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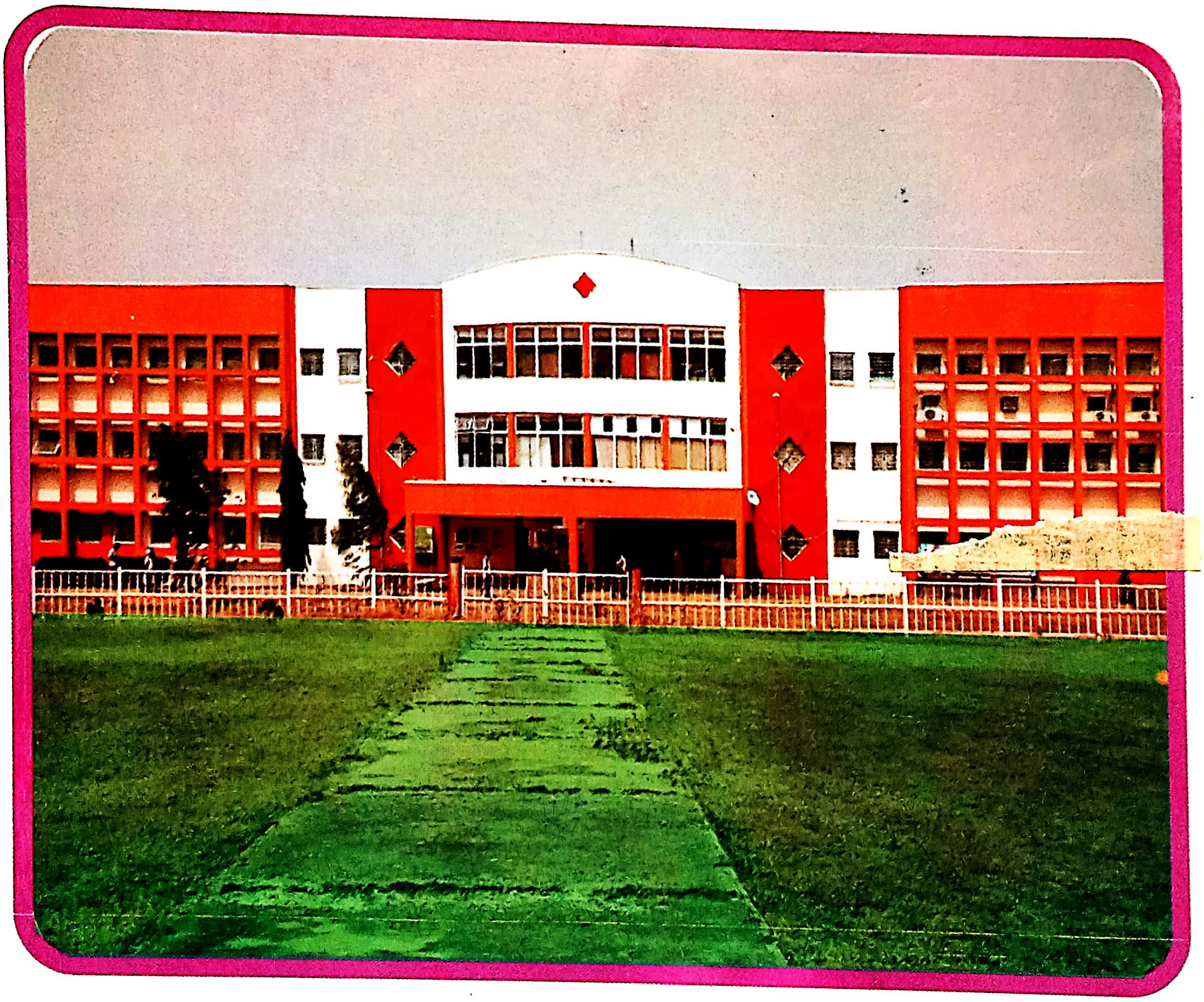

