Temporary Road Signage-Stability by the road-side

Voon Bu Yan

Andrew Guzzomi
Mechanical Engineering
The University of Western Australia

Edward Rose & Madge Castle
CEED Client: Main Roads Western Australia

Abstract

This project investigates the stability of temporary road signage. This project shall provide experimental data regarding the instablity of bi-pod leg designs and consider alternate solutions to increase stability. Rotation of bi-pods legs is the principal cause of instability of road signages, with the attachment of welded washers being a current approach to lock the legs and limit rotation. The welded washer approach has been proposed by previous investigations, but has not yet been properly analysed and evaluated in the field. Alternative locking devices are also being considered in this investigation, and have been found to tyield similar results to the welded washer approach. Further research is needed into material choices for such locking devices – aluminium is currently being used but may not be the cheapest possible choice.

1. Introduction

Temporary Road signage with bi-pod legs have been found to fall in the field due to instablity induced by natural and vehicle induced wind loading- indeed previous research has determined that fallen road signage is often attributable to wind generated from passing road trains (Main Roads Western Australia, 2019). This project aims to analyse the instability of road signages under wind loading and explores potential solutions to increase the stability of current road signage designs. According to Kumar et al (2023), instability arises due to the angular rotation of bi-pod legs, and stability will be improved if the legs are restarined to make the signage behave as a rigid body. The installation of welded washers on bi-pod legs has been proposed to limit the angular rotation of the legs. This project will further examine the performance of the welded washer approach, and evaluate alternative designs (which do not require substantial changes to current road signage configurations). Increasing the stability of current road signage could contribute to reducing road accidents.

Welded washers are ne way of “locking” the legs to limit rotation. This project ontroduces two alternatve “locker” designs that would be placed directly on the legs, eliminating the need for welding and the associated labour costs. These lockers are being designed using NX software and manufactured with a 3-D printer with an ABS plastic filament. For the purpose of field experrimentation, prototypes will be fabricated from aluminium or steel instead of ABS plastic filament, to minimise the risk of material failure under loading.

2. Analysis and Experimental Process

The drag force F_p acting on the surfaces of temporary road signage due to the action of wind cis given by:

$$F_D = \frac{1}{2}\rho v^2 C_D A \quad (1)$$

Where ρ is density of fluid , v is velocity, C_D is drag coefficient and A is the frontal area of road signage (in the plane perpendicular to the incident wind).

The equation for stability of temporary road signage can be generate by drawing a free body diagrams:

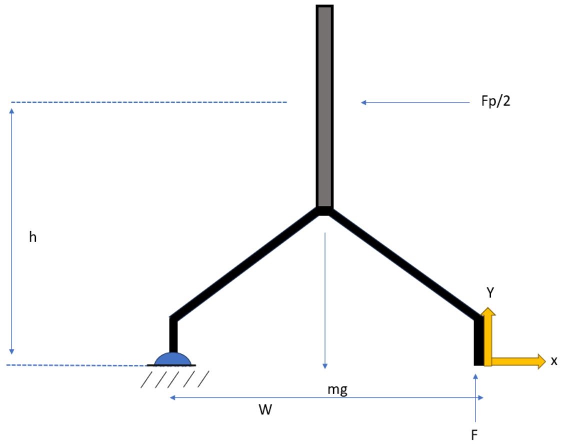

Figure 1 Free body diagram of road signage under wind loading – side view

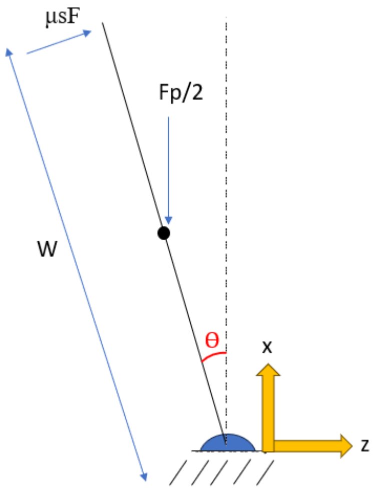

Figure 2 Free body diagram of road signage leg under wind loading – top view

From figure 1, the moment sum parallel to the xy plane about the fixed constraint at equilibrium gives

$$FW + \frac{F_P h}{2} - \frac{mgW}{2} = 0 \quad (2)$$

From figure 2, the sum of the forces in the x direction is:

$$\frac{F_P W}{4} sin\theta - \mu_s FW cos\theta = 0 \tag{3}$$

Assuming sin θ ~ θ for small angles, equation (2) can be rewritten as

$$\frac{F_P W}{4}\theta = \mu_s WF \tag{4}$$

Substituting equation (2) into equation (4) yields

$$\frac{F_P W}{4}\theta = \mu_s W(\frac{mgW - F_P h}{2W}) \tag{5}$$

And rearranging

$$(w\theta + 2\mu_s h)F_p = 2\mu_s mgW \tag{6}$$

Substituting the drag force equation (equation (1)) into equation (6) and rearranging yields an equation for the wind velocity required to cause the sign to fall:

$$v = \sqrt{\frac{4\mu_s mgW}{(w\theta + 2\mu_s h)(C_D \rho A)}} \tag{7}$$

From equation (7), the angle of leg rotation θ directly affects the wind velocity required to cause the road signage to fall, with the required wind velocity decreasing with increasing angle of rotation. The intent of the welded washer and locker approaches is to increase the wind load required to cuase instability by limiting leg rotation.

2.1 Field Experiments with the Welded Washer and Locker approaches

The welded washer approach is being tested in the field with three parameters being varied:

- The outside diameter of the washer
- The separation of the washers
- The installation angle of the washer

A typical welded washer configuration is shown in figure 3.

