Designation: ~~E3004 – 20a~~ E3004 – 22

Standard Specification for Preparation and Verification of Clay Blocks Used in Ballistic-Resistance Testing of Torso Body Armor[1]

This standard is issued under the fixed designation E3004; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

At the time when work on this specification was undertaken, different ballistic-resistant body armor test protocols required different impactors for verification of the clay blocks placed behind the test items, and the lack of detailed guidance about the clay blocks resulted in different practices for preparation and verification. To improve laboratory-to-laboratory consistency, major stakeholders sought to harmonize practices related to the preparation and verification of the clay blocks used for testing of ballistic-resistant body armor.

1. Scope

1.1 The purpose of this specification is to provide standardized methods for preparation and verification of backing assemblies used in ballistic-resistant torso body armor testing and to reduce variability within and between laboratories.

1.2 The backing assembly is a clay block that contains ROMA Plastilina No. 1®[2] clay as the backing material. The clay serves as a witness material and provides a measurable indication of test item performance.

1.3 This specification identifies two clay-verification impactors that may be used: (*1*) cylindrical and (*2*) spherical. Purchasers and other users will specify the clay-verification impactor to be used.

1.4 This specification is primarily directed toward test laboratories but may be applicable to body armor manufacturers, researchers, and end users performing ballistic-resistance testing of body armor.

1.5 *Units*—The values stated in SI units are to be regarded as standard. The values given in parentheses are mathematical conversions to non-SI units that are provided for information only.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

---

[1] This specification is under the jurisdiction of ASTM Committee E54 on Homeland Security Applications and is the direct responsibility of Subcommittee E54.04 on ~~Personal Protective~~Public Safety Equipment ~~(PPE)~~.

Current edition approved ~~July 1, 2020~~Oct. 1, 2022. Published ~~July 2020~~October 2022. Originally approved in 2015. Last previous edition approved in 2020 as ~~E3004 – 20.~~E3004 – 20a. DOI: ~~10.1520/E3004-20A.~~10.1520/E3004-22.

[2] U.S. Government standards require ROMA Plastilina No. 1®, from Sculpture House, Inc., as the backing material for ballistic-resistance testing.

2. Referenced Documents

2.1 *ASTM Standards:*[3]

E3005 Terminology for Body Armor

2.2 *NIST Standard:*[4]

NIST Special Publication 330 The International System of Units (SI), 2008 Edition, Barry N. Taylor and Ambler Thompson, Editors

3. Terminology

3.1 The terms and definitions of Terminology E3005 apply for the following terms: *backing assembly, backing fixture, backing material, bridge gauge, clay block, clay package, clay-verification impactor, depth gauge, striking device*, and *test item*.

4. Significance and Use

4.1 U.S. Department of Defense and U.S. Department of Justice standards for assessing the performance of ballistic-resistant torso body armor require the use of backing assemblies made with Roma Plastilina No. 1®. It can be demonstrated that the way the clay block is handled prior to and during ballistic testing can have a significant influence on deformation of the clay when a test item is struck by a projectile during testing.

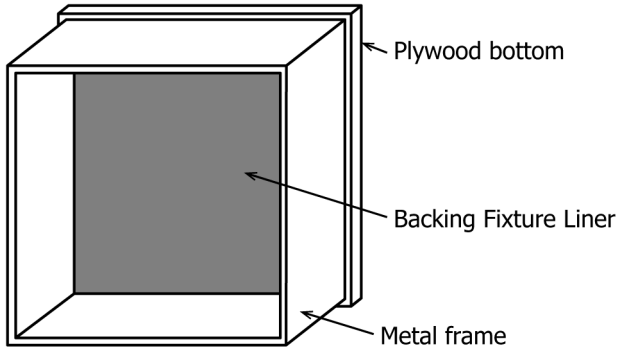
4.2 At the time when work on this specification was undertaken, different ballistic-resistant body armor test protocols required different impactors for verification of the clay blocks placed behind the test items, and the lack of detailed guidance about the clay blocks resulted in different practices for preparation and verification. To improve laboratory-to-laboratory consistency, major stakeholders sought to harmonize practices related to the preparation and verification of the clay blocks used for testing of ballistic-resistant body armor.