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COMPUTATION OF WIND LOAD FORCES ON TALL BUILDING USING VISUAL BASIC

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ABSTRACT

This paper presents computation of wind load forces on tall buildings of regular shape (circular, octagonal & hexagonal, square, rectangular), using Visual Basic. The conventional hand computations of wind loads which are most times rigorous and cumbersome to handle using both NSCP 1 and BS 6399 are presented. A programme called WAND is developed for the analysis using Visual Basic. Application of this programme is made on a 10-storey building and its drifts were computed. LIRA – a universal structural designing soft ware based on finite element method (FEM) is used to compute deflections from the given codes. Results obtained are compared. Drift of a 10-storey building is found to be 7.3mm (NSCP 1) and 50mm (BS 6399) using conventional hand computations; 7.40mm (NSCP 1) and 49mm (BS 6399) using WAND programme; 8.32mm (NSCP 1) and 48.7mm (BS 6399) using LIRA respectively. While this makes computation faster and accurate it does enable comparison to be made for the efficiencies of the codes, thus making the programme adequate for computation of wind load forces on building and enhancing revision on codes of practice in developing countries to be made.

Keywords: Analysis, Codes, Computations, Drift, Wind load.

1.0 INTRODUCTION

The effect of wind load on structures has continued to pose a great danger to the global community. In its publication New Steel Construction (2005), the US National Institute of Standards and Technology makes 30 recommendations to improve the safety of tall buildings on the collapse of the World Trade Centre. Among the eight core structural recommendations is: increased structural integrity – the standards for estimating the load effects of potential hazards (progressive collapse, wind) and the design of structural systems to mitigate the effect of those hazards should be improved to enhance structural integrity. Information and knowledge on the interaction of wind with structures whose effects are characterized with drift and acceleration becomes very important to a structural engineer (Bungale 1988) and details of this dynamic response of structures can be found in texts like Holmes (2001) and Sachs (1978). Thus, many methods have been employed to mitigate the effect of wind load on structures working from conventional hand computations to computer-aided software so as to also achieve better, precise, reliable result and subsequently structural integrity. Such computer programmes have been utilized to solve the problems of complexity in the analysis of wind and indeed in all design spheres of Civil Engineering. Simiu et al, (1986) assert that in certain situations it may be necessary to employ micrometeorological and aerodynamic models of tall buildings and to achieve this computer programme is needed. One of this is developed based on FORTRAN by Melaragno (1982) where he also makes use of a computer programme

STRUDL II developed at the Massachusetts Institute of Technology (MIT) to analyse the behaviour and deformation patterns of wind loading effects on tall buildings. Several Engineers have also put forward programmes executed in Microsoft Excel to analyse wind loads. However fewer designers have taken advantage of Visual Basic's excellent Graphic User Interface (GUI) to develop a programme that is both exact in its computations of wind loads and relatively easy to use.

It is the focus of this work to therefore present a programme developed using visual basic to compute wind loads on tall building according to Nigerian Standard Code of Practice (1973) and in comparison with Btritish Standard (1997).

2.0 VISUAL BASICS

Visual Basic is a tool that allows the development of Windows (Graphic User Interface – GUI) applications. The applications have an appearance of familiarity to the user. Visual Basic is event driven, meaning the code remains idle until called upon to respond to some event (button pressing, menu selection etc). Once an event is detected, the code corresponding to event procedure is executed. Programme control is then returned to the event procedure.

The original Visual Basic for DOS and Visual Basic for Windows were introduced in 1991. Visual Basic 3.0 with a vast improvement over previous versions was released in 1993. Visual Basic 4.0 was released in late 1995 in which 32 bit application support was introduced. Visual Basic 5.0 released in late 1996 initiated ActiveX controls, creation of new environments and phased out 16 bit application support. The current edition Visual Basic 6.0 was released in 1998 and offers a great variety of functions and flexibility making it the programme of choice for this thesis work.

Table 1 Wind velocities used in design

Exposure	Conditions of exposure	Design velocity km/h
A. Coast to 160km inland	Open country	112
	Built up areas	96
B. 160 – 480 km inland	Open country	120
	Built up areas	104
C. More than 480 km inland	Open country	144
	Built up areas	128

Source: Nigerian Standards Organisation (1973).

Table 2 Basic Wind Pressures

Height above sea level	Basic wind pressure in N/m^2 from design wind velocity in Km/hr					
	96	104	112	120	128	144
3	40	45	50	60	70	80
6	45	50	60	70	80	95
9	50	60	70	80	90	110
12	55	65	75	85	100	125
15	60	70	80	95	105	140
18	65	75	85	100	115	155
24	70	85	100	115	140	170
30	80	95	110	125	170	190
36	85	100	115	135	155	200
42	90	110	125	145	165	210
48	100	115	135	155	175	220
54	105	120	140	160	185	235
60 and over	110	125	145	170	190	240

Source: Nigerian Standards Organisation (1973).

