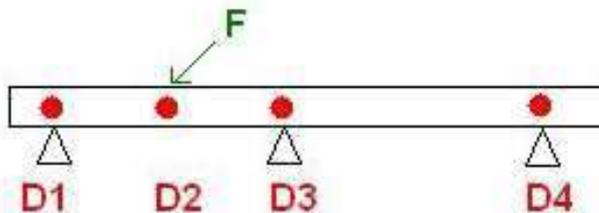


Estimated data

Test data

2.2.4. CRASH BARRIER DIAMETER 120 mm. REINFORCED BASE BOLT M-30. LOAD APPLIED BETWEEN SUPPORTS

2.2.4.	Diameter (mm)	Height (mm)	Ø Rod (mm)	Length (mm)	No. Anchorings	Base:
	120	150	30	1500	3	reinforced



Load applied between supports (D2)

Load (kg)	Comparator readout (mm)				Observ.	Deformation (mm)			
	L1 left	L2 centre	L3 right	L4 exterior		L1 left	L2 centre	L3 right	L4 exterior
0	2.12	2.55	1.13	1.98		2.12	2.55	1.13	1.98
100	2.51	3.51	1.67	2.01		0.39	0.96	0.54	0.03
200	2.88	4.32	2.20	2.08		0.76	1.77	1.07	0.1
400	3.45	5.43	3.98	2.15		1.33	2.88	2.85	0.17
600	4.95	6.32	3.60	2.23		2.83	3.77	2.47	0.25
1000	5.20	8.56	5.22	2.40		3.08	6.01	4.09	0.42
1250	6.50	10.75	6.68	2.54		4.38	8.2	5.55	0.56
1500	7.72	12.77	8.04	2.67		5.6	10.22	6.91	0.69
Unloading at 10 min	0	5.90	7.65	5.20	2.40	3.78	5.1	4.07	0.42
	0	5.23	6.65	4.60	2.38	3.11	4.1	3.47	0.4

2nd load. Constant increase up to 2000 kg without deformation readout.

Load (kg)	Comparator readout (mm)				Observ.				
	1	2	3	4					
0	2.12	2.55	1.13	1.98					
2000	9.75	16.97	11.2	2.95		7.63	14.42	10.08	0.97
2500	11.12	20.51	13.10	3.01		9.00	17.96	11.97	1.03
3000	12.38	23.71	14.80	3.05		10.26	21.16	13.67	1.07
3500	13.91	27.61	16.63	3.11		11.79	25.06	15.50	1.13
4000	15.29	31.42	18.30	3.15		13.17	28.87	17.17	1.17
4500	16.70	35.44	20.05	3.22		14.58	32.89	18.92	1.24
5000	18.32	40.00	22.10	3.31		16.20	37.45	20.97	1.33
5500	20.12	45.10	24.45	3.43		18.00	42.55	23.32	1.45

Comparators tared when maximum run exceeded.

5500	3.59	3.35	3.26	1.80					
6000	6.25	11.00	6.81	2.03		20.66	50.20	26.87	1.68
6500	8.44	17.20	9.83	2.25		22.85	56.40	29.89	1.90
7000	10.97	24.30	13.37	2.54		25.38	63.50	33.43	2.19
7500	13.58	31.15	16.93	2.86		27.99	70.35	36.99	2.51
8000	16.50	38.92	21.00	3.27		30.91	78.12	41.06	2.92
8500	19.71	47.85	25.72	3.76		34.12	87.05	45.78	3.41

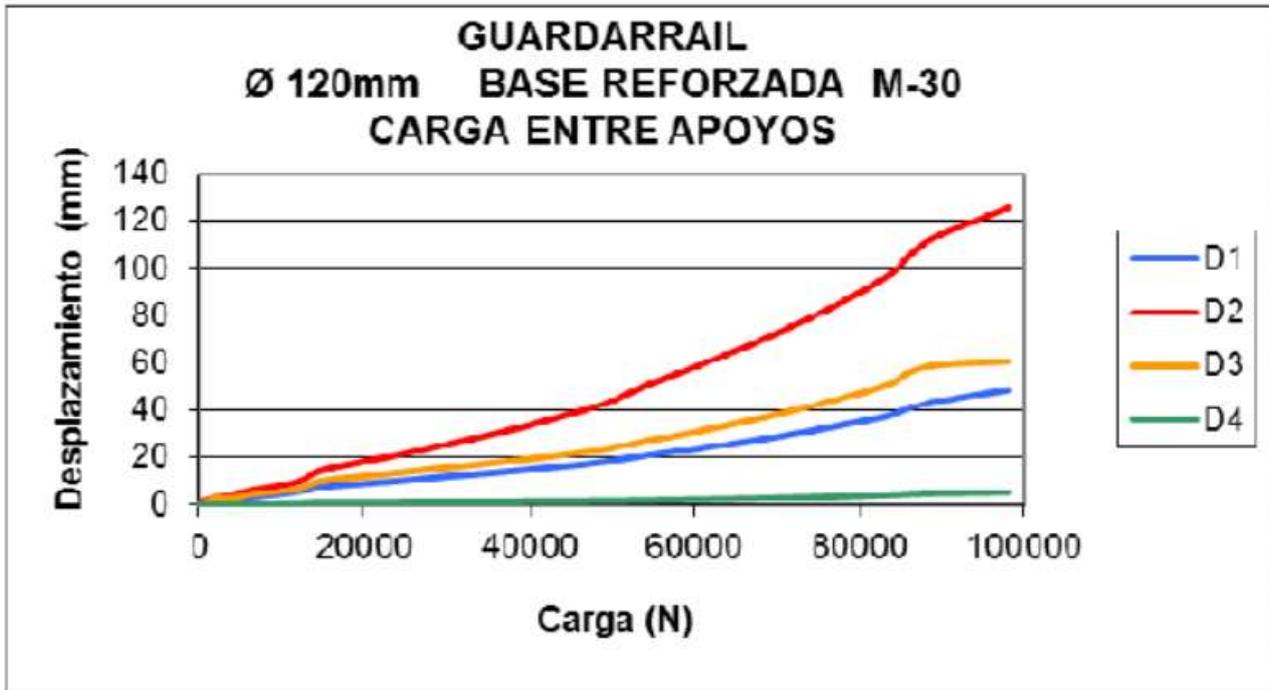
Comparator L2 tared when maximum run exceeded.

8500	19.71	3.07	25.72	3.76					
9000	23.00	12.45	30.60	4.27		37.41	96.43	50.66	3.92
10000	28.48	27.35	38.32	4.92		42.89	111.33	58.38	4.57
10500	34.29	41.95	40.52	5.45		48.70	125.93	60.58	5.10

3rd load.

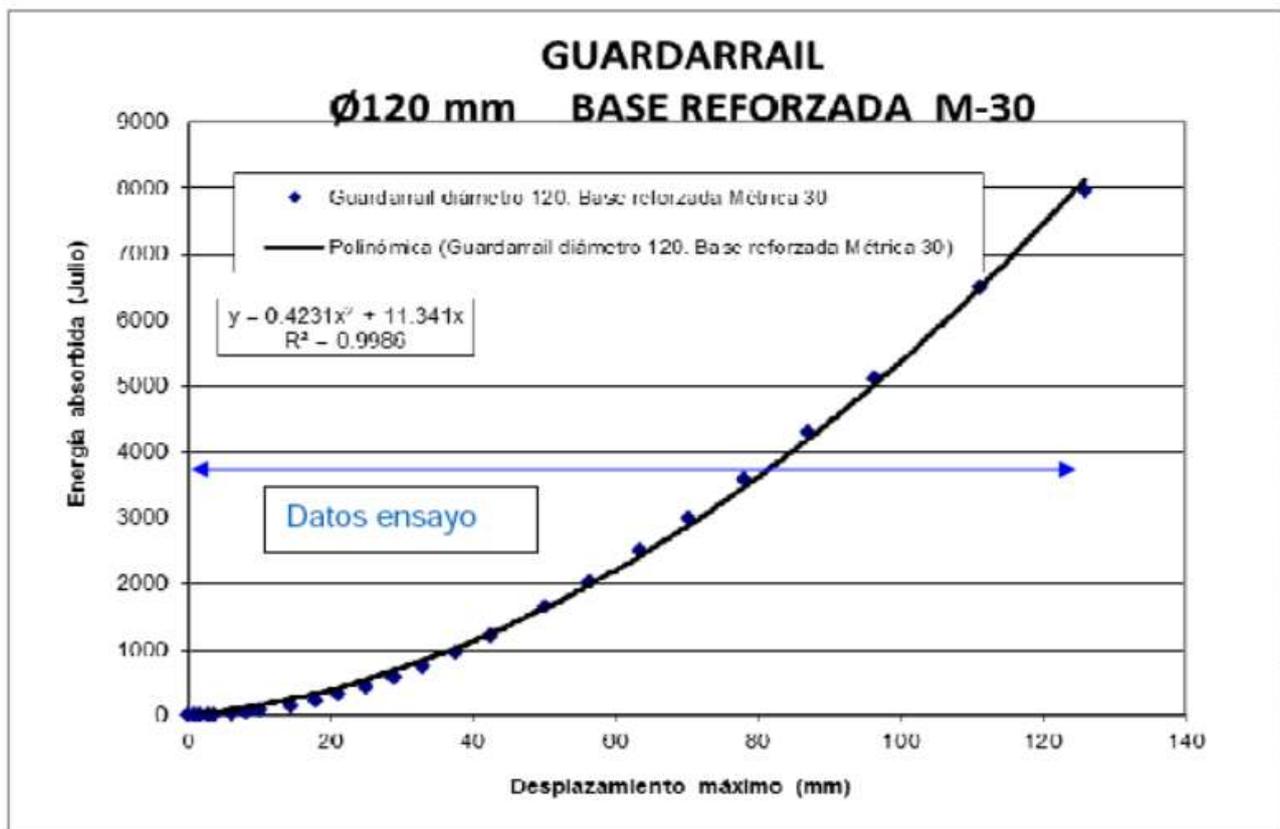
Loaded up to breakage, constant increase in load up to 5500 kg.
Test halted because hydraulic jack cannot load more.
Unloaded, and state of rods, and floor grout observed.

