CWA 15044 Test and Evaluation of Digger D-250

May 2014.

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Abstract

A test of the Digger D-250 was on request from the manufacture Digger DTR performed in Sweden by SWEDEC in May 2014. Performance and survivability tests were done in accordance with the European Committee for Standardisation (CEN) Workshop Agreement ”CEN Workshop Agreement 15044; Test and Evaluation of Demining Machines”, available at Geneva International Centre for Humanitarian Demining website (www.gichd.org). On request by the manufacturer the survivability test was extended using not only an 8 kg antitank mine but also two 5 kg AT-mines.

Executive summary

During the last week of May 2014, the Digger D-250 was tested at one of SWEDEC facilities – the Norra Kulla Test Site - near Eksjö, Sweden. This test was planned and facilitated by SWEDEC. The methodology specified in CEN Workshop Agreement”CEN Workshop Agreement 15044; Test and Evaluation of Demining Machines” was used. It started with a performance test and ended up with an extended survivability test. The machine was tested with a tiller tool. These tests make the content of this report. The tracked, remotely controlled Digger D-250, weight approximately 12 tonnes, fits into what is normally regarded as the medium class of machines (6-20 tonnes).

The Digger D-250 with equipped with tiller triggered or neutralized 441 out of 450 mines, 98 % of the targets. The machine detonated 375 of 450 mines with the tiller.

One observation from earlier tiller tests is that a tiller in some cases depending on the soil can move a mine without triggering it. This could be an explanation to what happened during the test o flat surface laid mines in the top soil lane when only 11 of the 50 detonators were triggered. However, the result from this test was that 49 out of 50 mines were not functional (detonated or neutralized).

The penetration of the witness boards during the tests where as expected for a tiller tool quite even without any variation (chapter 4). The machine has always been clearing to the required depth and deeper than strictly necessary.

The tendency to clear deeper than necessary as seen on the witness boards was done by purpose by the manufacture because based their experience the hit angle on the mine is important. Digging depth approximately 8 cm below the top of the mine has shown to be optimal in order to ensure high triggering rate.

The survivability test was on request from Digger extended by having two different sizes of AT-mines, 5 kg and 8 kg of TNT equivalent explosive weight. The CWA stipulated target used during the test was the Swedish Anti-Tank Mine 41-47 boosted with plastic explosive, giving a total of 8 kg of TNT equivalent explosive weight.

During the survivability test, two tillers have been tested. The first one has been designed for AP mine clearance but it was tested on an AT mine to see if it could resist that kind of detonation. The second tiller had a stronger construction made for AT mine survivability.

The result after the first AT mine detonation (5 kg) was that the tiller shaft was bent and had some damage. However the frame of the tool was not affected. The machine itself except for the leakage showed only smaller damages from metallic scatter.

The manufacturer changed the tiller shaft a put on a stronger one. The result after the second 5 kg AT mine detonation was only minor repairable damages. Then the machine was tested against the CWA 8 kg mine resulting in more damages on some parts of the tiller which was reparable. However an oil leakage from the hydraulic system was noticed. This fault was caused by untightened pipe connector and the chock from the detonation. These errors were also repairable and the leakage was easily fixed by re-screwing the affected pipe connector.

Table of Contents

Test Data Sheets (not included in this report) are available on request from SWEDEC.

1. Introduction

During the last week of May 2014, the Digger D-250 was tested at one of SWEDEC facilities – the Norra Kulla Test Site - near Eksjö, Sweden.
Agreed tests to be carried out according to CEN Workshop Agreement 15044:2004 were Performance Test and an extended Survivability Test.
These tests, planned and facilitated almost entirely by SWEDEC, were requested and partially funded by Digger DTR, the manufacturer of the machine.

An overall description of the test facilities, the test targets and the test methods are given in chapter 6. This information is relevant to any machine tested at this site.

2 Machine Description

2.1 DIGGER D-250 Medium weight Multi-tool Mine Clearance System

The Digger D-250 medium weight flail/tiller system (figure 1) is a remotely controlled (figure 2) tracked mechanical mine clearance machine, operated within visual line-of-sight by the operator.

Different tools (tiller, flail, manipulator arm, and gripper) can be attached to the Digger D-250. During this test the Digger D-250 was only equipped with the tiller tool (figure 3).

The operator controls the machine from a man-portable transmitter unit using visual observation of the machine.


Figure1. Digger D-250


Figure 3. Tiller tool


Figure 2. Remote Control

3. Trial Description

3.1 Test Team

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Joachim Engblom, SWEDEC
Tobias Andersson, Ing 2
Jonathan Ek, SWEDEC
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Dir. of Research Curt Larsson, SWEDEC (test advisor)

3.2 Trial Conditions

A complete description of the test areas, facilities, tools and the test procedures can be found in chapter 6.

Soil compaction levels (actual) can be found in the test data sheets not included in this report but available from the Test protocols on request from SWEDEC.

To summarize the soil conditions[1] for the Digger D-250 test are indicated below:
- Sand: 90% (1.8 kg/dm³)
- Gravel: 94% (2.0 kg/dm³)
- Topsoil: 85% (1.7 kg/dm³)

Depths, number of mines and witness panels:
- Depths tested in each soil: 0 cm, 10 cm and 15 cm DOB[2].
- Number of test target mines at each depth: 50
- Witness panels included with each set of 50 targets: 3 - one at the start, one at the mid-point and one at the end of each test lane.

4. Test Results

4.1 Results against mine targets

This section summarizes the performance of the machine. In addition to simply tabulating numbers, the data is given a statistical treatment as suggested by the CEN Workshop Agreement.

[1]Soil compaction levels (intended)
[2] DOB = Depth Of Burial as defined in chapter 6.4

4.2 Tabular Data and Explanations

Table 1 and 2 shows the number of mines that were triggered, the number of mines with separated detonators (neutralized), and the number of intact mines at each depth and in each soil condition. This table also indicates the number of untriggered detonators which were found separated from their main charges. In total the machine run over 450 mine targets, 50 mine targets at each depth.

During each test, at least three people were responsible for counting the explosions of detonators. When a test had been completed, any remaining detonators were sought, detected using metal detectors, marked, removed and taken care of (neutralized). In case the fuses can't be found right away additional steps can be taken - the soil can be turned over twice with a farm plough.

Table 1. Mine targets triggered, separated detonators and whole mines, with tiller tool.

	0cm			**10cm**			**15cm**		
	Triggered	*Separated detonators*	*Intact mine, Live*	*Triggered*	*Separated detonators*	*Intact mine, Live*	*Triggered*	*Separated detonators*	*Intact mine, Live*
Sand	*39/50*	*7*	*4*	*47/50*	*2*	*1*	*44/50*	*5*	*1*
Gravel	*45/50*	*4*	*1*	*48/50*	*1*	*1*	*50/50*		
Topsoil	*11/50*	*38*	*1*	*43/50*	*7*		*48/50*	*2*	

The numbers in table 1 are taken from the test protocol. This table shows detonated mines with those left damaged, non-functional. There were 50 targets for each test condition.

The machine triggered 375 of 450 mines with the tiller. 9 mines were left live and intact, and 66 were neutralized with live detonators separated for the main charge.

First assumption for the result (non-triggered detonators) could have been that the automatic control system was not always able to maintain the digging tool in a constant position. Consequently, the oscillating depth variations of the digging tool could then have affected the result, see figure 4.

