COMPUTATIONAL FLUID DYNAMIC ANALYSIS OF WIND LOADS ACTING ON GROUND MOUNTED SOLAR PANELS

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COMPUTATIONAL FLUID DYNAMIC ANALYSIS OF WIND LOADS ACTING ON GROUND MOUNTED SOLAR PANELS

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ABSTRACT

COMPUTATIONAL FLUID DYNAMIC ANALYSIS OF WIND LOADS ACTING ON GROUND MOUNTED SOLAR PANELS

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Solar energy becomes more important day by day as a result of being part of renewable energy and increasing energy consumption. Although development of photovoltaic panels is enjoying the attention of many researchers, there has not been enough study towards determination of the loads acting on supporting structures of these systems yet. In this thesis, CFD analysis is mainly employed in order to model, analyze and understand the effects of the wind forces acting on solar panels. Also, different from previous studies in this field, this study is more focused on the consecutive placement of ground mounted solar panels and realizing the importance of the sheltering effect. Wind tunnel testing is used to verify the numerical analysis. Moreover, CFD analysis and experiments available in the literature are considered for verification of the method employed in the analyses carried out in the thesis. Steady state SST k-ω turbulence model is considered in CFD analysis. Both 2D and 3D analyses are carried out, and it is observed that for the case of solar panel arrangements considered in this thesis, 2D analyses provides accurate results with robust modelling and solution in terms of computation time. Thus, 2D analyses approach is undertaken in the parametric analyses presented in the later part of the thesis, where sheltering effect in solar farms is investigated by considering 10 rows of panels. Parametric analyses are performed for both forward and reverse wind flows by considering panel length, clear height from the ground, spacing between 2 consecutive solar panels and tilt angle (inclination) as variables.

Keywords: Solar panels, wind loads, sheltering effect, computational fluid dynamic analysis

ÖZ

ZEMİNE MONTE GÜNEŞ PANELLERİNE ETKİYEN RÜZGAR YÜKLERİNİN SAYISAL AKIŞKANLAR DİNAMİĞİ İLE ANALİZİ

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Güneş enerjisi, yenilenebilir enerjinin bir parçası olması ve gün geçtikçe artan enerji tüketimi sebebiyle önemini sürekli arttırmaktadır. Her ne kadar kullanılacak fotovoltaik hücrelerin geliştirilmesi bir çok araştırmacının dikkatini çeken bir konu haline gelse de, güneş panellerinin destek yapıları hakkında yapılmış çalışmalar hala çok sınırlı sayıdadır. Bu çalışmada, güneş panellerine etkiyen en önemli yük olan rüzgar yükü incelenmiştir. Rüzgarın etkilerini bulma amacıyla, sayısal akışkanlar dinamiği analizleri yürütülerek etki eden rüzgar kuvvetleri incelenmiştir. Bundan önceki yapılmış çalışmalardan farklı olarak bu çalışmada arka arkaya sıralanmış güneş panelleri ve arka arkaya yerleştirilme sonucunda ortaya çıkarak önemli etkileri bulunan siper etkisi üzerinde durulmuştur. Yürütülen sayısal çalışmaları desteklemek amacıyla rüzgar tüneli deneyleri gerçekleştirilmiştir. Diğer taraftan literatürde sunulan çalışmalar da tezin kapsamı içinde yürütülen sayısal çalışmaların doğrulanması için kullanılmıştır. Sürekli durumlu SST k-ω türbülans sayısal modeli ile analizler gerçekleştirilmiştir. Doğrulama çalışmalarında kullanılan 3 boyutlu ve 2 boyutlu sayısal modellerin karşılaştırılması sonrasında benzer sonuçların elde edilmesinden dolayı, analizlerin hızını arttırmak amacıyla tezin devamında ardarda yerleştirilen panellerde oluşan siper etkisinin incelenmesi kısmında 2 boyutlu modellemelerle devam edilmiştir. Bu etkilerin bulunması amacıyla 10 panel ardarda yerleştirilmiş, normal ve ters rüzgar akışlarına ek olarak, farklı panel uzunluğu, yerden yükseklik, arka arkaya konan iki güneş paneli arasındaki mesafe ve panellerin eğimleri değişkenler olarak dikkate alınarak parametrik analizler yürütülmüştür.

Anahtar kelimeler: Güneş paneli, rüzgar kuvveti, siper etkisi, hesaplamalı akışkanlar dinamiği analizi

To My Family…

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CHAPTER 1

INTRODUCTION

1.1. General

Alternative energy sources have been promoted due to the diminishing resources, rising costs and sustainability concerns faced by carbon based fossil fuels. Nuclear power and hydropower have received great attention in 20th century besides fossil fuels, and 21st century is witnessing the rising awareness and need for the development and use of renewable energy sources. Wind energy and solar energy are in this regards the most promising renewable energy sources that receive significant amount of research and development. These energy sources are considered to be safe and much less harmful to the environment. Once the construction of a wind farm or solar farm is completed, the yearly operating costs are significantly lower compared to the other forms of energy production.

With regards to the technological developments on the solar energy front, the development of cheaper and energy efficient photovoltaic (PV) panels is the main emphasis. In the last decade, attention is also rising with regards to the safety of the solar panels that are ground mounted or placed on the roofs. There are now applications of ground mounted solar panels, called as solar farms, which are now under construction and expected to occupy more than 100 km^2 of land in only a single project. The enormous amount of land use and material use to support the safety of solar panels clearly requires attention, and researchers and engineers need to provide not only the safety of solar panels against potential environmental actions but also the optimal use of the supporting structures.

The structural supporting systems have smaller cost percentage relative the PV panels, yet the supporting system design for the solar panels should take into account all further risks in the first design stage and the supporting structure should be strong enough to protect the PV panels, thus allowing the panels to generate electricity throughout the service life without problems.

The most important load on the PV panels is found to be caused by the wind. Although the load calculations are in advanced level with regards to the wind forces acting on several engineering structures, wind loads acting on the solar panels and their effect on analysis and design of the steel supporting structures are still inadequate due to lack of experience and knowledge. Even though it is known that private companies have different analysis approaches, accuracy and reliability of their knowledge cannot be detected since their underlying fundamental assumptions and calculations with regards to the loads acting on solar panels are kept confidential, thus not available to the outside engineers and researchers.

In terms of consideration of wind loads in the design phase of a structure, ASCE 7-10 (ASCE, 2010) and Euro code 1 (CEN, 2004) sufficiently provide an estimation of wind loads acting on mono-slope free roofs and canopies. This type of a structure may represent a single ground mounted solar panel standing alone; however, there are no suggestions with regards to how the wind loads acting on consecutively placed solar panels in a solar farm can be calculated. In this regards, the use of wind tunnel experiments and the use of CFD analysis are the main approaches undertaken by solar energy companies.

With regards to the research efforts on the analysis of wind loads acting on solar panels, most of the studies focused on roof solar panels. Research studies on the determination of wind loads acting on ground mounted solar panels placed on open terrains have attracted small attention by the researchers. It is known that the wind flow is mainly blocked by the first row of the panels in solar farms; therefore the wind loads acting on the following rows of solar panels exhibit completely different trends. The reason for the change is due to the variations in the direction and speed of the wind after facing not only the first row of panels but as well as the following rows. Inclination of the panels, spacing between the panel rows, and clear distance of the panels from the ground, length of the panels, and the direction of the wind altogether influence the wind loads acting on the array of panels. Currently in the design guidelines, there are no suggestions with regards to how much the wind loads would be on a row of panels placed in a solar farm.

This thesis in this regards is attempting to provide a contribution in terms of analysis of wind loads acting on not only single placed ground mounted solar panels but also on solar panels that are placed consecutively in solar farms, where the emphasis will be the widely used flat-plate PV panels. Computational fluid dynamic (CFD) analysis by using ANSYS FLUENT (ANSYS Inc., 2011) is employed in order to model, analyze and understand the effects of the wind forces acting on solar panels. Wind tunnel testing is also carried out in order to present a verification of the numerical analysis. CFD analysis and experiments available in the literature are considered for further verification of the method employed in the analyses carried out both in 2D and 3D. Steady state SST k-ω turbulence model is used in CFD analysis. 2D CFD analysis approach is undertaken in the parametric analyses performed in the later part of the thesis, where sheltering effect is investigated with the placement of 10 consecutive panels. Parametric analyses are undertaken for both forward and reverse wind flows by considering panel length, clear height from the ground, spacing between 2 consecutive solar panels and tilt angle (inclination) as variables.

1.2. Organization of Thesis

This thesis contains eight chapters. The brief contents of these chapters besides the first chapter are summarized as follows:

In Chapter 2, literature survey on both experimental and numerical determination of wind loads acting on solar panels is presented.

In Chapter 3, details about the numerical analyses of fluid flow by computational fluid dynamic analysis (CFD) and the features of computational modelling of the wind and the solar panels is described through the use of ANSYS FLUENT CFD program.

In Chapter 4, comparison and verification studies of the numerical analysis results with available data in the literature are discussed. Analyses are carried out both in 2D and 3D, and the influence of supporting structures is discussed, as well.

In Chapter 5, wind tunnel test carried out as part of this thesis is presented. The results of the experiments are also verified by the use of CFD analysis method employed in this thesis.

In Chapter 6, a comparison study of the structural system design loads is undertaken between ASCE-07/10 (ASCE, 2010) specification and CFD analysis by using a single solar panel case. The wind loads for the solar panel is found according to ASCE-07/10 through the use of mono-slope free roof data available in that specification. These loads are compared with CFD analysis for both forward and reverse wind flow cases.

In Chapter 7, parametric analysis is carried out to study the sheltering effect on solar farms. 10 consecutive panels are analyzed for both forward and reverse wind flows by considering panel length, clear height from the ground, spacing between 2 consecutive solar panels and tilt angle (inclination) as variables, resulting in 360 analyses cases.

In Chapter 8, a brief summary of the studies undertaken within the scope of the thesis, conclusions obtained from the research study, and future research recommendations are discussed.

CHAPTER 2

BACKGROUND ON SOLAR PANELS AND WIND LOADS ACTING ON SOLAR PANELS

In this chapter, after the presentation of general information on solar panels, prior research studies carried out on the determination of wind loads acting on solar panels are given.

2.1. General Information on Solar Panels

There are different geometrical arrangements and configurations on how to place solar panels on a field. In this regard, two categories can be mentioned: 1) geometry of the solar panel, 2) configuration of solar panel arrays on solar farm.

In the first category, panels can be constructed to lie on a plane, i.e. placed flat, or they can be constructed to form a parabolic shape. Between these two options, flat-plate construction of solar panels is the most widely used one in practice. In the second category, solar panels are allowed to provide rotation either about an axis or point, where these two cases are demonstrated in Figure 2.1. The arrangement shown in Figure 2.1.a is the most widely used and practical choice in terms of constructing solar farms. In this configuration, the solar panels can be allowed to rotate about an axis to track the sunlight by the use of mechanical devices or they can be fixed against this rotation due to economic reasons or ground settlement problems that may alter the effectiveness of solar tracking system in the long run. As can be seen in Figure 2.1.b, the set of panels are stacked and supported on the ground by a single column. This configuration of solar panels is also named as heliostat, which includes mechanical movement devices with solar tracker system to track the sun about a point, thus allowing 360˚ rotation. In this configuration, the elevation of solar panels is higher compared to Figure 2.1.a, thus taking on higher wind speeds and since the surface area of the solar panels is larger per supporting column, these result in the necessity for construction of stiffer and stronger structural members and foundations. Furthermore, as a result of the use of solar tracking system and mechanical movement devices, heliostats eventually become expensive, as well.

Figure 2.1.a. Standard flat-plate solar panel placement

Figure 2.1.b. Solar panel configuration with solar tracker system (Heliostats)

In this thesis, the first configuration shown in Figure 2.1.a, i.e. flat-plate solar panels, is considered towards determination of wind loads. This configuration offers the most economical solution in terms of construction ease and land use, and equivalently results in optimal energy production throughout the service life of the panels.

2.2. Literature Review on Wind Loads Acting on Solar Panels

In order to carry out experimental or numerical research studies on wind loads, it is necessary to conduct a detailed work to consider the meteorological conditions, atmosphere and structure of earth where the uncertainties are very high (Holmes, 2001). The effects of wind loads on structures vary considering the following type of structural categories:

- Low-rise buildings

- High-rise buildings (individually and/or together with other structures)

- Large roof structures: stadiums, airports, etc...

- TV and radio towers, delicate structures such as chimneys

- Bridges

- Electric transmission lines

- Other structures: walls, roofs, new additions to the existing buildings, etc...

Each structure is unique with its shape, therefore the unique geometry results in varying effects of wind loads. Sometimes the determination of the wind loads gets harder with the involvement of the vibrations which requires difficult multi-physics analysis of the problem. American Society of Civil Engineers' Minimum Design Loads for Buildings and Other Structures document (ASCE, 2010) contains one of the most important and detailed wind load calculations for the structures listed above. Another one is published by the European Union, namely, Eurocode-1(CEN, 2004). Other than these named documents just above, many countries, institutions and even cities have additional regulations. In Turkey, TS498 (TSE, 1997) Design loads for buildings is used to determine the wind loads on the structures; however this regulation is claimed as inadequate in terms of covering the mentioned categories listed above. Although European and North American standards are prepared in a more detailed manner, nothing is available in these documents with respect to the determination of wind loads acting on panels placed in solar farms. The most suitable wind load case for a solar panel is found under the name of "open buildings/mono-slope free roofs" (ASCE, 2010). However, solar panels very much differ than a mono-slope roof not only in terms of geometrical shape, usage and cost of PV panels but also in terms of the consecutive and dense placement of these panels inside a solar farm. In determination of wind loads acting on panels, clear elevation from the ground, length and inclination of panels, spacing of the consecutively placed panels all influence the level of wind loads, as well as the direction of the wind as seen in Figure 2.2.

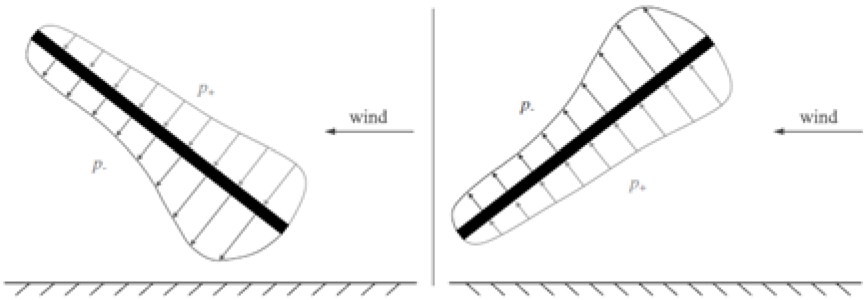

Figure 2.2. Pressure acting on a solar panel under forward and reverse wind (Assmus & Koehl, 2012)

There are relatively few research studies with respect to the determination of wind load and its effects on solar panels that are placed on the roofs or ground supported in solar farms.

In terms of research studies on solar panels placed on roofs, one of the first studies was conducted by Chevalien et al. (Chevalien & Norton 1979) and included numerous wind tunnel tests on solar panels located at the roof of the buildings.

In the last one and a half decade, researchers focused more significantly on solar panels placed on roofs. Koop et al. (Kopp, Surry, & Chen, 2002) conducted experiments on the vortex effects created at corners and near the sides of the panels due to winds acting in different angles. In order to reduce the impact of severe typhoons acting on solar water heaters placed on the roof of buildings, Chung et al. (Chung, Chang, & Liu, 2008) carried out experimental studies in order to reduce the uplift forces.

Kopp (Kopp, 2013) studied influence of different angle of attack of wind and consecutive placement of panels placed over low-rise building roofs.

Maffei et al. (Maffei, Telleen, Ward, Kopp, & Schellenberg, 2014) provided recommendations for solar panels placed on low-slope roofs, where they reported ASCE 07/10 is inadequate in terms of providing guidance in calculating wind loads on solar panels placed on roofs.

Different than other studies, Schellenberg et al. (Schellenberg, Maffei, Telleen, & Ward, 2013) conducted response history analysis to determine the nonlinear structural behaviour of solar panels under vibrating effects of wind loads. In that study, wind loads were applied as given time varying forces, thus aerodynamic effects were considered to be acting uncoupled with respect to the solution of the structural problem.

Despite numerous research studies, published in prestigious international journals, on solar panels located on the roofs of buildings, scientific studies on the determination of wind loads acting on ground mounted panels placed in open terrain includes deficiency. This is also indicated by one of the authorities in this research area The Wind Engineering Energy and Environment Research Institute of Western Ontario University (Jubayer & Hangan, 2012). It is worth to point out that Jubayer and Hangan's study contained first presentation of an ongoing study on the effects of wind forces on ground mounted panels placed in solar farms, where details on this study is provided on the next page.

Placement of consecutive rows of solar panels is expected to cause differences in acting wind pressures. Recently research studies try to study this effect that is called as sheltering effect. In one of such studies, behavior of solar panels located in open terrain under the action of wind loads were studied by Shademan and Hangan, (Shademan & Hangan, 2009) through computational fluid dynamics analysis. The study was published in the proceedings of a conference and stands far away from being finalized. In the study, sheltering effect was investigated by considering three consecutive rows of solar panels as shown in Figure 2.3. Furthermore, different wind angle of attacks and different panel inclinations were also investigated. This study by Shademan and Hangan emphasis that the minimum drag coefficient for the downstream body happens as the gap between the consecutive solar panels is equal to the width of the solar panel. In addition, it is found that the sheltering effect is lesser as the wind direction is skewed (see Figure 2.4). The drag coefficient is subjected to significant changes from 1st panel to 2nd panel due to sheltering effect.

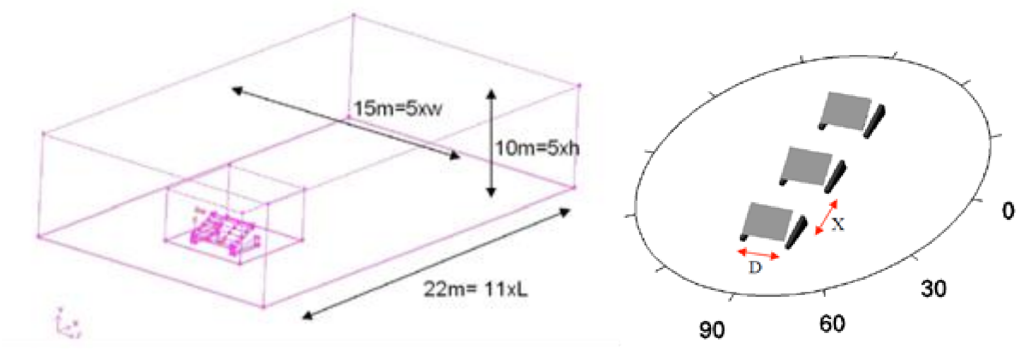

Figure 2.3. CFD analysis domain and model by Shademan and Hangan (2009)

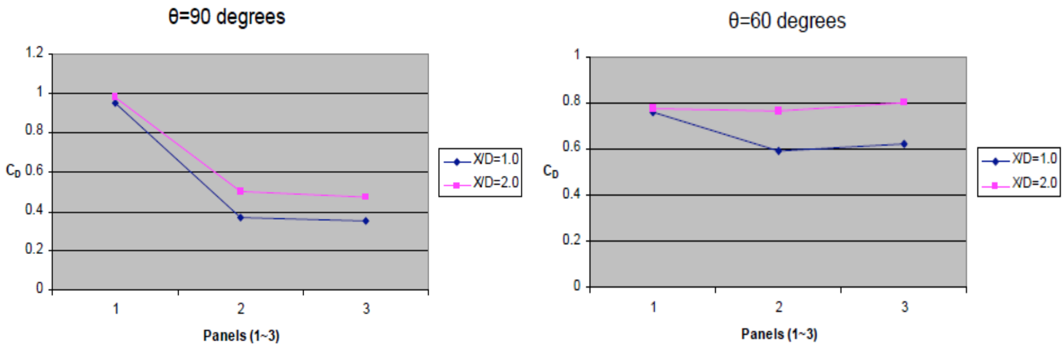

Figure 2.4. Drag Coefficient changes with sheltering effect for 60˚ and 90˚ (Shademan and Hangan, 2009)

In another study, Bitsuamlak, et al. (Bitsuamlak, Dagnew, & Erwin, 2010) conducted computational fluid dynamics analysis on ground mounted solar panels (See Figure 2.5), where the study was also published in the proceedings of a conference and appears to be part of an ongoing research work. In that study, wind pressure of the solar panels is found to be maximum in direction of 180˚ wind direction and the consecutive placement of panels was also investigated. Most important outcome of that study was that the first row panel provides sheltering effect on the other rows.

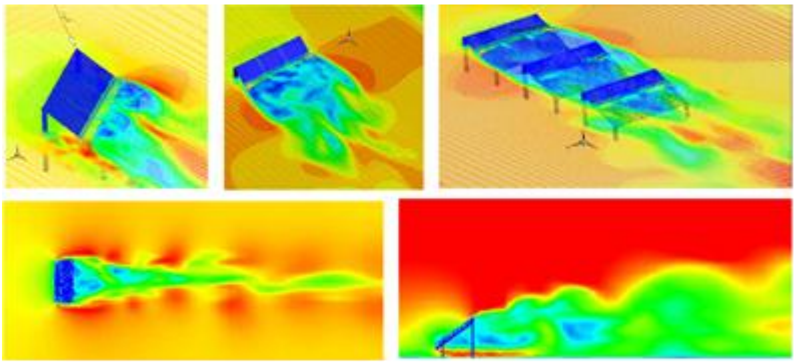

Figure 2.5. Mean velocity contours for single placed and 3 consecutively placed solar panels (Bitsuamlak, et al. (2010))

The study by Jubayer and Hangan (Jubayer & Hangan, 2012) is similar to the above studies and is part of an ongoing research work on the determination of wind loads acting on ground mounted solar panels. The study also considered the use of computational fluid dynamics analysis. An important observation stated in the paper was the fact that scientific studies lack presentation of wind loads acting on ground mounted panels placed in solar farms. In that study, full scale and model scale versions of a single solar panel that is ground supported was considered for CFD analysis. The model scale was stated to be considered for future wind tunnel tests that will be conducted by the authors. Conclusions from this study appear to be rather the repetition of known facts, and it was stated that the influence of the inclination of the panel will be studied as part of the ongoing research work.

In a recently published journal paper, Warsido et al. (Warsido, Bitsuamlak, & Barata, 2014) conducted the first research study that tries to identify the importance of sheltering effect on solar panels, where the authors carried out wind tunnel tests to study the consecutive placement of solar panels and the spacing effects on the wind loading of solar panels. In their study, plexiglass plate of 0.3m by 0.045 was used to represent 9.14m x 1.34 m solar panel model with a scale of 1:30. The solar panels were placed with 25˚ of inclination with a clear height of 81.28 cm from the ground (see Figure 2.5). During the tests, wind speed was set to15 m/s at the velocity inlet. It has been observed that outer layer panels were subjected to relatively higher wind loads compared to inner layer panels. Also, Warsido et al. stated that, lateral spacing between the panels has minimal influence on the force and moment coefficients. In the study by Warsido et al., it is stated that force and moment coefficients are in increasing trend with the increasing longitudinal spacing between panels. Different than Shademan and Hangan’s study, 10 consecutive solar panels were used and different lateral spacings were considered by Warsido. Similar to Shademan and Hangan’s study, Warsido also showed that significant decrease on the wind loads acting to the second row of panels. Different than Shademan and Hangan, Warsido’s study showed that unusual wind loadings are possible as the spacing between the panels are reduced.

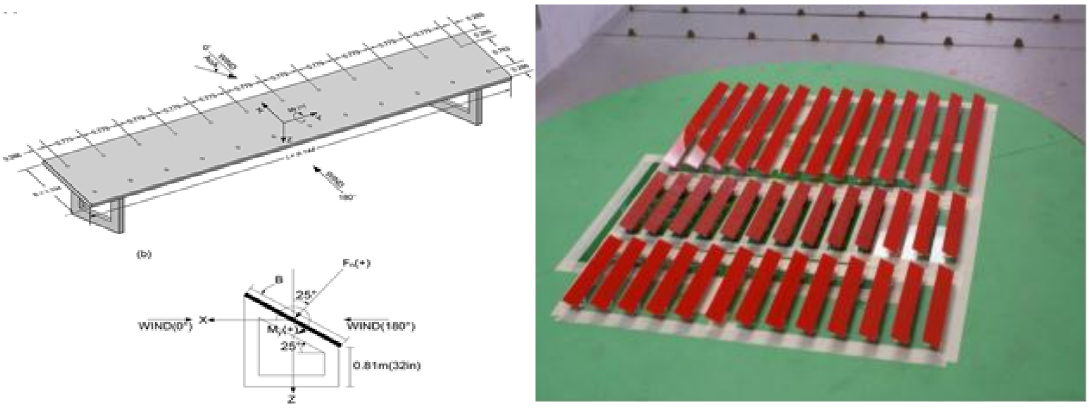

Figure 2.6. Solar Panel Details and Experiment Configuration (Warsido et al. (2014))

Different than above listed studies, there are also research works to understand the effects of vibrations caused by wind on an individual solar panel, as well. One of such studies was presented by Assmus and Koehl (Assmus & Koehl, 2012), where wind tunnel tests were conducted by the use of the set up shown in Figure 2.6. In their study, the authors tried to find out the vibrations caused under varying conditions, where the experiments were undertaken for 50, 90, 130 km/h wind speeds and the panel placement angles ranged from 25˚ and 60˚. The deformations and vibrations were recorded with sensors, and the cracks that occurred on PV cells were observed by using electroluminescence.

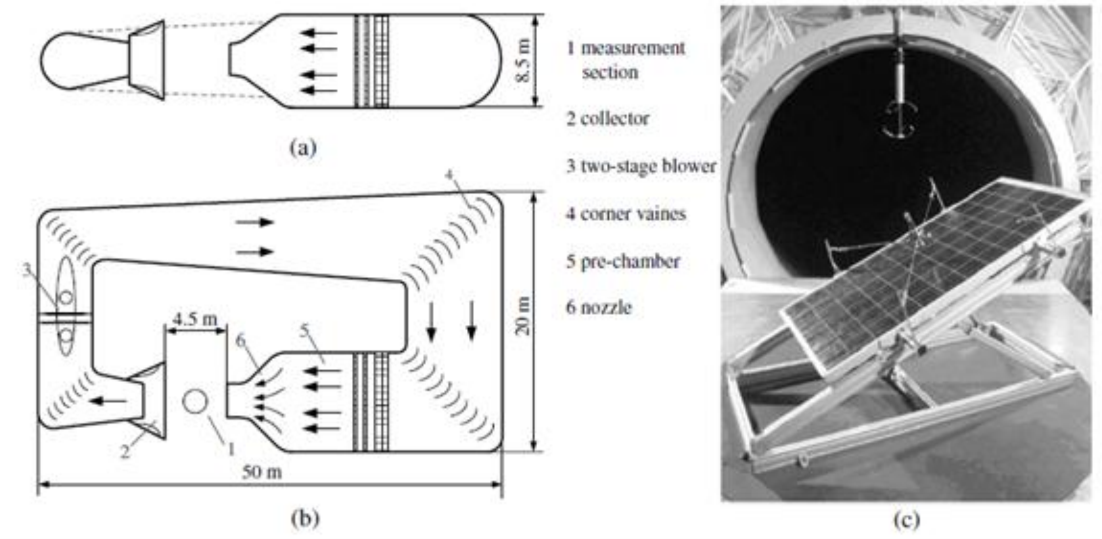

Figure 2.7. Wind tunnel test setup by Assmus and Koehl (2012)

In terms of studying the importance of vibration effects on panels, Gong et al. (Gong, Wang, Li, Zang, & Wu, 2013) conducted experiments for the heliostats type of solar collectors as shown in Figure 2.7. In their study, wind tunnel tests were conducted and pressure contours on the panels were determined. As a result of the studies carried out on the wind flow around heliostats, it was concluded that much more detailed studies should be carried out.

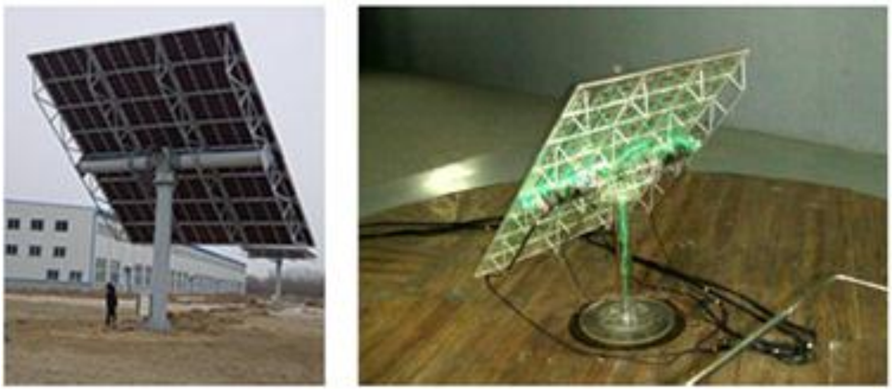

Figure 2.8. Prototype and scaled model of heliostats by Gong et al. (2013)

Instead of using wind tunnel tests, it is also possible to record the real wind pressures acting on panels that are placed in open terrain, as well. An example study in that regards was carried out by Gong et al. (2012) with single row of parabolic solar panels. By collecting data, the effects of wind were studied through the use of several pressure sensors placed on the panels. By measuring natural wind velocity and using different solar panel placement angles, the pressures were recorded. By the way, it is also possible to produce winds as done at Florida International University's Wall of Wind test set up shown in Figure 2.8, where the purpose of constructing such a test set up is to have more detailed studies about the great damages caused by hurricanes around Florida. In the study by Bitsuamlak et al. (2010) this testing facility was used and pressure sensors were placed on panels, and the recorded experimental results were compared with the results obtained through numerical analysis.

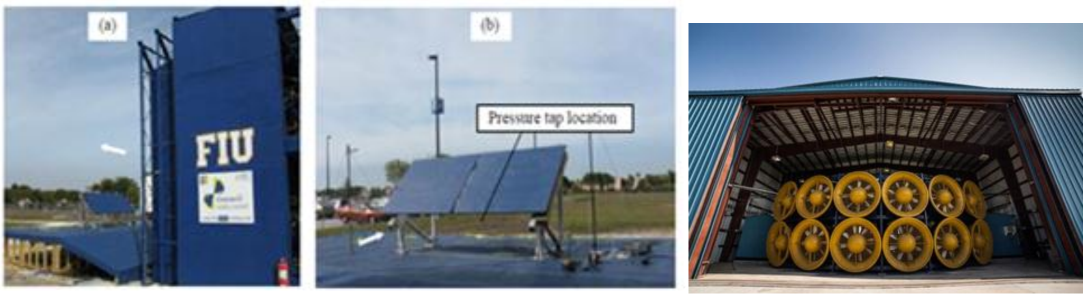

Figure 2.9. Open field test setup for the solar panels and Wall of Wind testing facility by Bitsuamlak et al. (2010)

CHAPTER 3

CFD ANALYSIS DETAILS

In this chapter general information on computational fluid dynamic (CFD) analysis, modelling and theoretical background of CFD will be presented. Conducting experimental research studies by the use of wind tunnel tests on ground mounted solar panels is a difficult task mostly due to physical limitations of research laboratories. In order to assess the sheltering effect that is present, several panels should be placed in wind tunnels in a consecutive fashion. While it is always possible to use scale models, even the use of scale models may not allow carrying out reliable wind tunnel tests in regular wind tunnels. It is thus important to have a wind tunnel testing facility that is large enough to compensate the physical requirements of carrying out such a test. In that regards, such large testing facilities are only available in very few laboratories around the world.

Instead of carrying out wind tunnel tests, it has also become popular to use CFD analysis tools to realize the solution of engineering problems. In this thesis, ANSYS FLUENT is used in order to model the effects of wind forces acting on solar panels. In terms of modeling the physical problem at hand, 2 dimensional (2D) and 3 dimensional (3D) modeling of the problem is possible. In order to describe the problem, a solar panel array with the dimensions of 2.4 m×7.2 m is considered as produced by First Solar Inc. (First Solar, 2014). The solar panel array consists of 24 solar panels with each 1.2 m×0.6 m and placed with 4 rows and 6 columns, where these solar panels are designed to be placed without any gap between them. The thickness of the panels is 7 mm. In order to perform CFD analysis, a volume of fluid that will be air in this case is needed to be specified. This volume will provide the domain where the fluid will flow. The boundary of the domain as well as the boundary between the fluid flow and solar panels should be carefully provided to the CFD analysis tool.

In this chapter, the recommendations are given mainly for 3D CFD analysis; however, they are also valid for 2D CFD analysis. Therefore, 2D CFD analysis recommendations will not be represented in here once more. The only difference between these two options is in the domain description and meshing.

3.1. Domain Dimensioning

A detailed document with regards to the basic requirements on carrying on CFD analysis are available in COST Best Practice Guideline for the CFD simulation of Flows in the Urban Environment (Franke, Hellsten, Schlünzen, & Carissimo, 2007). In the numerical analyses that are carried out in this thesis these guidelines are followed carefully in order to provide sufficient amount of domain for the flow of air around solar panels.

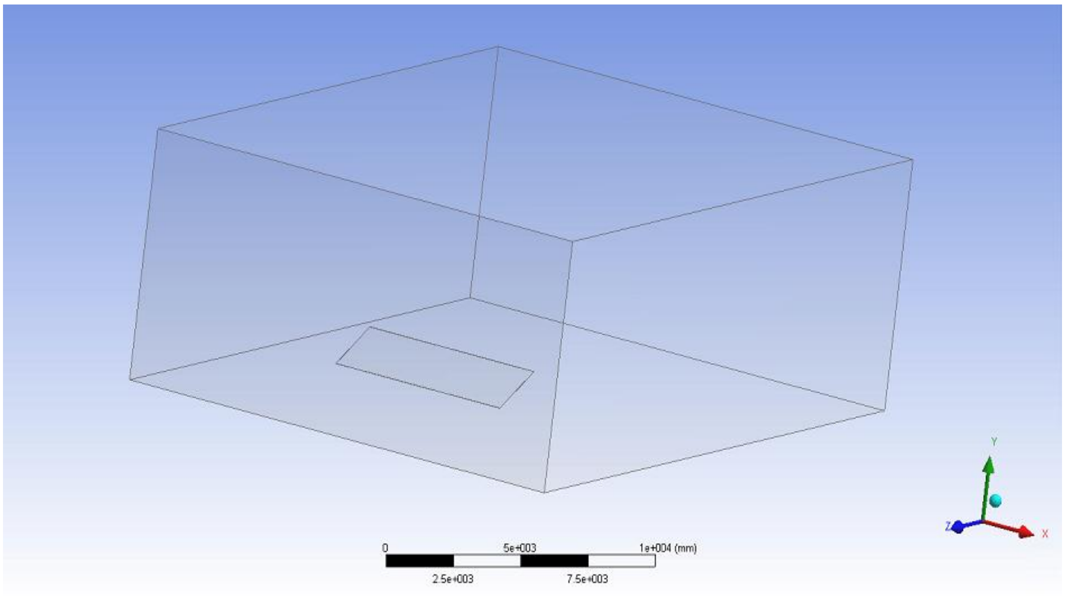

Figure 3.1. CFD Model General View

The recommendations for the description of volume of air domain that needs to be specified are as follows in this document: the domain top should be at least 5*H* above the top of the object that is of interest, where *H* is stated as the height of the object. In this thesis, *H* is taken as the height from ground to the highest point on the panel. Therefore, the total height of the domain becomes 6*H*. With regards to the flow of wind from inlet, at least 5*H* distance of air domain should be provided before the wind first hits the object. After air flows around the object, it is also necessary to provide at least 15*H* distance of air to flow up to the outlet to permit flow to be redeveloped in the wake region. With regards to the 3D modeling, it is also necessary to provide 5*H* distance of air to flow in the lateral directions past the object of interest, as well. By providing 5*H* lateral domain, the blockage ratio of the object falls below 3% as recommended by COST Guidelines. The representative domain of air and the panel are shown in Figure 3.1.

3.2. Domain Meshing and Boundaries

Meshing of the domain of air and panel needs to be done carefully after creating the geometry of the parts. Mesh generator of ANSYS is used for this purpose to generate the grids for meshing. Tetrahedrons are selected with patch conforming method. Face size meshing is also added to the mesh generator in order to increase the accuracy of CFD analysis. There are 6 faces of solar panel used for the face sizing, where 2 of these faces are the top and bottom faces of the panels and the rest of the faces are resulting due to the thickness of the panel on the edges.

The top boundary and side boundaries of the air domain are specified as symmetry to enlarge the flow space near these boundaries, where this boundary specification also eliminates the need for mesh refinement near these boundaries. The bottom part of the air domain is defined as rough wall boundary condition that needs the specification of roughness height and constant. It is also important to specify the boundary condition between the air and the solar panel and the supporting structural system of the panel (if exists), where this boundary is selected as smooth wall in this thesis.

The front face of the air domain is defined as velocity inlet and the back face is assigned as pressure outlet. There is no pressure difference specified inside the air domain. Since the panel volume is much cramped compared to the volume of air domain, the element sizes through the thickness of the panel are refined significantly. It is also necessary to accurately capture the rather turbulent flow of air near the wall regions, as well. This necessitates significant mesh refinement near the bottom wall region and around the panels. In order to audit the mesh quality, 3 levels of mesh refinement are considered as suggested by COST Guidelines, where these meshes are labelled as coarse, medium and fine. It is important to ascertain that the model is mesh independent with respect to mesh refinement, i.e. the difference in results obtained from medium and fine meshing should be small such that fine meshing solution can be accepted as the converged solution in terms of mesh refinement.

Pictorial views of the meshing of the air domain as well as the panel are demonstrated in Figures 3.2 to 3.5. In these figures, both the meshing for the cases of panel with or without supporting structures is shown.

