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Structural analysis and comparative study of photovoltaic panel mounting systems in Northern Cyprus

Kuzey Kıbrıs'ta güneş paneli taşıyıcı sistemlerinin yapısal analizi ve karşılaştırılması

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Abstract

Northern Cyprus has made efforts to lessen its reliance on oil products and increase the usage of solar energy and installation of Photovoltaic (PV) panels. The design of lightweight structures, such as PV panel mounting systems, is significantly influenced by the characteristics of wind loads. Inaccurate calculations or a failure to take the wind load into account have recently resulted in substantial financial losses and damage to equipment and structures. In addition, the installation manner has remarkable effects on the output and efficiency of the PV panels. The wind loads on roof-mounted PV panels are examined in this study by considering two different heights for the building and different span lengths based on two loading standards; ASCE 7-16 and TS498, and the results and accuracy of each result are evaluated. Additionally, 64 rooftop PV panel mounting systems were developed to investigate the effects of factors including beam span length, load resisting system, column arrangement, available roof area, and required spacing between arrays. Deflection of the beams, cost of the mounting systems, weight of the mounting systems, and aesthetics of the building after installing PV panels are evaluated in this study.

Keywords: ASCE 7-16/TS498, Northern Cyprus, PV panel mounting system, PV solar panels, wind loads.

Özet

Kuzey Kıbrıs, petrol ürünlerine olan bağımlılığını azaltmak için güneş enerjisi kullanımını ve fotovoltaik (PV) panel kurulumunu artırmak için gayret göstermektedir. PV panel taşıyıcı sistemleri gibi hafif yapıların tasarımı, rüzgar yükünden dolayı önemli ölçüde etkilenebilmektedir. Yanlış hesaplamalar veya rüzgar yükünün hesaba katılmaması, son zamanlarda önemli finansal veya ekipman kayıplarına ve yapılarda hasara neden olmuştur. PV panellerin kurulum şeklinin ilgili panellerin verimliliği üzerinde dikkate değer etkileri vardır. Bu çalışmada çatıya monte PV panellerdeki rüzgar yükleri, bina için iki farklı yükseklik ve farklı açıklık uzunlukları dikkate alınarak iki farklı standarta göre incelenmiştir; ASCE 7-16 ve TS498'e göre, yapı elemanlarinin boyutlandirilmasinda, alınacak yüklerin hesap değerleri dikkate alınarak sonuçlar karşılaştırılmış ve incelenmiştir. Ek olarak, panel kiriş açıklığı uzunluğu, yük taşıma sistemi, kolon düzeni, mevcut çatı alanı, dizilimler arasındaki gerekli boşluk gibi faktörlerin etkilerini araştırmak için 64 farklı çatı PV panel taşıyıcı sistemi geliştirilmiştir. Bu çalışmada PV panellerin montajından sonra kirişlerin sehimi, taşıyıcı sistemlerinin maliyeti, taşıyıcı sistemlerinin ağırlığı ve montaj sonrası bina estetiği değerlendirilmiştir.

Anahtar Kelimeler: ASCE 7-16/TS498, Kuzey Kıbrıs, panel taşıyıcı sistemi, PV güneş panelleri, rüzgar yükleri.

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Introduction

The total estimated annual solar radiation reaching the earth's surface is more than 7500 times the total annual energy consumption of the world (Okoye & Abbasoğlu, 2013, WEC resources solar (2013), Kassem et al, 2019a). Energy from the sun can be directly converted into electrical energy using photovoltaic (PV) panels (Kassem et al, 2019a). Loads on the mounting system of PV panels, especially wind loads, depending on various factors related to the geographical condition, surrounding condition, installation location, and mounting system characteristics. Various research has been carried out and multiple methods have been employed to study wind loads on PV panels in various settings in recent years (Sauca et al., 2019)

A climate change hotspot is a region where the climate is particularly sensitive to global warming (Giorgi, 2006) and faces more risks and challenges than other regions due to climate change (Fan et al., 2021). According to recent research, the Mediterranean region is a climate change hotspot (Hochman et al, 2022; Barcikowska et al., 2020) and is predicted to suffer the greatest negative effects of climate change and would experience considerable increases in temperature, decreases in rainfall, and modifications to average wind speeds (Zachariadis, 2012).

Cyprus is surrounded by the Mediterranean Sea and climate change has affected this island over the last decades with a wide range of consequences, such as changes in rainfall levels, changes in temperatures, droughts, and extreme weather events such as hurricanes and tornados, which have affected the average wind speed in this island. Besides, tornadoes were rare occurrences in the Mediterranean region, however, their number and strength have increased (T-Vine, 2020, Agencies, 2020). On January 27, 2003, four tornadoes with wind speeds of up to 190 km/h impacted Cyprus. On January 22, 2004, this region was hit by a number of tornadoes with top speeds of roughly 140 km/h. (Sioutas et al, 2006). Additionally, a windstorm with an 80 km/h wind speed was recorded in North Cyprus on December 11, 2013 (Reşatoğlu et al., 2018). Overall, only 27.51% of the island is free from storm risk, while 51.19% of the island is at high risk of storms (Özşahin, 2012).

Extreme weather and climatic conditions have destructive socio-economic and ecological effects (Deryng et al., 2014; Ferrarezi et al., 2019) and change typical weather characteristics such as wind speed and wind load on buildings, structures, and equipment, which led to many injuries, fatalities, and great economic losses. (Kassem et al, 2019b, Online News for North Cyprus, 2020). As a result, severe adverse effects of climate change in a variety of industries and sectors should be anticipated in the future (Zachariadis, 2012), serious negative effects of climate change should be expected in the coming decades and therefore, the consideration of wind loads in the design of any type of structure has become more important (Reşatoğlu et al., 2018, Zachariadis, 2012).

According to data on human and financial losses, windstorms are among the disasters that cause the most financial harm, as the following figures illustrate (Reşatoğlu et al., 2018).

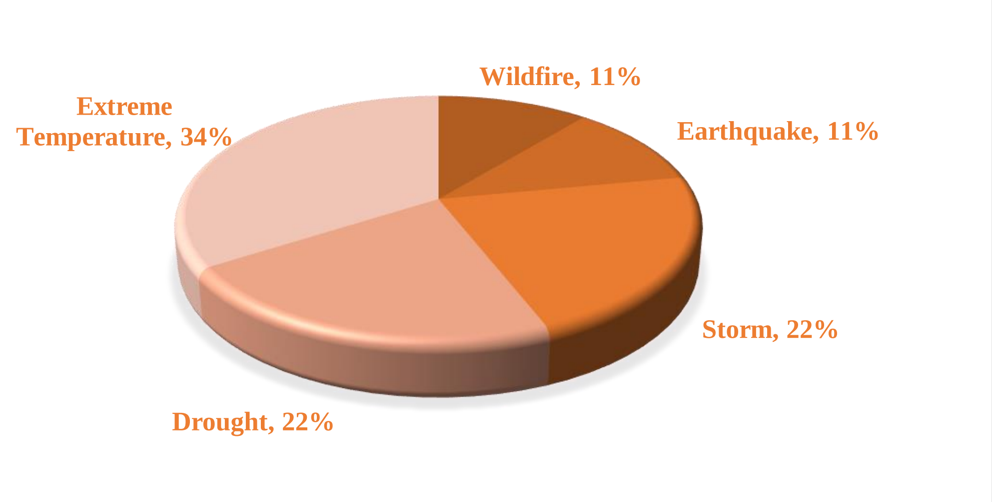

Figure 1. Disaster frequency due to disasters between 1990 and 2014 in Cyprus (Reşatoğlu et al., 2018).

