# 1 WIND LOADS

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## 1.1 INTRODUCTION

The best chance to reduce disaster caused by storms is to build the structures conforming to the state-of-the-art in wind engineering or at least for normal structures to the wind codes (Münchner Rückversicherungs-Gesellschaft 1989). Structures and their components should be built with sufficient resistance. Very exposed terrains like the top of mountains and exposed coastal regions need special regulations imposed by the government.

**An** important influence on damage control have *insurance companies*. They have the possibility to steer to a certain point the public, the industry and the authorities, and may force the policy holders to prevent damage.

## 1.2 STATIC AND DYNAMIC WIND LOADS

The dynamic pressure acting on the surface of the building is proportional to the square of the wind velocity. **At** the edges of the roofs and the walls in the wind direction the pressure and suction forces may reach the multiple of the usual dynamic wind pressure. Generally the distribution is more erratic if the shape of the building is irregular and sharply-edged. The damage on roofs and facades shows clearly, where the extreme pressures have an influence. Often designers are suprised by the locations of the damage, which means that the *engineering education* is incoinplete.

In the design of buildings and components the indications and prescriptions of the codes should be used. In certain cases the static approach to wind loads does not show the true interactions between the structure and the wind flow. The unsteady and turbulent flow can cause resonance of the structure. Fig.1.1 shows a design mistake in the concept of cooling tower construction. Damages may occur even at moderate wind velocities. The parameters of

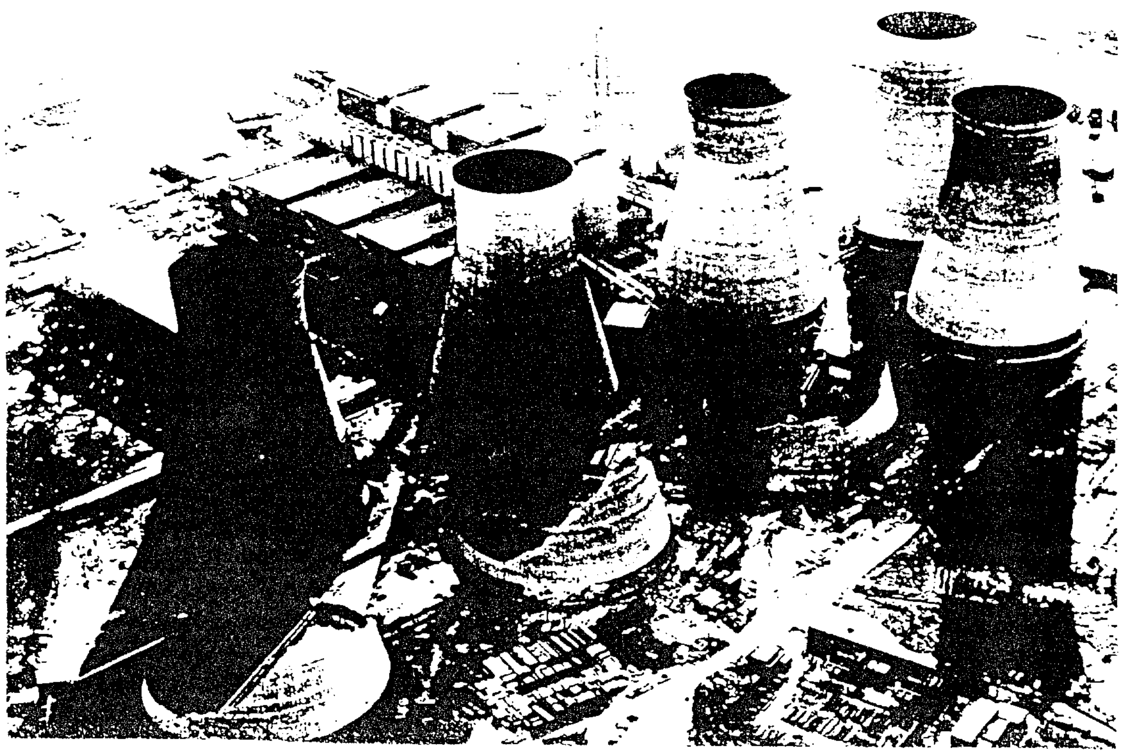

Fig. 1.1 Cooling towers damaged by exceptional wind load.

vortex shedding used in the codes are known. The modem tendency to higher and at the same time lighter structures make them more susceptible to vibration.

Wind engineering deals with *wind-induced vibrations.* Measurements in situ and in wind tunnels together with computer simulations of the wind flow allow specialists to predict the wind loads on unusal and new structures.

## 1.3 CODES

Most of the countries have detailed design regulations concerning wind action. Some are not compelling and sometimes even contradictory. Therefore, engineers tend to save money with measures against wind load. Economically this is certainly the wrong way since even in extremely exposed coastal regions the savings are less than **4** percent, compared to perhaps the total loss of the structure. The basic values of wind velocities are often derived from a wind velocity (as a mean over 10 minutes) measured in the average every 50 years. These values are converted to peak pressures.

