Journal of Engineering and Applied Sciences 13 (17): 7364-7372, 2018
ISSN: 1816-949X
© Medwell Journals, 2018

Establishment of Windstorm-producing Thunderstorms Hazard Threshold in Peninsular Malaysia

[1]Mohd Fairuz Bachok, [2]Supiah Shamsudin, [3]Roslan Zainal Abidin,
[4]Ponselvi Jeevaragagam and [4]Sobri Harun
[1]Faculty of Civil Engineering, Universiti Teknologi MARA Cawangan Pahang,
Pahang, Malaysia
[2]FDL Facile Global, Kuala Lumpur, Malaysia
[3]School of Engineering and Technology Infrastructure,
Infrastructure University Kuala Lumpur, Selangor, Malaysia
[4]Faculty of Civil Engineering, Universiti Teknologi Malaysia, Skudai, Johor, Malaysia

Abstract: Establishment of guideline to distinguish between low risk and high-risk windstorm occurrences is important in windstorm disaster management, especially, for purpose in disseminating early warning to the public and local authorities. Hazard threshold as supporting tool in windstorm early warning system, so that, monitoring of these phenomena only to be focused on high-risk windstorm occurrences. High-risk windstorm occurrences are occurrences with a higher intensity than hazard threshold whereby if this particular windstorm did occur, it could cause significant damages. Significant damages are damages that causing loss property, injury and claim life to the human. In order to establish this supporting tool, 56 windstorm occurrences from 6 regions in Peninsular Malaysia were selected as study cases. Estimation of intensity for each significant damage also taken into account the effect of local conditions. Besides, the damages and meteorological station should be underneath the same convective cluster and in-position with wind direction that had intensity. Through this study, it was found that the hazard threshold in Peninsular Malaysia is 9.0 m/sec (32.4 km/h) of gust speed at 1 min duration.

Key words: Early warning system, hazard threshold, supporting tool, windstorm-producing, thunderstorms, windstorm

INTRODUCTION

Severe weather initiates thunderstorms to produce its by-products such as heavy rain, hail, downdraft (downburst and gust front) and even Tornado. Water and wind are two main elements associated with these thunderstorm by-products whereas heavy rain and hail associated with water while downdraft and Tornado associated with wind. Downdraft and Tornado are the hydro-meteorological hazard and one of the most impressive natural disasters because it can potentially create a situation of damages. Hence, there is a need to forecast and monitor severe thunderstorms because they could produce phenomena which markedly affect mankind. However, not all downdraft and Tornado produce damages. Damages that caused by the action of the wind only will occur when wind effects on objects exceeding their strength or resilience limits. Downburst, especially, microburst is very common but most are not severe (Wakimoto, 2001). As a result, there should be a guideline to identify between low risk (low possibility cause significant damages) with high-risk windstorm occurrences (high possibility cause significant damages) in purpose for disseminating early warning.

Mohd Fairuz *et al.* found that there are more than 1000 windstorm occurrences in Malaysia been recorded from the year 2000-2012. It was collected from three main resources which are reported in the mass media, government agencies and local authorities reports. The records from mass media taking into account the windstorm that causes damages only, since, mass media more interested to report news related to a windstorm that causes large-scale damages, involving injury and loss of human life. While, reports from government agencies such as the Department of Social Welfare and Police Department is a report that were reported by the victims, so, they could claim compensation due to damages to their home or premises. Local authorities received reports

Corresponding Author: Mohd Fairuz Bachok, Faculty of Civil Engineering, Universiti Teknologi MARA Cawangan Pahang, Pahang, Malaysia

from the public usually related to uprooted trees that block the traffic. However, it is believed that the number of windstorm occurrences is much higher as most of the occurrences were not reported nor recorded due to some certain factors such as not causing any damages, causes small-scale damages, damages to the areas without human settlement and damages produced on private or government premises which can be managed by the owner. Leitao (2003) agreed that weak Tornadoes are under-reported, since, this type of Tornado does not produce remarkable effects. Nevertheless, Dobrovolny and Bradzil (2003) also agreed that most cases in written records are dealing with strong wind that caused some damage whereby more destructive of the events, they will be more frequent evidence and detail of the damages.

