ASTM

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Standard Test Method for
In Situ Measurement of Masonry Deformability Properties Using the Flatjack Method[1]

This standard is issued under the fixed designation C 1197; 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.

1. Scope

1.1 This test method describes an in situ method for determining the deformation properties of existing unreinforced solid-unit[2] masonry. This test method concerns the measurement of in-situ masonry deformability properties in existing masonry by use of thin, bladder-like flatjack devices that are installed in saw cut mortar joints in the masonry wall. This test method provides a relatively non-destructive means of determining masonry properties.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 *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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*
E 74 Practice for Calibration of Force Measuring Instruments for Verifying the Load Indication of Testing Machines[3]

3. Summary of Test Method

3.1 Two flatjacks inserted into parallel slots, one above the other, in a solid-unit masonry wall are pressurized thus inducing compressive stress on the masonry between them. The installation is shown in Fig. 1. By gradually increasing the flatjack pressure and measuring the deformation of the masonry between the flatjacks, load-deformation (stress-strain) properties may be obtained. Maximum compressive strengths may be measured in certain cases.

4. Significance and Use

4.1 Deformation and strength properties are measured only on the masonry between flatjacks. Boundary effects of the
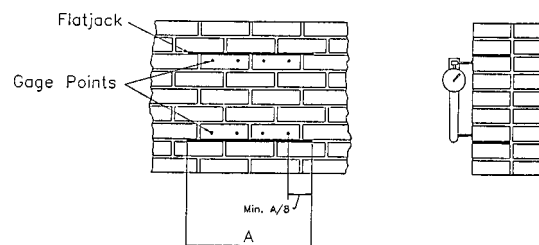

FIG. 1   Deformation Properties Using Two Flatjacks

collar joint behind the wythe tested and adjacent masonry are neglected. In the case of multi-wythe masonry, deformability is estimated only in the wythe in which the flatjack is inserted. Deformability of other wythes may be different.

5. Apparatus

5.1 *Flatjack*:

5.1.1 A flatjack is a thin envelope-like bladder with inlet and outlet ports which may be pressurized with hydraulic oil. Flatjacks may be of any shape in plan, and are designed to be compatible with the masonry being tested. For determining load-deformation properties of masonry, flatjacks are typically rectangular or semi-rectangular as shown in Fig. 2.

5.1.2 For determination of masonry deformability properties, dimension A (see Fig. 2) should be equal to or greater than the length of two masonry units. Dimension B should be equal to or greater than the thickness of one wythe and not less than three in. (76 mm). The radius, *R*, for circular and semi-rectangular flatjacks shall be equal to the radius of the circular saw blade used to cut the slot.

5.1.3 Flatjacks shall be made of metal or other material such that the flatjack in a slot in masonry will be capable of applying operating pressures up to 1000 psi (6.9 MPa).[4] Metal flatjacks suitable for this purpose shall be made of type 304 stainless steel sheet of 0.024 to 0.048 in. (0.61 to 1.2 mm) in thickness with welded seams along the edges, and incorporating hydraulic inlet or outlet ports.

5.1.4 Calibrate all flatjacks as described in Section 7 to determine their pressure-applied load characteristics.

5.2 *Hydraulic System*—An electrically or manually operated hydraulic pump with hydraulic hoses is required. Hose
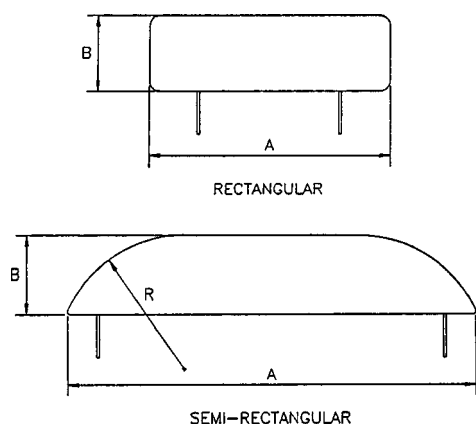

FIG. 2   Flatjack Configurations

connections shall fit the flatjack inlet port. Measure pressure using gages calibrated to a traceable standard having both an accuracy of 1 % of full hydraulic scale and an appropriate operating range. The hydraulic system shall be capable of maintaining constant pressure within 1 % of full scale for at least 5 min.

