MATEC Web of Conferences **354**, 00032 (2022) https://doi.org/10.1051/matecconf/202235400032
*SESAM 2021*

# Construction and safety aspects for the arrangement of mobile explosive deposits

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**Abstract.** The execution of the blasting works involves the management of the problem of storage of explosive materials. This aspect is easier to solve in the case of mines activities with long exploitation time and where storage capacities are arranged, according to the legislation that provides constructive and safety criteria depending on the type and quantity of explosive materials stored. In the case of isolated blasting works, those for road construction, building demolition, underwater or forestry, etc., storage facilities must be arranged for shorter periods of time and smaller capacity, but which must comply with security, environmental and risk requirements, such as high-capacity deposits with long duration of activity. Considering that for the execution of such blasting works, the national legislation provides the possibility of arranging temporary explosive depots, of small capacity, but without specifying the constructive details and the necessary safety requirements to be observed, mentioning only that they must be executed on the basis of a specialized project. This paper presents a series of tests conducted by INSEMEX, in order to establish recommendations regarding the constructive and safety requirements that must be observed when designing and building mobile explosive depots.

## 1 Introduction

The blasting techniques today experience a wide area of applicability, exceeding the field of the mining industry. Due to the diversity of the conditions in which they are executed, they often require a special organization regarding the transportation and storage of the explosive goods near the blasting field. Typical cases are the isolated blasting works, those for road construction, building demolition, underwater or forestry, where the storage facilities must be arranged for shorter periods of time and smaller capacity, but which must comply with security, environmental and risk requirements.

At EU level, the method of possession and storage of explosive materials is very well regulated, but there are also certain peculiarities, especially regarding the method of storage in the case of blasting works performed in the above-mentioned applications [1,2]. In

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Romania, the manner of possession, use, transport and storage of explosive materials for civil use is regulated according to Law 126/1995 and the Technical Norms for the application of the law, including the completions and modifications appeared after the publication of these documents [3,4,5]. If for explosive storage arranged for long-term use such as those of the producers or the basic ones, there are detailed regulations regarding the constructive and security requirements that they must meet, for the temporary storage facilities, there are not enough details regarding the constructive requirements that they must comply with.

Considering the specificity of the activities of the General Inspectorate for Emergency Situations - IGSU, in particular in the field of pyrotechnics, respectively for destruction of ammunition left unexploded during armed conflicts, there was a need to arrange temporary mobile depots to store explosive products in the immediate vicinity of the place where war ammunition is identified and destroyed. IGSU contracted a specialized company in order to arrange ISO 1C type containers or similar as temporary explosive and war ammunition depots and INSEMEX was contracted in order to test the resistance of this type of depot against to an accidental detonation of the stored explosive products.

The article presents the tests performed by INSEMEX, of some constructive variants of explosive material storage pockets in order to identify the most adequate constructive solutions which, in case of an accidental detonation, should not lead to the initiation of the rest of the deposited explosives. Subsequently, these tested variants can become the basis for recommendations on how to design and build temporary explosives depots.

## 2 Methodology

### 2.1 Legislative requirements regarding the construction and arrangement of explosives depots

According to the destination, the period of use and location, the explosive deposits are classified as follows [3,4]:

a) at the producer - from which the customer deposits are supplied;

b) basic - from which the supply of customer deposits is made;

c) for consumption - from which blasters are supplied;

d) complexes - in which one part is arranged as a basic depot, and the other, as a consumption depot;

e) permanent - which can be basic or for consumption, with a use time of more than 2 years;

f) temporary - which can only be for consumption depot, with a use time of up to one year;

g) at surface - consisting of one or more buildings or rooms arranged on the hillside;

h) underground - consisting of mining constructions for access, storage, handling and distribution, including installations, accessories and auxiliaries, necessary for servicing the depot;

i) mixed - consisting of surface buildings and underground chambers.