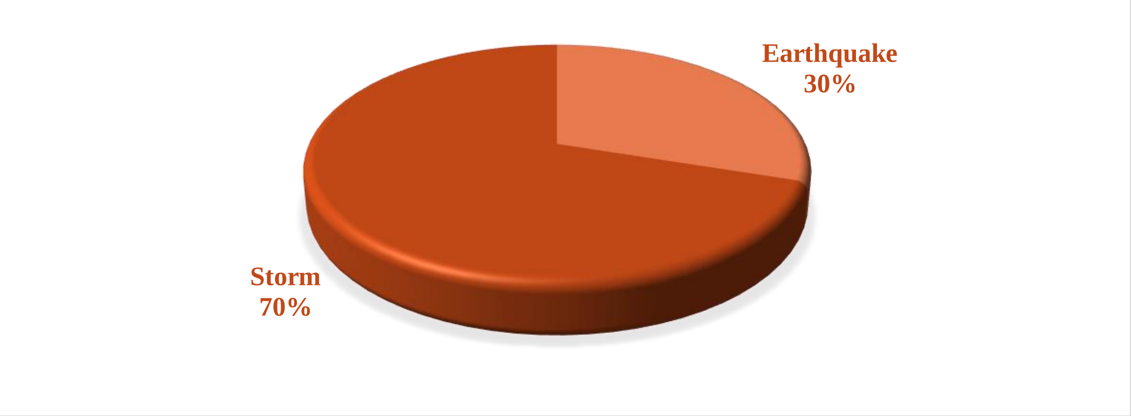

Figure 2. Economic damage frequency due to disasters between 1990 and 2014 in Cyprus (Reşatoğlu et al., 2018).

The objective of the work

PV panel mounting systems, especially those installed on roofs, are exposed to strong winds that can cause partial or total loss of the PV panel arrays, possible damage to adjacent facilities, human and financial losses, electricity shortages, power outages, and damage to other buildings (Naeiji et al, 2017). Therefore, trustworthy data and proper wind load assessment on PV panel mounting systems are essential for the safe, efficient, and economical design of mounting systems (Moravej et al, 2015). Based on the recent works, the turbulence in the atmospheric boundary layer, surrounding conditions, and installation-related parameters, such as tilt angle, array spacing, panel size, and position all have an impact on the wind acting on PV panels (Li et al, 2022)

According to KIB-TEK (Turkish Electricity Authority of Cyprus), the number of PV panels installed in Northern Cyprus climbed by 855% between 2014 and 2020, and the tendency to install PV panels is growing daily. But ensuring the safety of the panels and residents throughout different conditions is a crucial issue.

In this study, wind loads on flat roof-mounted PV panels are calculated using two different loading standards; ASCE 7-16 (American Society of Civil Engineers, 2017) and TS498 (Turkish standard,1997), while the effects of span length and building height on wind loads are evaluated. Considered variables are illustrated in Figure 3.

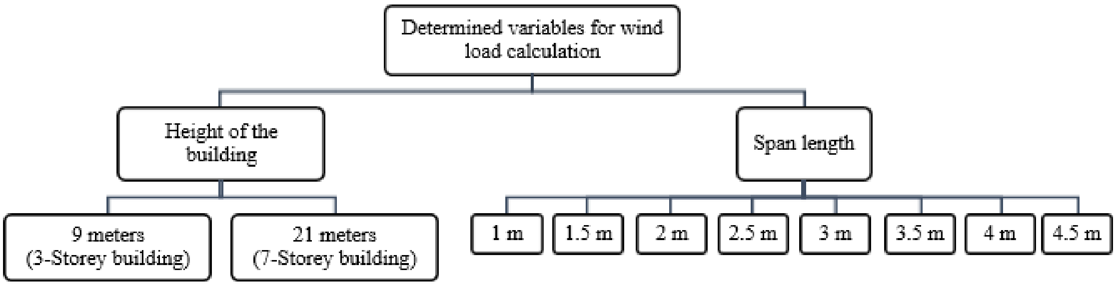

Figure 3. Determined variables for wind load calculation (Author)

On the other side, mounting systems of PV panels are designed and analyzed for installation on flat roofs in Nicosia, North Cyprus, while different parameters are taken into the account such as the height of the building, span length, column arrangement, load resisting system, and the number of panels. The load analysis and structural design are done according to the related structural standards, the appropriate tilt angle of panels, aesthetics, landscape, and weather condition of the study area. The procedures given in ASCE 7-16 are used to calculate the loads, and AISC 360-16 (Specification for Structural Steel Buildings) is followed for designing the steel structure.

The findings of the study identify the optimum mounting systems of PV panels on flat roofs in the study area based on the number and size of PV panels, the best tilt angle for PV panels according to geographical conditions, aesthetics, structural standards, the weight of the mounting systems, and cost analysis.

Methodology

Selected codes

In this study, the methods presented in two different standards are used to calculate wind loads in rooftop PV panel installation systems. TS498 is widely used in Northern Cyprus for load calculations on various structures, and ASCE 7-16 provides load calculations and load combinations for the design of different types of structures, especially rooftop PV panels. Wind loads have been calculated using these two standards by considering two different wind directions, which are shown in figure 4. The wind blows in the + X direction, creating uplift loads on PV panels, hence it is known as uplift wind load and the wind blows in the -X direction, creating downward loads on PV panels, hence it is known as downward wind load.

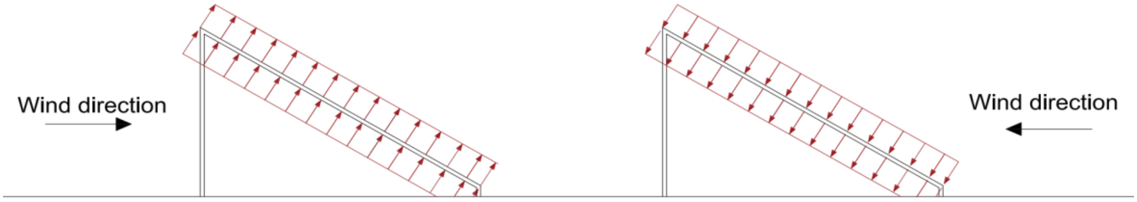

Figure 4. Uplift and downward wind load on PV panels (Author)

Wind load calculations based on TS498

According to TS498, the wind load on various structures depends on wind affected area, net wind pressure which relies on the height from the ground, and aerodynamic load factor which relies on geometrical properties and structural conditions. According to this standard, the magnitude of the wind load is calculated with the following equation.

$$W = C_f q A$$

Where W is Wind load resultant magnitude (kN), Cf is aerodynamic load factor, $q\ is$ net wind pressure ($\frac{kN}{m^2}$) and A is the affected area (m2).