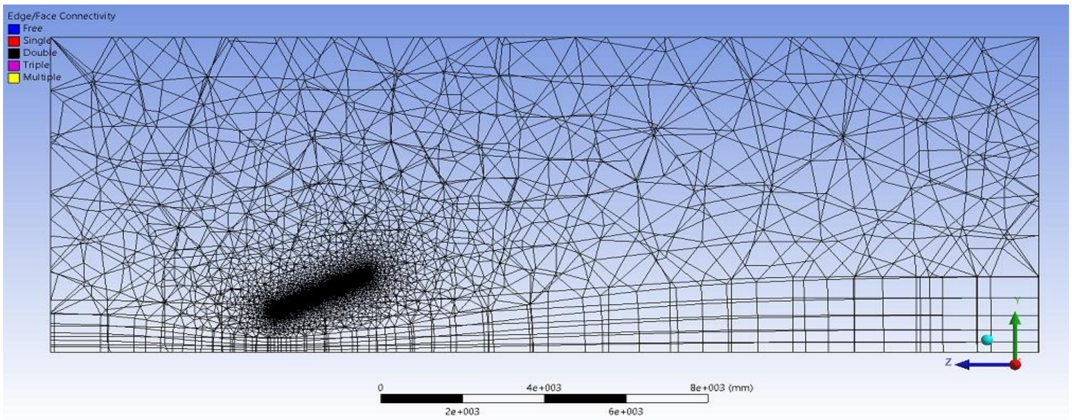

Figure 3.2. CFD Model Mesh Side view

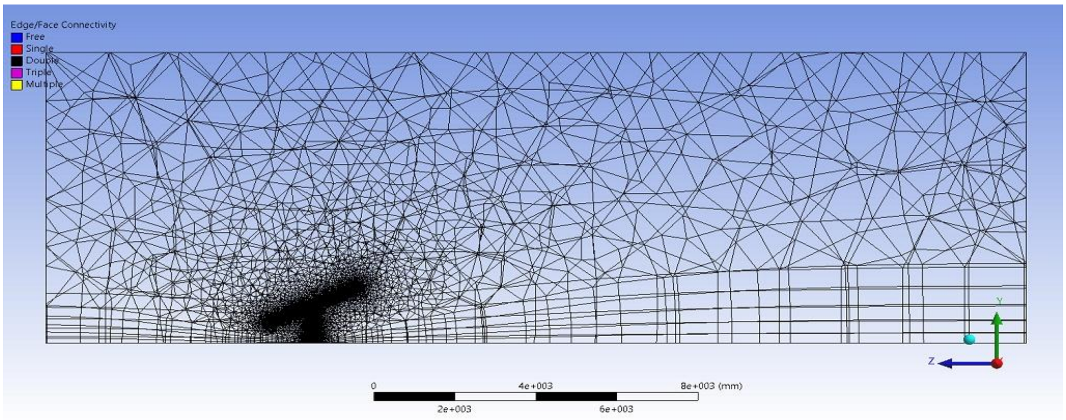

Figure 3.3. CFD Model Mesh side view (with column)

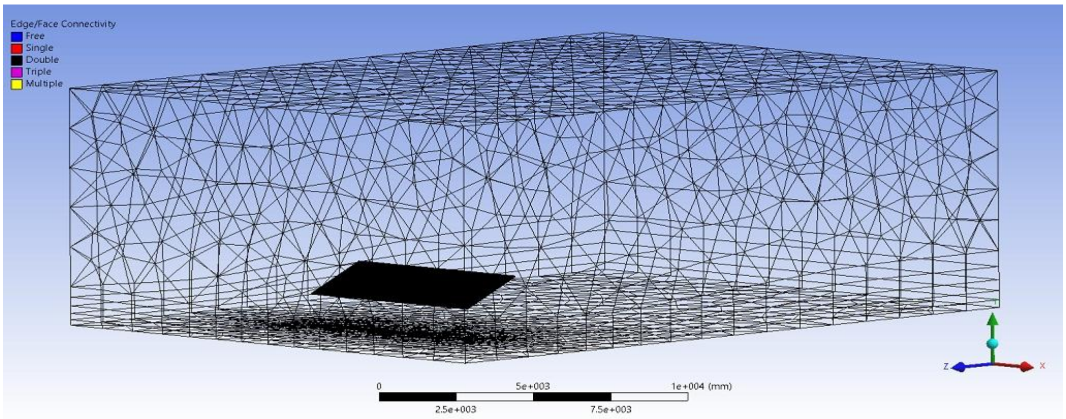

Figure 3.4. Mesh General View and Panel Mesh (without supporting columns)

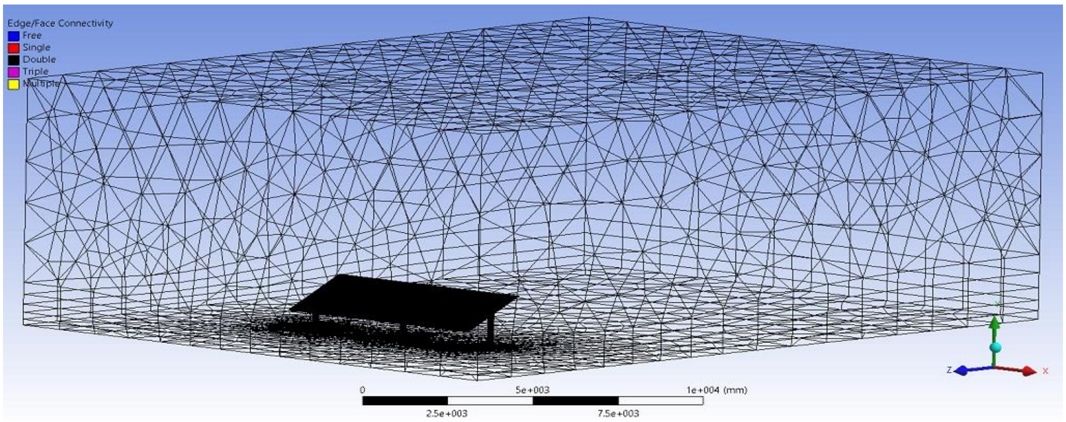

Figure 3.5. Mesh General View and Panel Mesh (with supporting columns)

3.3. SST k-ω Model

FLUENT Module in ANSYS V13 is used to carry out CFD analysis in this thesis. The analysis set to be double precision. For the solver, pressure-based solver is preferred. The velocity formulation is appointed to be absolute. Steady state solution is considered to be representative enough in terms of obtaining the dominant wind loads acting on the solar panels. For the viscous model, SST k-ω model proposed by Menter (Menter, 1994) is chosen.

SST k-ω turbulence model was proposed by Menter in order to construct k-ω formulation from the standard high Reynolds number version of k-ε model (Menter, 1994). By combining the equations proposed by k-ε model and Wilcox model (Menter, 1994) and by multiplying both formulations with a blending function, Menter tried to use the strongest parts of these two proposed formulations. In this way, the resulting k-ω model uses the accuracy of Wilcox model to represent the behavior of fluid flow near wall regions and takes advantage of the modeling capabilities of k-ε model in activating outer wake region and free shear layers.

SST k-ω model was originally proposed for the solution of problems related to aeronautical engineering; however it has effected industrial applications in many engineering fields. Detailed discussion with regards to the use of this model is provided by Menter et al. (Menter, Kuntz, & Langtry, 2003). SST k-ω model formulation of Menter et al. (2003) is represented by following equations (ANSYS Inc., 2011);

$$\frac{\partial(\rho k)}{\partial t} + \frac{\partial(\rho u_i k)}{\partial x_i} = \tilde{G}_k - Y_k + S_k + \frac{\partial}{\partial x_j}[(\Gamma_k)\frac{\partial k}{\partial x_j}] \qquad (3.1)$$

$$\frac{\partial(\rho \omega)}{\partial t} + \frac{\partial(\rho u_j \omega)}{\partial x_j} = \left[(\Gamma_\omega)\frac{\partial \omega}{\partial x_j}\right] + G_\omega - Y_\omega + D_\omega + S_\omega \qquad (3.2)$$

Equation 3.1 represents the k-equation and Eq. 3.2 represents the ω equation.

ρ is the density.

k is the turbulence kinetic energy.

ω is the specific dissipation rate.

$\widetilde{G}_k$ is the turbulence kinetic energy due to mean velocity gradients.

Γ_ω and Γ_k represent the effective diffusivity of ω and k, respectively.

Y_ω and Y_k represent the dissipation of ω and k due to turbulence, respectively.

D_ω represents the cross-diffusion term.

S_ω and S_k are user-defined source terms.

$$\Gamma_k = \mu + \frac{\mu_t}{\sigma_k} \tag{3.3}$$

$$\Gamma_\omega = \mu + \frac{\mu_t}{\sigma_\omega} \tag{3.4}$$

Where σ_ω and $\sigma_k$are the turbulent Prandl numbers for ω and k, respectively.

The turbulent viscosity, $\mu_t$is computed as the following:

$$\mu_t = \frac{\rho k}{\omega} \frac{1}{\max\left[\frac{1}{\alpha^*}, \frac{SF_2}{a_1 \omega}\right]} \tag{3.5}$$

Where S is the strain rate magnitude.

$$\sigma_k = \frac{1}{\frac{F_1}{\sigma_{k,1}} + \frac{(1-F_1)}{\sigma_{k,2}}} \tag{3.6}$$

$$\sigma_\omega = \frac{1}{\frac{F_1}{\sigma_{\omega,1}} + \frac{(1-F_1)}{\sigma_{\omega,2}}} \tag{3.7}$$

And $\alpha^*$is the coefficient that damps the turbulent viscosity causing a low-Reynolds number correction.

Where the blending function:

$$F_1 = \tanh\left\{\left\{\min\left[\max\left(\frac{\sqrt{k}}{\beta^*\omega y}, \frac{500\mu}{\rho y^2\omega}\right), \frac{4\rho k}{\sigma_{\omega,2} D_\omega{}^+ y^2}\right]\right\}^4\right\} \tag{3.8}$$

$$D_\omega{}^+ = \max\left(2\rho\frac{1}{\sigma_{\omega,2}}\frac{1}{\omega}\frac{\partial k}{\partial x_j}\frac{\partial \omega}{\partial x_j}, 10^{-10}\right) \tag{3.9}$$

Second blending function:

$$F_2 = \tanh\left[\left[\max\left(\frac{2\sqrt{k}}{\beta^*\omega y}, \frac{500\mu}{\rho y^2\omega}\right)\right]^2\right] \tag{3.10}$$

Where, y is the distance to the nearest wall and $D_\omega{}^+$is the positive portion of the cross-diffusion term.

$$D_\omega = 2(1 - F_1)\rho\frac{1}{\omega\sigma_{\omega,2}}\frac{\partial k}{\partial x_j}\frac{\partial \omega}{\partial x_j} \tag{3.11}$$

By blending k-ε and k-ω models by $\alpha = \alpha_1 F + \alpha_2(1 - F)$, the constants came out to be: $\beta^* = 0.09$, $\alpha_1 = 5/9$, $\alpha_2 = 4/9$, $\sigma_{\omega,2} = 0.856$.

In the numerical analysis, the parameters (ANSYS Inc., 2011) to solve the equations are set as the following;

$\alpha^*{}_\propto = 1$, $\alpha_\propto = 0.52$, $\alpha_0 = \frac{1}{9}$, $\beta^*{}_\propto = 0.09$, $\beta_i = 0.072$, $R_\beta = 8$, $R_k = 6$, $R_w = 2.95$ $\zeta^* = 1.5$, $M_{t0} = 0.25$, $\sigma_k = 2.0$, $\sigma_w = 2.0$

As the fluid, air is chosen with density of 1.225 kg/m3 and viscosity of 1.7894e-05 kg/m-s.

3.4. Specification of Boundary Conditions

Supersonic/Initial gauge pressure is set to zero in ANSYS FLUENT Solver, since same air pressure is considered to be present at every point. For the velocity inlet, z-direction of velocity (m/s) is specified, i.e. the direction normal to the inlet face. For the turbulence part, intensity and viscosity ratio method is chosen. For external flows, turbulent viscosity ratio is typically selected between the ranges of 1% to 5%. Since the flow is calm at the inlet part, the turbulent intensity is set to 1% in this study. Turbulent viscosity ratio is fixed to be 10. In the pressure outlet part, gauge pressure is set to zero, and intensity and viscosity ratio method is chosen. In the outlet region, although the distance between the panel and the outlet is sufficient enough, the turbulence level is still expected to be higher than the inlet face due to the encounter of obstacle (solar panel). Therefore, backflow turbulent intensity is adjusted to 5% and backflow turbulent viscosity ratio is still kept as 10. Solar panel located in the domain is stationary; therefore dynamic meshing is not needed, i.e. structural vibrations of the panel are ignored in this study.

The pressure-velocity coupling scheme is chosen for the solution methods. Therefore, the solver will solve both pressure and velocity equations simultaneously in every single step. Solving these two equations together will help to reach convergence much faster by using nearly twice as much resources of computer.

ANSYS FLUENT is utilized in the numerical analysis part of this thesis. The analysis prescribed to be double precision. For the solver, pressure-based solver is selected. The velocity formulation is specified to be absolute. Steady state solution is considered only. For the viscous model, SST k-ω without low Reynolds corrections is chosen. As the equations, pressure-velocity coupled solution is selected. In the computation part, convergence of the solutions is ascertained by selection of appropriate tolerance values and by observing the convergence charts of drag, lift and moment coefficients.

In order to set up 2D CFD analysis, the analysis type from Advance Geometry Options in ANSYS is changed to 2D, and the geometry of the model is specified in XY plane in current study. A rectangle with dimensions of panel from side (2.4 m x 7 mm) is sketched and the domain of air is provided as a rectangular body with 6H in height, 5H from inlet to panel and 15H from panel to outlet. All bodies are drawn as surface bodies in the geometry sketches. After the domain of air is sketched, panel body is subtracted from the domain as done in 3D process. As a result of this operation, the domain for fluid flow is established. In order to construct meshing of the body parts, element sizes are specified and triangular mesh is selected. Similar to 3D case, near the ground and the edges of the panel, mesh refinement is necessary in order to get accurate results from CFD analysis. The entrance of the domain is entitled as velocity inlet, the top of the domain is specified as symmetry boundary, bottom of the air domain is called as rough wall, the boundary between the panel and air is specified as smooth wall, and the exit is specified as pressure outlet.

The velocity profile of the empty domain is shown in Figure 3.6. Velocity of 40 m/s is assigned at the velocity inlet and the analysis of air domain is started. This analysis is run to the convergence state. The domain height and lengths are set to 6.5m and 40m respectively. The bottom part of the domain, the road, has roughness coefficients therefore it reduces the wind velocity at the bottom part. The velocity is converged to 0 m/s at the very bottom. As the height increases, the velocity profile is changed to meet 40 m/s. This evolution is transpired up to 25-30 cm from the ground where it is stabilized afterwards.

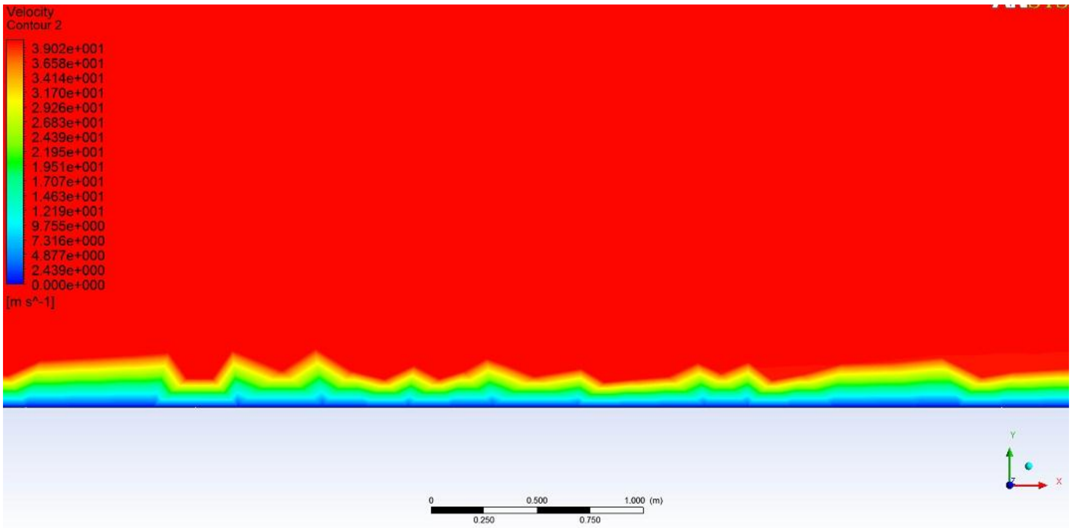

Figure 3.6. CFD Velocity Profile of Empty Domain (for v= 40 m/s)

The wind trend is not stabilized in this bottom region, due to the roughness coefficient and the vortexes it is causing. As the wind flow interacts with the bottom part, the roughness causes a disturbance and vortex on the wind trend; therefore there is no smooth wind flow at the bottom of the domain. The solar panels used in this thesis are placed with 0.5m and 1m clear distances from the bottom. Consequently, the first panel is directly subjected to 40 m/s wind load.

CHAPTER 4

VERIFICATION STUDY (LITERATURE)

In this chapter, numerical modeling and analysis tools presented in previous chapter are going to be verified by available data in literature. For the purpose of verification study, numerical analysis conducted by Jubayer et al. (Jubayer & Hangan, 2012) and the experimental study by Warsido et al. (Warsido et al., 2014) are considered.

Jubayer conducted a numerical study to predict the wind loading on a set of ground mounted solar panels. In his study, the single solar panel with columns is examined. In study of Jubayer, the drag, lift and moment coefficients are represented and these results will be compared with the coefficients found in this thesis.

Warsido's study will be compared with the consecutive solar panel analyses handled in this study. In Warsido's study, experiments are planned to see the lateral and horizontal spacing effects on the wind loading of solar panels. However, as mentioned in study of Warsido, the lateral spacing has no major effect on the wind loads on the solar panels. Therefore, in the study for this thesis, only horizontal spacing is used as variable, which has a major impact on the wind loads as mentioned in Warsido's study.

4.1. Comparison with Jubayer and Hangan (2012)

Jubayer (Jubayer & Hangan, 2012) conducted a numerical study to predict the wind loading on a set of ground mounted solar panels, where the single solar panel with columns was examined. In this study, drag, lift and moment coefficients were presented, and these results will be compared with the coefficients found as part of the numerical study carried out in this thesis.

The solar panel considered in the study of Jubayer and Hangan consisted of 4×6 arrays resulting in total 2.4-m × 7.2-m in dimensions. More detailed discussion on this solar panel setup is available in Chapter 3. Inclination of the panel was fixed to be 25° with respect to horizontal. The clear distance from the ground is approximately 0.59 m, where the mean height of the panel is 1.1 m. Jubayer and Hangan carried out computational fluid dynamic analysis of the panel through the use of 3D unsteady Reynolds-Averaged Navier-Stokes (RANS) method and SST k-ω turbulence model in OpenFOAM CFD program. The front and side views of the panel are displayed in Figure 4.1. Also, the computational domain is shown in Figure 4.2. As can be seen from Figure 4.1, Jubayer has considered the use of 3 supporting columns along the width of 7.2 m distance; however, the columns and the panels were not placed in contact with each other, thus allowing air flow between them. It is worth to emphasize that in their analysis both the panel and the columns were assumed to remain rigid, thus structural vibrations in these panels were not studied as coupled with fluid flow problem.

Figure 4.1. Dimensioning of the Solar Panel by Jubayer and Hangan (2012)

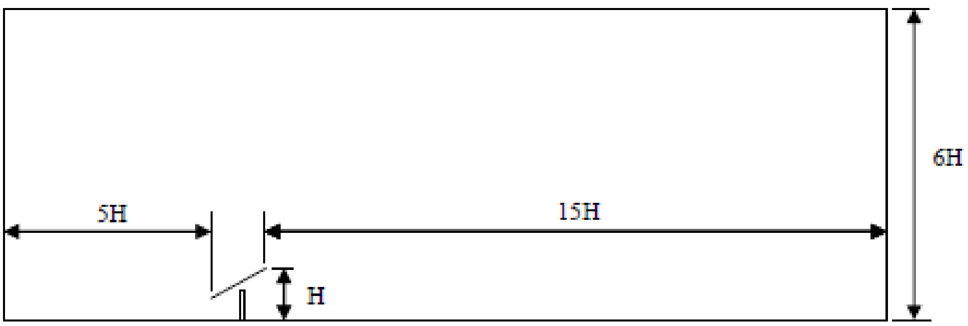

Figure 4.2. Dimensioning of the CFD domain by Jubayer and Hangan (2012)

Jubayer conducted the study with a reference velocity set to 17.5 m/s at 10 m height with aerodynamics roughness length of 0.03m to represent open terrain. The bottom part of the domain was demonstrated as rough wall with a roughness height and constant. The sides of the domain were modelled as symmetry whereas the supporting structures and panels were categorized as smooth walls. Also, the simulations were undertaken as transient, but the analyses were allowed to reach to reach steady state conditions then which the discussion of results was provided. The solar panels were analyzed in both full scale and model scale, where the model scale was considered for a future wind tunnel test study that will be undertaken by the authors.

As part of the verification study in this thesis, the full scale solar panel setup by Jubayer and Hangan is considered with and without supporting columns in order to assess the importance of considering these in CFD analysis. Different than Jubayer's research, contact with panel plane and supporting columns was created in this thesis, since this would reflect the real case more closely. In addition to these analyses cases in 3D, 2D model of the same panel without supporting columns is considered for CFD analysis, as well.

The solution method is set to SST k-ω with default FLUENT values presented in Chapter 3. The Low Reynolds correction option is not assigned to this analysis. The velocity is set to 17.5 m/s at the velocity inlet with turbulent intensity of 1% and turbulent viscosity as 10. At the pressure outlet, the turbulent intensity is assigned as 5% and turbulent viscosity as 10. The model design is shown in Figure 4.3 and Figure 4.4. More detailed discussion on specifying the domain, setting up the boundary conditions and domain meshing for this solar panel analysis with and without the supporting columns is available in Chapter 3.

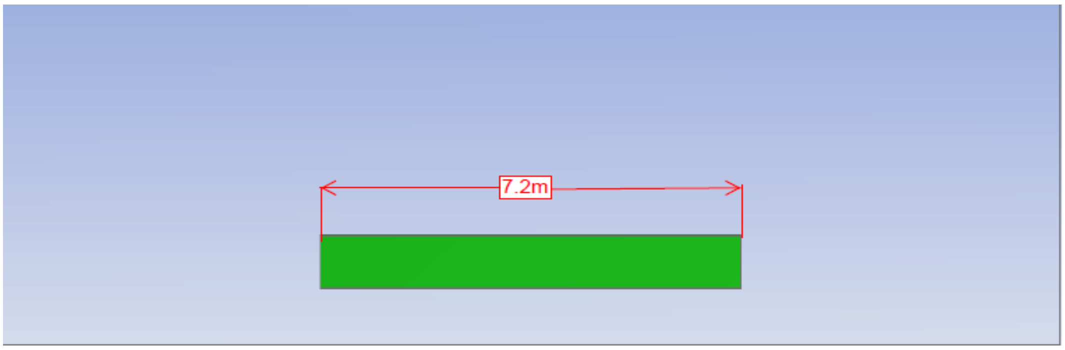

Figure 4.3. CFD 3D Analysis Solar Panel Width

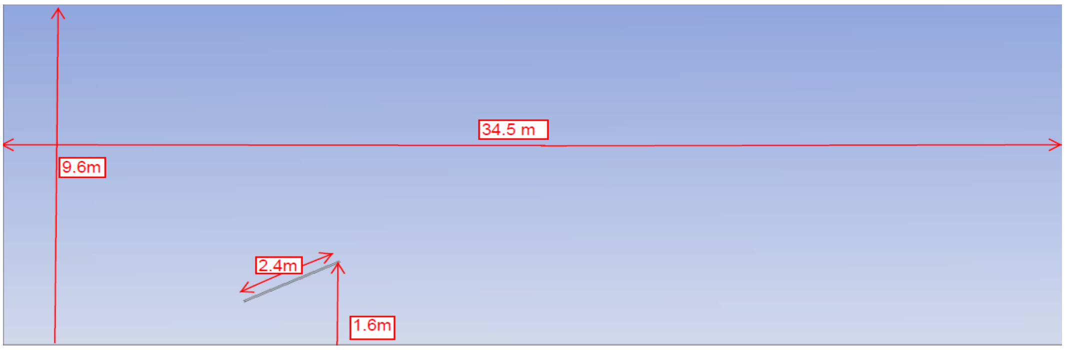

Figure 4.4. CFD Domain Dimensioning

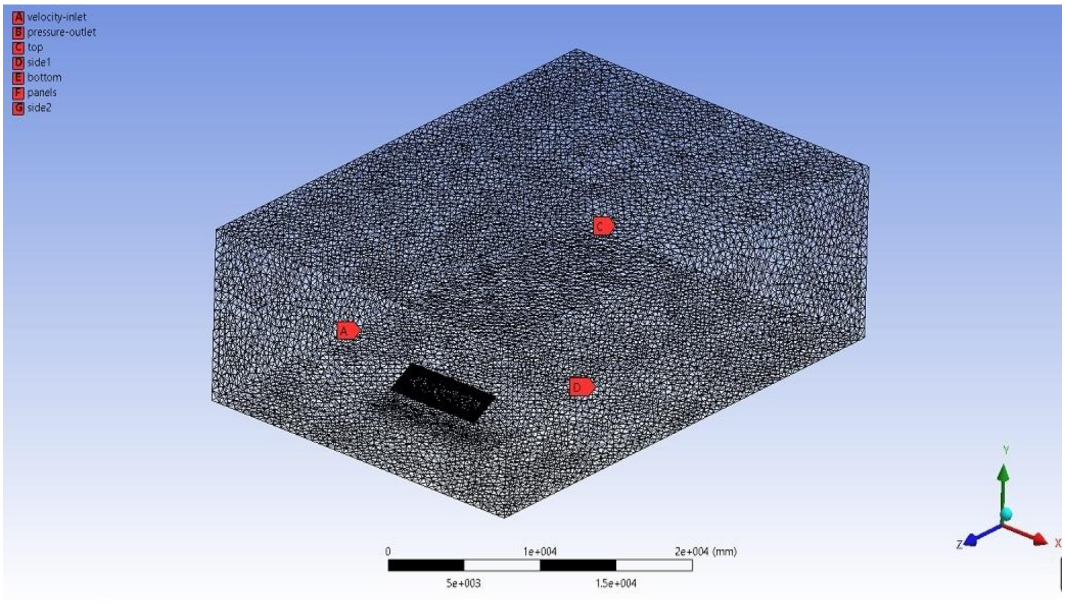

Figure 4.5. CFD Domain Mesh and Boundary Conditions

Lift (C_l), drag (C_d) and moment (C_m) coefficients are calculated through the use of following equations:

$$C_l = \frac{F_l}{\frac{1}{2}.\rho.v^2.A} \tag{4.1}$$

$$C_d = \frac{F_d}{\frac{1}{2}.\rho.v^2.A} \tag{4.2}$$

$$C_m = \frac{M}{\frac{1}{2}.\rho.v^2.A.s} \tag{4.3}$$

F_d is the drag force (N)

F_l is the lift force (N)

ρ is the mass density of the fluid (kg/m^3)

v is the speed of the fluid relative to the object (m/s)

A is the reference area. (m^2)

s is the chord length.

Density of air ρ air is taken as of 1.225 kg/m^3, velocity is taken as 17.5 m/s and the reference area, A, is taken as 17.28 m^2 in this study.

Results reported by Jubayer and Hangan are given in Table 4.1, whereas the results obtained from CFD analysis conducted in this thesis are revealed in Table 4.2. A comparison of the results presented in both tables clearly demonstrate close match between both studies. The drag, lift and moment coefficients are similar, and small differences in results could be attributed due to the use of different tools and coefficients to solve the equations of fluid flow and the use of different analysis programs and the differences nearly the same with each other.

In the Table 4.2., there are 3 different outcomes of different element numbers presented. In order to prove that the results are meshing independent, there are 3 sizes of mesh elements used. By correlating the results of 3 different element size results, the mesh independency is shown clearly.

Table 4.1. Drag, Lift and Moment Coefficients by Jubayer and Hangan (2012)

	Drag Coefficient	Lift Coefficient	Torque Coefficient
Model Scale	0.56	-1.2	0.12
Full Scale	0.54	-1.15	0.14

Table 4.2. Drag, Lift and Moment Coefficients Obtained in Current Study

	Drag Coefficient	Lift Coefficient	Torque Coefficient
3D CFD Model (5654033 elements)	0.578	-1.217	0.110
3D CFD Model (2888212 elements)	0.582	-1.209	0.099
3D CFD Model (1621967 elements)	0.586	-1.193	0.099
3D CFD Model with columns (9677985 elements)	0.522	-1.052	0.095
2D CFD Model (265287 elements)	0.594	-1.218	0.110
2D CFD Model (86057 elements)	0.596	-1.198	0.105

The results of 3D CFD analyses carried out in this thesis show that there is good correlation with the results presented in literature, and the description of the domain of the problem is realistic, the meshing method provides converged solution, the numerical solution method employed works. Thus, the use of the numerical methodology presented in Chapter 3 can be used in a parametric study.

By the way, it is observed that 3D CFD analysis of the model with columns results in smaller wind loads acting on the panels compared to the case without columns. While this might be an advantageous situation, number of meshes significantly increases due to the presence of columns and the necessity to fine meshing around the columns. Increase of mesh number furthermore causes significant increases in solution times and data storage, as well. It is evident that CFD analysis without supporting columns actually gives on the safe side wind loads.

A comparison of 3D and 2D analyses results also reveal close estimations attained by 2D modeling approach. The panel width 7.2 m is rather significant, and most of the wind pressures created across the width is quite uniform except than at the lateral ends. 2D analysis provides robust solutions due to decrease in geometry and mesh number. Actually, the number of meshes used in 2D analysis dropped to 5% of its value in 3D analysis as can be seen in Table 4.2. One last point to mention, 2D analysis provides on the safe side estimations of wind loads, as well. Thus, carrying out a parametric analysis through the use of 2D modeling approach will definitely allow significant amount of time gain in carrying out research on the determination of wind loads acting on consecutively placed solar panels.

4.2. Comparison with Warsido et al. (2014)

Warsido (Warsido et al., 2014) recently published the results of an experimental study conducted in wind tunnel. In their study, wind loads were observed by changing the lateral and horizontal spacing between panels. More detail on this study is available Chapter 2 and the experimental setup is available in Figure 2.5. The experiment was conducted by the use of scaled model setup in order to replicate the full scale model.

In this thesis, 2D computational fluid dynamics analyses are carried to compare the results with the results obtained from the experiments conducted by Warsido. The sheltering effect observed in the study of Warsido is intended to be assessed as part of the numerical analysis carried in this thesis. For this purpose, the full scale model is constructed in ANSYS, i.e. panel length is 1334 mm with an inclination of 25˚

from horizontal and clear height of 0.81 m from ground. The wind speed was provided as 15 m/s in the paper. Analysis is run by using ANSYS FLUENT by following the numerical methods presented in Chapter 3.

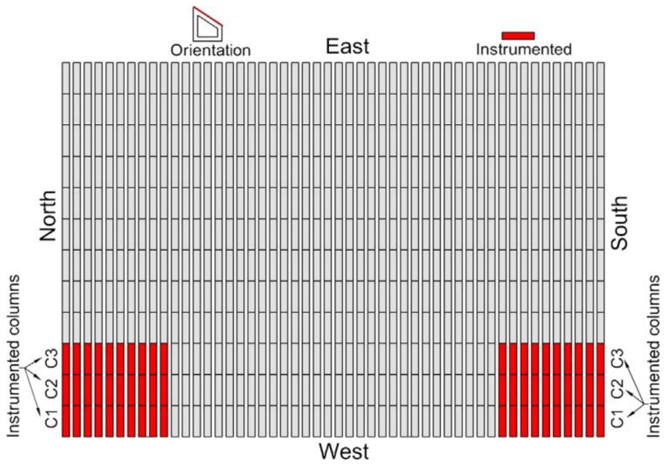

Figure 4.6. Experiment Orientation and Naming by Warsido et al. (2014)

In the study by Warsido, the normal force and moment coefficients were calculated through the measurement of pressures on the panels. The pressure values recorded through the testing were then calculated as peak, mean and root of mean square values as discussed in the paper. The mean values presented by Warsido are considered for comparison with the steady state analysis results carried out in current work in this thesis. CFD analysis was carried out in 2D, thus the results closer to the middle columns of the experimental setup are considered. C3 column shown in Figure 4.6 is selected for this purpose. In the study by Warsido, lateral spacing was also considered as a varying parameter, but it was observed to be resulting in smaller wind loads on the panels, thus the results with zero lateral spacing on column C3 are presented in Figure 4.7 for various horizontal spacing between consecutively placed solar panels. The results shown in this figure by Warsido are named as C3Y0×24, C3Y0×48 and C3Y0×72, which means the testing section is C3 with no lateral spacing and with horizontal spacing of 0.61 m, 1.22 m and 1.83 m. These horizontal spacing values result in spacing factors close to 1.0, 2.0 and 3.0, where spacing factor is the clear distance D between each consecutively placed panel divided by sinus of the inclination θ multiplied by the length of panel L. The results of drag force and lift force obtained from current analysis are converted to normal force. Normal force and moment coefficient results are presented in Figures 4.8 and 4.9, respectively.

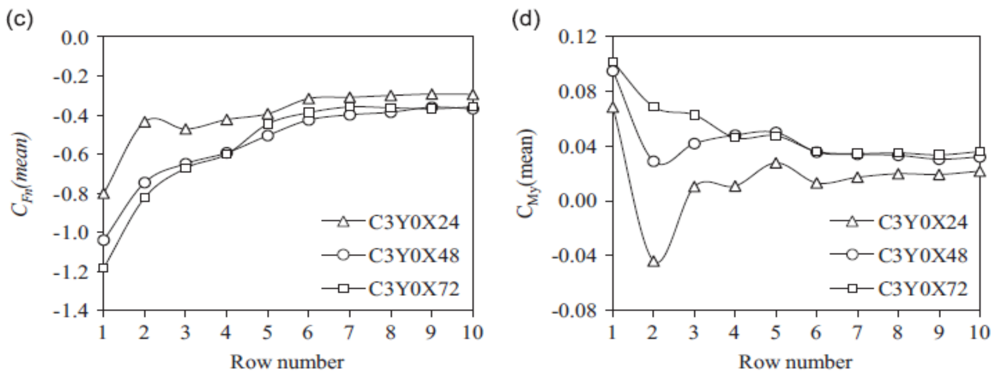

Figure 4.7. Mean Normal Force (left) and Moment Coefficients (right) by Warsido et al. (2014)

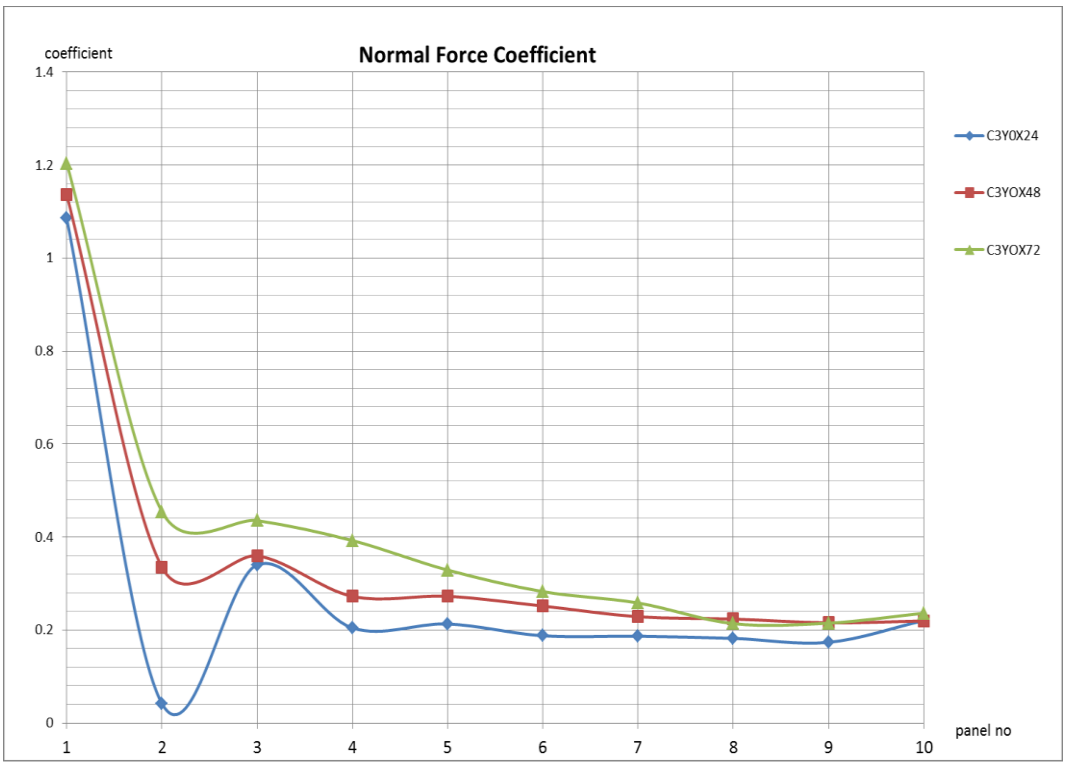

Figure 4.8. Normalized Force Coefficient by CFD conducted

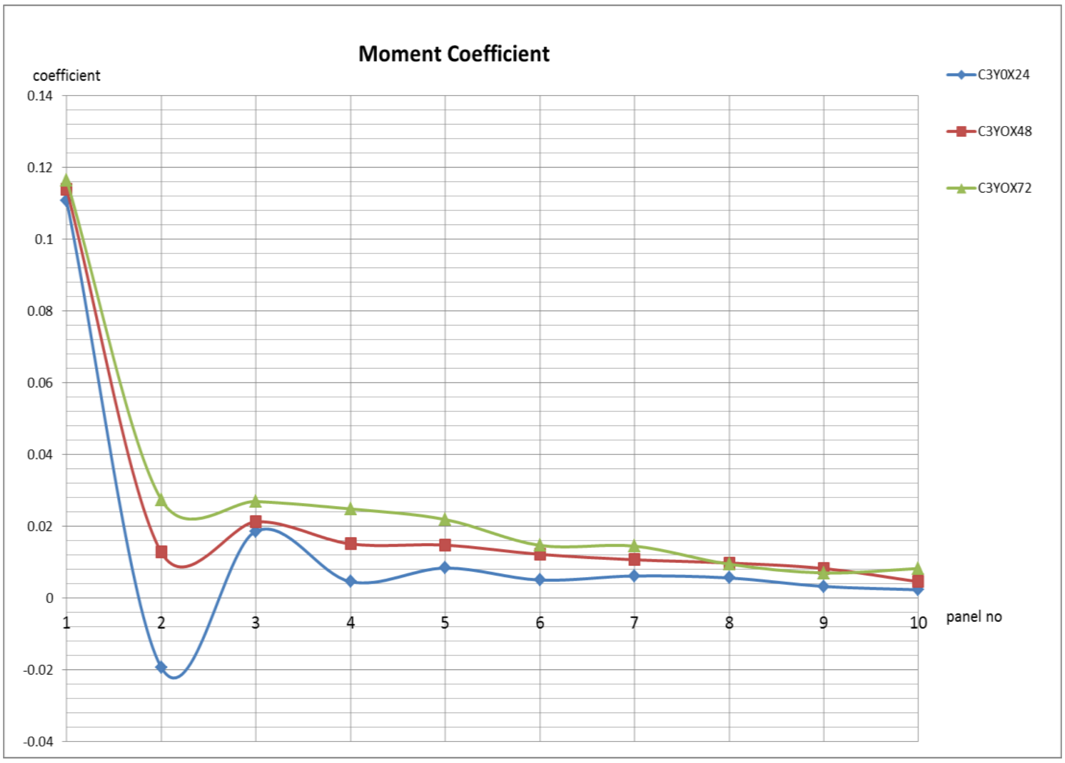

Figure 4.9. Moment Coefficient by CFD conducted

A comparison of the normal force coefficients in Figure 4.7 and Figure 4.8 clearly demonstrate similar trends in terms of values as well as capturing the sheltering effect through the consecutively placed solar panels. In both the experiment and the numerical analysis, normal force coefficients are observed to be converging to the same value at 10th panel. Only the case with spacing factor close to 1.0, that is to say 24 inches (0.61 m) horizontal spacing between panels resulted in reduced normal forces. While the normal force coefficient is close to 1.2 as the panels are separated from each other, it was observed by Warsido that this coefficient drops to 0.8 for SF close to 1.0. In the numerical analysis, the same normal force coefficient of 1.2 is also obtained for SF close to 3.0, but the drop observed in the experiment was not achieved in the numerical analysis for the case of SF close to 1.0.

