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Investigating The Effect Of Wind Load On Multi-Storey Building

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Abstract— This work has investigated the effect of wind load on multi-storey building. A Finite element modelling and analysis on an example problem is performed in MIDAS/gen software to study the effect of wind on multi-storey building. The deflections, shear forces and bending moments of the frame structure were determined. Manual computation based on the BS code (BS 6399, Part 2, 1997) was also included. The study revealed that the first floor had lowest wind load of 112N/m^2 while the last floor (roof) had the highest value of 272 N/m.^{2} with displacement, shear force and bending moment value of (0.0086m) and 103.2445kN and 191 kNm respectively. Conclusively, the average wind speed, dynamic wind pressure, wind force, displacements (0.0013m to 0.0086m) increases and shear forces (1023.2343kN to 103.2445kN) decreases while the overturning moment (191kNm to 123kNm)decreases with increase in height. This implies that at greater heights, structures are more susceptible to wind loads. Thus, wind has a greater effect on tall building.

Keywords— wind load, multi-storey buildng, finite element, midas/gen, dynamic pressure, wind speed

I. INTRODUCTION

A structure refers to a system of two or more connected parts use to support a load. It is an assemblage of two or more basic components connected to each other so that they serve the user and carry the loads developing due to the se
lf and super-imposed loads safely without causing any :serviceability failure (Holme, 2011). Wind in general exerts forces and moments on the structure and its cladding and eventually distributes the air in and around the building mainly termed as wind pressure. Wind is defined by its strength and direction of blowing. High speed winds of short duration are called Gusts (Kumar and Swami, 2012).

Sometimes because of unpredictable nature of wind it takes so devastating form during some Wind Storms that it can upset the internal ventilation system when it passes into the building. For these reasons the study of air-flow is becoming integral with the planning a building and its environment. Wind forces are studied on tall buildings, low buildings, equal-sided block buildings and roofs and Cladding. Almost no investigations are made in the first two categories as the structure failures are rare, even the roofing and the cladding designs are not carefully designed, and localised wind pressures and suctions are receiving more attention.

Wind effects on structures continue to pose danger that continues to attract the attention of scientist round the globe. This is because of its trend of effect that changes with time, a dynamic problem, and inadequate information on the response of structures to wind action (Zhang et al., 1993). Wind loading competes with seismic loading as the dominant environmental loading for structures. They have produced roughly equal amounts of damage over a long time period, although large damaging earthquakes have tended to occur less often than severe windstorms (Douald, 1988).

II. LITERATURE REVIEW

The wind sensitivity of buildings and structures depends on several factors, the most important of which are the meteorological properties of the wind, type of exposure, and the aerodynamic and mechanical characteristics of the structure. An inventory of those various factors is presented; including indications of their relative influence on the global response (Davenport, 1998).An overview of the progress wind engineering has made over the past seven decades. There were papers on the galloping instability of prisms by (Parkinson, 1963) and of transmission lines, The treatment of gust pressures was discussed by (Harris and Davenport, 1963) and these were corroborated qualitatively from full scale measurements of pressures on the facade of a tall building (Newberry, 1963).

Recent trends towards slender, flexible and light-weight buildings have resulted in a large number of buildings being susceptible to wind induced motion and human perception of building motion has become a critical consideration in modern building design (Naylor, 2005). (Isyumov, 1999) overviewed the action of wind on tall buildings and structures with emphasis on the overall wind-induced structural loads and responses. Local wind pressures have great effect on components of the exterior envelope and on buildings in pedestrian areas. These may include buildings and structures of unusual shape, those located in complex settings or those with dynamic systems which amplify the time varying wind forces and whose motions may in turn alter the force field.

The Australian and New Zealand Wind Loading Standard stipulates that structures having a height to breadth ratio of 5 or more should be designed using dynamic analysis, the code also stipulates that the wind loads of structures taller than two hundred metres must be analyzed using the wind tunnel modelling technique. If the wind energy that is absorbed by the structure is found larger than the energy dissipated by structural damping, then the amplitude of oscillation will continue to increase and will finally lead to destruction (Swami,1987). (HolmesandLewis,1986) performed extensive experimental work on the fluctuating pressure measurements. (Niraj and Sharbanee, 2008) studied nine models with different rectangular cross-sections and were tested in a wind tunnel to study the characteristics of wind forces on tall buildings.

