



**International Test and Evaluation
Program
for Humanitarian Demining**

Lessons Learned

**Test and Evaluation of Mechanical Demining Equipment
according to the CEN Workshop Agreement (CWA
15044:2004)**

**Part 1: The effect of soil condition on measurements of
ground penetration depth and machine performance**

ITEP Working Group on Test and Evaluation of Mechanical Assistance Clearance Equipment
(ITEP WGMAE)

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Background

Since the inception of the CWA 15044:2004 many machine trials have been performed and lessons have been learned about how best to perform the tests. Perhaps the most significant lesson is in the area of soil conditions and the effect of these conditions on measurements of machine performance and ground penetration depth. This document attempts to convey the main aspects of this experience. Most of the experience is born of mistakes and the normal evolution of test methods.

Obviously, the discussion about ground penetration applies almost exclusively to ground penetrating machines such as flails and tillers.

The hardness of the ground plays a major part in determining the ability of a machine to penetrate to a given depth. In very hard ground the machine will be less capable and in softer ground the machine will be more capable. By extension, if there are soft spots or soft zones in a section of hard ground, the machine will be able to penetrate better in those soft spots/zones than in the surrounding hard ground. If the desire then, is to measure the ability of the machine in the hard ground, it is important not to compromise the data by creating soft spots/zones in the area where the measurements are to be taken.

Ground Penetration Depth Measurements

Different methods can be used to measure the ground penetration depth of the machine working tool. The method which shall ultimately be selected depends on the type of test (performance test, acceptance test), the ground conditions (hard, soft) and the logistics.

Direct Measurements

If the ground is hard and dry, the ideal way to measure ground penetration depth is to run the machine over a piece of ground, sweep away the loose soil which covers the processed area, and measure down from a straightedge to the untouched soil surface as shown in Figure 1. Taking several measurements across the width of the machine path, provides a snapshot of the penetration depth at that location. Taking several such snapshots along the path gives a more complete picture.

This is the easiest, fastest, and most reliable way of collecting information about the ground penetration ability of a machine, whether during Performance Tests, Acceptance Tests, or even informally when a machine is moved to a new location with different soil conditions. It is important, however, that enough measurements be taken at each location. We are concerned mostly with small antipersonnel mines. This implies that measurements should be taken at intervals of approximately 1/2 of the mine width, or about every 25-35mm.



Figure 1 – Measuring ground penetration depth directly

Indirect Measurements

It may not always be possible to sweep away the loose soil without disturbing the underlying, untouched soil. In these cases a method of measuring the depth indirectly is needed. It was for this purpose that the fibreboard measurement technique described in the CWA 15044 (Annex 1, Paragraph 2.6) was developed. In this technique, thin sheets of a frangible material (such as fibreboard) are inserted into the ground, on edge, across the path of the machine. When the machine processes the area, the hammers or teeth cut away portions of the fibreboard. What remains of the fibreboard can be recovered following the test. Each fiberboard provides a snapshot (see Figure 2) just like the direct measurements.



Figure 2 – Measuring ground penetration depth indirectly using fibreboards

Proper installation of fibreboards is critical in order to obtain a realistic representation of the ground penetration depth of the machine tool. While simple in concept, the use of fibreboards can be difficult in practice, especially outside of test facilities where certain equipment is available. In the background discussion above, it was stated that it is important to avoid creating a soft zone in the area where you are trying to make measurements. Intuitively this makes sense, but the importance is often overlooked when fibreboards are placed for a test.

If fibreboards are to be used to measure ground penetration depth correctly, it is critical to avoid creating soft zones near the fibreboards. Figure 3 shows an acceptable method of installing fibreboards in which a very narrow slit is created and the fibreboard is inserted into the slit.

By contrast, Figure 4 shows a problematic installation of a fibreboard which produced an incorrect measurement of the ground penetration depth. For the installation of the fibreboard in the very hard and dry soil, small shovels were used to dig a narrow trench in which the fibreboard was inserted. The soft zone, created by the refilling of the trench around the fibreboard, was easy to penetrate for the flail hammers. Hence, while the flail hammers were having difficulty with the surrounding hard ground, they managed to penetrate the fibreboard trench to the full depth of the fibreboard. Viewing the results from the fibreboard would lead to the impression that the machine was penetrating uniformly and deeply. When direct measurements were made in a location away from the fibreboard trench, the results were clearly very different, showing irregular and at times very shallow penetration.

To summarize, fibreboards or similar indirect measurement techniques can be very useful in testing the ground penetration of certain demining machines. It is critical, however, that they be installed in such a way that they do not distort the information by creating soft spots/zones around the fibreboard.



Figure 3 – Proper fibreboard installation



Figure 4 – Improper fibreboard installation producing misleading results.

