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Tests of Hesco shelters November 2010

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English summary

To investigate the protective properties of Hesco Concertainer gabions, charges have been detonated against gabions of different sizes. The experiments simulated direct hits of weapons according to threat levels specified in STANAG 2280.

Charges were fired against open Hesco units with different fill materials. The materials were frozen. The units were not destroyed by the ordinary charges simulating 120 mm and 155 mm shells, but the shaped charges simulating RPG-7 penetrated the walls. The amount of debris increased with the grain size of the fill material and was largest with the shaped charges. Still the amounts were quite small.

Ordinary shell charges were also detonated against a shelter with walls made of Hesco units and a roof of piled steel covered with Hesco cells. The charges produced craters, which did not perforate the wall or the roof. The peak pressures of the first blast wave inside the shelter were measured to between 3 and 5 kPa.

A 420 kg TNT charge simulating a car bomb was detonated 20 m from a Hesco wall. The wall consisted of two parts, with one buried 0.5 m below the ground. The pressure was measured 3 m behind the middle of each of the two parts, 1 m above ground level. The peak pressure was 40 kPa behind the highest part and 34 kPa behind the lowest. As these values are the result of reflections, the uneven terrain may explain that the highest pressure is behind the highest part. The positive phase impulse at the two gauges was 520 and 530 Pas.

After a second test series is completed, all the test data will be interpreted more thoroughly.

Sammendrag

For å undersøke beskyttelsesevnen til gabioner av type Hesco Concertainer, er det gjort en serie sprengningsforsøk mot gabioner av ulike størrelser. Ladningene som ble detonert, simulerte våpentrusler spesifisert i STANAG 2280.

Ladninger ble satt av mot åpne Hesco-enheter med ulike fyllmaterialer. Det var tele i materialene. Veggene ble ikke ødelagt av ordinære ladninger som simulerte 120 mm og 155 mm granater, men bikubeladningene som simulerte RPG-7, trengte gjennom veggene. Mengden av utkast økte med kornstørrelsen i fyllmaterialet og var størst med bikubeladningene. Generelt var imidlertid mengdene ganske små.

Ordinære ladninger ble også satt av mot et shelter med vegger av Hesco-enheter og tak av spuntstål dekket med Hesco-elementer. Kratrene som ble dannet av sprengningene, gikk ikke gjennom veggen eller taket. Maksimaltrykkene til den første trykkbølgen inne i shelteret ble målt til mellom 3 og 5 kPa.

En ladning på 420 kg TNT som simulerte en bilbombe, ble detonert 20 m fra en Hesco-vegg. Veggen besto av to deler, der den ene delen var gravd 0,5 m ned i bakken. Trykket ble målt 3 m bak midten av hver av de to delene, 1 m over bakken. Maksimaltrykket var 40 kPa bak den høyeste delen av veggen og 34 kPa bak den laveste. Disse verdiene kommer etter at trykkbølgen har reflektert i bakken, så når det høyeste trykket er bak den høyeste veggen, kan det trolig forklares med det ujevne terrenget. Impulsen til positive fasen av trykkbølgen var 520 og 530 Pas ved de to målerne.

En grundigere tolkning av forsøksresultatene vil bli gjort etter at en ny forsøksserie er gjennomført.

Contents

1 Introduction

Figure 1.1 Hesco units

Hesco Bastion Concertainer units [1] are field fortifications extensively used by Norway and other countries for force protection. A Hesco unit consists of geotextile covered with a mesh of steel wires, see figure 1.1. The units are made in different sizes, and usually several units are joined together. They can form simple walls or be a part of or cover a complete structure. At the place of erection the units are filled with available soil materials.

A series of tests have been planned to investigate the protective properties of Hesco units. The effect of different fill materials is considered to be a matter of particular concern. The first tests, which are described in this report, were carried out at Setermoen in November 2010. The tests were designed according to threat levels specified in STANAG 2280 [2]. Uncased charges were detonated to simulate direct hits of certain weapon threats. These threats are RPG-7 (level B4), 155 mm artillery (level C5), 120 mm mortar (level C4) and a 400 kg VBIED (Vehicle-Borne Improvised Explosive Device, level E2).

