STANAG 2280
(Draft Edition 3)
(3.8.3)

NATO STANDARDIZATION AGREEMENT
(STANAG)

CLASSIFICATION OF FIELD FORTIFICATIONS AND DEPLOYABLE PROTECTIVE STRUCTURES

ANNEXES:

A. Definition of threat classes
B. Handover form for protective structures - design level / quality control
C. Reference values for material thickness - threat class A - C
D. Guidelines for classification / handover and testing
E. Reference values - sources and comments

RELATED DOCUMENTS:

a.	STANAG 2238	AJP-3.12 Joint Engineering
b.	STANAG 2394	Land Force Combat Engineer Doctrine
c.	STANAG 2858	Land Force Tactical Doctrine
d.	STANAG 4569	Protection Levels for Occupants of Logistic and Light Armoured vehicles
e.	AAP-6 (2002)	NATO Glossary of Terms and Definitions
f.	AAP-19 (C)	NATO Combat Engineer Glossary
g.	MC-472	NATO Military Concept for Defence against Terrorism
h.		Bi-SC Force Protection Directive 80-25

AIM:

1. The aim of this agreement is to standardize the classification and documentation of field fortifications and protective structures in order to:

   a. Facilitate the handover / takeover of field fortifications and deployable protective structures between NATO nations, and

b. assist in the construction or procurement of field fortifications and deployable protective structures

2. This document is not a substitute for national design manuals and procedures. Annex C and D will however facilitate the construction of field fortifications and improve compatibility between national guidelines and procedures.

DEFINITIONS:

3. The following terms and definitions are used for the purpose of this agreement:

a. Field fortification
An emplacement or shelter of a temporary nature which can be constructed with reasonable facility by units requiring no more than minor engineer supervisory and equipment participation (AAP6 (2002))

b. Deployable protective structure
Complete structure acquired prior to deployment, which is placed or assembled on site without the use of additional protective materials.

AGREEMENT:

4. The Participating Nations agree to adopt the table of threat classes outlined in annexes A, and to use the appropriate designation when describing protective capabilities to other NATO nations.

5. The Participating Nations agree to adopt the documentation form given in annex B and the guidelines given in Annex C during handover of field fortifications and protective structures to other member nations, in order to describe the qualification procedures used during design and construction.

6. The Participating Nations agree that the table in Annex D give representative reference values for required thickness of different materials in order to provide adequate ballistic protection. If the use of a nationally approved design tool or performed tests have resulted in values that deviate from these references, this shall be specifically mentioned in the documentation form.

7. The participating Nations agree that the information provided may be used at all levels.

RESTRICTIONS:

8. The STANAG does not cover the technical specifications for standard infrastructure or designs.

IMPLEMENTATION OF THE AGREEMENT:

9. This STANAG shall be considered implemented when a nation has issued the document with annexes to commanders in the field, to those responsible for establishing and operating a field unit, and to all instances involved in the handover of field fortifications and protective structures to another NATO nation.

	A **Small / medium calibre projectiles**	**B** **Rifle grenades - shoulder launched weapons**	**C** **Mortars and artillery - indirect fire / near miss**	**D** **Mortars and artillery - indirect fire / surface hit**	**E** **Mortars and artillery - indirect fire / delay fuze**	**F** **IEDs / car bombs**
5	*Automatic cannon* *< 30 mm APDS*	*(open)*	*(open)*	*(open)*	*(open)*	*< 5000 kg TNT* */ equivalent*
4	*Machine gun* *< 14.5 mm AP*	*Large shoulder launched AT* *SC < 150 mm*	*Artillery* *< 155 mm*	*Artillery* *< 155 mm*	*Artillery* *< 155 mm*	*< 1000 kg TNT* */ equivalent*
3	*Sniper / assault rifle* *< 7.62 mm AP*	*Small shoulder launched AT* *SC < 90 mm*	*Mortar* *< 120 mm*	*Mortar* *< 120 mm*	*Mortar* *< 120 mm*	*< 250 kg TNT* */ equivalent*
2	*Assault rifle* *< 7.62 mm*	*Rifle/AGL grenade* *SC < 40 mm*	*Mortar* *< 82 mm*	*Mortar* *< 82 mm*	*Mortar* *< 82 mm*	*< 50 kg TNT* */ equivalent*
1	*Pistol / PDW* *< 9 mm*	*(open)*	*Mortar* *< 60 mm*	*Mortar* *< 60 mm*	*Mortar* *< 60 mm*	*< 10 kg TNT* */ equivalent*
	IMPACT LOADING			**COMPLEX LOADING**		

STANAG 2280 – HANDOVER FORM

Installation details - ID, type and materials		Design level					
	5						
	4						
	3						
	2						
	1						
		A	B	C	D	E	F

Class	Description of quality control of design level			
A	Certified - industrial / mil standard		Field tested - on site	
	Calculated or estimated		Field tested - other location	
	Comments / references			
B	Certified - industrial / mil standard		Field tested - on site	
	Calculated or estimated		Field tested - other location	
	Comments / references Make a special note if THERMOBARIC warheads (TBX) are considered			
C	Certified - industrial / mil standard		Field tested - on site	
	Calculated or estimated		Field tested - other location	
	Comments / references			
D	Certified - industrial / mil standard		Field tested - on site	
	Calculated or estimated		Field tested - other location	
	Comments / references			
E	Certified - industrial / mil standard		Field tested - on site	
	Calculated or estimated		Field tested - other location	
	Comments / references			
F	Certified - industrial / mil standard		Field tested - on site	
	Calculated or estimated		Field tested - other location	
☐ VEHICLE STOPPING ☐ FRAGMENTS ☐ PRESSURE ☐ NO SECONDARY FRAGMENTS	Comments / references SITUATION / VEHICLE / CHARGE WEIGHT / DISTANCE as appropriate			

APPROVED	DATE / PLACE	NAME / RANK

ANNEX C

REFERENCE VALUES FOR MATERIAL THICKNESS - THREAT CLASS A - C

C1 SUMMARY OF VALUES – PENETRATION DEPTH

All Numbers in cm. N.D. = No Data. See notes on the following page.

