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WIND LOAD ESTIMATION ON TALL BUILDING PART I: COMPARISON OF RUSSIAN AND NIGERIAN CODES OF PRACTICE

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ABSTRACT

This paper presents a comparison study of Russian and Nigerian standards and codes of practice on wind load estimation for tall buildings. Despite the similarity of the philosophy on which the codes were developed some sizable scatter exist among the wind loading estimation by the codes under similar wind flow conditions and location. Hence the paper seeks to present this scatter as regards static behaviour of a 10-storey building. It is to be noted that the scatter in the predicted wind load arises primarily from the variations in wind field factors and their values recommended in both codes.

Keyword: Codes and standards, static behaviour, wind load, comparison, deflection, tall building

1. INTRODUCTION

Every nation has either developed or in the process of developing its own codes of practice because of its environmental factors peculiar to it among others. In this wise Nigeria and Russia have theirs namely NSCP I [1] and SNiP [2] respectively. Codes have generally been written since 1970 [3] and a lot of researches are still on, in order to perfect these codes as deeper understanding grows about the response of structures to wind load.

Some of these researches that have been carried out in this area of comparison, have been made limited to most international codes and standards which include works listed in [4 – 7]. Recommendations from these studies are being adopted by major international codes and standards [6], in the bid to unify their application globally. With this rising trend for the international codes and standards, some of the national codes are becoming unpopular.

NSCP I has been written since 1973 and undergoing perfection, but cannot attain this in isolation except compared with other existing national codes and standards. Hence in this study SNiP is chosen for this comparison study.

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2. RUSSIAN CODE AND STANDARD (SNIP)

SNiP recommends that wind load on tall buildings shall be estimated as the sum total of average and pulsation excitations. Procedure of wind load calculation is outlined below.

Basic wind pressure map and zoning: Wind pressure on the entire territory of the Russian federation is distributed into 8 zones (I, Ia, II, III, IV, V, VI, VII) and have 3 exposures A, B and C, where A – open country with no obstruction; B - township territory with obstruction more than 10 meter height; C – large cities territory with obstructions more than 25 meter height. Here the nominal wind pressure is already deduced and therefore, for any given location, is obtained directly from the Table given for all the zones (I, Ia – VII) from the map. These values are obtainable from Tables 5, 6 and 7 of the Code.

Wind pressure coefficient. Application of pressure coefficients and others like shape factor, height factor, dynamic coefficient to the nominal wind pressure proceeds to obtain design wind load.

Design wind load. The design wind load is obtained from Eq. (1) through Eqs. (2 and 3) as shown below:

$$w = w_c + w_p, \tag{1}$$

$$w_c = w_0 . k . c, \tag{2}$$

$$w_p = 1.4 w_{ph} (z/h) \xi, \tag{3}$$

where w_c – is the average wind pressure, w_p – wind pressure due to pulsation; w_0 – nominal wind pressure; w_{ph} – nominal pulsation wind pressure at the top height (h) of the building; k – height factor; ξ – dynamic coefficient; z – height at which pulsation wind pressure is being determined.

3. NIGERIAN STANDARD CODE OF PRACTICE (NSCP I)

In NSCP I wind load on tall buildings are estimated as average excitation alone. But the pressure coefficients, shape factor and uniform distribution of the wind pressure along the vertical surfaces of the building recommended by NSCP I, even though differ from that of SNiP seem to compensate for the differences. Procedure of wind load calculation is outlined below.

Basic wind pressure map and zoning: The entire territory is subdivided into 3 zones (I–160 km from the coast; II–160-480 km inland; II– more than 480 km inland) according to their distances from the sea coast and have 2 basic exposures (A– open country; and B– built up areas). Unlike in SNiP, for any given location the basic (nominal) wind speed is first obtained directly from the Table according to exposure and subsequently, the nominal wind pressure from Table 4 and 5 of the Code respectively.

Wind pressure coefficient: For separate standing vertical surfaces of a tall buildings, pressure coefficient c_e= 0.67 and 0.33 is recommended for windward and leeward faces respectively.

Design wind load: Design wind load from NSCP I can be calculated from Eq. (4) below:

$$P=f_s.q_0.c_e, \quad (4)$$

where q_0 – is the nominal wind pressure; v_0 – is the nominal wind velocity; f_s – is the shape factor obtainable from Table 6 of the code; c_e – is the pressure coefficient.

4. STATIC BEHAVIOUR OF A 10-STOREY BUILDING

To demonstrate the static behaviour of a tall building and also account for the differences between NSCP I and SNiP, an example of an existing building is employed. A 10-storey reinforced concrete framed building [8], which is considerably tall enough for this study. The building consists of rigid moment resisting frames spaced at 4.5m along the length of the building with uniform cross-sectional area and constant stiffness for both the girders and the struts.

