BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi” din Iaşi
Volumul 68 (72), Numărul 2, 2022
Secţia
CONSTRUCŢII DE MAŞINI
DOI:10.2478/bipcm-2022-0020

DESIGN AND EXECUTION OF DEMOLITION WORKS BY BLASTING OF INDUSTRIAL CONSTRUCTIONS – TECHNICAL AND SAFETY ASPECTS

BY

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Received: June 20, 2022
Accepted for publication: June 30, 2022

Abstract. The paper describes the practical way and security conditions of realizing the demolition of an industrial chimney located in an oil refinery platform, having in the immediate vicinity sensitive equipment and constructions. The chimney has a height of 150 m and consists of the outer tubular structure of reinforced concrete and an inner chimney made of refractory brick masonry. In order to establish the possible secondary effects generated by the blasting works, a risk assessment was made with reference to seismic wave, air shock wave, noise, dust and the level of shock generated by the impact of chimney construction with the soil. The demolition work was carried out successfully and due to protection and safety measures no unwanted events were recorded, and the measured values of the seismic wave generated by the impact with the ground of the chimney were non-dangerous, being below the values estimated in the risk assessment.

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Keywords: blasting techniques, risk assessment, chimney overturn, explosives, demolition

1. Introduction

The restructuring of industrial activities has as a consequence the conservation or decommissioning of constructions or areas that can later be the object of the development of new projects. As a result, the blasting techniques today knows new fields of applicability, going beyond the sphere of the mining industry. Due to the diversity of the conditions in which it is executed, they often acquire the character of special blasting work. These blasting processes usually belong to the least polluting, economical and professionally interesting. Since there are no developed specific instructions for this type of work, the technical solutions must be chosen carefully, each application being a special case.

The effects of demolition works are a concern that is the basis for establishing the demolition solution. Numerous researches and works carried out worldwide (Zou *et al*., 2017) have shown how important it is to address and solve these aspects regarding the side effects of the execution of a demolition work with the help of blasting works (Wang *et al*., 2020).

The paper describes the practical way for the demolition of an industrial chimney located in an oil refinery platform, having in the surrounding area very sensitive constructions and installations. The aim for cleaning the area it is the construction of a new cogeneration plant for providing the oil refinery with electricity and technological steam.

In order to establish the possible secondary effects generated by the execution of the chimney demolition by blasting works, a risk assessment was made with reference to seismic wave, air shock wave, noise, dust and the level of shock generated by the impact chimney construction with the soil (Kovacs *et al*., 2019). The demolition work was carried out successfully and due to protection and safety measures no unwanted events were recorded, and the measured values of the seismic wave generated by the impact with the ground of the chimney were non-dangerous, being below the values estimated in the risk assessment.

2. Industrial chimney construction description

The industrial chimney was located inside a large Romanian oil refinery as is shown in Fig. 1 and served a thermoelectric plant in order to provide water for thermal heating and domestic hot water for the inhabitants of the city.

In the immediate vicinity of the chimney that is being demolished, there are a large number of objectives and pipeline networks, the most sensitive and important of which are (Fig. 2):

- to the north-west, at 120 m, 6 KV power station;
- to the west, at 200 m, cooling tower;

- to the south-west, at 70 m, trestle with pipes;
- to south-west, at 120 m, chemical station;
- to south-east, at 40 m, boiler building;
- to the south-east, at 90 m, trestle with pipes;
- to east, at 72 m, gas and boiler operation building;
- to north-east, at 135 m, fuel depot.

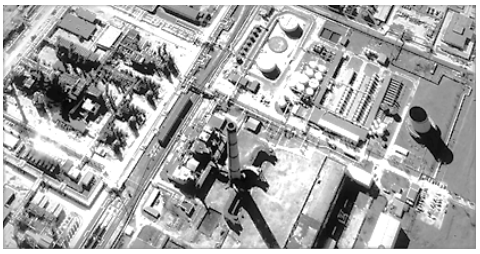


Fig. 1 – Oil refinery platform.



Fig. 2 – Chimney neighbouring objectives.

