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Review Paper on Brick Bonds

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Abstract : The results of an experimental campaign of GFRP – clay brick bond is presented. The experimental investigation is focused on the effect of different clay brick types on the interface behaviour. Four different types of clay brick are considered, where the difference between bricks is not only due on their strength but also on their surface texture. The second focus point of the experimental campaign is the effect of mortar joint on the GFRP-masonry panel bond. A total number of 16 specimens has been tested and results in terms of debonding force and strain along the GFRP are here reported.

***Keywords**: Debonding, Masonry, FRP, clay brick.*

Introduction:

A great number of existing masonry structures are currently undergoing a severe process of structural strengthening. One of the most promising strengthening techniques is the use of Fiber Reinforced Polymers (FRP) sheets bonded to masonry structural elements [1][2]. Nevertheless, in most cases the failure type of strengthened elements is FRP debonding from the substrate. Many experimental results on bond between brick and FRP are actually available in the literature [3][4][5][6][7], while only few studies [8][9] can be found concerning bond between FRP and brick masonry panels, even if this is the real application and this type of bond could be affected by the presence of mortar between bricks. In this context, the main objective of the present research is the experimental investigation of: i) bond behaviour between brick masonry panels and FRP sheets, ii) the effect of the type of brick on the bond strength. In the present paper, results of an experimental campaign devoted to the investigation of bond behavior between GFRP and clay bricks or masonry panels are presented. In particular, sixteen specimens made of four different clay brick types were tested. Failure mode was observed in different cases, together with the measurement of bond strength and longitudinal Page 2 of 8 strain distribution along the GFRP bonded part. Finally, comparison between the bond behavior of single clay brick and masonry panel was done.

Bond strength requirements

The University of Minnesota Capital Planning and Project Management (CPPM) is responsible for the conceptualization, planning, design and construction of capital improvement projects for the campus. Standards and Procedures for Construction have been written by CPPM to assist architects, engineers, other design professionals, contractors and U of M staff in understanding the preferences of the University of Minnesota in the development, maintenance and repair of its facilities, and to explain the procedures, policies, and basic minimum requirements for materials and products included in construction projects. These Standards and Procedures are included, by reference, in every agreement between the Architectural/Engineering firm and the University of Minnesota, for professional services. The standards for unit masonry

include a quality control measure that requires flexural bond strength, using ASTM C1072 methods, to be no less than 80 pounds per square inch (psi) for all masonry/mortar units.

The Wisconsin Safety & Buildings Division Material Approval regularly completes product evaluations of manufacturer's products for use in State building projects.
The Type N and Type S mortar cement manufactured by Lafarge Corporation has been evaluated for conformance with s. COMM 53.312 (2) (c) under the current Wisconsin Administrative Building And Heating, Ventilating and Air Conditioning Code. Mixed with sand and water, the cementitious material is used to permanently bond masonry as specified in s. COMM 53.312 (6). The flexural bond strength of the Type N mortar was 100.7 psi. The bond strength of the Type S mortar was 108.8 psi.

Factors affecting bond strength

A major weakness of brickwork is poor bond strength. Taha and Shrive, 2005 advised that bond strength is dependent on many interrelated factors that can directly affect bond development (e.g. unit surface absorption, pore structure, mortar composition, mortar water retentivity and curing conditions) or indirectly affect bond strength (e.g. unit surface texture and workmanship). It was also suggested by Goodwin and West 1982 and by McGinley 1990 that both mortar quality and surface absorption criteria of the masonry unit are the most significant parameters in developing bond strength. While the surface absorption characteristics define the rate and volume of water to move from the mortar to the unit, the quality of the mortar defines the amount of water available at the interface and the strength of hydration products deposited in the unit surface pores.

This bond is affected by many interrelated factors associated with both masonry units and mortar. Lime (CH) is present in masonry mortar as a by-product of cement hydration, particularly at the mortar-unit interface where it produces a weak layer. Hence, Taha and Shrive, 2005 introduced varying amounts and types of pozzolans (fly ash types F and C, and slag) which react with the lime to produce strong calcium silicate hydrates. The intent was to enhance the bond strength of the masonry by altering the microstructure of the mortar-unit interface. An experimental examining the bond strength of mortar-unit joints was therefore carried out, using mortars with and without pozzolans. Statistically significant increases in bond strength were measured at 28, 90 and 180 days with 20% substitution of fly ash in the cementitious materials. No increases were observed with slag. Introducing pozzolans as a mineral admixture in masonry mortar, besides being an environmentally positive feature, can therefore be beneficial from economic and structural points of view.

