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HOW TO BLAST COOLING TOWERS

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ABSTRACT

In the present paper, all steps from the planning to the execution of a cooling tower blasting are explained. While blasting, emissions, such as noise, dust, vibrations and fly of debris, are unavoidable. They need to be identified and assessed during the planning process. Through accurate predictions, precise planning and careful implementation of protective measures, emissions can be quantified and their impact minimised so that blasting can be carried out successfully. The main goal of this controlled demolition is the collapse of the cooling tower. Afterwards, the debris can be removed with small excavators. The 59 cooling tower demolitions carried out so far in Germany show that blast demolition is a popular demolition option, especially for large cooling towers.

BACKGROUND AND HISTORY

56 cooling towers of conventional power plants and 3 cooling towers of nuclear power plants have been successfully demolished by blasting in Germany so far. Blast demolition is an economic dismantling procedure especially for high rised (e.g. chimney stacks, cooling towers) and massive (e.g. foundation plates) structures. Compared to mechanical demolition, blasting leads to significantly shorter demolition times and reduce dust, noise and vibration emission.

The first blasting concepts for cooling towers in Germany were developed in the 1980s, as it is described in Lippok (2006). The 150 m high cooling tower of the nuclear power plant Stendal (Germany), which never went into service, was the highest cooling tower in reinforced concrete construction in Europe at the time, which was demolished by explosives, see Melzer (1996). The 180 m high cooling tower in Hamm-Uentrop (Germany) that was blown up in 1991 had a completely different construction principle and is not comparable to the reinforced concrete natural draft cooling towers considered in this paper.

BLAST AND COLLAPS STRATEGY

In comparison to chimneys, which can be tilted or folded by several blast planes, cooling towers collapse at an early stage due to the thin cooling tower shell.

In the 1990s, Melzer developed a method for blasting cooling towers in Germany, which provides for the cooling tower to tilt in one direction. This blasting strategy, described by Melzer (1996), has been continuously improved in the last 30 years. To achieve this, 50 % of the columns and some sections in the lower edge of the shell are blown up. The diagonal drop slits on both sides have the task of shifting the tilting axis to a higher level (top of drop slit) in order to increase the height of fall during the vertical collapse and thus increase the destruction of the cooling tower shell.

