Tall Structures Behaviour Under the Action of Irregular Heat of the Wind of Cumulated Loadings

Gheorghe-Mugurel RĂDULESCU and Corina-Michaela RĂDULESCU, Romania

Key words: Tall structures,wind irregular heat,ossilation

SUMMARY

The realization of tall buildings is an interdisciplinary domain that was very little discussed in the specialty literature. The extent of this analysis theme covers all the phases that are the object of a tall construction building up, from design phase to the time behavior tracing. The present work analyses this domain starting with the existing data synthesize and carrying forward with technologies and devices elaboration that would improve the possibilities of topographical conduction of tall construction execution, with an ample analysis of the impact of very tall constructions developing in the last five years over the topographical technologies used for execution control and those time behavior tracing.

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1. TOPOGRAPHIC ANALYSIS OF TALL STRUCTURES CONDITION UNDER THE STRESS ACTION NEEDS A GOOD KNOWLEDGE ABOUT THOSE AND THE WAY THESE ARE INFLUENCING THE STUDY METHODS

The monitoring of very tall construction's action is a complex process, implying topographical, meteorological measurements, a good cognition of execution project, in fact of the predictions about structure's action in given circumstances.

The adopted topographical methods in this field and not only, must be adapted to the designer's field data needs, one geometrical ascertainment, without saying the conditions when it was recorded, is inconclusive.

The geodesist has to coordinate the entire process of data taking IN-Situ, geometrical, meteorological and structural, so having the chance of understanding the entire phenomenon.

2. THE VERTICAL CONSTRUCTION'S AXIS VARIATION – GREAT HEIGHT COLUMN ON IRREGULAR SOLAR HEAT

The constructions – column with closed section (cylindrical or in a shape of a truncated cone) carries on unilateral heating, by solar exposing, a parabolic deviation of the vertical central axis. In practice, the deformation model is amplified, considering that values α' and d' are sensible comparable with the real ones (α and d) and, anyhow, covering (1 figure).

The effects of this evolutional process can be classified into two groups:
- Influence of softness of vertical axis above construction functionality;
- Vertical and radial efforts variation in structure (estimated by ACI 505-54/98)

In antenna's case, the deviation from the vertical axis results changing the emission direction. It's appreciated that a $\alpha = 0,4^0$ deviation is perceived at a 100 km distance as a linear (D) 700 m deviation (2 figure).

Considering that the reception's stability and quality is in direct ratio with the position and stability of transmitter antenna, it has to be known exactly the admissible deviation (α, d) according to quality imposed to reception, at external side of transmitting zone.

Softness of vertical chimneys axis can lead to the change of density and distribution of emanated fume, for certain areas. For the residential constructions the effects are still studied, having as prevent purpose the possible discomfort of the inhabitants.
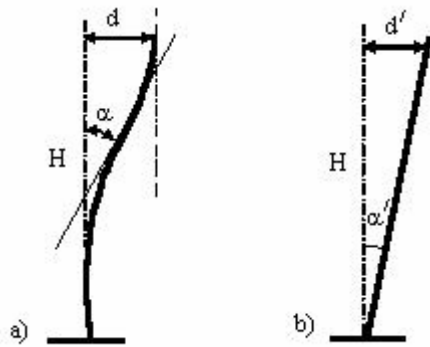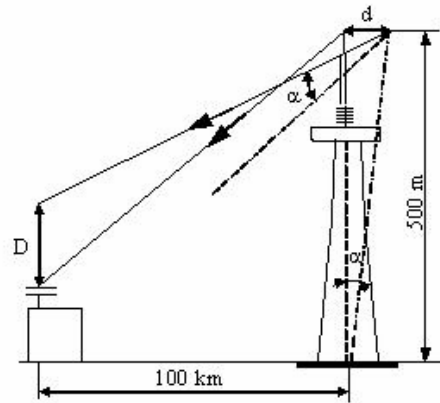
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Figure 1.   **Figure 2.**

3. THE VERTICAL AXIS VARIATION FOR THE GREAT HEIGHT COLUMN–CONSTRUCTIONS ON WIND ACTION

3.1 General approaching

In the activity of design for great height constructions, column-tower type is very important to know the behavior of the real structure at wind's static action but especially at wind's dynamic action. It is considered that in the action modeling as well as in structure reaction's evaluation it is very useful knowing real exploitation's behavior of some comparable structures.

