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CASE STUDIES
DESIGN & CONSTRUCTION OF REINFORCED BRICK VENEER

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ABSTRACT

For the past 15 years, a new system for installing brick on the exterior of buildings has been developing in the northwest United States. The system is derived from the convergence of two common uses of brick masonry. The first is reinforced brick masonry panels, and the second is brick veneer on steel studs. The new system is called reinforced veneer. It has been used on at least 12 projects and is receiving increased attention from owners and architects because of its performance and cost advantages. This paper describes reinforced veneer and presents three case studies. The case studies were selected to give the reader the broadest perspective on the capabilities of the system.

INTRODUCTION

When the architect is confronted with the requirement to design a brick exterior wall building, there are a limited number of approaches available. Using brick as a loadbearing system with its thick masonry walls has been the traditional choice. But in today's cost conscious environment, loadbearing brick buildings are too expensive. Using brick as a veneer is far more common and with the advancement of metal studs as a veneer backing, brick veneer has actually become a popular and common choice.

Another choice is to use reinforced brick panels. This approach, first used in

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Denver in the 1960's, is now common in several regions of the United States. More than 60 reinforced brick panel projects have been built in the Northwest since 1978. The system is very similar to precast concrete panels except that reinforced hollow clay masonry is used instead of concrete. Now, combining brick veneer on steel studs and brick panels, a new system is emerging. Called reinforced veneer, or reinforced brick curtain wall, the approach is gaining acceptance as a less costly, but higher performing option than either of its originators.

In most respects, the system is the same as the traditional veneer over a backing of steel studs. However, instead of ties between the veneer and the backing being placed at every two square feet of wall, ties are typically placed every 100 square foot of wall. Obviously, when tie spacing is increased, loads on the ties increase and the demand on the brick to span between the ties increases. The ties become many times more substantial than the typical veneer ties and are usually connected directly to the structure of the building. This is one major contributor to the cost advantage of the system. The more substantial, further-spaced ties cost less per square foot of wall than the conventional veneer ties spaced every two square feet.

Moreover, the attachment directly to the building structure eliminates the requirement for the back-up wall to resist load, thus significantly reducing the cost of the back-up wall. In the brick veneer on steel stud system, the back-up walls normally consist of 6-inch, 18-gauge studs at 16 inches on center. With reinforced veneer, the back-up wall becomes a 26-gauge, 4-inch stud at 16 inches on center. Additionally, in the traditional veneer systems, the stud connections to the tracks are often required to be welded whereas in the reinforced veneer system, conventional sheet metal screws are perfectly adequate.

But, there is a compensating cost increase. In order for the brick to span between the ties, it is necessary to increase the strength of the masonry. The easiest method available is to use brick with cells (voids through the unit with area greater than 1-1/2 square inches), place reinforcement in the cells, and grout the wall. Horizontal reinforcement is placed in bond beams as the brick is laid. The savings from the elimination of the ties and the reduction of the cost of the back-up wall exceed the cost of the strengthening of the masonry wall.

Besides the cost savings, the reinforced veneer system also offers improved performance. Connecting the ties directly to the structure with more substantial connectors provides the designer with more methods for isolating the veneer from the building. Poor isolation of the veneer from the building is a common cause of veneer failure. Also, the addition of the reinforcement to the brick changes the brick wall from a brittle material to one with considerable ductility. When, and if loads (wind or seismic) exceed service levels, the reinforced veneer system is expected to perform much better than its traditional brittle counterpart.

Reinforcing the brick also may solve other design problems. Brick lintels don't require ledger angles. Windows are connected to the brick, not to the back-up, thus making waterproofing easier. And architectural features such as brick soffits, cantilevered walls, and surface articulations are often easier to accomplish with the reinforced veneer system.

In order to further describe this system, three building examples have been selected. Each shows a different aspect of the reinforced veneer system and together provide the reader with some idea of the flexibility available in this type of design.

Each case is divided into three parts. The first presents the project statistics, the second presents the wall concept, and the third presents interesting aspects and lessons learned.

CASE ONE -- EVERGREEN HOSPITAL

Project Statistics
Size: 200,000 square feet; four stories.
Architect: Mahlum & Nordfors, Architects
Structural Engineer: KPFF Consulting Engineers
Contractor: Mortenson
Mason Contractor: Sterling Masonry

Wall Concept
The reinforced veneer on the Evergreen Hospital (Fig. 1) is very similar to a conventional brick veneer on steel studs. The project was originally designed as brick veneer on steel studs, but changed to reinforced veneer to save cost and improve performance. The wall concept is shown below (Fig. 2).