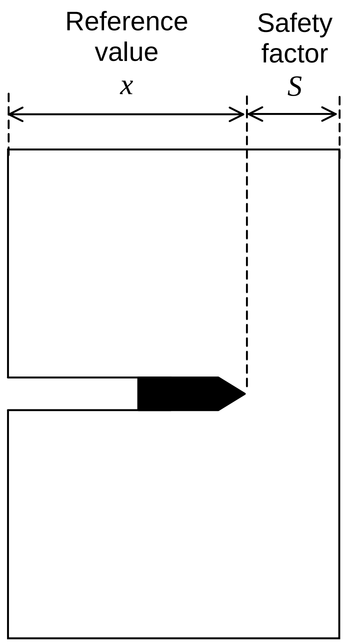
	A	B	C		
5	N.D.	-	-	Standard construction concrete. High strength concrete (150 MPa): Reduce to 50 %	**CONCRETE C25**
4	36	160	11		
3	21	64	4		
2	10	26	6		
1	N.D.	-	3		
5	N.D.	-	-	(no comments)	**STEEL BHN 360**
4	2.5	90	2,5		
3	1,5	35	0,7		
2	0.8	14	1,2		
1	N.D.	-	0.7		
5	N.D.	-	-	Dry and confined sand. Wet sand: add 50 %	**SAND 0-2 mm**
4	38	340	42		
3	23	132	16		
2	15	53	17		
1	N.D.	-	16		
5	N.D.	-	-	Granite, fraction ca 20 mm Bullets and fragments: Results depend on stone size. Bigger stones are good.	**GRAVEL**
4	50	300	51		
3	23	115	20		
2	15 x	46	25		
1	N.D.	-	20		
5	N.D.	-	-	Medium density soil. Loose soil: add 50 %	**SOIL (HUMUS)**
4	61	400	55		
3	41	155	21		
2	22	62	23		
1	N.D.	-	21		
5	N.D.	-	-	Moist, stiff, medium dense. Less stiff or more loose / wet: Add 50 - 100 %	**CLAY**
4	71	178	66		
3	51	69	32		
2	37	28	35		
1		-	32		
5	N.D.	-	-	Limited amounts of data	**TAMPED SNOW**
4	N.D.	N.D.	200		
3	200	N.D.	200		
2	200	N.D.	200		
1	N.D.	-	200		
5	N.D.	-	-	Note: Large and unpre-dictable deviations occur (wood types, moisture, rot...). Wood is generally not recommended as protection	**TIMBER (PINE)**
4	N.D.	267	270		
3	N.D.	104	40		
2	50	42	44		
1	N.D.	-	40		

C2 NOTES

The table on the previous page contains basic information about the required thickness of different materials in order to stop

- bullets,
- shaped charges,
- fragments.

This corresponds to threat class A, B and C. For the threat classes D, E and F the loading situation is more complicated, since several effects work together. One should therefore consult reference literature or confirmed test results in such cases.



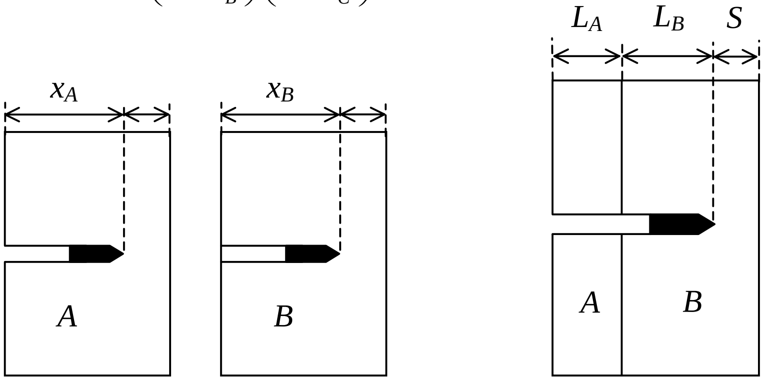
The numbers given in are "reference values" - that is, general estimates which will be close to reality in most cases. However, it is not possible or practical to cover all possible weapons. Note that particularly optimized weapons will exist within each threat class, but it would not be cost effective to design against them on every occasion. Based on intelligence, all protection measures should be tailored to the specific threat.

The numbers are penetration depths, which is different from protection thickness. This is more useful if the protection consists of more than one material, or a protection layer is added to an existing structure. If only one material is used (e.g.in Hesco Bastions), safety factors must be added as follows:

- Bullets and fragments: 50 %
- Shaped charges: 30 %

If more than one material is used, the following approximation can be employed (here indicated for 2 and 3 materials, but this can be generalized):

$$L_A = x_A\left(1-\frac{L_B}{x_B}\right)\ ,\ \ L_A = x_A\left(1-\frac{L_B}{x_B}\right)\left(1-\frac{L_C}{x_C}\right)\ ...$$



Sources / references for the table values are listed separately in Annex E.

GUIDELINES FOR HANDOVER / CLASSIFICATION AND TESTING

D1 GENERAL

The purpose of the STANAG 2280 is to provide:

- A common language to evaluate and classify threats
- A well defined handover procedure between nations
- A common understanding of the necessary protection against various threats

For these purposes the following parts of this STANAG are employed:

- Threat matrix
- Classification form
- Reference values for protection thickness

The handover form summarizes the thinking behind the various protective structures in a camp, so that a second nation who is moving in or taking over will have specific knowledge about the protection level. In brief, the form should answer the following:

- Which threats did you design for?
- How did you do it?
- How do you know it is working?

Note: Within the field of physical force protection it will often be necessary to invent new solutions or employ known principles in a new and creative manner. Both the STANAG itself and the handover form are supposed to be helpful tools, and not impose limitations or problems on the work of experienced engineers.

