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October 4, 2019

Re: Bridgewater Place Tower - On-Site Verification of Wind Microclimate Conditions

RWDI 1900495

PURPOSE

Wind effects play a key role in the comfort and safety of pedestrians in public spaces. Excessive wind conditions created by tall buildings could affect the usability of external areas, and in severe cases may pose a safety risk for pedestrians.

RWDI has been requested by Leeds City Council (LCC) to peer-review the wind studies that have been carried out to-date for Bridgewater Place (BWP) Tower. The most recent report prepared by the Buro Happold acting for BWP is attached at the end of this letter for reference.

This letter provides an overview of RWDI's peer-review and recommendations.

BACKGROUND

- BWP team originally carried out extensive wind tunnel tests to quantify the wind conditions and develop suitable mitigation options. This has been reviewed in the past, and the wind mitigation measures have since been built and implemented,
- There were also protocols for measuring the real on-site wind conditions prior to and subsequent to the construction of wind mitigation measures. This on-site monitoring assessed whether the Lawson safety criteria was exceeded in any critical areas, and identified two areas – one in the service yard of BWP and another on the south side – where the on-site measured conditions exceeded Lawson safety limits.
- Since then, BWP team carried out Computational Fluid Dynamic (CFD) simulations, to help identify further wind mitigation to resolve the safety condition to the south of the site. A large porous screen is proposed to the south of the site, as described in reports attached to this letter. For the safety exceedance in the service yard, a management approach is mentioned, although it is noted that no further details of this management protocol have been provided.



- During the latest CFD studies, an area on Back Row was identified as being marginally above the Lawson safety criteria. This area was not part of the on-site monitoring programme, so it is not yet clear of the conditions predicted by CFD are verified on-site

RWDI REVIEW AND RECOMMENDATIONS

We concur with the overall summary and conclusions of the report titled “BwP – Final Summary” by Buro Happold dated 3rd of October 2019 (rev04 Final). This includes the following key actions that will be taken;

- A porous screen (50% porous) will be installed to the south of Bridgewater Place Tower to improve the wind conditions at the edge of the road. This is expected to eliminate the safety risks at location 18.
 - o LCC should agree the timescales for implementation of this screen, and consider using temporary/interim safety measures (e.g. warning signs) before the screens are built to protect pedestrians.
- A management protocol will be used to eliminate the safety risks associated with the service yard, locations 22 and 88.
 - o No details of this management protocol have been presented to RDWI to-date. LCC should seek to verify the details of this management protocol, and a timeline for its implementation. Should the area be kept open for pedestrian access in the interim period, temporary measures as noted above may be used to reduce safety risks.
- At location 86 (Back Row) where CFD predictions indicate a safety concern, an on-site monitoring campaign will be carried out to verify the as-built wind conditions.
 - o LCC should seek to provide a temporary/interim safety measures as noted above until such time that the on-site monitoring is carried out, or until further wind mitigation measures are implemented if required.

Attachments:

- 1) Report titled “BWP – Final Summary” by Buro Happold, dated 3rd of October 2019 (rev04 Final).

BWP – FINAL SUMMARY

BUROHAPPOLD

ENGINEERING

03/10/2019 rev04 Final

CONTENTS

- Background
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- Position before Wind Mitigation Scheme
- Wind tunnel testing no Wind Mitigation Scheme
- On-Site Testing
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- Analysis
- Test Points Failures - Solutions
- Test Point 18 – Sample Screen
- Test Point 18 - Approximate location
- Traffic

BACKGROUND

- BuroHappold is appointed by CPPI Bridgewater Place as Structural, M&E and Wind Engineer in relation to the wind mitigation scheme constructed at Bridgewater Place (Wind mitigation Scheme).

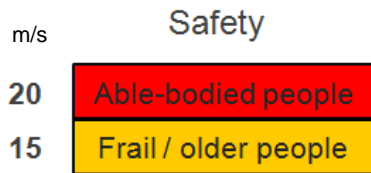
The Wind Engineer role included the following:

- Input into the design of the Wind Mitigation Scheme (having regard to all physical constraints at the property);
- CFD analysis;
- Co-ordinate wind testing for multiple iterations;
- On-site wind testing before the Wind Mitigation Scheme was constructed;
- On-site wind testing after the Wind Mitigation Scheme was constructed;
- Advice and testing of mitigation measures for failed test points.

