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MODELING THE RESPONSE OF THE COMPOSITE SHELL SUBJECTED TO WIND LOADING

MODELOVÁNÍ ODEZVY KOMPOZITNÍ SKOŘEPINY NA ZATÍŽENÍ VĚTREM

Miroslav Černý [1]

Paper is concerned with a modeling of the response of composite shell on the wind loading. Composite shell is based on polyester resin and reinforced by glass fibres. The mechanical properties of the polymer composite have been experimentally determined from mechanical tests. Shape of the shells has been designed to satisfy requirements for microwave transparency, airflow and sufficient stiffness. The real wind pressure on the composite shells has been substituted by the uniform loading affecting individual shell. Maximal load has been calculated according to Czech Standard. Typical composite shell has been investigated experimentally in testing room of Klokner Institute. The shell was fixed to two opposite edges of the supporting steel frame, the longitudinal edge remained free. The steel frame was constructed with a view to satisfy static and dynamic requirements within load test. Static response on the loading was measured for each loading step in eight points of the mesh by the displacement sensors (LVDTs) Lucas- Schaevitz E300 (USA) with range $\pm$ 10 and $\pm$ 20 mm and recorded by measurement system Hewlett- Packard 3852. The strains were measured by 56 strain gage couples located at top and bottom surfaces. The aim of dynamic testing was to verify the resistance of the shell subjected to fluctuate wind components. The eigenvalues have been evaluated by an impact method. The output signal has been measured simultaneously in reference and current points of the mesh (No.001-513) by 2 accelerometers PCB333 (Analog Devices, USA) and ADXL05 (Analog Devices, USA) and recorded by measurement system Hewlett- Packard 3852. The frequency spectrum of signal in 78 points has been calculated by FFT analysis in LabWindows 5.0 package (National Instruments, USA). The results of FFT analysis were used for determination of first two eigenfrequencies and eigenmodes. It has been found that the both static and dynamic mechanical behaviour of composite shells are strong dependent on anisotropy of composite material. Remarkable are advantageous high damping properties of the composite shells.

Fig.1 TV Tower Praděd

Keywords

Composites, shells, modeling, wind loading

Introduction

Fibre composites with polymer matrix have been used recently on TV towers and transmitters [1],[2]. Polymer composites have outstanding dielectric and corrosion properties important for such an application. Recently, composite shells have been used for cladding at the 3rd floor gallery of TV Tower

Fig.2 Assembly of Shells

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Praděd (1492 m above sea level, Fig.1). The shells of length 4500 m, width 1684 mm and height 400 mm have been supported in top and bottom by steel structure of gallery, adjacent longitudinal edges have been unsupported. At the 3rd floor are located radio- relay aerials and other equipment. The cladding consists of 62 composite shells of special sinusoidal shape (Fig.2). Shape of the shells has been optimized to satisfy requirements for microwave transparency (2- 8 GHz), airflow and sufficient stiffness. The thickness of the shell should correspond to requirements for microwave permeability. Shells were fabricated from laminated G/UP composite with polyester isophtalic resin. Two alternatives of reinforcement have been evaluated: woven and unidirectional glass fabrics interlaced by mats. Each composite shell had length 4500 mm, width 1684 mm and height 400 mm. The real wind pressure on the composite shells (Fig.3) has been substituted by the uniform loading affecting individual shell. Maximal load has been calculated according to Czech Standard:

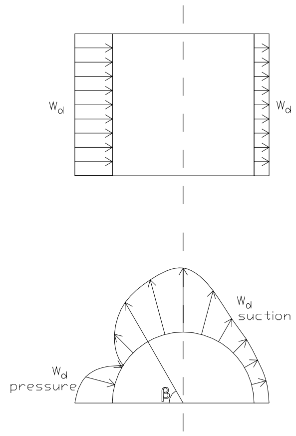

Fig.3 Wind Pressure

w_d= 1,3.0,85.1,2.1,0= 1,326 kN.m^{-2} (pressure)

w_d= 1,3.0,85.1,2.1,7= 2,254 kN.m^{-2}(underpressure)

