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A Review of the Literature on the Structure of Wind Turbulence, with Special Regard to its Effect on Buildings*

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It is becoming increasingly evident to designers that, with the introduction of new forms of construction and greater use of taller buildings, more account needs to be taken of the effect of wind turbulence in building design, e.g. with respect to loading of structural components, the human environment in the vicinity of buildings, the general weather tightness, natural ventilation, and the air pollution around buildings. A search of the literature on wind structure near buildings shows that existing knowledge is insufficient for design purposes. Available methods of investigating wind structure in the field are reviewed, and comments are made on the need to study conditions in urban areas.

INTRODUCTION

IT IS necessary for both building designers and urban planners to be familiar with the effect of wind on the structure of a building and the subsequent influence of that building on air movement in its neighbourhood. As buildings have become taller, faster flowing turbulent air streams have been encountered. Building constructions are thus subjected to stronger fluctuating forces than previously; this is especially significant where contemporary lightweight cladded structures are used. Concurrently, these winds are brought near the ground by the buildings themselves. Strong wind effects on and about high buildings, for example, slab blocks with adjacent pedestrian precincts, have become of increasing and immediate concern to the designers and planners. There is therefore an awareness of the need to design and space buildings to avoid structural damage and to ensure a comfortable climate. Additionally, there is need to increase the weather tightness of buildings, to improve the performance of natural ventilation, and to reduce air pollution about buildings, by taking more account of the behaviour of the wind.

One requirement towards achieving these aims is a detailed knowledge of the structure of wind in urban areas. As part of the Building Research Station's work in this field the present note has been prepared, reviewing available knowledge and pointing to areas where information is lacking.

ATMOSPHERIC TURBULENCE

In comparison with steady streamline flow, the atmosphere possesses remarkable variability. The flow of air over surfaces of varying roughness and temperatures produces a random motion termed turbulence. This is the significant characteristic of air flow, on which depends the rapid diffusion of properties such as momentum, heat, water vapour and pollutants. The presence of buildings especially tall buildings, increases surface roughness and this has considerable influence on the structure of wind about them.

Structure of turbulence

In the early study of atmospheric turbulence, detailed properties of the flow were avoided, since complex equipment is required for their observation, recording and analysis, so virtual diffusivities, analogous to molecular diffusion, were derived with mean values of the motion. Since about 1950, statistical concepts have been employed with field data to understand the processes involved in, and the resultant structure of turbulence.

The scattering and mixing of the flow is indicated by the intensity of turbulence (e.g. $\overline{(u^1)^2/u}$ where u represents the instantaneous wind along the

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direction of air flow, and u^1 indicates the fluctuations in wind about the mean flow, $\bar{u}$; the bar signifies the mean with respect to time. Hence $u = \bar{u} + u^1$). Additionally, the kinetic energy of the turbulent motion is represented by the average square of the fluctuating component, $\overline{(u^1)^2}$. Contributions to this kinetic energy can be determined from analyses of the continuous range of eddy sizes involved in the motion, via Fourier (spectral) analysis or correlations within the fluctuating component (PASQUILL, 1962). There is a range of scale lengths, or eddy sizes, through which the turbulent flow exists. Much of the energy is available in eddies of a scale characteristic of the distribution of mean velocity (the integral or macro-scale of turbulence, L). There is a continual transfer of energy from large to small scales through the action of inertial forces. Gradually, all influences of the energy-containing eddies, derived from the mean flow and heating sources, is lost and ultimately the energy is dissipated by viscous forces into heat.

At small scale lengths, beyond that containing the maximum energy, a universal relationship exists between the energy and a power of the eddy length. Here, local isotropic conditions are said to exist: the statistical properties of the flow are unaffected by rotation or deflection of the reference axes: $\overline{(u^1)^2} = \overline{(v^1)^2} = \overline{(w^1)^2}$, i.e. the root mean square of the fluctuations of wind speed along wind (u^1), lateral to the wind (v^1) and vertically perpendicular to the wind (w^1) are equal, and there is a distinct relationship between the energy distributions of the lateral compared with the longitudinal and vertical components of turbulence. The eddy length below which viscous forces dominate and an isotropic situation may be said to exist, is called the micro-scale of turbulence λ.

