Wind effect on high-rise buildings of different geometry: comparing CFD simulation and wind tunnel test results

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Introduction

In the past, tall buildings were built with symmetric and conventional geometric shapes in order to better predict their structural behaviours. Nowadays, as engineering and architecture evolved, more asymmetric shapes are being used for high-rise buildings. The current research investigated the wind effect for a conventional square shape building and a helical shape building of similar size. Using Star-CCM+, a computational fluid dynamics (CFD) software, the force and pressure coefficients induced by different wind speeds were calculated and were compared to the existing data using wind tunnel tests. This comparison showed how the 1: 500 scale tests predicted the wind-induced pressure, drag and lift aerodynamic coefficients to full-scale computational tests and allowed for better understanding of how wind tunnel tests and CFD analysis relate to real world wind-structure interaction. These findings can contribute to wind-induced disaster risk reduction planning.

Turning Torso, Malmo, Sweden
http://bocadolobo.com/blog/architecture/25-world-tallest-skyscrapers/

Methods

In order to answer the research question, the geometry of a building model previously tested in the wind tunnel (Tamura et al., 2012) was modelled as a CAD model in Star-CCM+. A square conventional building shape was selected and was compared with a helix shape .

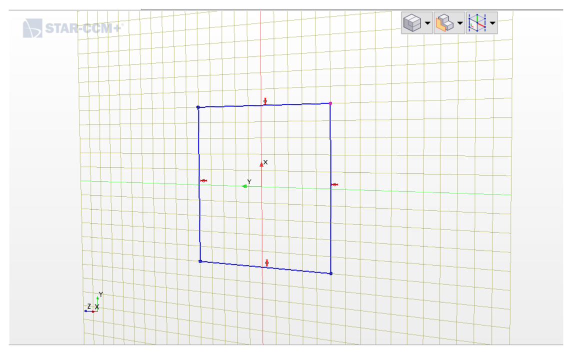

Figure 1: Sketch plane

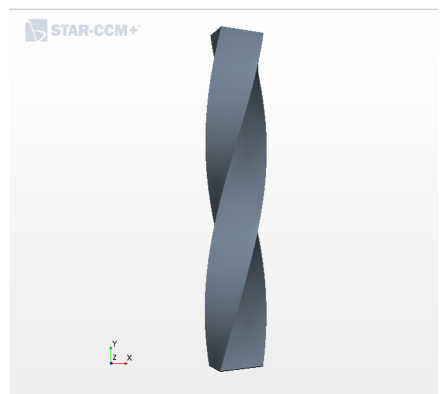

Figure 2: Helix building CAD drawing

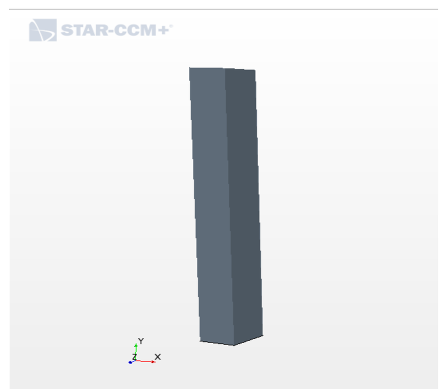

Figure 3: Square building CAD drawing

Once the geometry was created with the proper dimensions then the fluid domain was generated, which acted as a virtual wind tunnel, in order to contain the fluid flow.

Figure 4: Fluid domain

The mesh of calculating elements was created, with controlled dimensions, such that the mesh was very fine in the proximity of the building, to capture the complex flow formations and the generated turbulence, and was coarse far from the investigated model.

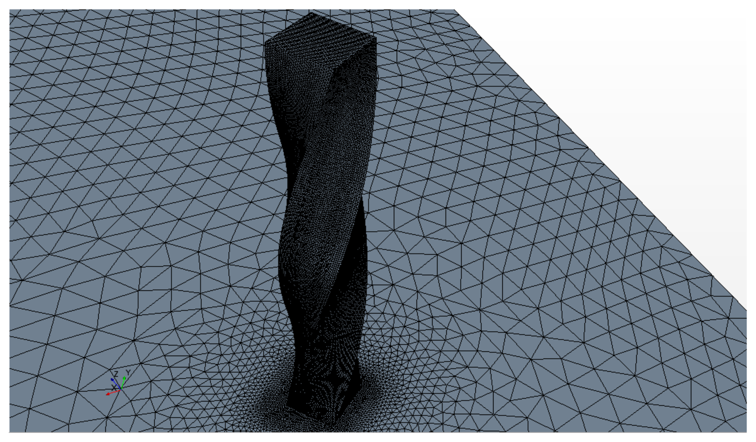

Figure 5: Computing mesh

The fluid properties were specified, some of these included "constant density", "K-ε turbulence model", and inlet velocity of 25 m/s. The simulations were run for both models in order to obtain the drag and lift coefficient for each model. The CFD results were compared to the wind tunnel test outcomes.