However the time needed for the system to adjust itself only takes a second. During that short time frame there is very little chance that the tiller is on a target and it should therefore not be a problem since the tiller is according to witness boards still digging deep enough. A more likely explanation is that when the tiller hits a mine on its edge, the mine will rotate and the detonator is not activated by the tiller. However the mine is most often neutralized anyway since it is broken apart and the detonator is separated from the main charge.

To shortly summarize what was observed seeing the bumps in figure 4, is that the oscillations don't seem to have any real impact on the clearance result. On the other hand the "edge hit" phenomena can be seen in the numbers because when a mine isn't well maintained in the ground like in sand 0cm. This was also when more escaping mines were observed. From that point, if one goes deeper one gets less live mines and if one goes for harder grounds the mine will be better maintained. One can also see this in the numbers from sand (6 live) to gravel (2 live) to top-soil (1 live). The conclusion is that the "edge hit" phenomenon is the likely reason of why mines are escaping.

Figure 4. Oscillations on surface after the machine in the gravel lane.

4.2.1 Debris and Scatter

When a demining machine (as the Digger D-250) engages a mine target it may leave the mine in a number of different conditions. The target may be left intact and fully functional or it may be intact but damaged. It may also be slightly damaged or completely broken apart.

After each test in the series, the test lanes were searched as described above, and the materials of interest were assembled and inspected. These materials included detonators, detonator components, intact mine targets, and mine bodies with most of or the entire (inert) main charge intact. The photos in figures 5-13 show the collected debris.

Figure 5, Sand 0 cm, TILLER

Figure 6, Sand 10 cm, TILLER

Figure 7, Sand 15 cm, TILLER

Figure 8, Gravel 0 cm, TILLER

Figure 9, Gravel 10 cm, TILLER

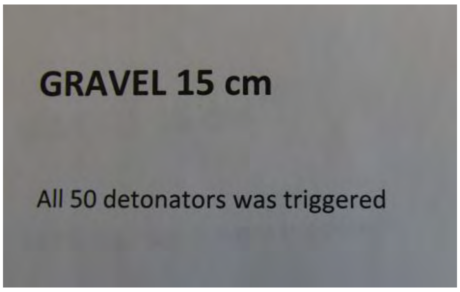


Figure 10, Gravel 15 cm, TILLER

Figure 11, Topsoil 0 cm, TILLER

Figure 12, Topsoil 10 cm, TILLER

Figure 13, Topsoil 15 cm, TILLER

4.3 Depth and Consistency of Penetration

4.3.1 General

Fibreboards were used to measure the depth and consistency of penetration across the path of vehicle. Examples are shown in figure 14- 40.

Sand witness board: mine DOB = 0 cm (surface), **TILLER**:

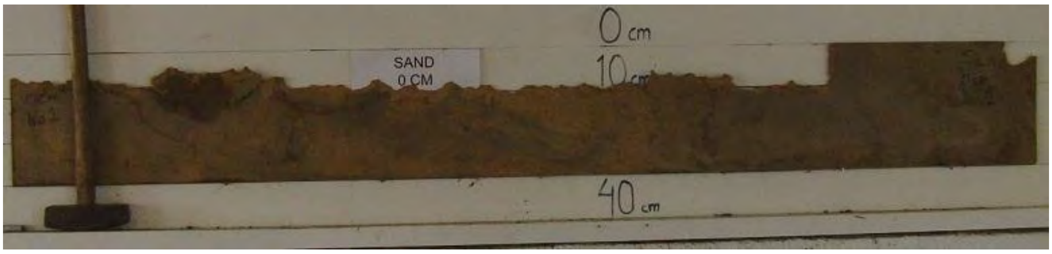


Figure 14. Sand 1, 0 cm

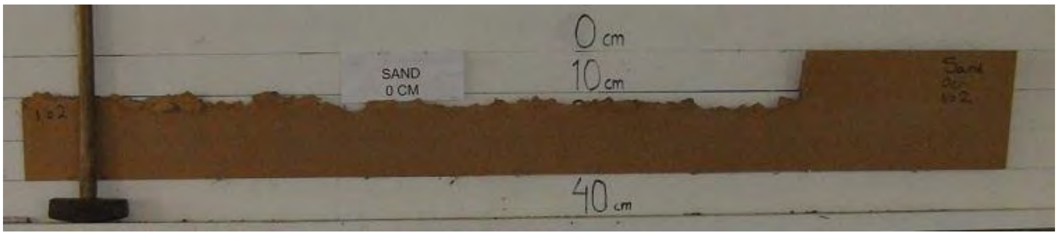


Figure 15. Sand 2, 0 cm.

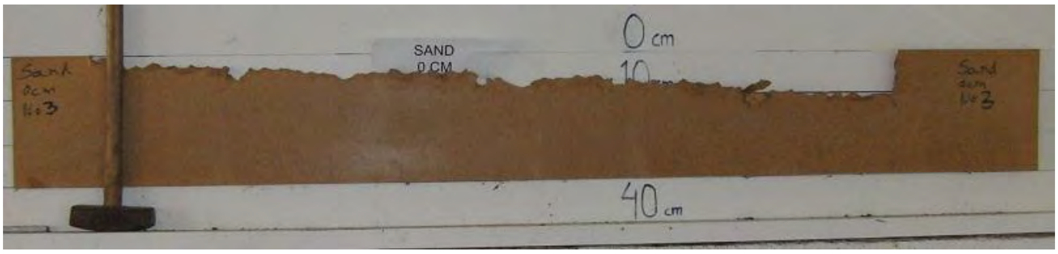


Figure 16. Sand 3, 0 cm

Comment:
The first board shows some variations over the width. The second board had a depth down to 9 - 13 cm. However board three shows more depth variations between 2-3 cm and down to 10 cm. This is a large variation during the length of 25 m between board one and the third board. The tiller tool seems to be digging more on its right side than the left. . This typically happens in side slopes variations terrains. The left track goes on a bump and the entire tiller rotates laterally. But this situation has been observed for all machines that have no roll angle correction between the tool and the prime mover. This lane also shows some bumps on the surface but it is not visible on the fibre boards.

Sand witness board: mine DOB =10 cm, **TILLER**:

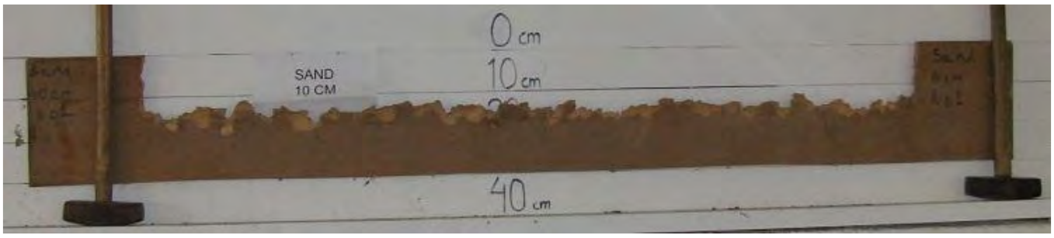


Figure 17. Sand 1, 10cm

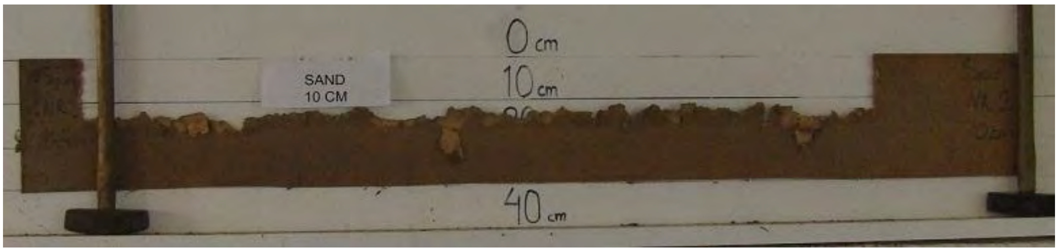


Figure 18. Sand 2, 10cm

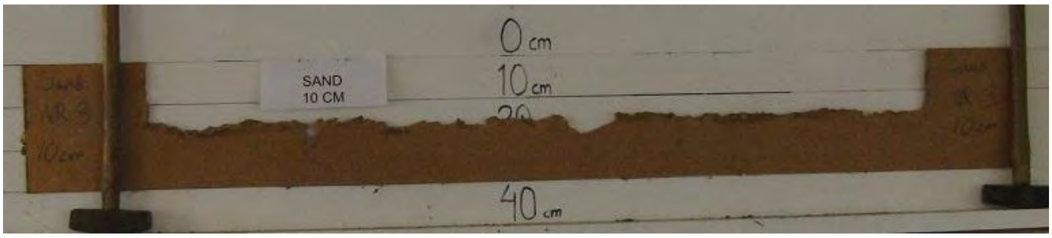


Figure 19. Sand 3, 10cm

Comment:
The clearance depth was down to more than 10 cm. The cutting profile is straight and horizontal.

Sand witness board: mine DOB = 15 cm, **TILLER**:

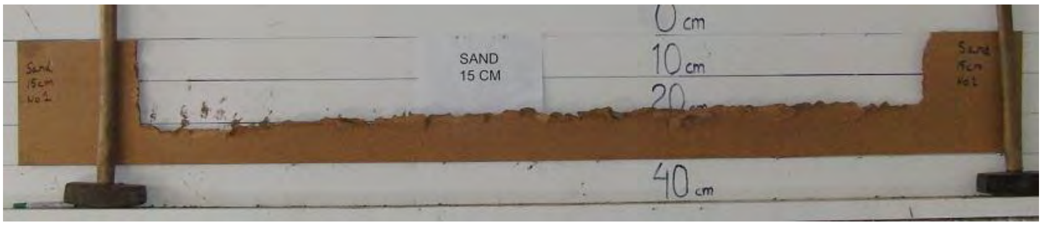


Figure 20. Sand 1, 15 cm

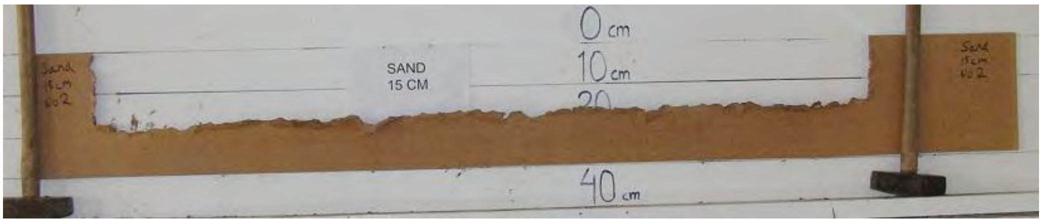


Figure 21. Sand 2, 15 cm

Figure 22. Sand 3, 15 cm

Comment:
The clearance depth was down to 15 cm or more. A slight right to left side inclination can be seen here.

Topsoil witness board: mine DOB = 0 cm (surface), **TILLER**:

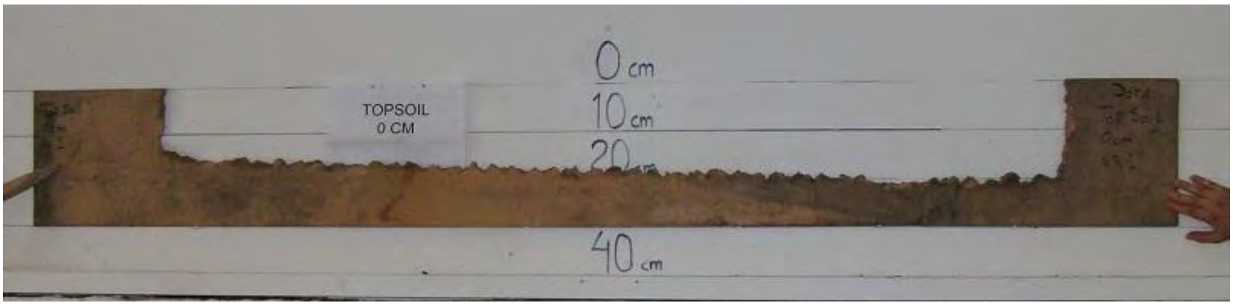


Figure 23. Topsoil 1, 0cm

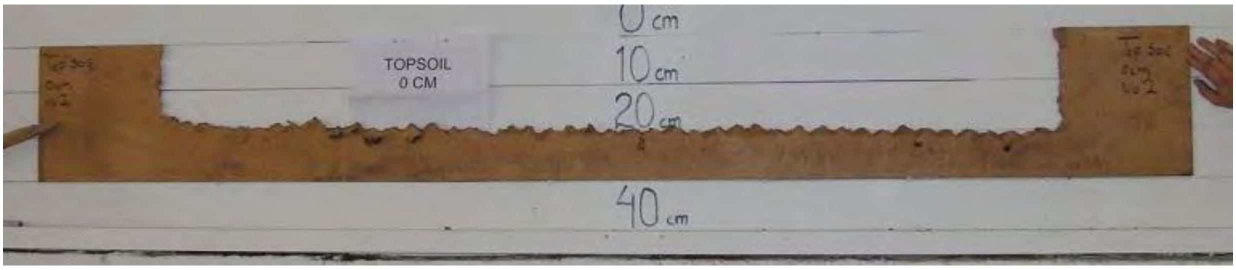


Figure 24. Topsoil 2, 0 cm

Figure 25. Topsoil 3, 0 cm

Comment:
Clearance depths down to 15 cm or below. However two of the boards (first and second) show an inclining line from left to right.

