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

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ABSTRACT

In this second part of a two-paper, presents a comparison study of Russian and Nigerian standards and codes of practice on wind load estimation on tall building with reference to its dynamic behaviour. Under the same conditions of wind flow, dynamic analysis of the building is carried out using numerical method and the differences in the drifts and accelerations estimated for both codes are identified to be related to wind field factors and values recommended by both codes. The result of the dynamic analysis indicates that Nigerian code of practice is more conservative than the Russian.

Keyword: Codes and standards, dynamic behaviour, wind load, drift, acceleration, numerical method

1. INTRODUCTION

Most of the research work carried out in the area of comparing codes for wind load estimation on buildings and structures are in most cases limited to international codes [1-4] and hence their recommendations are being adopted by some of these codes. However their unified global application can be more effective when local wind factors as applicable to region of construction are also considered. These factors vary from one nation and region to another, and to account for them national codes need to be compared in order to bring these factors into view. The result can subsequently serve in correlating them even with the international codes.

This study therefore considers in this wisdom the Russian standard, SNiP [5] and Nigerian standard code of practice, NSCP I [6], comparing the dynamic behaviour of a 10-storey building structure according to both codes, subjecting it to the same simulation of dynamic wind load [7].

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2. CONFIGURATION OF 10-STOREY BUILDING

To investigate the scatter in both codes NSCP I [6] and SNiP [5] from the dynamic behaviour of a tall building, an example of an existing building is employed the same as in the first part of this two-paper study. 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.

The analytic frame with masses M1=M2=……M9=51 ton and M10=61 ton lumped at the central column of the analytic frame is shown in figure 1. Procedure of the computations is according to both codes and is outlined in part one of this two-paper. The wind load at the nodes of the frame, are presented in Table 1, which shall be used for dynamic analysis.

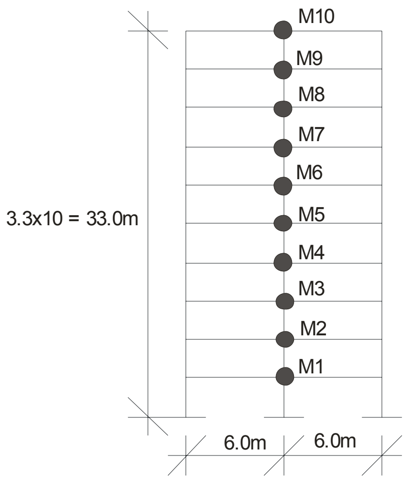

Figure 1. 10-storey analytic frame model of the building.

3. DYNAMIC BEHAVIOUR OF THE STRUCTURE

Dynamic analysis of the 10-storey building proceeds with the simulation of the already deduced wind load at the nodes presented in table 1 with the real wind speed record taken from [7]. After the conversion of this speed to pulsation wind load, it was compared with the wind loads at the nodes for both loads and at all floors and through their proportionality both converted to dynamic load, variation of wind load with time [9]. For SNiP the pulsation wind load deduced using the code was first converted to the dynamic wind load and then added to the average wind load recommended by the code to obtain the needed dynamic load. But in the case of NSCP I, only the static wind load recommended by code was used for the simulation because pulsation wind load is not defined in this code. The resultant dynamic wind loads for both codes are presented in the appendix, a programme written in MatLAB for the dynamic analysis using numerical analysis [10,11].

Further calculations involve the use of the numerical method for the dynamic analysis where differential equations of moving lumped masses at the node (Figure 1) are integrated. Generally these equations at any given time *t,* are written in matrix forms which take the form of Eq. (1) below:

Table 1. Summary of wind load for the 10-storey frame

	Floor number	NSCP I Total wind load, F (kN)		SNiP 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

$$\mathbf{M}\ddot{\mathbf{Y}}_t + \mathbf{C}\dot{\mathbf{Y}}_t + \mathbf{K}\mathbf{Y}_t = \mathbf{R}_t , \qquad (1)$$

where **M,C,K**– matrix of masses, damping and stiffness respectively; R_t– vector representing external excitations; $Y_t, \dot{Y}_t, \ddot{Y}_t$– vectors of displacements, velocities and accelerations of a system with definite number of degree of freedom.

