WIND DIRECTIONALITY FACTOR ON
OFFSHORE PLATFORM IN MALAYSIA WATER

By

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CERTIFICATION OF APPROVAL

Wind Directionality Factor on Offshore Platform in Malaysian Water

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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Ashraf bin Che Abdullah

ABSTRACT

In designing offshore structure, wind load are being considered as one of the load that are acting on the topside platform. The ASCE 7-10 equations specifies on how to calculate the wind pressure based on some factor, where wind directionality is one of them. This research is focusing on the suitable factor to be used based on the conditions of Malaysian water, which is the South China Sea.

Measured wind data collected at three different locations across the Malaysian water is taken into consideration in this research. These data will give the pattern of the wind that blows across Malaysia, which will be influenced by the monsoon season in Malaysia, namely the southwest monsoon and the northeast monsoon. These monsoons will influence the direction of the wind that will be acting on the platform.

From the result of the data, the wind directionality factor can be calculated based on the percentage of frequency in which the wind load is acting on one particular direction. The result will be compared with the original reduction factor mentioned in the ASCE codes.

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CHAPTER 1

INTRODUCTION

1.1. Project Background

According to Malaysian Meteorological Department (MMD), wind in Malaysia can be categorized into four, namely the southwest monsoon, northeast monsoon and two shorter periods between the two major monsoons, called the inter-monsoon seasons.

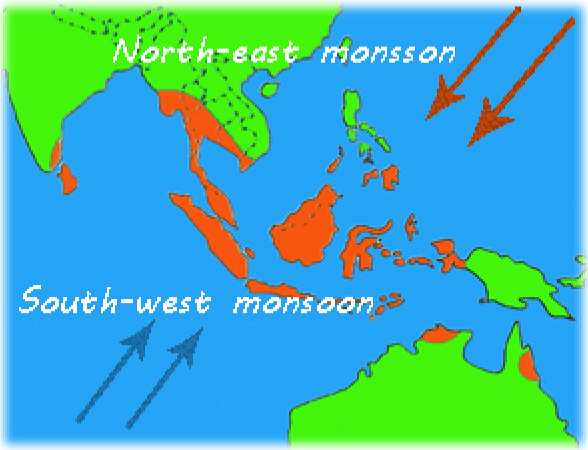


Figure 1 : Malaysian Monsoon

The southwest monsoon season is usually occurs during mid of May or early June and ends in September and the wind flow is generally light, below 15 knots. Meanwhile for the northeast monsoon season, it usually start in early November and ends in March. During this season, the wind blows steadily from the east or northeast around 10 to 20 knots. The winds over the east coast states of Peninsular Malaysia are generally higher compared to the west coast and may reach 30 knots or more.

During the two intermonsoon seasons, which occurs during the month of April and October, the winds are generally light and vary. During these seasons, the equatorial trough lies over Malaysia. During the months of April to November, typhoons frequently develop over the west Pacific region and move across the

Philippines, where southwesterly winds over the northwest coast of Sabah and Sarawak region may increase to reach 20 knots or more.

Table 1: Wind Season

Wind season	Month
Southwest monsoon	May-September
Northeast Monsoon	November-March
Intermonsoon	April and October

For this research, three sets of wind data from three different area of the Malaysia water is taken to be analysed. These data is taken from the platforms at the respective locations and the data is collected at 10 minute intervals. The three platforms taken are Dulang for Peninsular Malaysia Operation (PMO), Samarang for Sabah Operation (SBO) and Tukau for Sarawak Operation (SKO).

Dulang is discovered in 1981, and is a major oil field in the Malaysian Basin. Located 130 km off the east coast of Peninsular of Malaysia and has a water depth of 76 m. The Dulang field is approximately 24 km long and 3.5 km wide. The data collected from the field is taken from 1999 until 2006.

The Tukau Field is located nearby Lutong, some 30 km offshore of Sarawak, Malaysia and has a water depth of about 160 ft. The wind data for this platform is taken from 1999 to 2003, around 5 years. Meanwhile, Samarang field was initially developed in 1975 and is located offshore of Sabah, East Malaysia, about 72 km northwest of the Labuan Gas terminal. The field surrounds a shallow reef with a water depth of 9 metre. The wind data for this particular location is taken from 1999 until 2008.

1.2. Problem Statement

Wind directionality factor is used to calculate wind loads based on the ASCE code, where the factor is specified to be 0.85. This value is obtained from wind data through various research and studies. However, this value may not be accurate to be used in the Malaysian region, thus this research will used the wind data across Malaysian region to come up with a suitable wind directionality factor of its own.

In Malaysia, there are two major wind season, called northeast monsoon and southwest monsoon. In this research, focus will be on the northeast monsoon due to its higher wind loads compared to the southwest monsoon, which acts on the platform at three regions across Malaysian water, namely PMO, SBO and SKO. Thus, the wind that comes from the north, northeast and east will only be considered in this research throughout the year. From the wind data, wind directionality factor will be derived to be used to calculate wind loads which will act on the platforms.

1.3. Objectives

The objectives of this research are:

- To learn the wind phenomenon in Malaysia by studying the wind data collected at the three separate locations around Malaysia.
- The results of the research can be used to alter the constant of wind directionality factor used in the ASCE 7-10 equation by giving a more accurate coefficient based on the wind data in Malaysia. This can prevent the platforms in Malaysia from being overdesign because the wind loads in Malaysia is lower compared to the North Sea as well as Gulf of Mexico.

1.4. Scope of Work

This research covers the wind data collected at three platforms located at three different locations of Malaysia, namely PMO, SBO and SKO. The data collected for the three platforms is 5 years, which starts from 1999 until 2003. The data obtained is a measured value data, which is recorded by the measuring equipment at each of the platform. However, there have been some missing values, some for a few intervals and some for the whole month. As for the few intervals, the value will be interpolated linearly whereas for the missing value for the whole month, the data had to be omitted from the research as this research will be categorized based on monthly basis. After sorting out the data according to its wind direction, a density graph will be plotted. The wind directions that is being considered is only three, which are north, northeast and east directions.

For this research, no lab works is needed as all the wind data has been collected at the offshore locations in the oil field. Only analysis of the result of the data is necessary in order to come up with a more suitable wind directionality factor value to be used in the ASCE equation.

1.5. Feasibility of the Project

The research will be done during the two semesters, namely FYP 1 for the first semester and FYP 2 for the second semester. For the FYP1 and FYP2, the duration of time for the research is 14 weeks for each of the semester. As the research scope of this study has been limited into just three of the wind directions, this makes the task for this study becomes easier. Gantt chart has been drafted to make sure that this project will be able to be completed within the given time frame.

CHAPTER 2
LITERATURE REVIEW

2.1. Offshore vs Onshore Wind

Offshore winds are generally stronger, less turbulent, and more constant than onshore winds (Swenson S., 2009). The average and extreme wind speeds of the offshore winds are often higher than those on land. Due to the low turbulence offshore, this reduces the fatigue loads, but wind interactions must be taken into account during designing process.

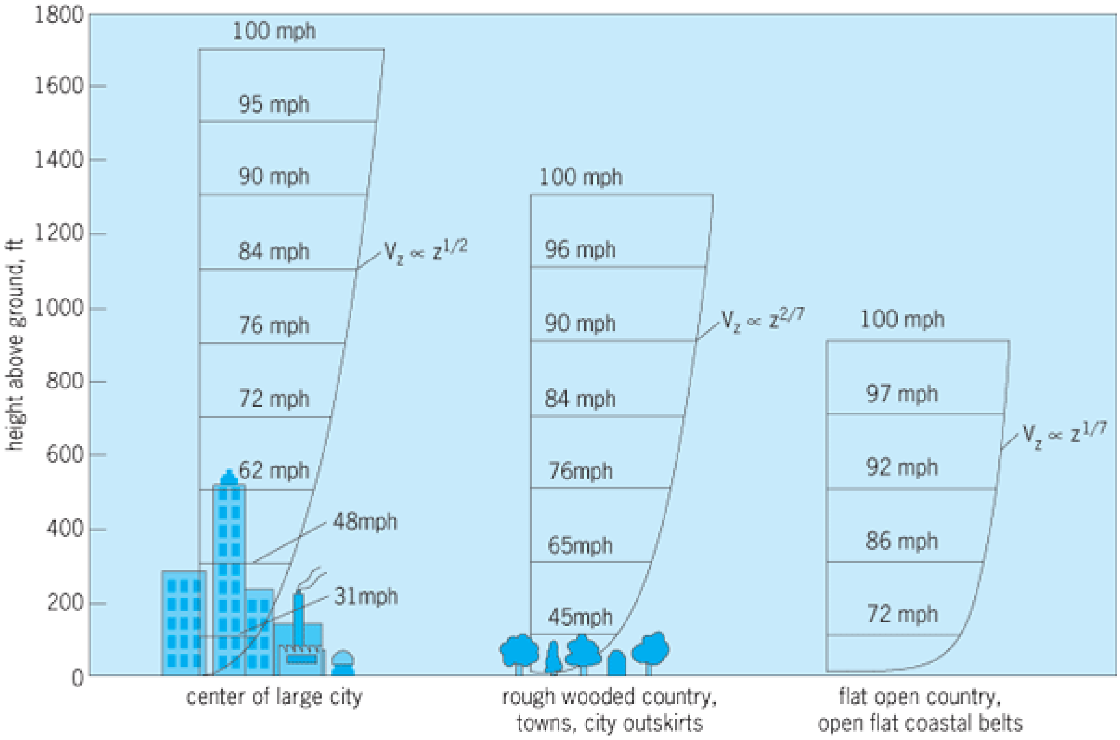


Figure 2 : Wind Speed

Figure 2 shows the comparison of the wind speed in three different areas, namely in the city, rough wooden country and flat open country. It is shown that the wind speed at open areas is generally higher compared to areas where there is a tall building structure because the flow of the wind will be interrupted by the building and thus, making the wind speed becomes slower. However, in open areas such as the sea, the wind speed will be higher at the same height and this makes wind loads as an important consideration during designing an offshore structure.

2.2. Wind Loading

In the consideration of the effect of wind loading on a structure, it is very important to differentiate between stiff and flexible structures. Normally, the calculation for the wind loading on a stiff structure is simple meanwhile it will be more complicated to calculate the effect of wind loading on a flexible structure.

Basically, wind produces three different types of effects on structure, which are static, dynamic and aerodynamic (Adhikari, S. n.d.). When the structure deflects as a result from the wind load, then the dynamic and aerodynamic effects should be consider during the analysis, in addition to the static effect. Sound knowledge of fluid and structural mechanics helps in understanding of details of interaction between wind flow and civil engineering structures or buildings.

If the construction is very stiff, it is allowable to assume the wind load to be static (Brorsen, M. 2007). As for flexible structure, it is necessary to consider the wind load as a dynamic load in order to capture possible resonance problems. Dynamic loads can exist in both the flow direction and perpendicular to that. However, the existing method only considers the dynamic loads in the flow direction.

There are three forms of wind induced motion, which are galloping, flutter and ovalling. Galloping is transverse oscillations of some structures due to the development of aerodynamic forces which are in phase with the motion. It is characterized by the progressively increasing amplitude of transverse vibration with increase of wind speed. Non circular cross sections are more susceptible to this type of oscillation (Adhikari, S. n.d.).

Flutter is unstable oscillatory motion of a structure due to coupling between aerodynamic force and elastic deformation of the structure (Adhikari, S. n.d.). Perhaps the most common form is oscillatory motion due to combined bending and torsion. Long span suspension bridge decks or any member of a structure with large values of d/t are prone to low speed flutter.

