



TECHNICAL NOTES on Brick Construction

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Technical Notes 40 - Prefabricated Brick Masonry - Introduction Revised August 2001

INTRODUCTION

The desire of the construction industry to minimize on-site labor and reduce construction time has resulted in the prefabrication of building components. Methods for the prefabrication of masonry have been developed by several segments of the brick industry: mason contractors, brick manufacturers, equipment manufacturers and others closely associated with the industry.

This *Technical Notes* covers the history, advantages, disadvantages, considerations for prefabrication, fabrication methods, materials, specifications and present applications of prefabricated brick masonry.

There are several recent developments which make prefabrication of brick masonry possible. The most important is the development and acceptance of a rational design method for brick masonry. Other factors, such as research with new and improved brick units and mortars, have aided the rapid progress in the prefabrication process.

This *Technical Notes* deals only with prefabricated brick masonry using full size brick units. Prefabricated elements of thin brick facing units, in conjunction with concrete, fiberboard or other backings, are discussed in *Technical Notes 28C*.

HISTORY AND DEVELOPMENT

Individual uses of prefabricated brick masonry have occurred for more than 100 years. Brick piers were laid on boards for use below sea level in Galveston, Texas prior to 1900. The prefabrication of brick masonry involving equipment rather than bricklayers had its early development during the 1950's in France, Switzerland and Denmark. At the same time, the Structural Clay Products Research Foundation, which was once a part of the Brick Industry Association's Engineering & Research Division, developed a prefabricated brick masonry system. This system, known as the ³SCR building panel² was used in the construction of several structures in the Chicago area.

Most of the early methods of panelization were attempts to mechanize the bricklaying process to produce standard panels, using unskilled labor. Later trends, especially in the United States, have been toward the retention of skilled labor using conventional masonry construction practices and devising various means to increase mason productivity. (See FIG. 1)

There are several different methods or systems of prefabrication being used in the U.S. today. Some systems employ proprietary mechanized equipment, while others are not patented but are merely methods of prefabrication developed by individual manufacturers or mason contractors.

ADVANTAGES OF PREFABRICATION

There are several advantages of prefabrication over conventional masonry construction. By using panelized construction, the need for on-site scaffolding is virtually eliminated. If an off-site plant is used, the work and storage area for masonry materials at the job site are kept to a minimum. When proper scheduling of delivery is maintained, the panels can be erected as they are delivered, eliminating any need for panel storage at the site.

The use of panelization also makes possible the fabrication of complex shapes. These shapes can be accomplished without the need for expensive falsework and shoring necessary for laid in-place masonry. Complicated shapes with returns, soffits, arches, etc., are accomplished by using jigs and forms. Repetitive usage

of these shapes can lower costs appreciably; the more re-uses, the lower the per panel cost. The designer is able to obtain more complex shapes and different bonding patterns when including brick masonry panels. (See FIG. 2) Fabricating a panel in running bond and rotating it results in soldier courses in running bond which are expensive and difficult to execute if conventionally laid. Sloped sills and soffits, along with other shapes and patterns, are easily achieved in this manner.

One of the distinct advantages of prefabrication is the possibility of year round work and multi-shift workdays. Off-site construction permits the labor force to work under conditions not affected by weather. The use of prefabricated masonry may eliminate the need for cold weather construction practices. Prefabrication requires stringent quality control. Building panels on a standard form in a single location makes this easier to attain. Mortar batching systems can be tightly controlled by automation or sophisticated equipment. In a factory, the curing conditions are more consistent, since they are less affected by weather changes.

Panelization on some projects may save construction time. In most cases it is possible to fabricate masonry panels prior to ground breaking, thus keeping far enough ahead of the in-place construction work to permit panel placement when needed. In the case of bearing wall structures, construction time could be shortened since panels have completely cured when erected. This allows the construction crew to immediately start erection of the next floor level and thus expedite construction.

In some cases, the structure of the building, or the perimeter beams, may be downsized due to the ability of the prefabricated masonry panel to span column to column. This distributes the wall load directly to the columns thus lowering the floor load at the slab edge.

The savings in construction and time can also provide economy to the building owner. Earlier completion allows earlier occupancy. In the case of rental or commercial properties, this allows the owner to have income production start sooner.

DISADVANTAGES OF PREFABRICATION

As with any construction method, prefabrication has inherent disadvantages as well as advantages. Prefabrication of masonry to date has not achieved the economy of construction originally desired on flat wall areas. Typically, prefabricated masonry costs are the same or higher than most conventionally laid-in-place masonry on a square foot (square meter) cost basis.

