Modelling the airflow at the Clifton Suspension Bridge site

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Introduction & Background

Suspension bridges are highly prone to wind effects due to their long deck span.

Previous studies [1] have highlighted the role of the terrain in reducing the wind speed at the Bridge's deck.

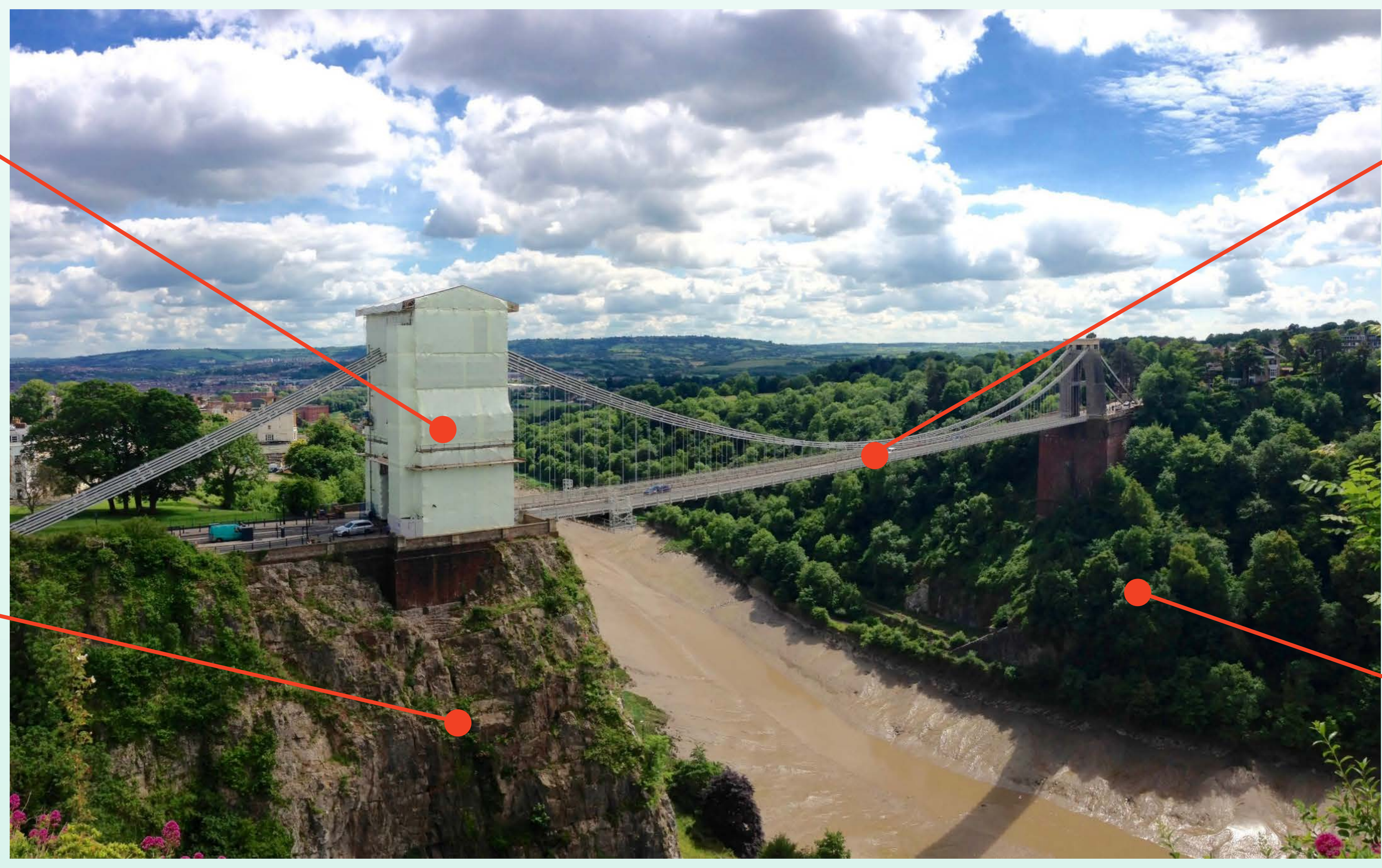

Figure 1: View of the Clifton Suspension Bridge looking South.

