# JoST

ISSN: 2251-0680

# Journal of Sustainable Technology

Volume 4, No. 1, April, 2013

Journal of Sustainable Technology JoST Volume 4, No. 1, April, 2013

CERAD
CENTRE FOR RESEARCH AND DEVELOPMENT
THE FEDERAL UNIVERSITY OF TECHNOLOGY, AKURE, NIGERIA.

www.jost.futa.edu.ng

*Centre for Research and Development (CERAD)* *JoST 2013*
*The Federal University of Technology, Akure, Nigeria*

# Design guide for structures service life against wind gust

**ADESOGAN, S.O.**
**Department of Civil Engineering, Federal University, Oye-Ekiti, Nigeria.**

**ABSTRACT: This paper gives a qualitative view of wind hazard in urban centres of southern Nigeria. It is observed that strong winds associated with rain storms at the beginning of the rainy season are a threat to urban centres as they directly affect buildings and infrastructures. Wind hazards also have indirect social and economic consequences on the communities affected. Much of the damages done to the infrastructures are as a result of inappropriate designs that have not taken into consideration the maximum wind speed in environment. This paper provides a guide to designs in wind environments for engineers in the design office. It modeled the wind speed in eight different urban centres of Nigeria and from there got the maximum design wind speed for southwestern Nigeria. The model was developed using Cook-Mayne (CM) method which adopted Monte Carlo techniques for obtaining wind load of a prescribed probability. The model gives the increase in the design speed at different calculated risks and at different structures desired. The best fitting line for Western Nigeria is given as $V_{max} = 90.88 + 11.5Y$**

**Key words:** Cook-Mayne; maximum; wind speed; life-time: margin of risk

JoST. 2013. 4(1): 18-26.
Accepted for Publication, March 11, 2013

## INTRODUCTION

The persistent media reports on rainstorm disasters for the past few years throughout the country and the plight of the affected people prompted the need for this research. The cost effect of the annual rip-offs with an assumed rip-off rate of about 1.5 houses per 1000 houses was estimated to be about 105 million Naira, sufficient to build about 200 new average fast-track low cost houses (Adesogan, 2011). Analysis of the annual rip-offs also indicated that about 90,000 man-days are wasted annually in reinstating the ripped-off roofs. The total homelessness effect from the annual ripped-off roofs has been estimated to be about 3600 persons and from environmental considerations, 300 logs are wasted on the reinstatement of the ripped-off roofs annually(Olomola,2002).

The collapse and the ripping off of roofing systems during rainstorms especially in the rural areas is a common occurrence in Nigeria throughout the rainy months. During these rainstorm disasters, a large number of our people are rendered homeless and personal and public properties worth several millions of Naira are always destroyed (Adenekan, 2000). It is widely acknowledged that disasters in developing countries are an integral part of their poverty cycle, and the gross domestic product lost due to natural disaster (including damages such as roof failure induced by natural disaster) is estimated to be about 20 times greater in developing countries than in developed countries (UNDP human development report 1994) (Adesogan,2011). The developed nations

Correspondence to: Adesogan, S.O., sunday.adesogan@fuoye.edu.ng

are not excluded from natural disaster each year several million American adults suffer injury or property damage due to natural disasters (Solomon, 1989). In several large household probability samples it has been discovered that approximately one-third of adults report exposure to a natural disaster during their life span. In addition, recent events confirm the potential impact of various natural disasters (e.g., the Great Midwest floods of '93; the Southern California fires of '93, Hurricanes Andrew '92, Iniki '92, and Hugo '89; the Oakland Hills fire '91, and the Loma Prieta earthquake '89) (Parry et. al,1995) . Victims of disasters can experience a variety of losses such as loss of loved ones, health, material possessions, animals, work, social environment, and dreams. When confronted by such losses, each person has to go through the grieving process and deal with their disaster experience in their own way. Some emotional reactions such as fear, sadness, pain or anxiety are linked to what has happened and these emotions affect the behaviour of individuals. The important message to share with those affected is that these reactions or behaviours are human, natural and normal. It's the disaster that is abnormal (Olaleye, 2005).

In Nigeria strong wind gusts are usually associated with linesqualls and harbingers of rainfall in West Africa (Ayoade, 1980). Figures 1 to 4 show the aftermath of a severe windstorm in different part of Ibadan on Monday the 18th of February, 2013. Despite the obvious pertinence of infrastuructures in everyday life, cases abound of structures ceasing to meet their intended functions as a result of failure/collapse. It is the incessant cases of structural failures and the exacerbating damages associated with it that has necessitated this paper.

