

how it might work....
engineering with 3 equations
and the internet....

Simon Smith

the 3 equations.....

$$\sum F_v = 0$$



.....for objects not to move then equilibrium has to exist in translational and rotational directions.....

1. forces acting up and down must balance
2. forces acting left and right must balance
3. turning forces acting clockwise and anticlockwise must balance

$$\sum F_H = 0$$



$$\sum M_p = 0$$



who said that.....

- **First Law**

A body will remain at rest, or in a uniform state of motion unless acted upon by a force

- **Second Law**

A force acting on a body will cause it to move (more strictly speaking accelerate).

Force is related to acceleration by the equation,
force=mass x acceleration ($F = ma$)

- **Third Law**

Every action has an equal and opposite reaction

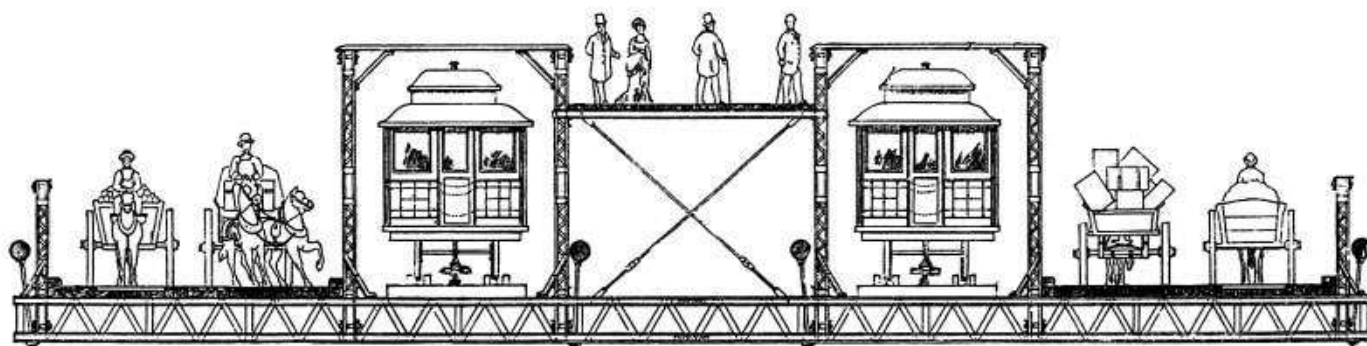


Isaac Newton
17th century

Brooklyn Bridge NY – 1883

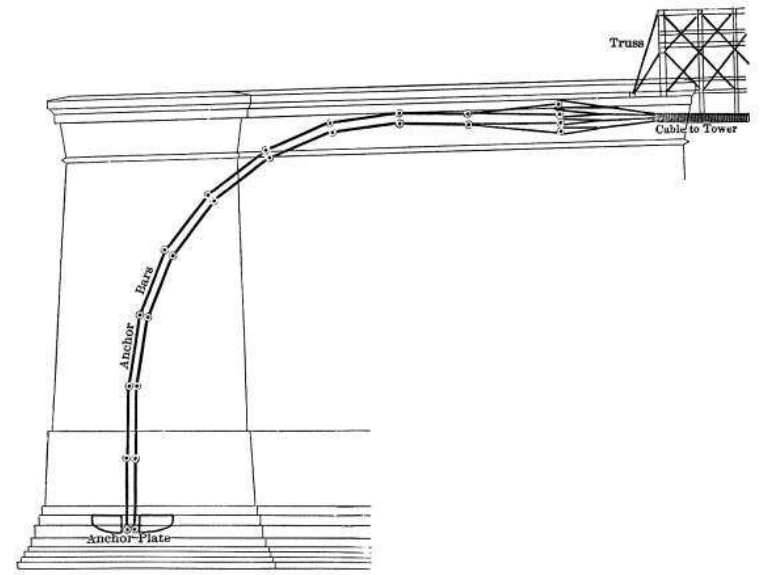
....cable design....



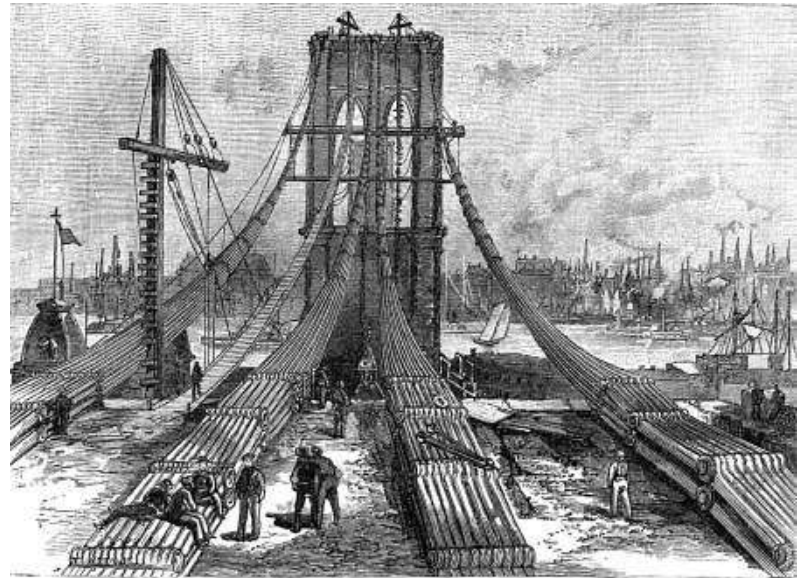


SECTION OF BRIDGE, SHOWING FOOT, RAIL, AND CARRIAGE WAYS.

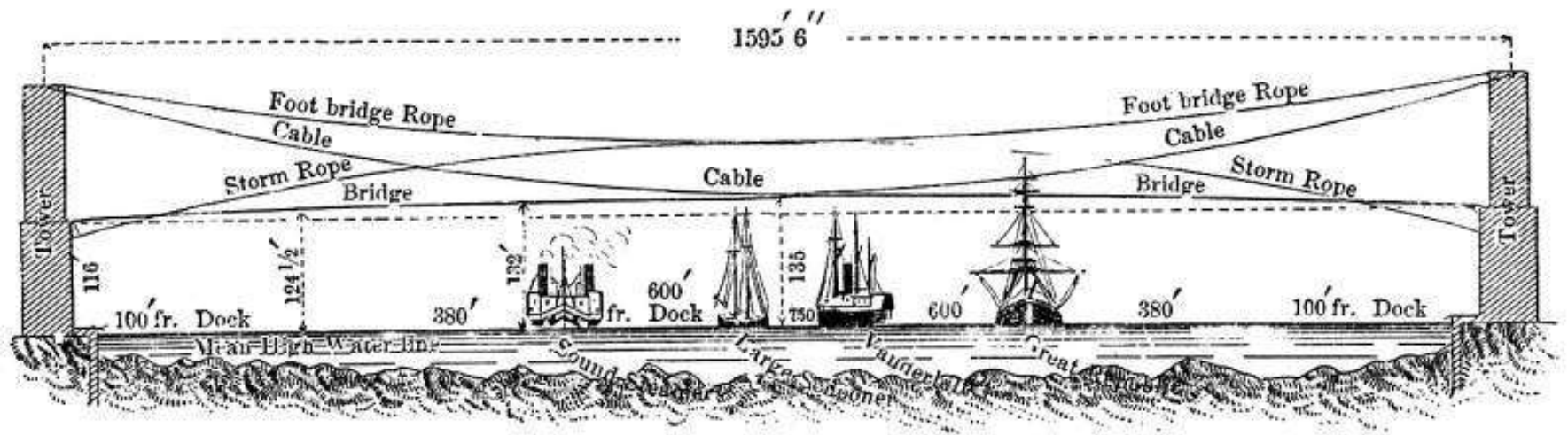




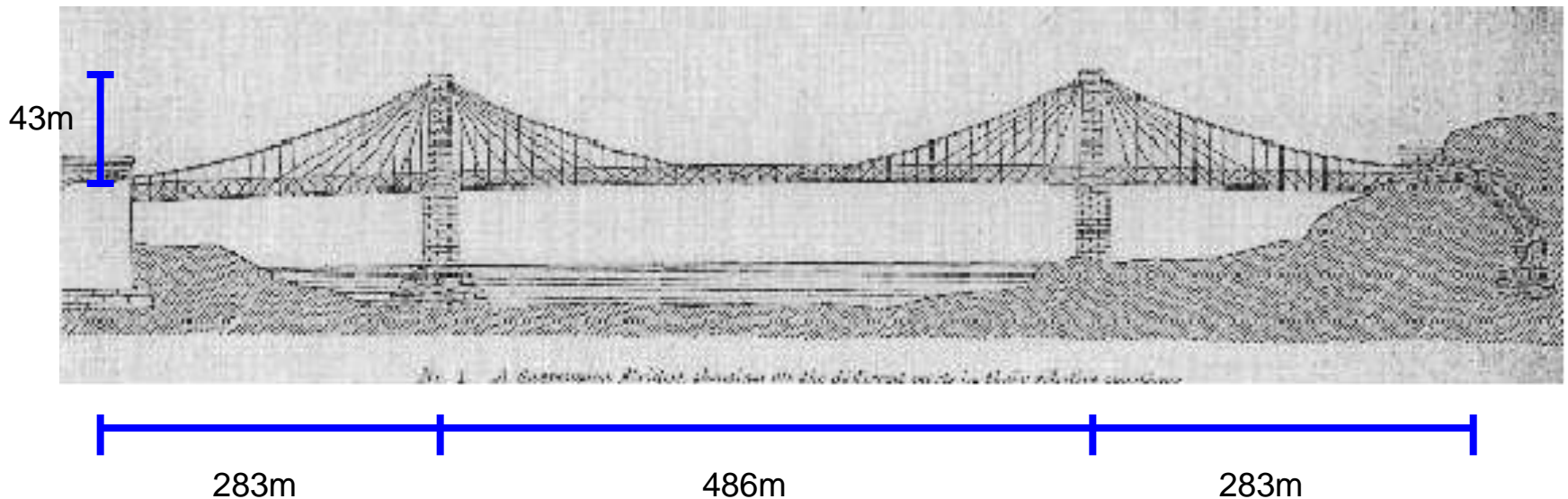
SECTION OF TOP AND BACK OF ANCHORAGE—SIDE VIEW.