The preparation and performance of the tests were made by the Norwegian Army Weapons School with support from the Norwegian Defence Logistics Organisation, the Military Academy and Norwegian Defence Research Establishment (FFI). FFI was responsible for the test registrations by pressure transducers and video cameras.

In this report the test results are presented. A second test series is scheduled in June 2011. After that a more thorough analysis and interpretation of the test data will be performed.

2 The tests

All the tests were captured by a HD video camera.

The pressure measurements were made with two tapered pencil gauges of type PCB 137 A23. Values were sampled with a frequency of 250 kHz. The recorded data were filtered by a fourth-order Bessel filter with a cut-off frequency of 22 kHz.

2.1 Test 1

2.1.1 Description

The purpose of test 1 was to study the effect of different fill materials to the debris thrown out of MIL 3 Hesco bastions when a charge is detonated at the side of the walls. In addition the penetration of shaped charges into the walls was investigated.

A MIL 3 wall is made of 1 m x 1 m x 1m cells, usually with five cells horizontally lined up. The cells are open at the top. In the test they were filled with 22 mm gravel, crushed rock or soil from the location.

The test charges were TNT blocks of 3.5 kg (simulated 120 mm mortar ammunition) and 7.0 kg (simulated 155 mm artillery ammunition) and 3.5 kg shaped charges (simulated RPG-7). Table 2.1 shows details of the individual tests.

Test number	Charge	Fill material	Distance wall - witness plate
1.1	3.5 kg TNT	22 mm gravel	46 cm
1.2	7.0 kg TNT	22 mm gravel	52 cm
1.3	7.5 kg TNT	Crushed rock	
1.4	3.5 kg shaped charge	Mixed materials	42 cm
1.5	3.5 kg shaped charge	22 mm gravel	23 cm
1.6	3.5 kg shaped charge	Local soil	45 cm

Table 2.1 Charge and fill materials in the firings of test 1

Because of rain and snow the masses originally filled into the cells were to a large degree kept together by ice. Two charges were set off at some distance from the wall to break up the blocks, but the effect was limited.

A high-speed video camera filmed the back side of the walls during the explosion in test number 1.1, 1.2 and 1.4, see figure 2.1.

Figure 2.1   High-speed video camera used in test 1

Pictures of the walls and the charges are shown in figures 2.2-2.6. Witness plates of aluminium (1 m x 1 m x 0.001 m) were set up behind the walls to register debris.

Figure 2.2   Setup of test 1.1 with 3.5 kg TNT

Figure 2.3   Setup of test 1.2 with 7.0 kg TNT

Figure 2.4 Setup of test 1.3 with 7.5 kg TNT

Figure 2.5 3.5 kg shaped charge in test 1.4

Figure 2.6 Position of 3.5 kg shaped charge in test 1.5

Test 1.6 was different from the other shots of test 1 because in this test MIL 2 units were set up in a 2 x 2 x 2 configuration, see figure 2.7. A MIL2 cell is cubic and has side lengths of 0.61 m. The barrier was tested with a 3.5 kg shaped charge.

Figure 2.7 Setup of test 1.6 with a 3.5 kg shaped charge

2.1.2 Results

In the tests with TNT slabs of a total mass of 3.5 kg or 7.0 kg, the front side of the walls collapsed, but there was no penetration through the walls. Several stones were thrown out from the top of the walls, yet no holes were made in the witness plates. There was some more debris with crushed rock than with gravel in the walls. Figures 2.8-2.11 show pictures of the walls after the detonations.

Figure 2.8 Front side of wall after test 1.1

Figure 2.9 Front side of wall after test 1.2

Figure 2.10 Front side of wall after test 1.3

Figure 2.11 Back side of wall after test 1.3

The shaped charges caused penetration of both the walls and the witness plates. This was also the case with the double wall in test 1.6. In addition the witness plates were penetrated by stones, see figures 2.12-2.18.