PEDESTRIAN DESIGN CRITERIA



Use of Space	Lawson Comfort Criteria Classification	Beaufort Scale	Speed (m/s)	Maximum allowable occurrence
Uncomfortable for all uses	10	B5	10.95	2% (~7 days)
Road / Car Parks	9	B4	8.25	4% (~15 days)
	8	B4	8.25	2% (~7 days)
Business Walking	7	B3	5.6	6% (~22 days)
Pedestrian Walking	6	B3	5.6	3% (~11 days)
	5	B2	3.35	6% (~22 days)
Pedestrian Standing	4	B2	3.35	4% (~15 days)
Entrances / Sitting	3	B2	3.35	2% (~7 days)



Use of Space	Lawson Comfort Criteria Classification	Beaufort Scale	Speed (m/s)	Maximum allowable occurrence
Unsafe for able-bodied people	Unsafe	B8	20	0.025% (~2 hours)
Unsafe for frail / older people	Unsafe	B7	15	0.025% (~2 hours)

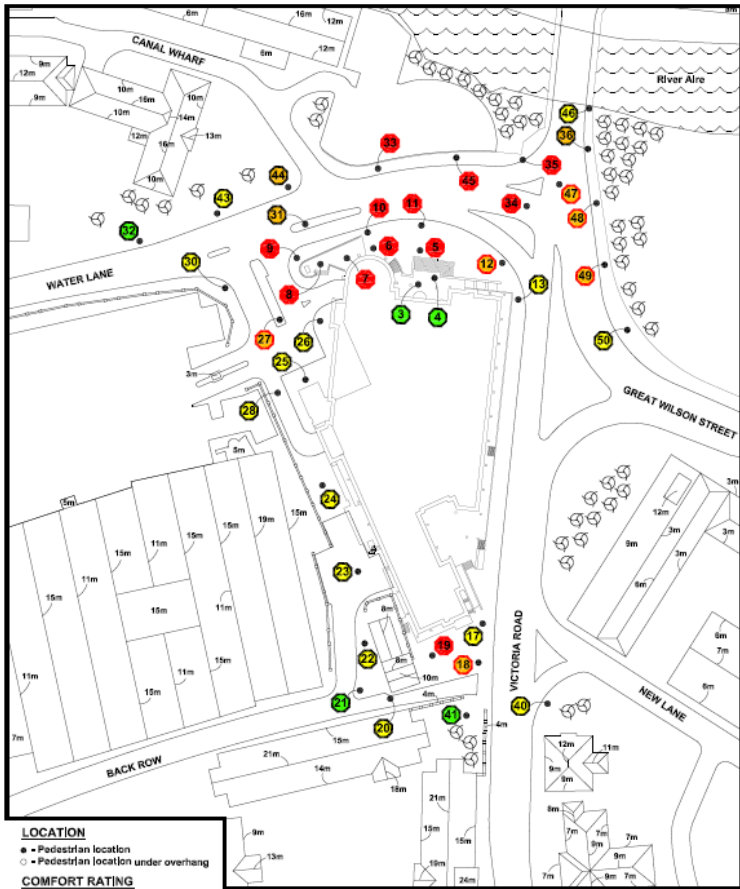
POSITION BEFORE WIND MITIGATION SCHEME

- The base position with no wind mitigation scheme was tested in the wind tunnel by CPP, a world leading wind test facility.
- [90] points were tested in the wind tunnel against the Lawson safety criteria.
- Lawson safety criteria = wind speed is more the threshold level for more than 2 hours per year.
- 15 m/s is used for the frail and elderly.
- The Lawson threshold used for the frail and elderly is a wind speed of 15 m/s and the wind speed for the able-bodied is 20 m/s.
- Of the [90] points that were tested in the wind tunnel, 35 failed the Lawson safety criteria at 15 m/s.
- The next slide shows all the points that were tested in the wind tunnel. There are 2 plans showing the original test points and additional test points.
- The Lawson failures are the points that have a red outline to them. Points with a black outline are a pass.
- The failures are concentrated at the front of the property but there are a small number of failure points to the rear.

PROJECT DEVELOPMENT

- The BuroHappold in conjunction with the rest of the design team worked up multiple different options for the wind scheme.
- 30 options were tested in the CCP wind tunnel test facility and 90 tested using CFD (computational Fluid Dynamics)
- The final scheme comprises 3 porous baffles over Water Lane and 5 porous screens and canopy attached to the building North and west elevations. A meshed door screen was also provide to the south of the building.

