PREFABRICATED BRICK PANELS

ALBERT R. BISSADA

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ABSTRACT

The growing importance of industrialization of buildings is reflected in the development of numerous systems of construction based upon the application of prefabricated traditional materials. These industrialized processes have resulted in the production of better buildings built faster and more efficiently than by traditional methods.

This report will discuss leading European systems of industrialized buildings in which the prefabricated elements are essentially of masonry materials. Prefabricated brick panels forms the subject matter of this report. New methods and techniques developed in North America and Europe will be outlined also. The report will present relevant data on the physical properties of the unit, and fabrication of the panels; compressive strength, shearing strength, heat transfer and other properties which are all essential in the theory and practices necessary to design prefabricated brick panels.

ACKNOWLEDGEMENTS

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1. INTRODUCTION

The trend of reducing time and labour content for house construction to cut costs, has been given another fill up by the introduction of factory-made brick panels.

Many companies have developed some manufacturing processes and, spread their product on the market. This is the case with the Canada Brick Company. A test house built by Armstrong Homes at Ambro Heights subdivision, in Brampton , saw the 1200 lbs panels raised at the rate of one every 20 minutes with the use of light cranes. With additional experience, it is expected that the erection time can be reduced possibly by, as much as 50%, and, a complete house consisting of 40 panels completed in a single day.

The test house is one of several innovative designs of the subdivision having as its main purpose cost minimization. Armstrong is building about 200 lots in Ambro Heights, offering 12 distinctly different models at prices ranging, from $29,500 to $36,500[7] .

The Canada Brick Panel is the end product of research patented by the Canadian Structural Clay Association , in collaboration with the Federal Department of Industry. Canada Brick officials envisage a great future for the panels which are watertight monolithic masonry slab with a clean brick face and regular mortar joints. They eliminate the high wages paid to the bricklayers. They also use the load bearing capacity of brick wall to support the roof without conventional wood framing. The fact that the panels can be erected, regardless of the weather, results in better year-round operation and faster closeins.

In Sudbury, a 33-suite apartment project that employs timber frame, modular construction is expected to take half the time of conventional methods and reduce costs. The modules are manufactured in Portland, Ontario.

The brick panel industry has, in a few years, expanded from almost nothing to today's state of about 11,000,000 sq. yd. per year, with a wide range of designs. When compared with the production of bricks, or the total building activity, the brick panel industry is not impressive.

Some of the brick panel plants have been rather expensive ventures. Nevertheless, valuable experience has been gained particularly in the new techniques. The outlay has proved to be worthwhile and the industry can look forward to high grouth rate. However, a faster rate could be acheived by a more intimate international cooperation between manufacturers. The importance of such close cooperation cannot be over emphasized.

2. PROPERTIES OF DIFFERENT TYPES OF BRICK AND CLAYS

2.1 Definition

Structural products are defined in the American Standard for the coordination of dimensions of building materials and equipment as "Building material units which, when assembled in a structure, support their own weight". They may be load-bearing (designed to support loads in addition to their own weight) or non-load-bearing (designed to support no loads other than their own weight).(1)

2.2 Brick

Brick is the oldest of the structural clay products group, and in fact, the oldest manufactured building material, was probably one of the first products that man manufactured from clay. The origin of brick is attributed to the potter. However, after the organization of the brick mason's craft, which it is claimed occured during the construction of King Solomon's temple, the masons often manufactured the brick which they used and thus contributed to the art of brickmaking as well as the masonry construction.

For centuries, brick has been a term applied to a solid building unit of a dry or burned clay of various sizes, but never larger than one man could handle easily. Many of these bricks contain recessed panels or "frogs" in which the ancient clay workers frequently molded inscriptions relating to the structure in which the brick to be used.