CRASH BARRIER Ø 20 mm. REINFORCED BASE M-30. LOAD BETWEEN SUPPORTS



Displacement (mm)

Load (N)



Crash barrier diameter 120 Reinforced base Metric 30

Polynomial (crash barrier diameter 120 Reinforced base Metric 30)

Test data

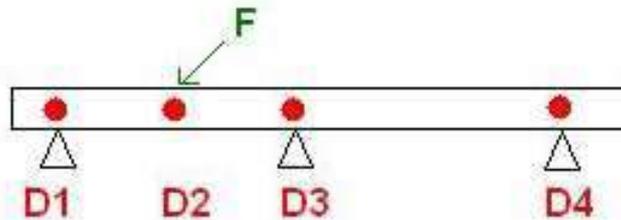
Luis Forcano Obón.

Tenured Professor - University of Zaragoza

Technical and Industrial Engineer. Assoc. Member 2483.

2.2.5. CRASH BARRIER DIAMETER 100 mm. REINFORCED BASE BOLT M-20. LOAD APPLIED BETWEEN SUPPORTS

2.2.5.	Diameter (mm)	Height (mm)	Ø Rod (mm)	Length (mm)	No. Anchorings	Base:
	100	150	20	1500	3	reinforced



Load (kg)	Comparator readout (mm)				Observ.	Deformation (mm)			
	L1 left	L2 centre	L3 right	L4 exterior		L1 left	L2 centre	L3 right	L4 exterior
0	7.48	4.02	5.22	10.64		7.48	4.02	5.22	10.64
500	8.10	6.39	6.18	10.61		0.62	2.37	0.96	-0.03
1000	8.80	9.12	7.33	10.55		1.32	5.1	2.11	-0.09
1500	9.90	13.10	9.45	10.45		2.42	9.08	4.23	-0.19
2000	12.40	19.55	12.95	10.30		4.92	15.53	7.73	-0.34
2500	14.90	25.55	15.29	10.25		7.42	21.53	10.07	-0.39
3000	16.90	30.88	17.13	9.16		9.42	26.86	11.91	-1.48
3500	18.70	37.66	19.61	10.10		11.22	33.64	14.39	-0.54
4000	20.41	44.63	27.22	10.05		12.93	40.61	22	-0.59

Comparator 1-2-3 tared when maximum readout exceeded.

4000	10.92	4.65	4.45	10.05					
4500	13.50	15.60	8.69	10.05		15.51	51.56	26.24	-0.59
5000	14.62	25.12	12.47	10.35		16.63	61.08	30.02	-0.29
Unloading at 10 min	0	13.85	0.79	1.95	10.4				
0									

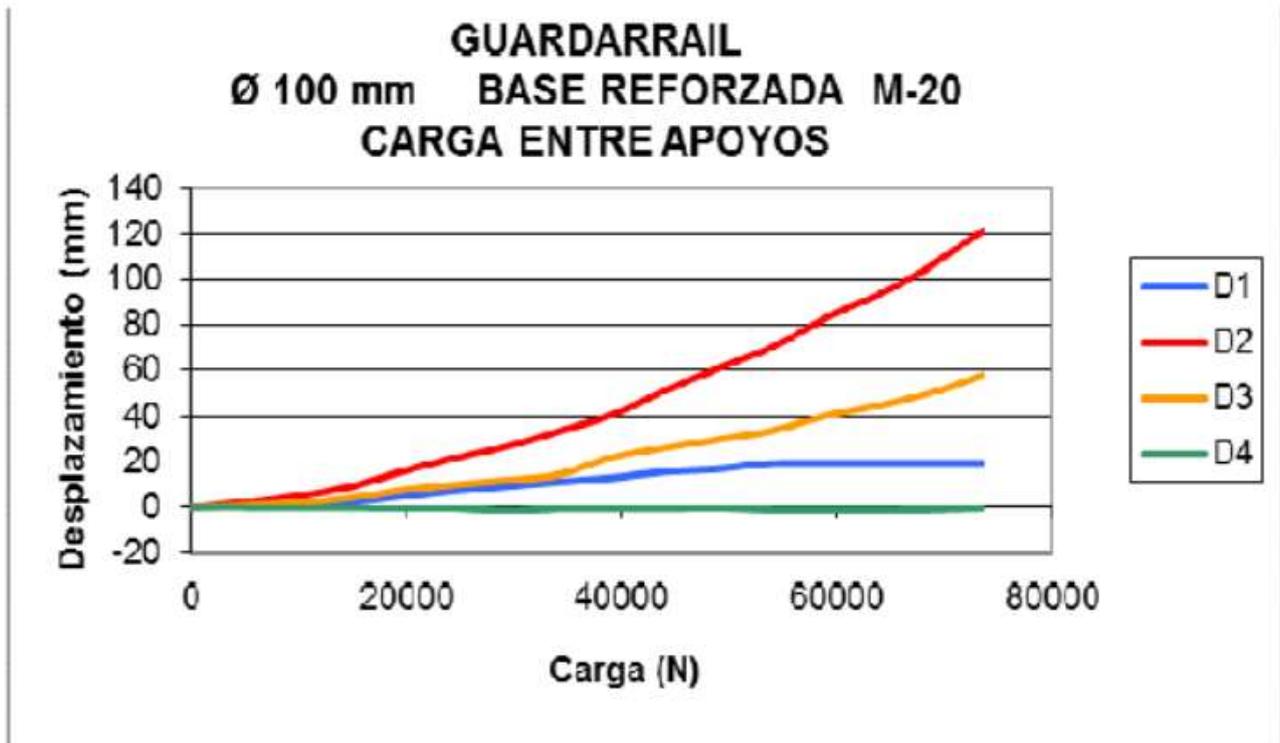
2nd load. Constant increase up to 5000 kg without deformation readout.

5000	17	26.12	13.92	9.55					
5500	17.02	34.15	16.10	9.45		19.03	70.11	33.65	-1.19
6000	17.05	46.75	22.33	9.29		19.06	82.71	39.88	-1.35

Comparator 2 tared when maximum readout exceeded.

