Water Penetration Through Masonry Walls
Field Investigation

Duncan Dining Center
Texas A&M University

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Introduction

Is Poor Workmanship also Poor Customer Service?

Is it Beneficial Project Management to simulate the addition to a Texas Style Older Building with Contemporary Methods Resembling Older Materials?

- **Who is the Customer?**

  "A customer is anyone who is affected by a product or service."[1]

- **What Defines Customer Satisfaction?**

  Customer satisfaction must become the focus of corporate thinking. Providing customers with goods and services that meet their expectations and needs at a price they are willing pay is paramount....If you satisfy customers, profits will increase in the long run; but don't forget, satisfying customers, not increasing profits, must be your primary goal...A price tag cannot be put upon the advantages of a satisfied customer extolling the virtues of your company's products or services.[2]

Introduction

❑ What is the Cost of Poor Construction Quality?

The cost of quality divides logically into two areas: cost associated with not doing things right, and costs associated with trying to prevent them from going wrong.[3]

This Case Study investigates the Owner's concerns with water entering though the exterior brick veneer two years after the completion of construction.

Named for William Adam Duncan, director of subsistence (food services) from 1920 to 1937, the Duncan Dining Hall (Duncan) anchors the south end of the Quadrangle and the location for twelve (12) dormitories for the Corps of Cadets and designed by Alfred C. Finn, a prominent Houston commercial architect. Constructed in 1939 and with load-bearing unreinforced clay masonry bricks and sand-lime mortar Duncan is a true **Texas Style Older Building.[1]**

From an original paper "Water Penetration Through Masonry Walls: Laboratory and Field Investigations"(2) materials extracted, with the primary author's permission, form the base information for this Case Study.

Over the past eighty-nine years, Duncan experienced many renovations, including the 1988 additions, the subject of this Case Study and constructed with a brick veneer facade to harmonize with the existing building.

Goals and Objectives

Problem

- In the Fall of 1990, reports were received by The Texas A&M University Physical Plant regarding water entering from the new addition's roof through the parapet expansion joints.

Project Goals

- Determine why water is entering the building? – Figure 1.
- Why are there holes in the mortar joints? – Figures 3 and 4.
- Recommend the solution options.

Figure 1 – New Entry Canopy Circa 1988

Objectives

- Implementing moderate evasive investigation methods:
  - Remove portions of the masonry veneer and expose the internal flashing details.
  - Sample areas along the line of the new entry canopy abutting the existing building.
- Investigate the condition of the mortar, the brick, and the flashing materials.
  - Determine the respective compliance with the project specifications.
  - Render an opinion of the quality of the overall workmanship of installation.
- Conduct the work in a manner minimizing disruption of the Dining Hall's business operations.

Parameters

❑ Building Conditions

- The building opened for occupancy in the Fall of 1988. The addition's façade is comprised of tumble bricks with tooled concave joints of widths varying from 3/8" to 3/4", presenting an aged appearance simulating the existing building's masonry walls, Figure 2.
- The expansion joints between the existing building and the addition do not satisfactorily seal the construction joint and fail under water pressure.
- Various areas of the building's facade displayed staining and efflorescence as evidence of water entering and exiting the brick veneer cladding Figure 3.

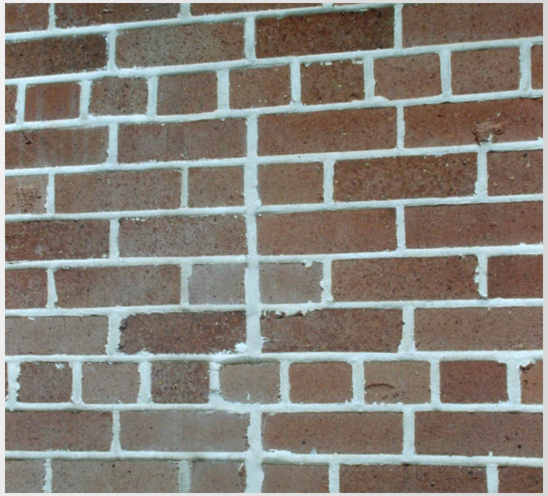

Figure 2 – Simulated older veneer.

