HISTORY AND DEVELOPMENT OF HOLLOW BRICK FOR REINFORCEMENT

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In many areas there are requirements, or desires, for reinforcing. The hollow shape of concrete block was developed and became more competitive than conventional brick construction in these areas.

A new clay shape was developed to provide most effective reinforcing installation and most efficient use of material. A new Standard was developed for manufacture, also methods of design, mortar and grouting for high quality structural and aesthetic economical use.

They are through-the-wall units of 12, 10, 8, 6, and 4" thickness. An extensive program of testing was carried out on the 4" units (3 1/2" thick) relating the physical properties of mortar in compression and in splitting; strength in compression and splitting; brick in compression and splitting; brick prisms or assemblages in compression and shear; wall elements in vertical bending; wall elements in horizontal bending; bars in bond beam elements vs joint reinforcing; wall elements at large height to thickness ratios with concentric and eccentric loads; bolt values in thin walls for vertical load and for horizontal shear, with wood and with steel ledgers.

Standard residential details have been approved by codes so that engineering is not required for wind and earthquake resistance for one and two story homes.

HISTOIRE ET DEVELOPPEMENT DE BRIQUES CREUSES POUR MACONNERIE ARMEE

Il se peut qu'on veuille ou qu'on souhaite renforcer certaines endroits d'une maçonnerie. Les blocs creux de béton étaient plus compétitifs et étaient employés au détriment des matériaux conventionnels en terre cuite.

Un nouveau modèle de bloc en terre cuite a été développé. Ce bloc a permis de construire des bâtiments plus solides et a été d'un usage plus pratique. Un nouveau type-Standard naquit, ainsi que des nouvelles méthodes de calcul, pour aboutir à une maçonnerie plus esthétique, plus économique et de meilleure qualité.

Leurs différentes épaisseurs sont de 4, 6, 8, 10 et 12 pouces. On a effectué des essais détaillés sur le format de 4 (3 1/2) pouces. On en a déduit :

1) Les propriétés physiques en compression et à la rupture du mortier riche, du mortier faible et de la brique.

2) Le comportement de la maçonnerie soumise à la compression et au cisaillement.

3) La flexion verticale et horizontale des murs.

4) Les différences entre des barres en bottes et des armatures dans les joints.

5) La résistance de poutres des murs très hautes par rapport à leurs épaisseur sous charges concentriques et essentriques.

6) Les valeurs limites pour parois minces sous charges verticales et sous tranchants.

Des détails standardisés ont été définis par les normes de sorte qu'un seul calcul de résistance au vent et aux secousses sismiques n'est requête pour les constructions à un ou deux étages.

GESCHIEDENIS EN ONTWIKKELING VAN HOLLE, BEMAPENBARE BAKSTEEN

In vele streken is het nodig of gewenst, metselwerk te bewapenen. De holle betonblokken zijn daarvoor zeer geschikt, en zijn in deze streken meer competitief geworden dan conventioneel metselwerk.

Een nieuw baksteenprofiel werd ontworpen om de beste wapening mogelijk te maken en het meest efficiënte gebruik van het materiaal. Een nieuwe methode voor de fabrikatie was nodig, alsmede ontwerpmethoden en goede metsel en betonvulling om tot een aanvaardbaar esthetisch en economisch ontwerp te komen.

Er zijn eenheden van 12, 10, 8, 6 en 4" dik. Een extensief proefprogramma werd uitgevoerd op de 4" eenheden (3 1/2" dik) in verband met de fysische eigenschappen van de mortel inzake druk en splijting, betonvulling onder druk en splijting, baksteen onder druk en splijting, mortelprisma's onder druk en bij afbakening, muurelementen onder horizontale en vertikale buiging, wapeningstijgers in metselwerk balken in vergelijking met de gewone gewapende voegen, muurelementen van grote hoogte onder centrische en ecntrische belasting, puntlasten op dunne muren veroorzaakt met houten en met stalen opleggingen, en de daaruit resulterende druk- en schuifspanningen.

De standaarddetails die in de woningbouw voorkomen zijn in normen goedgekeurd, zodat geen berekeningen meer vereist worden voor weerstand tegen wind en aardbevingen bij huizen van één en twee verdiepingen.
The author's early experience started in 1925 on construction jobs as bricklayer, hod carrier, bricklayer in schools, and in brick and tile walls, partitions, etc. Theoretical training was at the California Institute of Technology with graduate work, particularly in masonry structures. Since then experience was as structural engineer in private practice and for the Power Division of Bechtel Corporation. It was in the latter capacity that he designed one of the largest brick buildings in the western area, some 800 feet long, 90 feet high and 400 feet wide. Since 1951 he has been Consulting Structural Engineer for Masonry Institute of America.