Net wind pressure (q) can be calculated with the following equation.

$$q = \frac{\rho v^2}{2g}$$

Where ρ is an air density (1.25 kg/m3), ν is the wind velocity and given by the standard for different heights. In addition, the standard has provided a table and net wind pressure (q) can be obtained considering the height of the structure from the ground.

The aerodynamic load factor (C_f) depends on the geometrical properties and tilt angle of the desired surface and the condition of the area where the building is located, which is obtained from tables provided in the standard.

Wind load calculations based on ASCE 7-16

According to ASCE 7-16, the wind load on the rooftop PV panels mounting system is calculated by considering the risk category for rooftop structures and rooftop equipment, determination of the basic wind speed for the applicable risk category, determination of wind load parameters, including wind directionality factor (K_d) , exposure category (A, B, C, or D), topographic factor (K_{zt}), and ground elevation factor (K_e), velocity pressure exposure coefficient (K_z) . Based on this standard, velocity pressure (q_z) is determined by the following formula.

$$q_z = 0.613 K_z K_{zt} K_d K_e V^2$$

The net pressure coefficient for rooftop PV panels (GC_{rn}) is determined using the parapet height factor (γ_p), panel chord factor (γ_c), array edge factor (γ_E) , and nominal net pressure coefficient $(GC_{rn})_{nom}$ for rooftop PV panels which is determined using the normalized building length (L_b), Characteristics of the building include mean roof height of a building, width and length of a building, and normalized wind area for rooftop PV panels (A_n), and the effective wind area (A).The net pressure coefficient for rooftop PV panels (GC_{rn}) is calculated using the following formula:

$$(GC_{rn}) = \gamma_p \gamma_c \gamma_E (GC_{rn})_{nom}$$

The wind pressure for rooftop PV panels is calculated by using the following equation.

$$p = q_z(GC_{rn})$$

Modeling of PV panels and variables

Two different types of flat-roofed residential buildings with the same available roof area (10m × 20m) but two different orientations to the north have been considered and rooftop PV panel mounting systems are designed to be installed on the roof of these buildings (Figure 5).

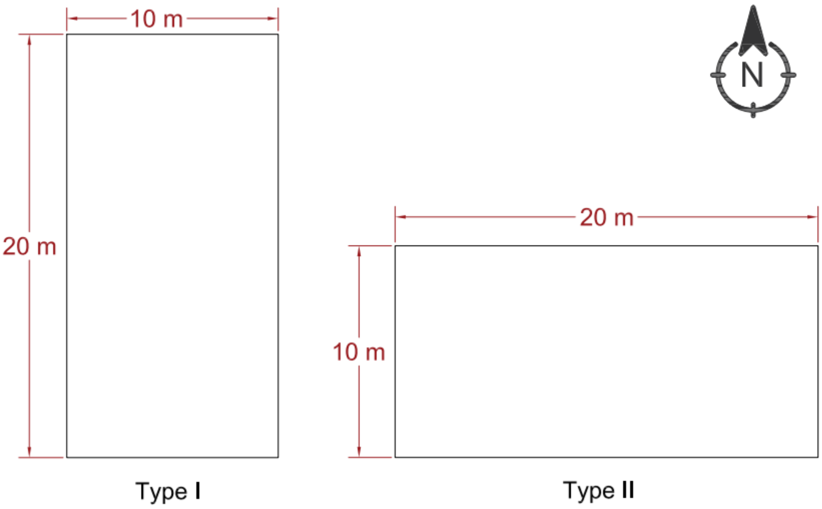

Figure 5. Plan view of the orientation of buildings to the north (Author)

PV panel arrays are installed at a distance of at least 1 meter from the edge of the roof for aesthetic reasons and to facilitate access. PV panels in the Northern hemisphere should face south, and the proper slope angle for PV panels in this area (Nicosia, Northern Cyprus) is 31-32 degrees based on the Nicosia standards for rooftop PV panels. In addition, an appropriate distance must be provided between the panel arrays to prevent the shadows of the panels on each other. The calculations for the distance between the arrays are as follows:

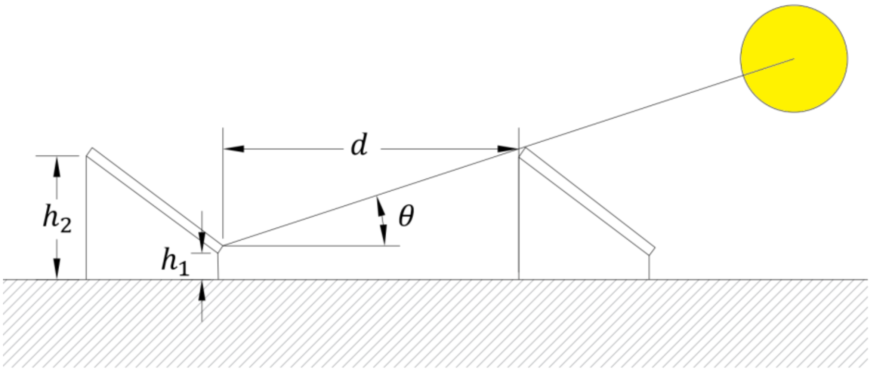

Figure 6. The distance between the arrays of PV panels (Author)

$$d = \frac{h_2 - h_1}{tan\theta}$$

Where is the shortest side of the installation system, h_2 is the highest side of the installation system, θ is the solar elevation angle and d is the distance between two arrays.

Afterward, the optimal mounting system is determined based on the weight of the mounting system, the cost of the mounting system, and aesthetics.

- ✓ **Type I**

56 PV panels (7 rows of 8 panels) can be installed on the roof of residential building Type I (Figure 5). 32 mounting systems are designed to support 56 panels on the roof of this type of building by considering the following variables.

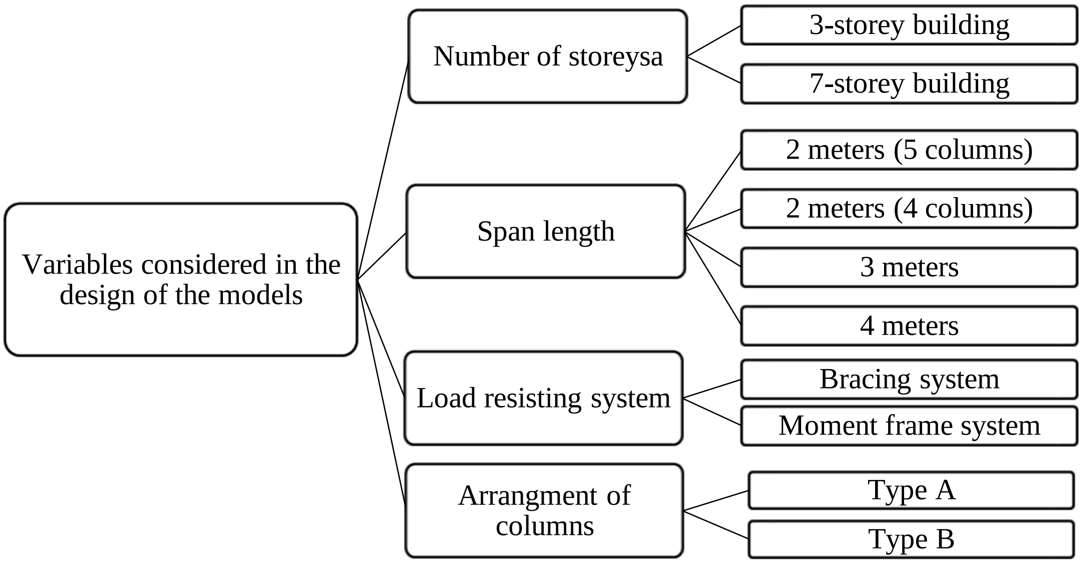

Figure 7. Variables considered in the design of mounting systems for (Type I) buildings (Author)

Type A and Type B of column arrangements are shown in figure 8.