Based on the fact that windstorm occurrences could cause a various state of damages from no damages, small-scale damages, large-scale damages and so on, despite a high frequent number of occurrences, therefore, a guideline in identifying the state of damages by windstorm occurrence, especially, distinguished between occurrence could cause significant damages or otherwise should be established. Taking into account that if there is no specified hazard threshold but only concern about the possibility of windstorm occurrence, this will actually cause frequent warning being disseminated to the public. Public and local authorities whose often receiving the warning but did not experience any damages would cause their confidence to the warning system eroded and eventually might lose their confidence. The frequent false warning will not only have jeopardized on warning system operation but also cost, energy and time being wasted by public and local authorities which had planned an early preparation (Khairulmaini, 2007).

Establishment of hazard threshold is proven to be important because this guideline has been used in 23 European countries as the severe thunderstorm warning criteria, although, the threshold is different from one country to another. Spain set a lowest hazard threshold which is equivalent to 11 m/sec while the Netherlands is the country with the highest threshold of 28 m/sec. Warning philosophies and assessment of significant damages among the countries were the factors contributing to this matter. Apart from gust speed, hail is also one of the criteria (Rauhala and Schultz, 2009). USA set Tornadoes, damaging winds or gusts = 26 m/sec or hail diameter = 1.9 cm as severe weather criteria (Johns and Doswell III, 1992). Moreover, differences in construction and surrounding in the country indicates that the hazard threshold in Malaysia cannot be adapted directly accordance to any country but must be established locally. Hail is not considered as one of the criteria because the hail phenomenon is rare in Malaysia. Therefore, by looking at the needs and significance of this hazard threshold, it is desirable that it should be produced as a supporting tool in the windstorm early warning system in Peninsular Malaysia. Early warning system not intended to prevent disaster but it is still necessary because it could provide lead time for the public to save lives and sometimes gives people enough time to safeguard property (Anonymous, 2002).

MATERIALS AND METHODS

In order to establish this threshold hazard, several considerations need to be concern which are:

- Selection of meteorological station is according to the three aspects, namely topographic, distance from coast and population density
- Collection of study cases is subjected to a windstorm occurrence in district with meteorological station, causing significant damages and met the regional, week, month and time period classification
- Analysis of the damages only for the damages located underneath the same convective cluster with meteorological station and in-position with wind direction that had intensity
- Estimation of damages intensity should be taken into account the effect of local conditions

Thus, in establishing the hazard threshold, it needs a selection of the meteorological station, determination of significant damages, collection of windstorm occurrences, estimation of significant damages intensity and establishment of hazard threshold.

Selection of meteorological station: Selection of meteorological station is according to the three aspects, namely topographic, distance from the coast and population density. These are due to the factors that reflect variability in probability of windstorm occurrence such as topographic effects, sea land areas contrast, differences of climatic background, population density and site observational possibility (Sioutas, 2011). Moreover, hazard threshold is the minimum gust speed that could possibly cause significant damage and this parameter can only be recorded by the meteorological station. Thus, the district with the meteorological station only will be considered. This study set 2 districts to represent each of those aspects whereby for the topographic aspect (location of meteorological station either at high and low altitude), distance from the coast aspect (location of meteorological station either near and far from the coast) and population density aspect (population at district either high and low population density). As a result, 6 meteorological stations at 6 districts in Peninsular Malaysia need to be selected. Through information from Malaysia Meteorological

Fig. 1: Coordinate of existing meteorological station in Peninsular Malaysia

Department (MET Malaysia), the existing meteorological stations are coordinated into the map, so that, the district where the location of the meteorological station with its altitude and distance from the coast can be identified (Fig. 1). The population at the district is estimated by referring to the report published (Anonymous, 2011a, b).

Determination of significant damages: The approach that had been taken in determining the significant damage is by comparing the gust/wind speed specified by a some country as criteria of severe weather with the damages scale such as Beaufort scale (Burroughs *et al.*, 2003), Enhanced Fujita (EF) scale (Potter, 2007) and Tornado and Storm Research Organization (TORRO) scale (Meaden, 1976) in purpose to identify the significant damage for each country. This comparison is made between the gust/wind speed specified by damages scale, so that, the type of damages that to be addressed can be made known and should be compared with the damages scale produced or used by the same country. Through the comparison, significant damages will be identified and its associated gust speed will be taken as a hazard threshold. Comparison with these three damage scales is considered relevant, even though Beaufort scale refers to the impacts by a straight-line wind while TORRO scale refers to the impacts by a Tornado because severe thunderstorms were convective storms induced phenomena that includes Tornadoes, damaging winds or gusts or hail with damaging wind gusts or large hail or Tornado (Johns and Doswell, 1992). Moreover, Marshall found that damages to a particular structure, its general appearance look very similar whether it is caused by the Tornado, hurricane, downburst or straight-line winds if not subjected to any specific wind speeds.

