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## APPLICATION OF EXPANSIVE MORTARS FOR THE FORMATION OF ARTIFICIAL SCREENS DURING BLASTING IN URBAN AREAS

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### Abstract

*During construction of buildings in urban areas, sometimes there is a need to blast solid rock mass in the immediate vicinity of the surrounding buildings. In that case, the aim is not only to increase the efficiency of blasting, but also to reduce harmful effects of ground vibration induced by blasting. At the same time, it is very important to protect the buildings located in the safe zone from the blast site as well as remaining rock mass around the blast site. This can be achieved by the formation of artificial screens. Artificial screens represent discontinuities in the rock mass placed between the blasting site (source of seismic waves) and building to be protected. The formation of artificial screens using expansive mortars is presented in the paper. Expansive mortars are environmentally friendly products. They do not cause shock waves, ground vibrations, air blast, flyrock and do not release toxic fumes as side effects of blasting process which may occur. They do not cause excessive breakage to the surrounding rock mass.*

**Keywords:** expansive mortar, artificial screens, pressure, rock breaking, building foundation.

### INTRODUCTION

During construction of buildings in urban areas, the removal of rock mass for the purpose of making foundations is usually done by mechanization. However, in some cases there is a need to build the building in solid rock mass. In that case, to excavate foundations, it is necessary to break the large quantity of solid rock mass that cannot be broken by machinery. Then the special blasting techniques can be applied, using small-diameter holes with small amounts of explosive charges. Of particular importance is the choice of optimal delay time of initiation system and initiation pattern. Sometimes, despite the significant reduction of the quantity of explosives in blastholes and the selection of an adequate initiation pattern, it is necessary to additionally reduce the intensity of seismic waves caused by blasting, to protect the surrounding buildings [1]. One of the methods is the formation of artificial screens that represent a discontinuity in the rock mass located between the blast site and the building to be protected [1].

Artificial screens in our Country are mostly carried out in the form of a crack using the method of contour blasting during production blasting or road construction and other construction works. Contour blasting methods mean the use of small-diameter explosive charges or a detonating cord. Delay time of initiation system are very small and sometimes

explosive charges of contour blast holes are initiated simultaneously. The paper presents the first attempt of applying the expansive mortar to form a crack as the discontinuity in rock mass that has the function to protect buildings from seismic waves from blasting.