The ovalling oscillations are characterized by periodic radial deformation of the hollow structure. Walled structures with open ends at one or both ends such as the oil storage tanks, and natural draught cooling towers, in which the ratio of the diameter of minimum lateral dimension to the wall thickness is of the order of 100 or more, are prone to these oscillations.

2.3. Malaysian Platforms

Malaysia has 249 offshore installations in four regions, which are Peninsular Malaysia, Sarawak, Sabah and Malaysia Thailand Joint Authority (MTJA). Around that figure, 60% of the platforms have exceeded the design life of 25 years. Figure 3 shows the locations of the oil field across Malaysian water. This is because most of the platforms were designed based on API and ASCE standards, which is developed based on more extreme conditions in the Gulf of Mexico and North Sea (Selamat, I.M. 2013). The calmer metocean condition across Malaysian water, which is the South China Sea will results in an overdesign platforms, which is not economical. Due to the high load considerations, this will results in heavier and larger structural member to be used for the platforms.

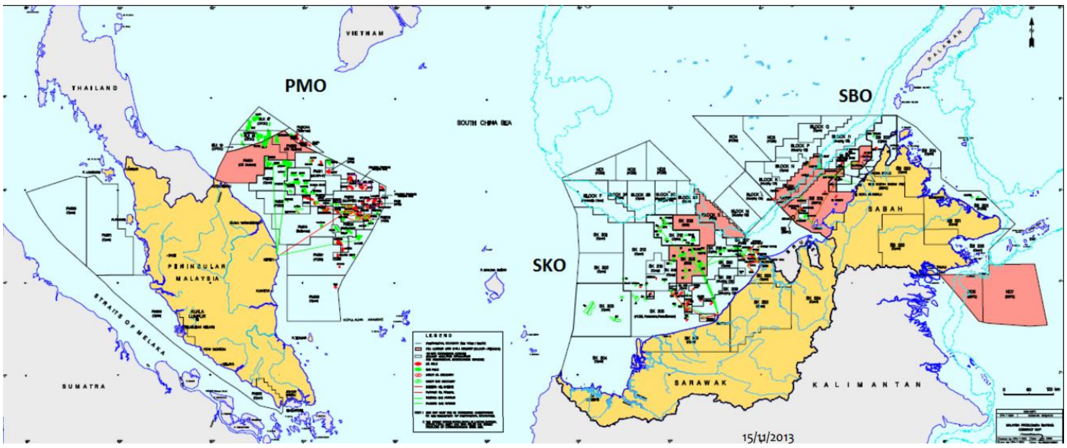


Figure 3 : Platforms across Malaysian Water

2.4. ASCE 7-10

$$q_{z10} = 0.00256\ K_z K_{zt} K_d V^2$$

Where:

q_{z10} = ASCE 7-10 velocity pressure evaluated at mean roof height (psf)

K_z = Velocity pressure exposure coefficient

K_{zt} = Topographic factor

K_d = Wind directionality factor

V = Basic wind speed (mph) from ASCE 7-10 maps referred to as ultimate wind speed maps in 2012 IBS

The directionality factor (K_d) used in the ASCE 7 wind load provisions for components and cladding is a load reduction factor intended to take into account the less than 100% probability that the design event wind direction aligns with the worst case building aerodynamics (Laboy, S. et al., 2012). For most ordinary buildings, the ASCE 7 Standard specifies for the directionality factor a blanket value of 0.85 for all buildings and building components, even though the actual value depends upon the extreme wind climate (Rigato, A. et al., 2001). Besides, the wind directionality in the ASCE-7 Standard does not distinguish between buildings with known orientation and buildings whose orientation is not specified (Hanzlik, P. et al., 2005).

2.5. Wind Directionality Factor K_d

Among the important aspect that should be considered the wind directionality reduction factor is the structure orientation. A building could be oriented in such a way that a certain building zone would attain the load for which it was designed, suggesting that no reduction in the load was necessary for that zone (Vega, R.E., et al., 2009).

However, while that particular structure part reached its design load, other parts of the structure zones will not have experienced the maximum design loads because the critical angle of attack of one zone is not the same for all the other structure parts. If the design extreme storm happens at least once during the life of the structure, which is the typical consideration in engineers design, that means that many structure components were over-designed (Vega, R.E., et al., 2009). As a result, the cost of the structure becomes higher and uneconomical.

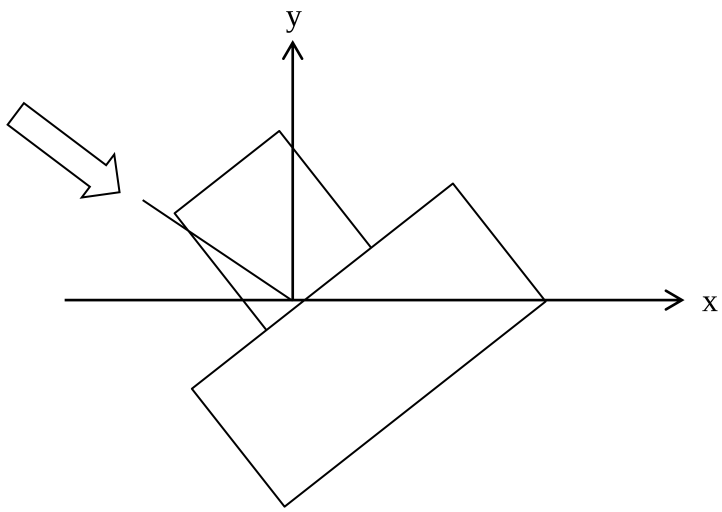


Figure 4 : Definition Sketch of Wind Blow against a Building

Wind induced structural response, including pressure to the structural members and is directional dependent (Li, C, W. n.d.). Basic knowledge of wind is that the wind speed will not be uniform in all directions. Consideration of the wind directionality effect can help in producing an economical but at the same time, a safe design of the structure.

Wind varies in its speed and direction, and thus making it difficult to predict the intensity or the direction of the winds that can cause effect to the structure. The wind directional dependencies may arise from several effects:

- The density of the directionality of wind loads for each direction, such that the winds corresponding to the design return period may have lower values due to different attack angle of the winds.
- The possibility that the extreme wind may not occurs in the least favourable orientation of the structure, in which that even if given an extreme wind event, the probability that the wind direction will impact the structure or the structural component in its critical direction is very small. This takes in account that the wind load on any structural component varies with wind direction.
- The possibility that the surrounding upwind terrain surface roughness category conditions are directionally varied. ASCE 7 allows for directional wind load

calculations only for the main wind resisting system, based on the highest wind loads resulting from the exposure categories in two 45° upwind sectors to either side of the selected approaching wind direction.

2.6. Wind Directionality Effects

Basically, there are four main methods to estimate the wind directionality effects, which are the method of the one-dimensional sample of largest yearly wind effects, the sector-by-sector approach, the out-crossing of the limit-state boundary method, and the method utilized by the NBCC (2005) and ASCE 7 Standards (2005), which is irrespective of wind directionality or building orientation (Vega, R.E., 2008). These methods are described as follows.

The first method is the one-dimensional method, which is considered a simple procedure in the calculation of extreme wind load effects based on directional properties of extreme winds, building aerodynamics and given building orientation. It is based on the creation of a wind effect time-series from annual directional maximum wind speeds that have been previously allocated to directional sectors and allocation of a peak pressure coefficient to respective sectors for a predefined building orientation (Vega, R.E., 2008).

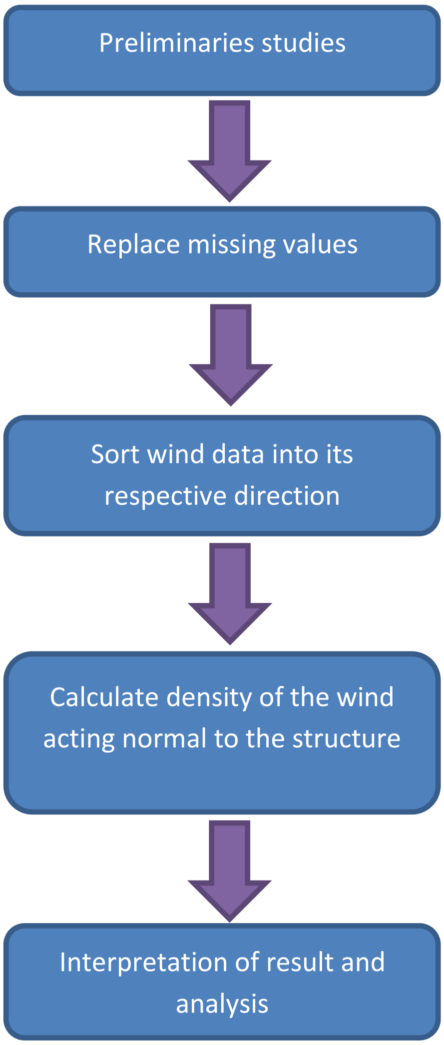
For the second method, which is the sector-by-sector approach, is quite similar to the first method with the exception that extreme value analysis is done for each direction separately assuming data allocated in sectors is independent. The former method only takes the maximum and minimum wind load effect to create two one-dimensional samples from where inferences are drawn directly for higher mean recurrence intervals irrespective of wind direction. The sector-by-sector approach maintains the multi-dimensional information provided by the directionality of extreme winds and loading coefficients.

As for the third method, which is the out-crossing of the limit-state boundary method, was the method introduced by the pioneer of the wind directionality issue, Davenport (1977), and later used by Holmes (1981). This method is a form of reliability analysis with certain assumptions that permit special attention. A function of structural failure and wind loads are defined for the estimation of the mean failure rate or out-crossing rate. The critical aspect of this method is precisely in the estimation of the mean out-crossing rate.

Lastly is the method used by the NBCC (2005) and ASCE 7 Standards (2005). The method used in both of these Standards is based on the fact that there must be a probability smaller than 100% that the most aerodynamically unfavourable direction of a building coincides with the wind direction of strongest winds. Since these Standards define wind climatology irrespective of wind direction and pressure coefficients based on maximum pressure coefficients irrespective of direction, then it would seem obvious to reduce the loads by some factor (Vega, R.E., 2008).

CHAPTER 3

METHODOLOGY



3.1. Project Activities

Preliminary research and studies are being done in order to learn the theory and concept of the wind loads and wind directionality factor used in the ASCE equation. Past research studies regarding the topic are read to have a better understanding about the subject. Important point and discussion of the project is noted down for future analysis of the results from this research.

For this research, the data from the three platforms, one each from the three offshore locations in Malaysia, namely Peninsular Malaysia Operation, Sabah Operation and Sarawak Operation are used, for at least five years of wind data. Since that there is some missing values in the collected data, the missing value will be interpolated linearly so have a complete set of data monthly. However, if the data is missing for the whole month, then that particular month had to be omitted from the research. The following table shows the availability of the wind data for the 3 platforms and their respective year. These set of data is further categorized into the respective monsoon season. If there is any missing month for the specified monsoon, it will be considered missing for the whole monsoon season.