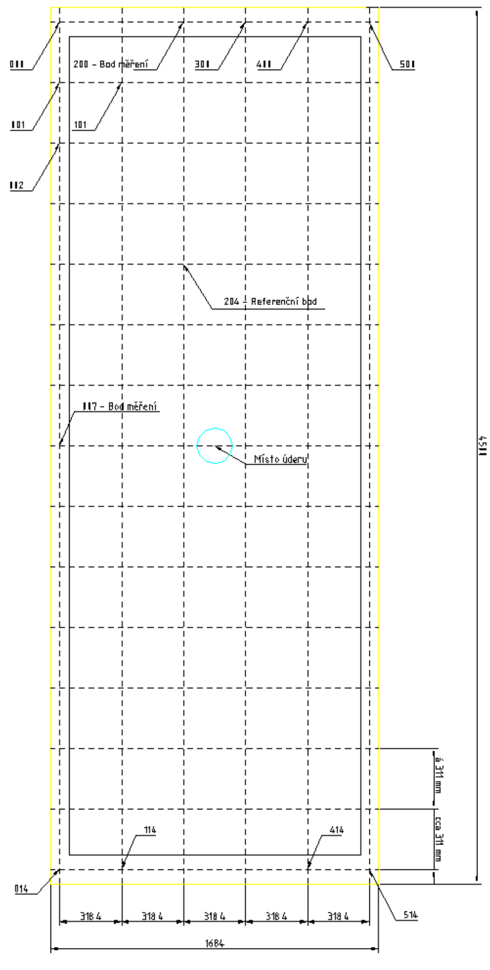

Fig.4 Mesh of Points

Testing of the shell

Typical composite shell has been investigated experimentally in testing room of Klokner Institute. The shell was fixed to two opposite edges of the supporting steel frame, the longitudinal edge remained free. The steel frame was constructed with a view to satisfy static and dynamic requirements within load test [3]. The results of testing correspond to composite (1), which has been chosen for application.

The surface of the shell has been divided into regular mesh of points with distance 200 x 200 mm (Fig.4). Uniformly distributed loading has been applied by loading bags in the steps (0; 0.25 w_d; 0.5 w_d; 0.75 w_d; 1.0 w_d) until the design load w_d= 2.3 kN.m^{-2} has been reached.

Static loading

Static response on the loading was measured for each loading step in eight points of the mesh by the displacement sensors (LVDTs) Lucas- Schaevitz E300 (USA) with range ± 10 and ± 20 mm and recorded by measurement system Hewlett- Packard 3852. Measured signal was digitized by integrating voltmeter HP 44701A (speed up to 1000 ksa.s^{-1}) and multiplexer HP 44736A and stored in memory of PC

Pentium. The displacements have been evaluated by numerical analysis in LabWindows 5.0 package (National Instruments, USA). The strains were measured by 56 strain gage couples located at top and bottom surfaces.

Table 1

Displacements measured by LVDT sensors

	Displacement [mm]							
Load [$kN.m^{-2}$]	A1	A2	A3	A4	A5	A6	A7	A8
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
62	0.95	1.20	7.27	7.92	18.18	18.28	10.31	12.21
115	1.10	1.17	11.91	12.39	27.17	27.34	15.13	16.88
177	1.45	1.56	19.55	18.60	42.60	40.07	22.78	24.97
230	1.96	2.31	24.08	22.88	48.34	45.47	25.61	28.23