The latest development in effective Reinforced Brick Masonry has been the Hollow Unit. The History of development in可以说 exists in a timeline, perhaps outlining the description of the hollow reinforceable brick and its use.

The modern development of reinforced masonry was required to resist earthquakes. Masonry is very strong in compression, durable, fire resistant, man's oldest permanent construction. However, the Wonders of the World were masonry were destroyed by earthquakes. Masonry of the past was weak in tension. Reinforcing makes it one of the best quake resistant materials.

California engineers have been living with the fear of earthquakes since the 1906 quake which destroyed San Francisco.

After the Long Beach, California earthquake of 1933 there was intensive development of Reinforced Masonry in the codes, kept intense by frequent small quakes, and large quakes such as: El Centro, 1940; Terrance, 1941; Desert Hot Springs, 1949; Kern County, 1952; Eureka, 1954; Chiles, 1960; Alaska, 1964; Borrego Mountain, 1968; Sanda Rosa, 1959; San Fernando Valley, Los Angeles, 1971.

REINFORCED BRICK MASONRY is now being used as the generic term for all reinforced brick masonry, whether of the more popular grouted type, or the type with reinforcing in bed joints, or in filled cells or holes in the brick units, as will be discussed later.

From an architect's standpoint, Reinforced Brick Masonry seems to offer the designer greater flexibility in treatment and use of finished materials than any other comparable material or method. There is freedom of choice in selection of masonry materials, of patterns, of types, of sizes, etc. In addition the finish surface or material is not applied merely as a covering, it serves as part of the structure as well. It can be said that the finish becomes an active load-carrying participant rather than a passive load, or burden.

It is a mystery why this method is not used more, other than in the area in which it was initially developed, and where it is the only kind of masonry used.

HISTORY

Reinforced Brick Masonry was reported to have been used 140 years ago in England and later in France and in India. The author's first personal experience with reinforced brickwork was as a very small child in 1911 on the construction of the State Hospital at Agawam. The reinforcing consisted of flat steel straps in the bed joints with notches or holes for vertical bars. The installation was not well regarded by the masons, they felt that "they had built the Pyramids without steel and steel was not necessary." However, while reinforcement has been used for a long time, and sometimes rather haphazardly, to strengthen masonry, reinforced brick masonry in the modern sense is a relatively new construction requiring new design procedures and new construction methods. In the past years since 1933, especially, these have been developed from experimental investigations and observations of construction of hundreds of buildings under ordinary vertical loads, and under the influence of earthquakes. The trained and practical observation as well as the laboratory work has confirmed the soundness of the reinforcing principles.

LONG BEACH EARTHQUAKE

Reinforced Brick Masonry was developed and has experienced its greatest use and improvement in the Southern California area. It was there that the Long Beach quake of 1933 demolished the cheaply built, poorly designed, loosely tied, boom built, brick structures. Bricks were salvaged and cleaned from the debris by the simple expedient of sweeping off the loose, powdery mortar dust. It was said at the time that the purpose of the mortar was obviously to "keep the brick apart" rather than to bond them together.

For example, there was a stack of brick on a pallet adjacent to a collapsed brick structure. The pile was still undisturbed and standing relatively true, not having mortar to keep the brick apart, while the brick building was a pile of debris similar to the photo of the church in Bakersfield.

Some of the brick structures that were demolished by the Long Beach quake were identical to many of the brick structures now built in all parts of the world (since the last big earthquake occurred in those areas). The first quake, for many, will probably be the last. We do not predict another quake, but the records show quakes have occurred all over the world in the past.

Many of the buildings referred to in the Long Beach quake had not been designed to resist any lateral force so the factor of safety against lateral force was 0-- hence they collapsed.

The buildings that suffered worst as a group were the school buildings. These had certain undesirable characteristics in common. There was excessive, massive, ornate "gingerbread" embellishment around the top. There were high window openings, imposing top-heavy entrances, a minimum of structural material to
back up the fancy facing, a minimum of roof structure and detail connection - one effect of undue emphasis of a competitive bidding system - Inadequate inspection of the quality with the resultant minimum cement content, and low regard for workmanship.