The chimney has a height of 150 m and consists of the outer tubular structure of reinforced concrete, having a radius from the bottom side (level + 16 m) of 6.85 m, respectively 5.43 m at the top side (level +150 m), as well as from the inner chimney made of refractory brick masonry with a radius of 4.65 m. The thickness of the reinforced concrete wall is variable, from 62 cm in the lower area to 21 cm at the top, and the wall thickness of the brick chimney is constant, 20 cm.

The foundation of the concrete chimney is of reinforced concrete screed type (Fig. 3) with a diameter of 31.50 m and a thickness of 1.80 m, which rests at the lower level of - 4.40 m on 45 reinforced concrete piles with a diameter of 1500 mm, which have a length of approx. 36 m and is embedded in the layer of sand, limestone and sandstone. The walls of the chimney made of brick masonry are supported on a foundation with its own structure of reinforced concrete pillars of 50 x 50 cm up to a height of +14.50 and on consoles formed by the sliding wall and ring beams in the form of a wheel with spokes at each 8.00 m between elevations +14.50 and +150.00 m. Between the reinforced concrete wall and the brick chimney wall, there is a free space used for the internal control of the

structure and which in the area of elevation 16 - 25 m is about 1.6 m (Fig. 3). Related constructions - flue gas ducts, are made of solid brick masonry and reinforced concrete and are developed up to elevation + 17.5 m (Fig. 4).



Fig. 3 – Free space between chimney walls.



Fig. 4 – Chimney foundation.

3. Chimney blast demolition

3.1. Considerations on demolition by blasting works

Carrying out a large number of demolitions works with the help of explosives, characterized by a high degree of difficulty, showed that the use of the blasting technique is a safe alternative and often the most appropriate in terms of efficiency and safety. Compared to conventional demolition procedures, the use of blasting works offers the following advantages in terms of hazards, environmental protection and work:

- blocking for a short period of time some neighbouring parts and traffic areas - periods of time limited only to the duration of the actual execution of the blasting works - compared to the usually long restrictions on the use of these spaces and areas, to demolition by conventional means;
- rapid removal of the state of danger, especially where buildings are in an advanced stage of deterioration;
- avoiding working at height for long periods of time;
- avoiding for a long time the presence of dust, noise, vibrations, etc.

Demolition of tall buildings is done by two methods used:

- sequential demolition;
- demolition by collapse of the building.

The sequential demolition process consists in dismantling the construction into sequences (parts), from top to bottom, in the reverse order in which it was built. The displacement of the constructive elements in the established sections is done with the help of the energy of the explosives. The sequential demolition procedure is adopted in the case of buildings located in densely built and populated areas, where the neighbouring buildings to be protected are of great importance and are located very close to the building to be demolished.

The overturning demolition (collapse) procedure is adopted in the case of tall buildings where the access of demolition equipment to the upper floors is expensive and difficult to achieve, the impact with the ground of the collapsed building does not generate effects that exceed the protection requirements of neighbouring buildings and there is space (platform) in the direction of fall (Laszlo *et al*., 2020). Adopting this procedure using the explosive energy greatly shortens the demolition time, reduces the cost of work compared to the volume of demolished material given the fact that the collapse is "helped" by the gravitational force of the mass of the resistance structure.

The above considerations require that in the demolition design phase a thorough analysis of the structure resistance be made regarding the level of strength, stability, the existence of weaknesses that can be transformed by explosion into failure mechanisms, the existence of elements that can hinder or stop collapse, distribution of construction mass and position of center of gravity of this mass, determination of direction of collapse, etc. At the same time, the magnitude of the side effects from the crash and the explosions must be calculated.

3.2. The demolition process

The complete tubular development of the chimney (without the existence of technological gaps such as the chimney flues) is made above the screed, starting from the elevation +17.5 m. Above elevation +14.5 m, at intervals of 8.00 m, between the sliding wall and the brick masonry wall, there are consoles formed by annular beams in the shape of a wheel with spokes. Over these reinforced concrete brackets and spokes are placed nets to facilitate staff access to inspect the condition of the chimney construction. The access to these platforms is made by a metal staircase arranged inside, in the free space of 1.6 - 1.0 m. When demolishing the chimney, the overturning procedure will be applied in a given direction. The existence at the elevation +23.0 m of the first visit / work platform inside the chimney, determined the choice of the area from this elevation for the execution of the chimney overturning cut in the direction North, North - East (Fig. 5).