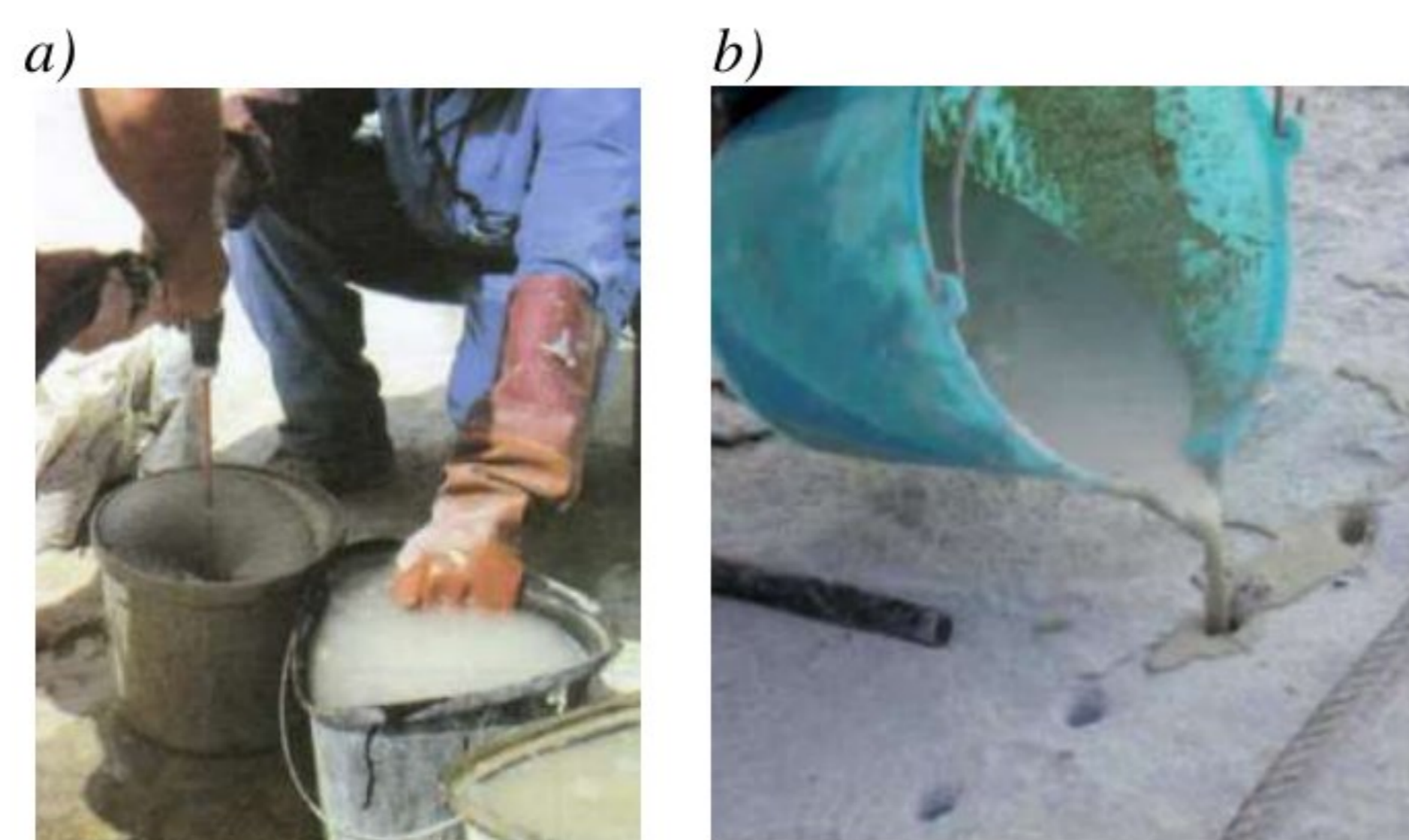
The tendency in the world today is to find new solutions that can be applied to break solid rock masses, and which will be an adequate replacement for commercial explosives in sensitive areas. The reason for this is the problems related to blasting in urban areas, in road and railroad construction, demolition works, secondary breaking, rock breakage for foundation, trenching, stabilization of slopes and similar civil construction operations especially in urban areas as well as quarrying of dimension stone. In all cases mentioned, there is a problem of removing solid rock mass or concrete structures in an efficient way, while protecting the environment.

One of these solutions are expansive mortars, which are increasingly used in mining and construction, especially in cases where there are buildings declared as cultural heritage, industrial and other objects that are very sensitive to ground vibration, when the use of explosives is prohibited.

### **EXPANSIVE MORTARS**

Expansive mortars have developed from a need to full fill the requirement in civil engineering works especially demolition works in urban areas where the explosives are not permitted [2]. Nowadays, expansive mortars have found a wide range of application in excavating foundations, levelling rocks for road works, trenching, underground excavations, marine and submarine excavations, removing boulders, demolition of concrete or reinforced concrete etc. They have quickly found the application in mining particularly in dimension stone mining for splitting the primary blocks from the rock massive or squaring the primary blocks into commercial ones.

Expansive mortars can be in the form of a cartridge - capsule type and in bulk - bulk type. The cartridges of expansive mortars must be immersed in water before loading the holes while the bulk type should be mixed with water before pouring into the holes (Figure 1). Expansive mortars in bulk are powdery materials which are mixed with water at a certain percentage, depending on the type of expansive mortars. The mixture is poured into previously drilled holes.