Collection of windstorm occurrences: There are 10 windstorm occurrences being set in the study need to be collected for each district with the overall total of windstorm occurrences equal to 60 as study windstorm occurrences. For study windstorm occurrences, beside produces the damages, these occurrences should also need to met classification for region (Central, East Coast, Northern and Southern), week (1st-5th), month (Jan.-Dec.) and time period (midnight, early morning, dawn, morning, late morning, noon, early afternoon, afternoon, late afternoon, evening, early night, night and late night). This is to ensure the study cases are adequate and applicable at any location, time and condition in Peninsular Malaysia. Main sources were from mass media, report from government agencies such as Department of Social Welfare and local authorities. Location, date, time and damages are the details that need to be recorded for each windstorm occurrences. Time series of 1 min gust speed graph for 24 h (1 day) duration is a chart that acquired. The purpose is through this chart, if there is a series of gust speed anomaly (Fig. 2), it can be confirmed that high possibility of windstorm occurred on that particular day. Moreover, the time duration of the windstorm occurrence also can be determined.

Estimation of significant damages intensity: The damages from each study windstorm occurrences will be assessed by examining the report and photo. However, further assessment focusing on identification of significant damages only. These damages will be coordinated in the local conditions wind multiplier map which are (terrain (roughness) multiplier map, shielding multiplier map and topographic (hill-shape) multiplier map) where as all of these maps are embedded in Google Earth Pro map (Fig. 3). Significant damages that are underneath the same convective cluster with the meteorological station, occurred during the maximum gust speed and in a position of the wind direction only being considered to be estimated their intensity (Fig. 4). The reason of damages and meteorological station located underneath the same convective cluster need to be considered because both are believed receiving the same intensity, since, the downdraft was produced from the same