5.3 *Displacement Measurement*—Measure displacements of the masonry with electronic instrumentation, for example, a Linearly Variable Differential Transformer (LVDT) mounted to the surface of the masonry between the flatjacks, or by a mechanical gage extensometer which measures the distance between fixed gage points on the masonry as shown in Fig. 1. The method or device used to measure deformations shall be capable of deformation measurements up to $\frac{3}{16}$ in. (5 mm). Deformation measurements shall have an accuracy of at least ±0.005 % of gage length. Record measurements manually at discrete intervals, or continuously by automatic data recording.

5.4 *Attachment of Measurement Devices*—Attach brackets for mounting electrical displacement measuring devices or gage points to be used with mechanical devices securely to the surface of the masonry to prevent movement and ensure the required measurement accuracy. Use rigid adhesive for discs and brackets and cementitious grout for plugs. If gage points are used, the gage points shall have a conical depression at their center, compatible with the pointed elements of the extensometer. The angles of the depression of the cone and the extensometer points shall be the same.

6. Preparation of Slots

6.1 Slots in masonry are normally prepared by removing the mortar from masonry bed joints to avoid disfiguring the masonry. Remove all mortar in the bed joint, that is, pressure exerted by a flatjack shall be directly against the cleaned surfaces of the masonry units.

6.2 The plan geometry of the slot shall be similar to that of the flatjack being used. Plan dimensions of the prepared slot shall not exceed those of the flatjack by more than ½ in. (12 mm). Slots shall be parallel and aligned vertically, and shall be separated by not more than 1.5 times the length of the flatjack.

6.3 Prepare rectangular slots into which rectangular flatjacks are to be inserted by drilling adjacent or overlapping holes (stitch drilling) and subsequently using a drill, bar, or tool to remove mortar and produce a slot of desired dimensions with smooth upper and lower surfaces.

6.4 Prepare slots for circular and semi-rectangular flatjacks using circular saws of sufficient radius to provide the depth required (Fig. 2, dimension B). Use carbide or diamond tipped blades to remove all mortar from the slot.

7. Calibration

7.1 A flatjack has an inherent stiffness which resists expansion when the jack is pressurized. Therefore, the fluid pressure in the flatjack is greater than the stress the flatjack applies to masonry. A flatjack must be calibrated to provide a conversion factor, K_m, to relate internal fluid pressure to applied stress.

7.2 Calibrate flatjacks in a compression machine of at least 100 kip capacity which has been calibrated according to Practice E 74.

7.3 Place a 2 in. (50 mm) thick steel bearing plate on the lower platen of the compression machine. The bearing plate shall be of sufficient size to completely cover the flatjack being calibrated. Place the flatjack on the lower bearing plate such that the edge of the flatjack with the inlet/outlet ports is coincident with the edge of the bearing plate. Place steel spacers around the other edges of the flatjack. The thickness of the spacers shall be equal to approximately 1⅓ times the combined thickness of the two steel sheets used in fabrication of the flatjack. Place the upper 2 in. (50 mm) thick bearing plate on top of the shims and flatjack, and align it to be directly above the lower bearing plate. Position the bearing plate/flatjack/shim assembly on the lower platen such that the centroid of the area of the flatjack is within ¼ in. (6 mm) of the axis of thrust of the test machine. The calibration setup is illustrated in Fig. 3.

7.4 Raise the moveable platen such that the non-moveable platen is in contact with the top bearing plate. Apply a pre-load sufficient to provide full contact between the bearing plates and the spacers, equivalent to 10 psi over the gross area of the flatjack.

