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Forces Generated by the Free Fall of DEMICHAIN

The free fall of an array of heavy chains (360 kg/sq m) generates extensive pressure in the depth of the ground. These pressures have been measured and compared to the threshold pressures that trigger anti-personnel landmines. When dropped from moderate heights (1 m), chains can generate enough pressure to set off active landmines buried 20 cm, provided that the area of their pressure plates is larger than a few square centimeters.

by Christian Baras, Bernard Gautier, Robert Goepfert, Jean-Pierre Hancy, and René Joecklé
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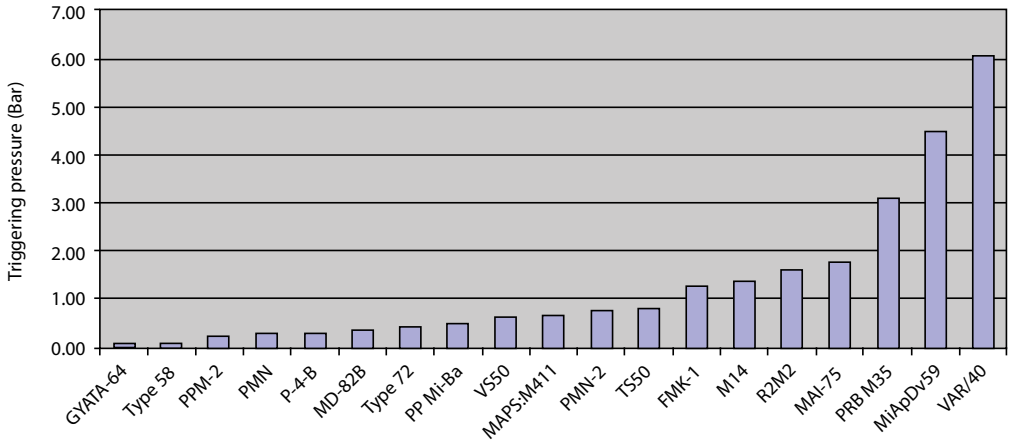

Figure 1: Triggering pressure for various AP landmines.
All graphics courtesy of GICHD.

First designed by Jacques Demichelis, the DEMICHAIN concept involves dropping an array of heavy chains on mine-contaminated ground. The force of the chains delivered into the ground sets off active landmines buried beneath the surface. This article reports the recent progress made toward improving the technology and shows the advantages as well as the limitations of the DEMICHAIN technique.[1] After examining the amount of stress necessary to trigger the pressure plate of a buried anti-personnel (AP) mine, the study examined the relationship between stress waves and the drop height of the array of chains. Buried load cells measure the forces delivered by the falling chains. Discussion on the efficiency of the DEMICHAIN concept begins by comparing the results of the forces measured by the load cells with the characteristics of buried AP mines.

Overview of AP-Mine Characteristics

AP mines are detonated when a force exerted through the soil on the pressure plate is larger than the predetermined triggering force, which equates to the trigger pressure multiplied by the area of the triggering plate. The study examined the most frequently used AP mines and summarized their triggering force as listed in *Jane's Mines and Mine Clearance (Jane's).*[2]

The surface of the pressure plate is not listed in the handbook and was estimated using the outer diameter of the landmine. An interpolation was made based on a picture. By measuring the ratio between the diameter of the pressure plate and the mine's outer diameter, the latter of which was provided in *Jane's*, the diameter of the pressure plate and its surface was determined. This provided an approximate value and allowed us to deduce the triggering pressure, as illustrated in Figure 1.

A pressure of less than 2 bars sets off most mines, as seen in Figure 1. Three of the mines examined required greater amounts of pressure to trigger a detonation. However, these mines must be installed on the surface along with the small pressure plate, which is placed above ground.

Overview of DEMICHAIN Concept

DEMICHAIN involves arranging heavy chains in a horizontal array to form an area that exhibits a uniformly distributed mass. This array of heavy chains hangs horizontally over contaminated ground. When released, the array falls to the ground and delivers a wave of vertical stresses. The basis of this theoretical principle can be found in Scott and Pierce's *Soil Compaction by Impact*, which describes the process of soil being hit by the free fall of a uniformly distributed mass.[3]

When a uniformly distributed mass is dropped from a moderate height, one can assume that the behavior of the ground is elastic. After a very short time, the surface of the ground moves at the velocity of the falling mass and is compressed. The vertical stress generated at the impacted surface is proportional to the velocity of the falling mass and the

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High mass density chain arrays used during testing.