Studying on models, in aerodynamic tunnels, the structures behavior in the mentioned category at wind's action, it's offering dates to whom can give a trust limited from simulation possibilities of real conditions. Therefore, the latest field research made in Universities from Sydney – Australia, Nottingham - UK, Kansas and Salt Lake City – USA, although these give dates about real structure modeling, of wind actions and the structure's reactions to these actions, are still in confirmation phase. There are big difficulties and therefore **the importance of measurements,** which are made from this point of view on real structures, **is growing**

Size, shape and oscillations frequency due to wind is important for constructions stability study, but, it must be said that the difficulties appeared at tower oscillations measurements under the wind action are special and they came from several directions. It's hard to quintile the effects of different solicitation factors, the continuous haste of the construction (practically there isn't a repose state) makes heavy sighting and tracing the structure; wind characteristics are usually recorded from the ground, and the transposition through proportional calculus with height does not totally correspond to the real solicitations.

3.2 Considerations regarding wind effect measurement onto some tall constructions

The observation of studied structure's oscillations, under wind effect, was usually made using the recording method of some buffers movements placed on structure or with theodolite of precision. When the research were started there weren't in the bibliography where we had

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access only very few results, from the second category. The used machines are usually precision ones, provided with zenithal oculars. Pointing the center of sighting is made in a calm period and the theodolite sighting axis stays unchanged along the observation cycle. As sighting centers, may be used fixed elements, visible from the traced structure's interior, e.g. optical beacon, and in the control measurements, the metallic elements of the platforms.

Determinations were centralized in the frequency settling directions (respectively of duration) and the oscillations amplitude as well as of oscillatory figures. It's considered that regarding a direction perpendicular onto axis of sighting, the complete tower oscillation is given by the interval between two alternate passes of the sighting center through the center of reticular wires of the machine. (3 figure)

The precision wherewith were evaluated the oscillations amplitude has to be $\pm$ 10 mm – conditioned by the possibilities of distance pointing for station –chimney top.

The oscillation recordings from the two stations must be realized in the same time and were timed by two instruments set in the same system (origin).
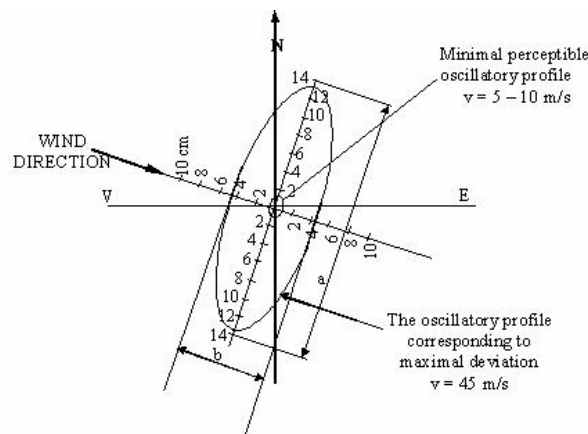

Figure 3. Wind oscillated figure

It is possible, after the obtained data correlation onto both perpendicular directions, that it is not to overpass an error of $\pm$ 1 s for settling the duration of one complete oscillation. That's how it is established that the oscillatory figures are ellipses whose long axis is perpendicular on wind direction. The characteristics of wind were recorded on ground, in open field nearby traced structure (3 figure).

3.3 General problems regarding wind action onto cylindrical (or in the shape of truncated cone) constructions

The wind represents, periodically or quasi-periodical, a soliciting factor on specific time interval for tall constructions.

