

## FREE VIBRATION ANALYSIS OF LAMINATED STRUCTURES WITH VISCOELASTIC LAYERS

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**Summary.** *This paper presents the comparisons between various beam theories for the free vibrational analysis of viscoelastic structures. The weak forms of the governing equations have been derived through the Principle of Virtual Displacements and solved with the Finite Element Method (FEM). The structural matrices have been derived in terms of 'fundamental nuclei', according to the Carrera Unified Formulation (CUF). The solutions of the complex eigenvalue problem are presented in terms of natural frequencies and modal loss factors. Structures with constant and frequency-dependent damping properties have been considered. Both Equivalent-Single Layer (ESL) and Layer-Wise (LW) approaches have been assessed with 3D FE solutions and with those available in the literature. The comparisons reveal that the 1D-CUF elements represent valuable tools for the modelling of viscoelastic structures, especially when the constraining layers are made of composite materials.*

$\eta_c$		$f_1$	$f_2$	$f_3$	$f_4$	$f_5$	$f_6$	$f_7^+$	$f_8^+$
0.6	3D FE	65.482	298.815	743.877	1390.127	2251.993	3326.500	951.889	2880.341
	LE9	65.958	301.061	750.048	1403.173	2276.609	3370.587	1031.45	3120.379
1.0	3D FE	67.558	303.724	748.305	1392.644	2253.705	3327.623	952.250	2882.174
	LE9	68.050	306.001	754.503	1405.708	2278.336	3371.720	1031.851	3122.600
1.5	3D FE	70.130	311.292	756.439	1397.345	2256.962	3329.754	952.722	2884.177
	LE9	70.643	313.614	762.687	1410.441	2281.621	3373.871	1032.369	3124.899

'+' : frequencies related to torsional mode shapes.

Table 1. Frequencies,  $f$  [Hz], as functions of the core loss factor  $\eta_c$ .

$\eta_c$		$f_1$	$f_2$	$f_3$	$f_4$	$f_5$	$f_6$	$f_7^+$	$f_8^+$
0.6	3D FE	14.634	13.836	9.105	5.280	3.403	2.315	0.910	0.979
	LE9	14.577	13.758	9.071	5.264	3.389	2.302	0.885	0.980
1.0	3D FE	19.945	21.463	14.882	8.742	5.654	3.852	1.473	1.535
	LE9	19.781	21.201	14.776	8.703	5.629	3.829	1.429	1.517
1.5	3D FE	22.573	28.934	21.553	12.964	8.436	5.763	2.138	2.166
	LE9	22.333	28.319	21.272	12.877	8.390	5.726	2.068	2.119

'+' : loss factors related to torsional mode shapes.

Table 2. Loss factors,  $\eta$  (%), as functions of the core loss factor  $\eta_c$ .