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Swedish Rescue Service Agency

Report on a second blast test of the ROFI Face Mask

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The work related to this paper “Report on a second blast test of ROFI face” was conducted at SWEDEC with support from the Swedish Rescue Service Agency, SRSA, during November 2008.

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Abstract

During the period August to November 2007 a new type of Personal Protective Equipment (PPE), the Body Armour “Armadillo“ and a Face Mask made by ROFI Industrier AS in Norway, were tested with guidance from a Comité Européen de Normalisation (CEN) developed CEN Workshop Agreement (CWA 15756:2007).

Out of this CWA the test protocol for blast testing of PPE was used. The test was undertaken with a pedestrian version 50th percentile male Hybrid III anthropomorphic dummy as wearer of the PPE during the test. It was dressed in the PPE and was placed in a kneeling position in front of an explosive charge. Because to difficulties in producing the explosive charge (mine described in the CWA containing 240 g of TNT) an equivalent explosive compound was used. The explosive compound used was so called “Svensk sprängdeg m/46”, which is a mixture of 86% Pentyl and 14% mineral oil giving a detonation speed 6914 m/s and maximum detonation pressure 18,4 GPa which compared to TNT’s 6930 m/s and 21 GPa is almost an equivalent.

However due to a misunderstand the charge was treated as a pure Pentyl compound having quite different data, 8400 m/s and 34 GPa. Therefore the weight of the m/46 charge was reduced by a factor 1,66 giving a charge of 145 g. Since both the Body Armour and the Face Mask were not penetrated by any fragments during the blast the equipment was considered to meet the requirements stated in the CWA. This result was then reported by SRSA, report no. SRV Diarienr 339-9978-2007, to ITEP and published on their website.

When discovering this mistake a new blast test for the Face Mask was set up using 240 g of m/46. The distance from the centre of the top surface of the simulated mine to the nose of the dummy was set according to the CWA (550 mm and at 70º from the horizontal). The evaluation of the test results was focused on analysing whether the Face Mask could withstand the effects caused by an Anti Personnel Mine blast. The results show that the polycarbonate (visor) is damaged (broken) giving severe damage to the witness sheet behind the visor.

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Introduction

The new CEN Workshop Agreement (CWA) on a test protocol for testing PPE used in HMA attempts to more realistically replicate mine effects than earlier standards. The test protocol is made up from three different sets of tests. According to the test protocol new PPE shall be tested as follows:

- Ballistic Test to evaluate the protection against secondary fragments;
- Blast Test to show how the different pieces of equipment function as a system;
- Ergonomic Suitability Test to assess the degree to which the PPE is fit for purpose.

These tests are intended to give guidance to key stakeholders involved in the design, procurement and utilisation of PPE in the HMA.

In 2007 SRSA decided to do tests on the new ROFI Face Mask as a response to requests of their own and a request from UNMAS. SRSA also wanted to test the new body armour Armadillo from ROFI as a part of their procurement process of HMA PPE. Supported by SWEDEC, SRSA furthermore decided to only perform one part of the tests protocol stated in the new CWA.

The Ballistic test was not performed due to lack of equipment and trained personnel. Neither the Ergonomic Suitability Test was performed since it was deemed to be useful only in a later stage of their procurement process.

The results from this test were reported in December 2007 (report no. SRV Diarienr 339-9978-2007), but after discovering a mistake when calculating the amount of TNT equivalent explosive compound, in this case “Svensk Sprängdeg m/46”, a second blast test was done in November 2008. In this document the results from this second test is reported.

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Face Mask

Front view of mask

Mask viewed from behind

Mask viewed from right side

The mask consists of a piece polycarbonate, fastening straps and a new composite material in three pieces, joined together in a characteristic profile. The new composite material pieces are joined together by four rivets with flatrounded heads (two on each side). The polycarbonate piece is screwed to the composite by four screws (two on each side) on to the outside of the mask. The screws are screwed into threaded rivets imbedded in the composite. Compared to the mask in the first test the attachment to the composite has been modified and seems to be stronger.

Threaded rivets imbedded in the composite

Inside view: Threaded rivets imbedded in the composite (new mask on the right hand side)

Only the parts of the polycarbonate nearest the screw/rivet joint are in contact with the composite. The fastening straps are made out of elastic straps with Velcro tape stitched on to it. The straps are slipped through slots in the composite, at the back end near the wearers' ears and at the top near the wearers' forehead. Individual fitting of the mask can be made by adjusting the straps and Velcro. The manufacturer has provided the masks with two sets of cushions that can be placed on Velcro tape on the inside of the mask. This provides the mask with additional fitting possibilities.

Also the visor is a bit higher covering more of the upper front part of the mask as shown in the picture below.

New face mask on the right with a higher visor.

