A14 Orwell Bridge Overview of Aerodynamics Study

Simon Amor

Head of Planning and Development

A14 Orwell Bridge

Orwell Bridge

- Construction of the bridge started in October 1979 and was completed in December 1982.
- The bridge opened to road traffic in 1982 and carries the A14 (then A45) over the River Orwell just south of Ipswich in Suffolk, England.
- The main span is 190 metres which, at the time of its construction, was the longest pre-stressed concrete span in use.
- The total length is 1,287 metres with a width of 24 metres and a clearance at its highest point of 43 metres.

Current Protocol for High Winds

- Safety is our first imperative and any closure of Orwell Bridge is carried out with that in mind.
- This current protocol works on the assumption that the bridge will be closed to all traffic if wind gusts of 50mph are predicted perpendicular to the bridge and at 60mph in all other directions.
- Wind speed thresholds are based on historic data and have not been updated since the bridge opened.
- The decision to close the bridge is based on Met Office forecasts. This enables us to inform drivers in advance of any potential closures and reduce the impact of traffic on the diversion route through Ipswich.

Current Protocol for High Winds

- We must implement road closures before the wind speeds reach 50mph. This enables us to safely install signs and cones.
- When high winds are forecast, and if time permits, we will place resources on stand-by and liaise with partners at an early stage, allowing the bridge to be closed at the optimum moment and minimising impact on diversion routes.
- Fixed signs are installed for road closures. These signs have reduced the amount of time it takes to close and re-open the carriageway. It is now possible to close/re-open the bridge in 20 minutes, as opposed to over 50 minutes previously.

Separation of high sided vehicles?

- Frequently asked questions
- Requires resource and stacking space for parked vehicles
- We do not have the ability to safely filter vehicles
- Neither the police or Highways England have the resource to carry out and enforce filtering
- Welfare issues for parked drivers

Closure data

- Below is a summary of the previous closures due to high winds on Orwell Bridge since 2013.

Date	Duration (minutes)	Wind speed max (mph)
27 October 2013	541	74
23 December 2013	388	66
26 December 2013	541	61
14 February 2014	681	65
27 March 2016	381	67
22/23 November 2016	N/A	50
23 February 2017	628	70
22/23 November 2017	435	60
2/3 January 2018	988	66
18 January 2018	N/A	72
23 January 2018	261	49
29 April 2018	470	52
29 November 2018	N/A	N/A
13 March 2019	451	60.39
16 March 2019	371	51.89
2 November 2019	355	57.26
13 January 2020	341	46.08
14 January 2020	672	62.41

Communication Cascade Plan

- We have developed a cascade plan highlighting key groups engaged when closing/opening Orwell Bridge.
- The information is passed onto our stakeholders included within the plan who then circulate to the wider community through their own communication processes.
- We also use traditional and social media to inform customers. The electronic messaging signs across the road network are also utilised.