With the invention of the extrusion of stiff-mud brickmaking machines, some manufactures produced brick containing holes or cores running parallel to either the length or height dimension of the unit. These cores were introduced as an aid to uniform drying and burning of the clay and as a mean of reducing the weight of the unit.(1)

2.3 Structural clay tile

These are machine-made products and were first produced in New Jersey in 1875. They are characterized by the fact that they are hollow units with parallel cells (hollow spaces). In 1921 the American Society for Testing and Materials proposed standard definitions of the term relating to hollow tile in which the unit was designated as hollow tile and defined as "hollow burned clay masonry unit with parallel cells". These definitions were adopted as standard in 1924 but were later withdrawn. In 1933, standard definitions of the terms relating to structural clay tiles were proposed in which the units were designated as "structural clay tile" and defined as "hollow burned clay masonry building unit with parallel cells".

2.4 Different types of clay

a) Surface clay: Found near the surface and are of sedimentary character.

b) Shales: Clays subjected to high pressure until they have hardened almost to a form of slate.

c) Fire clays: Occuring at greater depth and are usually mined.

As a rule, fire clays contain fewer of the metallic oxides than shales and surface clays, and have more unirform chemical and physical properties.

In general, it will be noted that shales and surface clay contain a higher percentage of oxides ranging from 25.54% to 11.53% . Compared to the shales and surface clays, the oxide content of the fire clays is very low, ranging from 1.39% to 9.25% . Fluxes lower the fusing point of the clays, softening point of shales and surface clays. (1)

2.5 Properties of structural clay products

As would be expected, all properties of structural clay products are affected both by, the composition of the raw material and the manufacturing process.

a) Colour: It depends upon the chemical composition, intensity of burning and method of burning. Iron has probably the greatest effect on colour of any of the oxides or fluxes commonly found in clays.

b) Texture: Much of the production of brick and tile is with smooth or sand-finished textures. These textures may be applied to give increased bond to mortar, plaster or stucco, or to produce a desired appearance.

c) Size variations: Clay shrinks during drying and burning and allowance is made for this shrinkage when the unit are formed. However, absolute uniformity is almost impossible and consequently specifications for brick and tile include permissable variations in sizes which will permit economical manufacture.

d) Absorption and Compressive Strength: They are both affected by the properties of clay, method of manufacture and degree of burning. In general, the plastic clay used in the stiff-mud process , have higher compressive strength and lower absorption than clays used in the soft-mud process or dry-mud process. Since compressive strength and absorption are also related to firing temperatures, these properties, together with saturation coefficient, are taken as a measure of durability. (1)

3. CLASSIFICATION - PRODUCT SPECIFICATIONS - SIZES

3.1 Definitions

a) Solid masonry unit: The ratio of the net cross-sectional area in every plane parallel to bearing surface, to gross cross-sectional area in the same plane equals: 0.75

b) Hollow masonry unit: The ratio of the net cross-sectional area in every plane parallel to bearing surface, to gross cross-sectional area in the same plane is smaller than 0.75

c) Building or structural unit: The specifications for which include measures of durability, strength and other structural properties.

d) Structural facing unit: Structural or building unit designed for use where one or more faces will be exposed in the finished wall.(1)

3.2 Building brick

Requirements for building brick are included in ASTM specifications C62

a) Grade SW : Brick intended for use where a high degree of resistance to frost action is desired, and the exposure is such that the brick may be frozen when permeated with water. Ex : Brick used in foundation.

b) Grade MW : Brickintended for use where exposed to temperature below freezing but unlikely to be permeated with water.

c) Grade NW : Brick intended for the use as back up of interior masonry.(1)

3.3 Facing Brick

Requirements for facing brick are included in ASTM specifications C216

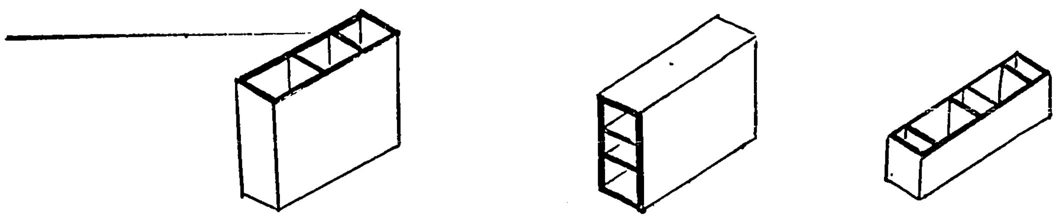
a) Type FBX : Bricks for general use in exposed interior and exterior masonry walls and partitions. A high degree of mechanical perfection, narrow colour range and minimum permissible variation in size are required.

b) Type FBS : Same as (a) except wider colour range and greater variation in size is permissible.

