DEMOLITION OF A COOLING TOWER

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SUMMARY

During the re-planning of a nuclear power station (at that moment in construction) close to Stendal, it was necessary to blast one out of three finished, 150 meters high cooling towers, that were never used. Unfortunately there were no prior experiences blasting a cooling tower of this size. Therefore extensive calculations were necessary for a safe elimination of the structure.
In this paper, the rough draft of this blasting and the performed calculations are explained.

1. IN GENERAL

At the moment of the political turn and the reunification of East- and West-Germany the government of the "GDR" built up an atomic power station in Arneburg close to Stendal to supply the Altmark-area and the surrounding cities with energy.

The doubts about the security of eastern atomic power stations were one reason to stop the construction after the reunification and to break down the project. Another reason was the planning of a rough draft how to supply the area of the former "GDR" with energy.

Because of the substitution of the nuclear power station by a coal-fired power station it was necessary to pull down some useless buildings and to blast one out of three cooling towers. With the height of 150 meters these three structures belong to the biggest cooling towers ever constructed. There were three impressive diameters:

diameter water seal:	120 meters
minimal diameter:	69 meters
diameter at the top:	74 meters

The column-framework with openings for air intake is 8 meters high and binds in a 80 cm voluminous, bottommost edge of the cooling shell. The smallest shell thickness is only 20 cm. If the thickness of the wall is compared with the shell of eggs, one will notice that the wall is much thinner in proportion to the diameter.

At the top of the towers one can see a ring which limits the ovalisation during wind action and which also affects essentially the stability- and vibration behaviour [1] of the cooling towers.

Figure 1. Area of the planned nuclear power station

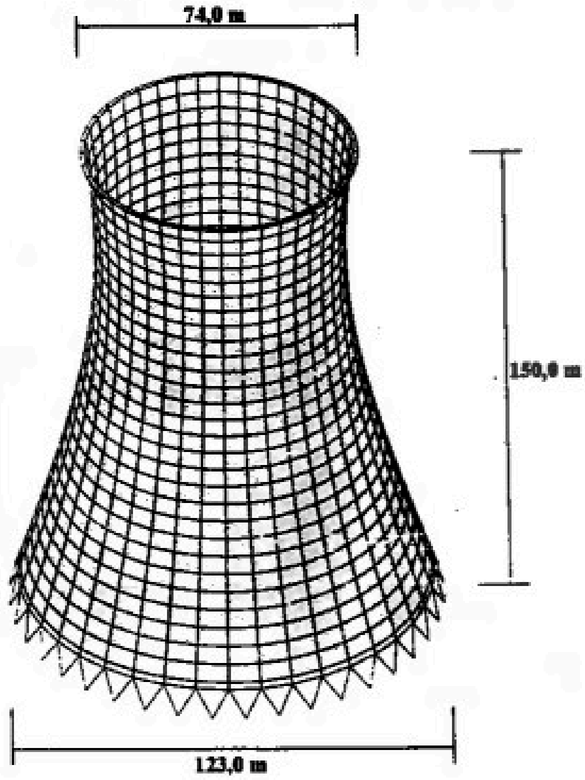

Figure 2. Geometry of the cooling tower

2. ROUGH DRAFT OF BLASTING

The assignment was to develop a qualified rough draft to blast the shell construction, consisting of 24.000 t reinforced concrete. Because of the direct neighbourhood of the other two cooling towers, the possibilities were very limited.

At the Ruhr-Universität Bochum a rough draft [2], was worked out. According to this, the cooling tower B2 was going to trip over onto the free area, lateral of the towers, represented in figure one. To realize this plan it was necessary to blast the eight meters high columns in the area of the down dip and to weaken the shell by slits (at a height of 15 meters the shell is only 25 cm thick). For that purpose a cable-operated excavator, armed with a 1,7 t heavy demolition ball should smash eight vertical slits with a height of 38 meters and a width of 1 meter into the front area of the shell, starting 4 meters above the columns.

The 4 meters high ring at the foot of the edge was necessary, to prevent a serious disturbance of the shell support of the structure and also to guarantee stability against dead weight and wind pressure forces. The lateral distances of the slits should be in average 90 meters, so that double-crooked plate-elements would be left between the slits.