Table 2 : Wind Data

Month	Dulang					Tukau					Samarang				
	99	00	01	02	03	99	00	01	02	03	99	00	01	02	03
Jan	Not Available	Available	Available	Available	Available	Not Available	Available	Available	Available	Available	Not Available	Available	Available	Available	Not Available
Feb	Not Available	Available	Available	Available	Available	Not Available	Not Available	Available	Available	Available	Not Available	Available	Available	Available	Available
Mar	Not Available	Available	Available	Available	Available	Not Available	Available	Available	Available	Available	Not Available	Available	Available	Available	Available
Apr	Not Available	Not Available	Available	Available	Available	Not Available	Not Available	Available	Available	Available	Not Available	Not Available	Available	Available	Available
May	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available
June	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available
July	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available	Available	Not Available	Available
Aug	Available	Available	Not Available	Available	Available	Available	Available	Not Available	Available	Available	Available	Available	Available	Not Available	Available
Sept	Available	Available	Not Available	Available	Available	Available	Available	Not Available	Available	Available	Available	Available	Available	Available	Available
Oct	Available	Available	Available	Available	Available	Available	Not Available	Available	Available	Not Available	Available	Available	Available	Available	Available
Nov	Available	Available	Not Available	Available	Available	Available	Available	Available	Available	Not Available	Available	Available	Available	Not Available	Available
Dec	Available	Available	Not Available	Available	Available	Available	Available	Available	Available	Not Available	Available	Available	Available	Not Available	Available

Monsoon	Dulang					Tukau					Samarang				
	99	00	01	02	03	99	00	01	02	03	99	00	01	02	03
NE	Not Available	Available	Not Available	Available	Available	Not Available	Not Available	Available	Available	Not Available	Not Available	Available	Available	Not Available	Not Available
Apr	Not Available	Not Available	Available	Available	Available	Not Available	Not Available	Available	Available	Available	Available	Not Available	Available	Available	Available
SW	Available	Available	Not Available	Available	Available	Available	Available	Not Available	Available	Available	Available	Available	Available	Not Available	Available
Oct	Available	Available	Available	Available	Available	Available	Not Available	Available	Available	Not Available	Available	Available	Available	Available	Available

Available

Not Available

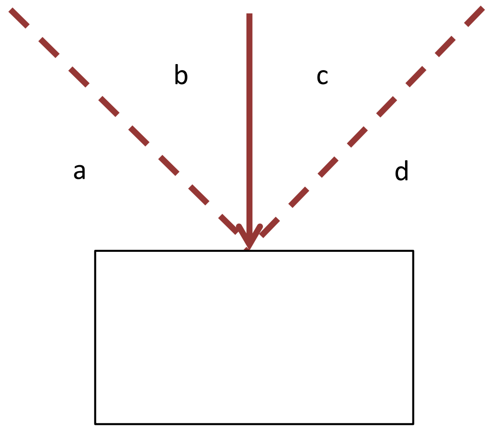
The wind data consist of lots of information such as wind direction, wind speed, air temperature and many more. The data is sorted out to give only the wind direction and wind speed as this research will be focusing on those data. The data will be summarized into its respective directions, which are north, northeast and east as those are the only directions that is being considered.

Table 3 : Wind Directions

Wind Direction	Angle (˚)
North	337.6 - 360, 0 - 22.5
Northeast	22.6 - 67.5
East	67.6 – 112.5
Southeast	112.6 – 157.5
South	157.6 – 202.5
Southwest	202.6 – 247.5
West	247.6 – 292.5
Northwest	292.6 – 337.5

The result of the summarized data will be analysed to come up with a suitable wind directionality factor to be used in the ASCE equation.

3.2. Wind Directionality Factor Calculation



$$Wind\ Directionality\ Factor\ (\%) = \frac{b + c}{a + b + c + d}$$

where, a,

b,

c,

d are the density of the wind acting on that direction

Based on the above formula, the wind directionality factor will be calculated based on the density of wind coming from 45^{o} to the left and 45^{o} to the right of wind load, which acting normal to the structure and divided with the total density of wind load acting in front of the structure.

The above calculation will be repeated for 3 cases, where the building will be rotated 22.5^{o} each. Figure 4 shows the building orientation and its angle from the true north. Wind load will be acting normal to the structure for all the three cases.

3.3. Structure Orientation

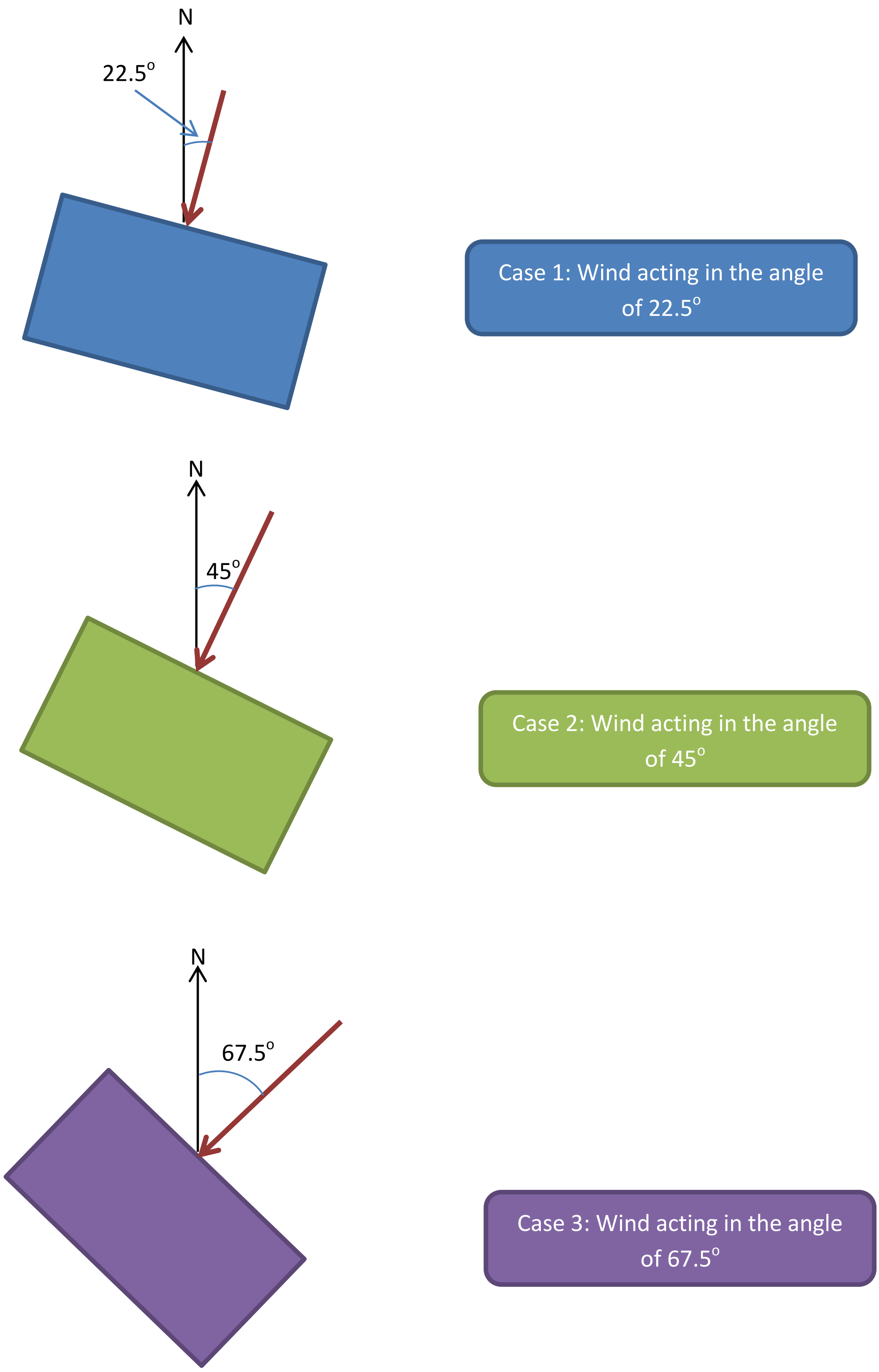


Figure 5 : Building Orientation

3.4. GANTT CHART

FYP1

Activity	Week 1	2	3	4	5	6	7	8	9	10	11	12	13	14
Topic selection	■	■												
Preliminary research work		■	■	■	■									
Extended proposal submission						■								
Research works							■	■	■	■	■	■	■	■
Proposal defense									■					
Replacing missing values										■	■	■	■	■
Interim report														■

FYP2

Activity	Week 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Replacing missing data for all the platform	■														
Sorting data for Dulang platform		■	■												
Sorting data for Tukau platform				■	■										
Sorting data for Samarang platform						■	■								
Progress report submission								■							
Analysis the result of the data									■	■	■	■			
Pre-SEDEX											■				
Submission of Technical Paper													■		
Oral Presentation														■	
Submission of Project Dissertation															■

3.5. TOOLS

Software

- Microsoft Excel

Microsoft Excel is a spreadsheet application which features calculation, graphing tools, pivot tables, and a macro programming language called Visual Basic for Applications. The wind data collected is tabulated in the Microsoft Excel format, which can be easily filtered and sorted out by using the functions provided.

- Microsoft Access

Microsoft Access is a database management system that combines the relational Microsoft Jet Database Engine with a graphical user interface and software-development tools. It stores data in its own format based on the Access Jet Database Engine. It can also import or link directly to data stored in other applications and databases.

Microsoft Access is used to sort out the data according to its wind direction by specifying the wind angle for its respective wind direction. Microsoft Access can also counts the number of wind that blows in that specific direction, which makes it easier to sum up all the data given.

- IBM SPSS Statistics

IBM SPSS Statistics is an integrated family of products that addresses the entire analytical process, from planning to data collection to analysis, reporting and deployment. This software is used to interpolate the missing data from the given wind data. This software is handy since the missing data can be up to 1000, which can take a lot of time if it is done manually. Besides, this software has a lot of other functions to analyse the given data.

CHAPTER 4

RESULTS AND DISCUSSION

4.1. Missing Values

Table 4 : Missing Values

Month	Dulang					Tukau					Samarang				
	1999	2000	2001	2002	2003	1999	2000	2001	2002	2003	1999	2000	2001	2002	2003
Jan		1705	705	16	0		981	1086	5	2		552	270	63	
Feb		452	630	3	0			588	6	7		608	463	2	4
Mar		300	748	3	2		120	866	3	5		153	240	7	2
Apr			323	3	5			214	81	6			219	6	5
May	479	312	594	102	4	1506	196	306	9	22	255	160	140	26	8
June	1048	245	180	2	5	783	79	110	6	12	490	244	379	18	4
July	1287	428	762	6	21	909	1007	294	4	3	1113	363	587		5
Aug	696	223		2	36	677	226		6	19	1239	166	14		9
Sept	1585	637		3	69	786	1092		14	70	783	139	3	7	3
Oct	1553	527	370	1	231	960		15	7		871	127	29	5	7
Nov	1328	544		2	204	635	412	54	0		980	508	179		5
Dec	1178	1428		1	119	259	856	8	4		392	737	5		2

Table 4 shows all the missing values recorded for each available wind data according to the respective month. The highest missing value recorded is during the month of January in the year 2000 at Dulang platform whereas there is no missing value recorded during the month of January and February in the year 2003 for Dulang platform and also at Tukau during November 2002.

<u>Missing Values</u>

$$\frac{1705}{4464} \times 100\% = 38.2\ \%$$ (Dulang January 2000)

$$\frac{1506}{4464} \times 100\% = 33.7\ \%$$ (Tukau May 1999)

$$\frac{1239}{4464} \times 100\% = 27.8\ \%$$ (Samarang August 1999)

The above calculation shows the highest percentage of missing values for each of the platform. Based on the results, there is a lot of missing data for all the three platforms during the year 1999 until 2001. However, the missing values are decreasing significantly in the year 2002 and 2003. From thousandths of missing value, the number goes down to only around tenths, except during October, November and December for Dulang platform in the year 2003.

Table 5 shows the calculated directionality factor for the 3 platform based on the 3 cases mentioned in the methodology. The wind data is divided into its respective monsoon season. The column marked with green colour indicates the value nearest to the 0.85 value, which is the value specified in the ASCE codes, based on the three cases for each of the monsoon season available.