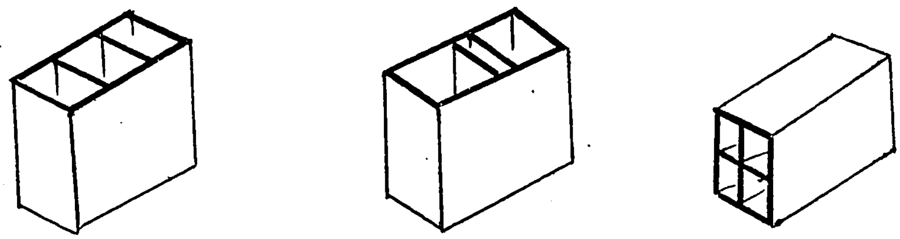
c) Type FBA : Bricks manufactured and selected to produce characteristic architectural effects.[1]

3.4 Physical Requirements

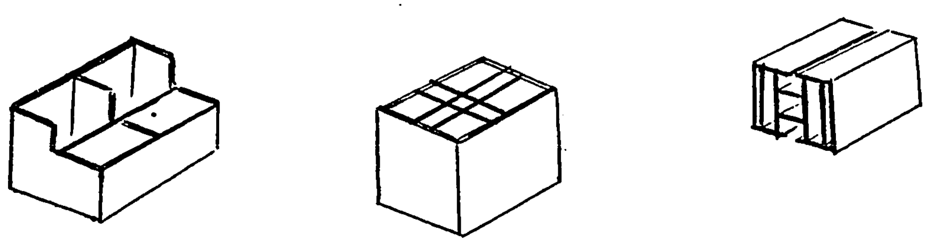
Physical requirements are summarized in table (1) and (2) .



4 in. Wall Thickness



8 in. Wall Thickness



12 in. Wall Thickness

Fig. 1 Some Various Standard Shapes of Load-Bearing Structural Clay Tile.

4. VARIOUS PROPERTIES OF BRICK STRUCTURAL CLAY TILE

4.1 Weight

The true specific gravity ofclays and shales used for the production of structural clay products will range from 2.6 for the more porous burning clay to 2.8 for the densest burning materials.
Unit volume = 0.071 lbs/cu.in. or 123 lbs/cu.ft.

4.2 Water Absorption and Saturation Coefficient

Absorption is defined as the weight of water (expressed as a percentage of the dry weight of the unit) which is taken up by the unit under a given method of treatment.

Water absorption is determined by a number of methods such as partially or totally immersing the unit in cold distilled water for various periods of time ranging from few minutes up to several days, by boiling from 1 to 5 hours, or by treating specifications covers 24 hours submersion and 5 hours backing, also 1 hour boiling tests.

$$\text{Per cent absorption} = \frac{W-D}{D} \times 100 \qquad (4.1)$$

Where W = wgt of specimen after immersion
D = dry wgt of specimen

$$\text{Saturation coefficient} = \frac{W_2 - W_1}{W_3 - W_1} \qquad (4.2)$$

Where W_1 = dry wgt of specimen
W_2 = saturated wgt of specimen after 24 hours submersion in cold water.
W_3 = saturated wgt of specimen after 5 hours submersion in boiling water.