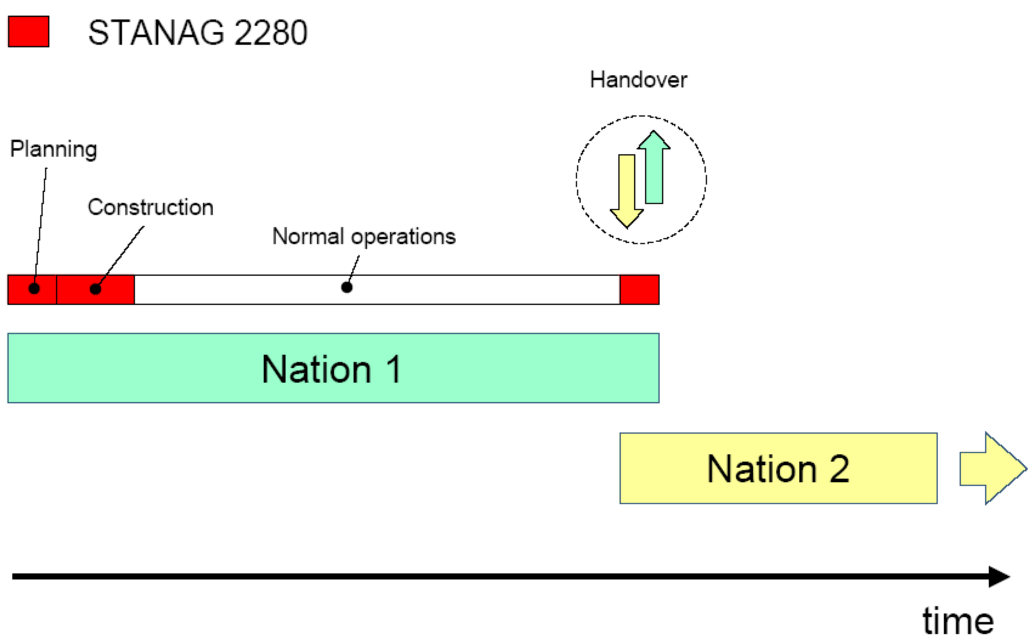


Figure 1

D2 HANDOVER FORM – PRACTICAL GUIDELINES

One handover form is to be made for each structure type - e.g. living shelters, observation posts, perimeter protection and so on. It also works for vehicle arresting equipment. The form can (and should) be used already in the planning and construction phase. However, it is simple enough to be filled in by hand if necessary.

The threat matrix (Annex A and below) describes threat levels for small / medium calibre projectiles (A), rifle grenades / shoulder launcehed weapons (B), indirect fire (C, D, E) and IEDs (F).

Note that the threat matrix can not cover all possible threats and weapons. In cases where a protective structure has been designed to withstand a weapon which is not specifically covered by the matrix, the most relevant class should be given and a note made on the specific weapon.

For instance, direct impact of a Type 63 unguided rocket will have an effect between impact of a 120 mm mortar round (D3 / E3) and a 155 mm artillery grenade (D4 / E4). Hence, class D3 / E3 should be given with an additional comment.

			(Near miss)	*(Surface hit)*	*(Delay fuze)*	
	A	**B**	**C**	**D**	**E**	**F**
5	< 30 mm APDS	(open)	(open)	(open)	(open)	5000 kg TNT
4	< 14.5 mm AP	Large shoulder launched AT	155 mm artillery	155 mm artillery	155 mm artillery	1000 kg TNT
3	< 7.62 mm AP	Small shoulder launched AT	120 mm mortar	120 mm mortar	120 mm mortar	250 kg TNT
2	< 7.62 mm	Rifle / AGL grenade	81 mm mortar	81 mm mortar	81 mm mortar	50 kg TNT
1	< 9 mm	(open)	60 mm mortar	60 mm mortar	60 mm mortar	10 kg TNT
	IMPACT LOADING			*COMPLEX LOADING*		

Figure 2: STANAG 2280 threat matrix (same as Annex A)

Some practical examples on use of the different sections of the handover form is shown below. There is no standard solution to this, and the user could supply additional documentation if needed.

<table>
<tr><td rowspan="7">Installation details - ID, type and materials (Example)
Objects no. 12-24. Living shelters, ISO steel container with 3mm walls, 70 mm insulation and gypsum inner walls. No special ballistic protection. Sectioning walls between and around the containers, 200 mm concrete blocks (cast fixed) to a hight of 1 meter to protect against fragments.</td><td></td><td colspan="6">Design level</td></tr>
<tr><td>5</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>4</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td></td><td></td><td>X</td><td></td><td></td><td></td></tr>
<tr><td>2</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>1</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>A</td><td>B</td><td>C</td><td>D</td><td>E</td><td>F</td></tr>
</table>

Figure 3: Example. The miniature version of the threat matrix in the top section of the handover form summarizes the design level of the structure (i.e. the threats the structure has been designed to defeat).

C3	**Certified - industrial / mil standard**		**Field tested - on site**	**X**
	Calculated or estimated		**Field tested - other location**	
	Comments / references (C3) A section of the concrete wall was tested against a live 120 mm shell in january 2004 (report attached). The wall will stop 155 mm fragments as well (calculated), but it is estimated that the air blast could damage the wall.			

A3	**Certified - industrial / mil standard**	**X**	**Field tested - on site**	
	Calculated or estimated		**Field tested - other location**	
	Comments / references (A3) The container system was delivered according to STANAG 4569 Level 3 (7,62 AP). Note that the roof is unprotected			

A4	**Certified - industrial / mil standard**		**Field tested - on site**	**X**
	Calculated or estimated		**Field tested - other location**	
	Comments / references (A4) The observation post with additional sandbag protection was field tested against 12,7 mm AP ammunition in january 2004. See attached test report.			

B3	**Certified - industrial / mil standard**		**Field tested - on site**	
	Calculated or estimated	**X**	**Field tested - other location**	
	Comments / references (B3) The perimeter consists of a double layer of Hescos filled with sand / gravel. According to the reference values in this STANAG and the Norwegian Handbook, protection will be given against a standard RPG-7.			

