

Straight Fibre Variable Stiffness Laminates: Using laminate blending instead of fibre steering (PPT)

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Straight Fibre Variable Stiffness Laminates

using laminate blending instead of fibre steering

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Structure of this presentation

**Introduction to
variable stiffness &
laminate blending**

**Proposed
method**

Discussion

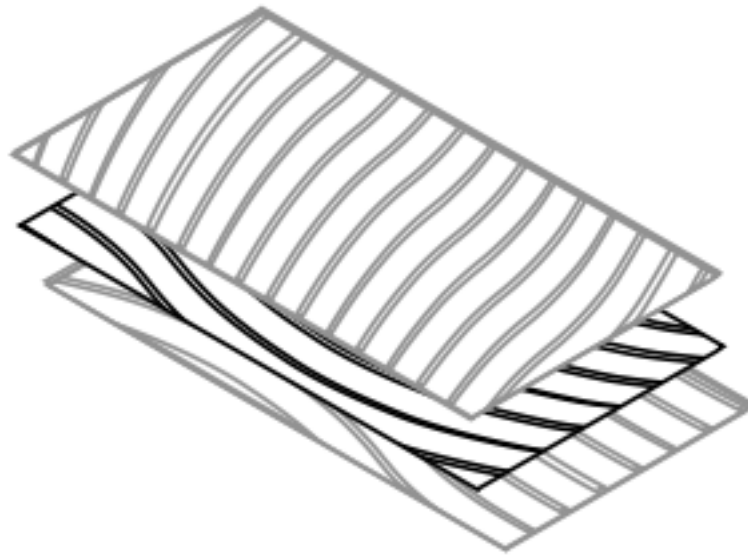


**Motivation
of current
work**

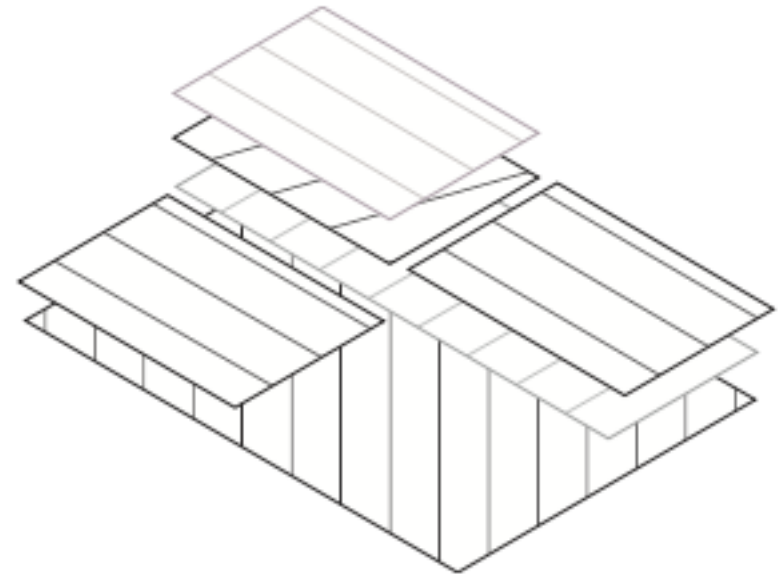
Results

Conclusions

Variable Stiffness Laminates



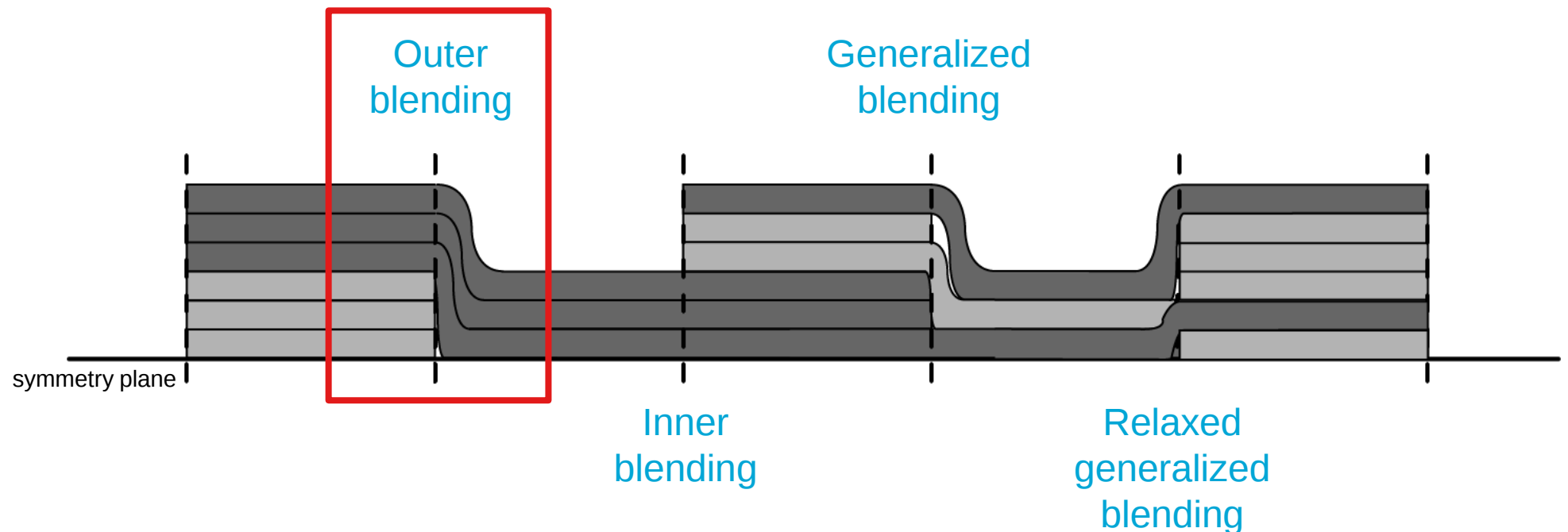
Continuous fibre angle variation



Multi-patch laminate

Laminate Blending