4.3 Initial Rate of Absorption (Suction)

The pores or small openings in burned clay products function as capillaries whick tend to draw water into the unit. This action is referred to as the initial rate of absorption or suction which has an important effect on the adhesion or bond between brick and mortar.

$$S = 30(W' - W) / A \tag{4.3}$$

Where S = Suction in grams per minute.
W = Weight of unit prior to partial immersion in grams.
W'= Weight of unit after partial immersion for 1 minute.
A = Net cross-section area of surface of unit immersed in sq.in.

Numerous tests of the tensile strength of bond between mortar and bricks, and the permiability of brick and tile walls to water penetration indicate that, other factors remaining constant, maximum bond strength and minimum water penetration are obtained with brick having suction not exceeding 20 grams(0.7 oz) per minute when laid. To obtain this value, wetting of the brick before laying is oftenly required.(1)

Fig. 2 shows the relation between compressive strength and absorption.

4.4 Compressive Strength

The compressive strength of structural clay products is defined as the maximum resistance of the unit to a gradually increasing load applied at right angle to the plane of the bearing surface of the unit. In general, the compressive strength of brick is based on gross area for load bearing wall tile.

Table 1 Physical Properties of Buiding Bricks

Designation	Minimun Compressive Strength		Max. Water Absorption by 5-hr boiling		Maximum Saturation Coefficient	
	Average	Individual	Average	Individual	Average	Individual
Grade SW	3200	2500	17.0	20.0	0.78	0.80
Grade MW	2500	2200	22.0	25.0	0.88	0.90
Grade NW	1500	1200	No limit	No limit	No limit	No limit

N.B. The saturation coefficient is the ratio of absorption by 24-hr submersion in cold water to that after 5-hr submersion in boiling water

Table 3 Physical Properties of Facing Bricks

Grade	Max. Water Absorption by 1-hr boiling		Minimum Compressive Strength			
			end construction		Side construction	
	Average	Individual	Average	Individual	Average	individual
LBX	16	19	1400	1000	700	500
LB	25	28	1000	700	700	500

