



# Mast, towers, chimneys



**Florea Dinu**

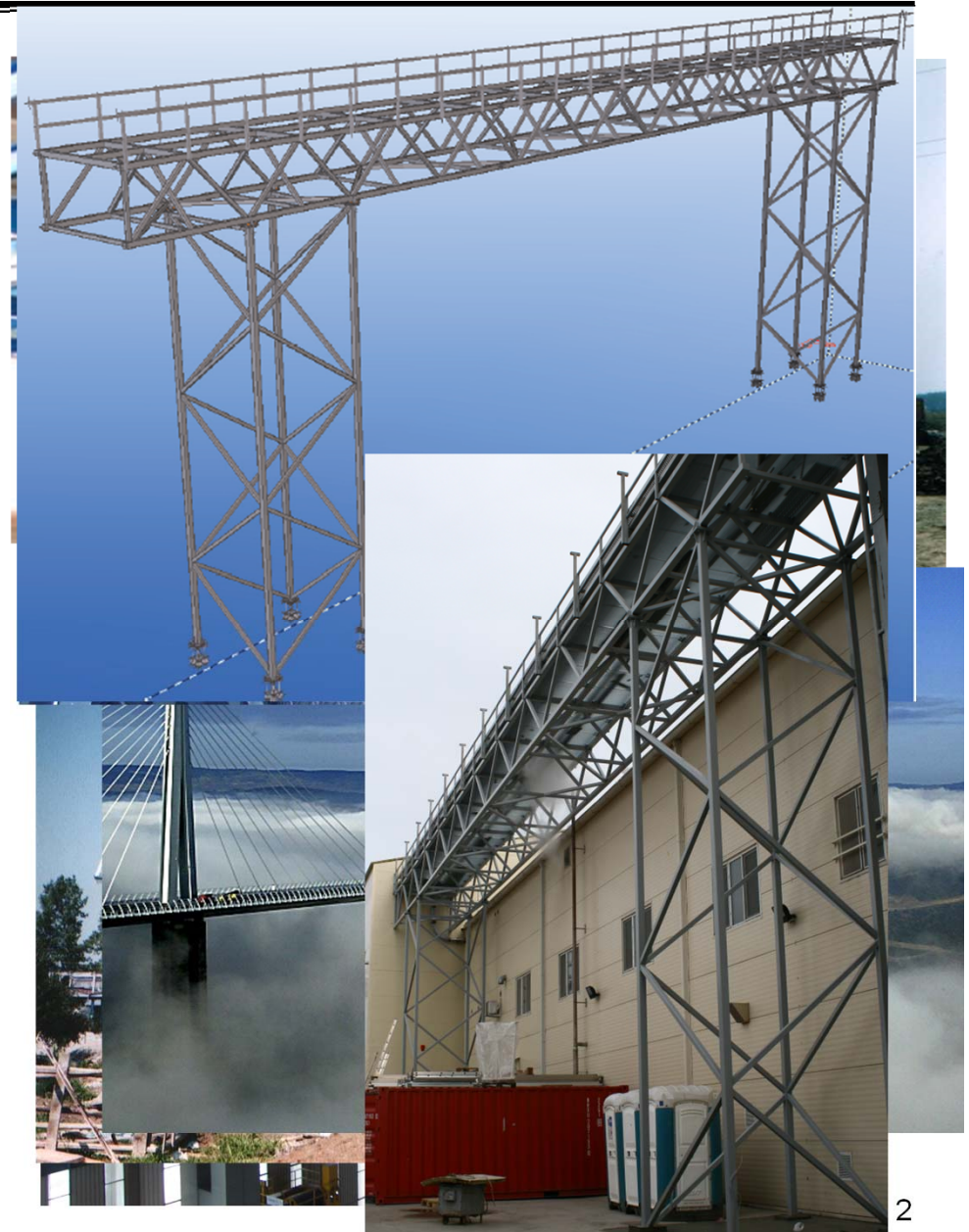
**Lecture 18: 27/02/2014**

European Erasmus Mundus Master Course  
**Sustainable Constructions**

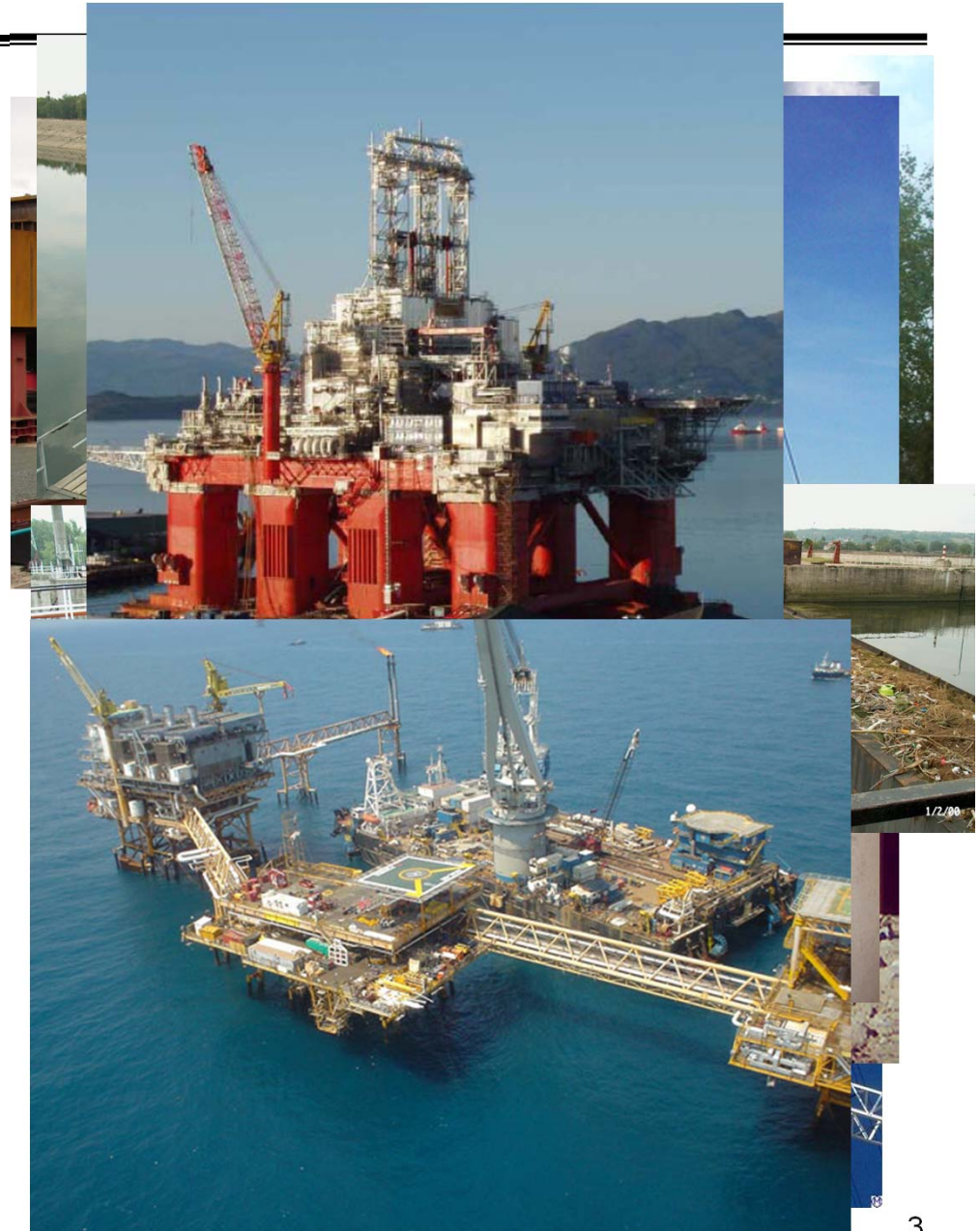
**under Natural Hazards and Catastrophic Events**

520121-1-2011-1-CZ-ERA MUNDUS-EMMC

- Steel structures for buildings
  - single storey industrial buildings with/without gantry cranes (warehouses, industry, )
  - Multistorey buildings (offices, residential, etc)
  - Social/cultural buildings, sport arenas, exhibition halls, shopping centers
  - Residential steel housing
- Steel structures for bridges
  - Steel railway bridges
  - Steel road bridges
  - Steel pedestrian bridges
- Industrial buildings (other than buildings):
  - Steel trestles
  - Steel platforms
  - Industrial transport and lifting equipments, etc



- Special steel structures
  - pylons, antennas
  - reservoirs, bunkers
  - pipes
  - cooling towers
  - chimneys
  - steel pilings
- Steel structures for hidrotechnical constructions
  - gates and guide vanes, cofferdams
  - gate locks
  - pressure pipe lines
- Offshore platforms



- Mast, towers, chimneys:  
configurations, design, detailing
- Within the last decades the need for tall structures raised
  - radio, television communication
  - exhaust gases.
- Latest developments in the mobile communication exponentially growth the need for towers and masts, however smaller in height but larger in number.
- There are many challenges for the engineers associated with this tall and slender structures