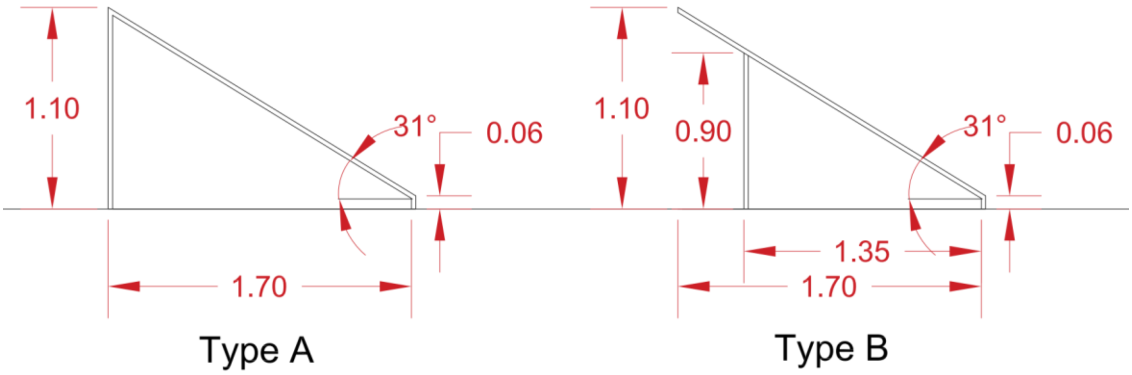

Figure 8. Section view of the arrangement of columns: Type A and Type B (Author)

The span lengths and column arrangements for these models are shown below:

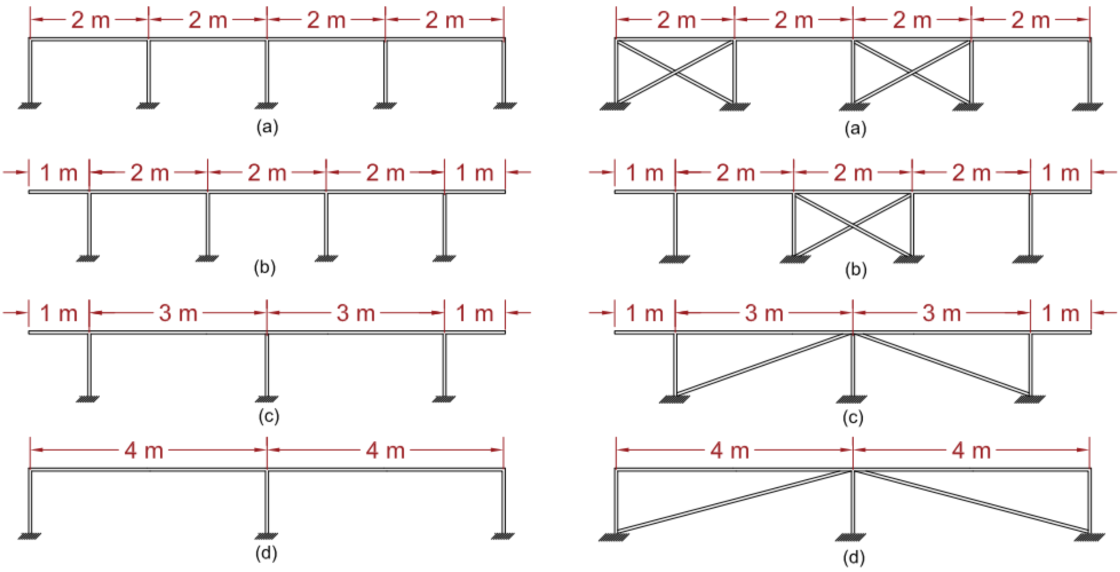

Figure 9. *Span lengths and column arrangements for (Type I) building, (a) 2 meters (5 columns), (b) 2 meters (4 columns), (c) 3 meters, (d) 4 meters (Author)*

✓ **Type II**

54 PV panels (3 rows of 18 panels) can be installed on the roof of structure Type II. 32 mounting systems are designed to support 54 panels on the roof of this type of building by considering the variables below.

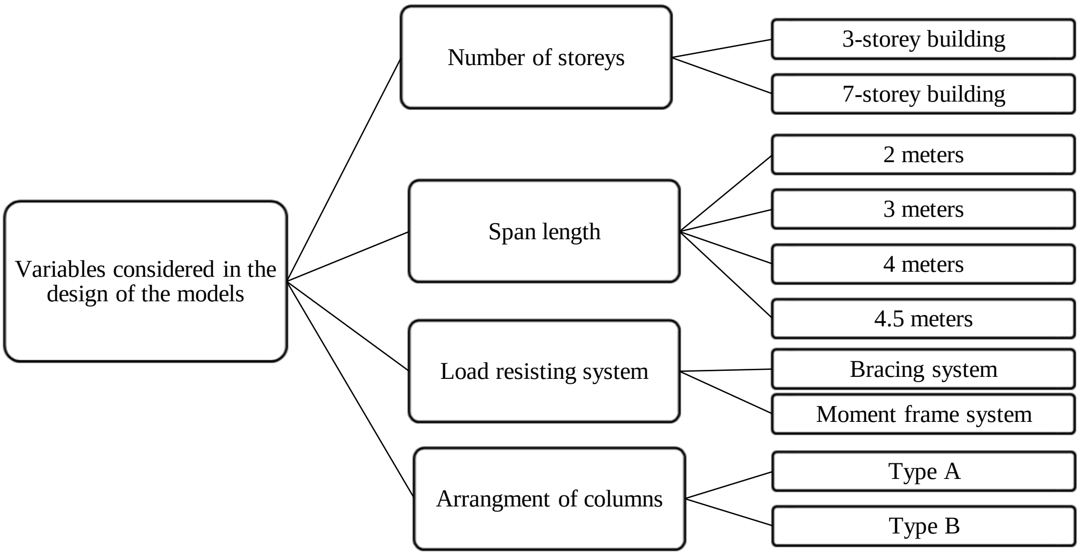

Figure 90. Variables considered for the design of mounting systems for Type II buildings (Author)

The span lengths and column arrangements for these models are shown below:

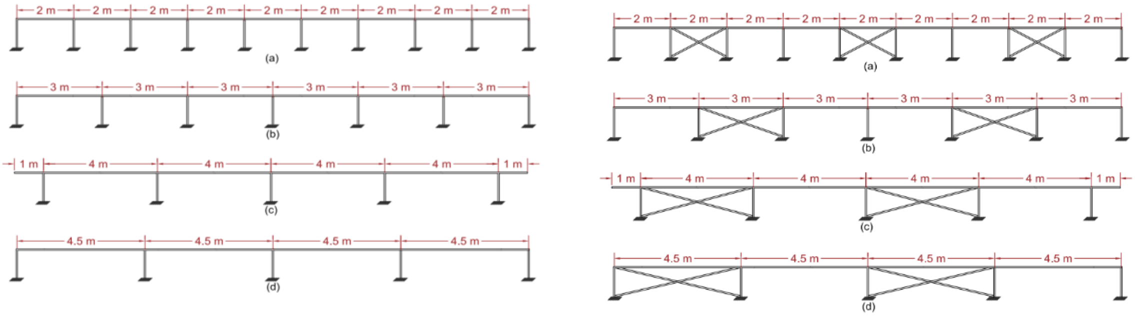

Figure 101. *Span lengths and column arrangements for building (Type II), (a) 2 meters, (b) 3 meters, (c) 4 meters, (d) 4.5 meters (Author)*

Material Properties

ST37-2 is selected for this study.

Load Combinations

37 load combinations are used in the design of the mounting systems of PV panels and developed in accordance with ASCE 7-16, including dead load, wind loads in two directions, seismic loads in two directions, 5% eccentricity in two directions, and 30% orthogonal load (applied at zero eccentricity) in two directions.

Results and Discussion

Wind loads calculations

The calculated wind loads based on mentioned standards and variables are presented in the following tables.

Table 1.
Wind loads based on TS498 (Author)

Span length	**Wind load direction**	**Number of storeys** **3-storey building**	 **7-storey building**
For all span lengths	Uplift loads (N/m)	313	430
	Downward loads (N/m)	499	685

Table 2.
Wind loads based on ASCE 7-16 (Author)

Span length (m)	Wind load direction	Number of storeys 3-storey building	 7-storey building
1	Uplift loads (N/m)	889	1463
	Downward loads (N/m)	592	975
1.5	Uplift loads (N/m)	741	1217
	Downward loads (N/m)	497	809
2	Uplift loads (N/m)	713	1153
	Downward loads (N/m)	478	769
2.5	Uplift loads (N/m)	691	1091
	Downward loads (N/m)	461	729
3	Uplift loads (N/m)	663	1061
	Downward loads (N/m)	442	706
3.5	Uplift loads (N/m)	641	985
	Downward loads (N/m)	428	657
4	Uplift loads (N/m)	591	935
	Downward loads (N/m)	392	625
4.5	Uplift loads (N/m)	542	901
	Downward loads (N/m)	361	602

According to ASCE 7-16, wind loads that rooftop PV panels can withstand depends on a number of factors that can be divided into four categories; geographical condition, surrounding condition, installation location, and mounting system characteristics (e.g. building risk category, basic wind speed in the area, type of structure, exposure category of the area, topographic condition of the area, ground elevation above sea level in desire area, the height of the building, height of the PV panel at the top and bottom edge of the arrays, height of parapet, panel size, length and width of the building, the title angle of PV panels, shape, dimensions and arrangement of PV panel arrays, and distance between the mounting system and the edge of the roof). While according to TS498, the wind load on various structures depends on wind affected area, net wind pressure which relies on the height from the ground, and aerodynamic load factor which relies on geometrical properties and structural conditions.

Considering different parameters and effects of different geometrical characteristics provides large differences between the results obtained based on each of these standards. In the following figures, the uplift and downward wind loads for 7-storey buildings based on TS498 and ASCE7-16 have been shown.

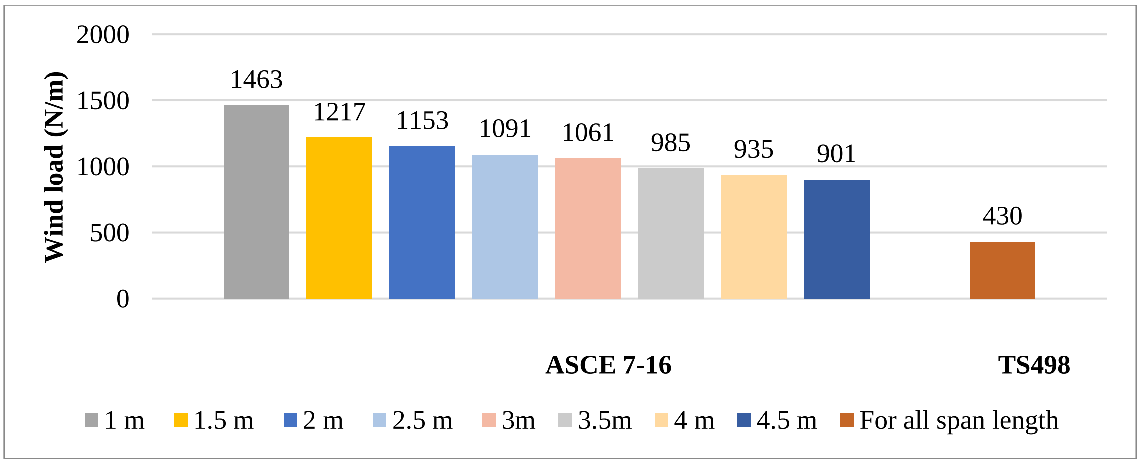

Figure 112. Uplift wind load (7-Storey buildings) (Author)

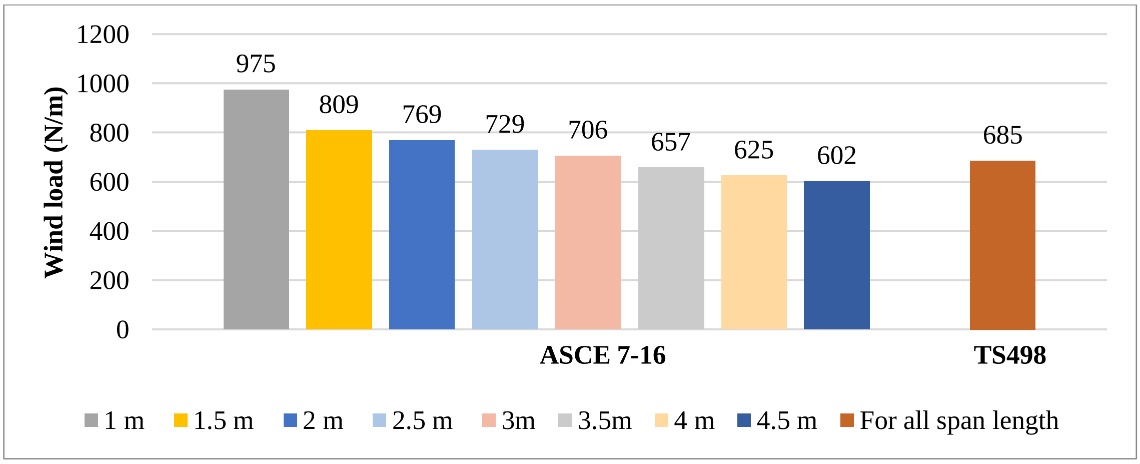

Figure 13. Downward wind load (7-Storey buildings) (Author)

- A comparison between the two standards shows that while TS498 provides equal wind loads for all span lengths of mounting systems, span length is an effective parameter in calculating wind load based on ASCE 7-16.
- The downward wind load on PV panels is significantly less than the uplift load for each building height in accordance with ASCE7-16. In addition, increasing the span length increases the effective wind area, and increasing the effective wind area reduces the nominal net pressure coefficient and thus reduces the wind load. Therefore, wind load decreases with increasing the span length of mounting systems based on ASCE 7-16.
- According to TS498, the downward wind load on PV panels is significantly greater

than the uplift load for any building height, but according to ASCE 7-16, the downward wind load on PV panels is significantly less than the uplift load for any building height and span length.