❑ Project Conditions

- Faculty and students are not inconvenienced and sometimes displaced after rainstorms, disrupting schedules, and class continuity.
- Damage to the interior finishes and materials increases with each storm. Physical Plant postponed repairs until a resolution to the leakage.

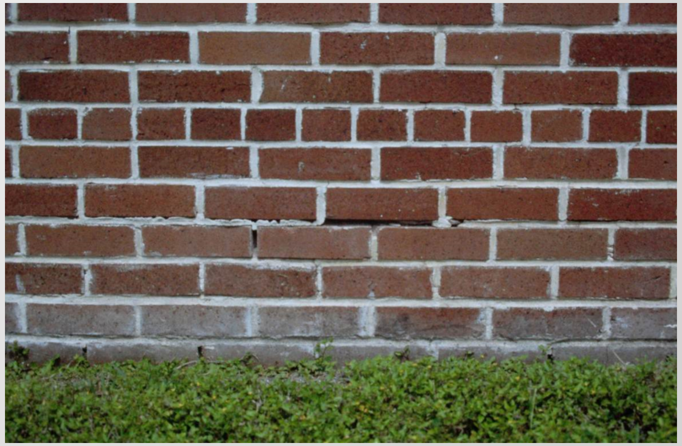

Figure 3 – Efflorescence at the lower portion of the wall.

❑ Project Materials - Hand tools, brick, and a sand-lime mortar mixture.

Parameters

- **Project Criteria**
  - The building is situated on the East portion of the original campus and in a prominent location.
  - The investigation cost is absorbed by Physical Plant's Maintenance and Operations Budget.
  - The Owner's base project criteria
    - Conduct investigation operations in the least obtrusive manner.
    - Restore openings with materials from the building's reserve stock.
    - From the information gathered, determine if the contractor's work followed the building architect's specifications.

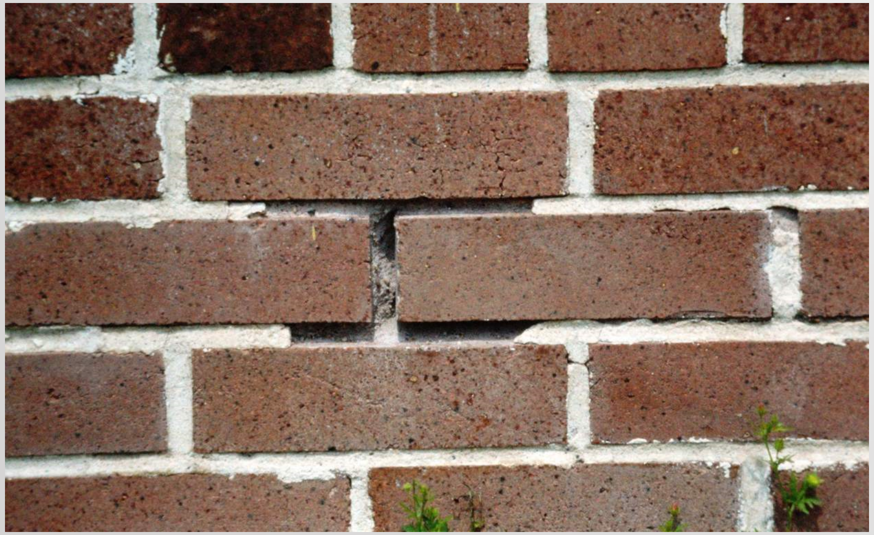

Figure 4 – Mortar voids in new wall.

Figure 5 – Un-tooled joints in new wall.