*Figure 1 Procedure of using the expansive mortar in bulk; a) mixing with water, b) pouring into the holes [2]*

Depending on the reaction time, expansive mortars start to expand. Under confinement, this expansion can generate significant expansive pressure. When the resultant force exceeds the tensile strength of material, cracking occurs through the predetermined direction or pattern. During splitting process, the holes are drilled in the line - the predetermined direction of splitting. In processes of breaking the rock or concrete (demolition works, excavating foundations etc.) the holes are drilled in predefined pattern. The pressure of expansive mortars provides silent cracking and breaking the rock or concrete along this pattern. There are expansive mortars with slow and fast reaction. The reaction time of expansive mortars depending on temperature is given in Table 1.

**Table 1** Reaction time of expansive mortars depending on temperature [2]

Temperature (°C)	Reaction time (h)	
	Slow reaction	Fast reaction
50	8	3
40	12	4
30	15	5
20	20	10
10	30	15

Expansive mortars have the following advantages in relation to other technologies of rock breakage:

- rock breakage do not cause shock waves and explosion,
- rock breaking is carried out without noise and air blast,
- no smoke, dust or toxic fumes,
- no ground vibration and flyrock,
- the process of rock breakage do not cause excessive damage to the surrounding rock mass,
- ecological and environmentally friendly product,
- storage and transport are not hazardous to the environment,
- the use and preparation of expansive mortars is very simple and safe for operators.

Expansive mortars are highly alkaline products so the operator must wear safety goggles and rubber gloves,

- expansive mortars do not require special authorizations or licenses like explosives,
- there is no need for a highly skilled operator,
- there is no limit to the time period when expansive mortars can be used during the day.

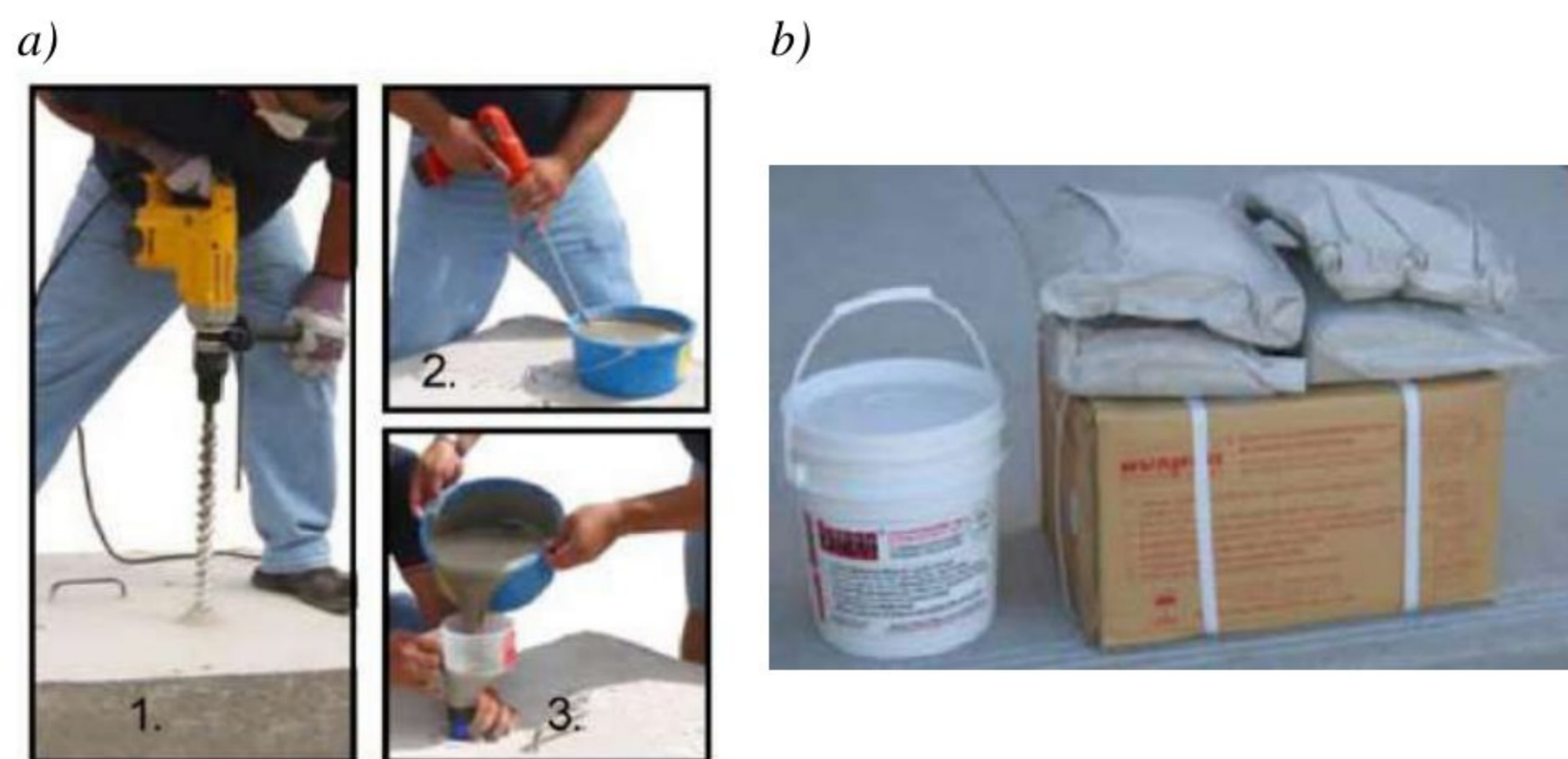
The disadvantages of expansive mortars are:

- expansive mortars cannot be applied at very low temperatures,
- the earlier types of expansive mortars were related to a much higher price than commercial explosives, however, currently there are expansive mortars with more affordable prices,
- the application of expansive mortars in fractured rocks is limited.

Nowadays, there are various expansive mortars in market. In order to present the detail characteristics and fields of application in further part of the paper three expansive mortars are presented.

### Expansive mortar Dexpan

The expansive mortar Dexpan [3] is used for demolition and concrete breaking, excavating and rock breaking as well as stone quarrying. Dexpan is a powder which is mixed with water and poured into previously drilled holes (Figure 2a). The expansion within holes develops a pressure of 1241 bar providing silent cracking that breaks reinforced concrete and rock safely and quietly without noise, vibration, and dust. Dexpan provides controlled demolition according to drilling pattern breaking reinforced concrete or rocks [3].



*Figure 2 a) Phases of using Dexpan: 1 – drilling, 2 – mixing Dexpan with water, 3 – pouring the mixture into holes; b) Packages of Dexpan [3]*

Packing of Dexpan may be plastic container or box with bags, (Figure 2b). There are three types of Dexpan depending on temperature [3]:

- Dexpan I for temperatures from 25 to 40°C,
- Dexpan II for temperatures from 10 to 25°C,
- Dexpan III for temperatures from -5 to 10°C .

Dexpan [3] can be used for:

- demolition and concrete breaking (demolition of mass reinforced concrete, foundations for machinery, partial demolition of various concrete structures, reinforced concrete cutting),
- excavating and rock breaking (excavation of rock, splitting the boulders, rock and slab breaking for road expansion, excavation associated with tunnelling, construction works),
- stone quarrying and dimension (limestone, onyx, marble, granite quarrying).

### Expansive mortar FRACT.AG

FRACT.AG [4] is a highly expansive mortar which expands when poured into a hole and develops a pressure higher than 8000 t/m<sup>2</sup> on the walls of holes. FRACT.AG is environmentally friendly. It releases no toxic fumes or harmful substances of any kind [4].

FRACT.AG can be used in any type of rock formation, concrete, reinforced concrete or tiled structure in [4]:

- excavating foundations,
- levelling rocks for road works,
- excavating trenches for pipe laying,
- underground excavations,
- marine and submarine excavations,
- removing boulders,
- demolition of concrete or reinforced concrete piers, towers, walls, wharves, etc.
- demolition of foundations.