Figure 2.12 Front side of wall after test 1.4

Figure 2.13 Back side of wall after test 1.4

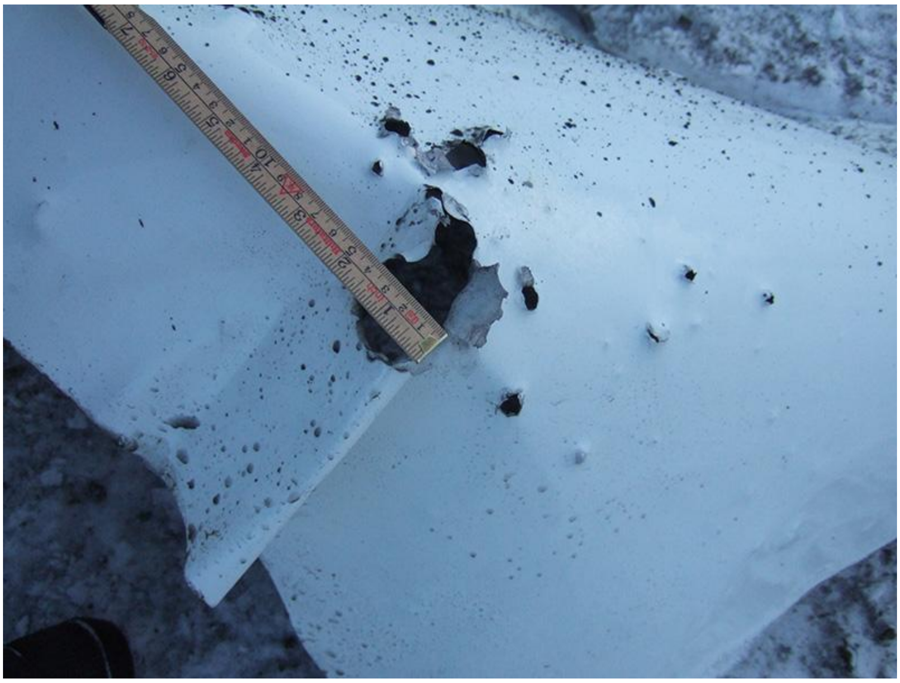

Figure 2.14 Witness plate after test 1.4

Figure 2.15 Back side of wall after test 1.5

Figure 2.16 Witness plate after test 1.5

Figure 2.17 Back side of wall after test 1.6

Figure 2.18 Witness plate after test 1.6

The debris from the walls perforated by the shaped charges was clearly more extensive than the debris produced by the ordinary charges. The largest stones were thrown farthest away, but also the amount of debris increased with the grain size.

By using a computer code designed to extract fragment velocities from high-speed video [3], the velocities of five stones in test 1.1 are found during their flight. The average values are between 2.6 m/s and 5.2 m/s.

A manual inspection of video frames gives the velocities shown in table 2.2. The masses of the observed stones are calculated from the stone volume estimated from the frames, and an assumed density of 2700 kg/m^3.

Test number	Charge	Description	Velocity / m/s	Mass / g
1.1	3.5 kg TNT	First phase with a few stones from the side of the wall	18	10
		Subsequent phase with a lot of stones from the top	2,4	9
			3,4	10
1.2	7.0 kg TNT	Falling stone	9,6	11
1.4	3.5 kg shaped charge	Upward moving stone	18	100

Table 2.2 Velocity and mass of some flying stones

2.2 Test 2

2.2.1 Description

In test 2 charges were detonated at the side and on the top of a UTOPS shelter. This type of shelter consists of MIL 1 walls (1.06 m depth) and a roof of piled steel covered with a layer of MIL 2/5 cells (0.61 m height). The cells in the wall and in the roof were filled with in situ soil material. Figure 2.19 and 2.20 show pictures of the shelter.

Figure 2.19 Entrance of the UTOPS shelter

Figure 2.20 Inside of UTOPS shelter

Two pressure gauges were used in the experiments. Figure 2.21 shows the position of the transducers and the charges. The sensors pointed towards the centre of the shelter, except in the last shot where they pointed downwards.