The 214 meter-span Clifton Suspension Bridge has survived 152 years without any initial wind analysis.

The Avon Gorge runs parallel to a N-S axis and is suspected of sheltering the Bridge from S-W dominant winds. [2]

Methodology

Terrain Data

- A 1.5x2 km area of interest was selected to incorporate key terrain elements assumed to have an impact on the local wind properties.
- 3D Terrain elevation data was gathered from Ordnance Survey.
- The Bridge's vicinity was scanned using LIDAR technology which was transformed into a CAD model.
- The 2 terrain datasets were merged to form a geometry CAD file scaled to 1/100th with high resolution at the Bridge's location.

Wind Data

- Regional wind data was collected from Bristol Airport METARs for a period of 365 days to eliminate seasonal trends.
- 4 half-days periods with strong winds from the 4 cardinal directions were identified.
- Local wind data measured by the Bridge's 2 anemometers matching the 4 cases was retrieved.
- Analysis of the regional and local winds allowed to formulate a preliminary correlation hypothesis.

3D Computational Domain

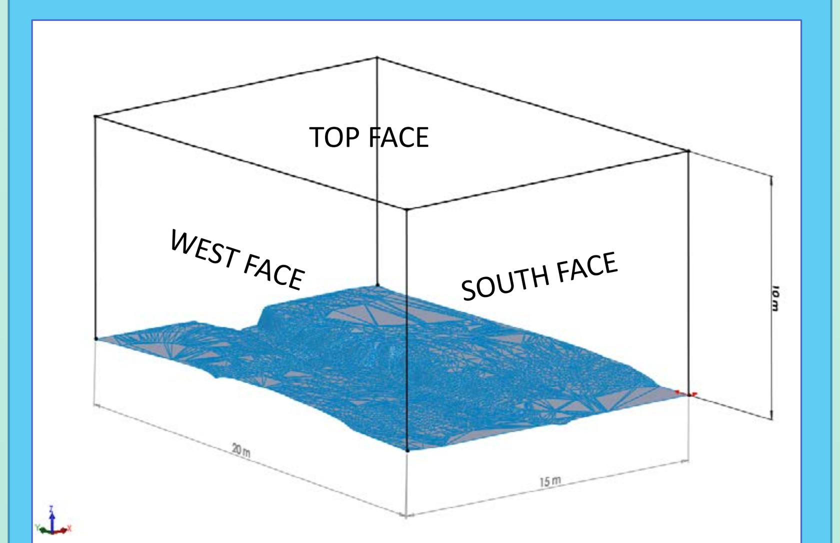

Figure 2: The Computational Domain.

A 1 km high cuboid was formed above the merge terrain geometry.

Boundary Conditions

Wind Direction	Date & Time	Airport 20-min mean wind
North	21/11/2015 07:50	7.60 m/s
East	13/02/2016 07:50	7.15 m/s
South	29/12/2015 20:20	9.39 m/s
West	08/20/2016 16:50	13.86 m/s

Figure 4: The 4 Wind Cases used as Boundary Conditions.

Use of a constant inlet velocity profile was sufficient to capture turbulence.