5. Equipment

5.1 The equipment used for preparation and verification of clay blocks shall be as described below:

5.1.1 *Backing Fixture*—The backing fixture shall be a rigid, metal frame with a plywood bottom. The inside dimensions of the metal frame shall be ~~610~~610 mm ± 2 mm ~~(24.0~~(24.0 in. ± ~~0.08 in.)~~ 0.08 in.) by ~~610~~610 mm ± 2 mm ~~(24.0~~(24.0 in. ± 0.08 in.) with a depth of ~~140 ± 2 mm (5.5 ± 0.08 in.).~~ 140 mm ± 2 mm (5.5 in. ± 0.08 in.). The top and bottom edges of the metal frame shall be planar. Plywood, of any grade, that is nominally "~~¾ in." or "18 mm,"~~ in." or "18 mm," shall be attached to the outside of the metal frame to form the bottom of the fixture and shall be removable. See Fig. 1.

5.1.2 *Backing Fixture Liner*—A liner, such as ~~0.08 to 0.13 mm (3 to 5 mil)~~ 0.08 mm to 0.13 mm (3 mil to 5 mil) polyethylene sheeting, shall be inserted into the backing fixture to prevent the clay oils from coming into contact with the plywood. The liner shall be placed against the plywood bottom of the backing fixture and shall not extend up the inside surfaces of the metal frame.



NOTE 1—The plywood bottom is shown larger than the metal frame for illustrative purposes only.

FIG. 1 Backing Fixture

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[4] Available from National Institute of Standards and Technology (NIST), 100 Bureau Dr., Stop 1070, Gaithersburg, MD 20899-1070, http://www.nist.gov.

NOTE 1—The backing fixture liner is intended to be a barrier between the clay and the plywood and may be sheeting, a coating (for example, spray, paint, shellac), or any other barrier that prevents leaching of oil into the plywood.

5.1.3 *Bridge Gauge*—The bridge gauge shall be a rigid assembly that rests on two parallel strike face edges of the backing fixture and supports a depth gauge that can slide back and forth on the assembly to measure depths across the surface of the backing material. The depth gauge tip that touches the clay shall be hemispherical or spherical with a diameter of ~~6.35 ± 0.0254 mm (0.25 ± 0.001 in.)~~ 6.35 mm ± 0.0254 mm (0.25 in. ± 0.001 in.) and attached to a cylindrical stem having a minimum length of ~~38.1 mm (1.5 in.)~~ 38.1 mm (1.5 in.) and maximum diameter of ~~6.35 mm (0.25 in.)~~ 6.35 mm (0.25 in.) such that only the tip touches the deepest location of the indentation. The bridge gauge (independent of the backing fixture) shall have a resolution of ~~0.01 mm~~ 0.01 mm or better with an accuracy of ±0.1 mm or better.

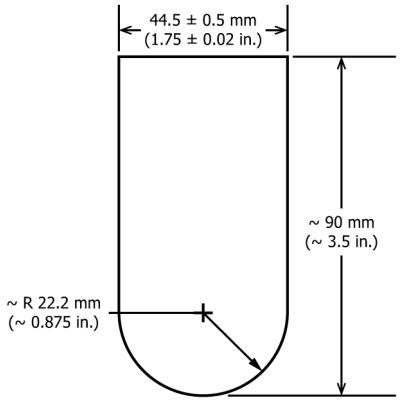
5.1.4 *Conditioning Chamber*—The chamber shall be temperature controlled, be sufficiently large, and have continuous circulation of air with the intention of uniformly heating all clay blocks in the chamber.

5.1.5 *Cylindrical Clay-verification Impactor:*

5.1.5.1 The impactor shall be a steel, constant diameter cylinder having a hemispherical end of diameter equal to the cylinder diameter and a smooth transition from the hemispherical end to the cylinder body. A drawing specifying the dimensions of the impactor is provided in Fig. 2.

5.1.5.2 The impactor mass shall be ~~1.0~~1.0 kg ± ~~0.005 kg~~0.005 kg (2.20 lb_m ~~(2.20 ± 0.01 lb~~0.01 lb_m).

NOTE 2—To achieve the required mass, the length of the entire impactor will be approximately 90 mm (3.5 in.).