The size of brick masonry panels is limited primarily by transportation and erection limitations. Architectural design may, in some cases, need modification to use prefabricated brick masonry.

Another disadvantage of prefabricated brick masonry, as in other panel systems, is the limited adjustment capabilities during the construction process. In-place masonry construction allows the brick mason to build masonry to fit the other elements of the structure by adjusting mortar joint thickness over a large area so that it is not noticeable. With prefabricated elements, the adjustments must take place in the connections and the joints between panels. The use of prefabricated elements sometimes requires other crafts or trades to adopt more stringent construction tolerances for their work beyond the standard construction practices for their respected trades.

CONSIDERATIONS OF PREFABRICATION

The designer must evaluate each project to determine the feasibility and adaptability of prefabrication to that project. Basic questions that must be considered prior to a decision should include, but not necessarily be limited to, the following for each individual project:

1. Is the building layout, plan and elevation suitable to prefabrication?
2. Is there a location on-site suitable for panel fabrication and storage?
3. Is it desirable to use off-site prefabrication due to the limited size of the building site?
4. What is the completion schedule and what time of year is construction to take place?
5. Are structural design solutions unrealistic when prefabrication is used?
6. Can a reasonable level of quality control in all trades be achieved if prefabricated brick masonry is utilized?
7. Is prefabrication, based on answers to questions 1 through 6, an economical answer?

Contacting a fabricator during the design development or construction document phase of a project may be advisable to determine whether particular elements can be constructed using prefabricated masonry. A fabricator can also advise how different panels can be supported from the building structure.

FABRICATION METHODS

There are two basic manufacturing methods being used in brick masonry prefabrication: hand-laying and casting. The equipment used in prefabrication as practiced today varies widely. It ranges from simple conventional masonry hand tools to highly sophisticated automated machinery.

Hand-laying

The hand-laying method of prefabrication is similar to conventional laid in-place masonry. That is, the brick are placed in mortar by a mason, except it is accomplished in an area removed from the final location of the masonry element. The bricklaying may be done using conventional bricklaying tools, automated equipment or both. Automated equipment typically has several components:

1. Devices (such as forms or jigs) for establishing the shape of the panel and locating courses.
2. Scaffolding to keep the bricklayer at a comfortable position (See FIG. 3).
3. Material delivery to the bricklayer.
4. Mortar application.

The hand-laying method will usually employ the conventional mason's tools: trowel, jointing tool, etc. In addition, the hand-laying method may also utilize corner poles, jigs, and templates for special shapes. The hand-laying method will usually employ some type of adjustable scaffolding. Adjustable scaffolding can greatly increase mason productivity and reduce fabrication costs. Mechanized and pneumatic mortar spreaders may also be used in the hand-laying method to distribute mortar to the bed joints.

This method is particularly adapted to a mason contractor serving as the prefabricator since the contractor's regular labor force can be employed. The fabrication operation can be performed either at an off-site plant or an on-site temporary production facility. Casting

The casting method of fabrication involves the combining of masonry units, mortar and grout into a prefabricated element using unskilled labor. The casting method is performed with the element either in a horizontal or a non-vertical position. In general, the casting method lends itself to automated equipment that requires a form or an alignment device, some method of placing units and reinforcement, and a method for introducing mortar or grout.

The usual practice is to place the units, either by hand or machine, and fill the form with a grout at atmospheric pressure or under moderate pressure. This method of prefabrication usually takes place in an off-site plant.

There are specialized tools used in the casting method. Jigs and forms provide for the alignment of the brick and the spacing for the joints. The casting method may require that the face of the unit be protected from contamination by the mortar or grout. This is usually done by applying a contact surface to the exterior face of the brickwork. Pressure at the contact surface of the brick face is created by either an inflated form face or by applying a load to the brick and forcing it into a soft material. Some prefabrication has employed the casting method and automated unit placing machinery. This equipment places the unit with proper joint width by machine in lieu of hand placement of units in jigs or forms. Pressurized grouting systems have also been widely used in the casting method of prefabrication.

MATERIALS

Masonry Units

Both solid brick and hollow brick have been used in prefabrication. Solid brick masonry units are those which have coring of less than 25 per cent of the bedding area. Hollow brick units are cored in excess of 25 per cent but no more than 60 per cent of the bedding area. The hollow units are suitable for and used in applications where reinforcement is required. Reinforcement is often required not only for in-place structural reasons but for loads and stresses included during panel handling.

Unit face size is based on economy and appearance, just as in conventional masonry. Dimensional tolerances of the size and face of brick may be more stringent if the casting method is used to form the prefabricated masonry.