F4	**Certified - industrial / mil standard**		**Field tested - on site**	
	Calculated or estimated		**Field tested - other location**	**X**
X VEHICLE STOPPING ☐ FRAGMENTS ☐ PRESSURE ☐ NO SECONDARY FRAGMENTS	Comments / references (F4) The vehicle blockade system has been successfully tested against a 6 t truck in 40 km/h in the UK. Furter details can be given on request.			

F3	**Certified - industrial / mil standard**		**Field tested - on site**	
	Calculated or estimated	**X**	**Field tested - other location**	
X VEHICLE STOPPING **X** FRAGMENTS ☐ PRESSURE ☐ NO SECONDARY FRAGMENTS	Comments / references (F3) Hesco perimeter. Will stop passenger vehicles / vans (estimated) and high velocity fragments from detonating VBIED. Residual risk from falling fragments.			

Figure 4: Individual examples - documentation of the quality control of a design level

Some comments on the different alternatives in the following table are given below.

	Certified - industrial / mil standard	(a)	**Field tested - on site**	(b)
	Calculated or estimated	(c)	**Field tested - other location**	(d)

(a) Certified - industrial / military standard

This means that the protective structure has been tested and classified according to a trustworthy industrial or military standard. This will typically be the case for containers and similar deployable structures, which have been tested by the supplier of the equipment. The threat will often be small and medium calibre projectiles.

(b) Field tested - on site

The structure, or a similar structure built from exactly the same type of local materials, has been tested on site against the actual weapons. In this way, problems with deviating properties of local geomaterials are avoided. Tests can typically be performed for class A, B and C: Small / medium calibre weapons, shoulder launced weapons and the fragmenting effect from mortar and artillery rounds. For complex loadings, i.e. direct hits from heavier weapons, see below.

Basic guidelines for sound "on-site" test procedures for class A, B and C are given in chapter 3 of this Annex. As a minimum requirement, the test should be documented to a level sufficient for others to replicate the test (or modified test) at a later stage.

(c) Field tested - other location

The term "other location" can imply a different operational camp, or a dedicated test range. In the latter case, even tests with complex loadings may be performed - i.e. direct hits from heavier weapons, or complicated IED situations.

Note that the quality of (geological) materials can vary considerably between sites.

(d) Calculated or estimated

This is a strict requirement, in so far as "estimate" means that the structure has been designed by trained personnel according to approved design tools and sound engineering practice. Normally, a representative test has not been carried out. This procedure will normally only be used for class A, B and C, as the complex loading situations are too difficult to handle with simple tools.

D3 THREAT CLASSES AND FIELD TESTS

This section gives brief description and useful comments of the individual threat classes.

Furtermore, practical guidelines for field tests of projectile impact (Threat Class A, B, C) are given. The guidelines should, as a minimum, be followed whenever field tests are performed. Test reports should follow the handover form.

For the threat classes D, E, F, which implies complex loadings, tests will often require special skills and equipment. It is assumed that such tests are performed in accordance with normal scientific procedures, and no guidelines are given in this document.

A Small / medium calibre projectiles

General remarks

There are a large number of small and medium calibre weapons and ammunition types on the market. Their effect in a target will depend on several factors: Mass, shape, impact velocity, projectile hardness and obviously the target material itself.

For instance, with assault rifle ammunition, the (previously) standard NATO 7,62 mm ammunition has nearly twice the muzzle energy compared to the russian AK-47 projectile (appr. 3500 vs 2000 J) – it is heavier and goes faster. However, the AK-47 projectile has a steel core where the NATO 7,62 uses lead. So however less energetic, 7.62 x 39 (and also 5.56 x 45) with steel core can be more efficient against some materials and personal protection systems.

Note also there can be some conficion regarding the correct designations of various rounds and projectiles. This is often because different countries (or defence organizations, such as NATO) uses different names, and the producers may use names which deviates from the official defence terms.

As for exact data, use of different sources will often yield slightly different results. There is also a particular issue when it comes to muzzle velocity. This is determined by the round and the pipe length – i.e. the particular weapon. The stated velocity figures can often be results from a particular test- or reference weapon, but this is seldom indicated.

The following "rules of thumb" should be noted:

(a) For scaling of a known result for penetration *in the same material* to another velocity, or even another projectile (of approximately the same geometry and hardness), the expression below can be used with some care:

$$x_B = x_A \left(\frac{m_B}{m_A}\right)\left(\frac{A_A}{A_B}\right)\left(\frac{v_B}{v_A}\right)^2$$

In this formula the penetration depth *x* and the mass *m*, cross sectional area *A* and velocity *v* is known for projectile *A*. The penetration *in the same material* for a different projectile *B* can then be estimated. (*B* can be the same projectile as *A* with a different velocity.)

(b) Typical velocities for various projectiles

Round	0 m	100 m	200 m	300 m	400 m	500 m	Bullet
5,56 x 45	930	832	740	650	574	500	4,0 g
7,62 x 39	710	631	547	471	399	343	7,9 g
7,62 x 51	854	778	709	642	578	518	8,65 g
7,62 x 54	804	733	667	606	550	500	12,0 g
12,7 x 99	926	883	840	799	759	721	44,4 g
12,7 x 107	840	802	766	730	696	662	48,3 g
14,5 x 114	976	936	897	859	822	786	63,4 g

Typical threats (examples)

A1 Pistol / Personal Defence Weapon < 9 mm

- 7N25 round - PM / Makarow pistol and PP-90 sub machine-gun
  Calibre 9x18 mm
  Projectile mass 3,55 g
  Muzzle velocity 520 m/s
  Muzzle energy 480 J

- 9 mm - Glock pistol - IMI 9 mm sub machinegun
  Calibre 9x19 mm
  Projectile mass 7,5 g
  Muzzle velocity 400 m/s
  Muzzle energy 600 J

A2 Assault rifle < 7.62 mm

- M1943 for AK-47 and similar
  Calibre 7,62 x 39 mm
  Projectile mass 8,0 g
  Muzzle velocity 740 m/s
  Muzzle energy 2190 J