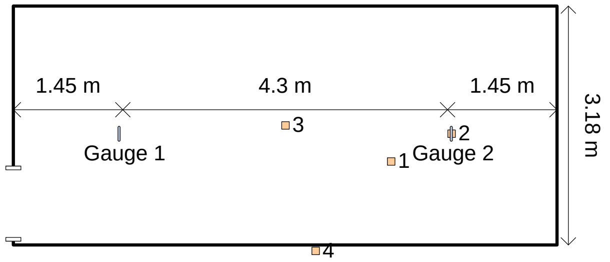

Figure 2.21 Plan view of the inside of the UTOPS shelter with pressure gauges and charges

The placement and the type of charges used in the different experiments are given in table 2.3. The charges were made of 0.5 kg slabs of TNT.

Test number	Charge mass	Position
2.1	3.5 kg	On the roof, 2.2 m from end wall, 1.0 m from right wall
2.2	3.5 kg	On the roof, above the gauge farthest in
2.3	7.5 kg	On the middle of the roof
2.4	7.5 kg	At the side, 3.2 m from inner wall

Table 2.3 Charges in the test 2 firings

Figure 2.22 shows the charge used in test 2.4.

Figure 2.22 Charge setup in test 2.4

2.2.2 Results

The pressure recordings in test 2 are shown in figures 2.23-2.25. In test 2.2 the pressure was not registered.

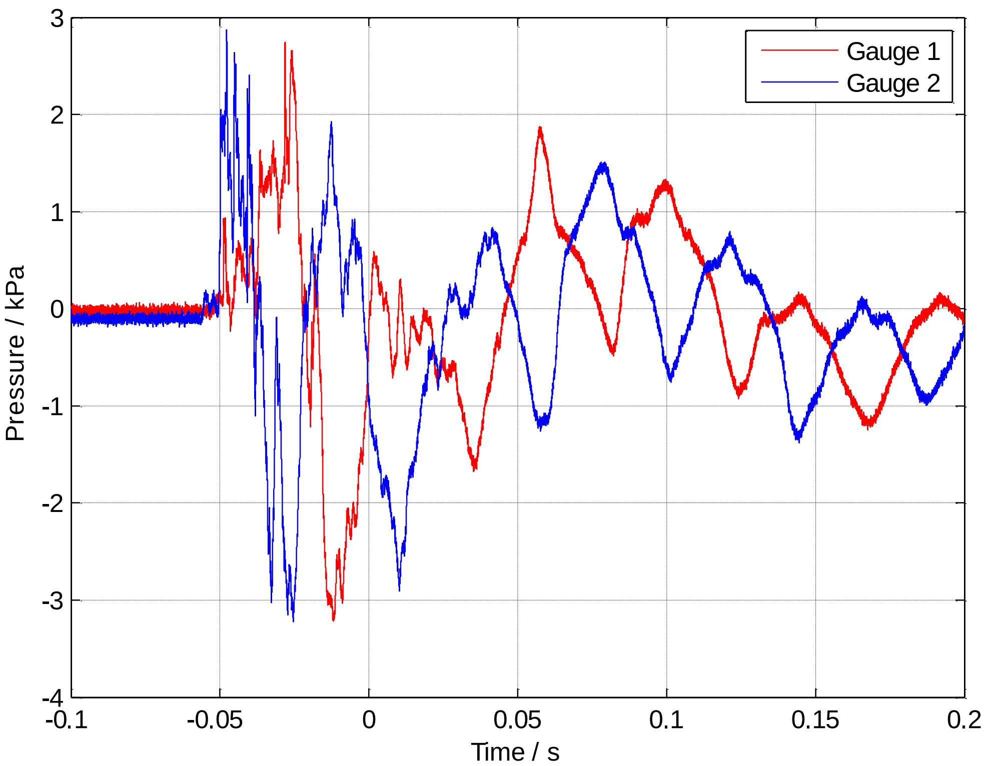

Figure 2.23 Pressure recordings in test 2.1

The peak values of the pressure in test 2.1 were 2.7 kPa (gauge 1) and 2.9 kPa (gauge 2). The charge was closest to gauge 2. Beyond the peak values the pressure-time history is rather complicated because of reflections of the pressure wave.

The pressure wave arrived at the gauges at -0.05 s. The duration of the first positive segment at gauge 1 was 28 ms, and the impulse was 26 Pas. At gauge 2 the first pressure wave lasted 11 ms and gave an impulse value of 16 Pas.