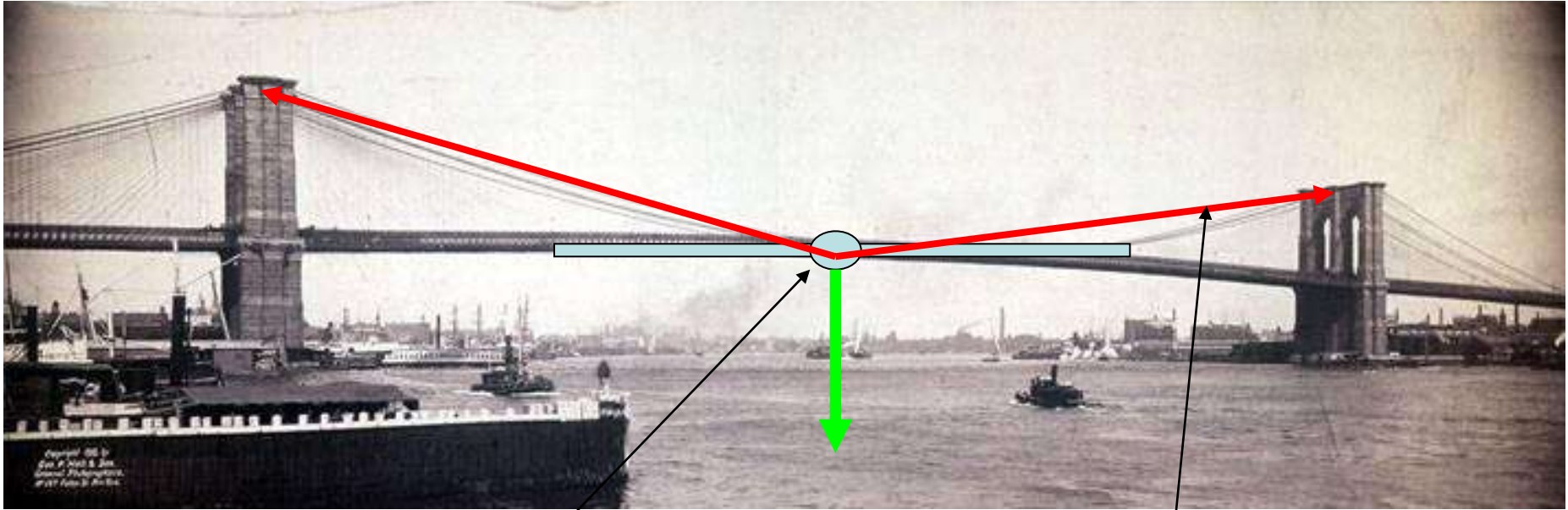
THE BROOKLYN ANCHORAGE.



ELEVATION OF BRIDGE, SHOWING TEMPORARY ROPES USED IN CABLE-MAKING.



structural model

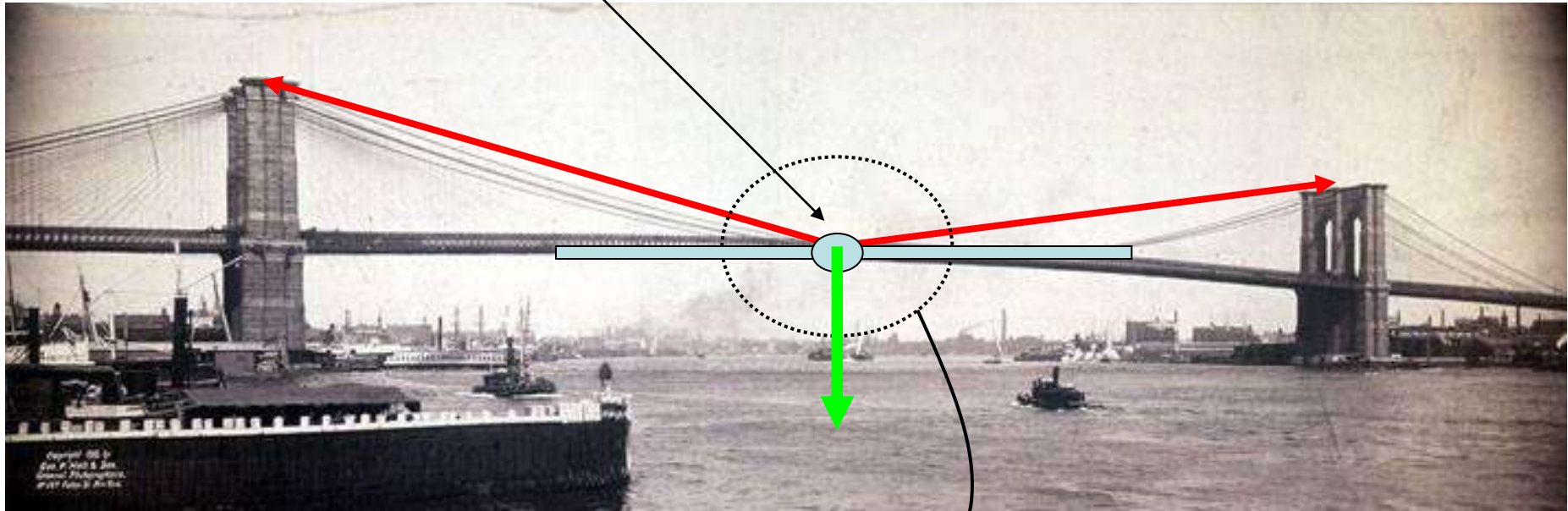


load from bridge deck concentrated at centre of span, point load representing half the span of the bridge

suspension cables represented by simplified straight 'wires' to centre of span

Deck area 243m x 24m (5800m²)

Represents load of 4000t based on 700kg/m²

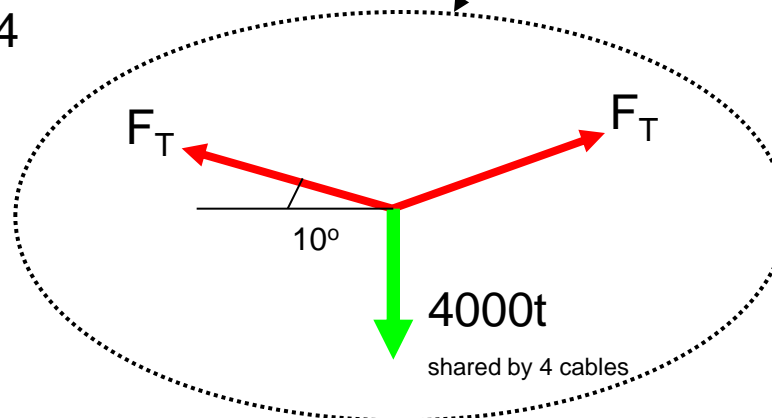


Using vertical equilibrium tension force in cable is given by:

$$2 \times F_T \times \sin 10^\circ = 4000t / 4$$

therefore $F_T = 2880t$

$$\Sigma F_v = 0$$



<http://www.inventionfactory.com/history/RHAbbridg/bb.html>

‘....Number of supporting cables: 4

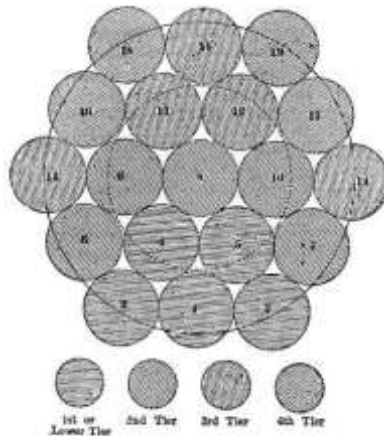
Diameter of each cable: 15 ½ inches

Length of each single wire in cables:

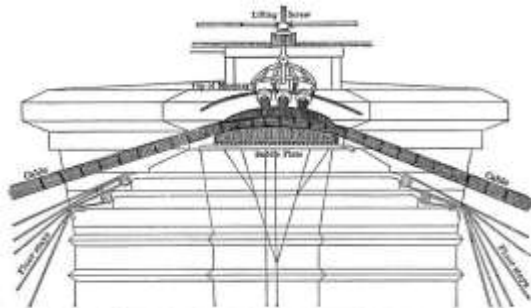
Diameter of each single wire in cables:

A cable contains 19 strands, containing 2381 wires at a total of 21,432 wires in each cable..??

