composite fences
FRANGIBILITY

INDEPENDENT IN-DEPTH research

presented:
IESALC Fall Technology Meeting

by:
Pierpaolo Turri

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FOREWORD

- This research collects the results of 6 months experimental survey concerning **frangibility** of **airport fencing supporting elements** made by **FRP** (Fiberglass Reinforced Polyester) pultruded profiles.

- Tested elements are integral part of the **FRANGIBLE FENCING SYSTEM** type "FibreFENCE MESH”, designed and manufactured by Fibre Net s.r.l. (Italy).

- All tests were performed under the supervision and direction of **Department of Civil Engineering, University of Trieste** (Italy)

UNIVERSITÀ
DEGLI STUDI DI TRIESTE
Dipartimento di Ingegneria e Architettura

NORMATIVE APPROACH

Frangibility tests were based on the following guidelines:

- ICAO Doc 9157 **Aerodrome Design Manual**, Part 6 “Frangibility” 1st Edition 2006

- ICAO Annex 14 **Aerodromes**, Vol. 1 “Aerodrome Design and Operations” 6th edition 2013

- EASA “Certification Specifications and Guidance Material for Aerodromes Design, **CS-ADR-DSN** Issue 3 - December 2016

NORMATIVE APPROACH

Frangibility test procedures are detailed on ICAO Doc 9157 chapter 5.
The following structures are addressed:

- Elevated runway and taxiway edge
- Taxiing guidance signs
- PAPI/APAPI and T-VASIS/AT-VASIS
- Approach lighting towers and similar structures
- Wind direction indicators/transmissometers/forward-scatter meters
- ILS/MLS structures

But………..

WHAT ABOUT FENCINGS?

WHAT ABOUT FENCINGS?

- Fencings belong to “airport equipment or installation” possibly located into operational area (doc 9157 chapter 1.3.6)
- In such a case, **they are specifically required** to be of minimum mass and **frangible** (doc 9157 chapter 1.3)

PROBLEM:

HOW TO TEST / MEASURE / CERTIFY FENCING FRANGIBILITY?

To date, neither ICAO, nor EASA are detailing a specific testing procedure (speed, mass) nor performance requirements (force, energy) regarding FENCING frangibility!

HOW WE FACE THIS REGULATORY GAP?

- Being specific testing procedures missing, ***the most reasonable way*** to proceed is to pinpoint a comparable structure (in terms of dimensions, mass etc), to be used as reference for testing procedure.

- On this purpose, "***approach lighting towers and similar structures***" (doc 9157 chapter 5.2.8 on) was identified as the closest regulated structure

- ***ALL TESTS IN THIS RESEARCH ARE MADE ACCORDING TO THE STANDARDS SPECIFIED INTO ABOVE MENTIONED CHAPTER***

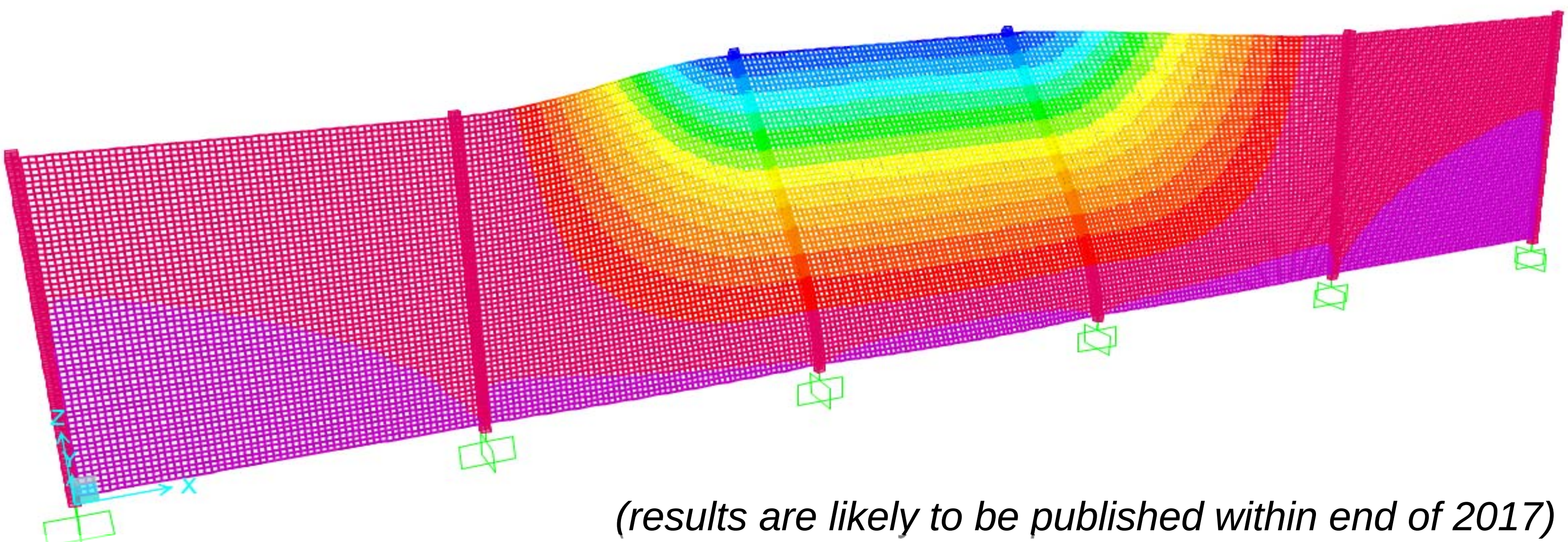
TEST METHODOLOGY DEFINITION

- According to doc 9157 chapter 5.2.8-9, tests have to be performed:
  - By means of a vehicle-driven impactor
  - Mass equivalent to 3.000 kg airplane
  - At high speed of 140 km/h (75kt) representing an impact during flight
  - At intermediate speed of 80 km/h (43 kt) and
  - At low speed of 50 km/h (30 kt) representing impact during taxiing

Present tests were conducted at 50 km/h (30 kt) being the most realistic impact condition by an aircraft on a fairly low structure as a fence.