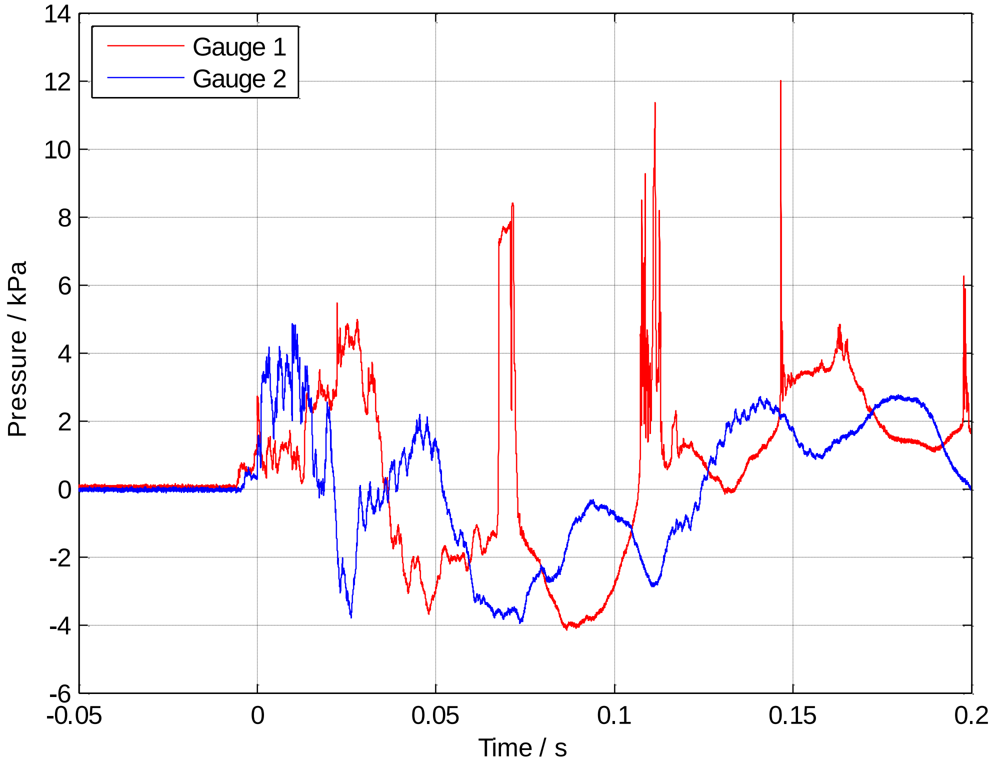

Figure 2.24 Pressure recordings in test 2.3

In test 2.3 the maximum pressure values up to 0.05 s were 5.5 kPa for gauge 1 and 4.9 kPa for gauge 2. The subsequent recordings are the result of several reflections, and gauge 1 gives a maximum pressure of 12 kPa at 0.146 s. At later times the pressure values at gauge 1 reaches 28 kPa.

The first positive phase of the pressure at gauge 1 from -0.006 s gave an impulse of 86 Pas during the 45 ms duration. At gauge 2 the first pressure wave arrived 2 ms later and had a duration of 26 ms and an impulse of 52 Pas. The second and third positive phase of the pressure at gauge 1 produced impulse values of 33 and 43 Pas respectively.