A “male” locker which limits rotation from the inside the road signage frame, while a “Female” fitting is also under consideration that fits outside the road signage frame. The mechanism of falls in road signages is shown in Figure 4 by observing the bi-pod legs responses to induce wind load.

Figure 3 The welded washer approach installed in the field

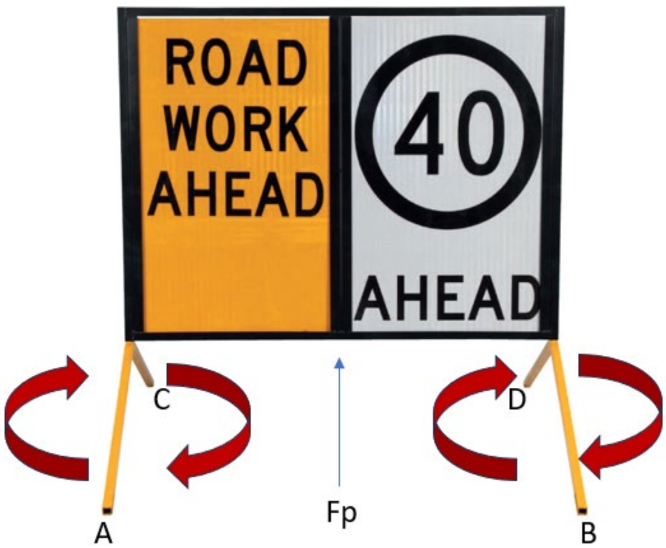

Figure 4 Bi-pod legs fall mechanisim due to wind load

3. Results and Discussion

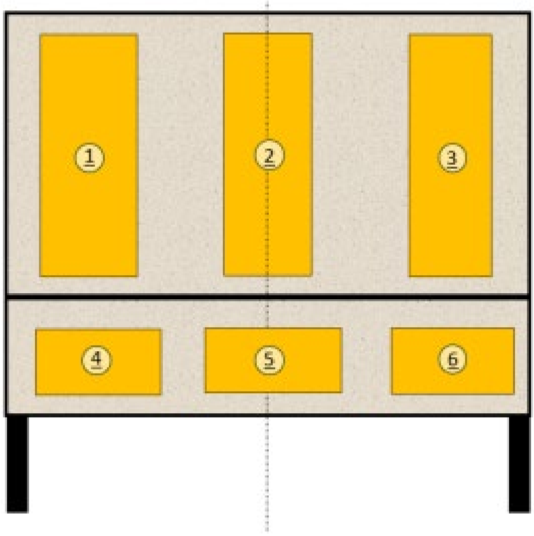

Figure 5 Load application regions

This project used a digital force gauge to apply load to 6 different regions on the road sign surface (as illustrated in figure 5) to find the worst case for road signage instability. This expriment was repeated with different road surfaces; Asphalt, Gravel and Cement.

	Washer approaches				
	Initial (N)	Fall mechanism	Modified (N)	Fall mechanism	%Diff
1	63	Yes, Rotational	71	Yes, exceed threshold	12.69%
2	72	Yes, Rotational	82	Yes, exceed threshold	13.89%
3	68	Yes, Rotational	75	Yes, exceed threshold	10.29%
4	104	Yes, Rotational	126	No, position shifted	21.15%
5	113	Yes, Rotational	114	No, position shifted	0.88%
6	90	Yes, Rotational	125	No, position shifted	38.89%

Table 1 Uniform load experiment for Asphalt road surfaces "Washer"

	Female Locker approaches				
	Initial (N)	Fall mechanism	Modified (N)	Fall mechanism	%Diff
1	63	Yes, Rotational	73	Yes, exceed threshold	15.87%
2	72	Yes, Rotational	84	Yes, exceed threshold	16.67%
3	68	Yes, Rotational	70	Yes, exceed threshold	2.94%
4	104	Yes, Rotational	137	No, position shifted	31.73%
5	113	Yes, Rotational	117	No, position shifted	3.53%
6	90	Yes, Rotational	128	No, position shifted	42.22%

Table 2 Uniform load experiment for Asphalt road surfaces "Locker"

To date, experiments have been completed for Asphalt surfaces. Both the welded washer and female locker approaches increased the force required to cause the road signage to fall. Surfaces 1 and 3 are furthest away from the connection between the sign body and the bi-pod legs, and as expected they sustain the lowest forces at the onset of instability.

4. Conclusions and Future Work

Both the welded washer and locker approaches have been found to increase the stability of temproary road signages by limiting the angular rotation of bi-pod legs. Experiments are ongoing, with further field and wind tunnel tests to be completed. Future work will include considering the material section for the lockers, as more ecnomical options than aluminium may prove suitable.

5. Acknowledgements

My deepest thanks to many who involved in this project.These included my supervisor, Prof. Andrew Guzzomi, who gave me irreplaceable guidance and advice. I would also like to thank my mentors, Edward Rose & Madge Castle and other Main Roads staff who have provided support throughout the project. I would like to extend my thanks to Dr. Jeremy Leggoe and Kimberlie Hancock for organizing the CEED program, giving me this opportunity gain professional experience.

6. References

Kumar, A. N., Guzzomi, A.L., Amoh-Gyimah ,R, Ellis, P Wiseman, B.(2023). Understanding and Improving Temporary Road Sign Stability. Journal of Road Safety, 34(1). https://doi.org/10.33492/JRS-D-22-00037

Main Roads Western Australia. (2019). *An Evaluation of the Stability of Temporary Road Signs*. Main Roads Western Australia.