Technical and safety aspects at the demolition by blasting works of a cooling tower with a high of 72.00 m

Robert Laszlo[1*], *Cristian* Radeanu[1], *Stefan* Ilici[1], *Mircea* Grecea[1], and *Miklos* Levente[2]

[1]National Institute for Research and Development in Mine Safety and Protection to Explosion – INSEMEX Petroşani Department of Safety Explosives and Pyrotechnic Articles, 32-34 G-ral Vasile Milea St., 332047 - Petroşani, Hunedoara County, Romania
[2]Industrial Demolition Company, 107A, Strada Mare Street, Dîmbău, Romania

Abstract. From the point of view of demolition, one of the most interesting construction categories is the hyperboloid shape cooling towers. These seemingly fragile structures support at the base on a reinforced concrete belt and pillars. An important element to be taken into account when choosing the demolition solution is the slope of the tower. As this ratio between tower height and base diameter is greater (4-5), the easier is the demolition of the tower by overturning, respectively by moving the centre of gravity of the construction away from its base. In the case of the cooling tower described in this article, its height was 72.00 m and the base diameter of 52.00 m - the slope ratio index being less than 2, which was why the chosen solution of demolition was that of partial lateral collapse followed by a total crash of the tower on its position. The article describes how to perform the demolition of the cooling tower, the technical and safety solutions adopted for its successful collapse in the intended direction, in very sensitive location conditions regarding the constructions and installations in its immediate vicinity.

1 Introduction

At the present stage of greening of the old productive units, the demolition process using blasting works have an increasing application due to the reduced time consumption, labour and expenses. A large number of demolition works by using explosives are characterized by a high degree of difficulty, have shown that the use of the blasting technique is a proper alternative from the point of view of efficiency and security.

The basic idea when performing a building demolition is that the destructive effect on the neighbouring objectives to be protected has to be negligible, the number of elements destroying by blast has to be as small as possible, as well as like the explosive quantities that are blast at once. One of the interesting construction categories, from the point of view of demolition, is the hyperboloid - shaped cooling towers. The towers are constructed of a freely supported structure of reinforced concrete of hyperboloid shape. This apparently

*Corresponding author: robert.laszlo@insemex.ro

fragile structure is rest on the base support consisting of a reinforced concrete ring belt and pillars. If a comparison is made on a scale between the thickness of the tower shell and that of an egg's shell, then the egg shell should have a thickness of only 0.10 mm. From this perspective, the cooling towers possess a "shell" much thinner than that of an egg. Such constructions take very well the external - induced shocks, their own weight and those of the temperature variations. A higher unilateral stress may, however, be fatal to the stability and integrity of such a construction [1]. The article describes how to perform the demolition of the cooling tower, the technical and safety solutions adopted for its successful collapse in the intended direction, in very sensitive location conditions regarding the constructions and installations in its immediate neighbouring.

2 Cooling tower construction description

The cooling tower was located inside a large Romanian oil refinery, being in the form of a rotating hyperboloid made of reinforced concrete, by sliding with variable section.

The location of the cooling tower on the refinery platform is shown in Fig.1.The cooling tower had a height of 72.00 m, with a basic diameter of 52.00 m, respectively 33.00 m at the crown. The role of such towers is the recirculation and cooling of industrial water which is then used to cool the installations from the platform. In the immediate vicinity of the cooling tower that is being demolished, there are the following objectives (Fig. 2):

- to the north, at 35.0 m, gas and steam pipes;
- to the east, at 54.0 m, cooling tower no. 4;
- to the south-east, at 21.0 m, power station 6 kva;
- to the south, at 19.0 m, power cables.

Fig. 1. Cooling tower site location - .

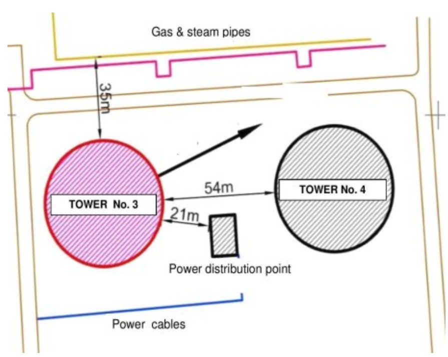


Fig. 2. Location of neighbouring objectives.

The structure of the tower consists of the following component elements (Fig. 3 and Fig. 4):

- inclined pillars supporting the tower body;
- vertical pillars supporting the console of the outer ramp;
- the circular belt located at the top of the inclined pillars;
- rotary blinds, in the access area at the bottom of the tower;
- the tower body itself, in the form of a hyperboloid;
- coronation (ring belt) at the top of tower;
- central water distribution room located at the base, inside the tower;
- structure of the cooling and distribution system located at the base, inside the tower.