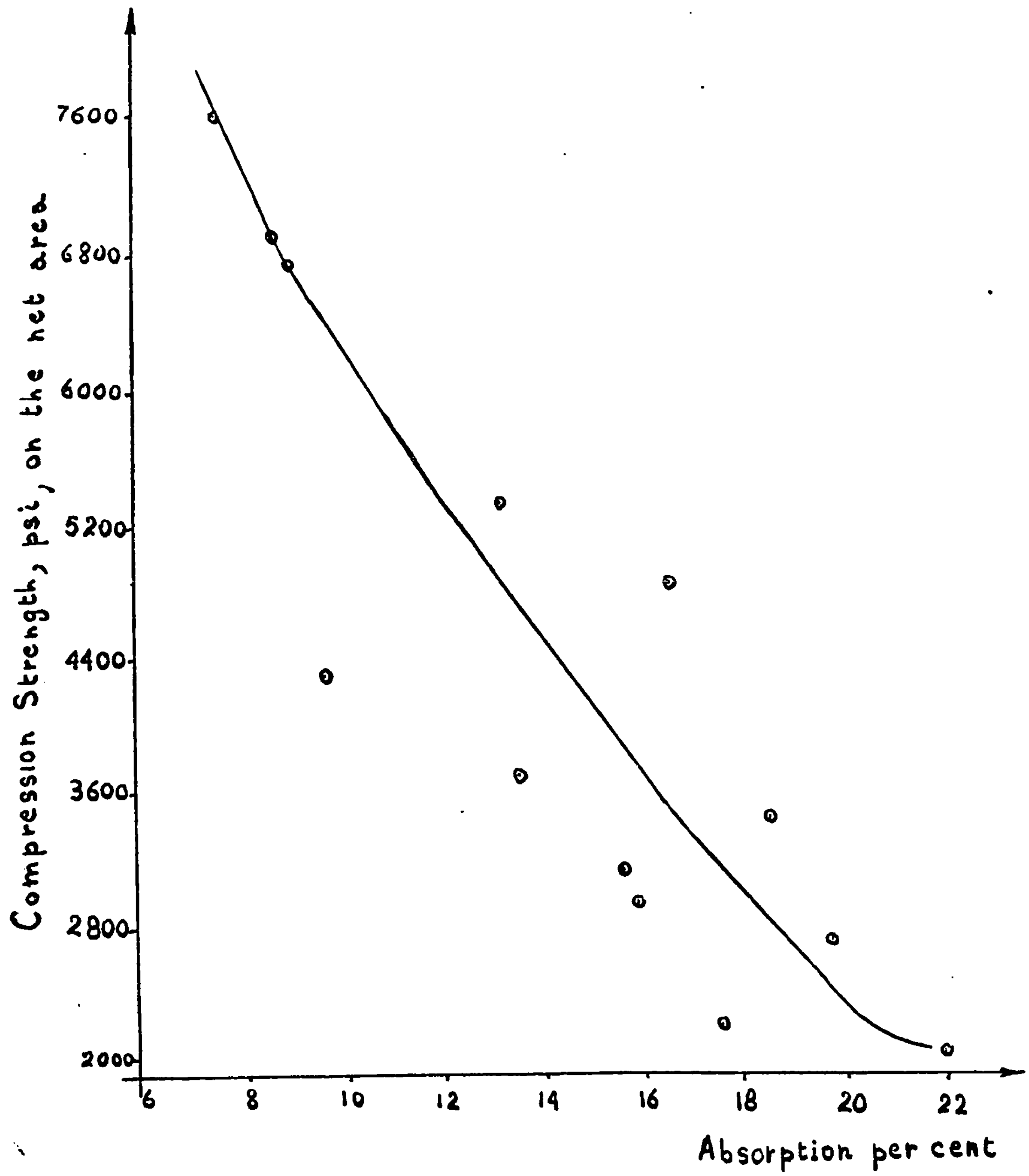


Fig. 2 Relation between compressive strength and absorption.

The report on the compressive and transverse strength of brick by J.W. McBurney denotes the following remark:"The tendency of soft mud brick is to give higher unit strengths tested on edge than when tested flat".The compacting effect on the structure of the edge-set brick by superimposed weight of the other bricks in the kiln is offered as a tentative explanation of the tendency toward higher strenght on edge. Compressive strength is affected not only by the raw materials and the method of manufacture used in the production of the tile, but also by the unit design.
Table 3 gives the distribution of strength properties of brick from all parts of the U.S.A.(1)

4.5 Modulus of Elasticity and Poisson's Ratio

It will be noted that the values of E are intermediate between the high values for shales and the low values for surface clay. As temperature or length of the butning period is increased, clay burns to daker colour, absorption is reduced and compression strength and E are increased.
The results of tests at the Watertown Arsenal show E for building brick ranging from 1.4×10^6 to 5×10^6 and the ratio of the lateral expansion to longitudonal expression(Poisson's Ratio) ranging from 0.0434 to 0.114.
Table 4 gives the modulus of elasticity for different types of structural caly tile.(1)

4.6 Transverse Strength (Modulus of Rupture)

It is the resistance of a brick to a load when the brick acts

Table 3 Distribution Of Strength Properties Of Brick From All Part of The U.S.A.

Compressive Strength, Flatwise		Modulus of Rupture	
Range, psi	%age of Product.	Range, psi	%age of Product.
21001 to 22500	0.46	2101 to 3450	6.95
19501 to 21000	0.69	1951 to 2100	3.00
18001 to 19500	0.46	1801 to 1950	2.74
16501 to 18000	2.04	1651 to 1800	7.57
15001 to 16500	1.49	1501 to 1650	8.34
13501 to 15000	3.71	1351 to 1500	5.34
12001 to 13500	4.76	1201 to 1350	7.12
10501 to 12000	7.78	1051 to 1200	10.55
9001 to 10500	8.61	901 to 1050	10.44
7501 to 9000	11.92	751 to 900	13.60
6001 to 7500	15.47	601 to 750	11.74
4501 to 6000	16.81	451 to 600	7.52
3001 to 4500	17.97	301 to 450	4.35
1501 to 3000	7.46	151 to 300	0.37
0 to 1500	0.36	0 to 150	0.37

