Structural Behaviour of Bending Active Structures

THE IMPACT OF LOAD DISTRIBUTION, GEOMETRY, TEMPERATURE AND WIND LOADS ON THE STRUCTURAL PERFORMANCE

With the advanced development and growth of engineering in the construction industry, the use of lightweight structures has received a significant attention due to their many advantages, such as lightness, portability and multi-purpose uses. Therefore, novel ideas and methods in construction and design have gained popularity in the building sector. The development of the Bending Active Theory plays a crucial role in the development of a new generation of lightweight structures.
A PhD research project carried out at the University of Nottingham by Mohammadmahdi Barari Reshtehroudi under the supervision of Dr. Paolo Beccarelli, Prof. John Chilton and Prof. Jonathan Hale investigated the impact of load distribution, geometry, temperature and wind loads on the structural performance of Bending Active Structures. The research helped to develop insight into the architectural design, assessment of the structural performance, validation of the numerical methods with experimental tests and manufacturing of one-to-one scale structures and mock-ups. The research is based on the extensive use of experimental tests and numerical simulations, providing valuable resources for architects and engineers to support the design and manufacturing of lightweight bending active structures.

Experimental research

The experimental research focused on two main areas: 1/ the evaluation of structural behaviour and material performance and 2/ the investigation of the lateral force's impact by means of structural tests and wind tunnel tests.

The structural behaviour of bending active members and material performance were investigated through several laboratory tests which included bending tests, loading tests, tensile tests and tests designed to understand the effect of temperature. Wind tunnel tests were carried out to assess the effects of lateral force, such as wind load on light and flexible structures. A scale model was manufactured and tested in two configurations, open and closed, to measure the aerodynamic data at different angles with incremental steps of 15 degrees.

Numerical modelling

Numerical models have been used in conjunction with physical models when the experimental tests were affected by unexpected limitations such as construction costs, model's size, access to the labs and testing inaccuracies. The numerical models were initially calibrated with the experimental results and then employed to investigate the following key factors:

- The structural behaviour of different materials and introducing suitable materials for the bending active structures applications.
- The effect of various cross-sectional area on bending active structure performance.
- The behaviour of bending active structures with different f/L ratios.
- The behaviour of bending active structures with various dimensions and equal f/L.
- The behaviour of bending active structures under various loading situations.

Figure 1a-b. Experimental setup for the point loading test

Computational Fluid Dynamic (CFD) was adopted to investigate the effect of wind on bending active structures and address some limitations of the experimental activity, such as time and costs associated with each geometry tested. This study evaluated the reliability of CFD simulations in ANSYS by comparing the results obtained from the experimental data and the numerical model's output.

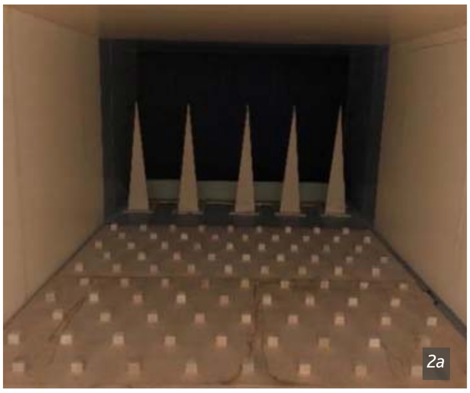
Key Results

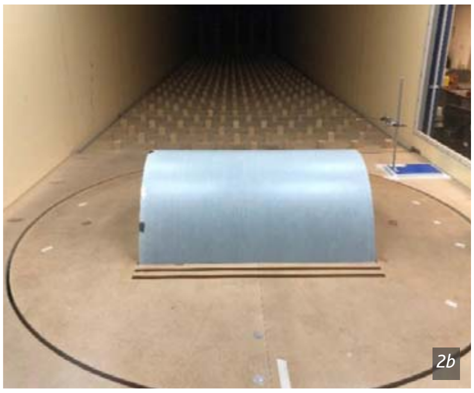
Results obtained from temperature loading indicated that the GFRP materials' behaviour and resistance parameters were influenced by temperature loading. In the case of a single temperature change, target temperature loading, the modulus of elasticity, and yield stress did not change significantly. However, with cyclical temperature changes, the material became more brittle and the range of elastic behaviour decreased. As bending active structures' behaviour is defined only in the elastic range, therefore, by increasing the modulus of elasticity, the amount of stress created in the structure increased and the structure would enter the plastic range with less stress created. Therefore, this becomes an essential aspect of being considered in the design and manufacturing of bending active structures.