7.5 The distance between platens must be held constant during the calibration procedure. Fix the displacement of the test machine at this point if using a displacement controllable machine. If not, attach displacement gages (mechanical or electrical) such that the distance between platens established by the procedures of paragraph 7.4 can be held constant when using a force-control test machine.

7.6 Pressurize and depressurize the flatjack three cycles with the maximum pressure in the flatjack not to exceed 1000 psi (2.069 MN/m^2) nor the stress applied to the flatjack by the compression machine to exceed 1000 psi (2.069 MN/m^2) based on the gross area of the flatjack.

7.7 Increase the pressure in the flatjack in 50 to 100 psi (344.8 to 689.5 KN/m^2) increments up to 1000 ± 50 psi (6.895 MN/m^2 ± 344.8 KN/m^2) while holding the distance between platens constant. At each increment, record flatjack hydraulic pressure and force measured by the test machine.

7.8 Calculate the load applied by the flatjack as internal pressure times gross flatjack area. Plot flatjack load versus load measured by the test machine with the flatjack load on the horizontal axis of the plot. The slope of the line equals the flatjack constant, that is, the conversion factor:

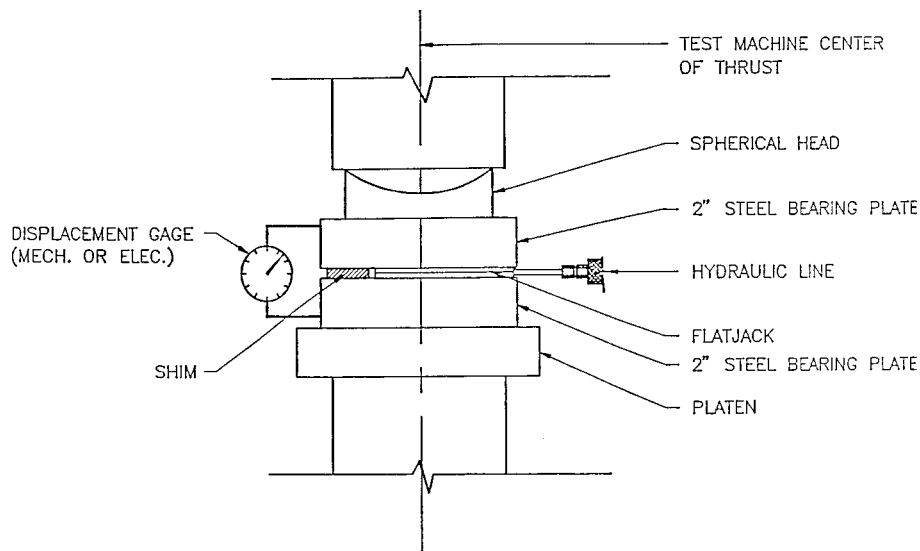$$K_m = P_{\text{machine}} \div P_{\text{flatjack}}$$

(1)

FIG. 3   Flatjack Calibration Setup

7.9 Recalibrate flatjacks after using five times or when distortion appears excessive.

8. Procedure

8.1 The location where masonry deformability estimates are conducted is dictated by engineering objectives. The basic arrangement is illustrated in Fig. 1. At the desired location or locations the following steps should be taken.

8.2 Select and mark a visible line on the masonry to define the location and length of slots to be formed.

8.3 Prepare the slots[5] (see Section 6) and record the measured slot dimensions. Clean slots of all mortar and brick particles prior to the insertion of flatjacks. Slots shall be separated by at least five courses of masonry, but not more than 1.5 times the length of the flatjack.

8.4 Attach at least four equally spaced pairs of gage points or electrical measuring device mounting brackets on the center of the course immediately below the upper slot location and on the center of the course immediately above the lower slot location as shown in Fig. 1. The first and last measurement points should be located at least a distance $A/8$ in from the ends of the slot, where A is the flatjack length as shown in Fig. 2.