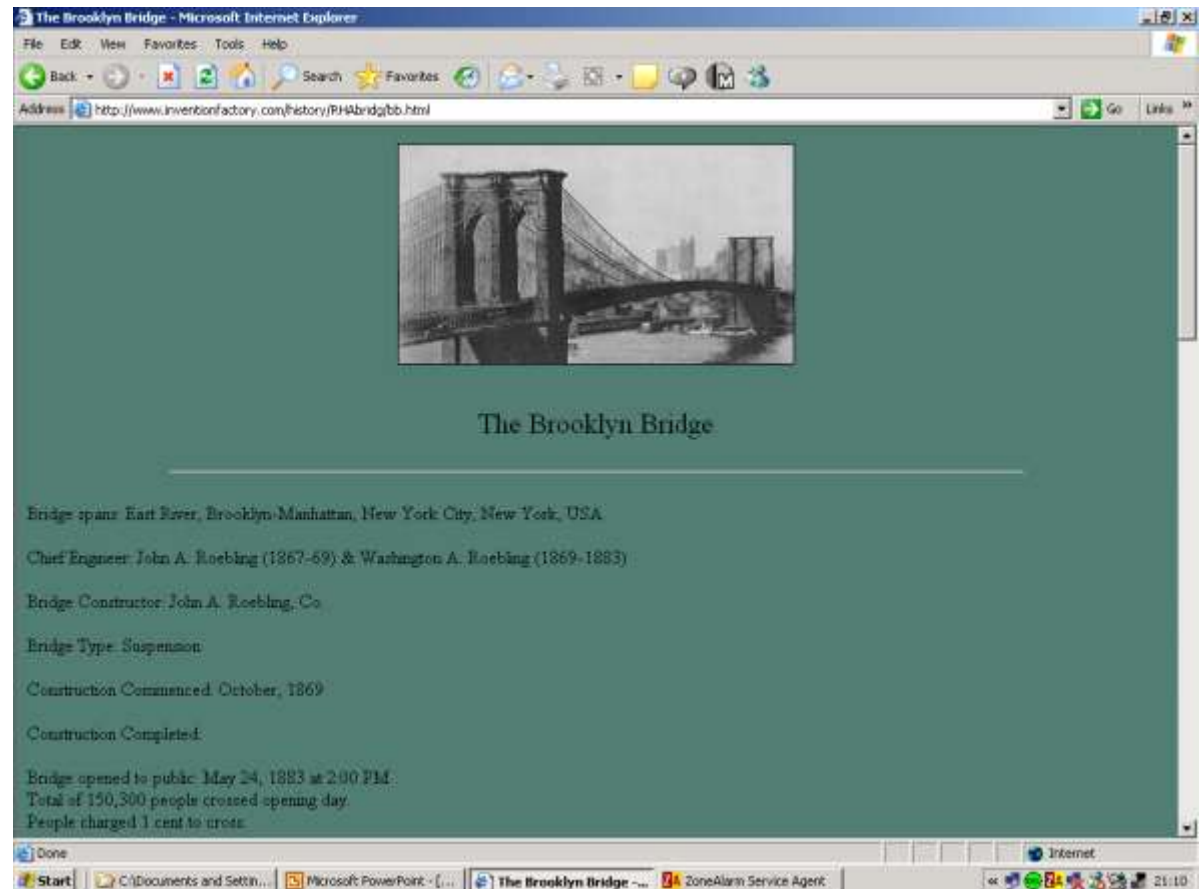
Ultimate strength of a cable: 11,200 tons.....'



SECTION OF CABLE, SHOWING STRANDS.



SECTION OF TUBES, SHOWING GABLE-PLATE AND LIP/WEDGE OF STRAND INTO PITCHER



<http://www.endex.com/gf/buildings/bbridge/bbridgefacts.htm>

‘.....Inventor and manufacturer of steel wire cable - John A. Roebling
Tested cable wire strength - 160 ksi
Maximum load on single cable (Live and Dead Load) - 6,000 kips
Ultimate strength of cables - 24,600 kips
Cable factor of safety - $24,600/6,000 = 4.1$
Maximum cable sag - 130 feet.....’

<http://www.unc.edu/~rowlett/units/dictK.html>



‘....kip [1]

an informal unit of force, sometimes used by engineers to express the amount of weight borne by a structure.

One kip equals 1000 pounds (453.59 kilograms) of force or about 4.4482 kilonewtons.

The name of the unit is an abbreviation of "kilopound.".....’

6000 kips = 2722 t

...we calculated 2880 t...