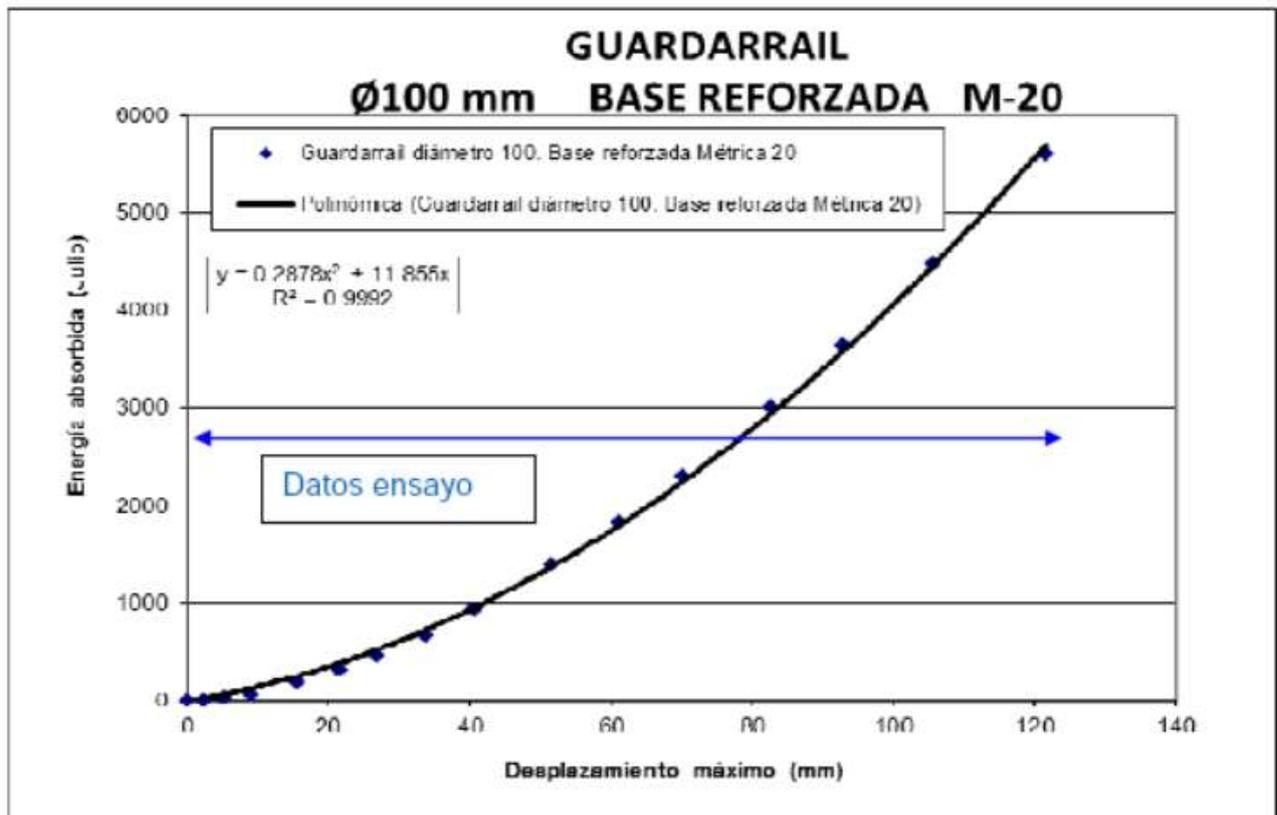
6000	17.05	3.03	22.33	9.20					
6500	17.05	13.27	26.85	9.33		19.06	92.95	44.4	-1.31
7000	17.05	25.95	32.60	9.65		19.06	105.63	50.15	-0.99
7500	17.05	41.90	40.52	10.27		19.06	121.58	58.07	-0.37

CRASH BARRIER Ø 100 mm. REINFORCED BASE M-20. LOAD BETWEEN SUPPORTS



Displacement (mm)

Load (N)



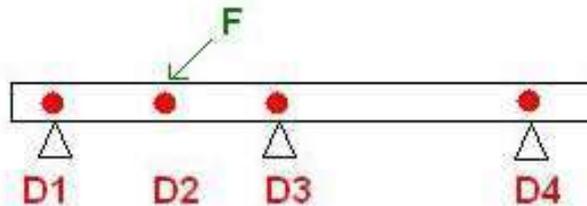
Crash barrier diameter 100 Reinforced base Metric 20

Polynomial (crash barrier diameter 100 Reinforced base Metric 20)

Test data

2.2.6. CRASH BARRIER DIAMETER 120 mm. REINFORCED BASE BOLT M-20. LOAD APPLIED BETWEEN SUPPORTS

2.2.6.	Diameter (mm)	Height (mm)	Ø Rod (mm)	Length (mm)	No. Anchorings	Base:
	120	150	20	1500	3	reinforced



Load (kg)	Comparator readout (mm)				Observ.	Deformation (mm)			
	L1 left	L2 centre	L3 right	L4 exterior		L1 left	L2 centre	L3 right	L4 exterior
0	4.08	3.83	4.23	9.61		4.08	3.83	4.23	9.61
500	5.22	5.94	5.30	9.66		1.14	2.11	1.07	0.05
1000	6.54	8.04	6.28	9.72		2.46	4.21	2.05	0.11
1500	8.25	10.50	7.12	9.76		4.17	6.67	2.89	0.15
2000	10.85	14.75	10.10	9.81		6.77	10.92	5.87	0.2
2500	13.25	18.86	12.37	9.97		9.17	15.03	8.14	0.36
3000	15.65	22.96	14.80	10.15		11.57	19.13	10.57	0.54
3500	18.70	28.22	17.93	10.47		14.62	24.39	13.7	0.86
4000	21.15	32.73	20.53	10.78		17.07	28.9	16.3	1.17
4500	24.54	38.93	24.29	11.28		20.46	35.1	20.06	1.67
5000	27.50	44.70	27.75	11.75		23.42	40.87	23.52	2.14
Unloading at 10 min	0	17.10	23.20	15.80	10.7				
	0	13.22	16.50	12.69	10.56				

2nd load. Constant increase up to 5000 kg without deformation readout.

5000	24.72	31.63	25.1	11.95					
5500	28.12	38.60	29.04	12.44		24.04	34.77	24.81	2.83
Unloading	0	8.78	4.77	9.88	12.36	28.11	43.12	29.23	3.39

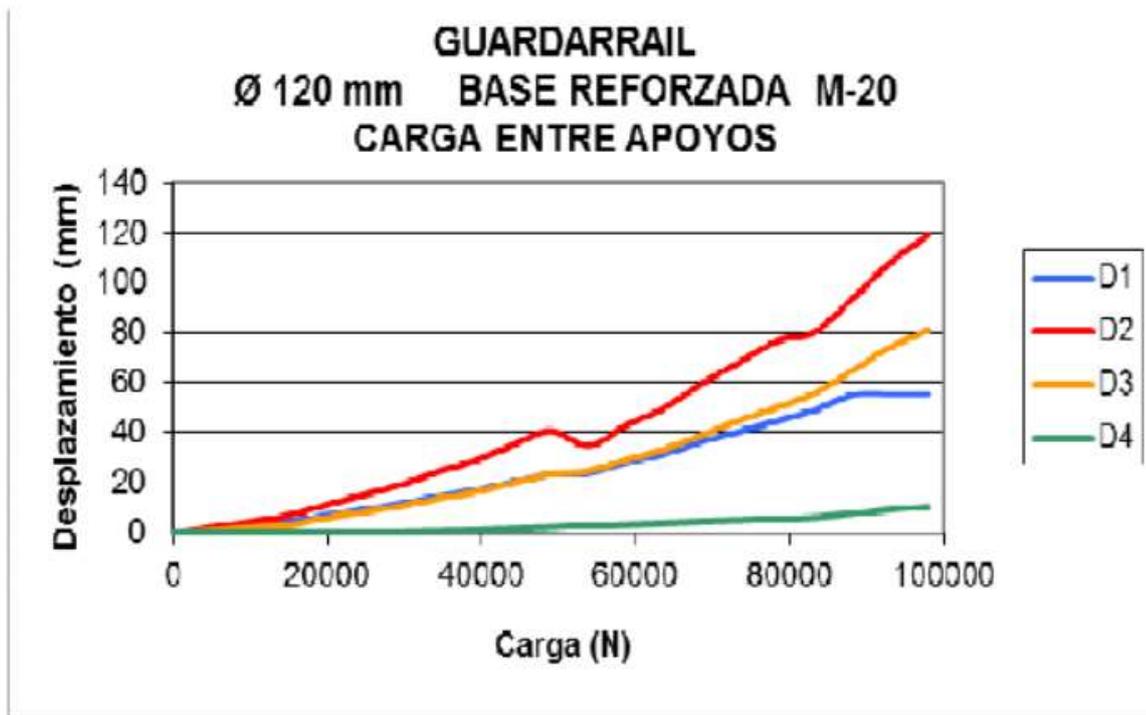
Comparators tared when maximum readout exceeded.

6000	12.85	13.12	14.30	12.92					
6500	16.32	20.02	18.40	13.40		31.58	50.02	33.33	3.87
7000	21.15	29.72	24.25	14.00		36.41	59.72	39.18	4.47
7500	25.42	38.40	30.20	14.43		40.68	68.40	45.13	4.90
8000	29.62	46.90	35.36	15.03		44.88	76.90	50.29	5.50
8500	34.02	50.60	41.09	15.75		49.28	80.60	56.02	6.22
Unloading	0	12.75	2.36	12.60	15.77				

Comparators tared when maximum readout exceeded.