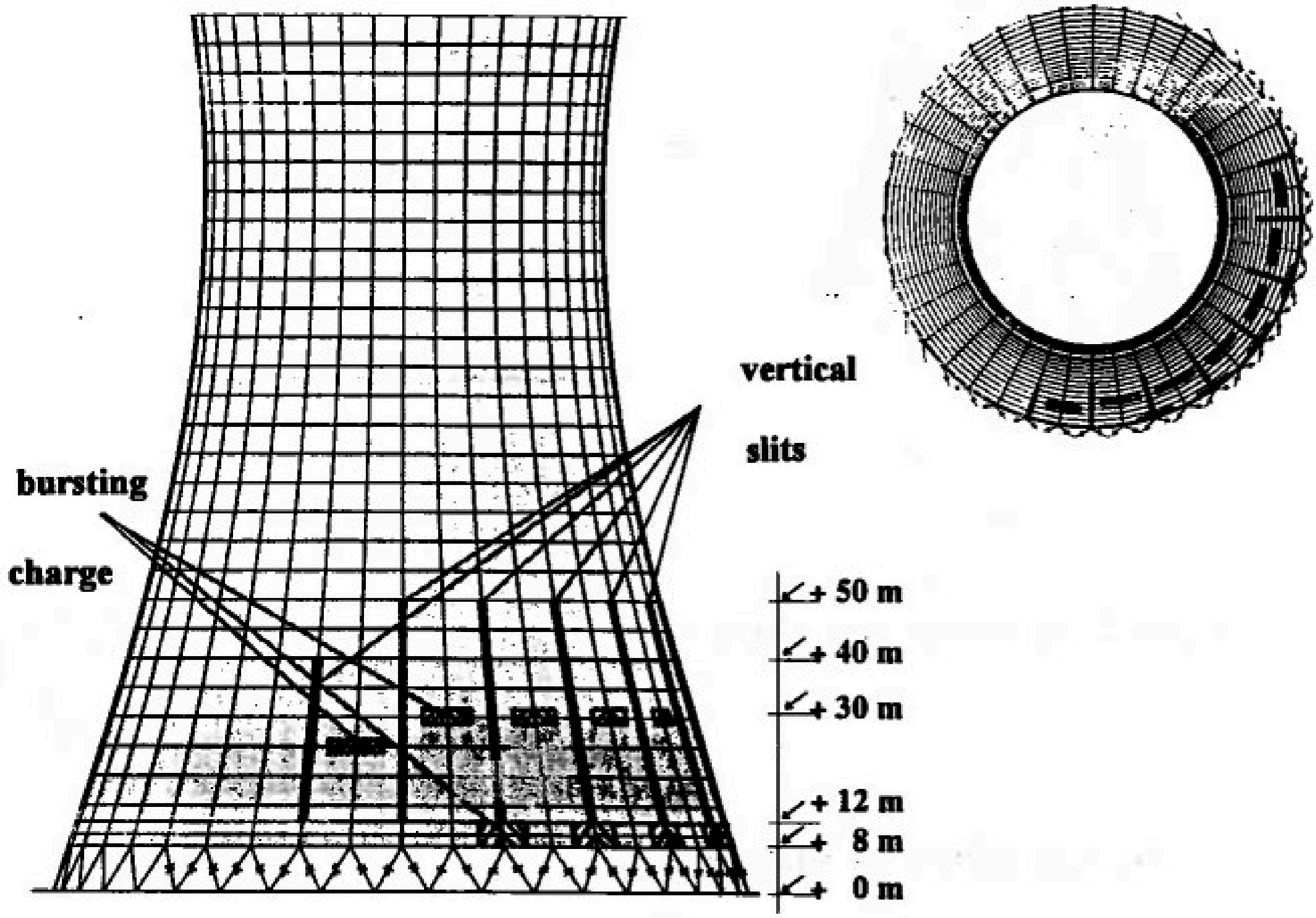

Figure 3. First plan of the slit arrangement

3. CALCULATION OF THE STABILITY IN AN INTERMEDIATE STAGE

At the Institute for Concrete Structures at the Technical University Darmstadt calculations have been executed concerning the bearing strengths of the shell for different intermediate stages, i.e. during the slit works and also in the slited stage.

Cooling towers are designed to resist a lot of different loadings. Because of the thin shell and the enormous height, wind or earthquake action are the most important loadings of these structures.

The wind stress acting on the cooling tower, in the undisturbed as well as in the slited stage, was found out with the help of wind-loading guidelines according to [3].