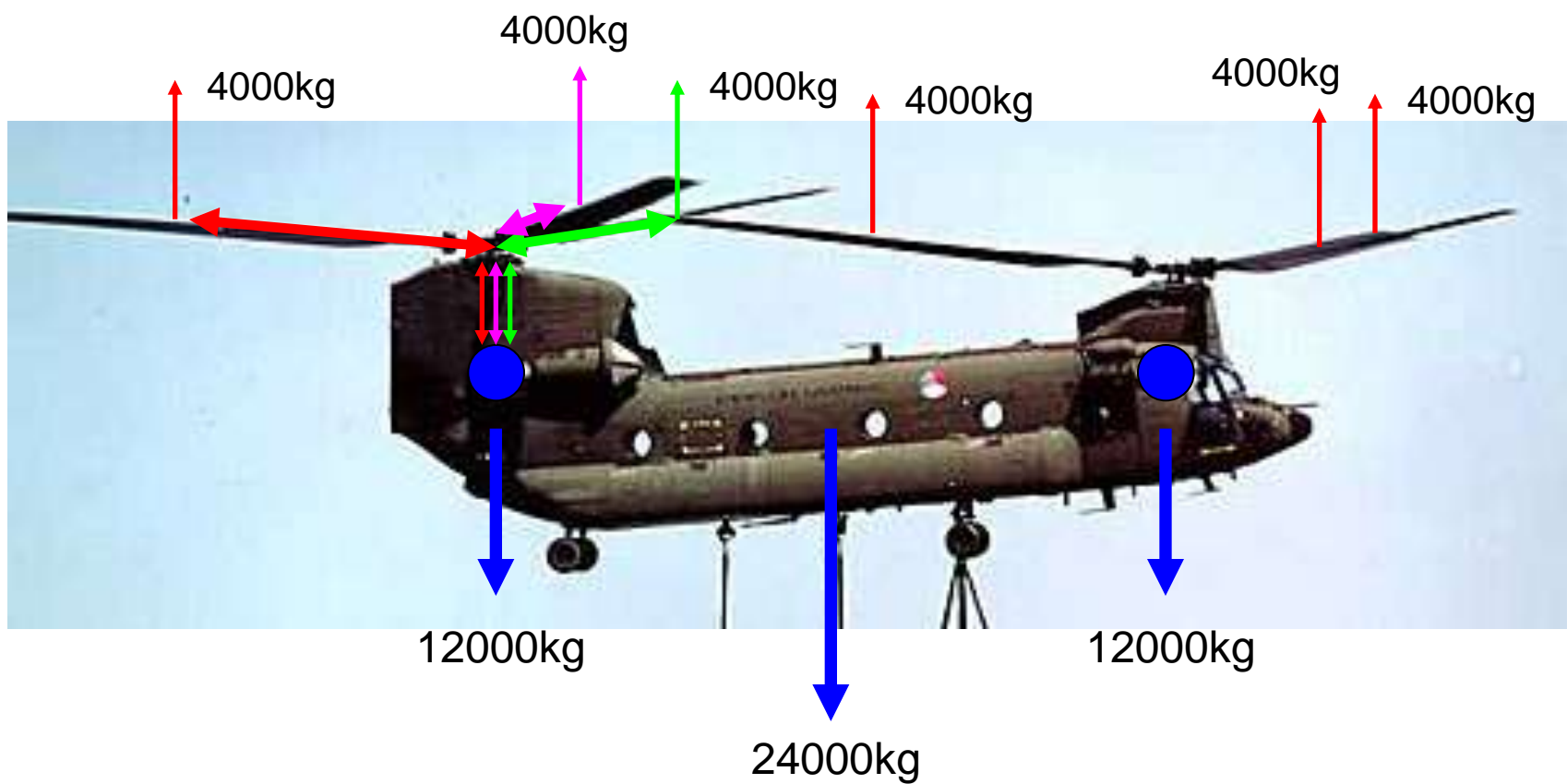


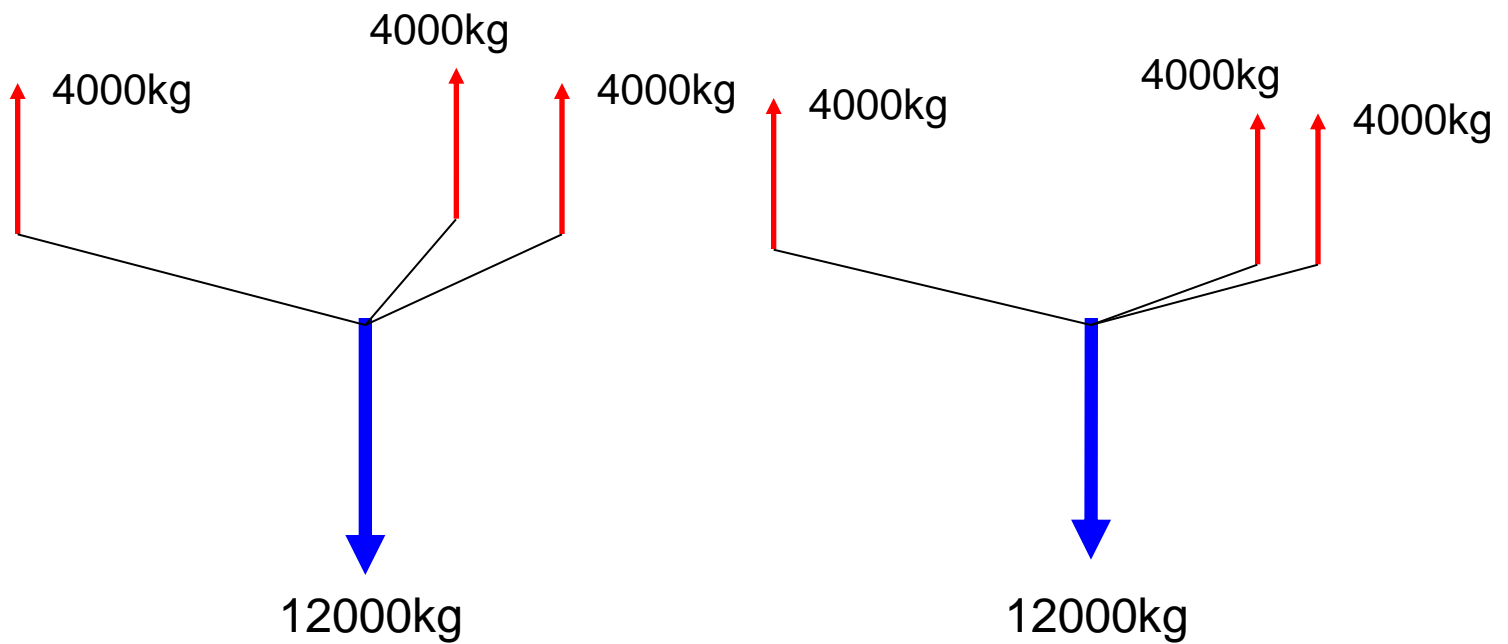
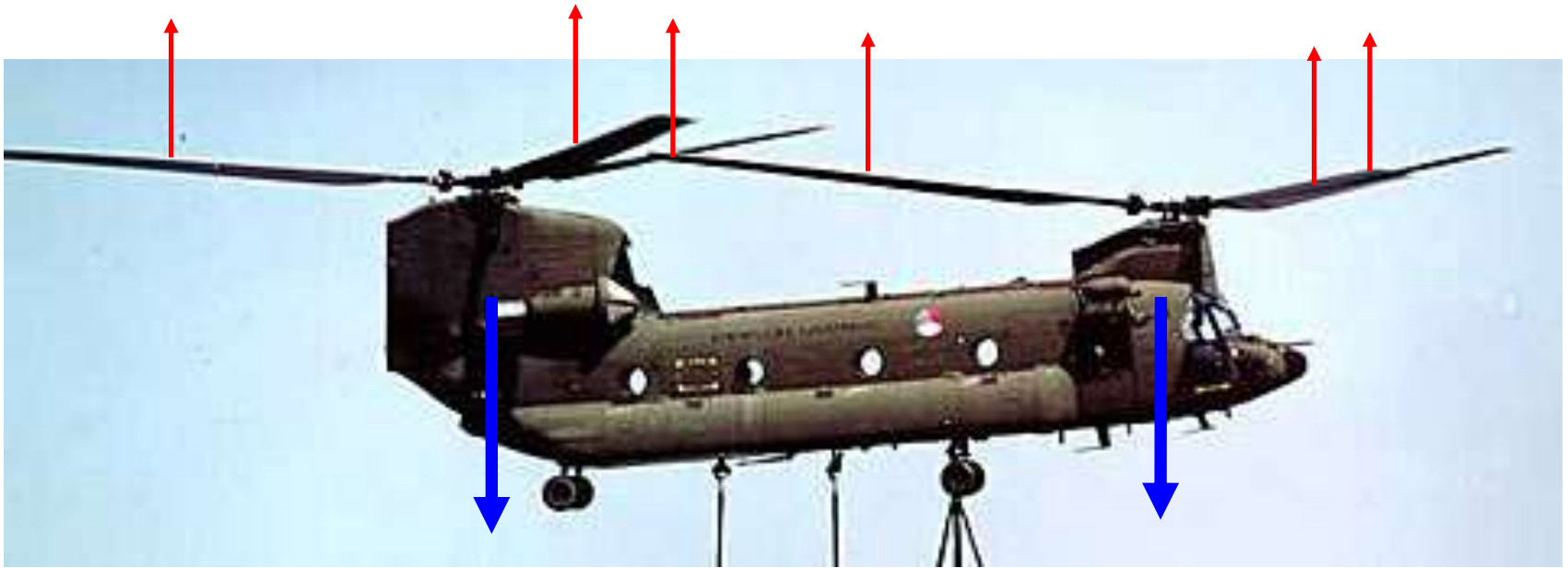
chinook helicopter

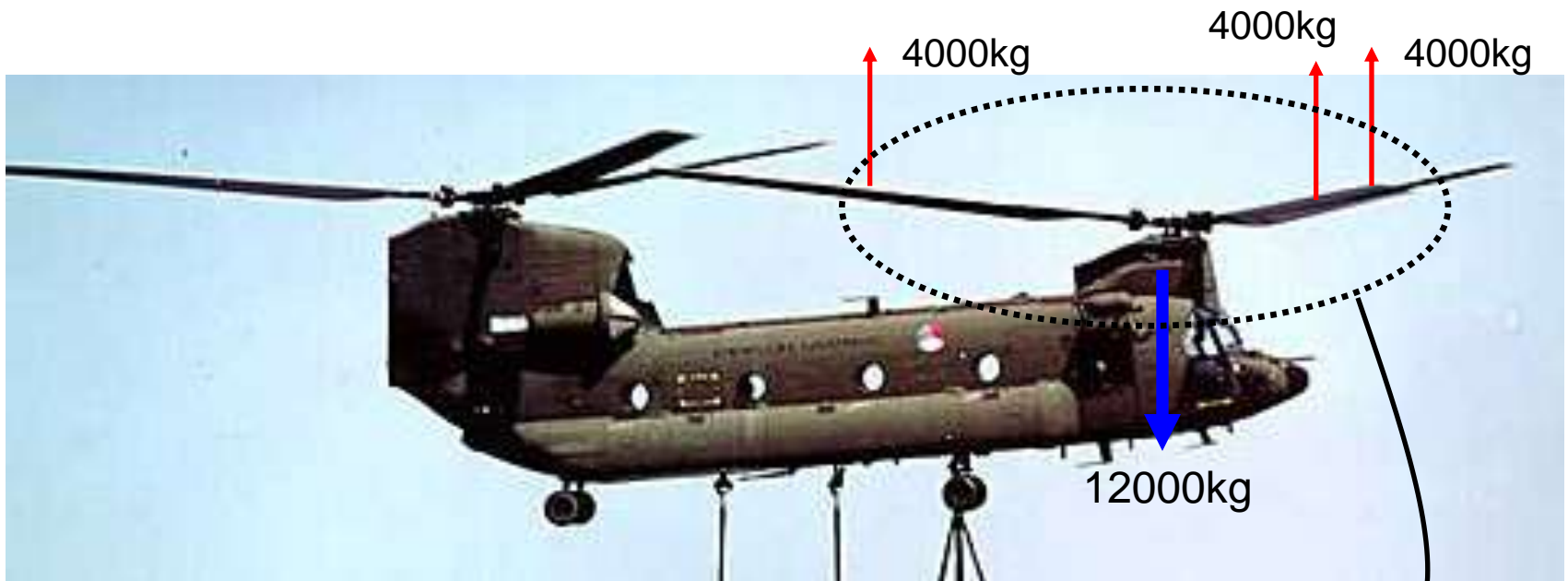
...rotor blade design...