The **inclined pillars** of the tower are prefabricated of reinforced concrete with octagonal section, having the main dimensions of 0.45 x 0.40 m. The tower rests on 36 pairs of "Λ" shape of inclined pillars, with a height of 4.45 m.

Fig. 3. Cooling tower body.

Fig. 4. Cooling tower at the base side.

The **vertical pillars** supporting the console - the outer ramp, are rectangular in shape, with dimensions of 0.40 x 0.18 m and a height of 4.0 m. The **ring belt** is the main element of resistance and support of the tower. The belt has a height of 1.40 m and a variable thickness with an average of 0.55 m. The **tower body** is the second element of resistance of the construction. The hyperbolic tower body has a variable thickness on height, ranging from 0.47 m starting from the level + 7 m and 0.14 m up to the level + 28 m, from where the thickness of the body remains constant at 0.12 - 0.10 m, up under the belt from the topside of tower.

3 Cooling tower blast demolition

3.1 Considerations on demolition by blasting works

The basic idea of a demolition is that the destructive effect on the neighbouring buildings needed to be protected is negligible, the number of the elements that are destroyed by the blast must be as small as the explosive quantities that are blasted at once. Each construction creates a special case, separately, the calculation of the blasting parameters adapting according to each situation.

The explosive load required for the dismantling of a certain constructive part, is dependent on the type of explosive used, the material being shot, the type of construction being demolished and the geometry of the location of the blasting holes. The choice of a demolishing method by blasting variants is conditioned by the physical state of the construction, by the existence of objectives in the vicinity of the demolition construction, by the possible effects of the demolition on these objectives [2].

The demolition process chosen must meet the following requirements:

- directing the fall to protect the nearby active constructions and maintain the production/activity process;
- protecting buildings near the target, against seismic action, shock wave, and throwing concrete or metal pieces under the effect of the explosion;
- destroying the integrity of the construction, so that the dismantled elements can be transportable or loaded with mechanical means.

3.2 The cooling tower demolition process

One of the interesting categories of construction, from the point of view of demolition, is the cooling towers of hyperboloid form. An important element to be taken into account when choosing a demolition solution is the slenderness of the cooling tower. In this context, the slenderness is the ratio between the height of the tower and its diameter at the base. As this ratio is greater (4-5), the easier is the demolition of the object by overturning or by moving the centre of gravity of the building outside from the plan of its base.

In the case of the cooling tower described in this article, the slenderness index is less than 2, which is why a combined demolition variant was chosen - the partial lateral collapse followed by a total crash of the tower on its plan position.

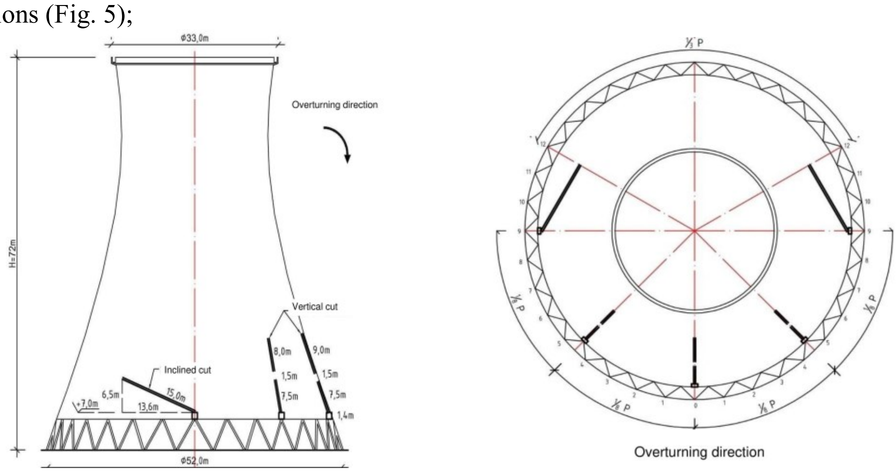
This has been done by blasting at least half of the support legs (pillars) and parts of the ring belt in a selected direction, followed by a crash on the tower itself, facilitated by the pre-created cuts in the tower jacket.

The un-blasted support pillars, opposite the tipping direction, functioned as a "hinge", allowing the creation of a striking energy by collapsing the other half of the tower. This striking energy was indispensable to induce a dynamic tension in the hyperboloid of the tower and to make it slip along the cuts previously created in its body.

4 Preparatory stages for demolition of tower structures

In order to demolish the cooling tower, the following phases have been completed [3, 4]:

- decommissioning and sectioning of the elements of the cooling and distribution system inside the tower (beams and pillars supporting cooling system, water collection system resulting from condensation) and of the connections between them and the ring belt of the tower body on at least 1/3 of the surface from the overturning direction;
- creation of a discontinuous vertical cut in the position of overturning axis and above the ring belt (level +7.0 m). The cut with the width of approx. 0.30 m will have a first section of 7.5 m long (between level +7.0 m and +14.5) and a second section of 9.0 m long (between level + 16.0 m and + 25.0 m) with a discontinuity of 1.5 m between the two sections (Fig. 5);



side view top view

Fig. 5. Location of the cuts on tower body.