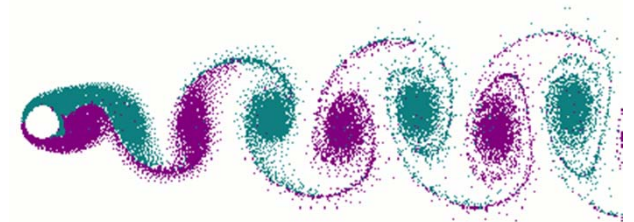
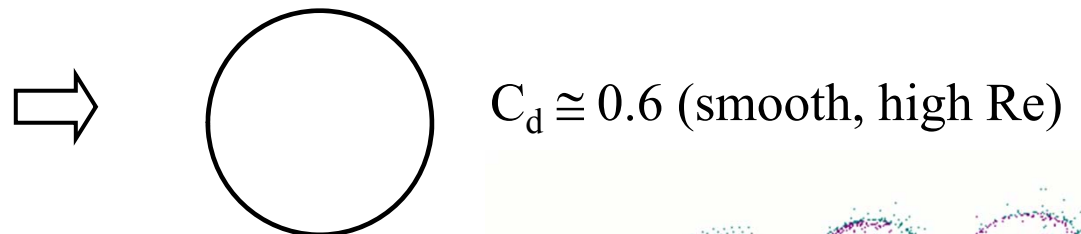
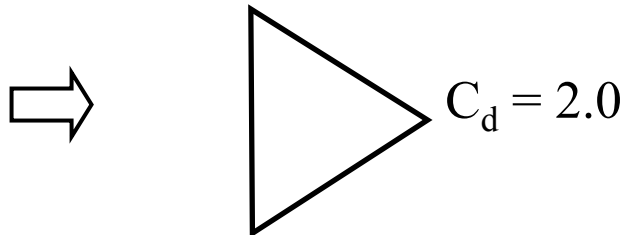
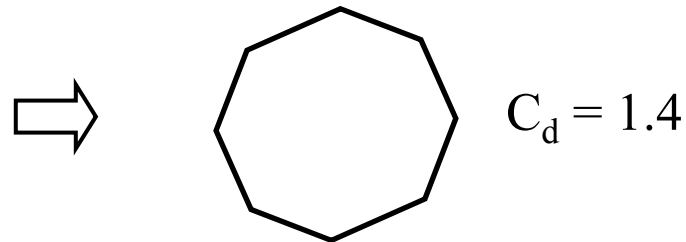
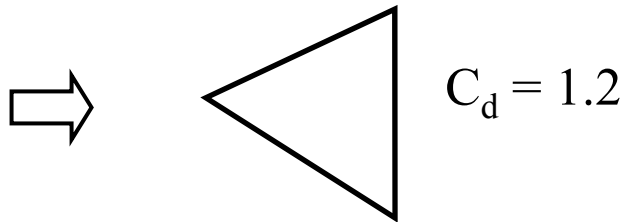
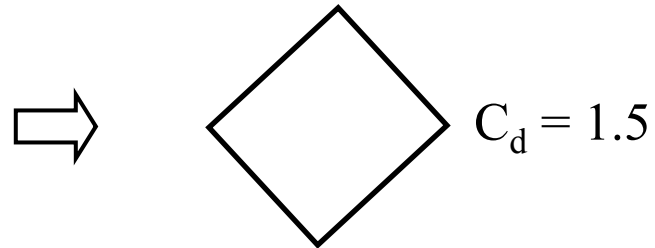
The tallest mast in the World, the 648 m high long wave mast in Konstantynow, Poland collapsed in 1991

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## Basis of the design

- Design provisions are given in EN 1993-3-1:2006 (Eurocode 3: Design of steel structures - Part 3-1: Towers, masts and chimneys – Towers and masts) and EN 1993-3-2:2006 (Eurocode 3: Design of steel structures - Part 3-2: Towers, masts and chimneys – Chimneys)
- Particularities
  - Slender structures (height/width is high)
  - Mode shape in first mode - non linear
  - Higher resonant modes may be significant
  - Cross-wind response significant for circular cross-sections
- The first step is the choice of the overall layout of the structure
- As the predominant loading of towers and masts is nearly always the wind load, it is important to calculate the wind resistance of the structure, including its ancillaries (ladders, platforms, aerials, feeders and cables) - it is important to minimise the wind resistance of the structure itself
- For self-supporting towers, the choice of cross-section (triangular or square), as well as the profiles for the legs and the bracing members will also depend on slenderness of the members, the practical profile sizes, connections, the facilities for hot dip galvanising, transportation and erection, etc.

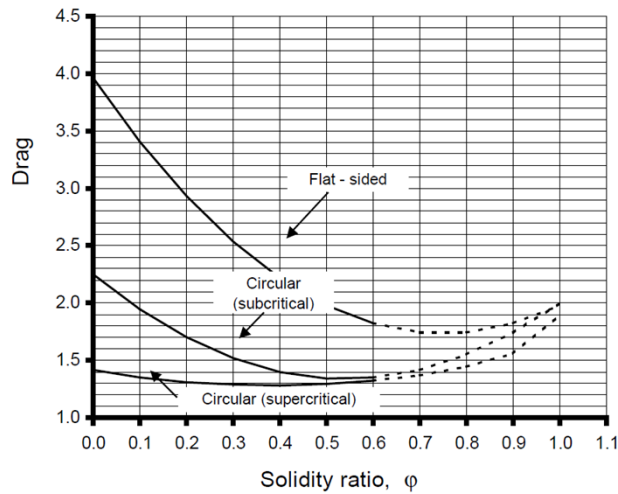
## Drag coefficients for tower cross-sections



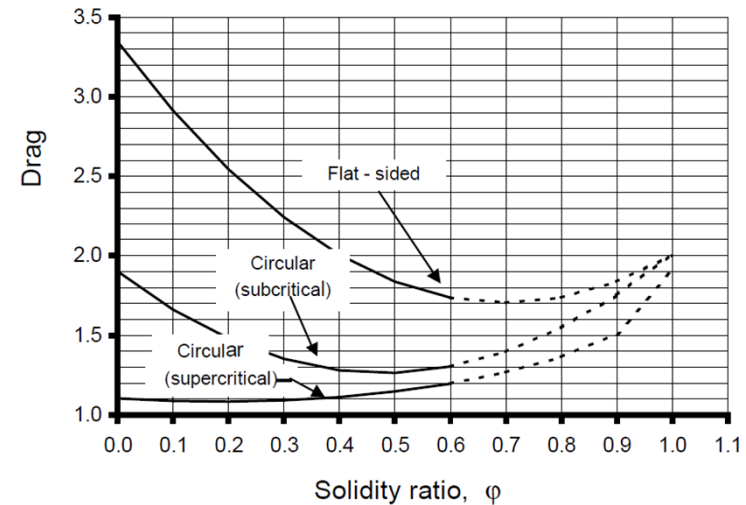
A vortex around a cylinder

## Drag coefficients for lattice tower sections

Variation of drag coefficient with solidity ratio



Square structures



Triangular structures

$$C_{Nf} = 1,76 C_1 [1 - C_2 \phi + \phi^2]$$

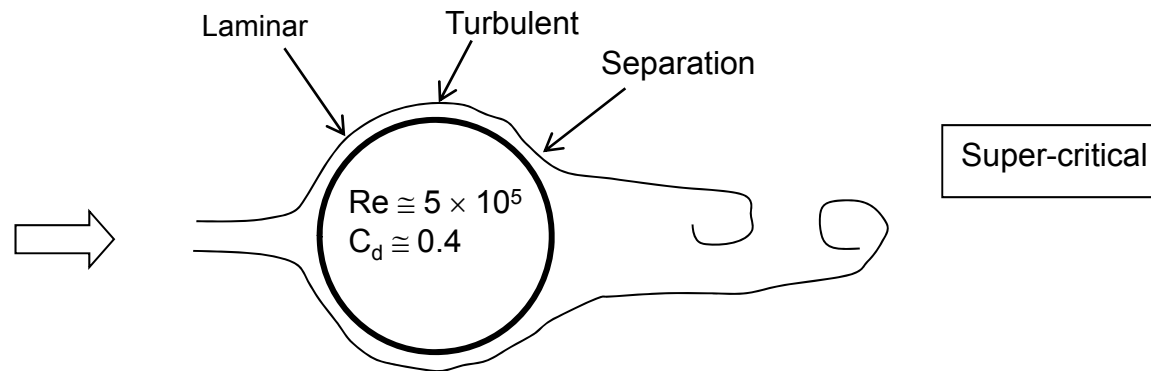
$$C_{Nc} = C_1 (1 - C_2 \phi) + (C_1 + 0,875) \phi^2$$

$$C_{Nc,sup} = 1,9 - \sqrt{\{(1 - \phi) (2,8 - 1,14C_1 + \phi)\}}$$

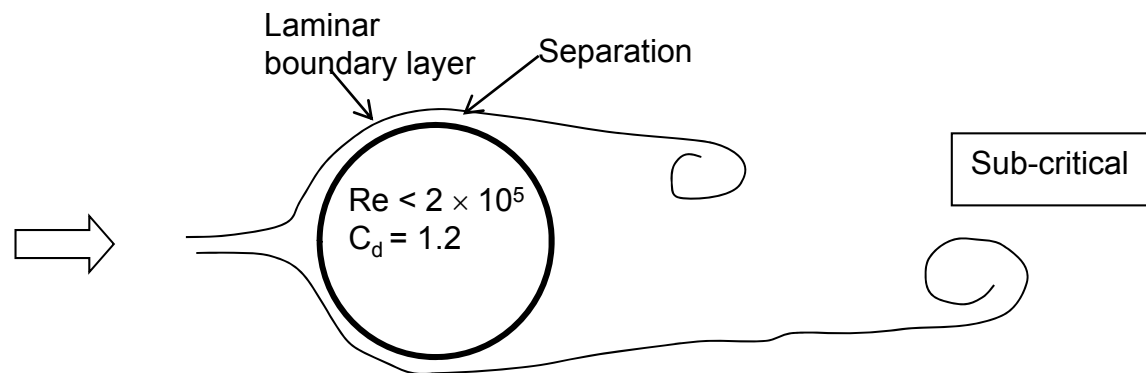
with:

- C1 equal to: 2,25 for square structures.  
1,9 for triangular structures.
- C2 equal to:  
1,5 for square structures;  
1,4 for triangular structures.

$\delta$  = solidity of one face = area of members ÷ total enclosed area



Reynolds number is the ratio of fluid inertia forces in the flow to viscous forces



Flow regimes for a circular cylinder with smooth surface

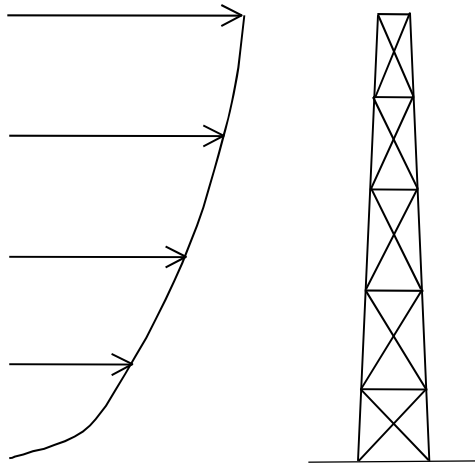


## Dynamic effects

Towers, masts and chimneys should be examined also for:

- gust induced vibrations (causing vibrations in the direction of the wind);
- vortex induced vibrations for towers or masts containing prismatic cylindrical or bluff elements or shrouds (causing vibrations perpendicular to the direction of the wind);
- galloping instability (causing vibrations of the guys).