<u>Topsoil witness board: mine DOB =10 cm, **TILLER:**</u>

Figure 26. Topsoil 1, 10cm

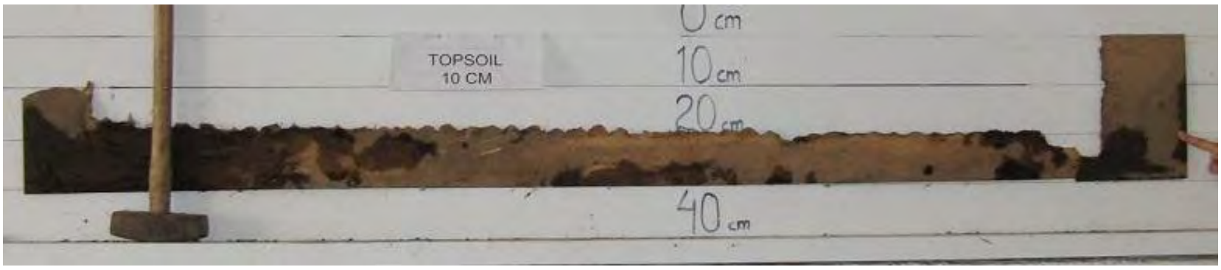


Figure 27. Topsoil 2, 10cm

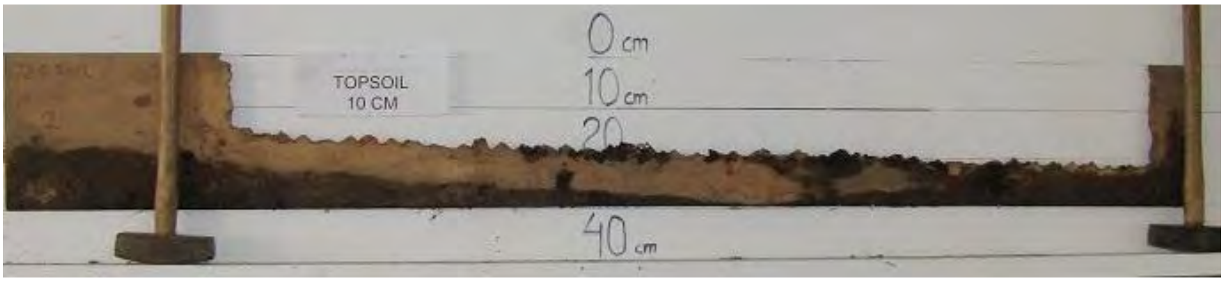


Figure 28. Topsoil 3, 10cm

Comment:
The first board shows a penetration depth down to 20cm. Board two and three had a depth down to 15-20cm. Two of the boards had a straight profile while the third shows an inclination from left resulting in a clearing depth between 12-20 cm.

<u>Topsoil witness board: mine DOB = 15 cm, **TILLER:**</u>

Figure 29. Topsoil 1. 15 cm

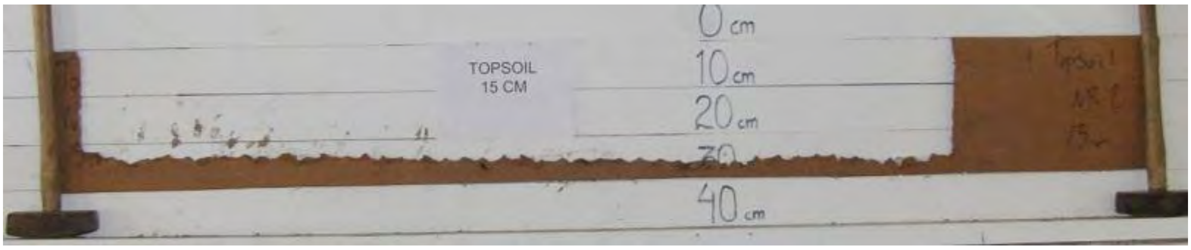


Figure 30. Topsoil 2. 15 cm

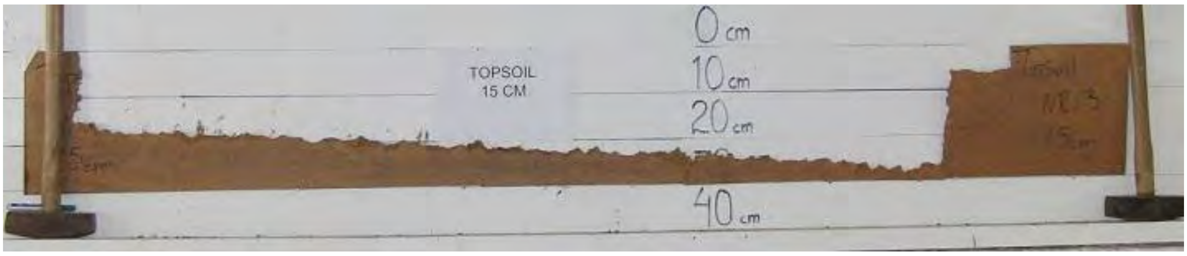


Figure 31. Topsoil 3. 15 cm

Comment:

The first and the third board had a penetration down to 20-25 cm; the second board had a penetration down to 27–28 cm. The third board was penetrated down to15-27 cm. All boards show some inclination from left to right.

<u>Gravel witness board: DOB = 0 cm (surface), **TILLER**:</u>

Figure 32. Gravel 1. 0 cm

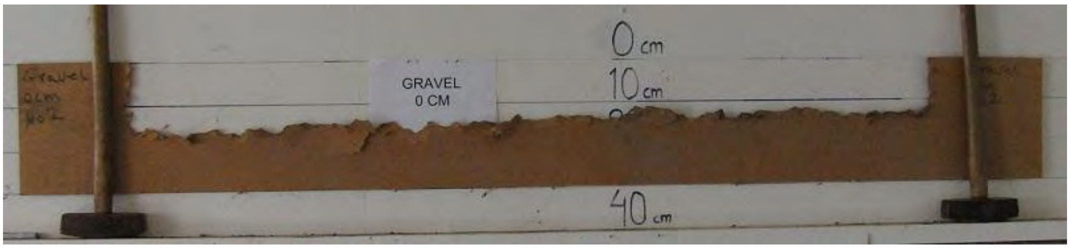


Figure 33. Gravel 2. 0 cm

Figure 34. Gravel 3. 0 cm

Comment:
All boards had a straight penetration down to 10 cm or below. An observation is, recalling the earlier discussion concerning oscillations on the gravel surface after the machine (figure 4), is that one cannot see any indications of that phenomena on the witness boards.

