

Using Optimisation in the Design of Composites

A Design Methodology for the Implementation of Structural Orthotropic Composite Materials in High Performance Systems

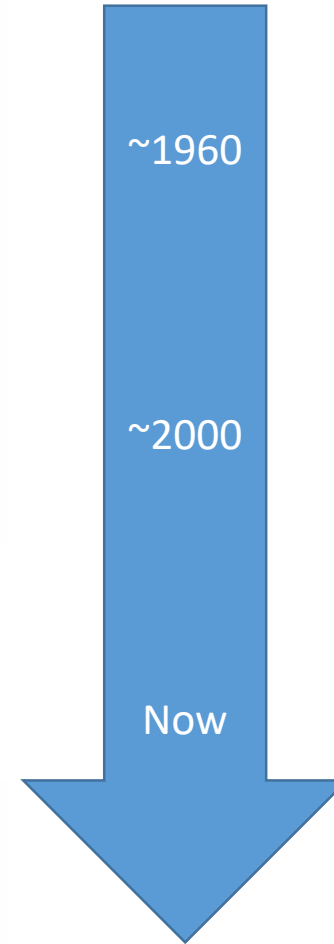
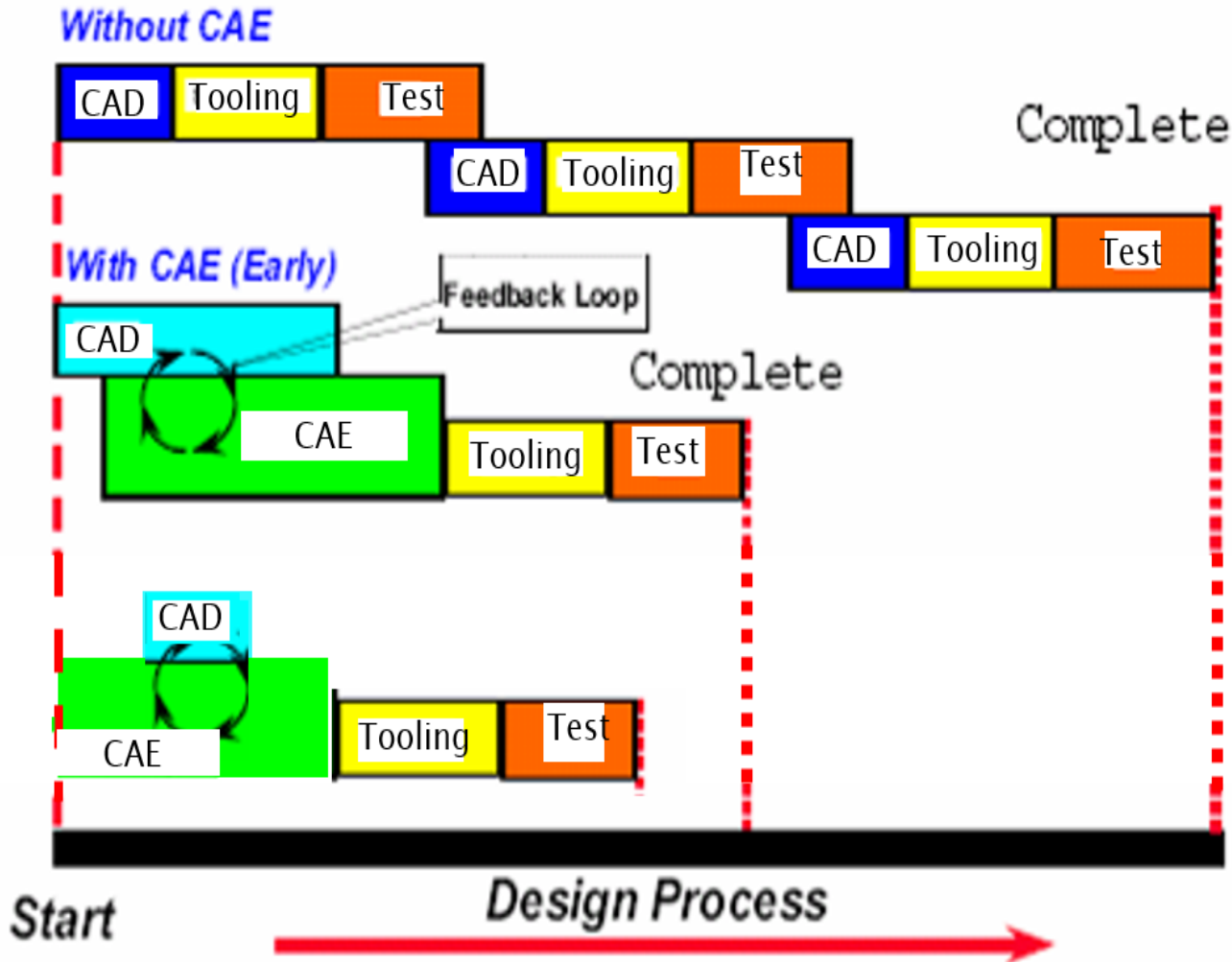


Objectives

- To Propose a methodology....which led to....
- Establish desirable structural characteristics
 - Material level testing
 - Component level testing
 - Mock Field testing
- Design and manufacture boards
- Testing of boards to prove the methodology
 - Local testing of boards
 - Mock Field testing
 - Subjective field testing