The input data for the programme written in MatLAB for the dynamic analysis using numerical method are presented in the appendix. It is important to note that the analysis is assumed a linear problem and hence treated this way.

4. RESULTS AND DISCUSSIONS

Results of the analysis which include drifts, accelerations and bending moment at the central column of the analytic frame model are presented in the Figures 2, 3 and 4 respectively. In figure 2 peak displacement is recoded in both codes at time t=1.2 sec. And all precedes the allowable displacement of 66.0 mm. Their discrepancy is put at 18%. In Figure 3, peak acceleration is prominent at time t=1.8 sec for NSCP I and t=2.0 for SNiP. Discrepancy is put at 44% with only NSCP I exceeding the allowable limit of 0.1 m/s^2 [12]. Further more, in figure 4 the maximum bending moment in the column from NSCP I is also more than SNiP by 32% and this peak is recorded at t=2.0 sec for both codes.

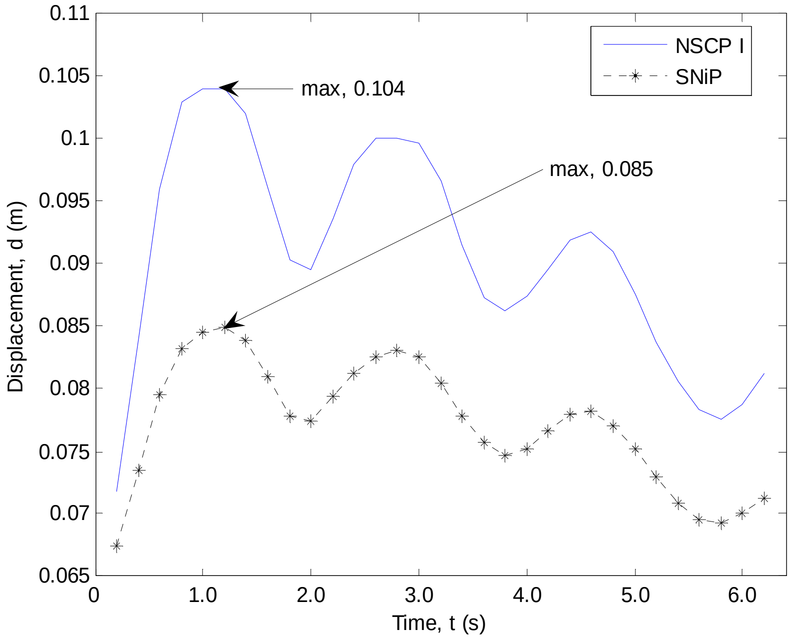

Figure 2. Displacements at the 10th floor.

