UDC – 53.043:699.83

NEW TECHNOLOGIES FOR DIAGNOSTICS AND REDUCTION OF INTENSITY OF SURFACE WIND OF HIGH-RISE BUILDINGS

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https://doi.org/10.56243/18294898-2025.2-45

Abstract

Numerous observations of the process of surface winds at the base of skyscrapers have nevertheless not enabled scientists to create a physically based technology to combat them. Consequently, administrations of large cities are forced to restrain the pace of urban construction to ensure the safety of citizens. The version proposed in the article is based on the fundamental laws of physics about the movement of air masses and considers the process of formation of surface wind as a consequence of the formation of the difference of temperature fronts on both sides of a high-rise building facing south.

Keywords: ground wind, high-rise building, skyscraper, volume of air.

Introduction

High-rise construction appeared back in the 1950s in America at the turn of the Industrial Revolution, when production began to develop in fast-growing cities, which entailed a large influx of people. High-rise buildings had many advantages over low and medium-rise buildings and completely solved the problems of growing megacities. The question of the impact of high-rise buildings on the environment arose at the same time when high-rise construction itself began. The interest in studying the impact of high-rise construction on the environment was caused by the unusual behavior of air masses near high-rise buildings. This was manifested in the fact that some buildings literally attracted winds to themselves and vortex flows appeared in their surface part, creating great inconvenience for pedestrians [1].

Known versions of the causes of surface winds

In these years, such winds were first felt by Chicago residents, but the city authorities and scientists could not take effective measures to combat them, so the city hall limited itself to building railings around skyscrapers to provide some safety for pedestrians who were thrown by the wind on the roadway.

In 2015, the 160-meter Walkie-Talkie skyscraper in the City of London (Fig. 1) was found to have this property, which was of particular concern to the city authorities, who have been steadily tightening the standards for skyscraper construction every year for the safety of pedestrians and cyclists [2,3], thus curbing the city's growth rate.

The cause of hurricane-force surface winds at the base of skyscrapers has been the focus of attention of experts in the field for decades. However, numerous observations of the properties of these winds have not yet allowed to create a unified theory from the position of which it would be possible to develop an effective technology to combat them.

The main version is the following - "Wind acceleration near skyscrapers is caused by the downward flow effect. This occurs when the wind hits a building and, with no other place to go, is pushed up, down and sideways. The air pushed downward increases in velocity at street level." [4, 5]. However, this version is in contradiction with the laws of Newtonian mechanics, according to which no body, and in this case a mass of air pushed downward, can acquire acceleration without the influence of an external force, and the noted version does not specify the mechanism of any force on the noted mass of air. Moreover, its velocity will decrease due to friction against the lower floors of the building and due to collision with the wind blowing perpendicular to its direction at the level of these floors. Therefore, this volume of air will not be able to maintain the speed of the wind rushing against the skyscraper, especially since much of its energy will be lost when it hits the street, when the wind must change direction to blow along it.

New methodology for studying surface winds

Research conducted at the State University of Architecture and Construction of Armenia has shown that the surface wind of skyscrapers can occur even in conditions of absolutely windless weather and along with a huge number of “problem-free” skyscrapers is observed only in those that are directed with the broad side to the south or at an angle to it.

Such buildings themselves generate the surface wind around themselves in the following way - the sun-warmed facade of the building across its width and height forms a powerful upward flow of warmed air, forming a low-pressure area at its base. This area draws in cooler air from the surrounding streets and especially the much colder and heavier air from the north side of the skyscraper, where it has created a large shadow area due to its size and has kept the nighttime cool for a long time. These air currents, which girdle the skyscraper on both sides from north to south and are directed towards it from all nearby streets, create the surface winds recorded at the base of the skyscraper.

The proposed version is in full compliance with the laws of physics describing the process of wind formation as a consequence of atmospheric pressure difference. Moreover, it provides an exhaustive explanation of all observations about the behavior of these winds in the vicinity of skyscrapers. In this context, the observation that - "wind acceleration occurs if the building has absolutely right angles" [4, 6] is very interesting. However, in the laws of physics and in known technical solutions there is no such concept that a right angle of a building or any other structure can serve as a source of additional energy for the wind and accelerate it. On the contrary, it is known from the theory of tunnel ventilation that straight (unrounded) corners of tunnel portals counteract the drawing of fresh air into it.

In fact, the reason for strong winds is not the presence of right angles in a building, but the fact that buildings of rectangular construction containing right angles have a larger surface area and create a greater upward flow than buildings with rounded construction, such as Gherkin (Fig. 2) in London [6] and Burj Khalifa (Fig. 3) in Dubai [4], which are less warmed by the sun and do not create a sufficiently powerful upward flow, which is also dissipated due to the narrowing of their structure towards the top.