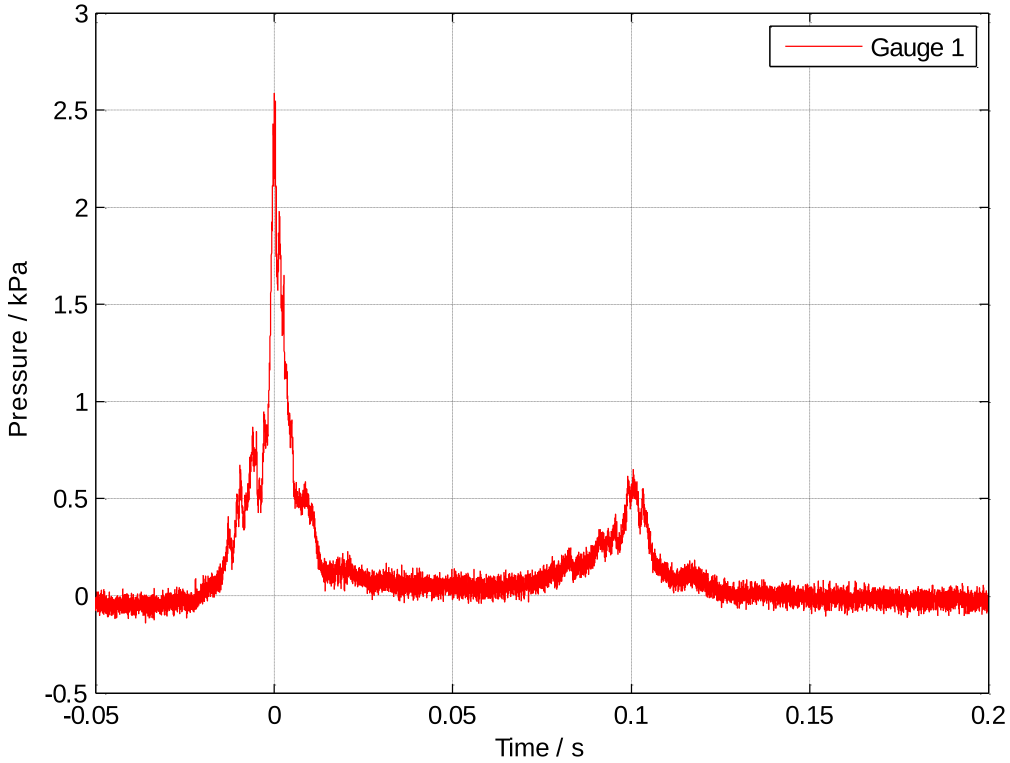

Figure 2.25 Pressure recordings in test 2.4

In test 2.4 only gauge 1 recorded pressure values. The maximum of the first peak was 2.6 kPa. The curve shows the effect of a low gain level, giving a minimum pressure step of 0.088 kPa. The amplitude of the oscillations is however reduced by the filtering.

The impulse of the first peak from -0.021 s was 20 Pas, and the duration was 35 ms.

The detonation of 3.5 kg TNT on the roof of the shelter in test 2.2 caused deflection in the roof below the charge, visible from inside the shelter. This was similar in test 2.3, but with a larger deflection.

The charges produced craters in the roof or in the wall. After test 2.3 the crater depth was 50 cm. The crater in the wall after test 2.4 had a depth of 0.45 m, the width was 1.0 m, and the height 0.7 m, see figure 2.26.

Figure 2.26 Crater in the wall after test 2.4

2.3 Test 3

2.3.1 Description

In test 3 a charge of 420 kg TNT was detonated 20 m from a MIL 10 wall placed on the ground beside a MIL 10 wall buried 0.5 m below the ground. A MIL 10 wall is 1.52 m deep and 2.12 m high, and the width of each wall was 15 m (ten cells). The walls were filled with local soil, which consisted of sand, silt and some stones. The charge simulated a car bomb (VBIED).

Figure 2.27 Charge in test 3

The main object of the test was to compare the pressure behind the two walls to discover a possible pressure leakage below the unburied wall. Hence pressure transducers were placed 3 m behind the middle of the two walls about 1.0 m above the ground with the sensors sideways. In addition pieces of cardboard were fastened to the wall just above the ground to get indications of a pressure leakage. A HD video camera recorded the test.

The terrain in front of and especially behind the wall was rough and with a significant slope. There was snow on the ground.

2.3.2 Results

The detonation of 420 kg TNT did not make any harm to the MIL 10 barricades, see figure 2.28.

Figure 2.28 MIL 10 walls after test 3

The pressure recorded 3 m behind the wall is shown in figure 2.29.