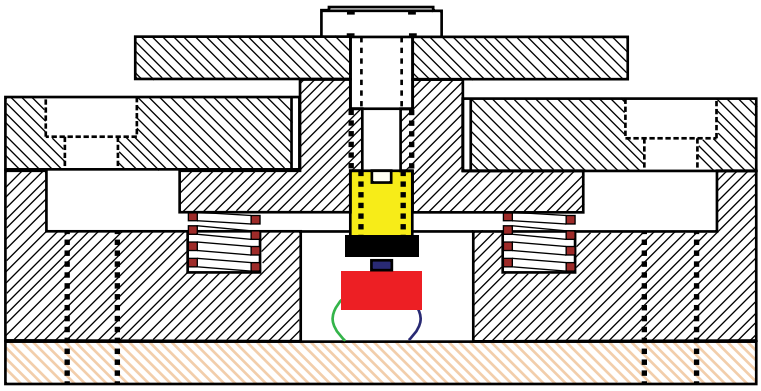

Figure 2. Mockup of standard landmine.

elastic constant of the ground. Under the impacted surface, the stress is uniformly distributed and spreads in-depth into the ground at the velocity of sound. This vertical stress wave can then produce a force on the pressure plate of an active mine sufficient enough to detonate it.

Scott and Pierce show that the maximum pressure is obtained at the surface and is directly proportional to the height from which a uniformly distributed mass free falls, regardless of the specific mass. Similarly, duration of the pressure wave is directly proportional to the specific mass per unit area of the array of chains.

Experimental Studies

Three studies were conducted successively.

Tests on Standard Landmines. Using electronic mockups (Figure 2) that exhibit the same geometrical characteristics of standard AP mines, the *Association de Recherches de Techniques Innovantes en Déminage Humanitaire* (ARTID) tested DEMICHAIN.[4] Buried at depths up to 20 cm, these devices contained pressure plates retained by compression springs. As soon as the load on the pressure plates reached 150 newtons, an electric switch depressed, showing that a mine would have detonated. During testing, an array of chains was released into a free fall over the ground. These initial tests, conducted by ARTID, showed that the DEMICHAIN concept is capable of triggering buried mines, even if mines are buried at depths up to 20 cm.

Tests on Practice Landmines. The *Anti-personnel Mine Ban Convention* allows countries to possess a small number of active landmines for research. The French Ministry of Defense owns a limited number of AP mines, which could not be used for this study (see the STOCK5000 in Rapport CNEMA 2011–2012).[5] However, the French Ministry of Defense provided the opportunity to use practice mines, which differ from real mines in that the explosive material is replaced by a smoke-emitting material. The available practice mines in France are MI AP DV X 59. The test program was performed in *Etablissement Technique de Bourges* at Bourges and showed that the DEMICHAIN system is only efficient if the top of the landmine is located toward the ground's surface. Due to the small area of the pressure plate for MI AP DV x 59, a rather high pressure level must be developed in order to exert a sufficiently high force on the pressure plate. Notably, this type of landmine is not normally buried.

Measuring Chain-generated Stress. An FC22 load cell by Measurement Technologies using the strain-gage technology was adapted in a housing in which a piston of 3.1 cm in diameter slides freely and transmits the force exerted on the free surface of the piston to the load cell. Four of these pressure sensors were buried in the ground. A digital oscilloscope simultaneously recorded the four generated signals (0 to 5 V for a nominal pressure of 7.3 bars).

A series of 59 successful tests were performed using different DEMICHAIN systems and detector depths. Most of the tests were conducted in a mix of sand and gravel, while several tests involved vegetated ground.

For the first series of tests, an array of chains with a mass per length unit of 6 kg/m and spaced 6.2 cm apart provided a mass density of less than 100 kg/sq m. The temporal aspect was relatively irregular. The study team built a reinforced array of chains with a higher mass density (360 kg/sq m); this exhibited a greater force than did the previous array of chains. The fall height was limited to 1.5 m, which would yield forces within the operational limit of the load cells.

From the tests, the pressure seems directly proportional to the height from which the array of chains is dropped. The pressure does not exhibit a large decrease in function of the depth. The duration of the pressure impulse at half of the maximum height is about 6 to 7 ms. Comparing this value to the delayed detonation time (which is not available in literature) built into several AP mines to avoid nearby explosions could yield interesting results. These results are summarized in Table 1.

This research could benefit from having these values compared to the triggering pressures of other AP mines with the exception of those that exhibit a very small pressure plate, as a modest fall height of 1 m will trigger mines buried at depths of 20 cm.

DEMICHAIN's Advantages

DEMICHAIN maintains many advantages in contrast to other landmine-remediation tools and activities. Primarily, the forces developed

Fall height (m)	Measured pressure range (Bar)	Minimum observed pressure (Bar)
1m	2.6–4.8 Bar	2.6 Bar
1.5m	4.7–7 Bar	4.7 Bar

Table 1. Summary of test results.

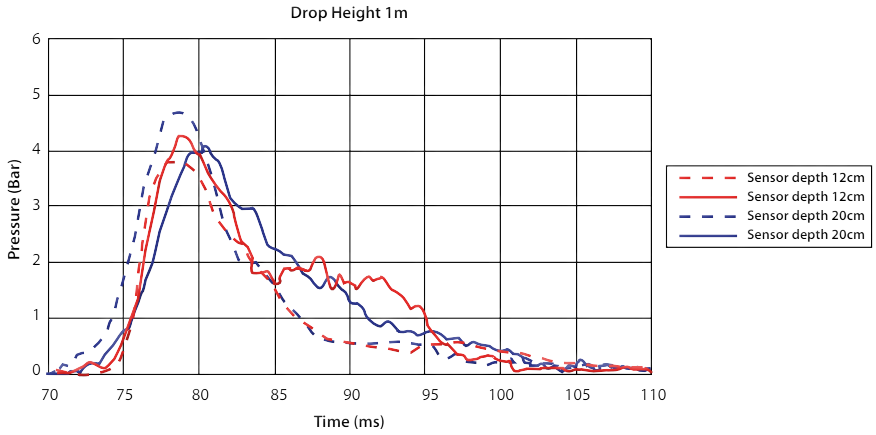

Figure 3. Pressure values for load cells used during a test with a drop height of 1 m.