FRACT.AG is a powder (Figure 3) that is mixed with clean water before use, in a ratio of 30% of the overall weight (1.5 liters of water for each 5 kg package) [4]. Water is poured first in a large container then gradually the powder is added to water stirring all the time to obtain a smooth, lumpfree mortar. After preparation time of 5 to 10 minutes the mortar is poured into holes.



**Figure 3** Expansive mortar FRACT.AG [4]



**Figure 4** Expansive mortar SPLITSTAR [5]

Four types of FRACT.AG are available in market [4]:

- RED – for temperatures near 5°C,
- GREEN – for temperatures from 5 to 20°C,
- YELLOW – for temperatures from 20 to 35°C,
- BLUE – (multipurpose) to use in demolition work with hole of diameter 40 mm (the temperature affects the reaction time).

### **Expansive mortar SPLITSTAR**

Expansive mortar SPLITSTAR [5] is a non-toxic and cementations powder, which consisting of calcined oxides of calcium, silicon, and aluminium (Figure 4). Expansive mortar SPLITSTAR becomes a highly powered amazing expansive pressure of 11200 t/m<sup>2</sup> when mixed with water. Marble, granite, limestone, plain concrete, reinforced concrete, boulders, and ledge are fractured overnight without noise, vibration, or fly rock. Especially, used as environment constraints or when explosive is not permitted for use [5].

Expansive mortar SPLITSTAR [5] develops rise of highly expansive capabilities at the consistent volume exceeding 122 MPa (11200 t/m<sup>2</sup>) more than enough to break up any materials to be cut or demolished. The tensile strength for most rock is less than 5–25 MPa (500–2500 t/m<sup>2</sup>, 50–250 kg/cm<sup>2</sup>), reinforced concrete breaks at 3–5 MPa (30–50 kg/cm<sup>2</sup>, 300– 500 t/m<sup>2</sup>).

Expansive mortar SPLITSTAR [5] is used for:

- quarrying marble and granite, limestone, sandstone; cracking nature ground,
- breaking rock into pieces; deposition of falling rocks,
- demolishing concrete structure, chipping defective concrete piles, etc.
- in the field as a new method of demolition, expansive mortar SPLITSTAR can effectively be use in the construction and civil engineering fields as follows: bridges dams, ledge boulders, machinery bases concrete piers, slabs 6" thick and more marble and granite.

Types of expansive mortar SPLITSTAR [5] are:

- SCA-1 (25–40°C),
- SCA-2 (10–25°C),
- SCA-3 (-5–10°C).

### **ARTIFICIAL SCREENS**

One of methods to reduce seismic effects during blasting involves the formation of artificial screens in the path of propagation of seismic wave (Figure 5). These screens can be made using machinery or blasting methods. Artificial screens can be continuous or discontinuous [6]. The last type involves the blasting of a row of boreholes with a certain intermediate space between the holes.

Artificial screens establish two zones [6]:

- the protected zone from ground vibration induced by blasting,
- the zone where the effect of blasting increases.