### Along wind: gust response factor



$$\text{Shear force : } Q_{\max} = \bar{Q} \cdot G_{\text{shear}}$$

$$\text{Bending moment : } M_{\max} = \bar{M} \cdot G_{\text{bending\_moment}}$$

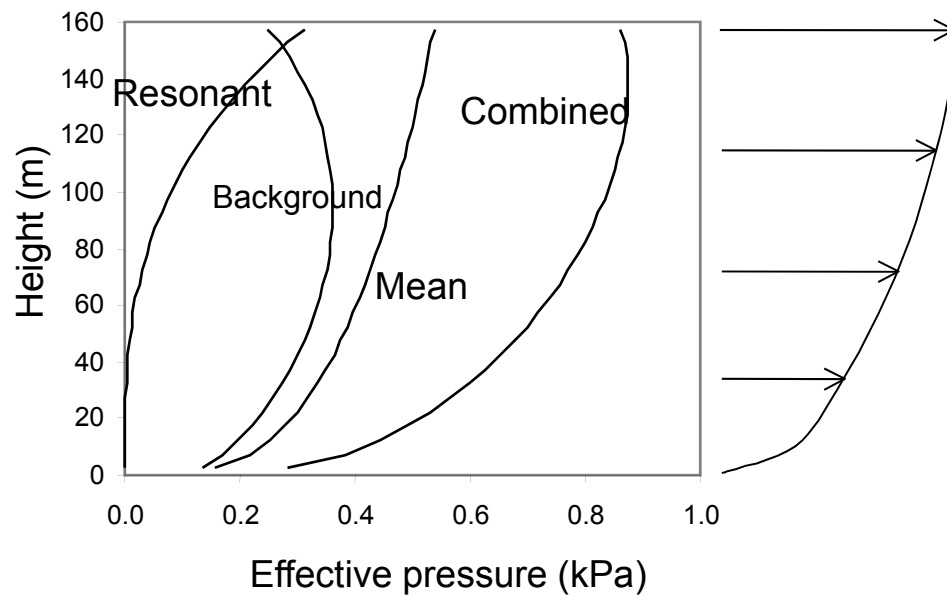
$$\text{Deflection: } x_{\max} = \bar{x} \cdot G_{\text{deflection}}$$

The gust response factors for base bending moment and tip deflection differ - because of non-linear mode shape

The gust response factors for bending moment and shear depend on the height of the load effect,  $z_1$  i.e.  $G_q(z_1)$  and  $G_m(z_1)$  increase with  $z_1$

## Along-wind response - effective static loads

Separate effective static load distributions for mean, background and resonant components (one mode)

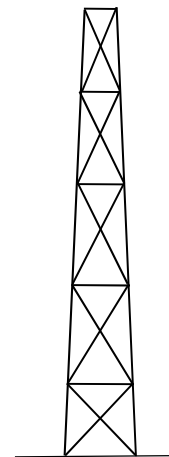


Combined mean, background and resonant load distributions for a 160 m tower

The mean wind loading on a structure can be obtained simply by relating the mean local pressure or force per unit length to the mean wind speed

The background wind loading is the quasi-static loading produced by fluctuations due to turbulence, but with frequencies too low to excite any resonant response.

The equivalent load distribution for the resonant response in the first mode can be represented as a distribution of inertial forces over the length of the structure



## **Cross-wind response of slender towers**

- For lattice towers, excitation mechanism is lateral turbulence
- For 'solid' cross-sections, excitation by vortex shedding is usually dominant (depends on wind speed)
- Two models :
  - i) Sinusoidal excitation
  - ii) Random excitation
- Sinusoidal excitation has generally been applied to steel chimneys where large amplitudes and 'lock-in' can occur - useful for diagnostic check of peak amplitudes in codes and standards
- Random excitation has generally been applied to R.C. chimneys where amplitudes of vibration are lower. Accurate values are required for design purposes. Method needs experimental data at high Reynolds Numbers.

## Sinusoidal excitation model

- Assumptions:
  - sinusoidal cross-wind force variation with time
  - full correlation of forces over the height
  - constant amplitude of fluctuating force coefficient
  - ‘Deterministic’ model - not random
  - Sinusoidal excitation leads to sinusoidal response (deflection)

## Random excitation model (Vickery/Basu)

- Assumes excitation due to vortex shedding is a random process
- ‘lock-in’ behaviour is reproduced by negative aerodynamic damping
- Peak response is inversely proportional to the *square root of the* damping
- In its simplest form, peak response can be written as :

$$\frac{\hat{y}}{b} = \frac{A}{[(Sc/4\pi) - K_{ao}(1 - \frac{y^2}{y_L^2})]^{1/2}}$$

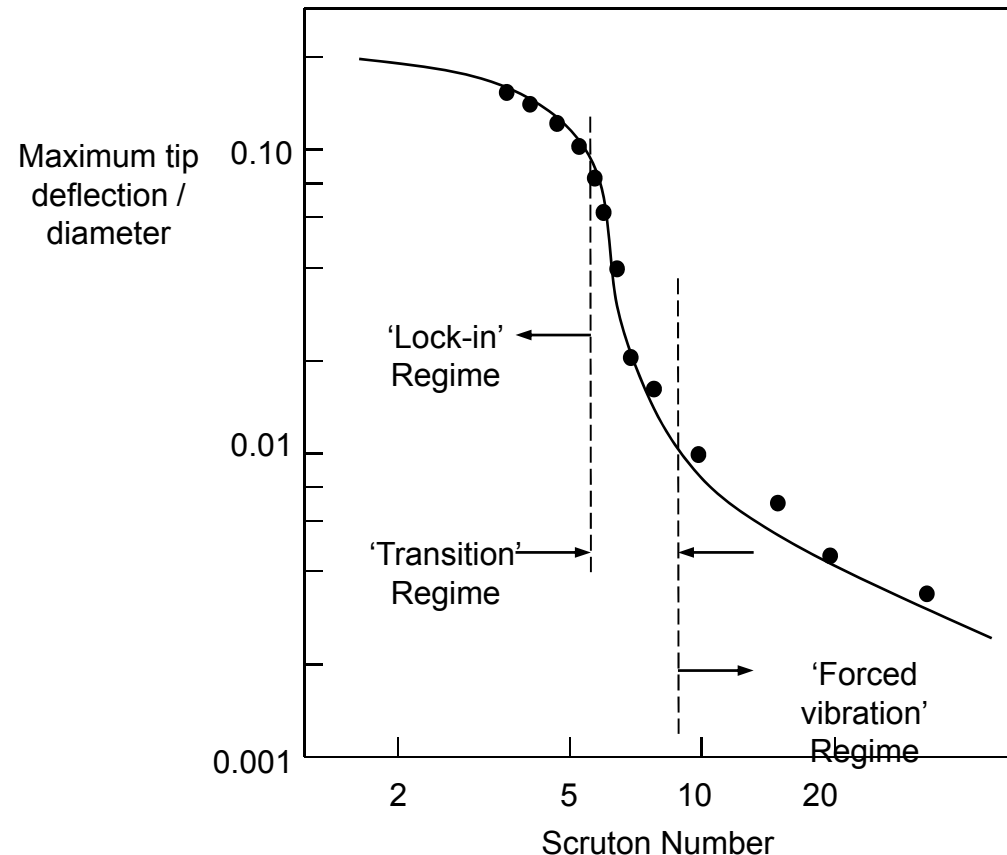
A = a non dimensional parameter constant for a particular structure (forcing terms)

$K_{ao}$  = a non dimensional parameter associated with aerodynamic damping

$y_L$  = limiting amplitude of vibration

## Random excitation model (Vickery/Basu)

- Previous equation can be used to define three response regimes:
  - a randomly 'forced' vibration regime, at high values of Scruton number;
  - a 'lock-in' regime for low values of Scruton number, in which the response is driven by the negative aerodynamic damping, and is largely independent of  $A$ ; and
  - a transition regime between the above two regimes.



- These three regimes, with an empirical fit based on Equation (11.19), are shown in Figure and compared with experimental data from a model chimney

## Scruton Number

- Scruton number A non-dimensional parameter incorporating the ratio of structural mass to fluid mass, and structural damping, which is a measure of the propensity of a structure to resonant dynamic response
- The Scruton Number (or mass-damping parameter) appears in peak response calculated by both the sinusoidal and random excitation models

$$Sc = \frac{4\pi m \eta}{\rho_a b^2}$$

$m$  is the average mass per unit length along the structure

$\eta$  is ratio of damping to critical

$\rho_a$  is air density

$b$  is base of tower or pole

Sometimes a mass-damping parameter is used  $= Sc / 4\pi = K_a = \frac{m\eta}{\rho_a b^2}$

Clearly the lower the  $Sc$ , the higher the value of  $y_{\max} / b$  (either model)

$Sc$  (or  $K_a$ ) are often used to indicate the tendency to vortex-induced vibration

## Scruton Number and steel stacks (chimneys)

$Sc$  (or  $K_a$ ) is often used to indicate the tendency to vortex-induced vibration

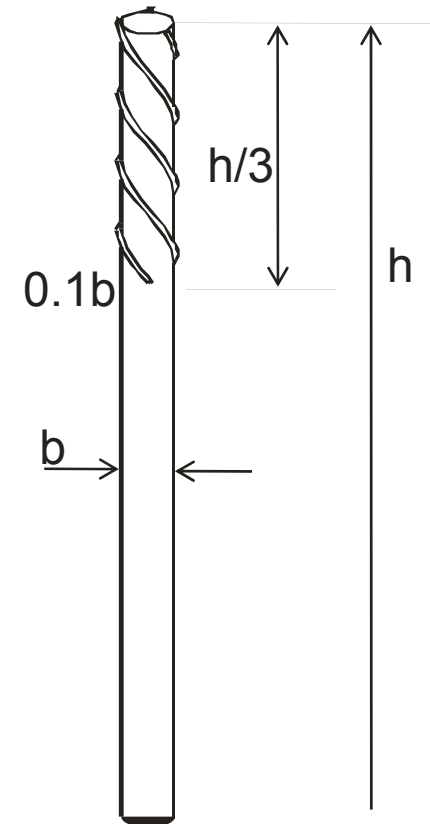
e.g. for a circular cylinder,  $Sc > 10$  (or  $K_a > 0.8$ ), usually indicates low amplitudes of vibration induced by vortex shedding for circular cylinders

Design Codes on Steel Stacks (chimneys) provides criteria for checking for vortex-induced vibrations, based on  $K_a$

Mitigation methods are also discussed : helical strakes, shrouds, additional damping (mass dampers, fabric pads, hanging chains)

## Helical strakes

For mitigation of vortex-shedding induced vibration :



Eliminates cross-wind vibration, but increases drag coefficient and along-wind vibration



## Towers and Masts

- Towers and Masts are typically tall constructions specially designed to support the phase conductors and shield wires of transmission lines, antennas for radio communication (television, radio, GSM and Internet traffic), floodlight projectors, wind turbines or platforms for inspection.
- Towers and masts may also be required to raise antennas above tree lines and roof tops for line of sight connections. The characteristic dimension of a tower is its height.
- The terms “tower” and “mast” are often used for the same type of structure. In order to avoid confusion, a tower will be considered as a self supporting structure while a mast is supported by stays or guys.
- There are three most common types of towers/masts that are used today:
  - Monopoles
  - Self supporting towers
  - Guyed masts.
- Selecting one solution or another is based in general on four major considerations: load, footprint, height and budget. Each factor can be critical in the selection of the type of structure.