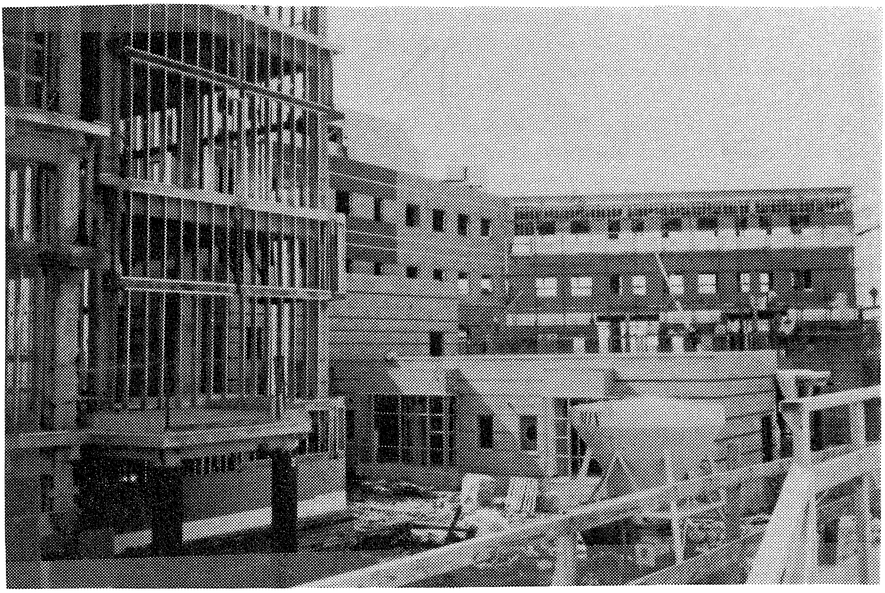

Fig. 1 Evergreen Hospital

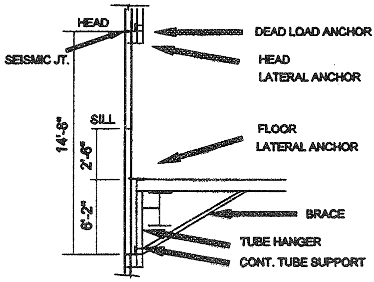

Fig. 2 Evergreen Hospital Wall Concept

The brick masonry is supported on continuous angles located at the window head. These angles, or ledgers, are supported on a tube girt system suspended from angle hangers and kickers (Fig.3). The stud wall is light gauge and used only for the support of the water and air barrier, and interior gypboard. Dowels were welded to the ledgers (Fig.4); the brick laid by threading over the dowels; and then when the masonry reached the head location, bars were dropped into the vertical cells and the wall grouted (Fig.5).

The masonry units were nominal 4x4x12 inch with two 1-3/4 x 3-1/2 inch cells. The design f'_m was 4,000 psi (Fig.6).

Lateral bracing consisted of galvanized 1/8-inch thick plate with holes for vertical reinforcement passed through. These plates occurred at the floor line and at the underside of the ledger and were spaced approximately 10 foot on center horizontally.

The lateral anchor under the ledger was designed to be flexible in the direction parallel to the plane of the wall and rigid in the direction perpendicular to the plane of the wall. This design provides isolation of the wall from the floor to floor movements caused by wind and seismic forces.

Interesting Aspects and Lessons Learned

The design team required the mason contractor to demonstrate the ability to grout the small cells of the 4-inch units. Masonry sand and grout-aid were specified for the grout, but were not initially provided for the grout test panel. Initial grouting efforts were not very successful. However, once the mason saw the difference using the proper sand and additives, grouting proceeded with no problems (Fig.7).

The general contractor provided the support for the ledger angles and the kickers. He also welded the dowels to the ledger. Weldable rebar was specified, but initially was not provided. The engineer, during a site observation, easily broke off the bars and, as a consequence, stopped construction until the proper reinforcement dowels were provided.

The design team provided a design of the brick support system. This design stopped at the ledger angle leaving the wall design to the contractor. Typical lateral connectors were detailed, but the exact location was not shown on the contract documents. The contractor was to locate and size the reinforcement in the wall and identify the required lateral anchor locations. This approach caused some confusion and resulted in a $16,000.00 claim by the contractor for inadequate design documents.

