Wind Load on Conveyor Galleries

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Abstract

Wind loading is a critical consideration in structural design, influencing the safety, functionality and durability of buildings and infrastructure. Assessing wind loads on industrial structures such as conveyor gallery is challenging due to their complex, elongated structures, susceptibility to aerodynamic interference from nearby elements, and the need to consider dynamic effects, making accurate wind load calculation difficult. This article discusses the cause of variation in the drag coefficient and the impact of some multipliers from AS/NZ 1170.2:201.

Keywords: conveyor galleries, AS1170, drag coefficient, CFD

1. Introduction

Understanding the wind loads acting on industrial structures, such as conveyor galleries, is critically important to avoid failures. A thorough understanding of factors influencing wind loads provides engineers with an opportunity to ensure these structures are efficiently designed with confidence in wind loading assumptions.

This paper explores a number of facets of the determination and validation of wind loads specifically associated with conveyor galleries. This includes:

1. Design wind speeds determined in accordance with relevant code, for instance AS/NZS 1170.2:2021.
2. Aerodynamic drag and pressure coefficients and calculation of wind loading on structure.
3. Validation of results via wind tunnel testing.
4. Alternative techniques for validation, such as computational fluid dynamics (CFD)

In Australia, the primary design standard for the determination of wind loads on structures, is AS/NZS 1170.2:2021. The determination of wind speed and design wind pressures to the standard is subject to several factors. The final design wind pressure on a structural element is determined via the following formula:

$$p = (0.5\ \rho_{air})\left[V_{des,\theta}\right]^2 C_{shp} C_{dyn}$$

Where,

$p = design\ pressure\ in\ pascals$

$\rho_{air} = density\ of\ air$

$V_{des,\theta} = design\ wind\ speed$

$C_{shp} = aerodynamic\ shape\ factor$

$C_{dyn} = dynamic\ response\ factor$

2. AS/NZS 1170.2:2021: Wind Speed ($V_{des,\theta}$)

Key factors in the determination of the relevant design wind speed ($V_{des,\theta}$) include: the regional wind speed (V_R), wind direction multiplier (M_R), local terrain and height ($M_{z,cat}$), local shielding (M_S), climate change allowances (M_c) and local topography (M_t).

The terrain/heigh multiplier, $M_{z,cat}$, is based on the height of structure and 'terrain category' from AS1170.2. It can have a significant impact on the design wind speed with values ranging from 0.75 to 1.39.

The wind direction multiplier, M_d, is based on statistical probability of peak winds to occur in each cardinal direction and allows engineers to optimise designs based on a structure's orientations.

The wind directional factors are separated 4 distinct groups based on the governing weather patterns in each region.

1. Region A0: Dominated by non-synoptic winds (e.g., thunderstorms).
2. Regions A1 & A4: Dominated by extra-tropical synoptic winds (large-scale pressure systems).
3. Regions A2, A3, A5 & B1: Influenced by a mix of synoptic and non-synoptic winds (B1 includes tropical cyclones).
4. Regions B2, C & D: Dominated by tropical cyclones.

Cardinal directions	Region A0	Region A1	Region A2	Region A3	Region A4	Region A5	Region B1	Regions B2, C, D
N	0.90	0.90	0.85	0.90	0.85	0.95	0.75	0.90
NE	0.85	0.85	0.75	0.75	0.75	0.80	0.75	0.90
E	0.85	0.85	0.85	0.75	0.75	0.80	0.85	0.90
SE	0.90	0.80	0.95	0.90	0.80	0.80	0.90	0.90
S	0.90	0.80	0.95	0.90	0.80	0.80	0.95	0.90
SW	0.95	0.95	0.95	0.95	0.90	0.95	0.95	0.90
W	1.00	1.00	1.00	1.00	1.00	1.00	0.95	0.90
NW	0.95	0.95	0.95	0.95	1.00	0.95	0.90	0.90

NOTE In Region A0 non-synoptic winds are dominant. In Regions A1 and A4, extra-tropical synoptic winds are dominant. Extreme winds in Regions A2, A3, A5 and B1 are caused by a mixture of synoptic (extra-tropical large-scale pressure systems, or tropical cyclones in the case of B1) and non-synoptic (thunderstorm) events. In Regions B2, C, and D, extreme winds from tropical cyclones are dominant.