Field investigations

Turbulent motion can be examined either by sampling parcels of air passing one or more points (Eulerian time—or space—variance) or by following the parcels themselves (Lagrangian time-variance). The former method has been utilized with equipment such as anemometers or vanes, and the latter by means of traces of smoke or neutral-density balloon paths. Although the Lagrangian system follows directly the actual flow pattern, it is difficult to establish and to trace and record a continuously emitting source. It is more practicable to employ the Eulerian system and, to avoid multiplicity of expensive complex equipment, the time-variance of momentum at one point is most frequently recorded. In early field work bi-vanes (bi-directional vanes) were employed in this capacity, although the graphical records of the combined vanes were difficult to interpret; rapid response hot-wire anemometers were used in the laboratory only. Today, modern techniques in electronic circuitry have improved the quality and stability of hot-wire equipment, and these anemometers are now widely employed in the field.

Field measurements of turbulence have been taken over smooth, open surfaces for example, at Porton, Cardington and O'Neill (characteristic roughness length Z_0 less than 1 cm). The only rough site examined in detail is the wooded, rolling country about Brookhaven National Laboratory, Long Island (Z_0 approximately 1 m). A rougher site at Peekskill has been utilized, but the inhomogeneity of the neighbourhood was significant here. Data have been collected in London, W. Ontario, and Manhattan, New York, with Z_0 of the order of 1–3 m; the analysis of these measurements has not been published fully yet. Recently turbulence measurements have been taken in and around Reading, in conjunction with a study of air pollution. At the moment, methods for analysis of the data only are being studied. (MARSH, personal communication.)

Atmospheric turbulence has been examined through a large height range, from rather less than 1 m to rather more than 500 m. Measurements at the lowest levels are of concern in micrometeorology and agricultural research, the highest levels in aircraft operations. The lower few 100 ft is the important air layer about buildings. This has not been explored in any detail in urban areas.

A fairly wide range of stabilities has been sampled in turbulence studies, more particularly convection conditions. Since strong winds are significant to building problems, results of work in neutral stabilities are of more concern in this context.

Results

Average turbulence intensities in the field lie between 15 and 20 per cent, and these ratios vary with roughness and stability, and between the three components of the motion. Fifteen per cent is common in neutral stabilities, but at rougher sites (Brookhaven), this intensity can increase to 22 per cent. OWEN (1964) suggests intensities of 12½ per cent can occur at 15 m (50 ft) over open downland ($Z_0 = 1$ cm) and, very tentatively, on a roof 61 m (200 ft) over a city ($Z_0 = 1$ m), 33 per cent would be more typical. In unstable conditions turbulence intensities are five times those in stable conditions. The intensity of the u-component of motion is more often greater than that of the remaining components.

The turbulent energy spectra vary with stability among the different components. Neither an increase in mean flow nor roughness appears to effect the shape of the spectra, but tends to increase the spectral estimates at all frequencies. The lateral and longitudinal components of velocity (u and v) possess more energy at low frequencies than the vertical component, w, indicating that the scales of turbulence are greater in the lateral and longitudinal directions, x and y. In neutral stabilities, the macro-scale of turbulence in the u-component is about three times the height of measurements ($L=3z$), the scale length is doubled in unstable conditions and halved in stable conditions. The macro-scale of turbulence in the w-component is about one-sixth of these values. Interpolation formulae have been derived by Davenport and by Panofsky and McCormick to describe the spectra of the u- and w-components of a turbulent motion in terms of the mean velocity and the turbulent intensity. For limited data, over open country these formulae appear fairly satisfactory. Agreement has been found, apparently, with spectra derived from the recently collected New York data, also.