TEST METHODOLOGY DEFINITION

- Field tests costs and complexity are extremely high, and this is acknowledged by ICAO itself (doc 9157 chapter 6.1). Alternative methods to evaluate airport structures frangibility are therefore allowed.
- Taking advantage of this possibility, **intermediate speed** (80km/h - 43 kt) and **high speed** (140km/h - 75kt) tests have been performed by means of FEM numerical modelling and simulation.



(results are likely to be published within end of 2017)

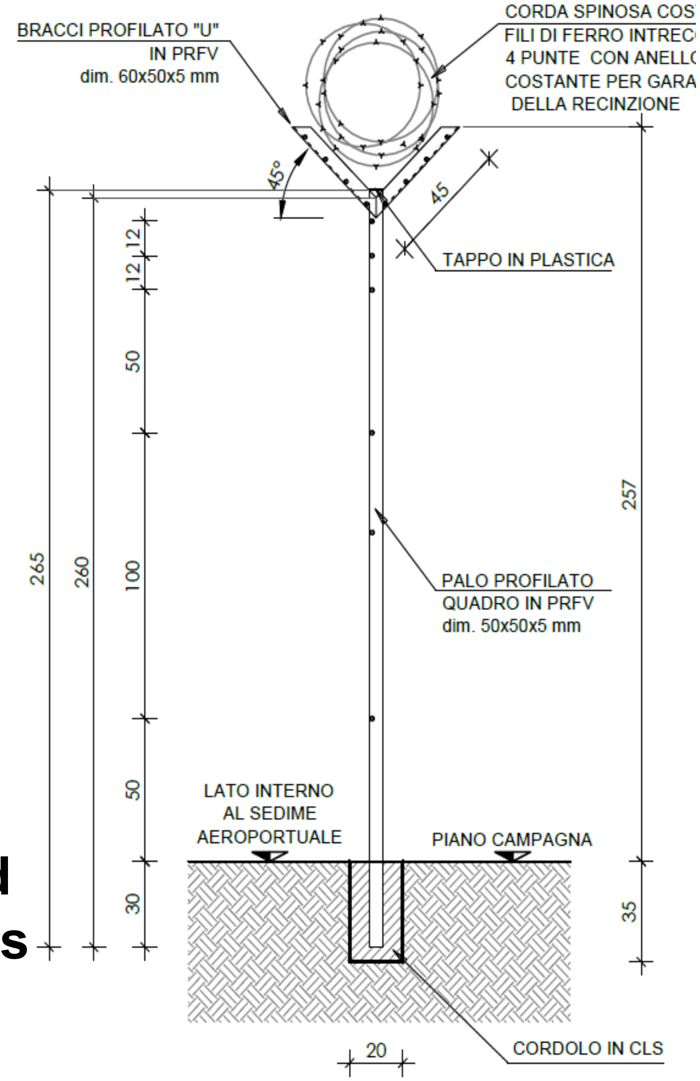
SPECIMENT SPECIFICATIONS

- **The whole fence is 100% made in F.R.P. (Fiberglass Reinforced Polyester)**

Characteristic	Normative reference	Value
Strength in tension - axial	EN ISO 527-4	395 MPa
Young modulus in tension - axial	EN ISO 527-4	32.6 GPa
Young modulus in tension - transverse	EN ISO 527-4	19 MPa
Young modulus in tension - transverse	EN ISO 527-4	3.8 GPa
Strength in compression - axial	EN ISO 14126	360 MPa
Flexural strength - axial	EN ISO 14125	415 MPa
Pin-bearing strength - axial	EN 13706-2	154 MPa
Pin-bearing strength - transverse	EN 13706-2	70 MPa
Fiberglass	ASTM C1666M-07	E Type
Thermosetting resin		polyester

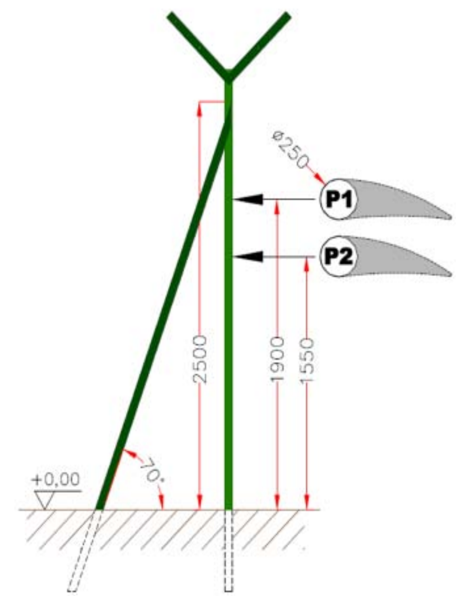
- **Posts: square section 50x50x5mm**
- **Struts: “C” section 60x50x5mm**
- **Outriggers: “C” section 60x50x5mm**

NB: mesh was intentionally NOT considered because of its negligible influence on results



- **Height of the impactor is calculated as mean wing height of popular G/A aircrafts:**

Type	MTOW	Overall Height	Wing height	Wing span
	Weight (kg)	*(m)*	*(m)*	*(m)*
Piper Meridian M500	2.329	3.40	**1.20**	13.10
Piper Mirage	1.977	3.40	**1.20**	13.10
Piper Seneca	2.165	3.00	**1.00**	11.90
Cessna Turbo Stationair	1.633	2.83	**2.00**	10.97
Cessna Supercargomaster	3.995	4.60	**2.50**	15.87
Cessna Citation Mustang	3.921	4.09	**1.50**	13.16