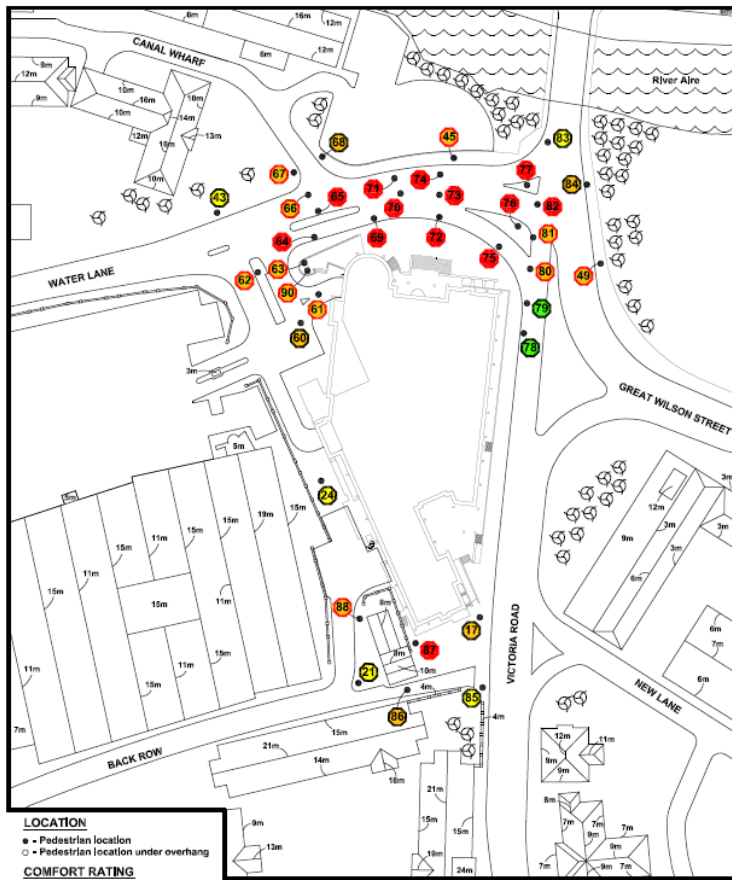
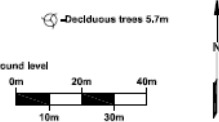
Wind tunnel test no mitigation scheme



- LOCATION**
- Pedestrian location
 - Pedestrian location under overhang
- COMFORT RATING**
- Pedestrian sitting
 - Pedestrian standing
 - Pedestrian walking
 - Business walking
 - Uncomfortable
- DISTRESS RATING**
- Pass
 - Fail

CONFIGURATION AC
Winter

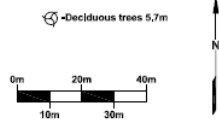
● Points 3-13, 17-28, 30-36, 40, 41, 43-50
 ○ Points 5-13, 17-28, 30-36, 40, 41, 43-50 located at ground level
 ○ Points 3, 4 located at north entrance



- LOCATION**
- Pedestrian location
 - Pedestrian location under overhang
- COMFORT RATING**
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CONFIGURATION AC
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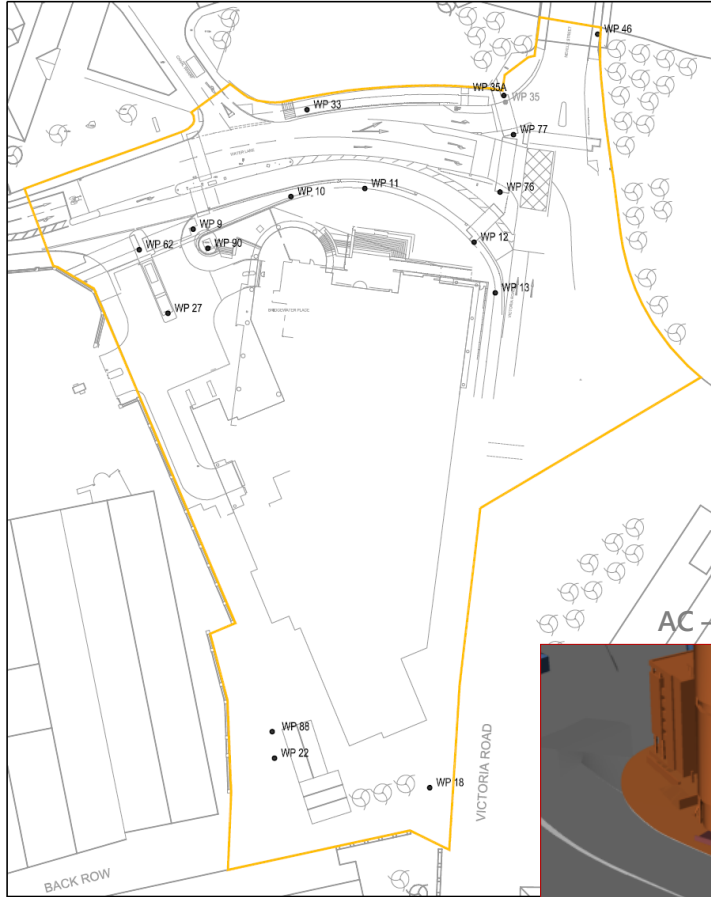
● Points 17, 21, 24, 43, 45, 49, 60-68, 80
 ○ All points located at ground level