It is also quite true that taller skyscrapers create stronger winds. However, the reason is not that their upper floors face stronger winds [6], but that their larger surface creates a stronger upward flow. It is certainly true that higher altitudes are dominated by faster winds, but such a wind would need to overcome much greater frictional resistance against all floors of the building before reaching street level.

In some works, the presence of strong winds at the foot of skyscrapers is explained by the «channeling» effect [6], where the wind is forced through a narrow space, entering a canyon between two skyscrapers. It is also suggested that "the wind between two skyscrapers is compressed and accelerated. It is exactly like using a nozzle to increase the velocity of water" [7] . However, the physical basis of wind and water motion are diametrically opposite - wind moves due to the fact that the force of atmospheric pressure «pushes» the air from the high pressure area to the low pressure area, and water moves due to the fact that the Earth's gravity «attracts» a certain mass of water with some constant force and therefore, according to the law of conservation of energy, the speed of water increases when the volume and, accordingly, the mass of water passing through the narrowing openings of rivers decreases.

This is not the case with wind. There is no physical force that «pulls» it into the narrowing opening - it hits obstacles, is dispersed and partially thrown back. This effect is clearly demonstrated in practical wind energy classes by a fan blowing into a funnel. Experience shows that the same amount of air passes through the outlet nozzle of the funnel and at the same velocity as through the same opening in a smooth barrier. This is explained by the fact that the wind, reflecting from the conical walls of the funnel, creates an air cushion in front of the entrance to its nozzle, the pressure in which is directed against the wind blowing into the funnel.

The same thing happens when the wind hits buildings - it dissipates from hitting them and the air thrown into the space between the buildings creates a barrier to the oncoming wind, preventing it from accelerating, as in the case of the funnel. However, the observation that the narrow streets of London generate stronger surface winds than the wide streets of New York [4] is quite true. This is explained by the fact that skyscrapers of the same size in London and New York form the same upward flow, but the air, which, according to the stated version, is «pulled» into its place (in this case by analogy with water) along the narrow London streets, has a higher speed in comparison with the movement of the same volume of air along the wide streets of New York.

The large number of «problem» skyscrapers and stronger surface winds in England can also be explained by the fact that, due to weather conditions, English architects are more inclined to “sunny” orientation of skyscraper facades and prefer to clad their structures with heat-absorbing materials. Examples of this are the cladding of Bridewater Place in Leeds (Fig. 4) with aluminum, which is the second most heat-absorbing material after copper, and the bright Walkie- Talkie cladding in London (Fig. 1), on the reflected rays of the sun, according to journalists [2], you can cook eggs.

Recommendations on design and diagnostics of skyscrapers aerodynamics

Thus, it can be stated that the proposed version fully explains all the reasons for the formation of surface winds and manifestations of their properties in the vicinity of skyscrapers. This allows us to formulate some recommendations for their design:

- high-rise buildings should face south with a narrow side;
- even in such an arrangement, building facades should not contain heat-absorbing cladding to avoid surface winds during sunrise and sunset hours;
- buildings located to the north of the projected skyscraper will contribute to the reduction of its surface winds, as the warming of their facades will draw some of the cold air from the northern courtyard of the skyscraper to itself;
- the presence of buildings to the south of the projected skyscraper will increase its surface winds, as in their shadow areas will be formed an additional volume of cold air, which will rush to skyscraper as soon as its heating will create an upward flow of air and will form, as a result, an area of low pressure at its base.

Consequently, the surface wind of each skyscraper is the result of the complex influence on its «wind situation» of all nearby buildings. Therefore, the diagnosis of the expected surface winds on each street should be carried out by the technology of computer modeling, in the program of which it is necessary to introduce algorithms of the underlying physical phenomena:
1 - air moves from a high-pressure region to a low-pressure region;
2 - warmed air rises upwards.

Diagnostics is also possible by analogy with tests of buildings in a wind tunnel [6], but for the case of studying surface winds it is necessary to build a model of a residential complex from heat-absorbing material, simulate the sun by means of a thermal radiator and register the air movement on the streets of the model by means of smoke or micro sensors. The warming effect of building facades can be enhanced by realizing their local heating by means of built-in electric heaters.

Technologies to reduce the intensity of surface winds

However, the diagnosability in the design of new skyscrapers leaves open the following question – «buildings that create wind flow problems are large, beautiful and expensive, so they cannot simply be demolished» [4, 6] . Currently, to reduce the intensity of surface winds near these buildings, protective barriers are used [8] , which partially disperse or deflect the already generated wind from the sidewalks without having any effect on the causes of its occurrence.

In this perspective it is of interest the method of counteracting the process of formation of surface wind [9], based on the statement of the above-mentioned version that a large volume of cold air is formed in the northern part of the building, which creates the greatest pressure at its base, pushing the air from there to the southern side of the building, where the upward flow of air formed a low-pressure area.