Table 4 Modulus of Elasticity of Structural Clay Tile

Kind of clay	Source	Nominal size	Mod. of Elasticity $\times 10^6$
Shale	Ind.	8x12x12 in.	4.345
50% fire clay 50% shale	Ala.	8x12x12 in.	4.814
Fire clay containing 15% shale	Ohio	8x12x12 in.	2.731
High lime surface clay	Ill.	8x12x12 in.	1.620
Shale	Lowa.	8x12x12 in.	6.059
Shale	Ky.	8x12x12 in.	4.826
Dence burning fire clay	Ohio	8x12x12 in.	2.426
Open burning fire clay	N.J.	8x12x12 in.	3.080
Open burning fire clay	N.J.	8x12x12 in.	2.920
Open burning fire clay	Texas	8x12x12 in.	1.818
Surface clay	N.J.	8x12x12 in.	3.595
Surface clay	Mass.	8x12x12 in.	4.418
Surface clay	N.Y.	8x12x12 in.	1.825
Shale	Lowa.	8x5x12 in.	4.994
Shale	Lowa.	8x5x12 in.	6.059
Shale	Kan.	8x5x12 in.	2.657
Dence burning fire clay	Ohio.	8x5x12 in.	5.443
Dence burning fire clay	Ohio	8x5x12 in.	3.325

as a bean supported at both ends.

$$MR = \frac{3WL}{2bd^2} \qquad (4.4)$$

Where MR = Modulus of rupture lb/sq.in.
W = Total load in lbs at point of breaking.
L = Span between support in inches.
b = Width of brick in inches.
d = Depth of brick in inches.

4.7 Tensile and Shearing Strengths

Tensile strength tests of brick constructed at the National Bureau of Standard, provided limited data which indicates that tensile strength is between 30 and 40% of transverse strength. Punching shear tests on brick and tile indicate strength in shear from 35 to 45% of the net compressive strength of the unit.(1)

4.8 Resistance to Abrasion

Affected by the degree of burning and by the nature of the raw material. In general, it can be said that bricks cover much of the same range of resistance to abrasion as that obtained in natural building stones . J.W. McBurney, R.H. Brink and A.R. Eberle conclude:

a) The abrasive resistance of brick increases with their compressive strength.

b) The abrasive resistance of brick decreases as water absorption increases.

c) Under the conditions of test, abrasive losses determined on the same bricks tested dry.(1)

5. COMPRESSIVE STRENGTH OF BRICK AND TILE WALLS

The principal factors affecting the compressive strength of walls are:

a) Compressive and other strength measures of the units.

b) Strength of mortar and its thickness.

c) Workmanship.

d) The proportion of gross area giving a bearing at bed joints particularly in the case of end construction.

Tests carried by Professor W.J. Krefeld in 1937 at Columbia University show that the compressive strength of the walls decreased at a fairly uniform rate with increase in height to thickness (h/t) to six, behind which the decrease up to an h/t ratio of 12 was slight. As a result of these tests, the author proposes the correction factors given in table 5 below.

Table 5 Strength Correction Factors

Ratio height to thickness	Strength Correction Factor	h/t	Strength Correction Factor
1.1	0.45	4.5	0.93
1.5	0.59	5.0	0.96
2.0	0.67	5.5	0.98
2.5	0.75	6.0	1.00
3.0	0.80	8.0	1.03
3.5	0.85	10.0	1.06
4.0	0.89	12.0	1.09

The factors in the previous table are based on a height to thickness ratio of six and are to be applied to test specimen built of similar materials, with the same method of bonding and by the same workmanship that will be used in the full size member. These factors may also be used to estimate the strength of reinforced brick masonry walls with minimum reinforcement. However, it has been found that the ultimate compressive strength developed in reinforced brick masonry flexural members is more nearly equal to the strength of masonry prism having an h/t equal to two.[1]

6. BRICK WALLS

6.1 Estimating Brick Wall Strengths.

Results of compressive test of 168 solid and hollow brick walls (6 ft.x 9 ft.) and, of 129 wallettes (18 in. x 34 in.) are reported in the National Bureau of Standards Research paper N°108 by A.H. Stary, D.E. Parsons and, J.W. McBurnay.