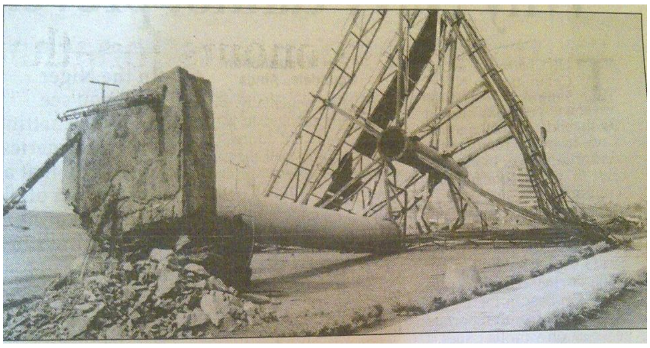

**Figure 1: A bill board destroyed by Storm at Tollgate**
**Source: The Nation Newspaper of 19 February, 2013**

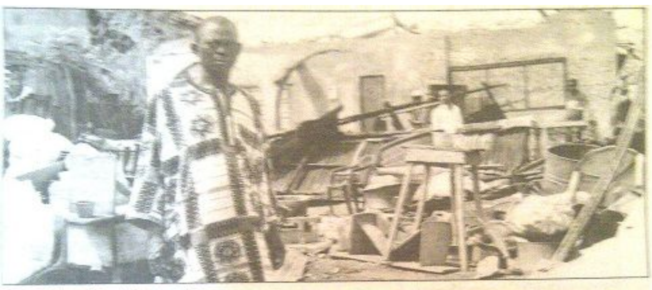

**Figure 2: An Affected building at Oranyan**
**Source: The Nation Newspaper of 19 February, 2013**

**Figure 3: Another area in Omi-adio affected by the storm**
**Source: The Nation Newspaper of 19 February, 2013**

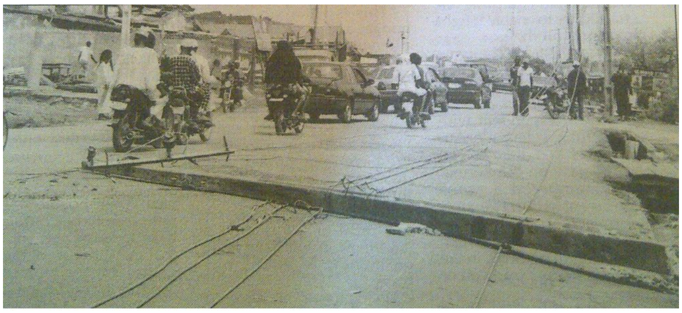

**Figure 4: PHCN pole affected by the storm**
**Source: The Nation Newspaper of 19 February, 2013**

## METHODOLOGY

The research is a purposeful data gathering survey to the Ministry of environment in Oyo state and Ibadan Metrological station. Data of maximum wind gust from the states in South-Western states were obtained from the metrological station in Ibadan for a period of five years (2002 – 2006). The methodology used in the paper is to model the wind speed of the area using Cook-Mayne (CM) method which adopted Monte Carlo techniques for obtaining wind load of a prescribed probability

This method approaches both the wind speed and pressure coefficient from an extreme value point of view. Cook – Mayne method noted that the probability density function of V follows a Weibull distribution so that the extreme value of V follows a Fisher Tippet type 1 distribution. Thus

$$P(v) = \exp(-\exp(-y_v)) \qquad \text{Eqn. 1}$$

Where $P(v)$ is the probability of the variable and $y$ is the calculated risk

It is generally accepted that the wind force (F) can be related to the maximum wind speed (V) by a relation of the form:

$$F = CV^2 \qquad \text{Eqn. 2}$$

Where C is a coefficient of proportionality called the shape factor

The structure's lifetime (T) can also be related to the probability (P) that the maximum velocity will not exceed the extreme value $V_{max}$, by the relation,

$$T = (1 - p)^{-1} \qquad \text{Eqn. 3}$$

For example if the required lifetime is 50 years, a maximum annual velocity $V_{max}$ which has not occurred for 98% of the annual records is stipulated. Sometimes the recording time may be too short for the required probability. In such cases extrapolation is possible if the available readings can be reduced to a certain graph. This method of extrapolation can be clarified by taking Abeokuta's record as an example. In this technique the maximum annual velocities ($V_{max}$), after being checked for homogeneity and consistency, are plotted against the reduced variate (V), as shown in Fig.4