Performance Test - Soft Holes in Hard Ground

One of the criticisms of CWA 15044 is that it places tight restrictions on the soil conditions for the Performance Tests. These conditions make it difficult or even impossible to execute the Performance Tests anywhere except in established test facilities.

The ITEP demonstration trial of two flails, which took place in Nairobi using test lanes with unprepared local soil, has shown that strict control of the soil conditions is essential to obtain valid performance results (see final trial report at <http://www.itep.ws/pdf/NairobiFinal.pdf>)

The Nairobi trial showed that when target mines are placed in very hard soil, they create localized soft spots in the surrounding hard ground. This was alluded to earlier in the discussion about how to install fibreboards properly. In the Nairobi tests a curious disconnect was found between the number of test mines triggered and the apparent (in)ability to penetrate the soil shown by the measured ground penetration depth. That is, both machines neutralised a very high percentage of the mine targets, while at the same time doing a remarkably poor job of penetrating consistently and uniformly to the depth necessary to engage those same mine targets.

In creating an artificially laid mine-lane for testing, holes are dug into which mine targets are placed, and soil is then poured in on top of the mines to cover them. Ideally, the loose soil will be allowed to compact and coalesce with the surrounding undisturbed soil over the course of several years to replicate real minefield conditions. This is not practical for most machine tests, and no practical way of quickly aging the loose soil has been discovered. Hence, for such trials, the soil on top of the mines is very soft, especially in comparison to the surrounding, extremely hard soil encountered in the Nairobi demonstration trial. To illustrate the problem, consider the imaginary example, shown in Figure 5, in which mines have been encased in a large block of concrete. At one spot, a mine has been placed in a hole in the concrete, which has been backfilled with a layer of soft leaves. In the first panel of Figure 5, a single flail hammer approaches the hard concrete surface. When it hits the surface, it bounces as shown in the second panel, perhaps chipping the surface, and is pulled around for another strike. With the very hard surface, the hammers have limited surface penetration, and the effectiveness against the mines is minimal. In panel 3 the hammer has reached the soft, leaf-filled hole. Of course, it plunges deeply into the hole and triggers or breaks the mine. If the hole is very deep or very narrow, it is more difficult for the hammer to reach the mine, but it is a very easy target if the hole is relatively large and shallow. Finally, in the fourth panel, the hammer has moved on and is prepared to resume the chip-and-bounce process as it hits the hard surface again. Very clearly, the results with the mine in the soft hole are not representative of what the machine is doing to the mines under the hard surface.

While the mines were not encased in concrete in the Nairobi test lanes, the imaginary example is actually reasonably close to the situation that was encountered. Consider the image in Figure 6. It is quite obvious that the flail hammers have achieved inconsistent and only relatively shallow penetration in the hard surface. Figure 7 demonstrates that at least some of the apparently deeper hammer penetration is due to the mine burial holes themselves. The deepest part of this particular profile still has the remains of the sand used to fill the hole. It was not possible to determine whether all of the deepest penetrations were due to the mine burial holes.

While the example of Figure 5 is admittedly extreme and unrealistic, the photographs shown in Figure 6 and Figure 7 demonstrate that the example actually tells the story in an accurate way for the real-world situation encountered when mine targets are buried in hard soil as was the case in the Nairobi demonstration trial.

This discussion applies for any kind of test target, whether one is using inert WORM targets, real mines, SWEDEC live-fuze targets, or any other mine surrogate or stimulant. The problem is not the mine target itself, but rather the hole needed to bury the target.

One might reasonably ask whether all trials conducted in which the mines are placed in holes which are soft, relative to the surrounding soil, are therefore suspect. The answer is that it will depend on the capability of the machine and how hard the surrounding soil is. If the soil is hard enough that the machine cannot reliably cut to the depth necessary to engage the mines, then yes, the data at that depth of burial might be suspect if it shows an apparently good rate of kill. On the other hand, if the machine is able to penetrate the surrounding soil, then one can conclude that the machine is actually engaging the mines and the mine target data is valid.

This all means that when the surrounding soil is extremely hard, and the mines are covered with soft soil in oversized holes (as was the case for Nairobi demonstration trial), then test data will be prone to give artificially high performance indications. It is therefore critically important to evaluate the ground penetration depth measurements to see whether the machine is indeed penetrating uniformly, and to the necessary depth. If the ground penetration depth measurements show a smooth profile and a consistent ability to dig to a given depth, then the data from the mine targets is probably realistic. If the ground penetration depth profile is uneven, it suggests that the soft holes are compromising the performance results obtained from the mine target data and that the obtained clearance rate might be biased. In this case, the ground penetration depth profile provides the more valid measurement of performance.