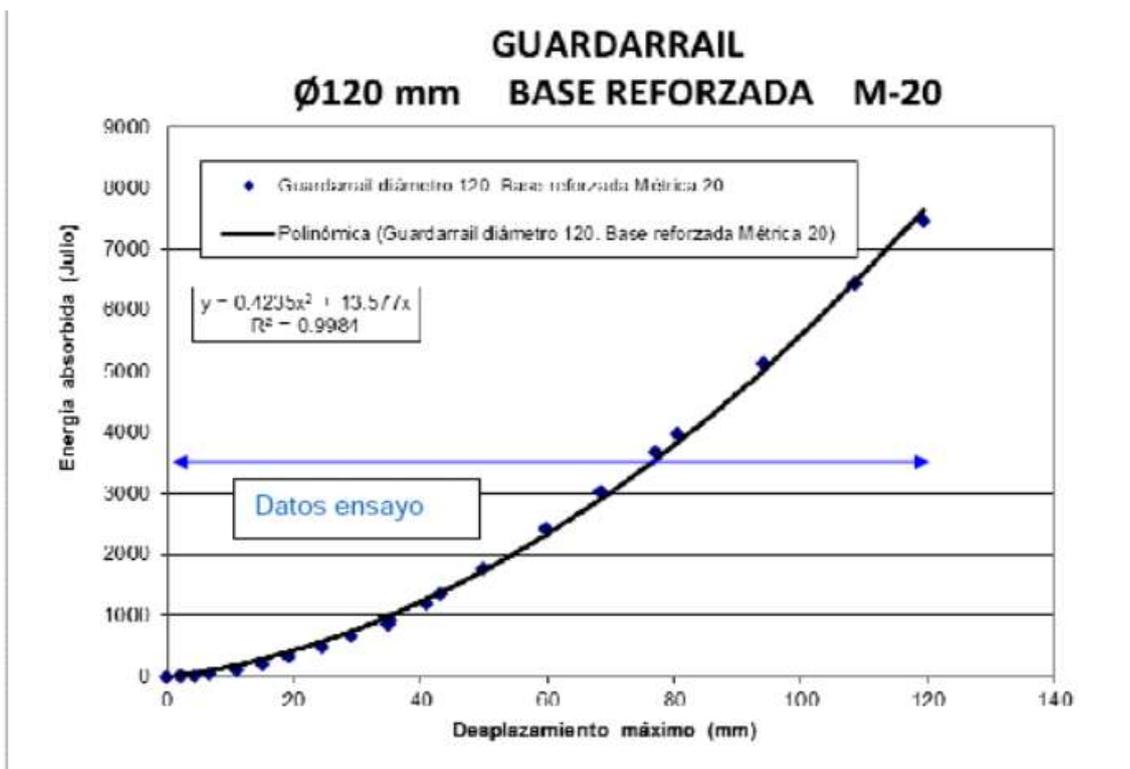
9000	18.67	15.75	21.71	17.15		55.20	93.99	65.13	7.60
9500	18.94	30.25	31.12	18.79		55.47	108.49	74.54	9.24
10000	18.93	41.00	37.80	20.01		55.46	119.24	81.22	10.46

CRASH BARRIER Ø 120 mm. REINFORCED BASE M-20. LOAD BETWEEN SUPPORTS



Displacement (mm)

Load (N)



Crash barrier diameter 120 Reinforced base Metric 20

Polynomial (crash barrier diameter 100 Reinforced base Metric 20)

Test data

F.E.M. MODELLING WITH STATIC LOADING:

3.1. INITIAL CONSIDERATIONS

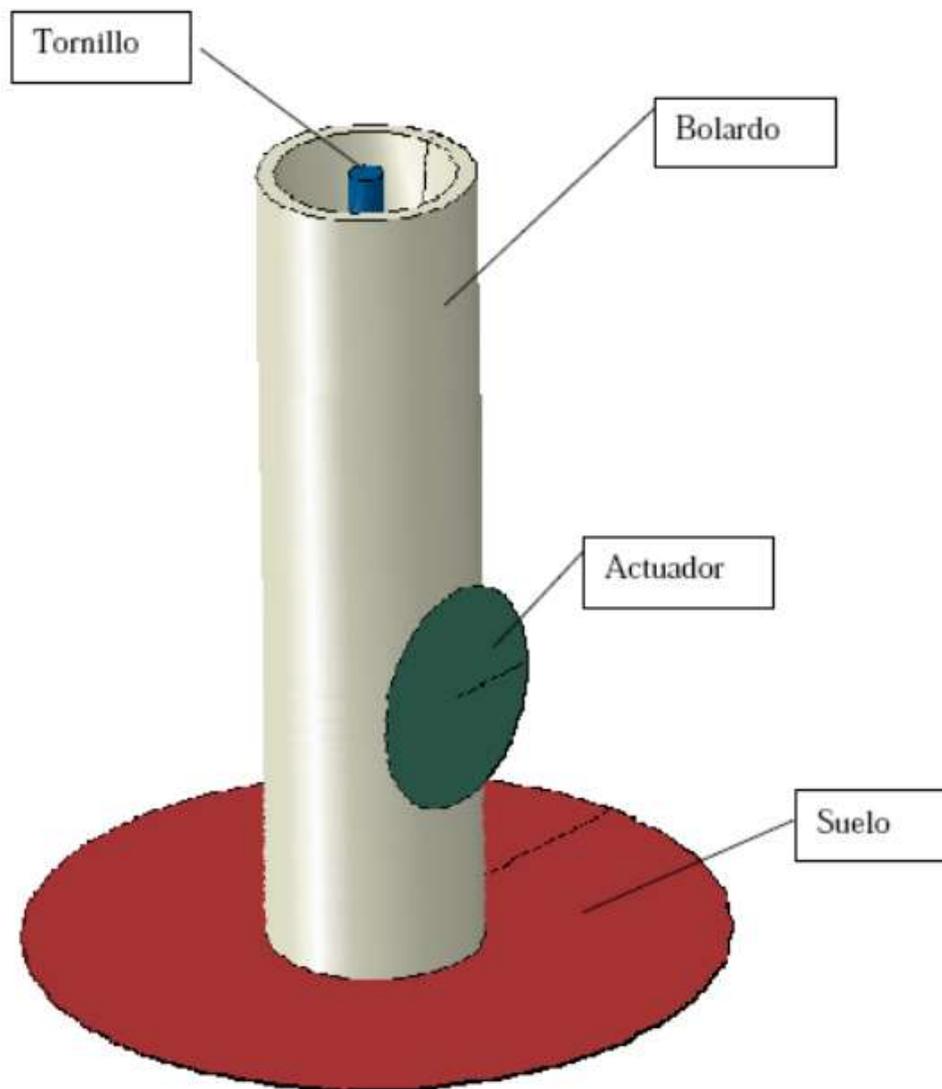
When analysing the results obtained as below, using numeric modelling as prescribed, for the purpose of interpreting as reliably as possible the trials performed, we bore in mind the following considerations:

- The analysis undertaken consisted of a static calculation and therefore it is considered that the actions applied have a character that is semi-static.
- Lacking real curves for tension-deformation behaviour for the materials of the various elements being analysed, these were simplified using a bilinear elasto-plastic curve defined using the characteristic values of said materials and corresponding to low velocities of deformation.
- For the contacts between the various elements we considered that rubbing existed as defined by a uniform value of 0.29 for all elements. In this modelling of the barriers we considered that the bases worked together with the barrier itself and therefore they have been modelled conjointly with the same solid element.
- Lacking real values for the force of pre-loading in the fixing bolts, we considered a pre-loading value of 20 kN in all cases.
- Since as a result of the tests we deduced that the M-30 bolt weakened the polystyrene section, giving results in conjunction that were inferior to those attained for M-20s, each of the crash barrier modellings were made using only M-20s with reinforced feet, as the placement of this foot represents considerable increases in resistance as compared to non-reinforced feet.
- Different types of steel were also tested (A-4.6 and A-8.8) and we obtained results showing that although A-8.8 steel is more resistant up to its yield point, since it is made with more carbon content, as soon as it exceeds its elasticity limit, it breaks sooner than the A-4.6 version, as this is more ductile, and has a higher deformation capacity than the former, which is what this product actually needs, as the proposed limit of 80mm makes this steel exceed its elasticity limit in all cases to a higher degree.