Propose Methodology

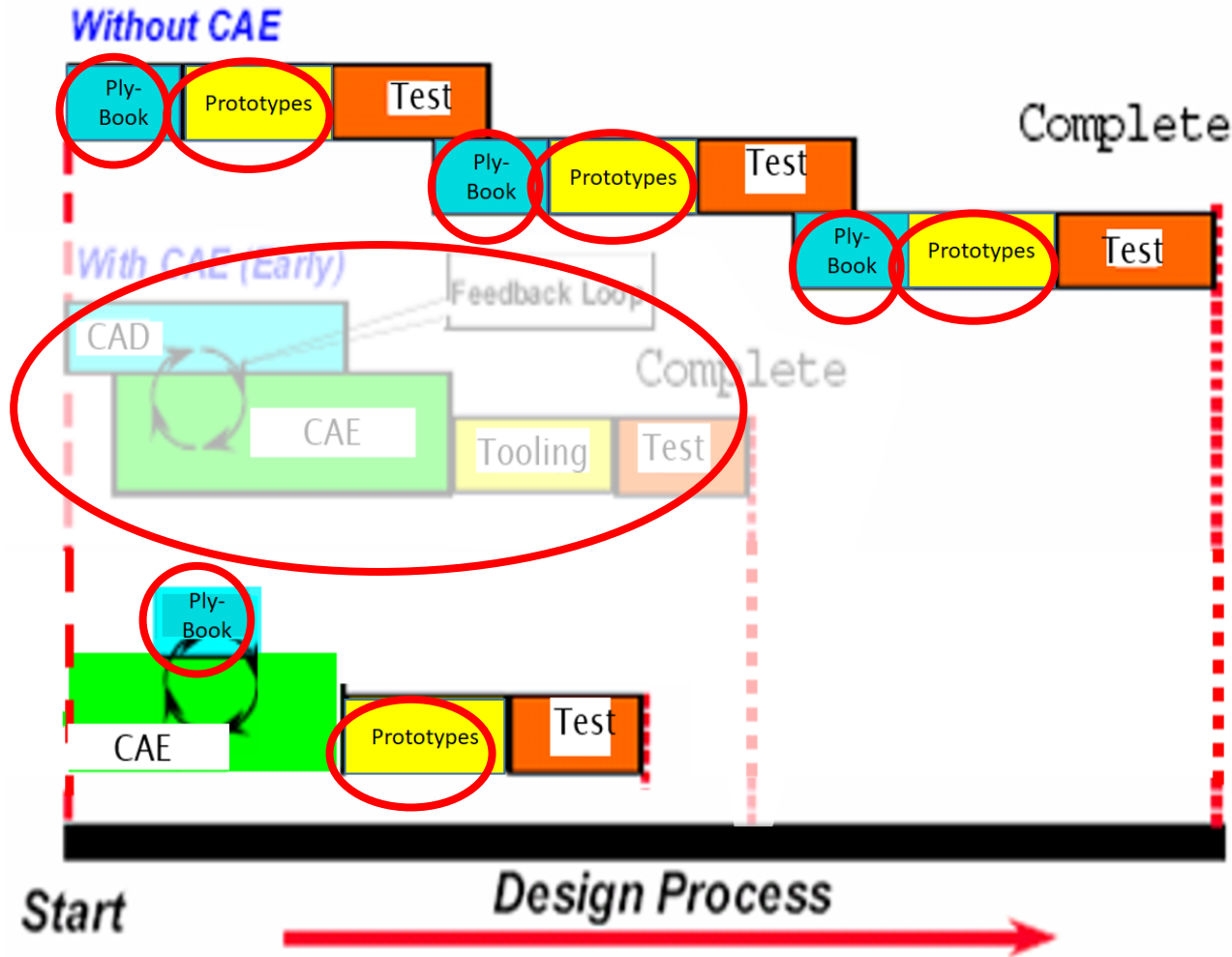
- Automotive industry



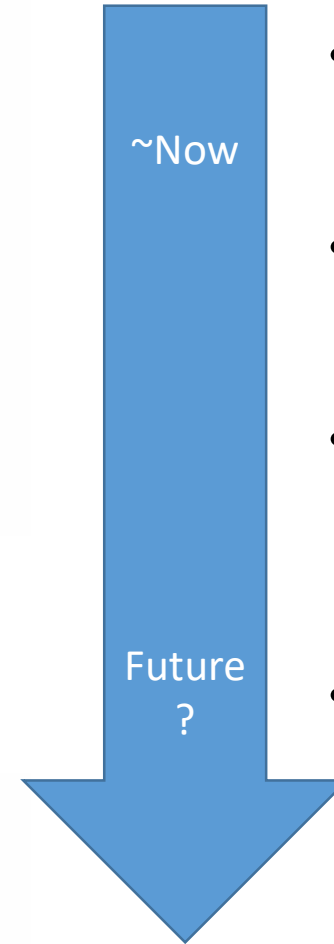
- Many Resources
 - Time
 - Money
- Things have changed
 - Hardware
 - Software
 - Cloud computing
- SMEs should be using this!