  (The Ball round utilizes a steel core projectile)

- 5,56 mm NATO for M16 and similar
  Calibre 5,56 x45 mm
  Projectile mass 4,0 g
  Muzzle velocity 930 m/s
  Muzzle energy 1730 J

A3 Sniper / assault rifle < 7.62 mm AP

- 7,62 mm for Dragunov 7,62 mm SVD sniper rifle and similar

  Calibre 7,62 x 54 mm
  Projectile mass 9,8 g (7N14, steel core)
  Muzzle velocity 830 m/s
  Muzzle energy 3376 J

  (The Heavy Ball D with a lead core has a projectile mass of 12 g / velocity 804 m/s)

- To be decided

  Calibre
  Projectile mass
  Muzzle velocity
  Muzzle energy

A4 Machine gun < 14.5 mm AP

- To be decided

  Calibre
  Projectile mass
  Muzzle velocity
  Muzzle energy

- To be decided

  Calibre
  Projectile mass
  Muzzle velocity
  Muzzle energy

A5 Automatic cannon < 30 mm APDS

- To be decided

  Calibre
  Projectile mass
  Muzzle velocity
  Muzzle energy

- To be decided

  Calibre
  Projectile mass
  Muzzle velocity
  Muzzle energy

Field testing

The aim of the described field test is to emulate the effect of short bursts of automatic fire at close range. The following procedure should be followed:

A group of 3 individual shots is fired at a distance of 50 m against a representative section of the protective structure. Witness plates of 0.5 mm aluminium or a weaker material (such as unlaminated cardboard, as used for practice target materiel) is placed behind the target.

After a series of 3 shots, the target component and witness plates are carefully examined by experienced personnel. If no damage is seen on the witness plates, the protection is considered sufficient. If there is reasonable doubt whether another test would give the same result, repeated series of 3 shots are fired with inspection after each series.
The documentation should be kept in a compact and readable format. It must, as a minimum, contain the following:

- Date and place of test
- Name and rank of test leader
- Ambient conditions: Temperature and estimated wind speed
- Description of the protective structure
- Weapon type, version (in particular: barrel length), manufacturer, serial number
- Ammunition type, version, manufacturer, military supplier, LOT

Pictures should be included as considered appropriate.

B Rifle grenades - shoulder launched weapons

General remarks

Hollow charges can penetrate from 4 to 8 - 9 warhead calibers in steel. For typical "2nd generation weapons" the figure vill usually be around 5 calibers. For penetration in other materials, scaling with the density of steel and the density of the new target density gives to a first approximation:

$$X = X_{steel} \sqrt{\rho_{steel} / \rho_{target}} .$$

This may not be valid for porous materials.
The impact fuze ensures optimum detonation distance of the shaped charge. "Rocket screens" and similar concepts may be used to trigger the warhead prematurely.

Typical threats (examples)

B1 (open)

B2 Rifle/AGL grenade SC < 40 mm

- 40 mm DM 12 HEDP rifle grenade
  Calibre: 40 x 46 mm
  (shaped charge / fragments)
  Maximum range: 400 m
  muzzle velocity: 72 m/s

B3 Small shoulder launched AT SC < 90 mm

- <u>RPG-7 with PG-7N warhead</u>
  Warhead calibre: 70 mm
  Maximum range: 500 m
  Armour penetration: 400 mm (5,7 calibers)

- <u>RPG-26 Aglen</u>
  Warhead calibre: 72,5 mm
  Effective range: 250 m
  Armour penetration: 440 mm (6,1 calibers)

- <u>M72 A4</u>
  Warhead calibre: 66 mm
  Maximum range: 350 m
  Armour penetration: 355 mm (5,4 calibers)

B4 Large shoulder launched AT SC < 150 mm

- <u>RPG-27 Tavolga</u>
  Warhead calibre: 105 mm
  Effective range: 200 m
  Armour penetration: 750 mm (7,1 calibers)

- <u>RPG-7 with PG-7VR tandem warhead</u>
  Warhead calibre: 105 mm
  Effective range: 200 m
  Armour penetration: 750 mm (7,1 calibers)

- <u>Eryx guided AT weapon</u>
  Warhead calibre: 135 mm
  Effective range: 600 m
  Armour penetration: 900 mm (6,7 calibers)

B5 (open)

Field testing

The proposed test consists of a single firing with a representative weapon from a distance of 50 m against a representative section of the protective structure. The weapon might be fired remotely mounted in a suitable test rig. Alternatively, a static firing of a warhead can be performed.

For detection of perforation or spalling , witness plates of 0.5 mm aluminium or a weaker material (such as unlaminated cardboard, as used for practice target materiel) is placed behind the target. After the firing, the target component and witness plates are carefully examined by experienced personnel. If no damage is seen on the witness plates, the protection is considered sufficient. If there is reasonable doubt whether another test would give the same result, the test is repeated.

If the construction uses rocket screens or similar to activate the fuze prematurely, special care must be taken regarding the effect of blind shells.
National safety rules apply. Note in particular the danger of radial fragments.
The documentation should be kept in a compact and readable format. It must, as a minimum, contain the following:

- Date and place of test
- Name and rank of test leader
- Ambient conditions: Temperature and estimated wind speed
- Description of the protective structure
- Weapon type, version (in particular: warhead), manufacturer, serial number
- Static or live firing

Pictures should be included as considered appropriate.

C Mortars and artillery - indirect fire

General remarks

Mortars have been produced in calibers 50-160 mm, with maximum range up to 10 km. Minimum range will normally be around 70 m. A conventional mortar grenade is fin stabilized and fored from a smooth bore barrel. Mortars are normally fired at elevations > 45°, and the grenade will have an similar impact angle. Modern fuzes are of the proximity type, so that the grenade detonates in an optimum height (3-6 m). Simple impact fuzes are also widely used, while delay fuzes are not so common.