Table 3 Shape factor

Horizontal cross section	Ratio of height to projected surface with (H/W)		
	X< 4	4 < X < 8	8 < X < 16
Circular	0.7	0.7	0.7
Octagonal & hexagonal	0.8	0.9	1.0
Square	0.8	0.9	1.0
Rectangular	1.0	1.15	1.3

Source: Nigerian Standards Organisation (1973).

3.0 METHODOLOGY:

The principal method and procedure adopted in this study for the programme are in accordance with Nigerian Standard Code of Practice for wind loads (NSCP 1973), BS (1997) and conventional method of wind loads analysis.

NSCP 1 (1973):

In this code, wind load on tall buildings are estimated as average excitation alone (NSCP 1973, Auta 2006a & 2006b). Wind pressures on buildings are calculated using certain parameters such as hourly mean wind speed, height of site above sea level, distance from sea, exposure (town, country) and the building height. The entire territory is subdivided into 3-zones according to their distances from the sea coast and has 2-basic exposures (Table 1). The procedure is outlined below:

- The wind velocity is first obtained directly from Table 1 in accordance with the conditions of wind exposure of the site. The design wind velocities given in the table are based on the highest gust velocities recorded by the Nigerian Meteorological Services.
- Using the design velocity obtained above, the basic pressure acting over the building surface is obtained from the table of basic wind pressures

given in the NSCP (1973) and reproduced as Table 2 below using equation (1). From Sachs (1978),

$$P_0 = 0.631V_e^2 \quad \text{...} (1)$$

Where V_e is the design or effective wind speed and P_0 is the basic wind pressure (Sachs 1978, BS 1997, Mendis 2007).

- The value obtained for basic wind pressure is used to compute for the design wind pressure on the building using equation (2); From Sachs (1978),

$$P = f_s P_0 C_e \quad \text{...} (2)$$

where f_s is the shape factor dependent on the shape of the building taken from Table 3; while C_e is the pressure coefficient 0.67 and 0.33 for the windward and leeside respectively. This is taken as 1 for the windward side and zero for the leeward side in this study.

- The value P obtained is then taken as the site wind pressure.
- The horizontal wind forces are then computed from the wind pressure, P. This is presented in Fig. 1.

BS 6399-2 (1997):

The British Standard Code of Practice BS 6399-2 outlines a method for estimating wind loads on Buildings as follow:

- From the wind speed map in the code of practice, determine the basic wind speed of the location.
- The site wind speed V_s is calculated as $V_s = V_b S_a S_d S_s S_p$ (BS 6399-2 clause 2.2.2)

Where V_b = basic wind speed S_a=altitude factor =1+0.001xheight of building above sea level (this works if topography is not significant, but as a general rule, any site halfway up a hill or ridge or cliff will have increased loading and a more detailed calculation of S will be required) (BS 6399-2 clause 2.2.2.2, 1997). S_d = direction factor to account for the wind direction (BS 6399-2 table 3,1997). S_s = Seasonal factor may be used to reduce the basic wind speeds for buildings expected to be exposed to the wind for specific sub annual periods, in particular for temporary structures and those under construction. For all permanent structures, S_s = 1(BS 6399-2 clause 2.2.2.4, 1997) S_p = Probability factor =1for all normal design applications (BS 6399-2, clause 2.2.2.5, 1997).

- Effective wind speed V_e is calculated as $V_e = V_s S_b$ (BS 6399-2, clause 2.2.3, 1997)

Where S_b = terrain and building factor to account for the terrain of the building site and its location (BS 6399-2, Table 4).

- Dynamic pressure $q_s = 0.613V_e^2$ (BS 6399-2 clause 3.1.2.1, 1997).
- Calculate wind loads as; $p_e = q_s C_{pe} C_a$ (BS 6399-2 clause 3.1.3.1.1, 1997).
- Where C_{pe}= external pressure coefficient (BS 6399-2 clause 3.1.2.2, 1997); C_a = size effect factor = 1; Internal $p_i = q_s C_{pi} C_a$; C_{pi} = internal pressure coefficient (BS 6399-2 clause 3.3.5, 1997); wind load acting on the structure $p = p_e - p_i$ (KN/m^2) (BS 6399-2 clause 3.1.3.1.3, 1997).
- The final horizontal wind forces for BS 6399 are presented in Table 4.