Considering the location of the cooling tower and its shell roughness, the wind-zone II in combination with the pressure distribution-graph K 1,3 was chosen. The influence for a wind period of n = 10 years was calculated.

The dynamic pressure distribution $q_e(z)$ over the height z is after VGB-BTR [5]:

$$q_E(z) = \varphi \cdot n \cdot r \cdot 0{,}9 \cdot \left[\frac{z}{10}\right]^{0{,}22}$$

where: $\varphi = 1{,}1$ dynamical elevation factor

$n = 1{,}2$ group arrangement factor

$r = 0{,}8$ reduction factor for a wind period of 10 years

The pressure distribution across the cooling tower is divided into three areas :

1. 0°- 73°: $$c_p = 1 - 2{,}3 \cdot \left[\sin\left(\frac{90}{73} \cdot \varphi\right)\right]^{2{,}166}$$

2. 73°- 97°: $$c_p = -1{,}3 + 0{,}8 \cdot \left[\sin\left(\frac{90}{24}(\varphi - 73°)\right)\right]^{2{,}395}$$

3. 97°-180°: $$c_p = -0{,}5$$

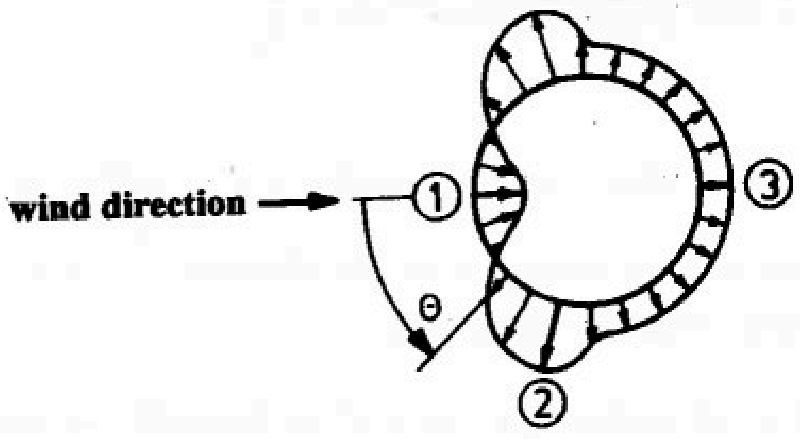

Figure 4. Pressure distribution graph across the circumference

The static internal pressure is accepted as constant over the height and the circumference:

$$c_{pi} = \frac{p_i}{q} = -0{,}5$$

For the definition of p_i, the dynamic pressure $q_e(z)$ at the top of the cooling tower (z=150 meters) was chosen. Parallel to the windloading, the effect of the jerky loadings of the building , which result from work in the slits, should be taken into account.

Analyses at the beginning showed that a jerky stimulation with a demolition ball by a height of 20 meters resulted in a maximum acceleration of 2.2 m/s^2 (figure no. 5) at the top of the tower edge of the undisturbed shell.