It is worth to point out that a previous numerical study by Shademan and Hangan (2009) on 3 consecutively placed solar panels did not result in such significant drops on the normal forces acting on the first panel for SF equals to 1.0. While a sheltering effect is expected on the consecutive panels and a reduction might be expected on the first panel due to wake of wind flow, such significant drops on the first panel for the case of SF close to 1.0 requires further study both experimentally and numerically. It might actually be the best idea to test the sheltering effect through the use of constructed full scale solar panels on open terrain through the placement of pressure taps on them. However, the use of spacing factor of 1.0 with 25˚ inclined solar panels is actually an unrealistic condition to face in solar farms due to the shadowing issues reducing energy production. Besides optimality issues with regards to the placement of solar panels in real applications, it is always warranted to study scientifically the drop reported by Warsido as the panels significantly approach each other.

Comparison of moment coefficients in Figure 4.7 and Figure 4.9 actually reveal a better match between the experimental and numerical results and clearly demonstrate a confidence on the analysis employed in this thesis. In both the experiment and numerical analysis, it is observed that moment coefficients become relatively insignificant, i.e. close to zero, as the results of wind loads at 10^{th} panel are considered. It can be concluded that sheltering clearly diminishes the torque effects produced on the inner panels placed in solar farms.

While general trends are very well captured between the experimental data and numerical analysis, differences are also evident, as well. These differences might be resulting due to the experimental conditions available in wind tunnel versus the analysis assumptions employed through the use of 2D approach as discussed in detail in Chapter 3. It is also important to keep in mind that the testing and data recording on scaled model setups in any wind tunnel test might always yield unreliable results with regards to reflecting the full scale model conditions in real applications, and similar arguments also hold true with regards to the use of computational fluid dynamic analysis, as well. Despite the differences, capture of overall trends between the experimental and numerical results clearly provides a confidence on the CFD analysis employed in this thesis.

CHAPTER 5

VERIFICATION STUDY (EXPERIMENT)

As part of the numerical analysis study carried out on the determination of wind loads acting on inclined solar panels, it was also intended to carry out an experimental study in order to assess the accuracy of the analysis methodology employed in this thesis.

In this chapter, an experimental study carried out in Aerodynamics Laboratory of Middle East Technical University's Center for Wind Energy (METUWIND) is presented, and then the experimental results are also verified with numerical analysis.

5.1. Experiment Setup

The experiments are conducted in the suction type low speed wind tunnel present at METUWIND. The wind tunnel has a 1×1 m^2 cross sectional area with 2 m of fully transparent test section as can be seen in Figures 5.1 and 5.2. The tunnel has 45 kW electrical motor with hertz controller to adjust the velocity. This electrical motor operates a 1.2 m diameter axial fan. The maximum velocity that can be obtained by the tunnel is 24 m/s.

For the purpose of replicating an inclined solar panel, a blunt body is constructed through chipboard that has sufficient strength, rigidness and weight. The blunt body can be seen in Figure 5.2, and it has the dimensions of 2 cm × 20 cm × 96 cm and weighs 23N. The strain gauges used in this experiment have enough strength to hold a body weight of 50 N.

Figure 5.1. Wind Tunnel used at METUWIND

Figure 5.2. Chipboard Blunt Body with Aluminum Ends (Left Side) and Blunt Body Placed in the Wind Tunnel (Right Side)

In order to place the blunt body into the experimental setup, 2 aluminum bodies with 2 cm × 2 cm × 20 cm blocks are attached to the ends. These aluminum ends are then attached to the main chipboard body with 3 screws at each side. The whole body is attached to the strain gauges through the use of 1 cm diameter of aluminum rods, where aluminum is chosen for strength and lightness. While preparing the experimental setup, one of the most critical details is to place the constructed blunt body correctly inside the wind tunnel. In order to record the forces acting on the body, the load cells should be placed precisely.

The whole body is attached to the experimental setup with the help of shackle for the sake of correctness of the results. Subsequently, the strain gauges are set to zero, and the 45 kW motor of the wind tunnel is started. Right after the start, data recording is not collected up until the end of 1 minute in order to make sure that the flow is steady. For the data processing, the LabView program is used. This computer application is capable to gather 10000 data per second. Data is collected for nearly 5 seconds in every recording trial, where the data recording procedure is repeated for 5 times for each trial. The data is assembled for 5 seconds, then the motor of the wind tunnel is continued to work, after 1 minute the second set of data is collected. This procedure is repeated, and then the collection of 5 data sets is completed. After having nearly 50000 data for 1 trial and 5 trials for each data set, the approximate measurements for 1 data set are nearly resulting in 250000 data. Each data collected is consists of 6 values, which are the forces (in terms of Newton N) and moments (in terms of N.m) along x, y and z directions columns. The average of each data set is calculated, and the results of any set of data recording are compared with the rest of the data sets. In order validate the set of recordings, this recording procedure is repeated 3 times in different days, and it was ensured that all 3 sets of recording are nearly the same with each other so that the results can be considered as the reliable measurements related to the experiment carried out in the wind tunnel. LabView application has a special feature to adjust the inclination angle of the object. At the very beginning of experiment, the blunt body is aligned to be parallel to the wind side tunnel walls as can be seen in Figure 5.2, and this position is marked as 0˚ inclination during the tests. After running the tests, the body rotation is reset to zero and checked again to make sure that it is not rotated The maximum force that could be applied to the body was reached at 10m/s velocity at 35˚ inclination. After that, the strain gauges limit is exceeded. Therefore, to confirm the numerical analyses, the experiments on the blunt body are conducted up to 35˚ at 10 m/s wind speed. Average of the results under 5 m/s wind speed and 10 m/s wind speed for varying inclinations for the blunt body are presented in Table 5.1.

Table 5.1. Experiment Data Set Average

Velocity	5 m/s	
Inclination	**Drag Force (N)**	**Lift Force (N)**
0˚	0.2882	-0.5531
15˚	0.953	-1.8719
25˚	1.7679	-2.4703
30˚	2.2092	-2.8822
35˚	2.6085	-3.0839
45˚	3.538	-3.4902
50˚	4.4345	-3.4044
55˚	4.9712	-3.2606
60˚	5.4364	-2.971
65˚	5.8439	-2.6851
70˚	6.3227	-2.2467
75˚	6.5801	-1.7784
80˚	6.6608	-1.3611
85˚	6.8366	-0.7401
90˚	6.7549	-0.2364

Velocity	10 m/s	
Inclination	**Drag Force (N)**	**Lift Force (N)**
0˚	1.2389	-2.5316
15˚	4.4354	-8.3647
25˚	7.73	-10.9035
30˚	9.6105	-11.9703
35˚	11.5262	-12.9678

An important point to emphasize in the experimental results presented in Table 5.1 is especially visible at 0˚ and 90˚ inclination cases. It was observed that the blunt body used during the experiments did not result in expected drag and lift force values due to the physical geometry of the chipboard, either due to thickness of chipboard and possibly due to slight irregularities present on its surface. It is furthermore possible that slight misalignments in setting up these extreme cases of inclinations in the wind tunnel testing could have caused increased errors in these extreme cases, as well. For example, at 0˚ inclination, it would be expected to get close to zero lift force, while this was not case at 5 m/s and 10 m/s wind speeds, where the lift force is even greater than the drag force. It is also worth to point out that the blunt body considered is expected to represent a solar panel, and since no solar panel is actually placed with such extreme inclinations in open terrains, the error in conducting the experiments at 0˚ and 90˚ inclination does not cause any issue with regards to the comparison study that will be undertaken in the later part of this chapter.

5.2. CFD Analysis of Wind Tunnel Test on Blunt Body

In order to perform numerical analysis of the experiment conducted in the wind tunnel, the experimental setup is modeled in ANSYS FLUENT. The domain of air is created to represent 1 m × 1 m cross-section of wind tunnel with sufficient distance of air to flow before and after reaching the blunt body (Figure 5.3).

A body part is formed with dimensions of 96cm × 20cm × 2cm to represent the chipboard blunt body, where side view of the body is shown in Figure 5.4. This body is located 2 cm away from each side and centered at the middle of the cross-section of the numerical wind tunnel. Meshing of the body parts is attained at 3 different levels (coarse, medium and fine) in order to ensure that converged numerical results are reached with regards to creating an accurate representation of the model in the numerical environment in ANSYS.

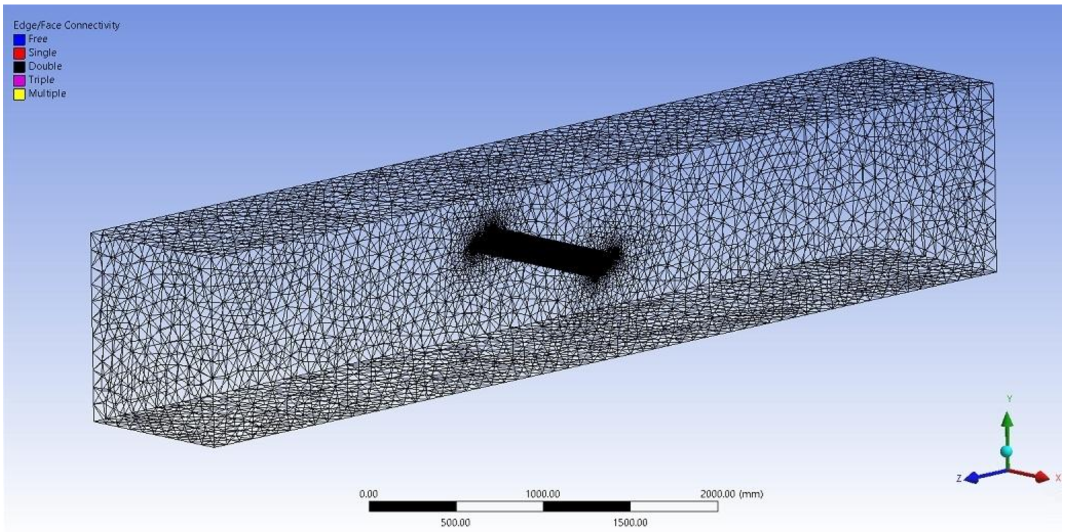

Figure 5.3. CFD Setup Mesh of the Wind Tunnel Experiment

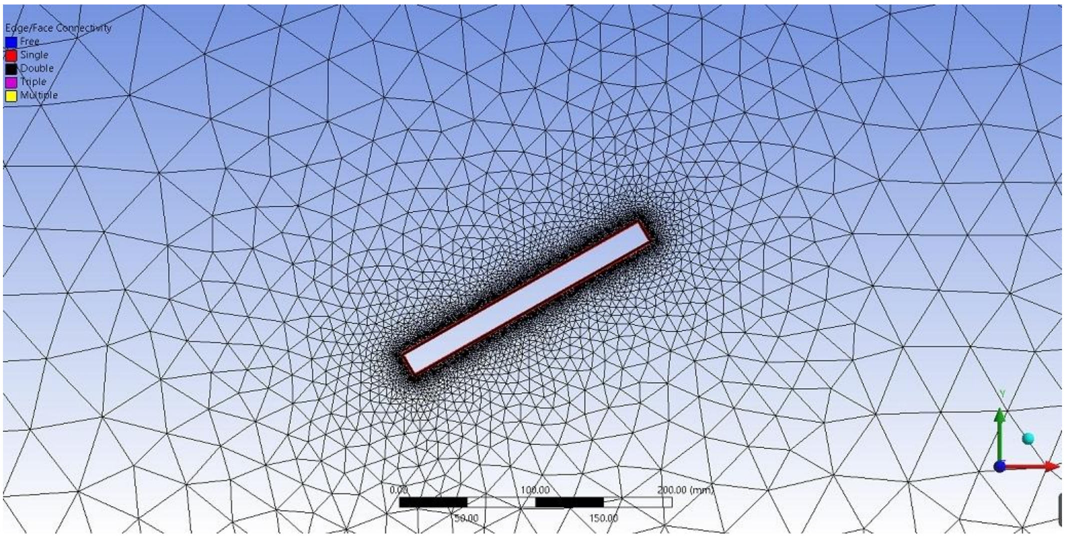

Figure 5.4. CFD Mesh Detail of the Solar Panel (Closer Look)

Numerical analysis is carried out for wind speeds of 5m/s, 10m/s and 20m/s at the velocity inlet with turbulent intensity of 1% and turbulent viscosity as 10. At the pressure outlet, the turbulent intensity is assigned as 5% and turbulent viscosity as 10. The model is run with SST k-ω method as discussed in Chapters 3 and 4. The results of the CFD analyses are presented in Table 5.2 for various inclinations for the blunt body.

Table 5.2. 3D CFD Analyses results

Velocity	5 m/s		10 m/s		20 m/s	
Inclination	**Drag Force (N)**	**Lift Force (N)**	**Drag Force (N)**	**Lift Force (N)**	**Drag Force (N)**	**Lift Force (N)**
0˚	0.3304	-0.0045	1.3243	0.0002	5.2987	0.05320
15˚	1.1420	-2.6669	4.5671	-10.6078	18.4147	-43.0105
25˚	1.9287	-3.1642	7.7357	-12.6852	31.2578	-51.4601
30˚	2.3883	-3.4082	9.6114	-13.7233	37.933	-53.9326
35˚	2.8440	-3.5613	11.4459	-14.3264	46.4243	-58.1116
45˚	3.7564	-3.6700	15.0423	-14.6788	61.0876	-59.5389
90˚	7.4075	0.0009	29.5824	0.0035	118.7269	0.0153

In addition to 3D analyses, 2D analyses are conducted to perform much faster numerical analyses and to assess whether the results of 2D analyses are reliable enough to represent 3D case for the wind tunnel test carried out in this thesis. To conduct these analyses, first the blunt body of 20 cm × 2 cm is created with a domain height of 1 m, and then sufficient amount of air domain is provided before and after the blunt body. The body is subtracted from the domain to permit flow of air. The velocity is set to 5m/s, 10m/s and 20m/s at the velocity inlet with turbulent intensity of 1% and turbulent viscosity as 10. At the pressure outlet, the turbulent intensity is assigned as 5% and turbulent viscosity as 10. Please note that, the forces are actually obtained in N/m unit in 2D analysis. The values from numerical analyses are multiplied by 0.96 m of the real width of the body to get the forces presented in Table 5.3. A comparison of the numerical results obtained from 3D and 2D clearly demonstrate that 2D analyses accurately represents the calculation of wind loads acting on a blunt body positioned to occupy the width of the cross-section of a wind tunnel.

Table 5.3. 2D CFD Analyses Results for 5 m/s, 10 m/s and 20 m/s

Velocity	5 m/s		10 m/s		20 m/s	
Inclination	**Drag Force (N)**	**Lift Force (N)**	**Drag Force (N)**	**Lift Force (N)**	**Drag Force (N)**	**Lift Force (N)**
0˚	0.298	0.046	1.202	0.163	4.833	0.628
15˚	1.098	-2.627	4.423	-10.573	17.787	-42.553
25˚	1.931	-3.257	7.763	-13.075	31.178	-52.475
30˚	2.345	-3.416	9.413	-13.696	37.770	-54.916
35˚	2.850	-3.599	11.446	-14.441	45.926	-57.886
45˚	3.770	-3.796	15.114	-15.228	60.573	-61.011
50˚	4.222	-3.789	16.930	-15.205	67.859	-60.900
55˚	4.972	-3.554	19.998	-14.251	80.174	-57.080
60˚	5.626	-3.286	22.590	-13.181	90.508	-52.793
65˚	6.314	-2.960	25.341	-11.874	101.503	-47.563
70˚	6.855	-2.499	27.507	-10.025	110.156	-40.138
75˚	7.238	-1.935	29.037	-7.759	116.292	-31.069
80˚	7.568	-1.324	30.373	-5.308	121.647	-21.252
85˚	7.755	-0.687	31.123	-2.754	124.640	-11.027
90˚	7.801	0.014	31.304	0.052	125.387	0.213

Velocity streamlines corresponding to wind speeds of 5, 10 and 20 m/s are shown through Figure 5.5 to 5.8. As can be seen, the wind speed increases at the top and at the bottom when wind gets in contact with the panel. When the wind flow reaches the obstruction, the streamlines are changed to create vortex behind the panel. The same trends are observed in Figure 5.7 for 10m/s and Figure 5.8 for 20m/s wind speeds. Although the wind velocities are different, the characteristics of the streamlines are proven to be equivalent. Therefore, it is seen that the change of wind speed does not alter the main characteristics of wind flow around the blunt body.

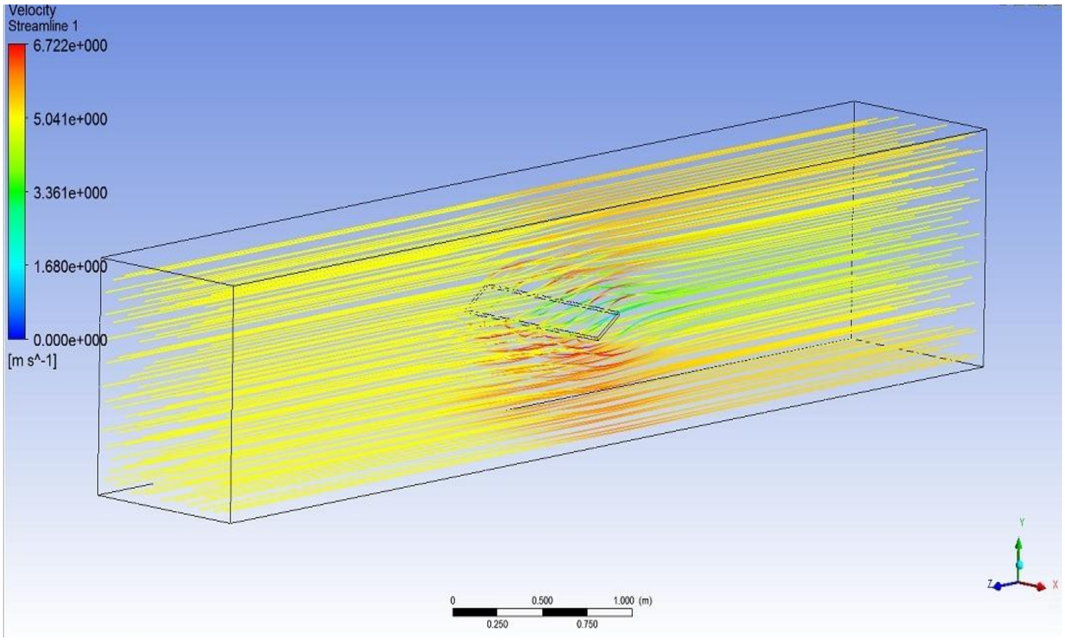

Figure 5.5. Velocity Streamline of CFD Analysis of Wind Tunnel Test at a Wind Speed of 5 m/s

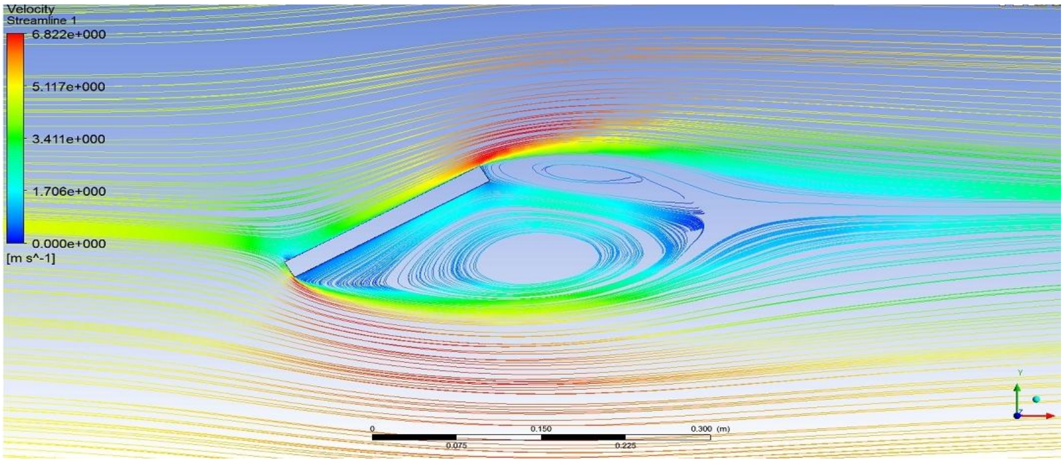

Figure 5.6. Velocity Streamline of CFD Analysis near Blunt Body at a Wind Speed of 5 m/s

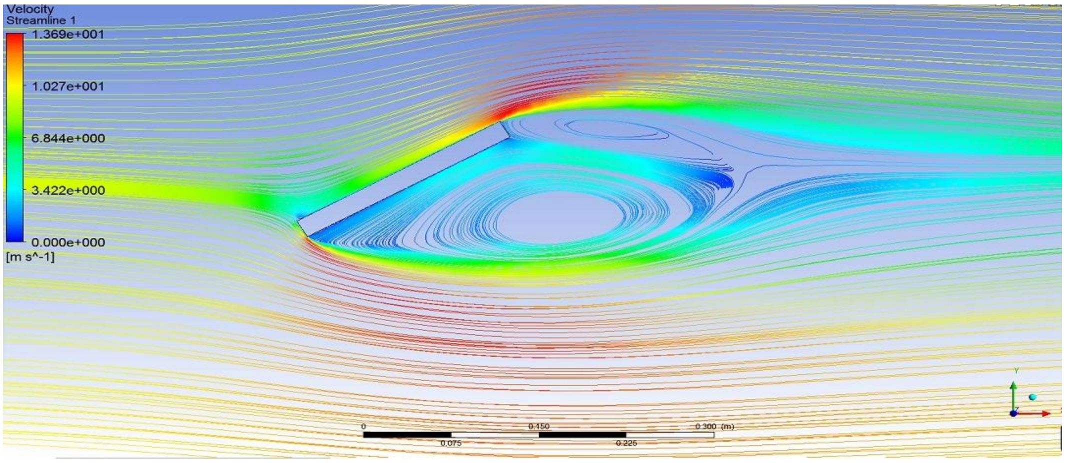

Figure 5.7. Velocity Streamline of the CFD Analysis near Blunt Body at a Wind Speed of 10 m/s

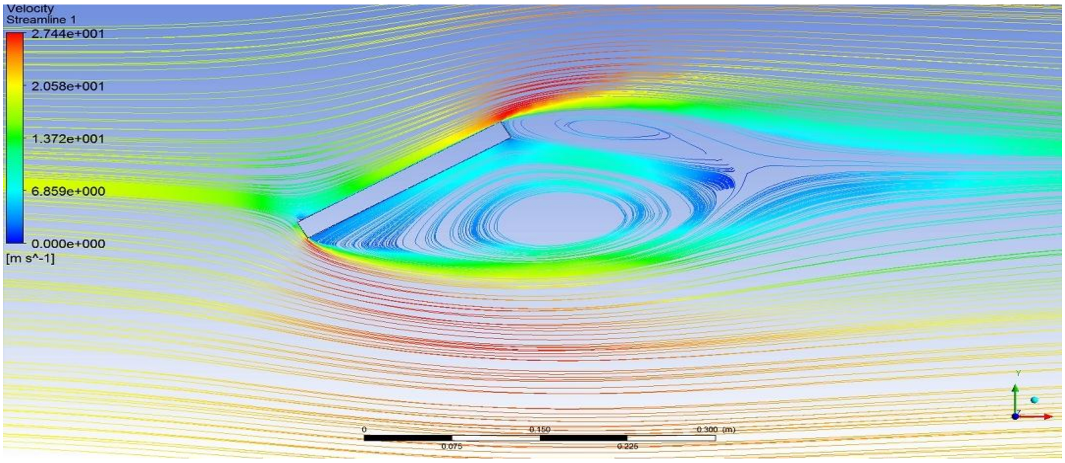

Figure 5.8. Velocity Streamline of CFD Analysis near Blunt Body at a Wind Speed of 20 m/s

5.3. Comparison of the Experimental and Numerical Results

Results of the numerical analysis carried out in 2D are compared with the experimental results in Table 5.4. Excluding the extreme cases of 0˚ and 90˚ inclination as discussed at the end of Section 5.1, it is observed that the bulk of the experimental and numerical results show similar trends and are sufficiently close to each other with an error of 5% to 20% for most practical inclinations.

Table 5.4. Wind Tunnel Experiment Results vs. 2D CFD Analyses Results

Inclination	**EXPERIMENTAL** **Velocity:** 5 m/s		**NUMERICAL** **Velocity:** 5 m/s	
	Drag Force (N)	**Lift Force (N)**	**Drag Force (N)**	**Lift Force (N)**
15	0.953	-1.872	1.098	-2.627
25	1.768	-2.470	1.931	-3.257
30	2.209	-2.882	2.345	-3.416
35	2.609	-3.084	2.850	-3.599
45	3.538	-3.490	3.770	-3.796
50	4.435	-3.404	4.222	-3.789
55	4.971	-3.261	4.972	-3.554
60	5.436	-2.971	5.626	-3.286
65	5.844	-2.685	6.314	-2.960
70	6.323	-2.247	6.855	-2.499
75	6.580	-1.778	7.238	-1.935
80	6.661	-1.361	7.568	-1.324
85	6.837	-0.740	7.755	-0.687
Inclination	**EXPERIMENTAL** **Velocity:** 10 m/s		**NUMERICAL** **Velocity:** 10 m/s	
	Drag Force (N)	**Lift Force (N)**	**Drag Force (N)**	**Lift Force (N)**
15	4.435	-8.365	4.423	-10.573
25	7.730	-10.904	7.763	-13.075
30	9.611	-11.970	9.413	-13.696
35	11.526	-12.968	11.446	-14.441

In light of discrepancies observed in results, it is important to discuss the causes of these, as well. First of all, it is worth to point out that the experimental setup might not have been exactly replicated in the numerical environment. Human error, measurement errors in carrying out the experiments always exist in any test especially conducted in a wind tunnel. Furthermore, environmental conditions and unpredictable factors, such as temperature are not taken into account in the numerical model. In the numerical analysis, the conditions are near to the ideal, the smoothness of the blunt body is perfect without irregularities, and the body has no additional friction on the sides due to material imperfection and the placement of connecting rods in the experiment. The experimental blunt body is made of regular imperfect chipboard. Furthermore, the end connection rods of the chipboard to the strain gauges of the wind tunnel might have also resulted in slight changes in expected results with respect to the numerical model.

In the light of these potential indiscretions, the found results of experiment and numerical analyses are sufficiently tolerable. With these analyses, it is seen that the steady state SST k-ω model and analysis presented in Chapter 3 provides reliable methodology in calculating wind loads acting on blunt bodies compared to carrying experiments in wind tunnel.

CHAPTER 6

COMPARATIVE ANALYSIS WITH ASCE 07/10

In this chapter, comparison between the design wind loads acting on the solar panels and the supporting structures calculated through the numerical analyses methodology presented in Chapter 3 will be compared with the design wind loads calculated through the use of ASCE 07/10 (ASCE, 2010) specification for mono-slope free roofs.

6.1. Wind Load Calculations according to ASCE 07-10

The wind loads are found according to the specification in the following calculations by using the mono-slope free roof wind coefficients. There are 8 different cases specified for the wind load calculations. These cases are due to normal wind flow direction (0˚) and reverse wind flow direction (180˚), due to obstructed and unobstructed wind flows. Furthermore, two different loading cases are presented in ASCE, namely Load Case A and Load Case B, where these load cases provide an envelope on the maximum wind forces as obtained through wind tunnel tests.

Wind loads calculated through the specification in ASCE are compared with the results obtained from the numerical analysis methodology presented in Chapters 3 and 4. Both the normal and reverse wind flow analyses are undertaken. However, wind flow below a solar panel is an unobstructed flow, thus obstructed wind flow analyses will not be undertaken in the comparative study, yet the results of ASCE for all 8 cases will be provided.

The wind calculations are done according to ASCE 07/10 (ASCE, 2010) by considering the following parameters and equations. First of all, recall that a single solar panel with the length of 2.4 m with clear height from the ground set at 0.59 m with mean height of 1.1 m from previous chapter.

The following parameters are considered in calculating the wind force acting on this panel:

K_d = 0.85 is the wind directionality factor is used for the fact that the probability that the maximum wind may not impact the structural system in its weakest orientation. It can be found ASCE 07/10 Table 26.6-1. (ASCE, 2010)

K_z represents terrain exposure constant and is chosen to be D. Exposure Type D is selected for unobstructed areas and water surfaces outside hurricane prone regions. This category includes smooth mud flats, salt flats, and unbroken ice that extend 20 times the building height in the upwind direction. Since the solar panel farms are constructed in open terrains with no obstruction with flat surface, this category is applicable. The detailed information can be found at ASCE Chapter 26.7.2 Surface Roughness Categories and Chapter 26.7.3 Exposure Categories. (ASCE, 2010)

α is the 3-sec gust-speed power law exponent from Table 26.9-1, which is 11.5 for this calculations. (ASCE, 2010)

z_g is the nominal height of the atmospheric boundary layer used in ASCE 07/10 standard and can be found in Table 26.9-1. (ASCE, 2010) In this study, it is taken as 213.36m.

z is the height above ground level, the height is approximately 1.65m for this study.
K_z represents the velocity pressure exposure coefficient evaluated at height z. (see Equation 6.1)

$$K_z = (2.01)\left(\frac{4.572}{z_g}\right)^{2/\alpha} \tag{6.1}$$

$K_z = 1.03$

K_{zt} is the topographic factor for wind speed-up over hills, ridges and escarpments.

This study is only focused on the flat areas, therefore it is taken as 1.

G, Gust Effect Factor:

Assume rigid structure f > 1.0

$\mathrm{G} = 0.85$

Velocity Pressure is calculated by Equation 6.2:

$$q_z = (0.613)\ K_z\ K_{zt}\ K_d\ V^2 \tag{6.2}$$

where V is the wind speed and taken as 17.5 m/s and $\theta = 25$ for all cases. Therefore: $q_z = 164.36\ \mathrm{N/m^2}$

Please note that all the signs are converted according to the one used throughout this study.

In the next steps, the wind loads on the structural system are calculated according to different load cases. The abbreviations used in the below calculations are explained in the following:

p_{NW0A1} is the net design pressure to be used in determination of wind loads for buildings.

C_{NW0A1} : C_N is the net pressure coefficient to be used in determination of wind loads for open building, where;

W and L are the parts of the panel shown in ASCE Figure 27.4-4. (ASCE, 2010)

0 and 180 represent the wind direction.

A and B are the load cases shown in ASCE Figure 27.4-4. (ASCE, 2010)

“1” represents the clear wind flow and “2” represents obstructed wind flow.

6.1.1. CASE 1: Wind Direction $\gamma = 0$, Clear Wind Flow, Load Case A

$$C_{NW0A1} = -1.5 + -0.3\frac{\theta - 22.5}{30 - 22.5}$$

$$C_{NL0A1} = -1.6 + -0.2\frac{\theta - 22.5}{30 - 22.5}$$

$$C_{NW0A1} = -1.6$$

$$C_{NL0A1} = -1.67$$

$$p_{NW0A1} = q_z.G.C_{NW1}$$

$$p_{NW0A1} = -223.58\ N/m^2$$

$$p_{NL0A1} = q_z.G.C_{NL1}$$

$$p_{NL0A1} = -233.36\ N/m^2$$

<u>Drag and Lift Force and Moment Calculations</u>

P_{NW}=	-223.580	N/m^2
P_{NL}=	-233.360	N/m^2
Total Force Normal to the Panel=	-548.328	N/m
Drag Force =	-231.733	N/m
Lift Force =	-496.954	N/m
Torque =	7.042	N.m/m

6.1.2. CASE 2: Wind Direction $\gamma = 0$, Clear Wind Flow, Load Case B

$$C_{NW0B1} = -2.4 + -0.1\frac{\theta - 22.5}{30 - 22.5}$$

$$C_{NL0B1} = -0.3 + -0.2\frac{\theta - 22.5}{30 - 22.5}$$

$$C_{NW0B1} = -2.43$$

$$C_{NL0B1} = -0.37$$

$$p_{NW0B1} = q_z.G.C_{NW1}$$

$$p_{NW0B1} = -339.56\ N/m^2$$

$$p_{NL0B1} = q_z.G.C_{NL1}$$

$$p_{NL0B1} = -51.70\ N/m^2$$

<u>Drag and Lift Force and Moment Calculations</u>

P_{NW}=	-339.560	N/m^2
P_{NL}=	-51.700	N/m^2

Total Force Normal to the Panel=	-469.512	N/m
Drag Force =	-198.424	N/m
Lift Force =	-425.522	N/m
Torque =	-207.259	N.m/m

6.1.3. CASE 3: Wind Direction $\gamma = 0$, Obstructed Wind Flow, Load Case A

$C_{NW0A2} = -1.5$

$C_{NL0A2} = -1.7 + -0.1\frac{\theta - 22.5}{30 - 22.5}$

$C_{NW0A2} = -1.5$

$C_{NL0A2} = -1.73$

$p_{NW0A2} = q_z.G.C_{NW2}$

$p_{NW0A2} = -209.60\ N/m^2$

$p_{NL0A2} = q_z.G.C_{NL2}$

$p_{NL0A2} = -241.74\ N/m^2$

<u>Drag and Lift Force and Moment Calculations</u>

P_{NW}=	-209.600	N/m^2
P_{NL}=	-241.740	N/m^2
Total Force Normal to the Panel=	-541.608	N/m
Drag Force =	-228.893	N/m
Lift Force =	-490.864	N/m
Torque =	23.141	N.m/m

6.1.4. CASE 4: Wind Direction $\gamma = 0$, Obstructed Wind Flow, Load Case B

$C_{NW0B2} = -2.3$

$C_{NL0B2} = -0.9 + -0.2\frac{\theta - 22.5}{30 - 22.5}$

$C_{NW0B2} = -2.3$

$C_{NL0B2} = -0.97$

$p_{NW0B2} = q_z.G.C_{NW2}$

$p_{NW0B2} = -321.39\ N/m^2$

$p_{NL0B2} = q_z.G.C_{NL2}$

$p_{NL0B2} = -135.54\ N/m^2$

Drag and Lift Force and Moment Calculations

P_{NW}=	-321.390	N/m^2
P_{NL}=	-135.540	N/m^2
Total Force Normal to the Panel=	-548.316	N/m
Drag Force =	-231.728	N/m
Lift Force =	-496.943	N/m
Torque =	-133.812	N.m/m

6.1.5. CASE 5: Wind Direction $\gamma = 180$, Clear Wind Flow, Load Case A

$$C_{NW180A1} = 1.7 + 0.4\frac{\theta - 22.5}{30 - 22.5}$$

$$C_{NL180A1} = 1.8 + 0.3\frac{\theta - 22.5}{30 - 22.5}$$

$$C_{NW180A1} = 1.83$$

$$C_{NL180A1} = 1.9$$

$$p_{NW180A1} = q_z.G.C_{NW3}$$

$$p_{NW180A1} = 255.72\ N/m^2$$

$$p_{NL180A1} = q_z.G.C_{NL3}$$

$$p_{NL180A1} = 265.50\ N/m^2$$

Drag and Lift Force and Moment Calculations

P_{NW}=	255.720	N/m^2
P_{NL}=	265.500	N/m^2
Total Force Normal to the Panel=	625.464	N/m
Drag Force =	264.333	N/m
Lift Force =	566.863	N/m
Torque =	-7.042	N.m/m

6.1.6. CASE 6: Wind Direction $\gamma = 180$, Clear Wind Flow, Load Case B

$$C_{NW180B1} = 2.2 + 0.4\frac{\theta - 22.5}{30 - 22.5}$$

$$C_{NL180B1} = 0.7 + 0.3\frac{\theta - 22.5}{30 - 22.5}$$

$$C_{NW180B1} = 2.33$$

$$C_{NL180B1} = 0.8$$

$p_{NW180B1} = q_z.G.C_{NW3}$

$p_{NW180B1} = 325.58\ N/m^2$

$p_{NL180B1} = q_z.G.C_{NL3}$

$p_{NL180B1} = 111.79\ N/m^2$

Drag and Lift Force and Moment Calculations

P_{NW}=	325.580	N/m^2
P_{NL}=	111.790	N/m^2
Total Force Normal to the Panel=	524.844	N/m
Drag Force =	221.809	N/m
Lift Force =	475.670	N/m
Torque =	153.929	N.m/m

6.1.7. CASE 7: Wind Direction $\gamma = 180$, Obstructed Wind Flow, Load Case A

$$C_{NW180A2} = 0.5 + 0.1\frac{\theta - 22.5}{30 - 22.5}$$

$C_{NL180A2} = -1$

$C_{NW180A2} = 0.53$

$C_{NL180A2} = -1$

$p_{NW180A2} = q_z.G.C_{NW4}$

$p_{NW180A2} = 74.06\ N/m^2$

$p_{NL180A2} = q_z.G.C_{NW4}$

$p_{NL180A2} = -139.74\ N/m^2$

Drag and Lift Force and Moment Calculations

P_{NW}=	74.060	N/m^2
P_{NL}=	-139.740	N/m^2
Total Force Normal to the Panel=	-78.811	N/m
Drag Force =	-33.307	N/m
Lift Force =	-71.43	N/m
Torque =	153.933	N.m/m

6.1.8. CASE 8: Wind Direction $\gamma = 180$, Obstructed Wind Flow, Load Case B

$$C_{NW180B2} = 1.3 + 0.3\frac{\theta - 22.5}{30 - 22.5}$$

$$C_{NL180B2} = 0.1\frac{\theta - 22.5}{30 - 22.5}$$

$$C_{NW180B2} = 1.4$$

$$C_{NL180B2} = 0.03$$

$$p_{NW180B2} = q_z.G.C_{NW4}$$

$$p_{NW180B2} = 195.63\ N/m^2$$

$$p_{NL180B2} = q_z.G.C_{NW4}$$

$$p_{NL180B2} = 4.19\ N/m^2$$

<u>Drag and Lift Force and Moment Calculations</u>

P_{NW}=	195.630	N/m^2
P_{NL}=	4.190	N/m^2
Total Force Normal to the Panel=	239.784	N/m
Drag Force =	101.337	N/m
Lift Force =	217.318	N/m
Torque =	137.837	N.m/m

6.2. Comparison of Analyses Results with ASCE 07/10

A summary of the load case results are presented in Table 6.1.

Table 6.1. Drag and Lift Forces and Moments according to ASCE 07-10

CASE 1	Drag Force =	-231.733 N/m
	Lift Force =	496.954 N/m
	Moment =	7.042 N.m/m
CASE 2	Drag Force =	-198.424 N/m
	Lift Force =	-425.522 N/m
	Moment =	-207.259 N.m/m
CASE 3	Drag Force =	-228.893 N/m
	Lift Force =	-490.864 N/m
	Moment =	23.141 N.m/m
CASE 4	Drag Force =	-231.728 N/m
	Lift Force =	-496.943 N/m
	Moment =	-133.812 N.m/m
CASE 5	Drag Force =	264.333 N/m
	Lift Force =	566.863 N/m
	Moment =	-7.042 N.m/m
CASE 6	Drag Force =	221.809 N/m
	Lift Force =	475.670 N/m
	Moment =	153.929 N.m/m
CASE 7	Drag Force =	-33.307 N/m
	Lift Force =	-71.43 N/m
	Moment =	153.933 N.m/m
CASE 8	Drag Force =	101.337 N/m
	Lift Force =	217.318 N/m
	Moment =	137.837 N.m/m

The analyses results are given in Table 6.2 and will be compared with ASCE 07/10 specification results. Please note that in Table 6.1 the coefficients are given for both the obstructed and unobstructed cases. In this thesis unobstructed cases are not analyzed, consequently are not compared with the specification results. These results are provided in above table in order to help future researchers to ease the comparison and sake of completeness when obstructed wind flow cases are of interest for solar panels, as well.