Notes:
1. The material shall be steel with a smooth finish.
2. There shall be a smooth transition from the hemispherical end to the cylindrical body.

FIG. 2 Impactor

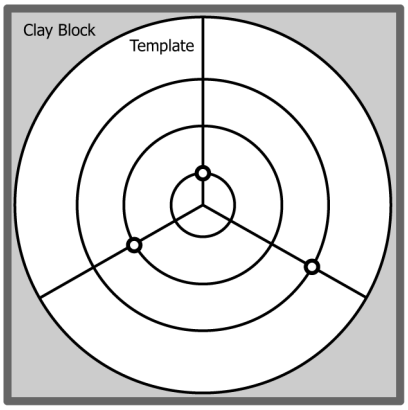


FIG. 3 Template for Impact Locations

5.1.6 *Spherical Clay-verification Impactor:*

5.1.6.1 The impactor shall be a steel sphere[5] having mass of ~~1043 ± 5 g (2.29 ± 0.01 lb)~~ 1043 g ± 5 g (2.29 lb ± 0.01 lb) and a diameter of ~~63.5 ± 0.05 mm (2.5 ± 0.001 in.).~~63.5 mm ± 0.05 mm (2.5 in. ± 0.001 in.).

5.1.7 *Striking Device*—The striking device shall be a metal, straight-edged blade capable of spanning two parallel strike face edges of the backing fixture so that the backing fixture serves as the reference for the clay block surface. The striking device shall be sufficiently rigid to facilitate creation of a flat clay surface that is even with the strike face edges of the backing fixture.

5.1.8 *Template*—A circular template shall be used to mark the impact locations on the surface of the clay. The template shall fit within the internal backing fixture dimensions. The impact location centers on the template shown in Fig. 3 are spaced approximately ~~50 mm (2 in.), 127 mm (5 in.), and 203 mm (8 in.)~~ 50 mm (2 in.), 127 mm (5 in.), and 203 mm (8 in.) from the center and approximately 120° apart.

5.1.8.1 The template shall be centered on the clay block, with the template's outer perimeter extending to the inner edge of the backing fixture frame.

5.1.8.2 The purpose of the template is to ensure that the three impact locations meet the drop spacing requirements below:
(1) Minimum of 76 mm (3.0 in.) from backing fixture edge to nearest indentation edge.
(2) Minimum of 152 mm (6.0 in.) between impactor indentation centers.

5.1.9 *Test Setup for Cylindrical Clay-verification Impactor*—The test setup for clay block verification using the cylindrical clay-verification impactor shall consist of a guide tube through which the impactor is dropped (hemispherical end down) onto a clay block that rests on a movable support. See Fig. 4 for an example test setup including guide tube dimensions and spacing between the guide tube and the clay block surface.

5.1.9.1 *Guide Tube*—The guide tube length shall be such that the impactor is within the tube prior to release and entirely out of the tube at impact with the clay block surface. The guide tube length shall be sufficient to minimize yaw of the impactor at the clay surface. The guide tube inside diameter shall be sized to allow the impactor to drop freely and minimize yaw. The guide tube shall be solidly mounted to a fixed surface.

NOTE 3—Holes or slots along the length of the guide tube may be useful to limit effects of air on the impactor as it drops through the tube.

5.1.9.2 *Movable Support*—The support upon which the clay block rests shall allow positioning of the clay block to set the impact locations, keep the clay block level, keep the drop distance constant when the clay block is positioned for different impact locations, and prevent the block from moving vertically due to the impact from the impactor.

[5] A sphere, reference P/N 3606, supplied by Salem Specialty Ball Co., Inc., P.O. Box 145, West Simsbury, CT 06092, has been found to be satisfactory, although any steel sphere meeting the requirements listed in this section is acceptable.