Iterative Process

23.9 Million-Cell Mesh

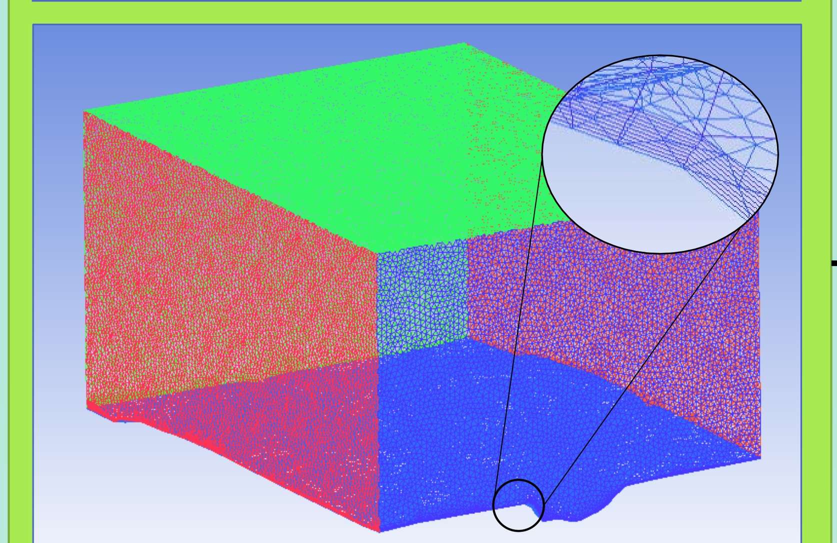

Figure 3: The Final Tetra Mesh with a detailed view of the Prism Layer.

Solver

- Star-CCM+® running on Lyceum2.
- A Realizable k-ε RANS turbulence model selected due to the complexity of the geometry.
- Data from the simulation was collected using:
  - 2 point probes situated at Bridge's anemometers location
  - 3 line probes following the bridge line and two towers.

Validation of the model

- Regional wind measured at the airport was used as inlet conditions.
- The measured data by the probes was compared to the bridge anemometers readings for the same date & time.
- 4 runs from the 4 different wind cases were required to check the consistency of the results across the domain.
- 3 additional runs were necessary to lower the discrepancy to satisfactory average of 25%.

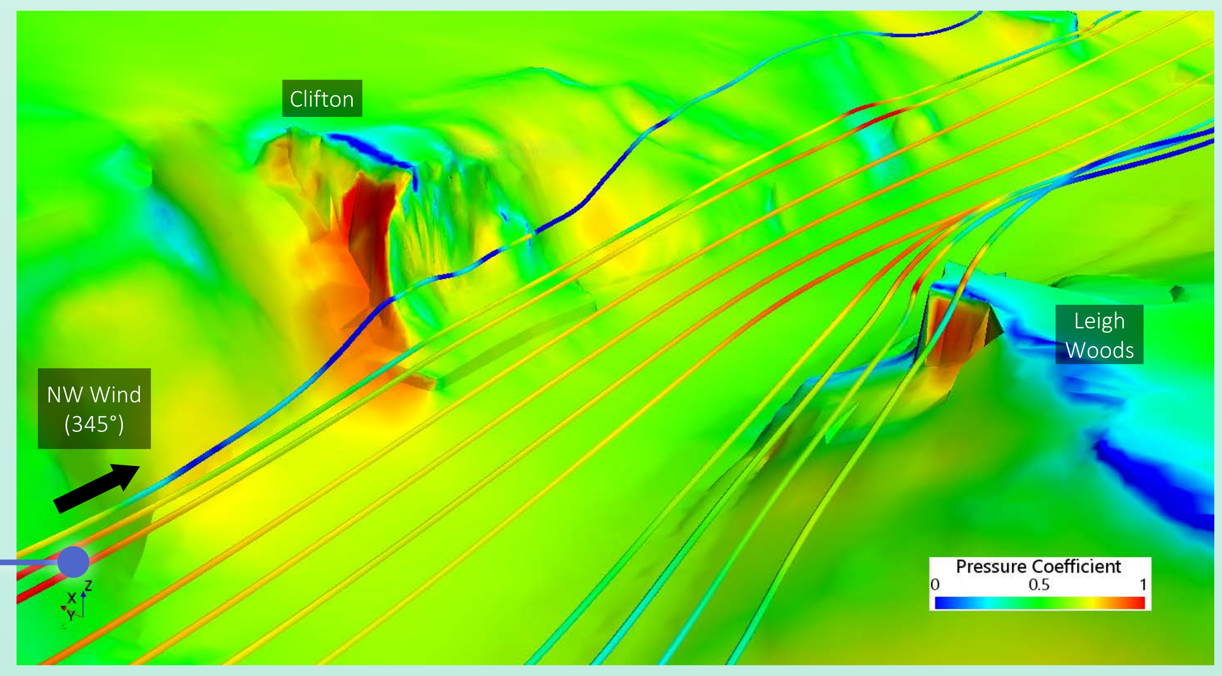

Figure 5: Solver window showing the pressure coefficient at terrain surface and velocity streamlines.

