Temporary Road Signage – Stability by the Road Side

Anandanarayanan Nanda Kumar

Andrew Guzzomi
Department of Mechanical Engineering
The University of Western Australia

Peter Ellis, Richard Amoh-Gyimah and Brendon Wiseman
CEED Client: Main Roads Western Australia

Abstract

Temporary road signage is used throughout road networks to regulate traffic and give warnings to road users. Wind and other factors induce frequent collapse of road signage and this has become a community concern that needs to be addressed. Baseline studies have been conducted by the client to understand the cause of failure of signage and propose ways to stabilise them. This project aimed to gain an understanding of sign stability in the presence of passing road trains and investigate the possibility of stabilising temporary road signage through appropriate design modifications. Simulations and experimental trials were carried out to assess stability. This analysis used ANSYS Fluent for fluid dynamics simulation to determine failure points, and the experimental trials followed Main Roads' experimental methodology. The findings from the simulation showed that the current design is unstable and highly prone to wind induced failure. Simulations suggested that the passage of road train moving with a speed of 100 km/h could induce a velocity of 8.6 m/s on the sign, which is greater than the maximum permissible velocity sustainable for a sign which is assumed to be rigid. The signage is likely to be more unstable when mobility is included and hence even more prone to collapse.

1. Introduction

Road users often experience construction or maintainance works along their routes while commuting. The commuters are warned about the works with the help of temporary road signage. This signage advises the users of any hazards due to change in the road environment and direct and regulate traffic flow. Although temporary road signage is an efficient way of warning road users, its inability to remain stable against the wind induced loading and vehicle induced loading has been a major issue and poses serious risks to the commuters and site workers. Hence it is vital to stabilise the signage to let it serve its function without compromising safety. The client's need to stabilise the road signage that falls on wind loads was emphasised after a fatal accident in regional Western Australia in which some of the signage on approach to the worksite had fallen. To ensure fallen signs do not present a hazard to road users the sign legs are designed to swivel within the frame so that it flattens out. This has motivated the client to think of different ways to stabilise the signage.

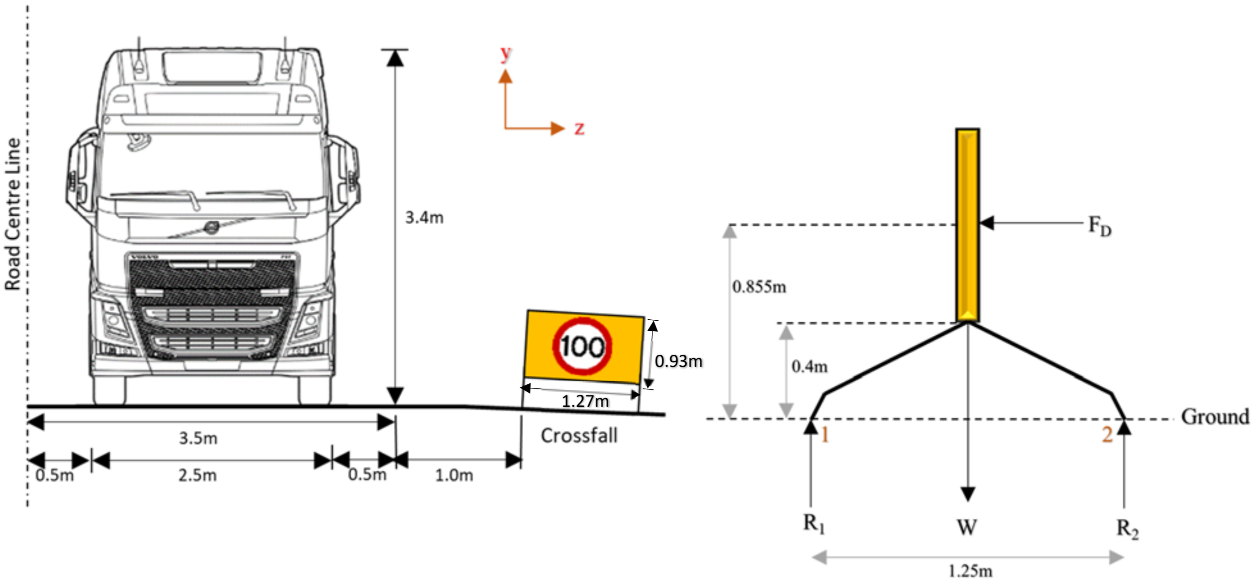
It was evident from the previous study (Main Roads Western Australia, 2020) that the movement of heavy trucks and road trains are the main reason that induce the sign to collapse. The project started by analysing the results of field trials (Main Roads Western Australia, 2020) conducted by the client in Great Northern Highway, near Bindoon township which is located in the Wheatbelt region. The field trials used a simple observational technique to analyse when the road signs fell over and were undertaken with different signboards, legs and stabilisers to understand their stability against the wind gusts from heavy haulage vehicles. These previous trials by Main Roads WA only considered the weight of the signboard as an essential parameter to understand the stability of temporary road signs. In addition to the weight of the signboard, the surface area, centre of pressure, wind loading and aerodynamics are considered in this current study.

