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İÇİNDEKİLER / CONTENTS

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Peak Velocity Pressure of Air Traffic Control Towers: A Comparative Study

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Abstract

The aim of the study was to compare the structural resistance of air traffic control towers (ATCTs) in Europe over 100 feet (30.48 meters) in height by determining their peak velocity pressure. A comprehensive examination was conducted on the ATCTs of 64 airports across Europe, with a reference to the EN-1991-1-4 criteria. The findings revealed notable differences in wind speeds and peak velocity pressure values experienced by ATCTs located in diverse geographical regions of Europe. The Athens Airport ATCT recorded the highest peak velocity pressure at 2.52 kN/m², while the lowest value was recorded at Zagreb Airport ATCT at 0.89 kN/m². These differences play a crucial role in determining the structural resistance of ATCTs. ATCTs exposed to high peak velocity pressures should use stronger materials and incorporate aerodynamic designs. Considering the significant influence of geographical location on wind loads, these results provide important insights into the safety of existing and future ATCTs. It is recommended that these findings be extended by investigating ATCTs in different geographical regions and that structural design strategies against wind loads be more thoroughly investigated in future studies.

Key Words: Air traffic control tower; Peak velocity pressure; Wind loads.

JEL Classification: M10, M19.

Hava Trafik Kontrol Kulelerinin Tepe Hız Kaynaklı Rüzgar Basınçları: Karşılaştırmalı Bir Analiz

Öz

Çalışmanın amacı, Avrupa genelindeki 30.48 metre (100 feet) üzerindeki hava trafik kontrol kulelerinin tepe hız kaynaklı rüzgar basınçlarını belirleyerek yapısal dayanıklılıklarını karşılaştırmaktır. Bu amaçla, EN-1991-1-4 kriterlerini referans alınarak Avrupa'daki 64 havalimanının hava trafik kontrol kuleleri incelenmiştir. Çalışmada Avrupa genelindeki farklı coğrafi bölgelerdeki hava trafik kulelerinin maruz kaldığı rüzgar hızları ve tepe hız kaynaklı rüzgar basıncı değerlerinde önemli farklılıklar bulunmuştur. Atina Havalimanı hava trafik kontrol kulesi 2.52 kN/m² ile en yüksek tepe hız kaynaklı rüzgar basıncına ulaşırken en düşük değer 0.89 kN/m² ile Zagreb Havalimanı hava trafik kontrol kulesi için tespit edilmiştir. Bu farklar kulelerin yapısal dayanıklılığının belirlenmesinde önemli bir rol oynamaktadır. Yüksek tepe hız kaynaklı rüzgar basıncına maruz kalan kuleler için daha sağlam malzemeler kullanılmalı ve yapıların aerodinamik tasarımı dikkate alınmalıdır. Coğrafi konumların rüzgar yükleri üzerindeki belirgin etkisi göz önünde bulundurulduğunda, bu bulgular mevcut ve yapılacak olan hava trafik kontrol kulelerinin emniyeti için önemli ipuçları sunmuştur. Gelecekteki çalışmalarda farklı coğrafi bölgelerdeki hava trafik kontrol kulelerinin incelenmesi ve rüzgar yüklerine karşı yapısal tasarım stratejilerinin daha kapsamlı bir şekilde araştırılması yoluyla bu bulguların genişletilmesi önerilmektedir

Anahtar Kelimeler: Hava trafik kontrol kulesi; Rüzgar yükleri; Tepe hız kaynaklı rüzgar basıncı.

JEL Sınıflandırma: M10, M19.

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1. INTRODUCTION

Air travel is a vital component of global mobility in today's interconnected world, enabling the transfer of people and goods over long distances (Gheorghe, & Sebea, 2010; Ishutkina, & Hansman, 2008). The complex system of air traffic control (ATC), which is essential to maintaining the efficiency, safety, and orderliness of air travel, is at the center of this complicated network (Chaloulos, 2011). The core of aviation operations is air traffic control, which manages aircraft movement both in the air and on the ground. The primary goal of ATC is to prevent collisions between aircraft, while also facilitating the expeditious and orderly movement of flights (Degas et al., 2021). This critical function ensures that air travel is seamlessly integrated into the broader transportation network by extending beyond the management of specific airports to include regional and global airspace management. Central to the operation of ATC are the air traffic control towers (ATCTs) located at airports worldwide (Moravej, Vafaei, & Bakar, 2016). These iconic structures serve as command centers, overseeing all aircraft movements within their airports and surrounding airspace. Among their primary functions is the coordination of take-off and landing, a task that demands precision timing and communication to ensure the safe and efficient flow of traffic. Additionally, ATCTs play a key role in managing ground operations, including taxiing, runway assignments, and gate utilization, further enhancing the overall efficiency of airport operations (Shiomi et al., 1997).

Given the critical role that mixing height plays in the take-off and landing cycles of aircraft, where it influences the required distance and duration to reach the 3.000 feet threshold, a comprehensive assessment of both present and expected air traffic patterns is to be conducted by the ATCT (Dalkıran, 2021). The height of the ATCT is crucial. It allows air traffic controllers to effectively monitor and oversee both the airport and its surrounding airspace, enabling them to maintain control. Moreover, structural reliability throughout the operational lifespan of the ATCT is imperative. Lastly, the ATCT must ensure consistent and dependable communication between controllers and aircraft during its operational tenure, as emphasized by ICAO regulations (International Civil Aviation Organization [ICAO], 1984).