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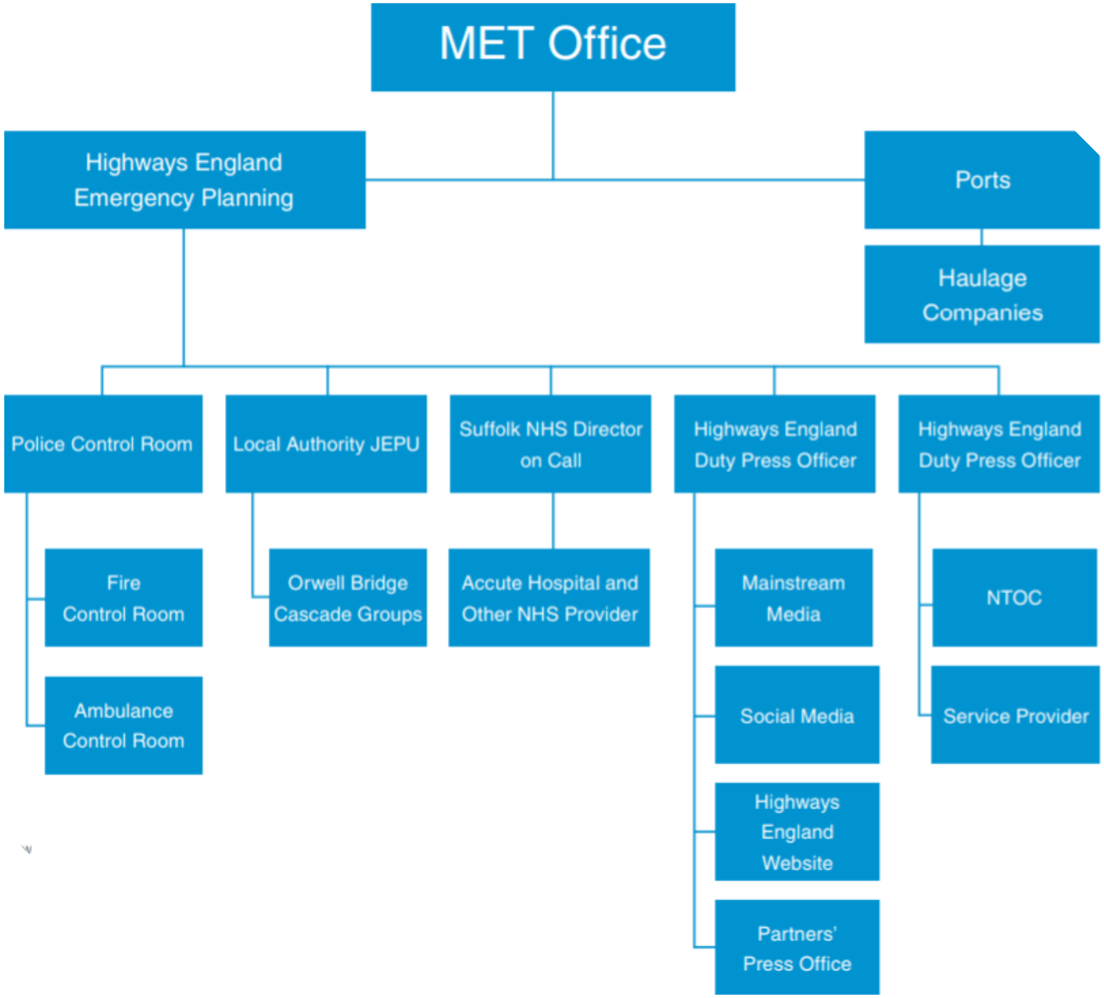
Communication Cascade Plan



Aerodynamics Study

- In October 2018, Highways England appointed City University of London to carry out an aerodynamics study of Orwell Bridge.
- The study applied the latest computerised technologies available with the objective of confirming that the current protocol is the safest option available and to also explore any relaxation opportunities.
- The study reviewed vehicle driving stability under high winds and the development of detailed bridge models for the assessment of traffic stability on Orwell Bridge.

Aerodynamics Study

City University of London outlined five key stages in delivering this study including:

- The development of the finite element (FE) (computer) model of the bridge.
- Definition of the Orwell Bridge environment, including the simulation of pavement irregularities and the wind velocity time-histories for the dynamic analysis.
- Definition of the aerodynamic forces on the bridge deck and on vehicles, two & three-dimensional (2D and 3D) computational fluid dynamic (CFD) analyses.
- Development of static vehicle models and assessment of the driving stability for different types of vehicles and wind incidence angles.
- Development of a dynamic model that captures complex interactions between the wind, the vehicles and the bridge to assess the driving stability.