Definition: designing a composite laminate such that for all segments of the structure some or all plies of the stack continue in the adjacent segments

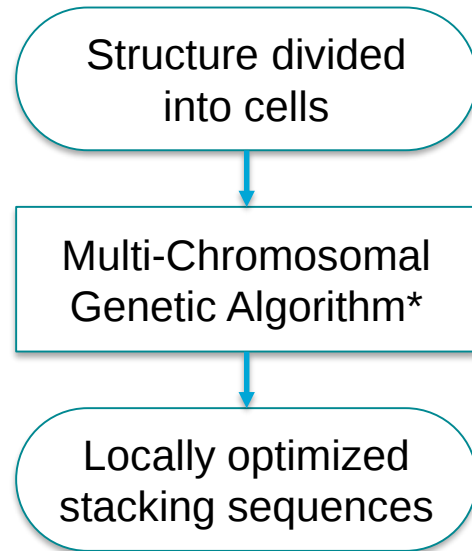


Motivation

To investigate to which extent it is possible to mimic the mechanical behaviour of variable stiffness composite laminates by means laminate blending instead of fibre steering.

SFVS Laminates

Methods



7 encoded ply orientations $\{0^\circ, 15^\circ, 30^\circ, 45^\circ, 60^\circ, 75^\circ, 90^\circ\}$

Cell 1: 4 5 1 2 6 7 1 1 $\Rightarrow [\pm 45 / \pm 60 / 0_2 / \pm 15 / \pm 75 / 90_2 / 0_4]_S$

Cell 2: 4 2 3 2 2 7 7 1 $\Rightarrow [\pm 45 / \pm 15 / \pm 30 / (\pm 15)_2 / 90_4 / 0_2]_S$