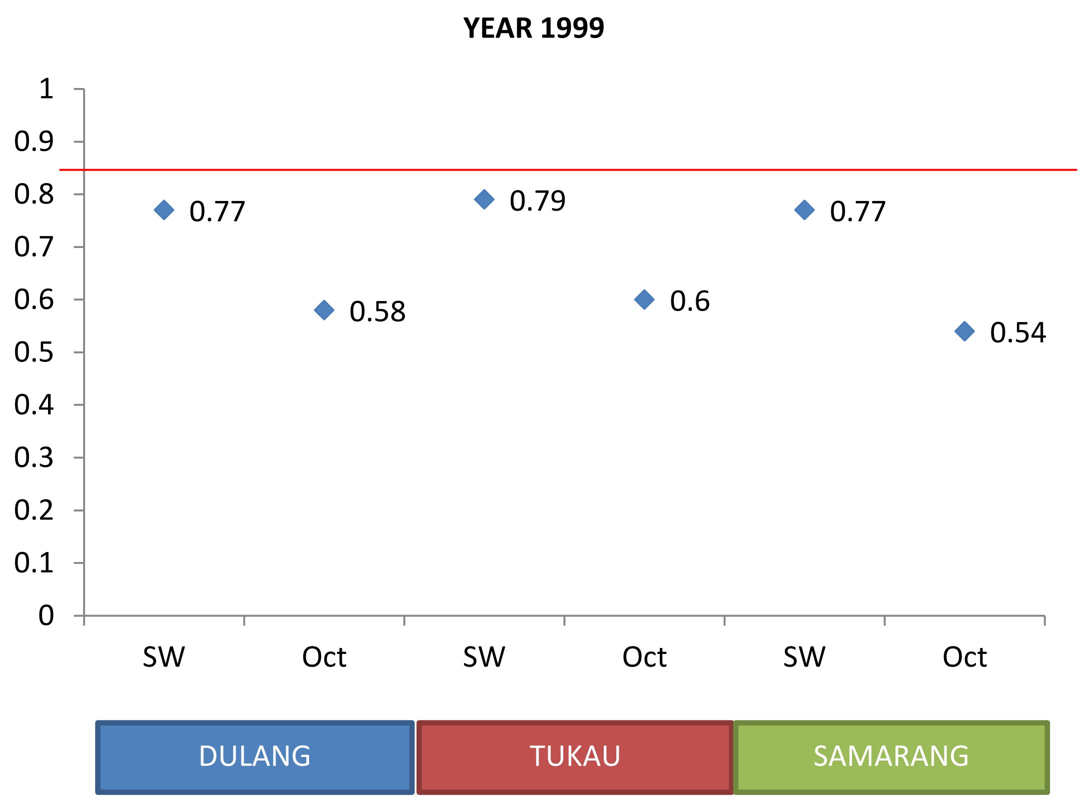
4.2. Wind Directionality Factor

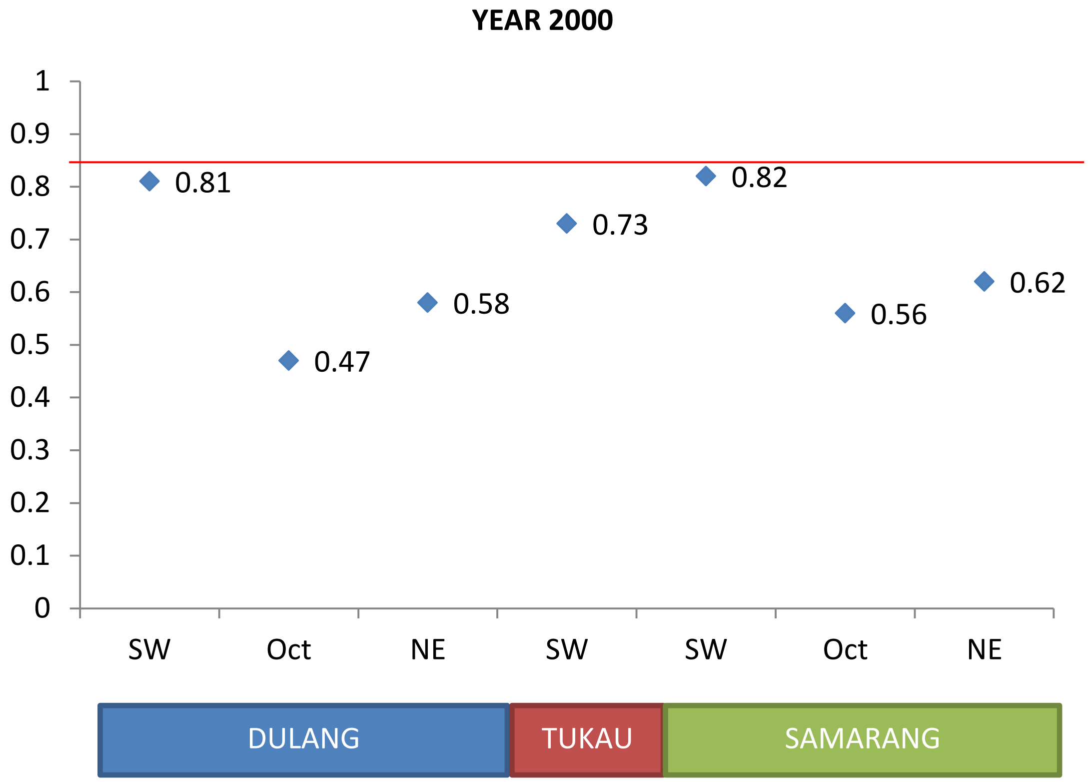
Table 5: Directionality Factor

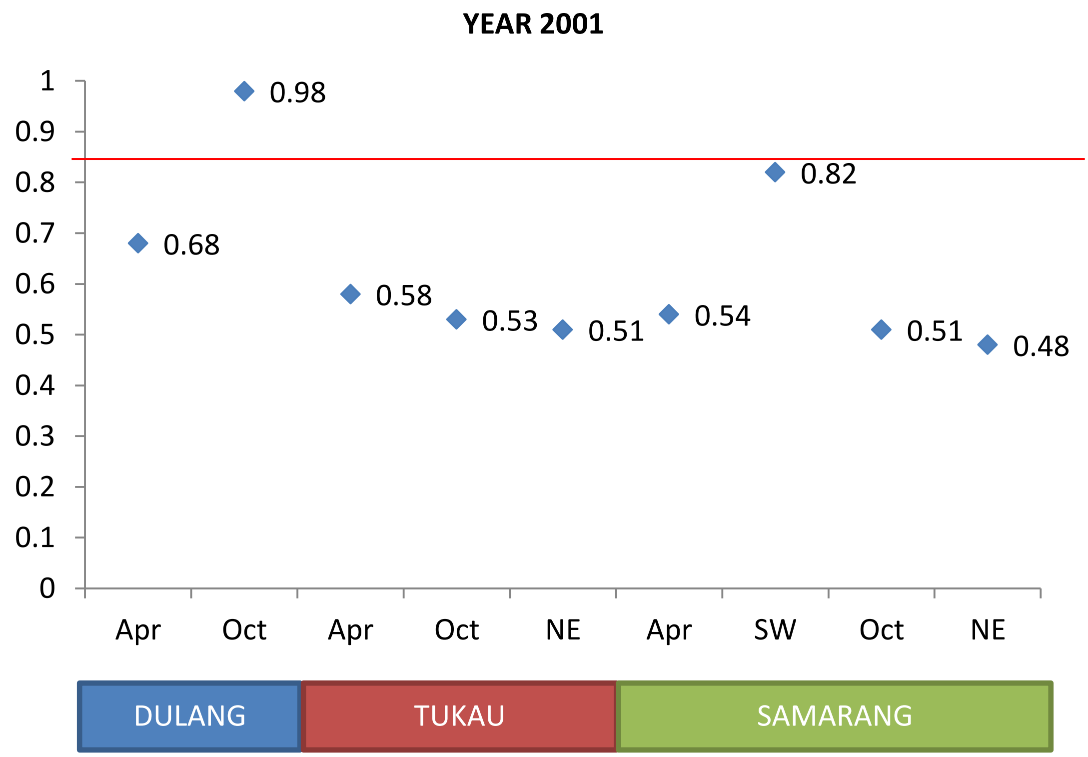
Season	Case	Dulang					Tukau					Samarang				
		1999	2000	2001	2002	2003	1999	2000	2001	2002	2003	1999	2000	2001	2002	2003
NE	1		0.58		0.75	0.33			0.51	0.52			0.53	0.48		
	2		0.47		0.81	0.33			0.39	0.42			0.62	0.43		
	3		0.36		0.33	0.33			0.33	0.35			0.56	0.43		
Apr	1			0.68	1.00	0.09			0.58	0.76	0.63			0.53	0.80	0.82
	2			0.49	0.96	0.22			0.39	0.59	0.49			0.49	0.82	0.82
	3			0.39	0.63	0.74			0.33	0.43	0.39			0.54	0.65	0.62
SW	1	0.77	0.54		0.73	0.17	0.73	0.73		0.84	0.85	0.68	0.77	0.77		0.87
	2	0.73	0.74		0.66	0.26	0.79	0.69		0.81	0.86	0.77	0.82	0.82		0.90
	3	0.61	0.81		0.56	0.75	0.63	0.59		0.70	0.74	0.69	0.73	0.77		0.80
Oct	1	0.58	0.47	0.98	0.49	0.37	0.60		0.53	0.52		0.52	0.41	0.51	0.53	0.46
	2	0.40	0.36	0.57	0.49	0.37	0.46		0.32	0.37		0.54	0.56	0.44	0.59	0.57
	3	0.43	0.35	0.08	0.53	0.51	0.40		0.26	0.38		0.51	0.49	0.43	0.36	0.57

From the results, five graphs have been plotted based on each year. The factor closest to the 0.85 is selected based on the three cases and the red line in each indicates the benchmark factor set by ASCE. The graph will show the distribution of the factor clearly. If the reduction factor is above the red line, this indicates that the wind load will be less reduced as the factor is closer to one. However, if the reduction factor is below the red line, then the wind load can be reduce further and thus, reducing the loads acting on the offshore platform.

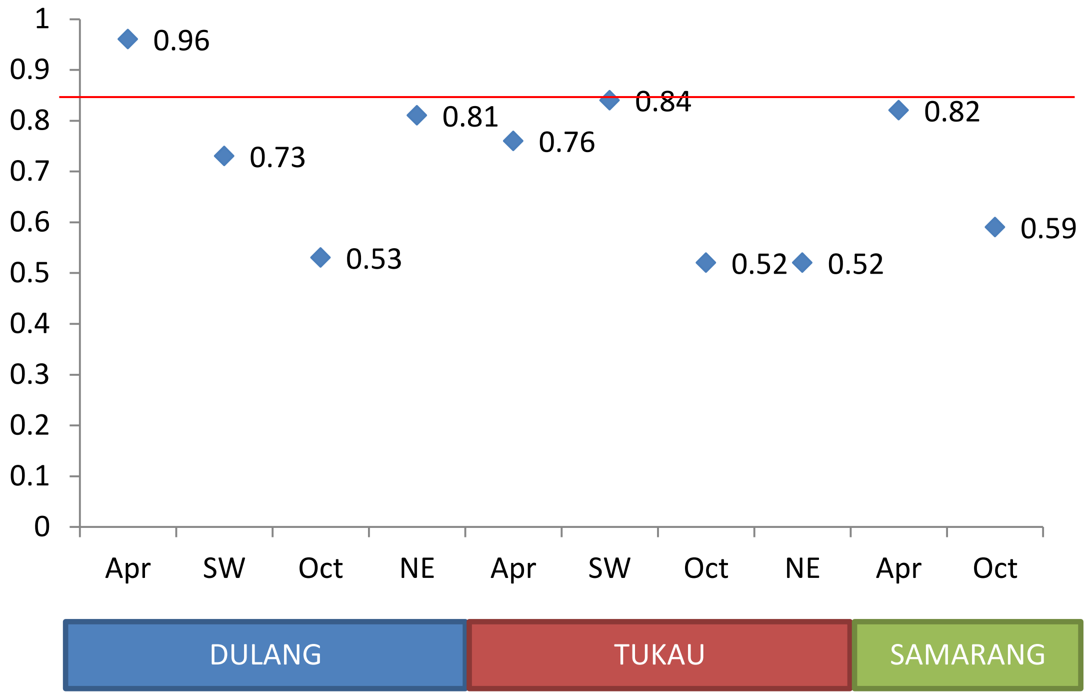
On the x-axis of the graph, the available wind monsoon is plotted for all three platforms whereas the y-axis is the reduction factor calculated. The graph is to compare the wind directionality factor for one particular year, since that the wind will blow at the same time for all three platforms. However, the results for each of the platform are different due to the locations of the platforms.