Fig. 5 – Turning direction and cut location.

This platform allowed the execution of preparatory works - drilling of mine holes in the body of the concrete and brick chimney, as well as those of loading with explosives and initiation means in conditions of increased safety (Fig. 6), compared to the alternative in which these works would have been executed outside the chimney from self-lifting platforms.

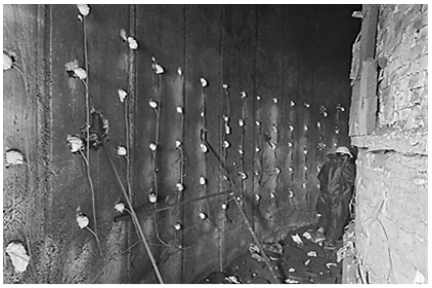


Fig. 6 – Cut preparation at level +23 m.

3.3. Preparatory stages for demolition of chimney structure

Given that in the immediate vicinity of the chimney, at a distance of 150 - 200 m in the direction North, North - East, there are no objectives to be protected, its demolition will be in this direction. In order to demolish the chimney structure, the following phases have been completed:

- creation by blasting works of two openings (windows) at the limits of the detachment cut, located at 2/3 of the inner perimeter, having a width of 1.2 m (corresponds to twice the thickness of the reinforced concrete wall) and a height of 1.2 m - corresponds to the height of the arrangement of four rows of holes along the length of 2/3 of the inner perimeter of the reinforced concrete chimney (Fig. 7). The realization of the two openings also served to establish the way in which the reinforced concrete structure behaves under the action of explosive loads (Laszlo and Fissgus, 2016);

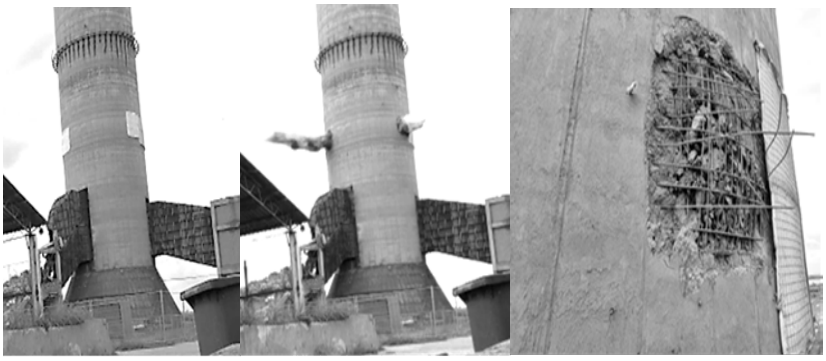


Fig. 7 – Realization of two windows at the limits of the detachment cut.

- realization of the detachment cut for which purpose will be drilled in the concrete wall, from inside the chimney, starting from the elevation +23.5 m, from bottom to top, 6 rows of holes placed in the square network (Figs. 6 and 8), as follows:

✓ row 1 of holes, starting from the elevation +23.5 m, on the opening of 1/4 of the inner perimeter of the reinforced concrete chimney (9.8 m), with a number of 23 holes. The holes will be arranged symmetrically on either side of the axis of the overturning direction;

✓ row 2 holes drilled above row 1 holes, on the opening of 1/2 of the inner perimeter of the reinforced concrete chimney (19.6 m), with a number of 45 holes. The holes will be arranged symmetrically on either side of the axis of the overturning direction;

✓ rows 3,4,5 and 6 holes drilled above row 2 holes, on the opening of 2/3 of the inner perimeter of the reinforced concrete chimney (26.2 m), with a number of 4 rows x 57 holes per row. The holes will be arranged symmetrically on either side of the axis of the overturning direction.