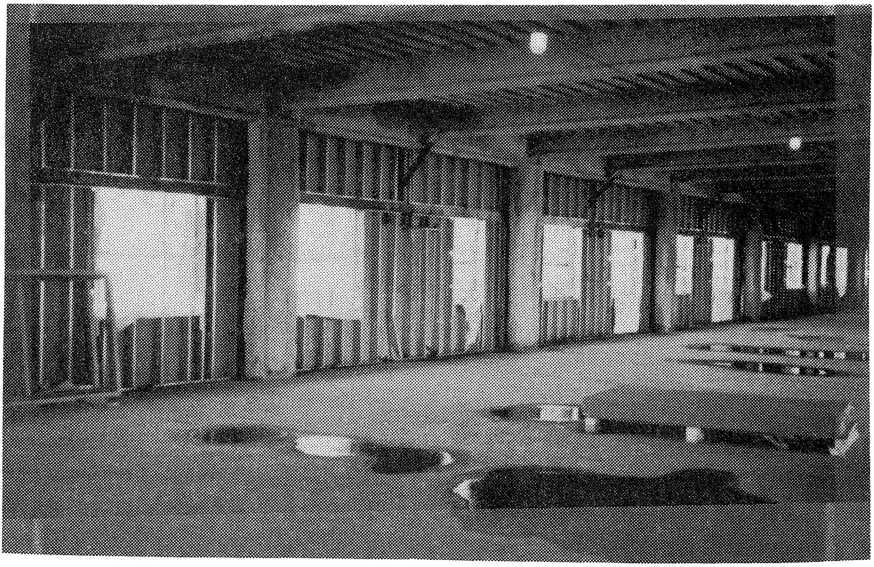

Fig. 3 Tube Girt System and Bracing

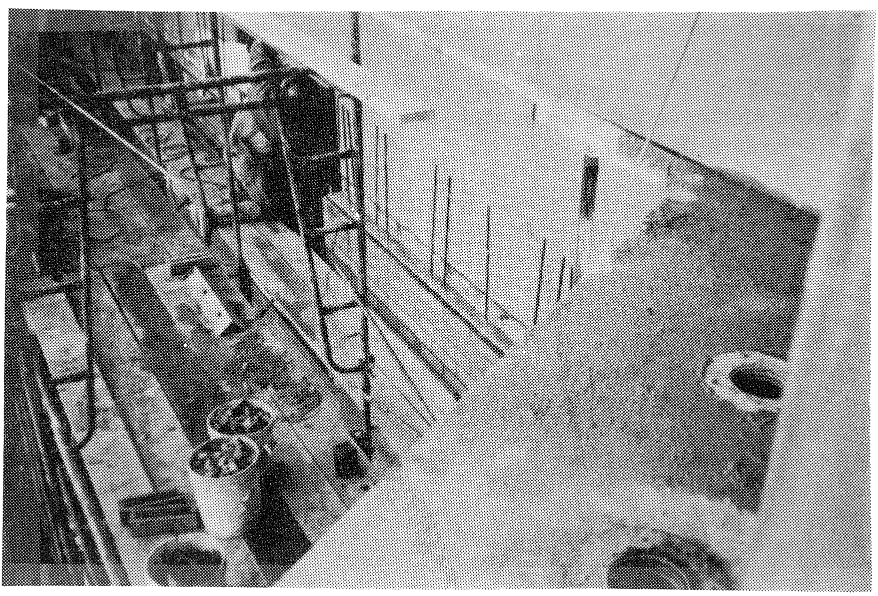

Fig. 4 Dowels Welded to Ledger

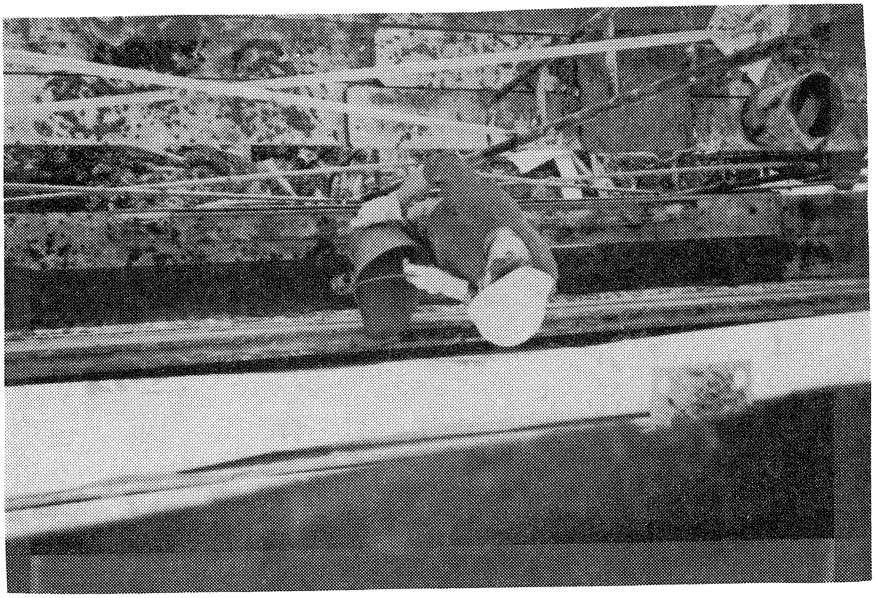

Fig. 5 Grouting

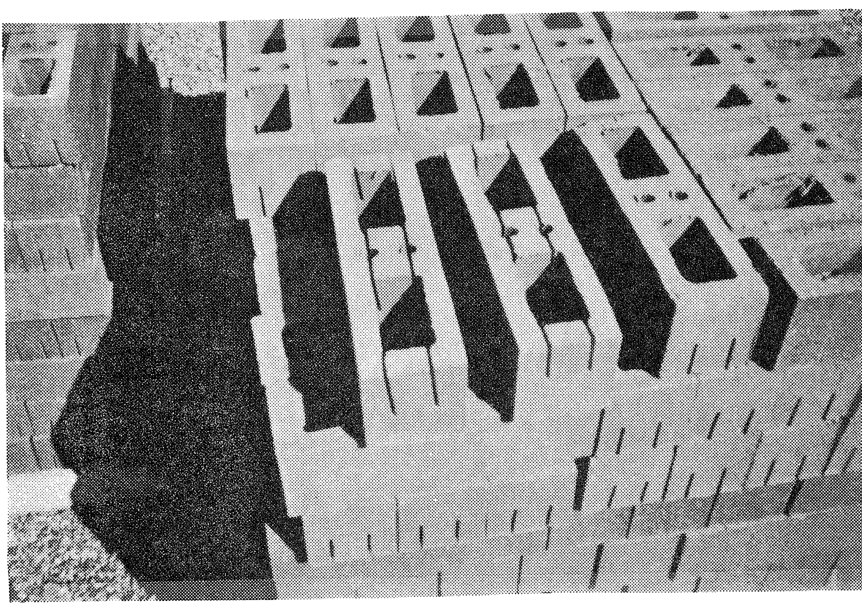

Fig. 6 Masonry Units

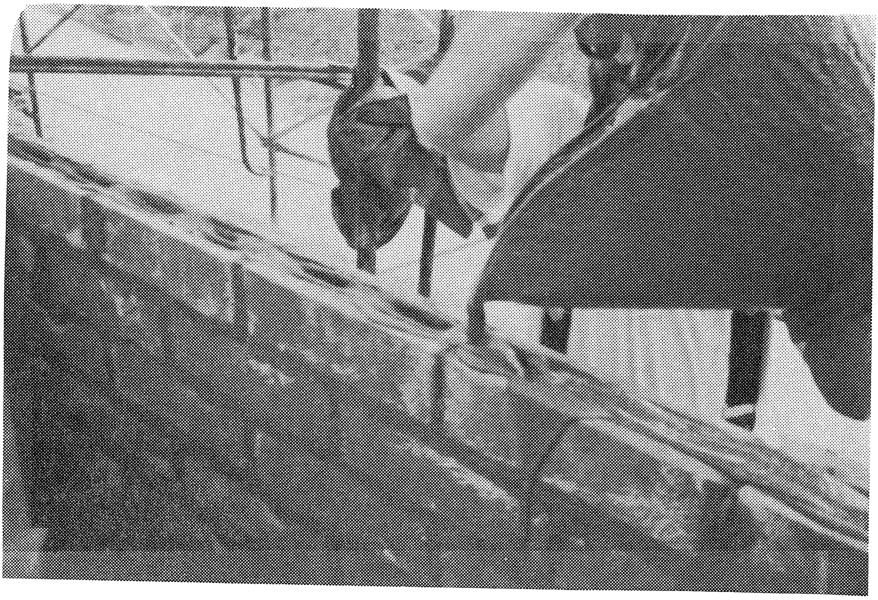

Fig. 7 Grout Material

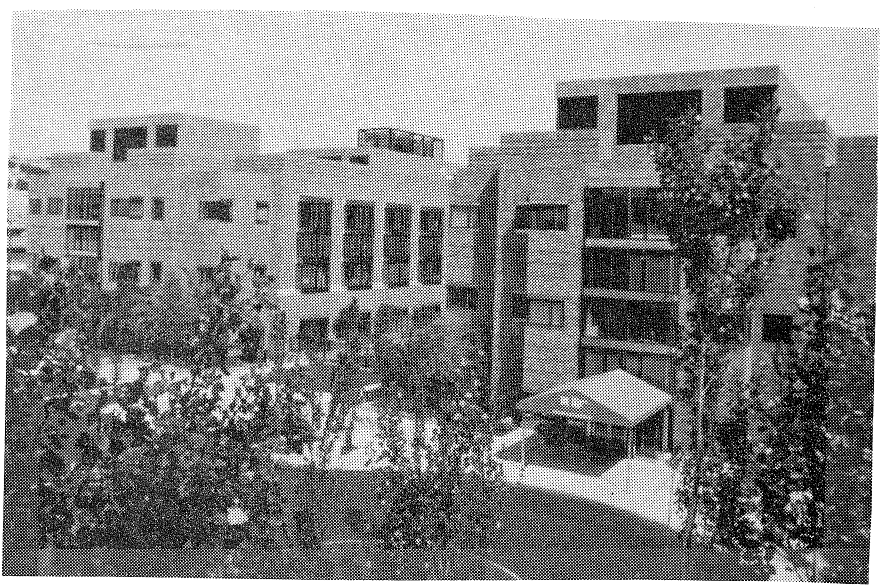

Fig. 8 Fred Hutchinson Cancer Research Center

CASE TWO -- FRED HUTCHINSON CANCER RESEARCH CENTER

Project Statistics
Size: 247,000 square feet, 4 stories
Architect: Zimmer Gunsul Frasca Partnership
Structural Engineer: KPFF Consulting Engineers
Contractor: Baugh Koll
Mason Contractor: Lund Masonry, Inc.

Wall Concept
The reinforced veneer on this project was supported at the base of the structure (Fig.8). The only connection to the building is lateral braces periodically spaced at each floor. The building is a concrete frame and is designed to move laterally inside the structural brick box exterior wall. Because of the magnitudes of the potential lateral movements, the design was based on service load lateral displacements. At higher levels of displacement, the brick will be damaged at the corners and short walls.

A back-up light gauge metal stud wall provided water and air protection and support for the interior gypboard. Lateral bracing consisted of galvanized angles periodically penetrating this stud wall to make the attachment to the reinforced veneer (Fig.9).