New or old buildings, chambers buried in a hillside or mobile depot can be used as temporary depots. When designing the depot, the studies and specialized documentation regarding the location are taken into account, as well as the minimum safety distances from the objectives in the vicinity. Mobile deposits can be assimilated with niche for storing explosive materials underground and at the surface. Thus, for activities carried out in quarries or blasting engineering works, the explosive materials can be stored in mobile metal or concrete niches, executed on the basis of a project approved by the territorial labor inspectorate within which the respective companies operate. The means of initiation and ignition are kept both underground and at the surface in specially arranged niches, located at a distance of at least 6 m from the niche intended for the storage of the explosives.

Explosive niches must be lined with timber or concreted and have steel sheet doors at least 3 mm thick, provided with locks. Niches for detonators must be lined at the bottom with felt or rubber mat [4,5].

## 2.2 Requirements regarding the arrangement of a mobile container type depot

One of the options for arranging a mobile depot is to use an ISO 1C type container so as to allow the storage of both explosive materials and initiation means.

According to the IGSU requirements, the pyrotechnic container must be dimensioned in order to be able to store 50 kg TNT equivalent and 1000 detonators, the dimensions of the container being 6058 x 2438 x 2 438 mm. The container is divided into two compartments, with two individual doors and armored inside with steel plates so as to ensure that it can withstand the accidental detonation of a load of 1.5 kg. TNT equivalent. The first compartment will have arranged on the wall opposite the access door, a number of 20 pockets for storing explosive and detonators, arranged in five pieces in four rows. [6,7] (Figure 1).

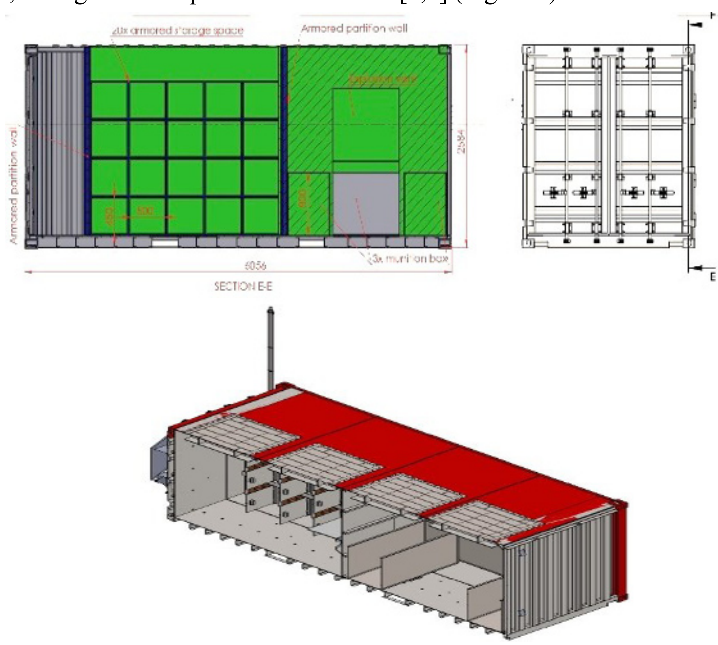



**Fig.1.** Modification of a container in a mobile explosives depot

The pockets will be provided with doors and will be arranged at a distance of 100 mm from each other. The storage capacity of the container compartment is 25 kg TNT equivalent, (explosive materials as well as detonators), distributed of 1.3 kg TNT equivalent per pocket.

The second container compartment will have a storage capacity of 25 kg TNT equivalent, and can be stored unexploded ammunition, for which purpose the compartment will be equipped with three boxes arranged along the length of the side walls inside, with a height of 0.8 m and a width of 0.6 m.

The two compartments, in the ceiling area, will be provided with pressure relief and for the realization of a natural ventilation system, the side walls will be provided with slots. Also, the floor of the container and the inside of the pocket boxes will be covered with anti-spark material (tego). The access doors will be provided with two locks in special construction, and the hinges will be of buried type.

The container will be provided with an alarm system against unauthorized intrusions, smoke detectors, lightning rod installation, perimeter lighting installation - LED type as well as with fastening elements for loading and unloading on a load runner [6,7].

## 2.3 Constructive variants for arranging the mobile container type depot

The mobile container type depot will be lined on the inside with armor steel type ARMOR S-500 of 6.5 mm thickness. For the arrangement of the 20 pockets for storing the explosive materials, several constructive variants were designed and tested, aiming at minimizing the effects of an accidental detonation of the explosive materials on them.