- **To extend research results, all tests were made at 2 different heights:**

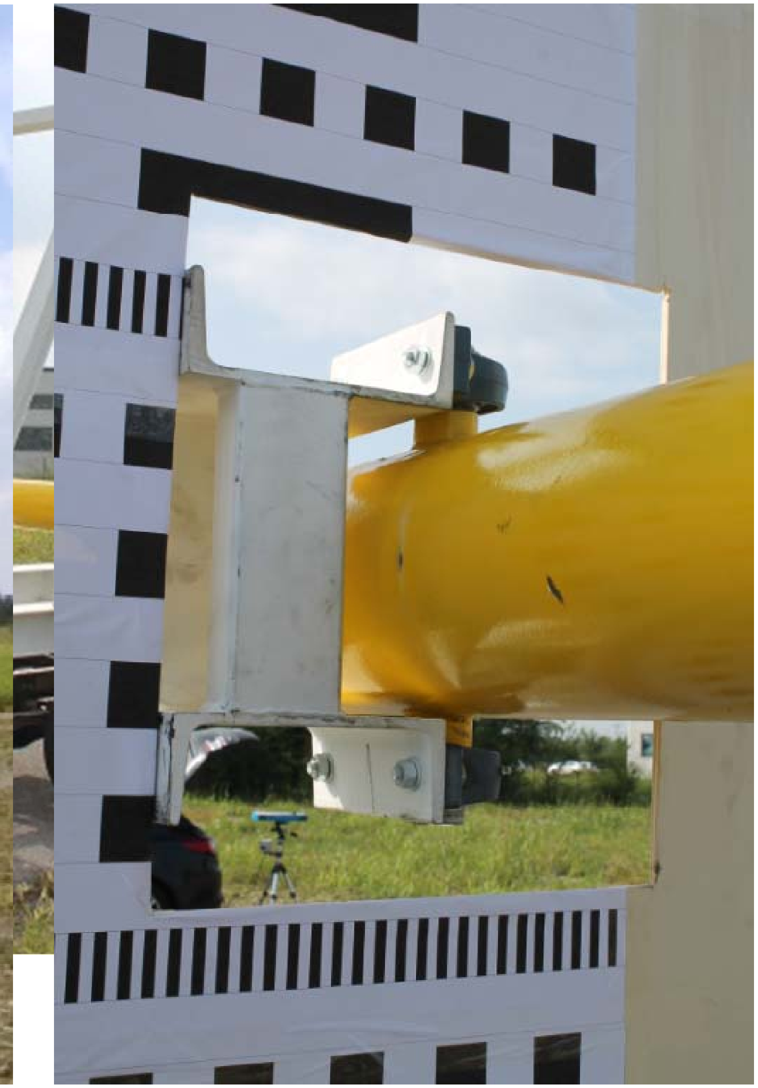
P1 = 1,90m (6ft 3in) **P2 = 1,55m** (5ft 1in)

IMPACTOR DESIGN

According to doc. 9157 chapter 5.2.10, impactor is made as follows:

- external diameter: approx 250 mm
- wall thickness: 10 mm
- overall length: 3.000 mm
- load cell between impactor and interface