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In case of objectives that are over 200 m height and a shape of truncated cone (furnaces, telecommunication towers, antennas), the study of wind influence is heavier because of some factors, like:
- wind speed variation on heights (implicit also of pressure) different to the other constructions;
- increasing buffer zone, fact that decreases the possibilities of some simplifying hypothesis's simulation;
- absence of some profound studies regarding those structures behavior in the critical superior domain;
- chaotic character of model's behavior into wind tunnels;
- existence of some *n* – liberty degrees leads on appraisal only approximate the solicitations;
- the disaccord between theoretical studies and the real model behavior, etc.

The practice, on the other hand, presents as sure, the next conclusion: whatever the dynamic solicitation type (wind, earthquake, sunny) the construction oscillations into specified section, are produced taking the shape of an ellipse. (4 figure)

At the level of entire structure it can be estimated that oscillatory figure would have the shape of a quasi – screw conic – elliptic.
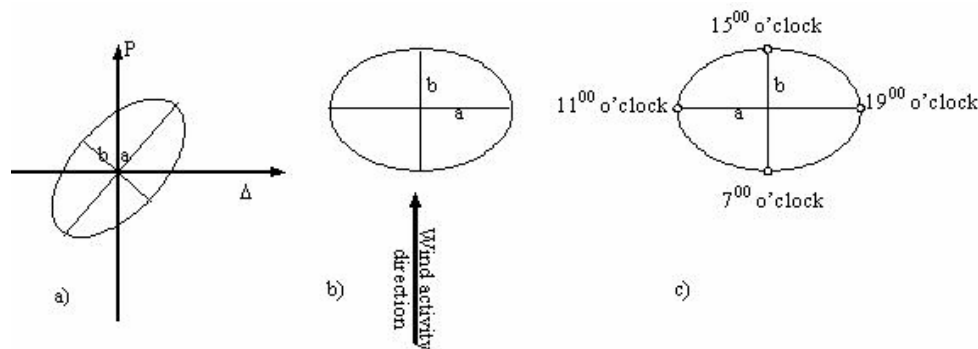

Figure 4. Real figure's oscillations for different solicitation type
a) earthquake; b) wind; c) sunny

Strictly coming back at wind's action analysis on studied assembly (cylinder or conic), we know that this implies settling the definitive differential equations. Because solving them implies a very large amount of calculus, it's necessary to adopt some simplifying hypothesis that would bring some advantages in this purpose. The main condition of the simplified studied models is that the results must be compatible with those who would define the real process. Irrotational motion, in which the effect of fluid's viscosity is neglected (μ=0), being one of the simplifying hypothesis, is in the case of the study of inter-relation fluid-conical assembly, limited by increasing the buffer zone. As in the case of some other structure types, motion field of the fluid may be split into two regions:

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- main current where it may be admitted the hypothesis $\mu = 0$;
- the buffer zone and the limit layer where the fluid motion is rotational, the viscosity must be considered $\mu \neq 0$;

In these areas, the fluid particles present a rotation that may be defined using a vortex vector $\vec{W}$
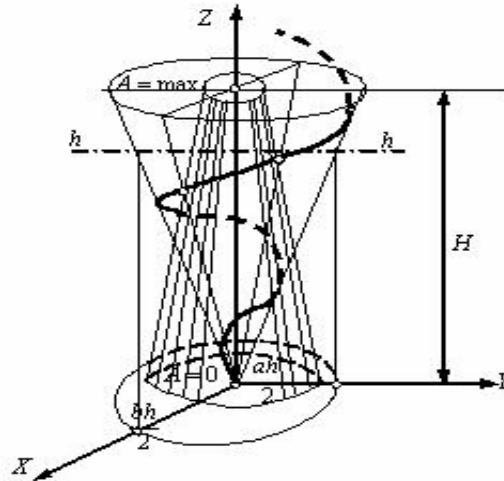

Figure 5. The oscillatory figure provoked by the dynamic solicitations of the level of entire structure

In Cartesian coordinates (x, y, z):

$$\vec{W} = \left(\frac{\partial_w}{\partial_y} - \frac{\partial_v}{\partial_z} \right)\vec{i} + \left(\frac{\partial_u}{\partial_z} - \frac{\partial_w}{\partial_x} \right)\vec{j} + \left(\frac{\partial_v}{\partial_x} - \frac{\partial_u}{\partial_y} \right)\vec{k} \qquad (1)$$

where $\vec{v} = u\vec{i} + v\vec{j} + w\vec{k}$ is speed vector. Obvious that the hypothesis $\mu = 0$ implies $\vec{W} = 0$.