structural model



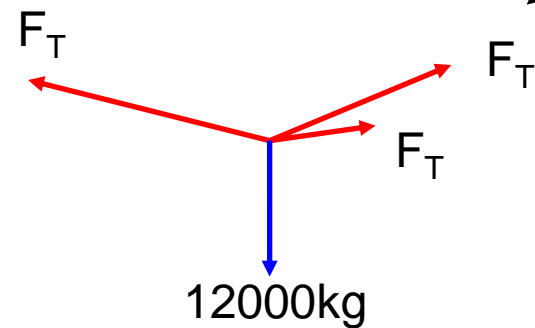




use vertical equilibrium to find the
tensile force in each rotor blade:

$$3 \times F_T \times \sin 6^\circ = 12000 \text{ kg}$$

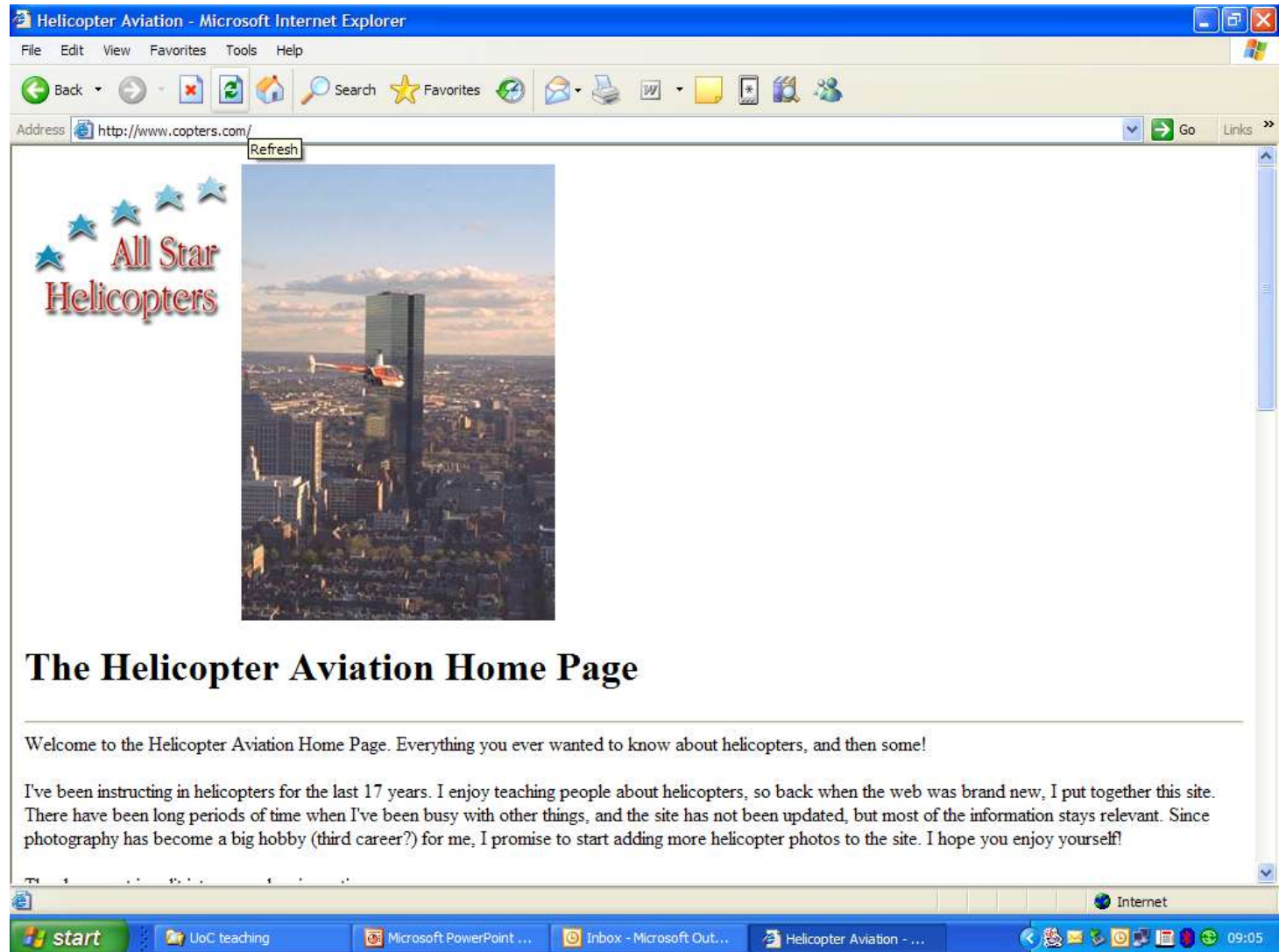
$$\text{therefore } F_T = 38267 \text{ kg}$$



$$\Sigma F_v = 0$$

www.copters.com/aero/centrifugal_force.html

‘...larger helicopters may develop up to 40 tons of centrifugal load on each blade ...’



‘....Spc. Shawn Hernandez, 7th Battalion, 158th Aviation Regiment, leads a line of eight Soldiers carrying and fully supporting a 356-pound CH-47 Chinook rotor blade.....’

what is the RPM required to achieve 38627kg centrifugal force in rotor blade?

$$F \text{ (N)} = \text{mass (kg)} \times \text{angular velocity}^2 \text{ (rads}^{-1}\text{)} \times \text{radius (m)}$$

$$386\text{KN} = 356\text{lb} \times \text{angular velocity}^2 \times 4.57\text{m}$$

$$v = \sqrt{\frac{386000\text{N}}{161.5\text{kg} \times 4.57\text{m}}} = 22.87\text{rad/s}$$

With a rotor diameter of 18.3m and blade centre of mass at half this.....

$$22.87\text{rad/s} = 218\text{ rpm}$$



Spc. Shawn Hernandez, 7th Battalion, 158th Aviation Regiment, leads a line of eight soldiers carrying and fully supporting a 356-pound CH-47 Chinook rotor blade. Each Chinook has a blades, which were removed and packed inside the helicopter base which they were placed. Then the pulled helicopter were loaded, two-by-two, onto several Air Force cargo transport aircraft.



<http://www.boeing.com/rotorcraft/military/ch47d/ch47dspec.htm>

‘.....Rotor System:

- Three blades per hub (two hubs)
- Fibreglass construction
- Speed: 225 r/min
- Manual ...’

**..we calculated an
rpm of 218....**

http://www.boeing.com/rotorcraft/military/ch47d/ch47dspec.htm - Microsoft Internet Explorer

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Address http://www.boeing.com/rotorcraft/military/ch47d/ch47dspec.htm

Boeing Home Integrated Defense Systems CH-47D/F

Background info
technical specs
news releases
photo gallery
chinook news

CH-47D/F Chinook Specifications

Powerplant:

- Two Textron Lycoming T55-L712 engines

Rotor System:

- Three blades per hub (two hubs)
- Fiberglass construction
- Speed: 225 r/min
- Manual folding blades

Performance at 50,000 lb:

SL cruise: 143 kn.
Rate of climb: 1,522 ft/min.
Range: SL and ISA, 230 nmi.

Crew:

Cockpit-crew seats: 2
Cabin-troop seats/litters: 33/24

Weights:

Max gross: 50,000 lbs.
Empty: 23,401 lbs.

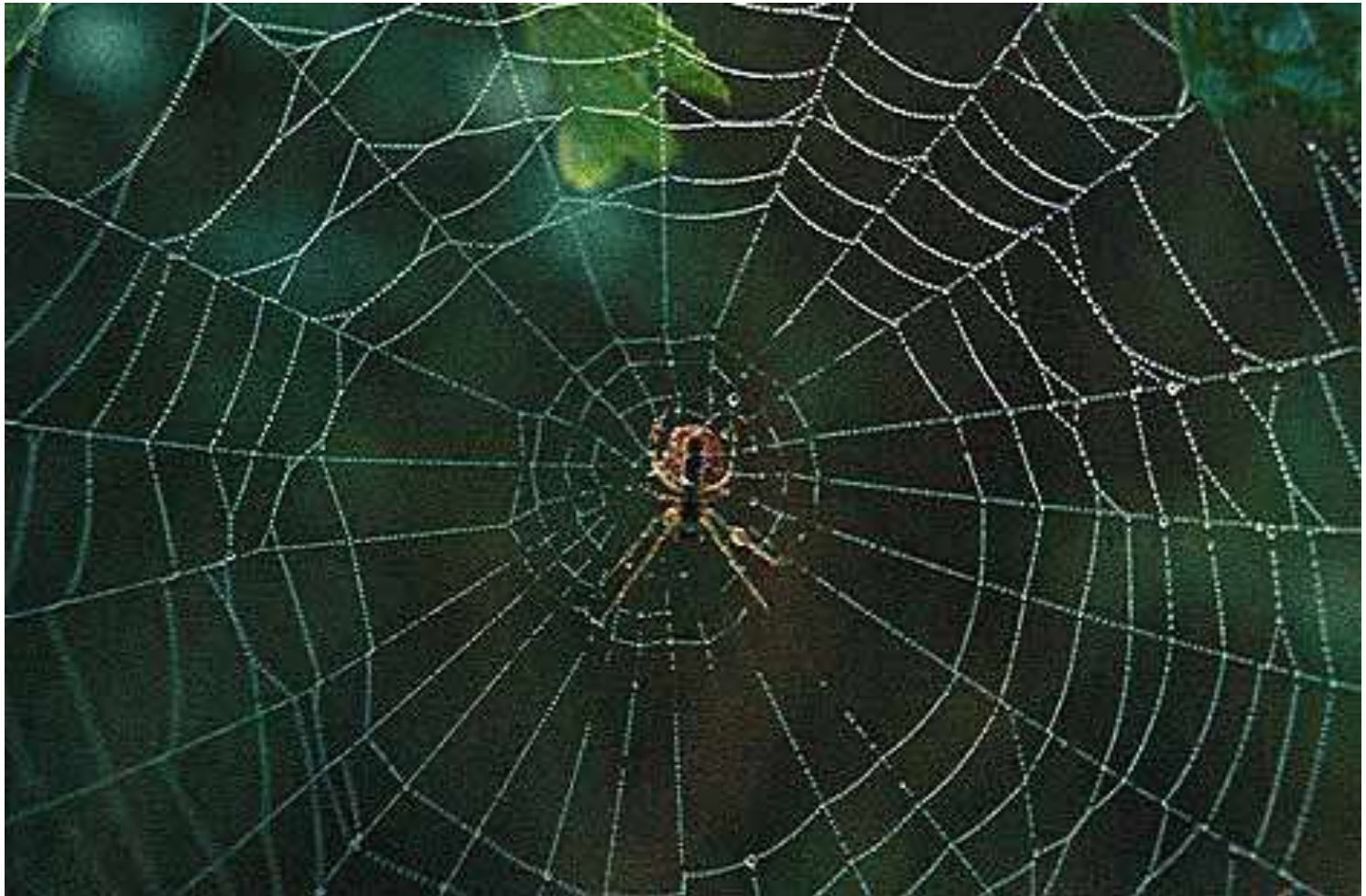
60 ft
Rotation
99 ft
39 ft 2 in
18 ft 11.5 in
10 ft 11 in
22 ft 6 in

[CH-47D](#) | [Background Info](#) | [Technical Specs](#) | [News Releases](#) | [Photo Gallery](#) | [Chinook News](#)

http://www.boeing.com/ids/

Start Microsoft PowerPoint - [...] http://www.boeing.co... ZA ZoneAlarm Service Agent Internet 21:44

spider webs
...silk thread design...