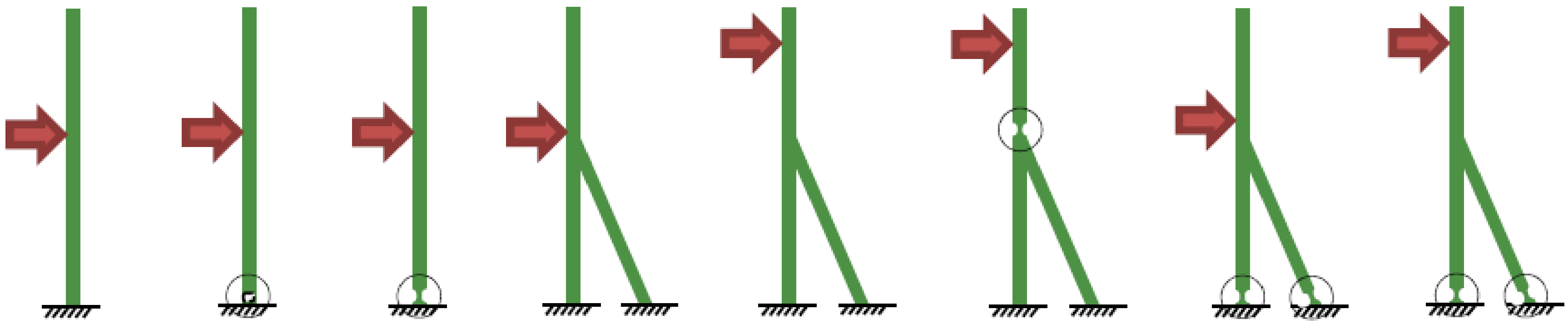
IMPACTING VEHICLE SET-UP



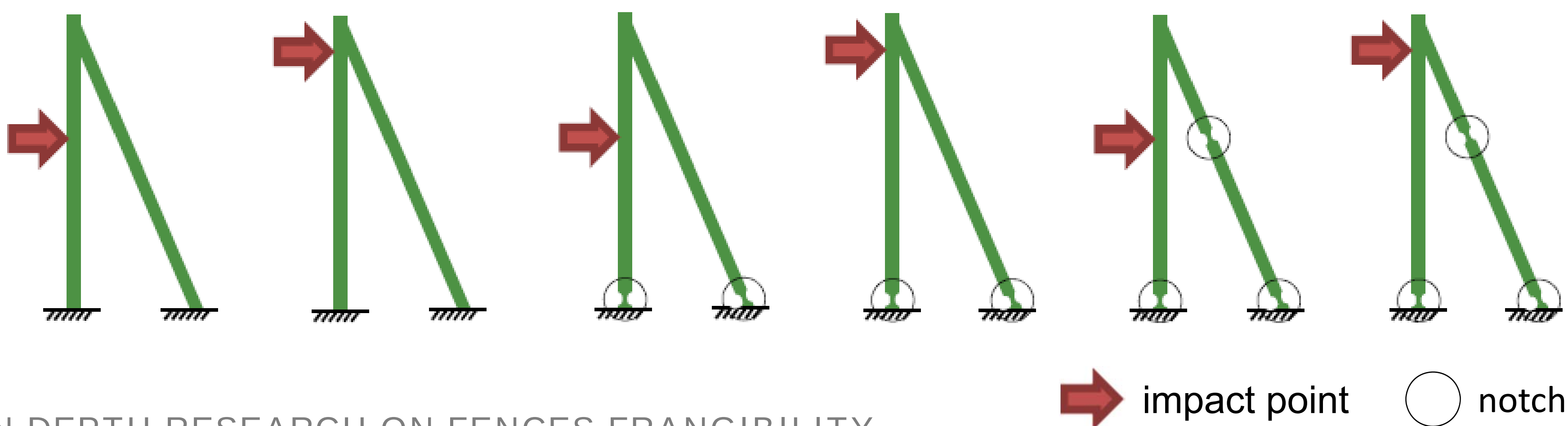
SPEED MEASUREMENT DEVICE

- **Device type: Sodi Autovelox 104/C**
- **Device sensitivity: 0,29 km/h**

SPECIMEN DESIGN AND IMPACT POINT MATRIX



14 different posts desing and impact points tested



IN-DEPTH RESEARCH ON FENCES FRANGIBILITY

SPECIMEN DETAILS

Post + high strut

notch

(where foreseen)