Table 6.2. Drag, Lift and Moment Coefficient Results according to 2D CFD Analysis

	Normal Wind Direction	Reverse Wind Direction
Drag Force =	267.411 N/m	-235.448 N/m
Lift Force =	-548.328 N/m	488.904 N/m
Moment =	118.850 N.m/m	-105.884 N.m/m

Comparison of the results is undertaken between Table 6.1 Case1&2 and Table 6.2 reverse wind direction case and Table 6.1 Case5&6 with Table 6.2 normal wind direction case. In these comparisons, it is intended to find whether one of two cases for each wind direction is compatible with the wind loads given in the specification or not.

Reverse wind direction cases (180˚ wind flow) are covered in Case 1 and Case 2. Case 1 is the case with larger total force acting on the panel with lower torque. In Case 2, the total load on the panel is smaller whereas the torque is increased compared to Case1. The design drag load for Case 1 is -231.733 N/m, which is very similar to the analysis result of -235.448 N/m. Also, the design lift load is 496.954 N/m where the design lift load for analysis result is 488.904 N/m. For the design moment load, the result of the analysis is -105.884, while the result for the specification is 7.042 N.m/m. As can be seen from this comparison the analysis results for the reverse wind flow is closely matching and compatible with wind forces calculated through ASCE Specification.

Normal wind direction cases are covered in Case 5 and Case 6. For this wind flow direction, it is found that the analysis results are analogous to Case 5. The design drag load for Case 5 is raised to be 264.333 N/m and found as 267.411 N/m in the numerical analysis. The design lift loads are settled at 566.863 N/m and -548.328 N/m for the analysis and the specification results, respectively. For the design moment load, the specification gives -7.042 N.m/m and it is found as 118.850 N.m/m in the CFD analysis conducted. Similarities between the results show that CFD analyses are proven to have identical results to the load cases shown in ASCE 07-10.

CHAPTER 7

PARAMETRIC STUDY

In this chapter, parametric study is carried out by using computational fluid dynamic (CFD) analysis methodology presented in Chapters 3 and 4 in order to study the sheltering effect on solar farms.

7.1. Parametric Study Variables

Consecutively placed solar panels are analyzed for both forward and reverse wind flows by considering panel length, clear height from the ground, spacing between 2 consecutive solar panels and tilt angle (inclination) as variables.

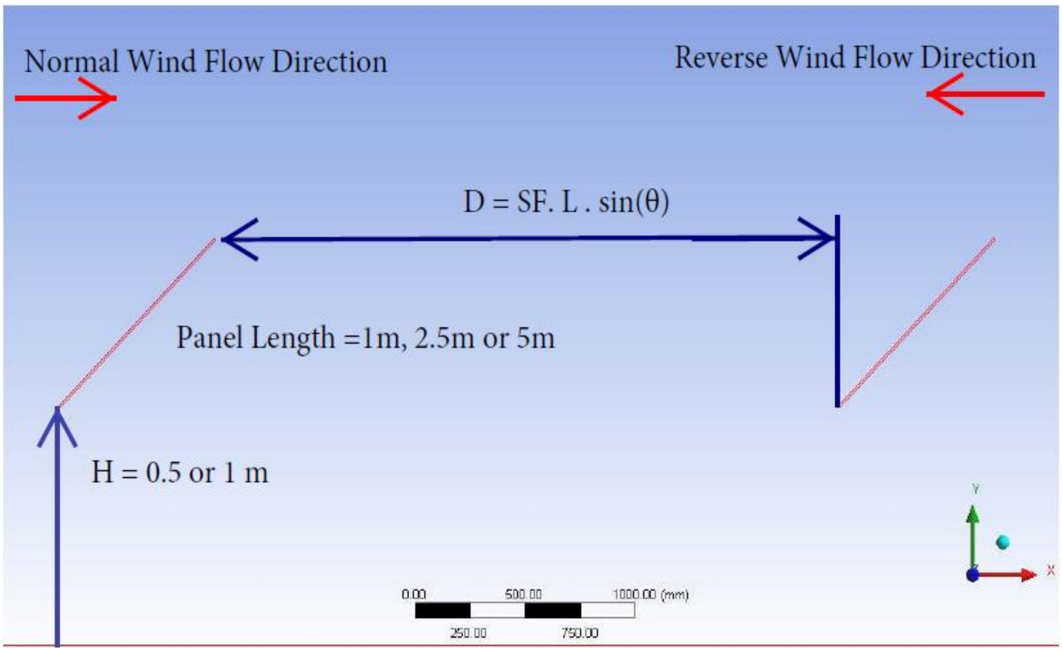

Figure 7.1. Parametric Study Details

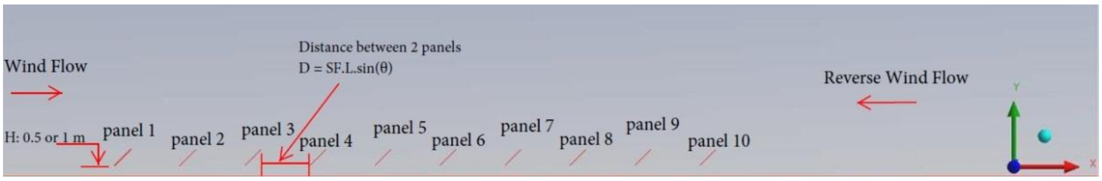

Figure 7.2. CFD panel setup and wind directions

Horizontal distance *D* between the panels is taken as the shortest distance from the end projection of a panel to the nearest edge of the next panel as shown in Figures 7.1 and 7.2. This distance is related to the panel length L, inclination angle θ and a spacing factor SF as given in the next equation.

$$D = \mathrm{SF}.\, L.\sin(\theta) \tag{7.1}$$

Where;

SF = Spacing factor is calculated through an optimization process so that shadowing of panels within a time range of target during daytime is eliminated in order to increase energy production.

D = Horizontal distance is the distance between front most panel's end and posterior panel's start.

L = Length of the panel

θ = Inclination angle of the panel is determined in order to maximize energy production.

Calculation of an optimum value of inclination and spacing factor is out of the scope of this thesis. These parameters are going to be selected such that most of the cases of interest can be covered as much as possible.

In this study, 2 different clear front heights from the ground, 3 different panel lengths, 5 different spacing factors between the panels, 6 different panel inclinations and lastly normal and reverse wind flows are considered resulting in 360 CFD analysis cases in total, where the results are documented in Appendix. These parameters are selected by referring to Figure 7.1 as follows:

H, clear height from the ground: 0.5 m and 1.0 m

L, panel length: 1000 mm, 2500 mm and 5000 mm

SF, space factor: 1, 2, 3, 4 and 5.

θ, inclination of panel (IoP): 7.5˚, 15˚, 22.5˚, 30˚, 37.5˚ and 45˚.

Ground mounted solar panels are always placed with a clear front height from the ground in order not to be obstructed by vegetation, snow accumulation, water flow and these kind of unseen reasons. Furthermore, in some cases, grazing of animals is also asked for by the owner of the solar farms. Two different clear front heights from the ground are tested to see the influences of the clear front height on the effective wind loads acting on the consecutively placed solar panels.

Spacing factor is taken as another parameter. It is known that the horizontal distance between the solar panels are calculated through an optimization process, thus the influence of different SF values on wind loads acting on the panels are needed to be investigated. The wind flow is different depending on the distance between the panels, which creates an important unpredictability with regards to the calculation of wind loads, as well.

The reason for selecting the 6 inclination angles is due to ASCE 07/10. In this specification, wind load coefficients on mono-slope roofs are provided for the same 6 angle values. By carrying out parametric analyses through consideration of the same angles will allow direct comparison for the design engineers in practice.

Panel lengths are chosen as 1000 mm, 2500 mm and 5000 mm since most of the projects have the panel lengths chosen between 1000 mm and 5000 mm. In this study, 2500 mm is also added to see the trend and provide data for better interpolation.

The wind speed of 40 m/s is chosen, since this value practically provides the target design wind speed for most regions in USA as specified by ASCE 07/10. It should be noted that the drag coefficients, lift coefficients and torque coefficients will be provided, thus the values corresponding to different wind velocities can be found through the use of these coefficients in a standard manner as done in the specifications available in ASCE 07/10, as well.

In the analyses, COST guidelines as discussed in Chapter 3 are applied to the description of the domain for CFD analysis. Also, the solar panels are assumed to be placed alongside each other in the lateral direction so that 2D analyses results provides accurate representation of the wind loads acting on the consecutively placed solar panels for both frontal and reverse wind flows. It is important to emphasize that by considering 2D analysis, oblique flow of wind on the panels cannot be studied.

The reason for the choice of 2D analysis is due to the nature of computation power needed to carry out 3D analysis for consecutively placed panels for 360 different cases of CFD analysis. In order to determine sheltering effect, 10 consecutively placed solar panels are considered as shown in Figure 7.2, where the reason for this choice is provided in the next section. Even with the simplification considered by the use of 2D analysis approach, all of the analyses were concluded in about 1 month duration.

7.2. Verification for Using 10 Consecutively Placed Solar Panels

In order to carry out the parametric analysis, first of all the influence of the number of consecutively placed solar panels on the resulting sheltering effect and wind loads acting on each panel is needed to be studied. In the case of a real solar farm application, several solar panels would be placed consecutively. With regards to carrying out numerical analysis, the choice of lesser number of panels definitely allows reduced modeling effort and computation time, but in that case an accurate determination of sheltering effect may not be reached with respect to the reality faced in a solar farm.

For this purpose, the cases of 3, 5 and 10 consecutively placed solar panels are considered towards CFD analysis with the methodology presented in Chapters 3 and 4. Each panel length is 2.4 m, clear front height is taken as 0.50 m and inclination of each panel is set to 25˚. Analysis conducted for a wind velocity of 17.5 m/s. For each case of number of panels used, spacing between the panels is selected to vary as 2 m, 4 m and 8 m, resulting in approximately spacing factors of 2, 4 and 8, as well.

Table 7.1. Drag and Lift Coefficients for 10, 5 and 3 Consecutively Placed Solar Panels under Varying Spacing Values of 2 m, 4 m and 8 m

	2 m Spacing		**4 m Spacing**		**8 m Spacing**	
Panel	**Drag (N/m)**	**Lift (N/m)**	**Drag (N/m)**	**Lift (N/m)**	**Drag (N/m)**	**Lift (N/m)**
1	0.515	-1.106	0.552	-1.189	0.579	-1.246
2	0.131	-0.277	0.267	-0.571	0.364	-0.782
3	0.188	-0.400	0.241	-0.515	0.315	-0.678
4	0.150	-0.319	0.213	-0.456	0.259	-0.557
5	0.146	-0.310	0.188	-0.404	0.240	-0.515
6	0.142	-0.303	0.180	-0.386	0.221	-0.475
7	0.127	-0.272	0.162	-0.349	0.205	-0.440
8	0.122	-0.260	0.157	-0.337	0.202	-0.434
9	0.118	-0.252	0.145	-0.310	0.187	-0.401
10	0.120	-0.256	0.147	-0.316	0.190	-0.409
Panel	**Drag (N/m)**	**Lift (N/m)**	**Drag (N/m)**	**Lift (N/m)**	**Drag (N/m)**	**Lift (N/m)**
1	0.587	-1.261	0.606	-1.303	0.632	-1.359
2	0.187	-0.398	0.303	-0.650	0.363	-0.780
3	0.209	-0.445	0.261	-0.561	0.293	-0.628
4	0.171	-0.364	0.218	-0.467	0.247	-0.529
5	0.173	-0.371	0.203	-0.436	0.226	-0.485
Panel	**Drag (N/m)**	**Lift (N/m)**	**Drag (N/m)**	**Lift (N/m)**	**Drag (N/m)**	**Lift (N/m)**
1	0.583	-1.253	0.608	-1.306	0.632	-1.358
2	0.166	-0.352	0.306	-0.655	0.398	-0.855
3	0.238	-0.509	0.268	-0.575	0.315	-0.675

Drag and lift force values obtained from CFD analyses are given in Table 7.1. In order to observe the trends of the forces acting on each panel for varying number of panel placements and spacing values, plots of the results presented in Table 7.1 are provided in Figures 7.3 to 7.8, as well. In these figures, is observed depending on spacing between the panels, the wake effects from a panel onto the next panel change. The use of 3 and 5 panel placements do not accurately capture a stabilized value of forces acting on the rear panels. It is observed that the forces are mostly converging asymptotically to a value by the use of 10 consecutively placed solar panels, thus the parametric analysis discussed in Section 7.1 is carried out by the use 10 panels.

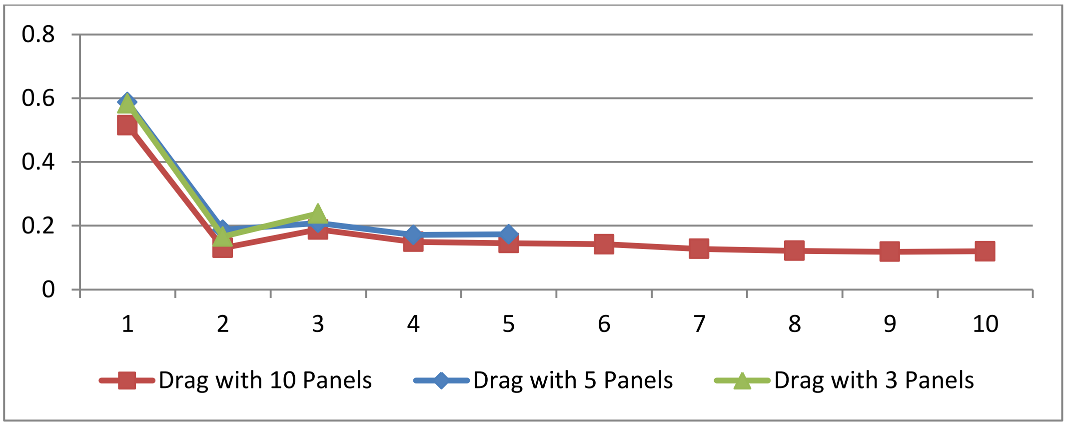

Figure 7.3. Drag Coefficients for 3, 5 and 10 Panel Placements with 2 m Spacing

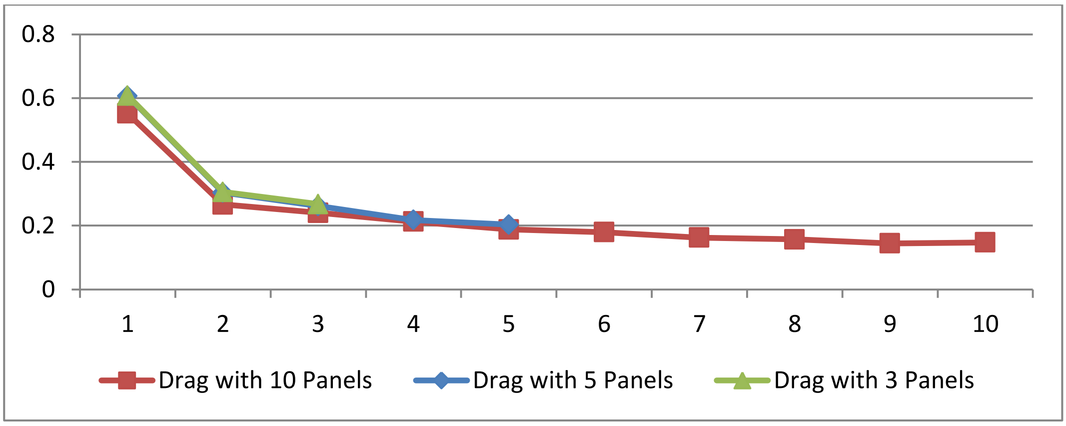

Figure 7.4. Drag Coefficients for 3, 5 and 10 Panel Placements with 4 m Spacing

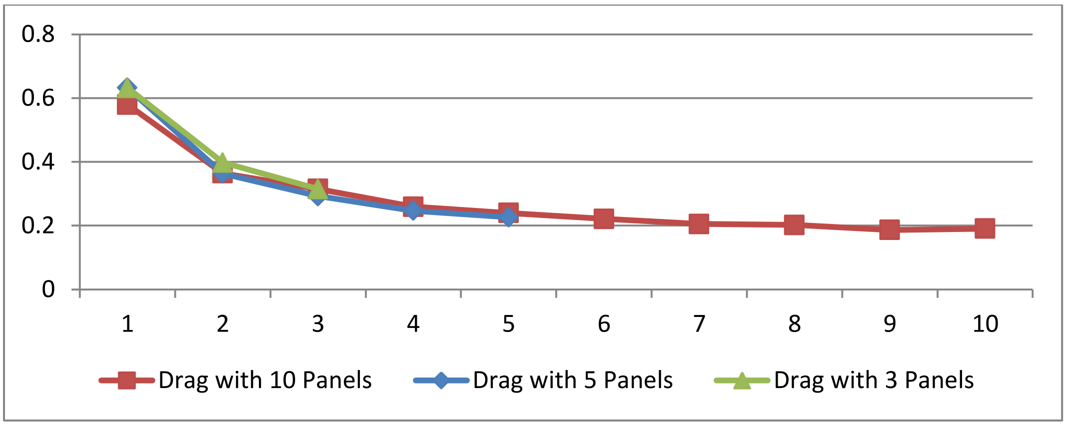

Figure 7.5. Drag Coefficients for 3, 5 and 10 Panel Placements with 8 m Spacing

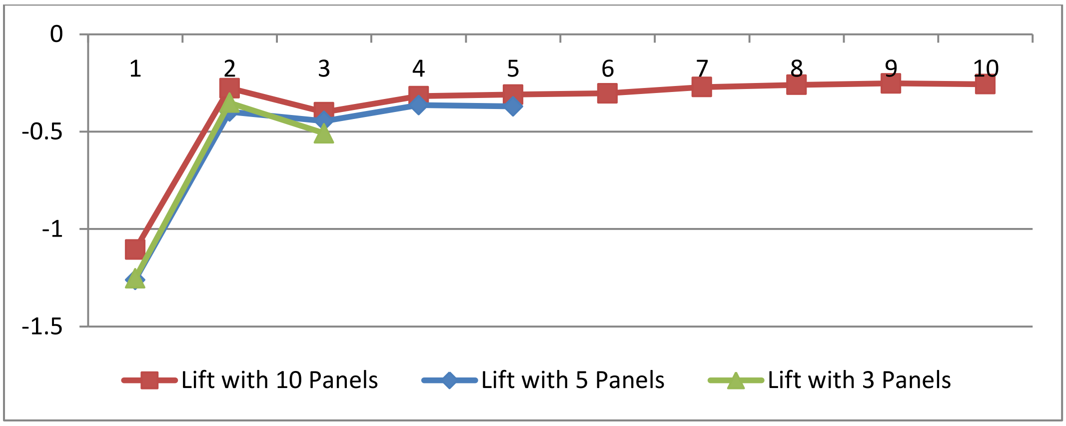

Figure 7.6. Lift Coefficients for 3, 5 and 10 Panel Placements with 2 m Spacing

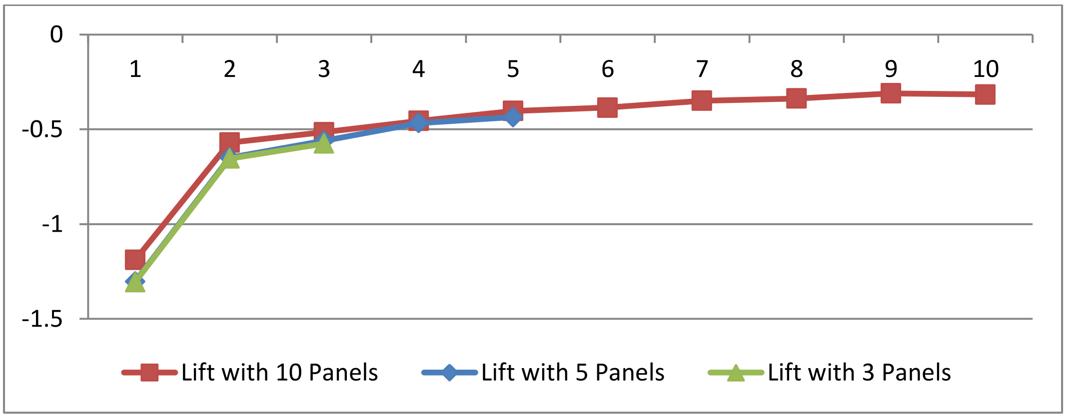

Figure 7.7. Lift Coefficients for 3, 5 and 10 Panel Placements with 4 m Spacing

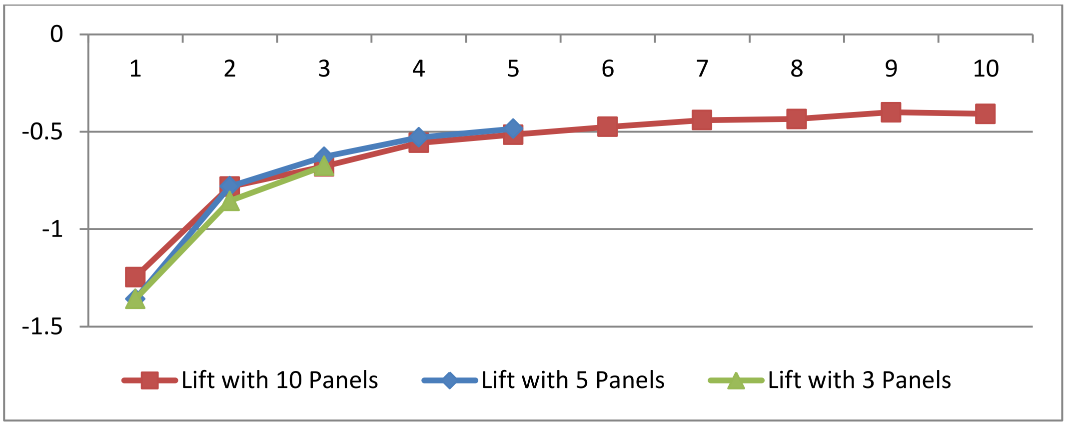

Figure 7.8. Lift Coefficients for 3, 5 and 10 Panel Placements with 8 m Spacing

7.3. Effect of Clear Front Height from Ground

The effect of clear front height from the ground on the wind loads acting on the consecutively placed solar panels is discussed in this section. It is assumed that each solar panel is assumed to be placed with the same clear front height from the ground, where two different values are considered for CFD analyses, which are 0.5 m and 1.0 m. Please refer Figures 7.1 and 7.2 for the presentation of the computational domain. While the conducted CFD analyses considers 360 different cases as discussed in Section 7.1, presentation of the results for all these cases is a cumbersome task to undertake. For demonstration purposes in this thesis, the results of the following parameters are going to be presented only: panel length L of 2.5 m, spacing factor SF of 3.0, inclination of panel IoP of 22.5˚. Analyses are carried out for both normal and reverse wind flow directions.

Drag, lift and moment coefficients on each panel are presented in Figures 7.9, 7.10, and 7.11, respectively. For the purposes of discussion, it is important to point out that for the results of 0.5 m clear front height, the coefficients at 10th panel show slight discrepancy with respect to the 9th panel result. This phenomenon occurs due to the fact that after 10th panel, flow of wind is free, while the same is not true for prior panels. Thus the result of 9th panel can be taken as the asymptotically converged values for following discussions. For 1.0 m clear front height, it is observed that 10th

panel results are very similar to 9th one due to the fact that free flow of air under the panels allows stabilized results even at the last panel.

In these figures, it is observed that the drag coefficients on each panel increases as the clear height increases for normal wind flow direction. The increase in drag on the first panel is relatively insignificant compared to the increase of drag on the consecutive panels. As the clear height from the ground increases twofold (100% from 0.5 m to 1.0 m), the stabilized drag force on the panels increase more than 60% for the case analyzed.

For the reverse wind flow, the drag force on the first panel facing the wind is higher for 0.5m clear front height case, and the increase compared to 1.0 m clear height is quite significant this time. The reason for the increase on the first panel drag is due to the type of obstruction provided by the inclination of the panel to the wind flow. For this case, the reversed wind flow can more easily flow under the panel compared to flowing above the panel, and lowered clear height causes a narrow passage of this wind flow underneath, thus resulting in increased drag on the first panel facing the flow for lowered clear front height.

Despite this phenomenon on the first panel for reverse wind flow, lowered drag forces are observed on all other panels similar to the case in normal wind flow. The first obstruction provided by the front panel facing the reverse wind flow results in significant reductions on the consecutive panels, and as the first panel attracts more drag due to lowered clear height, smaller drag forces are attracted by others. As the clear height from the ground increases twofold (100% from 0.5 m to 1.0 m), the stabilized drag force on the panels increase close to 100%, as well. This clearly shows that special attention should be paid on the design of the panels and supporting structures for the reverse wind flow case.

The lift coefficients on the panels for both normal and reverse wind flows show similar trends as observed for the drag coefficients.

With regards to the discussion on moment coefficients, the same type of trends present in drag and lift forces are not observed. For the case of normal wind flow, the moment coefficient on the first panel is significantly higher than the succeeding panels for both clear front heights. Actually, it can be said that almost only the first panel experiences significant moment action, and the moment actions on the rear panels can be ignored.

A closer look at the moment coefficients on succeeding panels for normal wind flow shows quite interesting physical actions. The moment coefficients are significantly higher for the panels with 1.0 m clear height in real panels, where this increase is especially visible after the third panel. For 0.5 m clear front height case, it is observed that the sign of the moment action is reversed, while the sign remains the same for 1.0 m height in succeeding panels.

For the reverse wind flow, it can also be argued that only the very first panel faces only moment action, while the rear panels show insignificant moment actions. For both clear front heights, the moment coefficients remain the same sign as the starting panel, and the levels of moment actions are very close to each other despite the change in clear front height.

As a conclusion on moment coefficients, it is observed that only the first solar panel experiences significant moment action while the moment action on succeeding panels can be ignored for both the normal and reverse wind flow directions. It is furthermore observed that the change in the front height has relatively small influence on the moment coefficients of the first panel, as well.

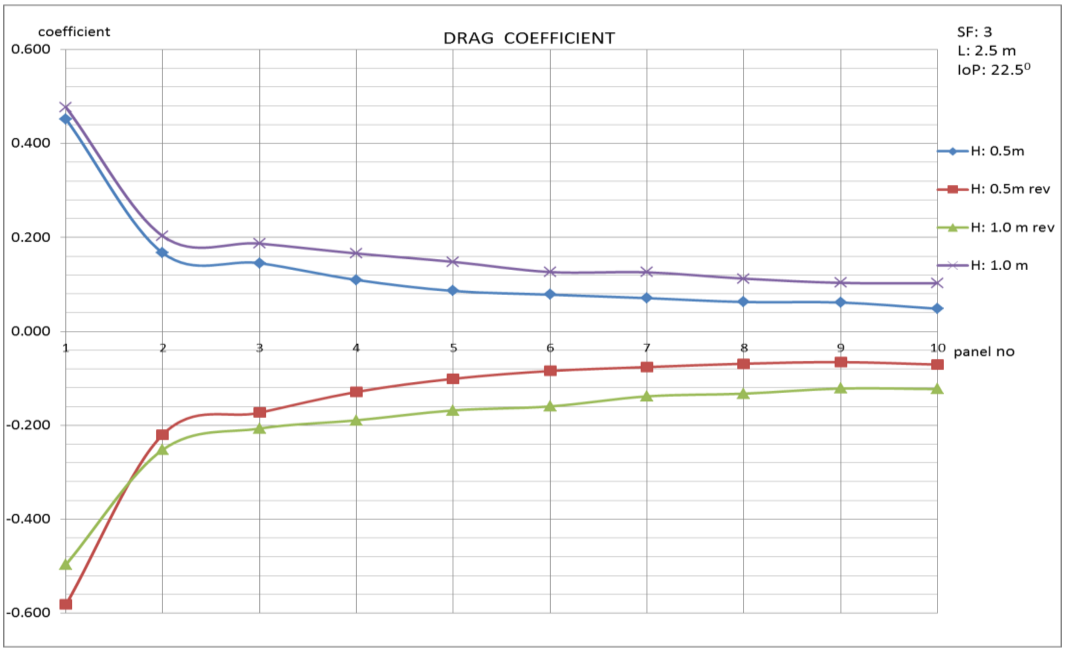

Figure 7.9. Drag Coefficients on Panels for Clear Front Heights H: 0.5 m and 1.0 m

Figure 7.10. Lift Coefficients on Panels for Clear Front Heights H: 0.5 m and 1.0 m

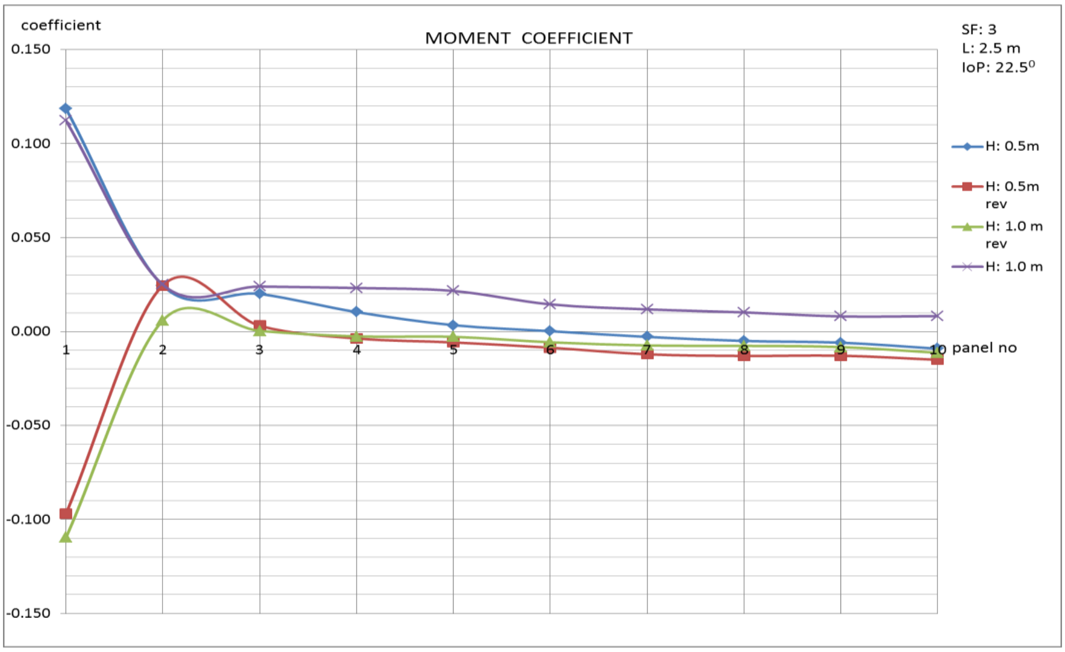

Figure 7.11. Moment Coefficients on Panels for Clear Front Heights H: 0.5 m and 1.0 m

7.4. Effect of Panel Length

In this section, the change of panel length on the wind loads acting on consecutively placed solar panels will be investigated. For this purpose, panel lengths of 1.0 m, 2.5 m and 5.0 m are considered. Since the parametric analyses contain a large volume of data after carrying out 360 CFD analysis cases, discussion on the influence of panel length will only be presented for the rest of the parameters other than panel length set to the following: clear height from ground H is taken as 0.5 m, spacing factor SF is set to 3.0, and inclination of panel IoP is considered as 22.5˚. The results of CFD analyses are presented for drag, lift and moment coefficients in Figures 7.12, 7.13 and 7.14, respectively, for both the normal and reverse wind flows. Before embarking on a discussion, it is worth to emphasize that the wind flow is free after 10^{th} panel, and this results in slight changes in the coefficient values attained at 10^{th} panel. For this reason, the coefficient values of 9^{th} panel can be taken as the asymptotically converged ones for the bulk of the panels that would be placed in solar farms.

For the normal flow direction, the drag coefficient on the first panels under varying panel lengths is very close to each other. Furthermore, it is also observed that increasing the panel length from 1.0 m to 2.5 m or 1.0 m to 5.0 m results almost the same level of slight increase on drag. A similar observation also holds for the drag experienced by the succeeding panels. The drag coefficients at 9th panel are observed to be very close to each other under varying panel lengths, except than a slight increase on drag for 1.0 m panel length. Physical reason behind these changes is due to the sheltering effect provided by longer panels onto the succeeding panels.

For the case of reverse wind flow, a totally different picture arises for the first panels in Figure 7.13. It is observed that as the panel length increases from 1.0 m to 2.5 m, drag increases close to 50%, and as panel length increases from 1.0 m to 5.0 m, drag coefficient almost doubles. The reason for this significant increase can also be traced in the discussion on the characteristics of wind actions apparent for the reverse wind flow under varying clear front height in previous section. As the panel length increases, the reverse wind flow finds a much larger obstruction surface, thus a larger volume of wind has to pass underneath the panel through a fixed clear front height of 0.5 m. As the panel length reduces, the amount volume in this regards finds it easier to pass underneath the panel through 0.5 m gap. This physical action completely reverses trend right after the second panel. It is also important to see that the drag on the second panel is the same for all panel lengths. The drag on the 9th panel for all panel lengths also get very close to each other as can be seen in Figure 7.13. The sheltering effect for 5 m panel length is the largest and for 1 m panel length is the lowest.

The lift coefficients on the panels for both normal and reverse wind flows as presented in Figure 7.14 show similar trends as observed for the drag coefficients in Figure 7.13, thus no further discussion on lift coefficient is necessary. With regards to the discussion on moment coefficients, for both cases of wind flow directions, it is observed that only the very first panel facing the wind experiences the largest moment actions, and the succeeding panels experience diminishing moment actions that may very well be ignored.

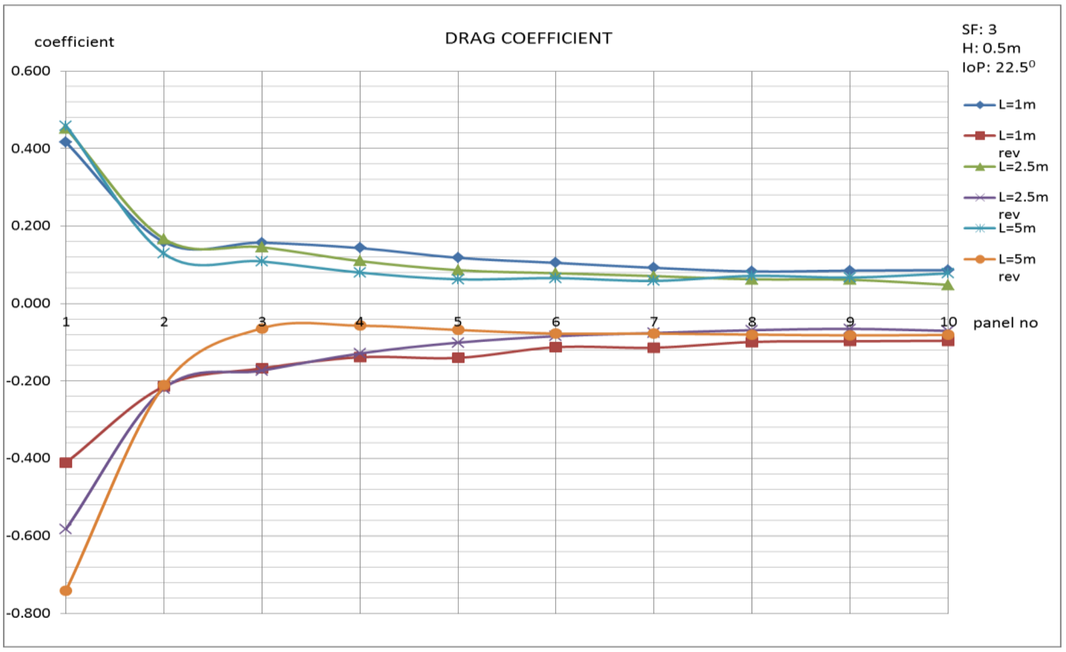

Figure 7.12. Drag Coefficients on Panels for Panel Lengths L: 1.0m, 2.5m and 5.0m

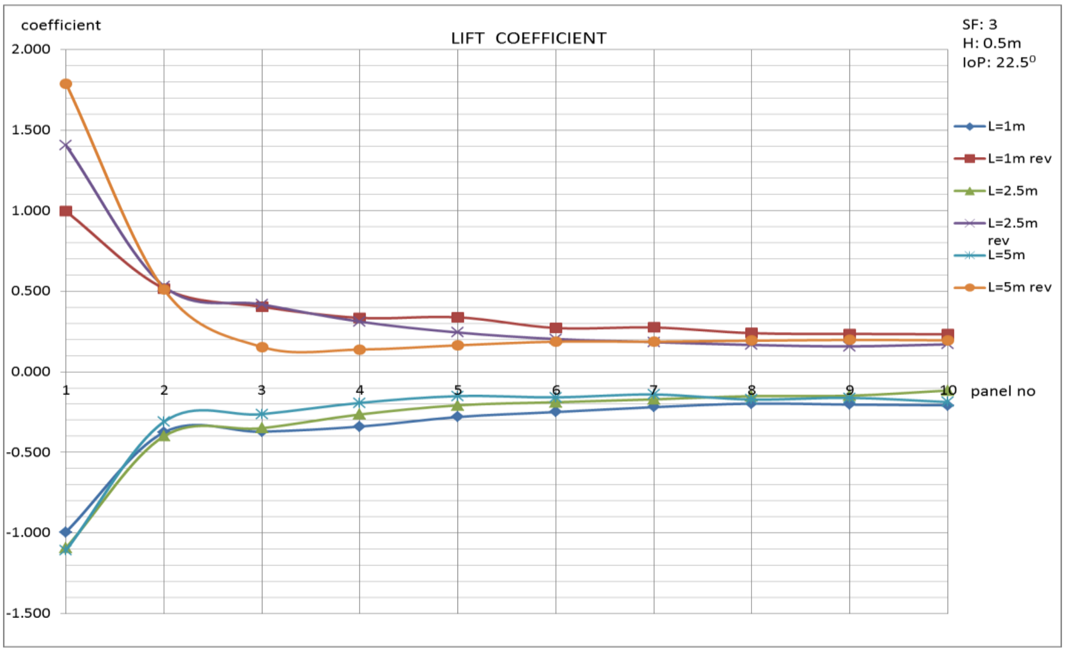

Figure 7.13. Lift Coefficients on Panels for Panel Lengths L: 1.0m, 2.5m and 5.0m

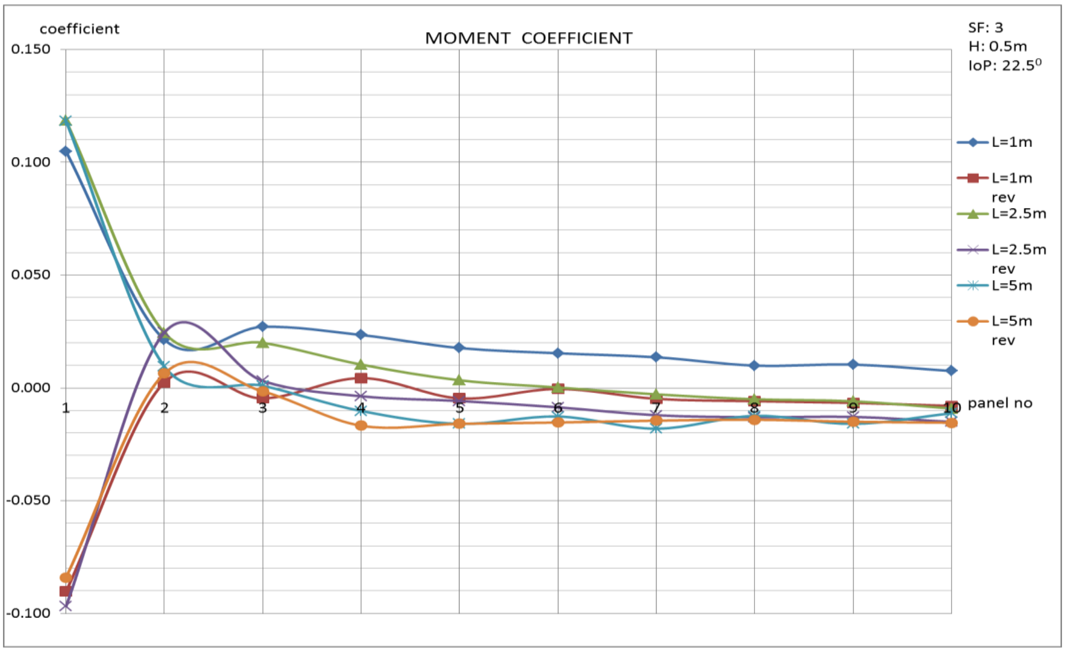

Figure 7.14. Moment Coefficients on Panels for Panel Lengths L: 1.0 m, 2.5 m and 5.0 m

7.5. Effect of Spacing Factor

In this section, the effect of spacing factor, i.e. the distance between the consecutively placed panels, on the wind loads acting on each panel will be investigated. For this purpose, spacing factors SF of 1.0, 2.0, 3.0, 4.0 and 5.0 are taken into account. Similar to the previous presentations in Sections 7.3 and 7.4, the rest of the parameters will be fixed to the following values: the panel length L is set to 1.0 m, clear front height H is taken as 0.5 m for each case, and inclination of panel IoP is considered to be 22.5˚. Actually providing spacing factor of 1.0 for above panel inclination is an unrealistic value to consider in solar farms due to the fact that panels will cast shadow on each other and reduce energy production. Despite this situation, CFD analysis is still undertaken in order to demonstrate the physical changes resulting from this change. The results of CFD analyses are presented for drag, lift and moment coefficients in Figures 7.15, 7.16 and 7.17, respectively, for both the normal and reverse wind flows. Once again the coefficient values of 9th panel can be taken as the asymptotically converged ones for the bulk of the panels that would be placed in solar farms, since there is slight change in the 10th panel value in the analyses due to the free flow conditions after the last panel.