Propose Methodology

- Composite Industry Example

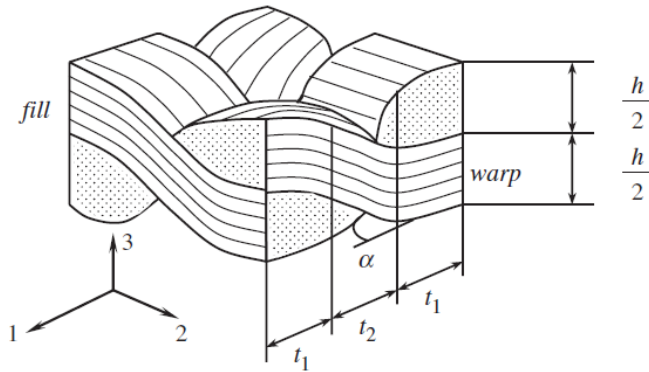
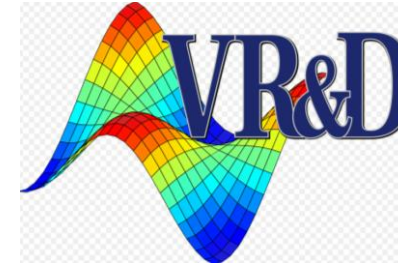


- CAD led design not necessary
- Ply-Books are generated instead of 'CAD'
- Prototypes are build instead of 'Tooling'
- Same benefits
 - Quicker to market
 - Better products
- For CAE to be successful
 - Material properties must be understood
 - Desirable structural characteristics must be understood



Establish material properties

- Micromechanical v Macromechanical

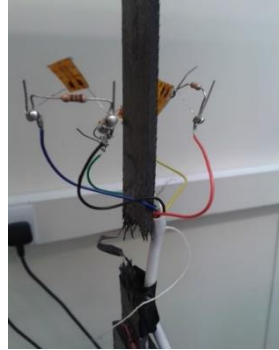


V

Property
Youngs Modulus in the longitudinal direction (E_1)
Youngs Modulus in the lateral direction (E_2)
Poissons Ratio (ν_{12})
Inplane shear modulus (G_{12})
Transverse shear modulus (1-Z plane)(G_{1z})
Transverse shear modulus (2-Z plane)(G_{2z})
Mass density (ρ)
Allowable longitudinal stress in tension (X_t)
Allowable longitudinal stress in compression (X_c)
Allowable transverse stress in tension (Y_t)
Allowable transverse stress in compression (Y_c)
Allowable inplane shear stress (S)
THICKNESS /laminate

Establish material properties

- Tensile Testing: E722, 3k, 2x2 twill 205g/m²



- Young's Modulus in Longitudinal direction
- Young's Modulus in Lateral direction
- Poisson's Ratio
- Allowable longitudinal stress in tension
- Allowable lateral stress in tension
- In-Plane shear modulus

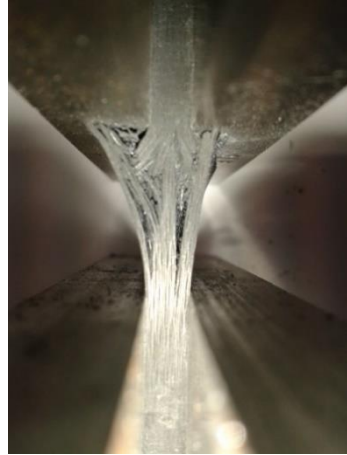
- Flexural Properties: E722, 3k, 2x2 twill 205g/m²



- Flexural stiffness

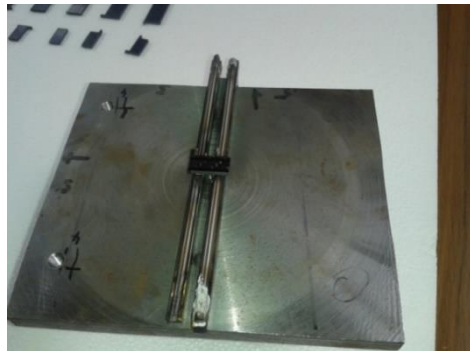
Establish material properties

- Compressive properties: E722, 3k, 2x2 twill 205g/m²



- Longitudinal compressive strength
- Lateral compressive strength

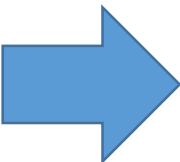
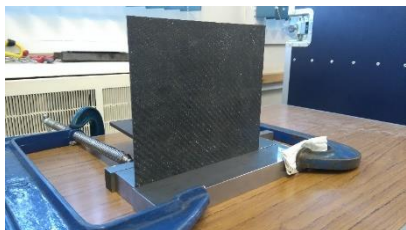
- Interlaminar shear strength: E722, 3k, 2x2 twill 205g/m²



- Interlaminar shear strength

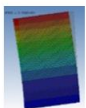
Establish material properties

- Correlation using vibration testing

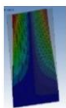


4.2.4.1 $[0]_8$ sample

The following responses were predicted

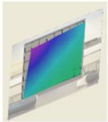
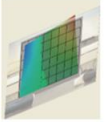