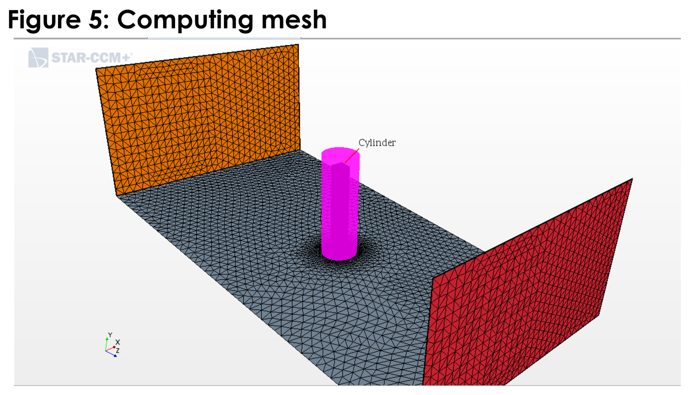

Figure 6: Volumetric mesh control

Results

The wind-induced pressure coefficient was plotted on the surface of the models, along with the wind velocity streamlines formed around the geometry of the building models.

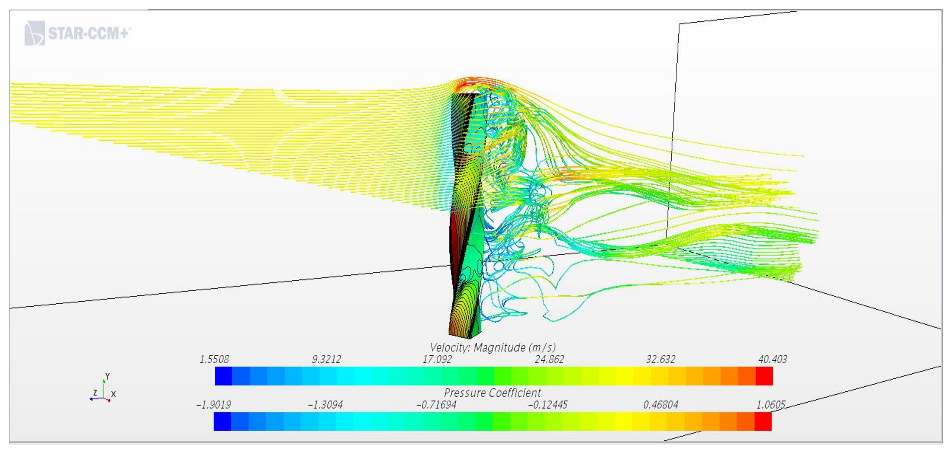

Figure 7: Wind streamlines on helix

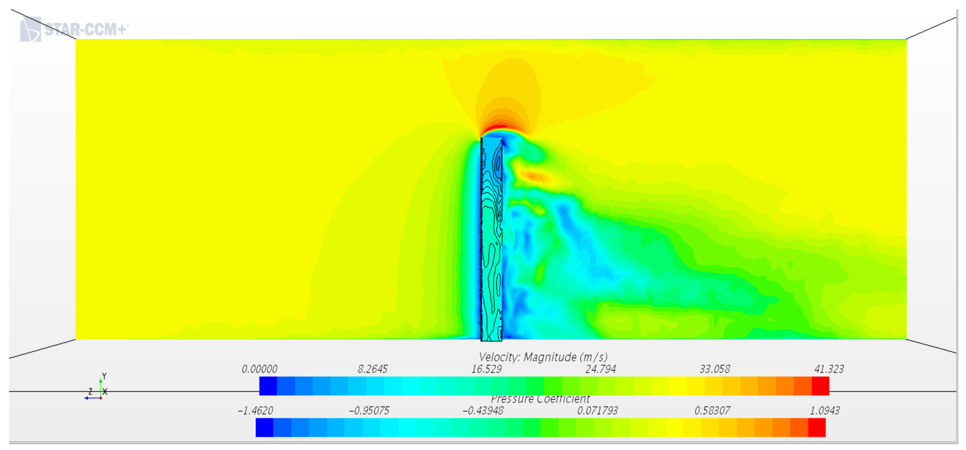

Figure 8: Wind magnitude on square building

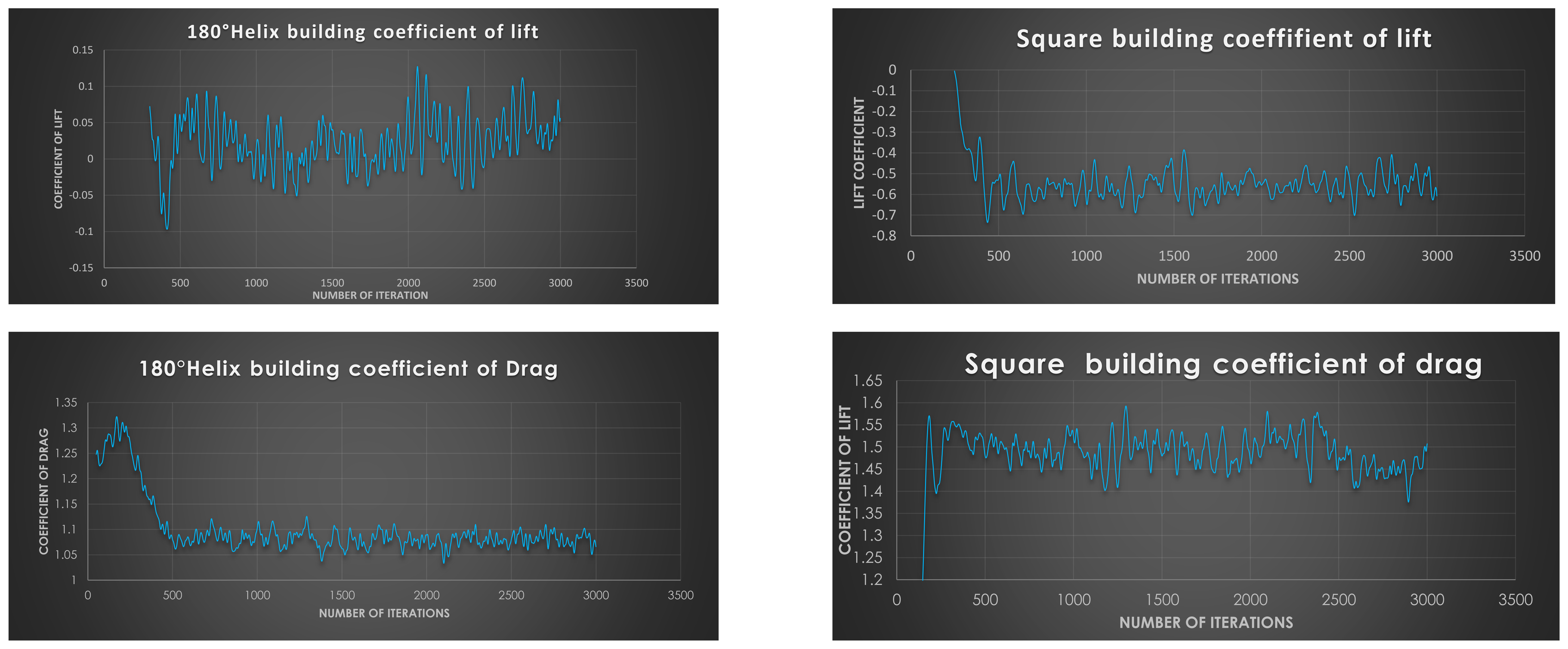

Figure 9: Graphics of force coefficients over Iteration history

The average value of the stabilized CFD solution was compared to the values found in the wind tunnel study performed by Tamura et al. year 2012.

	Drag Coefficient	Lift Coefficient
Helix building current project	1.080336	0.023118
Helix building WT study (Tamura et al., 2012)	1.053	0.0793
Square building current project	1.48624	0.555209
Square building WT study (Tamura et al., 2012)	1.142	0.377

Conclusions

The results obtained in the current CFD study were in good agreement with the wind tunnel test results (Tamura et al., 2012). Based on the pressure, drag and lift coefficients, it can be concluded that the helix shaped building model has better aerodynamic properties than the conventional square shaped building. Furthermore it can be concluded that Computational Fluid Dynamics (CFD) is an appropriate tool for comparing and optimizing buildings' wind characteristics at full scale. However, because the results found did not perfectly match the wind tunnel results, CFD analysis with coarser meshes cannot be employed to substitute the standard wind tunnel tests, but this represents an ideal tool to complement the experimental tests.

References

Hideyuki Tanaka, Yukio Tamura, Kazuo Ohtake, Masayoshi Nakai, Yong Chul Kim, (2012) Experimental investigation of aerodynamic forces and wind pressures acting on tall buildings with various unconventional configurations, Journal of Wind Engineering and Industrial Aerodynamics 2012,179-191.

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