Post + low strut

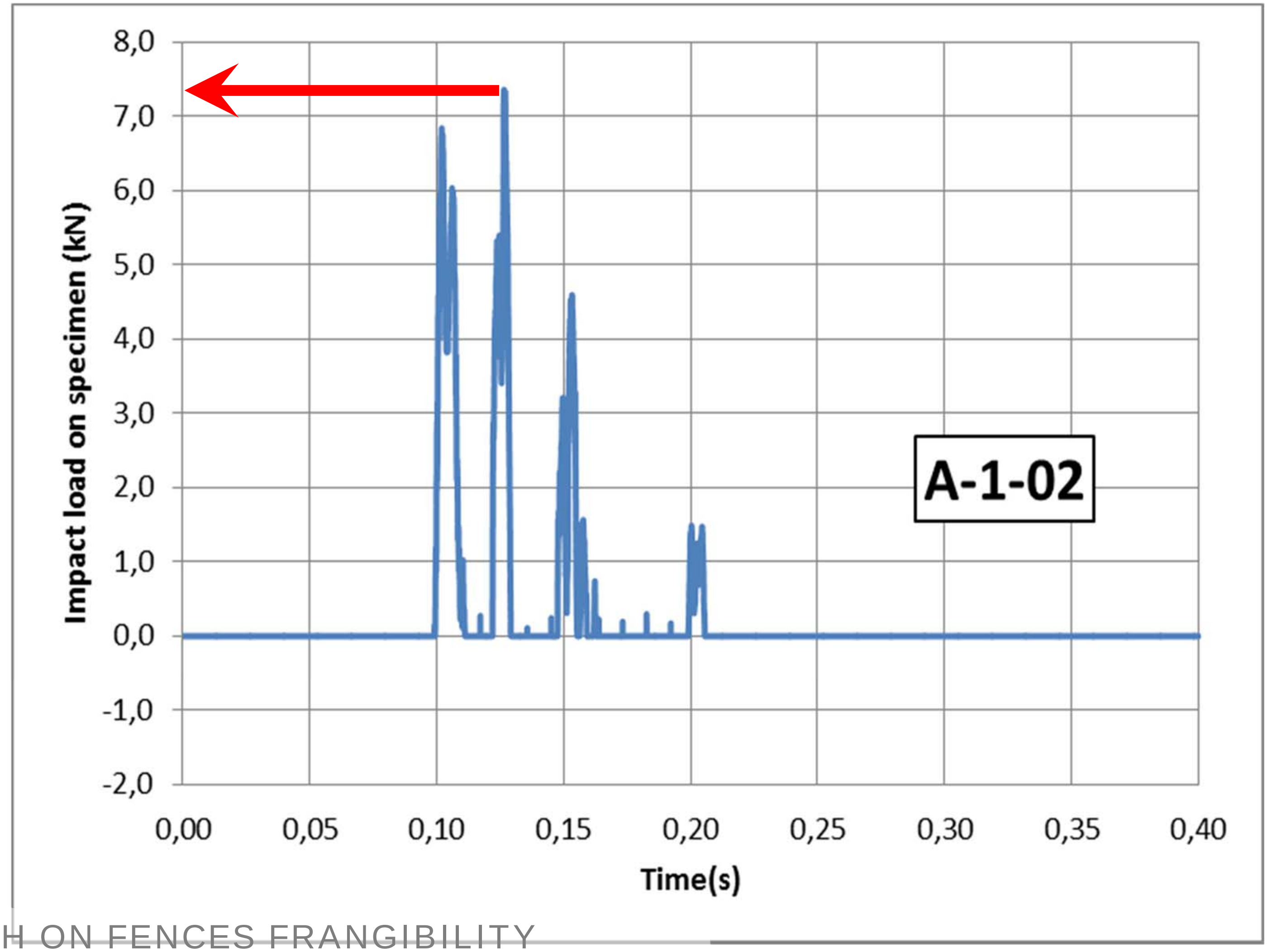
IMPACT TEST – VIDEO 1

IMPACT TEST – VIDEO 2

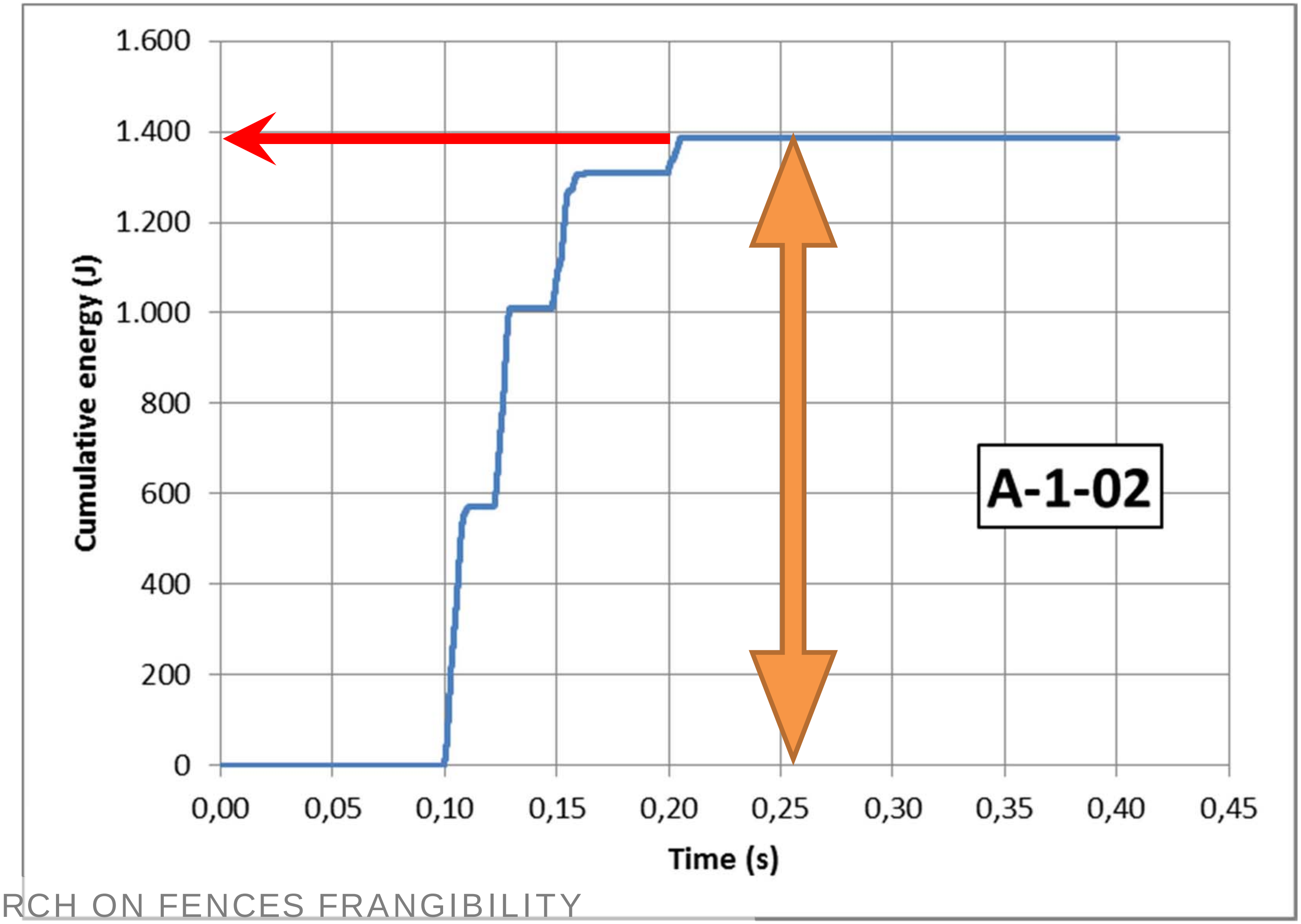
IMPACT TEST - VIDEO 3

RESULTS OBTAINED

IMPACT LOAD CHART



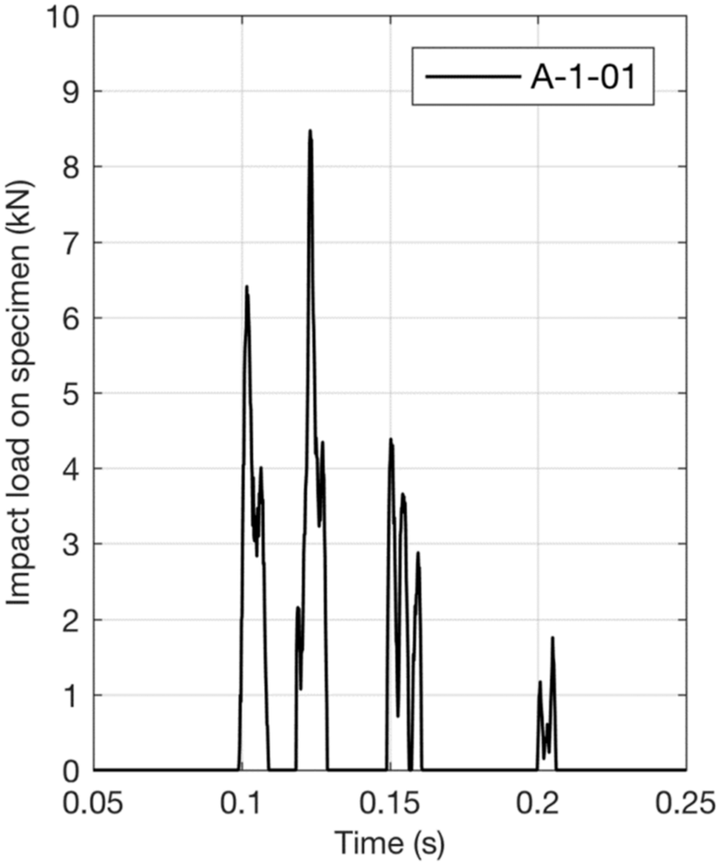
IMPACT ENERGY CHART



FAILURE MECHANISM

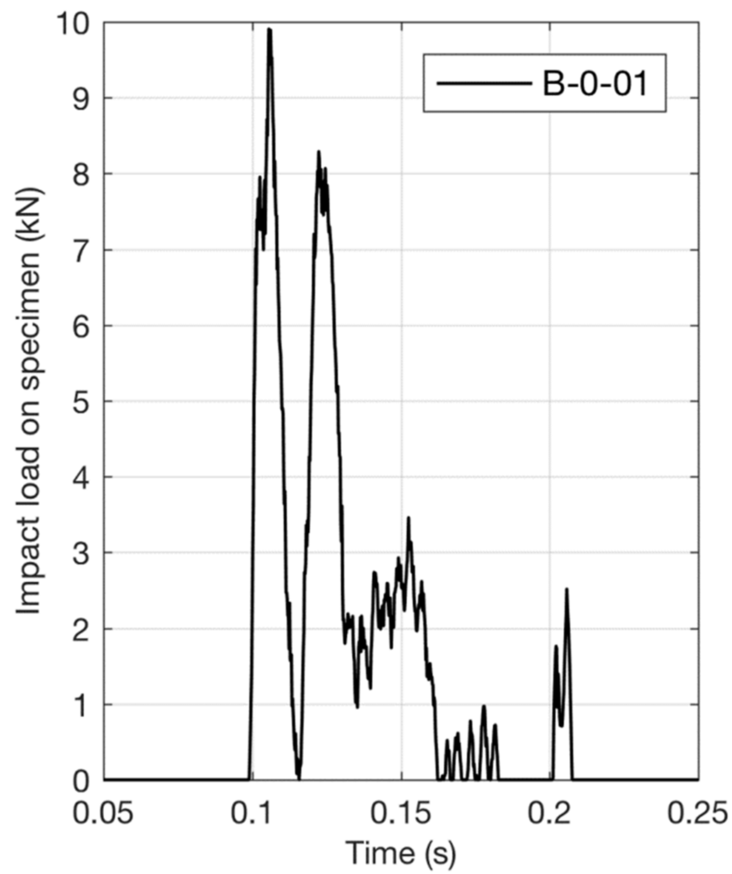
FAILURE MECHANISM

Simple Post – no struts



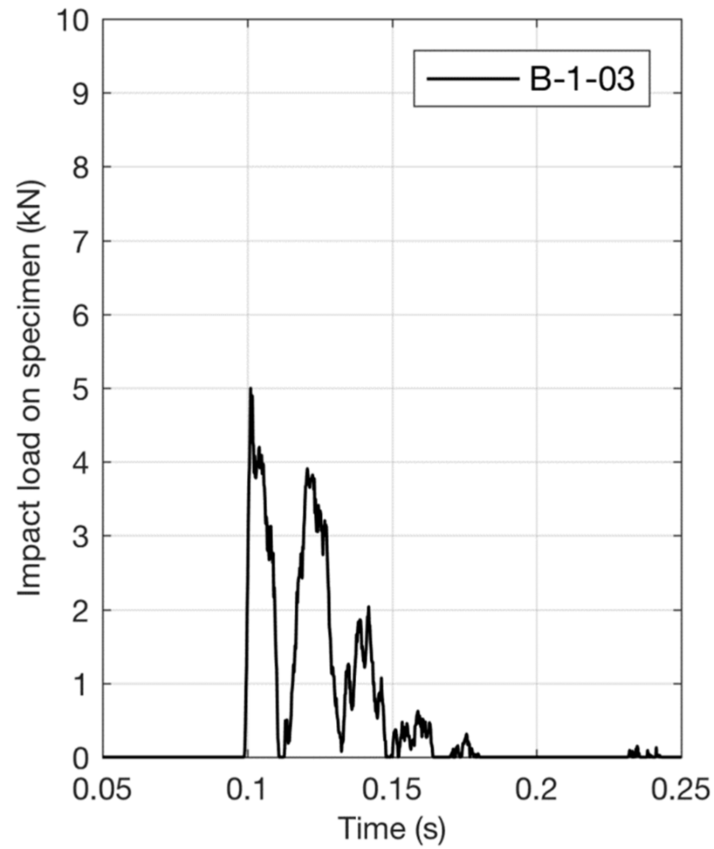
FAILURE MECHANISM

Post + low strut



FAILURE MECHANISM

Post + high strut



OVERALL RESULTS

Type	Specimen	Impact load	kN	Impact energy	J
		Individual	*Mean*	*Individual*	*Mean*
A-1	A-1-01	8.6	**8.0**	1438	**1378**
	A-1-02	7.4		1387	
	A-1-03	8.1		1396	
	A-1-04	8.0		1289	
A-2	A-2-01	6.0	**6.4**	1160	**1051**