First mode is 37.3Hz



Second mode is 51.5Hz

The experimental results were as follows

test	Mode 1	Mode 2
		
1	37.5	60.9
2	43.8	62.5
3	43.8	60.9
Average	41.7	61.4
stdev	3.6	0.9

	[0]8		[30/-30]4		[45/-45]4		[90]8	
	Mode 1	Mode 2	Mode 1	Mode 2	Mode 1	Mode 2	Mode 1	Mode 2
Test 1	37.5	60.9	32.8	103.1	35.9	106.3	40.6	67.2
Test 2	43.8	62.5	42.2	107.8	34.4	110.9	46.9	65.6
Test 3	43.8	60.9	39.1	106.3	35.9	115.6	50.0	68.8
Average	41.7	61.4	38.0	105.7	35.4	110.8	45.8	67.2
stdev	3.6	0.9	2.4	12.4	0.9	4.5	2.4	0.9
Predicted with TESTED material properties	37.3	51.5	30.1	81.6	37.0	88.2	37.9	51.9
Difference (Hz)	-4.4	-9.9	-7.9	-24.1	1.6	-22.7	-7.9	-15.3
Difference (%)	11.8	19.3	26.4	29.6	-4.3	25.8	20.9	29.5

Poor correlation – Material properties needed scaling!

Establish material properties

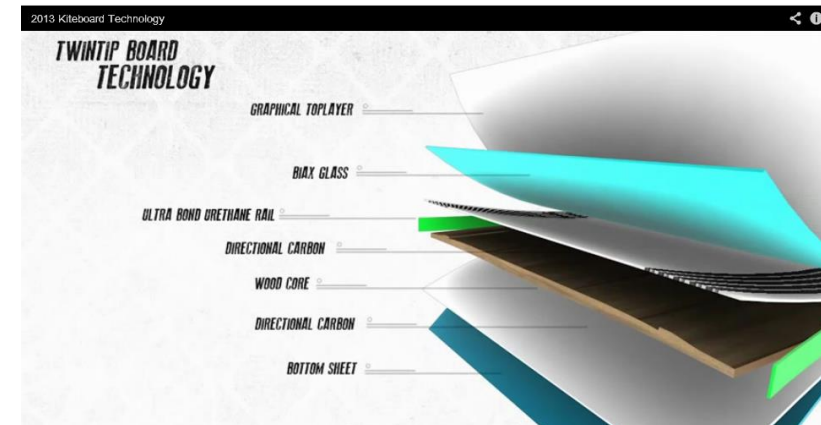
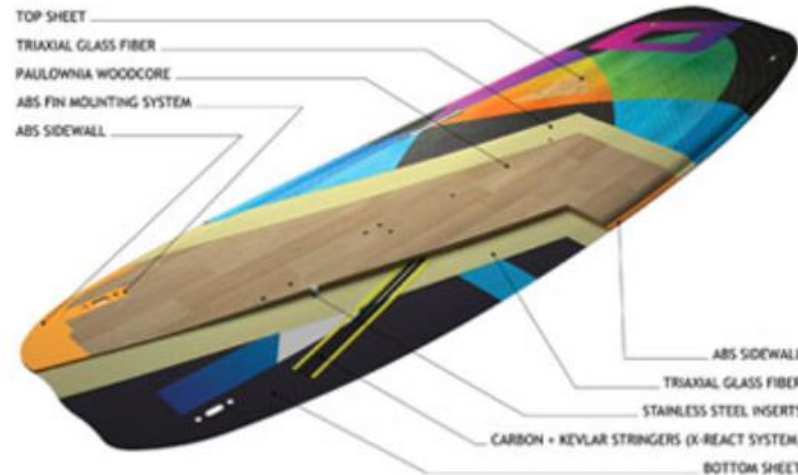
- Correlation using vibration testing

	[0]8		[30/-30]4		[45/-45]4		[90]8	
	Mode 1	Mode 2	Mode 1	Mode 2	Mode 1	Mode 2	Mode 1	Mode 2
Test 1	37.5	60.9	32.8	103.1	35.9	106.3	40.6	67.2
Test 2	43.8	62.5	42.2	107.8	34.4	110.9	46.9	65.6
Test 3	43.8	60.9	39.1	106.3	35.9	115.6	50.0	68.8
Average	41.7	61.4	38.0	105.7	35.4	110.9	45.8	67.2
stdev	3.6	0.9	4.8	2.4	0.9	4.7	4.8	1.6
Predicted with TESTED material properties	37.3	51.5	30.1	81.6	37.0	88.2	37.9	51.9
Difference (Hz)	-4.4	-9.9	-7.9	-24.1	1.6	-22.7	-7.9	-15.3
Difference (%)	11.8	19.3	26.4	29.6	-4.3	25.8	20.9	29.5
Predicted with SCALED material properties	42.8	66.8	35.3	95.5	32.1	102.1	42.8	66.8
Difference (Hz)	1.1	5.4	-2.7	-10.2	-3.3	-8.8	-3.0	-0.4
Difference (%)	2.6	8.7	-7.2	-9.7	-9.3	-8.0	-6.6	-0.6