The measurements made on constructions on hand or on exploitation, lead to the fact that this secondary wind effect (KARMAN) produces deformities (oscillations) more powerful than the generating force, in case of significant charges.

3.4 Transversal oscillations of wind's direction (KARMAN effect)

Aeolian actions of this kind are studied after it was settled through one of known methods, the number of oscillations of studied body and wind action among the predominant direction. Next, it will be presented synthetically a few aspects related to KARMAN effect.
Transversal oscillations to wind direction are produced only when aero dynamical negative amortization is bigger than the positive assembly amortization.
The conical tubular structure will oscillate always transversal onto wind direction in an own frequency. The assembly's amortization is limiting the amplitudes. There are two domains:
a) $R_e < R_{e\,critic}$ - laminar domain (critic inferior);
b) $R_e > R_{e\,critic}$ - turbulent domain (critic superior).
where R_e is Reynolds coefficient (number) and it can be determined as follows:

$$R_e = \frac{V \cdot D}{\nu_{cin}}$$ (2)

- V – wind speed (m/s);
- D – structure's diameter for h=0,7 H (m);
- ν_{cin} - air kinematical viscosity;

(usually $\nu_{cin} = 1,45 \cdot 10^{-5}$) (m/s)
- $R_{e\,crit} = 350.000$ (generally).

In the critic inferior domain the transversal oscillations phenomenon is caused by the KARMAN vortexes that are regularly changing with a vortex frequency S= 0.2.
The continuous changing frequency of the vortex will be:

$$f = S \frac{V}{D}$$ (3)

- S – Strouhal's number

f becoming liable so as the structure will oscillate in own frequency and not in vortex's frequency.

In the critic superior domain these phenomenon still don't have a satisfying solving. It could be reminded the idea that this phenomenon is a resonance oscillation of a weak amortizable system by its impulsion with a continuous frequency spectrum.

Coming back at forming KARMAN's vortex (6 figure) must be said that this phenomenon takes place behind the cylinder and is moving with a smaller speed than the main current, having a regular density. The alternate forming of the vortexes produces transversal motive power. For the calculus of those above, the current relation is:

$$P = C_a \cdot q \cdot D \text{ (kP/m)}$$ (4)

- P - transversal motive power;
- C_a – lateral pressure coefficient;

- $q = \frac{1}{2} \cdot v^2$ - dynamic pressure.

As regards the C_a term, there are some non-correlations between the values presented in specialized literature from different countries. Therefore, it is recommended:
- $C_a = 0,8$ in critic inferior domain ($R_e < 350.000$)
- $C_a = 0,2$ in critic superior domain ($R_e > 350.000$)
while the correspondently would result $C_a = 1,1 \div 2$ respectively
- $C_a = 1,1 \div 0,2$ regarding the ratio $R_e / R_{e\,crit}$.

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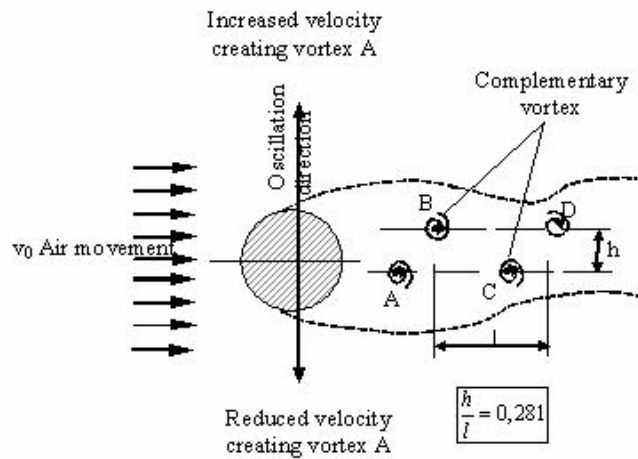Cairo, Egypt April 16-21, 2005