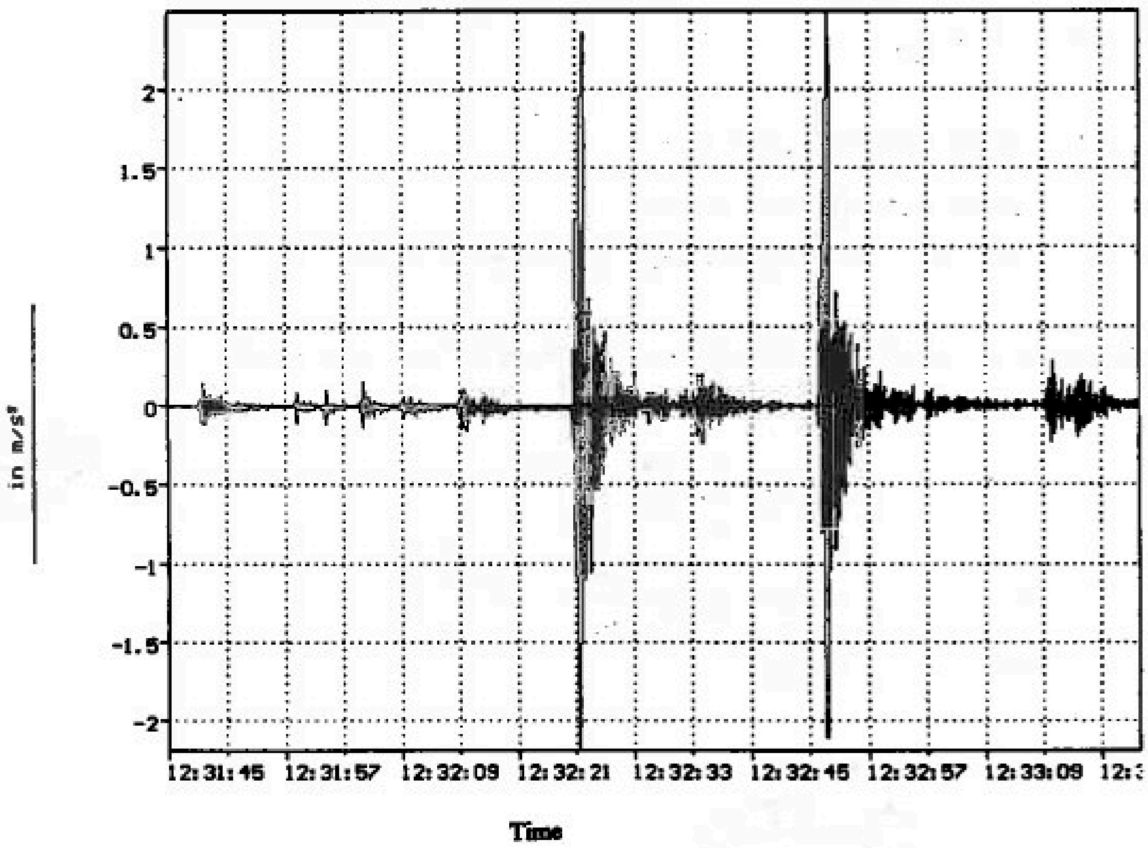

Figure 5. Acceleration-time graph at the top of the tower as a result of a jerky stimulation

The performed calculations of the shell bearing strength with the determined structure loadings resulted in an unsufficient stability of the intermediate stage.

A sufficient stability of the superposition of dead weight and wind for the saddle-shaped hyperbolic paraboloid between the vertical slits could not be asserted. As well was the jerky stimulations during work in the slits seen as very critical. Therefore it was necessary to revise the demolition rough draft.

The number of vertical slits was reduced to four. With the help of a round, undistroyed area of 4 meters width, which is in a height of 30 meters, the stability of the plate-elements was raised. Beside this two diagonal slits, facing each other, were made. The slits had an angle of 45° upwards and one can see between the circulated lower ring and in a height of 25 meters.