<u>Gravel witness board: DOB = 10 cm, **TILLER:**</u>

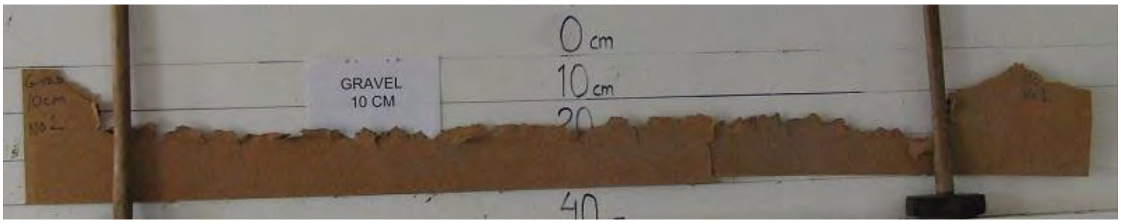


Figure35. Gravel 1. 10cm

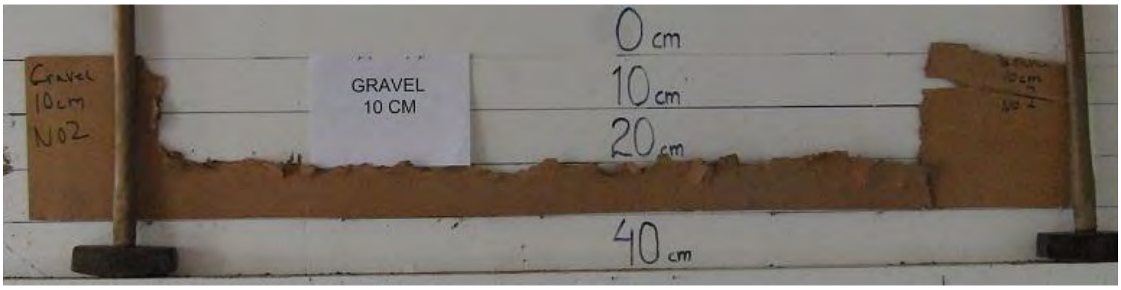


Figure 36. Gravel 2. 10cm

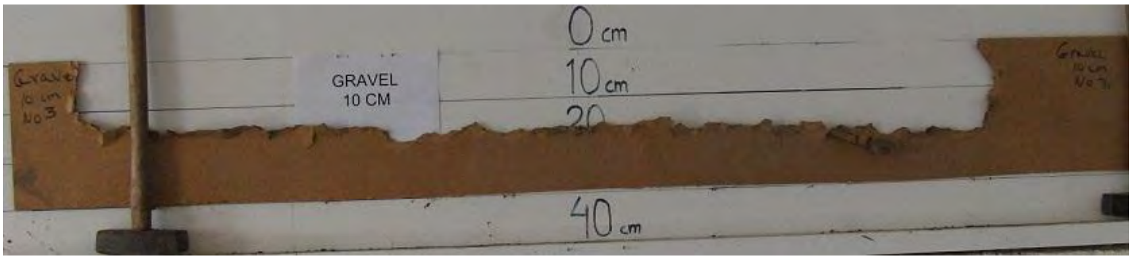


Figure 37. Gravel 3. 10cm

Comment:
All boards had a straight penetration well below 10 cm

Gravel witness board: DOB = 15 cm, **TILLER**:

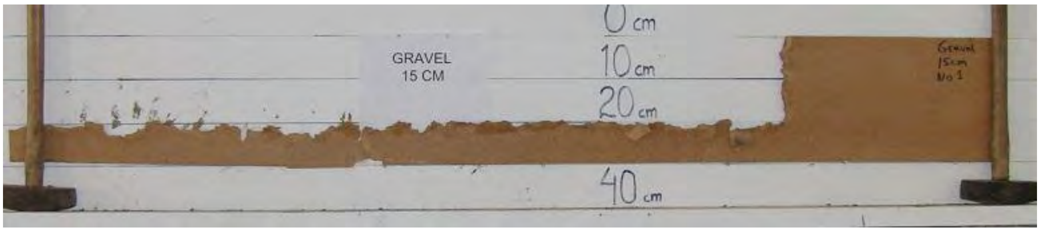


Figure 38. Gravel 1. 15 cm

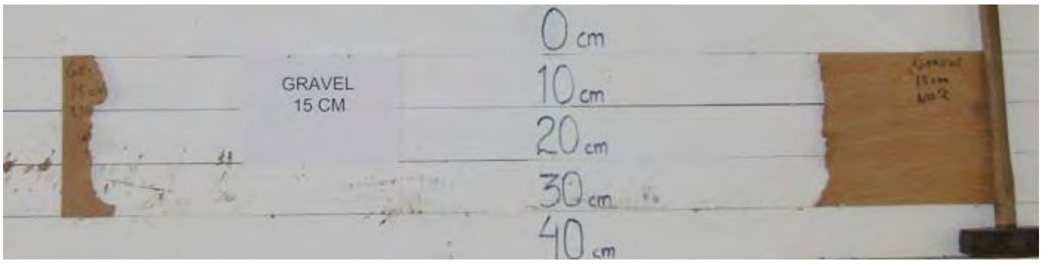


Figure 39. Gravel 2. 15 cm

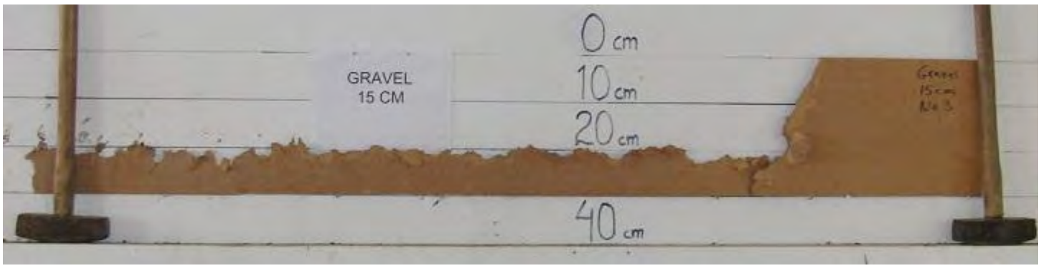


Figure 40. Gravel 3. 15 cm

Comment:

All boards had a straight penetration down to approx. 20 cm. However since the machine doesn't dig deeper than 25 cm (at 25 cm the tool frame is on the ground surface) a piece of the witness board in figure 39 must be missing.

Summary Witness board

The machine has a ground levelling system with depth sensors and an automatic regulation for keeping the tiller at a certain depth. The maximum depth penetration was set to 23 cm for DOB=15 cm, 18 cm for DOB=10 cm and 10 cm for DOB=0 cm.

On some of the witness boards an inclination is shown. Almost all of the inclined profiles were observed in the topsoil lane (except the last for sand DOB=0 cm) and this behaviour is observed on each depth. While doing topsoil DOB=10 cm, it was raining and for topsoil DOB=15 cm the soil was quite wet due to the rain during Sunday. This inclination could be explained if the soil is getting more muddy on the right side of the lane because then, the right track is going deeper in the ground and the whole machine inclines on the right side.

There are only two possibilities to explain an inclined cutting profile physically:

1) The machine follows the ground side slopes variation with a delay compared to the tool. So when the machine, following the ground inclination is rolling on the right side, maybe the tiller is on a flat region because it is more than 1 m in front of the tracks and the cutting profile shows a right side inclination.

2) The machine rolls right if the ground under the right track is softer than the one under the left track even if the ground is perfectly flat.

In this case the second possibility is the most reasonable one for the wet topsoil lane. A measurement of the compactness of the lane was not done after the rain and for sure it would have shown less hardness due to higher water content. It was also observed that water accumulated on the right side when raining. This would probably add to the explanation of the inclination from left to right on the witness boards. However, the observed inclination had, according to facts in table 1, no impact on the clearance performance of the machine.

5. Survivability Test

The CEN Workshop Agreement methodology calls for survivability testing using antipersonnel and/or antitank mines. Anti-personnel mines are required to test all machines for susceptibility to damage from normal operational conditions created by triggering anti-personnel mines. Machines which are advertised for use against anti-tank mines are also required to be tested against anti-tank mine charges to ensure that they are capable to absorb anti-tank mine blasts without undue levels of damage.

5.1 Trial Descriptions

The test facilities for survivability testing near Eksjö have been used to test different types of equipment in recent years. The blast range includes a gravel bed 4 m wide and 20 m long. The bed contains compacted sand. The lane is located at an angle of about 75 degrees from the safe house. The operator manoeuvres the machine from the safe house and can decide both forward speed and course. The Digger D-250 did clear three Anti-Tank mines with the tiller. One high speed camera was used during the tests.

5.2 Anti-Tank Mine

According to the CEN Workshop Agreement the mine should have a net explosive weight of 8 kg. The anti-tank mine used in this trial was the standard Swedish m/41-47 mine. The total weight of the m/41-47 mine is 6 kg and it contains 5 kg of TNT. The mine was boosted with plastic explosive which corresponds to 3 kg TNT giving an AT-mine with a TNT equivalent explosive weight of 8 kg.