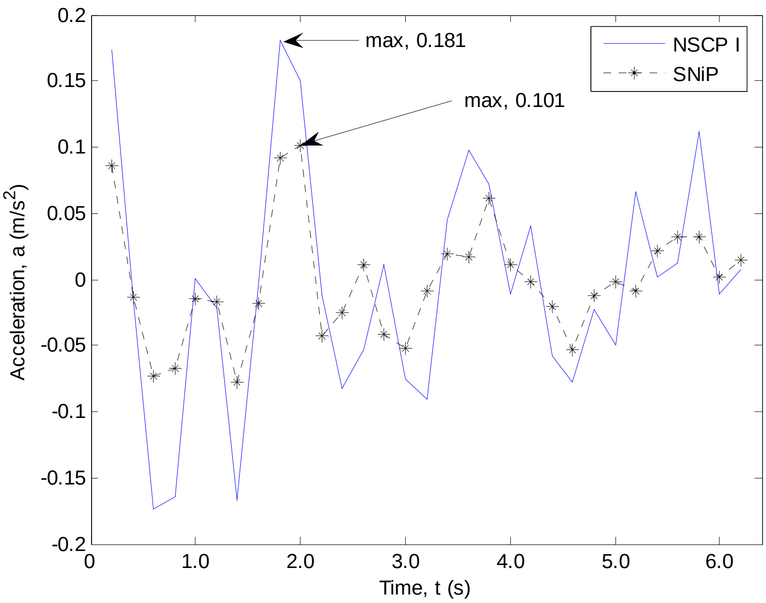

Figure 3. Accelerations at the 10th floor

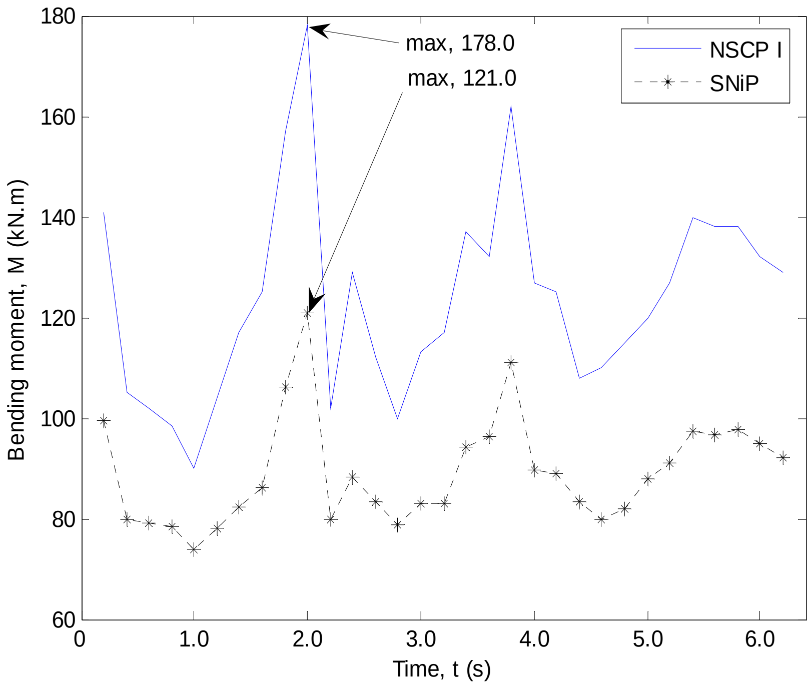

Figure 4. Bending moment at the lower part of the central column.

In the entire dynamic analysis, higher values are prominent only in NSCP I even though the codes estimated wind loads were subjected to the same simulation. Again the absence of the definition of pulsation wind load in NSCP I where factors such as dynamic coefficient and height factor present in SNiP should also be accounted for in NSCP I, seemed to be compensated for, by the uniform distribution of design wind pressure over the vertical surfaces of the building.

5. CONCLUSIONS

In this second part of the two-paper study, wind estimation per NSCP I and SNiP has been presented with reference to dynamic behaviour of the building using numerical analysis in MatLAB. Even though the NSCP I seem to be more conservative again than SNiP implies the need for wind pulsation and factors such as dynamic and height factors not to only be introduced but defined as well. This will go long way to enhance optimum design of building structures.

Important still to conclude that the differences existing between the two codes in comparison are still traced down to the variations in wind field factors, their values and the absence of dynamic parameters in the case of NSCP I.