Some of the problems pertaining to wind codes will be shortly discussed. First not all countries can provide the necessary *meteorological data* over a sufficiently long period, especially in topographically exposed terrains. Changes of the climate cannot be predicted with the necessary reliability.

Secondly the wind codes are no more readable for ordinary engineers or architects. Only with typical examples for wind actions in courses for professionals will this problem be resolved. The regulations often show buildings of simple shape whereas very complex structures must be built in daily application. This problem becomes even more acute in the context of roofs and facades. For many structural shapes the pressure and suction distributions are not known. The investor often is not willing to pay wind tunnel testing for better load prediction. Experience of damage is not transferred to the knowledge of engineers. Only a few years after major disasters engineers are forced to reduce expenses against wind action. The influence of neighbouring buildings is not sufficiently taken into account. The danger of debris transported by wind in agglomerations is also not considered. The many details which have to be accounted for in design against wind action ask for a long experience in the profession of engineers, architects and especially workmen. All the preceding aspects taken into account will allow us to build structures which resist storms.

## 1.4 POSSIBILITIES TO PREVENT DISASTERS

Every year insurance companies all over the world pay damages of a huge extent. They would be able to collect data of all the damages and to transmit the *experiences* to the interested engineers and architects. This happens very seldom, but it could be the decisive step to a disaster-resilient strategy. Since there is still no move in this direction, some typical arguments for damages and possible preventions will be discussed. The whole spectrum of essential causes, even such beyond wind storms, will be discussed.

### 1.4.1 Roofs

Why are roofs damaged most of all? Causes include larger wind velocity with increasing height over ground, vortex shedding at sharp comers and cantilevering roofs, small roof weight, insufficient anchoring of the roof to the building, poor fixing of the skin to the roof structure and inexistent maintenance of roof elements such as chimneys or antennas. Roof damage is especially annoying because the rain destroys the insulation and increases the total damage considerably. The parts loosened from the roof are transported by the wind. They hit other buildings. Sometimes the stability of the whole building is threatened if the roof is blown off. Measures against these kinds of damage can be derived from what has been said

**Fig.1.2** Roof damaged **by falling tree during** a storm.

The trees must have a reasonable distance from the building or they should only reach the eaves (Fig.1.2). Due to a limited overhang suctions and pressures are reduced. Reliable connections between the roof and the underlying structure are important. Nails are normally not the ideal solution. The skin of the roof can be fixed to the beams by screws.

### 1.4.2 Exterior walls and facades

Exterior walls are damaged by extreme storms only. Since more and more expensive and at the same time sensitive materials are used, the wind forces will impair curtain walls and panels more frequently in the future. Debris and hailstones increase the damage to such buildings dramatically. Glass areas are even more sensitive to wind actions (Fig.1.3). Resonacce vibrations are an additional cause of failure. The same is valid for gates and sliding doors of hangars and halls. Because of the demand for small weights the gates are produced of light metals. Under high wind pressure this material may deform extremely. Often the gates leave the frame and are therefore destroyed. Possible preventive measures are given as examples.

The elements of the facade and of the insulation need *sufficient anchoring* to the masonry and to the steel profiles. The material should be resistent against hail. Big glass elements should have flexible suspensions and subdivided panels. Light metal gates should be stiffened to such an extent, that the deformations are limited according to the dimensions of the frame. The determining elements must be maintained and checked on corrosion. It is important to take into account the internal pressure correctly.

### 1.4.3 Airdomes and tents

Airdomes are a modem development in civil engineering whereas tents are rediscovered today. Both are very susceptible to wind action, especially if certain important safety measures are overlooked (Fig.1.4). The material is normally PVC with a thickness of 0.7 - 1.2 mm. In the interior a small overpressure is needed. The wind forces on the domes are modest. Damage starts if the interior pressure is not increased early enough or if the anchors cannot withstand the lift forces. Therefore, the following rules should be respected for airdomes.

At least two bellows must be installed, which can quickly increase the interior pressure with the upcoming storm and which are able to maintain the pressure if one below fails. Since the electricity is often interrupted during storms, an emergency power generator is needed. The steering of the bellows should be connected with an anemometer, which allows to increase the pressure if the critical wind velocity is reached.

**Fig.1.3** Damages on building facade **due** to storm.

The bearing structure of a tent has to be designed to extremely high wind actions. The safety regulations of tents normally consider this problem for severe hazard situations. Important is the anchoring of the cables into the ground. If the material is tearing, the situation is modified completely. The wind entering the tent may cause a so-called 'flying' building.

### 1.4.4 Scaffolding and cranes

The sufficient anchoring of temporary structures is often neglected (Fig.1.5). This leads to heavy damages not only for the scaffolding and the cranes but also for the environment. Cars, buildings and sometimes even persons may be harmed. Some simple rules have to be respected to prevent damage.

**Fig.1.4** Roof damage of air dome.

The scaffolding needs a safe connection with the building under construction or under repair. Weather forecasts have to be followed to stop working early enough. The maintenance of scaffolding and cranes is important. The cranes should be fixed to the rails with bolts and Joints. The crane-jib should be free to adapt itself to the wind direction, without threatening neighbour buildings. A further possibility is to take apart the crane or the scaffolding shortly before the storm arrives.