ON-SITE TESTING

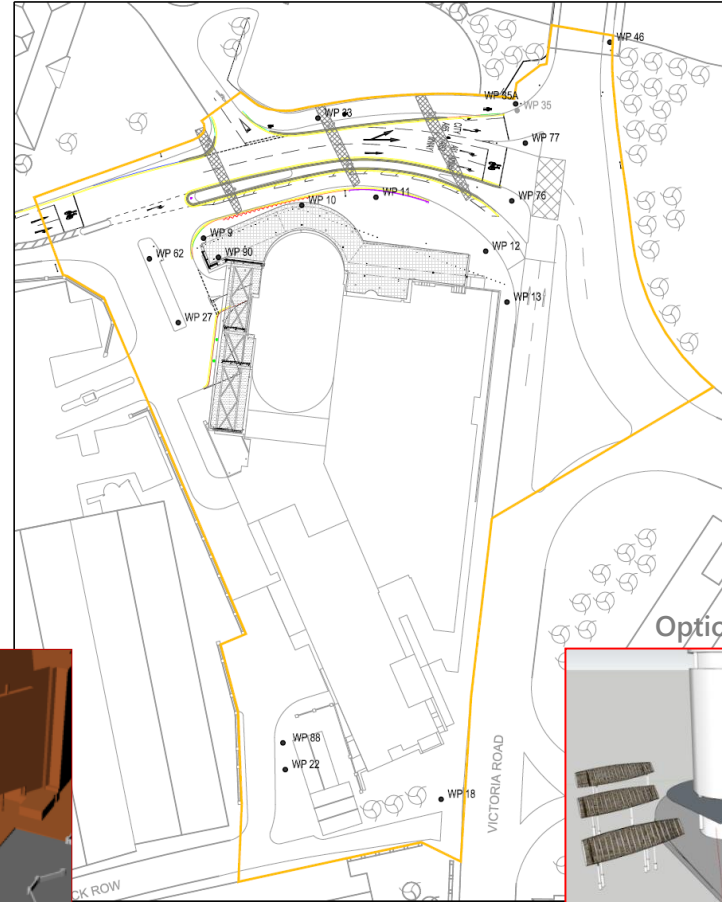
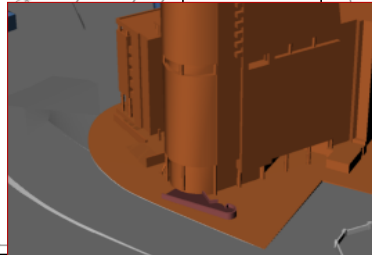
- Testing was carried out before and after the Wind Mitigation Scheme was constructed at 16 points, and in accordance with a protocol agreed with the Leeds Council wind advisor.
- The next slide shows the 16 test points (for the existing and new road layout). They were selected as the best representative points from the failure points identified in the wind tunnel and CFD results (noting that it was not possible to have test points in the middle of the road).
- The before and after wind speeds were measured when wind speeds at Leeds Bradford Airport were above an agreed threshold. The data was then collected for the airport, roof anemometer and ground level for further correlation of measurements in order to show the relative reduction in wind speeds at Bridgewater Place after the Wind Mitigation Scheme was constructed.
- The data was then sent to CSTB for analysis and a copy of their report is provided by CPPI.
- BuroHappold produced a summary of the CSTB analysis.