Bonding agents

Adhered veneer relies on a bonding agent between the thin brick units and the backup substrate. Adhered veneer construction may be classified as either thin bed set or thick bed set. The thin bed set procedure typically utilizes an epoxy or organic adhesive, and is normally used on interior surfaces only. For areas subject to dampness, he Brick Industry Association suggested that only clear and dry masonry surfaces or concrete surfaces should be used for backup. For dry locations, the backing material (substrate) may be wood, wallboard, masonry, etc.

The thick bed set procedure is used on interior and exterior surfaces. The backing material may be masonry, concrete, steel or wood stud framing. Wire lath may be attached with mechanical fasteners and used with the thick bed or it may eliminated if the masonry wall is heavily scarified (Williams, Griffith, Jr., "New Bricklike Tile Veneer", *Building Standards*, July-August, 1982). For applications over steel studs, procedures are similar to those used for concrete or masonry backup; however, wallboard and building felt must be installed over the studs before the lath and mortar bed are placed

The model building codes (Building Officials and Code Administrators, International, 4051 West Flossmoor Road, Country Club Hills, Illinois; Southern Building Code Congress International, Inc., 900 Montclair Road, Birmingham, Alabama; International Conference of Building Officials, 5360 South Workman Mill Road, Whittier, California) do not specifically address the usage of thin brick veneer in all of the methods of installation mentioned in the Brick Industry Association's Technical notes. Thick set and thin set adhered veneer have been used for many years with thin brick units, ceramic tile and architectural terra cotta; therefore, these methods are addressed in the model codes.

Panel Brick Manufacturing, Inc. prepared a guide specification in electronic media, as an aid to specifiers in preparing written construction documents for Thin Brick Brickettes © and Panel Brick Veneer. http://www.thinbrickbyowensboro.com/GuideSpecs.html

Their recommendation for panel systems of thin brick was to apply an exterior, waterproof, synthetic rubber-base adhesive, that complies with APA specification AFG-01, to bond Brickettes to a backer board. The rigid backer board was to be of a high density, nail base, asphalt impregnated fiberboard manufactured by Temple-Inland Corporation, which meets Federal specification LLL-1-535B, Class E, Style 2 and conforms to Industry Standards ANSI/AHA A194, 1-1985 Type IV, Class 2 and AST

Advantages and disadvantages of thin brick veneer

The advantages of the thin brick , as identified by Panel Brick Manufacturing, Inc. included the following: the product is specially formulated to cure at room temperature; while traditional (or thick) brick requires a high temperature to cure, the product is much lighter than traditional brick, therefore, the need for footings or other structural reinforcements is eliminated, the product cost far less than traditional brick; the thin brick product has a natural appearance and texture that resembles older brick, color is an integral part of each brick. Other advantages of thin brick listed by the Brick Industry Association include: interior thin brick veneer finishes can be applied by homeowners or other moderately skilled craftsmen, thin brick veneer is more durable and longer lasting than aluminum, wood, or vinyl sidings, prefabrication with thin brick veneer is easily and economically done, better sound and fire resistance properties may be obtained using thin brick veneer than with some non-masonry sidings, and cleanup costs often incurred in conventional brick veneer construction may be reduced.

Some of the disadvantages of thin brick veneer listed by the Brick Industry Association are: the durability and overall quality of thin brick veneer systems may not be equivalent to conventional brick veneer, brick veneer does not provide the structural properties of conventional brick veneer, sound and fire resistance properties are less than those of conventional brick masonry veneer, thin brick veneer does not provide the thermal mass of conventional brick veneer.

The summation of the advantages and disadvantages of thin brick by the Brick Industry Association was that thin brick veneer is popular with homeowners for redecorating or renovating because the homeowners can obtain an attractive finish and may do the work themselves. Thin units are also used in commercial construction, applied one unit at a time, or applied in large prefabricated panels. Small, lightweight, interlocking modular panels are available and are installed as a siding. Thin brick veneer can provide the same architectural effects as conventional brick masonry, but does not have the same structural, thermal or fire resistance qualities.

The literature revealed that several manufacturers produce and are experimenting with various formulations for thin brick. The market appeared to indicate that thin bricks are used in both the commercial and residential applications. In addition, thin brick can be used as exterior and interior wall treatment.

Method

The purpose of this study was to compare the relative effectiveness of selected techniques for fastening the individual and paneled thin bricks to various substrates. The brick had previously been manufactured by Bayland, LLC. by pressing the slurry of Portland cement and paper residual into wooden molds. The thin brick panels were produced with a ¼” fiberglass mesh throughout its center.