- Load on tower
  - The loading capability of a tower depends on the structure of the tower. The more surface area of equipments (eg. antennas), coaxial cables, brackets and other equipment mounted on the tower and exposed to the wind, the more robust tower is required.
  - The wind load is proportional to the area of the exposed structure and distance from the attachment to the ground. Curved and perforated shapes (grids and trusses) offer less wind resistance and are therefore preferred to achieve a low wind load. Solid dishes are quite vulnerable to wind load and should be avoided in windy environments.
  - When it is considered necessary, wind tunnel tests may be performed to evaluate the wind action.
- Tower footprint
  - The footprint of a tower is the amount of free space on the ground that is required
  - Depending on the structure of the tower, it requires more or less space for installation.
  - For tall guyed masts (> 30m), each guy anchor is typically 10-15m from the base of the mast. For a mast with 3 guy wires per level, that results in a footprint of approx. 90 – 200 m<sup>2</sup>.
- Height of tower
  - Adding guys cables to a structure will allow higher height.
- Budget
  - “The smaller the tower base, the more costly to purchase and install the tower”
  - Monopoles have the smallest footprint of all towers, and are hence the most expensive towers. It is followed by self supported towers and then guyed masts which require the largest footprints. Depending on the tower type, certain tools, machinery and cranes are needed to assemble the tower which must be taken into consideration in the final budget.

## Other factors to be considered in design:

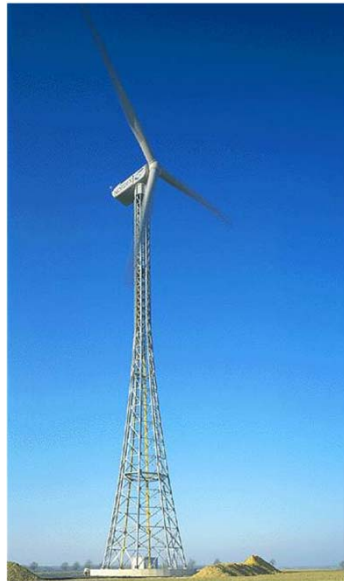
- mean aerial height for each aerial system
- directions for the various directional antennas,
- wind drag on each element of the array and dependent on wind direction, size, weight and disposition of all feeders and cables,
- the permitted angular rotations in azimuth and elevation of each aerial above which the broadcast signal is significantly reduced,
- the need for all-weather access to some of the aerials,
- besides the known antenna and aerial configuration the possible future extension should be defined,
- atmospheric ice formation on the structure and aerials and its likelihood to occur with high wind,
- wind drag of the structure itself without ice and with ice if feasible,
- the degree of security required,
- the available ground area and access to the site,
- the geological nature of the site,
- the overall cost of land, foundations and structure,
- the cost and implications of future maintenance or structural replacement,
- any special planning considerations imposed by statutory bodies,
- the aesthetic appearance of the structure.

## Towers

- A self supporting tower (freestanding tower) is constructed without guy wires.
- Self supporting towers have a larger footprint than monopoles, but still require a much smaller area than guyed masts.
- Self supporting towers can be built with three or four sided structures.
- They are assembled in sections with a lattice work of cross braces bolted to three - four sloping vertical tower legs. They can be used for power transmission lines, lighting, wind turbines, communications, etc.



Power transmission line



Wind Turbine - Lattice Tower



Radio Lattice Tower

## Towers

- The highest structures are from reinforced (or prestressed) concrete (Toronto 553 m, Moscow 540 m ...)
- In steel towers are difficulties with vibrations and position stability (they are lightweight).

### The highest steel towers in the world:

(both steel structures with reinforced concrete core)

Tokyo Skytree, 634 m, 2012



Canton Tower (China), 600 m, 2010



Tashkent, Uzbekistan 375 m  
(1985)



Alma-Ata, Kazakhstan  
370 m (1983)

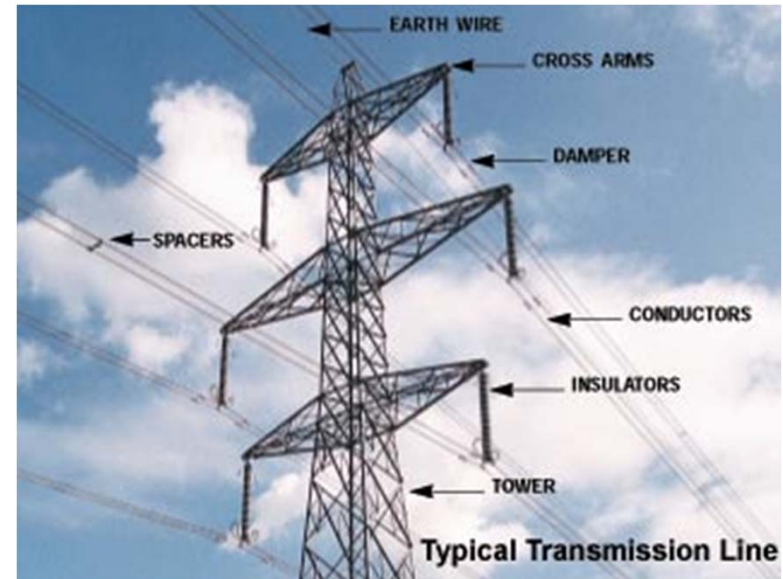


Sydney  
305 m (1981)

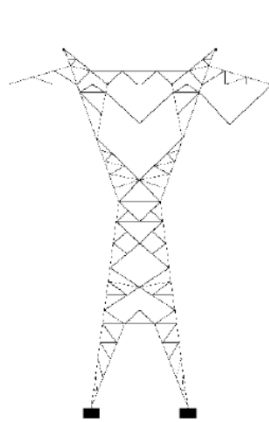


## Transmission lines

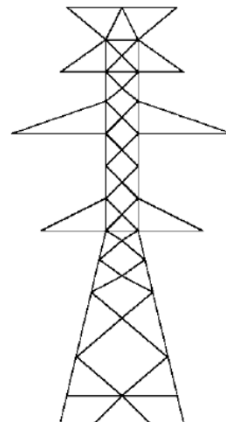
- Transmission structures support the phase conductors and shield wires of a transmission line. The structures commonly used for transmission lines are either lattice type or pole type.
- Lattice structures are usually composed of steel angle sections. Each structure type can also be self-supporting or guyed. Structures may have one of the three basic configurations:
  - Horizontal
  - Vertical
  - Delta
- depending on the arrangement of the phase conductors.



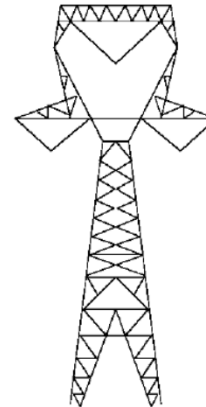
Typical transmission line



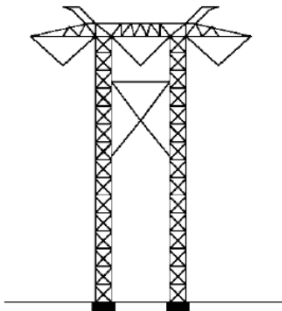
Lattice  
Self-Supported/  
Horizontal Structure



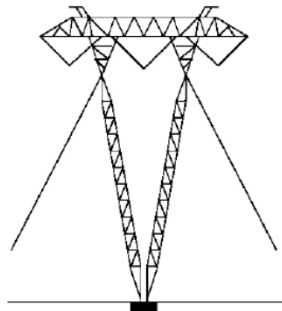
Vertical  
Configuration



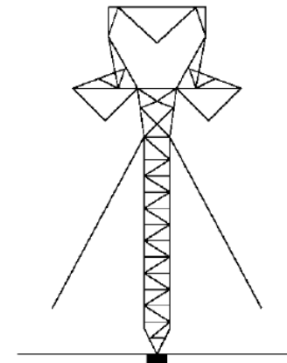
Lattice  
Self-Supported/  
Delta Structure