<http://www.tiem.utk.edu/~gross/bioed/bealsmodules/spider.html>

‘....from the stress-strain graph we can see that the spiral's mean extensibility, which is the maximum strain (or stretch) before breaking, was 476%, as compared to the radii's mean extensibility of 39.4% The tensile strength of the capture spiral is 1338 MPa, while the tensile strength of the radial thread is 1154 MPa. For comparison, the tensile strength of "mild" steel is 400 MPa....’

The screenshot shows a Microsoft Internet Explorer window with the title 'SPIDER SILK: STRESS-STRAIN CURVES AND YOUNG'S MODULUS'. The address bar shows the URL 'http://www.tiem.utk.edu/~gross/bioed/bealsmodules/spider.html'. The page content includes an introduction to tensile materials, the importance of spider webs, a question about the web's properties, a table of variables, and a methods section.

SPIDER SILK: STRESS-STRAIN CURVES AND YOUNG'S MODULUS

Introduction: Solid materials are often categorized by their mechanical behavior. One such category is tensile materials, which operate by resisting being pulled upon. Four common types of tensile materials are found in living organisms: silk, collagen, cellulose, and chitin. Silk and collagen are both composed of proteins, while cellulose and chitin are composed of polysaccharides (sugars). The properties of tensile materials are often investigated using stress-strain tests, which involve pulling on a sample from each end. Spider webs, which function in prey capture for many species, are made of silk, a well-studied example of a tensile material.

Importance: Spider webs must be able to withstand destruction from a variety of forces. Wind affects the strands of the web and the substrate(s) to which the web is anchored (leaves, branches, blades of grass, etc.). Additionally, insects flying into the web exert force not only upon impact, but as they struggle to free themselves.

Question: How does the web of a spider balance the conflicting requirements of being strong enough to trap prey, fine enough to resist wind disturbance, and flexible enough to resist deformation from struggling insects and movement of anchoring substrate?

Variables:

σ	stress (MPa)
ϵ	strain (dimensionless)
E	Young's modulus of elasticity (MPa)

Methods: A strain on a material can be defined as any change in the material's dimension, and any force acting on a material produces a stress. With tensile materials, strain (ϵ) is the same as stretch, and is simply the ratio of the change in size to some basic (or original) size (often given as a percentage, $\epsilon = 0.1$ indicates that each unit of length has extended by 10%). The unit for stress (σ) is the pascal (Pa) or megapascal (MPa), which is the force per unit area (a newton or meganewton, respectively, per square meter). Young's modulus of elasticity (E), also known as the elastic modulus, is the ratio between stress and strain:

$$E = \sigma / \epsilon$$

and has the same units as stress. E is the slope of the stress-strain graph: the steeper the slope, the stiffer the material. The maximum height of the stress-strain curve

The taskbar at the bottom shows the Start button and several open applications: Microsoft PowerPoint, SPIDER SILK: STRESS..., ZoneAlarm Service Agent, C:\Documents and Sett..., and Microsoft Excel - spider...

http://en.wikipedia.org/wiki/Spider_silk

‘...**Spider silk** is a [fibre](#) secreted by [spiders](#). Spider [silk](#) is a remarkably strong material. Its [tensile strength](#) is comparable to that of high-grade [steel](#) -- according to [Nature](#) (see reference below), spider silk has a tensile strength of roughly 1.3 [GPa](#), while one source [\[1\]](#) lists a tensile strength for one form of steel at 1.65 GPa. However, spider silk is much less dense than steel; its ratio of tensile strength to density is perhaps 5 times better than steel—as strong as [aromatic nylon](#) filaments, such as DuPont's [Kevlar](#)....’



The screenshot shows a Microsoft Internet Explorer browser window displaying the Wikipedia article for "Spider silk". The address bar shows the URL "http://en.wikipedia.org/wiki/Spider_silk". The page layout includes a navigation sidebar on the left with links like "Main Page", "Community Portal", and "Search". The main content area features the article title "Spider silk", a summary paragraph, a table of contents, and a section titled "Properties of spider silk". The summary paragraph states: "Spider silk is a fibre secreted by spiders. Spider silk is a remarkably strong material. Its tensile strength is comparable to that of high-grade steel -- according to Nature (see reference below), spider silk has a tensile strength of roughly 1.3 GPa, while one source [1] lists a tensile strength for one form of steel at 1.65 GPa. However, spider silk is much less dense than steel; its ratio of tensile strength to density is perhaps 5 times better than steel—as strong as aromatic nylon filaments, such as DuPont's Kevlar." The "Properties of spider silk" section begins with: "Spider silk is also especially elastic, able to stretch up to 40% of its length without breaking. This gives it a very high toughness (or work to fracture), which according to 'Liquid crystalline spinning of spider silk' (Nature, vol 410, p. 541), 'equals that of commercial polyaramid (aromatic nylon) filaments, which themselves are benchmarks of modern polymer fiber technology.' The notion that spider silk is stronger than any other fiber now known is thus erroneous, especially considering current research with carbon nanotubes that have yielded stronger fibers. Nonetheless, there is much interest in duplicating the silk process artificially, since spiders use renewable materials as input and operate at room temperature and low pressure." The section also mentions that spider silk is made of complex protein molecules. There are two images: a spider web made by a lynx spider and a close-up of a spider on its web.

Spider silk - Wikipedia, the free encyclopedia - Microsoft Internet Explorer

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Spider silk

From Wikipedia, the free encyclopedia

Spider silk is a fibre secreted by [spiders](#). Spider [silk](#) is a remarkably strong material. Its [tensile strength](#) is comparable to that of high-grade [steel](#) -- according to [Nature](#) (see reference below), spider silk has a tensile strength of roughly 1.3 [GPa](#), while one source [\[1\]](#) lists a tensile strength for one form of steel at 1.65 GPa. However, spider silk is much less dense than steel; its ratio of tensile strength to density is perhaps 5 times better than steel—as strong as [aromatic nylon](#) filaments, such as DuPont's [Kevlar](#).

Contents [hide]

- 1 Properties of spider silk
- 2 How does the spider make the silk?
- 3 Artificial spider silk
- 4 References
- 5 External links

Properties of spider silk

Spider silk is also especially elastic, able to stretch up to 40% of its length without breaking. This gives it a very high [toughness](#) (or work to fracture), which according to "Liquid crystalline spinning of spider silk" (*Nature*, vol 410, p. 541), "equals that of commercial polyaramid (aromatic nylon) filaments, which themselves are benchmarks of modern polymer fiber technology." The notion that spider silk is stronger than any other fiber now known is thus erroneous, especially considering current research with [carbon nanotubes](#) that have yielded stronger fibers. Nonetheless, there is much interest in duplicating the silk process artificially, since spiders use renewable materials as input and operate at room temperature and low pressure.

Spider silk is made of complex [protein molecules](#). This, coupled with the spider's preference for isolation from other species, has made the



A spider web made by a lynx spider



bee mass 0.1 gram

bee speed 10m/s

The bee is stopped when it's kinetic energy is absorbed by the spider web deflecting.....