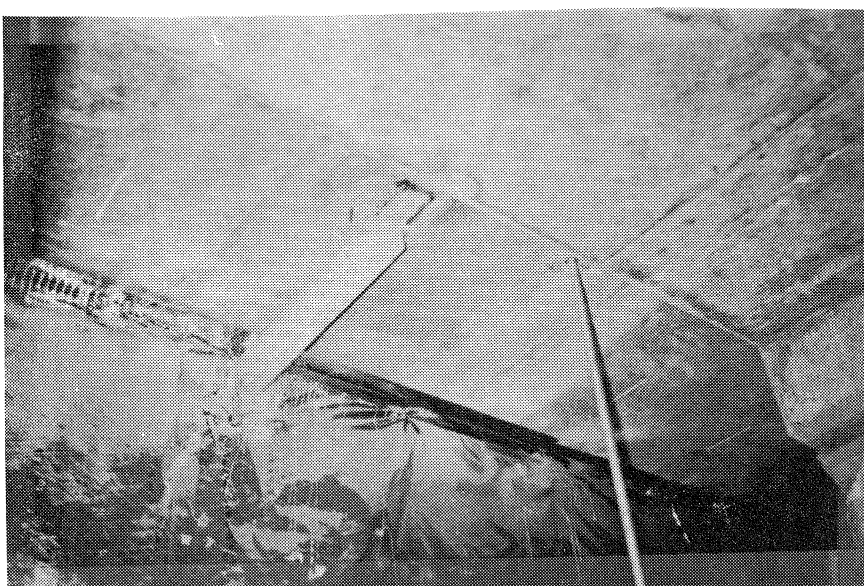

Fig. 9 Angle Brace, Underside of Floor

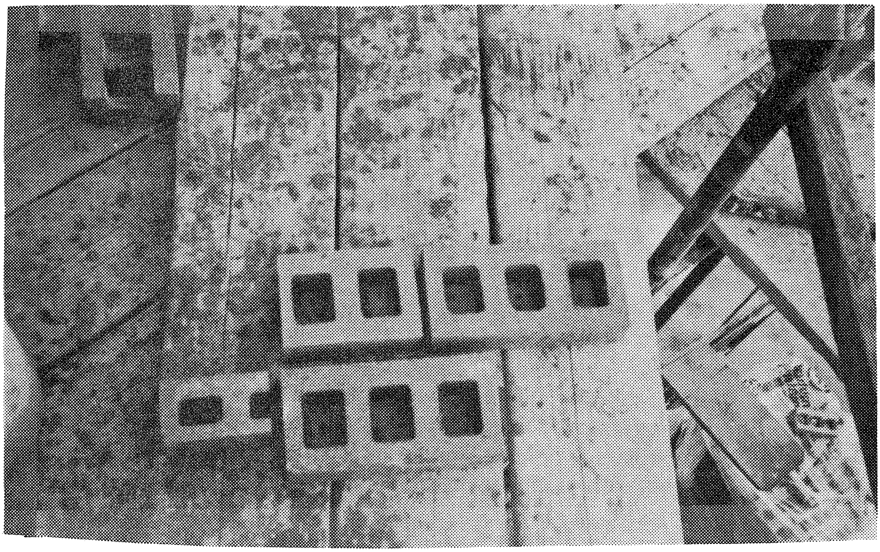

Fig. 10 Custom Brick

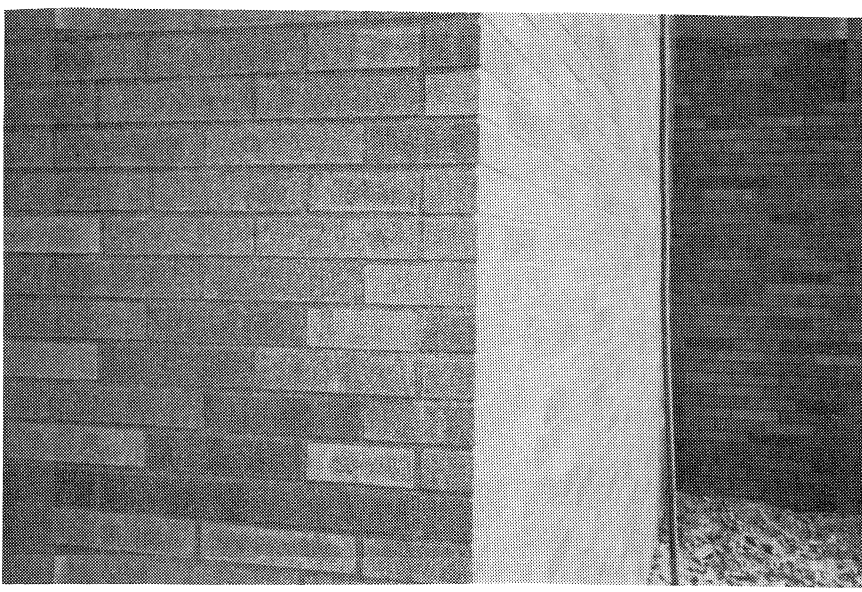

Fig. 11 One Third Bond Corner

Interesting Aspects and Lessons Learned
The architect designed several custom brick shapes for this project. The brick was laid in 1/3 bond with the head joint repeating with each third course. In order to reinforce the brick, a three-cell configuration was selected. Additional special shapes were developed to provide the detailing of the project (Fig.10). A corner constructed with this 1/3 bond pattern is very interesting (Fig.11). The brick was manufactured in Summit, Colorado and shipped by rail to Seattle. Special pallets were developed to fit inside the rail cars.

For this project, a complete design was provided by the design team in the contract documents and there were no claims. The design was prepared both as a brick veneer on steel studs system and as a reinforced veneer system. The reinforced veneer option was selected because it cost less.

CASE THREE -- PROVIDENCE MEDICAL CENTER

Project Statistics
Size: 120,000 square feet, 6 stories
Architect: NBBJ, Seattle, Washington
Structural Engineer: ABKJ, Seattle Washington
Contractor: Sellen Construction Company, Inc.
Mason Contractor: Barkshire Panel Systems
Engineer for Mason Contractor: KPFF Consulting Engineers

Fig. 12 Providence Medical Center

Wall Concept

The reinforced veneer on the Providence Medical Hospital project (Fig. 12) was designed to perform to a high level of lateral displacement. The building structural design is a steel moment frame in one direction and a steel braced frame in the other. Because of the many corners and large floor to floor drift displacements, the dead load anchors were selected to be reacted at each floor. The concept is to build a brick box in the shape of the outside wall, extending from window head to window head, but with the dead load support at the level of the floor (Fig. 13).