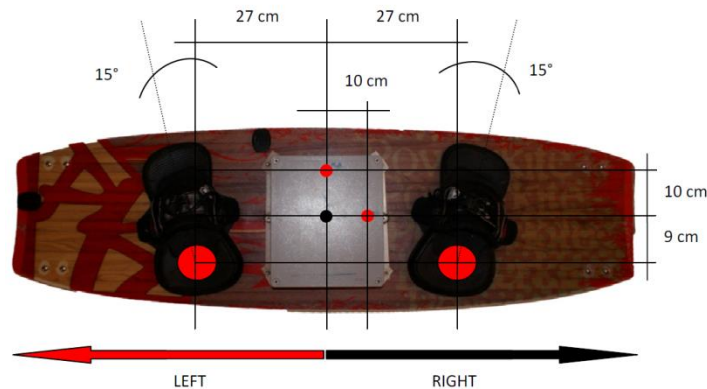
- Expensive material testing resulted in poor correlation
 - Not Necessary?
- Correlation is possible with scaled results?

Establish desirable structural characteristics

- Construction of the board



- Previous Research



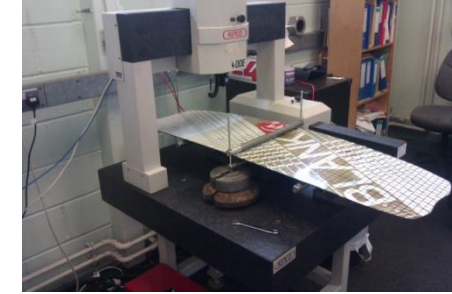
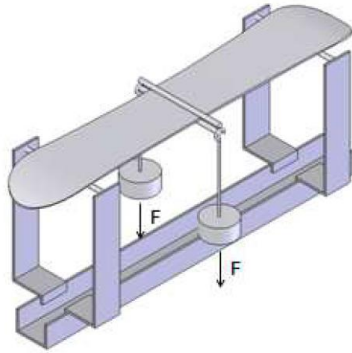
Establish desirable structural characteristics

- Previous Research

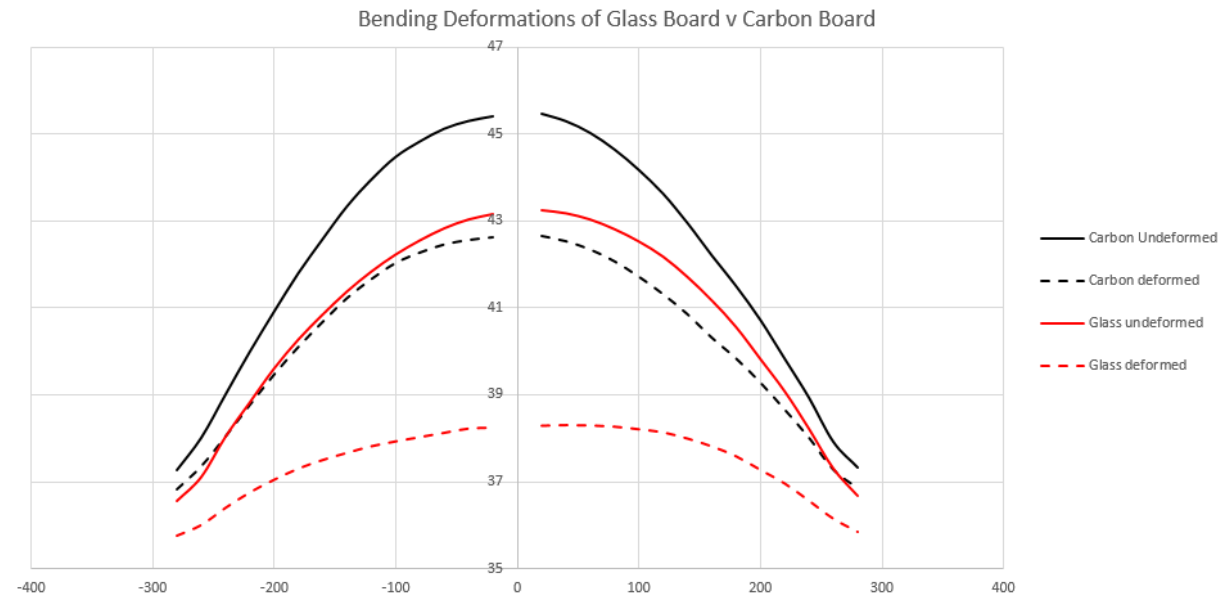
Observation	Characteristic	Field	Reference
The influence of bindings has little impact on the frequency response of the board.	Frequency	Kitesurfing	(13)
Vibrations of a board are closely related to their performance	Frequency	Snowboarding	(33) (34)
'Soft' boards have a lower natural frequencies and larger damping	Frequency	Snowboarding	(35)
Damping of the ski is significantly influenced by bindings	Damping	Ski-ing	(23)
Carbon fibre dampens vibrations	Damping	Tennis	(40)
Torsional characteristics play a predominate role in dealing with vibrations, and to a lesser extent Bending modes	Torsional stiffness	Ski-ing	(23)
Torsional stiffness is important for freestyle and freeride boards	Torsional stiffness	Snowboarding	(28)
Freeride boards possess the greatest levels of bending stiffness and torsional stiffness	Torsional stiffness	Snowboarding	(28)
The stiffness of the centre section of the board has little impact on the frequency response of the board.	Centre stiffness	Kitesurfing	(13)
Manoeuvrability increases with centre stiffness	Centre stiffness	Snowboarding	(28)
The central stiffness of the board influences manoeuvrability and stability	Centre stiffness	Snowboarding	(24)
There has been a trend in increasing the centre stiffness	Centre stiffness	Snowboarding	(24)
'Give' is necessary for a novice	Global stiffness	Snowboarding	(27)
Bending stiffness distribution is crucial for feel	Global stiffness	Snowboarding	(28)
Freestyle bending stiffness characteristics have less fluctuation	Global stiffness	Snowboarding	(28)
Increased stiffness at the heel an shovel increase feedback	Global stiffness	Snowboarding	(28)
Freeride boards should have a balanced blend of performance attributes	Global behaviour	Snowboarding	(28)
Freestyle boards should be 'lively', manoeuvrable, forgiving and stiff	Global behaviour	Snowboarding	(28)
The core material influences the final properties of the structure	Global behaviour	Snowboarding	(30)
The core geometry influences the final properties of the structure	Global behaviour	Snowboarding	(31)
Carbon fibre is stiffer and more shock absorbent	Global behaviour	Cycling	(41)
Carbon fibre boards produce more 'pop'	Global behaviour	Skateboarding	(44)
Carbon fibre boards have more strength and control	Global behaviour	Snowboarding	(46)