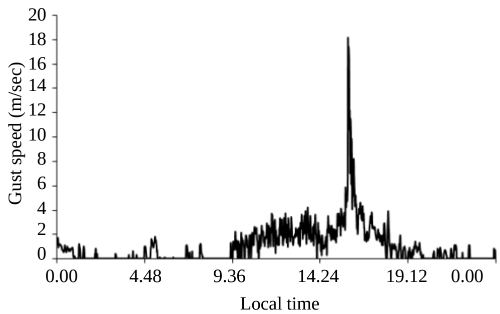

Fig. 2: Gust speed anomaly during windstorm occurrence

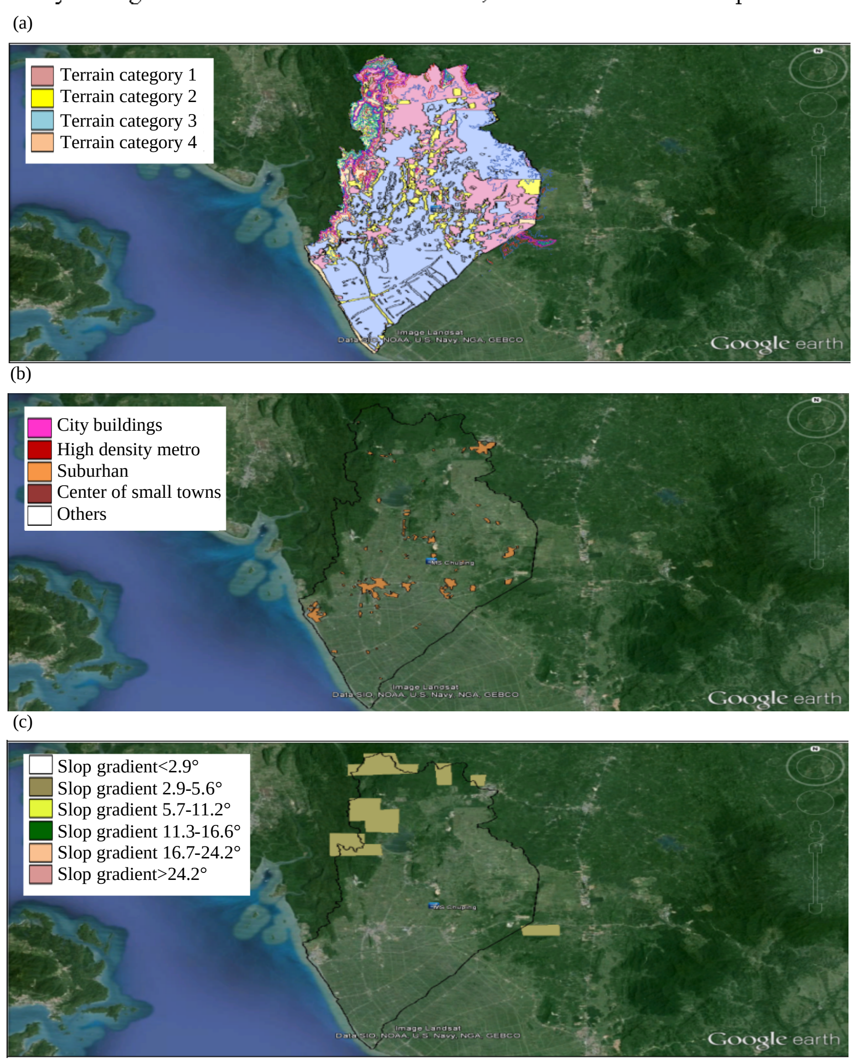

Fig. 3: Typical local conditions wind multiplier map embedded in Google Earth Pro map: a) Terrain (roughness) multiplier map embedded in Google Earth; b) Shielding multiplier map embedded in Google Earth and c) Topographic (hill-shape) multiplier map embedded in Google Earth

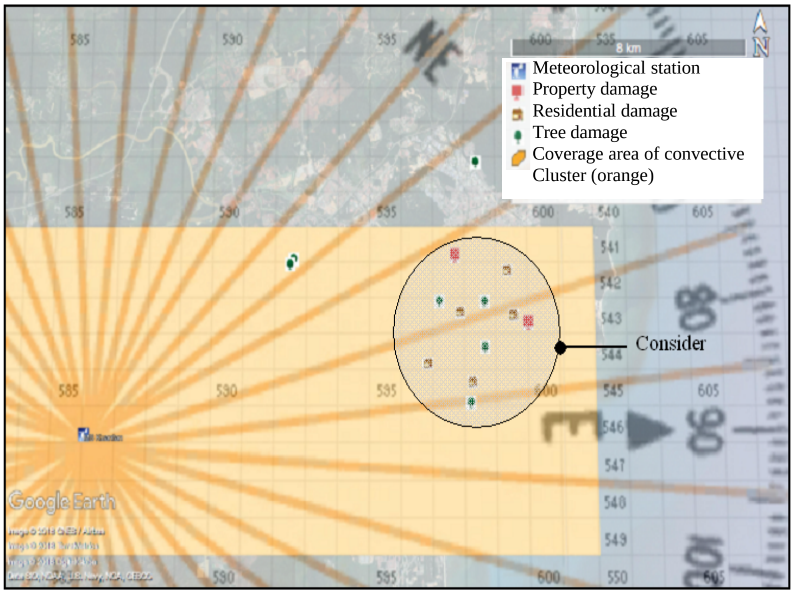

Fig. 4: Damages being considered (damages located underneath the same convective cluster with meteorological station and in position with wind direction)

Table 1: Districts of study windstorm occurrences

Meteorological station number	Altitude (m)	Regions	Districts	Estimation population (No.)	Distance from coast (km)	Remarks
48604	22.0	Northern	Perlis	198.288	18.1	Population density (low)
48603	4.0	Northern	Kota Setar	354.513	15.4	Topographic (low altitude)
48679	37.8	Southern	Johor Bahru and Kulai	1.081,978	35.5	Population density (high) and distance from coast (far)
48657	15.0	East coast	Kuantan	344.319	11.8	Distance from coast (near)
48619	35.0	East coast	Kuala Terengganu	298.304	1.4	Topographic (high altitude)

resource. The maximum gust that been recorded by meteorological station needs to be multiplied by local conditions wind multiplier of an area where the damages located, so that, actual gust speed can be estimated.