ie: $\frac{1}{2} \times \text{mass} \times \text{velocity}^2 = \text{force} \times \text{distance}$

$$\frac{1}{2} m v^2 = F d$$

spider silk strength 1150N/mm²

spider silk diameter 0.015mm

web diameter say 15cm



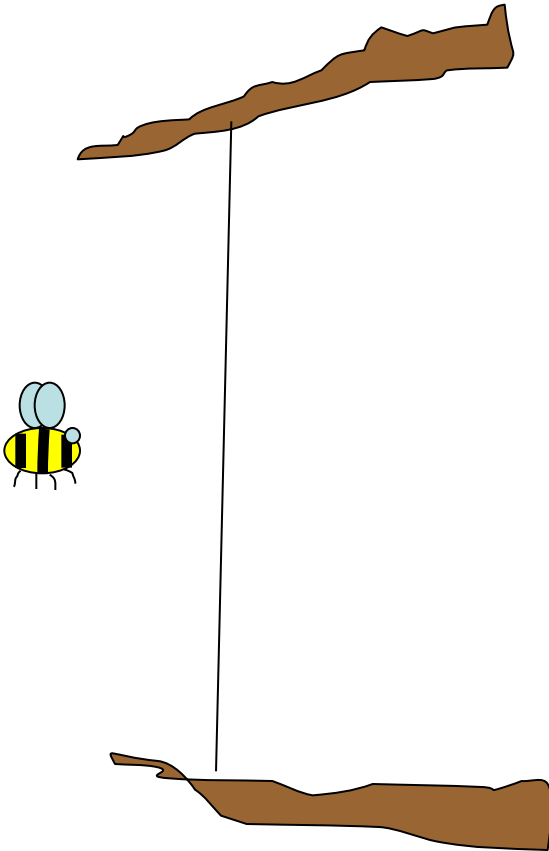
structural model

radial webs act in tension
under fly impact load

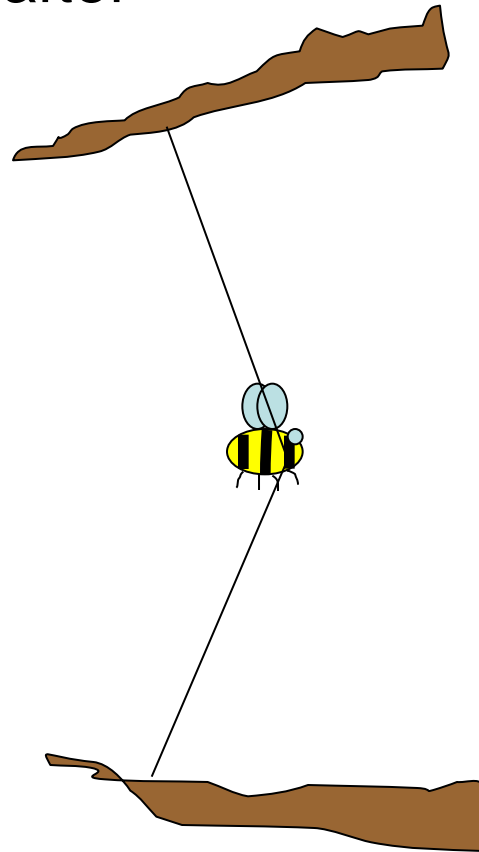


structural model

before



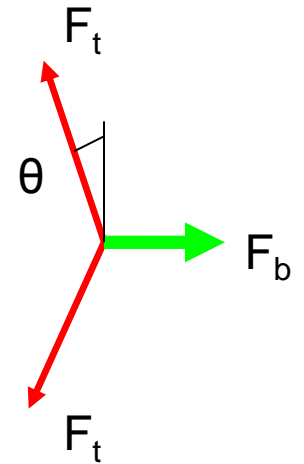
after



distance to stop

A horizontal double-headed arrow between two vertical lines, indicating a distance.

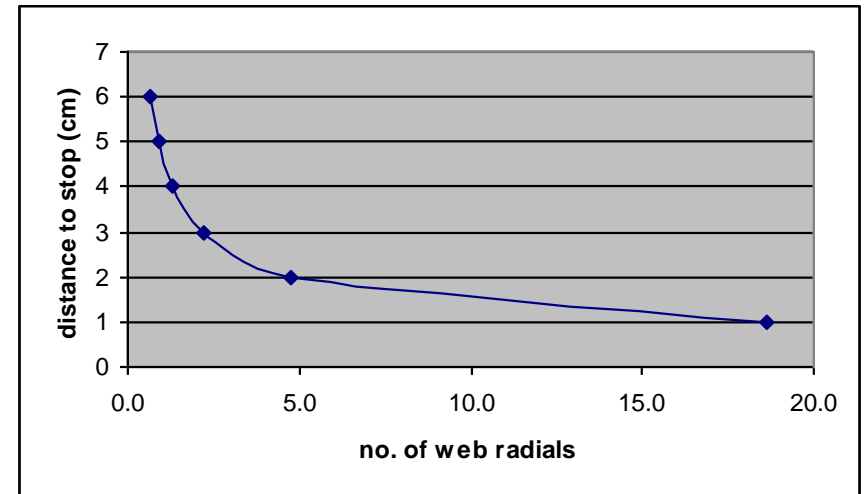
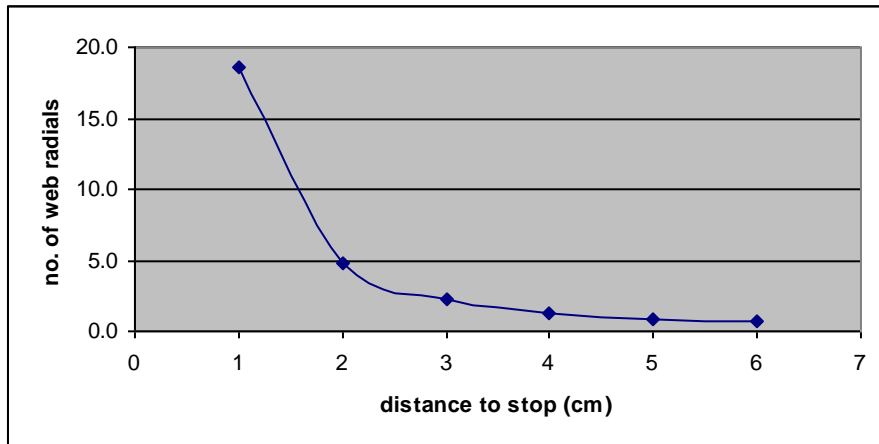
model



$$\sum F_H = 0$$

$$F_b = 2 \times \sin \theta \times F_t$$

speed (m/s)	10	10	10	10	10	10
distance to stop (cm)	1	2	3	4	5	6
kinetic energy (J)	0.005	0.005	0.005	0.005	0.005	0.005
stopping force (N)	0.500	0.250	0.167	0.125	0.100	0.083
spider web diameter (cm)	15	15	15	15	15	15
web silk strength (N/mm ²)	1150	1150	1150	1150	1150	1150
web silk diameter (mm)	0.015	0.015	0.015	0.015	0.015	0.015
web angle (deg)	7.59	14.93	21.80	28.07	33.69	38.66
web silk elongation (%)	0.9%	3.5%	7.7%	13.3%	20.2%	28.1%
silk breaking force (N)	0.20	0.20	0.20	0.20	0.20	0.20
no. web radials req'd	18.6	4.8	2.2	1.3	0.9	0.7



cleopatra's needle
...stopping it falling over...





Paris



Cairo



Luxor



Rome

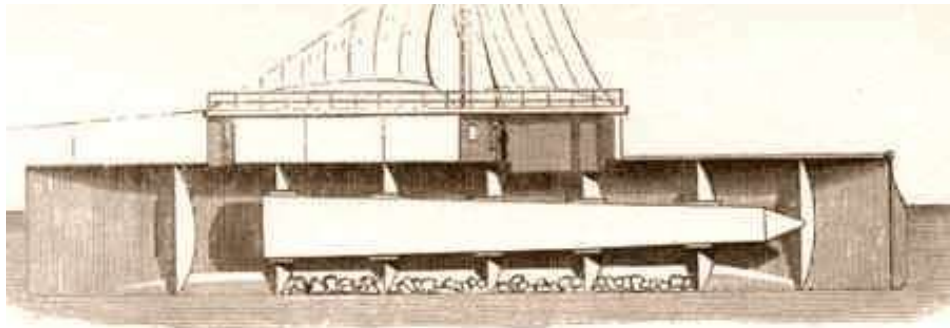
<http://www.historic-uk.com/HistoryUK/England-History/CleopatrasNeedle.htm>

'....a specially designed cigar-shaped container ship (called the Cleopatra) was used to convey the needle to London, towed by a steam ship called the Olga.

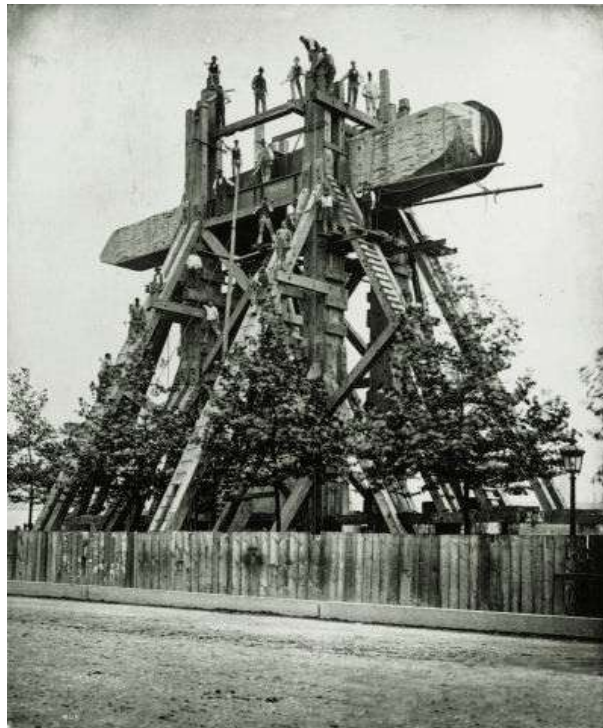
...during the sea journey, stormy seas were encountered and 6 men lost their lives when the Olga had to cut the Cleopatra free.

.....five days later a ship spotted the Cleopatra floating peacefully and undamaged off the northern coast of Spain, and towed her to the nearest port, Ferrol.