Establish desirable structural characteristics

- Component Level Testing: Bending Centre Section

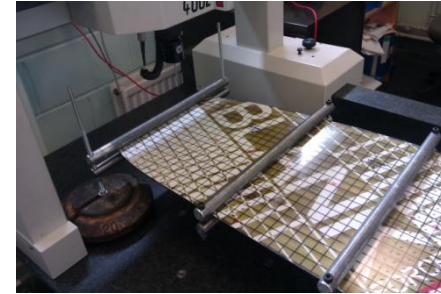
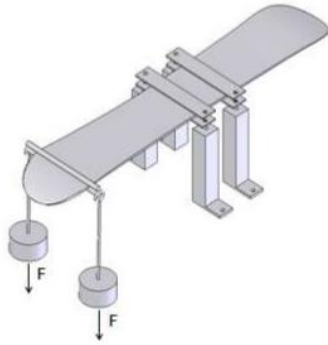


Bending stiffness arrangement for sections 2 and 3 (28)

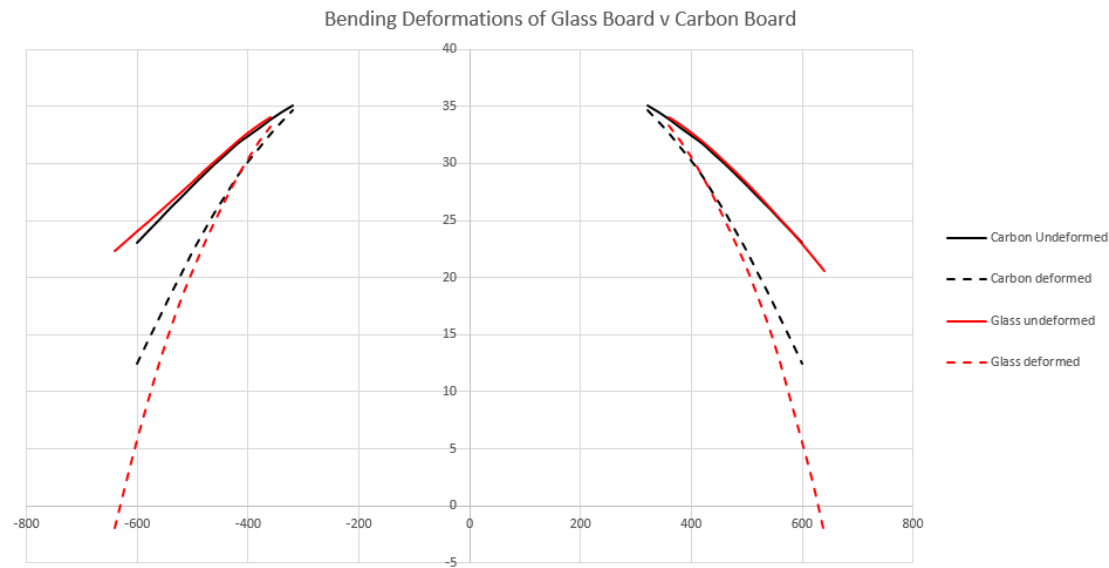


Establish desirable structural characteristics

- Component Level Testing: Bending Tip Sections

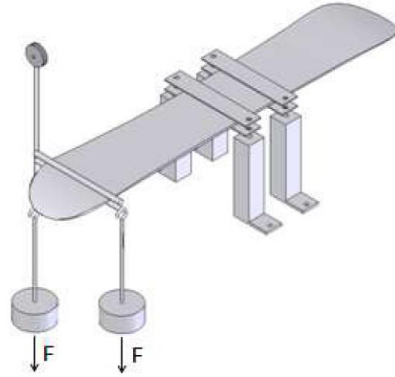


Bending stiffness arrangement for sections 1 and 4 (28)