Table 2

Location of LVDT's

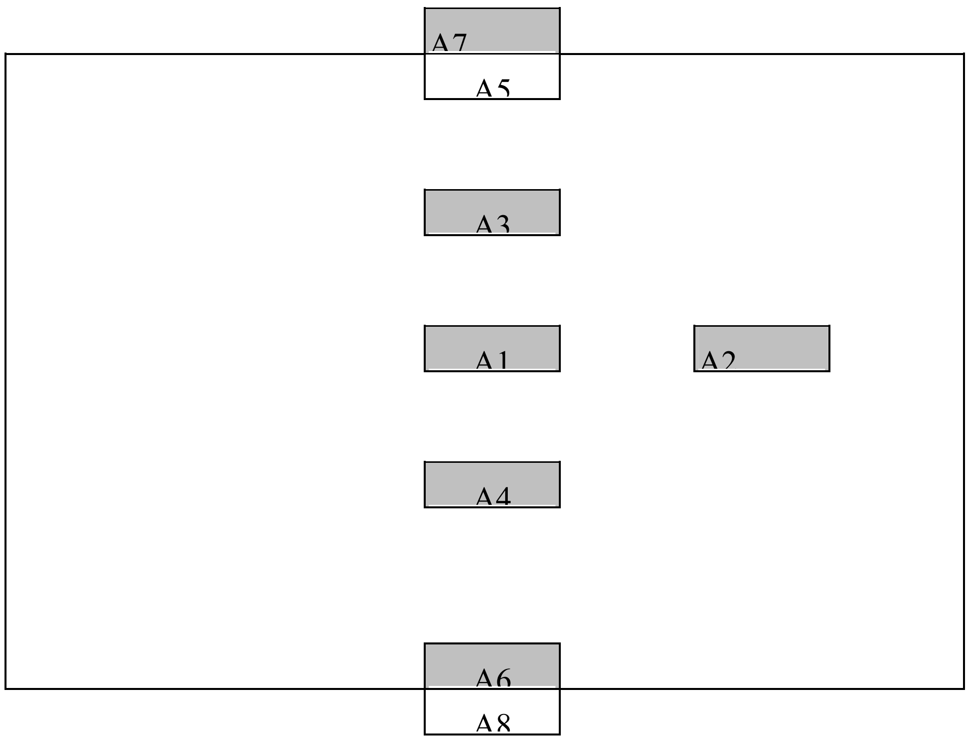

Table 3

Strains measured by strain gages

Type	q_d	T3	T4	T5	T6	T7	T8
ε_m	0.25	-327.1	-263.7	-91.2	23.6	-12.8	-50.1
	0.50	-473.5	-399.4	-145.7	15.6	19.4	23.6
	0.75	-731.1	-694.3	-244.0	34.5	64.0	100.4
	1.00	-873.2	-920.3	-279.7	49.6	63.8	88.8
ε_o	0.25	-6.4	-5.4	218.4	-42.4	9.8	56.7
	0.50	-9.6	-17.2	318.4	5.1	23.8	43.3
	0.75	-25.6	-89.8	455.8	42.9	56.4	68.0
	1.00	-103.1	-193.0	437.9	35.3	88.0	129.7

Type	q_d	T9	T10	T11	T12	T13	T14
ε_m	0.25	138.7	113.6	-20.5	-183.8	-72.9	125.3
	0.50	283.8	211.5	-33.0	-275.7	-147.8	188.1
	0.75	514.6	394.5	-30.7	-399.7	-250.6	298.5
	1.00	590.6	469.6	-34.2	-461.0	-345.0	351.1
ε_o	0.25	85.1	227.1	264.0	-49.4	81.4	322.9
	0.50	165.7	382.5	422.8	-95.9	84.1	407.4
	0.75	299.9	660.8	699.3	-164.5	94.2	491.2
	1.00	353.6	822.4	883.2	-214.7	67.0	438.2

Type	q_d	T15	T16	T17	T18	T19	T20
ε_m	0.25	300.1	156.0	-111.5	-366.6	-77.8	81.3
	0.50	462.4	250.9	-168.3	-492.5	-85.9	118.6
	0.75	733.1	399.6	-256.0	-659.9	-112.5	144.6
	1.00	869.0	476.3	-300.4	-680.1	-105.4	133.8
ε_o	0.25	-47.8	-55.0	101.2	-82.4	-26.6	-5.4
	0.50	-69.4	-114.9	115.2	-117.8	-49.4	-1.1
	0.75	-96.7	-152.9	209.0	-163.6	-72.5	3.2
	1.00	-106.7	-197.1	215.5	-181.8	-87.5	9.8

Type	q_d	T21	T22	T23	T24	T25	T26
ε_m	0.25	-63.0	-0.4	28.4	-286.3	-345.1	-106.6
	0.50	-10.2	19.5	18.4	-441.3	-461.6	-173.1

	0.75	27.4	59.6	44.9	-631.1	-785.8	-267.5
	1.00	-31.5	55.5	70.5	-736.9	-1173.4	-322.1
ε_o	0.25	109.4	38.8	9.9	3.1	-245.4	305.9
	0.50	62.0	41.0	52.2	45.8	-407.1	497.4
	0.75	70.3	61.5	103.7	30.4	-738.2	742.3
	1.00	157.7	94.8	113.6	-63.1	-1017.3	815.8

Table 4

Location of strain gages

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Dynamic Testing

The aim of dynamic testing was to verify the resistance of the shell subjected to fluctuate wind components. The resistance can be characterised by eigenvalues of the shell i.e. by eigenfrequencies and eigenmodes. The eigenvalues have been evaluated by an impact method. Dynamic response on the hammer impact at the top of the shell was measured at the same time in two points.