Specially-shaped units are often employed in fabricated masonry panels. Special units made for returns other than at right angles allow continuity in bond. Channel-shaped units accommodate the placement of reinforcement. Single and multiple wythe panels of the units outlined above have been used in prefabricated work, but single wythe panels are most commonly used.

Mortar and Grout

Prefabrication may use either conventional mortar or mortar with additives to increase bond strength. If the panel is not reinforced, care must be taken to determine compatibility of the brick and mortar. Testing should be performed with the mortar and brick selected for construction to determine if the combination will indeed produce the required flexural strengths for the project.

Most masonry panels utilize steel reinforcement to resist tensile and shear stresses due to handling and in-service loads. Fine grout is used to surround the reinforcement and create a homogeneous element. (See Technical Notes 17A for material requirements of reinforced brick masonry.)

SPECIFICATION FOR PREFABRICATED PANELS

The American Society for Testing and Materials (ASTM) has developed a standard specification for prefabricated masonry panels that includes many items that should be considered when using prefabricated brickwork. The ASTM C 901 Specification for Prefabricated Masonry Panels contain the following sections: Materials and Manufacturing; Structural Design; Dimensions and Permissible Variations; Workmanship, Finish and Appearance; Quality Control; Identification and Marking; Shop Drawings; and Handling, Storage and Transportation. Each section is discussed below.

Materials and Manufacture

The appropriate ASTM material standards for brick and structural clay tile for use in prefabricated masonry are referenced in this section of ASTM C 901. Brick must meet the requirements of one of the following standards: ASTM C 62 for building brick, ASTM C 216 for facing brick, ASTM C 652 for hollow brick, or ASTM C 126 for ceramic glazed units. Standards for brick that are not included in ASTM C 901, but which can be used to construct prefabricated brick masonry panels are ASTM C 1088 for thin brick veneer and ASTM C 1405 for single fired, glazed brick.

Mortar and grout must meet the requirements specified in ASTM C 270 and ASTM C 476, respectively.

All metal embedded in masonry panels, except structural reinforcement, must be coated with a corrosion-resistant material or be made of stainless steel Type 304 or 316. This includes all ties, fittings, anchors and lifting inserts. The corresponding specifications for zinc coatings, copper-coated wire, stainless steel, and all types of reinforcement are referenced in this section of ASTM C 901.

Structural Design

Structural design of prefabricated masonry panels must be performed in accordance with the local building code and ASTM C 901. Where there is no local building code, a national model code should be used. Panels must be designed for all loads and restraining conditions from fabrication to installation and in-service performance. Wind, seismic, and other dynamic loads must be considered as mandated by the building code.

Differential movement between dissimilar materials within a panel and between panels and their supports must also be considered.

Lifting devices and their connections must have an ultimate capacity of four times the dead weight of the appropriate portion of the panel. Inclination of the lifting forces must also be considered.

Dimensions and Permissible Variations

Panel sizes are based on multiples of the nominal sizes of the individual masonry units. The nominal thickness of panels shall be the sum of the nominal thickness of the masonry plus the nominal thickness of any cavities. Actual panel thickness must be determined for adequate strength, fire resistance, and other design criteria as required for the type of structure and occupancy.

Specified dimensions of the panel can vary from the nominal size by the thickness of one mortar joint or 1/2 in. (13 mm) maximum. Custom dimensions are permitted and should be shown on the drawings or specified, however modular dimensioning is recommended. (See Technical Notes 10A for more information on this subject.) Dimensional tolerances for panel size, thickness, and out-of-square are stated in this section of ASTM C 901.

Workmanship, Finish and Appearance

A sample panel should be used to establish acceptable workmanship and appearance for facing panels. Individual units and joints should be properly aligned. The location of anchors, inserts, and lifting and connection devices should not vary more than 3/8 in. (10 mm) from the specified location. Warpage is limited to a maximum of 1/8 in. (3 mm) for each 6 ft (1.8 m) of panel height or width.

Quality Control Brick.

The brick unit compressive strength and the initial rate of absorption of brick must be determined. A sample of at least ten units for each 50,000 units used in panel fabrication must be tested in accordance with ASTM C 67.

Mortar and Grout.

The proportions of mortar and grout must be determined as given in ASTM C 270 or C 476, respectively. Bond enhancing admixtures must be mixed in accordance with the manufacturer's specifications. Once the proportions are determined, the compressive strength of a sample of 12 specimens should be determined at intervals of 1, 3, 7, and 28 days to determine the relationship between early-age strengths and the 28-day strength for both mortar and grout. During production, at least one batch of mortar and grout should be sampled each day to determine 1, 3, or 7 day strengths.