Solution - Discovery

Minimal Evasive Investigation

- First step - Several random selected areas of the exterior wall.
  - Observe the conditions of the walls above the suspended ceiling system.
  - Observation of the water infiltration revealed potential defects with the construction of the expansion joint flashing assembly details.
  - Observations noted the water entering the building's interior along the line of the new exterior wall along the parapet

- Second Step - Remove brick prisms and observe the workmanship of the assembly's construction.
  - The brick used, a modular brick with dimensions of 2-5/8"H x3-5/8"W x 7 5/8"L.
  - The average prism, two (2) bricks long and four (4) brick tall is about sixteen inches (16")L x twelve inches (12")H.
  - The mortar used is of a sand-lime proportion to match the original blend.
  - Initial observation indicates poor workmanship and execution. The bricks appear to have been reset (moved or adjusted) after initially set in the bed course.[4,5]

Figure 6 – Top of removed brick with mortar – typical.

Figure 7 – Head joint of removed brick – typical.

Solution - Discovery

Minimal Evasive Investigation - Continued

- Third Step – Investigate the openings in the walls and observe the cavity and flashing assemblies.
  - Supported by the steel floor angle, two (2) soldier courses define the belt-course on every floor.
  - Typically a two-part steel flashing assembly diverts water collected in the cavity to the openings in the mortar joints called weep-holes. The wall-cavity should be clear of mortar and the back-side of the brick veneer clean of mortar so as not to catch water.

Figure 8 – Opening in the parapet wall

The Architect's Specification Requirements

- Comply with the Masonry portion of the project specifications - Section 04.
  - Particularly the workmanship requirements, moisture testing of the brick, and testing of the mortar.
- Install each assembly per the approved Shop Drawings and Flashing Details.

Figure 9 – Opening in the parapet wall

Solution - Observations

Observations of the Prisms

- Figure 10 shows a head joint cut from a portion of the wall of the new building. The brick, removed without resistance, indicates the lack of bond with the mortar. Such would be caused either by the brick's high IRA value and the mortar's low quality.[5]
  - The depressions on the mortar's surface indicate that the brick was either moved from its initial position and (possibly) additional mortar added to the joint or the mason did not use proper bricklaying technique by exerting adequate pressure to yield a tight head joint.
- Figure 11 shows a bed joint extracted from another location in the same wall, indicating the same deficiencies as in the previous head joint. In a few other joints, the mortar was so deficient in quality that it powdered when rubbed with fingers.
- Investigations of the flashing system indicated that the counter flashing assembly incorrectly installed, Figures 8 and 9, and on the east side of the entry, the weep holes omitted.

Figure 10 – Head joints

Figure 11 – Back of typical prism

Solution - Observations

Observations of the Empty Wall Openings

- Wall Cavity - Figures 8, 9, 12, and 13.
  The polyethylene moisture barrier is haphazardly installed, loose, and reasonably ineffective.
  - The arrow points to an overlap of the barrier behind which the upper leg of the flashing is concealed. However the poly-flashing deteriorated by the lime in the mortar is non-existent.
  - The limp poly-flashing has not sufficient integrity to contain and divert water from the interior wall cavity and into the building.
- Wall Cavity - Figure 13
  - The yellow area at the bottom of the picture is the urethane foam roof coating. During intense rain storms, gathering water rises up the sides and into the building.
  - The wall cavity also contains sufficient mortar to restrict the water entering the building.

