# How Much Height Matters to Wind Load Depends on the Surroundings: More in a City, Where the Wind Below Is Slow

— under the same upper wind, the ratio of dynamic pressure at **300** m to **10** m is **1.9037** over the sea and **6.2755** in a city — the separator is what stands around — [Paper 661]

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**Abstract**

**The taller a building, the stronger the wind it meets. Wind near the ground is dragged slow by the roughness of the surface and grows faster higher up. The growth is well described by a power of height, $z^{\alpha}$, and the exponent $\alpha$ differs with what is around.Under the same upper wind, how the roughness of the surroundings changes the effect of height is counted.No new theorem or law is claimed. First, the rougher the surroundings, the more height matters ——the ratio of dynamic pressure at 300 m to that at 10 m was 1.9037 over the sea, 2.7742 in open country, 3.8981 in suburbs and 6.2755 in a city** (Section 2). **Second, and this is the core.Height matters more in a city because the wind below is slow, not because the wind above is fast——with the upper dynamic pressure as 1, the dynamic pressure at 10 m is 0.5253 over the sea against 0.1149 in the city, and even at 300 m it is 1.0000 over the sea against 0.7209 in the city; the city is weaker at every height** (Section 2). **Third, the surroundings also set the exponent of the overturning moment——the overturning moment of a building of constant width grows as height to the power $2+2\alpha$, and the ratio between 200 m and 100 m was 4.5948 over the sea and 5.8159 in the city. Under the same upper wind, the overturning moment of a 100 m building in the city was 0.4144 of that over the sea** (Section 3). **Fourth, the separator is what stands around——how much height matters to wind load is set not by the building's material or shape but by the roughness of the ground upwind** (Section 4). **Keywords**: wind load, wind speed profile, terrain roughness, overturning moment, tall buildings.

**Scope of this paper (scope note)**: **No new theorem or law is claimed——describing wind speed near the ground by a power of height (Hellmann 1916), and the change of the exponent with ground roughness and its effect on wind load (Davenport 1961 and others), are both known.These are example values——the exponents and gradient heights (sea $0.10$ and $250$ m, open country $0.15$ and $350$ m, suburbs $0.20$ and $450$ m, city $0.27$ and $550$ m) are set as an example and are not claimed to be the values of any code.What is not treated——gusts, vortices behind buildings, building sway and local flows around neighbouring buildings are not treated; only the distribution of dynamic pressure is examined.Relation to earlier papers**: **Paper 454 showed that the resultant water thrust grows as the square of depth and the overturning moment as the cube, yet the width of a dam need only grow in proportion to depth——with wind, the force grows as height to the power $1+2\alpha$ and the overturning moment to $2+2\alpha$, and the surrounding ground sets the exponent.**What is added is **setting four roughnesses side by side under the same upper wind**, **showing that the ratio with height and the absolute value move in opposite directions**, **deriving the overturning moment by integration and closed form**, and **placing the separator on what stands around**.

## 1. Notation and the Question

**Setting**: **let $V_G$ be the speed of the upper wind (the wind above the gradient height $Z_G$), and write the speed of the wind near the ground as**

$$V(z) = V_G\left(\frac{z}{Z_G}\right)^{\alpha} \qquad (z \le Z_G)$$

**The dynamic pressure $\frac{1}{2}\rho V^2$ with which the wind pushes on a building is then $(z/Z_G)^{2\alpha}$ with the upper dynamic pressure as $1$.The exponent $\alpha$ and gradient height $Z_G$ were set as an example: sea $0.10$ and $250$ m, open country $0.15$ and $350$ m, suburbs $0.20$ and $450$ m, city $0.27$ and $550$ m.**

**Question**: **under the same upper wind, what sets how much height matters?**

## 2. The Effect of Height

**Computation 2.1**: **with the upper dynamic pressure as $1$, the dynamic pressure was derived at each height.**

| surroundings | 10 m | 100 m | 300 m | 300 m over 10 m |
|---|---|---|---|---|
| sea | 0.5253 | 0.8326 | 1.0000 | 1.9037 |
| open country | 0.3442 | 0.6867 | 0.9548 | 2.7742 |
| suburbs | 0.2181 | 0.5479 | 0.8503 | 3.8981 |
| city | 0.1149 | 0.3983 | 0.7209 | 6.2755 |

Aligning on the 10 m wind without regard to the gradient height, the ratio of 300 m to 10 m would be 1.9744 over the sea and 6.2755 in the city (over the sea the wind stops growing above 250 m, hence 1.9037 in the table).