Height is crucial in designing an ATCT. To ensure safety, the ATCT must clear obstacle limitation surfaces. The required height is determined by ensuring a 1° line of sight to the runway end, visibility of the entire active pavement, and no interference with approach or missed approach paths, as shown in Figure 1.

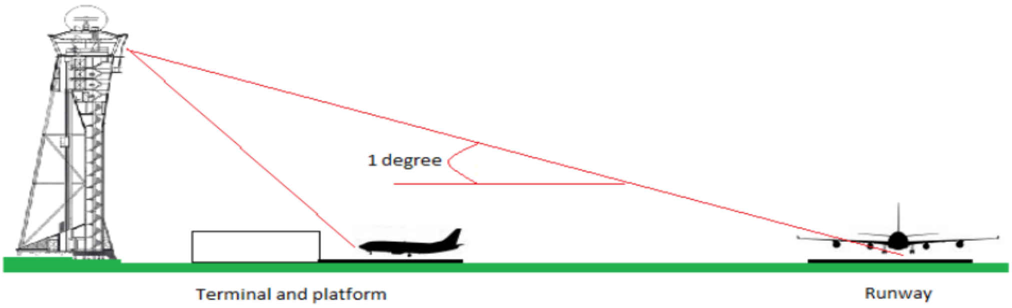

Figure 1. Minimum line of sight and direct visibility on active pavement (Hartmann, 2014)

With the increase in air traffic since the 1970s, there has been a significant rise in the number of ATCTs, as shown in Figure 2. Additionally, airports worldwide are expanding their runway infrastructure to accommodate increased air traffic, leading to the need for appropriate ATCT location and height (Prakash, Alam, & Duong, 2020). The highest ATCTs of each construction period are shown in Figure 3. The ATCT at Jeddah King Abdul Aziz Airport in Saudi Arabia, constructed in 2014, is the tallest ATCT in the world, with a height of 136 meters, as shown in Figure 4 (Panethos, 2024).

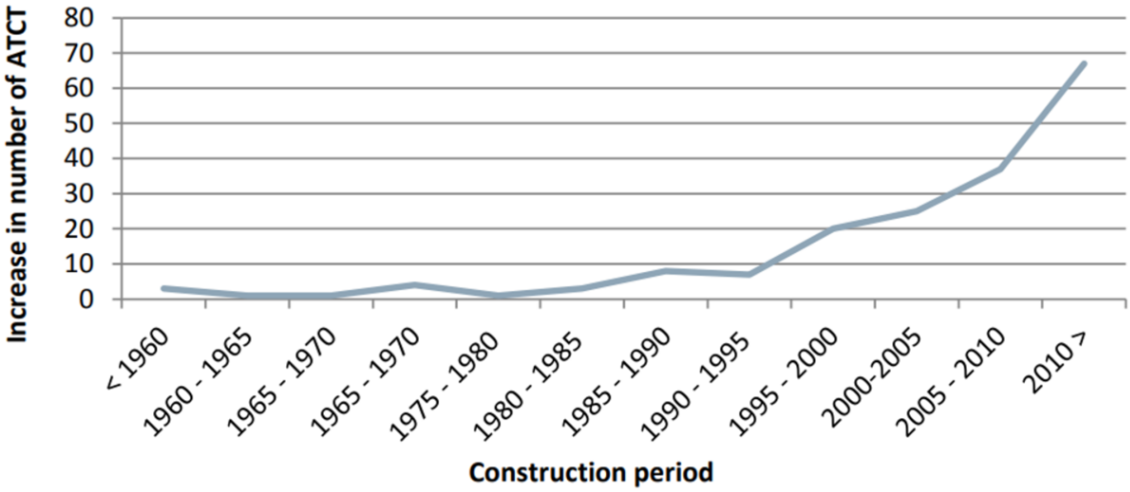

Figure 2. Air traffic control tower growth (Hartmann, 2014)

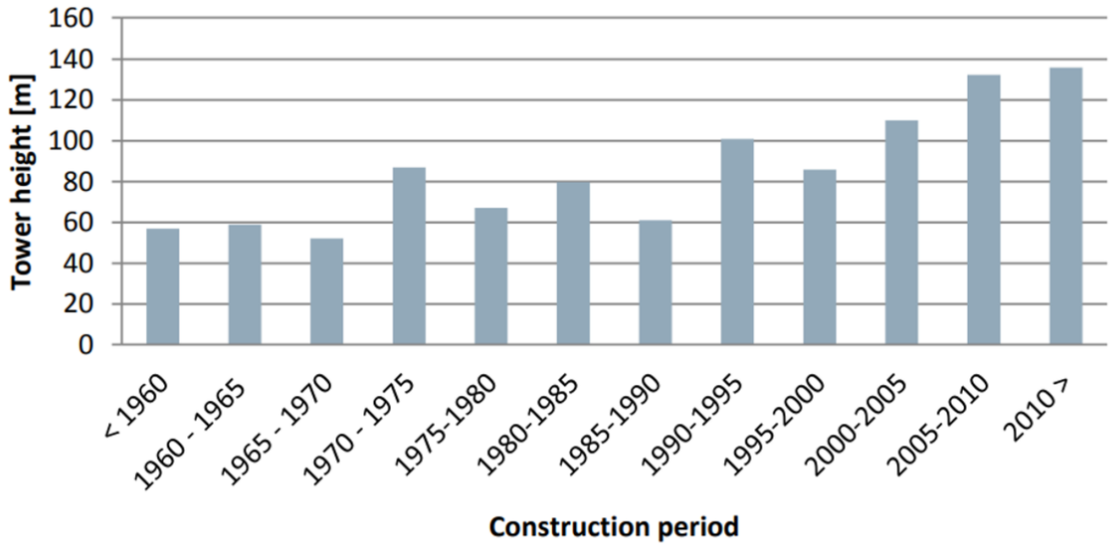

Figure 3. Maximum tower height development (Hartmann, 2014)