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APPENDIX I

```
% Numerical analysis of equations of moving mass (lumped mass)
% Input data
% Time interval of integration (dt)
dt=0.2;
% Coefficients of integration (a, a0, a1, a2, a3, a4 and a5)
a=0.5;b=0.25;a0=1/(b*dt^2);a1=a/(b*dt);a2=1/(b*dt);a3=(a-2*b)*dt/(2*b);a4=(a-b)/b;a5=(0.5-b)/b;
% Matrix of the bending moments from unit force (bs)
bs=[-0.666;-0.758;-0.819;-0.861;-0.870;-0.875;-0.876;-0.877;-0.877;-0.877];
% Initial bending moments (sf for SNiP and NSCP I from static analysis in the part I of the two-
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paper)
sf=89.97;%sf=125.52;
% Unit force displacement matrix of the structure (F)
F=1e-3*[0.017 0.022 0.022 0.023 0.023 0.023 0.023 0.023 0.023 0.023
0.022 0.049 0.055 0.056 0.056 0.056 0.057 0.057 0.057 0.057
0.022 0.055 0.084 0.090 0.091 0.092 0.092 0.092 0.093 0.093
0.023 0.056 0.090 0.119 0.126 0.127 0.128 0.128 0.129 0.130
0.023 0.056 0.091 0.126 0.155 0.162 0.164 0.165 0.166 0.167
0.023 0.056 0.092 0.127 0.162 0.192 0.200 0.202 0.203 0.205
0.023 0.057 0.092 0.128 0.164 0.200 0.230 0.238 0.241 0.243
0.023 0.057 0.092 0.128 0.165 0.202 0.238 0.269 0.278 0.281
0.023 0.057 0.093 0.129 0.166 0.203 0.241 0.278 0.310 0.319
0.023 0.057 0.093 0.130 0.167 0.205 0.243 0.281 0.319 0.353];
%Matrix of lumped masses (m) ; M1=[51 51 51 51 51 51 51 51 51 61];m=diag(M1);
% Matrix of damping (be1); be1=[0.090 0.276 0.481 0.691 0.934 1.143 1.404 2.120 1.658 1.806];be=diag(be1);
% Dynamic wind load (Fsnip and Fnscp)
Fsnip=1.75*[2.9851 3.0115 3.1544 3.2780 3.3191 3.3191 3.1956 3.1190 3.3191
3.5569 3.1190 3.3191 3.3191 3.2334 3.1956 3.0847 3.1190 3.0504 3.2345 3.0493
3.1190 3.0493 2.9851 2.9566 2.9018 2.8312 2.8312 2.7920 2.8312 2.8312 2.8777;
3.2963 3.3491 3.6348 3.8819 3.9642 3.9642 3.7171 3.5640 3.9642 4.4398 3.5640
3.9642 3.9642 3.7928 3.7171 3.4954 3.5640 3.4267 3.7950 3.4245 3.5640 3.4245
3.2963 3.2393 3.1295 2.9885 2.9885 2.9099 2.9885 2.9885 3.0813; 3.6084
3.6876 4.1163 4.4868 4.6103 4.6103 4.2397 4.0100 4.6103 5.3237 4.0100 4.6103
4.6103 4.3532 4.2397 3.9070 4.0100 3.8041 4.3565 3.8008 4.0100 3.8008 3.6084
3.5229 3.3583 3.1467 3.1467 3.0289 3.1467 3.1467 3.2860; 3.9195 4.0251
4.5967 5.0908 5.2554 5.2554 4.7612 4.4550 5.2554 6.2066 4.4550 5.2554 5.2554
4.9126 4.7612 4.3177 4.4550 4.1804 4.9170 4.1760 4.4550 4.1760 3.9195 3.8056
3.5860 3.3040 3.3040 3.1469 3.3040 3.3040 3.4896; 3.7735 3.9079 4.6353
5.2642 5.4736 5.4736 4.8448 4.4550 5.4736 6.6844 4.4550 5.4736 5.4736 5.0374
4.8448 4.2803 4.4550 4.1056 5.0430 4.1000 4.4550 4.1000 3.7735 3.6284 3.3490
2.9900 2.9900 2.7901 2.9900 2.9900 3.2264; 4.0856 4.2464 5.1167 5.8691 6.1197
6.1197 5.3673 4.9010 6.1197 7.5683 4.9010 6.1197 6.1197 5.5978 5.3673 4.6920
4.9010 4.4829 5.6045 4.4762 4.9010 4.4762 4.0856 3.9121 3.5778 3.1483
3.1483 2.9091 3.1483 3.1483 3.4310; 4.3967 4.5839 5.5972 6.4731 6.7648 6.7648
5.8889 5.3460 6.7648 8.4512 5.3460 6.7648 6.7648 6.1572 5.8889 5.1026 5.3460
4.8593 6.1650 4.8515 5.3460 4.8515 4.3967 4.1947 3.8055 3.3055 3.3055
3.0271 3.3055 3.3055 3.6347; 4.2629 4.4765 5.6326 6.6321 6.9649 6.9649 5.9654