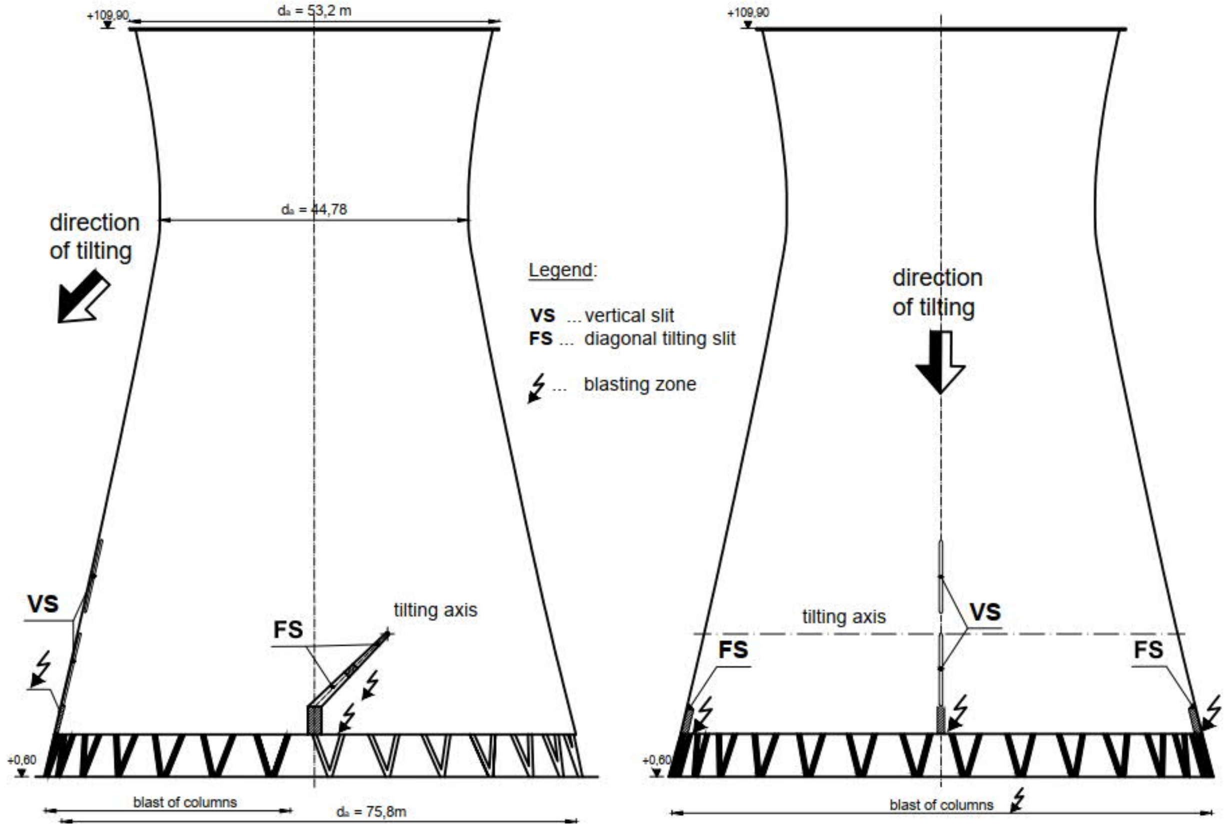

Figure 1: Blasting strategy for blasting a cooling tower with one vertical slit

Depending on the cooling tower geometry and the shell thickness as well as various conditions, further pre-weakening of the cooling tower shell is required. These are usually vertical slits of different heights above the columns that will be blasted.

In the beginning, the pre-weakening (slits in the cooling tower shell) were often made by wrecking balls. Later, excavator with chisel, shears and tongs replaced the wrecking balls. The most precise way to make the openings is by concrete saw cuts. This method was used in the last cooling tower blasting carried out in Germany.

Melzer (1996) and Melzer et al. (1998) have already carried out simplified simulations of the collapse behavior. Through current finite element simulations, the material behavior and the collapse can be predicted much more accurately. After 50 % of the supports and the shell areas have been blown up, the cooling tower tilts about its tilting axis, at the upper end of the diagonal slits. Between these two points, a horizontal circumferential crack develops in the shell, which, once fully formed, leads to the vertical collapse of the cooling tower shell (see figure 3). Figure 2 shows the cracking of the shell in detail determined by non-linear time history calculations.