The sight and memory of brick buildings, collapsed as piles of debris, was a factor that then eliminated brick production, especially perhaps since so much "used" brick was available in such good condition, unbroken and hardly stained.

It was obvious than that a different type of construction must be developed.

That earthquake of Long Beach in 1933 occurred at the time of day when school children were not in the buildings. The failures were so complete and total that building officials, engineers and architects realized that the loss of children could have been worse than the loss that is told of in the Pied Piper legend. They realized they must pay the piper and enact laws especially for schools - to protect our children in the future and prevent loss of a generation.

The codes of Los Angeles City and County and the Uniform Building Code of the West contained requirements for quake resistance from 1934 on.

These were simple ones initially that developed from $F = CW$ to $V = ZCKSW$.

These require more information as they develop and better use of reinforcing. The Hollow Reinforceable Brick is one of the best results of these studies.

DEVELOPMENT OF REINFORCED BRICK MASONRY

Recognizing the advantages of brick construction and the serious need for developing structures to resist quakes safely, California groups initiated active programs of engineering study. Mr Harry Bolin of the State Division of Architecture was one of the aggressive and far-seeing engineers who did much to develop the scheme of grouted reinforced masonry and to conduct tests which verified the soundness of the various factors. He established facts where there had been but speculation before.

One series of tests was especially interesting and valuable. It established that grout could, and should be poured very wet, even "sloppy", apparently violating the engineering concept of "water cement ratio". The grout might be poured, with a W/C ratio which would result in weak concrete, but, due to the absorption of the brick and the subsequent curing effect the grout core when actually tested could develop 5000-6000 psi in 20 days. Also, when poured thusly, the bond was extremely high.

The first noteworthy example of that program was the Vermont Avenue School which was then the University of California at Los Angeles, built in 1937. It was a two wythe brickwork with grout to bond it with reinforcing.

Many types of masonry were attempted and many special shapes were developed. The Grout Look Brick and the Port Costa Key Brick shown in the sketches are two. The mechanical key to the brick is a desirable feature eliminating one of the hazards of poor workmanship, namely poor bond. However, simultaneously research in mortar and grout had disclosed the fact that bond between brick and mortar could be so good as to be better than the strength of the material, under proper conditions. Therefore there was no need for special shapes, ordinary common brick of any shape and size would do. The only special consideration was good workmanship, i.e., clean damp brick, good workable cement mortar, sloppy wet cement grout. Other masonry units such as tile, stone, concrete block, etc., could serve interchangeably.

TYPES OF REINFORCED BRICK MASONRY

As mentioned above there are many effective types of Reinforced Brick Masonry. Some of these are listed below. The item in common is the use of reinforced elements and reinforcing bonded together by a cementitious material, generally cement mortar and grout.

Stone Masonry - Stones set in mortar

Cavity Wall Masonry - Space provided between wythes

Reinforced Solid Masonry - Solid masonry with the bars in the bed joint or between soaps, for example. (Includes Brick Box, etc.)

Reinforced Grouted Masonry - Wythes bonded together with grout collar joint between bonding them and bonding the reinforcing.

Composite Construction - Might be similar to reinforced grouted masonry, with hollow units in one wythe and solid in another.

Reinforced Hollow Unit Masonry - The units contain hollow spaces, and reinforcing may be in joints or in filled cells.

Improved use of mortar was developed in the search for adequate reinforcing methods. The mortar of the new Reinforced Brick Masonry is almost as unique a feature as is the reinforcing, and is a feature that insures the action of Reinforced Brick Masonry as a homogeneous element.

Two of the above, Composite and Hollow Unit, are described in more detail. The Brick Block, a form of reinforced solid masonry, is mentioned briefly.

There have been quite extensive tests on many of the aspects of the above types, too numerous to mention in this paper other than merely in passing, and they verify the practical effectiveness of the theories.

COMPOSITE GROUTED MASONRY CONSTRUCTION

This may be of many types, and one, the combination of structural glazed tile and common brick, is described here as an example. This type was used in a plant in which there were laboratory, office and storage rooms. Along one side wall there was an outer finish face, which was entirely of a Norman unit in stretcher bond. The inner wythe in the storage area was a jumbo brick, economical of labor. The laboratory was formed by intersecting walls of reinforced hollow glazed tile and by having the interior wythes of the exterior wall composed of glazed tile, bonded to the grout collar similar to the brick. Then in the office space adjacent in this same exterior wall, the interior wythe was a buff face brick in lieu of the Norman, jumbo or glazed tile. That particular wall
was an example, to a small degree, of the freedom and functional expression that might be achieved with Reinforced Brick Masonry.