- Load calculations based on TS498 offer smaller uplift wind loads than ASCE 7-16, while downward wind loads calculated based on TS498 are in the range of ASCE 7-16.
- Mounting systems that support PV panels are often lightweight structures, therefore wind loads can greatly affect them. On the other hand, since PV panel mounting systems have no walls or barriers, winds can easily create uplift loads on the systems and have significant effects on them. TS498 does not provide specialized wind load calculations for rooftop PV panel mounting systems, and wind loads are calculated with the same variables and the same approach on different buildings, including residential, commercial, industrial, and other structures. Therefore, wind loads on rooftop PV panel mounting systems are calculated the same as wind loads for closed structures such as residential buildings, where the uplift wind load is low. As a result, the downward wind load is greater than the uplift wind load when wind loads on the PV panel mounting system are calculated according to this standard. But, ASCE 7-16 provides wind loads on various structures using a variety of approaches and parameters and specifically provides wind load calculation methods for rooftop PV panel mounting systems, therefore the effect of the uplift wind load is well considered in this standard.

Since Cyprus is in the climate change hotspot and the financial losses brought on by wind are significant, it is recommended that ASCE 7-16 be used to calculate the load on rooftop PV systems. This is because ASCE 7-16 appears to be more reliable with regard to the considered parameters and the proposed method for calculating wind load on rooftop PV panels. It is also feasible to develop a loading standard for the loads acting on solar panels in accordance with the conditions in Cyprus, so that the relevant companies may use it to estimate the wind load on the PV panels and design safety mounting systems for PV panels.

Modeling of mounting systems

Deflection of the beams in mounting systems is highly important due to possible damage to PV panels and the destruction of PV cells. There is a strong relationship between wind load and building height. Increasing the number of storeys, increases both uplift wind loads and downward wind loads in accordance with ASCE 7-16. On the other hand, the Type B arrangement of columns decreases the required materials by 4% to 7%, but when all other parameters are fixed, models with Type A columns arrangement experience less beam deflection than Type B columns arrangement. In addition, increasing the span length increases the effects of column arrangement on the deflection.

It should be noted that increasing the span length affects the effective wind area and reduces the wind load based on ASCE 7-16. Thus, although wind loads decrease by increasing the span length, increasing the span length ultimately increases the deflection of the beams. While all parameters are the same, the mounting systems designed using the moment frame system experience less beam deflection than mounting systems designed using the bracing system, especially in larger span lengths.

Weight of the mounting system

The weight of the rooftop mounting systems of PV panels is of particular importance because these mounting systems are usually installed on the roofs of buildings that have already been constructed and the loads associated with these panels have not been included in the design of the building. As a result, designing a safe and lightweight mounting system is preferred. The weight of each mounting system with different span lengths, different building heights, and different load-resisting systems is shown in the following figures.

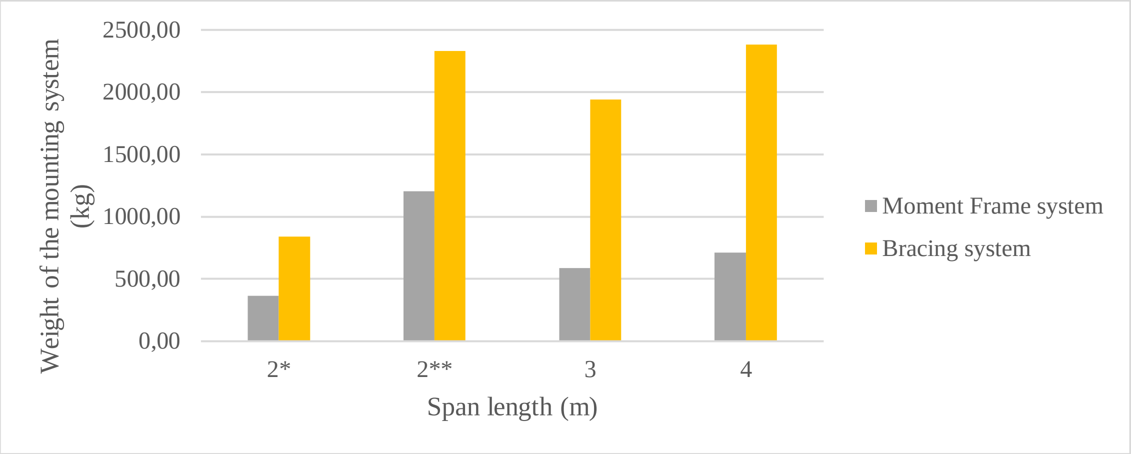

Figure 124. Weight of the mounting system vs. span length (7- storey building/ Type I) (Author)

2*: Mounting system with 2-meter span length and 5 columns
2**: Mounting system with 2-meter span length and 4 columns

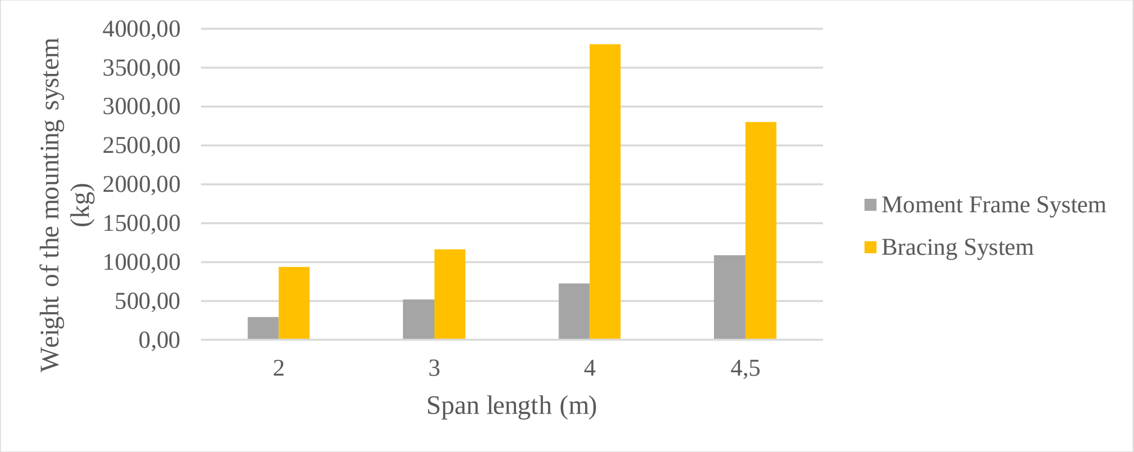

Figure 135. Weight of the mounting system vs. span length (7- storey building/ Type II) (Author)

According to the above figures, the following results can be found:

- Using the moment frame system reduces the weight of the entire mounting system compared to the bracing system.
- Increasing the span length reduces the number of columns, but larger steel frame sections are needed to control the deflection of the mounting system, resulting in an increase in the weight of the entire mounting system.
- Although the use of overhanging beams reduces the number of columns, the section size increase, and the weight of the entire mounting system increases.