Table 1 shows Abeokuta's annual maximum gust speeds between 2002 and 2006, arranged in an ascending order (Col. 2) with a corresponding rank r as shown in column 3, the probability of their non-recurrence, P (Col. 4), is calculated from the relation:

$$P = \frac{r}{N+1} \qquad \text{Eqn. 4}$$

Where: N, is the number of observations. Finally Column 5 indicates the reduced variate, Y, calculated from:

$$Y = -\ln(-\ln P) \qquad \text{Eqn. 5}$$

The required extreme value, $V_{max}$, is hence obtained from the linear relation, resulting from the best straight line through the field points which can be expressed as:

$$V_{max} = AY + B \qquad \text{Eqn. 6}$$

Where A, B are constants unique to the site. Numerical values for these constants can be found from the relations:

$$A = \frac{\sigma}{\sigma_N} \text{ and } B = V_{mean} - AY_N \qquad \text{Eqn. 7}$$

Where $\sigma_N$ and $Y_n$ are correction factors for a particular sample size, and $\sigma$ is the standard deviation. For a sample size of 40 (as for Abeokuta), Gumbel (1958) suggests the following values;

$$\sigma_N = 1.14132; \qquad Y_n = 0.54362$$

Calculating $\sigma$ as 21.55km/hr, the best straight line for Abeokuta can be obtained as:

$$V_{max} = 58.81 + 18.9Y \qquad \text{Eqn. 8}$$

Equation 6 is plotted in Fig. 4 and seems to fit through the field data in an acceptable manner. Extrapolation from that equation may be used for return periods beyond the present record.

The above technique is similarly followed for the 7 other stations at Ado Ekiti, Akure, Ikeja, Iwo, New Airport (Ibadan), Old Airport (Ibadan), Oshogbo. Similar graphs Fig. 5 – 11 are obtained and correspondingly similar equations to that of equation 6 are prepared as shown in Table 2. After this, the technique was adopted to calculate the maximum speed in the Zone (Fig. 12). It must be noted, however, that the numbers in Table 2 are corresponding to those in Fig. 4 – 12.

**Correction for the Maximum Speed**

Obviously the maximum velocity ($V_{max}$) for a return period of T years is in fact a statistical average, based on the mean value of several T-years. Thus if the return period T is increased, the percentage risk in selecting any design speed is decreased. Taking the example of Western Nigeria, Table 3 demonstrates the increase in the maximum allowable design wind speed at different calculated risks and at different structures desired lives. For example a factor of safety of not less than 1.87 times the average maximum velocity ($V_{max}$) is adequately needed if a structure of 100 years lifetime is to be constructed with a marginal risk not exceeds 10%.

Other corrections are necessary, for height, orientation factor, topographical and for gust period. This estimate may well be beyond the natural period of the structure, in which case a correction factor must be added.