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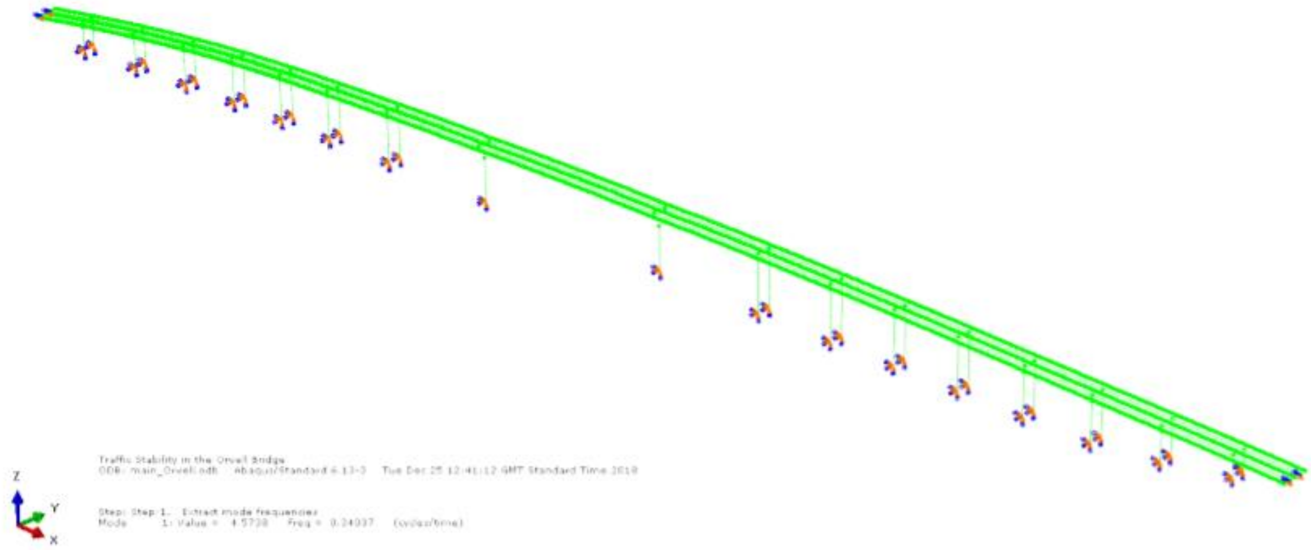
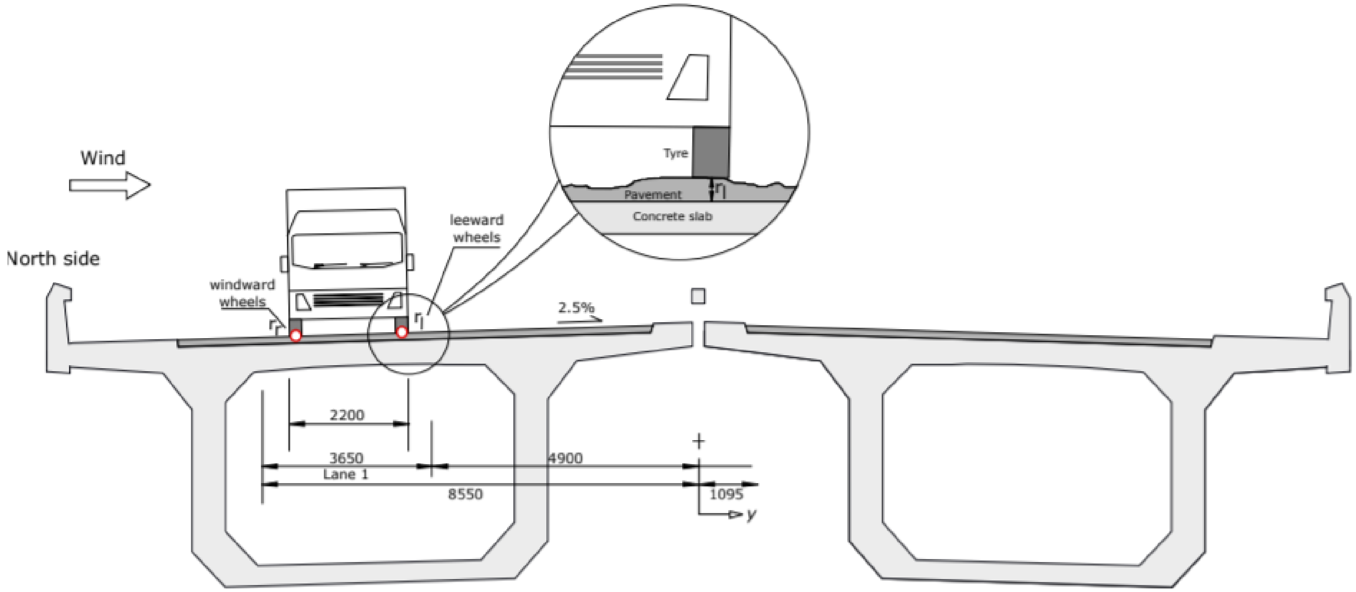
Stage 1

- A detailed computer model of the bridge was developed based on as-built drawings. The most critical location was to the cross-sections on the deck above the River Orwell, including its articulation with the piers.