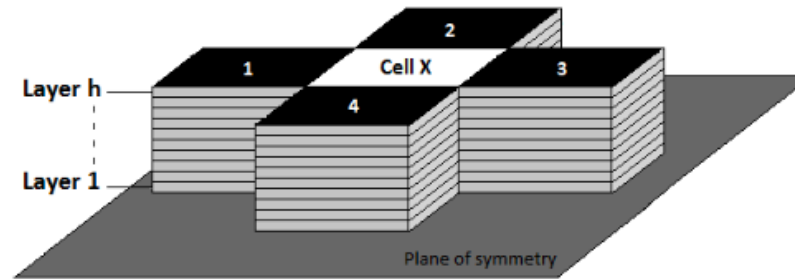
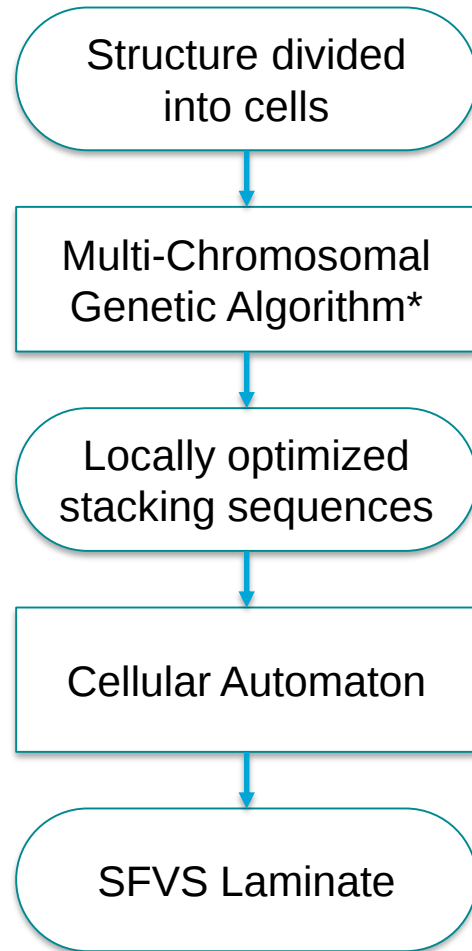
Cell 3: 4 5 3 2 2 1 1 1 $\Rightarrow [\pm 45 / \pm 60 / \pm 30 / (\pm 15)_2 / 0_6]_S$

Cell 4: 4 2 1 2 2 7 1 1 $\Rightarrow [\pm 45 / \pm 15 / 0 / (\pm 15)_2 / 90_2 / 0_4]_S$