MONITORING POINTS



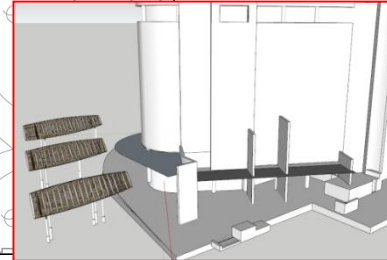
WIND MONITORING POINTS - EXISTING ROAD LAYOUT

AC - Existing



WIND MONITORING POINTS - PROPOSED ROAD LAYOUT

Option 6C - 3 baffles



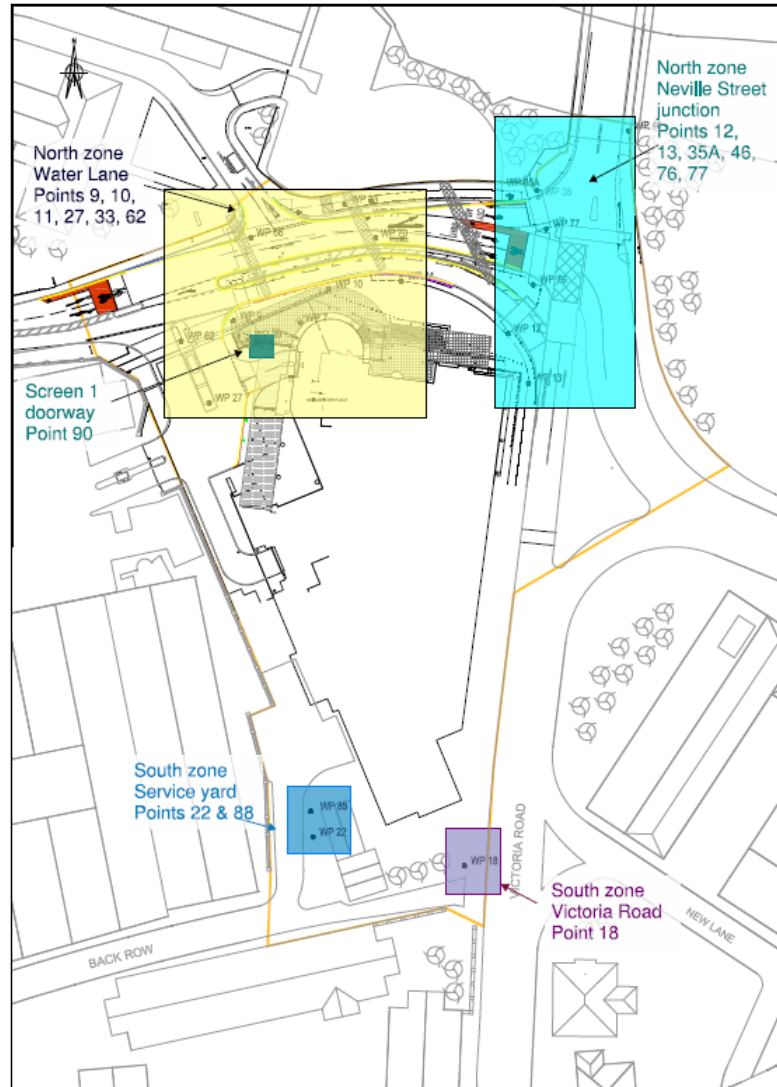
ON-SITE TESTING

BuroHappold grouped the monitor points into 4 zones (see next slide).

After the monitoring was completed, BuroHappold produced a summary analysis showing the number of hours of wind speed over the Lawson threshold of 15 m/s (GEM (Gust Equivalent Mean)).

- This shows that at the front of the building there are no Lawson failures at 15 m/s.
- This is a better position than that predicted by both the wind tunnel and the CFD analysis.
- There are 2 points which failed the Lawson safety criteria (at 15 m/s):
 - Wind point 88 – Service Yard;
 - Wind Point 18 – Courtyard at rear of Bridgewater Place.
- In addition, CFD analysis showed a possible marginal failure on Back Row by the Grove Inn. This point was not tested (but is being tested).