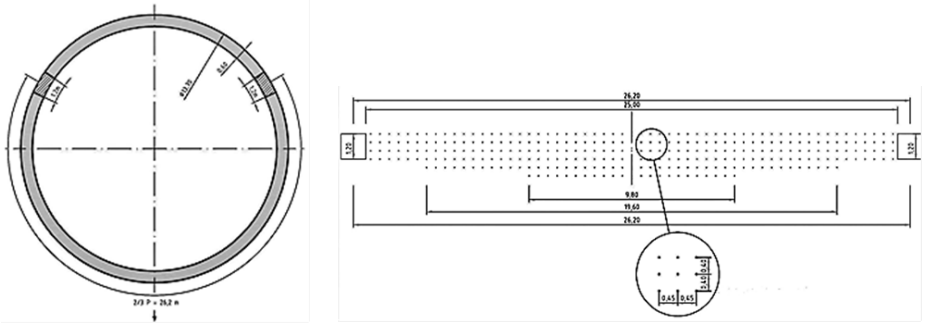


Fig. 8 – Realization of the detachment cut in the concrete wall.

- drilling two rows of holes in the wall of the brick chimney inside the concrete chimney, in order to make a section for loosening the brick masonry in the area of the detachment cut. For this purpose, at elevation + 25 m, two rows of 66 holes per row will be drilled on 2/3 of the perimeter of the brick chimney (19.47 m). The holes will be arranged symmetrically on either side of the axis of the overturning direction (Fig. 9);

- decommissioning in the area of the detachment cut of all additional elements such as metal stairs and lightning conductor.

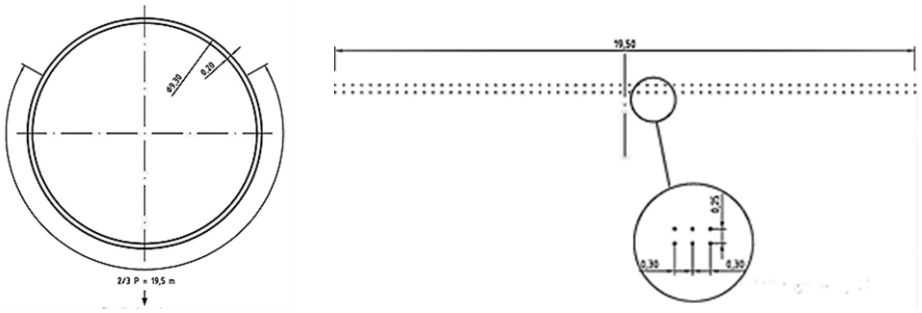


Fig. 9 – Section for loosening the brick masonry in the area of the detachment cut.

3.4. Blasting parameters

The blasting parameters, explosive types and quantities were taken in consideration in corelation with the type and the section of the construction structure to be demolish. For the removal of the detachment cut in the reinforced concrete chimney, the following drilling & blasting parameters (Tat *et al*., 1985) were used (Fig. 8):

- wall thickness, G p = 0.60 m;
- burden, W = 0.30 m;
- hole spacing, a = 0.45 m;
- row distance, b = 0.40 m;
- number of rows, Nr1 = 4 on 2/3 of perimeter x 56 holes/row; 1 on 1/2 of perimeter x 44 holes/row; 1 on 1/4 of perimeter x 24 holes/row;
- hole length, L h = 0.40 m;
- explosive charge per hole, Q h = 0.20 kg;
- total explosive charge, Q T = 60 kg.

To make a loosening zone in the brick masonry chimney, the following drilling & blasting parameters were used (Fig. 9):

- wall thickness, G p = 0.20 m;
- burden, W = 0.10 m;
- hole spacing, a = 0.30 m;
- row distance, b = 0.25 m;
- number of rows, Nr1 = 2 on 2/3 of perimeter x 66 holes/row;
- hole length, L h = 0.13 m;
- explosive charge per hole, Q h = 0.040 kg;
- total explosive charge, Q T = 6.0 kg.

In order to collapse the chimney construction in the expected direction, all the explosive charges from the concrete and brick chimneys are detonated instantly. Dynamite type explosive loads were placed in holes and the explosive charges in each hole were initiated with detonating cord. At the cut edge, the ends

of these secondary lines are connected to a detonating cord main line together with that one coming from brick chimney area. A non-electrical detonator was placed at the end of the detonating cord main line (Fig. 10).