III. MATERIALS USED IN THE PREPARATION

The MIDAs GEN Software was the principal tool used for the modeling (analysis and design) multi-storey building of the structure. This was done based on the British and Euro code embedded in the software tool. The manual computation was intended basically for comparism with the outcome of the software application which was done using Finite Element Analysis method..

IV. EXPERIMENTAL PROCEDURE

Computation of wind loads

The British Standard Code of Practice, BS6399, Part 2,1997: outlines a method for estimating wind loads on buildings was adopted.

The steps and procedure adopted are listed below:

1.) Wind Data collection

2.) Computation of wind load (Standard method)

3.) Manual calculation using finite element analysis.

4.) Modelling and analysing using MIDAS/gen software application.

Table 3.1 Wind speed distribution in year

Month(2011)	Wind speed m/s
JAN	25.01
FEB	31.85
MAR	32.34
APRIL	34.88
MAY	30.48
JUNE	24.29
JULY	22.85
AUG	23.52
SEPT	19.69
OCT	19.60
NOV	20.38
DEC	23.89

Source: Nigerian Meteorological Department, Ilorin, Kwara State

Average wind speed for the year was calculated by adding the wind speed of each year and divide the total by the total number of months in a year.

Average wind speed = 26.0m/s

Now, the design wind speed can be calculated as

$$V_S = V \times S_1 \times S_2 \times S_3 \text{ (m/s)} \ldots\ldots\ldots 3.1$$

To compute the dynamic wind pressure

$$q = 0.613 \times V_s^2 \, N/m^2 \ldots\ldots\ldots 3.2$$

Also, the wind force can be computed using

$$F = C_f q A e \ldots\ldots\ldots 3.3$$

Given that the elements carry point loads q_1 and q_2 at the nodes as shown below, then the equilibrium equation for the system can be written as:

$$\frac{EI\partial^4 w}{\partial x^4} = q \ldots\ldots\ldots 3.4$$

The continuous variable w and its derivative $\partial w/\partial x$

denoted by, can be approximated in term of the nodal

values $w_1, \Theta_1, w_2, \Theta_2$ *and* w_3, Θ_3 through simple

function of the space variable N, known as the **shape function.** Thus for each element,

$$w = [N_1\ N_2\ \ N_3\ N_4\ ]\begin{bmatrix} w_1 \\ \Theta_1 \\ w_2 \\ \Theta_2 \end{bmatrix} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.5$$

This can be made exact by choosing cubic functions.

$$\begin{cases} N_1 = {}^1/_{L^3}\,(L^3 - 3L^2 + 2x^3) \\ N_2 = {}^1/_{L^2}\,(L^3x - 2L^2x^2 + x^3) \\ N_3 = {}^1/_{L^3}\,(3L^3 - 2x^3) \\ N_4 = {}^1/_{L^2}\,(x^3 - Lx^2) \end{cases} \ldots\ldots\ldots\ldots 3.6$$

Substituting the above equation (3.5 and 3.6) and

applying Galerkin's method.Also, by applying Green's theorem to evaluate the integrals, equation (3.7)

$$\begin{bmatrix} {}^{12}/_{L^3} & {}^6/_{L^2} & {}^{-12}/_{L^3} & {}^6/_{L^2} \\ {}^6/_{L^2} & {}^4/_L & -{}^6/_{L^2} & {}^2/_L \\ {}^2/_{L^2} & -{}^{12}/_{L^2} & -{}^6/_{L^3} & -{}^6/_L \\ {}^6/_{L^2} & -{}^{12}/_{L^2} & -{}^6/_{L^3} & {}^4/_{L^2} \end{bmatrix}\begin{pmatrix} w_1 \\ \theta_1 \\ w_2 \\ \theta_2 \end{pmatrix} = q\begin{bmatrix} F_1 \\ M_1 \\ F_2 \\ M_2 \end{bmatrix} ..3.6$$