**Table: 1: Maximum Annual Wind Speed at Abeokuta**

| Month (1) | Max. Gust (Km/hr) (2) | Rank R (3) | Frequency F (4) | Reduced Variate y (5) |
|---|---|---|---|---|
| 28.02. 2006 | 39.07 | 1 | 0.024 | -1.32 |
| 28.02. 2005 | 39.41 | 2 | 0.048 | -1.11 |
| 31.07. 2006 | 40.97 | 3 | 0.073 | -0.96 |
| 28.02. 2003 | 41.66 | 4 | 0.098 | -0.84 |
| 30.06. 2003 | 43.32 | 5 | 0.122 | -0.74 |
| 31.05. 2002 | 43.99 | 6 | 0.146 | -0.65 |
| 30.04. 2003 | 44.15 | 7 | 0.171 | -0.57 |
| 31.03. 2004 | 47.37 | 8 | 0.195 | -0.49 |
| 31.03. 2005 | 49.38 | 9 | 0.220 | -0.41 |
| 31.10. 2003 | 49.93 | 10 | 0.244 | -0.34 |
| 31.10. 2004 | 51.63 | 11 | 0.268 | -0.28 |
| 30.09. 2002 | 53.60 | 12 | 0.293 | -0.21 |
| 30.11. 2004 | 56.99 | 13 | 0.317 | -0.14 |
| 31.07. 2003 | 58.98 | 14 | 0.341 | -0.07 |
| 31.03. 2006 | 60.78 | 15 | 0.366 | -0.01 |
| 30.06. 2002 | 61.71 | 16 | 0.390 | 0.06 |
| 30.04. 2002 | 61.88 | 17 | 0.415 | 0.13 |
| 30.09. 2003 | 62.00 | 18 | 0.439 | 0.19 |
| 31.01. 2003 | 64.61 | 19 | 0.463 | 0.26 |
| 31.01. 2006 | 67.17 | 20 | 0.488 | 0.33 |
| 31.12. 2004 | 67.30 | 21 | 0.512 | 0.40 |
| 28.02. 2002 | 67.95 | 22 | 0.537 | 0.48 |
| 31.10. 2006 | 69.00 | 23 | 0.561 | 0.55 |
| 31.12. 2006 | 69.09 | 24 | 0.585 | 0.62 |
| 31.05. 2004 | 70.39 | 25 | 0.610 | 0.70 |
| 31.03. 2003 | 73.20 | 26 | 0.634 | 0.79 |
| 31.01. 2002 | 74.86 | 27 | 0.659 | 0.87 |
| 31.08. 2003 | 74.87 | 28 | 0.683 | 0.96 |
| 30.06. 2004 | 78.16 | 29 | 0.707 | 1.06 |
| 30.11. 2006 | 79.94 | 30 | 0.732 | 1.16 |
| 31.12. 2002 | 80.96 | 31 | 0.756 | 1.27 |
| 30.04. 2004 | 88.07 | 32 | 0.780 | 1.39 |
| 31.08. 2004 | 97.65 | 33 | 0.805 | 1.53 |
| 30.09. 2004 | 98.15 | 34 | 0.829 | 1.67 |
| 31.07. 2002 | 100.68 | 35 | 0.854 | 1.85 |
| 30.09. 2006 | 103.39 | 36 | 0.878 | 2.04 |
| 31.03. 2002 | 103.77 | 37 | 0.902 | 2.27 |
| 31.08. 2006 | 107.87 | 38 | 0.927 | 2.58 |
| 31.07. 2004 | 108.96 | 39 | 0.951 | 2.99 |
| 31.08. 2002 | 110.10 | 40 | 0.976 | 3.72 |

**Table 2: Best Fitting Lines for Eight Stations in Western Nigeria**

| No | Station | Representative Equation |
|---|---|---|
| 1 | Abeokuta | $^{V}max = 58.81 + 18.9Y$ |
| 2 | Ado Ekiti | $^{V}max = 37.50 + 17.4Y$ |
| 3 | Akure | $^{V}max = 39.80 + 17.4Y$ |
| 4 | Ikeja | $^{V}max = 61.79 + 22.0Y$ |
| 5 | Iwo | $^{V}max = 47.95 + 18.4Y$ |
| 6 | New Airport, Ibadan | $^{V}max = 45.01 + 18.1Y$ |
| 7 | Old Airport, Ibadan | $^{V}max = 42.62 + 17.9Y$ |
| 8 | Oshogbo | $^{V}max = 54.03 + 17.9Y$ |
| 9 | Western Nigeria zone | $^{V}max = 90.88 + 11.5Y$ |

**Table 3: Maximum wind speed in Western Nigeria ($VD_{max}$ = 90.88Km/hr) at Different Desired Lives and Different percentages of Risk**

| Desired (Yr) | 20 | | | 50 | | | 100 | | |
|---|---|---|---|---|---|---|---|---|---|
| Calculated Risk | 0.632 | 0.300 | 0.100 | 0.632 | 0.300 | 0.100 | 0.632 | 0.300 | 0.100 |
| T (yr) | 20 | 56 | 187 | 50 | 157 | 530 | 100 | 315 | 973 |
| $V_{-MAX}$ (m/s) | 125 | 137 | 151 | 137 | 149 | 163 | 144 | 157 | 170 |
| $V_{-MAX}$ $VD_{max}$ | 1.38 | 1.51 | 1.66 | 1.51 | 1.64 | 1.79 | 1.58 | 1.73 | 1.87 |