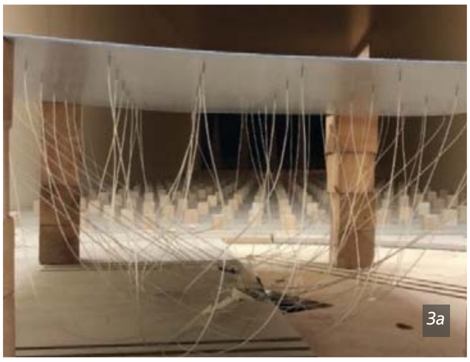
From the wind tunnel experiments and the CFD simulations, could be observed that, as expected, each part of the structure facing the wind flow was under positive pressure. Velocity changes in the Reynolds number range had no significant effects. However, at low velocities, scattering of the mean pressure coefficients was greater. In closed models, the structure behaved similarly to low-rise buildings. Under the wind flow perpendicular to the span (90 degrees angle), the structure was subjected to negative pressure on the edge of structure. On the contrary, in open models under the same wind conditions, due to the thin thickness of structure facing the flow, the pressure distribution values in the same area were considerably lower. In addition, in open models, the pressure values dropped significantly by changing the flow angle from parallel to perpendicular to the span. Moreover, with increasing height and the f/L ratio of the models, on the windward side near the ground, a horseshoe vortex area was observed which affected the distribution and intensity of the pressure on the model.

After performing laboratory testing in a wind tunnel, numerical simulations were performed in ANSYS software in two modes of rigid and flexible. In rigid numerical modelling, due to the non-application of structural features in modelling, the pressure coefficients obtained were lower than the laboratory values. However, when simulating a flexible model, the estimated numerical modelling results showed a good correspondence with the laboratory results.

✎ *Mohammadmahdi Barari Reshtehroudi*
Nottingham University
mahdi.bararireshtehroudi@nottingham.ac.uk







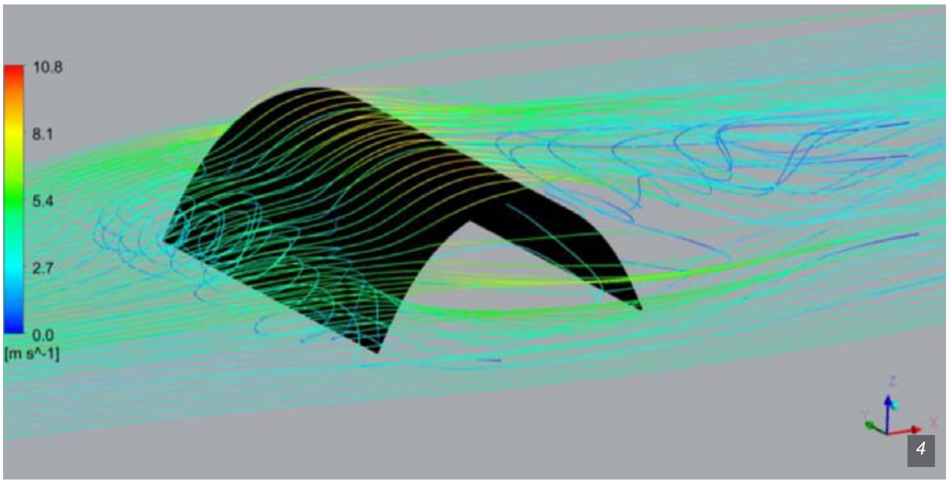


Figure 2a-b. Wind tunnel setup:Left) Spires and roughness elements. Right) Roughness elements and the structural model placed on the turntable

Figure 3a-b. Installed pressure taps

Figure 4. Flowlines in model MO716 (t=2sec) exported from Ansys software

TensiNet Symposium 2023 at Nantes University

The next TensiNet Symposium 2023 will be organized in collaboration with Nantes University in May or June 2023.

The focus will be on ***Membrane architecture: the seventh established building material. Designing reliable and sustainable structures for the urban environment.***

The 3 main topics are:

1. STRUCTURAL MEMBRANE:
contemporary, innovative, adaptive daring and impactful solutions
In Jules Verne's hometown, with its focus on innovation and futuristic issues, membrane architecture can provide answers to current problems, especially for ever denser cities and for a world that is always on the move.

2. TENSIONED MEMBRANE STRUCTURES:
the seventh building material
Recent advances in the design of membrane structures, development of a Eurocode dedicated to structural membranes: the word membrane must now be part of the daily vocabulary of architects, designers and decision-makers, and the specificities of membrane design must be part of the knowledge of all structural engineers.

3. STRUCTURAL MEMBRANE:
an answer to issues of the 21st century
Lightweight design, well-being, environmental impact, energy and acoustic performance, life cycle of materials and structures, end of life of membrane structures: these keywords are part of the current and future construction challenges and are an important message for the younger generations.

More information will follow in the upcoming months!