For both wind flow directions, it is observed that the drag coefficients on the first panel reduce as the spacing factor decreases from 5.0 towards 1.0 in Figure 7.15. This reduction is due to the wake effects behind the panels. As the spacing increases, the drag coefficient on the first panel gets closer to the case for a single panel placement case. By the way, it is observed that the drop in drag coefficient on the first panel as spacing factor reduces is more pronounced for the normal wind flow direction compared to the reverse wind flow.

With regards to the sheltering effect, it is observed that drag coefficients get very close to each other at 9th panel for both wind flow directions. This clearly shows that the choice of spacing factor does little affect the amount of sheltering on the bulk of the solar panels that will be placed in a solar farm. Thus, the choice of spacing can be simply done through optimization of energy production by eliminating shadowing problems of one panel onto the others. The lift coefficients on the panels for both normal and reverse wind flows as presented in Figure 7.16 show similar trends as observed for the drag coefficients in Figure 7.15.

For moment coefficients, the change in spacing factor has little effect on the moment action experienced by the first panel for both wind flow directions. While diminishing moment actions are experienced in succeeding panels, it appears that spacing factor of 1.0 especially creates significant variations on 2nd and succeeding panels due to the wake effects of the first panel. While this spacing value is unrealistic once, it is also observed that special attention should also be paid for the spacing factor of 2.0 for the moment actions experienced by 2nd and succeeding panels. Changes in the sign of moment actions are experienced in succeeding panels with respect to the first panel for narrow spacing cases. This physical phenomenon is observed to be eliminated as spacing factor grows.

As a summary, it can be concluded that the moment coefficient values and signs become more critical in the succeeding panels after the first panel facing the wind flow, while the drag and lift coefficients show clearly more uniform trends for any spacing factor.

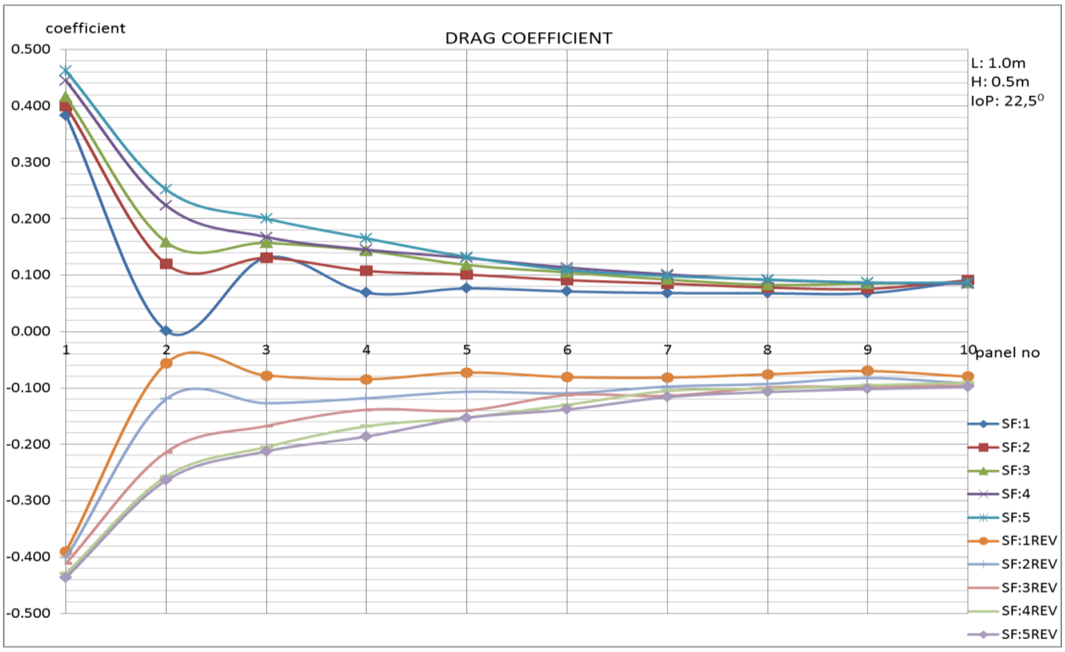

Figure 7.15. Drag Coefficients on Panels for Spacing Factors SF: 1, 2, 3, 4 and 5

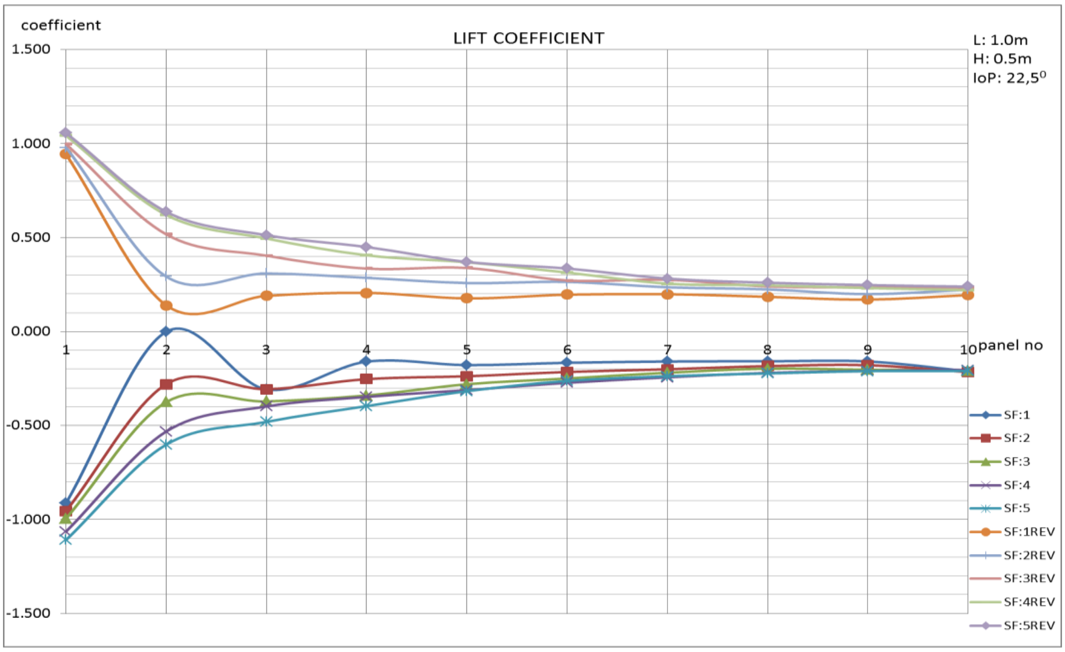

Figure 7.16. Lift Coefficients on Panels for Spacing Factors SF: 1, 2, 3, 4 and 5

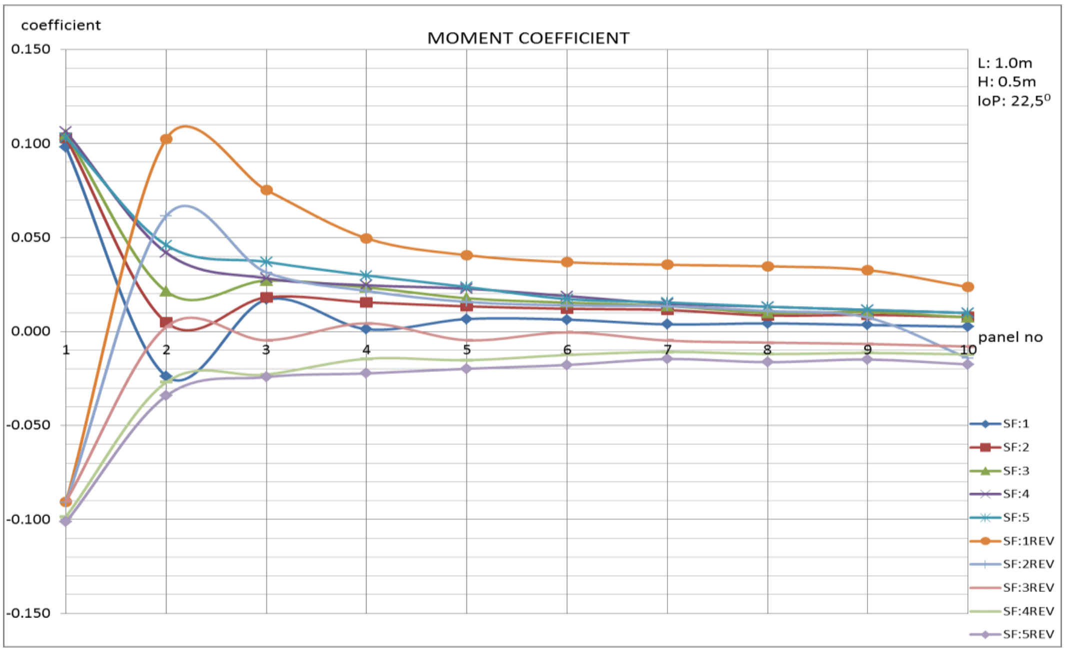

Figure 7.17. Moment Coefficients on Panels for Spacing Factors SF: 1, 2, 3, 4 and 5

7.6. Effect of Panel Inclination

In this section, the effect of panel inclination on the wind loads acting on each panel will be investigated. For this purpose, inclination values are taken as reported by ASCE 07/10 for mono-slope roofs as 7.5˚, 15˚, 22.5˚, 30˚, 37.5˚ and 45˚. All other values in between can actually be calculated through interpolation of data from given 6 inclinations. The rest of the parameters are fixed to the following values in order to provide a presentation here: the panel length L is set to 2.5 m, and spacing factor SF is chosen as 3.0. The results of CFD analyses are presented for drag, lift and moment coefficients in Figures 7.18, 7.19 and 7.20, respectively, for both the normal and reverse wind flows. Once again the coefficient values of 9th panel can be taken as the asymptotically converged ones for the bulk of the panels that would be placed in solar farms (see the discussion on this in previous sections).

For both wind flow directions, it is observed that panel inclination has a major effect on the wind loads acting on the panels. Speaking on drag coefficients presented in

Figure 7.18, as the inclination of panel IoP approaches from 7.5˚ to 45˚, the drag coefficients on the first panels facing the wind also increase in a similar trend.

With regards to the sheltering effect, the first panel significantly reduces the drag coefficients experienced by succeeding panels almost to the same values for all ranges of inclinations. The sudden decrease of drag for steep inclinations right after the first panel is due to the increased vortexes present right after the first panel. The level of vortex for lower inclination is relatively low, thus sheltering effect is also insignificant for lower panel inclinations.

With regards to the lift coefficient discussion, change of panel inclination significantly affects the lift values experienced not only on the first panels but also on the succeeding panels as can be observed in Figure 7.19. For the first panel, the lift coefficients increase as panel inclination increases. However, due to the sheltering effects, the lift forces are dramatically decreased in the succeeding panels for normal wind flow direction. For the reverse wind flow, similar trends are observed on the panels, and the panels with higher panel inclinations are more likely to receive larger wind loads compared to the one with lower panel inclination. It is furthermore observed that sheltering effect is lower for the panels with lower inclination angles, as well.

Moment coefficients show surprising trends for low panel inclination for both flow directions. It appears that the moment coefficients experienced by the first and succeeding panels for 7.5˚ panel inclination completely falls out of the trends observed by other panel inclinations. Thus special attention should be paid on the determination of moment actions for low panel inclinations, significant increases can be observed.

For panel angles other than 7.5˚, it is observed that moment actions experienced by 2nd and 3rd panels show irregularities due to the vortex created by the first panel facing the wind flow. After 4th panel, moment actions stabilize and are mostly reduce to much lower values that may very well be ignored for panel inclinations ranging between 15˚ to 37.5˚.

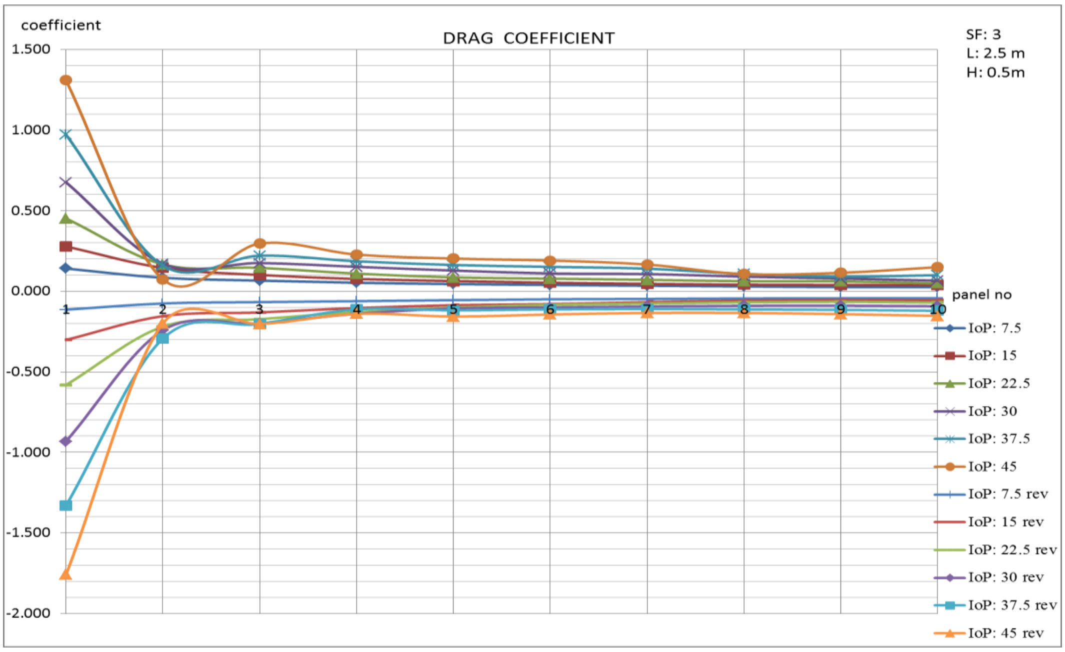

Figure 7.18. Drag Coefficients on Panels for Panel Inclinations IoP: 7.5˚, 15˚, 22.5˚, 30˚, 37.5˚ and 45˚

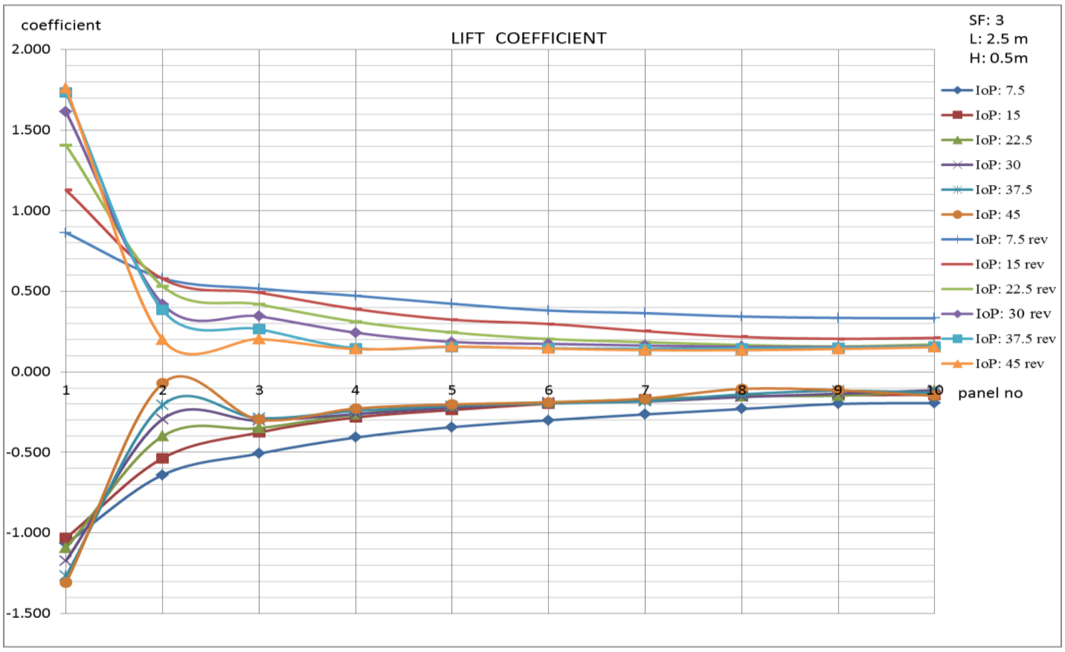

Figure 7.19. Lift Coefficients on Panels for Panel Inclinations IoP: 7.5˚, 15˚, 22.5˚, 30˚, 37.5˚ and 45˚

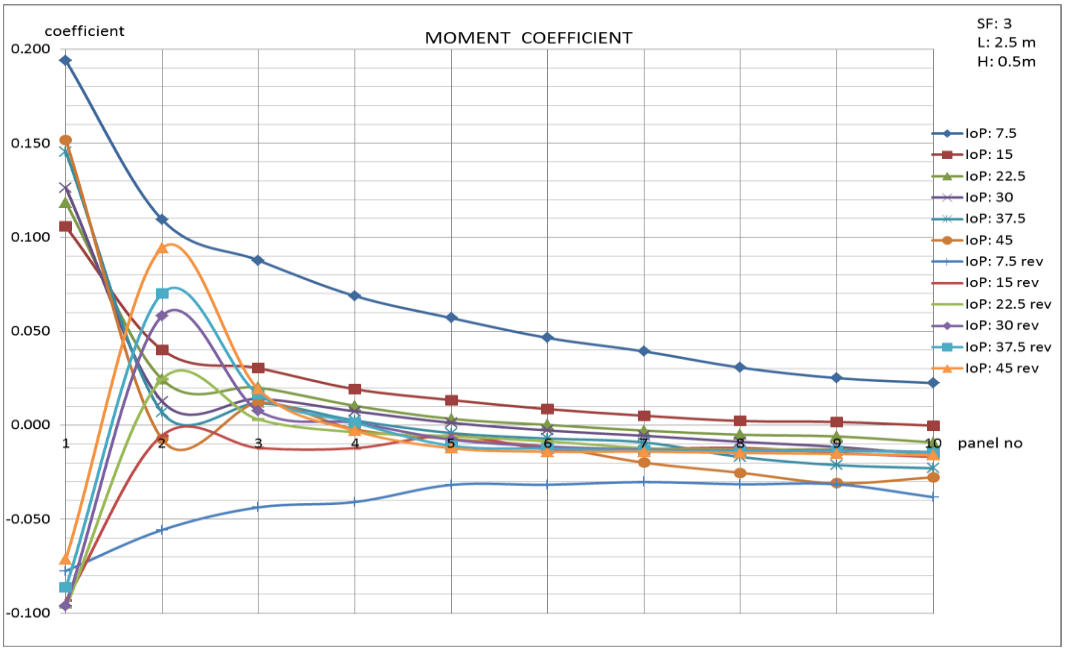

Figure 7.20. Moment Coefficients on Panels for Panel Inclinations IoP: 7.5˚, 15˚, 22.5˚, 30˚, 37.5˚ and 45˚

CHAPTER 8

CONCLUSION

8.1. Summary

Wind loads acting on single placed and consecutively placed ground mounted flat plate solar panels are investigated in this thesis. Computational fluid dynamic analysis is mainly employed in order to model, analyze and understand the effects of the wind forces acting on the panels and observe especially the sheltering provided by the first row of solar panels onto the succeeding panels in terms of drag, lift and moment coefficients.

In the first chapter of the thesis, general information about the scope, purpose and motivation of this study are presented. In the second chapter, general information about the types of solar panels constructed in practice, advantages and disadvantages of using one type of solar panel geometry and arrangement with respect to the others are mentioned. In addition to this information, literature review with regards to the determination of wind loads acting on solar panels is summarized. In the third chapter, important considerations with regards to carrying out computational fluid dynamic analysis on blunt bodies are explained. Details on domain definition, dimensioning and meshing methods and the numerical solution parameters are presented in depth.

In the fourth chapter of the thesis, comparison and verification of the numerical methodology presented in third chapter are undertaken by considering a numerical study undertaken in the literature by Jubayer and Hangan (2012). It is shown that the CFD analysis carried out in this thesis accurately replicate other studies. In addition to this verification study, the wind tunnel test by Warsido et al. (2014) is also considered for verification purposes.

In the fifth chapter, a wind tunnel test undertaken as part of the research study in this thesis is presented. The wind tunnel testing facility at Aerodynamics Lab of Middle East Technical University is used for this purpose. A blunt body made of chipboard is used and tested under varying inclinations and wind speeds. The same test is also modeled in the numerical environment and it is observed that the numerical methodology considered throughout this thesis provides very close results with the wind tunnel tests on blunt bodies. It is furthermore observed that 2D CFD analysis can equally provide close results with respect to 3D modeling for the case of wind tunnel test carried out.

In the sixth chapter of the thesis, ASCE 07/10 is considered for calculating wind loads acting on a single solar panel. Comparison between ASCE 07/10 specification on mono-slope roofs and CFD analysis results are prepared, and it is found that the results are very similar to each other.

In the seventh chapter, a detailed parametric analysis is undertaken by placing several rows of solar panels consecutively to study the wind loads acting on panels placed in solar farms. For this purpose, clear front height, panel length, panel inclination and spacing between the consecutively placed panels are changed in order to investigate the sheltering effect.

8.2. Conclusion

- Carrying out 3D CFD analyses on solar panels without supporting structures provide robust and on the safe side wind loads compared to 3D CFD analyses with supporting columns. If the width of solar panels is large enough, then carrying out 2D CFD analyses furthermore result in robust and on the safe side wind loads compared to 3D CFD analyses, provided that angle of attack of wind is not oblique.
- CFD modeling and solution methodology on single solar panels presented in current study provides close matches with respect to the studies available in literature and wind load coefficients provided for mono-slope roofs by ASCE 07/10.

- Carrying out parametric analyses on consecutively placed solar panels is suggested to be carried out through modeling and analysis in 2D.
- Wind load coefficients present on consecutively placed panels of solar farms should be studied and determined through the use of at least 10 consecutive panels in order to capture a close estimation of the wind flow across the solar farm.
- The obstruction of the first panel always provides significant amount of sheltering effect on the succeeding panels for both the normal and reverse wind flow directions. The maximum sheltering effect limits allowed by ASCE 07/10 can be realized for most of the panels that will be placed in solar farms, recalling that ASCE 07/10 allows consideration of sheltering effect for wind loads acting on solar panels with limits set to at most 65% reduction for components and claddings and 50% reduction for supporting structures. The first 4-5 rows of solar panels for both the reverse and normal wind flow directions are suggested to be paid special attention in calculation of wind loads.
- Clear distance from the ground has minor effect on the wind loads compared to the level of influence of the rest of the parameters considered in this thesis. For normal wind flow, drag and lift coefficients increase as clear height from ground increases, and for reverse flow, the drag and lift coefficients for the first solar panel increase as the panels are chosen to be placed closer to the ground. For both wind flow directions, moment coefficients remain nearly the same under varying clear height from ground.
- Panel length has major impact on the wind loads acting on solar panels. Although the drag, lift and moment coefficients are nearly the same for the normal wind flow direction, in the reverse wind flow direction, the drag and lift coefficients are conspicuously higher for the longer panels. Therefore, the use of higher panel lengths should be avoided as much as possible.
- Spacing factor also has major impact on the wind loads acting on solar panels. As the spacing between the panels is increased, the forces acting on the solar panels are increased, as well. The drag, lift and moment coefficients are directly correlated with the amount of spacing between the panels.

Therefore, when it is possible the solar panels should be placed as near as possible to each other, but close enough not to cause shadowing of one panel onto another. Closing down the gap between the consecutively placed panels extends the sheltering effect to the succeeding panels, which will decrease the wind loads acting on most of the panels in a solar farm, consequently will increase the safety of the structural supporting system and decrease the costs.

- Inclination of panels has the largest effect on the wind loads acting on solar panels. Panel inclination is chosen according to the latitude of solar farm to be constructed. Whether a panel system is fixed inclined or allowed to rotate about an axis (to follow sun) has major effect on the determination of wind loads. Small changes in panel inclination are observed to result in significant changes in wind loads. Using lower inclination angle usually decreases the drag, lift and moment coefficients. However, designer should be careful when using an inclination angle less than 15˚ for which sheltering effect is observed to be reducing.

8.3. Recommendations for Future Studies

- Optimization studies on wind loads acting on the panels and the supporting structures in terms of solar panel inclination, spacing factor and length of panel as variable parameters is worthy to investigate. Actually optimization of these parameters is attained through maximization of energy production from a solar farm depending on the latitude of the location on earth. While the cost of the structural supporting system does not constitute the major cost compared to the cost of photovoltaic panels, the percentage of the cost due to the supporting system use and construction may be further reduced while still preserving the maximum energy output from that solar farm.
- It is worth to emphasize that the research study carried out in this thesis only focused on steady state analysis. Unsteady analysis methods can be used to determine transient effects caused by the wind flow through consecutively placed solar panels.

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APPENDIX

PL = 1000mm	H = 0.5 m				H = 0.5 m			H = 0.5 m			H = 0.5 m			H = 0.5 m		
	SF = 1				SF = 2			SF = 3			SF = 4			SF = 5		
Normal wind IoP=7.5^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	0.124	-0.898	0.151	0.131	-0.944	0.145	0.139	-1.010	0.162	0.143	-1.049	0.163	0.145	-1.063	0.160
	panel2	0.059	-0.455	0.054	0.067	-0.529	0.075	0.076	-0.577	0.095	0.084	-0.635	0.108	0.091	-0.679	0.111
	panel3	0.058	-0.432	0.078	0.064	-0.486	0.084	0.067	-0.507	0.088	0.072	-0.546	0.094	0.074	-0.556	0.090
	panel4	0.046	-0.347	0.065	0.054	-0.408	0.073	0.060	-0.452	0.077	0.063	-0.476	0.081	0.064	-0.483	0.081
	panel5	0.043	-0.327	0.061	0.049	-0.376	0.064	0.055	-0.415	0.071	0.057	-0.434	0.069	0.060	-0.453	0.075
	panel6	0.041	-0.312	0.058	0.047	-0.360	0.061	0.048	-0.365	0.064	0.053	-0.402	0.068	0.056	-0.424	0.070
	panel7	0.039	-0.300	0.055	0.042	-0.324	0.057	0.046	-0.346	0.058	0.049	-0.370	0.060	0.051	-0.382	0.062
	panel8	0.036	-0.276	0.051	0.040	-0.304	0.053	0.044	-0.333	0.055	0.046	-0.346	0.058	0.048	-0.363	0.055
	panel9	0.034	-0.264	0.047	0.040	-0.311	0.052	0.042	-0.326	0.053	0.043	-0.328	0.051	0.046	-0.346	0.052
	panel10	0.038	-0.291	0.047	0.039	-0.299	0.050	0.040	-0.306	0.051	0.041	-0.312	0.052	0.043	-0.320	0.051
Reverse wind IoP=7.5^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	-0.093	0.604	-0.055	-0.102	0.735	-0.058	-0.106	0.761	-0.066	-0.108	0.780	-0.072	-0.118	0.864	-0.075
	panel2	-0.066	0.523	-0.067	-0.065	0.511	-0.046	-0.066	0.513	-0.047	-0.074	0.579	-0.066	-0.074	0.569	-0.066
	panel3	-0.045	0.353	-0.014	-0.054	0.425	-0.037	-0.057	0.444	-0.042	-0.062	0.486	-0.051	-0.063	0.481	-0.049
	panel4	-0.039	0.308	-0.010	-0.046	0.359	-0.028	-0.054	0.418	-0.036	-0.055	0.436	-0.040	-0.058	0.457	-0.045
	panel5	-0.038	0.297	-0.010	-0.043	0.335	-0.021	-0.048	0.371	-0.034	-0.051	0.397	-0.038	-0.055	0.423	-0.045
	panel6	-0.038	0.297	-0.010	-0.042	0.328	-0.023	-0.045	0.355	-0.030	-0.047	0.371	-0.035	-0.053	0.410	-0.040
	panel7	-0.035	0.280	-0.011	-0.042	0.326	-0.024	-0.043	0.338	-0.029	-0.048	0.376	-0.037	-0.048	0.376	-0.039
	panel8	-0.034	0.270	-0.011	-0.040	0.312	-0.023	-0.044	0.341	-0.032	-0.045	0.351	-0.033	-0.047	0.368	-0.039
	panel9	-0.035	0.274	-0.016	-0.038	0.303	-0.024	-0.044	0.348	-0.032	-0.045	0.351	-0.035	-0.049	0.380	-0.040
	panel10	-0.032	0.263	-0.017	-0.037	0.295	-0.027	-0.041	0.327	-0.039	-0.044	0.346	-0.045	-0.045	0.353	-0.047
Normal wind IoP=15^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	0.227	-0.824	0.077	0.247	-0.892	0.090	0.262	-0.954	0.093	0.297	-1.082	0.086	0.286	-1.040	0.094
	panel2	0.057	-0.217	-0.014	0.104	-0.383	0.025	0.149	-0.545	0.041	0.165	-0.608	0.049	0.185	-0.680	0.054
	panel3	0.096	-0.345	0.027	0.102	-0.372	0.031	0.114	-0.418	0.037	0.126	-0.463	0.038	0.136	-0.499	0.040
	panel4	0.057	-0.209	0.019	0.082	-0.299	0.022	0.097	-0.354	0.030	0.106	-0.387	0.033	0.112	-0.413	0.033
	panel5	0.064	-0.230	0.019	0.076	-0.276	0.023	0.088	-0.323	0.024	0.100	-0.369	0.027	0.105	-0.388	0.030
	panel6	0.056	-0.202	0.016	0.069	-0.252	0.021	0.080	-0.293	0.023	0.084	-0.311	0.025	0.091	-0.335	0.026
	panel7	0.053	-0.192	0.014	0.065	-0.236	0.021	0.073	-0.270	0.021	0.079	-0.289	0.022	0.080	-0.295	0.022
	panel8	0.056	-0.204	0.016	0.064	-0.234	0.018	0.069	-0.253	0.018	0.072	-0.266	0.019	0.071	-0.264	0.020
	panel9	0.054	-0.197	0.012	0.065	-0.238	0.016	0.063	-0.232	0.016	0.066	-0.244	0.017	0.069	-0.258	0.018
	panel10	0.069	-0.253	0.010	0.068	-0.252	0.015	0.071	-0.262	0.017	0.067	-0.249	0.016	0.068	-0.253	0.018
Reverse wind IoP=15^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	-0.202	0.736	-0.065	-0.209	0.771	-0.078	-0.224	0.825	-0.086	-0.238	0.879	-0.081	-0.247	0.911	-0.084
	panel2	-0.089	0.338	0.067	-0.115	0.432	0.019	-0.143	0.535	-0.022	-0.156	0.586	-0.037	-0.169	0.635	-0.048
	panel3	-0.073	0.274	0.052	-0.097	0.366	0.014	-0.122	0.458	-0.020	-0.133	0.499	-0.028	-0.139	0.524	-0.033
	panel4	-0.079	0.301	0.025	-0.085	0.320	0.007	-0.105	0.394	-0.015	-0.115	0.431	-0.022	-0.123	0.463	-0.032
	panel5	-0.055	0.209	0.026	-0.080	0.300	0.007	-0.093	0.349	-0.013	-0.106	0.396	-0.022	-0.109	0.410	-0.025
	panel6	-0.059	0.222	0.026	-0.078	0.294	0.006	-0.088	0.328	-0.014	-0.095	0.356	-0.017	-0.101	0.382	-0.024
	panel7	-0.058	0.219	0.022	-0.074	0.277	0.003	-0.084	0.314	-0.010	-0.091	0.341	-0.018	-0.093	0.351	-0.023
	panel8	-0.051	0.192	0.024	-0.075	0.280	0.000	-0.081	0.303	-0.009	-0.085	0.319	-0.017	-0.090	0.341	-0.024
	panel9	-0.055	0.207	0.019	-0.070	0.265	0.001	-0.074	0.278	-0.009	-0.080	0.300	-0.018	-0.086	0.322	-0.021
	panel10	-0.068	0.257	0.015	-0.081	0.304	-0.004	-0.080	0.300	-0.012	-0.084	0.318	-0.019	-0.088	0.333	-0.024
Normal wind IoP=22.5^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	0.384	-0.913	0.098	0.400	-0.955	0.103	0.416	-0.994	0.105	0.445	-1.064	0.106	0.462	-1.109	0.103
	panel2	0.001	-0.001	-0.024	0.120	-0.280	0.005	0.159	-0.375	0.021	0.223	-0.532	0.042	0.252	-0.601	0.046
	panel3	0.131	-0.308	0.017	0.130	-0.307	0.018	0.157	-0.372	0.027	0.168	-0.399	0.028	0.200	-0.481	0.037
	panel4	0.069	-0.160	0.001	0.108	-0.253	0.016	0.143	-0.340	0.023	0.145	-0.348	0.025	0.165	-0.397	0.030
	panel5	0.077	-0.179	0.007	0.101	-0.238	0.013	0.118	-0.280	0.018	0.130	-0.312	0.023	0.132	-0.317	0.024
	panel6	0.071	-0.166	0.006	0.091	-0.215	0.012	0.105	-0.250	0.015	0.114	-0.273	0.019	0.109	-0.263	0.017
	panel7	0.068	-0.159	0.004	0.085	-0.201	0.011	0.092	-0.219	0.014	0.101	-0.244	0.015	0.098	-0.238	0.015
	panel8	0.068	-0.158	0.004	0.078	-0.184	0.009	0.083	-0.197	0.010	0.092	-0.220	0.013	0.092	-0.223	0.013
	panel9	0.068	-0.159	0.003	0.076	-0.179	0.009	0.085	-0.203	0.010	0.087	-0.210	0.011	0.087	-0.211	0.012
	panel10	0.090	-0.211	0.003	0.091	-0.216	0.008	0.086	-0.208	0.007	0.084	-0.205	0.010	0.087	-0.211	0.010
Reverse wind IoP=22.5^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	-0.390	0.943	-0.091	-0.401	0.979	-0.091	-0.411	0.996	-0.090	-0.429	1.042	-0.098	-0.436	1.056	-0.101
	panel2	-0.057	0.140	0.102	-0.120	0.292	0.061	-0.214	0.517	0.002	-0.257	0.620	-0.027	-0.264	0.637	-0.034
	panel3	-0.078	0.190	0.075	-0.127	0.309	0.031	-0.167	0.404	-0.005	-0.205	0.495	-0.023	-0.213	0.513	-0.024
	panel4	-0.085	0.206	0.050	-0.118	0.286	0.022	-0.139	0.335	0.004	-0.168	0.406	-0.014	-0.186	0.450	-0.022
	panel5	-0.073	0.176	0.041	-0.107	0.258	0.016	-0.140	0.338	-0.005	-0.152	0.368	-0.015	-0.153	0.370	-0.020
	panel6	-0.081	0.196	0.037	-0.109	0.264	0.014	-0.113	0.272	0.000	-0.130	0.314	-0.012	-0.138	0.335	-0.018
	panel7	-0.082	0.198	0.036	-0.098	0.236	0.013	-0.114	0.275	-0.005	-0.105	0.255	-0.011	-0.116	0.282	-0.015
	panel8	-0.076	0.184	0.035	-0.093	0.224	0.011	-0.099	0.240	-0.006	-0.102	0.246	-0.012	-0.107	0.260	-0.016
	panel9	-0.070	0.170	0.033	-0.083	0.199	0.007	-0.097	0.235	-0.007	-0.096	0.231	-0.011	-0.102	0.247	-0.015
	panel10	-0.080	0.194	0.024	-0.092	0.223	-0.014	-0.096	0.233	-0.008	-0.091	0.221	-0.012	-0.099	0.239	-0.017