5.3 Test Methods

Following preparation of the test lane and installation of the mines as described above, the machine was prepared for a test run. The machine was positioned about 5 metres in front of the start of the test lane to allow the operator to get the machine operating in a consistent stable manner prior to the start of the lane. The camera was started and all personnel went into the safe house.

The operator started to tiller the ground. The mine was triggered by the rotating tiller. After the detonation the operator was told to stop the machine. The result from the detonation was first examined visually. When the test team was sure that no major damage or leaks had occurred, the Digger D-250 was started and all functions were tested.

5.4 Test Results

The survivability test was on request from Digger extended by having two different sizes of AT-mines, two 5 kg and one 8 kg of TNT equivalent explosive weight. The CWA target used during the test was the Swedish Anti-Tank Mine m/41-47 boosted with plastic explosive, giving a total of 8 kg of TNT equivalent explosive weight. One should also notice that this type of mine has a metallic casing giving a worse case when it comes to damage caused by splinter than a mine with a plastic casing.

The result after the first AT mine of a 5 kg AT-mine was that the detonation had impact on the tiller tool without damaging the other parts of the machine. The tiller shaft was bent and had some damage. This shaft had a single layer of 12 mm Hardox steel. If one had chosen to continue using this tiller tool the bending would cause damages on the belt drive.

The manufacturer decided that it was not possible to repair the shaft and replaced it with a new and stronger one (12 mm Hardox steel in two layers). However the frame of the tool was not affected. The machine itself, except for the leakage, showed only smaller damages from metallic scatter.

The manufacturer changed the tiller shaft and put on a stronger one. The new shaft had a different design and should according to the manufacturer be approximately 4 times stronger. Time for repairs and changing the tiller toll was approximately 4 hours for one mechanic.

The result after the second 5 kg AT mine detonation was fragmentation marks on the tiller and one of the tooth supports was broken off. Two teeth were loose. The shaft was intact without any bending. New tooth support was welded on the shaft and everything was checked and ready after two hours. Some small oil leakage from the hydraulic system was also observed.

Then the machine was tested against the CWA stipulated 8 kg mine resulting in more damages on some parts of the tiller which was reparable. However more oil leakage of hydraulic oil caused by un-tightened hydraulic adaptor. After tightening it the leakage stopped. The Digger D-250 could be driven itself from the site by the operator.

After four hours of repairs of hydraulic system, the teeth supports including welding and replacement of missing teeth the machine was ready for use again.

Photos from the survivability tests.

Figure 41. Results after detonation number 1. 5 kg AT-mine.

Figure 42. Results after detonation number two. 5 kg AT-mine.

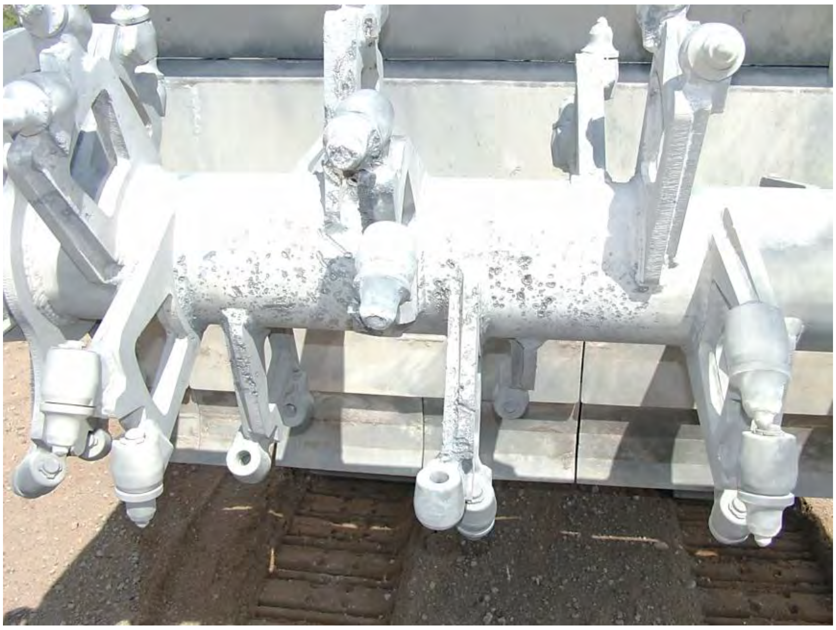


Figure 43. Results after third detonation. 8 kg AT-mine.

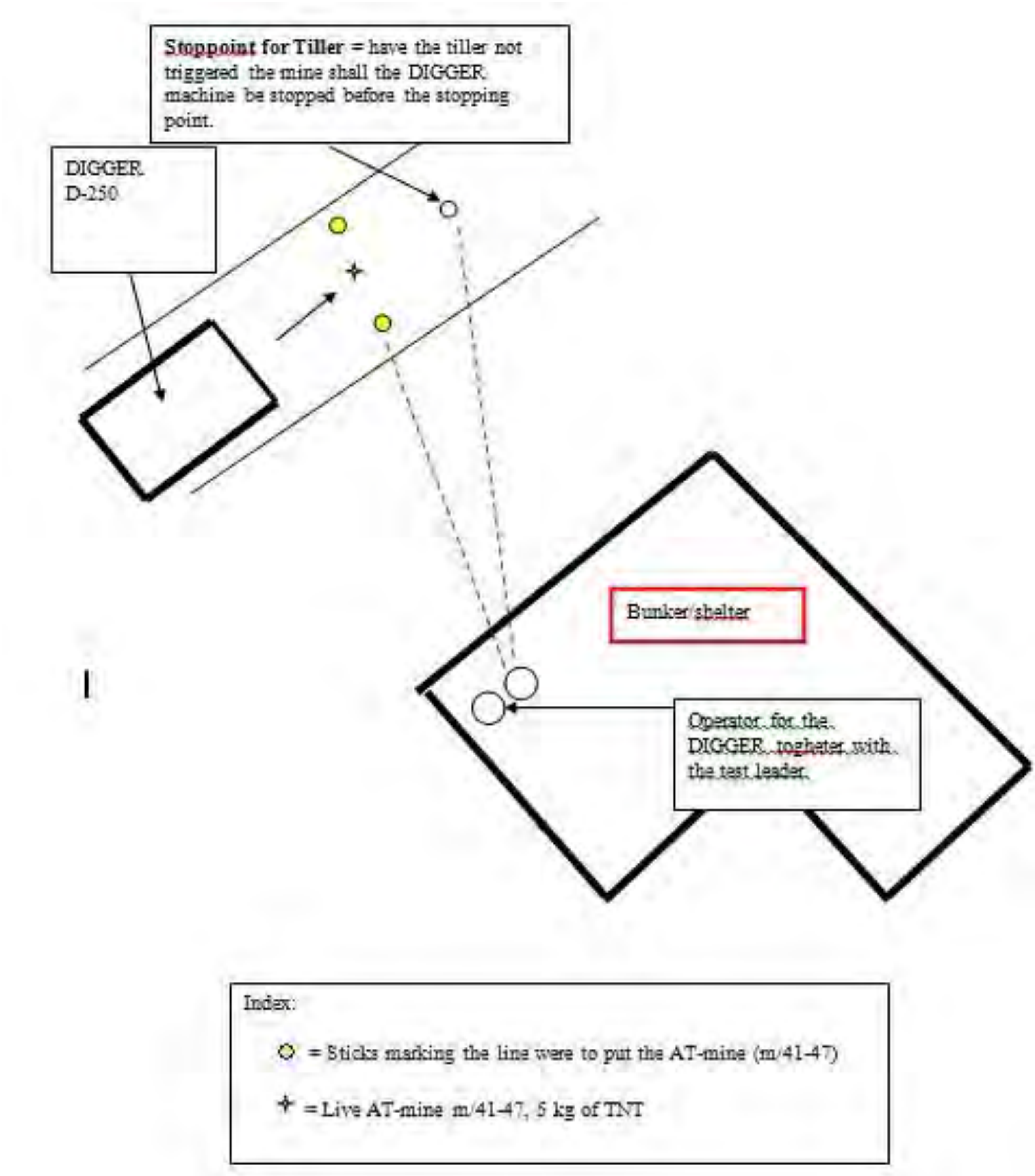


Figure 44. Sketch showing the arrangement for the survivability test with the D-250 at Demolitions Site no.1, Eksjö.