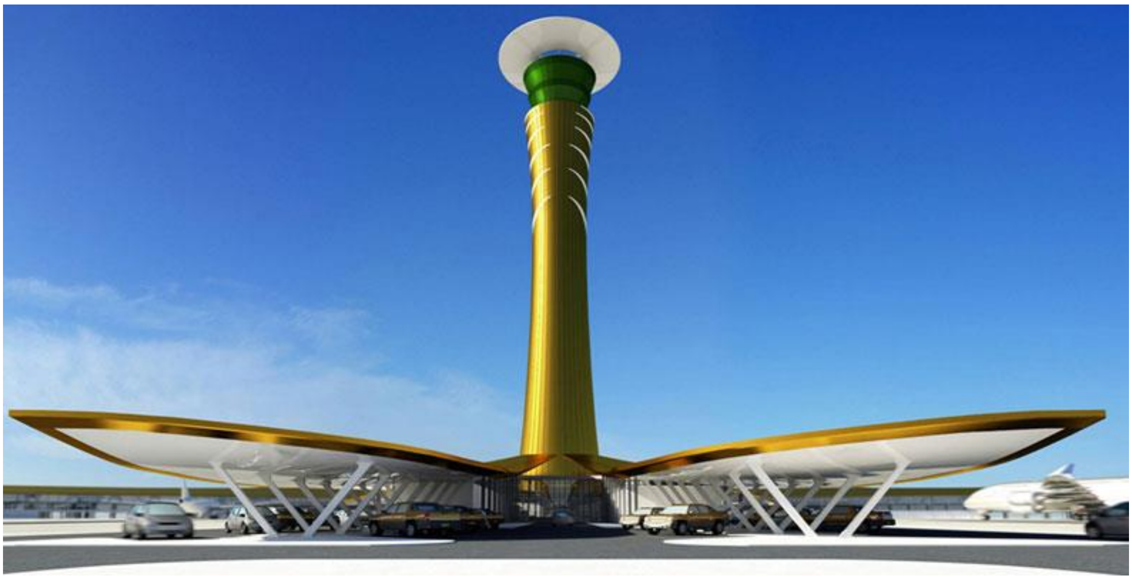

Figure 4. Jeddah King Abdul Aziz Airport ATC Tower (ACAMS, 2024)

Wind and earthquake actions are the most prevalent and significant lateral forces in structural engineering, as highlighted in the literature (Abu-Saba; 1995; Admassu, 2020; Heiza, & Tayel, 2012; Raju et al., 2013). Wind, a persistent force across the Earth's surface, varies in intensity depending on geographical location and annual probability of exceedance. Notably, the effect of fluctuating wind forces generated by turbulence predominates in most building scenarios, necessitating a focus on horizontal wind loading in structural frame calculations. Estimating wind climate involves determining basic and peak velocity pressures based on local wind maps and meteorological data. Similarly, earthquake hazard assessments rely on local seismic hazard and ground-type evaluations (Preciado, 2015). These factors serve as crucial boundary conditions for structural tower design, influencing decisions regarding tower height, capacity, and vulnerability analysis against local wind and earthquake hazards (Venanzi et al., 2018). Moreover, wind force predominance is attributed to peak velocity pressure and shape factor contributions, prompting strategies to minimize the latter through aerodynamic shapes like polygons or circles, particularly in designs facing high peak velocity pressures (Hartmann, 2014). In the literature review, Wilcoski and Heymsfield (2002) examined the earthquake performance of three ATCTs at different heights (15 meters and 9 meters) and aimed to determine safety performance and develop approaches to enhance performance using analyses conducted with the SAP 2000 program. Eshghi and Farrokhi (2003) investigated the seismic vulnerability of ATCT's, revealing the complex behavior of these reinforced concrete structures under seismic loading conditions through finite element analysis and push-over analysis. Sexton et al. (2004) studied the seismic retrofit of the King County International Airport ATCT post-Nisqually Earthquake, focusing on foundation enhancements via compaction grouting and drilled shaft installation to mitigate liquefaction, aiming to improve seismic resistance and detailing the construction process. Vafaei and Adnan (2011) investigated the structural health condition of 34 meters high ATCT at Iran's Kirman Airport during earthquakes using sensors and nonlinear time domain analysis. Hartmann (2014) aimed to develop an optimal structural design methodology for ATCTs worldwide by studying local effects, guiding designers toward the most suitable solution considering cost factors. Vafaei and Alih (2016) calculated seismic design response spectrum factors for three existing ATCTs in Iran (23.7 meters, 39.3 meters, 51.7 meters), noting a significant decrease in response spectrum factors with increasing tower height. Moravej et al. (2016) analyzed the seismic performance of Iran's Urmia International Airport ATCT (30.17 meters) using nonlinear time domain analysis and found the current design inadequate, failing to meet CP level earthquake performance. Sullivan et al. (2017) conducted structural design for an ATCT (9-story, 12.5-degree inclined and column-free) in Lyall Bay, Wellington, foreseeing that initially selected three earthquake acceleration records would be insufficient. Vafaei and Alih (2018a) performed analyses to determine seismic effects and safety vulnerabilities of ATCTs at different heights (9 meters, 23.7 meters, 51.7 meters), observing increased fragility with increasing height. Vafaei and Alih (2018b) conducted analyses in the nonlinear time domain to estimate seismic base shear forces in ATCTs using 45 earthquake acceleration records. Moravej and Vafaei (2019) evaluated the seismic performance of 30.17 meters high ATCT using the pushover analysis method and observed displacement demands of two stories. Sharma (2019) evaluated the design criteria of an ATCT located in Zone IV according to the Indian standard code, considering geographic location, number of floors, floor height, ground condition, load conditions, and foundation design. Amrutkar et al. (2022) examined the earthquake performance of ATCTs with different structural shapes (square, pentagon, hexagon, and octagon) at a height of 55 meters, observing that towers designed in octagonal shapes exhibited the least displacement and lateral drift. Finally, Boztepe and Aktaş (2023) investigated the earthquake performance and seismic isolation effect of ATCTs in Türkiye, noting insufficient research in the country and the need for further studies.