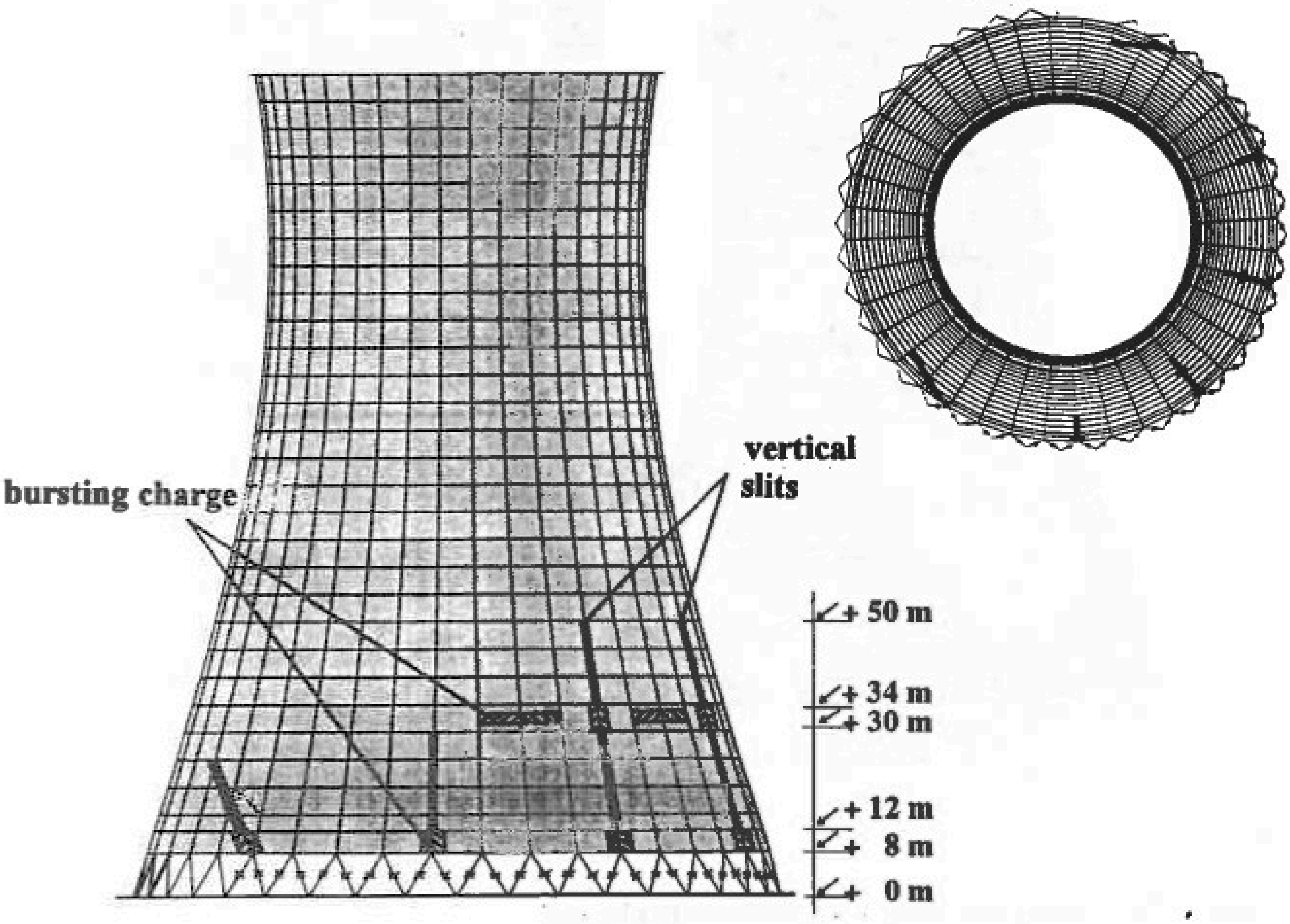

Figure 6. Arrangement of the slits for the blasting

To start the demolition process, the front half of the columns and also both circles in the area of the slits were to be blasted. By the impact of the slited shell into the cooling tower saucer energy should be inserted into the shell. This high energy input was to lead to a failure of the stability and consequently to a total falling-in of the whole cooling tower.

With the help of FE-calculations further stability calculations for the intermediate stage of the modified demolition rough draft were made.

As a consequence of the reduced effective length and the double width of the plate-elements a sufficient security was achieved.