Lattice  
H-Frame/  
Horizontal Structure



Lattice  
Guyed-Vec/  
Horizontal Structure



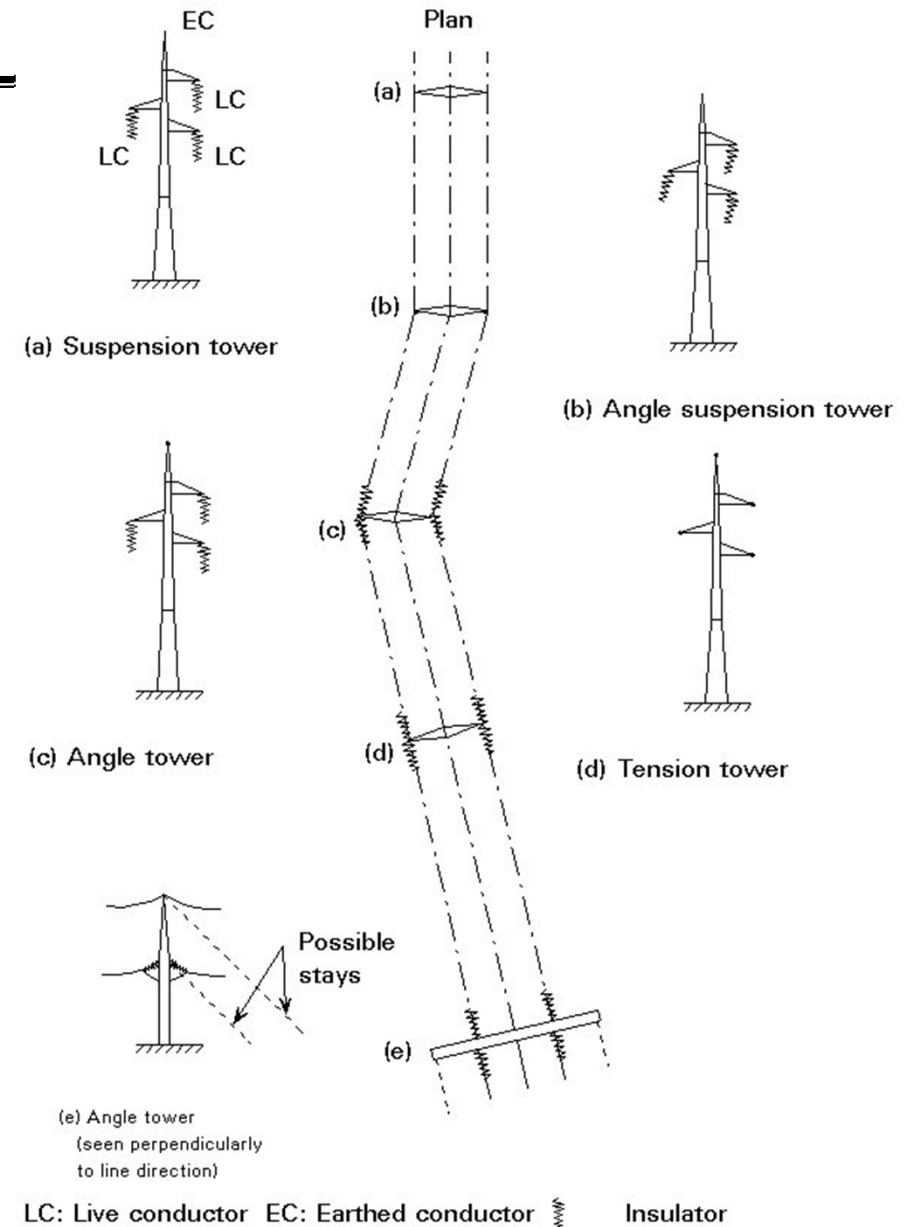
Lattice Guyed  
Single-Column  
Delta Structure

### Examples of transmission line structures



## Types of towers

- An overhead transmission line connects two nodes of the power supply grid.
- The route of the line has as few changes in direction as possible, based on the line route and the type of terrain it crosses. Depending on their position in the line various types of towers occur, such as:
  - suspension towers
  - angle suspension towers
  - angle towers
  - tension towers
  - terminal towers (dead-end type).



Types of towers along transmission lines



Various types of towers

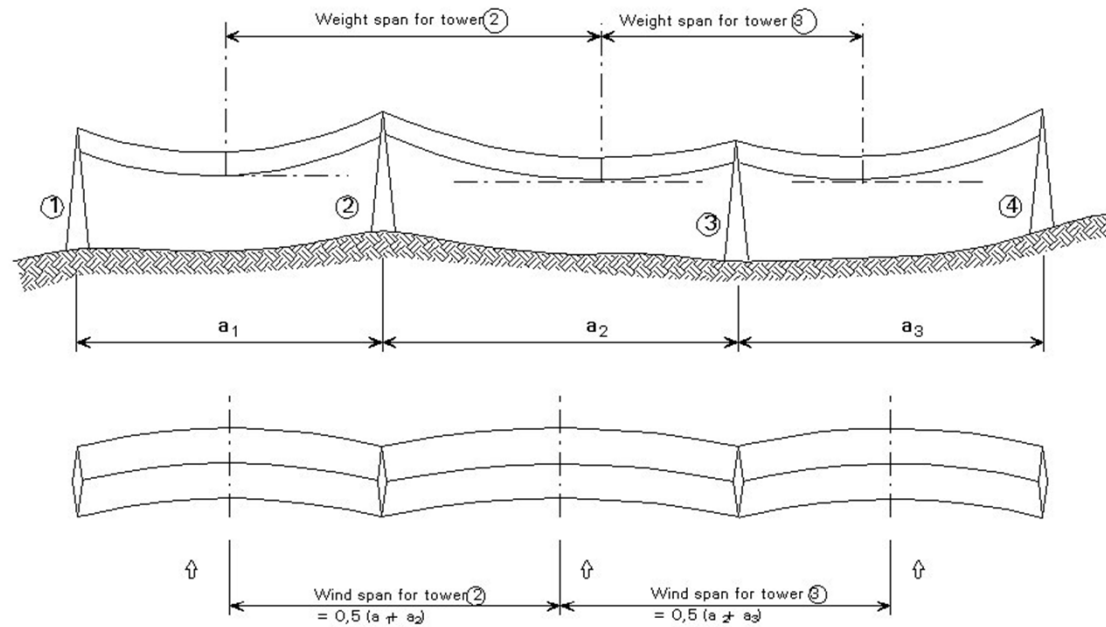


## Typical design problems are:

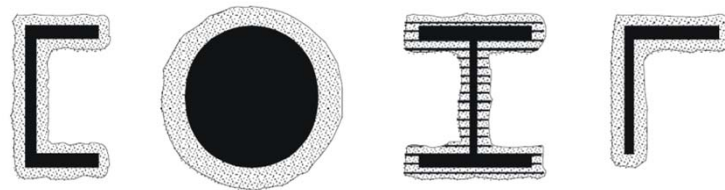
- establishment of load requirements.
- consistency between loads and tower design.
- establishment of overall design, including choice of number of tower legs.
- consistency between overall design and detailing.
- detailing with or without node eccentricities.
- sectioning of structure for transport and erection.

## The loads acting on a transmission tower are:

- dead load of tower.
- dead load from conductors and other equipment.
- load from ice, rime or wet snow on conductors and equipment.
- ice load, etc. on the tower itself
- erection and maintenance loads.
- wind load on tower.
- wind load on conductors and equipment.
- loads from conductor tensile forces.
- damage forces
- earthquake forces.

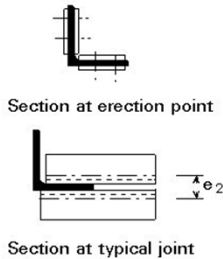
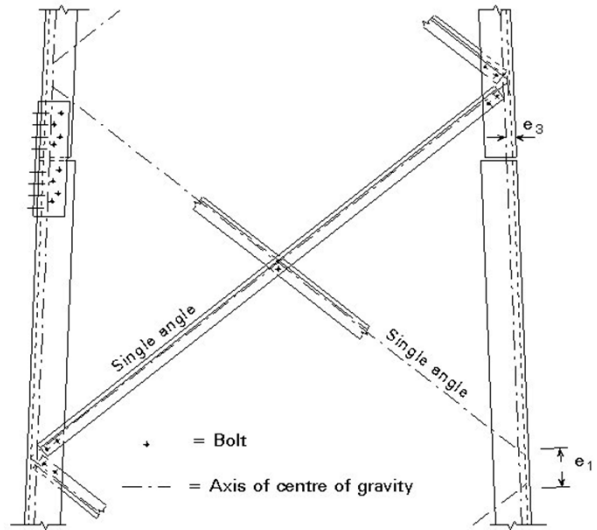


Weight spans and wind spans

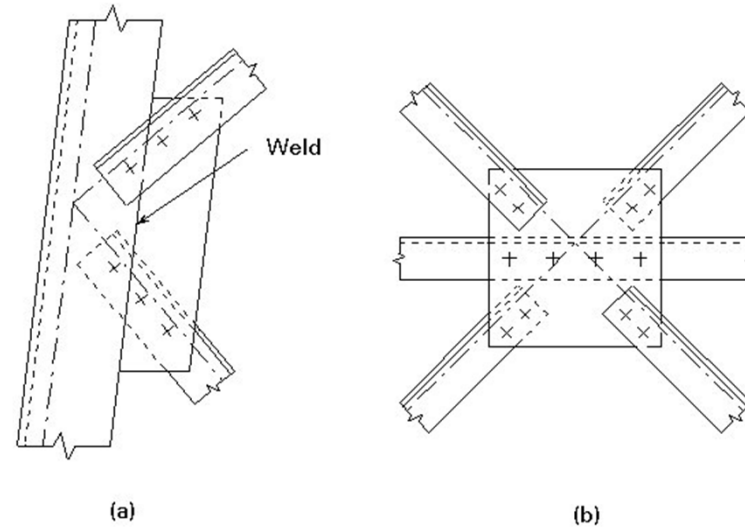


Ice thickness on structural members

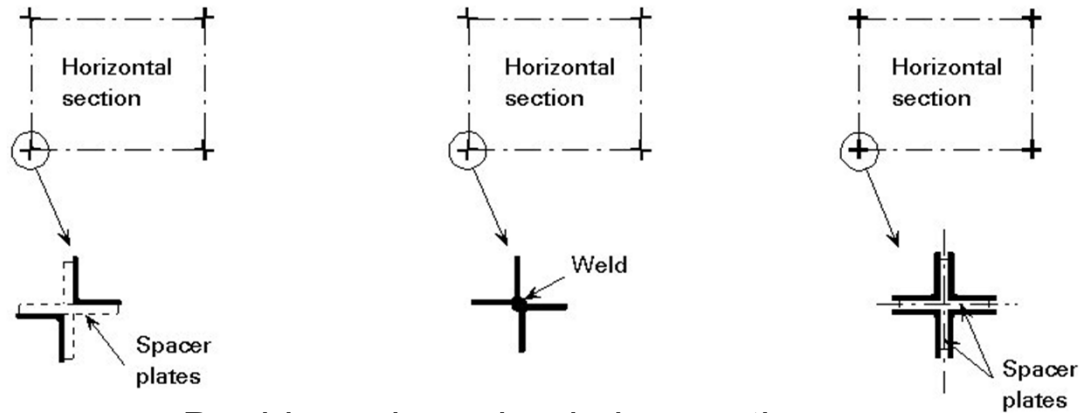
# Structural details



Segment of typical tower face

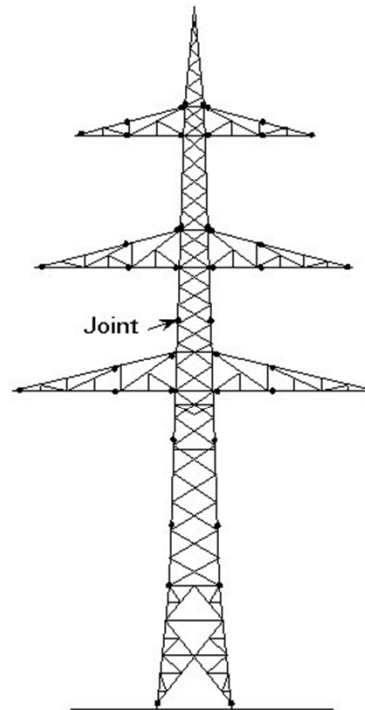
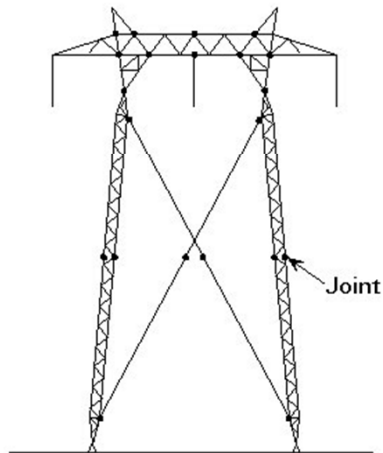