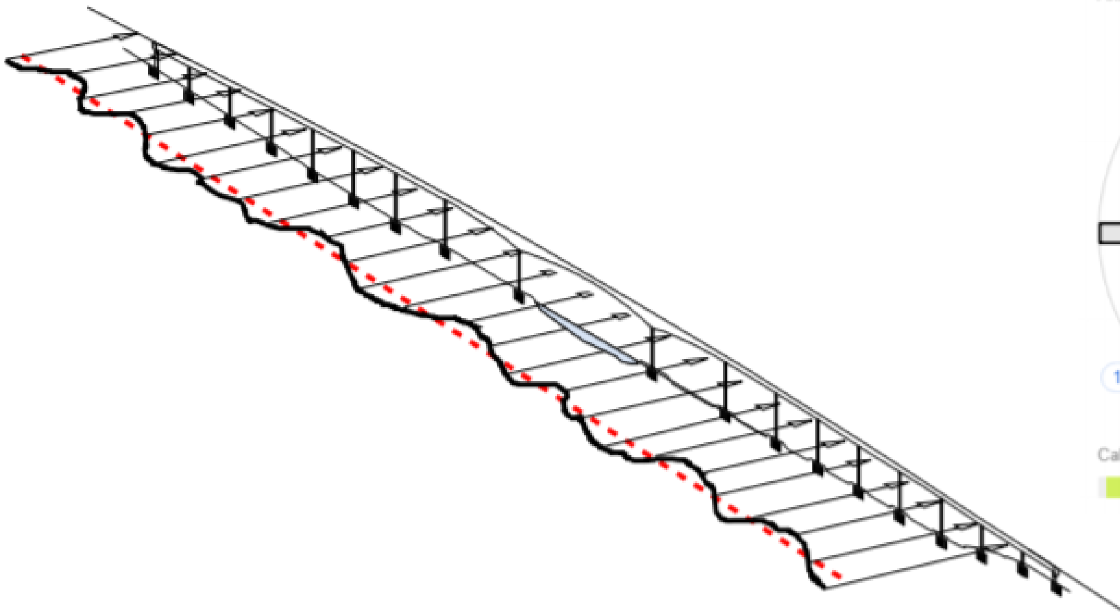


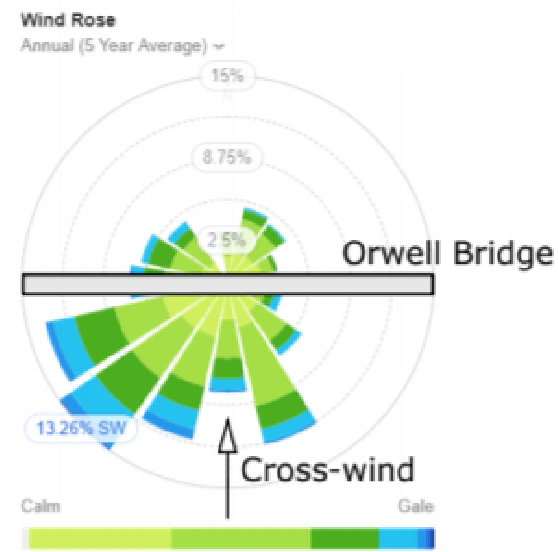
Stage 2

- Stage 2 captured the data for the carriageway condition, site specific wind speeds on the bridge and vehicles on the deck.



