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Standard Guide for Design and Construction of Brick Liners for Industrial Chimneys[1]

This standard is issued under the fixed designation C1298; 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 guide covers procedures for the design, construction, and serviceability of brick liners for industrial chimneys. The structural design criteria are applicable to vertical masonry cantilever structures supported only at their base, either by a foundation, a concrete pedestal, or by some means from the outer concrete shell. Excluded from direct consideration are single-wythe, sectional brick linings that are supported on a series of corbels cast in the outer chimney shell.

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:*[2]

C395 Specification for Chemical-Resistant Resin Mortars

C466 Specification for Chemically Setting Silicate and Silica Chemical-Resistant Mortars

C980 Specification for Industrial Chimney Lining Brick

E447 Test Method for Compressive Strength of Laboratory Constructed Masonry Prisms (Withdrawn 1997)[3]

E111 Test Method for Young's Modulus, Tangent Modulus, and Chord Modulus

2.2 *ACI Standard:*

307–88 Practice for the Design and Construction of Cast-In-Place Reinforced Concrete Chimneys[4]

2.3 *ASCE Standard:*

ASCE 7-88 Minimum Design Loads for Buildings and Other Structures (Formerly ANSI A58.1)[5]

2.4 *Other Standard:*

1991 Uniform Building Code, International Conference of Building Code Officials, California[6]

3. Terminology

3.1 *Notations:*

a	= brick dimension in radial direction (in.)
b	= brick dimension in tangential direction (in.)
c	= brick chamfer (in.)
C_e	= chimney deflection due to earthquake loads (in.)
d	= outside diameter of brick liner (in.)
D	= mean liner diameter at a given elevation (in.)
E_m	= masonry modulus of elasticity as established by performing brick prism test or by past experience, psi
f_b	= critical liner buckling stress, psi
f_d	= maximum vertical compressive stress due to dead load, psi
f_{de}	= maximum vertical compressive stress due to the combined effect of earthquake and dead load, psi
f_{dw}	= maximum vertical compressive stress due to the combined effect of wind and dead load, psi
f_m	= average ultimate masonry compressive strength established by performing brick prism test or by past experience, psi
f_v	= maximum shear stress due to wind or earthquake, psi
$F.S.$	= factor of safety
h	= total liner height (ft)
h_e	= height of liner above elevation being checked for buckling (ft)
L_e	= liner deflection due to earthquake loads (in.)
P	= constructional out-of-plumbness of liner with respect to shell (in.)
r	= average mean radius of liner (ft)
S	= shell deflection due to sun effect (in.)
T	= liner deflection due to differential temperature effects (in.)
t	= wall thickness (in.)
v	= coefficient of variation in brick prism tests
W	= shell deflection due to design wind loads (in.)
α	= coefficient of thermal expansion for brick liner (use 3.5×10^{-6} unless otherwise established) (in./in./°F)

[1] This guide is under the jurisdiction of ASTM Committee C15 on Manufactured Masonry Units and is the direct responsibility of Subcommittee C15.05 on Masonry Assemblies.

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[2] 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.

[3] The last approved version of this historical standard is referenced on www.astm.org.

[4] Available from American Concrete Institute (ACI), P.O. Box 9094, Farmington Hills, MI 48333-9094, http://www.aci-int.org.

[5] Available from American Society of Civil Engineers (ASCE), 1801 Alexander Bell Dr., Reston, VA 20191, http://www.asce.org.

[6] Available from International Code Council (ICC), 5203 Leesburg Pike, Suite 600, Falls Church, VA 22041-3401, http://www.intlcode.org.

4. Significance and Use

4.1 *History:*

4.1.1 For many years, brick liners have been used with an excellent record of performance. For the most part, however, the design and construction of brick liners has been based on past industry practice due to the lack of available information and knowledge of the physical properties of the brick and mortar, the thermal and seismic behavior of brick liners, and many related characteristics that were not properly or accurately defined.

4.1.2 The use of scrubbers, which lower gas temperatures and introduce highly corrosive condensates into the flue gas system, requires many new design considerations. The effect that scrubbers have on brick liners is an ongoing area of study, since a number of liners have experienced growth- and deflection-related problems which may be attributable, at least in part, to nonuniform temperature and moisture conditions within the liners.