The movement of this volume of air along the entire circumference of the building can be prevented by providing the air with a shortened corridor from the base of the north wall of the building to its south façade through several 30-50 cm diameter pipes that will run through the technical floors of the building and exit through its lobby at the second floor level, so as not to interfere with pedestrians and traffic. Design solutions will make it possible to make the pipe outlets look like portholes or other design structures.

From the perspective of theoretical physics, it can be argued that this technology can provide complete suppression of the surface wind around the building only if it is assumed that the pipes laid through the building present zero resistance to the air passing through them. In the real case, however, a very small amount of wind flow will continue to girdle the building due to the fact that the inner walls of the pipes will offer some non-zero resistance to air movement.

Therefore, the wind intensity in the pipes and in the direction around the building will be determined by the ratio of the resistance of these directions to the air flow in accordance with the well-known physical law of the movement of certain media in the direction of least resistance, which is a fundamental principle in both electrical engineering and computing technologies.

Consequently, it can be concluded that increasing the number of “parallel” installed pipes in a building will contribute to reducing the total resistance of the through corridor running through the building. It is also obvious that the increase of wind flow through the pipes will be promoted by the increase of their diameter, as in this case the internal resistance of the pipes will grow in proportion to the radius of the pipe, and its capacity - in proportion to the square of the radius.

Fig. 1. Walkie -Talkie skyscraper (160 m) in London

Fig. 2. Skyscraper Gherkin (180 m) in London

Fig. 3. Skyscraper Burj Khalifa (828 m) in Dubai

Fig. 4. Bridgewater Place skyscraper (112 m) in Leeds

Conclusion

The presented version gives an exhaustive explanation of all manifestations of the properties of surface winds. It allows us to formulate some recommendations for the design of high-rise buildings, providing the reduction of the effect of surface winds, as well as to develop a technique for diagnosing their interaction with high-rise buildings. A new technology for reducing the intensity of surface winds at the base of already built skyscrapers is proposed.

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ԲԱՐՁՐԱՀԱՐԿ ՇԵՆՔԵՐԻ ԳԵՏՆԱՄԵՐՁԱՅԻՆ ՔԱՄԻՆԵՐԻ ՆՎԱԶԵՑՄԱՆ և ԱԽՏՈՐՈՇՄԱՆ ՆՈՐ ՏԵԽՆՈԼՈԳԻԱՆԵՐ

Մ.Վ. Մարկոսյան, Հ.Հ. Այվազյան
Երևանի կապի միջոցների ԳՀԻ ՓԲԸ

Բարձրահարկ շենքերի հիմքերի շրջակայքում առաջացող գետնամերձային քամիների բազմաթիվ ուսումնասիրությունները մինչ օրս դեռևս թույլ չեն տվել գիտնականներին առաջադրել ֆիզիկայի տեսանկյունից հիմնավորված տեխնոլոգիա նրանց դեմ պայքարելու համար: Դրա հետևանքով խոշոր քաղաքների իշխանությունները ստիպված են սահմանափակել քաղաքաշինության աճը քաղաքացիների անվտանգությունը ապահովելու նպատակով: Հոդվածում առաջարկած վարկածը կառուցված է օդային զանգվածների շարժման ֆիզիկայի հիմնարար օրենքների վրա և դիտարկում է գետնամերձային քամիների առաջացումը որպես դեպի հարավ ճակատային մասով ուղղված շենքերի երկու կողմերի օդի զանգվածների միջև ջերմային տարբերության ձևավորման հետևանք:

Բանալի բառեր՝ գետնամերձային քամի, բարձրահարկ շենք, երկնաքեր, օդի զանգված

НОВЫЕ ТЕХНОЛОГИИ ДИАГНОСТИКИ И СНИЖЕНИЯ ИНТЕНСИВНОСТИ ПРИЗЕМНОГО ВЕТРА ВЫСОТНЫХ ЗДАНИЙ

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Многочисленные наблюдения процесса возникновения приземных ветров у основания небоскрёбов тем не менее не позволили учёным создать физически обоснованную технологию борьбы с ними. В связи с этим администрации больших городов вынуждены сдерживать темпы городского строительства для обеспечения безопасности граждан. Предложенная в статье версия основана на фундаментальных законах физики о движении воздушных масс и рассматривает процесс формирования приземного ветра как следствие образования разности температурных фронтов по обе стороны высотного здания, обращённого фасадом на юг.

***Ключевые слова*:** приземный ветер, высотное здание, небоскрёб, объём воздуха

Submitted on 03.02.2025
Sent for review on 10.02.2025
Guaranteed for printing on 26.07.2025