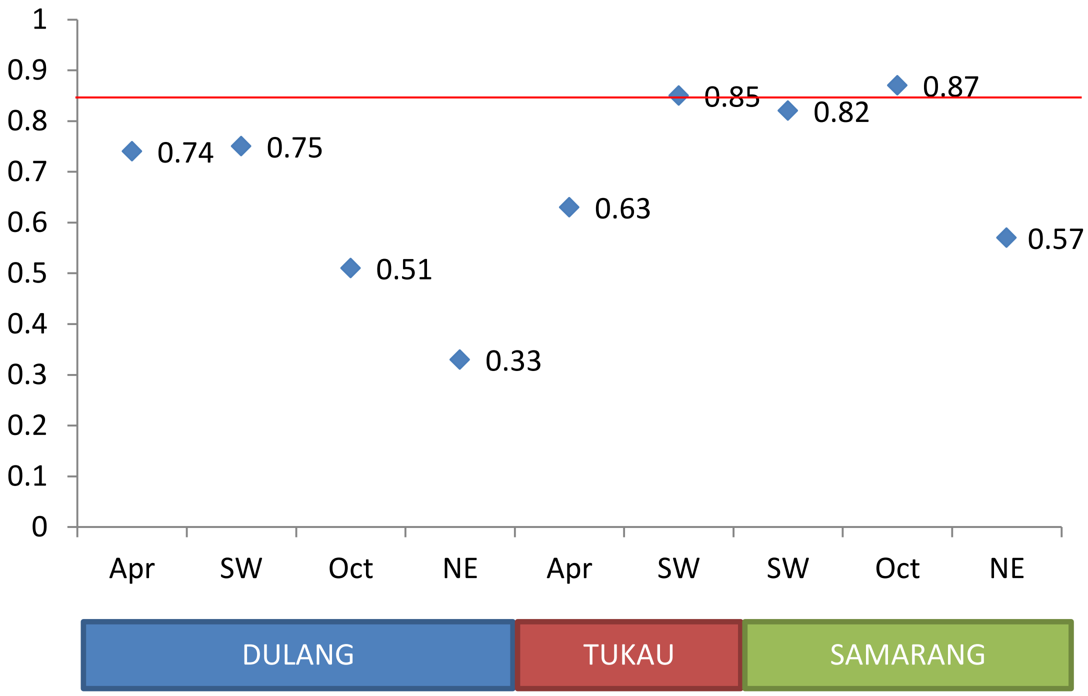

YEAR 2000
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.81
0.47
0.58
0.73
0.82
0.56
0.62
SW
Oct
NE
SW
SW
Oct
NE
DULANG
TUKAU
SAMARANG


YEAR 2001
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.98
0.68
0.58
0.53
0.51
0.54
0.82
0.51
0.48
Apr
Oct
Apr
Oct
NE
Apr
SW
Oct
NE
DULANG
TUKAU
SAMARANG

YEAR 2002



YEAR 2003



Based on all the graphs, it is found that most of the wind directionality factor calculated through this research is lower than 0.85, thus meaning that more reduction can be made to the wind load. Only during October 2001 and April 2002 for Dulang platform which results in 0.98 and 0.96 respectively, and October 2003 for Samarang platform which gives 0.87 factor, is exceeding the 0.85 value.

Table 6 : Cases Summary

Platform		Case 1	Case 2	Case 3
Dulang	1999	2		
	2000	2		1
	2001	2		
	2002	1	2	1
	2003			4
	TOTAL	**7**	**2**	**6**
Tukau	1999	1	1	
	2000	1		
	2001	3		
	2002	4		
	2003	2		
	TOTAL	**11**	**1**	
Samarang	1999		2	
	2000		3	
	2001	2	1	1
	2002		2	
	2003	1	2	
	TOTAL	**3**	**10**	**1**

Table 6 shows the summary of the results based on the graph plotted to show which cases are the one selected. For Dulang platform, the results shows that it is close between case 1 and case 3. For case 1, it indicates that more wind comes from the north direction whereas for case 3, most of the wind comes from east of the platform.

For Tukau platform, most of the occurred cases are case 1 and there is no case recorded for case 3. This is due to the fact that most of the wind originates from north direction and there is less wind from the east direction. As for Samarang platform, the highest cases is case 2, which amount a total of 10 whereas for case 1, it only occurs twice and once for case 3. This shows that there is no definite orientation of the structure can be specified. For Dulang field, the wind varies greatly from north to the east, whereas for Tukau and Samarang field, the winds are more consistent, where most of the winds are coming from north and northeast respectively.

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1. Conclusion

This research is mainly to investigate the wind directionality factor based on the wind data in Malaysian water. The factor is important during the designing stage of a platform, where it is used to calculate the wind loads acting on the structure. Based on ASCE codes, the factor is specified to be 0.85. Furthermore, the ASCE factor may be derived from the wind data in another region, which may not be the same as wind data in Malaysia.

From the results, it is shown that most of the wind directionality factor is below the one set by ASCE, which means that the wind load can be reduced further. The reduction of the load is important, as many of the platforms in Malaysia are overdesign and this has consumed a lot of money. By reducing the loads acting on the structure, the size of the members can also be reduced, and subsequently this can make the platform cheaper and more economical.

5.2. Recommendations

There are a few recommendations regarding this project, which are:

- The period of wind data used for the research must be longer, so that a more accurate result can be derived from the data. Longer time scale will allow more understanding of the wind pattern in Malaysia.
- Apart from the measured data, hindcast data must also be analysed and the results should be compare from one to another.
- The missing value for the wind data should be avoided, so that an actual wind speed for that particular time can be recorded. The missing data for the whole month should also be avoided if possible.

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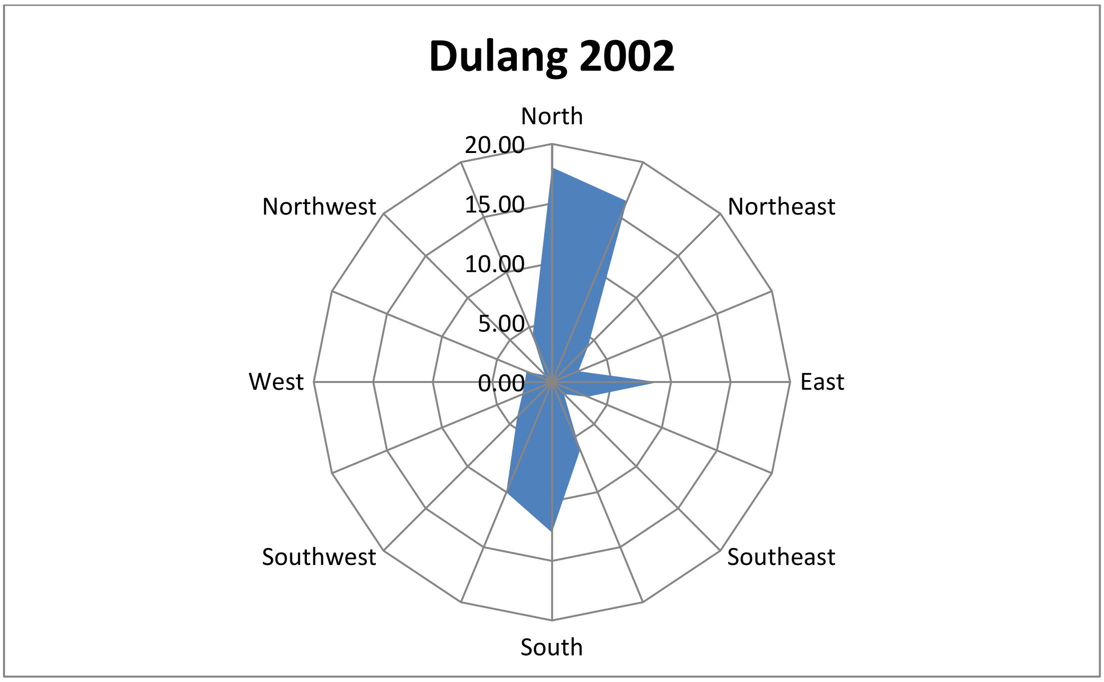
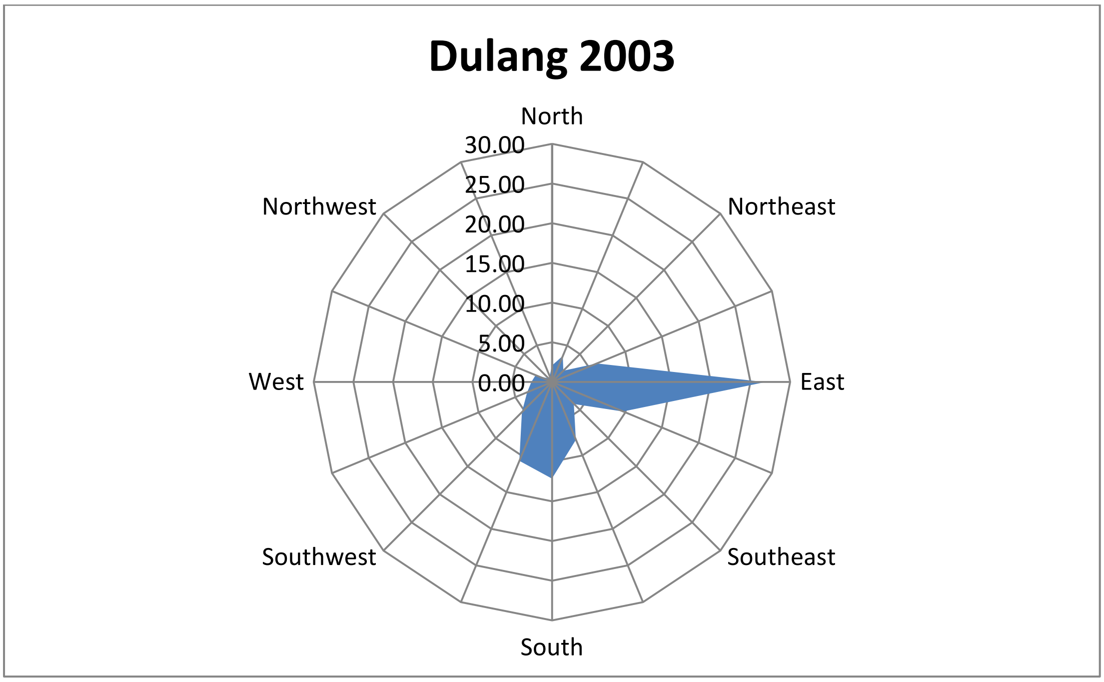
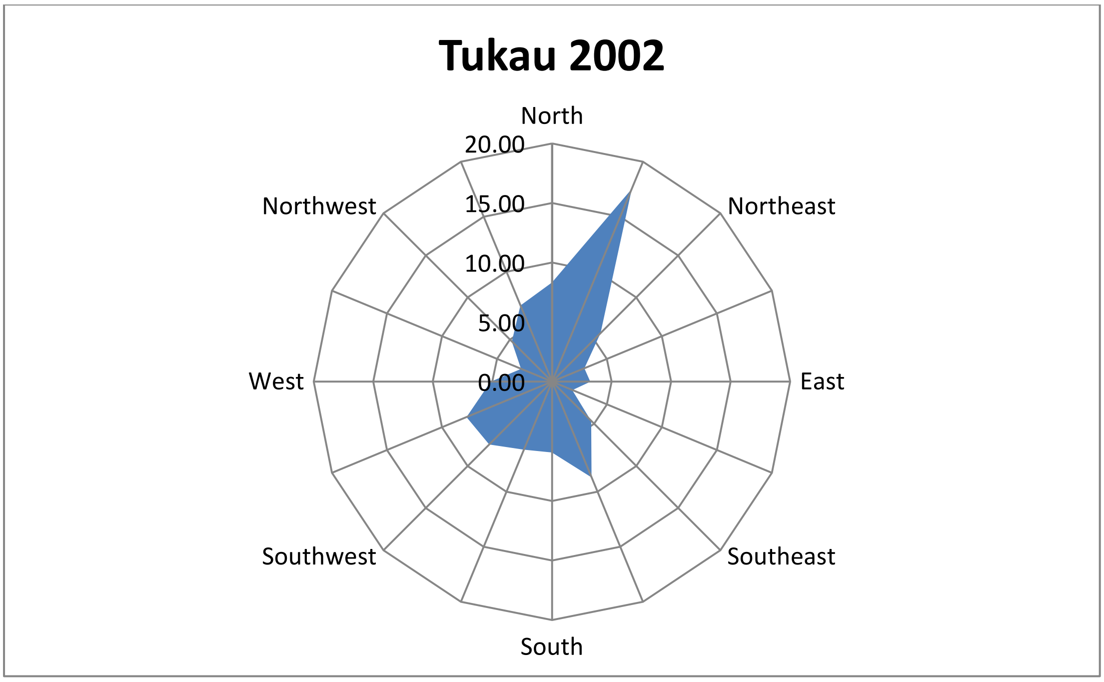
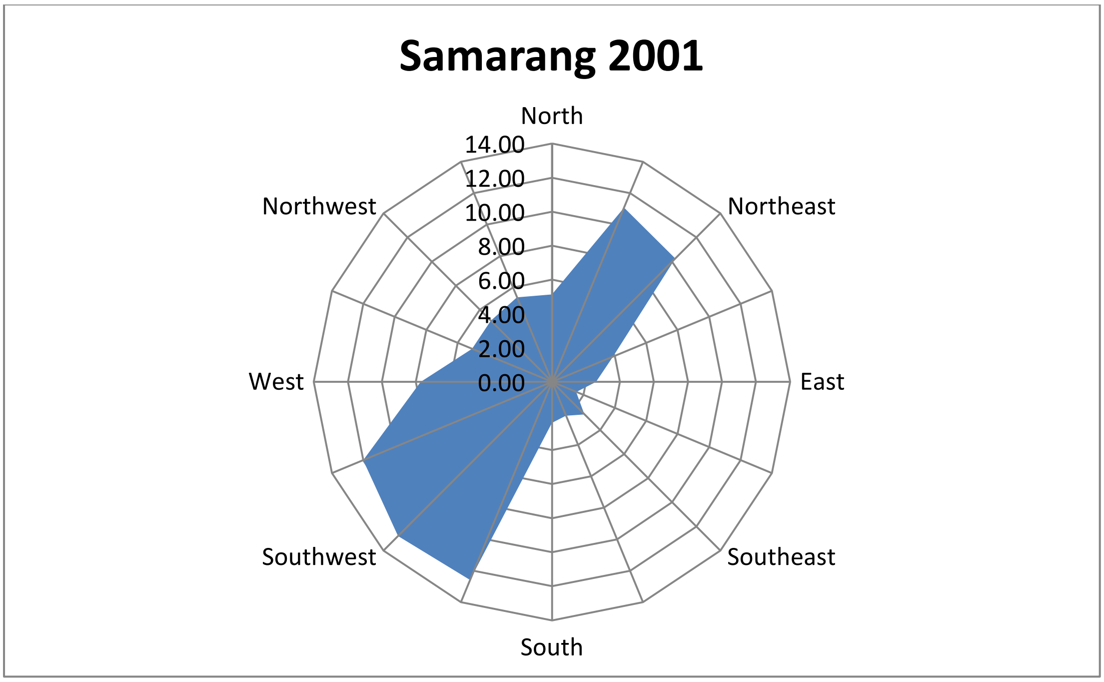
APPENDIXES