	A-2-02	6.8		942	
A-3	A-3-01	7.2	**6.4**	1222	**1205**
	A-3-02	5.6		1185	
B-0	B-0-01	10.0	**10.1**	3185	**3391**
	B-0-02	10.1		3597	
B-2	B-2-01	9.2	**9.1**	3025	**3420**
	B-2-02	9.0		3814	
C-0	C-0-01	7.0	**7.5**	6268	**5973**
	C-0-02	7.9		5677	
C-1	C-1-01	5.8	**7.1**	4290	**5079**
	C-1-02	8.3		5868	
C-2	C-2-01	6.6	**7.4**	5652	**4973**
	C-2-02	8.2		4293	
B-0	B-0-03	5.4	**5.4**	2796	**2750**
	B-0-04	5.3		2703	
B-1	B-1-03	5.6	**5.2**	1373	**1341**
	B-1-04	4.8		1309	
B-2	B-2-03	5.4	**5.6**	2682	**2987**
	B-2-04	5.8		3291	
C-0	C-0-03	5.9	**6.7**	3166	**3179**
	C-0-05	7.5		3192	
C-1	C-1-03	6.0	**7.4**	2992	**3316**
	C-1-04	8.7		3640	
C-2	C-2-03	8.1	**8.1**	2312	**2628**
	C-2-04	8.1		2943	

WHICH REFERENCE VALUES & LIMITS SHALL WE USE?