The slope of the high frequency end of the spectra conforms almost universally to a $-5/3$ power of the frequency, as theory implies. Similar conditions exist in the three components. The upper limiting eddy length for isotropic conditions appears to be of the order of the height of the sensing apparatus. The micro-scale of turbulence is 0 (10 cm), (LUMLEY and PANOFSKY, 1964), implying that the size of eddies associated with energy dissipation is roughly constant.

The range of eddy lengths covered by field observation spectra lies between 10 cm and 850 m. For example, JONES (1963) investigated eddy lengths between 0·64 and 840 m in an average wind speed of 5 m/s. To some extent, the lower limit is set by the size of the sensing head and the response of the apparatus, and the upper limit by the length of the period analysed. In general a range of frequencies 0–100 c/s is present in atmospheric turbulence.

Summary of available knowledge

The turbulence intensities probable in the atmosphere, and of interest in building research studies are at least 20–25 per cent and possibly greater. Significant eddies would be expected to be about average building height. Field data suggest significant eddy sizes between ½ (for the w-component) and three times (for the u-component) the height of observations. In the 6–31 m (20–100 ft) air layer above the ground important eddies could lie in the range of 3–92 m (10–300 ft). Recent measurements taken with pressure gauges by the Building Research Station indicate the presence of gusts of period 0·1 s, so a range of frequency to 10 c/s at least should be examined. On the whole, knowledge of wind structure in urban areas is insufficient for design purposes. Further research should be carried out, and it is necessary to consider available methods of measurement before deciding upon the best line of attack.

METHODS OF MEASUREMENT

Specialized equipment is required to measure the components of air flow in the lower few 31 m (100 ft) above rough terrain. The basic characteristics of the air flow are of a fluctuating nature. The intensity of turbulence in the flow may vary between 30 and 50 per cent about a mean value, which itself could have a magnitude of 1–16 m/s. The directional variation of the fluctuations about the mean may change by ±60°. The frequency of fluctuations within the flow may be in the range 0–100 c/s; significant pressure changes of 0·1 s (i.e. frequency 10 c/s) have been recorded on building faces.

The equipment should comprise sensing heads, facing into wind, and adequate instrumentation to record and present the data for analysis. For point measurements of turbulence at varying heights above the terrain, a light slender mast and outrigging booms should be employed, to minimize interference from supports. Hence, light sensing heads, emitting electrical signals through cables to distant ground equipment are required. A recording system for future analysis in the laboratory is necessary to examine the synchronous measurements of the fluctuating components at several heights; moreover, much continuous data are required to assess statistically the characteristics of the flow. To inspect the full range of possible frequencies, both the sensing head and the recording equipment should have an adequately rapid response.

Sensing head

A variety of sensing heads are available for turbulence measurements, employing the pressure of the wind, its cooling power over heated wires, or the speeds of sounds carried along by the turbulent air flow. Some characteristics of the various heads are given in Table 1.

Pressure probes. Differential pressure probes are employed most often to measure air turbulence from planes (LAPPE *et al.*, 1959). Both the relative wind velocity and the angular deviation to the vertical and horizontal can be derived with associated rate gyros and linear accelerometers.

Gustmeter. The Electrical Research Association has produced a gustmeter which records the drag of air flow on a light perforated sphere. Individual meters, pivoted in different planes, can be used to determine all components of turbulence (WAX, 1956).

Vanes. Most sensing heads require a vane to keep the head into wind, but individual vanes can be employed to measure lateral and vertical deflections from the mean wind by turbulent fluctuations (SMITH, 1961). Selsyns or variable potentiometers provide electrical outputs from the vanes (Lettau and Davidson, 1957). With the velocity of air flow in the direction of the wind, the relative velocity components can be derived.

Cup anemometer. The rotation of this anemometer records wind speed and its fluctuations along wind (Jones, 1965).