It is noted that while seismic performance is a major focus in the structural design of ATCTs, academic studies comparatively give less attention to wind effects. ATCTs, being tall structures, are significantly affected by both seismic and wind-induced lateral forces. These towers are often exposed to wind effects due to their height, making it imperative for them to withstand critical wind parameters such as peak velocity pressure, which plays a crucial role in determining structural resilience. Tall structures, especially under the influence of wind, face heightened stress, necessitating meticulous evaluation of their structural integrity, particularly for high-rise structures like ATCTs. This research aims to analyze peak velocity pressure values to assess and compare the structural resilience of ATCTs, contributing significantly to the literature on the safety and structural integrity of these towers. However, there are some challenges, such as the need for a more detailed examination of the performance of ATCTs under wind effects in different geographical regions. This study will pave the way for more comprehensive research on the structural resilience of ATCTs.

2. MATERIALS AND METHODS

The study examined 64 ATCTs over 30.48 meters tall located in Europe. The fundamental basic wind velocity values were determined using the Dlubal Software GmbH software, in accordance with the standards specified in EN 1991-1-4 and CTE DB SE-AE, as illustrated in Figure 5.

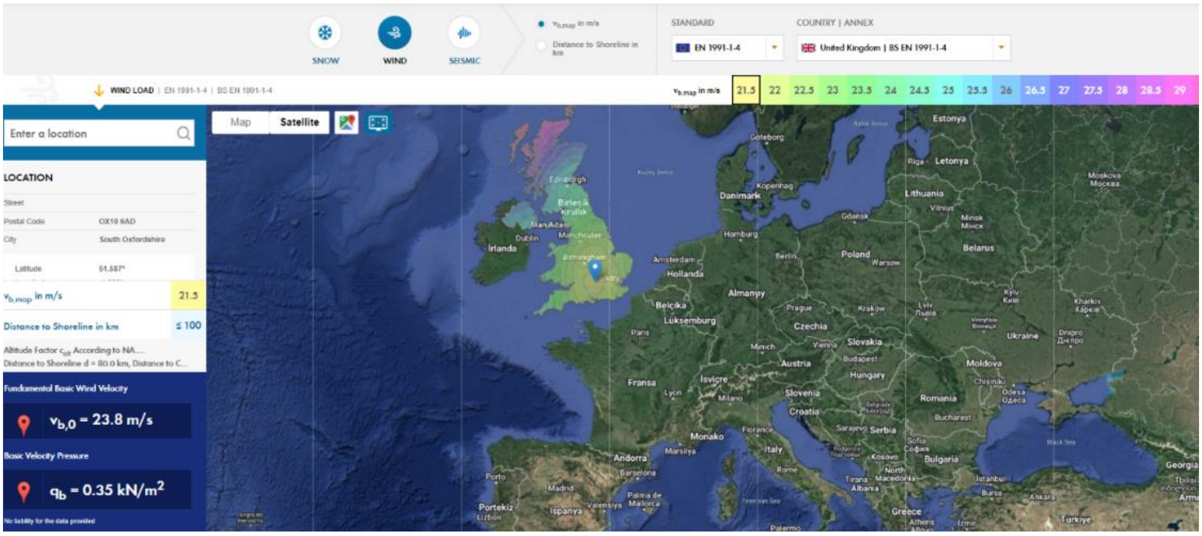

Figure 5. An example of fundamental basic wind velocity value (Dlubal, 2024)

Figure 6 illustrates the steps outlined below for calculating Peak Velocity Pressure based on EN-1991-1-4 standards (European Union, 2010). EN-1991-1-4, also known as "Eurocode 1: Actions on structures - Part 1-4: General actions - Wind actions", includes standards related to wind effects on structures. This standard provides guidance for calculating and designing the forces necessary for structures to withstand wind effects. It is particularly used for evaluating and designing structures to withstand wind loads appropriately.

Step 1: The heights of ATCTs (z) located in the European region that are over 30.48 meters (100 feet) were listed.

Step 2: Fundamental value of basic wind velocity ($v_{b,0}$) for each region where an ATCT is located was determined using Dlubal Software GmbH referencing EN 1991-1-4 and CTE DB SE-AE. The fundamental value of basic wind velocity describes a 10-minute mean at 10 meters above ground in open country terrain, incorporating annual risks and additional parameters (European Union, 2010).

Step 3: The value of orography factor (c_0) was determined to be 1.0, as referenced in EN 1991-1-4.

Step 4: The value of turbulence factor (k_l) was determined to be 1.0, as referenced in EN 1991-1-4.