### 1.4.5 Tanks, vessels and cooling towers

During construction tanks are often threatened by storms because the cover providing the necessary stiffness is missing. The overalling of the open section caused by vortex shedding in resonance with the structure can lead to complete structural failure (Fig.l.l).

The prevention of damage is possible if the tanks are connected sufficiently to the foundation and if overalling is prevented by stiffeners and tendons. The roof should be mounted during an early stage of erection.

### 1.4.6 Towers, masts and stacks

Because of rhe usually slender form, towers, masts (Fig.l.6) and stacks are highly susceptible to vibration. If certain measures are taken the risk of damage is small. Tendons can reduce long period vibrations, but tendons have to be checked against vibration and the anchorage in the ground must be guaranteed. The vortex shedding can be reduced by aerodynamic devices. Passive and active damping measures reduce wind induced vibrations.

### 1.4.7 Bridges

Similar vibration problems are observed with long span suspension bridges. Torsional vibratioric and galloping effects may cause the collapse of the bridge (Fig.1.7). Wind tunnel tests and detailed calculations allow to reduce the risk of failure. The section must be adapted to

**Fig.1.5** Damage of temporary construction by **wind.**

aerodynamic needs. Horizontal and vertical stiffeners as well as active and passive dampers connected to the hangers reduce vibrations.

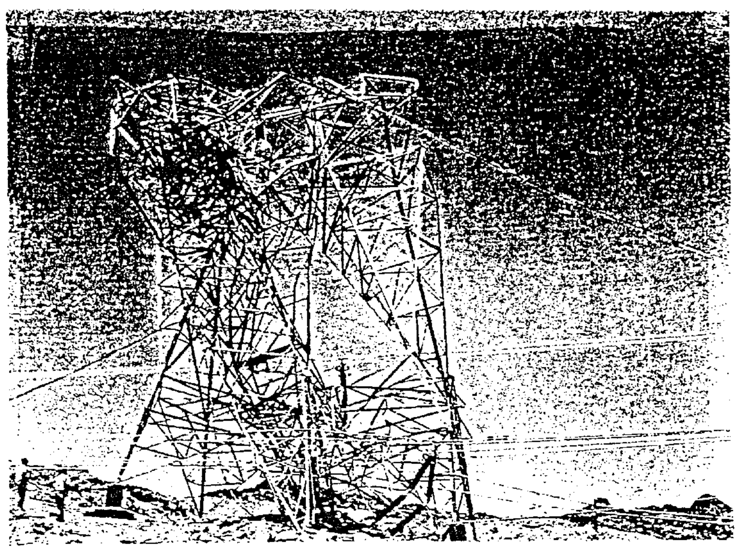

**Fig.1.6** Damage of mast due to **wind** storm.

### 1.4.8 **Erection** stages

During construction the storm risks are usually higher than for the final stage. The construction stages need exact hazard szenarios like the completed structure. Sheathing often gets similar wind forces as roofs and wails. Risks can be avoided by simple organizational measures.

Struts, bracings and tendons must be used to stabilize the construction stages, sometimes they may be mounted only shortly before the storm arrives. The material has to be secured (bundled, fixed) on the camp especially if light masses and big surfaces are involved.

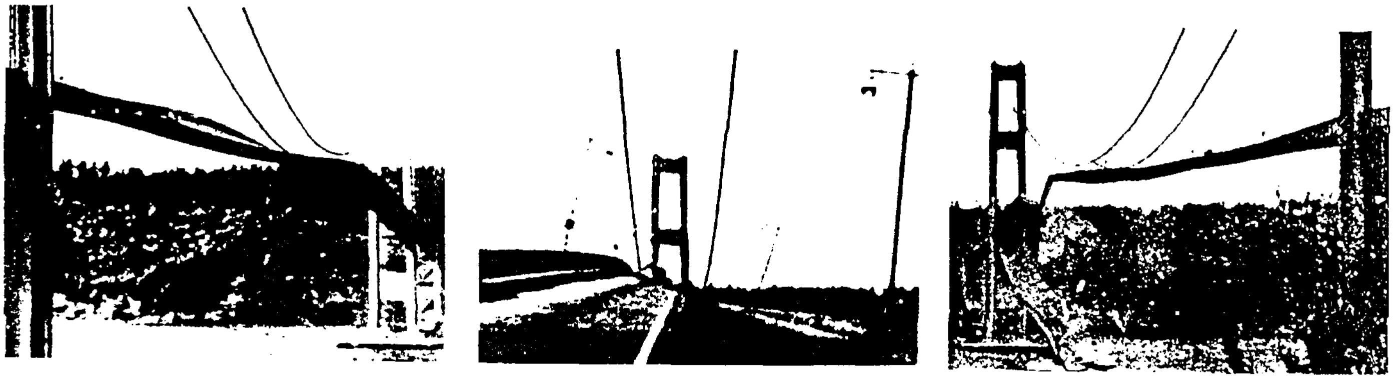

**Fig.1.7** Stages of damage of suspension bridge.

## REFERENCE

Münchener Rückversicherungs-Gesellschaft (1989). Storm.