Finite element routine programmed in Matlab

$$f = \frac{P_{cs}}{P_{cr}}$$

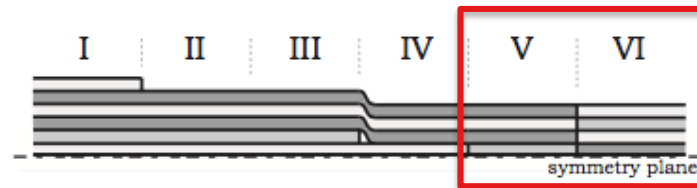
Methods



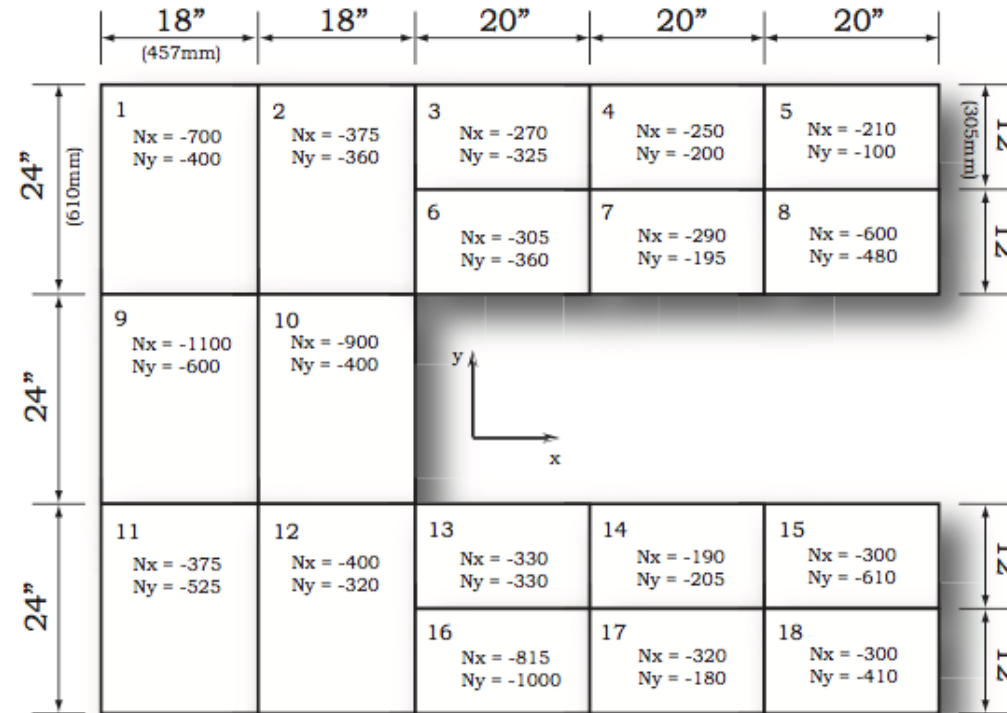
Stage 1: Patch formation → In-plane

Stage 2: Patch Extension → Through the thickness

Stage 3: Elimination of Butted Edges → In-plane



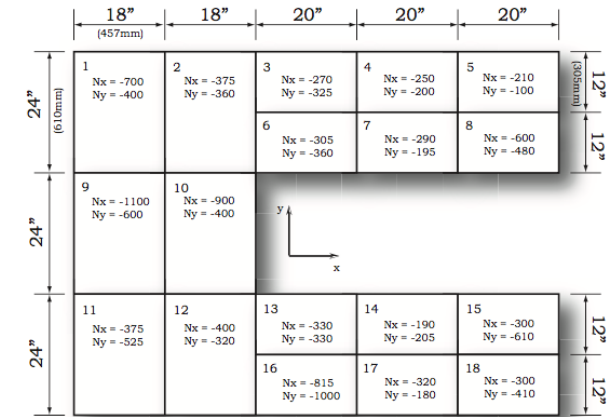
Horseshoe panel benchmark



Soremekun, G. A., Gürdal, Z., Kassapoglou, C. and Toni, D. (2002), 'Stacking sequence blending of multiple composite laminates using genetic algorithm', Composite Structures 56(1), 53–62.