Heated-bulb anemometer. A thermocouple heated to a known temperature, indicates the along-wind components of turbulence (Lettau and Davidson, 1957).

Hot-wire anemometer. A single hot-wire, or several wires in angular arrangements enable the velocity in one or more directions to be derived from the cooling experienced by the wire. Additional electronic circuitry can greatly magnify the frequency response of the wires (Bradshaw and Johnson, 1963; Swinbank, 1951; Webb, 1955).

Table 1. Characteristics of various sensing heads for atmospheric turbulence measurements.

Sensing head	Maximum height employed (m)	Weight (g)	Time response (s)	Limiting frequency (c/s)	Measurements				
					u	v	w	θ_v	θ_w
Pressure probes	500			5	x			x	x
Cup anemometer									
(*a*) Casella Sheppard (aluminium rotor)	153	15 (head)	2	1/3	x				
(*b*) Jones (expanded polystyrene)	4	4·8 (head)	0·1	10–15	x				
E.R.A. gustmeter	9		0·1	10–15	x	x	x		
Vanes:									
(*a*) Brookhaven bi-vane (aluminium)	108	1000	> 1	0·3				x	x
(*b*) Jones (expanded polystyrene)	4	4		< 1/6				x	
Heated-bulb anemometer	12		2	0·5	x				
Hot-wire anemometer (with additional electronic circuitry)	148		0·0025	75 (> 2000)	x	x	x	x	x
Sonic anemometer	12			10	x	x	x		

θ_v, θ_w are angles of declination and inclination respectively, x indicates the variables which can be measured with particular instruments.

Sonic anemometer. Since sound travels more rapidly with the wind than against it, this principle can be employed to determine the turbulent components of velocity in any direction. The Sonic anemometer has been employed experimentally, and is now available commercially in the U.S.A.

The Brookhaven bi-vane and an associated omni-directional anemometer have been employed frequently in turbulence studies, but they have a fairly low frequency response. Both the E.R.A. gustmeter and the polystyrene cup-anemometer and vane ensemble respond to higher frequencies, but an adequate response for building research studies is near their limit, so more responsive sensing heads would be advantageous. The polystyrene vane would require modifications to determine wind inclinations, also. Additionally, both these instruments, incorporating two or three individual heads must integrate turbulent conditions over a relatively large area. The frequency response of the hot-wire anemometer is sufficiently rapid for studies of air flow about buildings. Only this type of sensing head, of very small dimensions, can record the turbulent components of interest here (although the sonic anemometer is also a potentially promising fixed array, but as yet little studied or employed in this country). With a two-wire array, a vane is required to face the sensing head into wind, and its response is usually sluggish in comparison with the head. This problem may be overcome in part through using two-wire arrays, angled to the mean wind direction, on a light vane (Jones, 1961). A fixed array of three or more wires could be employed to determine the three components of turbulent air flow; this has been tried experimentally by MacCready (1953), and is a potential solution to the problem of measuring several turbulent components of an air stream. The hot-wire anemometer appears to be the most satisfactory sensing head to employ, therefore. The principles of its operation, the circuitry involved and the particular requisites for its use in the field are enlarged upon in the appendix below.

Recording equipment and analyses

A major consideration in turbulence studies is the selection of equipment to record the rapid, continuous outputs of the sensing heads without distortion and the loss of finer detail. The simplest record can be made with photography of banks of galvanometers or counters. More sophisticated equipment employing tape recorders, such as pen or ultra-violet tracings from sensitive galvanometers, are intermediate in cost and refinement.

Most recording systems require digitization of the stored signal to a useable form. Manual or, preferably, automatic chart readers with punched tape output enable easy access to computers for data analysis. This facility is available with tape recorder signals through an analogue-to-digital computer. Normally, such signals are applied to oscilloscopes, and various band-pass filters allow the turbulent intensity through a range of frequencies to be examined immediately. A turbulent spectrum can be built up either by photographing the screen, or by repeated application of the signals. The wider use of the data via a digital record is lacking in this system.

