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Guide to Thermal Properties of Concrete and Masonry Systems

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This guide reports data on the thermal properties of concrete and masonry constituents, masonry units, and systems of materials and products that form building components. This guide includes consideration of thermal inertia of concrete and masonry, passive solar design, and procedures to limit condensation within assemblages.

Keywords: aggregate; cement paste; concrete masonry unit; moisture; precast/prestressed concrete; specific heat; sustainability; thermal conductivity; thermal diffusivity; thermal resistance.

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CHAPTER 1—INTRODUCTION

1.1—Introduction

To reduce the use of nonrecoverable energy sources, authorities have adopted energy-conservation building codes and standards that apply to the design and construction of buildings. The design of energy-conserving buildings requires an expanded understanding of the thermal properties of the building envelope and the materials that comprise the envelope system.

This guide provides thermal-property data and design techniques that are useful in designing concrete and masonry building envelopes and determining energy code compliance. The guide is intended for use by owners, architects, engineers, building inspectors, code-enforcement officials, and all those interested in the energy-efficient design of buildings containing concrete or masonry components.

1.2—Energy conservation with concrete and masonry

Due to its inherent functionality and the availability of raw materials used in production, concrete and masonry are the world's most widely used building materials. Many civilizations have built structures with concrete and masonry walls that provide uniform and comfortable indoor temperatures despite all types of climatic conditions. Cathedrals composed of massive masonry walls produce an indoor climate with little temperature variation during the entire year despite the absence of a heating system. Even primitive housing in the desert areas of North America used thick masonry walls that resulted in acceptable interior temperatures despite high outside daytime temperatures.

Housing systems have been developed featuring efficient load-bearing concrete or masonry wall systems that provide resistance to weather, temperature changes, fire, and noise. Many of these wall systems are made with lightweight concrete to enhance both static and dynamic thermal resistance.

Numerous organizations have studied and reported on the steady-state and dynamic energy-conserving contributions that concrete and concrete masonry walls can make to thermal efficiency in buildings (Peavy et al. 1973; Petersen and Barnett 1980; Petersen et al. 1981; U.S. Department of Energy 1989; ASHRAE 2009; ANSI/ASHRAE/IES 90.1; Childs et al. 1983; National Concrete Masonry Association 2010; Portland Cement Association 1981, 1982). This increased energy efficiency may permit reductions in the required size and operating costs of mechanical systems. This reduction in energy usage is not recognized by steady-state calculations (*R*-values and *U*-values). Improved calculation methods are required to account for the dynamic, real-world performance of concrete and concrete masonry building elements.

1.3—Building enclosure requirements

In addition to structural requirements, a building envelope should be designed to control the flow of air, heat, sunlight, radiant energy, liquid water, and water vapor. It should also provide the many other attributes generally associated with enclosure materials, including fire protection, noise control, impact damage resistance, durability, aesthetic quality, and economy. Analysis of building enclosure materials should extend beyond heat-flow analysis to also account for their multifunctional purposes. The non-heat-flow subjects are beyond the scope of this guide, but this exclusion should not be taken as an indication that they are not crucial to the total overall performance of a building enclosure.

CHAPTER 2—NOTATION AND DEFINITIONS

2.1—Notation

a = fractional area
a_{gr} = fractional grouted area of wall
a_i = fractional area of insulation
a_{np} = fractional area of heat flow path for path number p of thermal layer number n
a_s = fractional area of steel
a_{ungr} = fractional ungrouted area of wall
a_w = fractional area of web of masonry unit determined using the dimensions of web in the same planes as the height and length of the masonry unit
C = thermal conductance, Btu/(h·ft²·°F) (W/(m²·K))
c_p = specific heat, Btu/(lb·°F) (J/kg·K)
fs = face shell thickness of concrete masonry unit, in. (mm)
h_c = heat capacity, Btu(ft³·°F) (J/(m³·K))
I = thermal inertia, Btu/(h$^{1/2}$·ft²·°F) (J/(m²·K·s$^{1/2}$))
k_c = thermal conductivity of concrete, Btu · in./(h·ft²·°F) (W/(m·K))
k_f = thermal conductivity of material placed in the cores of masonry units, Btu·in./(h·ft²·°F) (W/(m·K))
k_p = thermal conductivity of cement paste, Btu·in./(h·ft²·°F) (W/(m·K))