For terrain (roughness) multiplier is according to Table 1-6 in MS1553:2002 while shielding and topographic (hill-shape) multipliers are according to Table 5 and 6 in AS/NZS 1170.2:2011, respectively.

Determination of hazard threshold: Determination of the gust speed for significant damages is by collecting a number of the windstorm that cause the similar significant damages and subsequently recorded its associated actual gust speed. The lowest actual gust speed for significant damages among the windstorm will be considered as hazard threshold. In order to justify whether the lowest actual gust speed for significant damages is a hazard threshold, percentile test was carried out by taking the gust speed during the day of occurrence in purpose to determine the percentile of hazard threshold, thus, the hazard threshold can be made known whether the hazard threshold is anomaly value or otherwise.

RESULTS AND DISCUSSION

There are 60 windstorm occurrences that have caused physical damages are suggested to be collected as the study cases. The selection is based on altitude, population and distance from the coast factor whereby 20 cases will represent for each factor with 10 cases as the highest value while another 10 cases were the lowest values. Table 1 shows the selected windstorm occurrences in 6 districts in Peninsular Malaysia as the study cases. However, only 56 windstorm occurrences that had being selected. The number of this study cases were less than the suggested number due to the reduction number of cases in the Southern region.

Although, the number of study cases is lower than suggested number, the 56 cases are still adequate to establish hazard threshold that can be applied at any location and time in Peninsular Malaysia because these study cases not only met the criteria that contribute to the windstorm occurrence but also almost all classifications for location, date and time in Peninsular Malaysia as well (Table 2-5). Therefore, it is confirmed that the selected

Table 2: Breakdown of study cases based on region and state

Region/State	No. of cases	Total cases	Percentage
Central			
Selangor	0	0	0.0
Wilayah Persekutuan	0		
East coast			
Kelantan	0	19	33.3
Pahang	13		
Terengganu	6		
Northern			
Kedah	12	23	40.3
Perak	0		
Perlis	11		
Pulau Pinang	0		
Southern			
Johor	14	14	26.3
Melaka	0		
Negeri Sembilan	0		

Table 3: Breakdown of study cases based on week

Week	Days	Total cases (No.)	Percentage
First	1st-07th	18	31.6
Second	8th-14th	11	19.3
Third	15th-21st	13	22.8
Fourth	22nd-28th	14	24.6
Fifth	29th-31st	1	1.8

Table 4: Breakdown of study cases based on month

Months	Total cases (No.)	Percentage
January	1	1.8
February	1	1.8
March	7	12.3
April	5	8.8
May	7	12.3
June	8	14.0
July	2	3.5
August	4	7.0
September	10	17.5
October	7	12.3
November	2	3.5
December	3	5.3

Table 5: Breakdown of study cases based on time period

Period of maximum gust speed	Time	Total cases (No.)	Percentage
Midnight	01:01-04:00	4	7.0
Early morning	04:01-07:00	1	1.8
Dawn	07:01-10:00	0	0.0
Morning	10:01-12:00	0	0.0
Late morning	12:01-14:00	1	1.8
Noon	14:01-16:00	8	14.0
Early afternoon	16:01-18:00	15	26.3
Afternoon	18:01-19:00	12	21.1
Late afternoon	19:01-20:00	5	8.8
Evening	20:01-21:00	2	3.5
Early night	21:01-23:00	3	5.3
Night	23:01-00:00	4	7.0
Late night	00:01-01:00	2	3.5

occurrences are adequate and applicable as study cases in establishing hazard threshold due to its variety to comply with the criteria related to the windstorm occurrences.

The most important part that needs to be understood before hand in establishing wind storm-producing thunderstorms hazard threshold is an identification of damages that classified as significant damages. Then, determine the associated minimum gust speed that could cause the damages. Table 6 shows that the damages listed according to code 9 of Beaufort scale, code T0 of TORRO scale and code EF0 of EF-scale are damages that are considered as significant damages for each damage scales in most countries. When examined through damages listed in code 9, T0 and EF0 shows that the branches break (damages to tree), roof materials blown away (damages to structural and building), tent and antenna collapsed (damages to property) are least severe damages to building, structures, properties and tree but still possible could causes loss of properties, injury and claim human life. On the other hand, the intensity that could cause these damages, actually is the threshold that distinguished between windstorm occurrence could cause significant damages or otherwise. An area that has been predicted to be experienced maximum intensity higher than hazard threshold, the warning needs to be disseminated to the public and local authorities in the affected area. However, if otherwise, the warning should not need to be disseminated even though windstorm occurred (Table 6).