6 Test Facilities and Tools

The test facilities at Norra Kulla, near Eksjö, have been used to test various types of equipment in recent years. The site has three soil environments specifically for performance tests. Parallel lanes 5 m wide and 100 m long provide compacted sand, compacted gravel and compacted topsoil. The sand and gravel lanes are easily replicated almost anywhere. As the characteristics of topsoil may vary from one location to the next, data from the topsoil lane may not be quite as repeatable. The soil in each test lane is prepared as follows. Prior to a test the soil is loosened with ordinary agricultural or construction equipment, and then compacted using the vibratory compacter as shown in Figure 45-47. The soil compaction and moisture content are monitored until the compaction reaches a defined level for that soil type. Compaction and moisture content are measured using the CPN International model MC-3 Portaprobe, figure 48.

Figure 45. Preparations of test lanes. Step 1 - Ploughing the lane.


Figure 46. Step 2 – Running over the lane with a clod-crusher.

Figure 47. Step 3 – Compacting the lane

Figure 48. Step 4 - Measurement of compactness and moister content.

6.1 Soil Compaction

Ideally the soil would be compacted to virtually 100%, or its theoretical maximum level of compaction. This is very difficult to achieve and depends on the moisture content of the soil. Based on the results of soil analyses conducted for SWEDEC, the compaction levels shown below were selected to allow testing over a range of soil moisture contents, and are reasonable and practical approximations of well compacted soil.

· Sand: 90 % (1,8 kg/dm^3)

· Gravel: 94 % (2,0 kg/dm^3)

· Topsoil: 85 % (1,7 kg/dm^3)

An example of a soil analysis for the topsoil is shown in Figure 49. In this Swedish language chart, the horizontal axis refers to the moisture content (by weight), while the vertical axis shows the density, with a maximum occurring at 2,024 kg/dm^3. A 95 % compaction level (approximately 1,9 kg/dm^3) can only be achieved with soil moisture contents between 6 % and 12 %; this might restrict testing if the moisture content were out of range on a given day. As a comparison, compacting the topsoil to approximately 1,7 kg/dm^3 results in the soil reaching 85 % of its theoretical maximum compaction level. For the topsoil this is a useful target since it can be achieved without undue difficulty, and also because it is achievable over a wide range of moisture contents up to 18 % or greater. Similar analyses were done to select the compaction levels for the sand and gravel areas. Target compaction levels for the three soils were:

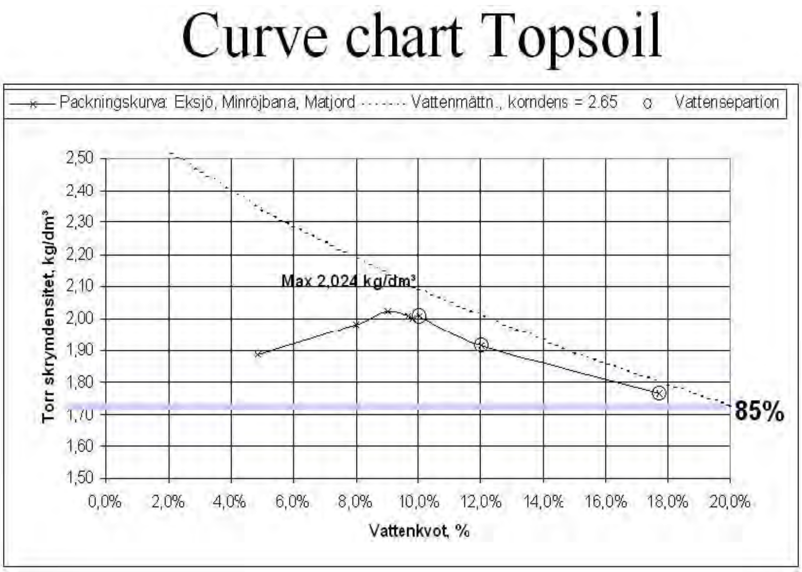


Figure 49. Top soil compaction as a function of water content.

6.2 Soil Particle Size Distribution

Samples from the sand, gravel and topsoil areas were analyzed to determine particle size distribution, with Figure 50 showing the results.

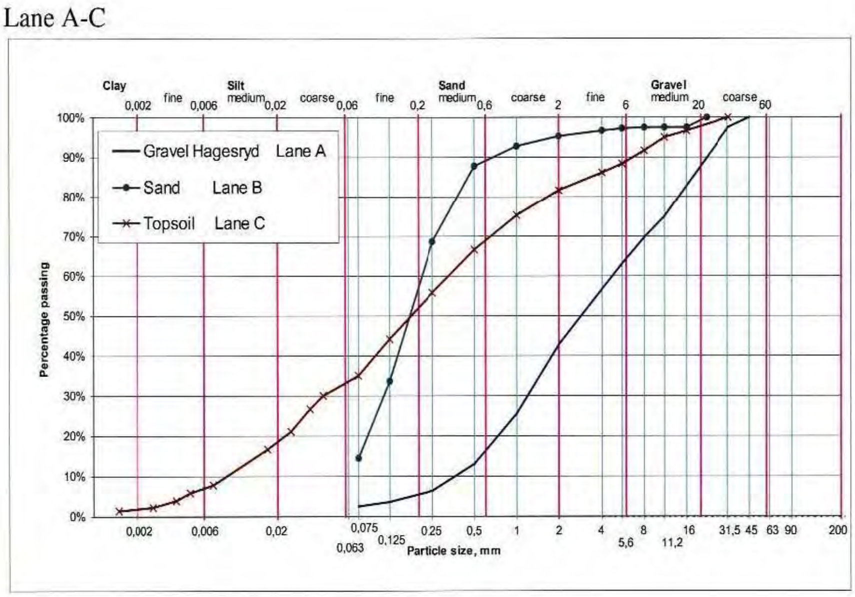


Figure 50. Particle size distribution

6.3 Test Targets

The test targets used in this trial were the standard SWEDEC mine surrogates shown in Figure 51 and 52. The targets make use of live detonators m/49B from the m/49 anti-personnel mine installed in inert, plaster-filled plastic bodies. These targets replicate many typical small antipersonnel land mines, which a machine might be expected to encounter.