The design of such composite shapes requires thorough visualization of stress paths, requiring that one delve into the higher orders of witchcraft.

The section of composite brick and tile construction illustrated are for further clarification of the type.

The test method which was used to check the increase of strength achieved by the grout as poured between the brick is shown in the sketch below.

![Sketch showing test method for checking grout strength](image)

**REINFORCED GROUTED BECK & TILE CONSTRUCTION**

**Typical Vertical Wall Section**

**Vertical Section at Pilaster**

**TYPICAL MASONRY TEST PRISM**

- Well oiled, non-absorbent plaster
- Typical for job
- Mortar
- Groat

Grout should be poured into place very wet to make thorough intimate bond with the masonry and reinforcing. The porous volume of masonry then sucks the water from the grout core leaving it with an excellent, effective water cement ratio. The tests showed that the grout samples taken in metal cylinders developed 1800 psi in 28 days. However the grout core, taken from the masonry enclosure or mould developed from 8000 to 8000 psi.

There are many advantages to Reinforced Masonry in addition to merely earthquake resistance.

**SAVINGS IN STEEL REINFORCING**

It is recognized that masonry shows less shrinkage cracking than concrete and therefore customarily less temperature reinforcing is required for masonry walls than for concrete walls. In addition unreinforced masonry panels can be included between reinforced portions for even greater savings. These savings in reinforcing steel might be very important, especially during times of acute steel shortages. In some instances the supporting structure can be incorporated in the masonry with no additional reinforcing.

The comparison of temperature steel required in masonry walls of various thicknesses as compared to that required for reinforced concrete walls is that concrete requires $0.025 \times \text{area each way}$, but masonry $0.002 \times \text{area}$ or $0.001 \times \text{area}$ if divided equally vertically and horizontally, i.e. concrete requires $2\times$ as much as masonry, primarily because of the lesser shrinkage in masonry.

**SAVINGS IN STRUCTURAL STEEL SUPPORT**

Advantage can be taken of the high compressive strength of masonry to carry vertical loads effectively by the wall. Then, if there is other consideration such as lateral force or moment imposed, special reinforcing can be added as required. In this way many building types can be constructed without requirement for supporting structural steel.

**ECONOMY OF REINFORCING AND LAYING**

Economy of placement is effected since the reinforcing can be placed easily and economically by the masons as desired.

Workmanship is important in all masonry work, but some of the uncertainty is removed by the pouring of the grout. It provides a weather barrier. It bonds the wythes securely together. It fills the portions of bed joint that may not have been filled full. It fills the back of the head joints providing a good bond in the event the mason had not used full shrouded joints. In fact some careful workmen leave the inside edges of the joint open so the grout will flow in and develop good mechanical bond in addition to adhesion. When RPM was initiated into the Utah area in a power plant program, it was necessary for the author to spend a few days indoctrinating the masons after their comment of "Oh, but we don’t lay masonry that way". Here are some examples of what the masons were told:

- "Don’t spread such a full bed - it squeezes out into the grout space".
- "Put more water in the grout so it is sloppy and pours easier".
- "Don’t put so much mortar on the head joints, it’s better if the back edge is not full then for mortar to extrude or drop into grout space".
- "Don’t narrow the bed - merely swipe it".
- "Don’t wet the grout too much, they won’t dry up the grout core".
- "Don’t put those headers across - do it as shown in the drawings".
- "Don’t put that angle over the opening, you don’t need it and it will rust".
- "Puddle the grout quick while it is still wet - don’t wait".
- "Don’t bother to tie the bars, you jiggle them too much, just lay them in".

One of the contractor’s foremen said: "But those are all things that will help us save money; we have a lump sum contract!" After that he was very cooperative and helpful and made constructive suggestions.
ECONOMY OF REINFORCING WALLS

It is recognized that steel reinforcing adds strength to walls, particularly with regard to buckling tendencies. This is recognized to a certain degree in the Uniform Building Code where the h/t ratio permitted for unreinforced bearing walls is 20, but for reinforced walls the h/t may safely be increased to 25. The additional strength is also recognized in 'non-bearing walls' in which the limitation for h/t is 20 for unreinforced walls but is 30 for reinforced walls.