Joints with gussets

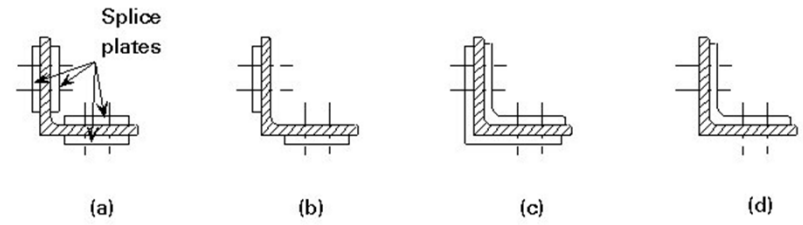


Double and quadruple leg sections

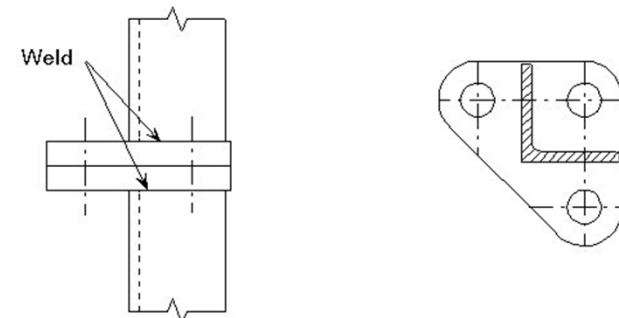
# Detailing of construction and erection joints



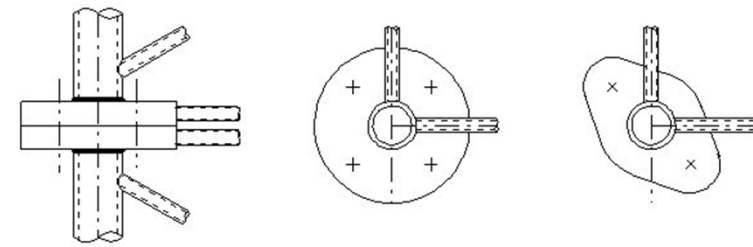
Only the leg and crossarm chord joints shown



Bolted angle section splice joints



(e) Bolted angle section butt plate joint



(f) Bolted tube section butt plate joint

## Monopoles for lighting

- These pole structures are used for street lighting, sports lighting, etc.
- Poles are flexible structures and may undergo relatively large lateral deflections under design loads.
- A secondary moment (or  $P - \Delta$  effect) will develop in the poles due to the lateral deflections at the load points. This secondary moment can be a significant percent of the total moment.
- In addition, large deflections of poles can affect the quality of lighting and therefore the lateral drift should be carefully monitored.
- To prevent excessive deflection effects, the lateral deflection under factored loads is usually limited to 5 to 10% of the pole height.



Monopoles for lighting

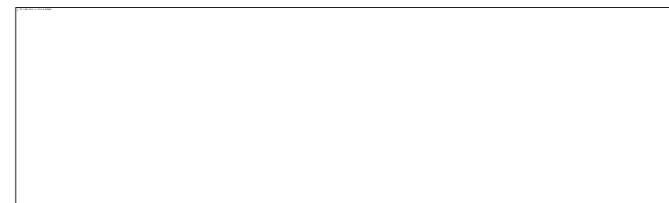
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## Design and fabrication

- Steel poles are fabricated from uniformly tapered hollow steel sections.
- The cross sections of the poles vary from round to polygonal shapes.
- In order to increase the effective area of the section, they are realized with 20-sided polygonal or 16-sided polygonal shapes.
- In these cases, the poles are formed into design cross-sections by braking, rolling, or stretch bending.
- Design of these monopoles is made for two limit states:
  - Ultimate limit state: The strength of the structure shall be sufficient to withstand the design loads. Particular attention should be paid to the nature of the door openings.

*Current practice and experience indicates that vibration and fatigue need not be considered as design criteria where the natural frequency of oscillation in the fundamental mode does not exceed 1 Hz.*

- Serviceability limit state: the deflection and the vibration of the structure shall not exceed any limits specified by the purchaser or user. For example, where the deflection is considered critical, it may be limited to  $1/40H_{mast}$  at  $2/3$  of the design wind speed



Steel monopoles with door opening



## Design and fabrication

- In case of polygonal cross-sections, when the thickness is reduced, special considerations must be given to calculation of member section properties (class section classification) and assessment of local buckling (in case of class 4).
- To ensure a polygonal tubular member can reach yielding on its extreme fibers under combined axial and bending compression, local buckling must be prevented.
- This can be met by limiting the width (diameter) to thickness ratio,  $D/t$  to a certain value, depending on the number of sides.
- When the limit is not satisfied, the moment capacity of the section should be corrected to account for the local buckling phenomenon.

### Example:

For masts of circular or regular polygonal cross section with 16 or more sides, and where the  $D/t$  ratio does not exceed 200, the moment capacity of the section  $M^*$  may be calculated as follows:

$$\begin{aligned}
 & \text{- for } \frac{D}{t} \leq \frac{NE}{180f_y} \quad \longrightarrow \quad M^* = \frac{M_p}{\gamma_m} \\
 & \text{- for } \frac{NE}{180f_y} < \frac{D}{t} \leq 200 \quad \longrightarrow \quad M^* = M_p \left\{ 0.9241 \times \left[ \left( 90 f_y D / NEt \right)^{-0.2858} \right] - 0.1266 \right\} / \gamma_m
 \end{aligned}$$

where:

- $D$  diameter or across flats dimension of the section [mm]
- $t$  is the section wall thickness [mm]
- $N$  is the number of sides and is taken as 20 for circular and polygonal sections with 20 or more sides, and as actual number of sides for polygonal sections with less than 20 sides
- $E$  is the Young's modulus of elasticity [N/mm<sup>2</sup>]
- $f_y$  is the yield strength [N/mm<sup>2</sup>]
- $M^*$  is the section design bending resistance [Nm]
- $M_p$  is the section plastic moment of resistance [Nm]

## Design and fabrication

- Pole sections are normally joined by telescoping or slip splices to transfer shears and moments. They are detailed to have a lap length no less than 1.5 times the largest inside diameter. It is important to have a tight fit in slip joint to allow load transfer by friction between sections. Locking devices or flanged joints will be needed if the splice is subjected to uplift forces.



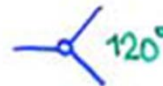
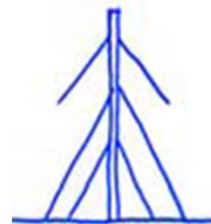
## Guyed masts

- A guyed mast is one of the most complicated structures an engineer may be faced with
- The number of masts collapses is relatively far greater than for other types of structures

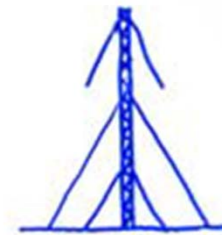
carry aerials of TV, radio etc.,

- or may be themselves emitters (then isolation - separation from ground is necessary).

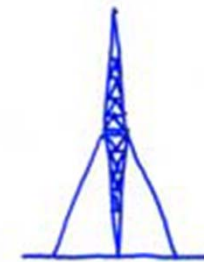
**According to structure:**



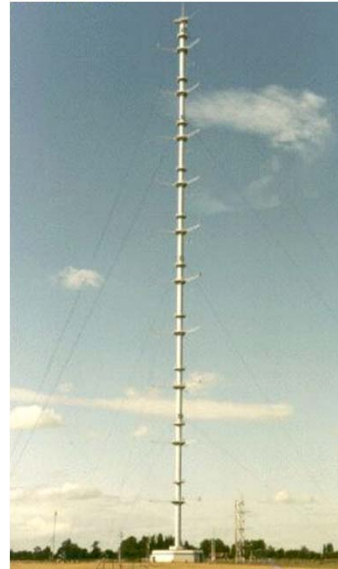
**solid structure**  
(tubes)



**truss structure**  
KVLY-TV (Fargo), 629 m



**variable section**



solid structure



variable section



truss structure

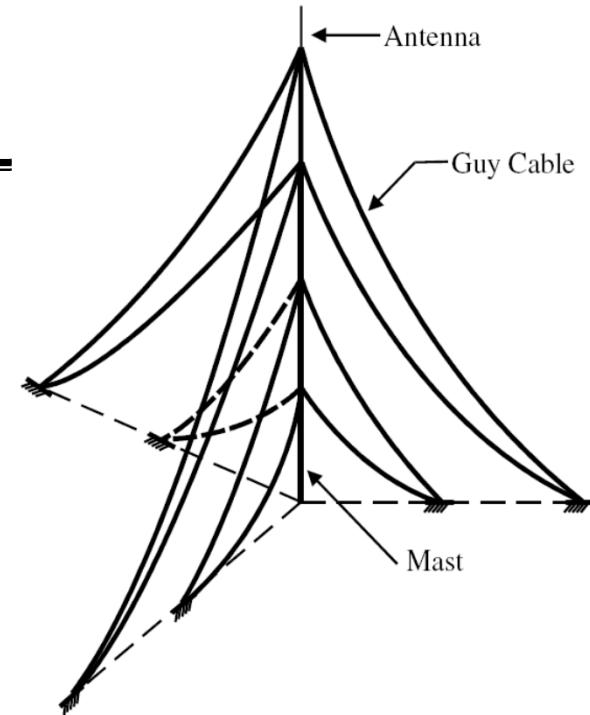


## Guyed masts

- Both solid or truss structures, usually repeated (line) production.
- Steel guyed masts can be designed for large heights (up to 600 – 700 meters high) and are both light and stiff to be designed and built in steel
- Mast's problems:
  - corrosion: - zinc dipping, hot-flame spraying (Zn + Al);  
- cables: locked sections, multiply corrosion protection,
  - cable sockets: - suffer from corrosion and fatigue (because subject to alternating moments due to oscillation bending),  
- anchored (stayed) required at more levels for possible replacement,
  - assembly: - climbing cranes, preference given to welding (bolted connections cause corrosion),
  - vibrations: - reduced by: dampers, splitters, helical strakes, spoiler plates, suitable shape.