4.0 THE PROGRAMME AND ITS APPLICATION TO WIND ANALYSIS

Visual Basic is a powerful programming tool and one of the most versatile and popular software development languages. It is a fully event driven language with strong support for proper software engineering techniques. It is used to create web pages with dynamic and interactive conten , develop large scale enterprise applica ns etc. All formulae and tables are embedd d in code developed using the program e. The programme is first started by c' cking the icon of the programme in the stand alone mode and entering p rsonal details on the welcome page that pops up as outlir ed l elow:

- A ter inputting these, the WAND homepage is displayed from which site location and the appropriate code (NSCP 1973) to be used for the analysis is selected (Figure 1 & 2).
- On clicking the enter button, another page for the input of other site and building details is displayed. The page displayed depends on the code selected for use (Figure 3 & 4).
- On clicking the appropriate buttons, wind pressures, storey forces and member forces are calculated (Figure 5 & 6);
- The deflections on each storey as well as the total and cumulative deflections are then calculated and a message box is displayed to show if deflection is within the allowable limits or not.

A summary of the program's step by step methodology is provided in the flowchart shown in Figure 8.

5.0 PROGRAM SOURCE CODES

The progr mme is provided in Forms 1 to 9. Here with s presented the first part (Form 1):

Form 1:

```
Privat Sub Command1_Click()
If Command1.Enabled = True Then Call
Form2.Show
Form1.Hide
Form2.Print "Welcome" & Form1.Text1
& " " & Form1.Text2 & " to the"
Form2.Print "Institute for the"
Form2.Print "Development of"
Form2.Print "Enhanced"
Form2.Print "Automated"
Form2.Print "Structural systems
(I.D.E.A.S.) inc."
Form2.Print "Wind Analysis and Design
(WAND) Program"
End Sub
Private Sub Form_Load()
End Sub
Private Sub mnuhelpabout_Click()
Dim msg As String
msg = "My Awesome Menu App" &
vbCrLf
msg = msg & "by me " & vbCrLf &
vbCrLf
msg = msg & "Copyright 2010 by me"
MsgBox msg, vbInformation, "About"
End Sub

Private Sub mnufileexit_click()

Dim Response As Integer
Response = MsgBox("Are you sure you
want to quit?", vbQuestion Or vbYesNo,
"Exit")
If Response = vbYes Then End
End Sub
Private Sub mnufileopen_click()
MsgBox "You chose the open command"
End Sub
```