Figure 1 Sandbags and how they are used (Main Roads Western Australia, 2020)

The primary objective of the current study is to identify the factors and their effects on the stability of road signage. The secondary objective is to identify if a more stable mechanism with minimal design changes is possible.

2. Materials and Methods

Roads in Australia have a slight crossfall to avoid flooding. The geometry of rural roads and the proportions of a typical road train in Western Australia is depicted in Figure 2(a). Also depicted is the typical location and size of temporary road sign.



(a) (b)

Figure 2 (a) Road geometry (b) Side View of road sign

2.1 Analytical Method

The stability of road sign is analysed using the free body diagram shown in Figure 2(b). The analysis is performed by assuming the road sign as a rigid body on a horizontal road surface. In addition, it is assumed that a uniform wind velocity at standard atmospheric conditions acts on the sign. Equation 1 expresses the drag force on the sign against blowing wind.

$$F_D = \frac{1}{2}\rho A C_d V^2 \tag{1}$$

Item Name	Number	Mass of each product (kg)
Multi-Message Sign	1	4.8
Bi-Pod Round Leg	2	3.4
Sandbag	4	15

Table 1 Item specifications

From Figure 2(b), it can be seen that the combined reaction forces from the front and rear legs are balanced by the weight. This yields equation 2.

$$2 \times (R_1 + R_2) = W \tag{2}$$

The moment on rear points on the legs equates to ;

$$\sum M_1 = 0$$

$$(2R_2 \times 1.25) - (W \times 0.625) + (F_D \times 0.855) = 0 \tag{3}$$

The condition of instability of road sign is given by;

$$R_2 = 0 \tag{4}$$

Equations 2, 3 and 4 are used to find the drag force (F_D), which in turn gives the maximum wind velocity for which the sign can remain stable.

2.2 Computational Fluid Modelling

In this project, the relevant parameters such as drag coefficient, vehicle and wind induced velocities and flow field around the road sign and a passing road train are analysed using ANSYS *Fluent.* The road sign and road train were separately simulated and their interaction is inferred from individual models due to the limitation of *Fluent* to build a coupled model. The velocity in the vicinity of road sign is calculated as the difference between input velocity and vehicle induced velocity. It is to be noted that the road sign CFD is complemented with force analysis of Section 2.1 to achieve the drag coefficient (C_d).

2.2.1 Road Sign

Inorder to analyse the stability of road sign, CFD is performed in a closed domain with a blockage ratio less than 3%. This value of blockage ratio leaves no error in the determined magnitude of drag coefficient (Altinisik, Kutukceken, & Umur, 2015). The signboard is simulated in the software without legs. This is done as the legs contribute negligible drag, however, warrant a much finer mesh. The boundary conditions of the domain include velocity inlet, pressure outlet, walls, ground and symmetry. Within the domain, the road sign is placed closed to the inlet boundary. A perpendicular uniform wind velocity of 10 m/s was supplied at the inlet of the computational domain to determine the drag coefficient and drag force. This value corresponds to the maximum wind velocity in Wheatbelt region measured at a height of 10 m (Online, World Weather, 2021).

2.2.2 Road Train

The purpose of road train simulation is to identify the magnitude and effect of wind induced from the road train along the sign. A 60 m heavy haulage truck, which resembles a real road train is designed in Solidworks, ignoring certain geometric features which likely have negligible influence on road sign stability. ANSYS *Fluent* was used to investigate the wind generated. To simplify the simulation, the road train is assumed stationary and walls are made to move with a velocity similar to the inlet velocity. A uniform inlet velocity of 100 km/h was used. The ground wall is considered rough to account for the roughness of the testing site and certain assumptions such as non-rotating tyres and zero yaw angle are made to optimise computation.

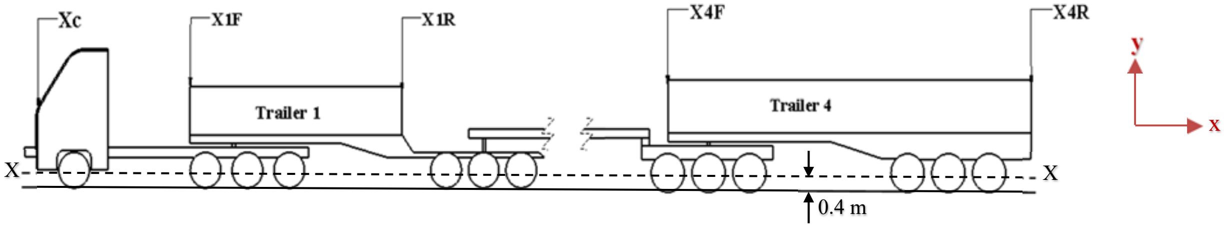


Figure 3 Side view of road train

Figure 3 shows trailers in a road train. X_c is the section at the cabin and the sections of the trailer at the beginning and rear are denoted by XnF and XnR, where n is the number of trailer from the prime mover. These regions were selected as these changes in geometry in relation to the road sign in reality may coincide with fluctuations in wind velocity.