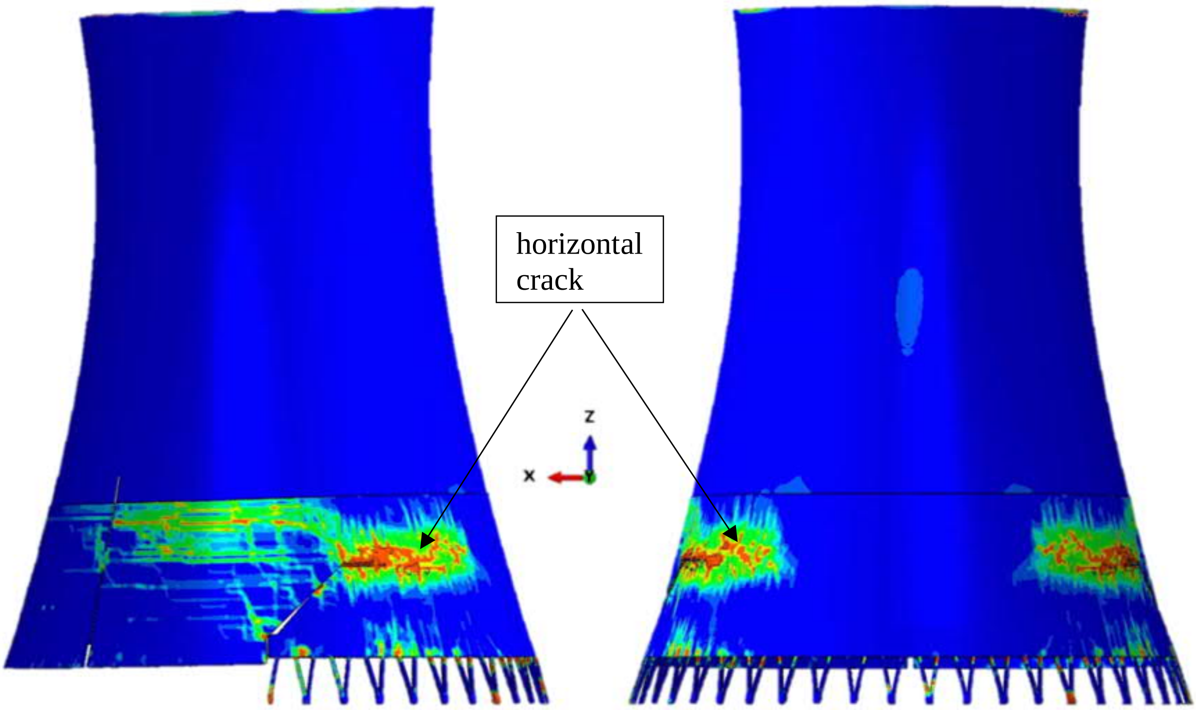

Figure 2: Numerical simulation of a cooling tower blast

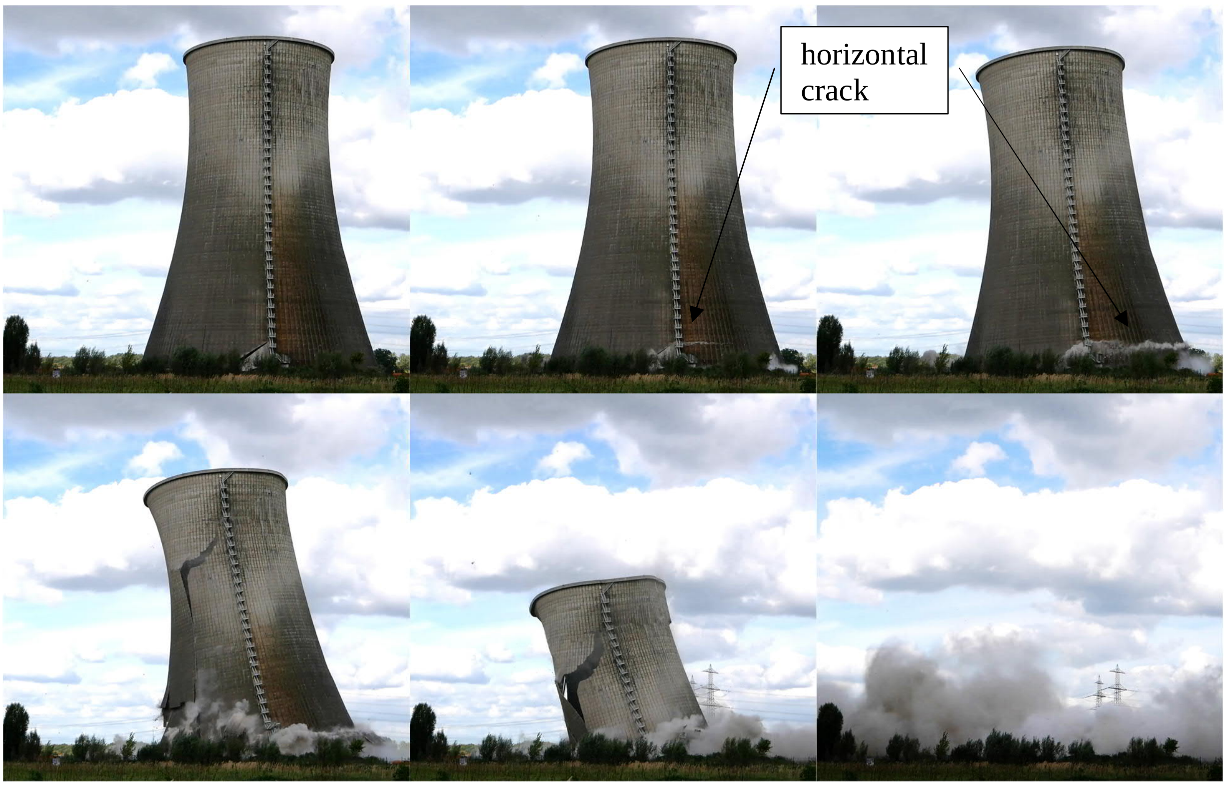

Figure 3: Collapse of the cooling tower at the power station Hamm (Germany) due to blasting

EMISSIONS CAUSED OF BLASTING

Before any building is blasted, its impact on the environment must be determined and evaluated. All objects to be protected (neighboring structures, pipelines, underground objects, plant parts, components, etc.) are taken into account. Emissions resulting from blasting are fly of debris, sound pressure, dust, vibrations and impact. These points are discussed below.

Fly of debris

Both the detonation and the impact can cause fly of debris. The flight distance due to detonation can be reduced by covering the blast zone. A reduction of the charge quantity can also lead to smaller flight distances - however, it must always be ensured that the component (column or shell section) is safely destroyed. Fly of debris as a result of blasting can also be stopped by protective barriers; this is particularly useful in the case of fly of debris as a result of impact.

Figure 4: Covering the blasting zones of the columns of the cooling tower at the power plant Luenen (Germany)

Sound pressure

The sound pressure during concrete blasting with borehole charges is usually negligible, because the blasting pressure is generated in the borehole. In the case of open lying charge (e.g. in the case of steel blasting), the sound pressure must be considered. The propagation of the detonation front can also be predicted using simulations.

Dust

Among various methods, blasting the water-filled cooling tower cup has established itself as the most effective dust-binding measure. Due to the detonation pressure, a waterfront is shot upwards. This water mist partially binds the dust produced because of the crushing of the concrete. However, dust formation is not avoidable. The blasting of the water-filled cooling tower cup was first carried out at the power plant Luenen, see Rapps and Schewcos (2021).