- creation of 2 vertical discontinuous cuts, above the ring belt (level +7.0 m) and placed on both sides, at 1/8 of the perimeter with respect to the overturning axis. The cuts with the width of approx. 0.30 m will have a first section of 7.5 m long (between level +7.0 m and +14.5 m) and a second section of 8.0 m long (between level +16.0 m and +24.0 m) with a discontinuity of 1.5 m between the two sections (Fig. 5);
- creation of 2 inclined continuous cuts and towards the tower back side, starting above the ring belt (level +7,0 m) and placed on both sides, at ¼ of the perimeter with respect to the overturning axis. The cut with a width of 0.30 m and a length of 15.0 m between the

height of +7.0 m and +13.5 m has a horizontal projection length of 13.60 m and a vertical projection of 6.5 m (Fig. 5);

- creation of breaking sections by blasting works, in the inclined supporting pillars from the half of the perimeter placed in the direction of tower overturning, respectively 19 pairs of inclined pillars;
- in order to make the breaking sections, 5 holes are drilled in each pillar, starting from +2.0 m distance above the ground level (Fig. 6);
- creation of breaking sections by blasting works, in the ring belt next to the each cut need to be executed in the tower body. To create these breakings, in each section were drilled 18 holes placed on 5 rows (Fig.7).

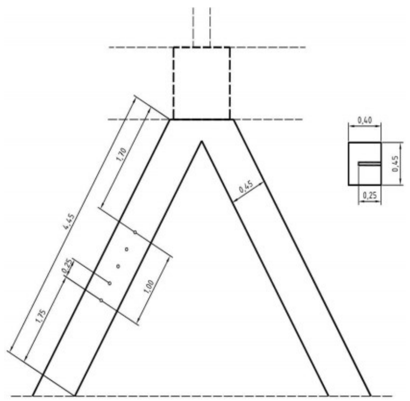


Fig. 6. Blasting holes position on inclined pillars.

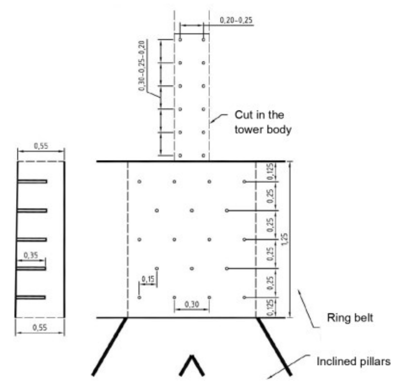


Fig. 7. Blasting holes position on ring belt and cuts.

5 Blasting parameters. Type of explosive and mode of initiation.

The explosive charges were dimensioned according to the section of the construction elements to be blasted [5].

For the 19 inclined pillars pairs of reinforced concrete, with section 0.45 x 0.40 m, are the following drilling & blasting parameters (Fig. 6):

- hole length, l_H = 0.20 - 0.25 m;
- explosive charge per hole, Q_H = 0.05 kg;
- total number of holes, N_{TH} = 5 holes x 38 pillars = 190;
- total explosive charge, Q_T = 9,5 kg and 230 lm of detonating cord (≈ 3 lm/pillar).

For the breaking sections in the ring belt, are the following drilling & blasting parameters (Fig. 7):

- hole length, l_H = 0.30 – 0.35 m;
- explosive charge per hole, Q_H = 0.075 kg;
- total number of holes, N_{TH} = 5 sections x 18 holes = 90;
- total explosive charge, Q_T = 6,5 kg and 50 lm of detonating cord (≈ 10 lm/section).

For the creation of vertical and inclined cuts on the tower body, are the following drilling & blasting parameters (Fig. 7):

a) vertical cut in the position of overturning axis:

- number of horizontal rows, N_R = 80;
- total number of holes per cut, N_H = 160 holes;
- total explosive charge, Q_T =7,8 kg and 90 lm of detonating cord.

b) vertical cuts placed at both sides at 1/8 of the tower perimeter:

- number of horizontal rows, N_R = 2 x 74 = 148;

- total number of holes per cuts, N_H = 2 x 148 = 296 holes;
- total explosive charge, Q_T = 2 x 7,5 kg = 15 kg. and 2 x 84 lm = 196 lm of detonating cord.

c) inclined cuts placed on both sides, at ¼ of the tower perimeter:

- number of horizontal rows, N_R = 2 x 26 = 52;
- total number of holes per cuts, N_H = 2 x 52 = 104 holes;
-total explosive charge, Q_T = 2 x 3,6 kg = 7,2 kg. and 2 x 30 lm = 60 lm of detonating cord.