- The component parts of a guyed mast are:
  - the foundation
  - the steel mast, which generally has a pinned foot
  - the guy cables
  - the structural accessories
  - the equipment (antenna)

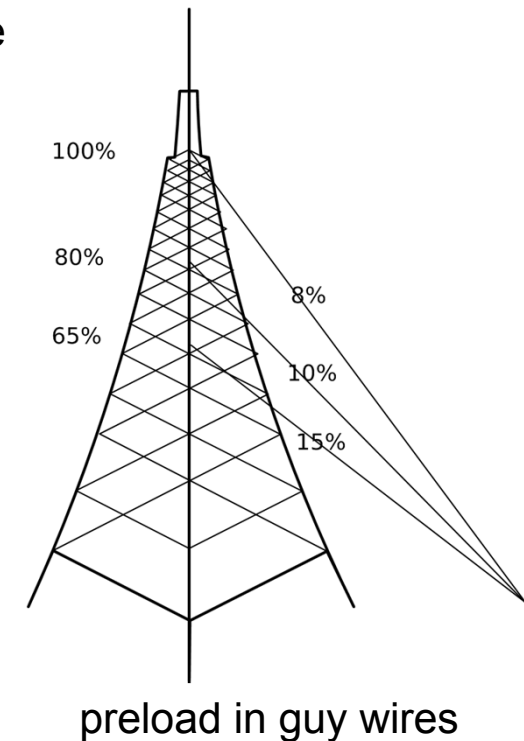


### Design of steel mast

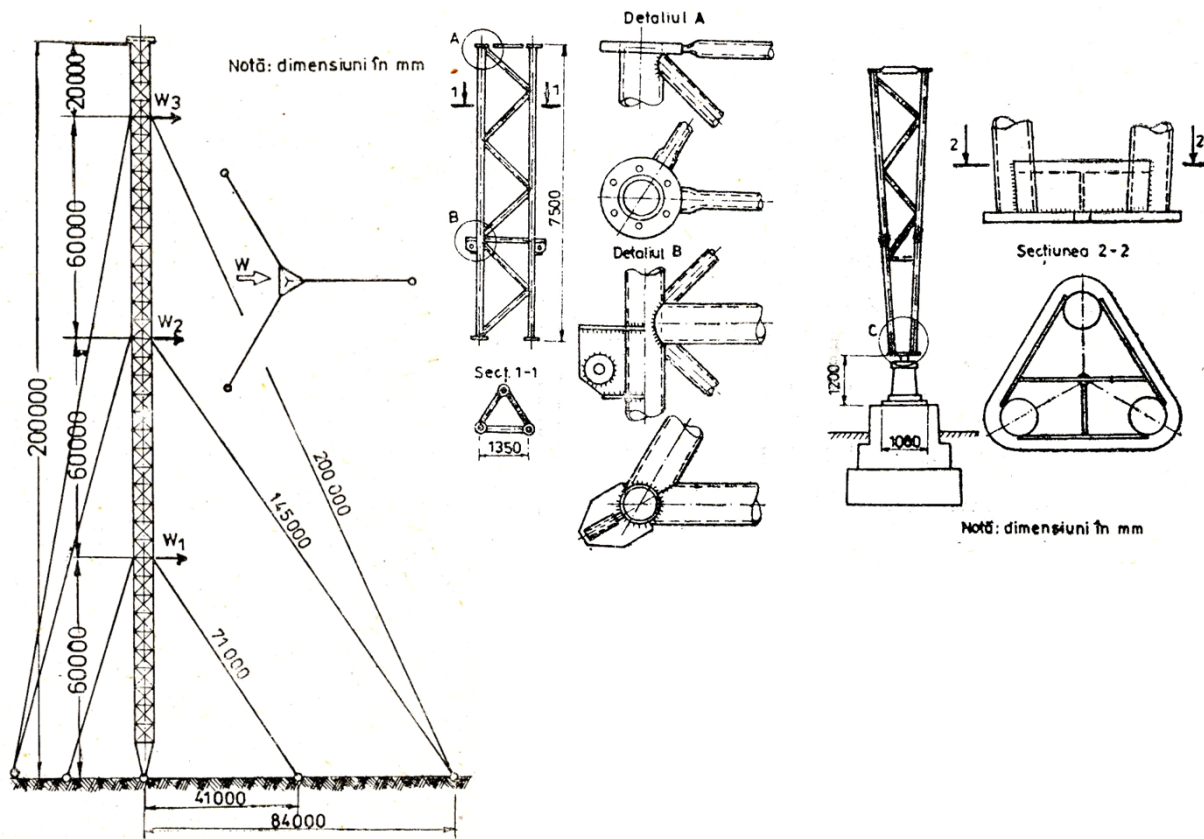
- Steel mast anchored at different heights, is loaded in bending due to wind, and compression from vertical loads (dead load, live load, pretension forces in the cables).
- Pretension force in cables is determined so that in case the cable is unloaded due to wind action, the cable should still be subjected to a tension force.
- Value of pretension force is about  $0.10 - 0.15 f_u$  (see Figure 36).
- After the internal efforts in members is determined (legs, diagonals), they are designed using relevant verifications.
- For one segment of the mast, members of the same type have similar sections.

## Design of steel mast

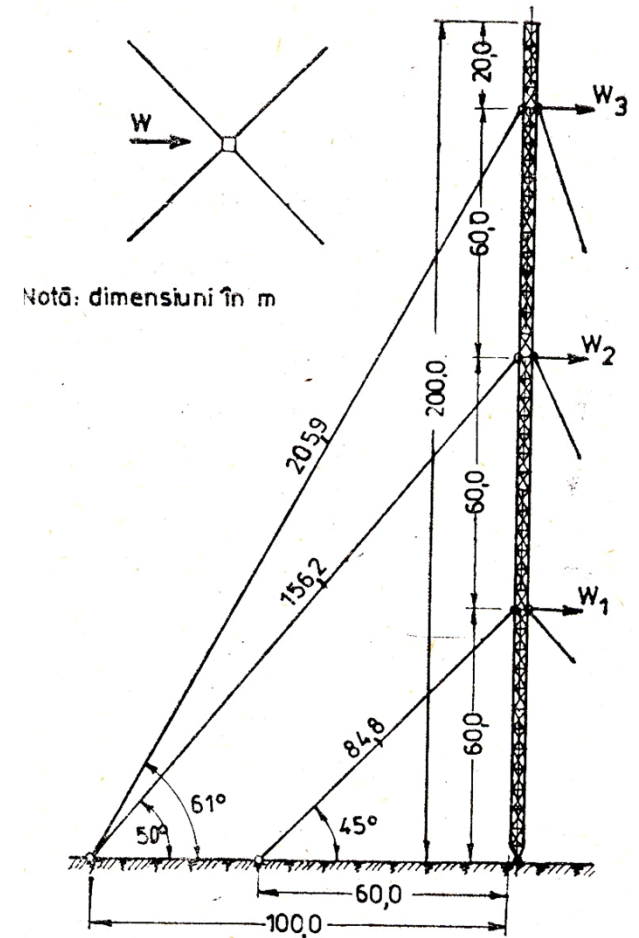
- Steel mast anchored at different heights, is loaded in bending due to wind, and compression from vertical loads (dead load, live load, pretension forces in the cables).
- Pretension force in cables is determined so that in case the cable is unloaded due to wind action, the cable should still be subjected to a tension force.
- As a rule, if the guy is attached in the top of the tower (100% ), the tension should be 8% of the tensile strength.
- For 80% of the tower's height, 10% tension should be applied.
- If the anchor point is at 65% of tower height, 15% tension can be applied as you loose a lot of wind load in this last type of installation.
- The breaking strength will improve the control of the flexibility and still not cut down on the cable strength. Normally, a tower has 2 – 3 levels of guys (depending on the height of the tower/mast) and three guys on each level. It is recommendable to use turnbuckles as it will allow you to fine tune your adjustments later on.
- After the internal efforts in members is determined (legs, diagonals), they are designed using relevant verifications.
- For one segment of the mast, members of the same type have similar sections.