It is mentioned that the most important element in the construction of the mobile container depot is the storage pockets for explosive materials, because, depending on how they withstand the effects of an accidental detonation, depends the integrity of the container and security in its vicinity. For this reason, special attention was paid to the construction of the pockets, establishing 3 variants that were tested at the explosion, and depending on the observed effects, changes were made to contribute to increasing their resistance [8,9]. The arrangement of the pockets on the wall of the container compartment is shown in Figure 2.

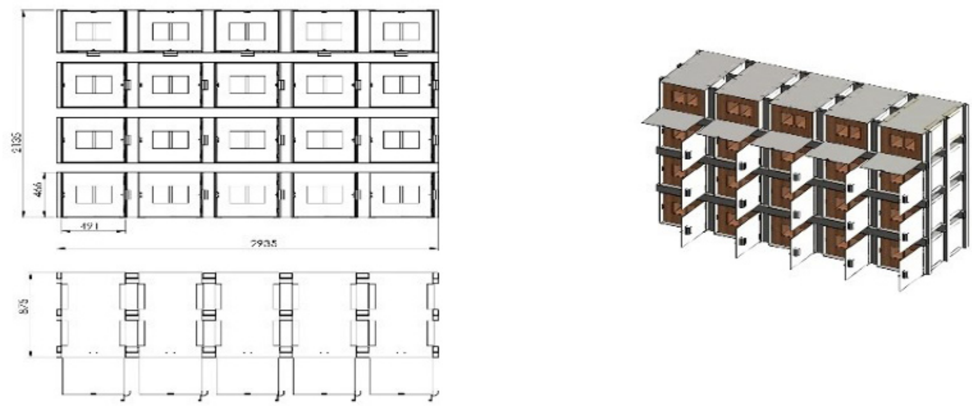


**Fig. 2.** The arrangement of the pockets on the wall of the container

One of the constructive solutions proposed for testing has a rectangular shape with a steel frame made of rectangular profiles of 50 x 100 x 4 mm made of S355 steel and the side closures made of ARMOR S-500 steel 6.5 mm thick (Figure 3).