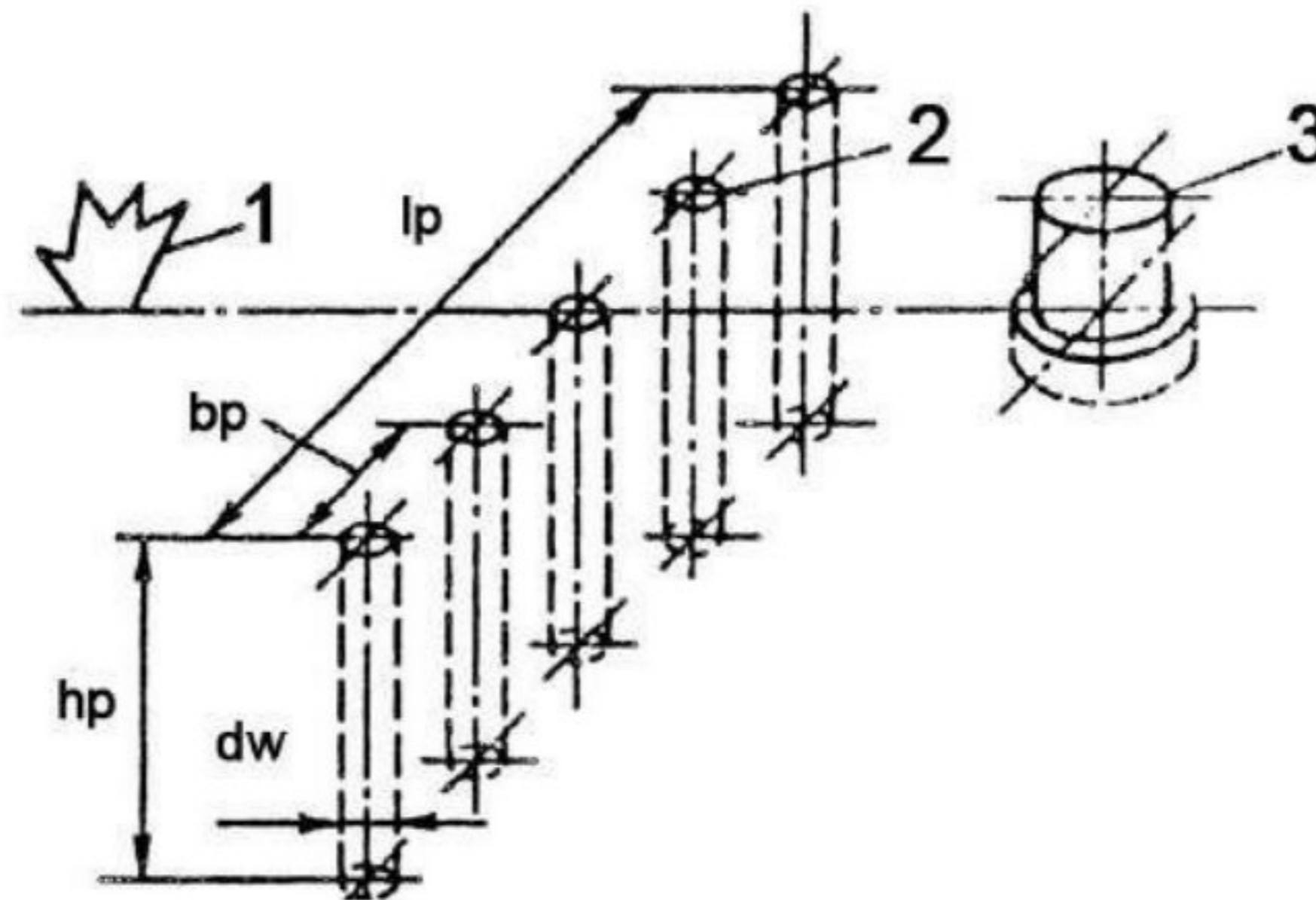
The artificial screens are divided into [6]:

- artificial screens in the form of cracks,
- artificial screens in the form of a layer of loose rock material.

Experiments carried out in the former USSR [6] led to the conclusion that the placement of artificial screens in most cases achieved its goal, i.e. there is a decrease in the intensity of ground vibration in the “protected zone” and the effect of blasting in the “blasting zone” increases. The experiments were conducted to establish the mathematical dependencies of changing the parameters of the screen (width, depth, length, filling...) that affect the ground vibration in the protected zone.

There are two methods of forming the artificial screen: 1) closer to the source of disturbance (blast site) and 2) directly in front of the object to be protected [6]. In the first method, the screen is temporary. During multiple blasting, and sometimes in individual blasting, it is recommended to create a screen directly in front of the object to be protected. In this case, the screen is made permanent and can be made using absorbent material. Regarding the shape, the artificial screen can be vertical or inclined with extensions in the upper or lower part [1].