....following her narrow escape, another steam-ship, the Anglia, was sent to tow the Cleopatra home. The 'needle' was winched into position on the Embankment in September 1878.....'



http://members.tripod.com/obeliscos_egipcios/images_en.htm



<http://www.victorianlondon.org/buildings/cleopatrasneedle.htm>

‘....as the weight of the obelisk is only 150 tons.....
...the obelisk is 66 feet long over all, and the base (8 feet 6 inches square)....’

Victorian London - Buildings, Monuments and Museums - Cleopatra's Needle - Microsoft Internet Explorer

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Obelisks
Agate, Stone, Jasper, Quartz, Rose Quartz, Amethyst and More

Milbank Precast Concrete
Design, manufacture, transport and fixing for all floors and precast.

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Victorian London - Buildings, Monuments and Museums - Cleopatra's Needle

This obelisk of ancient Egypt, which has been left lying so long half buried in the sand at Alexandria, is now about to be made an ornament to the city of London. Its removal has been considered a matter of such great expense that the British Government has not felt justified in undertaking it and, had it not been for the private generosity of Dr. Erasmus Wilson, and the ingenuity of the engineer, it would most likely have remained to form the foundations of the new houses leading to the Alexandria Railway Station....

The consulting engineer is Mr. B. Baker, well known by his connection with the Metropolitan Railway, and the work will be performed by Mr. Dixon. The removal of this obelisk will be accomplished in the following manner: A wrought-iron cylindrical pontoon, 92 feet long and 15 feet in diameter, tapered at each end to a vertical edge, will be its only support in the water. Its draught is 9 feet, and displacement 270 tons. If completely submerged, its power of floatation is equal to 705 tons, and as the weight of the obelisk is only 150 tons, with 30 tons ballast, it is evident that there is no chance of its foundering.

The pontoon is furnished with a series of bulkheads, or diaphragms, which support the obelisk at about every 10 feet, and suitable elastic packing secures it from shocks. The obelisk is 66 feet long over all, and the base (8 feet 6 inches square) will be placed forward, giving great buoyancy to the forepart, as the apex is close to the stern, which will be furnished with a rudder. On top of the pontoon and near its centre, will be placed a small deck house, with steering-wheel in the forepart and accommodation for three men. There is a long narrow hurricane-deck above the steering-room, and a short mast with two small sails surmounts the whole ... The boat will be towed by steamer to London, the sails being merely used for steadying purposes. It is calculated that the roll will not be excessive....

Illustrated London News, March 10th 1877



Cleopatra's Needle.—Victoria Embankment, opposite the end of Salisbury-street, Strand, between Waterloo-bridge and Charing-cross. NEAREST Railway Station, Temple; Omnibus Routes, Waterloo-bridge and Blackfriars-bridge; Cab Rank, Embankment.

Charles Dickens (Jr.), Dickens's Dictionary of London, 1879



<http://www.victorianlondon.org/cd-rom.htm>

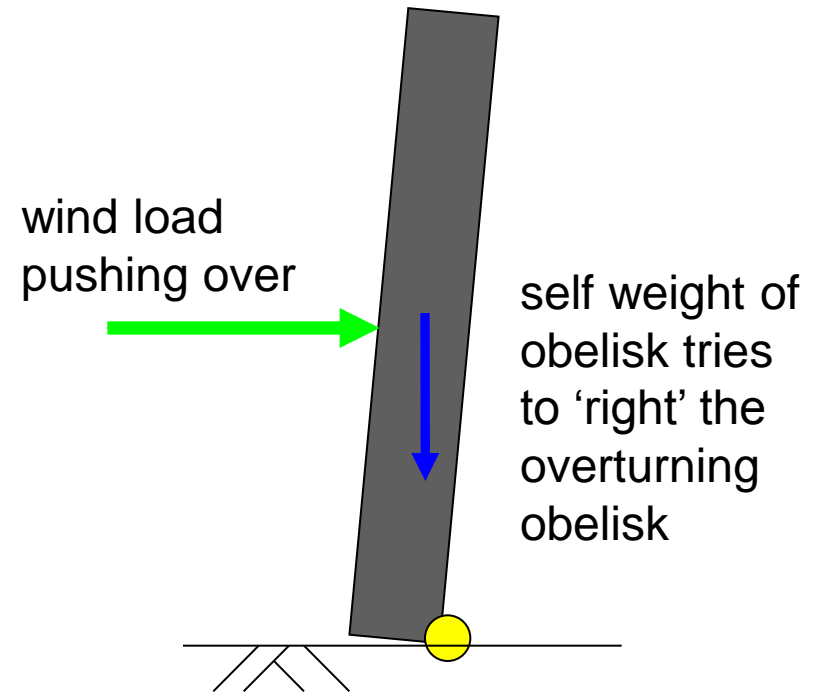
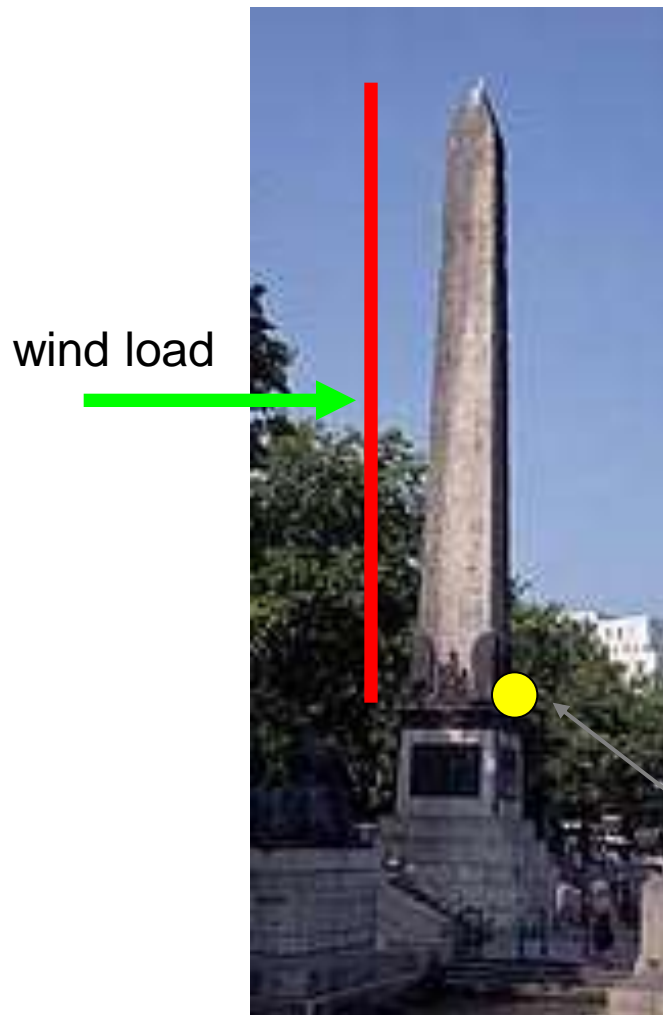
Start Microsoft PowerPoint - [...] Victorian London - Bui... ZoneAlarm Service Agent

Internet 22:47

why would it fall over.....

what stops it from falling over.....

do we have to 'bolt' down obelisk.....

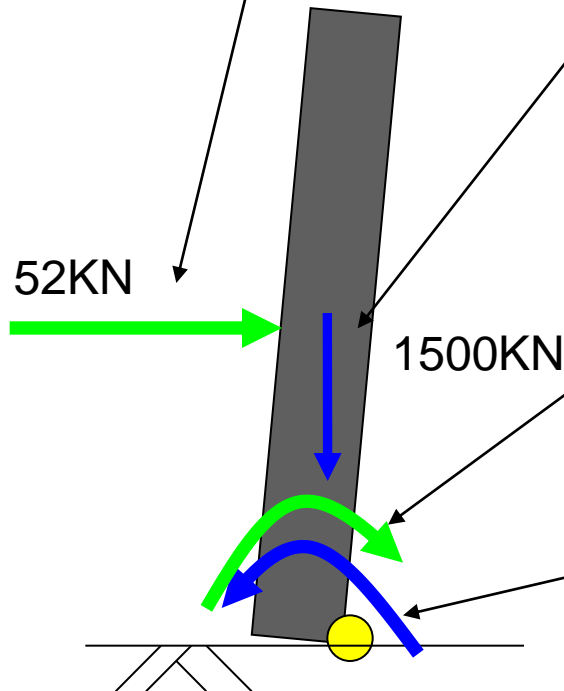


Point about which
obelisk would
rotate/topple over

....wind load on obelisk:
frontal area = $20\text{m} \times 2.6\text{m} = 52\text{m}^2$
unit wind load = 1KN/m^2 (100kg/m^2)
total wind load = 52KN

....self weight of obelisk:
mass = 150t
weight = 1500KN

In order for the obelisk to remain stable
the overturning force must be less or
equal to the restoring force.



the overturning force measured
about the point of rotation is:

$$52\text{KN} \times 10\text{m} = 520\text{KNm}$$

the restoring force measured about
the point of rotation is:

$$1500\text{KN} \times 1.3\text{m} = 1950\text{KNm}$$

**....therefore factor of safety against
overturning is nearly 4.....**

how far over could you push an obelisk before it becomes unstable?

.....until the centre of gravity of the obelisk 'wanders' outside of the obelisk base footprint.

cross represents centre of gravity of obelisk

dotted line represents a 'plumb' line

