DELMEC

Wind and Ice Loading: a Matter of Balance in Design

WHITE PAPER

JANUARY 2022

Introduction

Delmec supplies engineering design and support services all over the world, from the dry savannahs of South Africa to the frigid forests of northern Poland. As a result, a major part of our work involves considering the environment in which a tower is to be constructed.

This is particularly true when it comes to loading, as wind can have the biggest impact, increasing significantly when combined with ice loading.

Designing structures to accommodate ice loading incurs extra weight and cost. Bigger elements are required, resulting in towers with around 50% more weight than towers for which only wind loading is considered. This means that the decision isn't made lightly, but based on a number of key calculations.

This paper demonstrates the differences between wind and ice combination loading, their impact on a structure, and the importance of investigating weather conditions for specific locations.

Wind and Ice Loading

Ice on a tower increases the surface area for the wind loading and self-weight of the structure. In the case of ice, wind forces increase by 1.5 - 2 times.

To determine the wind loading on a structure, an engineering crew usually follows a relatively straightforward formula. For example, a 50m lattice tower is divided into sections with a height of 5m (length on leg element). With regard to ice loading on the structure, equal icing is assumed on all parts of the structure and equipment, at 3 cm thickness with ice weight of 7 kN/m3.

Wind pressure on top of the tower without considering ice is 2.603 kPa. When we factor ice into the calculations, the pressure goes up to 4.505 kPa. This shows pressure increases 1.73 times in situations of ice loading.

Commercial Considerations

In this section we will compare two types of tower. For both towers, calculations are carried out based on the same parameters such as loading, wind speed and location of the tower.

Tower "a" is a heavy tower capable of accommodating equipment when ice loading is considered.

Tower “b” is a lighter tower with member sizes reduced to the point where the tower is safe to use (stresses ratios below 100%).

	Max stress		Weight [t]
	ice	no ice	
Tower „a“	99%	68%	21.52
Tower „b“	overstressed	88%	11.59

Looking at the results for tower “a” from table above, the structure will be safe in case of ice loading, but will also have some extra capacity if it’s located in areas where ice loading will not occur. This means that it could accommodate extra operators if required in the future.

Tower “b” is lighter and cheaper, with 10 tonnes less steel for the same equipment loading than tower “a”, but can accommodate proposed equipment only in situations without ice loading. If ice loading occurs, the tower will be overstressed and unsafe to use.

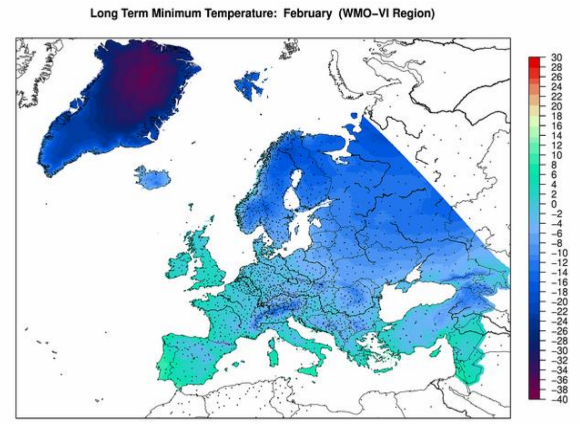
This demonstrates not only the impact of ice loading on the structure, but also the importance of investigating its location to see if ice loading will occur.

It’s safer to calculate towers with ice loading, but the difference in cost could be significant.

Weather Factors

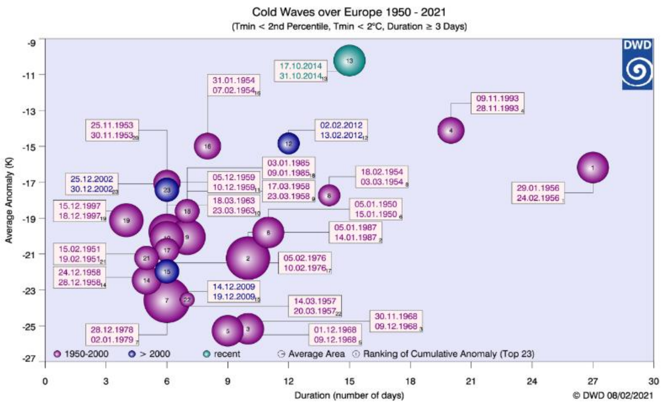
To check if the tower is in an area where icing is possible, we can consult existing weather data.