Test equipment

The test was undertaken with a pedestrian dummy as wearer of the face mask during the test, also dressed with a body protection in order not to destroy the dummy. Areas supposedly protected by the PPE were covered by a witness sheet. Materials used in the tests such as sand and simulated blast mines, was chosen to meet the criterions of the CEN protocol. The sand was dry with a distribution of particle size according to the table (0-1,5) mm and placed in a steel cylinder with a 660 mm diameter. The witness sheet was made out of cotton sheet. A simulated mine was made out of a charge with 240 g “Svensk Sprängdeg m/46” explosive (86 % Pentyl and 14 % mineral oil)). This explosive compound is a very close equivalent to 240 g of TNT according to the EOD IS database having detonation speed of 6914 m/s and maximum detonation pressure 18,4 GPa compared to TNT’s 6930 m/s and 21 GPa. In the tests an electric detonator was used and inserted from below to the centre of the charge. A smaller deviation from the protocol was made in the case of the plastic container for the charge. It had a thickness of (1.3 ± 0.3) mm in stead of the stipulated (2± 0,5) mm i.e. a somewhat thinner container.

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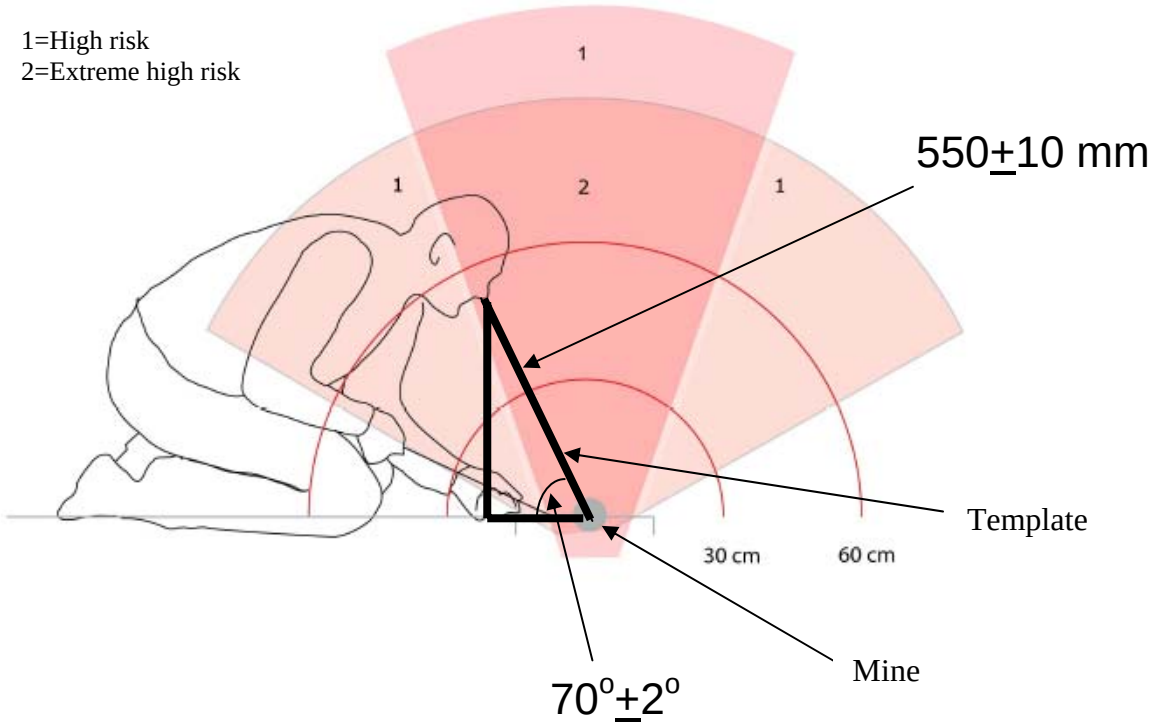
Test preparation

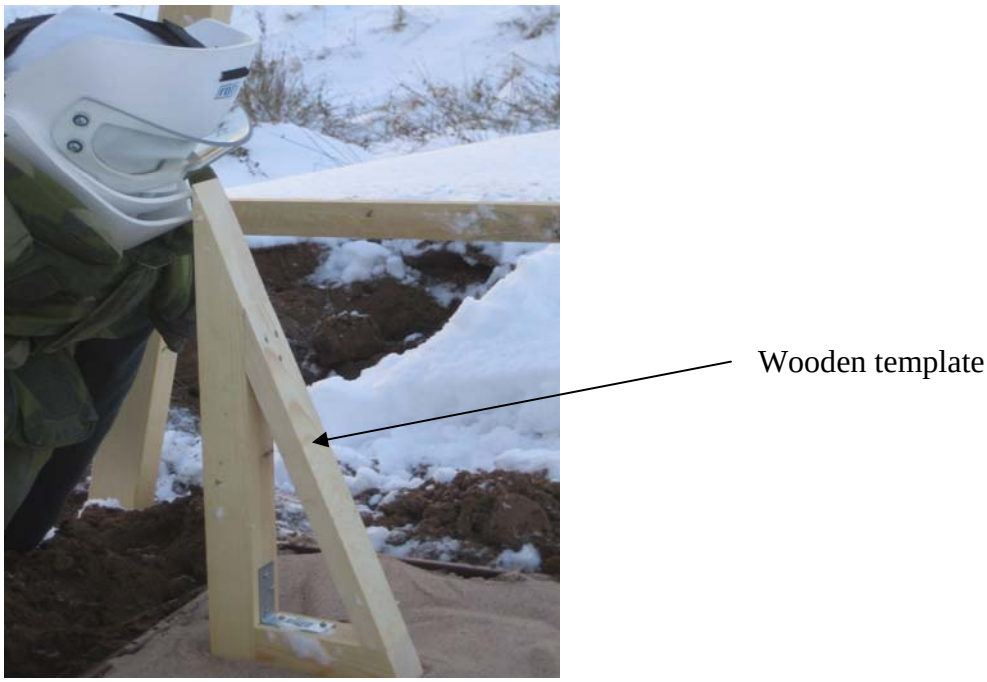


Setup according to the CWA.