It was noted that the ratio of wall strength to similar wallette strength is an average of 0.82 for the 8-in.walls and, 0.74 for the 12-in.walls.

For brick wall laid up with mortar having a compressive strength of not less than 2500 psi when cured wet for 28 days and, with complete filling of all mortar joints and smooth bed joints, wall strength will be approximately one third of the compressive strength of brick,provided that the brick strength exceeds 4500 psi. For brick having strength of 2500 psi.,the wall strength will be approximately 50% of the strength of the brick.

Based on the data reported by Talbot and Abrams in University of Illinois Bulletin No 27 ,"the compressive strength of Terracota block columns" D.E. Parsons has developed a formula for estimating the probable compressive strength of concentrically loaded masonry walls constructed of end construction hollow units.

$$M = b\sqrt{m\,u} \qquad (6.1)$$

Where M = Compressive strength of the masonry in lbs/sq.in.
b = Ratio of bearing area to gross area.
m = Compressive strength of mortar specimen in lbs/sq.in.
u = Compressive strength of the gross area of units in lbs/sq.in.

6.2 Modulus of Elasticity and Compression

In the tests reported in Bureau of Standard Research paper 108, compression deflection were observed and, stress strain curves were plotted for most of the walls tested. Regarding the modulus of elasticity , the report states: "For the walls laid in cement lime and cement mortars, the stress strained curves are, for low stresses , approximately straight lines. In general however, there is no value for modulus of elasticity which is consistant over a large stress range."

In general a higher value of modulus of elasticity is associated with high strength of brick, high strength of mortar and, type "A" of workmanship. Calculated values of modulus of elasticity derived from tests of reinforced brick flexure members and, obtained from the straight line formula used for the design of reinforced concrete and reinforced brick masonry, differ materially from values in Figure 3 . This is due partially to the fact that straight lines formula for design, are based on the assumption that the masonry carries no tensile stresses. This is incorrect until cracks develop in the masonry. The difference between the calculated values and those in figure is also due to the difference in the distribution of stress between fluxural and concentrically loaded compression members. As in the case of ultimate compressive strength,recommended values of modulus of elasticity for use in the design of reinforced brick masonry, are based upon the modulus of elasticity of masonry piers built of similar materials, the same type of workmanship , and the same bonding arrangements as the proposed construction.