105 – 155 mm artillery is the next step in threat. Larger calibers also exist, but are not so common. Artillery grenades can have a higher hit probability than mortars, since they are spin-stabilized. They can be fired at elevations < 45°. Typical range is 40 km, and typical impact velocities 340 m/s (long range) and 700 m/s (short range). Fuzes are similar to thise for mortars.

The fragmentation pattern for mortar and artillery grenades is determined by the material type, explosives type, amount of explosives relative to the casing thickness and the geometrical shape. A brittle casing will normally give smaller fragments. This will enhance the effect against personnel, and cast iron is therefore often used in mortar grenades. Artillery grenades are frequently made from forged steel, which gives fewer and heavier fragments.

Fragments are rapidly slowed down due to air resistance. The drag force is determined by the coefficient C_D and the front area. C_D is approximately constant for high velocities (>>Mach 1), which is true for fragments (1500 - 2500 m/s). This implies that the velocity falls exponenially, so that the speed will be halved after a fixed distance – which varies with the fragment mass, light fragments being slowed down quicker than heavy ones:

Fragment mass (g)	Half-speed distance (m)
0.01	3.8
0.1	8.1
1	17.4
10	37.5
100	80.9

The penetration capability of fragments can, as an approximation, be scaled similarly to projectiles by the relation

$$x_B = x_A \left(\frac{m_B}{m_A}\right)\left(\frac{A_A}{A_B}\right)\left(\frac{v_B}{v_A}\right)^2$$

That is, if you know the penetration depth *x* by one particular fragment *A*, the penetration in the same material by a different fragment *B* with different mass, area or velocity can be found from the formula above.

Typical threats (examples)

C1 Mortar < 60 mm

Type	Mass	Calibre	Explosive	Casing	Fuze
M73 (Yugoslavia)	1350 g	60 mm	220 g TNT	-	Impact
M91 (Yugoslavia)	2100 g	60 mm	400 g RDX/TNT	Cast iron	Impact / time
GMO-6PE A1 (Bulgaria)	1600 g	60 mm	200 g TNT	Cast Iron Prefrag. 500	Impact / time
M49A4 (USA)	1540 g	60 mm	190 g COMP B	Cast iron	Impact

C2 Mortar < 82 mm

Type	Mass	Calibre	Explosive	Casing	Fuze
NM 123A1 (Norway)	4340 g	81 mm	800 g RDX/TNT	Ductile cast iron	Proximity
M374 A2 (USA)	4236 g	81 mm	935 g COMP B	Forged steel or ductile cast iron	Proximity, impact
M43 A1 (USA)	3240 g	81 mm	585 g COMP B	Forged steel	Impact
M74 (Yugoslavia)	3050 g	82 mm	680 g TNT	Forged steel	Impact, delay

C3 Mortar <120 mm

Type	Mass	Calibre	Explosive	Casing	Fuze
M62 P1 (Yugoslavia)	12600 g	120 mm	2250 g TNT	-	Impact, time
OF-843 (Russia)	16020 g		2680 g TNT	Cast iron	Impact, time
M934 (USA)	14150 g		2999 g RDX/TNT	Forged steel	Impact, time, proximity

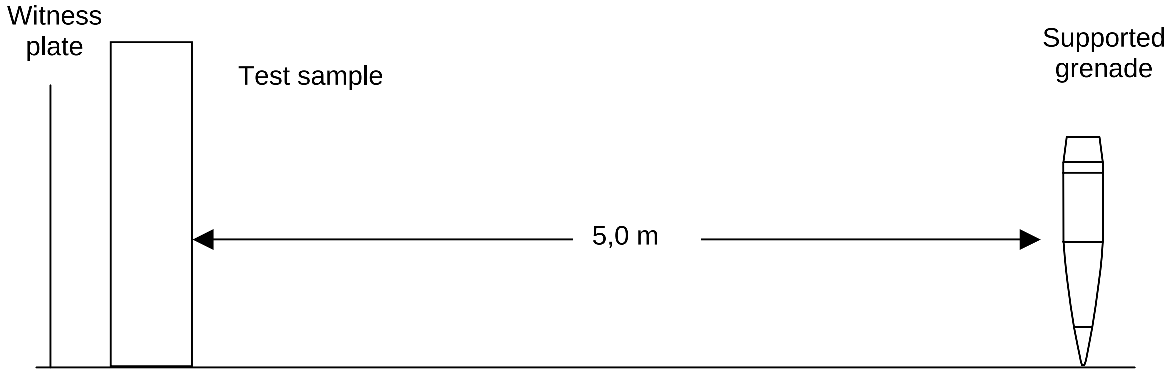
C4 Artillery < 155 nn

Type	Mass	Calibre	Explosive	Casing	Fuze
30F45 (Russia)	43,6 kg	152 mm	7,65 kg A-IV-2	Forged steel	-
30F33 (Russia)	33,4 kg	130 mm	4,2 kg	Forged steel	-
M107 (USA)	43,9 kg	155 mm	6,62 kg TNT	Forged steel	Impact, time, proximity

C5 (open)

Field testing

In STANAG 2280, the "near miss" criterion is defined as a distance of 5 m. This will also cover a close-in detonation of a shell with proximity fuze (in which case roof protection is vital). A live test / demonstration should look like this:



However, this setup is demanding on the size of the target. It is therefore recommended that a smaller distance is used, in order to ensure a sufficient number of fragment impacts on the structure, and make the results slightly conservative. 10 calibres should be considered a minimum standoff distance. For example, with a 155 mm grenade, the reduction of distance will only increase the fragment impact velocity fron 980 to 1010 m/s.

The documentation should be kept in a compact and readable format. It must, as a minimum, contain the following:

- Date and place of test
- Name and rank of test leader
- Ambient conditions: Temperature and estimated wind speed
- Description of the protective structure
- Weapon type
- Description of test details

Pictures should be included as considered appropriate.

D Mortars and artillery - indirect fire

A test which deals with combined and complex loadings requires specialized skills and equipment. The test procedures must be adapted to the design of the protective structure, and no strict guidelines can be given.