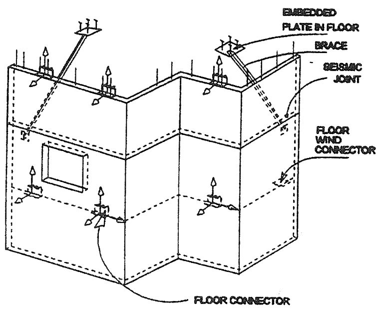

Fig. 13 Providence Hospital Wall Concept

This was achieved by adjusting the normal construction sequence. At the top of the masonry, styrofoam was placed on the brick. Brick was then laid on top of the styrofoam for a height of two feet past the floor while engaging a floor dead load connector. This portion of the wall was then grouted and allowed to cure for three days before proceeding to lay the rest of the wall. Caulk was placed over the face of the styrofoam which was left in the wall.

The design selected isolated connectors because, under some lateral load conditions, the wall produced uplift on the floor and it was felt that the best design was to provide specific points for these forces to be reacted. The corners provide much of the needed lateral bracing, thus the number of connectors to the structure is relatively few compared to some designs (Fig.14). Braces, when required, were held at least 10 feet from the corner allowing warpage of the brick to magnitudes greater than three inches without failure.

Interesting Aspects and Lessons Learned

The brick was a 5-inch unit. Custom shapes were provided (Fig.15). Additionally, the project used brick panels where scaffolding was difficult or where the support of the brick was not available (Fig.16).