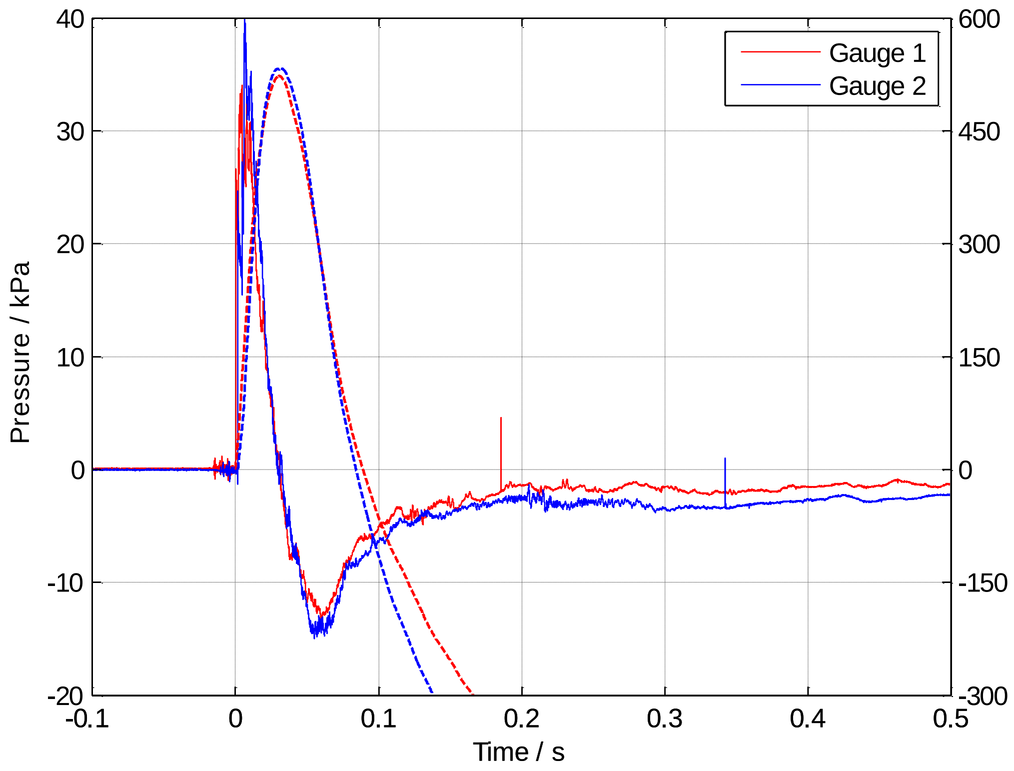

Figure 2.29 Recorded pressure (solid lines) and impulse (dashed lines) in test 3

Gauge 1 registered the pressure behind the buried wall, and gauge 2 behind the unburied wall. The maximum pressure was 34 kPa at gauge 1 and 40 kPa at gauge 2. After the test it was discovered that gauge 1 was rotated with the sensor pointing almost downwards. The duration of the positive phase of the pressure wave was 31 ms at gauge 1 and 28 ms at gauge 2. The pressure wave arrived at gauge 2 1.7 ms after the arrival at gauge 1. The impulse of the positive phase was 520 and 530 Pas for the two gauges.

If we look at the first 30 ms of the recordings, see figure 2.30, the maximum value of the first pressure wave is largest at gauge 1, which is reasonable. The maximum values of 34 kPa and 40 kPa are the result of reflections.