Completed Panels

Masonry assemblies must also be tested. One sample of three compression specimens must be tested for every 5000 ft² (465 m²) of panel production or every story height. Test one sample of three flexural specimens for each day's work. Specimens should be constructed and tested in accordance with ASTM Test Method C 1314 for compressive strength and ASTM Test Method E 518, horizontal beams with third-point loading, for flexure. Also, flexural bond strength may be evaluated by ASTM Test Method C 1072 or ASTM Test Method C 1357 in lieu of the method specified in ASTM C 901.

Identification and Marking.

Each prefabricated member must be marked to indicate its location on the structure, its top surface, and the date of fabrication. These marks shall correspond to those on the placing drawings.

Shop Drawings

Shop drawings consist of fabrication drawings and placing drawings. Fabrication drawings show details and locations of reinforcement, inserts, anchors, bearing seats, lifting inserts, coursing, size and shape of openings, and panel size and shape. Placing drawings show panel identification, location, reference dimensions, panel dimensions, dimension of joints between panels, and connection details.

Handling, Storage and Transportation

Care must be taken not to overstress, warp or otherwise damage the panels during manufacturing, curing, storage, and transportation. Damaged panels must be replaced, unless authorized by the architect or engineer.

INSTALLATION OF PANELS

Most panels are trucked to the job site and lifted into place by cranes. (See FIG. 4) Lifting devices are built into the panels for this purpose. These panels are usually attached to the structure by welding or bolting. (See FIG. 5) Connections between the panels and other structural elements of the building provide transfer of both vertical and horizontal loads. Typically per panel, there are only two connections located near the bottom that transfer the weight. These connections also transfer horizontal loads. The remaining connections transfer only horizontal loads.

PREFABRICATION EXAMPLES

The use of prefabricated brick masonry in construction has become quite widespread. Prefabricated brick panels have some very dramatic and aesthetically pleasing applications throughout the United States. Most of the projects built in the United States use single wythe, reinforced brick panels as non-loadbearing curtain wall panels. However, panelized brick construction is not limited to curtain wall applications and some loadbearing panels have been constructed.

Figures 6 through 10 show several recent construction projects using prefabricated brick masonry panels. The panels for these projects have been built utilizing the full spectrum of methods previously outlined.

CONCLUSION

Prefabricated brick masonry panels are an excellent solution to a multitude of problems commonly found on jobsites such as material storage concerns, tight construction schedules, and quality assurance issues. Also, there are a wide variety of possibilities that can be achieved with prefabricated panels that would either be cost prohibitive or impossible to construct with brick otherwise.

Architects, engineers, and specifiers are urged to work with the manufacturer of the panels to ensure that the desired effects and final goals can be realistically met as addressed previously in Considerations for Prefabrication; they can also reference ASTM C 901 for industry standards and material requirements.

Prefabrication of brick masonry is a rapidly developing field and future innovations and needs could greatly affect its value as a design solution.

The information and suggestions contained in this Technical Notes are based on the available data and the experience of the engineering staff of the Brick Industry Association. The information contained herein must be used in conjunction with good technical judgment and a basic understanding of the properties of brick masonry. Final decisions on the use of the information contained in this Technical Notes are not within the purview of the Brick Industry Association and must rest with the project architect, engineer and owner.

REFERENCES

1. Standard C901-00a Specification For Prefabricated Masonry Panels, American Society for Testing and Materials, Vol. 04.05, 2001.
2. ³Reinforced Brick Masonry - Materials and Construction², Technical Notes on Brick Construction 17A, Reston, VA, August 1997.
3. ³Thin Brick Veneer², Technical Notes on Brick Construction 28C, Brick Industry Association, Reston, VA, February 1990.



FIG.1

The *Wendel Wyatt Building*, Portland, Oregon ZGF Architects, Portland, Oregon (Courtesy of L.C. Pardue, Inc.)