An example of the practical result of this additional value would be for a story height of 20 feet. Obviously it would be necessary to use a wall thickness of 12 inches for unreinforced masonry but the grouted reinforced masonry could be 8 inches thin!

The unreinforced wall would require 50% more brick and labor and would add 50% more weight to be carried by the supporting structure. The foundation would have to support the additional wall weight, the additional structure weight and its own consequent additional weight.

Also, of course, by a little exercise of imagination it might be possible to eliminate much of the supporting structure, incorporating it within the reinforcing and strength of the RDM.

BOND BEAM

The "Bond Beam" is another element that can be built into the masonry effectively. The masons build to the bond beam area and continue right on through, placing the reinforcing as they go. This is as opposed to details which too frequently require that the masons stop when they come to the bond beam. Then carpenters come in to build forms, steel men to place reinforcing, concrete men to pour the beam, carpenters to strip and the masons to return and continue with the brickwork - all of which makes the hair of the superintendent, charged with the coordination and cost of construction, turn grey.

Bond beams of RDM were used effectively on the P.S. & E. Contra Costa Steam Plant, a building some 800' long 450' wide and 300' high. (Described in greater detail in ASCE Separate No. 342, No. 540 and an article in Engineering News - Record, July 5, 1951.) This plant was designed for a higher assumed seismic coefficient than generally considered adequate. In spite of the high design lateral force, and the 27-foot spans, the bond beams were of RDM, as were the high elements between the "slotted" windows. This enabled the masonry construction to proceed economically without interruption.

As mentioned before, this brick building is some 800' long and it is to be noted that there are no visible cracks in the front, rear or intermediate walls, although there are cracks in the concrete base portion at about 8 foot centers.

NEW IMPROVEMENTS

There were many years of use of the two wythe grouted construction and then the engineering development of new shapes.

Brick Blox

These were a solid brick cored the maximum of 25% permitted by ASTM. This cored space was provided in two large cells which were large enough to provide for nominal grout and reinforcing. There was not the ease of reinforcing and grouting that there was in the hollow concrete block however.

Denver

The hollow unit was developed further in Denver. It was a rather high strength unit, easily reinforced and was used as load bearing in a range of structures, e.g., some 1500 home tracts, one and two stories, to a group of 22 story bearing wall apartments.

Western States Clay Products Association

The group of brick manufacturers of the western USA who have been faced with the problems of reinforcing and competitive methods and material developed a Standard for the Hollow brick, details for use, and obtained proper code approvals. It has supplied a great part of the masonry construction market in that area.

The basic requirements are:

(a) A net area strength instead of gross
(b) A specific face shell thickness
(c) A minimum cross web specification
(d) A minimum size of reinforceable cell
(e) General quality requirements for fired clay brick

Probably the most important factor is the reinforceable cell. The initial requirement was 2" minimum dimension. This was considered as nominal or approximate. Also it should have not less than 5 square inches for one bar and not less than 7 square inches for a spliced bar or for two bars.

The net area strength, or actual strength, of material is used instead of the gross area strength. The measurement by gross area would permit a large variation in actual material strength for different amounts of coring. This unknown factor would be critical in engineered masonry where the governing stress is that of the outer fibers of a section.
Sketch at upper left shows typical wall sections constructed with special brick known as "Groutlock" brick. The bevelled edges of these units provide more space for both vertical and horizontal reinforcing, and give the impression of mechanical bond. Although such special shaped brick as shown here, on the Port Costa Key brick details, and L's and soaps - used on the Vermont School - have been developed in some areas for RBM, it can be designed and constructed with the conventional brick shapes and sizes found all over the country.

Sketch at lower left illustrates various RBM wall sections and thicknesses constructed with modular brick of conventional size. Variations are possible as brick sizes vary locally. In most cases the variation will be largely in the overall wall thickness when brick of different widths are used. Thickness of vertical or horizontal joints is determined by the size of reinforcing bars used. A minimum of 1 in. clearance should be maintained between the bars and the masonry units except that No. 2 (1/4 in.) bars may be used in 1 in. joints.

The specific face shell thickness is required in order to provide adequate face shell mortar bedding and for stability.

The web thickness is to provide stability in manufacture and laying, also transverse strength for development of "longitudinal shear", or 10/1 lb.

These requirements are spelled out in the attached Standard. Also some detail dimensions of typical units are shown.