The effectiveness of artificial screens in the form of rows of boreholes depends on the diameter of the holes, the distance of the boreholes in the row, the distance between the screen and the source of the seismic wave or the object to be protected [6].



**Figure 5** The placement of the artificial screen: 1 – blast site; 2 – artificial screen; 3 – object to be protected;  $hp$  – screen depth,  $bp$  – distance between screen holes,  $dw$  – hole diameter / screen width,  $lp$  – screen length [6]

### The formation of artificial screen using expansive mortar

During the blasting of rock to excavate foundation for the future housing and business complex in an urban area, an attempt was made to form the artificial screen using expansive mortar. Holes with a diameter of 38 mm were drilled with spacing of 25 cm [7]. Drilling was carried out using a self-propelled drill rig FlexiROC T15 R [8] produced by Epiroc for percussive rotary drilling. FlexiROC T15 R (Figure 6) is a compact, self-propelled, four-wheel drive drill rig. It enables drilling the holes with maximum length up to 9 m. Technical data of the drill rig FlexiROC T15 R are shown in Table 2.



**Figure 6** FlexiROC T15 R [8]

Due to the uneven terrain, the lengths of boreholes varied (from 2.8 to 5.8 m). Boreholes were drilled in one row [7]. The row of drilled boreholes marked with blue spray is shown in Figure 7.



**Table 2** Technical data of Epiroc tophammer surface drill rig FlexiROC T15 R [8]

Technical data	FlexiROC T15 R
Hole diameter	27 mm – 51 mm
Feed force, max	4 kN
Rock drill/ DTH hammer size	COP 1022 ; COP 1028
Compressor	Atlas Copco C55 C106 GD, screw compressor
Compressor working pressure, max	8.5 bar
Air capacity (FAD) of compressor at normal working pressure	23 l/s
Engine	48 kW
Transport dimensions (height/ length/ width)	2250 mm/4950 mm/1770 mm

The SPLITSTAR expansive mortar was used to fill the boreholes. The mortar was mixed with water according to the manufacturer's recommendation and poured into the boreholes. After that, the mortar was left overnight to expand in boreholes. The mortar expands and presses the walls of the boreholes in all directions. When the resulting force overcomes the tensile strength of the rock, the rock cracks in a predisposed direction (line of drilled boreholes). Figure 8 shows a crack formed by the action of expansive mortar. The artificial screen formed in this way reduces the intensity of ground vibration induced by blasting in the protected zone, but also improves the effect of blasting in the blasting zone.



**Figure 7** The row of drilled boreholes marked with blue spray [7]



**Figure 8** Crack formed by the action of expansive mortar [7]

## CONCLUSION

The paper presents one of the possibilities of applying the expansive mortars for the formation of artificial screens. Expansive mortars are environmentally friendly products. Expansive mortars do not cause shock waves, ground vibration, air blast, flyrock and do not also release toxic fumes. Storage and transport are not hazardous to the environment. The use of expansive mortars is very simple and safe for operators if they follow the Instruction Manuel from the manufactures.

Artificial screens represent discontinuities placed between the blasting site (source of seismic waves) and the object to be protected. Screens have a dual function. One is to reduce the intensity of seismic waves caused by blasting in protected zone, and the second is to improve the effect of blasting in the blasting zone.

Extensive research on the effect of artificial screens on the intensity of seismic waves was carried out during the USSR, especially artificial screens that are made using mechanization.

In our Country, artificial screens have been applied only in the form of a crack made by contour blasting methods. The intensive application of expansive mortars will certainly lead to their greater application in the field of the formation of artificial screens, especially in sensitive areas. Even in the form of a crack, artificial screens prove to be useful for reducing the intensity of seismic waves in the protected zone.

### **ACKNOWLEDGEMENT**

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