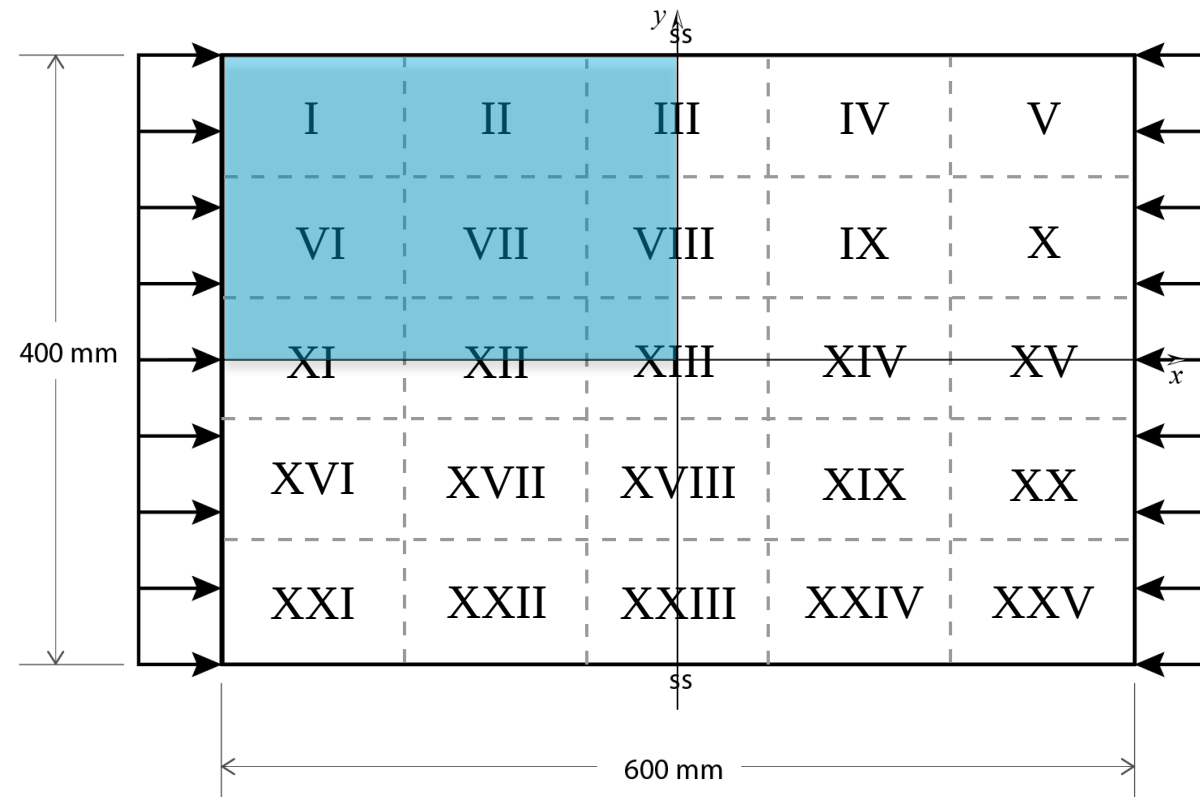
Results Horseshoe Panel Benchmark

	Soremekun et al.	Seresta et al.	Ijsselmuiden et al.		Adams et al.	Irisarri et al.	Proposed method
Section	Balanced	Balanced	Balanced	Unbalanced	Semi balanced	Balanced	Semi balanced
1	34	34	34	34	34	34	32
2	30	28	30	30	28	30	28
3	22	22	22	22	22	22	22
4	20	20	18	18	18	18	20
5	16	16	18	16	16	18	18
6	22	22	22	22	22	22	22
7	20	20	20	18	18	18	20
8	24	26	26	26	26	26	26
9	40	38	40	38	38	38	38
10	36	36	36	36	36	38	34
11	32	30	34	30	30	30	30
12	30	28	30	30	28	30	28
13	22	22	22	22	22	22	22
14	20	20	18	18	18	18	18
15	24	26	26	26	26	26	24
16	32	30	34	32	38	30	32
17	20	20	18	18	18	18	20
18	22	26	22	22	22	22	22
Total weight	29.20 kg	28.83 kg	29.48 kg	28.70 kg	28.63 kg	28.85 kg	28.31 kg