Figure 5: Collapse of the cooling tower at the power plant Luenen (Germany) (source: Fa. Hagedorn)

Vibrations

Due to vibration measurements during numerous cooling tower blastings in the past, a lot of knowledge has already been gained about the origin and propagation of vibrations.

Usually, the vibrations are predicted based on these measured values. Newer methods using simulation can make the prognosis more precise and are increasingly used in the nuclear environment. In the conventional environment, DIN 4150 Part 3 is used for the evaluation of blast and impact vibrations on structures. In the nuclear environment, the absence of damage can be assessed, for example, by comparison with the design earthquakes. When the water-filled cup will be blast, an additional prognosis of the vibration caused by the explosion will be necessary. Otherwise, a prognosis of the vibration caused by the impact of the debris will be sufficient.

Impact

As in the case of fly of debris, sometimes impact protection measures are necessary. These are e.g. covering sensitive surfaces with earth or construction of protective structures.

REQUIREMENTS TO THE PRE-WEAKENINGS OF THE COOLING TOWER

In the case of rotationally symmetrical cooling towers, any fall direction is generally possible. Therefore, the direction of fall is often determined by the neighborhood and defined by the arrangement of the blast zones and the pre- weakening (slits). There are two requirements for the pre-weakening: The Safety of stability and the safety of collapse.

Safety of stability

The pre-weakening is carried out in such a way that the stability of the weakened cooling tower is ensured until the time of blasting. Often reduced wind loads can be applied for this - very time-limited - dismantling condition. If this is the case, the wind speed on site must be constantly monitored in order to clear the site if the permitted wind speed will be exceeded. The discontinuity (bridges) in the diagonal slits, shown in Figure 1, which are blasted together with the columns, were necessary for stability.

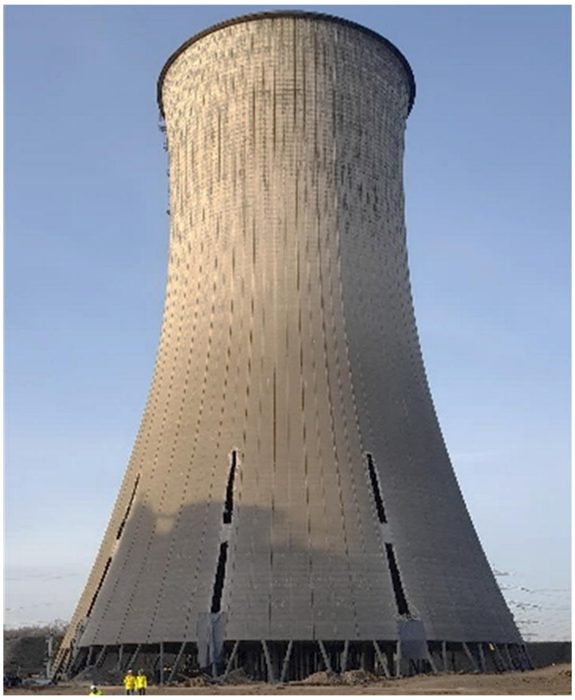

Figure 6: Pre-weakened cooling tower with three vertical slits at Knepper power station (Germany)

Safety of collapse

As already mentioned in the description of the collapse process, the pre-weakenings must be matched to the cooling tower geometry. The number and geometry of the slits depends on the shell thickness, the cooling tower height and the drop height of the debris. In order to create a balance between the safety of stability and collapse, several iterations are often necessary.

BLASTING TECHNOLOGY

Only concrete blastings are required to bring down the cooling tower. For this purpose, boreholes are made in the columns to be blasted as well as in the shell. Due to the small shell thickness, the borehole grid in the shell becomes very small and the preparation effort larger. The aim of the design is therefore to minimise the blast sections in the cooling tower shell as far as possible. Gelatinous patronised explosives or detonating cords are usually used in the boreholes. Electronic detonators have proven to be the safest means of detonation, as their functionality can be tested until shortly before detonation. The explosives are isolated by means of construction foam.

SUMMARY

The last 59 blastings of cooling towers in Germany show that this demolition method is a safe and economic method of demolition and can be implemented in accordance with the current state of the art and the relevant regulations. The cooling tower demolitions carried out in 2019 on a nuclear power plant site confirm that the demolition method commonly used in the conventional environment - demolition by blasting - can also be implemented safely in the nuclear environment. To transfer the blasting methodology into the nuclear sector, all these steps need to be carried out at highest reliability level.

Figure 7: Cooling tower in Knepper (Germany) power station after the blasting

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