These units have been made for through-the-wall units for 4", 5", 8", 10" and 12" thick walls. The 4" has been used in many residences, in one case for some tracts of 1500 homes each. In addition to bearing walls it has been used for curtain walls in industrial and commercial buildings. The 8" and 6" has been used for residences and for industrial and commercial curtains and for bearing walls in low and high rise load bearing structures.

Another very important function of walls is providing fire resistance or fire endurance of specific amounts. The ratings of various walls with grout and plaster are listed in the following table approved for use under the Uniform Building Code requirements for wall resistance ratings.

### FIRE RESISTIVE PERIODS - WALLS

<table>
<thead>
<tr>
<th>Wall of Hollow Brick</th>
<th>No. 8/8&quot; Plaster</th>
</tr>
</thead>
<tbody>
<tr>
<td>10&quot; not continuously grouted</td>
<td>3 hours 4 hours 4 hours</td>
</tr>
<tr>
<td>8&quot; solid grouted</td>
<td>4 hours 4 hours 4 hours</td>
</tr>
<tr>
<td>8&quot; grouted at reinforcing &amp; perlite filled</td>
<td>4 hours 4 hours 4 hours</td>
</tr>
<tr>
<td>8&quot; not continuously grouted</td>
<td>3 hours 4 hours 4 hours</td>
</tr>
<tr>
<td>6&quot; solid grouted</td>
<td>3 hours 4 hours 4 hours</td>
</tr>
<tr>
<td>6&quot; not continuously grouted</td>
<td>1 hour 2 hours 3 hours</td>
</tr>
<tr>
<td>4&quot; solid grouted</td>
<td>1 hour 2 hours 3 hours</td>
</tr>
</tbody>
</table>
The fire ratings were determined by calculation and by comparison of ratings of other clay units both solid and hollow. It is noted that an amount of material in a hollow unit shape provides more resistance than the same amount of material in a solid wall.

Also, it is to be noted that the addition of gypsum plaster is from 1.5 to 2.0 times as effective as the addition of masonry thickness. This is due to the fact that the gypsum material not only provides thickness of material but also it absorbs heat during calcining and loss of water of crystallization and latent heat of vaporization.

In order to verify some of the fire endurance values an unusual fire test program was carried out by the Western States Clay Products Association at the University of California. This was at the UC field station at Richmond by Professor Brady Williamson.

The standard fire exposure chamber and computer control and recording equipment was used but a "window panel" was built to provide spaces in which the heat flow through samples of various type wall construction could be checked simultaneously.

The "Window Wall" was constructed of brick to a standard fire panel size. However, 4 openings were provided in which different samples were built. In some cases two types were built in halves of the openings. In this way 8 different masonry assemblages could be tested at a time. Each sample was insulated from adjacent construction by thick asbestos barriers so that there would not be lateral heat flow, but only direct flow through. In addition, samples of relatively similar heat characteristics were used in each test so there would not be much tendency for other than direct heat flow through.

The extensive testing confirmed the values as approved in the Research Recommendation.

Another code factor has recently been included as important - energy conservation. This makes the use of hollow units desirable. The hollow spaces may be filled with insulation and provide great savings of energy.

In summary, the hollow reinforced unit masonry was developed because of a hardship. However, it demonstrates several advantages. It uses material efficiently, is faster and easier to lay, provides lighter structures, improves insulation, results in stronger more earthquake resistant structures. We may predict that it will be used at an increasing rate in the future.
WESTERN STATES CLAY PRODUCTS ASSOCIATION
Standard Specification for
Hollow Brick for
Reinforced Brick Masonry
(Hollow Masonry Units Made from Clay or Shale)

1.1 SCOPE. This standard specification covers hollow building and facing brick made from clay, shale or mixtures thereof and burned for use in brick masonry.

2.1 CLASSIFICATION. Brick are classified in the following types and grades according to compressive strengths and weatherability.

2.1.1 Grade 1 Brick - Brick suitable for general use in facing masonry exposed to the weather.

2.1.2 Grade II Brick - Brick intended for use as backup or interior facing masonry and not suitable for exposure to the weather.

3.1 PHYSICAL REQUIREMENTS. General. Paragraphs 3.7 to 3.10 shall apply only to brick to be used for facing purposes.

3.2 CORING. (a) No part of any hole shall be less than 3/4 inch from any edge of the brick, except for cored shell hollow brick and double shell hollow brick. Cores greater than 1 sq. in. in cored shells shall not be less than 1/2 in. from any edge. Cores not greater than 1 sq. in. in shells cored not more than 35 per cent shall be not less than 3/8 in. from any edge.

