DEVELOPMENT OF PRESTRESSED CLAY BRICK MASONRY WALLS

by

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GRADUATE COLLEGE
UNIVERSITY OF NEBRASKA

DEVELOPMENT OF PRESTRESSED
CLAY BRICK MASONRY WALLS

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University of Nebraska, 1995

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Prestressed masonry walls offer various advantages over the current system of veneer construction which has been shown to have several problems. The cracking of masonry walls at service loads, and corrosion of wall ties due to water penetration can be effectively eliminated by the simple technique of post-tensioning. Prestress significantly compensates for the low tensile strength of masonry which is critical at service loads. A new concept of using prestressed masonry for veneer construction has been developed, and a simple yet practical technique of post-tensioning utilizing high strength threaded bars was successfully used in this research.

This study included materials selection, analysis, design, and experimental testing of prestressed masonry wall panels. A total of fourteen panels of 3 x 6 ft were tested in the laboratory in two stages using newly developed two-cored brick units. The post-tensioned panels were tested for flexure to evaluate their capacity to resist out-of-plane loads. Stage I testing included six panels with three grouted and three ungrouted specimens. Results showed that the grouted specimens withstood approximately twice the capacity of the ungrouted specimens. In the Stage II testing, the prestressing force

and the end bearing conditions of the panels were varied to investigate their effects. Also, the post-tensioning was applied at two different ages to investigate how early the prestress could be applied. Prestress loss study was conducted on eight 3 ft x 4 ft panels, where the stress in the prestressing steel and strain in masonry were continuously monitored for 187 days after construction. These panels were exposed to different weather conditions.

This research study showed that the proposed post-tensioned veneer system is feasible. It can eliminate many of the problems associated with the conventional system of veneer construction, and the wall panels have an average factor of safety of 4.0 for cracking under service level wind loads. The results of the prestress loss study showed that moisture expansion of brick masonry significantly reduces the prestress losses in the reinforcing bars.

"Dedicated to my parents"

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NOTATION

a	=	depth of equivalent compression zone at nominal strength
A_m	=	cross-sectional area of masonry
A_n	=	net cross-sectional area of masonry
A_{ps}	=	area of prestressing tendon
b	=	width of section
c	=	distance from the neutral axis to extreme compression fiber
C	=	total compression force acting in the section
d	=	distance from the compression face of a flexural member to the centroid of longitudinal tensile reinforcement
ΔM_s	=	Incremental service load moment
E_m	=	modulus of elasticity of masonry
E_{ps}	=	modulus of elasticity of prestressing tendon
f_b	=	stress in the bottom fiber of masonry at cracking stage
f_{mi}	=	stress in masonry in the bottom fiber at initial prestress transfer
f'_m	=	specified compressive strength of masonry
$f_{m\,(bot)}$	=	stress in masonry in the bottom fiber
$f_{m\,(top)}$	=	stress in masonry in the top fiber
f_{me}	=	stress in masonry due to effective prestress
f_{ps}	=	stress in prestressing tendon at nominal strength
f_{pu}	=	specified tensile strength of prestressing tendon
f_{py}	=	specified yield strength of prestressing tendon
f_r	=	modulus of rupture of masonry
f_s	=	stress in tendon due to prestress and applied loads
f_{se}	=	effective prestress in the tendon
f_{si}	=	stress in tendon due to initial prestress
F_a	=	allowable average axial compressive stress for concentric applied load

F_{br}	=	allowable bearing stress
h	=	overall depth of the member cross section
I_g, I_{cr}	=	gross, cracked moment of inertia of the wall cross section
k	=	ratio of depth of the compressive stress in a flexural member to the depth, d
l	=	span length between the supports
L	=	clear span length between the supports
M	=	moment at midspan due to uniformly distributed load
M_a	=	applied moment in the member
M_{add}	=	additional moment acting in the member
M_{cr}	=	nominal cracking moment strength
M_d	=	moment due to dead load of the member
M_n	=	nominal moment strength
M_s, M_{ser}	=	service moment at the mid height of the panel
M_u	=	ultimate moment strength of the member
M_y	=	nominal moment strength at yield strength
n	=	modular ratio (= E_{ps}/E_m)
P_e	=	effective force in prestressing tendon
Q	=	applied factored load
r	=	radius of gyration
R	=	strength enhancement factor
R_4	=	interpolation coefficient
s	=	spacing of reinforcement
S	=	section modulus
T	=	total tensile force acting in the cross section
w	=	uniformly distributed load per unit length of the member
$(1-\alpha)$	=	coefficient to account for the variation in member stiffness due to cracking
δ_c	=	midspan deflection of the member
Δ_{cr}	=	midspan deflection of the member at cracking moment strength, M_{cr}