Step 5: Density of air (ρ) was determined to be 1.25 kg/m^3, as given in EN 1991-1-4.

Step 6: The reference height of terrain category II ($z_{o.II}$=0.05m) was determined in the study.

Step 7: Roughness length (z_0=0.05) was determined in the study.

Step 8: Terrain factor (k_r) was calculated the following formula (European Union, 2010).

$$k_r = 0.19 \,.\, \left(\frac{z_0}{z_{0.II}}\right)^{0.07} \tag{1}$$

Step 9: Turbulence intensity (I_v) was calculated the following formula (European Union, 2010).

$$I_v = \frac{k_1}{c_0 \,.\ln\left(\frac{z}{z_0}\right)} \tag{2}$$

Step 10: Roughness intensity (c_r) was calculated the following formula (European Union, 2010).

$$c_r = k_r \,.\, \ln\left(\frac{z}{z_0}\right) \tag{3}$$

Step 11: The season factor (c_{season})was set to 1.0 for ATCTs since they are non-temporary structures.

Step 12: Directional factor (c_{dir}) was set to 1.0 as recommended in EN 1991-1-4 4.2 Note 2.

Step 13: Mean wind velocity (v_m) was calculated the following formula (European Union, 2010).

$$v_m = c_r \,.\, c_0 \,.\, v_{b.0} \tag{4}$$

Step 14: Peak velocity pressure (q_p) was calculated the following formula (European Union, 2010).

$$q_p = [\,1 + 7\,.I_v\,]\,.\frac{1}{2}\,.\,\rho\,.\,v_m^2 \tag{5}$$

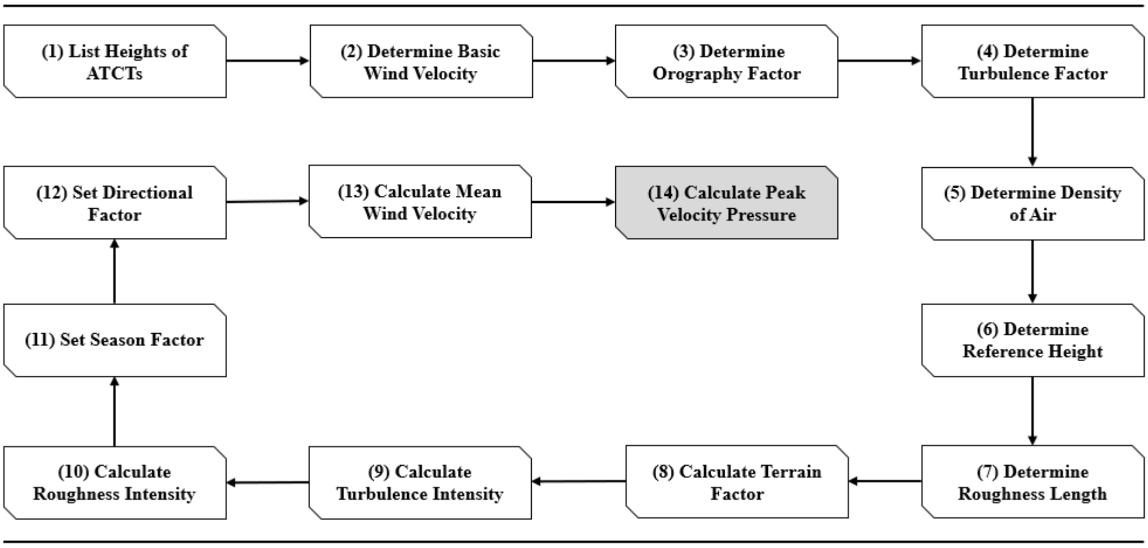

Figure 6. Calculating peak velocity pressure flow chart

3. RESULTS

The maximum peak velocity pressure values experienced by various ATCTs at airports across Europe are determined based on their heights and the average wind speeds in their respective regions. The results are shown in Table 1, with detailed values provided in the Appendix.

The data from the 64 airports examined indicate that the ATCT heights range from 32 meters to 111.86 meters. The tallest ATCTs are at İstanbul Sabiha Gökçen Airport and Paris Charles De Gaulle Airport (primary/north), both standing at 111.86 meters. In contrast, the shortest ATCT examined in the study is at Gdansk (Wałęsa) Airport, with a height of 32 meters.

Regarding wind speeds, significant differences were observed among the airports. The highest wind speed was recorded at Athens Airport at 33.00 m/s, while the lowest wind speed was recorded at Zagreb Airport at 20.00 m/s.

The peak velocity pressure values also showed considerable variability. Athens Airport had the highest peak velocity pressure at 2.52 kN/m², whereas Zagreb Airport showed the lowest peak velocity pressure at 0.89 kN/m².