For the trial, 50 targets are buried at each depth, in each soil. Based on three depths in each soil type, this translates to a total of 450 individual mine targets for a complete trial. To simplify the test procedures and data collection, each test comprises 50 targets, all at a single depth. Once that test has been completed, another 50 targets are placed at a different depth or in a different soil.
The targets are located approximately 0,5 m apart to minimize the effects of soil disturbance from one target to another. They are laid in a path whose width is approximately 50% of the width of the machine working tool.

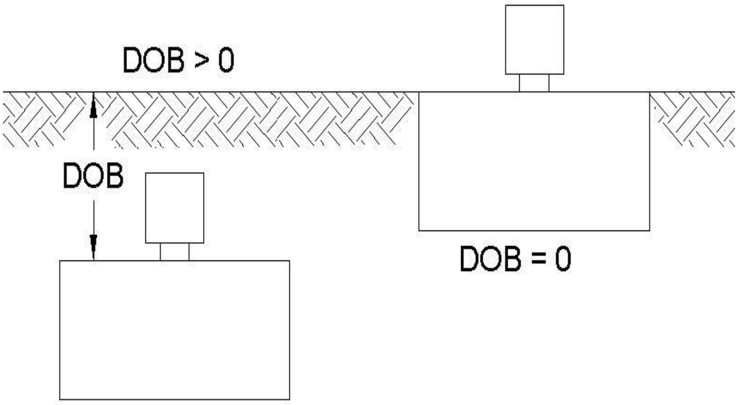
In other words, a machine with a 2 metre wide tool will have targets spread approximately 0.5m on either side of the machine centreline, for a total path width of 1 metre.

Figure 51

Figure 52

6.4 Mine Target Burial

The depth of burial (DOB) is measured from the top surface of the mine (not the top surface of the detonator), to the ground surface. Hence, a burial depth of 0 cm is illustrated in Figure 53. To minimize soil disturbance, the tool shown in Figure 54 was used to pull out a soil core just slightly larger than the mine body. The live detonators are installed moments prior to the beginning of the test.



DOB – Subsurface DOB – Surf

Figure 53

Figure 54. Tool for making holes.

6.5 Mine Target Level of Damage

In accordance with the CEN workshop agreement, the results of the tests against mine targets were evaluated as follows.

- Live, undamaged - Targets in this condition have not been damaged in any way, and remain fully functional.

- Damaged, functional - Targets in this condition have been damaged by the machine but remain functional. This could include mines which have had part of the main explosive charge broken away, but where the detonator/initiation train remains attached to the remaining explosive material. Alternatively it could be the detonator which has sustained damage, but remains functional and able to detonate the mine.

- Damaged and non-functional - targets in this condition have not been triggered, but have been broken apart to the point where they can no longer function. This may be as simple as having removed an intact, functional detonator from an intact mine body or it may be a complete mechanical shredding of all components of the mine and detonator. Examples are seen in Figure 55-56. In the top row of Figure 55 intact functional targets missed by a machine are shown. The second row shows detonators separated from their mine bodies and detonators still attached to the upper parts of the mine bodies but separated from what would, in a real mine, be the main explosive charge. The bottom row shows the lower bodies of targets which were broken apart without triggering the detonator and where the bulk of the plaster (the main charge in a real mine) remains intact.

- Triggered - Mines in this category have been triggered by the machine. Since real mine detonators are used in this trial, it is simple a matter of counting the detonations as the machine progresses.

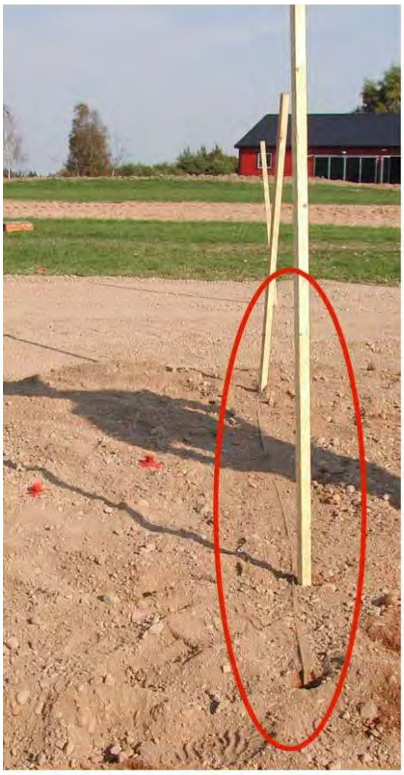
Figure 55. Examples of intact functional mines (top row), detonators separated from main charge (second row), and main charge separated from detonator (bottom row).

Figure 56. Detonators separated from main charge (left) and main charge separated from detonator (right).

6.6 Witness Boards

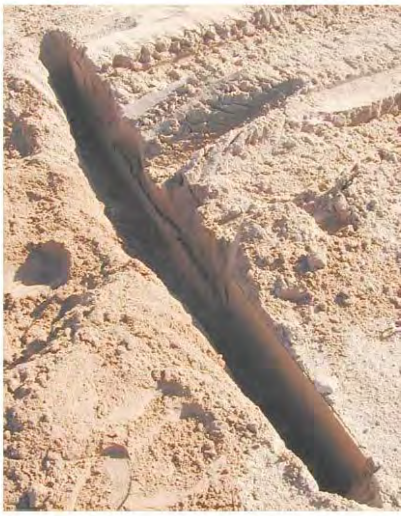
Along with the mine targets, witness boards are installed at three locations across each lane. At the start, middle and end of each test area, 3mm thick, 300 mm height, 3 m long and oil hardened (water resistant) fibreboards are installed across the full width of the flail head. Buried flush with the surface as shown in Figure 57**,** the boards act as witness panels to record the depth of penetration of the tiller/flail tools. This technique does not record the force with which the tiller/flail tools strike, but it does give a clear, unambiguous indication of depth of penetration. Figure 58 also shows a typical example of the witness boards after a test when some of the neighbouring soil has been removed to expose the boards.

A simple "pizza cutting" tool was used when installing the witness boards quick and easy without excessive disturbance of the surrounding soil. This tool, shown in figure 59, works very well in sand, topsoil and gravel.



Ready For Test

Figure 57.



After Test

Figurer 58.

Figure 59. Preparing for planting a witness board.

6.7 Test Methods

Following preparation of the soil in the test lanes, and installation of the mine targets and witness boards as described above, the machine will be prepared for a test run. The machine will be positioned about 5-10 metres in front of the start of the test lane to allow the operator to get the machine operating in a consistent, stable manner prior to the start of the lane. Cameras will be started and personnel put in place to count detonations from the triggered detonators and also make a spray mark along the lane whenever a detonator doesn’t go off.

In most cases, a manufacturer’s representative will be used as a machine operator to ensure that the machine is operated in the most effective manner. When all is ready, the machine operator is signalled to begin, and the machine is driven through the test area containing 3 witness boards and 50 mine targets. With four people counting detonator detonations and marking undetonated detonators, the number of ‘triggered mines’ can easily be determined.

Following the machine process, metal detectors will be used to locate any untriggered detonators and also the metal washers in the plaster-filled bodies. In this way, the untriggered detonators can be examined and ultimately discarded in a safe manner, and any untriggered or damaged mine casings can be inspected to determine the probable level of damage inflicted by the machine. Then, with all untriggered detonators removed from the area, the witness boards can be removed, labelled, and photographed. Finally all scrap metal in the lane was searched for and removed.

Along with the test lanes, the facilities at Norra Kulla provide office and administration space, warehouse and storage space, and basic workshop facilities.