Dynamite type explosive loads were placed in holes drilled in supporting pillars, ring belt and cuts on the tower body. The explosive charges were connected with detonating cord and initiated with non-electric detonators and connectors. The order of detonation of explosive loads it is presented in the Fig. 8.

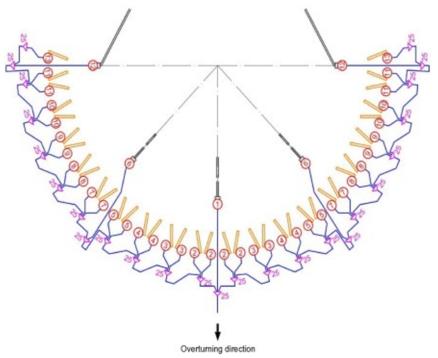


Fig. 8. Initiation network and the delay order.

Fig. 9. External protection against throwing effect.

The total amount of explosive used to demolish the cooling tower is as follows:

- Q_{Te} = 43.00 kg dynamite;
- Q_{Tdc} = 500.00 lm detonating cord;
- N_d = 45 pcs of nonelectric detonators;
- N_c = 25 pcs of nonelectric connectors,(25 ms delays).

6 Evaluation of the risks generated by the demolition works

The ***throwing of small material under the effect of the explosion***, is diminished by the installation of local means of protection made of rubber band, wire net, as well as by mounting an external protection around the construction, from materials such as textile cloth, at the level of openings where explosive charges are located. (Fig.9).

The ***seismic effect due to the detonation of the explosive charges*** at the demolition works of the cooling tower is negligible due to the distribution of the total load on a number of small loads (0.050 - 0175 kg dynamite / hole) placed in the structure in areas above the ground and initiated on groups with delay of the order of tens of milliseconds.

Seismic effect on the impact of falling on the ground of the structure that is being demolished [5,6], can result seismic effects whose size depends on the energy released to impact. This energy depends on the mass of the structure being demolished, the height of its centre of gravity and the strength of the land it falls on. Considering the constructive type of the cooling tower and the mechanism of its collapse, the impact with the soil generates low values of the seismic waves. For the objectives closest to the cooling towers, respectively the power station and the cooling tower 4, the value of the propagation velocity of the seismic waves, possible to be generated when the cooling tower collapses, is estimated to be lower than the one which can be considered admissible, of 2.10 cm/s.

The ***overpressure of the shock wave*** also has very low values, due to the distribution of the total explosive loads over a large number of holes with small loads, having an estimated value of 0.0293 kgf / cm^2. This value is not dangerous for the buildings and human bean safety.

7 Conclusions

At the present stage of greening of the old productive units, the demolition process using blasting works have an increasing application due to the reduced time consumption, labour and expenses. A large number of demolition works by using explosives and characterized by a high degree of difficulty, have shown that the use of the blasting technique is a proper alternative from the point of view of efficiency, quality and security.

Each construction creates a special case, the calculation of the blasting parameters are adapted according to each specific situation. Blasting parameters and explosive charges are dimensioned according to the type of material and section of the construction elements to be blasted. The most commonly used method of demolition is the collapse of the construction itself or its overturning in a given direction. For this purpose, numerous works of structural preparation, removal or reduction of the section of constructive elements are made beforehand. All this approaches are described in this article. Based on the blasting concept and risk assessment needed to take in consideration, it is presented the practical way of realizing with success the demolition by blasting works (Fig.10 and Fig. 11) of a hyperboloid cooling tower located in the immediate vicinity of sensitive objectives.

Fig. 10. Tower after demolition - back view.

Fig. 11. Tower after demolition - lateral view.

References

1. R.Laszlo, C.Fisguss, *Technical project for demolition by blasting works combined with classical works of 2 cooling towers from the premises of Petrom Ploiesti* (Petrosani, Romania, 2008).
2. S.Tat, M.Zaporojan, C.Fisguss *Explosives and blasting techniques applied in industry* (Petrosani, Romania, 1985).
3. A.Kovacs, R.Laszlo, E.Gheorghiosu, S.Ilici, G.Vasilescu, *Proceedings of the 19th International Multidisciplinary Scientific Geoconference SGEM 2019* **19,** 487-492 (2019).
4. R.Laszlo, Z.Eckehardt, I.M.Ille, *Proceedings of the third EFEE World Conference on Explosives and Blasting* **1,** 145-147, (2005).
5. R.Laszlo, C.Fissgus *Technical documentation for demolition by blasting works combined with classical works of the cooling tower of Energoterm CET Resita* (Petroşani, Romania, 2016).
6. R.Laszlo, C.Fisguss, M.Galvitu, *Technical documentation for demolition by blasting works combined with classical works of furnace no.6 from the premises of Arcelor Mittal Galati* (Petroșani, Romania, 2014).