3.2. BOLLARD DIAMETER 120 mm, HEIGHT 530 mm, METRIC 30.

3.2.1. Model:

We conducted a finite element model comprising two solids – one for the bollard and another for the bolt – as well as two rigid surfaces that represent the floor and the actuator, respectively. A bollard diameter of 124 mm was considered, as per manufacturing tolerance.



Modelling

Bolt
Bollard
Actuator
Floor

3.2.2. Materials:

Two materials were considered in the model: steel for the fixing bolt, and HMW-PE for the bollard. In both cases we took an elasto-plastic behaviour model defined using a bilinear curve. The properties defined for both materials, taken from characteristic values and expressed in true magnitudes, were as follows:

Steel:

Young Module 210000 Mpa
Poisson coefficient: 0.3
Elastic limit: 240 MPa
Plastic tension and deformation (in unit increases): 488 MPa and 0.1988

HMW-PE:

Young Module 850 Mpa
Poisson coefficient: 0.4
Elastic limit: 28 MPa
Plastic tension and deformation (in unit increases): 176M Pa and 1.386

3.2.3. Environment conditions and actions:

The iteration of the various components making up the assembly was modelled using the contact method, including frictional behaviour in a tangential direction and with no penetration in a normal direction and separation capacity between surfaces once contact was made. The friction coefficient defined was 0.29 as regards as surfaces.

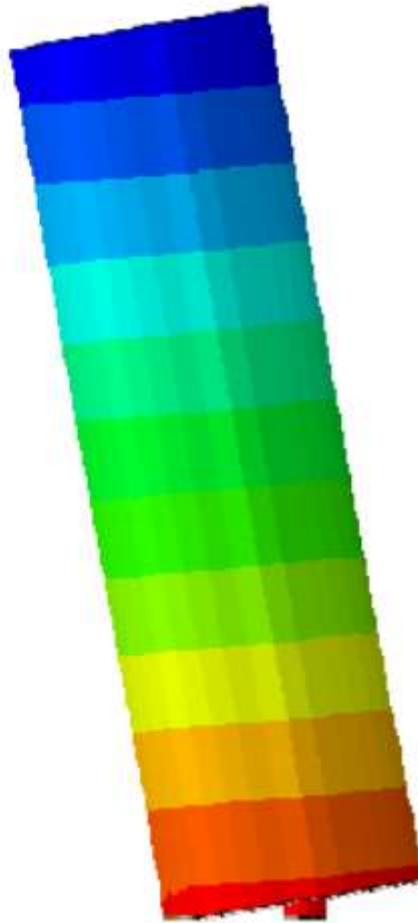
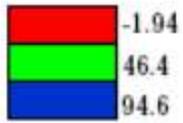
Likewise, the lower end of the bolt was recessed and a pre-load value of 20 kN was applied to simulate its fixing to the floor. Finally, a horizontal displacement was applied to the 30mm actuator to reproduce the conditions of the test done experimentally.

3.2.4. Analysis undertaken:

The analysis undertaken consisted of a static calculation, which was transitory and non-linear.

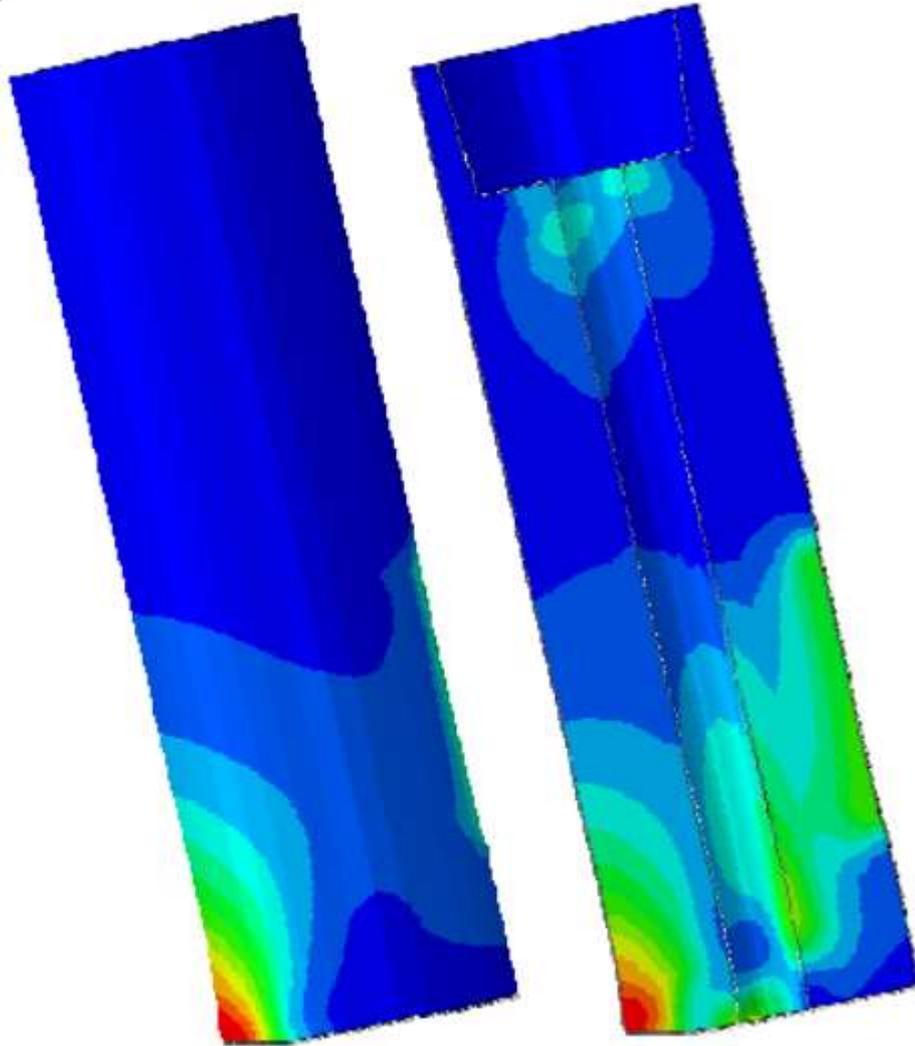
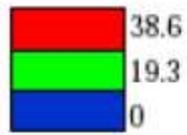
RESULTS:

Displacements:



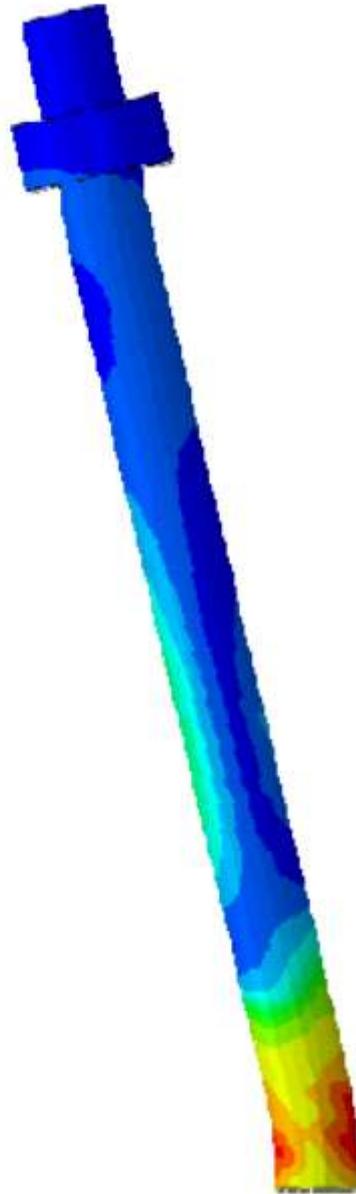
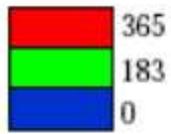
Horizontal displacements in mm for a horizontal displacement of the actuator of 30mm. (scaling factor = 1)

Tensions:



(sectional view)

Distribution of Von-Mises tensions on the bollard, in MPa, for a horizontal displacement of the actuator of 30mm. (scaling factor = 1)