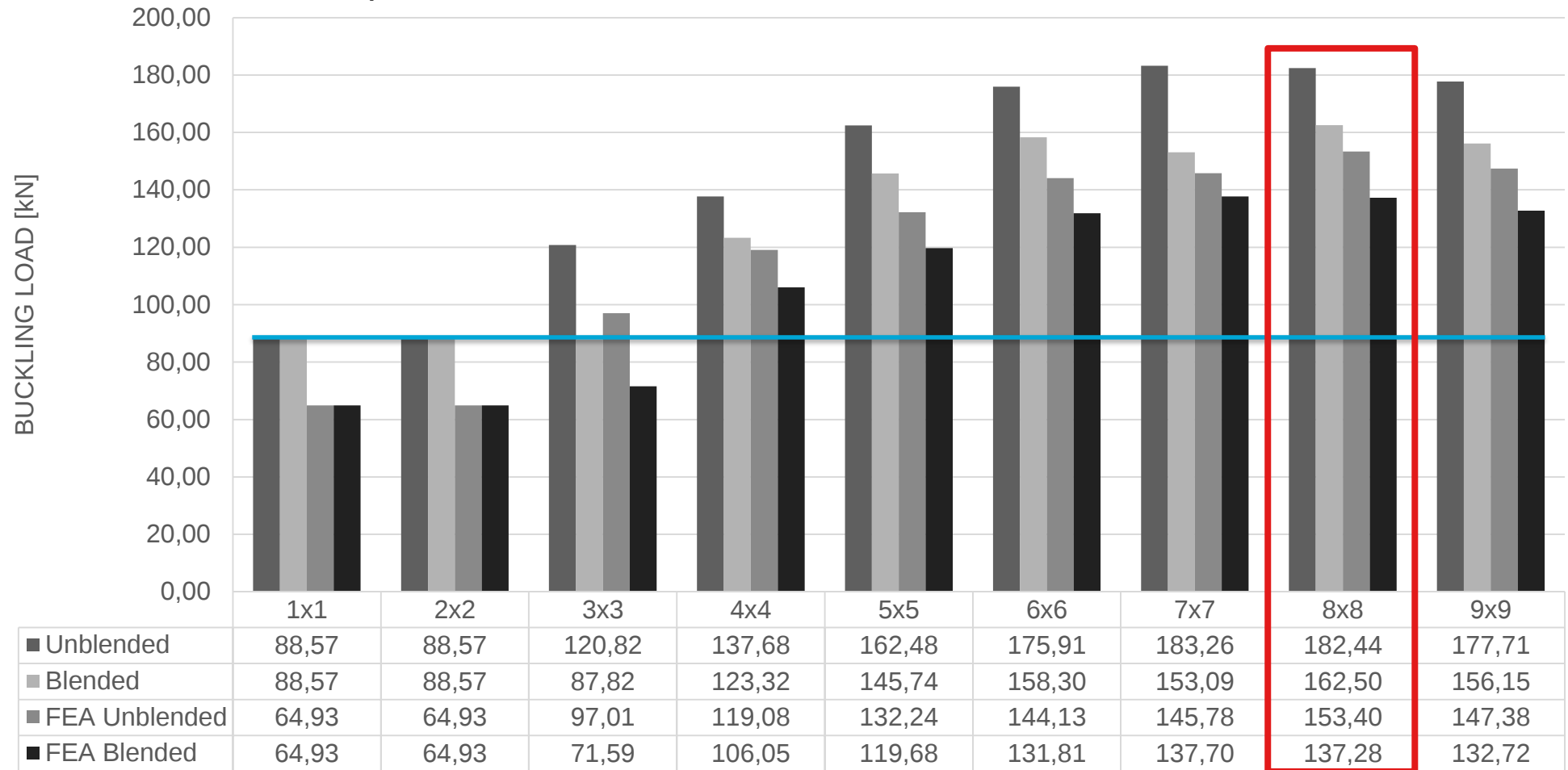
Uniaxially compressed plate

Balanced symmetric lay-up with 8 designed orientations $\rightarrow$ 32 plies in total



Results SFVS Laminates

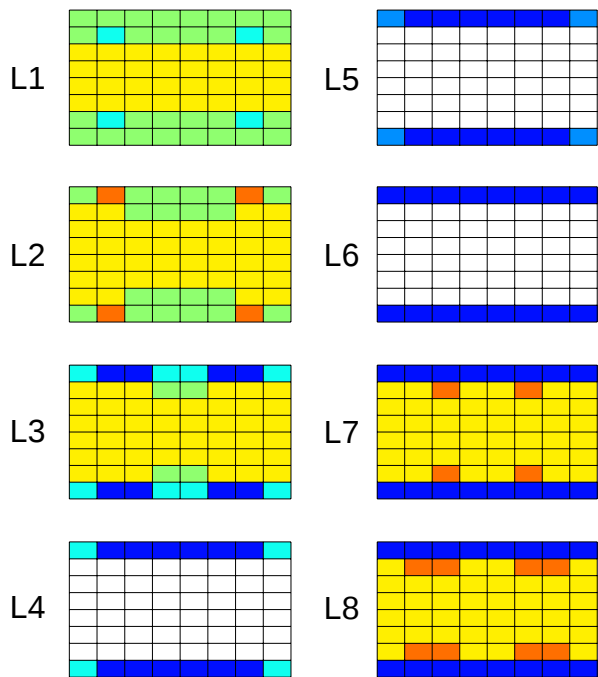
Best result after 10 repetitions



Results SFVS Laminates

UNBLENDED 182.4 [kN]

206% of best CS design



I: $[\pm 45_2/\pm 30_2/\pm 15/0_6]_s$

II: $[\pm 45/\pm 60/0_{12}]_s$

III: $[\pm 45/\pm 60/0_{12}]_s$

IV: $[\pm 45_2/\pm 30/0_{10}]_s$

V: $[\pm 45_2/\pm 60_6]_s$

VI: $[\pm 30/\pm 45/\pm 60_3/\pm 75_3]_s$

7II: $[\pm 45_2/\pm 60_5/\pm 75]_s$

VIII: $[\pm 45_3/\pm 60_5]_s$

[X: $[\pm 60_8]_s$]