The facilities used to conduct the test were located at the University of Wisconsin-Stout, Menomonie, WI. The study spanned a period of 6 weeks from January to March 2006. Construction of test walls with substrate and application of the bricks to the walls was performed in room 132 of the Applied Arts Building. A Bond Wrench Test Apparatus, manufactured by ELE International, Inc., was employed for determining comparative values of flexural bond strength per ASTM C-1072 test methods (see Figure 3). This phase of the investigation was performed in room 157 Jarvis Hall.

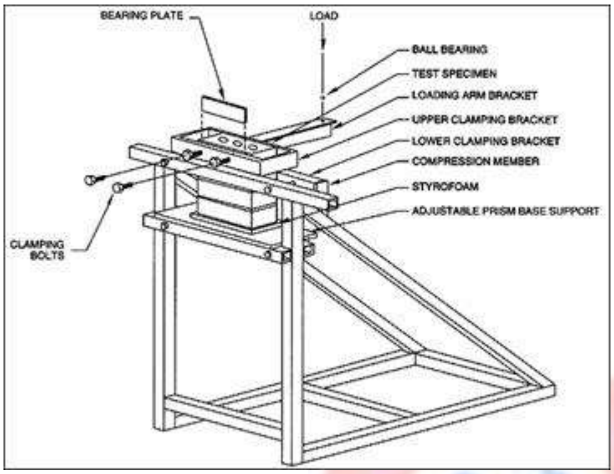

Figure 3 ELE, International Bond Wrench Test Apparatus

The bricks were removed from the shipping containers and allowed to assimilate to the atmospheric conditions of the testing facility. The offset-type, individual bricks supplied measured ½” x 2 ¼” x 7 ½” as shown in Figure 1. The brick panels measured ½” x 15” x 31 ¼” as shown in figure 2. Color was added to the bricks using assorted of aniline dyes.

Wall systems were constructed of premium grade, southern yellow pine 2x4’s spaced 16” on center. Substrate material, which included ½” cdx plywood and ½” gypsum, was attached to the wall systems. Plywood was attached using a Paslode Impulse Framing Nailer with 2” ring-shanked nails. The gypsum was attached with 1 ½” zinc-coated screws. The substrate was primed with a latex (water-based) primer. A wall made of cinderblock was also erected for adhesion test purposes.

An experienced tile setter was responsible for completing each of the fastening methods described below. After the individual bricks and brick panels were attached to the various substrates, approximately one half of the wall system was finished with sanded Portland-based grout, or unsanded grout, or stone mortar mix.

The fastening methods described below were performed for the study:

Results

The purpose of this study was to compare the relative effectiveness of selected techniques for fastening the individual and paneled thin bricks to various substrates. A distinction of the thin brick was that it was light weight and easy-to-handle. The material retained a fair amount of moisture when removed from the shipping containers, as evidenced by the smell and color of the product. The thin brick panels appeared to be especially moisture retentive. As the Portland cement cured and the moisture was released, the ends of the panels tended to curl up. The panels were rotated daily and weight was added to force the panels to lay flat. Some of the application tests were affected by using panels that were not flat.

The aesthetics offered by the aniline dyes appeared to be acceptable and did not affect the flexural bond strength of the adhesion method (figures 4 and 5). The bricks were not sealed, which allowed the color residue to release onto the hands of the tile setter when handling the bricks.

Figure 4

Figure 5

The individual bricks were machined prior to shipping in order to attain an accurate, straight offset edge. Some of the bricks, however, retained a curved offset edge. These were removed using a small-blade knife, which added to installation time and compounded straightness irregularities of the grout lines.The shortest application time per square foot was Method 11, in which three panels were applied to primed cdx plywood using mechanical fasteners. The panels were set into place then secured using a Paslode Implulse ™ Angled Finish Nail Gun with 1¼" 16 gauge angled finish nails. The nails were placed in the horizontal grout lines of the panels approximately every 5". The application of panels with the Paslode Impulse Angled Finish Nailer took 10 minutes. Using this method, fifty three square feet per hour can be applied.

Method 8 was a test of applying three square feet of individual brick applied to unprimed cinderblock using polyurethane construction adhesive. Vertical strips of adhesive were applied to the cinderblock approximately 2" apart. The individual brick were pressed into place beginning with a full brick on the bottom row. A brick was cut at 3 5/8" long to begin the second and fourth rows. The application of adhesive in vertical strips 2" apart and pressing individual bricks into place took 12 minutes. It was the most efficient method tested for applying individual bricks at 12.7 square feet per hour.

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5. http://www.thinbrickbyowensboro.com/GuideSpecs.html