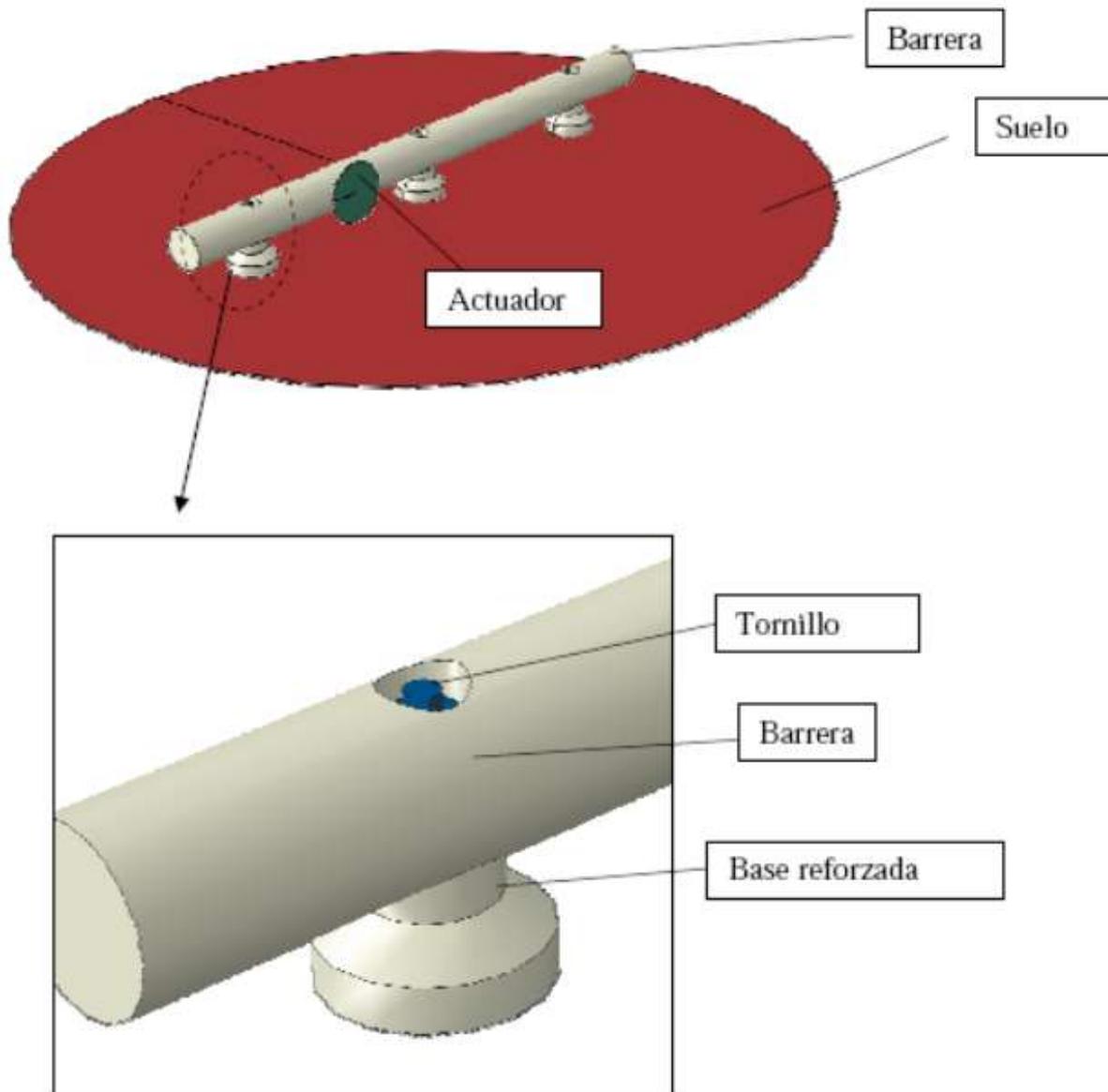


Distribution of Von-Mises tensions on the bolt, in MPa, for a horizontal displacement of the actuator of 30mm. (scaling factor = 1)

3.3. BARRIER DIAMETER 100 mm, REINFORCED BASE, METRIC 20.

3.3.1. Model:

We conducted a finite element model comprising four solids - one for the barrier and another for each of the three fixing bolts - as well as two rigid surfaces that represent the floor and the actuator, respectively. A bollard diameter of 102 mm was considered, as per manufacturing tolerance.



Barrier
Floor
Actuator
Modelling
Bolt
Barrier
Reinforced base

3.3.2. Materials:

Two materials were considered in the model: steel for the fixing bolts, and HMW-PE for the barrier. In both cases we took an elasto-plastic behaviour model defined using a bilinear curve. The properties defined for both materials, taken from characteristic values and expressed in true magnitudes, were as follows:

Steel:

Young Module 210000 Mpa
Poisson coefficient: 0.
Elastic limit: 240 MPa
Plastic tension and deformation (in unit increases): 488MPa and 0.1988

HMW-PE:

Young Module 850 Mpa
Poisson coefficient: 0.4
Elastic limit: 28 MPa
Plastic tension and deformation (in unit increases): 176 MPa and 1.386

3.3.3. Environment conditions and actions:

The iteration of the various components making up the assembly was modelled using the contact method, including frictional behaviour in a tangential direction and with no penetration in a normal direction and separation capacity between surfaces once contact was made. The friction coefficient defined was 0.29 as regards as surfaces.

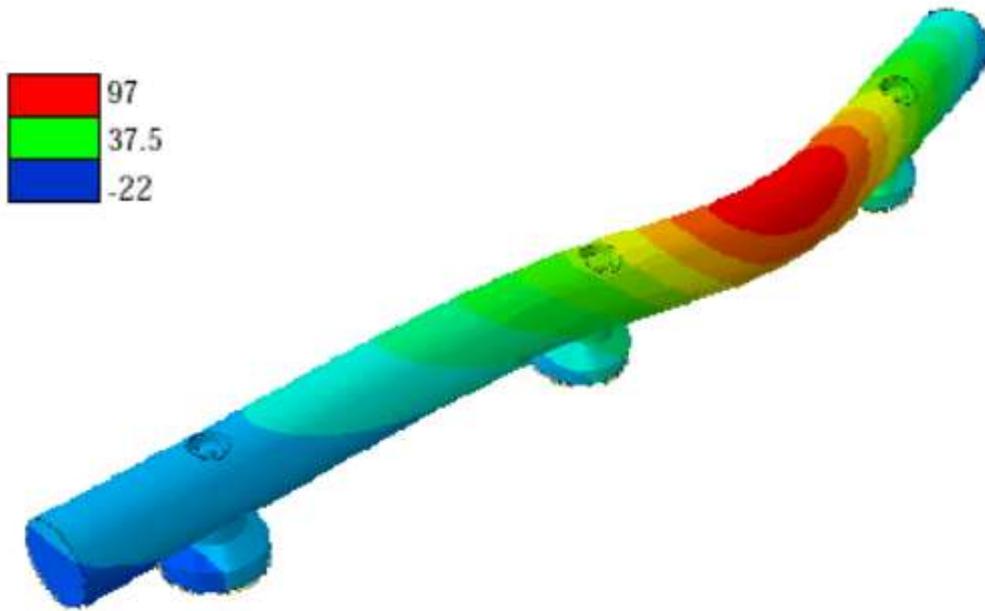
Likewise, the lower ends of the bolts were recessed and a pre-load value of 20 kN was applied to simulate their fixing to the floor. Finally, a horizontal displacement was applied to the 80 mm actuator to reproduce the conditions of the test done experimentally.

3.3.4. Analysis undertaken:

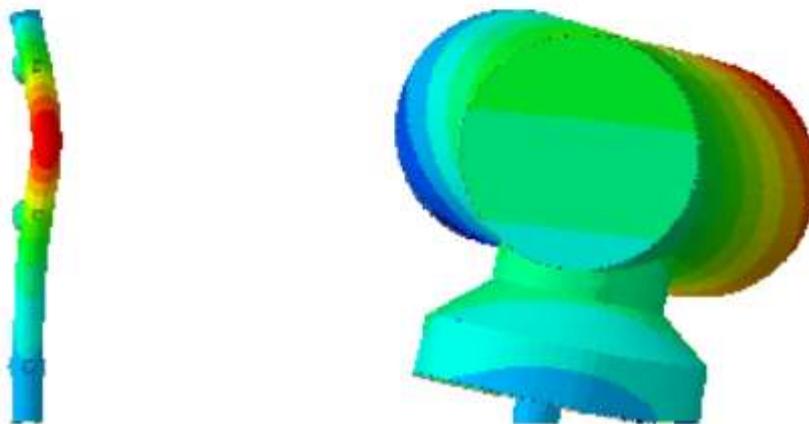
The analysis undertaken consisted of a static calculation, which was transitory and non-linear.