Results & Discussion

- Further simulation runs were completed using the validated model to confirm the correlation between and wind direction and speed seen at the Bridge.
- Reference wind speed were taken from the 12th February 2014 were the Bridge was closed due to excessive Southern winds.

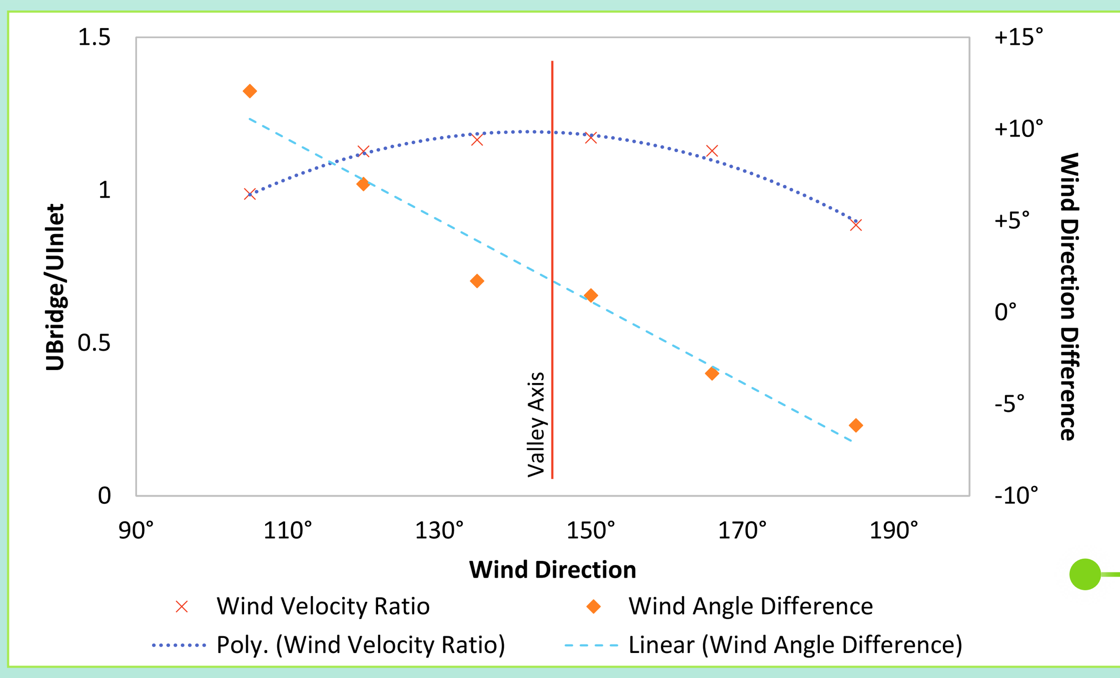

Figure 6: Wind angle difference and wind velocity ration at the Bridge midpoint.

- These additional runs have allowed to estimate the funnelling effect of the valley for different Southern wind directions.

- Simulation data provides strong evidence that the wind speed at the Bridge is largely impacted by the surrounding terrain (Avon Gorge).
- A sheltering effect in dominant Westerly winds can be seen as flow separates above at the valley's ridges reducing local airspeed (recirculation region).
- Inversely, Southern winds are critical as a funnelling effect is observed for winds from 120° to 180°. However these are rare which explains the Bridge's durability.

Acknowledgements

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References

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[2] Macdonald, J. H. G., 2004, Dynamic behaviour of the Clifton Suspension Bridge: Response to wind loading, Bristol Earthquake and Engineering Laboratory (BEELAB) report CSB703/REP/2, BEELAB, Bristol.