Post-Tensioned Masonry Meets Design Challenges

By Edward L. Freyermuth, CCCM

Post-tensioned reinforcing has been widely used in construction for many years. Its common uses are found in foundation slabs, precast concrete and even in some bridge construction. It has only been recently recognized in wall construction, specifically, masonry walls, where it is the primary reinforcing system used. One such system is the Integra Wall System, developed and manufactured by Superlite Block, an Oldcastle Architectural Products Company, located in Phoenix, Arizona.

Introduced in 1984, the post-tensioned system was originally designed for the Phoenix single-family home market. This was previously a market where the majority of single family homes were constructed with load bearing masonry exterior walls. When the Exterior Insulated Finish Systems (EIFS) were introduced, masonry construction suddenly became almost non-existent. Masonry construction in this market now faced two major challenges.

1. How to insulate a masonry wall to achieve the same or higher insulation levels as wood framed construction, and
2. How to provide a product that is cost effective and competitive with wood framed construction.

Since conventional masonry construction is required to be reinforced, addressing these challenges would call for a major change. The solution was post-tensioned masonry. These challenges were met by doing three things:

1. Changing the shape of the block to reduce thermal bridging.
2. Replacing as much of the conventional reinforcing as possible with post-tensioned reinforcing. This would eliminate much of the grouting common in masonry construction, and would greatly increase the area inside the wall to receive insulation.

Figure 2: Once the walls are in place, the steel rods are tensioned to a pre-engineered force of 7400 pounds using impact wrenches.

Figure 1: Open ended block available in 6 inch and 8 inch widths.

3. Finding an insulation material that would not only offer high insulation values, but also provide other properties not found in most insulation materials.

Post-tensioning utilizes double open ended units (*Figure 1*), with the center web reduced in height to decrease thermal bridging to a minimum. When laid in a running bond pattern, it provides an open cavity with the masonry units acting as a form for the insulation. Since the post-tensioned reinforcing system eliminated the grout in these areas, an almost continuous blanket of insulation can be provided. High grade polyurethane was developed for this application. The installation occurs during or after the wall construction. It provides not only the highest R-value per inch compared to other insulation materials, but also contains other properties that provide additional benefits.

While the post-tensioned system did not return the market to what it was previously, it did meet many of the challenges and save a market that would have most likely been lost entirely. To date, over 25,000 masonry structures have been built using post-tensioned reinforcing. Today, post-tensioning has become more than just a product for residential construction. It is now being used in commercial projects such as office buildings, retail and warehouse construction, municipal buildings and educational facilities such as churches and schools. A case study of one such project is included as a sidebar to this article.

How the Post-tensioning System Works

The vertical reinforcing consists of 7/16-inch (60 ksi) rods that are threaded at both ends. These rods, depending on the wall height, may be a single length or may be in multiple sections. They are connected to the proprietary anchors which are placed in a conventional concrete or masonry foundation. Horizontal reinforcing may include joint reinforcing as specified by the Structural Engineer.

Once erected, the walls are tensioned, usually within 24 hours. This is accomplished by using impact wrenches (*Figure 2*). In the case of taller walls, this may involve tensioning the wall at mid-height and again at the top of the wall. There is a special plated bearing block that is used at the top, or wherever the tensioning takes place. The tension assembly consists of a ½-inch steel plate, standard hardened washers

Figure 3: Polyurethane insulation is sprayed into the wall interior, allowed to expand, harden and dry. The excess is cut flush to the block.

and a Direct Tension Indicator (DTI) washer. This DTI washer is manufactured specifically for the system and is used to verify the level of tension forces. This is done by using a 0.02-inch feeler gauge or by observing the colored fluid that is squeezed from the washer.

Specially formulated polyurethane is installed while completing the tensioning (*Figure 3*). The excess insulation is removed, leaving the wall ready to receive whatever is next.

Benefits of Post-Tensioned Masonry Walls

Post-tensioned reinforcing, when properly designed, allows the wall to perform in a very ductile fashion. The 7/16-inch diameter steel rods are of a size that produces a wall where the steel ratio is only a small fraction of the balanced design steel ratio. This is a very desirable feature in ductile system design. The performance is easy to quantify because the engineering mechanics of the system are simple. The tension rod takes tension and, at design load levels, the face shell of the masonry unit takes all of the compressive forces. Under all loading conditions, the neutral axis is in the face shell and never in the cells of the units. Thus, the lack of grout has no engineering significance.

Structural benefits of the post-tensioning include increased flexural resistance to out-of-plane lateral loads and increased resistance to in-plane lateral loads over non-post-tensioned walls. A post-tensioned wall also resists flexural cracking and prevents cracks from opening more effectively than non-post-tensioned walls. The post-tensioning force is moderate, which precludes compressive failure in the masonry and provides ductile performance under both in-plane and out-of-plane lateral loads.

Design Standards

Post-tensioned masonry can be designed in accordance with the *Building Code Requirements for Masonry Structures* of the Masonry Standards Joint Committee (ACI 530). The Integra System also has International Code Council - Evaluation Services approval as a system.▪

Edward L. Freyermuth, CCCM, is the Sales Manager of the Integra Product Division of Oldcastle/Superlite Block in Phoenix, Arizona. He assisted in the development of the System and oversees the Sales and Marketing efforts of the product. For more information, please visit ***www.integrawall.com****.*

A Case Study

Project:
Desert Oasis Elementary School
Phoenix, Arizona

Owner:
Tolleson Elementary School District

Architect:
Architectural Resource Team, Inc.
Phoenix, Arizona

General Contractor:
Turner Construction
Tempe, Arizona

Masonry Contractor:
Roma Masonry
Phoenix, Arizona

Project Description

Desert Oasis Elementary is a K-8 grade school located in Phoenix, Arizona. The school contains 53,000 square-feet of academic area with 35 classrooms plus offices and specialty rooms, and a 12,300 square-foot multi-purpose building. The school is designed to accommodate 700 students. The exterior walls are constructed with a post-tensioned and insulated wall. The walls are printed on both sides to provide desired colors and finishes.

Design Challenges

Public Schools in Arizona are coordinated through the School Facilities Board and the Students First Program. This was designed to provide a level financial playing field for all School Districts. As a result, the budgets for new schools are set and the designs are expected to fall within pre-defined parameters. Since the use of masonry is the preferred material in school construcion, this sometimes presents quite a challenge as a result of budget constraints.

The post-tensioned system was chosen for this project since it was able to meet all of the design requirements and stay within the allowed construction budget. Since masonry walls provided the structural as well as the insulation requirements, no additional furring or add-ons were necessary. The walls were then painted on both the interior and exterior sides using color to achieve the desired aesthetics. A very cost effective wall was realized.