# Typical details



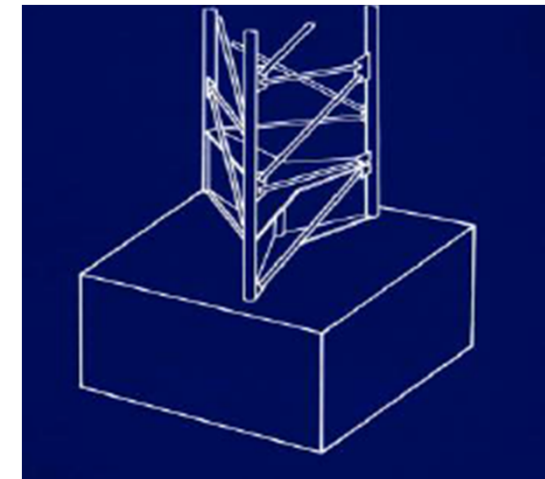
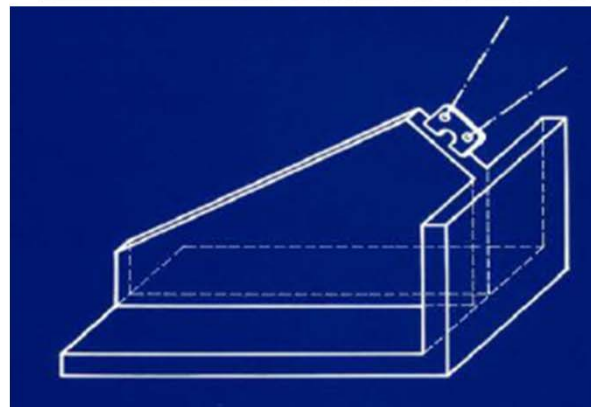
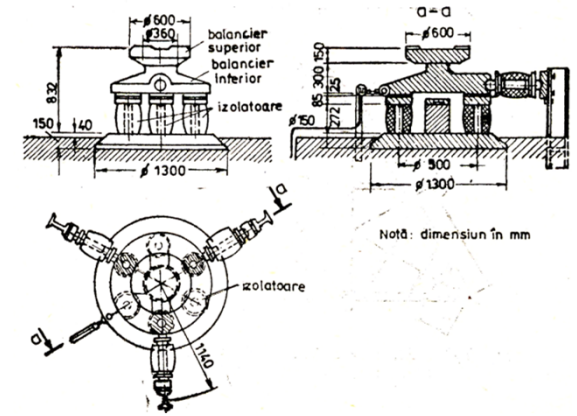
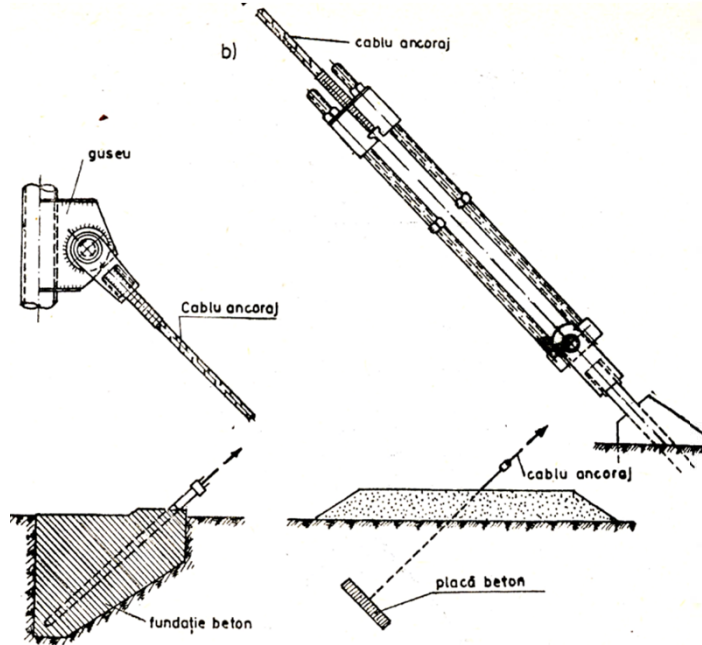
A steel mast with three faces



Masts with four faces



# Typical details



## The highest steel masts in the world

Warsaw (Gabin) (collapsed 1991)

646 m (1974)

Collapse caused by an error in replacing  
the guy-wires. The mast first bent and then  
snapped at roughly half its height.

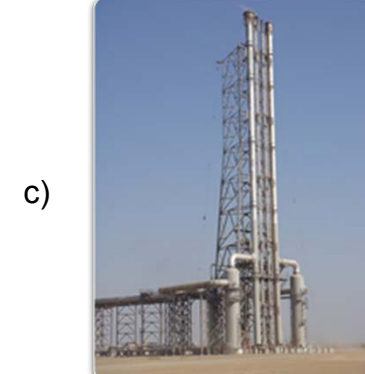
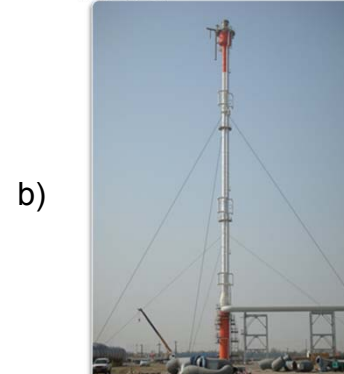


1. KVLV-TV mast (North Dakota)  
guyed mast, 629 m (1963)  
steel tube core + steel truss



## • Chimneys: configurations, design, detailing

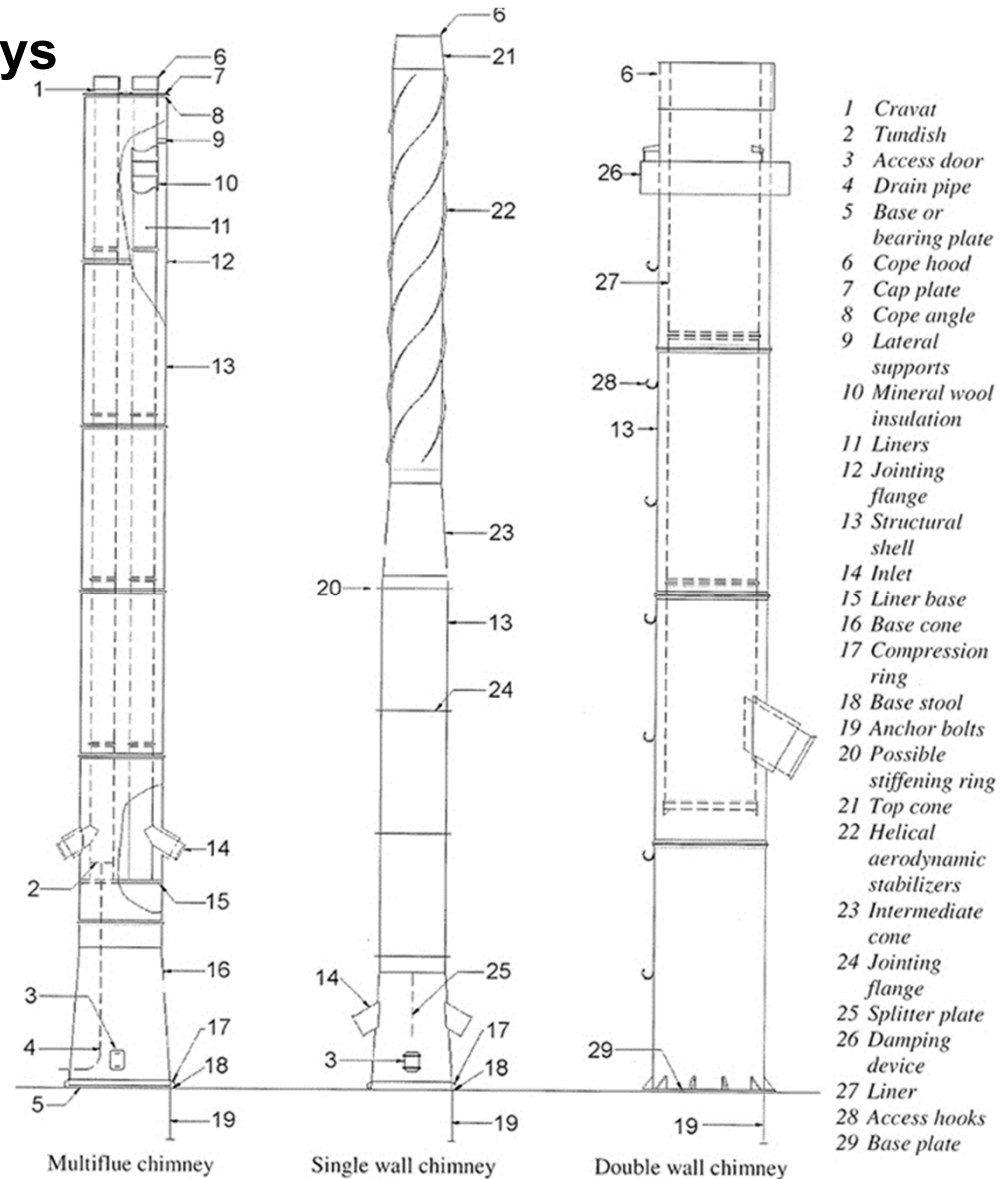
- Chimneys are vertical construction works (or building components) that conduct waste gases, or other flue gases, supply or exhaust air to the atmosphere
- Steel chimneys are also known as steel stacks
- Structures are similar to masts and can be:
  - a. Self-supported (cantilevered): for heights less than 60 m
  - b. Guyed chimney - is held in place by guys at one or more height levels - for heights more than 60
  - c. Supported - structurally supported at one or more height levels by a building or by any other bearing system – for heights more than 60



- Problems:
  - dynamic effects (vibrations, fatigue)
  - stability (both global and local in shells)
  - connection of smoke uptakes (cross-section weakening).

<http://www.zeeco.com>

## Definitions used for Chimneys



## Basis of design

- **Actions**

- Permanent actions
- Variable actions
  - Imposed loads: should be applied on platforms and railings (may be assumed to act in the absence of other climatic loads).
- Wind actions:
  - besides the drag forces due to the gusty wind acting in general in the wind direction, forces due to vortex shedding that cause cross wind vibrations of a chimney should be considered.
  - If chimneys are predicted to be subject to excessive wind vibrations, measures may be taken to reduce these in the design, or by installation of damping devices
- Internal pressures: this case should be treated as accidental loads
- Thermal actions
- Ice loads
- Seismic action
- Fire

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## **Ultimate limite states**

- Chimneys shall be checked for the following ultimate limit states:
  - static equilibrium;
  - strength of its structural elements;
  - overall stability;
  - local buckling of its structural elements;
  - fatigue (including low cycle fatigue if relevant) of its structural elements; and
  - failure of connections.

## **Serviceability limit states**

- The following should be considered:
  - deformations or deflections in the along wind direction and/or in the cross-wind direction
  - vibrations, oscillations or sway which may cause alarm among bystanders;
  - deformations, deflections, vibrations, oscillations or sway which cause damage to non-structural elements.
  - the maximum value of deflection in the along-wind direction:  $\delta_{\max} = h/50$
  - The maximum values for the vibration amplitudes at the top of a self-supporting chimney due to vortex shedding:

Reliability class	Limits to cross-wind vibration amplitude	
3	0,05	times the outer diameter
2	0,10	times the outer diameter
1	0,15	times the outer diameter

**This lecture was prepared for the 1<sup>st</sup> Edition of SUSCOS (2012/14) by Prof. Josef Macháček (CTU) and Michal Jandera, PhD. (CTU).**

**Adaptations brought by Florea Dinu, PhD (UPT) for 2<sup>nd</sup> Edition of SUSCOS**

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