- ICAO Doc 9157 **DOES NOT PROVIDE** any specification or acceptance criteria for **FENCING** frangibility tests.
- Again, the ***MOST REASONABLE WAY*** to proceed is to refer to the acceptance criteria of the structures (***approach lighting towers and similar structures***) used as reference for testing procedure:
  - *[cut] structure **should not impose a force** on the aircraft **in excess of** 45 kN*
  - *the **maximum energy imparted** to the aircraft [cut] should not exceed 55 kJ*
  - *[cut] failure mode of the structure should be one of the following: fracture, windowing, or bending*
  - *[cut] All individual components of the structure released by the impact should be kept to as low a mass as possible in order to minimize any hazard to aircraft.*
  - *contact time as short as possible to avoid a secondary impact*

SINGLE FENCE ELEMENT RESULTS ASSESSMENT

FIELD TEST RESULTS:	ICAO doc 9157 § 5 criteria	COMPLIANCY?
• Max impact load: **5 kN ÷ 10 kN**	< 45kN	✓
• Max impact energy: **1.0 kJ ÷ 6.0 kJ**	< 55kJ	✓
• Impactor contact time: **50 ms ÷ 100 ms.** Peak load contact time: **1 ms to 2 ms**	< 100ms	✓
• Failure mode does not cause specimen parts **separation**. Broken parts remain maintain a **good integrity**	no separation	✓

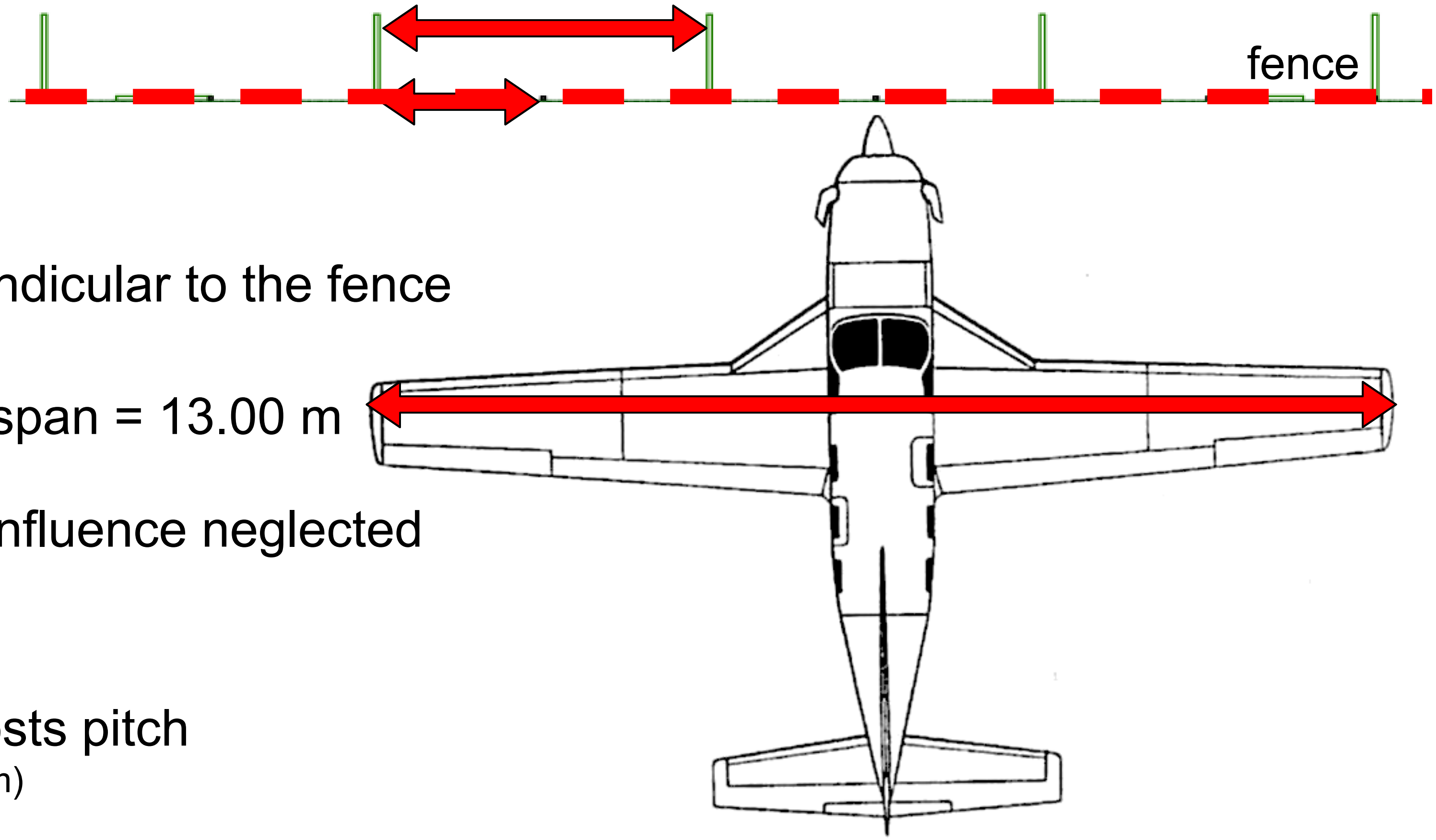
All values and results so far concered the impact on
SINGLE ELEMENT OF THE FENCE

BUT

Which are impact load and energy imposed to the aircraft in a real scenario?
(aircraft impacting on several posts simultanously)

In order to extend the research to a.m. scenario, the following hipotesys was considered:

RESULTS EXTENSION IN A REAL SCENARIO



- Impact perpendicular to the fence
- Aircraft wing span = 13.00 m
- GFRP mesh influence neglected

Variables:

- 3 different posts pitch
  (2,0m / 2,5m / 3,0m)
- 4 different perpendicular struts configuration
  (none, every 3 post, every 2 posts, every post)