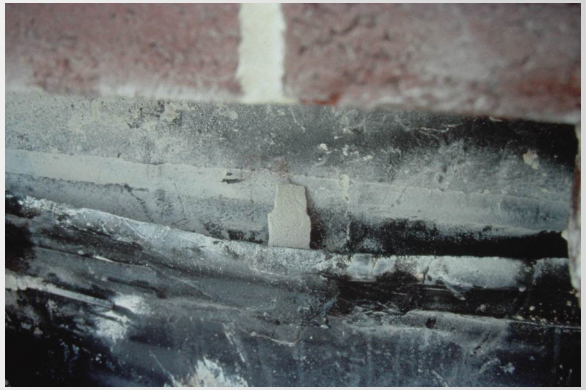

Figure 12 – Wall cavity

Figure 13 – Wall cavity

Solution - Observations

- **Observations of the Empty Wall Openings**
  - Upon review of the project specifications, indicated the following deficiencies:
    - No record of IRA (initial rate of absorption) tests to determine if the bricks were too wet or too dry before installation;
    - Type 'S' mortar - no records of the actual mortar installed;
    - Sample wall panels were built and approved for only color and texture;
    - No records of mortar tests from approved batches with the continuous inspection.
    - No records exist as to the observations of the inspection of the masonry during construction.

Summary

Is Poor Workmanship also Poor Customer Service? YES

- **Previous Research**

  The field investigations[4] conducted at Texas A&M University, College Station, supports the view that if the workmanship and detailing of masonry are substandard, the masonry work will leak regardless of the quality of materials and the joint profiles used. The **workmanship** is the single most crucial factor in obtaining water-resistant walls. Several other researchers have reported this fact. The destructive testing of samples of the leaky portions of the masonry form the actual buildings adds scientific evidence to the existing knowledge.

- **Workmanship**

  Proper bricklaying techniques, masonry detailing, and appropriate specifications for good practice should be inherent with the masonry trades. Throughout the construction design industry, there is a lack of understanding of its importance and, to some extent, the masonry contracting community. An aggressive strategy to educate architects and engineers on the benefits of proper **workmanship**,[5] wasteful, and costly avoidable errors, such as those in this Case Study , are eliminated.

Summary

Is it Beneficial Project Management to simulate the addition to a Texas Style Older Building with Contemporary Methods Resembling Older Materials? NO

- **The Secretary of the Interior's Standards for Rehabilitation - Standards 9 and 10**
  - 9 - New additions, exterior alterations, or related new construction shall not destroy historic materials that characterize the property. The new work shall be differentiated from the old and shall be compatible with the massing, size, scale, and architectural features to protect the historic integrity of the property and its environment.
  - 10 - New additions and adjacent or related new construction shall be undertaken in such a manner that if removed in the future, the essential form and integrity of the historic property and its environment would be unimpaired.

- **Comment**
  - Initially it seemed as a good idea to have the additions closely, if not exactly match, the original building's construction materials. Success may have followed if not for such poor workmanship and material control.

Highlights

Of Note

- The purpose of this case study is to discover the problem and not solve the problem - **Why is water entering the building?**
- Poor workmanship and execution of the details is **Why is water entering the building**. Once the water passes through the poorly constructed mortar joints and into the wall cavity, there are no paths for the water to drain to the exterior.
- Expecting to discover some flashing details poorly constructed, however the extent across the majority of the building walls was troubling.
- The recommended solution is to remove all the brick veneer cladding, flashing assemblies; repair damages, and properly install the brick veneer cladding as originally specified by the architect and bid by the general contractor.
- Also troubling is the amount of money paid to the masonry contractor for such mediocre work and falsely representing to the owner value received.
- The Texas A&M University Vice-President for Finance and Administration was not please to know that a three-year old building, costing the citizens of Texas millions of dollars, required extensive work to stop the water entering the building.

Highlights

- **References [ ]**

[1] - Juran on Leadership for Quality, An Executive Handbook (1989).

[2]- The Deming Guide to Quality and Competitive Position, Howard S. and Shelly J. Gitlow, (1987).

[3] - The Deming Management Method, Mary Walton, (1986)

[4] - Hines, S.T., 1992, Texas A&M University Physical Plant Report on the Condition of the Exterior of Duncan Dining Hall.

[5] - Hines, S.T., 1991, Relative Water Permeance of Mortar Joints in Masonry Walls, M. Arch., Thesis, University of Texas at Arlington, USA