The output signal has been measured simultaneously in reference and current points of the mesh (No.001-513) by 2 accelerometers PCB333 (Analog Devices, USA) and ADXL05 (Analog Devices, USA) and recorded by measurement system Hewlett- Packard 3852. Measured signal was digitised by high-speed voltmeter HP 44704A (speed up 100 ksa.s^{-1}) and high-speed multiplexer HP 44711A and stored in memory of PC Pentium. The frequency spectrum of signal in 78 points has been calculated by FFT analysis in LabWindows 5.0 package (National Instruments, USA). The results of FFT analysis were used for determination of first two eigenfrequencies and eigenmodes. Eigenfrequencies have been found from the frequency spectrum as resonance frequencies. Eigenmodes have been evaluated by the modal analysis from ratio of accelerations in current and reference points on respective resonance frequencies [4].

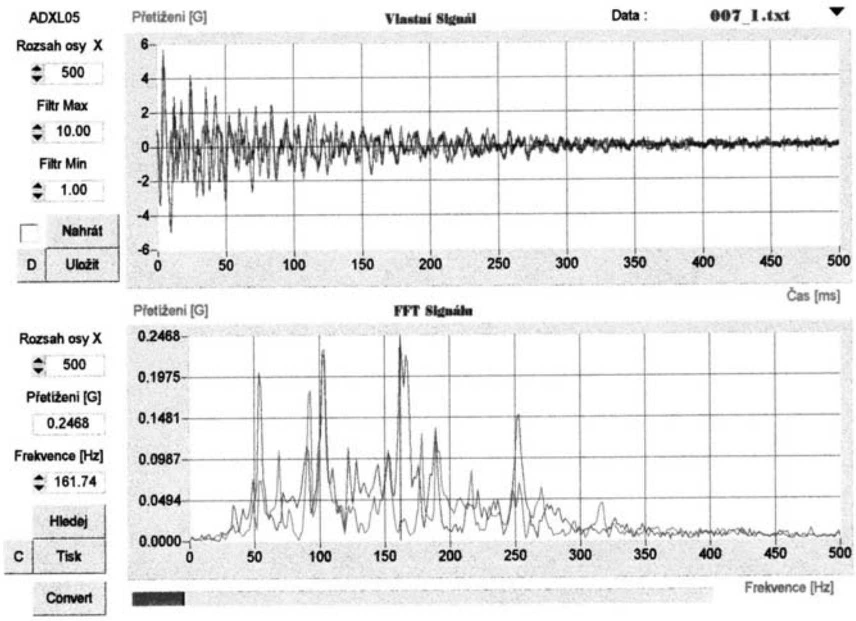

Fig.5 Measured signal and frequency spectrum of signal in point 007

The following eigenfrequencies of the composite shell evaluated in test-room (1) have been found: f_1= 59.126 Hz, f_2=151.97 Hz.

Material properties of the composite

The mechanical properties of the composite have been found out from mechanical tests (tension and Iosipescu shear test). Two alternatives of composites have been considered: (1) The composite with thickness 9.8 mm consisted of 6 layers of woven glass fabric 500 g.m^{-2} or (2) 6 layers of unidirectional glass fabric Rovinap 42-08 interlaced by 10 layers of glass mat 450 g.m^{-2} and both surfaces laminated by glass mat 300 g.m^{-2}. Polymer resin was isophtalic Viapal VUP 4686 BET. The following table 5 shows the obtained test data.

Table 5
Mechanical properties of composite

Property	Unit	(1)	(2)
Thickness	mm	9.8	9.8
Volume weight	$g.cm^{-3}$	1.492	1.521
Glass content	%	37.6	41.5
Tensile Strength	MPa	141	193
E-modulus in tension	MPa	17273	25681, 17140
Shear modulus	MPa	5976	8870
Poisson's Ratio	-	0.24	0.24

Conclusions

It has been found that the both static and dynamic mechanical behaviour of composite shells are strong dependent on anisotropy of composite material. Remarkable are advantageous high damping properties of the composite shells.

Acknowledgment

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