8.5 Insert the flatjack into the slot. Shim, as required, to achieve a tight fit and bridge over any interior voids in the masonry. See Annex A1 for a description of flatjack shims and their use.

8.6 Connect hydraulic hoses and fill the flatjacks until pressure begins to develop.

8.7 In order to *seat* the flatjack and any shims, pressurize the flatjack to approximately 50 % of the estimated maximum flatjack pressure (which corresponds to the estimated maximum compressive strength of the masonry). Reduce the flatjack pressure to zero.

8.8 Take initial measurements with mechanical devices (three repetitions) or initialize electrical devices.

8.9 Increase pressure slowly. Take displacement measurements at small increments of pressure. If measurements are to be taken manually, stop and hold the pressure for at least one minute or until pressure is steady at each incremental step, and record displacements (three repetitions at each gage point in the case of mechanical measurement devices). Monitor the flatjack pressure-masonry deformation ratio, p, during the test at each increment of pressure. If failure of the masonry between flatjacks is not desired, the test should stop when the above ratio begins to noticeably decrease.

8.10 In older masonry or masonry of low-strength units and low or zero cement content mortar, flatjacks are capable of loading the masonry between them to failure thus establishing maximum strength. However, this may also cause damage to the masonry in areas adjacent to the flatjacks.

8.11 Release pressure after the final displacement measurement has been taken.

8.12 Disconnect hoses and remove the flatjack. The slot may be filled with mortar or other suitable material of a color and strength similar to the original mortar.

9. Calculation

9.1 Calculate stress in the masonry between the flatjacks at any point in the pressurization process as:

$$f_m = K_m K_a p$$

$$(2)$$

where:
K_m = a dimensionless constant which reflects the geometrical and stiffness properties of the flatjack, as determined by the calibration procedure in Section 7,
K_a = the ratio of measured area of the flatjack to the average measured area of the slot, and
p = flatjack pressure, psi or MPa.

9.2 Calculate individual strain values by dividing the displacement recorded at each load increment by the gage length. Calculate the average strain value for each load increment as the average of the individual strains recorded at

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[5] The location of the slots shall be at least 1½ flatjack lengths from wall openings or ends. There should be sufficient masonry above the top slot to resist forces developed during pressurization of the flatjacks.

each measurement location.

9.3 Calculate the tangent modulus at any stress interval by:

$$E_t = \frac{\delta f_m}{\delta \epsilon_m} \qquad (3)$$

where:
δf_m = an increment of stress, psi or MPa, and
$\delta \epsilon_m$ = the corresponding increment of strain.
The chord modulus at any point, i, is given by:

$$E_{si} = \frac{f_{mi}}{\epsilon_{mi}} \qquad (4)$$

where:
f_{mi} = stress at point i, and
ϵ_{mi} = strain at point i.

10. Report

10.1 A report of each in situ deformation property measurement should include at least the following information:

10.2 Description of the test conditions, for example, site, geographical location, environmental conditions (for example, temperature), building identification, date of construction (if available), as-built details, and name of the engineer/technician conducting the test.

10.3 Identity and description of the specific test location in the structure and reason for the test.

10.4 Description and sources (if possible) of the masonry materials at the test location including a general condition statement, an elevation drawing, and other pertinent material data.

10.5 Method of forming the slot, a diagram of the slot,

adjacent masonry, location of gage points or brackets for electrical measurement devices, and all pertinent dimensions.

10.6 Description and source of the flatjack used, instrumentation, hydraulic system, flatjack installation, that is, use of shims, and other pertinent information.

10.7 Data sheets listing measurements taken at each pressure level.

10.8 Flatjack calibration factor, K_m, and derivation.

10.9 Flatjack/slot area ratio, K_a, and calculation.

10.10 Compressive stress calculations and modulus calculations.

10.11 Plot of measured stress and strain values.

10.12 Other observations.

11. Precision and Bias

11.1 Results from laboratory investigations conducted on old brick masonry have shown that variations between tests may be as great as 24 %. This variation may be considered to be within acceptable limits for old masonry; destructive tests conducted on prisms from the same test wall had a coefficient variation of 32 %.