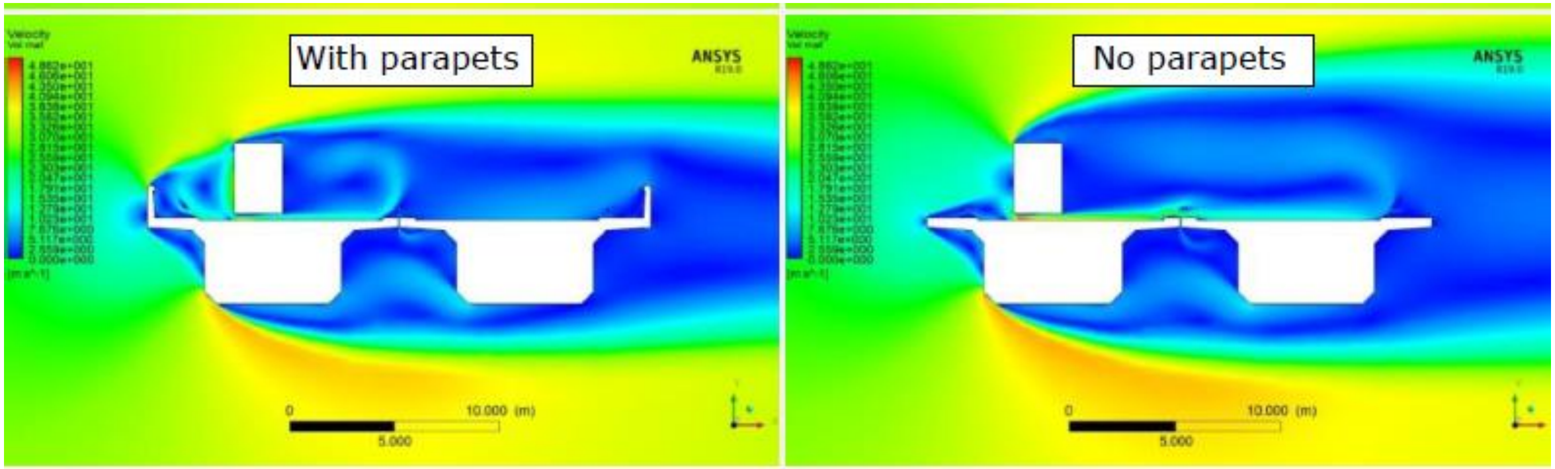
Stage 2




Wind Rose
Annual (5 Year Average)
15%
8.75%
2.5%
Orwell Bridge
13.26% SW
Cross-wind
Calm
Gale

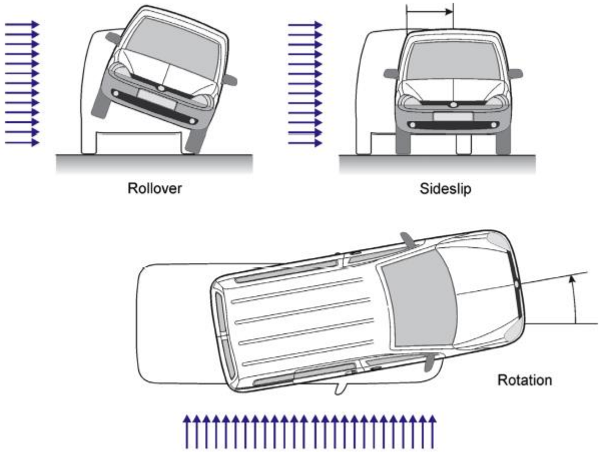
Stage 3

- Computational Fluid Dynamic (CFD) analysis was conducted to study the aerodynamic effects on the bridge deck.
- Two types of CFD analysis were carried out; two-dimensional (2D) and three-dimensional (3D).



Stage 4

- A preliminary assessment of the driving stability risk was conducted. The aim of the static analysis was to assess the accident risks for different types of vehicles and wind directions. The vehicles considered included a car, a bus, a large van, a truck and a tractor with a trailer.