Results:

Displacements:



(vista 3D)



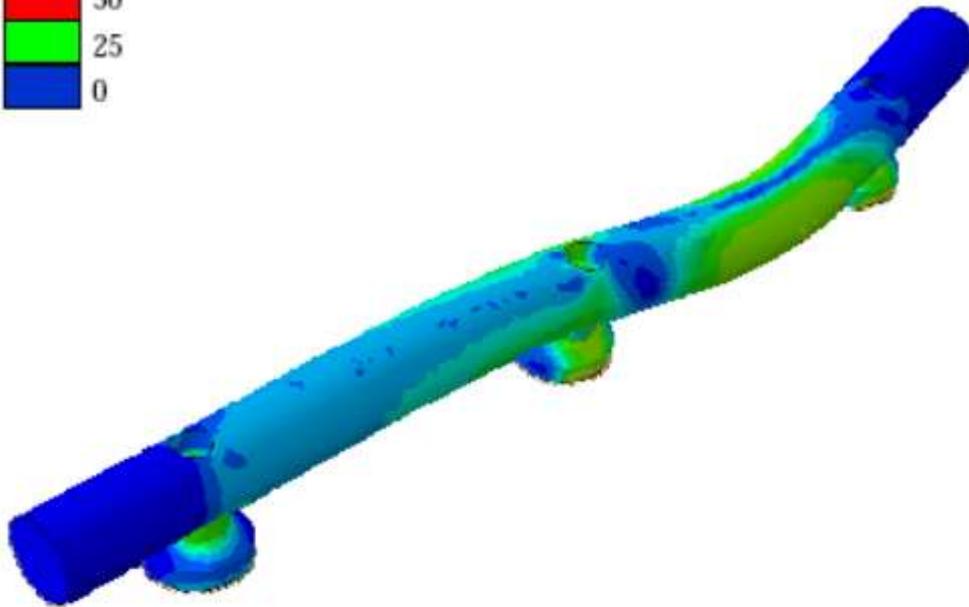
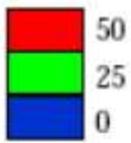
(3D view)

(top view) (central base detailed view)

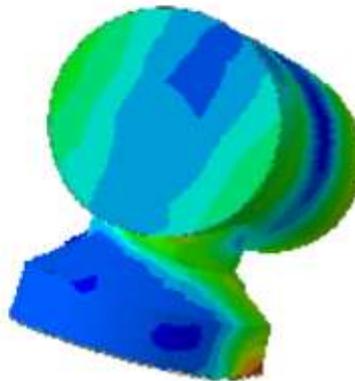
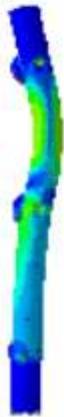
Horizontal displacements in mm for a horizontal displacement of the actuator of 80mm. (scaling factor = 1)

Tensions:

(Maximum tension: 75MPa, actuator contact zone)



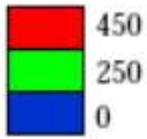
(vista 3D)



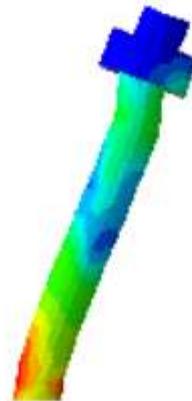
(3D view)

top view) (central base detailed view)

Distribution of Von-Mises tensions on the barrier, in MPa, for a horizontal displacement of the actuator of 80mm. (scaling factor = 1)



(vista 3D)



(3D view)

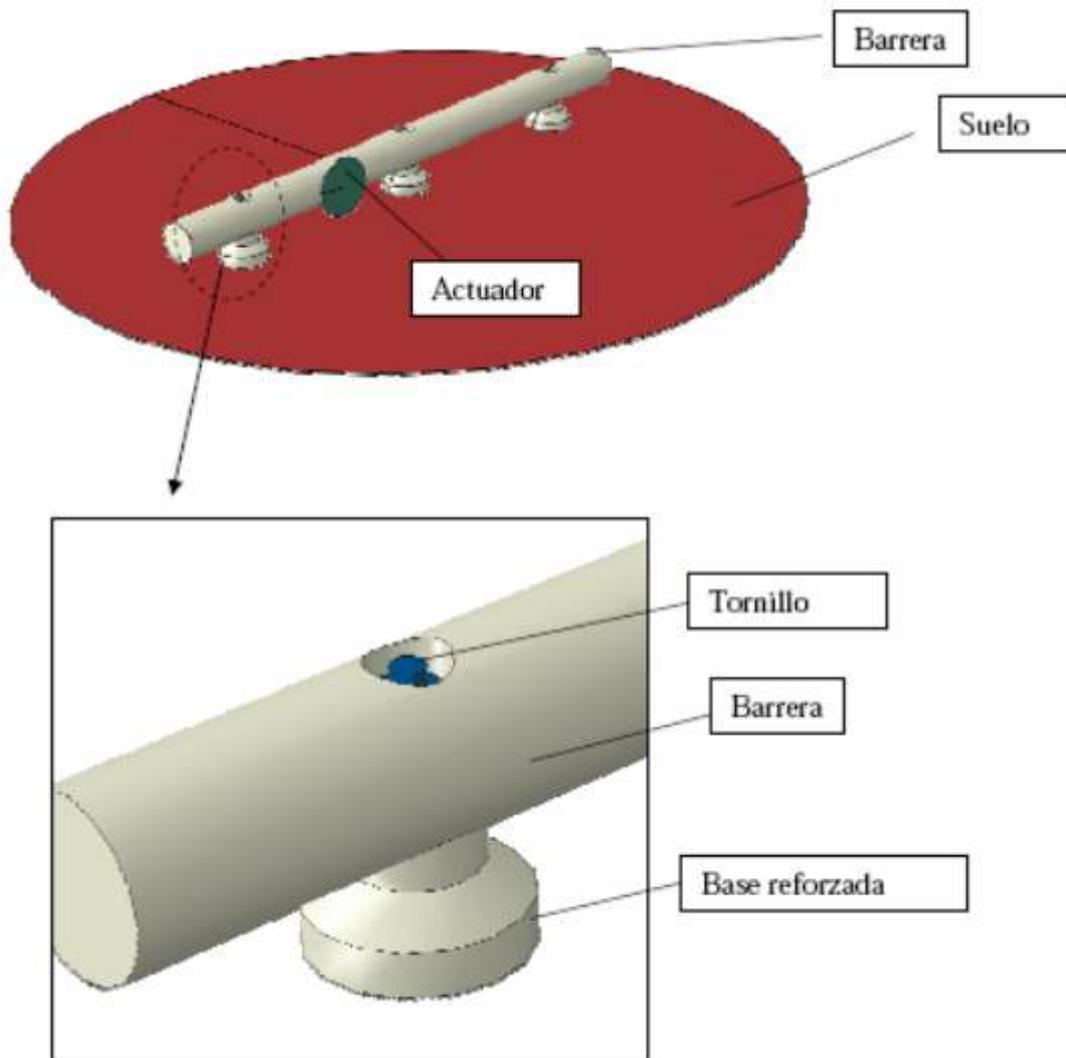
(detail of central bolt)

Distribution of Von-Mises tensions on the barrier, in MPa, for a horizontal displacement of the actuator of 80mm. (scaling factor = 1)

3.4. BARRIER DIAMETER 120 mm, REINFORCED BASE, METRIC 20.

3.4.1. Model:

We conducted a finite element model comprising four solids – one for the barrier and another for each of the three fixing bolts – as well as two rigid surfaces that represent the floor and the actuator, respectively. A bollard diameter of 124 mm was considered, as per manufacturing tolerance.



Barrier

Floor

Actuator

Bolt

Barrier

Reinforced base

Modelling

3.3.2. Materials:

Two materials were considered in the model: steel for the fixing bolts, and HMW-PE for the barrier. In both cases we took an elasto-plastic behaviour model defined using a bilinear curve. The properties defined for both materials, taken from characteristic values and expressed in true magnitudes, were as follows:

Steel:

Young Module 210000 Mpa
Poisson coefficient: 0.3
Elastic limit: 240 MPa
Plastic tension and deformation (in unit increases): 488MPa and 0.1988

HMW-PE:

Young Module 850 Mpa
Poisson coefficient: 0.4
Elastic limit: 28 MPa
Plastic tension and deformation (in unit increases): 176 MPa and 1.386

3.3.3. Environment conditions and actions:

The iteration of the various components making up the assembly was modelled using the contact method, including frictional behaviour in a tangential direction and with no penetration in a normal direction and separation capacity between surfaces once contact was made. The friction coefficient defined was 0.29 as regards as surfaces.