Gust speed of 7.6 m/sec is set as the lowest gust speed in assessing the intensity that could cause significant damages, since, 7.6 m/sec is the lowest maximum gust speed that been recorded by meteorological stations during windstorm occurrence. On the other hand, consideration for determining the intensity of the significant damages should begin with gust speed of 7.6 m/sec or higher. Through assessment of the intensity that causes damages for all windstorm occurrences, it found that the damages are almost similar with damages listed in code 8 of Beaufort scale, code T0 of TORRO scale and EF0 of EF-scale as well which the damages are branches break and loss of roof covering material. These damages produced at the intensity of 7.6 m/sec. However, it does not mean that the intensity of 7.6 m/sec is actual intensity causing these damages if the effects of local conditions are not taking as consideration, even though, it been recorded by the meteorological station. Thus, to determine the actual intensity, the local conditions factor need to be considered.

The hazard threshold is considered equal to 9.0 m/sec (32.4 km/h) based on the lowest intensity after taking into account local conditions factor and comparison between significant damages actual intensity among study windstorm occurrences (Table 7). There are 8 study windstorm occurrences only produce significant damages, meanwhile, the other occurrences produce different and more severe damages. The gust speed on the land surface should be at least 9.0 m/sec or higher

Table 6: Identification of significant damages by comparison between severe thunderstorm warning criteria with damages listed in existing damages scale

Scales/Codes	Damages	Numbers	Percentage
Beaufort			
6	Large branches sway, utility wires whistle	2	8.3
7	Trees sway, difficult to walk against wind	4	16.7
8	Twig snap off trees	9	37.5
9	Branches break, minor structural damage	4	16.7
10	Trees uprooted, structural damage	5	20.8
	Total		24
	100.0		
TORRO			
T0	Loose light litter raised from ground-level in spirals, tents, most exposed tiles, slates on roofs dislodged, twigs snapped and trail visible through crops	13	76.5
T1	Deckchairs, small plants, heavy litter becomes airborne, minor damage to sheds, more serious dislodging of tiles, slates, chimney pots, wooden fences flattened and slight damage to hedges and trees	4	23.5
	Total	17	100.0
EF			
EF0	Some damage to chimneys and tv antennas, break twigs off trees and pushes over shallow-rooted trees	1	100.0
	Total	1	100.0

Table 7: Significant damages and its associated intensity for each study case

Cases	Damages	Intensity (m/sec)
KS/3	Tree-branches break	9.0
KS/3	Wooden house-loss of roof covering material-zinc	9.0
KS/3	Wooden house-loss of roof covering material-zinc	10.1
KS/3	Wooden house-loss of roof covering material-asbestos	10.6
KS/8	Porch-loss of roof covering material-asbestos	9.7
KS/8	Porch-loss of roof covering material-metal	9.7
KS/8	Porch-loss of roof covering material-zinc	9.7
KS/8	Public house-loss of roof covering material-asbestos	9.7
CH/17	Public house-loss of roof covering material-zinc	10.4
CH/17	Wooden house-loss of roof covering material-asbestos	10.4
CH/17	Wooden house-loss of roof covering material-zinc	11.8
CH/21	Wooden house-loss of roof covering material-zinc	11.4
KN/32	Wooden house-loss of roof covering material-zinc	13.7
KN/32	Wooden house-loss of roof covering material-zinc	15.2
KN/32	Wooden house-loss of roof covering material-asbestos	15.2
KN/35	Wooden house-loss of roof covering material-zinc	12.0
KN/35	Wooden house-loss of roof covering material-asbestos	12.0
KN/35	Public house-loss of roof covering material-asbestos	12.0
JB/47	Wooden house-loss of roof covering material-zinc	14.6
JB/47	Public house-loss of roof covering material-asbestos	14.6
JB/47	Wooden house-loss of roof covering material-asbestos	14.6
JB/47	Public house-loss of roof covering material-tile	14.6
JB/47	School-loss of roof covering material-tile	14.6
JB/47	Small retail building-loss of roof covering material-tile	14.6
JB/47	Public house-loss of roof covering material-asbestos	16.2
JB/47	Public house-loss of roof covering material-tile	16.2
JB/47	Public house-loss of roof covering material-asbestos	18.4
JB/47	Wooden house-loss of roof covering material-zinc	19.3
JB/47	Public house-loss of roof covering material-tile	19.3
JB/47	Small retail building-loss of roof covering material-tile	19.3
JB/47	Institutional building-loss of roof covering material-tile	19.3
JB/47	Low rise building-loss of roof covering material-metal	19.3
JB/47	Walkway-loss of roof covering material-polycarbonate	19.3
JB/47	Walkway-loss of roof covering material-tile	19.3
JB/47	Warehouse building-loss of roof covering material-metal	19.3
JB/47	Public house-loss of roof covering material-tile	21.4
KA/54	Public house-loss of roof covering material-asbestos	18.4
KA/54	Public house-loss of roof covering material-zinc	18.4