The solution was solved using MATLAB

$$\begin{bmatrix} U_1 \\ U_2 \\ U_3 \\ U_4 \\ U_5 \\ U_6 \\ U_7 \\ U_8 \end{bmatrix} = \begin{bmatrix} \mathbf{0.0500} \\ \mathbf{0.0430} \\ \mathbf{0.0370} \\ \mathbf{0.0280} \\ \mathbf{0.0200} \\ \mathbf{0.0130} \\ \mathbf{0.00528} \\ \mathbf{0.0000} \end{bmatrix} \mathrm{m}$$

$$\begin{bmatrix} R_1 \\ R_2 \\ R_3 \\ R_4 \\ R_5 \\ R_6 \\ R_7 \\ R_8 \end{bmatrix} = \begin{bmatrix} \mathbf{161.5} \\ \mathbf{135.0} \\ \mathbf{105.0} \\ \mathbf{80.0} \\ \mathbf{50.0} \\ \mathbf{30.0} \\ \mathbf{0.0} \\ \mathbf{0.0} \end{bmatrix} \mathbf{kN}$$

$$\begin{bmatrix} M_1 \\ M_2 \\ M_3 \\ M_4 \\ M_5 \\ M_6 \\ M_7 \\ M_8 \end{bmatrix} = \begin{bmatrix} \mathbf{161.5} \\ \mathbf{168.2} \\ \mathbf{173.5} \\ \mathbf{177.2} \\ \mathbf{183.2} \\ \mathbf{185.7} \\ \mathbf{191.0} \\ \mathbf{2369} \end{bmatrix} \mathbf{kNm}$$

Software Application: MIDAS/Gen is a program for structural analysis and optimal design in the civil engineering and architecture domains. Part of MIDAS Family software package that is used for analysing and designing of different structures.

The following were the steps involved in modeling and analysing the structure (Senate building)

1. Creating the structural Diagram
2. Defining the Structural Properties
3. Defining the support conditions
4. Defining and Assigning of loads
5. Set analysis Option and run Analysis
6. Display of Desired Result.