Figure 6. KARMAN vortex's distribution

It is considered that a vortex appears on reduced values of Reynolds's number or on moderate wind speeds (V ≤ 25 m/s). It was seen, trough measurements on real models, that produced oscillations after normal wind directions have higher amplitudes than the longitudinal ones.
As regards the calculus mode for the estimation of transversal motion powers and of corresponding oscillations, E. Hampe recommends synthetically the next deployment (1 table), in which

- y_o- the maximal deflection on furnaces top due to the action of a P = 1,0 M_p force
- δ_n – deflection in certain n-position
- G_n – mass in n position
- D – the diameter of the furnace at $h = 0,7$ H height
- $S \cong 0,2$ STROUHAL's number
- $\nu_{cin} = 1,45 \cdot 10^{-5}$ (m^2/s) kinematical air viscosity
- ρ   = 0,125 (kp· s^2/m^4)

A possibility of diminution of KARMAN effect especially for reduced amortization's constructions is the diminution of transversal oscillations amplitudes, through spiraled shape envelopment. This is the main method used also on limitation of lately made skyscrapers oscillations (7 figure).

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Table 1

1	ESTABLISHING OF OWN OSCILLATIONS NUMBER n_e $n_e \cong 300 \sqrt{\dfrac{y_0 P}{\int \delta_n^2 G_n}}$ (oscillations / sec) (5)

$\downarrow$

2	ESTABLISHING THE RESONANCE SPEED V_{rez} $V_{rez} = \dfrac{n_e \cdot D}{S}$ (m/s) (6)

$\downarrow$

3	ESTABLISHING OF REYNOLDS COEFFICIENT R_e $R_e = \dfrac{v_{rez} D}{v_{cin}}$ (7)

$\downarrow$

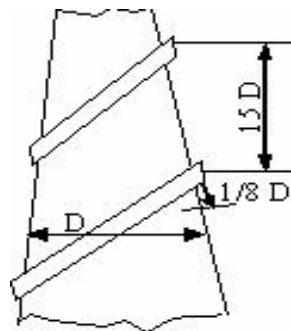|	

4	ESTABLISHING THE LATERAL FORCE P_L
	
	             critic inferior
	
	 $P_L = \left.\begin{matrix} 0{,}8 \\ 0{,}192 \end{matrix}\right\} \dfrac{\rho}{2} v_{rez}^2 D$ (kP/m) (8)
	
	             critic superior

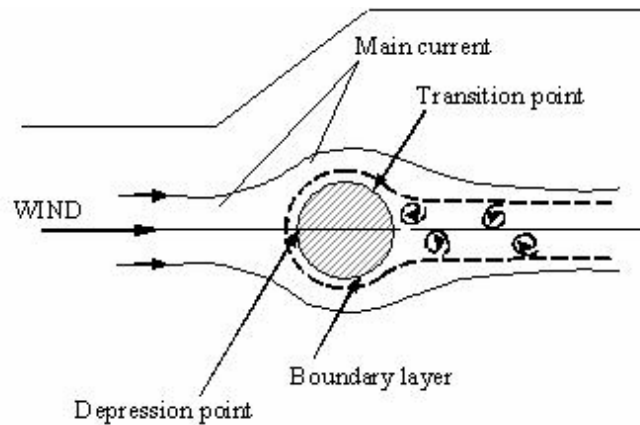**Figure 7.** A method for limitation of conical constructions oscillations

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Figure 8. The making of buffer zone for cylindrical-conic assembly

4. COUPLING OF FORCES – DESIGN RISK

4.1 Consequences of the incorrect estimation of the vertical axis evolution under the stress action

Previously it was accentuated the permanent ellipsis oscillating movement of the highest tubular buildings.