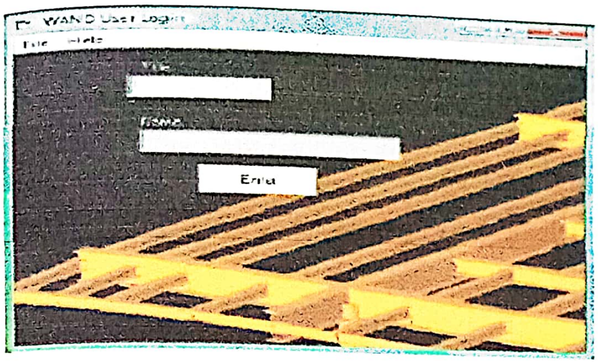

Figure 1 Log-in interface

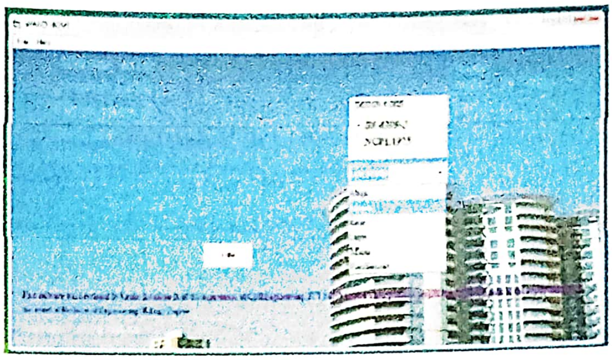

Figure 2 WAND home page

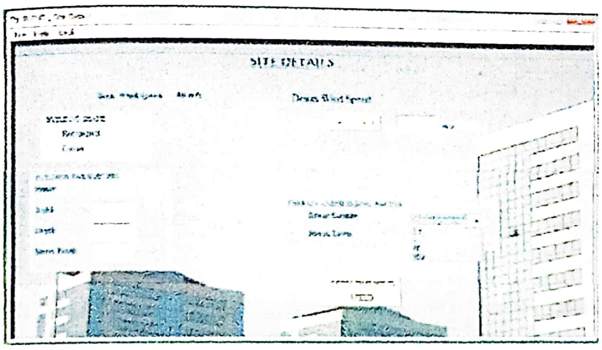

Figure 3 BS 6399 details page

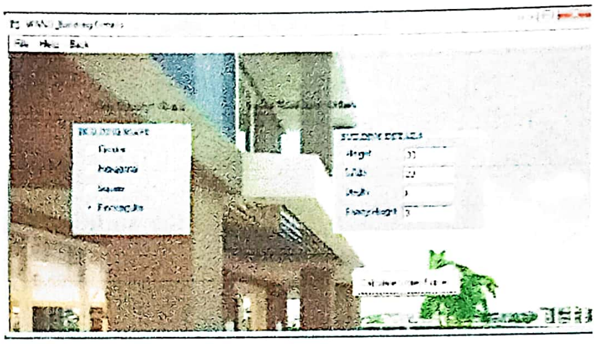

Figure 4 NCP 1 building details page

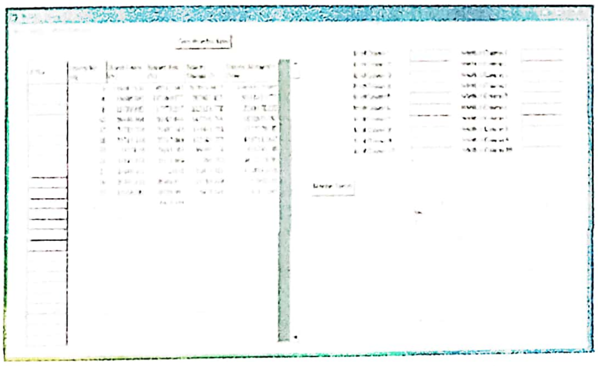

Figure 5 Storey forces using BS 6399-2

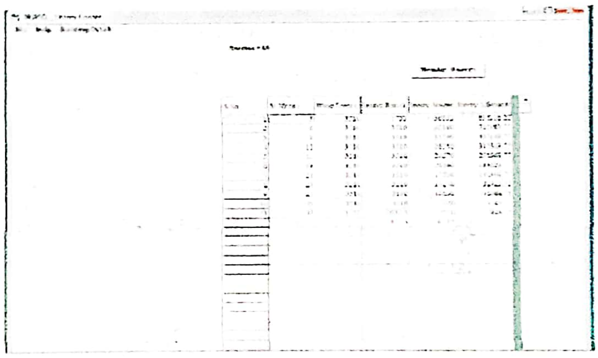

Figure 6 Storey and moments forces using NCP 1

6.0 CONVENTIONAL WIND ANALYSIS USING NSCP 1

The wind analysis of a structure is best illustrated by an example as is carried out below. The design is of a ten storey single bay rigid frame structure of 33m height, 20m width and 6m depth between bays. Each storey is of equal height of 3m. An average wind speed of 40m/s as obtained from the Nigerian Meteorological Agency for Minna is assumed for the design. The design steps are outlined below:

- Obtain a wind speed from meteorological data or wind speed maps of an area.
- Obtain a design wind speed and wind pressure from Nigerian code procedure described above.
- Obtain the horizontal load on each storey (W) by (Pressure, *P*) x (Storey height, *h*) x (Distance between frames, *l*)