X: $[\pm 60_8]_s$

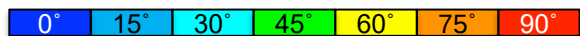
XI: $[\pm 60_8]_s$

KII: $[\pm 60_8]_s$

KII: $[\pm 60_8]_s$

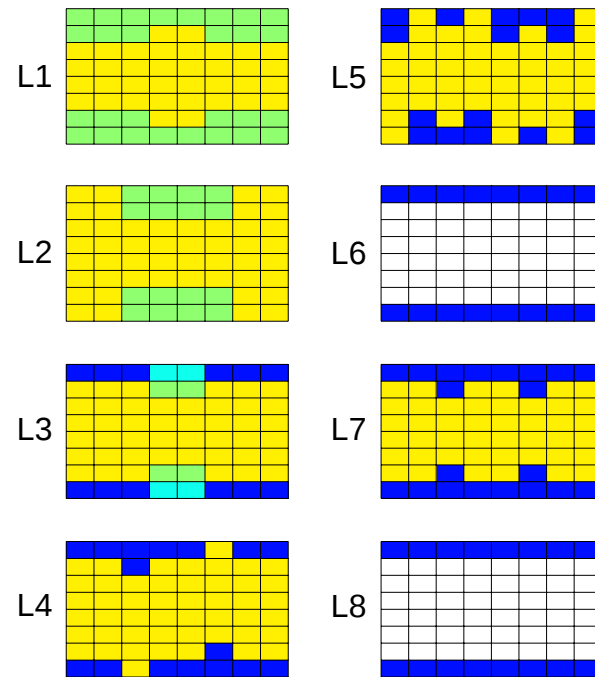
XIV: $[\pm 60_8]_s$

XV: $[\pm 60_8]_s$

XVI: $[\pm 60_8]_s$ 

BLEND 162.5 [kN]

183% of best CS design



I: $[\pm 45/\pm 60/0_4/\pm 60/0_6]_s$

II: $[\pm 45/\pm 60/0_{12}]_s$

III: $[\pm 45_2/0_2/\pm 60/0_8]_s$

IV: $[\pm 45_2/\pm 30/0_{10}]_s$

V: $[\pm 45/\pm 60_7]_s$

VI: $[\pm 45/\pm 60_3/0_2/\pm 60_3]_s$

VII: $[\pm 45_2/\pm 60_4/0_2/\pm 60]_s$

VIII: $[\pm 60/\pm 45_2/\pm 60/0_2/\pm 60_3]_s$

IX: $[\pm 60_8]_s$

X: $[\pm 60_8]_s$

XI: $[\pm 60_8]_s$

XII: $[\pm 60_8]_s$ XII: $[\pm 60_8]_s$ XIV: $[\pm 60_8]_s$ KV: $[\pm 60_8]_s$ XVI: $[\pm 60_8]_s$

Results SFVS Laminates

Crosssection X 1



Crosssection X 2



- Manual post-processing required
- Multiple interpretations possible

Results SFVS Laminates

Buckling load [kN] UNBLENDED		m								
		1	2	3	4	5	6	7	8	9
n	1	88.58				101.60				
	2		88.58			101.08				
	3			120.82		127.16				
	4				137.68	145.88				
	5	153.99	153.99	156.57	153.99	162.48	165.42	165.83	166.85	163.18
	6					172.53	175.91			
	7					178.18		183.26		
	8					179.02			182.44	
	9					174.95				177.71

Buckling load [kN] BLENDED		m								
		1	2	3	4	5	6	7	8	9
n	1	88.57				84.63				
	2		88.57			91.15				
	3			87.82		86.70				
	4				123.32	134.34				
	5	88.10	120.36	134.76	133.18	145.74	148.37	145.74	147.14	144.94
	6					156.04	158.30			
	7					161.11		153.09		
	8					161.99			162.50	
	9					155.98				156.15

Discussion

- Convergence for larger number of sections
- CA does not account for buckling load
- Load redistribution in transverse direction drives buckling load improvement
- Results are only valid for buckling load optimization
- Results are limited to constant thickness plates

Conclusion

- Blending implementation performs well for existing laminate blending benchmark
- Laminate blending can be used to design variable stiffness composite plates
- Buckling load improvement up to 183% of the best known constant stiffness design
- Behaviour similar to that of fibre steered plates reported in literature
- Current algorithm leaves room for improvement

Questions



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