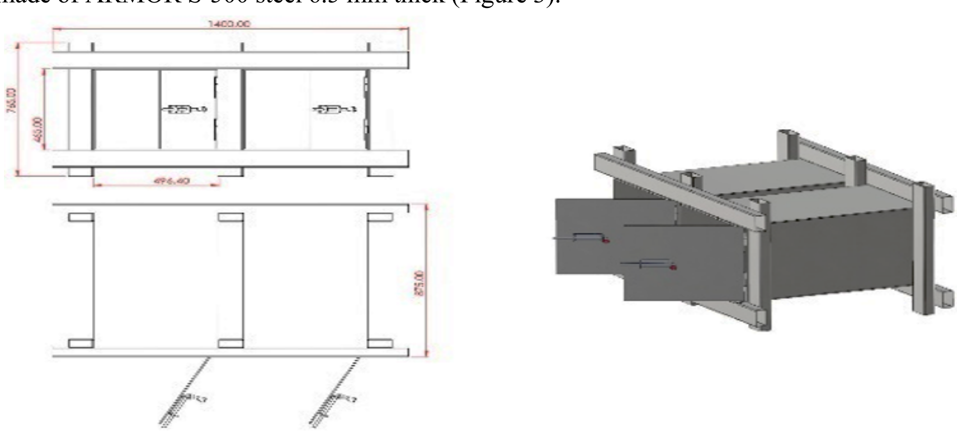


**Fig. 3.** Storage pocket with rectangular frame

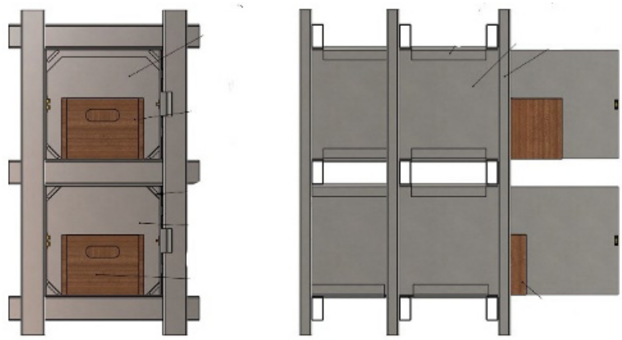


**Fig. 4.** Storage pocket with rectangular frame with inside storage box

Following the tests performed with this constructive variant, it was proposed to stiffen the body of the pocket box by welding on its outer edges some corner reinforcements. Also, in order to avoid the direct contact of the explosive materials with the floor and the walls of the pocket box, a storage box was made with three compartments made of tego type material, inserted in each pocket. (Figure 4).

Another constructive variant was the introduction of a steel tube inside the pocket, with the role of reducing the destructive effects of an accidental denotation on the body of the pocket and implicitly on the storage container. This alternative is shown in Figure 5.

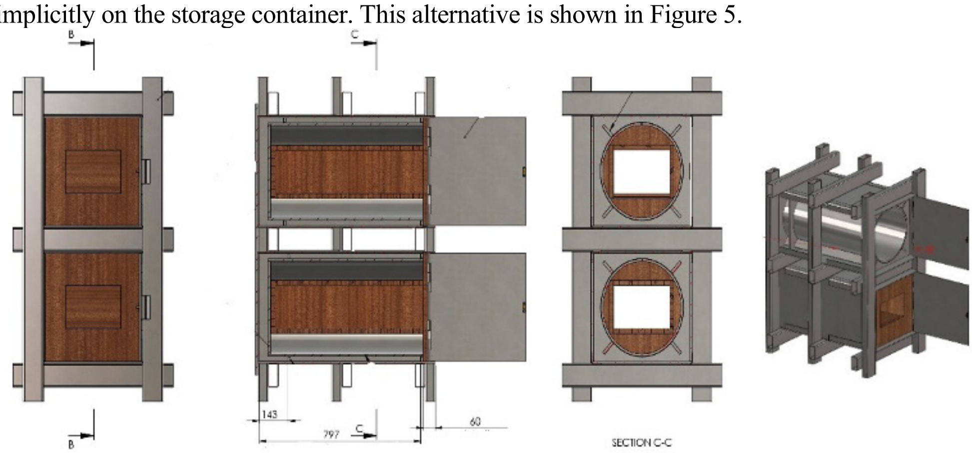



**Fig. 5.** Storage pocket with rectangular frame and steel tube placed inside

# 3 Results and discussions

## 3.1 Computer simulation of an explosion inside an ISO 1C container

In order to estimate the effects produced by the accidental detonation of an explosive charge, a computer simulation was performed by detonating a high-power explosive charge, placed inside an ISO 1C type container.

To solve the event scenario, a specialized software application of American origin type IMESAFR v2 Bundle was used, which allows a probabilistic assessment of the risk situations generated by the detonation of explosive charges of different types, based on grapho-analytical quantification results of specific associated hazards. in order to determine the level of safety or the corresponding degree of insecurity [10].

Following the simulation of the detonation inside the container, of a suspended explosive charge of 1.5 kg. TNT equivalent, as shown in Figure 6, results in a shock wave with values of 6.2 kPa (0.062 kg / cm$^2$) over a radius of 18.0 m (minor injury area), 8.3 kPa (0.083 kg / cm$^2$) over a radius of 13.6 m (irreversible injury area) and 15.9 kPa (0.159 kg / cm$^2$) over a radius of 8.0 m (fatality area).