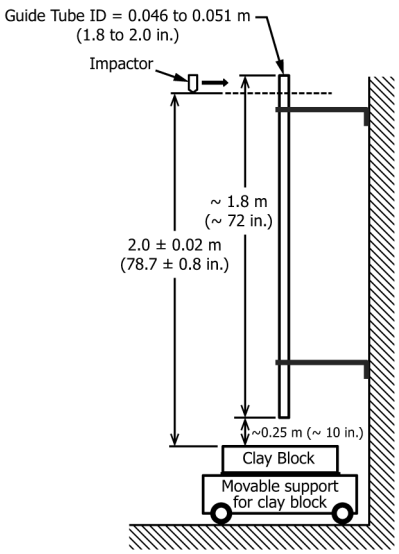


FIG. 4 Example Test Setup

5.1.10 *Test Setup for Spherical Clay-verification Impactor*—The test setup for clay block verification using a spherical clay-verification impactor shall consist of a mechanism to allow the sphere to drop freely from a height of ~~2.0 ± 0.02 m (6.56 ± 0.07 ft)~~ 2.0 m ± 0.02 m (6.56 ft ± 0.07 ft) onto the clay block surface.

NOTE 4—Use of the spherical clay-verification impactor does not require velocity measurement.

5.1.11 *Velocity Measurement Equipment*—The velocity measurement equipment shall be capable of measuring velocities in at least the range of interest with a resolution of ~~0.005~~0.005 m ~~m/s~~/s or better and an accuracy of ~~0.01~~0.01 m ~~m/s~~/s or better. See Appendix X1 for Velocity Measurement Guidance.

6. Procedures

6.1 *Characterization of Clay Block Verification Test Setup when Using a Cylindrical Clay-verification Impactor:*

6.1.1 Perform the following steps at installation of a new test setup (see 5.1.9) and periodically thereafter. These steps shall be performed without the clay block or its movable support in the test setup.

6.1.1.1 Verify that the guide tube is straight, plumb, and rigid.

6.1.1.2 Verify that the guide tube is solidly mounted so that it remains in the verified position.

6.1.1.3 To verify the performance of the test setup, the velocity of the impactor at the clay surface is required to be between ~~6.15~~6.15 m/s to ~~6.27~~6.27 m ~~m/s.~~/s. Perform an appropriate number of impactor drops through the guide tube to determine the drop distance at which a velocity in this range is achieved at the expected point of impact. The drop distance shall be measured from the impactor tip (rounded end) to the expected point of impact.

6.1.1.4 Record the drop distance. The drop distance shall be within ~~2~~2 m ± ~~0.02 m.~~0.02 m.

NOTE 5—If the measured drop distance does not meet this requirement, the test setup should be adjusted until the measured velocity and drop distance are within the required ranges.

6.1.2 The value of the measured drop distance shall be used during clay block verifications. The velocity is not required to be measured during actual clay block verifications.

NOTE 6—Provision should be made to ensure that the impactor is dropped the determined drop distance each time, such as by the use of a hard stop at the top of the guide tube.

6.2 *Clay Block Preparation Procedures:*

6.2.1 *New Clay Block Assembly:*

6.2.1.1 Fill the backing fixture with clay following the steps below:

(1) Open each clay package, and soften the clay by heating it; working it with kneading, pounding, or tamping; or combinations thereof.

(2) Press clay into the backing fixture, using a manual device (for example, mallet) or a machine (for example, hydraulic press or powered hammering tool), one layer at a time starting in the corners. One layer of flattened clay should be added at a time, and then pressed and blended into the previous layers to prevent voids.

(3) Continue layering, pressing, and blending of clay until the depth of the clay exceeds the strike face edges of the backing fixture.

(4) Remove excess clay at the surface by drawing the striking device at least once across the full length of parallel edges of the backing fixture.

NOTE 7—The striking device should be drawn across the same edges that the bridge gauge rests on during measuring and should be drawn in the same direction every time.

NOTE 8—If the striking device is drawn more than once and in orthogonal directions, the resultant clay surface must be planar.

(5) Visually verify that the clay surface is flat and flush with the backing fixture strike face edges. If voids in the surface are visible, fill those voids with additional clay, and repeat steps *(4)* and *(5)* until the surface of the clay is flat with no visible voids.

(6) Store the clay block indoors at room temperature or in the conditioning chamber.

6.2.2 *Determination of Conditioning Chamber Temperature:*

6.2.2.1 Set the conditioning chamber temperature at an initial temperature chosen by the test laboratory.

6.2.2.2 Place the clay block into the conditioning chamber.

6.2.2.3 Heat the clay block according to the requirements below:

(1) New clay blocks shall be heated for at least 24 ~~hours.~~h.