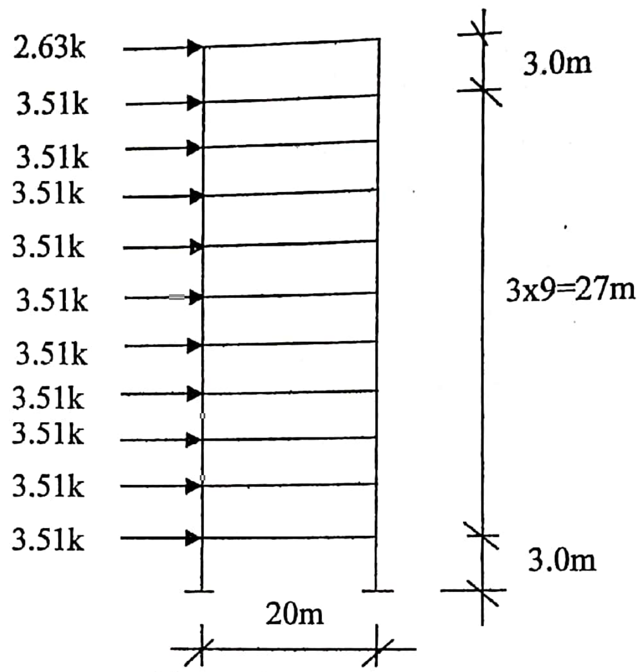

Figure 7: Frame of the building with wind load forces according to NSCP 1

- Obtain the reactive forces (P) at the different levels by: Roof and ground floor $= \frac{W}{2}$; other floors $= \frac{W_1 + W_2}{2}$
- Calculate the moments of inertia I of each storey about the neutral axis.
- Calculate the storey shears and moments in each storey by:
  Top storey shear = P_1, Top storey moment = $P_1(h_t/2)$, Other storey shears = $P_1 + P_2$, Other storey moments = Previous moment + (Previous shear x height) + (Storey reaction) x $(h_t/2)$
- Calculate the axial forces in the column using equation (3), from Mosley and Bomgey (1987) and Oyenuga (2001),

$$F = {}^{My}/_{I} \quad \text{......} \quad (3)$$

Where M = storey moment, y = Distance of the column from the neutral axis, I = moment of inertia about the neutral axis = $2(ad^2)$ (a = area of column or beam, d = distance from the neutral axis)

- Calculate beam shears by satisfying statical equilibrium which is the sum of forces at a joint should be zero (Mosley 1987, McGinley and Choo 1990, Oyenuga 2001)
- Calculate beam moments by multiplying the beam shears with half the beam length. Column moments are then calculated by satisfying moment equilibrium at the joints.
- Calculate column shears by dividing the column moments by half the storey height.
- Calculate the cantilever deflection Δ_c by first assuming the storey is acted upon by a UDL of P/h_t and then using equation (4), from Sachs (1978),

$$\Delta_c = wL^4/8EI \quad \text{......} \quad (4)$$

Where, L = storey height from the ground, E = Young's modulus of elasticity

- Calculate the shear deflection by using equation (5), from Bungale (1988),

$$\Delta_s = V h_t^2 [\left(\frac{h_c}{\Sigma I_c}\right) + \left(\frac{1}{\Sigma(I_b/L_b)}\right) \quad \ldots\ldots (5)$$

Where, V = accumulated shear from the top at storey inclusive, h_t = storey height, I_c = moment of inertia of column (Rectangle = $bh^3/12$, circular = $\pi D^4/64$), I_b = moment of inertia of beam/girder, L_b = Length of beam/girder

- Finally calculate total storey deflection Δ ,which should not exceed H/500 (Sachs 1978, BS 1997, Mendis 2007), using equation (6),

$$\Delta = \Delta_c + \Delta_s \quad \ldots\ldots (6)$$

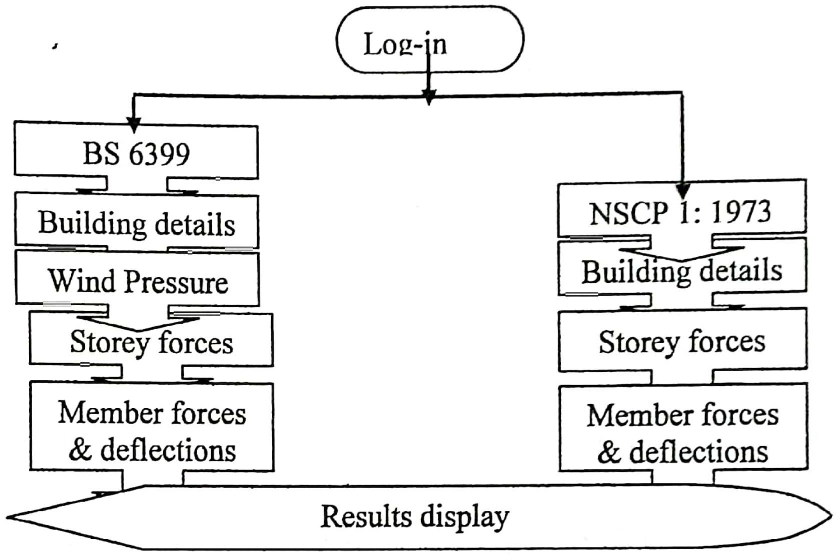

Figure 8 Flowchart of the programme WAND

Assumptions made:

- The entire structure is a single bay symmetrical frame
- All columns on a storey are of equal area (0.4m x 0.4m)
- Points of contra flexure are assumed at midpoints of beams and columns.
- All pressures and loads considered were only on the windward side for the purpose of the study as shown on Figure 7.
- Pressure coefficient is taken as C_e=1, to compensate for the account of leeward forces.