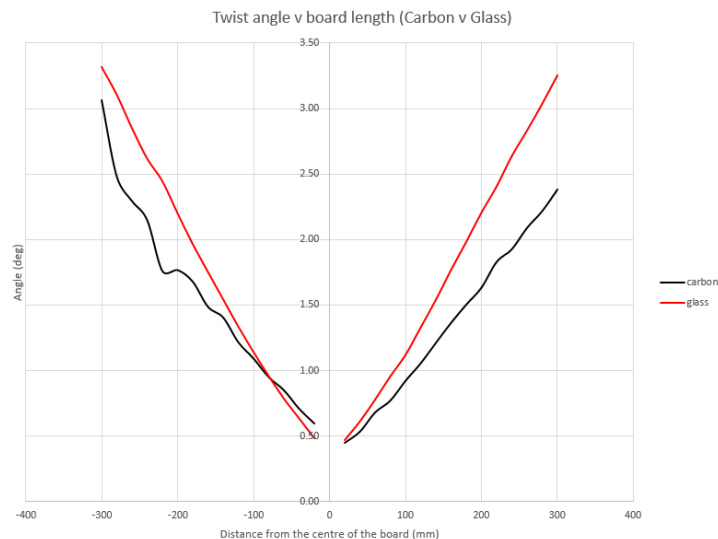


Establish desirable structural characteristics

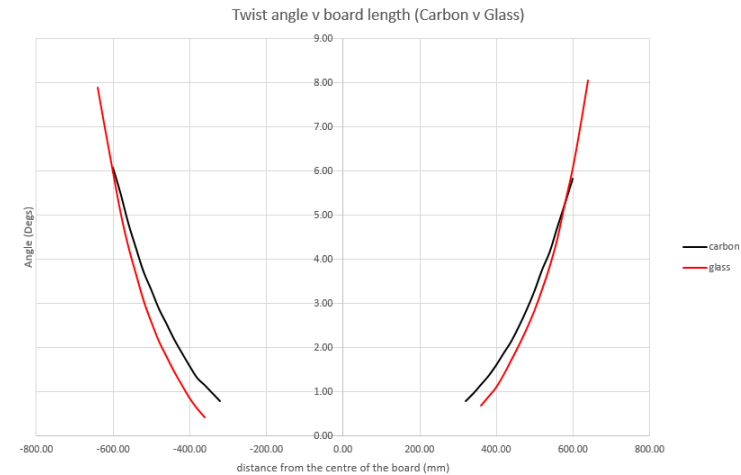
- Component Level Testing: Torsion (Centre & Tip)



Torsion stiffness arrangement (28)



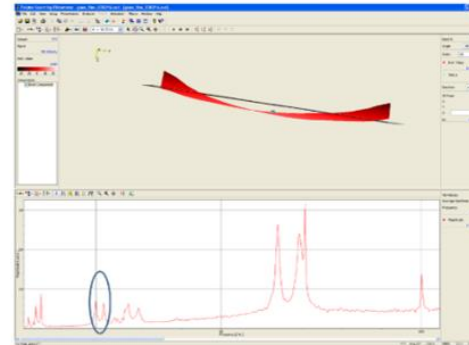
Centre



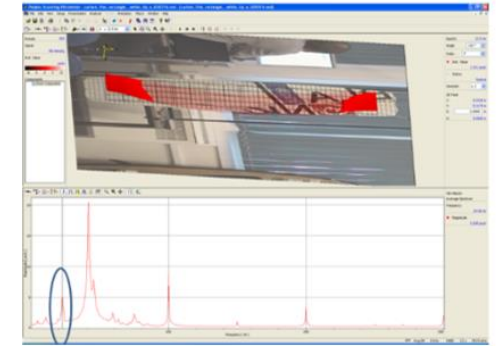
Tip

Establish desirable structural characteristics

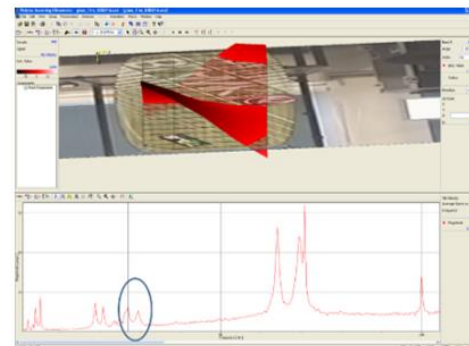
- Component Level Testing: Vibration



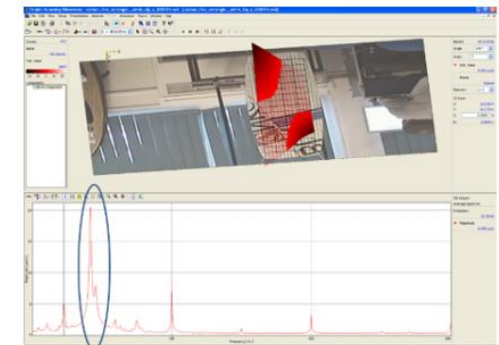
Glass board first bending mode = 18.75Hz