The ultimate selection of one from several satisfactory recording systems lies in balancing costs of equipment and efficiency of its utilization. The tape recorder with its associated oscilloscope and analogue-to-digital computer is the most complete yet expensive system. It is also fairly specialized in its use. Alternatively, the digitization of traces from relatively cheaper chart recorders can prove quite costly eventually. The availability of such recorders, together with their general usefulness in other fields suggests that chart recorders are more satisfactory for this particular project.

CONCLUDING REMARKS

With the introduction of new forms of construction and greater use of taller buildings, the designer needs to take more account of the effect of turbulence on the wind loading of structural components and on the human environment in the vicinity of buildings; improvements in the weather tightness of buildings, their natural ventilation and air pollution above buildings are also indicated.

A search of the literature has shown, however, that available knowledge of wind structure in urban areas is insufficient for design purposes and further research is required.

Available methods of measurement in the field have been examined and the requisite equipment for undertaking an investigation in urban areas outlined.

Information adduced from the literature suggests that a study of the structure of turbulence in urban areas should be made initially in large open spaces within a city, well away from building wakes; velocity profiles and wind structure data obtained in such areas, will be representative of the turbulent air streams which develop over a city. Subsequent measurements nearer the buildings will indicate the influence of the buildings on their immediate surroundings, and so the interaction between the turbulent airstream and buildings in urban areas may be more closely defined for simulation in a wind tunnel.

APPENDIX

Hot-wire anemometry

A wire, heated electrically, cools at a rate proportional to the air flow across it; the relationship between wind speed and the voltage through the wire is given by King's law:

$$v^2 = \frac{R_w l}{0{\cdot}24}(T_w - T_e)[K + 2\sqrt{(K\rho c_p d V)}]$$

where v = wire voltage, l = wire length, d = wire diameter, R_w = wire resistance, T_w = wire temperature, K = medium heat conductivity, c_p = medium specific heat, ρ = medium density, V = velocity normal to the wire. T_e = temperature of medium.

Wire material and dimensions

The quality of wire response, coupled with the strength of the wire, is achieved by compromise between wire materials and the dimensions of the wire.

The wire material should be a pure, inert metal; the materials most usually employed for hot-wire anemometers are platinum, nickel and tungsten, with respective temperature coefficients of resistance, at 300°C, of $21{\cdot}0 \times 10^{-6}$, $22{\cdot}5 \times 10^{-6}$ and $12{\cdot}4 \times 10^{-6}$ (Kaye and Laby, 1941, p. 90). Platinum is used most frequently. Davies and Fisher (1964) suggest platinum is the more suitable material for yawed hot-wires, for its thermal conductivity is lower than tungsten for example. The use of tungsten for hot-wires has been limited for smooth surfaced wires were unobtainable, dust could then rapidly accumulate on them and so the wire calibration altered severely. Davies has perfected a technique recently whereby identical wires can be produced readily, which retain their calibration indefinitely.

For high sensitivity, a high wire temperature is recommended, but the maximum temperature is limited by the heating current required (usually not more than 1–2 A). Additionally, high temperatures produce an aging effect on the wires. Working temperatures should not be greater than 400°C. Tungsten hot-wires cannot be employed at temperatures above 300°C, for the material oxidizes in such conditions.

The dimensions selected for the hot-wire are important. Reducing the wire diameter increases the signal-to-noise ratio of the record, and the frequency response of the wire; it also decreases end effects, flow interference, radiation errors and current consumption, and improves its quality of response directionally. However, the narrower the wire, the less its strength, and the greater its sensitivity to dirt accumulation and slip flow effects. Similarly, the greater the length of the wire employed, the greater the signal strength of the wire, the less important are end effects, and a directional improvement ensues; yet increased wire length reduces the aerodynamic strength of the wire and its space resolution. Wire length defines especially the smaller eddy length which can be accurately measured; to examine smaller lengths, end corrections must be made.