4.2 *Purpose*—The recommendations contained herein represent current industry practices and serve to define the pertinent considerations that should be followed in the design and construction of brick chimney liners.

5. Materials

5.1 *General*—The selection of suitable liner materials, those capable of resisting the environment to which they will be exposed, should be based on an evaluation of the unique operating conditions that exist in each application. Although it is not the intent to restrict the applicability of this guide, and while other materials may be appropriate in some applications, the chemical-resistant brick and mortar standards set forth in 5.2 and 5.3 define the type of materials used in the majority of brick liners that are specified, designed, and erected today. All portions of this guide reflect test data, design requirements, and other practices as they relate to these materials. The provisions of this guide should be carefully reviewed for applicability if other materials are specified or used. Due to a greater knowledge of overall plant operation, material capabilities, and the flue gas environment, the owner's technical representative should be responsible for selecting all liner materials.

5.2 *Brick:*

5.2.1 Unless the specific application precludes their use, brick conforming to the requirements of Specification C980 should be used. Specification C980 covers solid kiln-fired brick made of clay, shale, or mixtures thereof.

5.2.2 Three types of brick are defined in Specification C980: Types I, II, and III. By definition, the brick types vary, respectively, in decreasing degrees of absorption and acid solubility. These bricks generally are resistant to all acids and alkalies (with the exception of acid fluorides and strong, hot caustics). Types I, II, and III brick safely will withstand continuous temperatures up to 750°F. Generally, the bricks will withstand short-term exposure to temperatures in excess of 750°F, but the capability of the bricks to resist higher temperatures should be studied case by case. The selection of the brick type and the potential need for testing beyond the requirements of Specification C980 should be determined on an individual project basis.

5.2.3 Specification C980 brick Types I and II generally are available from any manufacturer who makes double-sized, kiln-fired, solid brick for corrosion-resistant applications. The stringent requirements for Type III brick, however, make it more difficult and expensive to manufacture. Consequently, availability of Type III brick is limited; therefore, before specifying Type III brick, determine both the necessity of its use and its availability.

5.3 *Mortar:*

5.3.1 Unless specific application requirements dictate otherwise, mortar should conform to the requirements of one of the brick types listed herein.

5.3.1.1 *Specification C466*—These widely-used mortars exhibit excellent resistance to most acids (except hydrofluoric acid), water, solvents, and temperatures to 1200°F. These mortars are also resistant to intermittent exposure to mild alkalies, but their primary capability is resisting the strong acids commonly found in fossil-fuel flue gas environments.

5.3.1.2 *Specification C395*—Organic resin-type mortars (such as Furan mortar) have been used in brick chimney liners, mainly due to their capacity to resist a wider variety of chemicals than inorganic mortars. Generally suitable for use over a wider pH range, they resist non-oxidizing acids, alkalies, salts, water, and temperatures to 350°F.

5.3.1.3 High alumina cement (HAC) mortars, while not generally used in brick chimney linings, also are available. They are usually used in conjunction with heat-resistive aggregates and may be suitable for some chimney applications.

5.3.2 It is important to recognize that the selection of the proper mortar is essential to successful functioning of a brick liner. The various types of chemical-resistant mortars should be evaluated to determine which is the most suitable for a given application and set of operating conditions.

5.4 *Appurtenances*—Due to the availability of a wide variety of metallic materials and the great variations in the flue gas conditions to which materials are exposed, it is beyond the scope of this document to make recommendations regarding the suitability of materials for liner appurtenances such as breeching ducts, bands, lintels, buckstays, hoods, caps, and doors. The selection of these materials can be made only by evaluating the specific factors and conditions that exist on each individual project. One must evaluate the operating environment, projected maintenance requirements, and other such technical and economic evaluation factors commonly associated with the process of material selection.

5.5 *Field Testing*—If it is determined that field testing is required for a particular project, the test methods and acceptance criteria should be agreed upon mutually by the material manufacturers, the contractor, and the owner's technical representative. Certification that the materials shipped for use on the project conform to the requirements of their respective ASTM specifications should be obtained from the manufacturer.

6. Construction Requirements

6.1 *Handling and Storage of Materials:*