Note in particular the danger of structural collapse, the problem of blind shells, the possible small delay of even an "instant" impact fuze and the non-trivial relation between a static and dynamic firing.

E Mortars and artillery - indirect fire

See comments under Class D.

F IEDs / car bombs

Materiel for the protection against Improviced Explosive Devices (IEDs), and most importantly vehicle bombs (Vehicle Born IEDs or VB IEDs) can be of very different types. It can be designed to stop vehicles, to stop fragments from the explosion, or protect personnel from the combined effect of blast and fragments. It can be of importance that no secondary fragments are produced.

No clear guidelines can be given for testing of equipment for reducing the effects of IEDs.

ANNEX E

REFERENCE VALUES - SOURCES AND COMMENTS

This Annex gives a reworked summary of the document "Values for STANAG 2280 - Draft Edition 1, April 1 2004, where open sources were used to find best estimates of protective material thickness of (geo)materials against different threats. *(Comment in Draft Edition 3: If classified results are included at a later stage, the STANAG must be classified accordingly.)*

In the table on Annex C, penetration depths are given, not protective thickness. The results are meant to act as reference values. They can be a useful guide as a quality control of the design tools, or as a rough guide during the construction of improvised fortifications if no other manuals are available. If the numbers are used for design purposes, a safety factor which depends on the nature of the structure must be included.

The different manuals used to predict the penetration depth of weapon types in different materials can, and will, give deviating answers. There can be numerous reasons for this;

- Several materials (such as soil) do not have uniquely defined properties. In many cases, manuals do not give such details and consequently, two sources can give very different estimates for the penetration of a given weapon.

- Formulas in handbooks are often based on experiments. Using a formula outside the range of validity can lead to wrong results.

- Sometimes, there are errors in the manuals. For instance, the otherwise reputable CONWEP code predicts that a 12,7 mm projectile can penetrate more than 7 meters of wood. (This may also be due to the formula being used outside the validity range.)

The table values in Annex C have been found through a comprehensive study of numerous protection manuals, and in addition some calculations and comparison to experiments have been carried out. For some materials and types of weapons no data have been found. This should be improved i an later version of the document.

As mentioned above, the values are given for penetration in a so-called semi-infinite target (that is, a very thick target). The limit thickness of a construction will be larger than this. However, a design will often be made up of more than one material (such as gravel and wood, or steel and sand). For this reason, we find that giving the limit thickness of different materials (if used alone) would be less useful.

For mortar and artillery shells, design fragments from CONWEP are used for 60 and 81 and 155 mm. For 120 mm, a brittle casing of cast iron is assumed, hence results close to those for 60 mm. 81 mm mortar grenades often have a steel body, hence larger design fragments.

			(Near miss)	*(Surface hit)*	*(Delay fuze)*	
	A	**B**	**C**	**D**	**E**	**F**
5	< 30 mm APDS	(open)	(open)	(open)	(open)	5000 kg TNT
4	< 14.5 mm AP	Large shoulder launched AT	155 mm artillery	155 mm artillery	155 mm artillery	1000 kg TNT
3	< 7.62 mm AP	Small shoulder launched AT	120 mm mortar	120 mm mortar	120 mm mortar	250 kg TNT
2	< 7.62 mm	AGL grenades	81 mm mortar	81 mm mortar	81 mm mortar	50 kg TNT
1	< 9 mm	(open)	60 mm mortar	60 mm mortar	60 mm mortar	10 kg TNT
		IMPACT LOADING			*COMPLEX LOADING*	

References

The following references are used in the footnotes to the individual tables later in the document.

- Norwegian Handbook: Forsvarets håndbok i våpenvirkninger (Norwegian military handbook for weapons effects)
- FFI: Semi-analytical numerical tool based on Cavity Expansion Theory. Norwegian Defence Research Establishment
- HI: Hærens Ingeniørhøyskole. Report created by students form the Norwegian Military Engineering College. Results from their own experiments with 5.56 mm and 7.62 mm against various materials.
- Jane's: Jane's Defence Equipment Library. Different types of data, sometimes from manufacturers, and sometimes confirmed test results
- TM5: TM5-855-01: US army technical manual (CONWEP). Mainly based on empirical formulas / experimental data.
- FM: FM 5-430-00-2/AFJPAM 32-8013: US army manual. Probably based on experiments, but this is not clear.
- EFD: Engineer Field Data (Headquarters, Department of the Army). Gives required thickness of various materials to protect against various threats (direct and indirect fire). It is not indicated in the section at our disposal how these thicknesses have been obtained, but presumably through experiments.
- CAM: Commander's Aide Memoire (Canadian Forces School of Military Engineering). Gives values for protective thickness of several materials. Not known where the values come from.
- DAHSCWE: Design and Analysis of Hardened Structures to Conventional Weapons Effects. Joined effort by Defense Spesial Weapons Agency, Army, Navy and Air Force. Supersedes TM5-855-1. Product of the combined research and field testing, other applicable referenced government documents and current design practise.
- NTNU: Experimental data from Norwegian Technical University (unpublished)

CONCRETE (C25)
All numbers in cm

	A	B	C	D	E	F
5	N.D. (4)					
4	**36** (1)	**160** (2)	**11** (1)			
3	**21** (1)	**64** (3)	**4** (1)			
2	**10** (5)	**26** (3)	**6** (1)			
1	N.D.		**3** (1)			

(1) Norwegian Handbook (See reference list above)
(2) DAHSCWE. Scaling of results for steel with a factor 1.82. Various other sources give a value of 250 cm, and this should be checked.
(3) DAHSCWE. Scaling of results for steel with a factor 1.82
(4) No data available
(5) Data from FFI (not published)

STEEL ARMOUR (BHN 360)
All numbers in cm

	A	B	C	D	E	F
5	N.D.					
4	**2.5** (6)	**90** (4)	**2.5** (1)			
3	**1.5** (6)	**50** (7)	**0.7** (1)			
2	**0.8** (6)	**14** (2)	**1.2** (1)			
1	N.D.		**0.7** (8)			