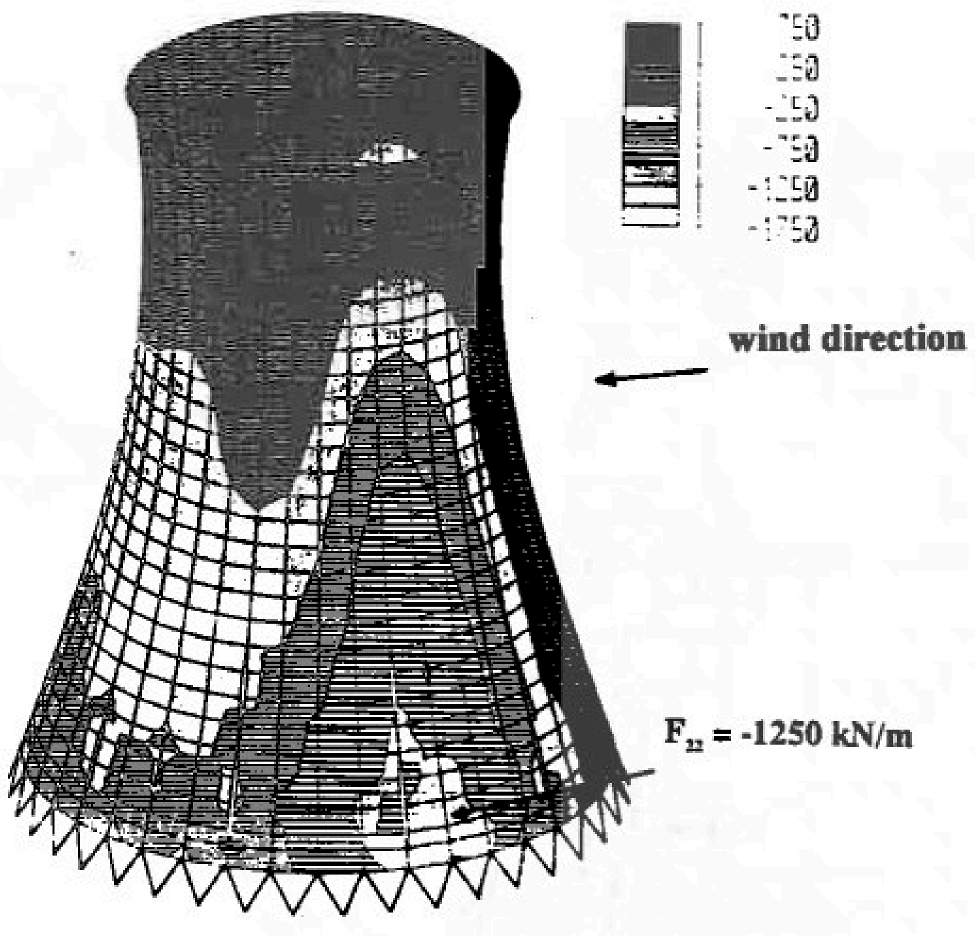

Figure 7a. Forces resulting from the FE-calculations

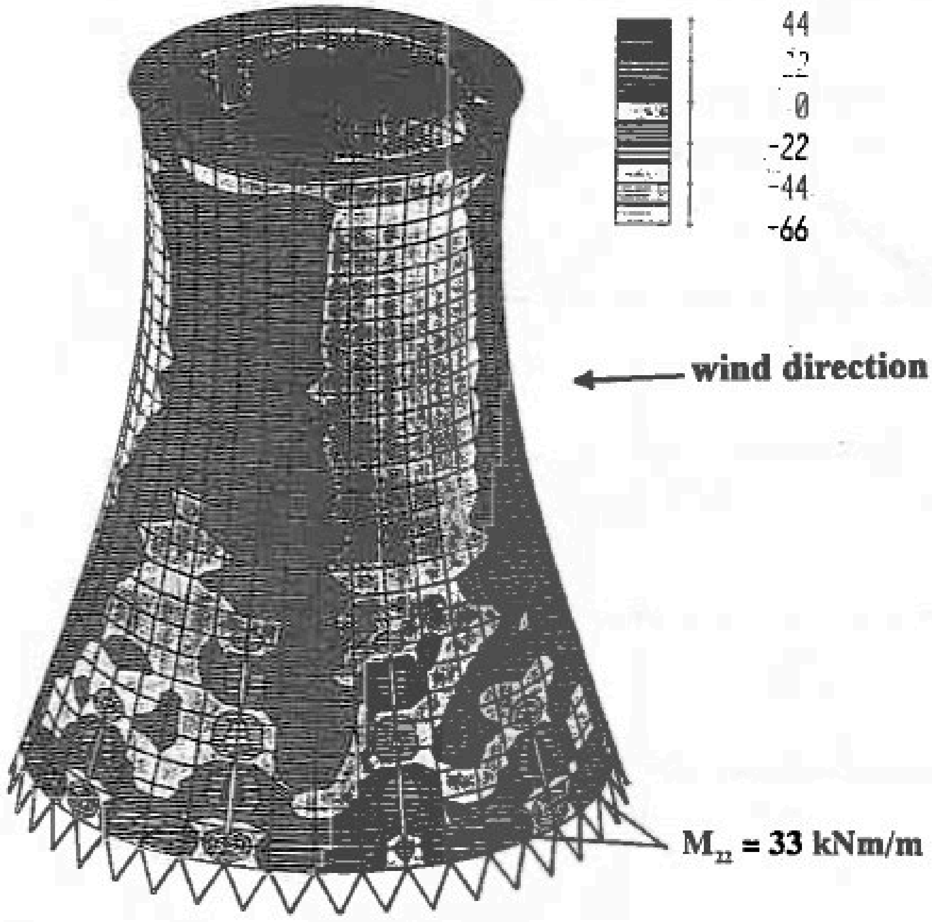

Figure 7b. Forces resulting from the FE-calculations

4. EFFECT OF GROUND MOTIONS ON THE NEIGHBOUR TOWERS

Because of the later usage in the planned coal-fired power plant both neighbour towers were not allowed to be damaged as a result of the blasting. Flying particles from the demolished tower were considered not to endanger the remaining two towers. However, the consequences of the collapsing tower, on the neighbour towers had to be discussed.