Appendix 1: Wind Ross for Completed Months in a Year



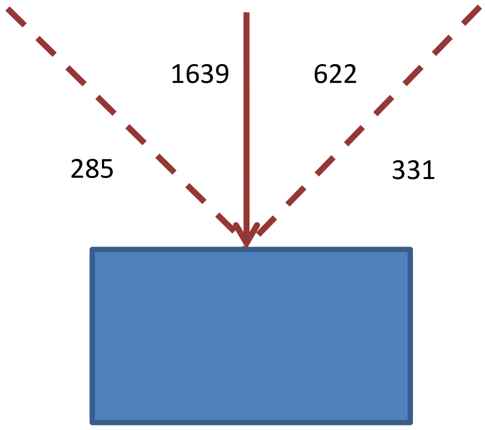



Tukau 2002
North
Northeast
East
Southeast
South
Southwest
West
Northwest
20.00
15.00
10.00
5.00
0.00


Samarang 2001
North
Northeast
East
Southeast
South
Southwest
West
Northwest
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00

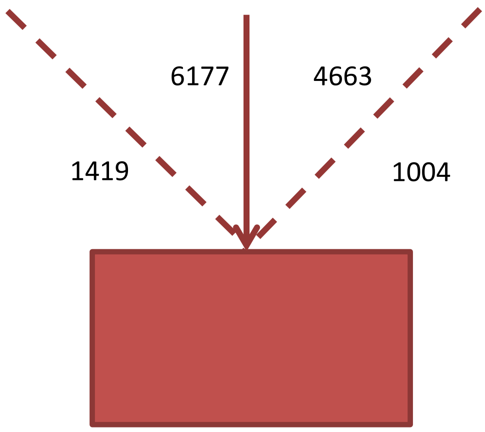
Appendix 2: Calculation Example Closest to 0.85 for each year

Southwest Tukau 1999



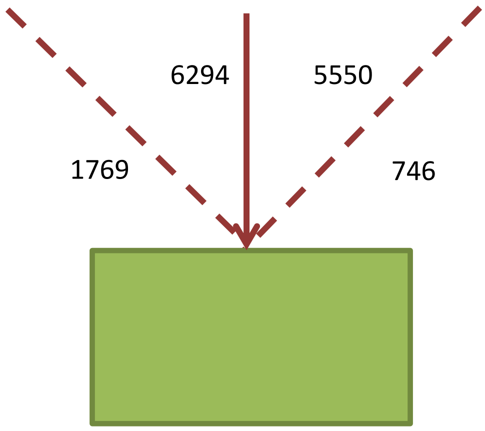
$$Wind\ Directionality\ Factor\ (\%) = \frac{1639 + 622}{285 + 1639 + 622 + 331} = 0.79$$

Southwest Samarang 2000



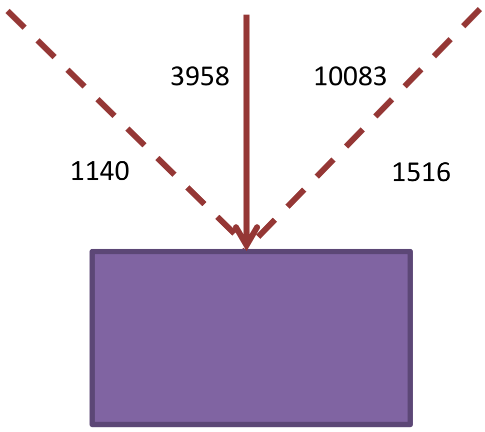
$$Wind\ Directionality\ Factor\ (\%) = \frac{6177 + 4663}{1419 + 6177 + 4633 + 1004} = 0.82$$

Southwest Samarang 2001



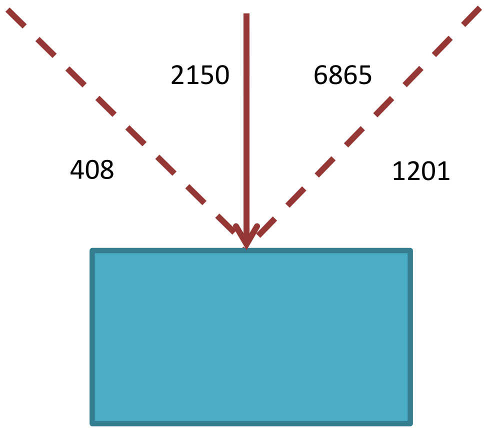
$$Wind\ Directionality\ Factor\ (\%) = \frac{6294 + 5550}{1769 + 6294 + 5550 + 746} = 0.82$$

Southwest Tukau 2002



$$Wind\ Directionality\ Factor\ (\%) = \frac{3958 + 10083}{1140 + 3958 + 10083 + 1516} = 0.84$$

Southwest Tukau 2003



$$Wind\ Directionality\ Factor\ (\%) = \frac{2150 + 6865}{408 + 2150 + 6865 + 1201} = 0.85$$

Appendix 3: Wind Classifications

Dulang 1999

Month	Degree (˚)																Total	No of Days
	0-22.5	22.6-45	45.1-67.5	67.6-90	90.1-112.5	112.6-135	135.1-157.5	157.6-180	180.1-202.5	202.6-225	225.1-247.5	247.6-270	270.1-292.5	292.6-315	315.1-337.5	337.6-359.9		
Jan																	0	0
Feb																	0	0
Mar																	0	0
Apr																	0	0
May	98	176	110	180	449	217	369	911	442	645	283	212	230	36	30	76	4464	31
June	23	30	17	15	45	48	121	698	800	1418	565	290	166	37	27	20	4320	30
July	4	6	9	10	12	40	110	869	1024	1303	483	349	199	18	9	19	4464	31
Aug	21	6	6	14	37	52	130	593	816	1718	517	331	141	26	30	26	4464	31
Sept	69	78	82	97	233	175	191	723	659	1124	454	208	154	26	9	38	4320	30
Oct	365	280	188	189	416	235	213	226	226	228	184	215	448	195	247	609	4464	31
Nov	517	708	606	320	312	61	49	78	58	60	69	90	494	193	220	485	4320	30
Dec	1075	1074	792	374	285	39	51	22	24	28	17	26	19	10	65	563	4464	31
TOTAL	2172	2358	1810	1199	1789	867	1234	4120	4049	6524	2572	1721	1851	541	637	1836	35280	
Percent	6.16	6.68	5.13	3.40	5.07	2.46	3.50	11.68	11.48	18.49	7.29	4.88	5.25	1.53	1.81	5.20		