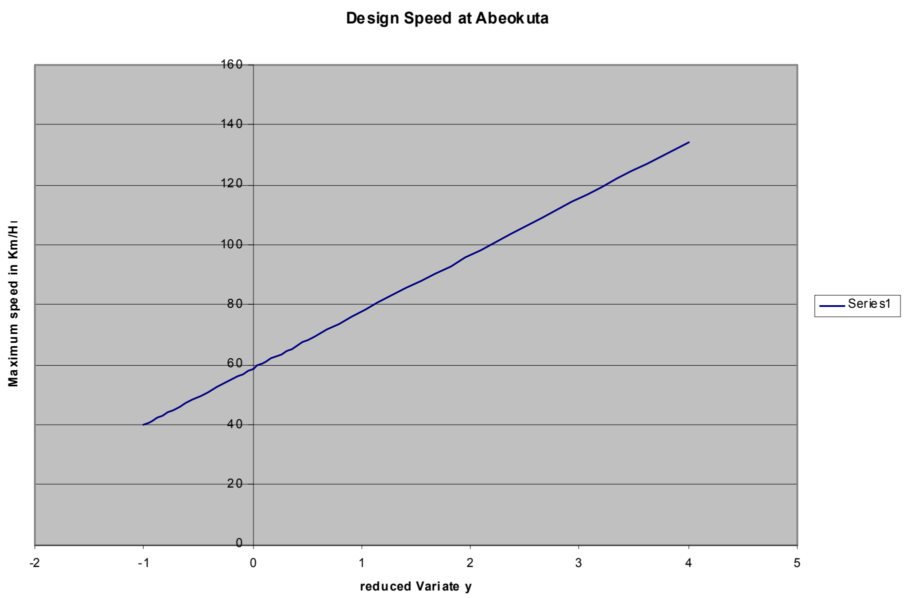


**Figure 4: Design Speed at Abeokuta**

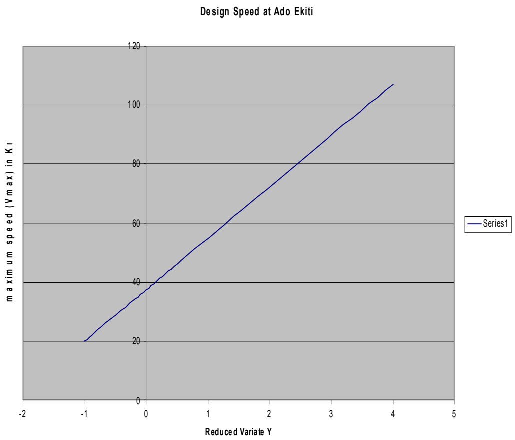


Figure 5: Design Speed at Ado Ekiti

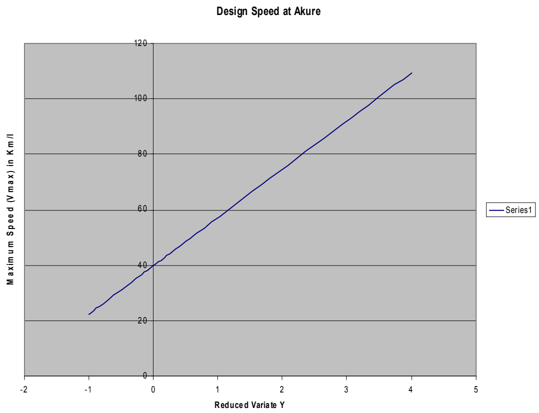


Figure 6: Design Speed at Akure

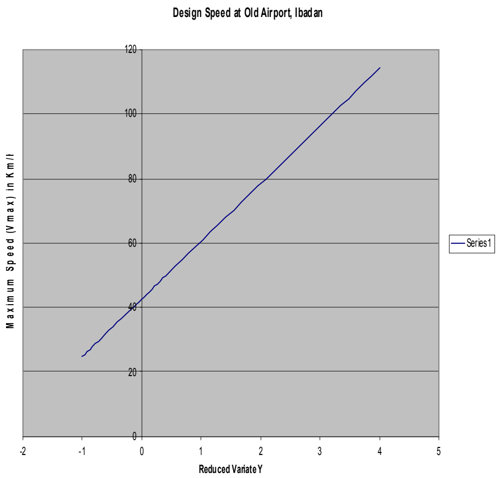


Figure 7: Design Speed at Old Airport, Ibadan

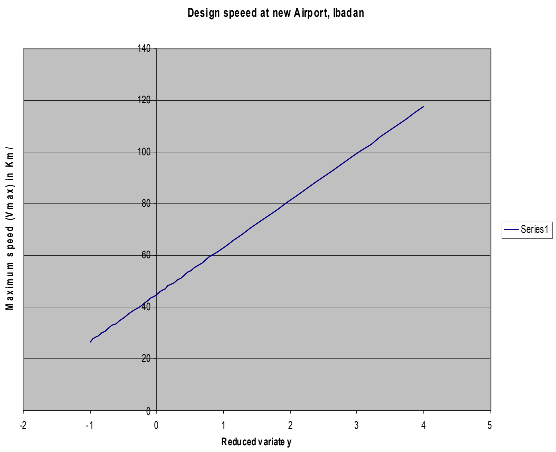


Figure 8: Design Speed at New Airport, Ibadan

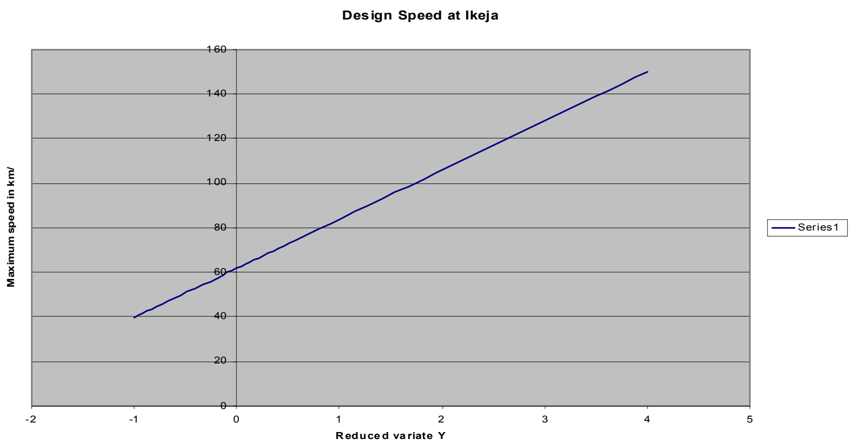


Figure 9: Design Speed at Ikeja

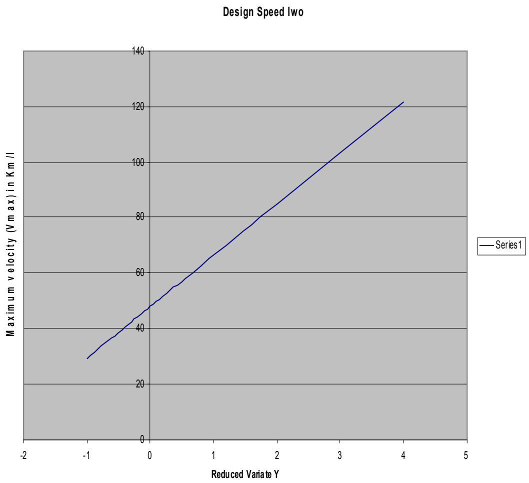


Figure 10: Design Speed at Iwo

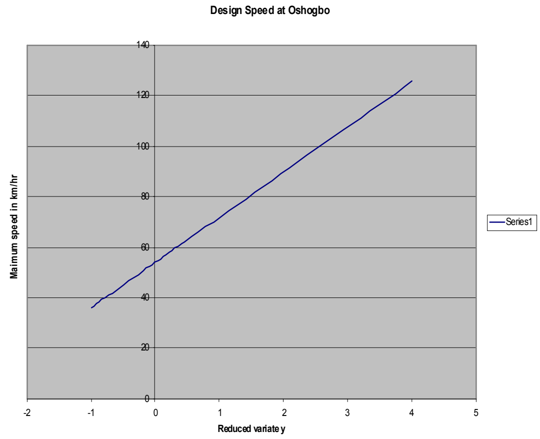


Figure 11: Design Speed at Oshogbo

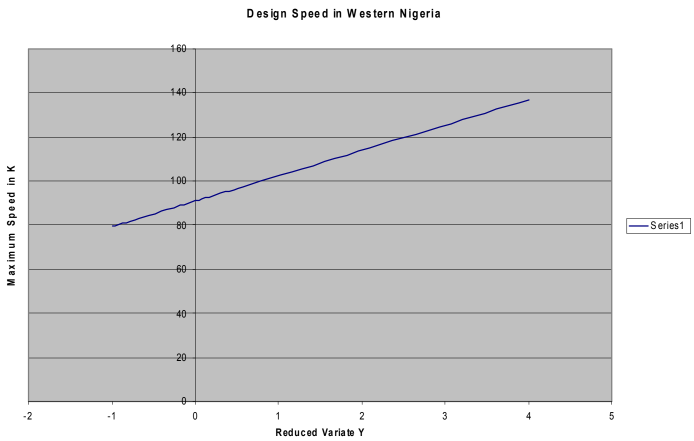


Figure 12: Design Speed in South-Western Nigeria

## RESULTS AND DISCUSSION

During rainstorm disasters, a large number of our people are rendered homeless and personal and public properties worth several millions of Naira are always destroyed. A great deal of these losses and inconveniences could be avoided, were the condition that lead to failure understood and precautions wee taken to guide against it. The causal factor of major rainfall disaster is wind. Wind being a fickle material needs to be given a great deal of interest. This model has therefore taken into consideration the fickleness of wind on structures.

The maximum design wind speed for various locations in Southern Nigeria could be obtained from the graphs above. Table 3 shows how the design engineers could vary the life span of a structure with various degree of probability in the design office. For example, if the desired life span of a structure is 20 years with 0.632 calculated risks, to obtain the max design wind speed, then proceed as follows:

$$\text{In}(.368) = 1$$

$$\text{In}(1) = 0$$

$$y = 0$$

and In(In(0.95)) = 2.97

From table 2 the design speed is
90.88 + 11.5Y = 90.88 = 125.03
but when the calculated risk is 0.3 then
In(-In(0.7) = 1.03 and the designed speed
90.88 + 11.5Y = 136.88

From the above, the new year of return period is obtained because the calculated risk has been correspondingly increased as follows

137 - 90.88 = 11y

y = 4.01

To obtain P, then - In(-In(p)) = 4.01

giving p = 98.21%

$$T = \frac{1}{(1-0.9821)} = 55.9 \text{ years}$$

Vulnerability to wind hazards can be reduced by the use of this model to obtain the adequate maximum design speed for any expected life span of the structure and at any degree of risk. Comparison of the model predictions and literatures show that a good forecast of maximum wind speed can be obtained by using the model. This model will enhance the design of structures against failure and supplement the design practice of using building codes and standards or performing experiments in wind tunnels

## RECOMMENDATIONS

From the research it is recommended as follows: That this model is to be incorporated into designs in Southwestern Nigeria and there should be a research in the area of characterization of windstorms by area and intensity. Also appropriate education and training of the whole community, more especially where wind hazards are a problem as in Southwestern Nigeria would be advantageous while Wind hazard awareness and preparedness should therefore be considered as integral aspects of development policy and planning of the environment in Nigeria at all levels of government.

## REFERENCES

**ADENEKAN O.I. (2000).** 'A Survey of Rainstorms as Weather Hazards in Southern-Nigeria', *Journal of the Environmentalist,* **20**(33)33-39

**ADESOGAN, S.O. (2011).** Roof Failure in the University of Ibadan, Unpublished Seminar Paper, Department of Agricultural Engineering, University of Ibadan, Nigeria.

**AYOADE, J.O. (1980).** A Note On Spatial And Seasonal Variations In Wind Speed Over Nigeria. *Singapore Journal of Tropical* Geography, **1**:11-15

**GUMEL, E.J. (1958).** Statistics of Exreme, Columbia University Press, New York

**THE NATION NEWSPAPER (2013).** Tuesday 19, February 2003, Vol.7, pg 8

**OLOMOLA, S.A. (2002).** Housing Today, The journal of the Association of housing Corporation of Nigeria, pp 38-39.

**OLALEYE, J.O. (2005).** Weather, climate and sustainable development, Text of a public lecture to commemorate the WHO day

**PARRY, M. and DUCAN, R. (1995).** The Economic Implication Of Climate Change In Britain, Earthscan Publications Limited 120 Pentonville Road, London N1 9JN

**SOLOMON O.A. (1989).** Causes and Effects of Natural Disasters in Nigeria, Unpublished Seminar Paper, Department of Civil Engineering, Obafemi Awolowo University, Ile-Ife Nigeria