(1) DAHSCWE (The formulas give the maximum plate thickness which can be penetrated.)
(2) Norwegian Handbook. Shaped charge 40 mm (1st generation), assumed standoff distance 20 mm
(3) Norwegian Handbook. PG-7M 2nd generation warhead, penetration 5 calibre diameters
(4) Jane's. Eryx 3rd generation warhead, penetration of 6.5 calibre diameters. Generally typical for 130 mm x 7 calibers
(5) -
(6) As (1), but adhusted according to data for known ammunition from Jane's
(7) 90 mm x 5.5 calibers
(8) No data. Assumed brittle casing, same value as C3

SAND (0-2 mm)
All numbers in cm

	A	B	C	D	E	F
5	N.D.					
4	**38** (2)	**340** (6)	**42** (4)			
3	**23** (1)	**132** (5)	**16** (4)			
2	**15** (1)	**53** (5)	**17** (4)			
1	N.D.		**16** (9)			

(1) NTNU. Consistent with HI (student report). CONWEP also give consistent estimates. EFD, CAM and FM give estimates that appear to be high, possibly as a safety factor (as they give protective thickness)
(2) TM5
(3) No data available
(4) FFI
(5) DAHSCWE Appendix D6.5. Based on this text, a scaling with the "density rule" is performed (density 1800 kg/m^3), and the result is multiplied with 1.8. Total scaling 3.76. TM5 - CONWEP and EFD - Engineer Field Data gives about 200 cm for RPG-7
(6) As (5), but note that the precursor (tandem charge) may give some effect in loose target materials
(7) -
(8) NTNU
(9) No data. Assumed brittle casing, same value as C3

GRAVEL (2-40 mm)
All numbers in cm

	A	B	C	D	E	F
5	N.D.					
4	**50** (3)	**300** (4)	**51** (2)			
3	**23** (3)	**115** (4)	**20** (1)			
2	**15** (5)	**46** (4)	**25** (2)			
1	N.D.		**20** (1)			

(1) Estimated from values for sand and (2)
(2) Data from EFD - Engineer Field Data. These are, however, questionable.
(3) NTNU
(4) DAHSCWE Appendix D6.5. Based on this text, a scaling with the "density rule" is performed (density 1800 kg/m^3), and the result is multiplied with 1.8. Total scaling 3.76. (Numbers will follow)
(5) Worst value of NTNU and HI

SOIL (HUMUS)
All numbers in cm

	A	B	C	D	E	F
5	N.D.					
4	**61** (2)	**400** (5)	**55** (3)			
3	**41** (2)	**155** (4)	**21** (3)			
2	**22** (1)	**62** (4)	**23** (3)			
1	N.D.		**21** (6)			

(1) HI. CAM and EFD give large deviations from the HI result. Results can be strongly dependent on soil types. Consistent with DASHSCWE
(2) Result from Field Manual, multiplied with a factor 2/3 to make the results more consistent with values for sand.
(3) DAHSCWE - Predicts soil to be easier to penetrate than sand, as expected
(4) DAHSCWE Appendix D6.5. See corresponding values for sand. A scaling with the "density rule" is performed (denity 1300 kg/m^3), and the result is multiplied with 1.8. Total scaling 4.42 relative to steel armour.
(5) As (4), but note that the precursor (tandem charge) may give some effect in loose target materials
(6) No data. Assumed brittle casing, same value as C3

CLAY
All numbers in cm

	A	B	C	D	E	F
5	N.D.					
4	**71** (4)	**178** (6)	**66** (5)			
3	**51** (3)	**69** (6)	**32** (5)			
2	**37** (1)	**28** (6)	**35** (5)			
1	N.D.		**32** (2)			

(1) HI adhusted by the soil equation in DAHSCWE
(2) No data. Assumed brittle casing, same value as C3
(3) Field Manual. Results multiplied by a factor 2/3.
(4) TM5-855 / CONWEP. Field Manual gives 100 % more (as protection thickness)
(5) DAHSCWE . CONWEP estimates are roughly 1.5 times higher.
(6) DAHSCWE. Scaling of results for steel with a factor 1.98 from the density rule. We assume a density of 2000 kg/m^3. Clay is a homogeneous material with very small particles and plastic behaviour, so the problems with sand and soil is probably not present
(7) HI adhusted by soil equation in DAHSCWE

TAMPED SNOW
All numbers in cm

	A	B	C	D	E	F
5	N.D.					
4	N.D.	N.D.	**200** (3)			
3	**200** (4)	N.D.	**200** (3)			
2	**200** (1)	N.D.	**200** (3)			
1	N.D.		**200** (2)			

(1) CAM - Estimates relatively consistent except upper bound of FM
(2) No data. Assumed brittle casing, same value as C3
(3) EFD. Engineer Field Data + 50 cm. We have added an estimated number since number given in EFD probably corresponds to a 15 m standoff.
(4) No estimate available in the references. We assume there is not much difference between the various 7.62 mm ammunition types in a soft material, hence we use (1)

TIMBER (PINE)
All numbers in cm

General note: Very different results from different sources. Wood type not always revealed. Timber should generally not be used as protective material.

	A	B	C	D	E	F
5	N.D.					
4	N.D. (3)	**267** (4)	**270** (5)			
3	N.D. (3)	**104** (4)	**40** (6)			
2	**50** (1)	**42** (4)	**44** (5)			
1	N.D.		**40** (6)			

(1) HI (student report). Other formulas give very different estimates, including 280 cm by CONWEP.
(2) Value expected to be close to the trusted A1. TM5 gives the results 190 cm and 240 cm, which we believe are much too high.
(3) No data, except from CONWEP which gives unrealistically high values.
(4) DASCHWE. Results for steel armour scaled with a factor 2.97.
(5) TM5/DASCHWE. Hard to believe, but at least a consistent set
(6) Estimated from (5) and values for other materials