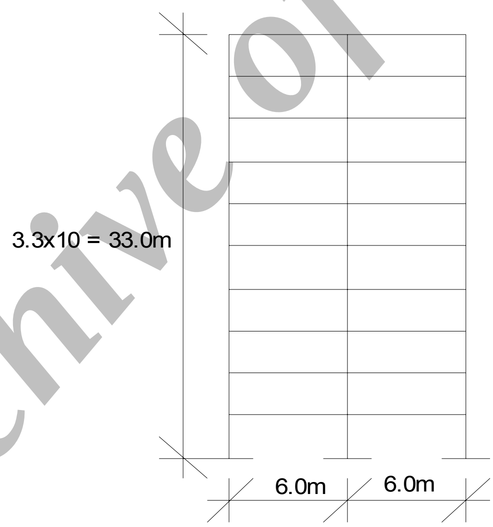

Figure 1. The 10-storey analytic frame model of a building.

The analytic frame is figured out in figure 1. Procedure of the computations is according to both codes as outlined previous paragraphs under both codes and summary of input data recommended by both codes for vertical structures such as the 10-storey building for the case study are presented in Table 1. The wind load at the nodes of the frame, are presented in Table 2. For this static analysis, a structural analysis software popularly known as Lira was used. However, it is to be noted that dead weight of the structure was not taken into account since the analysis is assumed for this study to be linear. The result of the analysis is presented in Table 3.

Table 1. Input data

	SNiP	NSCP I
Wind zone, exposure, nominal wind pressure and speed	Zone II; A – open country with no obstruction, near sea bank; w_0=0.30 kN/m^2 (table 5); v_0=22.18 m/s;	Zone I (equivalent zone); A– open country with no obstruction, near sea bank; *v_0=31 m/s (Table 4); q_0=1.125 kN/m^2 (Table 5). *v_0=31m/s^2 is the only value recommended within under which v_0^{SNiP}=22.18 m/s^2 fall with the same exposure A (Table 4).
Coefficients and factors	c=0.8, -0.6; w_{ph}=0.36m/s^2; k, ξ – vary in value with height z along the height of the building, h.	f_s=1 (table 6); c_e=0.67, -0.33; ±sign indicates windward and leeward sides of the building
Final wind load	Final wind load F is obtained from the expression F=A.w, where A – is the surface area=14.85m^2; w or P– final design wind pressure from Eqs. (1) and (4) for either codes applied appropriately.	

Table 2. Summary of wind load for the 10-storey frame

	Floor number	NSCP I		SNiP	
		Total wind load, F (kN)		Total wind load, F (kN)	
		Windward, F_{wi}	Leeward, F_{li}	Windward, F_{wi}	Leeward, F_{li}
Wind load at the nodes of the 10-storey analytic frame	1	F_{w1} = 16.791	F_{l1} = 8.271	F_{w1} = 3.562	F_{l1} = 2.672
	2	F_{w2} = 11.194	F_{l2} = 5.514	F_{w2} = 4.449	F_{l2} = 3.337
	3	F_{w3} = 11.194	F_{l3} = 5.514	F_{w3} = 5.338	F_{l3} = 4.004
	4	F_{w4} = 11.194	F_{l4} = 5.514	F_{w4} = 6.225	F_{l4} = 4.669
	5	F_{w5} = 11.194	F_{l5} = 5.514	F_{w5} = 6.668	F_{l5} = 5.001
	6	F_{w6} = 11.194	F_{l6} = 5.514	F_{w6} = 7.556	F_{l6} = 5.667
	7	F_{w7} = 11.194	F_{l7} = 5.514	F_{w7} = 8.444	F_{l7} = 6.333
	8	F_{w8} = 11.194	F_{l8} = 5.514	F_{w8} = 8.886	F_{l8} = 6.665
	9	F_{w9} = 11.194	F_{l9} = 5.514	F_{w9} = 9.329	F_{l9} = 6.997

10	F_{w10} = 5.597	F_{l10} = 2.757	F_{w10} = 4.886	F_{l10} = 3.665

Table 3. Result of the static calculations

		SNiP	**NSCP I**	**Discrepancy**
Static behaviour of the frame	Drift, δ_{max}, (mm)	24.0	28.0	16%
	Drift limit, δ_{lim}, (mm)		66.0	
	Maximum bending moment, M_{max}, (kN.m)	89.97	125.52	28%
	Minimum shear force, Q_{min}, (kN)	50.59	66.85	24%

5. DISCUSSION AND CONCLUSION

The result as indicated in table 3 under static calculations using Lira, show that the drift of the top floor for both codes are within limit of 66.0 mm, even though that of NSCP I is more than SNiP by 16%. Further more, the maximum bending moment in the column from NSCP I is also more than SNiP by 28% and its minimum shear force again more than that from SNiP by 24%. The high values obtained in all cases from NSCP I can be attributed to the uniform distribution of design wind pressure over the entire vertical surfaces of the building along its height [1]. Factors such as dynamic coefficient and height factor present in SNiP along side with the inclusion of pulsation wind load effect, which are not defined in NSCP I, seemed to be compensated for, by the uniform distribution of design wind pressure over the vertical surfaces of the building.

In conclusion, the study of wind estimation per NSCP I and SNiP has been presented as regard the static behaviour of the building. Even though the NSCP I seems to be more conservative than SNiP in simplicity and application, it can cause over design of a structure and hence can be uneconomical if the factors, such as criteria for wind pulsation, are not fully defined especially for tall buildings.

In the second part of this paper I intend to investigate the dynamic behaviour of the building according to both codes, using numerical analysis.

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