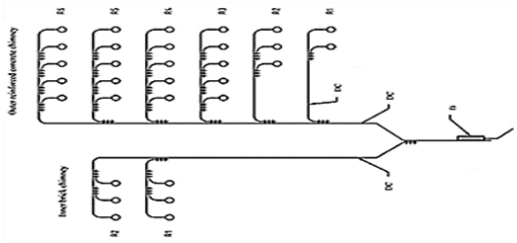


Fig. 10 – Initiation network.

The total amount of explosive used to demolish the chimney construction is as follows:

- total quantity of explosives, Q Te = 73 kg dynamite;
- total quantity of detonating cord, Q Tdc = 400 lm detonating cord;
- number of detonators, N d = 8 pcs of nonelectric detonators;
- number of connectors, N c = 10 pcs of nonelectric connectors/starters.

4. Risks evaluation

The success of the demolition by blasting works is also conditioned by the solution of the protection of the civil and industrial constructions against the action of the side effects of the explosions carried out during the demolition.

Blasting activities may include (Laszlo *et al*., 2014):

- seismic effects generated by the detonated explosive charge;
- seismic effects produced by the impact of falling on the ground of the structure that is being demolished;
- overpressure;
- dust and gas;
- throwing pieces of material under the action of the explosion.

The industrial constructions in the immediate vicinity of the chimney that was demolished are the boilers located at 40 m in a southerly direction from the chimney and the gas and boiler operation building located at 72 m in the east direction from the chimney. The two objectives being the closest to the chimney, were taken as a reference to assess the side effects of the demolition by blasting works. The seismic effect due to the detonation of explosive charges during the chimney demolition works is negligible due to the distribution of the total charge on a number of small charges (0.040 - 0.200 kg) placed in the structure in areas above ground.

The risk assessment showed that the oscillation velocity generated by the explosion shock, even if the explosive charges would detonate in holes drilled in

the ground, is 0.370 cm/s, a value that is below 2.1 cm/s chosen as admissible. The impact of a collapsing structure on the ground can result in seismic effects. Accordingly with the national standard concerning the admitted seismic levels of the peak particle velocity generated by blasting activities – energy release by explosion, there are established different corelations between the possible effects against civil and industrial buildings and the maximum level of the seismic action. In this view, the magnitude of the impact is corelated with energy released and depends on the weight of building which is collapsed, the building height and its center of gravity and as well as on the type of ground or if there is arranged a dumping bed on the overturning direction.

The risk assessment showed that at for the objective closest to the chimney - the boiler room, the value of the velocity of seismic waves possible to be generated at the impact of a collapsing structure of the chimney on the ground, is 1.032 cm/s, value lower than 2.10 cm/s the one chosen as permissible accordingly with the national standard. In order to reduce the impact with the ground, a damping bed was arranged in the direction of overturning the chimney according to those presented in Fig. 11 (Laszlo *et al*., 2008).

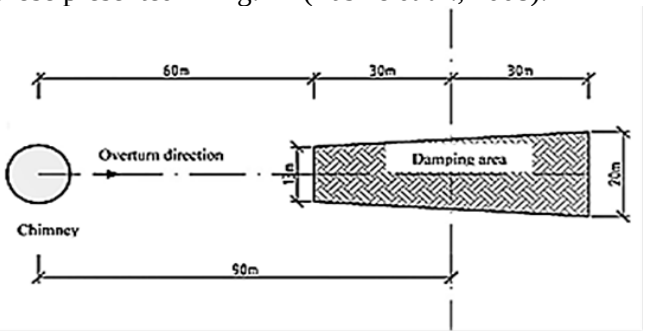


Fig. 11 – Dumping bed arranged on the overturning direction.

In order to verify the level of vibration induced in the ground by the impact when the chimney collapsed, three seismometers equipment were placed at the objectives considered the most sensitive. The results of the measurements are presented in Table 1 and they confirm that the seismic values induced by the collapse of the chimney are lower than the permissible ones.