Simulated mine in test bed.

The simulated mine was buried in the test bed and covered with 2 cm of sand. The PPE was fitted to the dummy according to manufacturer's instructions. On the inside, the mask was

fitted with the small pads provided by the manufacturer. The dummy was positioned for the test using a template with correct length and angle from mine to nose was used assuring the correct position as stipulated in the test protocol. The dummy was set into a kneeling position by using a fixture system that was able to hold it in position. The distance from the centre of the top surface of the simulated mine to the nose of the dummy was 550 ± 10 mm and at 70 ± 2º from the horizontal.



Positioning of dummy above simulated mine by using a wooden template.

Blast test

The test protocol stipulates that the test shall be carried out twice. If either of the tests is a failure, the test shall be repeated once. The PPE system was tested two times and both tests failed. A separate witness sheet and PPE were used in each blast. Since there were two failures the test was discontinued.

Evaluation

After each test the result was observed in three different steps:

First step:

Examination of blast effects without touching any part of the dummy.

After the blast an inspection of the blast site was carried out to see if any part of the Face Mask was missing and if so, where it might have landed. Broken and or missing parts was noted and collected. The ability of each part of the PPE to

stay in the original place was noted. Visual examination of the witness sheet was made on places visible without moving the dummy.

Second step:

Examination of blast effects after moving the dummy

In this step the Dummy was placed on its back next to the blast site and removed of all PPE. The Face Mask and witness sheet was examined for penetrations made by fragments. Especially the witness sheet over the eyes was examined for damage.

Third step:

Examination of the removed Face Mask.

After each blast the face mask and witness sheet was collected and placed in at plastic bag to be transported to the premises of SWEDEC where it was possible to analyse the material in an indoor environment.

In the third step, the witness sheet and Face Mask were examined by holding them against a source of light and thereby be able to see any penetrations from fragments. The Mask was also examined visually looking for any traces of penetration.

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Results

The purpose of this blast test was to examine the effect of a blast using the stipulated amount of explosives as written in the CWA and thereby correct the mistake made in the first test. The results also showed that the CWA needs to be reviewed since the severe effect on a face protection when using an explosive charge equivalent to 240 g of TNT at a distance of 55 cm. The face mask did not stay in place through the blast and the dummy was thrown backwards.

The threaded rivets holding the polycarbonate piece to the composite part did however withstand the strains of the blast but the polycarbonate piece was broken off a few cm from the threaded rivets. In the earlier reported blast test they were ripped out of the composite material.

In the first blast the polycarbonate piece was torn completely of and could never be found again. In the second blast the polycarbonate piece stayed attached to the mask on one side however it was severely damaged. The front surface of the mask showed clear damage from blast ejecta but nothing penetrated. The whiteness sheet over the eyes did show severe damage from heat and pressure.

First blast:

Result after 1st blast, right and front view

Second blast:

Result after 2nd blast right side.

Result after 2nd front view.

Mask seen from the inside with server damages.

As a comparison a mask from the first test using 140 g of TNT equivalent of explosives is shown below. One can easily see the difference in damages when adding another 100 g of the TNT equivalent.

Left: Face mask from first blast test using 140 g TNT equivalent (m/46)
Right: Face mask from second blast test using 240 g TNT equivalent (m/46)

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Discussion

This test of PPE have only considered the ability to meet the criteria concerning a blast test, stipulated in the CWA-protocol created by CEN, and it was also limited to test one part of personal protective equipment in HMA – the face protection. The PPE did not withstand the blast, neither secondary fragments (sand) nor heat. The blasts caused heat damage in the area of the dummies' eyes i.e. burning of the witness sheet. Consequently the area of the deminers' head that, according to the CWA, needs to be protected (the forward facing half of the head) has not been protected from fragment penetration in witness sheet. Because of this, the face mask is not considered to meet the requirements stated in the CWA.

However one can question if the simulated mine as stipulated in the CWA is statistically representative for blast mines. Even if a face mask would withstand a detonation of 240 g TNT at 55 cm distance without direct penetration of secondary fragments the observations from the test are that both the neck and the front head would have to take quite an amount of energy causing high risk for severe damages.

The conclusion is that one should add a test measuring forces on the head and neck of the dummy. Based on the results seen so far it is recommended that the CWA 15756:2007 is reviewed according to those conclusions and also by taking into consideration the size of a more statistically common antipersonnel blast mine instead of having a worst case as it is stated today.