In wind tunnel work, wire diameters 0·0005–0·001 in. (0·0127–0·025 mm) are common. The ratio of length of wire to diameter should be greater or equal to 100, preferably. In low-level turbulence studies, with an air flow of 0–3 m/s (0–10 ft/s), wires of 0·0001 in. dia. and lengths of 0·0025 and 1·27 mm (0·0001 in. and 0·05 in.) are recommended. Wire diameters five times greater are considered more suitable in very fluctuating air streams of high velocity. In the field, platinum wires have been used more frequently; wire diameters lie in the range 0·01–0·02 mm, and the lengths employed vary between 1 cm (MacCready, 1953) and 5 cm (Deacon, 1957).

Circuitry

A constant current can be passed through the hot-wire anemometer, and the wind speed occurring can be determined from the varying resistance of the wire. Alternatively, constant resistance, i.e. temperature, can be established through the hot-wire and its change in current indicates the relevant wind speed. The constant current method, although the simpler circuit to design, has several disadvantages. The self-time constant of the wire decreases with increasing flow; in high turbulence intensities, there is no single time constant, for the flow velocities vary over too wide a range. There is also a possibility of the wire burning out. The sensitivity of such a system changes with operating point, and so should only be used for low-level turbulence flows, $[\overline{(u^1)^2}]^{\frac{1}{2}}/\bar{u} < 0\cdot10$. With a constant temperature arrangement, however, the heat capacitance of the wire is diminished, a high frequency limit can be achieved, and the effective sensitivity of the hot-wire can be measured adequately. This latter system is recommended, therefore, where a hot-wire can be measured adequately. This latter system is recommended, therefore, where a hot-wire anemometer is employed to measure atmospheric turbulence close to the earth's surface.

Time response of a hot-wire

The response of a hot-wire is a function of its time constant, given by

$$M = Jms \frac{(R_w - R_e)}{i^2 R_0 \alpha}$$

where R_0 = wire resistance at 0°C, J = mechanical equivalent of heat, m = mass of wire, s = specific resistance of the wire material, α = temperature coefficient of resistance (for example, a platinum wire, 0·0025 mm dia., 3·81 mm long (0·001 and 0·15 in.) would have a time constant $M = 0\cdot001$ s for a wind speed 70 ft/s (21 m/s). The time constant of MacCready's larger wire was 0·0025 s for average high wind speeds. The response dropped slightly to 78 per cent at 40 c/s. Since the smaller the wire diameter, the greater the resistance per unit length, the time constant is approximately proportional to $d^{3/2}$, for a given air speed. A heated wire will respond to velocity fluctuations with an amplitude diminished in the ratio:

$$[1 + M^2\omega^2]^{-\frac{1}{2}}$$

where $\omega = 2n \times$ frequency, and with phase retardation $\tan^{-1}(M\omega)$. As the frequency increases the amplitude of output is not proportional to, nor in phase with, that of turbulence. The time constant M cannot be found very accurately, for the exact dimensions and purity of the wire are required. It can be found experimentally, either by injecting a small square-wave voltage across the hot-wire anemometer bridge to alter the balance point of the bridge systematically, or by subjecting the wire to a velocity step in a shock tube, and so determining the thermal time constant; fitting an exponential time function to the measured bridge output allows the frequency response of the wire to be estimated. $1/2\pi M$ is the frequency at which the wire response falls to $1/\sqrt{2}$ of its steady state value.

A high frequency cut-off can be achieved by compensating electronically for the thermal inertia of the wire, to extend the frequency range to many kc/s it is possible to achieve a flat response to $500/2\pi M$. The insertion of a current feedback to the wire bridge circuit (see figure 1) allows the thermal inertia of the hot-wire to be almost ignored; the wire response will depend mainly on the amplifier inserted in the circuit.