Cost analysis

The cost of various steel profiles was collected from the Northern Cyprus market for this study. Profiles with a length of 6 meters are sold and the costs are related to 6-meter profiles. Therefore, the number of profiles used for each type of mounting system is calculated, and then the cost of materials is calculated by considering the number of profiles.

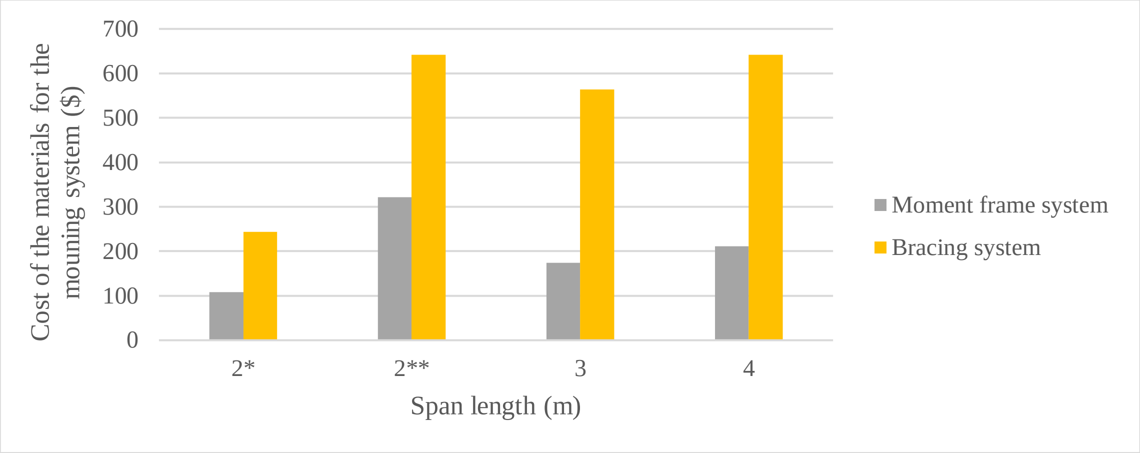

Figure 16. Cost vs. span length (7-storey building/ Type I) (Author)

2*: Mounting system with 2-meter span length and 5 columns
2**: Mounting system with 2-meter span length and 4 columns

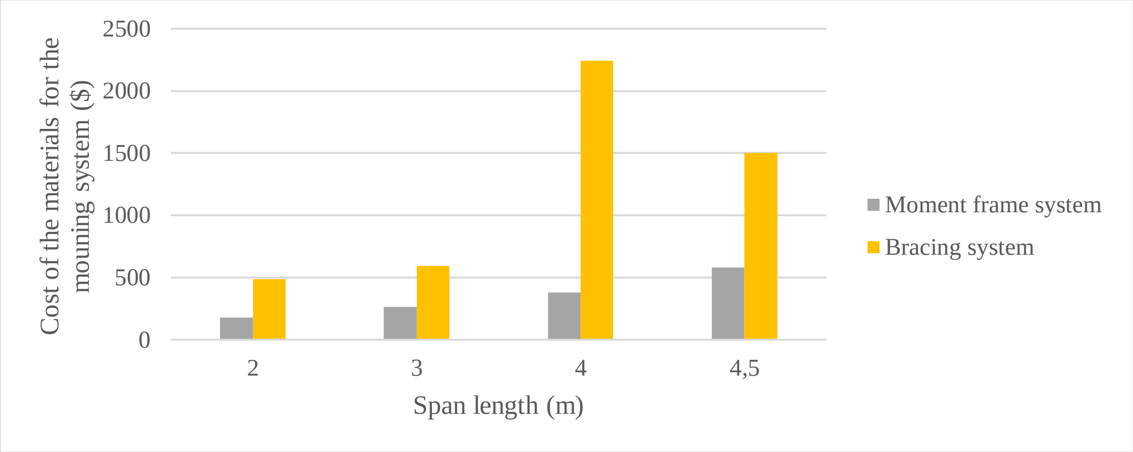

Figure 17. Cost vs. span length (7-storey building/ Type II) (Author)

According to the above figures, the following results can be found:

- When all the parameters are constant, designing the mounting system using the moment frame system is more cost-effective than using the bracing system.
- Increasing the span length reduces the number of columns and the entire length of the material, but due to controlling the deflection of the mounting system, the steel frame section size increases, which results in increasing the cost of the material.
- Although the use of overhanging beams reduces the number of columns, the size of the steel frame section increases, and with increasing steel frame section size, the cost of sections increases significantly.

Aesthetics

PV panel mounting systems are usually installed on the roofs of buildings that have already been constructed and therefore they are usually inconsistent with the architecture of the building, destroying the harmony of the façade, and affecting the aesthetics of the surrounding area. Thus, it is important to minimize the negative impact of rooftop PV panels on the aesthetics of the building and its surroundings.

First, minimize the visibility of the mounting system by placing at least 1 meter between the mounting system and the edge of the roof. Second, control the height of the mounting system and avoid using tall mounting systems. Third, minimize the number of columns and structural elements that result in reducing visual pollution.

In this study, a distance of 1 meter between the mounting system and the edge of the roof is considered. On the other hand, the height of mounting systems is 1.1 meters, which is the highest allowable height of rooftop mounting systems according to Nicosia standards for rooftop PV panels. In addition, it should be noted that mounting systems designed by using moment frame systems are preferred, because there is no bracing and the number of elements and visual pollution reduces, on the other hand, reducing the number of columns is desirable.

Conclusions

Solar panels, especially those installed on the roof, are subjected to a variety of loads throughout their service life, just like any other structure. Ignoring the loads on the mounting systems leads to improper design, which ultimately increases the risk of damage to the mounting systems and PV panels.

Wind loads on rooftop PV panels were calculated based on two different standards; TS498 and ASCE 7-16 in this study. The results show that since ASCE 7-16 specifically provides wind loads on PV panels, especially rooftop-mounted PV panels, the considered variables are accurate and the loads calculated according to this standard seem more reliable. Based on the results of ASCE 7-16 wind load calculations, uplift wind loads on PV panel mounting systems are 50% greater than downward wind loads, which have remarkable effects on the design of rooftop mounting systems.