> **Observation 2.2**
>
> this is the core: height matters more in a city because the wind below is slow, not because the wind above is fast.The ratio of 300 m to 10 m is far larger in the city, 6.2755, than over the sea, 1.9037. But the dynamic pressure itself is weaker in the city at every height, 0.7209 at 300 m against the sea's 1.0000——the ratio is large because its denominator, the wind near the ground, has been dragged down to 0.1149 by the buildings.

## 3. The Overturning Moment

Computation 3.1: for a building of constant width, the overturning moment about its base, $\int_0^H q(z) z dz$, was integrated numerically. The ratio between heights of 200 m and 100 m was 4.5948 over the sea, 4.9246 in open country, 5.2780 in suburbs and 5.8159 in the city, agreeing with the closed form $2^{2+2\alpha}$ within $10^{-4}$.Under the same upper wind, the overturning moment of a 100 m building in the city was 0.4144 of that over the sea.

> **Observation 3.2**
>
> the surroundings also set the exponent of the overturning moment.The overturning moment of water pressure goes as the cube of depth, fixed; the overturning moment of wind goes as height to the power $2 + 2\alpha$, which is 2.54 in the city and 2.2 over the sea——the price of building taller is greater in the city, yet a building of the same height receives less force there.

## 4. The Separator

**Observation 4.1**

**the separator is what stands around.What sets the exponent is not the building's material or shape but the roughness of the ground upwind. Whether the same building stands by the sea or in a town changes both how much height matters and how large the force is——the effect of height and the size of the force move in opposite directions with the roughness of the surroundings.**

**Observation 4.2**

**beside Paper 454.Paper 454 showed that the resultant water thrust grows as the square of depth and the overturning moment as the cube, yet a dam's width need only grow proportionally. For water the exponents are fixed——for wind, the force grows as height to the power $1 + 2\alpha$ and the overturning moment to $2 + 2\alpha$ , and the surrounding ground sets the exponent itself.**

**Observation 4.3**

**what is not said.The exponents and gradient heights are example values. Gusts, vortices, building sway and local flows around neighbouring buildings are not included——what is shown is that the height distribution of dynamic pressure is set by the roughness of the surroundings, and its two directions.**

## 5. Roll Call and Closing

1. **300 m over 10 m is 1.9037 over the sea** (Computation 2.1): **height matters little.**
2. **6.2755 in the city** (Computation 2.1): **height matters much.**
3. **the city's 10 m is 0.1149** (Computation 2.1): **slow below.**
4. **the city's 300 m is 0.7209** (Computation 2.1): **weaker than the sea above too.**
5. **the ratio is large because the denominator is small** (Observation 2.2): **the core.**
6. **moment ratio 4.5948 over the sea** (Computation 3.1): **$2^{2.2}$.**
7. **5.8159 in the city** (Computation 3.1): **$2^{2.54}$.**
8. **100 m moment, city over sea, 0.4144** (Computation 3.1): **less force.**

9. **effect and size move oppositely** (Observation 4.1): **with the roughness around.**
10. **what stands around** (Observation 4.1): **the separator; Paper 454.**

**Closing**: **Taller buildings meet stronger wind, but how much height matters is set by what stands around.Under the same upper wind, the ratio of dynamic pressure at 300 m to 10 m was 1.9037 over the sea and 6.2755 in the city, yet the dynamic pressure itself was weaker in the city at every height, 0.1149 at 10 m and still 0.7209 at 300 m.The overturning moment grows as height to the power $2 + 2\alpha$, and even for the same 100 m it was 0.4144 in the city of that over the sea——height matters more in a city because the wind below is slow.The separator is what stands around.Placed among the earlier papers——the exponents that were fixed for water in Paper 454 are set for wind by the surrounding ground.To be honest——the exponents are example values, and gusts and vortices are not included.**

## References


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