if to cause significant damages in Peninsular Malaysia. Actually, hazard threshold of 9.0 m/sec is near to the 10.0 m/sec which been categorized as thunderstorm wind. Choi (2000) categorized gust speeds >10.0 m/sec as a thunderstorm wind and found that the gust factors and turbulence intensities during thunderstorms are much higher than those of the non-thunderstorm winds over the same terrain and suggested that gust speeds during tropical thunderstorms should become the critical factor in defining design wind speeds for a place like Singapore.

Branches break and loss of roof covering material considered as significant damages because not only could cause loss of property but both the damages can become an airborne missile that could cause injury and claim life to the human. As an example, windstorm occurred on May 8, 2009 in Southern Illinois, 3 persons were killed by falling roof and tree. Moreover, falling trees and branches were the major cause of property damages based on eight windstorm occurrences assessed in the USA (Changnon, 2010). Meanwhile, people injury, loss of life and even vehicles damage were among serious damages that caused by falling branches and flying roof covering material during windstorm occurrence and these actually according to series of windstorm occurrences in the country that is reported in mass media. Thus, predicted windstorm-producing thunderstorms with intensity exceed than hazard threshold should be monitored closely.

Windstorm-producing thunderstorms that may release strong wind with gust speed above 9.0 m/sec will be categorized as a high-risk windstorm occurrence and need to be monitored and later disseminated warning to the public and local authorities in the potentially affected areas. The convective cluster that been identified that has high potential to produce strong downdraft via. radar imagery would be projected its maximum intensity. Once the maximum intensity is known then the intensity of each particular area underneath the convective cluster is estimated by taking into account the local condition factors. Areas that had identified with a potential to experience intensity exceeds than 9.0 m/sec should be warned. The higher the gust speed which exceeds than 9.0 m/sec, the more potentially severe the damages as listed in Beaufort, TORRO or EF-scale.

Gust speed equal to 7.6 m/sec is considered as the initial gust speed due to its lowest gust speed. In addition, according to percentile test run of gust speed for every 1 min during a whole day of the all study cases shows that average percentile for gust speed equal to 7.6 m/sec and almost all the cases are above the 90.0 percentile (Table 8). It is means 7.6 m/sec is an anomaly value which only been recorded when unusual phenomenon occurred which out of regularity that causes the drastically rise of gust speed (gust speed anomaly). The wind characteristics during thunderstorms are different compared to non-thunderstorm winds, since, its more turbulent and the gust speeds are a lot higher (Choi, 2000). Determination of initial gust speed actually enables the approximate occurrence time duration or risk time duration by determining the duration of gust speed that equal to 7.6 m/sec or higher.