Table 1. The height, basic wind velocity, and peak velocity pressure of ATCTs

ATCT	z(m)	$v_{b.0}$ (m/s)	q_p (kN/m²)
1. İstanbul (Gökçen), Türkiye	111.86	28.00	2.01
2. Paris (De Gaulle-p/n), France	111.86	24.00	1.47
3. Vienna, Austria	110.03	25.10	1.61
4. Amsterdam (Schiphol-p), Netherlands	100.89	27.00	1.83
5. İstanbul (IGA), Türkiye	94.79	28.00	1.94
6. Oslo, Norway	91.14	22.00	1.19
7. Paris (De Gaulle-s), France	89.92	24.00	1.41

8. Dublin, Ireland	87.78	25.17	1.55
9. London (Heathrow), UK	86.87	22.10	1.19
10. Dusseldorf, Germany	85.34	22.50	1.23
11. Belgrade (Tesla), Yugoslavia	74.98	21.00	1.04
12. Munich, Germany	74.98	22.50	1.20
13. Paris (De Gaulle-c), France	74.98	24.00	1.36
14. Leipzig, Germany	73.15	25.00	1.47
15. Berlin (Brandenburg), Germany	71.93	25.00	1.46
16. Copenhagen, Denmark	71.93	24.00	1.35
17. Madrid (Barajas), Spain	71.02	26.00	1.58
18. Frankfurt, Germany	70.10	22.50	1.18
19. Milan (Malpensa), Italy	70.10	25.00	1.46
20. Athens, Greece	68.28	33.00	2.52
21. Hannover (DFS), Germany	67.97	25.00	1.45
22. London (Luton), UK	65.53	22.10	1.12
23. Paris (De Gaulle-4), France	64.92	24.00	1.32
24. London (Stansted), UK	63.09	22.10	1.11
25. Barcelona (El Prat-p), Spain	61.87	29.00	1.91
26. Amsterdam (Schiphol-w), Netherlands	60.05	27.00	1.64
27. Brussels, Belgium	60.05	25.00	1.41
28. Cologne-Bonn, Germany	60.05	22.50	1.14
29. Manchester, UK	60.05	22.50	1.14
30. Rome (Da Vinci), Italy	57.00	27.00	1.63
31. Edinburgh (Turnhouse), UK	56.69	25.00	1.39
32. Rota (Naval Station), Spain	56.08	29.00	1.87
33. Zagreb, Croatia	55.17	20.00	0.89
34. Liverpool (John Lennon), UK	54.86	23.00	1.17
35. Trondheim, Norway	54.86	26.00	1.49
36. Malaga, Spain	54.56	26.00	1.49
37. Barcelona (El Prat-s), Spain	53.64	29.00	1.85
38. Venice (Marco Polo), Italy	53.04	25.00	1.37
39. Nottingham (East Midlands), UK	52.43	22.00	1.06
40. Paris (Orly), France	52.12	24.00	1.26
41. Sofia, Bulgaria	49.99	27.71	1.66
42. Nurnberg, Germany	47.85	22.50	1.09
43. Alicante, Spain	46.94	27.00	1.56
44. Bordeaux (Merignac), France	46.02	22.00	1.03
45. Newcastle, UK	46.02	23.50	1.18
46. Katowice, Poland	45.72	22.00	1.03
47. Izmir (Menderes), Türkiye	45.11	28.00	1.66
48. Bratislava, Slovakia	42.67	26.00	1.42
49. Bilbao (Sondica), Spain	42.06	29.00	1.76
50. Nuremberg, Germany	42.06	22.50	1.06
51. Prague, Czech Republic	42.06	27.50	1.58
52. Alguaire, Spain	41.15	29.00	1.75
53. Tenerife Norte, Canary Islands, Spain	41.15	29.00	1.75
54. Jersey, UK	39.01	24.00	1.18
55. Warsaw (Chopin), Poland	37.49	22.00	0.98
56. Farnborough, UK	35.36	21.50	0.93
57. Hamburg, Germany	35.05	25.00	1.25
58. Luxembourg (Findel), Luxembourg	35.05	24.00	1.15
59. Rzeszow (Jasionka), Poland	32.92	22.00	0.96
60. Ajaccio, Corsica, France	32.61	26.00	1.33
61. Krakow, Poland	32.61	22.00	0.95
62. London (Southend), UK	32.00	22.10	0.96
63. Berlin, Germany	32.00	25.00	1.23
64. Gdansk (Walesa), Poland	31.09	26.00	1.32

4. DISCUSSION

4.1. Air Traffic Control Tower Heights and Wind

İstanbul Sabiha Gökçen and Paris De Gaulle Airports, with their ATCTs standing at 111.86 meters, are subjected to some of the highest regional wind speeds (28.00 m/s and 24.00 m/s, respectively). Similarly, Vienna and Amsterdam Schiphol Airports, with ATCTs over 100 meters, also experience high regional wind speeds (25.10 m/s and 27.00 m/s, respectively).

Tall towers are more exposed to the aerodynamic effects of wind due to their larger surface area (Li et al., 1998). As wind speed and pressure values increase, the durability and stability of the materials used in the structural design of the towers become crucial. The effect of wind on the tower requires consideration of not only static loads but also dynamic loads (Sollenberger, Billington, & Scanlan, 1980). This necessitates accurate calculation of wind speeds and tower heights, and optimization of structural designs accordingly.

The relationship between height and wind speed plays a critical role in the design of ATCTs. For towers exposed to high wind speeds, it's important to use robust and durable materials for structural stability, consider aerodynamic design elements, and ensure periodic maintenance of ATCTs. These factors are essential to ensure that air traffic controllers can manage air traffic continuously, efficiently, and safely, even under high wind conditions.

4.2. Geographical Variations

The wind speeds and pressures experienced by ATCTs vary significantly depending on their geographical locations. This is an important factor that needs to be considered in their design and engineering. ATCTs in airports of Northern Europe generally experience lower wind speeds and peak velocity pressures. For instance, The ATCT in Oslo Gardermoen Airport has a wind speed of 22.00 m/s, while the ATCT in London Heathrow Airport has a wind speed of 22.10 m/s. Both have peak velocity pressures of 1.19 kN/m². These values reflect the cooler and more stable climate conditions in the northern regions.