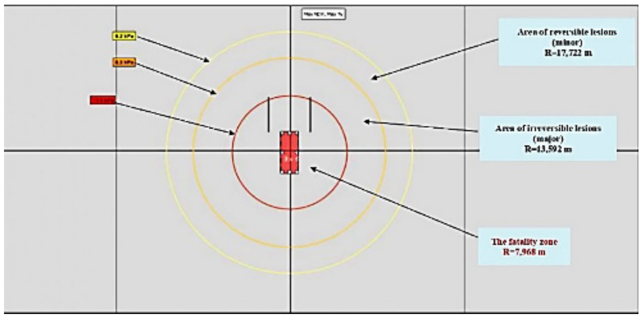



**Fig. 6**. Effects generated when a 1.5 kg. TNT equivalent load detonates inside the container

Considering that the simulation was done on an ISO 1 C container, it can be stated that following its interior arrangement with armor material with a thickness of at least 6.5 mm and the arrangement of the container with pressure relief, the estimated values of the above pressures presented are reduced to non-hazardous values (approximately 0.03 - 0.07 kg / cm$^2$).

According to Annex no. 3b): The degree of damage caused by the overpressure in the shock wave front on the various external objectives, in the Norms for the application of Law 126 /1995, these values of the overpressure in the shock wave front of 0.03 - 0.07 kg / cm$^2$ are not lethal, generating insignificant damages on the constructions - partial or total breakage of the windows [6.7].

### 3.2 Polygon testing of explosive material storage pockets

Until a constructive variant was established that corresponded from the point of view of the resistance requirements to the action of the explosions, the pockets were subjected to a series of tests by detonating explosive charges inside them, monitoring the effects produced by the explosion.

The tests were carried out under the coordination of the specialized personnel within INSEMEX, both in the explosive field of the institution and in a field of IGSU.

#### *3.2.1 Tests performed in the INSEMEX polygon*

In the INSEMEX Explosives Polygon was tested a set of 2 rectangular pockets (Figures 3 and 7 a). These were positioned on the access hall inside a reinforced concrete structure, and in each pocket was introduced a quantity of 1.3 kg of TNT explosive (Figure 7 c), the load from the pocket marked with 1 (Figure 7 b) being primed with an electric detonator and the one in the pocked marked with 2 not being primed, this having the role of a control sample, in order to see if it is influenced by the detonation of the load from the adjacent box.

a) b) c)

**Fig. 7. T**esting the pocket boxes at the INSEMEX polygon

Following the test, it was found that the pocket box in which the detonation occurred was almost completely destroyed, its ceiling and door being projected at 100 - 200 m distance from the reinforced concrete structure. (Figure 8).

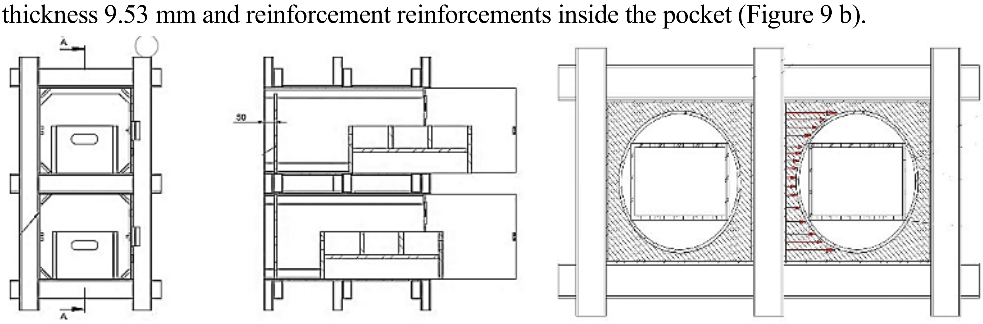
**Fig. 8.** The results of the pocket boxes testing at the INSEMEX polygon

Also, the side wall of the second pocket box was deformed and moved inwards, the door being projected outside the reinforced concrete structure and the control explosive was sprayed, not detonated.

These results highlighted the need to rigidify the areas between the pockets by adding an additional element in the support frame of the box, strengthening the welding line, strengthening the inner corners of the pocket by adding deflectors at 45° and the outer edges of the pocket by welding steel corner type elements (Figure 9 a).

Also, the padding of the pocket with wood / tego material was considered, as well as the introduction of a box made of the same material to keep the explosives at a distance of at least 100 mm from the walls of the pocket (Figure 9 a).