The effects of all parameters on the deflection of the beams of the mounting system, the cost and weight of the mounting systems, and the aesthetics of the building have been studied, evaluated, and compared. According to the findings of this study:

- Mounting systems designed with a moment frame system outperform those developed with a brace system in terms of beam deflection, size of steel frame sections, weight and cost of the complete mounting system, and aesthetics,
- Placing columns in the corner of the mounting system (Type A of column arrangement) provides better support for the beams, which reduces the deflection of the beams.
- Avoiding overhanging beams leads to a reduction in deflection of the beams and the steel frame sections, cost, and structure weight of the mounting system.
- Beam span length should be proportional to the weight and cost of the structure. In fact, although the number of columns decreases with increasing beam span lengths, a larger steel frame section is required to control the deflection of the beams, which eventually leads to an increase in the cost and weight of the mounting system. In other words, increasing the span length of the beams and reducing the number of columns reduce the length of the desired material, but require larger steel frame sections, which results in heavier and costlier mounting systems.
- The appearance of mounting systems, particularly those installed in urban areas and on building roofs, is critical and special considerations must be made to maintain and ensure the aesthetics of buildings and their surroundings. Thus, it is preferable to use a moment frame system and reduce the number of columns from an aesthetic point of view, while a distance of 1 meter between the mounting system and the edge of the roof and the allowable height of the mounting system is considered.

In light of the findings, optimal installation structures can be developed to limit damage to PV panels, mounting systems, and roofs as a result of natural disasters. Furthermore, the findings of the study have beneficial effects on reducing the negative effects of mounting systems on buildings and urban environments, improving PV panel performance, and increasing the willingness of residents to use PV panels.

Although the generation of power by using PV panels minimizes the reliance on non-renewable resources, contributes to the production of clean energy, and has fewer negative environmental consequences, considerations must be made to ensure system efficiency and optimal performance, maintain the system and individual safety, prevent financial losses, and limit the side effects.

Bibliographic references

Agencies, D. S. W. (2020, November 21). Tornadoes hit northern parts of Turkish Cyprus, Damage Power Grid. Daily Sabah. Retrieved May 10, 2022, from https://www.dailysabah.com/turkey/tornadoes-hit-northern-parts-of-turkish-cyprus-damage-power-grid/news

American Society of Civil Engineers (2017) Minimum Design Loads for Building and Other Structures ASCE/SEI 7-16. Reston, VA, USA: American Society of Civil Engineers. ISBN 9780784479964

Barcikowska, M. J., Kapnick, S. B., Krishnamurty, L., Russo, S., Cherchi, A., & Folland, C. K. (2020) Changes in the future summer Mediterranean climate: contribution of teleconnections and local factors. Earth Syst. Dynam., 11, 161–181, https://doi.org/10.5194/esd-11-161-2020

Deryng, D., Conway, D., Ramankutty, N., Price, J., & Warren, R. (2014) Global crop yield response to extreme heat stress under multiple climate change futures. Environ. Res. Lett., 9, 034011, https://doi.org/10.1088/1748-9326/9/3/034011

Fan, X., Miao, C., Duan, Q., Shen, C., & Wu, Y. (2021). Future climate change hotspots under different 21st century warming scenarios. Earth's Future, 9(6), e2021EF002027.

Ferrarezi, R. S., Rodriguez, K., & Sharp, D. (2019) How historical trends in Florida all-citrus production correlate with devastating hurricane and freeze events, Weather, 75, 77–83, https://doi.org/10.1002/wea.3512

Grechkina, O., Kornyushkina, A., Naruzhnaya, E., Tonkov, E., & Turanin, V. (2019). El lenguaje jurídico como medio de comunicación intelectual y jurídico. Revista Científica Del Amazonas, 2(3), 32-38. Recuperado a partir de https://revistadelamazonas.info/index.php/amazonas/article/view/15

Giorgi, F. (2006). Climate change hot-spots. Geophysical Research Letters, 33(8), L08707. https://doi.org/10.1029/2006gl025734

Hochman, A., Marra, F., Messori, G., Pinto, J. G., Raveh-Rubin, S., Yosef, Y., & Zittis, G. (2022). Extreme weather and societal impacts in the eastern Mediterranean. Earth System Dynamics, 13(2), 749-777.

Kassem, Y., Al Zoubi, R., & Gökçekuş, H. (2019a). The possibility of generating electricity using small-scale wind turbines and solar photovoltaic systems for households in Northern Cyprus: a comparative study. Environments, 6(4), 47.

Kassem, Y., Gökçekuş, H., & Güvensoy, A. (2019b). Solar Potential assessment in Near East University, Northern Cyprus. Int. J. Eng. Res. Technol, 12, 3061-3069.

Li, S., Mao, D., Li, S., Wang, Q., Yang, Q., Chen, Y., & Zhou, S. (2022). Wind load characteristics of photovoltaic panel arrays mounted on flat roof. Engineering Research Express, 4(1), 015027.

Moravej, M., Chowdhury, A. G., Irwin, P., Zisis, I., & Bitsuamlak, G. (2015). Dynamic effects of wind loading on photovoltaic systems. In 14th. International Conference on Wind Engineering (ICWE14), Porto Alegre, Brazil.

Naeiji, A., Raji, F., & Zisis, I. (2017). Wind loads on residential scale rooftop photovoltaic panels. Journal of Wind Engineering and Industrial Aerodynamics, 168, 228-246.

Online News for North Cyprus. (2020, November 22). Emergency meeting held to address storm damage. North Cyprus News. Retrieved May 10, 2022, from https://www.lgcnews.com/emergency-meeting-held-to-address-storm-damage/

Okoye, C. O., & Abbasoğlu, S. (2013). Empirical investigation of fixed and dual axis Sun tracking photovoltaic system installations in Turkish Republic of Northern Cyprus. Journal of Asian Scientific Research, 3(5), 440-453.

Özşahin, E. (2012) “Storm risk sensitivity analysis in cyprus using GIS,” Journal of Turkish Studies, Volume 7 Issue 4-II (7), pp. 2627–2642. Available at: https://doi.org/10.7827/turkishstudies.3882

Reşatoğlu, R., Mirata, T., & Karaker, L. (2018). Earthquake and wind load effects on existing RC minarets in north Cyprus. International Journal of Engineering & Technology, 7(4), 3074-308523

Sauca, A. C., Milchiş, T., & Gobesz, F. Z. (2019). Wind loading on solar panels. Technical Scientific Publications [Műszaki Tudományos Közlemények], 10(1), 73-78.

Sioutas, M., Doe, R., Michaelides, S., Christodoulou, M., & Robins, R (2006). “Mete orological Conditions Contributing to the Development of Severe Tornadoes in Southern Cyprus”. Weather, 61(1), pp 10-16,

Turkish Standard (1997). Turkish Standard Institute, The Calculation Values of Loads used in Designing Structural Elements. Ankara, Turkey.

T-Vine (2020, November 20). Freak weather, including a tornado, inflicts widespread damage across North Cyprus. Retrieved May 10, 2022, from http://www.t-vine.com/freak-weather-including-a-tornado-inflicts-widespread-damage-across-north-cyprus/

WEC resources solar (2013), JJ1264 - world energy council. (n.d.). Retrieved May 10, 2022. https://www.worldenergy.org/assets/images/imported/2013/10/WER_2013_8_Solar_revised.pdf

Zachariadis, T. (2012). Climate change in Cyprus: Impacts and adaptation policies. Cyprus Economic Policy Review, 6(1), pp. 21-37