In contrast, ATCTs in airports of the Mediterranean region are exposed to higher wind speeds and peak velocity pressures. For example, the ATCT in Athens Airport has a wind speed of 33.00 m/s and a peak velocity pressure of 2.52 kN/m², which are among the highest values in the study. Similarly, the ATCT in Barcelona El Prat Airport shows high values with a wind speed of 29.00 m/s and a peak velocity pressure of 1.91 kN/m². This reflects the influence of the warmer and more variable weather conditions in the Mediterranean region.

These geographical differences are crucial factors to consider in the design and construction of ATCTs. In regions with high wind speeds and peak velocity pressures, towers need to be constructed with durable and robust materials (Ahmed, Arthur, & Edwards, 2010; Gong, Zhu, & Chen, 2019). Additionally, these towers should be designed to withstand wind loads, incorporating aerodynamic shapes and reinforcing structural supports. The impact of geographical location on wind loads necessitates that structural engineers and designers develop optimal solutions by considering local climate conditions.

4.3. Peak Velocity Pressure and Safety

Peak velocity pressure is a critical parameter for the structural integrity and operational safety of ATCTs. Athens Airport, with the highest peak velocity pressure of 2.52 kN/m² in the study, requires the ATCTs structure to be highly resistant to wind loads. Similarly, Barcelona El Prat Airport also exhibits high values with a peak velocity pressure of 1.91 kN/m².

These high peak velocity pressures are an essential factor to consider in the structural design of the towers. High peak velocity pressure values necessitate the construction of towers with more robust materials and the optimization of structures aerodynamically. The impact of peak velocity pressure on safety becomes particularly evident under extreme weather conditions. Towers exposed to high peak velocity pressures are at greater risk during severe wind events (Sheng et al., 2018). Therefore, towers subjected to high peak velocity pressures should be designed to be more durable and secure, and they should undergo regular maintenance. These measures are necessary to ensure the safe and uninterrupted continuation of air traffic control operations. Structural engineering and aerodynamic solutions will enhance the ATCTs' resilience to wind loads, guaranteeing long-term performance and safety.

5. CONCLUSIONS

This study presents a comparative analysis of ATCTs at airports across Europe in terms of their heights, wind speeds, and peak velocity pressures. The findings indicate that ATCT heights vary from 32 meters to 111.86 meters, with wind speeds ranging from 20.00 m/s to 33.00 m/s. Peak velocity pressures vary between 0.89 kN/m² and 2.52 kN/m². These values highlight the critical nature of the wind loads that ATCTs are exposed to, emphasizing their importance in structural design and engineering.

The relationship between height and wind speed provides significant insights into how towers perform against wind loads. Tall ATCTs experience higher wind speeds, necessitating the use of more durable materials in construction. Geographical variations have a significant impact on airport wind speeds and peak velocity pressures. Airports in Northern Europe generally experience lower wind speeds and peak velocity pressures, while those in the Mediterranean region exhibit higher values. This underscores the need to consider local climate conditions in structural design.

Peak velocity pressure is a critical parameter for structural stability and safety. Towers exposed to high peak velocity pressures should be designed to be more durable and secure. Structural integrity of these towers should be optimized to resist wind loads effectively. In regions with high wind speeds and peak velocity pressures, more durable and aerodynamic structures should be designed, and towers should undergo regular maintenance and inspections to ensure safety.

In conclusion, the performance of ATCTs against wind loads should be carefully evaluated from both structural engineering and aerodynamic perspectives. These assessments are crucial for enhancing the operational efficiency and safety of airports. Future studies could expand on these findings by including airports from different geographical regions and examining structural design strategies against wind loads in more detail. Such analyses could provide insights into ensuring uninterrupted air traffic operations against potential structural risks.

Nomenclature

z	m	Height
$v_{b.0}$	m/s	Basic wind velocity
c_0	-	Orography factor
k_I	-	Turbulence factor
ρ	kg/m^3	Density of air
$z_{0.II}$	m	Reference height of terrain category II
z_0	m	Roughness length
k_r		Terrain factor
I_v		Turbulence intensity
c_r		Roughness intensity
c_{season}		Season factor
c_{dir}		Directional factor
v_m	m/s	Mean wind velocity
q_p	kN/m^2	Peak velocity pressure

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Conflict of Interest

The author declares no known conflict of interest.