3. Results

3.1 Analytical Method and CFD Modelling – Road Sign

By identifying the maximum safe force acting on the road sign, it is possible to estimate maximum velocity at which the road sign remains stable.The result obtained by complementing CFD with force analysis is presented in Table 2. As can be seen, the drag coefficient of the signboard is found to be 1.38, which is slightly higher than theoretical drag coefficient of 1.28 (National Aeronautics and Space Administration, 2021) for a 3D flat plate. This magnitude change is likely due to the clearance between the ground and bottom of signboard and resulting axisymmetric flow field.

Item Name	Actual Cd	Max. Force (N)	Max. Velocity (m/s)
Road Sign w/o sandbags	1.38	58.7	**7.5** (27 km/hr)
Road Sign with sandbags	1.38	488.0	**22.0** (79 km/hr)

Table 2 Data obtained from CFD Modelling with estimated C_d

3.2 CFD Modelling – Road Train

On simulation, velocity streamlines which gives the magnitude of velocity around the road train were obtained. Figure 4 depicts the results along plane XX (in Figure 3) which is 0.4 m above ground level. The maximum velocity recorded in the XX plane is 43 m/s, close to the cabin. It is to be noted that, the results presented is only the 'x' component of induced velocity from a passing road train which acts on the sign.

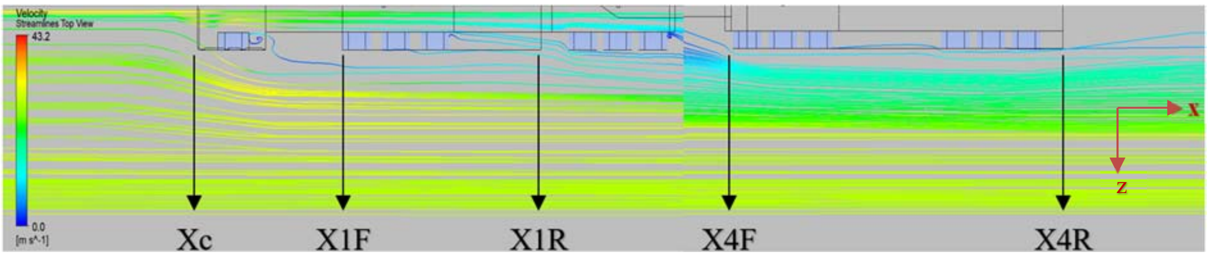


Figure 4 Velocity magnitude around the road train in the top plane

Though the wind velocity induced by the road train appeared to be in the direction opposite to the road train motion initially, its direction tends to reverse after the passage of the first trailer of the road train. Eventually, the velocity reaches its maximum value to tip the sign to the ground when the rear of the second trailer was in line with the road sign. Asymmetrical wind loading on the sign panel may cause failure earlier than expected as the current road sign leg mobility cannot transmit moment in the XY plane. The effect of passing road train on sign stability at different positions along the road train is shown in Figure 5. The values uncircled represents vehicle induced velocities against the movement of road train while circled represents velocities in the direction of road train motion.