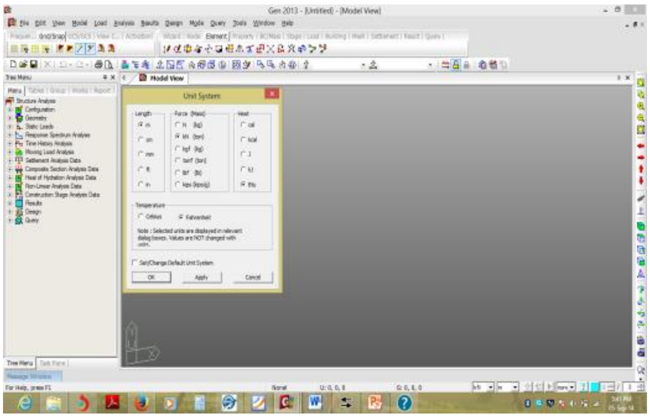

FIGURE 1: PRELIMINARY SETTING

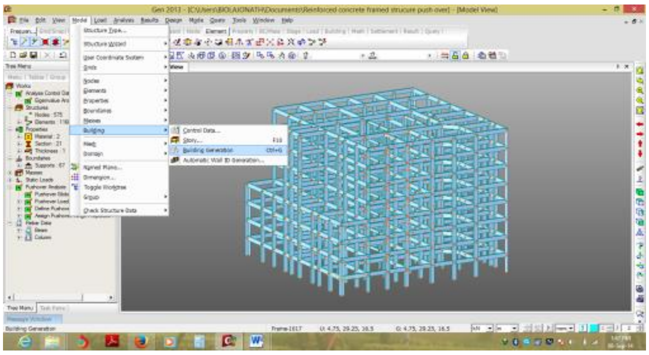

FIGURE 2: MODELLED STRUCTURE IN MIDAS/GEN

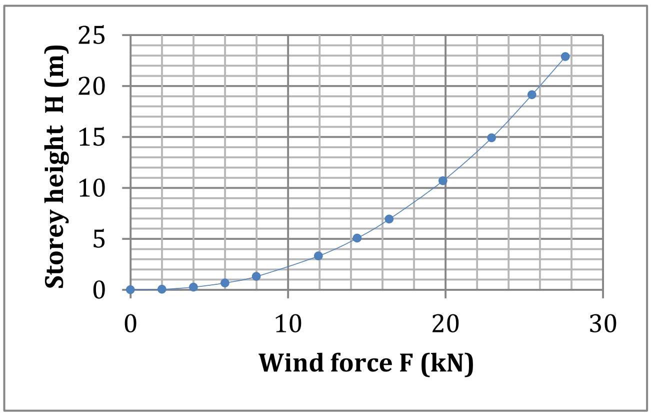

FIGURE 3.1:GRAPH OF WIND FORCE AGAINST STOREY LEVEL

V. RESULTS AND DISCUSSION

4.1 Result of Midas/gen

Table 4.1: Software output

Wind load	Floor	Overturning moment (B.F)	Forces (B.F)	Displacement m(B.F)
WY	8F	1.91E+02	103.2445	0.0086
WY	7F	7.83E+02	300.2344	0.0082
WY	6F	1.77E+03	498.544	0.0077
WY	5F	3.14E+03	645.5645	0.0068
WY	4F	4.89E+03	701.2334	0.0058
WY	3F	7.01E+03	825.6545	0.0044
WY	2F	9.49E+03	932.4355	0.0029
WY	1F	1.23E+04	1023.2343	0.0013

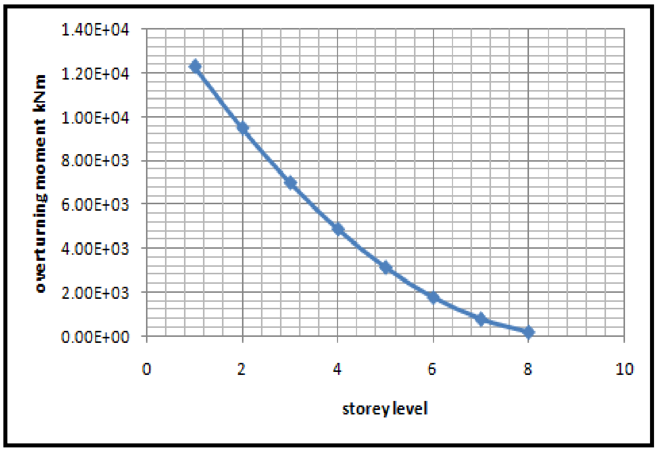

Figure 4.1: Graph of overturning moment against storey level

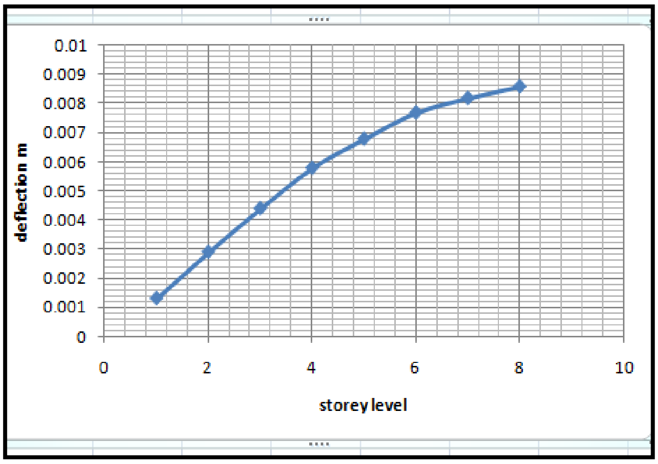

Figure 4.2: Graph of deflection against storey level

In table 4.1 above, the maximum displacements varies directly with respect to the storey level. That is, the displacement caused by the wind load on the structure increases due to increase in the storey level. When wind blows across a building, the earth provides a resisting force opposite to the direction of the motion to its velocity. This phenomenon causes the air velocity to reduce to zero. Meaning that effect of wind on part of the building close to the earth will be lesser compare to those at the top.

VI CONCLUSIONS

The study revealed that the first floor had lowest wind load of 112N/m^2 while the last floor (roof) had the highest value of 272 N/m.^{2} with displacement, shear force and bending moment value of (0.0086m) and 103.2445kN and 191 kNm respectively. Conclusively, the average wind speed, dynamic wind pressure, wind force, displacements (0.0013m to 0.0086m) increases and shear forces (1023.2343kN to 103.2445kN) decreases while the overturning moment (191kNm to 123kNm)decreases with increase in height. This implies that at greater heights, structures are more susceptible to wind loads. Thus, wind has a greater effect on tall building.

VII.ACKNOWLEDGMENT

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