□Given data:

Average wind speed = 40m/s; Building height = 33m; Building width = 20m; Column size = 0.4mx0.4m; Beam size = 0.4mx0.4m; Modulus of elasticity E = 200GPa; Moment of inertia about frame I = 18m^4; Moment of inertia of column I_c = 0.083m^4; Moment of inertia of beam (girder) = 0.083m^4.

- The conventional hand computation is done also using the BS code (1997) of practice and the result is presented in Table 4.

7.0 ANALYSIS USING THE PROGRAM

As stated above, the WAND program analyses and designs rigid frames using wind loads. Using the same parameters as those used for the hand design espoused above, similar results were obtained from the program. These results can be saved to any directory on the computer system in use and later opened using Microsoft word or any word processing software.

Table 4 Summary of Wind Load Forces Analysis.

Function	Floor	MANUAL NSCP	MANUAL BS 6399	Programme WAND NSCP	Programme WAND BS 6399	LIRA NSCP	LIRA BS 6399
Wind load forces, kN	Ground floor	1.76	6.53	1.76	6.53	1.76	6.53
	1	3.51	14.73	3.51	14.73	3.51	14.73
	2	3.51	17.58	3.51	17.58	3.51	17.58
	3	3.51	19.64	3.51	19.64	3.51	19.64
	4	3.51	21.18	3.51	21.18	3.51	21.18
	5	3.51	22.27	3.51	22.27	3.51	22.27
	6	3.51	23.13	3.51	23.13	3.51	23.13
	7	3.51	23.87	3.51	23.87	3.51	23.87
	8	3.51	24.52	3.51	24.52	3.51	24.52
	9	3.51	25.17	3.51	25.17	3.51	25.17
	10	3.51	19.23	3.51	19.23	3.51	19.23
	Roof	2.63	6.48	2.63	6.48	2.63	6.48
Moment, M_{max}, kN.m	Ground floor	529.14	3564.16	633.12	3564.16	620.7	3627.2
Shear force, Q_{max}, kN	Ground floor	33.35	217.78	36.86	217.78	18.92	109.13
Deflection Δ_{max}, mm	Roof level	7.30	50.00	7.40	49.00	8.32	48.70
Allowable deflection, Δ_{max} <H/500 mm	Roof level	<66, o.k	<66, o.k	<66, o.k	<66, o.k	<66, o.k	<66, o.k

8.0 DISCUSSION OF RESULTS

The result of the study is presented and tabulated on Table 3. From the result it is evident that maximum bending moment M_{max} will appear at the ground level as a result of the lateral (wind load) forces. The highest being recorded in results for computations based on BS 6399 in both manual, WAND and LIRA based computations and closely equal to 3564.16kN.m, but differ from LIRA (3627.2kN.m) by 2% from the rest.

The allowable deflection is considered to be, Δ_{max}=H/500 (Sachs 1978, BS 1997, Mendis 2007). In view of this, all cases of computations considered from Table 4, show that all deflections are within allowable. However, larger deflections were obtained in all cases of computations using BS 6399 with manual computation according to BS 6399 taking the lead of 50mm but yet <H/500=66mm.

The major factor in displaying results between the BS6399 and NSCP which was fairly constant (≈84.5%) is as a result of value of IE taken and assumption made such as uniform lateral load along the height of the building. This trend is affirmed by the result obtained from computations using LIRA whose computation are based on Finite Element Method (FEM).

CONCLUSION

Depending on the input, comparison of deductions and analysis of wind load has been made possible using the programme, WAND which is affirmed by the computations made using LIRA.

The programme has enhanced comparison of national codes on wind load to be made besides the fact that it has fastened computations to be made than the conventional hand computations which are rigorous, cumbersome and time consuming.

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