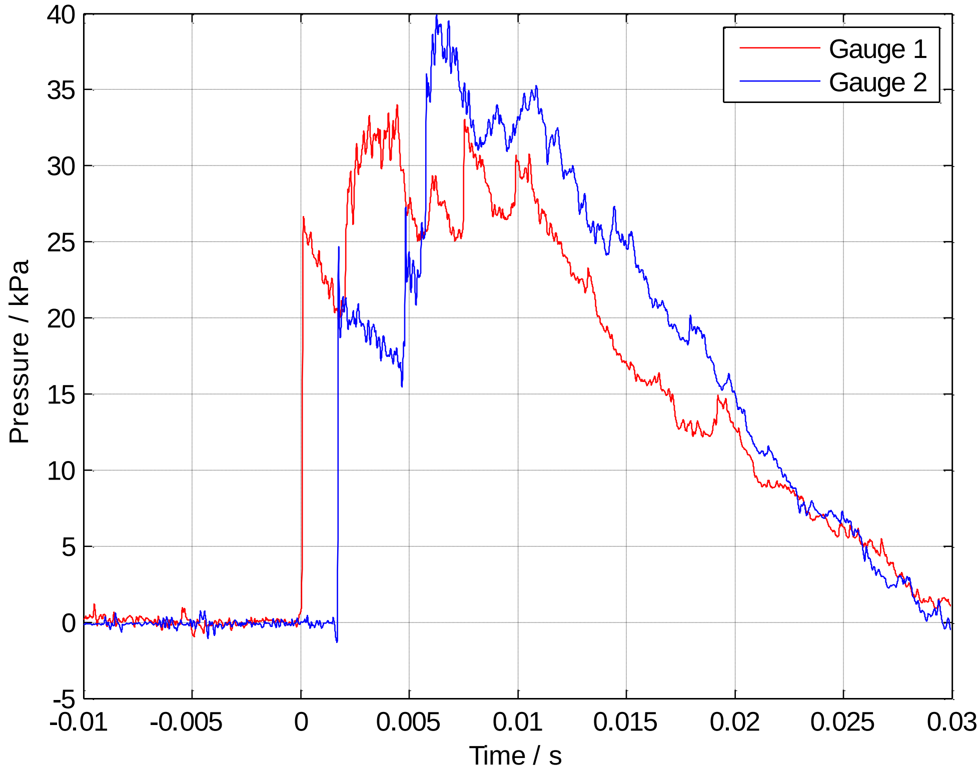

Figure 2.30 Segment of pressure recordings in test 3

2.4 Live firings

A real weapon will in general not have the same effect on a target as a bare charge. To test the effect of real weapons 155 mm artillery shells were fired against the UTOPS shelter and an INTOPS shelter. One shot hit the target, see figure 2.31.

Figure 2.31 Results of a direct hit by a 155 shell at an INTOPS shelter

3 Discussion and conclusions

The tested MIL 3 Hesco walls were not destructed by contact detonation of simulated artillery and mortars up to level C5. The type of fill material seems to be of little importance because only a small amount of debris was thrown out. Shaped charges penetrated the MIL 3 barricades, regardless of fill material, but the tests showed that the cells with larger stones produced more debris than the smaller ones. The conclusions above apply when the stones are encased in ice.

When weapon threats are simulated by contact detonation of bare charges, the impact load, the enhanced effect of a buried charge and the damping by the casing is not included. Therefore the effect of a hit by a real weapon is probably larger. Live firings were made to explore the differences, but all except one missed the targets.

When 3.5 kg TNT was detonated on the roof of the UTOPS shelter, the maximum pressure inside was measured to almost 3 kPa. With a 7.5 kg charge the value of the first peak was around 5 kPa. Then reflections lead to larger pressure values. With a 7.5 charge at the side of the shelter the maximum pressure of 2.6 kPa was measured at the first peak.

It is difficult to predict the direction of the shock wave inside a shelter, especially after reflections have started. Therefore it is uncertain what kind of pressure values the tapered pencil gauges gave during the tests. Tapered gauges are to be set up with their longitudinal axes and their tips pointing towards the blast source [4]. It might be a good assumption that the first pressure wave in our tests propagated radially from the charge. Then the incident pressure of this wave would have been measured if the tip of the gauge pointed against the charge. However, this was not the case in any of the test firings.

With the actual setup the incident pressure wave was probably to some extent reflected on the sensors in both test 2.1, 2.3 and 2.4 as the charge in test 2.4 was positioned below the gauges. The direction of the pressure waves arriving at the sensors at later times is so uncertain that it is impossible to know what kind of pressures that was measured.

The craters in the roof and in the wall of the UTOPS shelter did not break through. This is similar to the results for the MIL 3 walls, but there was no ice in the wall at which the charge of test 2.4 was detonated. The roof of the shelter was open for snow and rain.

Since the pressure wave from detonation of 420 kg TNT is assumed to propagate about normally over the MIL 10 wall, the pressure gauges probably registered values of the first pressure wave close to incident pressure values. The direction of the subsequent pressure waves is more difficult to assume with the uneven terrain, and the pressure values are more difficult to interpret. There are however no signs of any pressure leakage below the unburied wall.

A more comprehensive analysis of the test data will be performed when results from the next test series also are available.

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