(b) Cells for reinforcement shall not be less than 2" in any dimension nor less than 5 sq. in. in area when containing 1 rebar nor 7 square inches for 2 bars or spliced bars.

(c) Face shells and webs shall not be less than as indicated in Table 1.

(d) Double shell hollow brick with inner and outer shells not less than 1/2 in., may have cells not greater than 5/8 in. in width nor 5 in. in length between the inner and outer shell.

(e) Webs - The thickness of webs between cells shall not be less than 1 1/2 in., 3/8 in. between cells and cores, nor 1 1/4 in. between cores.

(f) Unexposed Edges - The distance of voids from unexposed edges, which are recessed not less than 1/2 in. shall not be less than 1/2 in.

3.3 DURABILITY. The durability of a brick in relation to its resistance to deterioration caused by freezing and thawing shall be determined by the physical property requirements in Table 2 or by the requirements of weaver in paragraphs 3.4 and 3.5.

3.4 WAFFER. If the average compressive strength is greater than 7,000 lb. per net area or the average absorption is less than 8.0 per cent after 24-hour submersion in cold water, the requirements for saturation coefficient in Table 2 shall be waived. The saturation coefficient shall be waived for use in areas where weathering index is 100 or less.

3.5 FREEZING AND THAWING. The requirements specified in Table 2 for water absorption (5-hour boiling) and saturation coefficient may be waived, provided a sample of five brick meeting all other requirements, when subjected to the freezing and thawing test as specified in ASTM Standard C67 - 1954. Standard Methods of Sampling and Testing Brick, results in no breakage and not greater than 5 per cent loss in dry weight of any individual weight of any individual hollow brick.

3.6 CLASSIFICATION BY COMPRESSIVE STRENGTH. When hollow brick are required having strength greater than prescribed in Table 2, the purchaser shall specify the desired minimum compressive strength according to the designation given in Table 3.

3.7 TOLERANCES OF DIMENSIONS. The maximum permissible variation in dimensions of individual units shall be not exceed those given in Table 4. Where a high degree of mechanical perfection is desired that maximum permissible variation figure as given in Table 4 may be reduced from those shown for 'Normal', to those designated 'X'.

3.8 WARPAGE TOLERANCE. The maximum permissible variation in warpage of individual units for facing shall not exceed that given in Table 5.

3.9 TEXTURE AND COLOR. At least one end of the majority of the individual brick shall have the same general texture and general color tone as the approved sample. The texture of the finished surfaces that will be exposed when in place shall conform to an approved sample consisting of not less than four stretcher brick, each representing the texture desired. The color range shall be indicated by the approved sample.

4.1 DELIVERY. A delivery of brick shall contain not less than 95 per cent whole brick.

5.1 SAMPLING AND TESTING. When tests are required the procedure shall be in accordance with ASTM Designation C67. Standard Methods of Sampling and Testing Brick, except that whole units, or symmetrical portions, shall be tested for compression. Absorption shall be based on actual net area.

6.1 VARIATION. Variations to Tables 3, 4, 5 and 6 to produce characteristic architectural effects resulting from non-uniformity in size, color and texture should be as agreed upon by the seller and purchaser prior to delivery.

---

**TABLE 1 Minimum Thickness of Face Shells and Webs**

<table>
<thead>
<tr>
<th>Nominal Width of Unit</th>
<th>Face Shell Thickness, inches</th>
<th>End Wires, inches</th>
<th>Web Thickness per Foot, in./ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Solid</td>
<td>Cored or Double</td>
<td></td>
</tr>
<tr>
<td>3&quot; by 4&quot;</td>
<td>3/4</td>
<td>1</td>
<td>1/5(b)</td>
</tr>
<tr>
<td>6&quot;</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>8&quot;</td>
<td>1 1/4</td>
<td>1 1/2</td>
<td>2</td>
</tr>
<tr>
<td>10&quot;</td>
<td>1 3/8</td>
<td>1 5/8</td>
<td></td>
</tr>
<tr>
<td>12&quot;</td>
<td>1 1/2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

4.1.17
TABLE 2 Physical Requirements

<table>
<thead>
<tr>
<th>Designation</th>
<th>Minimum Compressive Strength (psi, Net Area)</th>
<th>Average Individual Minimum</th>
<th>Maximum Water Absorption by 5-Hour Boiling Per Cent</th>
<th>Maximum Saturation Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade I Brick (Exposed)</td>
<td>3,000</td>
<td>2,500</td>
<td>17.00</td>
<td>0.78</td>
</tr>
<tr>
<td>Grade II Brick (not Exposed)</td>
<td>2,500</td>
<td>2,000</td>
<td>no limit</td>
<td>no limit</td>
</tr>
</tbody>
</table>

The saturation coefficient or C/B Ratio, is the ratio of absorption by 24-hour submersion in cold water to that after 5-hour submersion in boiling water.