Figure 1: Wind direction multiplier (AS 1170.2:2021)

The climate change factor, M_c, replaced the uncertainty factors, F_c and F_d in the 2021 revision of the standard. The topographical factor, M_t, is based on surrounding topography such as hill shapes. The shielding factor, M_s, considers shield from adjacent structures.

3. AS/NZS 1170.2:2021: Aerodynamic Parameters

For complex structures like conveyor galleries, it is challenging to accurately determine aerodynamic parameters such as the aerodynamic shape factor or drag coefficient. AS1170.2:2021 Appendix C provides methods to determine aerodynamic shape factors for exposed structural members, frames and lattice towers by utilising the drag coefficient of the structure or member. The drag coefficient, C_d, is a dimensionless quantity that is used to quantify the resistance of an object in a fluid. The drag coefficient is combined with additional factors such as the aspect ratio correction factors (K_{ar}) and the shielding factor for multiple frames (K_{sh}) to determine the aerodynamic shape factor (C_{shp}) of simple shapes, individual members and a series of multiple open frame structures such as truss style conveyor galleries.

While a ‘member-by-member’ method can be effectively used to determine the wind force on a truss structure in accordance with AS1170.2:2021, applying it to conveyor galleries is more complex. These structures often support additional equipment (e.g. walkways, conveyor idlers, conveyor belt, services, secondary structures etc.) which are common in bulk material handling assets. These attachments significantly increase the complexity of accurately determining the aerodynamic properties of the structure.

Due to the complex geometry of the equipment exposed to wind, AS1170.2:2021 can be substituted for experimental and computational methods to assist engineers in determining the aerodynamic properties of structures.

4. Case Study: Wind Tunnel Testing on Conveyor Galleries

Analytical Method (AS1170.2:2021)

As a case study, wind loads on a single open conveyor gallery were assessed using the analytical methods outlined in Appendix C of AS 1170.2:2021. Wind loads were calculated perpendicular to the gallery span and the results were converted into an equivalent drag coefficient based on the total bluff area $(Total\ Length \times Total\ Height)$ of the gallery, allowing for direct comparison with values obtained from small-scale wind tunnel tests.

The analytical assessment yielded an equivalent drag coefficient in the range of 1.6 to 1.7 for a gallery with a solidity ratio of around 0.2. The drag coefficient for the conveying equipment and fixtures were determined using engineering judgment and assumed drag values provided in AS 1170.2:2021.

Wind Tunnel Testing

Wind tunnel testing has shown a range of values for different conveyor gallery geometries / constructions and can be invaluable in optimising wind loads, compared with analytical methods.

Open truss galleries, which consist of exposed structural members tend to have lower drag coefficient when compared to enclosed galleries, especially if the structure is open on all sides and has low solidity. Typical drag coefficients values for conveyor galleries with low solidity (0.2 and under) range from 0.8 to 1.4, as measured through wind tunnel testing. These experimentally determined values are generally lower than those obtained using analytical methods for galleries with similar designs and solidity ratios.

Enclosed galleries, which are clad in metal sheeting or other materials, present a more uniform wind profile. These structures typically have drag coefficients between 1.3 and 2.0 as measured by testing, depending on cross-sectional shape, aspect ratio and wind direction.

5. Alternative Methods

Computational Fluid Dynamics (CFD) is the computational equivalent of wind tunnel testing. Its key advantages include the ability to be conducted in-house, with greater efficiency and at a lower cost compared to traditional wind tunnel testing. However, it is not recognised by AS 1170.2 as a prescribed method to determine aerodynamic parameters without additional wind tunnel testing. CFD is also limited to assessing models in steady state without dynamic effects considered in the simulation.

In conclusion, there is no universal method in determining wind loads on complex structures and careful consideration must be given each time wind loads are assessed. Wind tunnel testing remains the most accurate and reliable method to determine wind loads, particularly for for conveyor galleries, and can lead to more efficient designs by reducing conservatism in wind load estimates. In the absence in wind tunnel testing, engineers should apply and interpret relevant standards such as AS1170.2:2021 – noting they are generally designed to provide conservative results to ensure structural safety.

6. References

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