Table 8: Percentile test run result for gust speed for every 1 min during windstorm occurrence day

Cases	Percentile for gust speed 7.6 m/sec during windstorm occurrence day (from time 00:00-23:59)
KS1	99.7
KS2	99.4
KS3	99.7
KS4	78.5
KS5	99.2
KS6	97.8
KS7	99.2
KS8	90.8
KS9	98.1
KS10	99.9
KS11	99.9
KS12	97.8
CH13	99.9
CH14	99.9
CH15	99.9
CH16	99.4
CH17	99.4
CH18	99.7
CH19	93.3
CH20	99.5
CH21	99.2
CH22	99.9
CH23	99.5
KT24	100.0
KT25	98.5
KT26	98.3
KT27	90.3
KT28	45.1
KT29	98.1
KN30	99.4
KN31	97.4
KN32	98.1
KN33	99.0
KN34	100.0
KN35	98.7
KN36	98.8
KN37	99.2
KN38	98.4
KN39	99.4
KN40	98.1
KN41	93.6
KN42	98.6
JB43	100.0
JB44	99.9
JB45	98.6
JB46	99.2
JB47	98.5
JB48	99.5
JB49	99.0
JB50	99.1
JB51	99.0
JB52	98.6
KA53	97.6
KA54	98.5
KA55	99.8
KA56	98.8
Average	97.2

CONCLUSION

Hazard threshold needs to be established in order to identify high-risk windstorm occurrence which windstorm that could cause significant damages due to its maximum intensity higher than hazard threshold. After being identified, warning with the information of risk location, estimation time of occurrence and potential damages should be disseminated to the local authorities and public. On the other hand, hazard threshold distinguished between low risk with high-risk windstorm occurrences, so that, only high-risk windstorm occurrences need to be focused and monitored not only to avoid a false warning that could cause erode public reliability to the early warning but also to save time, energy and costs for early warning system operation and early preparation that had to be planned by local authorities and public. Thus, the establishment of this hazard threshold actually a supporting that could give an extra mile benefit to the windstorm disaster management in the country.

ACKNOWLEDGEMENTS

The researchers would like to express their sincere thanks to Department of Social Welfare Malaysia, Malaysia Meteorological Department, Kulai, Johor Bahru, Kuantan, Kuala Terengganu, Kota Setar and Perlis local authorities for their commitment and kindness in providing us a valuable data and information.

REFERENCES

Anonymous, 2002. Code of practice on wind loading for building structure (MS1553:2002). Department of Standards Malaysia (DSM), Putrajaya, Malaysia.

Anonymous, 2011. AS/NZS 1170.2:2011 Structural design actions Part 2: Wind actions. Australian/New Zealand Standard (AS/NZS), Joint Technical Committee BD-006, Australia/New Zealand.

Anonymous, 2011. Statistics handbook Malaysia. Department of Statistics, Putrajaya, Malaysia.

Burroughs, W.J., B. Crowder, T. Robertson, E. Vallier-Talbot and R. Whitaker, 2003. A Guide to Weather. Fog City Press, San Francisco, California, ISBN-13:978-1876778651,.

Changnon, S.A., 2010. An atlas of windstorms in the United States and their impacts. Master Thesis, Illinois State Water Survey, Champaign, llinois.

Choi, E.C., 2000. Wind characteristics of tropical thunderstorms. J. Wind Eng. Ind. Aerodyn., 84: 215-226.

Dobrovolny, P. and R. Brazdil, 2003. Documentary evidence on strong winds related to convective storms in the Czech Republic since AD 1500. Atmos. Res., 67: 95-116.

Johns, R.H. and C.A. Doswell III, 1992. Severe local storms forecasting. Weather Forecasting, 7: 588-612.

Khairulmaini, O.S., 2007. Early Warning Systems Do's and Don'ts in Environmental Hazard Management. Ministry of Science, Technology and Innovation, Uganda, East Africa,.

Leitao, P., 2003. Tornadoes in Portugal. Atmos. Res., 67: 381-390.

Meaden, G.T., 1976. Tornadoes in Britain: Their intensities and distribution in space and time. J. Meteorol., 1: 242-251.

Potter, S., 2007. Fine-tuning Fujita: After 35 years, a new scale for rating tornadoes takes effect. Weatherwise, 60: 64-71.

Rauhala, J. and D.M. Schultz, 2009. Severe thunderstorm and tornado warnings in Europe. Atmos. Res., 93: 369-380.

Sioutas, M.V., 2011. A tornado and waterspout climatology for Greece. Atmos. Res., 100: 344-356.

Wakimoto, R.M., 2001. Convectively Driven High Wind Events. In: Severe Convective Storms, Doswell, C.A. (Ed.). American Meteorological Society, Boston, Massachusetts, ISBN:978-1-935704-06-5, pp: 255-298.