(2) Any clay block that has been out of the conditioning chamber for more than one hour shall be heated for at least three times the time out of the chamber. Every clay block shall be heated for no less than three hours.

6.2.2.4 Record the conditioning chamber temperature.

6.2.2.5 Remove the clay block from the conditioning chamber and promptly perform the procedure specified in 6.3.

6.2.2.6 Perform the procedure specified in 6.4.

6.2.2.7 If necessary, adjust the temperature of the conditioning chamber based on the indentation depth measurements in the clay and repeat steps 6.2.2.2 – 6.2.2.7.

6.2.3 *Clay Block Temperature Conditioning Procedure:*

6.2.3.1 Prior to performing a clay block verification procedure, the clay block shall be heated to uniform temperature as described below:

(1) Verify that the conditioning chamber is set to the temperature determined in 6.2.2.

(2) Place one or more clay blocks into the conditioning chamber such that there is air flow around each clay block.

(3) Heat each clay block according to the requirements below:

(a) New clay blocks shall be heated for at least ~~24 hours.~~24 h.

(b) Any clay block that has been out of the conditioning chamber shall be reheated for no less than three hours.

(c) Any clay block that has been out of the conditioning chamber for more than one hour shall be reheated for at least three times the time out of the chamber but not more than ~~24 hours.~~24 h.

(d) Twenty four hours is the maximum time required for reheating any clay block, but a clay block may remain in the chamber indefinitely.

6.3 *Clay Block Verification Procedure: Prior to Ballistic Testing:*

6.3.1 *Overview:*

6.3.1.1 Each clay block shall be verified to ensure it meets the requirements prior to use as a backing assembly for ballistic testing of body armor. This method is based on dropping the impactor onto the surface of a conditioned clay block. The indentation created by the drop is then measured.

6.3.2 *Test Method:*

6.3.2.1 Visually inspect the test setup for proper alignment and absence of clay residue on the impactor, depth gauge, or other relevant items.

6.3.2.2 Remove a conditioned clay block from the conditioning chamber. Impactor drops shall begin within ten minutes of removing the clay block from the conditioning chamber.

6.3.2.3 Visually inspect the surface of the clay block. The clay block surface shall be homogeneous and free of ~~defects.~~indications that the clay is beyond its useful life, including cracking, abnormal coloring, oil deposits, or significant separation from edges of the backing fixture.

NOTE 9—The intention of this step is to avoid using a clay block that is filled with old clay having potentially degraded properties. ~~Examples of items to inspect for include cracking, abnormal coloring, oil deposits, and significant separation from edges of the backing fixture.~~The intention of this step is not to discard a clay block for superficial surface blemishes.

6.3.2.4 The clay block shall be removed from service if the surface requirements of 6.3.2.3 are not met, and all clay in that clay block shall be discarded.

6.3.2.5 Working the clay surface is not permitted during the verification procedure.

NOTE 10—Striking the clay surface is not considered to be working the clay surface.

6.3.2.6 Remove excess clay at the surface by drawing the striking device at least once across the full length of parallel edges of the backing fixture.

NOTE 11—The striking device should be drawn across the same edges that the bridge gauge rests on during measuring and should be drawn in the same direction every time.

NOTE 12—If the striking device is drawn more than once in orthogonal directions, the resultant clay surface must be planar.

6.3.2.7 Visually verify that the clay surface is smooth and free of defects before moving to the next step.

6.3.2.8 Place the drop template on the clay surface in an arbitrary rotational position. Mark the surface of the clay block (for example, by nicking the surface, laser marking, applying ink) to indicate the drop target positions, and remove the template.

NOTE 13—The requirement to place the drop template at an arbitrary rotational position is included for the purpose of ensuring different impact locations for each subsequent verification.

6.3.2.9 Place the clay block on the movable support and move it into the test setup. Verify that the surface of the clay block is level.

6.3.2.10 Position the clay block beneath the impactor release point such that the impactor is directly above one of the marks on the clay surface.

6.3.2.11 Measure and record the drop distance.