Carbon board first bending mode = 22.5Hz



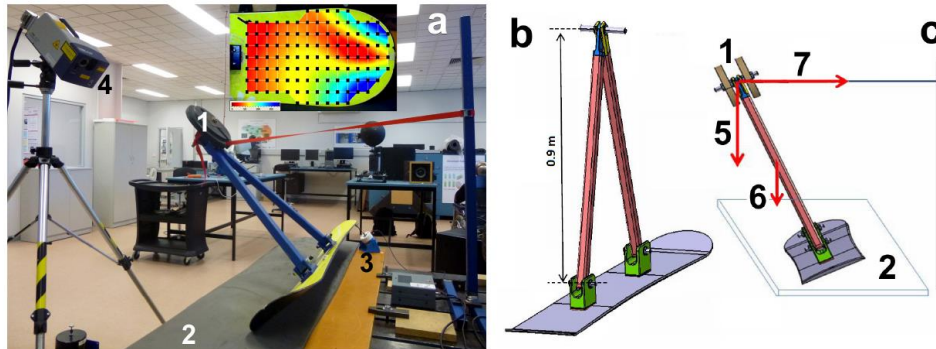
Glass first torsion mode = 26.9Hz



Carbon first torsional mode = 45.3Hz

Establish desirable structural characteristics

- Mock Field Testing

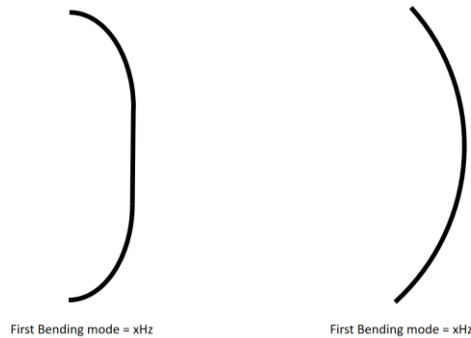


Mock field testing of a snowboard (117)

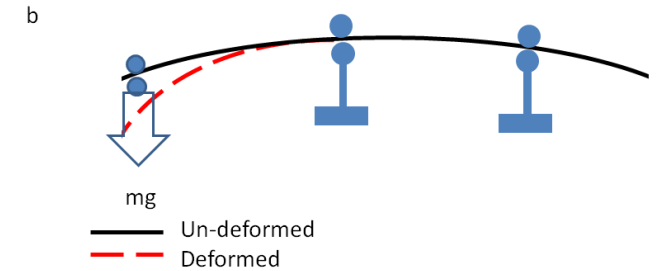
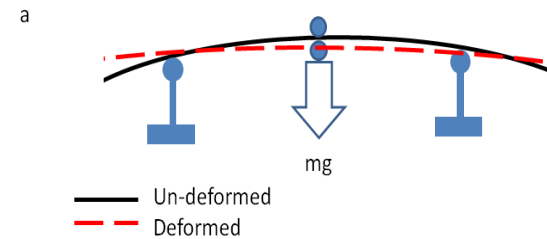


Next Steps...

- Design Boards: Optimise Lay-up to get desired response
 - Variables: Number of plies, Orientation of plies, Size of plies, Stacking sequence.
 - Objectives: Minimise Mass
 - Constraints: Static stiffness v Vibrational response



V



- Manufacture Boards
- Test boards using mock field testing to prove methodology....or otherwise!

References

13. Valsecchi, Marco. *PhD Thesis: Whole body vibration in kitesurfing*. 2009.
23. Foss, Gary and Glenne, Bard. Reducing On-Snow vibrations of Skis and Snowboards. *Sound and Vibration*. December 2007, p. 22.
24. *Structural Analysis of a Snowboard*. Biancolini, M, Reccia, L and Zanini, A. 2005. Associazione Italiana per L'Analisi delle Sollecitazioni.
27. *GRP Makes snowboard more affordable*. June 2000, Reinforced Plastics, p. 6.
28. Clifton, Patrick. *PhD: Investigation and Customisation of Snowboard Performance Characteristic for different riding styles*. 2011.
30. Borsellino, C, et al. Study of Snowboard Sandwich Structures. *Sandwich Structures 7: Advancing with Sandwich Structures and Materials*.
31. *Experimental Measurement of Selected Snowboard Mechanical Properties*. Grewal, D, Lund, C and Rossetter, E. s.l. : Journal of ASTM International, 2006, Vol. 3.
33. *Vibration of snowboard decks*. Fuss, Franz, et al. s.l. : Elsevier, 2010. 8th Conference of the International Sports Engineering Association (ISEA).
34. *Free Vibrations of a Snowboard*. Sakata, Toshiyuki, Kawai, Shigehiro and Kawada, Fumio. 1996, International Journal of Mechanical Science, Vol 38, pp. 579-588.
35. *Laboratory, Computational and Field Study of Snowboard Dynamics*. Buffington, Keith, et al. 2001, Materials and Science in sports, pp. 171-183.
40. Kutz, Myer. *Handbook of Materials Selection*. New York : John Wiley & Sons Inc, 2002.
44. *Carbon fibre skateboard outclasses wood*. 2005, Reinforced plastics, p. 5.
46. *Composites improve snowboards' strength and control*. December 1996, Reinforced Plastics, p. 9.
117. *Investigation and assessment of the edge grip of snowboards with laser vibrometry - a proposal of a standardised method*. Fuss, Franz Konstantin. s.l. : Elsevier, 2014.