With the help of a loading function describing the caving of the elements of construction in a certain time and a measurement of the transfer function a participate geotechnical office

(Geotechnik und Dynamik Consult, Berlin) made out a design-spectrum for the expected foundation acceleration.

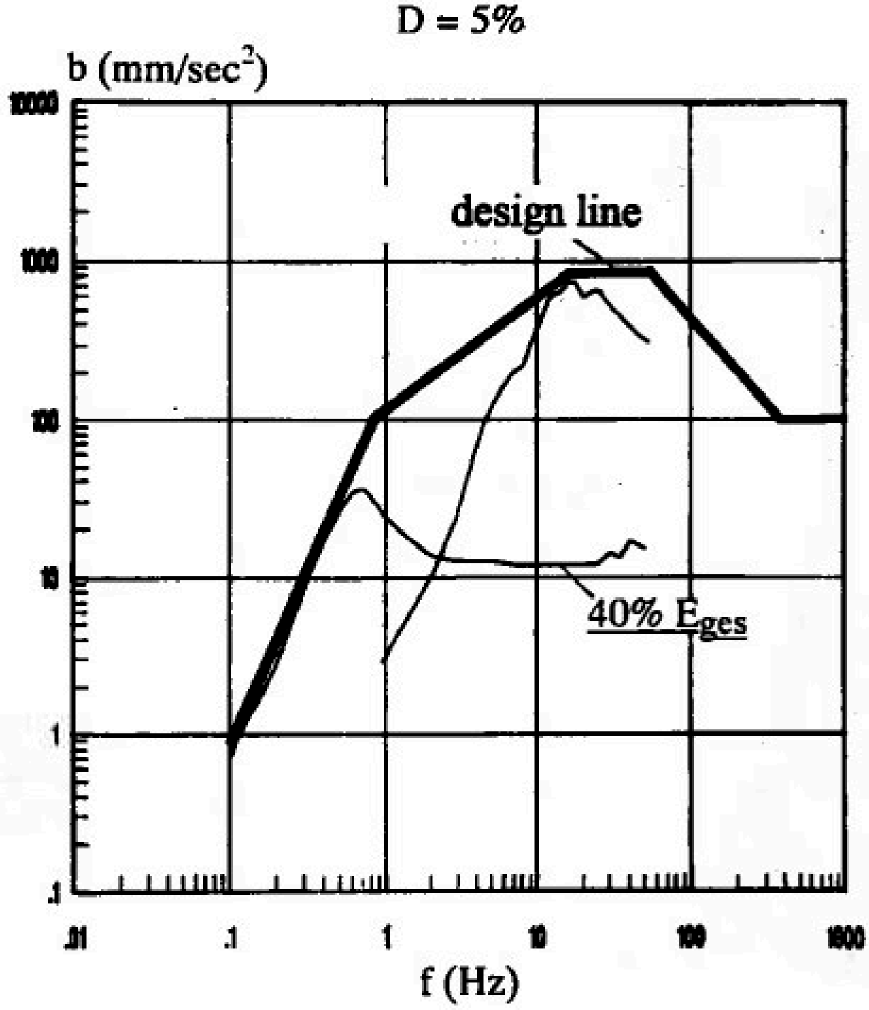

Figure 8. Acceleration spectrum

Based on this acceleration spectrum the Institut for Concrete Structures led through a dynamic calculation of the towers. The maximum calculated stresses did not impair their currency.

A recalculation of the given acceleration spectrum into a velocityspectrum made it possible to do a comparison with DIN 4150. The imposed ground motions did not cause structural damage. During the blasting the buildingvibrations were recorded and were discussed after that. The maximal measured tower accelerations were about 50 % higher than the calculated factors.

The higher resulting stresses are for this tower in an uncritical area, and the structure can be used in the future without problems.