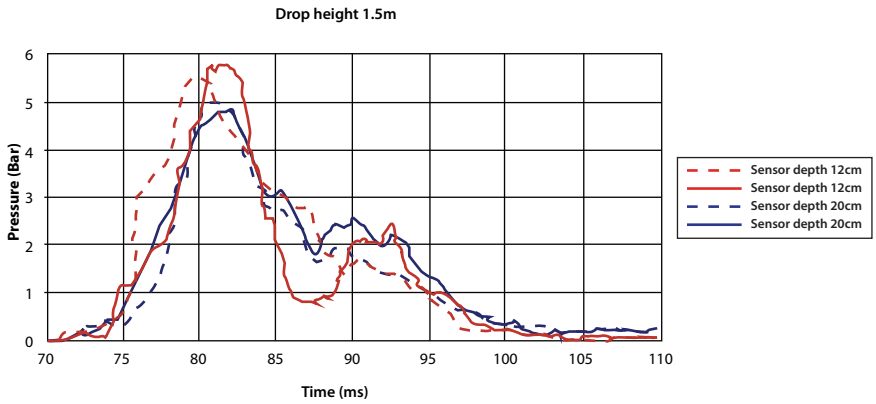

Figure 4. Pressure values of four load cell during a test with a drop height of 1.5 m.

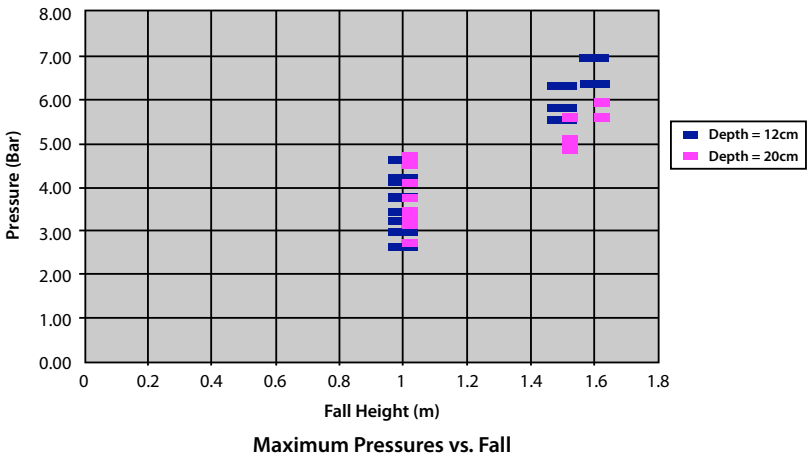

Figure 5. Pressure values for different tests as a function of the fall height.

are vertical and are, therefore, analogs to the forces developed by the targets of the mines. Moreover, the demining process does not change the soil's structure, ensuring the integrity of roads and paths. The developed forces decrease slowly in the depth; therefore, large soil depths (up to 45 cm with a larger surface array) can be demined with positive results. The issue for large depths of soil is the edge effects, which reduce dimensions of the maximum pressure zone.

The tool is not as sensitive to abrasion as flails are to sand. Furthermore, the tool consists of ordinary, inexpensive chains, which can be built in workshops and easily adapted to specific needs and lands. Thus, the DEMICHAIN tool can be mounted on an ordinary machine including cranes and hydraulic arms commonly used in demining. When a free-fall winch is used, DEMICHAIN can be remotely operated. Finally, forces in the soil that set off landmines will take place only at the end of the free fall; therefore the operation will be dangerous only at this moment. No permanent emission of dust will take place.

The DEMICHAIN concept does not require users to invest in a specialized piece of machinery, as devices need only be able to drop an array of chains onto the ground. Therefore, DEMICHAIN could be an affordable technique for small organizations or for reduced amplitude jobs, such as demining of paths and berms.

Conclusion

A free fall of an array of chains with a mass density of several hundred kg/sq m generates several bars of pressure in the ground, which is enough to trigger most buried AP mines up to 20 cm. This demining tool can also be used to reduce mined areas before using manual clearance; to detonate deeply buried mines, i.e., in sand or along river banks; or for control purposes of areas cleared with other techniques.

See endnotes page 67

Many thanks to Gilbert and François Schurrer, who warmly welcomed researchers into their farm and provided a tractor equipped with a hydraulic arm to lift the chains as well as an appropriate area containing sand and gravel.

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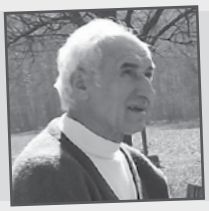

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