RESULTS EXTENSION IN A REAL SCENARIO

OVERALL IMPACT LOAD

(13,0m wingspan aircraft @ 50 km/h) ICAO doc 9157 § 5 limit: <45kN

Wing span (m)	13.00				Distance between posts (m)											
					2.00				2.50				3.00			
					Wind bracing presence				Wind bracing presence				Wind bracing presence			
					none	1 every 3 post	1 every 2 post	all posts	none	1 every 3 post	1 every 2 post	all posts	none	1 every 3 post	1 every 2 post	all posts
Impact height: 1,55 m	Type / Subtype for posts with wind bracing (if applicable)	A-1	Impact load	kN	52.2				41.76				34.80			
		A-2	Impact load	kN	41.6				33.3				27.7			
		A-3	Impact load	kN	41.8				33.4				27.9			
		B-0	Impact load	kN		56.6	58.8	65.5		45.3	47.1	52.4		37.7	39.2	43.6
		B-2	Impact load	kN		47.6	50.5	59.2		38.1	40.4	47.3		31.7	33.6	39.4
		C-0	Impact load	kN		50.9	50.3	48.4		40.8	40.2	38.7		34.0	33.5	32.3
		C-1	Impact load	kN		43.1	43.8	45.8		34.5	35.0	36.7		28.8	29.2	30.6
		C-2	Impact load	kN		43.9	44.9	48.1		35.1	36.0	38.5		29.3	30.0	32.1
Impact height: 1,90 m	Type / Subtype for posts with wind bracing	B-0	Impact load	kN		46.4	46.4	46.4		37.1	34.8	27.9		31.0	29.0	23.3
		B-1	Impact load	kN		46.1	46.1	46.1		36.9	34.4	27.1		30.7	28.7	22.6
		B-2	Impact load	kN		40.0	40.0	40.0		32.0	31.3	29.2		26.7	26.1	24.3
		C-0	Impact load	kN		49.4	49.4	49.4		39.5	38.4	34.9		32.9	32.0	29.1
		C-1	Impact load	kN		43.9	43.9	43.9		35.1	35.9	38.4		29.3	29.9	32.0
		C-2	Impact load	kN		45.4	45.4	45.4		36.3	37.8	42.1		30.3	31.5	35.1

RESULTS EXTENSION IN A REAL SCENARIO

OVERALL ENERGY IMPOSED

(13,0m wingspan aircraft @ 50 km/h)

ICAO doc 9157 § 5 limit: **<55kJ**

Wing span (m)	13.00				Distance between posts (m)											
					2.00				2.50				3.00			
					Wind bracing presence				Wind bracing presence				Wind bracing presence			
					none	1 every 3 post	1 every 2 post	all posts	none	1 every 3 post	1 every 2 post	all posts	none	1 every 3 post	1 every 2 post	all posts
Impact height: 1,55 m	Type / Subtype for posts with wind bracing (if applicable)	A-1	Impact energy	kJ	8.96				7.17				5.97			
		A-2	Impact energy	kJ	6.83				5.47				4.55			
		A-3	Impact energy	kJ	7.83				6.26				5.22			
		B-0	Impact energy	kJ		13.32	15.50	22.04		10.65	12.40	17.63		8.88	10.33	14.69
		B-2	Impact energy	kJ		12.63	15.03	22.23		10.10	12.02	17.78		8.42	10.02	14.82
		C-0	Impact energy	kJ		18.91	23.89	38.82		15.13	19.11	31.06		12.61	15.93	25.88
		C-1	Impact energy	kJ		16.22	20.42	33.01		12.98	16.34	26.41		10.81	13.61	22.01
		C-2	Impact energy	kJ		15.99	20.08	32.32		12.79	16.06	25.86		10.66	13.38	21.55
Impact height: 1,90 m	Type / Subtype for posts with wind bracing	B-0	Impact energy	kJ		11.93	11.93	11.93		9.54	10.73	14.30		7.95	8.94	11.92
		B-1	Impact energy	kJ		8.88	8.88	8.88		7.10	7.07	6.97		5.92	5.89	5.81
		B-2	Impact energy	kJ		11.69	11.69	11.69		9.35	10.90	15.53		7.79	9.08	12.94
		C-0	Impact energy	kJ		12.86	12.86	12.86		10.29	11.85	16.53		8.57	9.87	13.78
		C-1	Impact energy	kJ		12.40	12.40	12.40		9.92	11.75	17.24		8.27	9.79	14.37
		C-2	Impact energy	kJ		10.91	10.91	10.91		8.73	9.96	13.67		7.27	8.30	11.39

CLOSING RECAP & REMARKS

1. **THE AIM OF THIS RESEARCH WAS TO TAKE STOCK OF EXISTING REGULATIONS (ICAO / EASA / FAA?) CONCERNING AIRPORT FENCINGS FRANGIBILITY, AND TO TRY FINDING A COMMON STANDARD TO MEASURE, ASSES AND CERTIFY (?) IT**

2. **BEING FENCE FRANGIBILITY REGULATIONS & PROCEDURES CURRENTLY MISSING, ALL OUTCOMES OF THIS RESEARCH ARE BASED ON *THE MOST REASONABLE INTERPRETATION* OF THE *CLOSEST EXISTING NORMS;***

3. **THE WHOLE RESEARCH, TESTS AND ANALYSIS WERE PERFORMED WITH THE AIM TO ENSURE THE BEST ACHIEVABLE SCIENTIFIC INTEGRITY;**

4. **DESPITE RESULTS ARE NOT ADDRESSED TO A SPECIFIC NORM, THERE ARE ALL THE ELEMENTS TO ASSUME THEY ARE CONSISTENT, REPRESENTATIVE OF A REAL SCENARIO, RELIABLE AND TRUTHFUL;**

5. **WE WILL BE GLAD TO SHARE THIS EXPERIENCE WITH WHOM IT MAY BE INTERESTED IN DEEPENING THE RESEARCH ON AIRPORT FENCING FRANGIBILITY.**


QUESTIONS?


FIBRE NET
composite engineering
thanks for your attention!
FIBREFENCE
FENCING SYSTEM