5.3460 6.9649 8.8891 5.3460 6.9649 6.9649 6.2716 5.9654 5.0683 5.3460 4.7906
6.2805 4.7817 5.3460 4.7817 4.2629 4.0324 3.5882 3.0178 3.0178 2.7000 3.0178
3.0178 3.3933; 4.1290 4.3690 5.6680 6.7910 7.1650 7.1650 6.0420 5.3460
7.1650 9.3270 5.3460 7.1650 7.1650 6.3860 6.0420 5.0340 5.3460 4.7220 6.3960
4.7120 5.3460 4.7120 4.1290 3.8700 3.3710 2.7300 2.7300 2.3730 2.7300 2.7300
3.1520; 1.9915 2.1259 2.8533 3.4822 3.6916 3.6916 3.0628 2.6730 3.6916
4.9024 2.6730 3.6916 3.6916 3.2554 3.0628 2.4983 2.6730 2.3236 3.2610 2.3180
2.6730 2.3180 1.9915 1.8464 1.5670 1.2080 1.2080 1.0081 1.2080 1.2080 1.4444];
%Fnscp=1.493*[14.184 14.697 17.481 19.887 20.690 20.690 18.284 16.791 20.690 25.322
16.791 20.690 20.690 19.018 18.284 16.122 16.791 15.454 19.041 15.432 16.791 15.432

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14.184 13.628 12.558 11.186 11.186 10.421 11.186 11.186 12.090; %9.456 9.798 11.654
13.258 13.793 13.793 12.189 11.194 13.793 16.881 11.194 13.793 13.793 12.679 12.189
10.748 11.194 10.303 12.694 10.288 11.194 10.288 9.456 9.085 8.372 7.457 7.457 6.947
7.457 7.457 8.060;% 9.456 9.798 11.654 13.258 13.793 13.793 12.189 11.194 13.793
16.881 11.194 13.793 13.793 12.679 12.189 10.748 11.194 10.303 12.694 10.288 11.194
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13.258 13.793 13.793 12.189 11.194 13.793 16.881 11.194 13.793 13.793 12.679 12.189
10.748 11.194 10.303 12.694 10.288 11.194 10.288 9.456 9.085 8.372 7.457 7.457 6.947
7.457 7.457 8.060;% 9.456 9.798 11.654 13.258 13.793 13.793 12.189 11.194 13.793
16.881 11.194 13.793 13.793 12.679 12.189 10.748 11.194 10.303 12.694 10.288 11.194
10.288 9.456 9.085 8.372 7.457 7.457 6.947 7.457 7.457 8.060;% 9.456 9.798
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6.947 7.457 7.457 8.060;% 9.456 9.798 11.654 13.258 13.793 13.793 12.189 11.194
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9.798 11.654 13.258 13.793 13.793 12.189 11.194 13.793 16.881 11.194 13.793 13.793
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7.457 7.457 6.947 7.457 7.457 8.060;% 9.456 9.798 11.654 13.258 13.793 13.793
12.189 11.194 13.793 16.881 11.194 13.793 13.793 12.679 12.189 10.748 11.194 10.303
12.694 10.288 11.194 10.288 9.456 9.085 8.372 7.457 7.457 6.947 7.457 7.457
8.060;% 4.728 4.899 5.827 6.629 6.896 6.896 6.094 5.597 6.896 8.440 5.597
6.896 6.896 6.340 6.094 5.374 5.597 5.152 6.347 5.144 5.597 5.144 4.728 4.542
4.186 3.728 3.728 3.474 3.728 3.728 4.030];
k=inv(F);
c=m*be;r0snip=1.75*[2.9851;3.2963;3.6084;3.9195;3.7735;4.0856;4.3967;4.2629;4.1290;1.9915];
%r0nscp=1.493*[14.184;9.456;9.456;9.456;9.456;9.456;9.456;9.456;9.456;4.728];
% Initial vector (yn for SNiP and NSCP I)
yn=inv(m)*r0snip;
%yn=inv(m)*r0nscp;
% Computations
k1=a0*m+a1*c;k2=a2*m+a4*c;k3=a5*m+a3*c;k01=k+k1;g1=inv(k01);w1=g1*r0snip;
%w1=g1*r0nscp; v1=a1*w1;y1=a0*w1;
% Iteration process
 for j=1:31
p=Fsnip(:,j); %p=Fnscp(:,j);
r1=p+k1*w1+k2*v1+k3*y1;w3=g1*r1;v3=a1*(w3-w1)-a4*v1-a3*y1;y3=a0*(w3-w1)-a2*v1-a5*y1;
w1=w3;v1=v3;y1=y3;z=(w1(10))';y=(y1(10))';w=z+0.0629;t=1*j;s=-
m*y1;my=bs'*s+sf;t=0.2*j;sm=my';
%yz=[t sm];yz=[t w];%yz=[t y];disp(yz);end
```