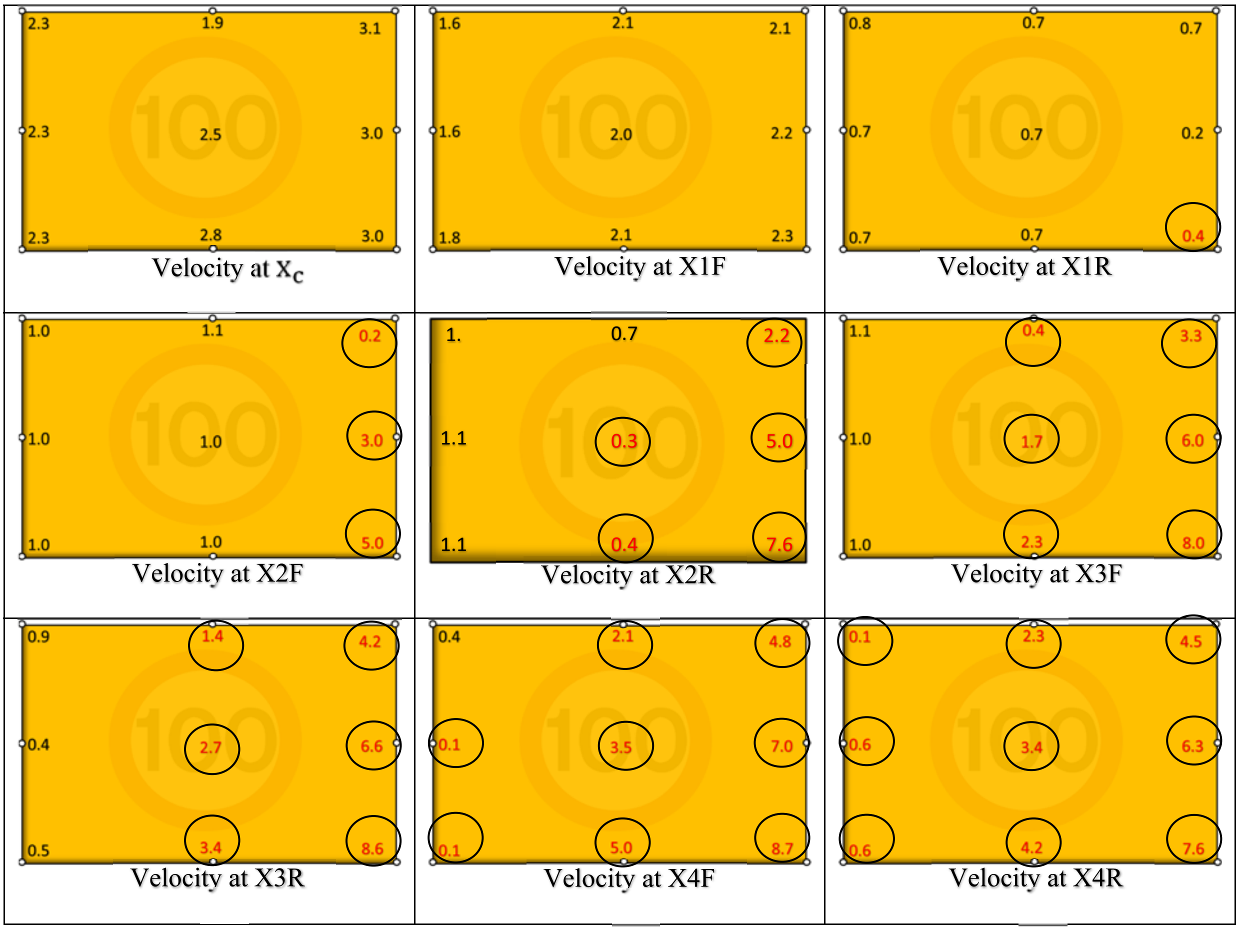


Figure 5 Representation of vehicle induced velocity at different points on sign

4. Conclusions and Future Work

The rigid road sign remains stable until an induced velocity of 7.5 m/s acts on it due to the combined wind induced and passing vehicle induced loading. A non-rigid sign is likely to collapse at lower velocities and is expected to be more unstable. Future work will concentrate on experimental analysis using onsite testings to provide further insight into sign stability and, in particular, the effect of leg mobility.

5. Acknowledgements

I would like to thank my mentors Peter Ellis, Richard Amoh-Gyimah and Brendon Wiseman for their unconditional support and for giving me an opportunity to undertake this project. A special thanks to Prof. Jeremy Leggoe for his advice and support. Last but not the least, I sincerely thank my family and friends for keeping me motivated and confident.

6. References

Altinisik, A., Kutukceken, E., & Umur, H. (2015). Experimental and Numerical Aerodynamic Analysis of a passenger car: Influence on the Blockage Ratio and drag coefficient. *Journal of Fluids Engineering*,137(8): 081104.

Main Roads Western Australia. (2020). *An Evaluation of the stability of Temporary Road Signs.* Main Roads Western Australia.

Main Roads Western Australia. (2021). *Heavy Vehicles Permit Order Scheme*. Retrieved from mainroads.wa.gov.au: https://aus01.safelinks.protection.outlook.com/?url=https%3A%2F%2Fwww.mainroads.wa.gov.au%2Fheavy-vehicles%2Fpermit-order-scheme%2Fget-a-permit-order-scheme%2Forders2%2F&data=04%7C01%7C22901001%40student.uwa.edu.au%7Cfdcb5c766192431f055308d8b926a858%7C058

National Aeronautics and Space Administration. (2021, May 13). *Shape effects on drag.* Retrieved from Shape effects on drag: https://www.grc.nasa.gov/www/k-12/airplane/shaped.html

Online, World Weather. (2021). *Pilbara Weather Average*. Retrieved from https://www.worldweatheronline.com/pilbara-weather-averages/western-australia/au.aspx

Volvo. (2021). *Volvo Trucks.* Retrieved from Volvo Trucks Specifications.