Dulang 2000

Month	Degree (˚)																Total	No of Days
	0-22.5	22.6-45	45.1-67.5	67.6-90	90.1-112.5	112.6-135	135.1-157.5	157.6-180	180.1-202.5	202.6-225	225.1-247.5	247.6-270	270.1-292.5	292.6-315	315.1-337.5	337.6-359.9		
Jan	374	1230	1749	765	228	18	15	1	2	4	1	2	2	1	2	70	4464	31
Feb	402	657	1204	877	489	52	35	22	16	8	9	8	21	12	7	357	4176	29
Mar	522	760	1004	799	885	133	74	68	30	13	9	23	21	9	10	104	4464	31
Apr																	0	0
May	232	138	67	63	150	145	383	777	523	807	347	292	258	55	60	167	4464	31
June	133	149	152	93	192	111	228	602	452	795	305	357	464	91	84	112	4320	30
July	14	8	7	12	31	47	147	842	1004	1472	528	186	117	22	11	16	4464	31
Aug	5	4	5	8	21	40	112	676	862	1671	622	261	131	22	18	6	4464	31
Sept	226	125	82	73	186	182	272	682	469	899	397	264	188	43	58	174	4320	30
Oct	311	132	106	111	179	98	119	168	154	214	242	451	912	392	429	446	4464	31
Nov	123	156	515	1671	739	286	183	143	67	36	29	28	36	59	115	134	4320	30
Dec	189	232	433	1279	617	281	155	85	55	32	43	56	123	183	355	346	4464	31
TOTAL	2531	3591	5324	5751	3717	1393	1723	4066	3634	5951	2532	1928	2273	889	1149	1932	48384	
Percent	5.23	7.42	11.00	11.89	7.68	2.88	3.56	8.40	7.51	12.30	5.23	3.98	4.70	1.84	2.37	3.99		

Dulang 2001

Month	Degree (˚)																Total	No of Days
	0-22.5	22.6-45	45.1-67.5	67.6-90	90.1-112.5	112.6-135	135.1-157.5	157.6-180	180.1-202.5	202.6-225	225.1-247.5	247.6-270	270.1-292.5	292.6-315	315.1-337.5	337.6-359.9		
Jan	84	170	632	1984	976	284	123	49	28	15	5	12	7	8	30	57	4464	31
Feb	115	266	633	1426	781	373	158	75	24	16	5	4	13	25	35	83	4032	28
Mar	296	503	352	403	379	619	676	345	199	152	162	123	45	32	37	141	4464	31
Apr	160	679	240	202	305	947	1053	297	122	88	96	29	20	14	15	53	4320	30
May	35	36	32	52	165	1079	1309	345	284	292	306	272	88	45	40	84	4464	31
June	80	50	50	82	157	588	687	389	472	435	648	432	69	45	42	94	4320	30
July	43	34	46	77	197	537	688	800	820	519	346	183	76	44	21	33	4464	31
Aug																	0	0
Sept																	0	0
Oct	2150	192	90	25	20	13	11	30	17	10	13	25	20	14	24	1810	4464	31
Nov																	0	0
Dec																	0	0
TOTAL	2963	1930	2075	4251	2980	4440	4705	2330	1966	1527	1581	1080	338	227	244	2355	34992	
Percent	8.47	5.52	5.93	12.15	8.52	12.69	13.45	6.66	5.62	4.36	4.52	3.09	0.97	0.65	0.70	6.73		

Dulang 2002

Month	Degree (˚)																Total	No of Days
	0-22.5	22.6-45	45.1-67.5	67.6-90	90.1-112.5	112.6-135	135.1-157.5	157.6-180	180.1-202.5	202.6-225	225.1-247.5	247.6-270	270.1-292.5	292.6-315	315.1-337.5	337.6-359.9		
Jan	2466	1142	239	0	0	0	0	0	0	0	0	0	0	0	6	611	4464	31
Feb	1803	1479	95	0	0	0	0	0	1	0	0	0	0	0	12	642	4032	28
Mar	1152	2496	438	0	0	0	0	0	0	0	0	0	0	0	6	372	4464	31
Apr	1442	2091	628	0	0	0	0	0	0	0	0	0	0	0	10	149	4320	30
May	1623	376	331	5	5	13	51	506	884	438	106	48	13	14	2	49	4464	31
June	50	59	5	4	27	63	91	861	1505	1135	281	112	55	36	18	18	4320	30
July	2	1	0	0	12	5	30	638	1795	1333	350	153	91	31	19	4	4464	31
Aug	48	45	2	3	22	10	32	401	1175	1188	433	385	368	310	33	9	4464	31
Sept	112	59	14	15	171	70	68	409	934	886	701	391	236	160	44	50	4320	30
Oct	446	454	137	106	461	290	89	214	248	200	221	256	355	553	214	220	4464	31
Nov	318	352	259	558	1485	478	187	144	68	67	60	67	60	70	50	97	4320	30
Dec	18	91	114	569	2505	759	197	74	25	16	16	3	22	41	8	6	4464	31
TOTAL	9480	8645	2262	1260	4688	1688	745	3247	6635	5263	2168	1415	1200	1215	422	2227	52560	
Percent	18.04	16.45	4.30	2.40	8.92	3.21	1.42	6.18	12.62	10.01	4.12	2.69	2.28	2.31	0.80	4.24		

Dulang 2003

Month	Degree (˚)																Total	No of Days
	0-22.5	22.6-45	45.1-67.5	67.6-90	90.1-112.5	112.6-135	135.1-157.5	157.6-180	180.1-202.5	202.6-225	225.1-247.5	247.6-270	270.1-292.5	292.6-315	315.1-337.5	337.6-359.9		
Jan	73	453	365	692	1841	772	215	24	10	7	3	0	0	1	2	6	4464	31
Feb	24	202	194	655	2140	641	138	25	2	2	0	0	0	1	1	7	4032	28
Mar	13	51	65	477	3074	459	143	127	27	9	1	4	1	3	5	5	4464	31
Apr	96	80	43	530	1982	552	255	266	102	76	66	72	69	46	41	44	4320	30
May	156	43	9	51	341	204	349	665	815	740	497	208	91	158	75	62	4464	31
June	16	6	2	6	82	39	131	977	1380	1029	374	153	48	45	16	16	4320	30
July	174	62	10	6	90	57	80	588	1055	916	410	306	279	275	82	74	4464	31
Aug	40	20	0	1	4	16	55	596	1625	1155	378	244	168	129	12	21	4464	31
Sept	5	6	0	7	45	28	44	433	1089	1253	655	378	269	85	12	11	4320	30
Oct	239	210	46	71	526	192	236	339	248	435	412	404	433	427	92	154	4464	31
Nov	45	306	189	462	2251	727	204	70	25	14	9	7	4	3	1	3	4320	30
Dec	215	439	143	262	1746	1399	200	30	9	5	7	1	2	4	0	2	4464	31
TOTAL	1096	1878	1066	3220	14122	5086	2050	4140	6387	5641	2812	1777	1364	1177	339	405	52560	
Percent	2.09	3.57	2.03	6.13	26.87	9.68	3.90	7.88	12.15	10.73	5.35	3.38	2.60	2.24	0.64	0.77		

Samarang 1999

Month	Degree (˚)																Total	No of Days
	0-22.5	22.6-45	45.1-67.5	67.6-90	90.1-112.5	112.6-135	135.1-157.5	157.6-180	180.1-202.5	202.6-225	225.1-247.5	247.6-270	270.1-292.5	292.6-315	315.1-337.5	337.6-359.9		
Jan																	0	0
Feb																	0	0
Mar																	0	0
Apr																	0	0
May	174	169	228	221	122	85	183	246	371	470	482	542	430	291	326	124	4464	31
June	197	174	186	102	81	80	154	158	253	578	739	723	410	197	127	161	4320	30
July	82	77	51	36	27	27	113	185	376	805	931	994	420	131	112	97	4464	31
Aug	166	130	133	112	136	84	139	199	286	556	717	791	453	216	243	103	4464	31
Sept	254	355	376	274	204	83	153	144	137	350	477	634	396	209	183	91	4320	30
Oct	313	281	188	155	228	108	213	188	232	465	540	482	335	259	280	197	4464	31
Nov	333	481	343	147	128	73	82	107	236	636	582	381	353	153	201	84	4320	30
Dec	285	533	472	179	120	52	122	128	253	802	562	418	244	104	152	38	4464	31
TOTAL	1804	2200	1977	1226	1046	592	1159	1355	2144	4662	5030	4965	3041	1560	1624	895	35280	
Percent	5.11	6.24	5.60	3.48	2.96	1.68	3.29	3.84	6.08	13.21	14.26	14.07	8.62	4.42	4.60	2.54		

Samarang 2000

Month	Degree (˚)																Total	No of Days
	0-22.5	22.6-45	45.1-67.5	67.6-90	90.1-112.5	112.6-135	135.1-157.5	157.6-180	180.1-202.5	202.6-225	225.1-247.5	247.6-270	270.1-292.5	292.6-315	315.1-337.5	337.6-359.9		
Jan	414	1807	1295	242	111	36	36	23	35	85	69	91	64	42	44	70	4464	31
Feb	479	856	680	241	146	62	123	90	143	405	247	262	154	110	96	82	4176	29
Mar	374	523	618	237	160	93	112	48	56	369	409	441	459	199	232	134	4464	31
Apr																	0	0
May	172	107	171	131	165	68	100	102	166	698	809	847	631	145	92	60	4464	31
June	216	110	214	175	182	123	186	158	143	662	554	561	423	228	231	154	4320	30
July	227	226	252	189	119	66	117	90	107	804	762	667	431	173	152	82	4464	31
Aug	140	141	206	106	88	81	186	121	98	738	864	801	465	209	146	74	4464	31
Sept	372	411	275	128	111	59	86	100	132	547	583	433	434	264	238	147	4320	30
Oct	29	28	35	41	33	25	67	87	141	962	1250	1319	336	64	25	22	4464	31
Nov	473	614	575	193	135	100	184	69	74	387	350	340	310	151	221	144	4320	30
Dec	292	345	344	238	105	56	114	105	122	463	626	545	454	259	317	79	4464	31
TOTAL	3188	5168	4665	1921	1355	769	1311	993	1217	6120	6523	6307	4161	1844	1794	1048	48384	
Percent	6.59	10.68	9.64	3.97	2.80	1.59	2.71	2.05	2.52	12.65	13.48	13.04	8.60	3.81	3.71	2.17		

Samarang 2001

Month	Degree (˚)																Total	No of Days
	0-22.5	22.5-45	45.1-67.5	67.6-90	90.1-112.5	112.6-135	135.1-157.5	157.6-180	180.1-202.5	202.6-225	225.1-247.5	247.6-270	270.1-292.5	292.6-315	315.1-337.5	337.6-359.9		
Jan	402	1254	1001	206	133	56	127	46	41	219	210	196	165	137	174	97	4464	31
Feb	241	1466	1036	110	15	0	4	15	20	129	169	190	193	116	238	90	4032	28
Mar	354	706	649	457	137	65	178	109	116	402	349	230	227	157	240	88	4464	31
Apr	158	251	275	147	181	82	166	129	109	783	493	403	433	285	318	107	4320	30
May	274	373	308	136	82	88	138	110	121	710	500	497	405	263	320	139	4464	31
June	93	52	76	104	129	86	152	124	127	651	748	656	390	255	306	371	4320	30
July	182	127	90	126	122	88	175	178	137	630	877	726	423	282	234	67	4464	31
Aug	69	25	40	76	79	76	79	54	89	776	1226	1284	262	150	127	52	4464	31
Sept	193	89	160	162	133	95	133	67	112	661	493	601	570	343	350	158	4320	30
Oct	178	168	112	70	112	72	107	140	176	806	784	688	474	252	244	81	4464	31
Nov	338	481	481	191	87	50	81	90	142	533	575	501	285	253	156	76	4320	30
Dec	220	832	1162	257	150	53	79	67	73	315	302	340	232	179	119	84	4464	31
TOTAL	2702	5824	5390	2042	1360	811	1419	1129	1263	6615	6726	6312	4059	2672	2672	2826	52560	
Percent	5.14	11.08	10.25	3.89	2.59	1.54	2.70	2.15	2.40	12.59	12.80	12.01	7.72	5.08	5.08	5.38		