GROUPED POINTS



WIND MONITORING POINTS - PROPOSED ROAD LAYOUT

ON-SITE TESTING RESULTS

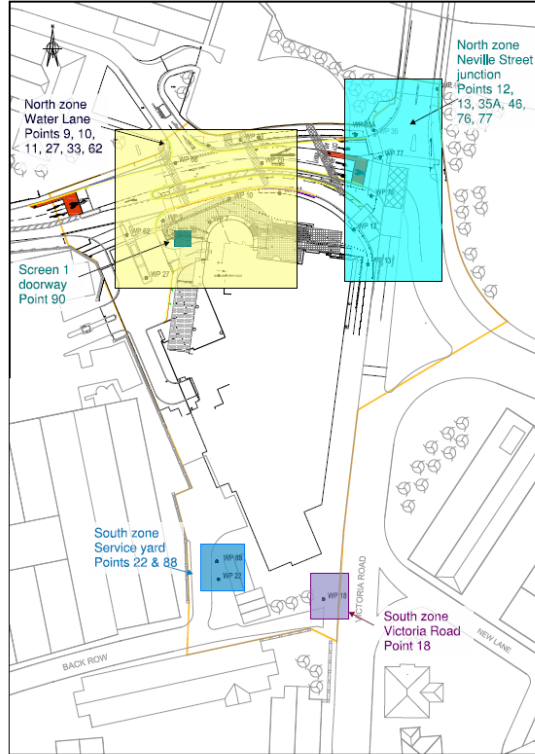
- We have reduced the wind speeds significantly along Neville street, below the pre mitigated BWP levels. The NE corner has lower wind speeds across the road.
- Along Water Lane we have reduced wind speeds significantly. The wind speeds are similar to those of the baseline, except at two locations under the baffles.
- We are experiencing wind acceleration at the south of the building that affects Victoria Road. Half the area across Victoria road is better than the baseline because the shelter provided by the building itself.
- We have a zone of wind acceleration at the south. The south zone "service yard" is a restricted area and traffic is not likely to travel fast here.

The next slides show the number of hours over both 15 m/s (Lawson safety for frail/elderly) and 20 m/s (Lawson safety for able-bodied) against the 2 hour threshold.

It also shows the wind test failure points at 15 m/s (none of the points failed at 20 m/s).

OVERVIEW

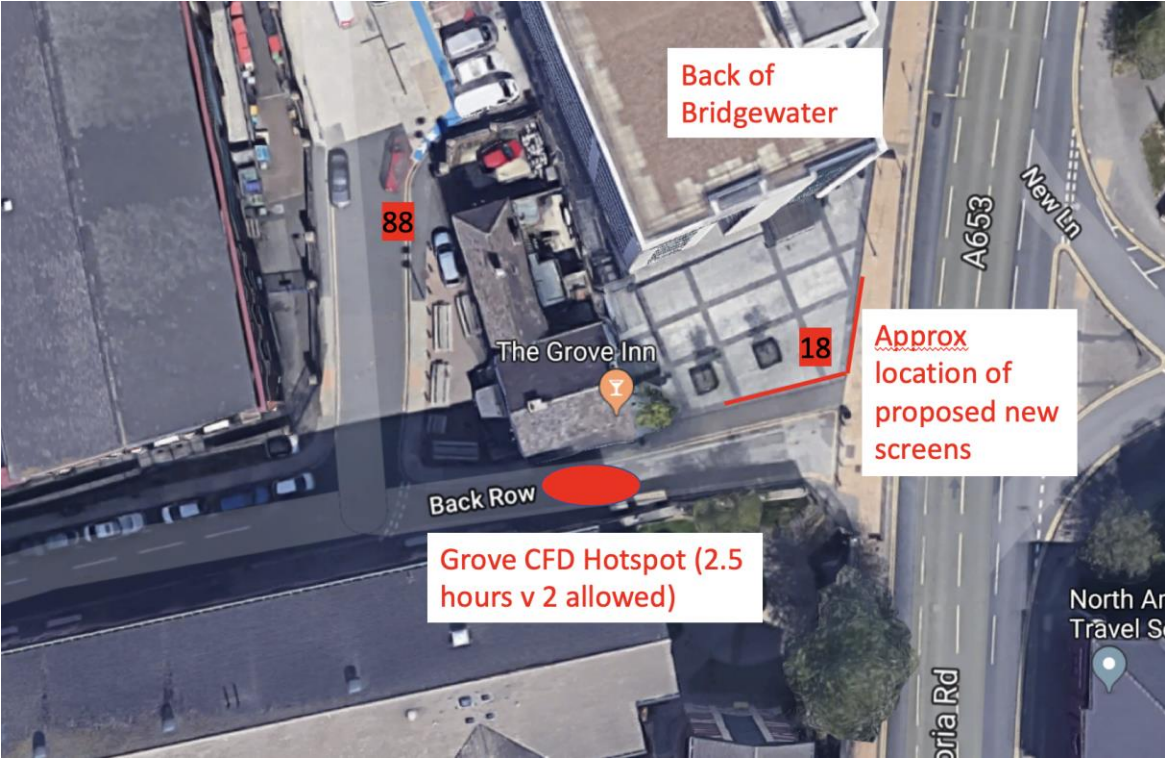
- Neville Road
- Water Lane
- Victoria Road