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Appendix

- Air Traffic Control Towers' Values

Air Traffic Control Towers	z (m)	$v_{b.0}$ (m/s)	I_v	c_r	v_m (m/s)	q_p (kN/m²)
1. İstanbul (Gokcen), Türkiye	111.86	28.00	0.130	1.465	41.0	2.01
2. Paris (De Gaulle-p/n), France	111.86	24.00	0.130	1.465	35.2	1.47
3. Vienna, Austria	110.03	25.10	0.130	1.462	36.7	1.61
4. Amsterdam (Schiphol-p), Netherlands	100.89	27.00	0.131	1.446	39.0	1.83
5. İstanbul (IGA), Türkiye	94.79	28.00	0.132	1.434	40.2	1.94
6. Oslo, Norway	91.14	22.00	0.133	1.427	31.4	1.19
7. Paris (De Gaulle-s), France	89.92	24.00	0.133	1.424	34.2	1.41
8. Dublin, Ireland	87.78	25.17	0.134	1.419	35.7	1.55
9. London (Heathrow), UK	86.87	22.10	0.134	1.417	31.3	1.19
10. Dusseldorf, Germany	85.34	22.50	0.134	1.414	31.8	1.23
11. Belgrade (Tesla), Yugoslavia	74.98	21.00	0.137	1.389	29.2	1.04
12. Munich, Germany	74.98	22.50	0.137	1.389	31.3	1.20
13. Paris (De Gaulle-c), France	74.98	24.00	0.137	1.389	33.3	1.36
14. Leipzig, Germany	73.15	25.00	0.137	1.385	34.6	1.47
15. Berlin (Brandenburg), Germany	71.93	25.00	0.138	1.382	34.5	1.46
16. Copenhagen, Denmark	71.93	24.00	0.138	1.382	33.2	1.35
17. Madrid (Barajas), Spain	71.02	26.00	0.138	1.379	35.9	1.58
18. Frankfurt, Germany	70.10	22.50	0.138	1.377	31.0	1.18
19. Milan (Malpensa), Italy	70.10	25.00	0.138	1.377	34.4	1.46
20. Athens, Greece	68.28	33.00	0.139	1.372	45.3	2.52
21. Hannover (DFS), Germany	67.97	25.00	0.139	1.371	34.3	1.45
22. London (Luton), UK	65.53	22.10	0.139	1.364	30.1	1.12
23. Paris (De Gaulle-4), France	64.92	24.00	0.139	1.362	32.7	1.32
24. London (Stansted), UK	63.09	22.10	0.140	1.357	30.0	1.11
25. Barcelona (El Prat-p), Spain	61.87	29.00	0.140	1.353	39.2	1.91
26. Amsterdam (Schiphol-w), Netherlands	60.05	27.00	0.141	1.347	36.4	1.64
27. Brussels, Belgium	60.05	25.00	0.141	1.347	33.7	1.41
28. Cologne-Bonn, Germany	60.05	22.50	0.141	1.347	30.3	1.14
29. Manchester, UK	60.05	22.50	0.141	1.347	30.3	1.14
30. Rome (Da Vinci), Italy	57.00	27.00	0.142	1.337	36.1	1.63
31. Edinburgh (Turnhouse), UK	56.69	25.00	0.142	1.336	33.4	1.39
32. Rota (Naval Station), Spain	56.08	29.00	0.142	1.334	38.7	1.87
33. Zagreb, Croatia	55.17	20.00	0.143	1.331	26.6	0.89
34. Liverpool (John Lennon), UK	54.86	23.00	0.143	1.330	30.6	1.17
35. Trondheim, Norway	54.86	26.00	0.143	1.330	34.6	1.49
36. Malaga, Spain	54.56	26.00	0.143	1.329	34.6	1.49
37. Barcelona (El Prat-s), Spain	53.64	29.00	0.143	1.326	38.4	1.85
38. Venice (Marco Polo), Italy	53.04	25.00	0.144	1.324	33.1	1.37
39. Nottingham (East Midlands), UK	52.43	22.00	0.144	1.321	29.1	1.06
40. Paris (Orly), France	52.12	24.00	0.144	1.320	31.7	1.26
41. Sofia, Bulgaria	49.99	27.71	0.145	1.312	36.4	1.66
42. Nurnberg, Germany	47.85	22.50	0.146	1.304	29.3	1.09
43. Alicante, Spain	46.94	27.00	0.146	1.300	35.1	1.56
44. Bordeaux (Merignac), France	46.02	22.00	0.147	1.297	28.5	1.03
45. Newcastle, UK	46.02	23.50	0.147	1.297	30.5	1.18
46. Katowice, Poland	45.72	22.00	0.147	1.295	28.5	1.03
47. Izmir (Menderes), Türkiye	45.11	28.00	0.147	1.293	36.2	1.66
48. Bratislava, Slovakia	42.67	26.00	0.148	1.282	33.3	1.42
49. Bilbao (Sondica), Spain	42.06	29.00	0.148	1.280	37.1	1.76
50. Nuremberg, Germany	42.06	22.50	0.148	1.280	28.8	1.06
51. Prague, Czech Republic	42.06	27.50	0.148	1.280	35.2	1.58
52. Alguaire, Spain	41.15	29.00	0.149	1.275	37.0	1.75

53. Tenerife Norte, Canary Islands, Spain	41.15	29.00	0.149	1.275	37.0	1.75
54. Jersey, UK	39.01	24.00	0.150	1.265	30.4	1.18
55. Warsaw (Chopin), Poland	37.49	22.00	0.151	1.258	27.7	0.98
56. Farnborough, UK	35.36	21.50	0.152	1.247	26.8	0.93
57. Hamburg, Germany	35.05	25.00	0.153	1.245	31.1	1.25
58. Luxembourg (Findel), Luxembourg	35.05	24.00	0.153	1.245	29.9	1.15
59. Rzeszow (Jasionka), Poland	32.92	22.00	0.154	1.233	27.1	0.96
60. Ajaccio, Corsica, France	32.61	26.00	0.154	1.231	32.0	1.33
61. Krakow, Poland	32.61	22.00	0.154	1.231	27.1	0.95
62. London (Southend), UK	32.00	22.10	0.155	1.228	27.1	0.96
63. Berlin, Germany	32.00	25.00	0.155	1.228	30.7	1.23
64. Gdansk (Walesa), Poland	31.09	26.00	0.155	1.222	31.8	1.32

Note: $c_0 = 1.00$; $k_I = 1.00$; ρ **(kg/m³)** =1.25; $z_{0.II} = 0.05$; $z_0 = 0.05$; $k_r = 1.19$; $c_{season} = 1.00$; $c_{dir} = 1.00$