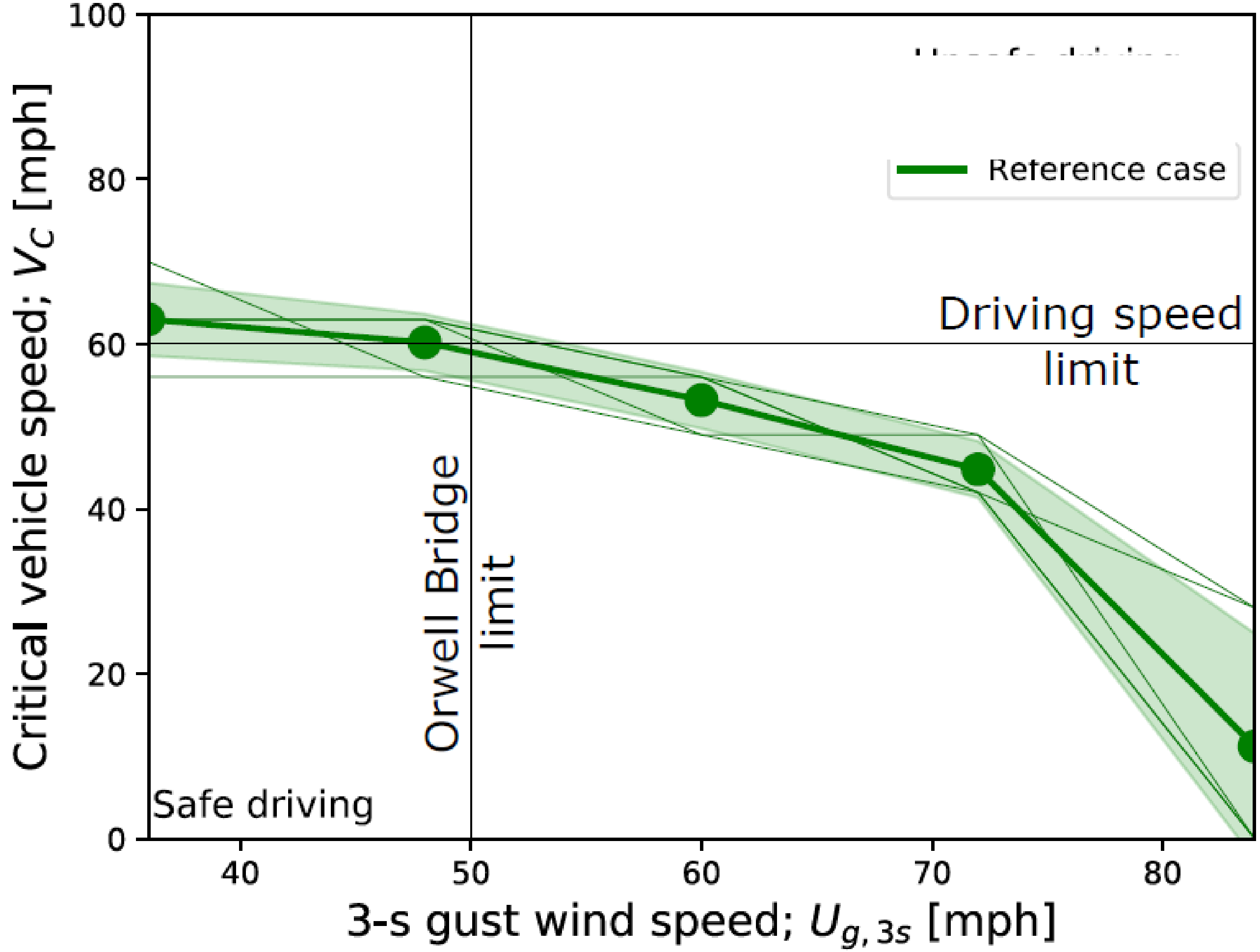


Stage 5

- The study was completed with a detailed analysis on the dynamic interaction between HGVs (critical vehicles), movement of the bridge, pavement irregularities and the turbulent wind.
- The model accounts for the variable sections of the deck, the randomness of the pavement and the wind histories.
- The wind is purely perpendicular to the deck in the dynamic analysis, but a factor of safety obtained in the static analysis is applied to account for wind directionality effects.
- Results for different cases are presented in the form of Critical Wind Curves (CWC), which give the critical vehicle speed above which vehicle accidents occur for each wind speed .

Stage 5 – Critical Wind Curve

- This is the reference critical wind curve obtained from the dynamic analysis. It is based on an unladen HGV and it ignores the possible shielding of the deck on the vehicles.