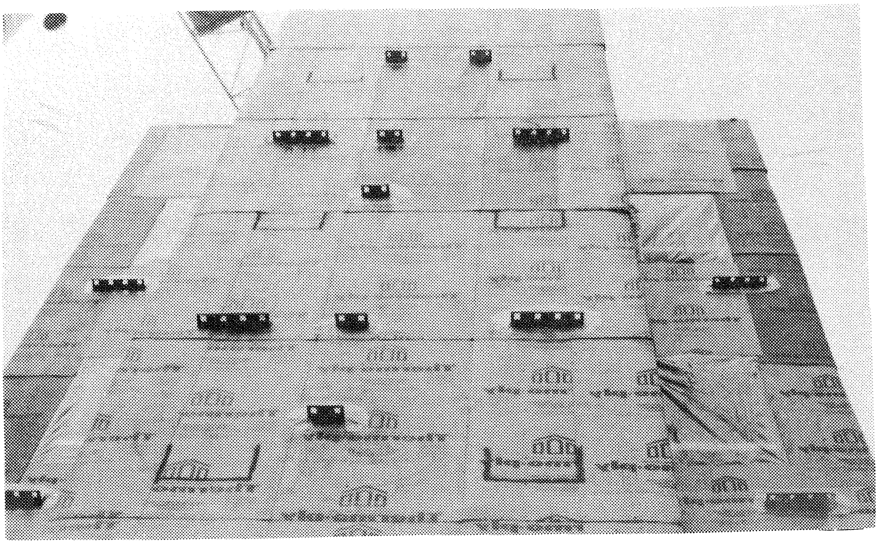

Fig. 14 Wall Connectors

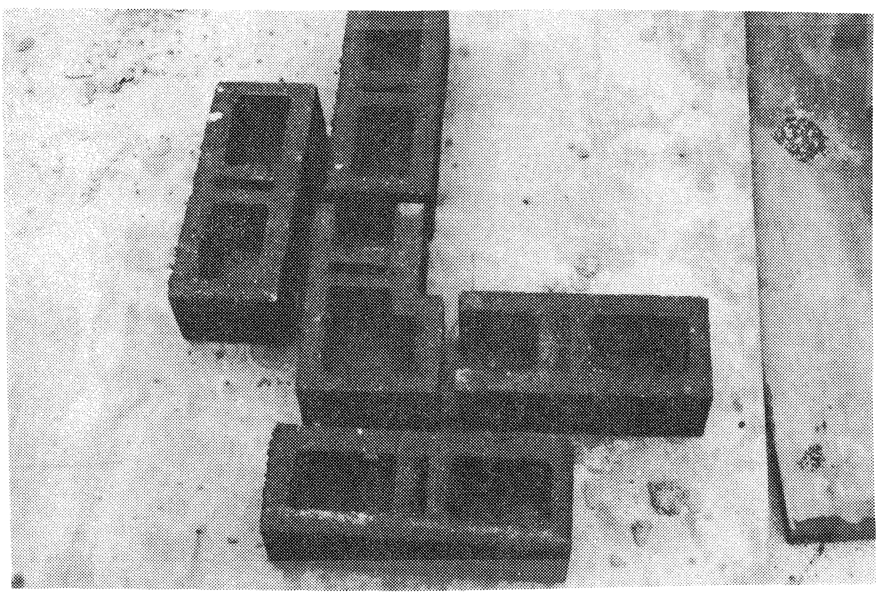

Fig. 15 Brick Shapes

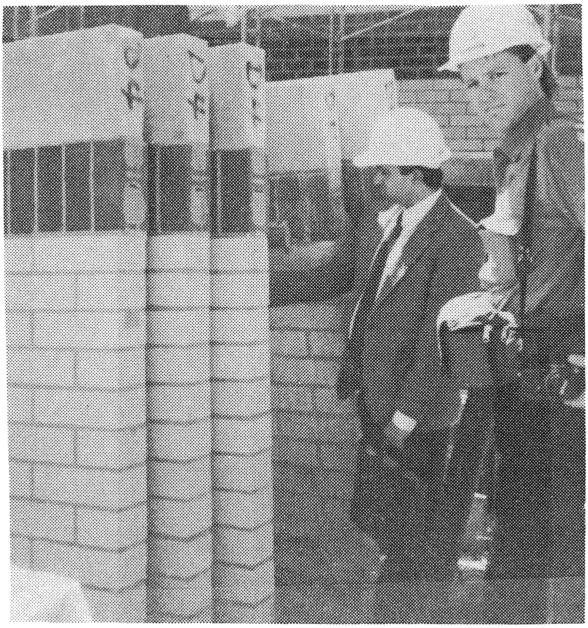

Fig. 16 Brick Panels and Reinforced Veneer

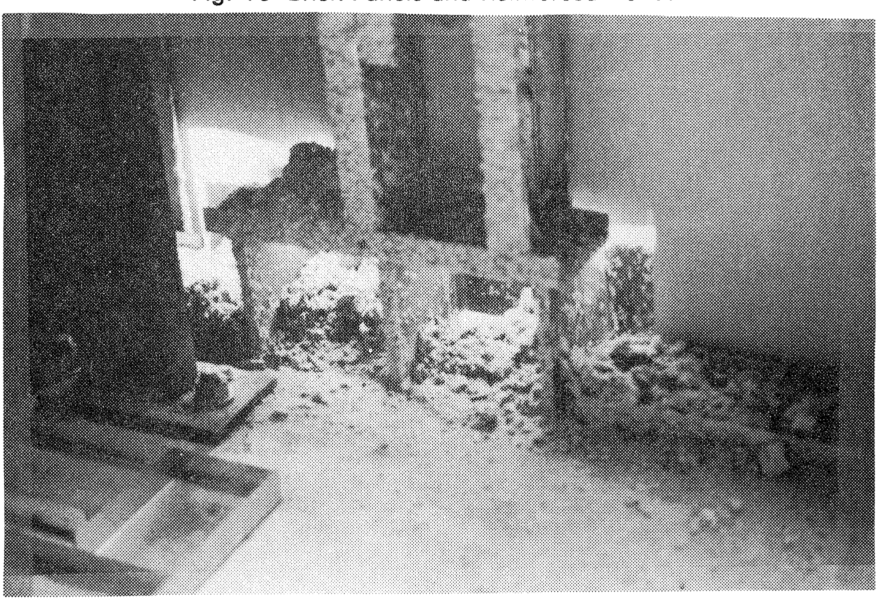

Fig. 17 Galvanized Connector

Because the loads on the connectors were large, their size and thicknesses are about the largest yet designed (Fig.17). Connectors were all galvanized.

The exterior wall package was left to the mason subcontractor to design. The contract documents did not contain the necessary information for the construction of the wall. The design of the reinforced veneer was prepared by the mason contractor. The project went smoothly and there were no claims.

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SHRINKAGE CHARACTERISTICS OF CONCRETE BLOCKS

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ABSTRACT

Shrinkage strain data from tests of blocks from twenty-four block plants in Ontario shows that the majority of shrinkage occurs during later stages of drying. From a fully saturated state, it is generally necessary to remove much more than half of the water before significant shrinkage begins. From this data, it appears that water content as an absolute rather than a relative value may be a better indicator of the benefits of predrying as a measure to preshrink the block and limit the potential for shrinkage in situ. Questions are raised regarding the benefits of current specifications for moisture-controlled block.

INTRODUCTION

Background

Concrete is known to expand when it absorbs water and to shrink when it dries. For concrete block construction, particularly when it is unreinforced, significant shrinkage will cause unsightly cracks in the tension-weak masonry. Besides being unsightly, these cracks can negatively affect rain penetration and strength characteristics. Although use of movement joints at relatively close spacing is an effective way of reducing the stresses caused by shrinkage and thereby minimizing cracking, it is logical to reduce the problem itself by limiting the amount of shrinkage that can occur. In this way, standardized

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