Δ_s	=	midspan deflection of the member at service load
$\varepsilon_{m\ (top)}$	=	strain in masonry in the extreme top fiber
$\varepsilon_{m\ (bot)}$	=	strain in masonry in the extreme bottom fiber
ε_{me}	=	strain in masonry due to effective prestress
ε_{mu}	=	strain in masonry at nominal strength
ε_{ps}	=	strain in prestressing tendon at nominal strength
ε_{pu}	=	strain at specified tensile strength in prestressing tendon
ε_{py}	=	strain at specified yield strength of prestressing tendon
ε_s	=	strain in the steel due to prestress and applied loads
ε_{se}	=	strain in prestressing tendon due to effective prestress
ϕ	=	curvature of the section
ρ	=	ratio of the area of flexural tensile reinforcement, A_s, to the area bd

CHAPTER 1
INTRODUCTION

1.1 General

Masonry has been in use for centuries in the construction industry and countless masonry buildings have been built around the world. Its simple method of construction, aesthetic appearance, and durability have popularized its use and applications. It has been favored for non-structural applications such as building claddings (veneers), partitions, infilled walls, etc. and limited structural applications. It is seldom used in load bearing and flexural applications due to its low tensile strength. Clay Bricks are very strong with compression strength normally exceeding 10,000 psi (69 MPa). These bricks when used with even the lowest grade mortar, result in a fairly strong masonry assemblage. The most common use of brick masonry in non-load bearing applications does not utilize the full potential of the engineering properties of the brick. If the engineering properties of brick masonry are exploited, a number of advantages such as better durability, improved efficiency, and greater resistance to impact or accidental loads can be obtained.

Currently, the most extensive application of clay brick masonry in the United States is in the construction of veneers. A veneer is defined as "a wall having a facing of masonry units, or other weather-resisting, noncombustible materials, securely attached to the backing, but not so bonded as to intentionally exert common action under load" [Brick, 1987]. The primary functions of a veneer are to transfer wind and externally applied loads to the structural components, and to give an aesthetically pleasing appearance to the building. It also provides a means of support to the thermal insulation barriers attached to the exterior walls of the building. A veneer is considered to be a non-structural element which supports no loads other than its own weight. Anchored veneer consists of a single masonry wythe as the exterior finish separated from a backing by an air space. Concrete masonry, steel studs, timber, or light structural steel members are commonly used as the backing. Wind load is transferred from the veneer to the backing by the ties which connect it to the backing at regular spacing. Brochelt [1988] describes the history of anchored masonry veneer and its structural design requirements.

1.2. Brick Masonry Veneer Walls

1.2.1 Current System of Construction

In the current system of construction, the veneer is attached to the back-up system using metal ties at regular intervals. These ties are embedded in the form of a grid behind the wall, and they are permanently secured to both the veneer wythe and the metal stud

back-up system. The UBC [Uniform, 1994] Section 1403 gives the height limitation, and design requirements for backing, anchor ties, and metal studs used in the construction of anchored veneers. Also BIA [Brick, 1987] addresses the considerations and recommendations for the design, detailing, materials selection and construction of brick veneer/steel stud panel walls. Typical brick veneer/steel stud wall construction is shown in Figure 1.1.

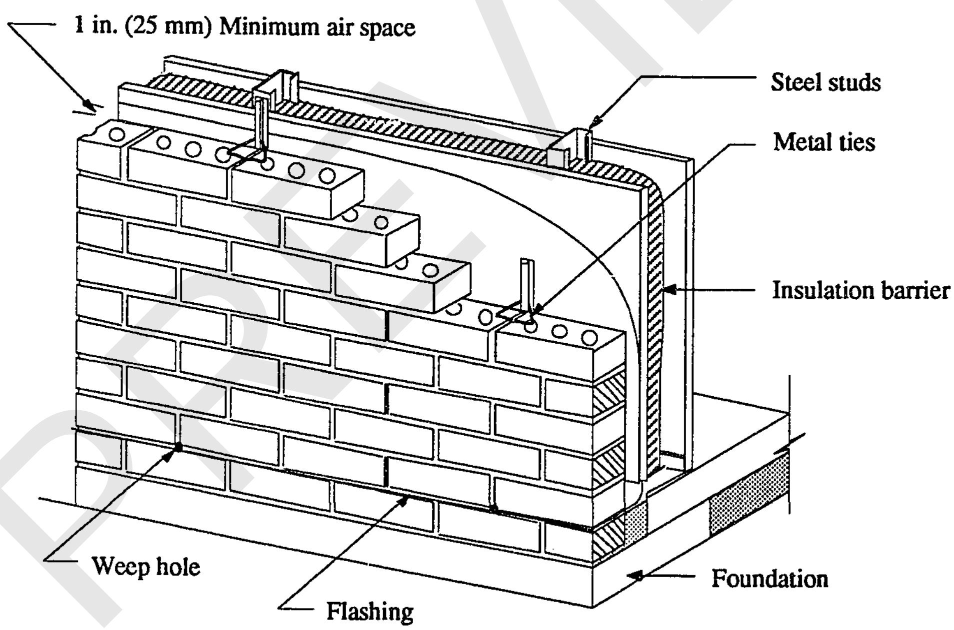

Fig. 1.1 Typical brick veneer/metal stud system