PL = 1000mm	H = 0.5 m S.F. =1				H = 0.5 m S.F. = 2			H = 0.5 m S.F. = 3			H = 0.5 m S.F. = 4			H = 0.5 m S.F. = 5		
Normal wind IoP=30^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	0.591	-1.026	0.113	0.595	-1.035	0.117	0.611	-1.060	0.118	0.637	-1.108	0.118	0.647	-1.126	0.122
	panel2	-0.089	0.157	-0.033	0.086	-0.142	-0.010	0.167	-0.283	0.013	0.252	-0.431	0.032	0.312	-0.537	0.044
	panel3	0.155	-0.262	0.013	0.168	-0.285	0.019	0.193	-0.329	0.025	0.229	-0.395	0.032	0.237	-0.409	0.033
	panel4	0.076	-0.125	-0.002	0.118	-0.199	0.012	0.164	-0.280	0.020	0.185	-0.319	0.024	0.202	-0.349	0.027
	panel5	0.090	-0.150	0.003	0.121	-0.206	0.013	0.147	-0.251	0.016	0.145	-0.249	0.016	0.164	-0.285	0.020
	panel6	0.079	-0.132	0.002	0.109	-0.184	0.008	0.127	-0.218	0.014	0.131	-0.227	0.013	0.137	-0.238	0.014
	panel7	0.076	-0.127	0.002	0.100	-0.170	0.009	0.120	-0.207	0.012	0.112	-0.194	0.010	0.125	-0.217	0.012
	panel8	0.080	-0.134	0.002	0.094	-0.160	0.007	0.104	-0.180	0.009	0.106	-0.184	0.008	0.103	-0.179	0.008
	panel9	0.075	-0.126	0.000	0.084	-0.144	0.005	0.100	-0.173	0.007	0.100	-0.174	0.005	0.111	-0.192	0.007
	panel10	0.099	-0.167	0.001	0.104	-0.179	0.005	0.093	-0.162	0.003	0.108	-0.188	0.006	0.109	-0.190	0.006
Reverse wind IoP=30^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	-0.607	1.051	-0.105	-0.645	1.119	-0.092	-0.655	1.137	-0.097	-0.673	1.167	-0.103	-0.685	1.186	-0.105
	panel2	-0.054	0.095	0.118	-0.111	0.194	0.089	-0.275	0.476	0.014	-0.297	0.515	-0.004	-0.322	0.558	-0.006
	panel3	-0.045	0.078	0.076	-0.173	0.302	0.038	-0.213	0.369	0.018	-0.265	0.458	-0.012	-0.292	0.505	-0.019
	panel4	-0.115	0.199	0.072	-0.159	0.276	0.028	-0.179	0.310	0.006	-0.204	0.353	-0.005	-0.218	0.378	-0.014
	panel5	-0.087	0.151	0.045	-0.126	0.219	0.034	-0.159	0.276	0.004	-0.169	0.293	-0.009	-0.186	0.323	-0.015
	panel6	-0.077	0.135	0.050	-0.114	0.198	0.020	-0.133	0.230	0.000	-0.139	0.241	-0.006	-0.165	0.285	-0.015
	panel7	-0.096	0.167	0.037	-0.114	0.197	0.018	-0.114	0.198	-0.001	-0.125	0.216	-0.008	-0.143	0.248	-0.014
	panel8	-0.084	0.146	0.041	-0.094	0.163	0.013	-0.109	0.189	-0.005	-0.119	0.207	-0.010	-0.116	0.201	-0.012
	panel9	-0.066	0.113	0.031	-0.102	0.177	0.008	-0.095	0.165	-0.004	-0.107	0.187	-0.010	-0.109	0.189	-0.014
	panel10	-0.079	0.138	0.020	-0.104	0.181	0.006	-0.101	0.176	-0.007	-0.108	0.188	-0.012	-0.111	0.192	-0.015
Normal wind IoP=37.5^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	0.846	-1.109	0.122	0.814	-1.061	0.123	0.848	-1.109	0.122	0.853	-1.115	0.125	0.884	-1.154	0.127
	panel2	-0.190	0.249	-0.039	-0.032	0.046	-0.028	0.185	-0.235	0.014	0.256	-0.330	0.027	0.324	-0.422	0.033
	panel3	0.146	-0.185	0.010	0.228	-0.293	0.021	0.228	-0.295	0.023	0.268	-0.348	0.028	0.274	-0.357	0.028
	panel4	0.080	-0.100	-0.001	0.152	-0.195	0.011	0.179	-0.232	0.017	0.215	-0.280	0.018	0.225	-0.294	0.019
	panel5	0.096	-0.121	0.001	0.137	-0.176	0.011	0.164	-0.212	0.015	0.184	-0.240	0.014	0.193	-0.252	0.015
	panel6	0.090	-0.114	0.001	0.124	-0.159	0.009	0.132	-0.171	0.008	0.158	-0.206	0.011	0.156	-0.204	0.009
	panel7	0.094	-0.119	0.002	0.115	-0.148	0.006	0.128	-0.166	0.007	0.133	-0.174	0.004	0.157	-0.205	0.008
	panel8	0.081	-0.102	0.000	0.111	-0.143	0.007	0.125	-0.163	0.006	0.128	-0.167	0.003	0.134	-0.175	0.005
	panel9	0.082	-0.103	0.000	0.107	-0.138	0.006	0.107	-0.140	0.003	0.112	-0.146	0.001	0.128	-0.166	0.003
	panel10	0.115	-0.147	-0.001	0.109	-0.140	0.002	0.113	-0.147	0.002	0.124	-0.161	0.000	0.132	-0.172	0.002
Reverse wind IoP=37.5^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	-0.892	1.161	-0.102	-0.931	1.214	-0.089	-0.934	1.218	-0.097	-0.949	1.236	-0.099	-0.964	1.255	-0.102
	panel2	0.075	-0.096	0.130	-0.103	0.136	0.096	-0.195	0.255	0.052	-0.322	0.419	0.025	-0.414	0.540	-0.006
	panel3	-0.120	0.157	0.095	-0.147	0.192	0.065	-0.247	0.321	0.023	-0.281	0.366	0.006	-0.311	0.405	-0.009
	panel4	-0.078	0.103	0.071	-0.158	0.207	0.041	-0.186	0.243	0.010	-0.251	0.327	0.002	-0.238	0.311	-0.010
	panel5	-0.133	0.173	0.044	-0.160	0.208	0.026	-0.188	0.245	0.009	-0.192	0.250	0.000	-0.189	0.246	-0.009
	panel6	-0.099	0.130	0.048	-0.131	0.170	0.024	-0.159	0.207	0.005	-0.165	0.215	-0.006	-0.164	0.214	-0.012
	panel7	-0.104	0.136	0.044	-0.127	0.166	0.016	-0.133	0.174	0.001	-0.137	0.179	-0.005	-0.138	0.181	-0.012
	panel8	-0.084	0.110	0.041	-0.100	0.130	0.014	-0.130	0.169	-0.002	-0.123	0.161	-0.009	-0.128	0.167	-0.013
	panel9	-0.071	0.092	0.035	-0.097	0.126	0.009	-0.104	0.136	-0.002	-0.109	0.143	-0.008	-0.121	0.158	-0.014
	panel10	-0.089	0.116	0.025	-0.104	0.135	0.003	-0.114	0.148	-0.007	-0.112	0.146	-0.010	-0.123	0.160	-0.015
Normal wind IoP=45^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	1.130	-1.130	0.122	1.072	-1.075	0.127	1.092	-1.093	0.123	1.107	-1.108	0.128	1.130	-1.131	0.130
	panel2	-0.285	0.287	-0.042	-0.053	0.057	-0.024	0.088	-0.084	0.003	0.265	-0.263	0.024	0.322	-0.322	0.031
	panel3	0.126	-0.122	0.005	0.202	-0.199	0.018	0.259	-0.258	0.026	0.293	-0.294	0.026	0.317	-0.317	0.026
	panel4	0.098	-0.094	0.001	0.170	-0.167	0.014	0.209	-0.208	0.015	0.222	-0.222	0.016	0.250	-0.250	0.016
	panel5	0.090	-0.086	0.002	0.167	-0.165	0.013	0.196	-0.196	0.013	0.190	-0.190	0.009	0.206	-0.206	0.011
	panel6	0.095	-0.092	0.002	0.116	-0.114	0.006	0.158	-0.158	0.009	0.177	-0.177	0.007	0.184	-0.184	0.007
	panel7	0.083	-0.080	0.000	0.135	-0.134	0.008	0.146	-0.146	0.005	0.165	-0.165	0.005	0.158	-0.158	0.003
	panel8	0.084	-0.082	0.000	0.113	-0.112	0.004	0.132	-0.132	0.002	0.135	-0.135	0.001	0.147	-0.147	0.001
	panel9	0.093	-0.092	0.000	0.113	-0.112	0.005	0.126	-0.126	0.000	0.140	-0.140	0.001	0.151	-0.151	0.001
	panel10	0.108	-0.106	-0.002	0.126	-0.126	0.000	0.129	-0.129	-0.003	0.135	-0.135	-0.001	0.150	-0.150	-0.002
Reverse wind IoP=45^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	-1.216	1.215	-0.094	-1.226	1.226	-0.084	-1.199	1.199	-0.083	-1.229	1.228	-0.088	-1.248	1.247	-0.089
	panel2	0.187	-0.184	0.121	0.019	-0.018	0.083	-0.288	0.288	0.059	-0.346	0.346	0.035	-0.433	0.432	0.007
	panel3	-0.120	0.121	0.093	-0.286	0.286	0.042	-0.283	0.283	0.025	-0.351	0.350	0.013	-0.319	0.319	-0.001
	panel4	-0.125	0.125	0.065	-0.137	0.137	0.048	-0.199	0.198	0.020	-0.230	0.230	0.003	-0.286	0.286	-0.008
	panel5	-0.095	0.096	0.057	-0.153	0.153	0.028	-0.175	0.175	0.009	-0.194	0.194	-0.002	-0.211	0.211	-0.008
	panel6	-0.139	0.139	0.051	-0.111	0.111	0.020	-0.135	0.135	0.004	-0.159	0.159	-0.005	-0.173	0.173	-0.011
	panel7	-0.066	0.067	0.044	-0.118	0.118	0.015	-0.130	0.130	0.000	-0.149	0.149	-0.008	-0.149	0.150	-0.011
	panel8	-0.086	0.086	0.035	-0.110	0.110	0.010	-0.123	0.123	-0.003	-0.139	0.140	-0.010	-0.138	0.138	-0.013
	panel9	-0.079	0.079	0.030	-0.088	0.088	0.007	-0.105	0.105	-0.004	-0.119	0.119	-0.010	-0.141	0.141	-0.015
	panel10	-0.076	0.075	0.025	-0.107	0.107	0.001	-0.113	0.113	-0.007	-0.130	0.130	-0.013	-0.138	0.138	-0.015

PL = 1000mm	H = 1.0 m SF = 1				H = 1.0 m SF = 2			H = 1.0 m SF = 3			H = 1.0 m SF = 4			H = 1.0 m SF = 5		
Normal wind IoP=7.5^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	0.121	-0.867	0.104	0.128	-0.928	0.108	0.131	-0.947	0.117	0.145	-1.056	0.113	0.145	-1.058	0.126
	panel2	0.049	-0.405	0.024	0.060	-0.489	0.054	0.070	-0.557	0.080	0.077	-0.586	0.096	0.083	-0.632	0.103
	panel3	0.048	-0.363	0.061	0.058	-0.440	0.075	0.066	-0.498	0.081	0.067	-0.506	0.086	0.072	-0.545	0.094
	panel4	0.043	-0.326	0.059	0.051	-0.386	0.066	0.058	-0.441	0.071	0.062	-0.471	0.076	0.066	-0.500	0.078
	panel5	0.037	-0.279	0.051	0.047	-0.356	0.059	0.052	-0.403	0.065	0.056	-0.423	0.070	0.062	-0.465	0.072
	panel6	0.034	-0.252	0.046	0.044	-0.336	0.054	0.051	-0.386	0.063	0.052	-0.393	0.064	0.055	-0.419	0.068
	panel7	0.032	-0.237	0.040	0.043	-0.335	0.056	0.048	-0.366	0.060	0.048	-0.366	0.059	0.053	-0.401	0.067
	panel8	0.034	-0.256	0.035	0.043	-0.328	0.054	0.044	-0.342	0.058	0.049	-0.375	0.057	0.050	-0.381	0.059
	panel9	0.039	-0.304	0.042	0.040	-0.315	0.053	0.044	-0.335	0.056	0.046	-0.358	0.058	0.049	-0.374	0.058
	panel10	0.040	-0.305	0.051	0.039	-0.301	0.056	0.041	-0.312	0.056	0.045	-0.342	0.059	0.047	-0.353	0.060
Reverse wind IoP=7.5^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	-0.099	0.656	-0.042	-0.104	0.752	-0.063	-0.107	0.766	-0.069	-0.113	0.815	-0.070	-0.118	0.861	-0.071
	panel2	-0.065	0.511	-0.065	-0.062	0.492	-0.044	-0.071	0.551	-0.056	-0.071	0.558	-0.063	-0.072	0.551	-0.067
	panel3	-0.040	0.320	-0.016	-0.048	0.380	-0.030	-0.057	0.448	-0.046	-0.059	0.460	-0.049	-0.064	0.493	-0.055
	panel4	-0.038	0.304	-0.016	-0.043	0.338	-0.029	-0.051	0.403	-0.040	-0.054	0.427	-0.045	-0.055	0.420	-0.046
	panel5	-0.034	0.277	-0.016	-0.041	0.328	-0.023	-0.046	0.369	-0.037	-0.051	0.398	-0.043	-0.052	0.404	-0.042
	panel6	-0.033	0.271	-0.015	-0.039	0.311	-0.025	-0.043	0.342	-0.031	-0.049	0.381	-0.041	-0.051	0.393	-0.041
	panel7	-0.032	0.257	-0.018	-0.040	0.318	-0.027	-0.043	0.340	-0.032	-0.046	0.367	-0.038	-0.048	0.374	-0.044
	panel8	-0.032	0.260	-0.017	-0.038	0.301	-0.026	-0.043	0.343	-0.034	-0.045	0.357	-0.039	-0.048	0.369	-0.038
	panel9	-0.031	0.253	-0.023	-0.037	0.299	-0.031	-0.042	0.339	-0.037	-0.044	0.348	-0.040	-0.047	0.363	-0.045
	panel10	-0.031	0.240	-0.027	-0.034	0.264	-0.034	-0.036	0.285	-0.040	-0.040	0.310	-0.046	-0.043	0.331	-0.051
Normal wind IoP=15^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	0.235	-0.850	0.068	0.237	-0.860	0.085	0.258	-0.935	0.085	0.270	-0.982	0.096	0.275	-1.002	0.091
	panel2	0.047	-0.185	-0.047	0.103	-0.391	0.012	0.126	-0.467	0.030	0.160	-0.588	0.043	0.178	-0.656	0.053
	panel3	0.083	-0.300	0.021	0.105	-0.382	0.031	0.116	-0.426	0.034	0.126	-0.464	0.039	0.140	-0.515	0.042
	panel4	0.061	-0.222	0.016	0.082	-0.299	0.024	0.102	-0.374	0.030	0.116	-0.426	0.034	0.123	-0.452	0.035
	panel5	0.065	-0.233	0.019	0.079	-0.287	0.024	0.089	-0.327	0.026	0.108	-0.396	0.032	0.114	-0.419	0.034
	panel6	0.055	-0.199	0.016	0.071	-0.261	0.022	0.088	-0.323	0.026	0.104	-0.382	0.029	0.109	-0.400	0.033
	panel7	0.056	-0.203	0.014	0.068	-0.248	0.019	0.081	-0.299	0.024	0.095	-0.350	0.025	0.102	-0.376	0.030
	panel8	0.055	-0.200	0.015	0.068	-0.252	0.020	0.078	-0.288	0.022	0.090	-0.332	0.027	0.099	-0.367	0.029
	panel9	0.052	-0.191	0.012	0.071	-0.260	0.020	0.085	-0.312	0.023	0.087	-0.322	0.025	0.094	-0.347	0.029
	panel10	0.077	-0.283	0.010	0.080	-0.299	0.021	0.088	-0.327	0.026	0.090	-0.335	0.025	0.099	-0.368	0.029
Reverse wind IoP=15^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	-0.186	0.676	-0.063	-0.198	0.720	-0.073	-0.216	0.794	-0.080	-0.235	0.865	-0.080	-0.246	0.903	-0.082
	panel2	-0.073	0.272	0.077	-0.115	0.435	0.022	-0.142	0.533	-0.025	-0.148	0.557	-0.032	-0.161	0.605	-0.049
	panel3	-0.099	0.379	0.027	-0.093	0.349	0.010	-0.110	0.413	-0.015	-0.129	0.484	-0.030	-0.134	0.505	-0.036
	panel4	-0.055	0.209	0.035	-0.082	0.308	0.004	-0.101	0.379	-0.013	-0.112	0.419	-0.025	-0.124	0.466	-0.032
	panel5	-0.059	0.222	0.028	-0.072	0.271	0.005	-0.089	0.334	-0.012	-0.099	0.372	-0.018	-0.109	0.410	-0.027
	panel6	-0.055	0.209	0.024	-0.074	0.279	0.001	-0.087	0.327	-0.009	-0.096	0.360	-0.019	-0.106	0.397	-0.025
	panel7	-0.053	0.200	0.023	-0.070	0.261	0.003	-0.087	0.328	-0.014	-0.098	0.368	-0.022	-0.102	0.382	-0.024
	panel8	-0.052	0.196	0.016	-0.067	0.253	0.000	-0.081	0.303	-0.013	-0.091	0.342	-0.019	-0.099	0.372	-0.027
	panel9	-0.051	0.194	0.013	-0.070	0.264	0.001	-0.082	0.307	-0.010	-0.090	0.340	-0.018	-0.098	0.371	-0.026
	panel10	-0.073	0.277	0.008	-0.083	0.312	-0.005	-0.094	0.354	-0.016	-0.101	0.380	-0.019	-0.102	0.386	-0.026
Normal wind IoP=22.5^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	0.389	-0.928	0.083	0.373	-0.895	0.105	0.414	-0.997	0.104	0.439	-1.055	0.102	0.446	-1.070	0.108
	panel2	-0.016	0.040	-0.041	0.089	-0.211	-0.002	0.162	-0.385	0.016	0.207	-0.495	0.035	0.247	-0.591	0.048
	panel3	0.130	-0.304	0.018	0.153	-0.362	0.025	0.170	-0.405	0.032	0.184	-0.439	0.031	0.197	-0.472	0.032
	panel4	0.066	-0.155	-0.002	0.106	-0.251	0.010	0.138	-0.328	0.024	0.170	-0.405	0.029	0.189	-0.453	0.035
	panel5	0.083	-0.194	0.007	0.099	-0.234	0.012	0.129	-0.306	0.020	0.160	-0.382	0.028	0.180	-0.433	0.032
	panel6	0.067	-0.157	0.003	0.101	-0.239	0.013	0.122	-0.289	0.019	0.141	-0.336	0.024	0.158	-0.380	0.028
	panel7	0.075	-0.175	0.005	0.098	-0.231	0.012	0.124	-0.295	0.021	0.137	-0.328	0.022	0.154	-0.371	0.029
	panel8	0.067	-0.156	0.002	0.099	-0.234	0.012	0.119	-0.285	0.017	0.129	-0.308	0.023	0.142	-0.341	0.024
	panel9	0.070	-0.165	0.004	0.090	-0.214	0.010	0.112	-0.267	0.018	0.124	-0.298	0.021	0.139	-0.334	0.024
	panel10	0.100	-0.236	-0.001	0.111	-0.263	0.009	0.123	-0.294	0.016	0.129	-0.310	0.020	0.137	-0.330	0.022
Reverse wind IoP=22.5^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	-0.372	0.900	-0.087	-0.362	0.877	-0.091	-0.381	0.920	-0.097	-0.398	0.965	-0.097	-0.409	0.994	-0.100
	panel2	0.027	-0.062	0.096	-0.106	0.259	0.056	-0.177	0.427	0.010	-0.221	0.534	-0.014	-0.257	0.622	-0.039
	panel3	-0.142	0.346	0.042	-0.143	0.345	0.020	-0.189	0.455	-0.013	-0.206	0.497	-0.025	-0.214	0.516	-0.027
	panel4	-0.070	0.171	0.060	-0.118	0.286	0.019	-0.153	0.370	-0.008	-0.160	0.386	-0.015	-0.196	0.473	-0.025
	panel5	-0.073	0.177	0.031	-0.106	0.255	0.014	-0.127	0.307	0.003	-0.156	0.376	-0.012	-0.179	0.432	-0.022
	panel6	-0.070	0.169	0.034	-0.096	0.232	0.017	-0.125	0.302	-0.002	-0.162	0.390	-0.019	-0.175	0.424	-0.027
	panel7	-0.070	0.168	0.035	-0.099	0.239	0.014	-0.124	0.299	-0.002	-0.155	0.375	-0.017	-0.155	0.374	-0.022
	panel8	-0.070	0.170	0.033	-0.089	0.216	0.010	-0.119	0.288	-0.003	-0.142	0.343	-0.012	-0.155	0.374	-0.020
	panel9	-0.069	0.167	0.027	-0.100	0.243	0.011	-0.124	0.299	-0.005	-0.144	0.348	-0.017	-0.144	0.349	-0.019
	panel10	-0.094	0.228	0.019	-0.105	0.254	-0.010	-0.133	0.321	-0.007	-0.145	0.351	-0.017	-0.153	0.371	-0.023

PL = 1000mm	H = 1.0 m				H = 1.0 m			H = 1.0 m			H = 1.0 m			H = 1.0 m		
	S.F. =1				S.F. = 2			S.F. = 3			S.F. = 4			S.F. = 5		
Normal wind IoP=30^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	0.602	-1.051	0.096	0.579	-1.008	0.116	0.608	-1.060	0.118	0.645	-1.120	0.117	0.641	-1.115	0.117
	panel2	-0.182	0.315	-0.036	0.064	-0.107	-0.013	0.180	-0.308	0.012	0.273	-0.470	0.032	0.306	-0.529	0.039
	panel3	0.180	-0.304	0.016	0.200	-0.341	0.023	0.214	-0.365	0.026	0.232	-0.399	0.031	0.284	-0.491	0.039
	panel4	0.063	-0.104	-0.007	0.131	-0.222	0.011	0.180	-0.307	0.020	0.216	-0.372	0.027	0.249	-0.432	0.032
	panel5	0.096	-0.161	0.003	0.134	-0.227	0.014	0.170	-0.290	0.021	0.209	-0.360	0.027	0.231	-0.400	0.030
	panel6	0.089	-0.149	0.001	0.121	-0.206	0.010	0.154	-0.263	0.019	0.197	-0.339	0.026	0.209	-0.362	0.028
	panel7	0.082	-0.138	0.002	0.113	-0.191	0.010	0.143	-0.245	0.016	0.183	-0.315	0.024	0.204	-0.353	0.027
	panel8	0.083	-0.139	0.002	0.119	-0.203	0.012	0.154	-0.264	0.018	0.172	-0.296	0.022	0.182	-0.315	0.024
	panel9	0.087	-0.146	0.000	0.120	-0.204	0.010	0.150	-0.259	0.017	0.163	-0.281	0.020	0.178	-0.309	0.022
	panel10	0.122	-0.206	-0.001	0.143	-0.245	0.009	0.159	-0.274	0.015	0.163	-0.281	0.018	0.173	-0.300	0.020
Reverse wind IoP=30^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	-0.545	0.942	-0.107	-0.595	1.033	-0.102	-0.603	1.045	-0.105	-0.615	1.068	-0.108	-0.638	1.107	-0.110
	panel2	0.028	-0.046	0.140	-0.012	0.022	0.079	-0.186	0.323	0.031	-0.283	0.489	-0.003	-0.355	0.615	-0.026
	panel3	-0.135	0.234	0.057	-0.221	0.382	0.029	-0.215	0.372	0.008	-0.270	0.468	-0.014	-0.297	0.514	-0.022
	panel4	-0.097	0.168	0.067	-0.125	0.217	0.030	-0.196	0.340	0.002	-0.234	0.404	-0.013	-0.267	0.462	-0.020
	panel5	-0.088	0.154	0.046	-0.126	0.218	0.024	-0.190	0.329	0.005	-0.225	0.390	-0.010	-0.252	0.436	-0.020
	panel6	-0.082	0.143	0.045	-0.140	0.243	0.021	-0.179	0.310	0.001	-0.200	0.346	-0.011	-0.229	0.396	-0.018
	panel7	-0.085	0.148	0.041	-0.130	0.226	0.017	-0.165	0.286	0.001	-0.182	0.315	-0.010	-0.229	0.396	-0.019
	panel8	-0.079	0.136	0.037	-0.113	0.194	0.017	-0.168	0.291	0.001	-0.196	0.340	-0.011	-0.206	0.358	-0.018
	panel9	-0.076	0.131	0.028	-0.128	0.221	0.013	-0.166	0.287	-0.001	-0.184	0.318	-0.010	-0.188	0.326	-0.017
	panel10	-0.098	0.170	0.019	-0.140	0.243	0.012	-0.169	0.292	-0.001	-0.185	0.320	-0.012	-0.200	0.346	-0.020
Normal wind IoP=37.5^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	0.882	-1.154	0.100	0.817	-1.064	0.121	0.842	-1.101	0.121	0.864	-1.128	0.125	0.881	-1.149	0.126
	panel2	-0.344	0.448	-0.016	-0.047	0.063	-0.018	0.108	-0.136	0.000	0.275	-0.355	0.026	0.368	-0.480	0.036
	panel3	0.208	-0.267	0.015	0.232	-0.298	0.023	0.270	-0.350	0.028	0.295	-0.384	0.031	0.344	-0.450	0.036
	panel4	0.063	-0.078	-0.008	0.149	-0.191	0.010	0.206	-0.265	0.019	0.271	-0.353	0.027	0.310	-0.405	0.033
	panel5	0.101	-0.127	0.001	0.140	-0.179	0.011	0.217	-0.280	0.019	0.255	-0.332	0.024	0.279	-0.364	0.029
	panel6	0.089	-0.113	-0.002	0.146	-0.187	0.010	0.205	-0.266	0.018	0.234	-0.305	0.022	0.255	-0.333	0.025
	panel7	0.097	-0.122	0.001	0.142	-0.181	0.009	0.199	-0.258	0.018	0.211	-0.275	0.018	0.253	-0.331	0.026
	panel8	0.086	-0.108	-0.001	0.142	-0.182	0.009	0.175	-0.226	0.015	0.210	-0.273	0.017	0.234	-0.305	0.021
	panel9	0.108	-0.137	-0.001	0.142	-0.182	0.010	0.193	-0.251	0.017	0.200	-0.261	0.015	0.214	-0.280	0.018
	panel10	0.137	-0.175	-0.004	0.172	-0.222	0.008	0.190	-0.247	0.013	0.193	-0.251	0.014	0.219	-0.287	0.019
Reverse wind IoP=37.5^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	-0.913	1.190	-0.108	-0.872	1.138	-0.103	-0.866	1.129	-0.109	-0.874	1.139	-0.109	-0.892	1.163	-0.110
	panel2	0.282	-0.365	0.094	0.051	-0.066	0.076	-0.152	0.199	0.051	-0.305	0.397	0.009	-0.378	0.491	0.000
	panel3	-0.169	0.219	0.045	-0.222	0.289	0.030	-0.306	0.398	0.008	-0.322	0.420	-0.003	-0.387	0.505	-0.021
	panel4	-0.097	0.127	0.060	-0.154	0.201	0.029	-0.228	0.296	0.013	-0.308	0.401	-0.005	-0.339	0.441	-0.014
	panel5	-0.115	0.151	0.047	-0.152	0.198	0.026	-0.232	0.302	0.011	-0.288	0.375	-0.008	-0.310	0.404	-0.016
	panel6	-0.099	0.129	0.052	-0.151	0.196	0.020	-0.209	0.272	0.007	-0.273	0.356	-0.009	-0.280	0.364	-0.016
	panel7	-0.068	0.089	0.046	-0.145	0.189	0.022	-0.193	0.251	0.007	-0.229	0.298	-0.006	-0.263	0.343	-0.014
	panel8	-0.078	0.101	0.038	-0.152	0.198	0.018	-0.201	0.262	0.002	-0.232	0.302	-0.006	-0.237	0.309	-0.013
	panel9	-0.087	0.113	0.032	-0.153	0.199	0.018	-0.191	0.248	0.005	-0.220	0.286	-0.006	-0.235	0.306	-0.015
	panel10	-0.125	0.163	0.025	-0.160	0.209	0.009	-0.213	0.278	-0.001	-0.213	0.277	-0.006	-0.220	0.287	-0.014
Normal wind IoP=45^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	1.199	-1.201	0.103	1.077	-1.077	0.124	1.083	-1.083	0.127	1.102	-1.103	0.124	1.127	-1.128	0.126
	panel2	-0.536	0.539	0.021	-0.121	0.122	-0.019	0.037	-0.033	-0.009	0.236	-0.234	0.019	0.383	-0.383	0.032
	panel3	0.174	-0.171	0.007	0.238	-0.237	0.021	0.350	-0.350	0.028	0.361	-0.361	0.032	0.392	-0.393	0.034
	panel4	0.085	-0.082	-0.003	0.169	-0.166	0.011	0.269	-0.268	0.020	0.332	-0.333	0.028	0.369	-0.369	0.031
	panel5	0.096	-0.092	-0.001	0.177	-0.175	0.013	0.272	-0.272	0.021	0.300	-0.301	0.024	0.321	-0.322	0.025
	panel6	0.095	-0.092	0.000	0.175	-0.173	0.012	0.231	-0.230	0.017	0.273	-0.273	0.020	0.311	-0.311	0.024
	panel7	0.103	-0.100	0.000	0.174	-0.172	0.013	0.216	-0.215	0.014	0.250	-0.250	0.019	0.285	-0.284	0.020
	panel8	0.097	-0.095	-0.002	0.155	-0.153	0.010	0.208	-0.208	0.013	0.240	-0.240	0.016	0.274	-0.275	0.019
	panel9	0.096	-0.094	-0.003	0.167	-0.166	0.009	0.212	-0.211	0.013	0.232	-0.233	0.015	0.255	-0.255	0.016
	panel10	0.143	-0.141	-0.003	0.181	-0.179	0.005	0.212	-0.211	0.010	0.232	-0.232	0.013	0.252	-0.252	0.015
Reverse wind IoP=45^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	-1.138	1.137	-0.118	-1.149	1.149	-0.099	-1.137	1.137	-0.099	-1.157	1.157	-0.103	-1.170	1.170	-0.104
	panel2	0.340	-0.338	0.117	0.188	-0.186	0.066	-0.085	0.085	0.050	-0.284	0.283	0.031	-0.429	0.428	0.006
	panel3	-0.155	0.155	0.055	-0.292	0.292	0.038	-0.355	0.354	0.013	-0.383	0.382	0.002	-0.442	0.442	-0.009
	panel4	-0.111	0.111	0.057	-0.183	0.182	0.041	-0.268	0.268	0.017	-0.335	0.335	0.001	-0.392	0.392	-0.011
	panel5	-0.083	0.083	0.052	-0.188	0.188	0.027	-0.300	0.299	0.016	-0.328	0.328	0.000	-0.349	0.349	-0.010
	panel6	-0.099	0.099	0.042	-0.179	0.179	0.026	-0.243	0.242	0.013	-0.305	0.304	-0.004	-0.327	0.327	-0.010
	panel7	-0.087	0.087	0.041	-0.166	0.165	0.024	-0.263	0.263	0.010	-0.275	0.275	-0.003	-0.305	0.305	-0.010
	panel8	-0.075	0.074	0.036	-0.158	0.158	0.020	-0.228	0.227	0.011	-0.262	0.262	-0.005	-0.285	0.285	-0.011
	panel9	-0.112	0.112	0.032	-0.162	0.161	0.019	-0.209	0.209	0.010	-0.258	0.258	-0.006	-0.267	0.267	-0.012
	panel10	-0.116	0.116	0.027	-0.188	0.188	0.013	-0.228	0.228	0.005	-0.237	0.237	-0.008	-0.260	0.261	-0.015

PL = 2500mm		H = 0.5 m SF = 1			H = 0.5 m SF = 2			H = 0.5 m SF = 3			H = 0.5 m SF = 4			H = 0.5 m SF = 5		
Normal wind IoP=7.5^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	0.129	-0.969	0.185	0.139	-1.053	0.188	0.141	-1.067	0.194	0.149	-1.130	0.211	0.146	-1.101	0.202
	panel2	0.067	-0.512	0.087	0.074	-0.568	0.102	0.084	-0.640	0.109	0.092	-0.704	0.123	0.095	-0.724	0.121
	panel3	0.056	-0.428	0.082	0.060	-0.461	0.079	0.066	-0.508	0.088	0.068	-0.519	0.089	0.071	-0.542	0.091
	panel4	0.047	-0.359	0.067	0.052	-0.402	0.069	0.053	-0.408	0.069	0.054	-0.419	0.068	0.056	-0.433	0.074
	panel5	0.042	-0.321	0.059	0.045	-0.344	0.058	0.045	-0.344	0.057	0.044	-0.339	0.055	0.046	-0.351	0.055
	panel6	0.036	-0.277	0.049	0.036	-0.277	0.046	0.039	-0.300	0.046	0.038	-0.295	0.044	0.039	-0.300	0.043
	panel7	0.032	-0.247	0.042	0.033	-0.254	0.038	0.034	-0.264	0.039	0.033	-0.252	0.035	0.032	-0.250	0.034
	panel8	0.030	-0.229	0.036	0.029	-0.226	0.032	0.030	-0.231	0.031	0.028	-0.214	0.027	0.029	-0.221	0.028
	panel9	0.027	-0.206	0.031	0.028	-0.214	0.029	0.026	-0.199	0.025	0.025	-0.190	0.022	0.027	-0.213	0.025
	panel10	0.028	-0.216	0.027	0.026	-0.201	0.024	0.025	-0.194	0.022	0.025	-0.191	0.019	0.027	-0.212	0.024
Reverse wind IoP=7.5^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	-0.102	0.766	-0.055	-0.109	0.825	-0.077	-0.114	0.863	-0.078	-0.117	0.885	-0.080	-0.125	0.950	-0.078
	panel2	-0.060	0.465	-0.023	-0.075	0.581	-0.056	-0.076	0.581	-0.056	-0.083	0.636	-0.065	-0.086	0.659	-0.066
	panel3	-0.052	0.400	-0.013	-0.059	0.452	-0.029	-0.067	0.516	-0.044	-0.071	0.543	-0.053	-0.075	0.579	-0.053
	panel4	-0.047	0.362	-0.010	-0.055	0.426	-0.032	-0.062	0.472	-0.041	-0.066	0.504	-0.047	-0.066	0.510	-0.049
	panel5	-0.045	0.351	-0.014	-0.052	0.399	-0.026	-0.055	0.422	-0.032	-0.056	0.429	-0.041	-0.060	0.463	-0.049
	panel6	-0.040	0.307	-0.009	-0.047	0.361	-0.029	-0.050	0.380	-0.032	-0.053	0.404	-0.040	-0.053	0.410	-0.043
	panel7	-0.040	0.308	-0.012	-0.044	0.335	-0.021	-0.047	0.364	-0.030	-0.048	0.372	-0.036	-0.050	0.385	-0.039
	panel8	-0.036	0.279	-0.008	-0.043	0.328	-0.023	-0.045	0.343	-0.031	-0.045	0.346	-0.036	-0.045	0.350	-0.039
	panel9	-0.038	0.292	-0.017	-0.040	0.311	-0.026	-0.044	0.335	-0.031	-0.042	0.326	-0.034	-0.043	0.332	-0.037
	panel10	-0.039	0.298	-0.020	-0.041	0.320	-0.030	-0.043	0.332	-0.038	-0.043	0.334	-0.042	-0.043	0.336	-0.044
Normal wind IoP=15^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	0.247	-0.914	0.104	0.274	-1.014	0.109	0.278	-1.032	0.106	0.298	-1.104	0.110	0.305	-1.133	0.115
	panel2	0.078	-0.290	0.011	0.114	-0.421	0.033	0.145	-0.537	0.040	0.156	-0.583	0.055	0.166	-0.622	0.061
	panel3	0.090	-0.332	0.027	0.093	-0.345	0.029	0.101	-0.377	0.030	0.108	-0.404	0.031	0.114	-0.428	0.032
	panel4	0.069	-0.255	0.015	0.075	-0.277	0.019	0.076	-0.283	0.019	0.083	-0.312	0.022	0.090	-0.338	0.025
	panel5	0.057	-0.212	0.013	0.058	-0.214	0.011	0.063	-0.237	0.013	0.068	-0.255	0.013	0.071	-0.266	0.016
	panel6	0.046	-0.169	0.008	0.052	-0.194	0.009	0.053	-0.198	0.009	0.056	-0.210	0.007	0.058	-0.218	0.012
	panel7	0.042	-0.157	0.005	0.046	-0.170	0.006	0.046	-0.171	0.005	0.053	-0.200	0.009	0.053	-0.200	0.010
	panel8	0.040	-0.147	0.003	0.040	-0.149	0.001	0.041	-0.152	0.002	0.048	-0.179	0.005	0.044	-0.165	0.005
	panel9	0.036	-0.134	0.001	0.038	-0.142	0.000	0.039	-0.145	0.002	0.039	-0.147	0.001	0.040	-0.151	0.003
	panel10	0.042	-0.156	-0.002	0.039	-0.144	-0.003	0.038	-0.144	0.000	0.047	-0.174	0.005	0.052	-0.195	0.007
Reverse wind IoP=15^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	-0.301	1.126	-0.076	-0.296	1.109	-0.087	-0.302	1.127	-0.093	-0.307	1.148	-0.096	-0.314	1.175	-0.094
	panel2	-0.078	0.294	0.096	-0.118	0.441	0.029	-0.154	0.577	-0.005	-0.184	0.687	-0.036	-0.192	0.718	-0.044
	panel3	-0.057	0.213	0.062	-0.110	0.413	0.007	-0.131	0.491	-0.012	-0.145	0.540	-0.028	-0.152	0.567	-0.036
	panel4	-0.088	0.327	0.027	-0.091	0.340	0.006	-0.104	0.389	-0.012	-0.118	0.442	-0.026	-0.115	0.431	-0.027
	panel5	-0.049	0.183	0.034	-0.079	0.297	0.001	-0.087	0.324	-0.005	-0.092	0.344	-0.019	-0.095	0.355	-0.023
	panel6	-0.071	0.267	0.012	-0.072	0.269	-0.004	-0.080	0.297	-0.013	-0.082	0.308	-0.021	-0.079	0.297	-0.021
	panel7	-0.056	0.208	0.018	-0.063	0.234	-0.003	-0.067	0.252	-0.013	-0.066	0.247	-0.016	-0.068	0.255	-0.021
	panel8	-0.046	0.172	0.014	-0.057	0.214	-0.006	-0.058	0.217	-0.012	-0.061	0.229	-0.018	-0.065	0.243	-0.020
	panel9	-0.046	0.174	0.004	-0.053	0.198	-0.009	-0.055	0.205	-0.015	-0.058	0.219	-0.018	-0.061	0.227	-0.020
	panel10	-0.055	0.205	-0.002	-0.055	0.206	-0.011	-0.056	0.211	-0.017	-0.059	0.220	-0.020	-0.062	0.231	-0.020
Normal wind IoP=22.5^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	0.421	-1.016	0.115	0.444	-1.072	0.112	0.452	-1.093	0.118	0.490	-1.183	0.115	0.486	-1.172	0.120
	panel2	0.027	-0.064	-0.026	0.123	-0.294	0.008	0.167	-0.400	0.024	0.218	-0.526	0.036	0.237	-0.572	0.041
	panel3	0.123	-0.294	0.013	0.129	-0.310	0.017	0.145	-0.350	0.020	0.145	-0.349	0.019	0.166	-0.402	0.026
	panel4	0.076	-0.182	0.002	0.089	-0.215	0.007	0.110	-0.265	0.010	0.115	-0.277	0.010	0.121	-0.292	0.014
	panel5	0.081	-0.194	0.003	0.082	-0.196	0.004	0.086	-0.208	0.003	0.098	-0.236	0.004	0.101	-0.244	0.006
	panel6	0.067	-0.161	-0.001	0.068	-0.163	0.000	0.078	-0.189	0.000	0.094	-0.226	0.004	0.094	-0.226	0.003
	panel7	0.053	-0.126	-0.003	0.068	-0.165	-0.003	0.071	-0.171	-0.003	0.071	-0.171	-0.003	0.071	-0.172	-0.001
	panel8	0.054	-0.130	-0.005	0.057	-0.138	-0.004	0.062	-0.151	-0.005	0.070	-0.169	-0.003	0.103	-0.249	0.002
	panel9	0.051	-0.123	-0.005	0.056	-0.136	-0.008	0.061	-0.148	-0.006	0.062	-0.149	-0.007	0.094	-0.227	0.004
	panel10	0.059	-0.141	-0.010	0.057	-0.138	-0.007	0.048	-0.116	-0.009	0.086	-0.207	0.000	0.088	-0.212	0.001
Reverse wind IoP=22.5^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	-0.557	1.343	-0.099	-0.578	1.396	-0.092	-0.582	1.405	-0.097	-0.590	1.425	-0.101	-0.616	1.488	-0.100
	panel2	-0.099	0.240	0.142	-0.157	0.379	0.071	-0.220	0.531	0.025	-0.273	0.658	-0.008	-0.266	0.643	-0.020
	panel3	-0.069	0.167	0.093	-0.135	0.327	0.028	-0.173	0.418	0.003	-0.194	0.468	-0.018	-0.183	0.441	-0.021
	panel4	-0.067	0.162	0.058	-0.121	0.292	0.012	-0.129	0.311	-0.004	-0.138	0.333	-0.014	-0.137	0.331	-0.020
	panel5	-0.102	0.246	0.033	-0.084	0.203	0.010	-0.101	0.244	-0.006	-0.106	0.257	-0.014	-0.115	0.278	-0.019
	panel6	-0.070	0.169	0.031	-0.074	0.180	0.000	-0.084	0.204	-0.009	-0.096	0.233	-0.017	-0.104	0.252	-0.019
	panel7	-0.053	0.127	0.018	-0.066	0.159	-0.005	-0.076	0.184	-0.012	-0.089	0.215	-0.016	-0.096	0.231	-0.018
	panel8	-0.059	0.142	0.011	-0.061	0.148	-0.008	-0.069	0.167	-0.013	-0.087	0.210	-0.016	-0.091	0.220	-0.017
	panel9	-0.049	0.118	0.005	-0.058	0.140	-0.010	-0.065	0.158	-0.013	-0.081	0.196	-0.015	-0.092	0.222	-0.018
	panel10	-0.059	0.141	-0.003	-0.063	0.153	-0.012	-0.071	0.171	-0.015	-0.084	0.202	-0.016	-0.095	0.229	-0.018