TABLE 3 Classification by Compressive Strength

<table>
<thead>
<tr>
<th>Designation</th>
<th>Compressive Strength psi of 5 Brick, Net Area</th>
<th>Individual Min. (psi, Net Area)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade I Only (Exposed)</td>
<td>2,500 to 3,000</td>
<td>2,000</td>
</tr>
<tr>
<td>Grade II (Exposed)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H 3,000</td>
<td>3,000 to 3,999</td>
<td>2,500</td>
</tr>
<tr>
<td>H 4,000</td>
<td>4,000 to 4,999</td>
<td>3,200</td>
</tr>
<tr>
<td>H 5,000</td>
<td>5,000 to 5,999</td>
<td>4,000</td>
</tr>
<tr>
<td>H 6,000</td>
<td>6,000 to 6,999</td>
<td>4,800</td>
</tr>
<tr>
<td>H 8,000</td>
<td>8,000 to 8,999</td>
<td>6,500</td>
</tr>
<tr>
<td>H 10,000</td>
<td>10,000 to 11,999</td>
<td>8,500</td>
</tr>
<tr>
<td>H 12,000</td>
<td>12,000 to 13,999</td>
<td>10,600</td>
</tr>
<tr>
<td>H 14,000</td>
<td>14,000 and above</td>
<td>12,300</td>
</tr>
</tbody>
</table>

TABLE 4 Tolerances of Dimensions

<table>
<thead>
<tr>
<th>Specified Dimension Inches</th>
<th>Maximum Permissible Variations From Specified Dimension, Plus or Minus, Inch</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal</td>
</tr>
<tr>
<td>Up to 3, inclusive</td>
<td>3/32</td>
</tr>
<tr>
<td>Over 3 to 4, inclusive</td>
<td>2/16</td>
</tr>
<tr>
<td>Over 4 to 6, inclusive</td>
<td>3/16</td>
</tr>
<tr>
<td>Over 6 to 8, inclusive</td>
<td>4/16</td>
</tr>
<tr>
<td>Over 8 to 12, inclusive</td>
<td>5/16</td>
</tr>
<tr>
<td>Over 12 to 16, inclusive</td>
<td>6/16</td>
</tr>
</tbody>
</table>

TABLE 5 Tolerances in Warpage

<table>
<thead>
<tr>
<th>Maximum Face Dimension (inches)</th>
<th>Maximum permissible Warpage (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal</td>
<td>Special &quot;X&quot; (See 3.71)</td>
</tr>
<tr>
<td>9 and under</td>
<td>3/32</td>
</tr>
<tr>
<td>9 to 12 inclusive</td>
<td>1/16</td>
</tr>
<tr>
<td>12 to 16 inclusive</td>
<td>5/32</td>
</tr>
</tbody>
</table>

TABLE 6 Maximum permissible extent of chippage from the edges and corners of finished face or faces into the surface

<table>
<thead>
<tr>
<th>Face</th>
<th>Chippage in Inches From</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smooth Face</td>
<td>1/4</td>
</tr>
<tr>
<td>Rough Face</td>
<td>5/16</td>
</tr>
<tr>
<td>Edge</td>
<td>Corner</td>
</tr>
<tr>
<td>Smooth Face</td>
<td>3/8</td>
</tr>
<tr>
<td>Rough Face</td>
<td>1/2</td>
</tr>
</tbody>
</table>

NOTES: Smooth texture is the unbroken natural die finish. Rough texture is the finished produced when the face is sanded, combed, scratched, or scored, or the die skin on the face is entirely broken by mechanical means as wire cutting or wire brushing.

The typical corner shown is for 12" long units, 8" thick. The corner lap for 6" thick units 12" long and 8" units 16" long would be simple half bond. Bond beam steel is to lap for continuity as in concrete.

WALL DETAILS

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