Samarang 2002

Month	Degree (˚)																Total	No of Days
	0-22.5	22.5-45	45.1-67.5	67.6-90	90.1-112.5	112.6-135	135.1-157.5	157.6-180	180.1-202.5	202.6-225	225.1-247.5	247.6-270	270.1-292.5	292.6-315	315.1-337.5	337.6-359.9		
Jan	160	2334	1931	32	0	0	0	0	0	0	0	0	0	2	4	1	4464	31
Feb	419	2495	1041	23	3	3	14	7	0	0	0	0	0	5	9	13	4032	28
Mar	830	1856	927	153	36	28	22	6	3	48	56	86	103	114	119	77	4464	31
Apr	756	1102	621	188	183	72	105	64	84	272	145	120	126	162	137	183	4320	30
May	352	424	311	213	181	82	179	177	102	370	346	444	437	481	254	111	4464	31
June	190	138	163	111	136	101	204	149	144	696	676	647	558	248	118	41	4320	30
July																	0	0
Aug																	0	0
Sept	193	192	226	129	66	51	110	140	163	861	552	799	479	180	115	64	4320	30
Oct	339	145	80	83	77	83	136	125	158	900	621	629	495	295	164	134	4464	31
Nov																	0	0
Dec																	0	0
TOTAL	3239	8686	5300	932	682	420	770	668	654	3147	2396	2725	2198	1487	920	624	34848	
Percent	9.29	24.93	15.21	2.67	1.96	1.21	2.21	1.92	1.88	9.03	6.88	7.82	6.31	4.27	2.64	1.79		

Samarang 2003

Month	Degree (˚)																Total	No of Days
	0-22.5	22.5-45	45.1-67.5	67.6-90	90.1-112.5	112.6-135	135.1-157.5	157.6-180	180.1-202.5	202.6-225	225.1-247.5	247.6-270	270.1-292.5	292.6-315	315.1-337.5	337.6-359.9		
Jan																	0	0
Feb	286	2295	1378	32	8	7	2	1	1	1	3	2	2	0	6	8	4032	28
Mar	552	1260	1150	140	93	102	173	126	37	165	70	105	91	152	120	128	4464	31
Apr	861	1245	541	138	177	139	145	67	49	206	89	92	98	170	150	153	4320	30
May	95	151	140	90	70	70	151	120	209	947	796	847	458	170	94	56	4464	31
June	336	222	310	204	145	126	184	139	86	356	416	457	479	389	281	190	4320	30
July	89	94	236	244	116	81	138	131	151	602	777	848	576	230	105	46	4464	31
Aug	246	133	168	96	99	87	192	129	150	722	728	718	570	212	145	69	4464	31
Sept	104	78	119	103	46	51	136	142	142	772	763	826	487	274	202	75	4320	30
Oct	120	189	224	43	38	38	132	130	121	693	790	665	544	372	275	90	4464	31
Nov	432	638	497	180	90	64	90	79	79	306	349	383	414	323	288	108	4320	30
Dec	293	1015	1605	197	73	44	64	35	64	415	281	154	79	47	54	44	4464	31
TOTAL	3414	7320	6368	1467	955	809	1407	1099	1089	5185	5062	5097	3798	2339	1720	967	48096	
Percent	7.10	15.22	13.24	3.05	1.99	1.68	2.93	2.29	2.26	10.78	10.52	10.60	7.90	4.86	3.58	2.01		

Tukau 1999

Month	Degree (˚)																Total	No of Days
	0-22.5	22.5-45	45.1-67.5	67.6-90	90.1-112.5	112.6-135	135.1-157.5	157.6-180	180.1-202.5	202.6-225	225.1-247.5	247.6-270	270.1-292.5	292.6-315	315.1-337.5	337.6-359.9		
Jan																	0	0
Feb																	0	0
Mar																	0	0
Apr																	0	0
May	224	172	147	172	140	91	290	505	408	314	564	348	342	155	223	369	4464	31
June	307	231	113	182	105	58	222	489	344	465	630	280	252	136	192	314	4320	30
July	87	88	51	60	52	69	273	626	383	519	865	460	363	169	201	198	4464	31
Aug	175	137	126	156	76	56	158	552	382	496	658	389	348	206	282	267	4464	31
Sept	272	233	171	200	158	77	207	317	280	374	553	397	342	139	171	429	4320	30
Oct	226	184	149	131	98	61	142	418	310	473	751	388	304	162	263	404	4464	31
Nov	378	595	177	121	82	55	40	111	548	857	698	307	145	83	58	65	4320	30
Dec	298	368	183	141	114	80	34	123	603	1073	716	272	157	140	67	95	4464	31
TOTAL	1967	2008	1117	1163	825	547	1366	3141	3258	4571	5435	2841	2253	1190	1457	2141	35280	
Percent	5.58	5.69	3.17	3.30	2.34	1.55	3.87	8.90	9.23	12.96	15.41	8.05	6.39	3.37	4.13	6.07		

Tukau 2000

Month	Degree (˚)																Total	No of Days
	0-22.5	22.5-45	45.1-67.5	67.6-90	90.1-112.5	112.6-135	135.1-157.5	157.6-180	180.1-202.5	202.6-225	225.1-247.5	247.6-270	270.1-292.5	292.6-315	315.1-337.5	337.6-359.9		
Jan	494	1275	1011	170	153	111	67	117	254	256	164	103	62	66	46	115	4464	31
Feb																	0	0
Mar	379	545	221	188	227	189	83	306	386	273	322	289	296	285	203	272	4464	31
Apr																	0	0
May	249	93	99	83	175	67	184	546	449	425	549	494	392	174	164	321	4464	31
June	292	134	126	203	202	93	273	520	439	329	439	347	289	120	174	340	4320	30
July	299	228	131	110	185	40	136	585	374	355	593	491	373	186	178	200	4464	31
Aug	278	96	51	43	151	40	88	477	331	416	752	541	313	180	210	497	4464	31
Sept	335	259	176	145	140	69	221	473	321	314	414	286	250	217	263	437	4320	30
Oct																	0	0
Nov	407	365	252	188	140	82	186	582	398	255	231	201	236	122	302	373	4320	30
Dec	408	325	133	125	76	32	51	394	358	384	662	458	297	130	193	438	4464	31
TOTAL	3141	3320	2200	1255	1449	723	1289	4000	3310	3007	4126	3210	2508	1480	1733	2993	39744	
Percent	7.90	8.35	5.54	3.16	3.65	1.82	3.24	10.06	8.33	7.57	10.38	8.08	6.31	3.72	4.36	7.53		

Tukau 2001

Month	Degree (˚)																Total	No of Days
	0-22.5	22.5-45	45.1-67.5	67.6-90	90.1-112.5	112.6-135	135.1-157.5	157.6-180	180.1-202.5	202.6-225	225.1-247.5	247.6-270	270.1-292.5	292.6-315	315.1-337.5	337.6-359.9		
Jan	573	870	381	323	226	62	98	293	317	275	281	179	157	60	103	266	4464	31
Feb	499	1312	371	249	134	15	28	227	159	174	149	101	92	46	230	246	4032	28
Mar	356	350	261	287	195	194	292	1113	214	157	319	61	83	59	93	430	4464	31
Apr	237	125	74	67	67	59	185	652	413	405	512	381	374	192	236	341	4320	30
May	372	269	105	139	205	188	328	694	364	243	216	191	213	213	243	481	4464	31
June	82	48	49	68	99	85	210	640	412	468	480	337	478	321	329	214	4320	30
July	265	196	53	57	108	87	189	447	342	497	529	357	436	272	297	332	4464	31
Aug																	0	0
Sept																	0	0
Oct	179	99	36	54	107	95	212	549	439	483	553	585	311	179	242	341	4464	31
Nov	245	300	142	174	187	104	115	390	519	491	521	461	211	160	134	166	4320	30
Dec	475	923	184	180	151	71	83	293	338	263	298	346	243	145	146	325	4464	31
TOTAL	3283	4492	1656	1598	1479	960	1740	5298	3517	3456	3858	2999	2598	1647	2053	3142	43776	
Percent	7.50	10.26	3.78	3.65	3.38	2.19	3.97	12.10	8.03	7.89	8.81	6.85	5.93	3.76	4.69	7.18		

Tukau 2002

Month	Degree (˚)																Total	No of Days
	0-22.5	22.5-45	45.1-67.5	67.6-90	90.1-112.5	112.6-135	135.1-157.5	157.6-180	180.1-202.5	202.6-225	225.1-247.5	247.6-270	270.1-292.5	292.6-315	315.1-337.5	337.6-359.9		
Jan	451	2389	899	205	133	46	45	66	23	10	10	11	17	9	35	115	4464	31
Feb	539	2487	509	146	78	28	47	60	14	6	7	2	0	1	9	99	4032	28
Mar	757	1653	436	191	148	78	88	157	126	66	54	37	34	44	198	397	4464	31
Apr	567	613	231	151	157	114	265	499	208	177	150	173	133	86	239	557	4320	30
May	326	191	97	117	147	78	245	433	396	380	366	273	355	258	351	451	4464	31
June	192	105	92	125	188	95	251	576	357	382	435	436	429	197	206	254	4320	30
July	134	54	40	61	102	52	257	535	472	422	796	677	402	144	205	111	4464	31
Aug	241	170	83	60	66	35	210	492	386	578	680	563	263	138	205	294	4464	31
Sept	198	124	107	111	161	118	267	584	256	330	436	579	382	185	224	258	4320	30
Oct	161	186	77	111	171	160	252	517	379	311	466	689	264	125	278	317	4464	31
Nov	277	240	110	93	132	69	196	397	333	381	357	458	310	199	365	403	4320	30
Dec	536	1005	355	179	211	99	328	253	172	201	159	184	118	91	189	384	4464	31
TOTAL	4379	9217	3036	1550	1694	972	2451	4569	3122	3244	3916	4082	2707	1477	2504	3640	52560	
Percent	8.33	17.54	5.78	2.95	3.22	1.85	4.66	8.69	5.94	6.17	7.45	7.77	5.15	2.81	4.76	6.93		

Tukau 2003

Month	Degree (˚)																Total	No of Days
	0-22.5	22.5-45	45.1-67.5	67.6-90	90.1-112.5	112.6-135	135.1-157.5	157.6-180	180.1-202.5	202.6-225	225.1-247.5	247.6-270	270.1-292.5	292.6-315	315.1-337.5	337.6-359.9		
Jan	415	1810	764	362	164	63	128	208	103	100	54	49	27	26	76	115	4464	31
Feb	529	2160	730	112	50	15	49	60	28	19	22	20	27	6	77	128	4032	28
Mar	637	982	419	252	261	105	279	223	169	171	139	147	131	73	150	326	4464	31
Apr	471	362	206	119	117	83	204	431	261	251	283	194	162	154	513	509	4320	30
May	104	59	64	55	97	54	265	518	231	547	605	674	630	213	225	123	4464	31
June	293	189	122	196	155	66	251	567	228	217	259	395	331	173	403	475	4320	30
July	183	168	120	248	118	65	337	389	253	407	714	612	324	194	221	111	4464	31
Aug	143	80	498	174	102	75	185	454	343	316	541	625	411	141	153	223	4464	31
Sept	228	196	133	114	74	36	232	594	449	417	385	518	312	168	231	233	4320	30
Oct																	0	0
Nov																	0	0
Dec																	0	0
TOTAL	3003	6006	3056	1632	1138	562	1930	3444	2065	2445	3002	3234	2355	1148	2049	2243	39312	
Percent	7.64	15.28	7.77	4.15	2.89	1.43	4.91	8.76	5.25	6.22	7.64	8.23	5.99	2.92	5.21	5.71		