PL = 2500mm	H = 0.5 m				H = 0.5 m			H = 0.5 m			H = 0.5 m			H = 0.5 m		
	S.F. =1				S.F. = 2			S.F. = 3			S.F. = 4			S.F. = 5		
Normal wind IoP=30^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	0.668	-1.160	0.131	0.663	-1.149	0.128	0.676	-1.173	0.126	0.680	-1.181	0.133	0.711	-1.232	0.134
	panel2	-0.068	0.121	-0.044	0.097	-0.165	-0.003	0.171	-0.294	0.013	0.233	-0.403	0.022	0.285	-0.494	0.028
	panel3	0.150	-0.258	0.008	0.170	-0.294	0.014	0.175	-0.303	0.014	0.210	-0.364	0.014	0.215	-0.373	0.016
	panel4	0.107	-0.183	0.000	0.121	-0.208	0.003	0.152	-0.263	0.007	0.162	-0.280	0.003	0.183	-0.318	0.009
	panel5	0.090	-0.154	-0.002	0.109	-0.188	0.001	0.128	-0.223	0.001	0.148	-0.257	-0.001	0.145	-0.252	-0.001
	panel6	0.079	-0.136	-0.004	0.091	-0.157	-0.003	0.110	-0.191	-0.003	0.118	-0.204	-0.009	0.136	-0.236	-0.005
	panel7	0.073	-0.125	-0.005	0.087	-0.151	-0.007	0.107	-0.185	-0.006	0.090	-0.157	-0.015	0.117	-0.203	-0.006
	panel8	0.067	-0.115	-0.006	0.078	-0.135	-0.009	0.091	-0.157	-0.009	0.118	-0.204	-0.010	0.133	-0.231	-0.005
	panel9	0.055	-0.094	-0.007	0.075	-0.129	-0.010	0.079	-0.136	-0.012	0.097	-0.168	-0.014	0.137	-0.238	-0.003
	panel10	0.057	-0.099	0.005	0.077	-0.134	-0.011	0.066	-0.114	-0.016	0.119	-0.206	-0.010	0.130	-0.225	-0.005
Reverse wind IoP=30^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	-0.883	1.528	-0.099	-0.933	1.615	-0.089	-0.932	1.614	-0.096	-0.947	1.641	-0.097	-0.959	1.662	-0.099
	panel2	-0.151	0.264	0.150	-0.188	0.326	0.101	-0.243	0.421	0.058	-0.323	0.559	0.020	-0.336	0.581	-0.008
	panel3	-0.029	0.052	0.103	-0.103	0.178	0.051	-0.199	0.344	0.008	-0.205	0.355	-0.006	-0.204	0.353	-0.015
	panel4	-0.100	0.174	0.067	-0.124	0.215	0.013	-0.140	0.243	0.001	-0.154	0.267	-0.013	-0.150	0.259	-0.017
	panel5	-0.114	0.198	0.033	-0.087	0.151	0.006	-0.107	0.185	-0.008	-0.125	0.217	-0.015	-0.141	0.244	-0.019
	panel6	-0.068	0.118	0.031	-0.078	0.135	-0.004	-0.100	0.173	-0.011	-0.122	0.211	-0.017	-0.136	0.236	-0.019
	panel7	-0.045	0.079	0.017	-0.073	0.126	-0.008	-0.094	0.163	-0.013	-0.117	0.202	-0.016	-0.130	0.225	-0.018
	panel8	-0.055	0.095	0.006	-0.072	0.124	-0.010	-0.090	0.156	-0.014	-0.115	0.199	-0.016	-0.132	0.228	-0.018
	panel9	-0.051	0.087	0.001	-0.067	0.115	-0.010	-0.089	0.154	-0.013	-0.109	0.188	-0.015	-0.140	0.243	-0.019
	panel10	-0.052	0.089	-0.013	-0.075	0.130	-0.011	-0.093	0.161	-0.014	-0.113	0.195	-0.016	-0.143	0.248	-0.019
Normal wind IoP=37.5^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	0.995	-1.297	0.144	0.960	-1.251	0.143	0.972	-1.267	0.145	0.981	-1.279	0.145	0.995	-1.297	0.145
	panel2	-0.102	0.135	-0.047	0.029	-0.035	-0.016	0.160	-0.207	0.007	0.276	-0.359	0.020	0.325	-0.425	0.023
	panel3	0.118	-0.152	0.002	0.196	-0.255	0.011	0.221	-0.288	0.012	0.248	-0.324	0.008	0.297	-0.387	0.014
	panel4	0.096	-0.124	-0.003	0.144	-0.187	0.001	0.186	-0.243	0.003	0.224	-0.292	0.000	0.239	-0.312	0.003
	panel5	0.098	-0.127	-0.005	0.127	-0.165	-0.004	0.163	-0.212	-0.004	0.179	-0.233	-0.009	0.197	-0.256	-0.009
	panel6	0.083	-0.107	-0.006	0.130	-0.170	-0.007	0.151	-0.197	-0.007	0.147	-0.191	-0.017	0.188	-0.245	-0.011
	panel7	0.082	-0.107	-0.007	0.113	-0.147	-0.008	0.140	-0.182	-0.009	0.139	-0.181	-0.015	0.182	-0.237	-0.011
	panel8	0.072	-0.093	-0.010	0.097	-0.127	-0.012	0.107	-0.140	-0.017	0.154	-0.201	-0.018	0.194	-0.253	-0.013
	panel9	0.074	-0.097	-0.008	0.106	-0.138	-0.013	0.090	-0.118	-0.021	0.154	-0.200	-0.017	0.189	-0.247	-0.012
	panel10	0.080	-0.104	-0.012	0.101	-0.132	-0.017	0.100	-0.130	-0.023	0.138	-0.180	-0.019	0.195	-0.254	-0.009
Reverse wind IoP=37.5^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	-1.296	1.688	-0.083	-1.333	1.737	-0.085	-1.331	1.734	-0.086	-1.355	1.765	-0.086	-1.360	1.771	-0.088
	panel2	-0.108	0.142	0.158	-0.215	0.281	0.132	-0.294	0.383	0.070	-0.376	0.490	0.028	-0.404	0.526	0.014
	panel3	-0.057	0.074	0.118	-0.084	0.109	0.054	-0.203	0.265	0.016	-0.199	0.260	0.002	-0.230	0.300	-0.011
	panel4	-0.175	0.228	0.064	-0.108	0.141	0.013	-0.112	0.146	0.001	-0.168	0.219	-0.014	-0.191	0.249	-0.018
	panel5	-0.055	0.072	0.058	-0.082	0.107	0.000	-0.119	0.155	-0.011	-0.154	0.201	-0.016	-0.178	0.231	-0.019
	panel6	-0.059	0.077	0.021	-0.094	0.122	-0.008	-0.112	0.146	-0.013	-0.147	0.191	-0.017	-0.174	0.227	-0.019
	panel7	-0.052	0.067	0.010	-0.080	0.103	-0.007	-0.110	0.143	-0.013	-0.155	0.201	-0.018	-0.183	0.238	-0.019
	panel8	-0.059	0.077	0.002	-0.080	0.103	-0.009	-0.113	0.147	-0.014	-0.151	0.196	-0.017	-0.184	0.240	-0.020
	panel9	-0.059	0.076	0.000	-0.079	0.102	-0.009	-0.116	0.150	-0.014	-0.157	0.205	-0.017	-0.189	0.246	-0.020
	panel10	-0.061	0.079	-0.002	-0.084	0.108	-0.010	-0.121	0.158	-0.014	-0.162	0.211	-0.018	-0.183	0.239	-0.020
Normal wind IoP=45^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	1.378	-1.378	0.155	1.323	-1.323	0.153	1.309	-1.310	0.152	1.331	-1.330	0.152	1.356	-1.356	0.152
	panel2	-0.270	0.271	-0.059	-0.094	0.096	-0.028	0.074	-0.072	-0.007	0.235	-0.235	0.012	0.324	-0.324	0.015
	panel3	0.155	-0.154	0.003	0.229	-0.229	0.011	0.296	-0.296	0.012	0.341	-0.341	0.009	0.371	-0.371	0.007
	panel4	0.098	-0.097	-0.006	0.181	-0.181	0.002	0.228	-0.228	-0.002	0.247	-0.246	-0.006	0.283	-0.283	-0.007
	panel5	0.120	-0.119	-0.004	0.157	-0.157	-0.004	0.203	-0.203	-0.007	0.264	-0.264	-0.012	0.256	-0.256	-0.013
	panel6	0.095	-0.094	-0.008	0.146	-0.146	-0.009	0.191	-0.191	-0.011	0.195	-0.195	-0.021	0.246	-0.246	-0.016
	panel7	0.097	-0.097	-0.008	0.133	-0.133	-0.014	0.166	-0.166	-0.020	0.173	-0.173	-0.021	0.237	-0.237	-0.016
	panel8	0.079	-0.078	-0.009	0.129	-0.128	-0.016	0.106	-0.106	-0.025	0.180	-0.180	-0.025	0.257	-0.257	-0.015
	panel9	0.087	-0.087	-0.009	0.135	-0.135	-0.018	0.114	-0.114	-0.031	0.192	-0.192	-0.024	0.256	-0.256	-0.014
	panel10	0.086	-0.086	-0.011	0.114	-0.114	-0.019	0.150	-0.150	-0.028	0.200	-0.200	-0.024	0.258	-0.258	-0.015
Reverse wind IoP=45^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	-1.748	1.747	-0.064	-1.769	1.769	-0.075	-1.760	1.760	-0.071	-1.788	1.788	-0.074	-1.788	1.787	-0.075
	panel2	-0.021	0.022	0.195	-0.145	0.145	0.134	-0.200	0.200	0.094	-0.388	0.388	0.048	-0.407	0.407	0.018
	panel3	-0.074	0.074	0.135	-0.084	0.084	0.065	-0.204	0.203	0.019	-0.227	0.227	-0.004	-0.251	0.251	-0.014
	panel4	-0.176	0.176	0.056	-0.107	0.107	0.014	-0.141	0.141	-0.003	-0.180	0.180	-0.014	-0.230	0.230	-0.021
	panel5	-0.076	0.076	0.047	-0.100	0.099	-0.002	-0.157	0.157	-0.012	-0.181	0.181	-0.018	-0.242	0.242	-0.021
	panel6	-0.022	0.022	0.028	-0.105	0.104	-0.007	-0.144	0.144	-0.014	-0.179	0.179	-0.018	-0.238	0.239	-0.021
	panel7	-0.029	0.029	0.007	-0.099	0.099	-0.009	-0.135	0.134	-0.014	-0.196	0.196	-0.019	-0.243	0.243	-0.022
	panel8	-0.066	0.065	0.001	-0.092	0.092	-0.009	-0.135	0.134	-0.015	-0.202	0.202	-0.019	-0.243	0.243	-0.022
	panel9	-0.055	0.054	0.000	-0.094	0.093	-0.010	-0.142	0.142	-0.015	-0.202	0.202	-0.019	-0.244	0.244	-0.022
	panel10	-0.064	0.064	-0.002	-0.099	0.099	-0.011	-0.153	0.153	-0.016	-0.206	0.206	-0.020	-0.240	0.240	-0.022

PL = 2500mm		H = 1.0 m SF = 1			H = 1.0 m SF = 2			H = 1.0 m SF = 3			H = 1.0 m SF = 4			H = 1.0 m SF = 5		
Normal wind IoP=7.5^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	0.124	-0.937	0.163	0.138	-1.045	0.187	0.141	-1.069	0.173	0.144	-1.091	0.185	0.144	-1.091	0.184
	panel2	0.065	-0.503	0.065	0.075	-0.582	0.097	0.085	-0.651	0.106	0.093	-0.716	0.119	0.095	-0.724	0.124
	panel3	0.059	-0.456	0.083	0.066	-0.505	0.089	0.073	-0.559	0.092	0.074	-0.570	0.095	0.078	-0.602	0.101
	panel4	0.051	-0.388	0.072	0.057	-0.438	0.075	0.063	-0.489	0.080	0.066	-0.513	0.082	0.070	-0.537	0.083
	panel5	0.046	-0.356	0.065	0.053	-0.410	0.069	0.058	-0.448	0.072	0.061	-0.469	0.077	0.063	-0.485	0.081
	panel6	0.045	-0.342	0.060	0.049	-0.380	0.065	0.053	-0.412	0.067	0.057	-0.441	0.073	0.058	-0.444	0.072
	panel7	0.041	-0.318	0.057	0.047	-0.361	0.062	0.051	-0.399	0.062	0.054	-0.416	0.061	0.056	-0.431	0.066
	panel8	0.039	-0.302	0.052	0.043	-0.334	0.054	0.048	-0.371	0.058	0.050	-0.391	0.062	0.053	-0.407	0.061
	panel9	0.039	-0.301	0.050	0.042	-0.325	0.053	0.045	-0.350	0.053	0.047	-0.362	0.057	0.050	-0.388	0.058
	panel10	0.040	-0.312	0.048	0.041	-0.315	0.050	0.041	-0.317	0.051	0.043	-0.331	0.053	0.045	-0.346	0.052
Reverse wind IoP=7.5^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	-0.087	0.629	-0.068	-0.103	0.776	-0.075	-0.106	0.793	-0.075	-0.109	0.819	-0.074	-0.115	0.868	-0.080
	panel2	-0.073	0.562	-0.066	-0.068	0.525	-0.048	-0.076	0.583	-0.062	-0.078	0.599	-0.065	-0.083	0.642	-0.075
	panel3	-0.053	0.405	-0.019	-0.058	0.444	-0.034	-0.064	0.491	-0.048	-0.068	0.524	-0.053	-0.073	0.560	-0.059
	panel4	-0.046	0.353	-0.015	-0.055	0.420	-0.029	-0.059	0.449	-0.040	-0.061	0.468	-0.048	-0.065	0.505	-0.053
	panel5	-0.044	0.336	-0.013	-0.050	0.382	-0.032	-0.057	0.439	-0.039	-0.060	0.462	-0.046	-0.061	0.473	-0.053
	panel6	-0.042	0.326	-0.014	-0.047	0.358	-0.025	-0.054	0.411	-0.039	-0.056	0.431	-0.044	-0.057	0.441	-0.042
	panel7	-0.041	0.313	-0.014	-0.045	0.346	-0.022	-0.050	0.383	-0.033	-0.054	0.414	-0.040	-0.055	0.428	-0.045
	panel8	-0.039	0.301	-0.012	-0.045	0.350	-0.025	-0.050	0.386	-0.035	-0.055	0.419	-0.043	-0.057	0.436	-0.046
	panel9	-0.038	0.295	-0.014	-0.046	0.350	-0.028	-0.051	0.388	-0.040	-0.052	0.405	-0.044	-0.054	0.415	-0.044
	panel10	-0.039	0.300	-0.018	-0.043	0.332	-0.034	-0.048	0.367	-0.041	-0.052	0.406	-0.049	-0.052	0.400	-0.051
Normal wind IoP=15^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	0.239	-0.887	0.093	0.267	-0.992	0.098	0.282	-1.049	0.104	0.299	-1.114	0.106	0.302	-1.123	0.106
	panel2	0.069	-0.259	-0.011	0.115	-0.428	0.030	0.149	-0.555	0.048	0.180	-0.673	0.055	0.196	-0.730	0.064
	panel3	0.105	-0.389	0.031	0.113	-0.421	0.035	0.126	-0.468	0.038	0.148	-0.551	0.046	0.158	-0.589	0.049
	panel4	0.072	-0.265	0.021	0.102	-0.379	0.032	0.120	-0.446	0.039	0.127	-0.473	0.039	0.140	-0.523	0.041
	panel5	0.074	-0.273	0.024	0.089	-0.332	0.027	0.102	-0.382	0.032	0.116	-0.434	0.034	0.125	-0.470	0.037
	panel6	0.070	-0.261	0.020	0.088	-0.326	0.025	0.098	-0.364	0.027	0.105	-0.391	0.028	0.105	-0.393	0.031
	panel7	0.063	-0.235	0.018	0.079	-0.293	0.023	0.087	-0.324	0.024	0.095	-0.356	0.027	0.096	-0.359	0.026
	panel8	0.064	-0.236	0.017	0.074	-0.277	0.022	0.081	-0.301	0.024	0.087	-0.325	0.025	0.094	-0.352	0.024
	panel9	0.061	-0.227	0.015	0.072	-0.268	0.018	0.073	-0.274	0.021	0.078	-0.294	0.019	0.088	-0.329	0.021
	panel10	0.072	-0.266	0.013	0.075	-0.282	0.014	0.074	-0.276	0.016	0.081	-0.304	0.018	0.081	-0.302	0.020
Reverse wind IoP=15^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	-0.231	0.864	-0.081	-0.242	0.907	-0.085	-0.253	0.946	-0.091	-0.270	1.009	-0.088	-0.262	0.979	-0.091
	panel2	-0.075	0.281	0.080	-0.133	0.499	0.017	-0.169	0.630	-0.022	-0.177	0.660	-0.036	-0.182	0.677	-0.039
	panel3	-0.092	0.346	0.044	-0.118	0.440	-0.002	-0.139	0.517	-0.018	-0.156	0.582	-0.035	-0.149	0.555	-0.024
	panel4	-0.081	0.303	0.028	-0.101	0.379	0.008	-0.124	0.462	-0.019	-0.145	0.542	-0.032	-0.142	0.530	-0.021
	panel5	-0.074	0.278	0.031	-0.096	0.361	0.000	-0.113	0.423	-0.015	-0.134	0.500	-0.031	-0.135	0.502	-0.022
	panel6	-0.066	0.247	0.025	-0.089	0.334	0.002	-0.110	0.412	-0.015	-0.122	0.455	-0.030	-0.118	0.438	-0.022
	panel7	-0.070	0.264	0.029	-0.088	0.328	0.001	-0.104	0.388	-0.018	-0.107	0.401	-0.023	-0.116	0.434	-0.022
	panel8	-0.066	0.247	0.023	-0.086	0.320	0.000	-0.097	0.363	-0.018	-0.104	0.389	-0.021	-0.113	0.419	-0.019
	panel9	-0.064	0.240	0.021	-0.082	0.308	-0.001	-0.093	0.348	-0.012	-0.102	0.380	-0.024	-0.107	0.398	-0.021
	panel10	-0.077	0.288	0.015	-0.090	0.337	-0.008	-0.094	0.351	-0.016	-0.097	0.363	-0.024	-0.109	0.407	-0.019
Normal wind IoP=22.5^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	0.418	-1.010	0.110	0.444	-1.072	0.111	0.477	-1.155	0.112	0.488	-1.181	0.119	0.494	-1.194	0.119
	panel2	0.020	-0.048	-0.024	0.124	-0.297	0.002	0.203	-0.488	0.025	0.264	-0.636	0.045	0.282	-0.682	0.050
	panel3	0.166	-0.396	0.023	0.172	-0.413	0.026	0.187	-0.450	0.024	0.218	-0.527	0.038	0.235	-0.569	0.041
	panel4	0.091	-0.216	0.002	0.140	-0.335	0.019	0.166	-0.400	0.023	0.192	-0.463	0.030	0.196	-0.474	0.032
	panel5	0.103	-0.245	0.009	0.130	-0.311	0.017	0.148	-0.357	0.022	0.166	-0.402	0.024	0.178	-0.430	0.027
	panel6	0.093	-0.223	0.004	0.116	-0.279	0.013	0.126	-0.305	0.014	0.157	-0.380	0.021	0.164	-0.396	0.024
	panel7	0.090	-0.215	0.004	0.108	-0.259	0.012	0.126	-0.304	0.012	0.135	-0.327	0.017	0.153	-0.371	0.021
	panel8	0.081	-0.193	0.003	0.100	-0.240	0.010	0.112	-0.271	0.010	0.134	-0.323	0.014	0.136	-0.328	0.017
	panel9	0.077	-0.185	0.002	0.099	-0.238	0.010	0.103	-0.250	0.008	0.121	-0.291	0.011	0.134	-0.324	0.015
	panel10	0.092	-0.219	-0.002	0.101	-0.243	0.007	0.102	-0.247	0.008	0.117	-0.283	0.009	0.131	-0.317	0.012
Reverse wind IoP=22.5^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	-0.468	1.129	-0.104	-0.491	1.187	-0.102	-0.496	1.199	-0.110	-0.518	1.252	-0.112	-0.534	1.290	-0.108
	panel2	-0.072	0.176	0.123	-0.148	0.358	0.069	-0.252	0.608	0.006	-0.285	0.687	-0.027	-0.303	0.731	-0.033
	panel3	-0.103	0.248	0.086	-0.170	0.409	0.027	-0.207	0.499	0.000	-0.247	0.597	-0.018	-0.278	0.672	-0.037
	panel4	-0.126	0.304	0.043	-0.159	0.384	0.016	-0.189	0.457	-0.003	-0.224	0.542	-0.022	-0.242	0.584	-0.033
	panel5	-0.102	0.246	0.054	-0.139	0.336	0.018	-0.168	0.406	-0.003	-0.194	0.468	-0.019	-0.211	0.509	-0.029
	panel6	-0.091	0.220	0.044	-0.131	0.316	0.014	-0.160	0.385	-0.006	-0.178	0.429	-0.020	-0.184	0.444	-0.027
	panel7	-0.096	0.232	0.042	-0.122	0.295	0.011	-0.138	0.334	-0.007	-0.158	0.381	-0.018	-0.170	0.411	-0.027
	panel8	-0.077	0.186	0.035	-0.109	0.262	0.008	-0.133	0.320	-0.008	-0.147	0.355	-0.018	-0.150	0.362	-0.024
	panel9	-0.087	0.210	0.029	-0.110	0.266	0.004	-0.122	0.294	-0.008	-0.134	0.323	-0.019	-0.140	0.337	-0.023
	panel10	-0.089	0.216	0.024	-0.110	0.265	-0.001	-0.123	0.297	-0.011	-0.137	0.330	-0.020	-0.134	0.323	-0.023

PL = 2500mm	H = 1.0 m				H = 1.0 m			H = 1.0 m			H = 1.0 m			H = 1.0 m		
	S.F. =1				S.F. = 2			S.F. = 3			S.F. = 4			S.F. = 5		
Normal wind IoP=30^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	0.677	-1.176	0.127	0.682	-1.182	0.132	0.687	-1.192	0.132	0.727	-1.260	0.131	0.721	-1.250	0.133
	panel2	-0.083	0.144	-0.035	0.082	-0.140	-0.007	0.179	-0.308	0.011	0.314	-0.543	0.034	0.347	-0.601	0.038
	panel3	0.197	-0.339	0.017	0.216	-0.372	0.020	0.260	-0.450	0.028	0.303	-0.526	0.036	0.335	-0.581	0.040
	panel4	0.115	-0.197	0.000	0.178	-0.307	0.013	0.226	-0.392	0.021	0.254	-0.440	0.027	0.294	-0.509	0.031
	panel5	0.120	-0.205	0.002	0.175	-0.302	0.015	0.195	-0.337	0.016	0.231	-0.400	0.020	0.256	-0.443	0.024
	panel6	0.118	-0.203	0.003	0.156	-0.269	0.012	0.178	-0.309	0.014	0.209	-0.361	0.015	0.229	-0.396	0.018
	panel7	0.109	-0.187	0.001	0.138	-0.239	0.006	0.170	-0.295	0.010	0.188	-0.325	0.011	0.220	-0.381	0.013
	panel8	0.106	-0.181	0.001	0.137	-0.236	0.008	0.155	-0.269	0.007	0.181	-0.314	0.011	0.195	-0.337	0.011
	panel9	0.097	-0.167	-0.002	0.131	-0.226	0.005	0.152	-0.263	0.005	0.183	-0.317	0.007	0.198	-0.343	0.010
	panel10	0.100	-0.172	0.019	0.131	-0.226	0.002	0.152	-0.263	0.004	0.185	-0.320	0.006	0.189	-0.327	0.008
Reverse wind IoP=30^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	-0.810	1.402	-0.121	-0.830	1.438	-0.112	-0.827	1.431	-0.114	-0.840	1.454	-0.119	-0.851	1.476	-0.119
	panel2	0.014	-0.023	0.148	-0.151	0.262	0.098	-0.275	0.476	0.044	-0.383	0.663	0.007	-0.437	0.756	-0.019
	panel3	-0.154	0.267	0.112	-0.193	0.334	0.042	-0.271	0.469	0.013	-0.327	0.565	-0.001	-0.368	0.638	-0.024
	panel4	-0.139	0.241	0.057	-0.179	0.310	0.029	-0.231	0.400	0.009	-0.306	0.530	-0.017	-0.322	0.557	-0.025
	panel5	-0.143	0.248	0.054	-0.171	0.296	0.024	-0.221	0.383	0.001	-0.263	0.455	-0.016	-0.269	0.467	-0.024
	panel6	-0.084	0.145	0.054	-0.159	0.275	0.018	-0.195	0.337	-0.002	-0.232	0.402	-0.017	-0.235	0.407	-0.023
	panel7	-0.099	0.172	0.040	-0.147	0.255	0.015	-0.181	0.313	-0.006	-0.207	0.358	-0.018	-0.216	0.375	-0.024
	panel8	-0.097	0.168	0.036	-0.137	0.238	0.009	-0.163	0.282	-0.006	-0.183	0.316	-0.018	-0.200	0.347	-0.024
	panel9	-0.112	0.195	0.030	-0.128	0.222	0.007	-0.151	0.261	-0.008	-0.178	0.308	-0.019	-0.185	0.321	-0.024
	panel10	-0.079	0.137	0.011	-0.135	0.233	0.001	-0.145	0.252	-0.010	-0.168	0.292	-0.020	-0.182	0.316	-0.024
Normal wind IoP=37.5^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	1.023	-1.333	0.145	0.992	-1.293	0.144	0.995	-1.297	0.147	1.041	-1.357	0.145	1.055	-1.375	0.146
	panel2	-0.258	0.336	-0.043	-0.036	0.048	-0.024	0.126	-0.162	-0.001	0.339	-0.441	0.027	0.457	-0.596	0.042
	panel3	0.262	-0.341	0.017	0.298	-0.388	0.023	0.364	-0.474	0.032	0.413	-0.538	0.034	0.427	-0.556	0.036
	panel4	0.125	-0.161	-0.005	0.214	-0.278	0.010	0.282	-0.367	0.020	0.344	-0.448	0.023	0.370	-0.483	0.029
	panel5	0.155	-0.200	0.002	0.214	-0.278	0.011	0.254	-0.331	0.015	0.304	-0.396	0.016	0.334	-0.436	0.021
	panel6	0.129	-0.167	-0.001	0.198	-0.257	0.009	0.233	-0.304	0.011	0.282	-0.368	0.011	0.306	-0.398	0.015
	panel7	0.120	-0.155	-0.001	0.177	-0.229	0.006	0.213	-0.278	0.008	0.261	-0.340	0.006	0.295	-0.384	0.011
	panel8	0.131	-0.169	-0.001	0.166	-0.216	0.004	0.207	-0.269	0.005	0.262	-0.341	0.006	0.277	-0.362	0.008
	panel9	0.109	-0.141	-0.004	0.155	-0.201	0.000	0.198	-0.259	0.002	0.231	-0.301	0.001	0.278	-0.362	0.006
	panel10	0.139	-0.180	-0.004	0.167	-0.218	-0.002	0.195	-0.255	-0.001	0.230	-0.300	-0.002	0.262	-0.341	0.002
Reverse wind IoP=37.5^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	-1.182	1.540	-0.123	-1.227	1.599	-0.109	-1.183	1.542	-0.105	-1.222	1.592	-0.115	-1.232	1.606	-0.118
	panel2	0.100	-0.129	0.152	-0.103	0.135	0.127	-0.254	0.330	0.087	-0.453	0.590	0.025	-0.542	0.707	0.006
	panel3	-0.202	0.264	0.103	-0.226	0.295	0.054	-0.310	0.403	0.036	-0.437	0.569	-0.004	-0.492	0.640	-0.019
	panel4	-0.130	0.169	0.063	-0.208	0.271	0.038	-0.307	0.399	0.028	-0.354	0.461	-0.008	-0.392	0.510	-0.021
	panel5	-0.152	0.198	0.058	-0.206	0.268	0.027	-0.279	0.363	0.027	-0.303	0.395	-0.011	-0.345	0.449	-0.025
	panel6	-0.147	0.192	0.059	-0.187	0.243	0.021	-0.290	0.377	0.026	-0.276	0.360	-0.017	-0.297	0.387	-0.025
	panel7	-0.102	0.133	0.048	-0.155	0.202	0.014	-0.314	0.409	0.009	-0.242	0.316	-0.017	-0.280	0.364	-0.027
	panel8	-0.130	0.169	0.042	-0.169	0.220	0.005	-0.315	0.409	0.023	-0.229	0.299	-0.020	-0.250	0.327	-0.025
	panel9	-0.115	0.150	0.037	-0.148	0.192	0.007	-0.311	0.404	0.016	-0.216	0.282	-0.022	-0.241	0.315	-0.027
	panel10	-0.106	0.138	0.025	-0.156	0.204	0.000	-0.339	0.440	0.013	-0.225	0.294	-0.025	-0.240	0.313	-0.029
Normal wind IoP=45^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	1.403	-1.403	0.153	1.363	-1.363	0.155	1.351	-1.351	0.152	1.387	-1.387	0.154	1.393	-1.394	0.155
	panel2	-0.386	0.387	-0.051	-0.139	0.141	-0.033	0.083	-0.082	-0.007	0.408	-0.409	0.024	0.491	-0.491	0.033
	panel3	0.219	-0.218	0.009	0.349	-0.349	0.024	0.433	-0.433	0.029	0.491	-0.491	0.025	0.559	-0.559	0.035
	panel4	0.159	-0.158	-0.002	0.245	-0.245	0.010	0.339	-0.339	0.016	0.401	-0.401	0.014	0.452	-0.452	0.021
	panel5	0.155	-0.154	-0.001	0.250	-0.250	0.011	0.321	-0.322	0.013	0.383	-0.383	0.006	0.438	-0.438	0.016
	panel6	0.140	-0.139	-0.001	0.224	-0.224	0.007	0.293	-0.294	0.008	0.347	-0.347	0.000	0.400	-0.400	0.010
	panel7	0.159	-0.158	-0.001	0.211	-0.211	0.005	0.271	-0.271	0.003	0.332	-0.332	-0.007	0.367	-0.367	0.005
	panel8	0.136	-0.136	-0.002	0.200	-0.200	0.003	0.258	-0.258	0.001	0.325	-0.325	-0.009	0.370	-0.370	0.002
	panel9	0.136	-0.135	-0.003	0.184	-0.183	-0.001	0.248	-0.248	-0.003	0.309	-0.309	-0.013	0.363	-0.363	-0.001
	panel10	0.152	-0.152	-0.003	0.201	-0.201	-0.003	0.256	-0.256	-0.004	0.301	-0.300	-0.015	0.353	-0.353	-0.005
Reverse wind IoP=45^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	-1.637	1.636	-0.109	-1.663	1.663	-0.104	-1.638	1.637	-0.105	-1.655	1.655	-0.107	-1.655	1.654	-0.107
	panel2	0.186	-0.184	0.138	0.059	-0.059	0.123	-0.236	0.236	0.104	-0.514	0.514	0.041	-0.600	0.600	0.030
	panel3	-0.146	0.146	0.112	-0.276	0.276	0.057	-0.394	0.394	0.034	-0.483	0.483	0.008	-0.602	0.602	-0.016
	panel4	-0.138	0.138	0.066	-0.267	0.267	0.040	-0.373	0.372	0.017	-0.412	0.412	0.000	-0.478	0.477	-0.020
	panel5	-0.154	0.154	0.059	-0.225	0.225	0.030	-0.300	0.300	0.007	-0.382	0.382	-0.008	-0.399	0.399	-0.023
	panel6	-0.119	0.119	0.050	-0.212	0.212	0.019	-0.287	0.287	0.000	-0.333	0.333	-0.011	-0.377	0.377	-0.027
	panel7	-0.142	0.142	0.040	-0.201	0.201	0.014	-0.247	0.247	-0.005	-0.300	0.300	-0.013	-0.339	0.339	-0.027
	panel8	-0.129	0.129	0.036	-0.191	0.190	0.010	-0.243	0.243	-0.010	-0.297	0.298	-0.015	-0.328	0.328	-0.030
	panel9	-0.109	0.109	0.029	-0.180	0.180	0.004	-0.229	0.229	-0.011	-0.274	0.274	-0.015	-0.321	0.321	-0.031
	panel10	-0.136	0.136	0.021	-0.168	0.168	0.001	-0.226	0.226	-0.015	-0.276	0.276	-0.016	-0.311	0.311	-0.031