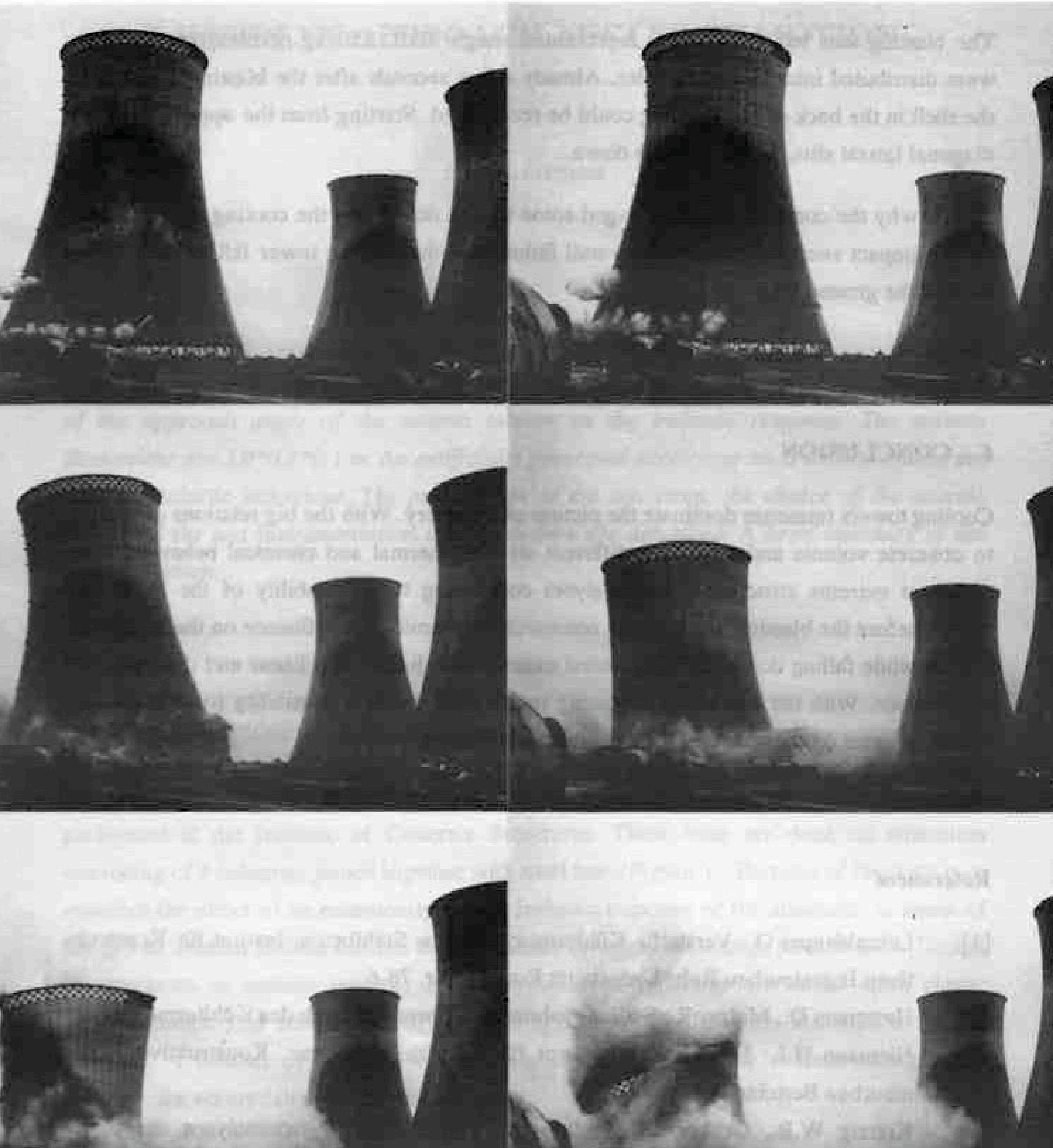

Figure 9. Blasting and process of falling

5. BLASTING AND PROCESS OF FALLING

The blasting was led through the represented rough draft. 250 kg of blasting explosives were distributed into 2500 drill holes. Already a few seconds after the blasting a failure of the shell in the back of the building could be recognized. Starting from the upper end of the diagonal lateral slits, the shell broke down.

That is why the complete building baged some meters down into the cooling tower saucer. By the impact energy it came to a overall failure and the cooling tower fell in itself in the field of the ground area.

6. CONCLUSION

Cooling towers immense dominate the picture of a scenery. With the big relations of surface to concrete volume and their very different statical, thermal and chemical behaviour they represent extreme structures. The analyses concerning to the stability of the weakened towers before the blasting and also the comments concerning the influence on the neighbour towers while falling down can be planned exactly with linear, non linear and dynamic FE-calculations. With the represented blasting rough draft exists a possibility to strip cooling towers of great dimensions and their neighbour buildings.

References

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