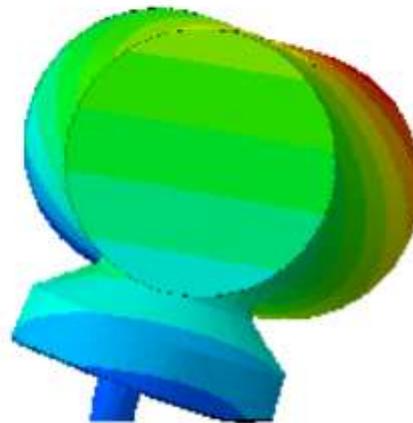
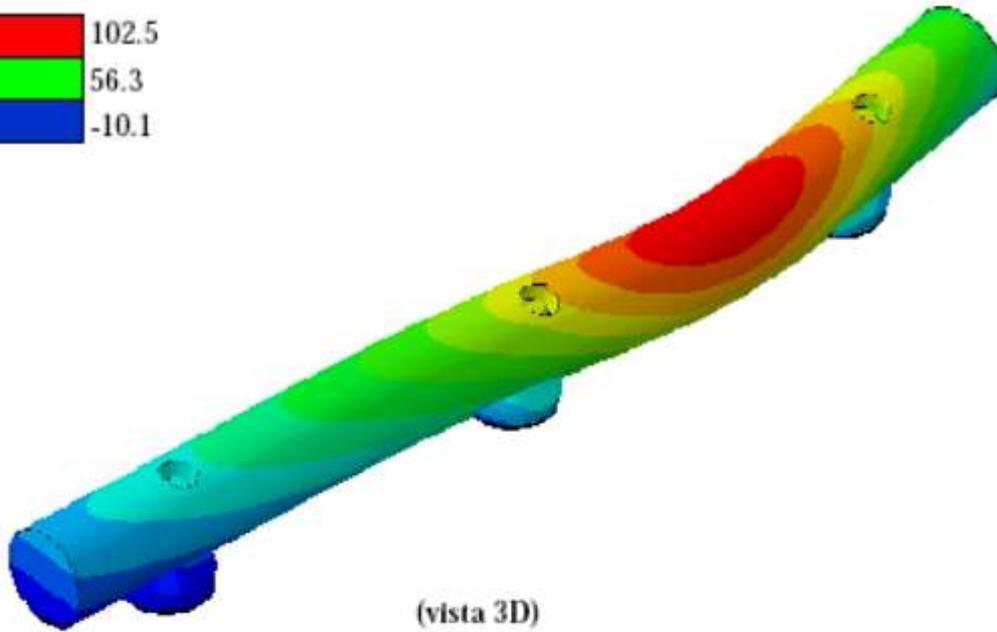
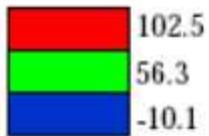
Likewise, the lower ends of the bolts were recessed and a pre-load value of 20 kN was applied to simulate their fixing to the floor. Finally, a horizontal displacement was applied to the 80 mm actuator to reproduce the conditions of the test done experimentally.

3.3.4. Analysis undertaken:

The analysis undertaken consisted of a static calculation, which was transitory and non-linear.

Results:

Displacements:

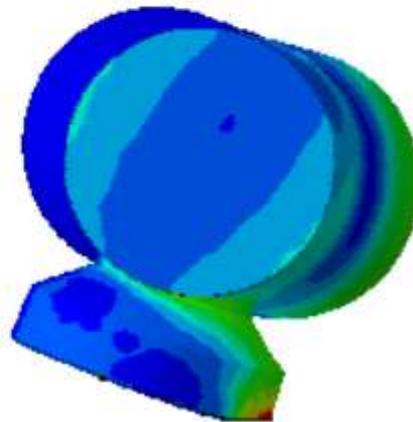
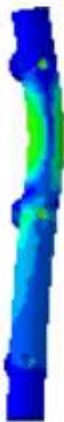
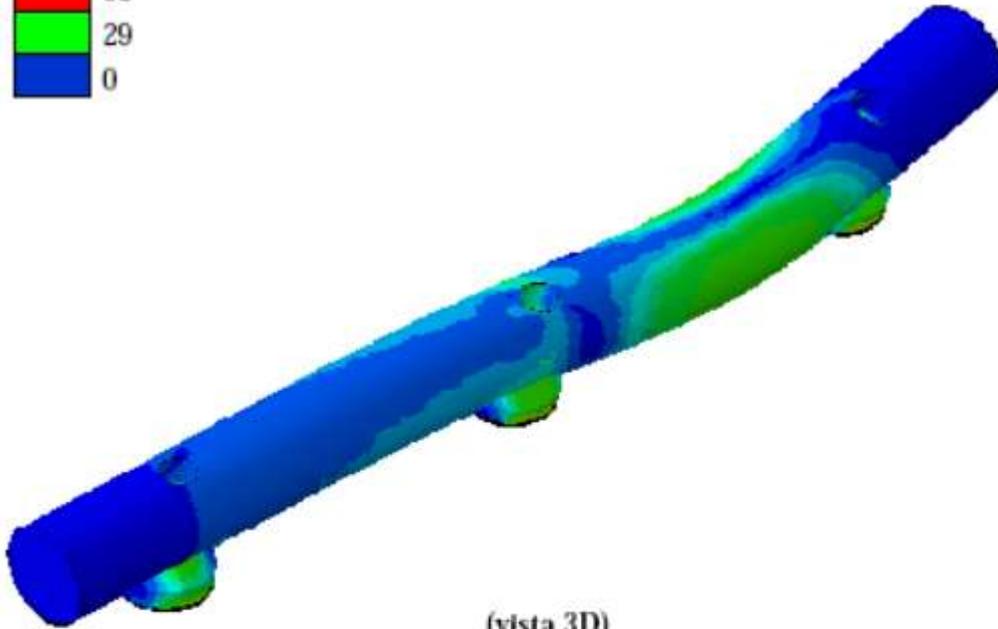
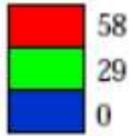


(3D view)

(top view) (central base detailed view)

Horizontal displacements in mm for a horizontal displacement of the actuator of 80mm. (scaling factor = 1)

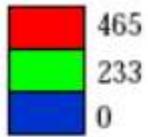
Tensions:
(Maximum tension: 64MPa,
actuator contact zone)



(3D view)

(top view) (central base detailed view)

Distribution of Von-Mises tensions on the barrier, in MPa, for a horizontal displacement of the actuator of 80mm. (scaling factor = 1)



(vista 3D)



(3D view)

(detail of central bolt)

Distribution of Von-Mises tensions on the bolts, in MPa, for a horizontal displacement of the actuator of 80mm. (scaling factor = 1)

4. CONCLUSIONS

After analysing all the results obtained, both the tests conducted by ENSAYA and the FEM modelling tests, we obtained 5 highly important and clear conclusions:

- a) The response of the crash barriers with non-reinforced feet and with reinforced feet was highly variable, with increase in deformation and therefore highly significant resistance capacities when using the reinforced foot. Therefore in view of the reduced economic repercussion between both variants, we recommend always using the reinforced foot version.
- b) From the tests undertaken on the two types of steel used for the anchoring bolts for the bollard or the crash barrier to the floor (A-4.6 and A-8.8), despite the fact that the elastic limit of the A-8.8 steel was more resistant, rupture deformation was lower with the A-4.6 steel due to its lower carbon content and therefore its reduced ductility. The performance of the A-4.6 steel is much higher for this type of joint as it provides greater plastic deformation than A-8.8 steel, even reaching deformations on the upper section higher than 80 mm (deformation limit of the bollard before hitting the wall, as these elements are placed at less distance from walls). We therefore recommend using A4.6 steel bolts.
- c) With the 2 diameters of steel bolt used for the crash barriers, although using M-30s is slightly more resistant as regards the bolt itself, the resistance capacity of the polyethylene is reduced, as there is less section available for the feet, which is why we recommend using the M-20 bolt.
- d) In none of the tests undertaken in an attempt to reach the polyethylene breakage point were we able to reach this point, as the grout used was a determining factor in obviating this; in any case the grout always used had a resistance compression at 24 hrs of 30 MPa and at 7 days 50 MPa.
- e) In none of the tests undertaken did the floor suffer any damage where the test was carried out, with a normal factory floor made of HA-25 concrete. This is an important advantage in respect of other anchoring systems, which when presented with an increase in loading outside normal user ranges can be damaged, whereas the PANELCHOK bollard and/or crash barrier can be replaced quickly and with minimum cost (replacing one bolt only) without having to repair the floor itself. Other systems existing on the market are normally bolted to the floor and when the bollard and/or crash barrier is broken, it seriously affects parts of the floor in the immediate vicinity, which must be repaired.

Zaragoza, 18 December 2014

The Technical and Industrial Engineer
Luis Forcano Obón
Assoc. Member 2483
Tenured Professor
University of Zaragoza

**EL INGENIERO TÉCNICO INDUSTRIAL
LUIS FORCANO OBÓN
Colegado N° 2.483
PROFESOR TITULAR
UNIVERSIDAD DE ZARAGOZA**