PL = 5000mm		H = 0.5 m SF = 1			H = 0.5 m SF = 2			H = 0.5 m SF = 3			H = 0.5 m SF = 4			H = 0.5 m SF = 5		
	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
Normal wind IoP=7.5^0	panel1	0.135	-1.030	0.210	0.141	-1.070	0.201	0.147	-1.123	0.210	0.150	-1.140	0.209	0.151	-1.155	0.214
	panel2	0.070	-0.536	0.094	0.075	-0.578	0.099	0.082	-0.631	0.110	0.082	-0.629	0.111	0.085	-0.648	0.115
	panel3	0.051	-0.389	0.068	0.052	-0.401	0.067	0.051	-0.393	0.061	0.049	-0.375	0.055	0.056	-0.432	0.066
	panel4	0.038	-0.288	0.045	0.037	-0.287	0.039	0.036	-0.275	0.033	0.037	-0.287	0.034	0.042	-0.319	0.041
	panel5	0.030	-0.229	0.029	0.031	-0.236	0.026	0.029	-0.223	0.023	0.032	-0.241	0.023	0.034	-0.259	0.031
	panel6	0.025	-0.188	0.018	0.025	-0.193	0.015	0.024	-0.180	0.012	0.027	-0.203	0.017	0.027	-0.204	0.017
	panel7	0.023	-0.173	0.011	0.021	-0.158	0.008	0.022	-0.171	0.006	0.023	-0.173	0.010	0.026	-0.194	0.014
	panel8	0.021	-0.158	0.007	0.019	-0.144	0.002	0.020	-0.156	0.005	0.021	-0.157	0.008	0.029	-0.218	0.021
	panel9	0.019	-0.145	0.002	0.020	-0.154	0.002	0.018	-0.137	0.003	0.019	-0.144	0.009	0.029	-0.217	0.023
	panel10	0.020	-0.155	0.000	0.019	-0.145	0.002	0.022	-0.168	0.006	0.036	-0.276	0.030	0.031	-0.235	0.024
	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
Reverse wind IoP=7.5^0	panel1	-0.153	1.170	-0.074	-0.148	1.127	-0.088	-0.174	1.340	-0.233	-0.146	1.112	-0.094	-0.154	1.172	-0.094
	panel2	-0.052	0.396	0.023	-0.080	0.612	-0.036	-0.161	1.237	-0.193	-0.098	0.747	-0.068	-0.104	0.790	-0.067
	panel3	-0.067	0.510	-0.019	-0.077	0.586	-0.036	-0.166	1.272	-0.177	-0.089	0.682	-0.058	-0.084	0.638	-0.057
	panel4	-0.054	0.414	-0.011	-0.060	0.461	-0.032	-0.170	1.301	-0.163	-0.069	0.531	-0.048	-0.070	0.533	-0.052
	panel5	-0.050	0.384	-0.015	-0.057	0.436	-0.032	-0.167	1.282	-0.161	-0.060	0.460	-0.046	-0.058	0.447	-0.047
	panel6	-0.042	0.324	-0.015	-0.049	0.377	-0.028	-0.175	1.334	-0.151	-0.054	0.411	-0.045	-0.055	0.420	-0.045
	panel7	-0.040	0.303	-0.022	-0.045	0.343	-0.033	-0.173	1.326	-0.153	-0.048	0.366	-0.042	-0.047	0.359	-0.045
	panel8	-0.036	0.273	-0.020	-0.043	0.327	-0.033	-0.174	1.325	-0.157	-0.043	0.327	-0.041	-0.043	0.329	-0.041
	panel9	-0.033	0.254	-0.021	-0.039	0.299	-0.031	-0.173	1.322	-0.159	-0.041	0.317	-0.039	-0.040	0.308	-0.044
	panel10	-0.034	0.263	-0.030	-0.037	0.286	-0.036	-0.173	1.319	-0.173	-0.038	0.295	-0.045	-0.040	0.306	-0.048
	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
Normal wind IoP=15^0	panel1	0.286	-1.064	0.131	0.297	-1.105	0.133	0.315	-1.173	0.132	0.273	-1.014	0.108	0.335	-1.247	0.128
	panel2	0.101	-0.375	0.015	0.123	-0.457	0.030	0.139	-0.520	0.037	0.157	-0.587	0.035	0.156	-0.586	0.047
	panel3	0.082	-0.303	0.012	0.091	-0.338	0.013	0.095	-0.356	0.014	0.117	-0.436	0.005	0.098	-0.365	0.017
	panel4	0.065	-0.240	0.003	0.074	-0.276	0.002	0.073	-0.273	0.003	0.058	-0.214	-0.003	0.081	-0.303	0.009
	panel5	0.052	-0.192	-0.005	0.063	-0.235	-0.007	0.049	-0.181	0.008	0.083	-0.306	0.008	0.071	-0.265	-0.001
	panel6	0.045	-0.169	-0.010	0.051	-0.189	-0.013	0.063	-0.235	-0.004	0.087	-0.324	0.015	0.088	-0.328	0.015
	panel7	0.044	-0.163	-0.015	0.045	-0.169	-0.015	0.059	-0.221	-0.004	0.091	-0.338	0.011	0.065	-0.243	0.004
	panel8	0.039	-0.146	-0.017	0.045	-0.166	-0.018	0.056	-0.210	-0.005	0.107	-0.397	0.008	0.080	-0.300	0.013
	panel9	0.037	-0.138	-0.019	0.048	-0.178	-0.020	0.059	-0.220	-0.004	0.065	-0.239	-0.013	0.084	-0.312	0.016
	panel10	0.030	-0.113	-0.021	0.041	-0.152	-0.020	0.049	-0.185	-0.011	0.115	-0.428	0.017	0.073	-0.274	0.010
	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
Reverse wind IoP=15^0	panel1	-0.461	1.722	-0.089	-0.449	1.674	-0.096	-0.451	1.685	-0.096	-0.451	1.684	-0.104	-0.460	1.718	-0.101
	panel2	-0.119	0.445	0.121	-0.112	0.419	0.072	-0.188	0.703	0.006	-0.211	0.787	-0.032	-0.205	0.766	-0.033
	panel3	-0.054	0.202	0.054	-0.129	0.483	-0.002	-0.143	0.532	-0.016	-0.141	0.527	-0.028	-0.144	0.538	-0.032
	panel4	-0.090	0.338	0.000	-0.088	0.329	-0.005	-0.103	0.383	-0.016	-0.104	0.390	-0.026	-0.111	0.417	-0.029
	panel5	-0.055	0.205	0.006	-0.083	0.312	-0.020	-0.088	0.329	-0.023	-0.086	0.323	-0.026	-0.097	0.362	-0.028
	panel6	-0.054	0.202	-0.010	-0.066	0.246	-0.018	-0.075	0.283	-0.024	-0.082	0.307	-0.027	-0.093	0.350	-0.028
	panel7	-0.050	0.186	-0.016	-0.062	0.232	-0.023	-0.072	0.268	-0.026	-0.080	0.298	-0.028	-0.089	0.332	-0.027
	panel8	-0.046	0.171	-0.020	-0.061	0.230	-0.026	-0.071	0.266	-0.026	-0.080	0.298	-0.026	-0.087	0.325	-0.027
	panel9	-0.046	0.171	-0.022	-0.060	0.224	-0.026	-0.070	0.262	-0.028	-0.078	0.293	-0.027	-0.086	0.323	-0.028
	panel10	-0.052	0.196	-0.027	-0.064	0.241	-0.029	-0.071	0.264	-0.030	-0.083	0.312	-0.029	-0.090	0.336	-0.029
	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
Normal wind IoP=22.5^0	panel1	0.441	-1.066	0.120	0.450	-1.087	0.117	0.459	-1.107	0.118	0.466	-1.125	0.119	0.469	-1.131	0.119
	panel2	0.052	-0.124	-0.027	0.099	-0.239	0.003	0.129	-0.310	0.010	0.160	-0.386	0.015	0.179	-0.433	0.018
	panel3	0.091	-0.218	-0.003	0.090	-0.217	-0.001	0.109	-0.263	0.001	0.114	-0.275	0.003	0.118	-0.286	0.004
	panel4	0.062	-0.149	-0.012	0.076	-0.184	-0.008	0.080	-0.193	-0.010	0.069	-0.167	-0.011	0.096	-0.232	-0.004
	panel5	0.055	-0.133	-0.016	0.067	-0.162	-0.012	0.062	-0.151	-0.016	0.092	-0.222	-0.005	0.105	-0.252	-0.001
	panel6	0.048	-0.115	-0.021	0.046	-0.112	-0.017	0.066	-0.158	-0.013	0.081	-0.195	-0.006	0.098	-0.236	0.000
	panel7	0.039	-0.093	-0.025	0.056	-0.134	-0.019	0.058	-0.141	-0.018	0.090	-0.218	-0.006	0.106	-0.255	0.000
	panel8	0.039	-0.093	-0.027	0.050	-0.121	-0.021	0.071	-0.172	-0.012	0.074	-0.178	-0.008	0.100	-0.243	0.000
	panel9	0.028	-0.067	-0.030	0.049	-0.119	-0.020	0.067	-0.162	-0.016	0.080	-0.193	-0.007	0.094	-0.228	-0.003
	panel10	0.036	-0.088	-0.034	0.052	-0.126	-0.023	0.078	-0.188	-0.011	0.092	-0.222	-0.003	0.095	-0.229	-0.002
	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
Reverse wind IoP=22.5^0	panel1	-0.732	1.766	-0.086	-0.743	1.794	-0.080	-0.741	1.789	-0.084	-0.755	1.823	-0.089	-0.768	1.853	-0.087
	panel2	-0.107	0.259	0.119	-0.126	0.305	0.084	-0.211	0.510	0.006	-0.194	0.468	0.000	-0.180	0.435	-0.012
	panel3	-0.041	0.100	0.069	-0.059	0.142	0.013	-0.064	0.154	-0.002	-0.091	0.219	-0.011	-0.094	0.227	-0.015
	panel4	-0.042	0.102	0.020	-0.055	0.134	-0.006	-0.057	0.138	-0.017	-0.080	0.193	-0.016	-0.090	0.218	-0.016
	panel5	-0.029	0.070	-0.001	-0.056	0.136	-0.013	-0.068	0.165	-0.016	-0.085	0.204	-0.016	-0.104	0.251	-0.017
	panel6	-0.047	0.114	-0.007	-0.052	0.126	-0.014	-0.078	0.187	-0.015	-0.093	0.224	-0.017	-0.105	0.252	-0.017
	panel7	-0.040	0.096	-0.006	-0.054	0.131	-0.013	-0.078	0.187	-0.015	-0.094	0.226	-0.016	-0.109	0.263	-0.017
	panel8	-0.043	0.103	-0.003	-0.063	0.151	-0.013	-0.080	0.193	-0.014	-0.090	0.217	-0.016	-0.108	0.260	-0.016
	panel9	-0.040	0.096	-0.002	-0.064	0.153	-0.012	-0.082	0.198	-0.015	-0.096	0.231	-0.017	-0.108	0.260	-0.017
	panel10	-0.047	0.114	0.000	-0.069	0.167	-0.014	-0.081	0.196	-0.015	-0.096	0.232	-0.016	-0.108	0.260	-0.017

PL = 5000mm		H = 0.5 m S.F. =1			H = 0.5 m S.F. = 2			H = 0.5 m S.F. = 3			H = 0.5 m S.F. = 4			H = 0.5 m S.F. = 5		
Normal wind IoP=30^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	0.722	-1.251	0.139	0.711	-1.233	0.138	0.716	-1.245	0.139	0.729	-1.265	0.140	0.731	-1.267	0.141
	panel2	-0.014	0.026	-0.042	0.065	-0.112	-0.018	0.153	-0.265	0.001	0.187	-0.324	0.007	0.220	-0.380	0.009
	panel3	0.093	-0.161	-0.004	0.153	-0.266	-0.003	0.154	-0.267	-0.006	0.175	-0.304	-0.005	0.185	-0.320	-0.003
	panel4	0.078	-0.134	-0.012	0.111	-0.193	-0.013	0.096	-0.166	-0.021	0.130	-0.225	-0.015	0.167	-0.289	-0.008
	panel5	0.072	-0.124	-0.015	0.075	-0.130	-0.020	0.100	-0.173	-0.026	0.123	-0.213	-0.015	0.166	-0.287	-0.008
	panel6	0.071	-0.123	-0.021	0.072	-0.124	-0.028	0.093	-0.161	-0.024	0.128	-0.221	-0.015	0.156	-0.271	-0.010
	panel7	0.058	-0.100	-0.023	0.067	-0.116	-0.029	0.100	-0.173	-0.023	0.148	-0.256	-0.014	0.155	-0.269	-0.009
	panel8	0.043	-0.074	-0.029	0.074	-0.129	-0.031	0.107	-0.186	-0.025	0.127	-0.221	-0.014	0.155	-0.269	-0.010
	panel9	0.054	-0.093	-0.029	0.065	-0.112	-0.030	0.094	-0.163	-0.027	0.126	-0.218	-0.014	0.155	-0.268	-0.008
	panel10	0.038	-0.066	-0.033	0.094	-0.162	-0.030	0.102	-0.176	-0.026	0.129	-0.223	-0.016	0.152	-0.264	-0.009
Reverse wind IoP=30^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	-1.161	2.011	-0.081	-1.203	2.082	-0.076	-1.200	2.079	-0.079	-1.206	2.088	-0.081	-1.211	2.097	-0.079
	panel2	-0.169	0.294	0.164	-0.120	0.209	0.131	-0.157	0.272	0.031	-0.213	0.370	0.029	-0.196	0.339	-0.004
	panel3	-0.036	0.062	0.093	-0.039	0.068	0.014	-0.060	0.104	-0.009	-0.079	0.138	-0.015	-0.088	0.153	-0.012
	panel4	0.018	-0.030	0.025	-0.039	0.068	-0.011	-0.073	0.126	-0.013	-0.114	0.198	-0.014	-0.148	0.255	-0.016
	panel5	-0.022	0.038	-0.007	-0.054	0.094	-0.009	-0.101	0.174	-0.011	-0.139	0.240	-0.015	-0.170	0.294	-0.017
	panel6	-0.039	0.067	-0.011	-0.067	0.116	-0.009	-0.115	0.199	-0.013	-0.140	0.243	-0.014	-0.160	0.276	-0.016
	panel7	-0.045	0.078	-0.009	-0.079	0.137	-0.009	-0.115	0.199	-0.012	-0.135	0.234	-0.014	-0.163	0.283	-0.016
	panel8	-0.051	0.089	-0.007	-0.079	0.136	-0.010	-0.107	0.185	-0.011	-0.135	0.234	-0.014	-0.159	0.276	-0.016
	panel9	-0.049	0.084	-0.007	-0.080	0.137	-0.009	-0.109	0.188	-0.012	-0.139	0.241	-0.015	-0.167	0.289	-0.017
	panel10	-0.052	0.089	-0.006	-0.085	0.147	-0.010	-0.112	0.193	-0.011	-0.144	0.250	-0.015	-0.160	0.277	-0.015
Normal wind IoP=37.5^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	1.103	-1.437	0.160	1.073	-1.399	0.156	1.092	-1.424	0.156	1.086	-1.416	0.156	1.094	-1.426	0.157
	panel2	-0.101	0.133	-0.051	0.021	-0.027	-0.025	0.141	-0.183	-0.003	0.191	-0.250	-0.003	0.238	-0.311	-0.003
	panel3	0.097	-0.126	-0.007	0.155	-0.202	-0.007	0.194	-0.253	-0.016	0.236	-0.308	-0.013	0.262	-0.341	-0.011
	panel4	0.089	-0.116	-0.013	0.161	-0.210	-0.019	0.122	-0.159	-0.031	0.193	-0.252	-0.024	0.242	-0.315	-0.016
	panel5	0.086	-0.111	-0.016	0.081	-0.105	-0.032	0.159	-0.207	-0.031	0.189	-0.247	-0.025	0.237	-0.308	-0.014
	panel6	0.086	-0.112	-0.024	0.090	-0.117	-0.038	0.135	-0.176	-0.033	0.180	-0.235	-0.024	0.228	-0.297	-0.014
	panel7	0.071	-0.093	-0.024	0.095	-0.124	-0.040	0.139	-0.180	-0.032	0.193	-0.252	-0.022	0.231	-0.301	-0.015
	panel8	0.045	-0.058	-0.029	0.088	-0.114	-0.042	0.135	-0.176	-0.030	0.171	-0.223	-0.022	0.241	-0.314	-0.014
	panel9	0.048	-0.062	-0.036	0.106	-0.138	-0.036	0.130	-0.169	-0.030	0.198	-0.258	-0.022	0.243	-0.317	-0.013
	panel10	0.070	-0.091	-0.039	0.108	-0.140	-0.039	0.155	-0.202	-0.031	0.187	-0.243	-0.022	0.234	-0.305	-0.015
Reverse wind IoP=37.5^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	-2.501	3.259	-0.107	-1.724	2.247	-0.064	-1.710	2.229	-0.067	-1.717	2.237	-0.069	-1.719	2.240	-0.067
	panel2	0.163	-0.212	0.289	-0.109	0.142	0.116	-0.106	0.139	0.064	-0.183	0.239	0.029	-0.182	0.238	0.004
	panel3	-0.074	0.096	0.072	0.007	-0.009	0.012	-0.070	0.091	-0.009	-0.087	0.113	-0.011	-0.130	0.170	-0.013
	panel4	-0.066	0.086	0.010	-0.024	0.031	0.003	-0.098	0.127	-0.009	-0.169	0.220	-0.014	-0.237	0.309	-0.018
	panel5	-0.128	0.166	-0.006	-0.010	0.012	0.005	-0.128	0.167	-0.010	-0.194	0.252	-0.015	-0.244	0.318	-0.018
	panel6	-0.105	0.135	-0.005	-0.077	0.100	-0.004	-0.149	0.193	-0.011	-0.188	0.245	-0.014	-0.246	0.320	-0.018
	panel7	-0.106	0.138	-0.007	-0.113	0.147	-0.009	-0.154	0.201	-0.012	-0.194	0.253	-0.015	-0.242	0.315	-0.018
	panel8	-0.117	0.152	-0.008	-0.112	0.145	-0.008	-0.139	0.181	-0.010	-0.192	0.250	-0.014	-0.226	0.294	-0.017
	panel9	-0.130	0.168	-0.008	-0.101	0.131	-0.008	-0.145	0.189	-0.010	-0.178	0.231	-0.013	-0.238	0.310	-0.018
	panel10	-0.125	0.163	-0.006	-0.101	0.131	-0.007	-0.151	0.197	-0.011	-0.210	0.273	-0.016	-0.232	0.303	-0.018
Normal wind IoP=45^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	1.591	-1.591	0.177	1.542	-1.543	0.173	1.540	-1.541	0.169	1.530	-1.530	0.171	1.537	-1.538	0.169
	panel2	-0.295	0.296	-0.045	-0.027	0.028	-0.026	0.099	-0.099	-0.008	0.194	-0.194	-0.004	0.274	-0.274	-0.009
	panel3	0.120	-0.120	-0.007	0.169	-0.169	-0.016	0.256	-0.256	-0.020	0.324	-0.324	-0.020	0.368	-0.368	-0.013
	panel4	0.100	-0.100	-0.016	0.134	-0.134	-0.035	0.162	-0.162	-0.038	0.262	-0.262	-0.033	0.345	-0.345	-0.017
	panel5	0.111	-0.111	-0.017	0.106	-0.106	-0.046	0.188	-0.188	-0.037	0.254	-0.254	-0.032	0.349	-0.349	-0.020
	panel6	0.085	-0.085	-0.017	0.099	-0.099	-0.048	0.183	-0.183	-0.038	0.256	-0.256	-0.031	0.336	-0.336	-0.022
	panel7	0.083	-0.083	-0.018	0.128	-0.128	-0.050	0.161	-0.161	-0.040	0.263	-0.263	-0.029	0.315	-0.315	-0.022
	panel8	0.076	-0.076	-0.022	0.129	-0.129	-0.047	0.174	-0.174	-0.038	0.249	-0.249	-0.031	0.339	-0.339	-0.019
	panel9	0.079	-0.079	-0.025	0.094	-0.094	-0.047	0.200	-0.200	-0.040	0.253	-0.253	-0.029	0.334	-0.334	-0.017
	panel10	0.081	-0.081	-0.024	0.143	-0.143	-0.044	0.180	-0.180	-0.038	0.260	-0.260	-0.029	0.340	-0.340	-0.019
Reverse wind IoP=45^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	-2.277	2.277	-0.038	-2.318	2.317	-0.052	-2.283	2.283	-0.052	-2.291	2.290	-0.054	-2.302	2.302	-0.051
	panel2	-0.121	0.122	0.184	0.041	-0.040	0.125	-0.067	0.067	0.058	-0.158	0.158	0.028	-0.156	0.156	0.003
	panel3	-0.054	0.055	0.100	0.020	-0.020	0.010	-0.033	0.033	-0.004	-0.068	0.067	-0.007	-0.190	0.190	-0.015
	panel4	0.075	-0.074	0.041	-0.010	0.009	0.009	-0.087	0.087	-0.006	-0.236	0.236	-0.016	-0.312	0.312	-0.019
	panel5	0.045	-0.045	0.009	-0.010	0.010	0.006	-0.173	0.173	-0.011	-0.249	0.249	-0.016	-0.328	0.328	-0.020
	panel6	0.004	-0.004	0.002	-0.131	0.130	-0.007	-0.179	0.179	-0.012	-0.248	0.248	-0.016	-0.334	0.334	-0.020
	panel7	0.006	-0.006	0.003	-0.139	0.138	-0.009	-0.179	0.178	-0.011	-0.264	0.264	-0.017	-0.308	0.308	-0.019
	panel8	-0.018	0.017	0.000	-0.137	0.137	-0.009	-0.196	0.196	-0.012	-0.257	0.257	-0.017	-0.341	0.341	-0.020
	panel9	-0.034	0.033	-0.002	-0.120	0.120	-0.008	-0.177	0.177	-0.011	-0.261	0.261	-0.017	-0.334	0.334	-0.020
	panel10	-0.042	0.042	-0.003	-0.135	0.134	-0.008	-0.193	0.192	-0.011	-0.276	0.276	-0.018	-0.329	0.329	-0.020

PL = 5000mm	H = 1.0 m				H = 1.0 m			H = 1.0 m			H = 1.0 m			H = 1.0 m		
	SF = 1				SF = 2			SF = 3			SF = 4			SF = 5		
Normal wind IoP=7.5^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	0.136	-1.039	0.204	0.149	-1.139	0.193	0.151	-1.154	0.197	0.150	-1.144	0.204	0.155	-1.184	0.215
	panel2	0.072	-0.555	0.093	0.086	-0.659	0.112	0.094	-0.718	0.118	0.098	-0.754	0.126	0.108	-0.826	0.140
	panel3	0.064	-0.491	0.086	0.071	-0.545	0.090	0.074	-0.568	0.093	0.084	-0.643	0.105	0.086	-0.656	0.102
	panel4	0.057	-0.442	0.073	0.063	-0.483	0.076	0.064	-0.489	0.076	0.070	-0.543	0.087	0.070	-0.539	0.084
	panel5	0.051	-0.393	0.066	0.054	-0.415	0.064	0.056	-0.435	0.065	0.060	-0.458	0.069	0.061	-0.468	0.068
	panel6	0.047	-0.362	0.058	0.047	-0.366	0.055	0.051	-0.395	0.056	0.053	-0.405	0.057	0.056	-0.426	0.059
	panel7	0.043	-0.329	0.051	0.044	-0.337	0.047	0.046	-0.355	0.048	0.048	-0.370	0.048	0.048	-0.370	0.049
	panel8	0.039	-0.300	0.045	0.040	-0.308	0.040	0.042	-0.319	0.040	0.045	-0.342	0.043	0.044	-0.335	0.041
	panel9	0.036	-0.277	0.038	0.037	-0.286	0.035	0.038	-0.293	0.034	0.041	-0.317	0.037	0.041	-0.318	0.037
	panel10	0.037	-0.289	0.033	0.036	-0.277	0.030	0.035	-0.269	0.027	0.037	-0.282	0.031	0.035	-0.272	0.029
Reverse wind IoP=7.5^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	-0.098	0.737	-0.083	-0.121	0.922	-0.088	-0.129	0.982	-0.095	-0.127	0.967	-0.093	-0.135	1.030	-0.094
	panel2	-0.086	0.656	-0.069	-0.083	0.639	-0.054	-0.090	0.688	-0.070	-0.096	0.734	-0.079	-0.102	0.777	-0.082
	panel3	-0.064	0.491	-0.021	-0.074	0.561	-0.042	-0.078	0.598	-0.057	-0.087	0.665	-0.065	-0.090	0.688	-0.069
	panel4	-0.058	0.445	-0.018	-0.068	0.521	-0.038	-0.075	0.571	-0.052	-0.078	0.596	-0.053	-0.083	0.635	-0.063
	panel5	-0.055	0.417	-0.016	-0.064	0.488	-0.035	-0.068	0.523	-0.044	-0.076	0.582	-0.058	-0.076	0.582	-0.060
	panel6	-0.052	0.402	-0.016	-0.060	0.457	-0.033	-0.065	0.500	-0.047	-0.070	0.536	-0.049	-0.073	0.558	-0.060
	panel7	-0.051	0.386	-0.016	-0.060	0.455	-0.034	-0.063	0.485	-0.043	-0.065	0.501	-0.050	-0.067	0.515	-0.056
	panel8	-0.050	0.384	-0.016	-0.058	0.443	-0.036	-0.060	0.458	-0.043	-0.062	0.473	-0.051	-0.064	0.487	-0.054
	panel9	-0.048	0.369	-0.021	-0.054	0.412	-0.033	-0.061	0.465	-0.044	-0.060	0.460	-0.047	-0.062	0.472	-0.052
	panel10	-0.049	0.379	-0.024	-0.056	0.430	-0.043	-0.058	0.446	-0.052	-0.060	0.463	-0.054	-0.058	0.446	-0.055
Normal wind IoP=15^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	0.276	-1.029	0.119	0.326	-1.215	0.119	0.334	-1.244	0.124	0.342	-1.275	0.125	0.350	-1.306	0.130
	panel2	0.111	-0.415	0.007	0.159	-0.593	0.043	0.197	-0.738	0.063	0.218	-0.815	0.073	0.224	-0.835	0.076
	panel3	0.131	-0.486	0.036	0.140	-0.522	0.038	0.153	-0.570	0.044	0.160	-0.599	0.046	0.172	-0.643	0.049
	panel4	0.096	-0.355	0.023	0.120	-0.449	0.029	0.127	-0.476	0.029	0.137	-0.511	0.036	0.139	-0.520	0.036
	panel5	0.092	-0.344	0.020	0.108	-0.402	0.022	0.109	-0.408	0.058	0.120	-0.450	0.024	0.123	-0.459	0.029
	panel6	0.081	-0.302	0.012	0.095	-0.356	0.011	0.107	-0.401	0.017	0.110	-0.410	0.022	0.114	-0.428	0.024
	panel7	0.078	-0.289	0.008	0.083	-0.312	0.009	0.092	-0.342	0.010	0.102	-0.381	0.017	0.110	-0.412	0.022
	panel8	0.069	-0.256	0.006	0.075	-0.281	0.002	0.086	-0.321	0.005	0.095	-0.355	0.015	0.107	-0.401	0.024
	panel9	0.065	-0.244	0.001	0.073	-0.274	-0.002	0.082	-0.307	0.004	0.090	-0.337	0.016	0.101	-0.376	0.020
	panel10	0.068	-0.253	-0.002	0.070	-0.260	-0.002	0.075	-0.281	0.001	0.082	-0.308	0.009	0.095	-0.353	0.017
Reverse wind IoP=15^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	-0.367	1.371	-0.121	-0.370	1.383	-0.102	-0.370	1.382	-0.112	-0.389	1.454	-0.101	-0.385	1.440	-0.110
	panel2	-0.104	0.390	0.107	-0.150	0.560	0.026	-0.222	0.831	-0.017	-0.245	0.913	-0.041	-0.254	0.950	-0.057
	panel3	-0.147	0.552	0.024	-0.168	0.625	-0.004	-0.194	0.723	-0.026	-0.203	0.758	-0.035	-0.213	0.796	-0.046
	panel4	-0.114	0.428	0.031	-0.147	0.550	-0.001	-0.169	0.631	-0.022	-0.182	0.679	-0.037	-0.188	0.702	-0.046
	panel5	-0.090	0.336	0.033	-0.130	0.485	-0.006	-0.152	0.568	-0.026	-0.163	0.610	-0.037	-0.164	0.611	-0.040
	panel6	-0.105	0.394	0.015	-0.111	0.416	-0.005	-0.136	0.506	-0.025	-0.142	0.532	-0.033	-0.145	0.541	-0.040
	panel7	-0.085	0.319	0.013	-0.115	0.429	-0.013	-0.123	0.458	-0.026	-0.130	0.487	-0.032	-0.134	0.500	-0.035
	panel8	-0.091	0.339	0.007	-0.099	0.372	-0.010	-0.110	0.410	-0.026	-0.120	0.449	-0.032	-0.124	0.463	-0.035
	panel9	-0.082	0.309	0.006	-0.094	0.350	-0.015	-0.104	0.390	-0.027	-0.111	0.417	-0.032	-0.115	0.432	-0.033
	panel10	-0.075	0.282	0.005	-0.097	0.365	-0.022	-0.105	0.392	-0.031	-0.112	0.421	-0.032	-0.117	0.438	-0.035
Normal wind IoP=22.5^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	0.463	-1.120	0.120	0.473	-1.143	0.120	0.483	-1.168	0.120	0.485	-1.172	0.128	0.521	-1.261	0.125
	panel2	0.042	-0.100	-0.020	0.151	-0.363	0.006	0.196	-0.473	0.021	0.245	-0.592	0.038	0.253	-0.612	0.042
	panel3	0.142	-0.342	0.008	0.172	-0.413	0.022	0.186	-0.450	0.026	0.194	-0.469	0.029	0.196	-0.474	0.028
	panel4	0.103	-0.247	-0.004	0.126	-0.305	0.012	0.139	-0.337	0.013	0.156	-0.377	0.016	0.161	-0.388	0.019
	panel5	0.096	-0.230	-0.007	0.103	-0.249	0.004	0.125	-0.303	0.007	0.135	-0.325	0.011	0.139	-0.335	0.012
	panel6	0.079	-0.190	-0.012	0.088	-0.213	-0.001	0.115	-0.278	0.003	0.124	-0.300	0.007	0.125	-0.303	0.008
	panel7	0.072	-0.173	-0.013	0.084	-0.204	-0.002	0.100	-0.241	0.000	0.110	-0.264	0.003	0.115	-0.277	0.003
	panel8	0.068	-0.165	-0.016	0.078	-0.189	-0.005	0.095	-0.229	-0.002	0.103	-0.248	-0.002	0.110	-0.266	0.003
	panel9	0.065	-0.157	-0.017	0.076	-0.184	-0.009	0.087	-0.210	-0.005	0.091	-0.220	-0.004	0.101	-0.245	-0.002
	panel10	0.072	-0.173	-0.024	0.079	-0.191	-0.008	0.081	-0.195	-0.008	0.080	-0.193	-0.006	0.107	-0.257	0.000
Reverse wind IoP=22.5^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	-0.621	1.500	-0.112	-0.649	1.566	-0.100	-0.653	1.575	-0.107	-0.654	1.580	-0.109	-0.666	1.608	-0.111
	panel2	-0.176	0.425	0.141	-0.199	0.482	0.077	-0.270	0.652	0.030	-0.283	0.683	0.010	-0.321	0.775	-0.025
	panel3	-0.052	0.126	0.105	-0.170	0.412	0.029	-0.201	0.484	0.001	-0.237	0.571	-0.018	-0.231	0.557	-0.021
	panel4	-0.126	0.304	0.053	-0.138	0.334	0.014	-0.166	0.400	-0.005	-0.178	0.430	-0.016	-0.186	0.449	-0.023
	panel5	-0.089	0.216	0.051	-0.118	0.284	0.005	-0.133	0.321	-0.010	-0.149	0.360	-0.018	-0.153	0.369	-0.023
	panel6	-0.090	0.217	0.038	-0.095	0.230	0.000	-0.115	0.277	-0.013	-0.127	0.307	-0.018	-0.136	0.329	-0.024
	panel7	-0.074	0.178	0.028	-0.090	0.217	-0.007	-0.102	0.246	-0.015	-0.114	0.276	-0.019	-0.122	0.296	-0.022
	panel8	-0.061	0.149	0.019	-0.085	0.205	-0.011	-0.093	0.224	-0.016	-0.110	0.265	-0.019	-0.119	0.288	-0.023
	panel9	-0.069	0.166	0.016	-0.076	0.184	-0.012	-0.088	0.212	-0.017	-0.104	0.250	-0.019	-0.117	0.282	-0.022
	panel10	-0.071	0.172	0.012	-0.081	0.197	-0.015	-0.094	0.228	-0.018	-0.103	0.250	-0.020	-0.121	0.293	-0.025

PL = 5000mm	H = 1.0 m				H = 1.0 m			H = 1.0 m			H = 1.0 m			H = 1.0 m		
	S.F. =1				S.F. = 2			S.F. = 3			S.F. = 4			S.F. = 5		
Normal wind IoP=30^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	0.738	-1.279	0.145	0.747	-1.296	0.141	0.758	-1.315	0.143	0.770	-1.332	0.146	0.785	-1.361	0.143
	panel2	-0.052	0.092	-0.047	0.129	-0.221	-0.009	0.222	-0.383	0.015	0.301	-0.522	0.028	0.347	-0.601	0.037
	panel3	0.194	-0.335	0.010	0.226	-0.391	0.016	0.258	-0.447	0.022	0.277	-0.479	0.022	0.289	-0.501	0.025
	panel4	0.136	-0.234	-0.002	0.161	-0.278	0.003	0.199	-0.345	0.006	0.220	-0.381	0.010	0.244	-0.422	0.014
	panel5	0.122	-0.210	-0.003	0.153	-0.265	0.000	0.185	-0.320	0.002	0.206	-0.356	0.004	0.216	-0.373	0.008
	panel6	0.110	-0.190	-0.004	0.129	-0.224	-0.004	0.166	-0.287	-0.003	0.186	-0.321	-0.001	0.205	-0.354	0.001
	panel7	0.101	-0.175	-0.004	0.131	-0.226	-0.009	0.152	-0.263	-0.007	0.168	-0.292	-0.006	0.185	-0.320	-0.004
	panel8	0.082	-0.141	-0.009	0.114	-0.197	-0.014	0.145	-0.251	-0.012	0.152	-0.263	-0.014	0.182	-0.316	-0.008
	panel9	0.084	-0.145	-0.010	0.114	-0.197	-0.014	0.127	-0.221	-0.018	0.131	-0.227	-0.015	0.179	-0.310	-0.007
	panel10	0.098	-0.169	-0.012	0.116	-0.201	-0.014	0.095	-0.165	-0.024	0.137	-0.237	-0.014	0.174	-0.301	-0.008
Reverse wind IoP=30^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	-1.025	1.774	-0.115	-1.079	1.868	-0.106	-1.082	1.873	-0.110	-1.083	1.875	-0.112	-1.092	1.891	-0.113
	panel2	-0.179	0.310	0.165	-0.136	0.236	0.128	-0.323	0.559	0.053	-0.398	0.688	0.027	-0.422	0.730	0.002
	panel3	-0.069	0.120	0.133	-0.209	0.361	0.044	-0.242	0.419	0.013	-0.281	0.486	-0.004	-0.307	0.532	-0.021
	panel4	-0.142	0.247	0.054	-0.164	0.285	0.021	-0.191	0.330	-0.001	-0.223	0.387	-0.018	-0.230	0.398	-0.023
	panel5	-0.108	0.188	0.051	-0.134	0.232	0.006	-0.168	0.291	-0.012	-0.184	0.319	-0.019	-0.200	0.347	-0.023
	panel6	-0.072	0.124	0.032	-0.122	0.212	-0.003	-0.146	0.254	-0.015	-0.168	0.291	-0.020	-0.187	0.324	-0.024
	panel7	-0.086	0.150	0.012	-0.108	0.186	-0.008	-0.138	0.238	-0.016	-0.162	0.281	-0.021	-0.173	0.300	-0.024
	panel8	-0.068	0.118	0.005	-0.102	0.177	-0.010	-0.133	0.231	-0.017	-0.157	0.272	-0.021	-0.172	0.299	-0.023
	panel9	-0.076	0.130	0.001	-0.098	0.169	-0.010	-0.127	0.219	-0.017	-0.154	0.266	-0.021	-0.175	0.303	-0.023
	panel10	-0.074	0.128	-0.002	-0.102	0.176	-0.012	-0.126	0.219	-0.017	-0.157	0.272	-0.021	-0.171	0.296	-0.023
Normal wind IoP=37.5^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	1.046	-1.363	0.150	1.118	-1.458	0.159	1.118	-1.457	0.161	1.123	-1.464	0.160	1.128	-1.471	0.161
	panel2	-0.267	0.349	-0.077	0.094	-0.121	-0.014	0.262	-0.342	0.012	0.353	-0.461	0.022	0.424	-0.553	0.030
	panel3	0.141	-0.182	-0.012	0.270	-0.352	0.010	0.330	-0.430	0.014	0.378	-0.492	0.017	0.408	-0.531	0.022
	panel4	0.111	-0.143	-0.024	0.232	-0.302	0.004	0.270	-0.352	0.002	0.323	-0.420	0.005	0.345	-0.450	0.008
	panel5	0.119	-0.154	-0.031	0.195	-0.254	-0.004	0.238	-0.310	-0.005	0.285	-0.372	-0.003	0.305	-0.398	0.001
	panel6	0.127	-0.165	-0.025	0.183	-0.239	-0.009	0.236	-0.308	-0.009	0.268	-0.349	-0.012	0.256	-0.334	-0.009
	panel7	0.088	-0.114	-0.033	0.164	-0.214	-0.014	0.223	-0.290	-0.014	0.235	-0.306	-0.022	0.231	-0.301	-0.012
	panel8	0.097	-0.126	-0.030	0.167	-0.218	-0.017	0.200	-0.261	-0.023	0.210	-0.273	-0.023	0.210	-0.274	-0.017
	panel9	0.087	-0.112	-0.033	0.149	-0.195	-0.020	0.136	-0.177	-0.032	0.214	-0.278	-0.028	0.194	-0.253	-0.019
	panel10	0.113	-0.146	-0.034	0.151	-0.197	-0.021	0.166	-0.216	-0.031	0.220	-0.287	-0.026	0.182	-0.237	-0.021
Reverse wind IoP=37.5^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	-2.280	2.970	-0.160	-1.595	2.079	-0.098	-1.573	2.050	-0.102	-1.585	2.065	-0.106	-1.585	2.067	-0.104
	panel2	0.111	-0.145	0.291	-0.188	0.246	0.161	-0.283	0.369	0.097	-0.456	0.594	0.039	-0.522	0.681	0.013
	panel3	-0.258	0.337	0.129	-0.224	0.292	0.053	-0.321	0.419	0.014	-0.333	0.434	-0.005	-0.363	0.473	-0.018
	panel4	-0.268	0.349	0.078	-0.156	0.203	0.022	-0.255	0.333	-0.005	-0.272	0.355	-0.018	-0.308	0.401	-0.026
	panel5	-0.176	0.229	0.040	-0.136	0.178	0.001	-0.203	0.264	-0.013	-0.234	0.305	-0.021	-0.275	0.359	-0.028
	panel6	-0.219	0.284	0.018	-0.141	0.184	-0.009	-0.187	0.243	-0.017	-0.228	0.298	-0.023	-0.261	0.340	-0.028
	panel7	-0.203	0.264	0.013	-0.130	0.169	-0.011	-0.181	0.236	-0.018	-0.225	0.294	-0.025	-0.269	0.350	-0.029
	panel8	-0.212	0.276	0.006	-0.134	0.174	-0.013	-0.176	0.229	-0.019	-0.219	0.286	-0.024	-0.280	0.365	-0.029
	panel9	-0.178	0.231	0.006	-0.119	0.155	-0.012	-0.175	0.227	-0.019	-0.224	0.292	-0.024	-0.276	0.360	-0.029
	panel10	-0.183	0.237	0.002	-0.129	0.168	-0.014	-0.185	0.240	-0.020	-0.231	0.301	-0.025	-0.277	0.361	-0.029
Normal wind IoP=45^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	1.622	-1.621	0.177	1.584	-1.584	0.175	1.575	-1.575	0.174	1.588	-1.588	0.175	1.585	-1.585	0.176
	panel2	-0.338	0.338	-0.063	0.020	-0.020	-0.024	0.191	-0.190	0.002	0.392	-0.393	0.018	0.497	-0.497	0.024
	panel3	0.254	-0.254	0.005	0.333	-0.333	0.012	0.452	-0.453	0.013	0.511	-0.510	0.013	0.560	-0.560	0.017
	panel4	0.180	-0.179	-0.008	0.274	-0.274	0.000	0.355	-0.355	-0.004	0.423	-0.423	-0.002	0.465	-0.465	0.002
	panel5	0.169	-0.168	-0.009	0.248	-0.248	-0.006	0.328	-0.328	-0.010	0.389	-0.389	-0.012	0.424	-0.424	-0.010
	panel6	0.161	-0.160	-0.009	0.239	-0.239	-0.013	0.312	-0.312	-0.016	0.339	-0.339	-0.024	0.389	-0.389	-0.016
	panel7	0.135	-0.134	-0.011	0.205	-0.205	-0.018	0.280	-0.280	-0.027	0.331	-0.331	-0.030	0.394	-0.394	-0.019
	panel8	0.133	-0.133	-0.013	0.221	-0.221	-0.021	0.210	-0.210	-0.038	0.315	-0.315	-0.031	0.404	-0.404	-0.019
	panel9	0.125	-0.125	-0.013	0.207	-0.207	-0.024	0.179	-0.179	-0.047	0.304	-0.304	-0.033	0.402	-0.402	-0.021
	panel10	0.131	-0.131	-0.013	0.201	-0.201	-0.027	0.221	-0.221	-0.042	0.301	-0.301	-0.038	0.403	-0.403	-0.021
Reverse wind IoP=45^0	PANEL NO	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff	Drag Coeff	Lift Coeff	Moment Coeff
	panel1	-2.158	2.157	-0.085	-2.189	2.189	-0.090	-2.146	2.145	-0.091	-2.159	2.158	-0.090	-2.164	2.163	-0.092
	panel2	0.061	-0.060	0.208	-0.088	0.088	0.174	-0.384	0.384	0.103	-0.573	0.573	0.046	-0.602	0.602	0.023
	panel3	-0.173	0.173	0.121	-0.240	0.240	0.052	-0.294	0.294	0.020	-0.356	0.356	-0.005	-0.428	0.428	-0.019
	panel4	-0.123	0.123	0.079	-0.185	0.185	0.015	-0.272	0.272	-0.007	-0.327	0.327	-0.022	-0.369	0.369	-0.027
	panel5	-0.076	0.076	0.047	-0.153	0.153	-0.001	-0.266	0.266	-0.018	-0.309	0.309	-0.026	-0.330	0.330	-0.028
	panel6	-0.111	0.111	0.027	-0.171	0.171	-0.010	-0.243	0.243	-0.021	-0.298	0.298	-0.028	-0.310	0.310	-0.026
	panel7	-0.092	0.091	0.011	-0.154	0.154	-0.011	-0.229	0.228	-0.021	-0.298	0.298	-0.028	-0.302	0.302	-0.025
	panel8	-0.106	0.106	0.006	-0.151	0.150	-0.013	-0.224	0.224	-0.022	-0.308	0.308	-0.029	-0.302	0.302	-0.025
	panel9	-0.102	0.102	0.003	-0.155	0.154	-0.014	-0.236	0.235	-0.023	-0.320	0.320	-0.030	-0.288	0.288	-0.024
	panel10	-0.106	0.106	0.000	-0.165	0.165	-0.016	-0.240	0.240	-0.023	-0.323	0.323	-0.029	-0.286	0.286	-0.024