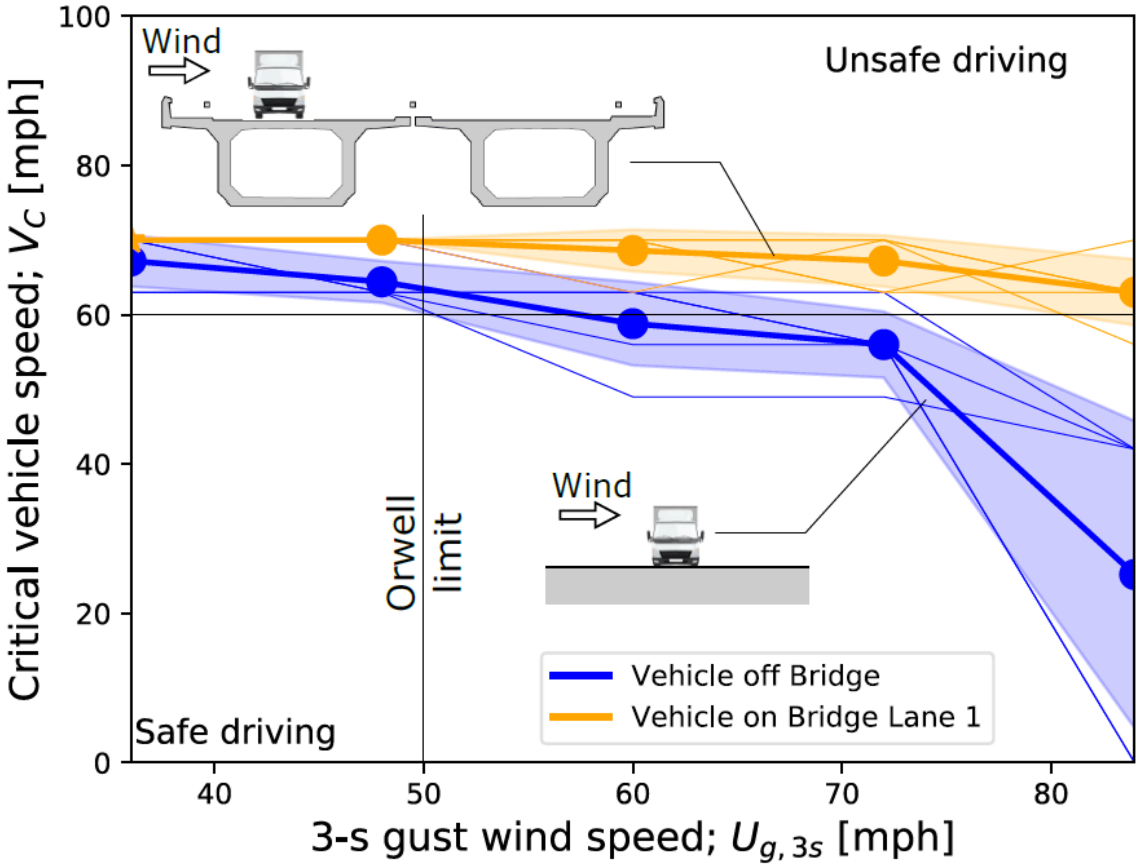
Study Findings

- The study found that high-sided unladen box vehicles are at the most risk travelling over the bridge in high wind conditions.
- The speed at which vehicles travel across the bridge had an effect on the results of the study. The difference between travelling at 40mph is considerably different at 60mph.
- From the initial findings the parapets seem to be the key focus element for future studies as they present the potential for increasing the wind speed closure threshold above 50mph.
- The results confirmed that traffic in lane 1 of the westbound carriageway is the most at risk in high wind conditions.

Results

- The results show that the current wind speed limit is adequate to protect traffic on the bridge driving at the maximum allowed speed.
- It has been observed that reducing speed or diverting high-sided vehicles could extend bridge operation on windy days.

- The results also indicate that the parapets at the edges of the deck may provide significant wind shielding to vehicles, and needs further experimental testing.



Next Steps

Based on the results obtained the following recommendations are made:

- Validate the numerical results with wind tunnel testing taking the parapets into account.
- Investigate the feasibility of running traffic in lane 2 in both directions during high winds.
- Carry out a review on implementing a reduced speed limit on the bridge under high winds (40mph)
- Review the feasibility of allowing the eastbound carriageway to stay open during high wind events.

Questions