Appear the next affirmations:

- Between the sub-dimensioning and supra-dimensioning, the design way alternates in function of the known information and the reference plane of the normative which is in use.
- Information concerning the behavior of the other similar constructions in the same conditions is useful, too. This kind of dates is given only by the direct measures with topological and geodesic methods.
- Variation of the vertical axis for the analyzed structures, with 100, 200 or 350 m high, under the non constant sun action and the wind action, recorded in various weather conditions, could be interested for the designer and for the effecters of other highest buildings, too.
- The classical methods for recording present some disadvantage which limit the informational flux. So, the different ways of recorder go down in value the compatibility of information received from the different sources. Therefore, is difficult to make a date bank.
- Absence of continuity gives to the dates a sequential character. The price is high and the difficulties are various.
- The modern methods, presented in this work, by the new devices and by the measure methods will be eliminate this shortcomings because they can make continuous and homogeneous determinations. But, the results of measures are given rarely and therefore is still difficult to make a dates bank in this domain
- Finely, weather conditions have an effect upon the structure and the device used for record the deviations, too. Hence the obtaining results passes from the functionally aspect to the representative aspect.
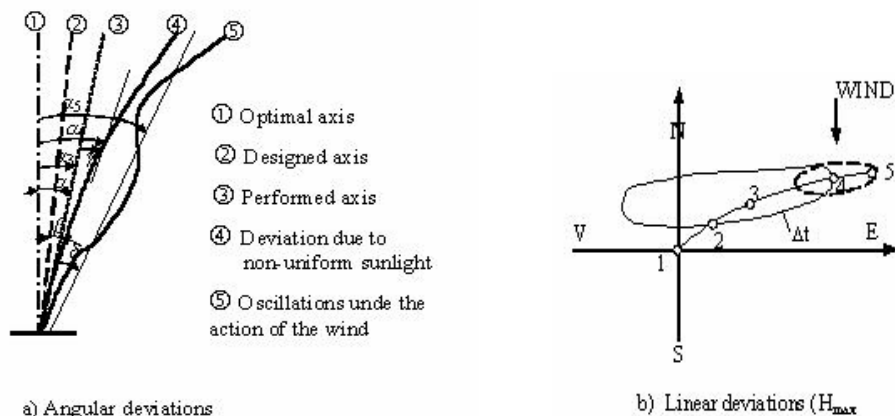
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Figure 9. Risk of the sequential presentation of dates

Risk of the sequential presentation of dates is to not permit to seize upon the discontinuity points in behavior of the structure. (9 and 10 figure).

- -Observe the importance of the angles α, β, γ and δ in the way of theirs order in direction to the maximal deviation.
- -An ordering $\alpha, \alpha, \alpha, \alpha, \alpha$, verifiable with an unfavorable gravitational conjecture might to generate a catastrophe, even if the values of angles are small enough.

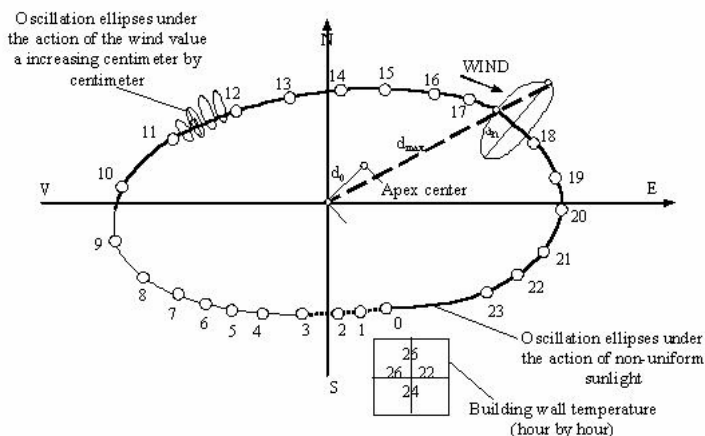In this way is possible to explain some tragic accident even if the limits design is respected.