A high amplifier transconductance keeps the wire at almost constant resistance. The maximum frequency response will depend on this transconductance, and on the amplifier's own frequency response. The amplifier transconductance $G = \Delta i/\Delta v$, where Δv is the error (out-of-balance) voltage, and i is the bridge current. The upper frequency limit of the hot-wire is increased by the factor

$$2G \, . \, R_w \frac{(R_w - R_e)}{R_e}$$

(e.g. for tungsten $\alpha = 4 \times 10^{-3}/°\mathrm{C}$, with $G = 10$ mA say, and $R_e = 3{\cdot}5\Omega$, $t = 200°\mathrm{C}$, so $R_w/R_e = 1{\cdot}8$ then the improvement factor is 100). An upper limit to the improvement factor is imposed by the appearance of high frequency oscillations with the closed loop system at high gain values. Stable, sensitive and carefully designed amplifiers must be used to avoid this.

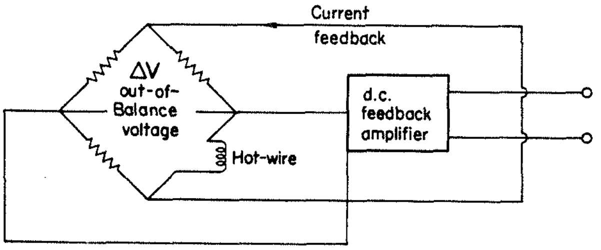

Fig. 1.

Linearization of velocity–voltage output

The non-linearity of the voltage–velocity calibration causes a spurious increase in spectral density at high frequencies in intense turbulence. Hence, a further refinement to the simple bridge circuit is essential if the hot-wire anemometer is to be used in such conditions. (A constant current circuit cannot be linearized adequately.) A linear output for the wind speed range 1–16 m/s has been achieved by DEACON and SAMUEL (1957) through the employment of a single germanium crystal element, whose non-linear characteristics counteracts that of the hot-wire. MACCREADY (1953) required three biased 6AL5 rectifiers (thermionic valves) to linearize the bridge response of his hot-wire arrangement. More recently, individual sections of the voltage–velocity calibration curve have been linearized by single rectifiers, selecting that particular part of the curve relevant to the average flow conditions occurring at that time.

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Il devient de plus en plus évident aux dessinateurs qu'avec l'introduction de nouvelles formes de constructions et avec un emploi plus grand de constructions élevées, il faudrait faire plus cas de l'effet de la turbulence du vent dans le plan des constructions, c.a.d. en ce qui concerne le chargement des composantes de structure, de l'environnement humain dans la vicinité des constructions, de la résistance générale au climat, de la ventilation naturelle et de la pollution de l'air autour de la construction. Une recherche dans la litterature de la structure du vent près des constructions indique que les connaissances actuelles sont insuffisantes en ce qui concerne les plans. Les méthodes de recherche de la structure du vent sont revisées et commentées et des commentaires sont faits sur la nécessité d'étudier les conditions dans les régions urbaines.

Es wird den Entwerfern im zunehmenden Masse augenscheinlich, dass durch die Einführung neuer Konstruktionsformen und die Verwendung höherer Gebäude der Einwirkung von Windturbulenz auf Bauentwürfe mehr Beachtung geschenkt werden muss, d.h. in Bezug auf Belastung der Strukturbestandteile, der menschlichen Umgebung in der Nähe der Gebäude, der allgemeinen Wetterfestigkeit, natürlichen Ventilation und Luftverunreinigung im Bereiche der Gebäude. Eine Forschung im Schrifttum über Windstruktur in der Nähe von Gebäuden zeigt, dass das bisherige Wissen für Entwurfszwecke unzulänglich ist. Zur Verfügung stehende Methoden der Forschung über Windstruktur auf diesem Gebiete werden überprüft und Kommentare über die Notwendigkeit, die Bedingungen in Stadtbereichen zu studieren, werden gegeben.