Another improvement was made by adding a section of pipe with a diameter of 406 mm, thickness 9.53 mm and reinforcement reinforcements inside the pocket (Figure 9 b).



a) b)

**Fig. 8.** Constructive modifications proposed following the explosives test

### *3.2.2 Tests performed at the IGSU polygon*

Considering the effects found during the first test regarding the dynamic phenomena and the design of the metallic elements of the pocket under the effect of the explosion, the decision was made to choose another test location that would have a much larger surface and provide additional safety if these effects would be repeated. The test action took place in a training ground used by IGSU specialists.

The tests were performed on two assemblies of two pockets arranged according to the proposed modifications following the first test.

In Figure 9 a) and b) is presented the first variant of the pocket with the lifts carried out both inside and outside it as well as the box of tego material that is inserted inside the pockets and in which the explosive materials will be placed.

a) b)

**Fig. 9.** Testing in the IGSU polygon the variant of the alveolus strengthened inside and outside

The test was done by inserting in the two pockets two loads of 1.3 kg TNT explosive (Figure 10 a), the load at the top pocket being primed with an electric detonator cap and the second load was used as a control sample, being inserted in the lower pocket (Figure 10 b).

a) b)

**Fig. 10.** Set up of the explosive charge

Following the detonation of the explosive charge, the dynamic and throw effects of metal fragments under the detonation pressure were much lower compared to the effects observed in the first test, the only projected element being the pocket door in which the explosion occurred (Figure 11). The walls of the pocket were deformed and broken, they also yielded on the welding line and the dynamic effect also deformed the walls of the neighboring pocket. The control explosive charge, located in the second cell, was not initiated.

**Fig.11**. The results of testing the strengthened pocket variant

In the second stage, the testing was done with the pocket variant in which a steel pipe was inserted and the facade and the inside walls of the pocket were lined with tego type material (Figure 12 a). Explosive charges of 1.3 kg TNT explosive each were introduced into the two pockets similarly to the previous test (Figure 12 b).

a) b)

**Fig.12.** Testing in the IGSU polygon the pocket variant with the inserted pipe

Following the detonation of the explosive charge, the only throw effect was that of the apocket door in which the detonation occurred, and the dynamic effects were reduced, limiting to the lateral rupture of the steel pipe and deformation in the same area of the neighboring pocket wall. (Figure 13 a).

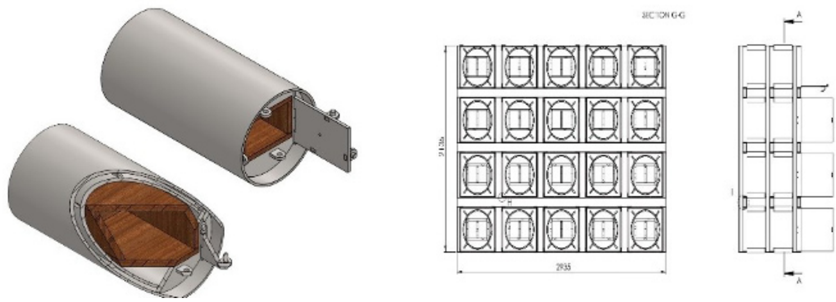
The neighboring pocket did not show any deformation inside it, and the control explosive charge remained unblasted. (Figure 13 b).

a) b)

**Fig. 13**. The results of testing the pocket variant with the inserted pipe

## 4 Conclusions

One of the most important aspects taken into account when designing and arranging a mobile explosive depot is the limitation to the maximum of the dynamic action and the throw effect of pieces of material under the pression of an accidental detonation. Tests performed on several constructive variants of pockets have proved that the solution of inserting a steel tube in the pocket with a rectangular frame gives a good enough resistance to limit the effects of an explosion



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a) b)

**Fig. 14**. Tubular cell with a steel tube placed inside

The tests will continue by trying a variant of steel tube inserted in a tubular cell (Figure 14 a) following that after they will be mounted in the container, to make a series of tests by detonating explosive charges inserted in the cells as well as freely suspended inside the container. On this occasion, both the values of the pressures produced by the explosion and the possible effects on the construction of the container will be monitored.

The use of these pockets/cells can be a viable solution in order to arrange a mobile depot, they can be joined like cells (Figure 14 b) and form an assembly that can be fixed inside a container or a concrete construction.

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