WIND MONITORING POINTS - PROPOSED ROAD LAYOUT

Zone	Point	MEASURED DATA		MEASURED DATA	
		AFTER (6C)		BEFORE (AC)	
		CSTB - App E		CSTB - App E	
		Annual		Annual	
		Pedestrians		Pedestrians	
		>15 m/s	>20m/s	>15 m/s	>20m/s
		h/y	h/y	h/y	h/y
NORTH - Water Lane	9	0	0		0
	10	0	0		0
	11	0	0		0
	27	0	0		0
	33	0	0		0
	62	0	0		0
	Summary	0	0	9	0
NORTH - Neville Street Junction	12	0	0		0
	13	0	0		0
	35A	0	0		0
	46	0	0		0
	76	0	0		0
	77	0	0		0
	Summary	0	0	9	0
SOUTH - Service yard	22	0	0		
	88	6	0	1	
SOUTH - Victoria Rd	18	5	0	0	
Screen 1 Doorway	90	1	0	~73	
Summary worst case		6	0	19	0

TEST POINT FAILURES (AT 15 M/S)



TEST POINT FAILURE – SOLUTIONS

Potential measures to deal with the 2 wind test point failures were discussed, as well as the predicted marginal failure at Back Row based on CFD analysis.

Wind test point 88

- We understand that this is being dealt with by way of a management protocol and so no physical measures are required.

Wind test point 18

- We have used CFD analysis to model the improvement to this area using 50% porous screens, and this shows a good improvement which we would expect (subject to detailed design work) to resolve the failure.
- The next slides show the images of the screens and their locations.

POINT 18 APPROXIMATE LOCATION OF SCREEN



WIND TEST POINT – SAMPLE SCREEN



TEST POINT FAILURE – SOLUTIONS

Back Row

- Based on CFD analysis, this is a marginal possible failure as the wind speed over 15 m/s is for 2.5 hours per year (i.e. 0.5 hours over the threshold).
- This area will be tested using the same methodology as the other 16 wind test points measured. This will corroborate if there is a Lawson safety failure.
- Based on the CFD analysis, screens would be required to be installed at Back Row to deal with the marginal failure.

TRAFFIC – WATER LANE, VICTORIA ROAD, NEVILLE ROAD

See attached letter with our considerations and overall recommendation a summary is found below:

- Based on the Lawson Safety Criteria, the wind mitigation measures have been assessed by wind tunnel, CFD and onsite measurement.
- The results indicate that there are no locations that exceed the criteria of 15m/s mean wind speed. Based on the [Lawson Safety Criteria], this is the limit above which the wind presents a safety risk, especially to more vulnerable members of the public and cyclists.
- In the absence of accredited principle for wind speed for vehicles, assumptions have been made on the basis that those appropriate for cyclists are also appropriate for vehicles.
- As this meets the requirements required for any planning application in the city, we are satisfied that on the basis of the Lawson Safety Criteria, which is accepted for the purpose of this exercise by Leeds City Council Planning Department to be a suitable criteria, the risk to pedestrians, cyclists and therefore vehicles is sufficiently reduced to allow the traffic restrictions to be lifted.
- It must be recognised that there is a residual risk, like anywhere in the city that is based on the same Lawson Criteria, where a combination of scenarios could coincide and result in a safety risk and an accident, and we cannot warrant that this will not occur.
- We would recommend that Leeds City Council approve the mitigation measures and the recommendations of this report.

B U R O H A P P O L D

E N G I N E E R I N G

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