Table 1

Measured vibration levels at the chimney collapse

Measuring location	Distance from location to chimney [m]	Peak Particle Velocity PPV [cm/s]
Boiler room	34	0.69
Demineralization station	122	0.27
Power station 110 kv	164	0.62

As the total quantity of explosives is split it and loaded in several holes there is expected to be generate a very low value of the airborne shock wave.

The risk assessment showed an estimated amount of overpressure value of 0.0238 Kgf/cm^2 (0.002256 MPa), a value which, in terms of the effects generated, is not dangerous for the buildings and human bean safety. The fact that the initiation network made up of the detonating cord (the detonating cord is the component that most contribute to the creation of the air shock wave) is located inside the chimney, also helps to reduce the value of the air shock wave propagated around the chimney.

Environmental pollution occurs to a very small extent and is very limited in time and space of action and is due to explosive gases and dust resulting from the partial crushing of concrete. Specific to the blasting works and especially the demolition works, is the fact that the gas generating event is limited in time and number. Thus, the duration of the emission source is in the order of hundreds of milliseconds. To reduce dust pollution, the surface on which the building is to fall will be sprayed with water, both before, during and immediately after its collapse.

Throwing of small material under the effect of the explosion, is diminished by the installation at the level of the detachment cut, where the explosive charges are located, of local means of protection with materials made of welded wire mesh with large mesh, flexible wire mesh with small mesh and an external protection. of geo-textile cloth placed 0.5 m away from the construction. The external protection shall cover the area of the explosive charges, exceeding by at least 1.0 m the lower and upper part of the detachment wedge. Also, to protect the buildings in the immediate vicinity of the chimney against large pieces of material thrown or detached during demolition, protective screens made of straw bales were placed outside them (Laszlo *et al*, 2005).

5. Conclusions

The restructuring of industrial activities has as a consequence the conservation or decommissioning of constructions or areas that can later be the object of the development of new projects. As a result, the demolition process using blasting works have a challenging application from the technical point of view but as well as due to the time consumption, labor and cost.

It can be appreciated that the mastery of the explosion phenomenon and the correct use of the explosion energy allows the execution of demolition works faster and much cheaper and from this point of view it is a factor of progress in the field of demolition and decommissioning.

One of the most used methods of demolition is the overturning demolition (collapse) procedure and is adopted in the case of tall buildings where the access of demolition equipment to the upper floors difficult to achieve, the impact with the ground of the collapsed building does not generate effects that

exceed the protection requirements of neighboring buildings and there is enough space in the direction of fall.

The paper presents the concept, risk assessment and the practical way of performing with success the demolition by blasting works of an industrial chimney with 150 m height located inside of an oil refinery and in the immediate vicinity of sensitive objectives (Figs. 12 and 13).



Fig. 12 – Sequences with the chimney overturning.



Fig. 13 – Chimney after demolition.

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PROIECTAREA ŞI EXECUTAREA LUCRĂRILOR DE DEMOLARE PRIN ÎMPUŞCARE A CONSTRUCŢIILOR INDUSTRIALE – ASPECTE TEHNICE ŞI DE SECURITATE

(Rezumat)

Lucrarea descrie modul practic şi condiţiile de realizare în securitate a demolării unui coş de fum industrial amplasat în incinta unei rafinării de petrol, având amplasate în imediata vecinătate echipamente şi construcţii foarte sensibile. Coşul de fum a avut o înălţime de 150 m şi a fost format din structura tubulară exterioară din beton armat şi un coş interior din zidărie de cărămidă refractară. Pentru stabilirea eventualelor efecte secundare generate de lucrările de împuşcare s-a făcut o evaluare de risc cu referire la unda seismică, unda de şoc aeriană, nivelul de zgomot şi de praf precum şi nivelul de şoc generat de impactul cu solul a construcţiei coşului de fum. Lucrările de demolare s-au desfăşurat cu succes şi datorită măsurilor de protecţie şi siguranţă luate, nu au fost înregistrate evenimente nedorite, iar valorile măsurate ale undei seismice generate de impactul cu solul a coşului de fum au fost nepericuloase, fiind sub valorile estimate în evaluarea de riscuri.