In addition to the questions posed in above, one might ask about the soft holes in the comparably hard soil of the properly prepared test lanes for a Performance Test – is the mine target data not also suspect? As noted above, the ground penetration depth measurements should be taken into consideration in evaluating this possibility, but there is a separate, and perhaps more important consideration. In these tests, the soil conditions are consistent, within the prescribed limits, from one machine test to the next. As a result, even if the clearance rates are artificially high or low, the conditions are *the same for every machine* and therefore the results can be compared for every machine. When the tests are moved out of standardised test lanes and performed 'in the field' the conditions are no longer the same and the results are no longer comparable.

The conclusions of the soft holes in hard soil discussion may be summarized as follows: (i) no reasonable way has yet been found to move the CWA 15044 Performance Tests out of the specialised test facilities; (ii) mine targets placed in very hard soil (for any type of test) may give highly misleading, and unreasonably optimistic results; and (iii) mine target data should be viewed in combination with the ground penetration depth information.

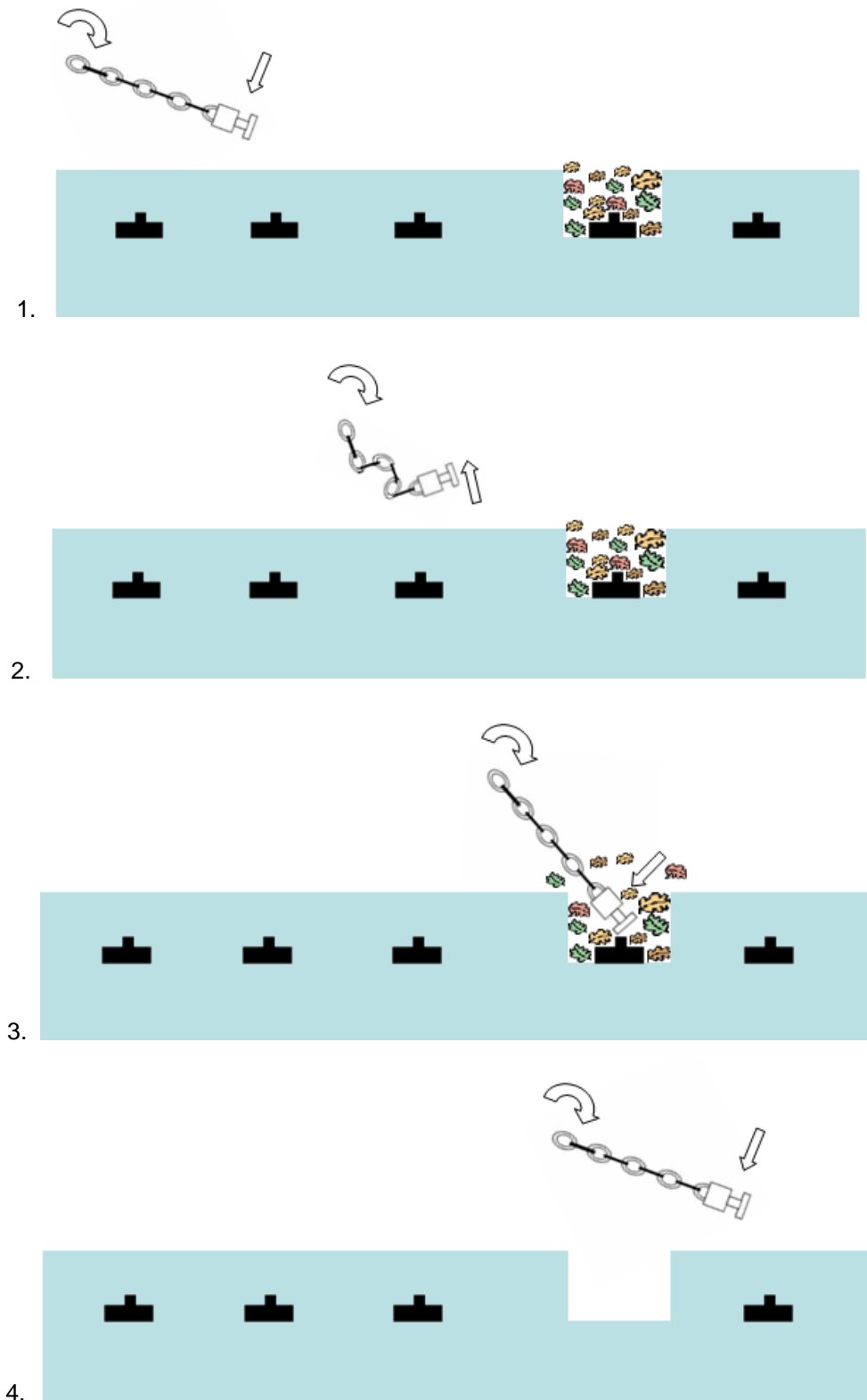


Figure 5: Hammer Strikes on Hard Surface – Hypothetical Example



Figure 6: Poor hammer penetration in hard surface



Figure 7: Deep Hammer Penetration in Soft Holes