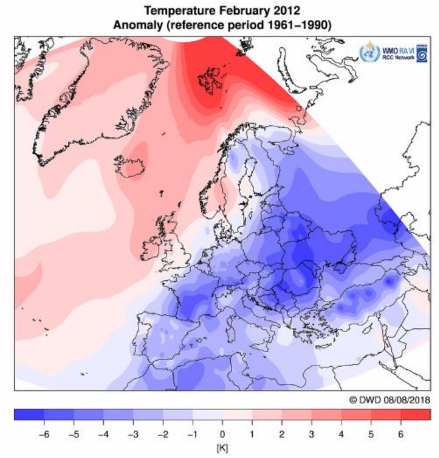
In this example, maps from the Deutscher Wetterdienst website show long-term minimum temperature levels and anomalies for Europe. As ice loading will occur at temperatures below 0°C, from the map below we can conclude that considering ice loading would not make sense in areas such as Ireland, Portugal and the United Kingdom, as well as southern parts of Spain, Italy, and Greece.



However, as towers should be designed for extreme weather situations, information about cold waves should be considered. The graph below shows cold waves over Europe from 1950 to 2021. In 2012, a cold wave lasted for 11 days with an average anomaly of -15°C.

The map below shows an anomaly for that period, during which most of Europe was colder – from 2°C to 7°C – than long-term minimum temperatures in February.





Conclusion

A number of factors should influence tower design decisions, including environmental situations and average weather temperatures, as well as reasonable costs and optimum safety levels.

It is, like everything, a matter of balance. If ice loading is required to be factored into locations where it will not occur, the resulting towers will be over-designed and too expensive. Conversely, if ice loading is not considered in areas where it might occur, we risk constructing overstressed and unsafe structures.

For clients with large portfolios across expansive territories, finding this balance can be challenging. For example, choosing just one design approach for the entire European area could have a significant impact on the whole portfolio, potentially leading to incorrect designs with overstressed structures, or over-designed towers that were more expensive than necessary.

All of the above shows the importance of taking the time to consider all the elements that might influence a structure's design. That includes investigating in detail the weather conditions of specific locations to find the safest and most economic solutions available.

This is part of what makes clients trust Delmec with their most complex challenges – we see the bigger picture, wherever we are in the world.

Further Reading

1. Erdelja, Nikola: Proračun antenskog tornja prema Eurokodu 3, Tehničko veleučilište u Zagrebu, Graditeljski odjel, Zagreb, 2021

2. Eurokod 1: Djelovanja na konstrukcije – Dio 1-4: Opća djelovanja – Djelovanja vjetra (EN 1991-1-4:2005+AC:2010+A1:2010), Hrvatski zavod za norme (HZN), Zagreb, 2012

3. Eurokod 1: Djelovanja na konstrukcije – Dio 1-4: Opća djelovanja –Djelovanja vjetra – Nacionalni dodatak, Hrvatski zavod za norme (HZN), Zagreb, 2012

4. Eurokod 3: Projektiranje čeličnih konstrukcija – Dio 3-1: Tornjevi, jarboli i dimnjaci – Tornjevi i jarboli (EN 1993-3-1:2006+AC:2009), Hrvatski zavod za norme (HZN), Zagreb, 2014

5. Eurokod 3: Projektiranje čeličnih konstrukcija – Dio 3-1: Tornjevi, jarboli i dimnjaci – Tornjevi i jarboli – Nacionalni dodatak, Hrvatski zavod za norme (HZN), Zagreb, 2014

6. Eurocode 3: Design of steel structures - Part 1-8: Design of joints, EUROPEAN COMMITTEE FOR STANDARDIZATION, Brussels, 2005

7. https://www.dwd.de/EN/ourservices/rcccm/int/rcccm_int_txtnnorm.html?nn=519122