Figure10. Risk of the sequential presentation of dates

4.2 Representation conditions of obtaining dates recorded to the vertical axis evolution

a) Exact determination of causes (clime characterization factors), correlated with exact recording of the effects (oscillations or attenuation angle of vertical axis).
b) Continuity of recordings – all over the execution and after that, periodically, in various combinations of forced conditions.
c) Global presentation of the cumulated effects.
d) Split the influences of each forced factor.

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e) Minimization of the measure error recordings and put the recordings in similar technique conditions.

f) Removing the environment effects on measuring methods;

g) Removing the errors of construction effects and stabilize in which proportion they influence the results. By distortion it, they are eliminate from statistical dates.

h) Absence of continuity gives to the dates a sequential character. The price is high and the difficulties are various.

i) The recorders will be effectuate for base and for peak of buildings, and from 50 to 50 meters, after two perpendicular directions (preferences NS - VE).

j) Optimal cost. It is relive that for the resident buildings with much more than 200 m high, the investment charge in recording device and usable methods can be by million dollars.

k) Reduced volume of work, decrease the human errors by the methods and by the usable devices. Today this thing is possible.

l) The method must be influenced by the atmospheric factors, in known and control limits.

m) Results of the measures it must to relieve coherently and faithful the relation from the causes and stress factors, from the effects and variation of the structure position in general and the peak in special

n) Dates given by the land surveyor to the designer it must to permit to define the outline of general action – higher structures; particular action – conical structures; special action – height, capacity, environment, base, soil, emplacement, relief, clime, neighborhoods, incidence of the special stress factors

In stage of design, consider that it is necessary to approach cautiously about the possibilities to coupling of stress factors, for highest buildings (9 and 10 figure). To know the general, particular and special model behavior of the building A, with parameters B, emplaced in zone C, characterized by the environmental factors D, make possible to estimate the unfavorable possibilities to coupling of forces. So, it can choose the optimal solution in limits to the maximal resistance.

5. CONCLUSIONS

Measurements made for this kind of constructions show that there is an elliptical movement of the vertical axis on a day time. Although the rotations are complete (in 22 - 30 hours),the buildings do not return to the initial position.From this point of view we can say that does not exist a rest position, at that by 2-6 hours the deviation speed is very less. Therefore, it is impossible to draw the real vertical axis of the building, it's longitudinal axis being in unison with vertical on base just incidentally and unpredictably.

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BIOGRAPHICAL NOTES

Gheorghe-Mugurel RADULESCU

Birth date   April 17, 1950
Employment   The Northern University, Baia Mare
Teaching position   Professor
Undergraduate education   The Faculty of Geodesy, Bucharest, 1974
                                  The Faculty of Mathematics, Cluj-Napoca, 1990

Scientific titles
Doctor of Engineering Sciences, with the major of Civil Engineering, in the area of expertise of Geodesy, Cartography, Fotogrammetry and Teledetection.
Thesis title: "Modern topographic technologies used in the execution and exploitation of high-rise buildings"Scientific coordinator: Prof. Univ. Dr. Eng. Vasile URSEA
Scientific activity
Articles published abroad, in international field journals, in the books of some international scientific meetings – 70
Field manuals for higher education published by native or foreign publishing houses –8
Published Workbooks of problems and Tutorials – 9
Other professional activities
Member   The Union of Geodesists from Romania,
President   The Society of Terrestrial Measurements from Romania.
President of the Organizing Committee and initiator of the First National Symposium of Topography TEHNOTOP 88, Baia Mare, may 1988.

CONTACTS

Prof.dr.ing.mat.Gheorghe-Mugurel RADULESCU,
North University Baia Mare, str.Victor Babes nr.62 A
4800 BAIA MARE
ROMANIA
Phone   + 40262212274
Mobile + 40721942189
Fax   + 40262276153
Email gmtradulescu@yahoo.com

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