11.2 Experimental and analytical investigations indicate that the in situ deformability test typically over estimates the average compressive modulus of the masonry by up to 15 %.

12. Keywords

12.1 flatjack; in situ; masonry; nondestructive evaluation

ANNEX

(Mandatory Information)

A1. FLATJACK SHIMS

A1.1 The use of shims may be necessary during testing to achieve a tight fit of the flatjack in the slot and to ensure uniform transfer of pressure (stress) to the masonry over the complete area of the flatjack. Excessive deformations of the flatjack will cause inaccurate test results and could change the flatjack calibration factor K_m. Also it may be difficult to remove the flatjack from the slot after testing if it has deformed into voids. Grouting of the flatjack in the slot is not allowed, as the grout from the slot would flow into voids and cracks, altering the local behavior of the masonry.

A1.2 Three types of shims may be used: single piece shims, multiple piece shims, and fluid cushion shims.

A1.2.1 *Single Piece Shims*—Stiff metal shims having the same shape and size as the flatjack can be used to span voids in the masonry (see Fig. A1.1). Single piece shims should be placed between the flatjack and the irregular masonry surface, and should be of sufficient thickness such that the flatjack fits tightly in the slot. To avoid damage to the flatjack after testing, it is recommended that the single piece shim be removed from
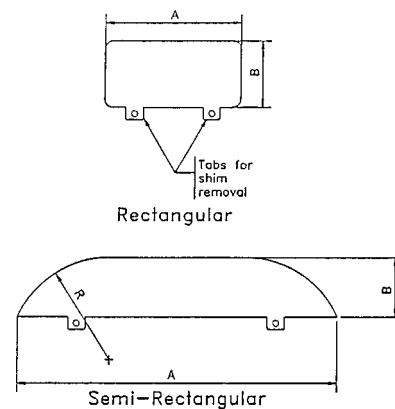

FIG. A1.1　Single Piece Shims

the slot before attempting to remove the flatjack.

A1.2.2 *Multiple Piece Shims*—Metal shims made of several pieces can be used if the slot is irregular or of nonuniform thickness over its length (see Fig. A1.2). The individual pieces must fit tightly together and, in the case of an irregular slot,
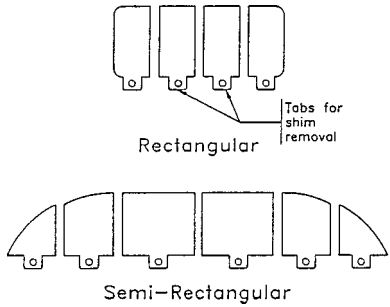
FIG. A1.2   Multiple Piece Shims

shall be of sufficient thickness to ensure a tight fit of the flatjack over its entire area. To avoid damage to the flatjack after the completion of testing, it is recommended that the multiple piece shims be removed from the slot before the flatjack is removed.

A1.2.3 *Fluid Cushion Shims*—Additional flatjacks, of geometry identical to the working flatjack,[6] may be used as fluid shims. The fluid shim or shims should be inserted adjacent to the working flatjack, against the surface of the masonry. It may be necessary to use more than one fluid shim if the slot is thick in order to ensure a tight fit of the working flatjack in the slot. In this case, install fluid shims above and below the working flatjack. The fluid shims are seated initially by pressurizing to 75 to 80 % of the maximum predicted masonry in situ compressive strength. This allows the shim to deform into voids and irregularities in the slot. The shim pressure should be reduced to 5 to 10 psi and the hydraulic line closed before proceeding with the test. After completion of the test, remove the working flatjack and the fluid cushion shim(s) from the slot.

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[6] A *working flatjack* is one used in the test to estimate in situ stress and is the active flatjack as opposed to flatjacks used as fluid shims.