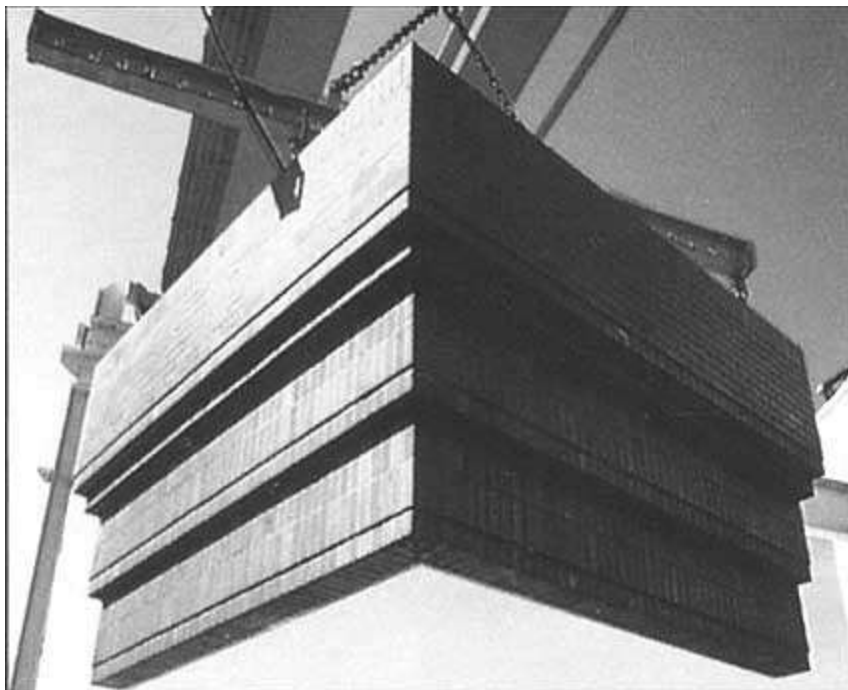


FIG. 2

Complex Shapes With Different Bonding Patterns (Courtesy of Vet-O-Vitz)



FIG. 3

Panel Prefabrication Plant, Automated Scaffolding (Courtesy of Vet-O-Vitz)



FIG. 4

Placing Panel (Courtesy of Vet-O-Vitz)

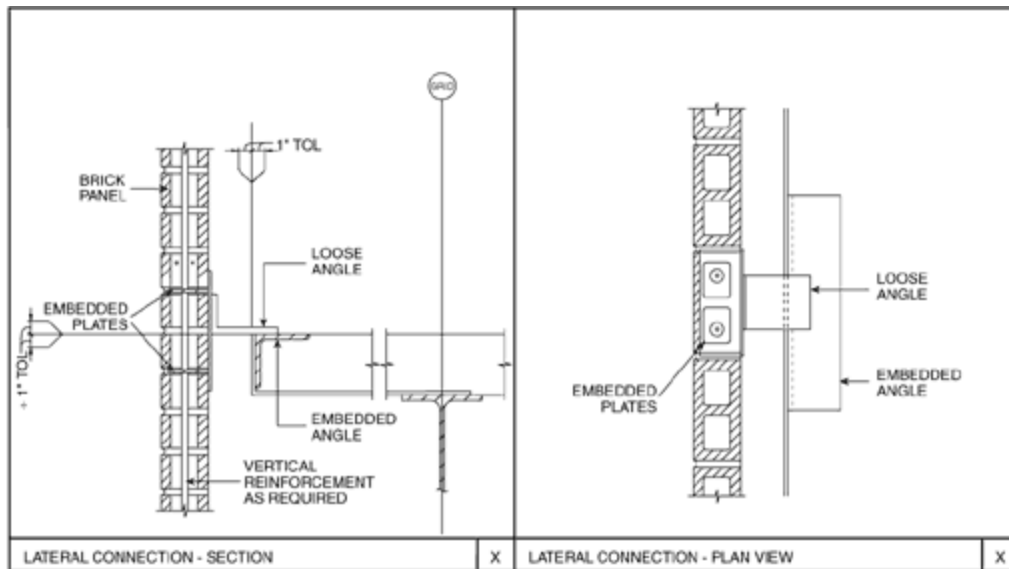


FIG. 5

Connection Detail



FIG. 6

**Turn Pike Metroplex, East Brunswick, New Jersey Gatarz Venezia Architects, East Brunswick, New Jersey
(Courtesy of Vet-O-Vitz)**



FIG. 7

The Center for Molecular Studies University of Cincinnati, Cincinnati, OH Frank O. Gehry & Associates, Santa Monica, CA (Courtesy of Vet-O-Vitz)



FIG. 8

Sand Lake Plaza, Dayton, OH Hixson Architects and Engineering, Cincinnati, OH (Courtesy of Vet-O-Vitz)



FIG. 9

The Port of Portland Headquarters Portland, Oregon ZGF Architects, Portland, Oregon (Courtesy of L.C. Pardue, Inc.)



FIG. 10

Safeco Field, Seattle, Washington NBBJ Architects, Seattle, Washington (Courtesy of L.C. Pardue, Inc.)