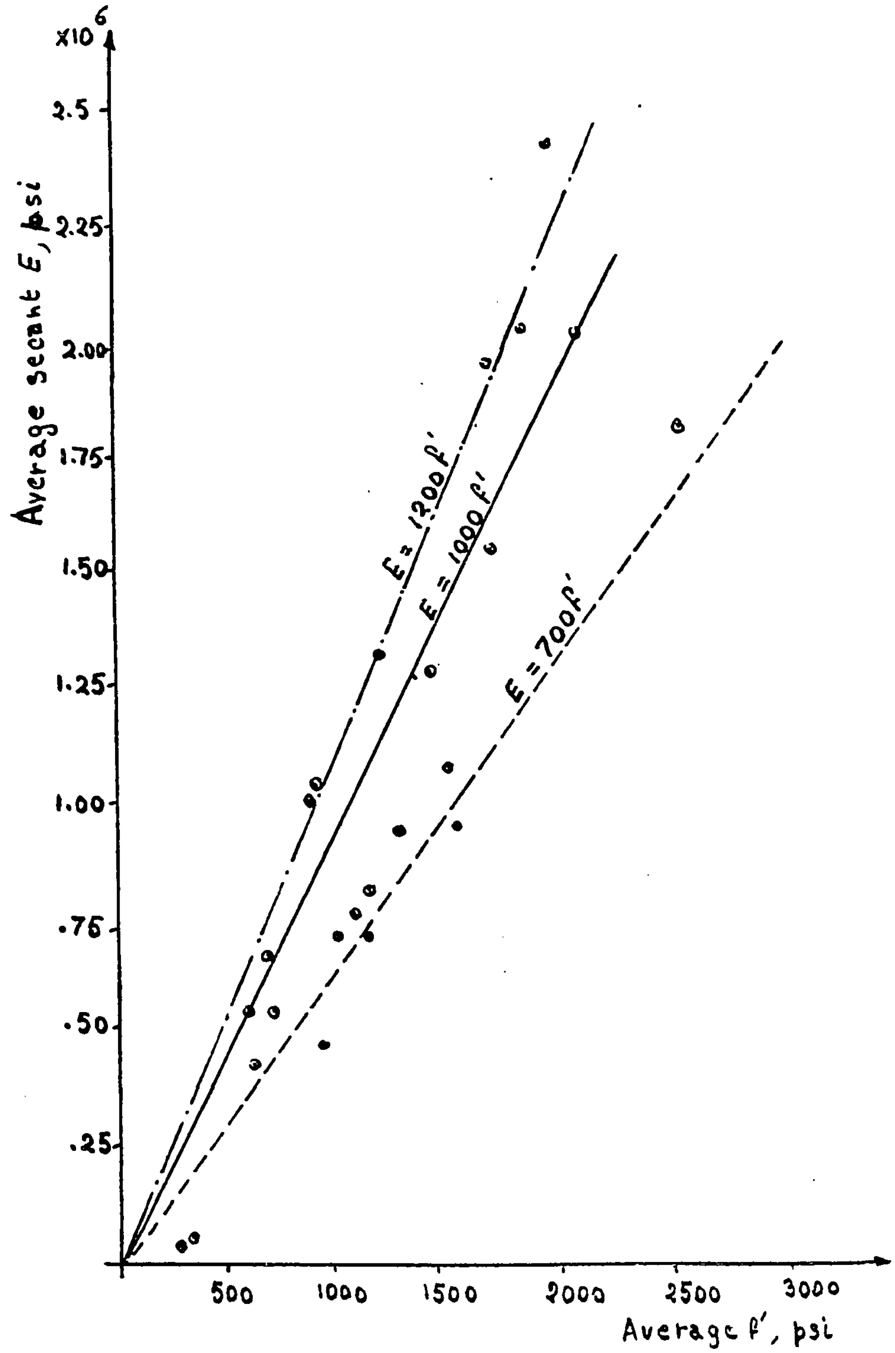


Fig. 3 Relation between Modulus of Elasticity and Ultimate Compressive Strength.

6.3 Transverse strength

The transverse strength, or resistance to lateral forces, of brick and tile walls depends primarily upon the type of masonry unit, the bond strength of the mortar and workmanship. Other factors affecting transverse strength are the water retentivity and the efficiency of mortar use, and the design of the unit which affects the width of the mortar beds normal to the span. Higher transverse strength is associated with the brick and side construction tile, suction of the unit when laid of 20 grams or under mortars of high bond strength, high water retentivity and high workability; the latter obtained by the use of the maximum water consistent with workability.[(1)]

Fig. 4 shows a typical transverse test assembly.

6.4 Location of Lateral Supports

The location of lateral supports has an important effect on the resistance of masonry walls to lateral forces. When the supports are spaced vertically and the bed joints are normal to the span, failure of walls subjected to transverse loading is usually at the bed joint and results from failure of the bond between mortar and masonry units.

However, when the lateral supports are spaced horizontally with the bed joints parallel to the span, failure resulting from transverse loading often occurs in the unit as well as in the mortar joints.

Data reported in the "Transverse strength of concrete block walls" by F.W. Cox and J.L. Ennenga, which was published in May 1958 in

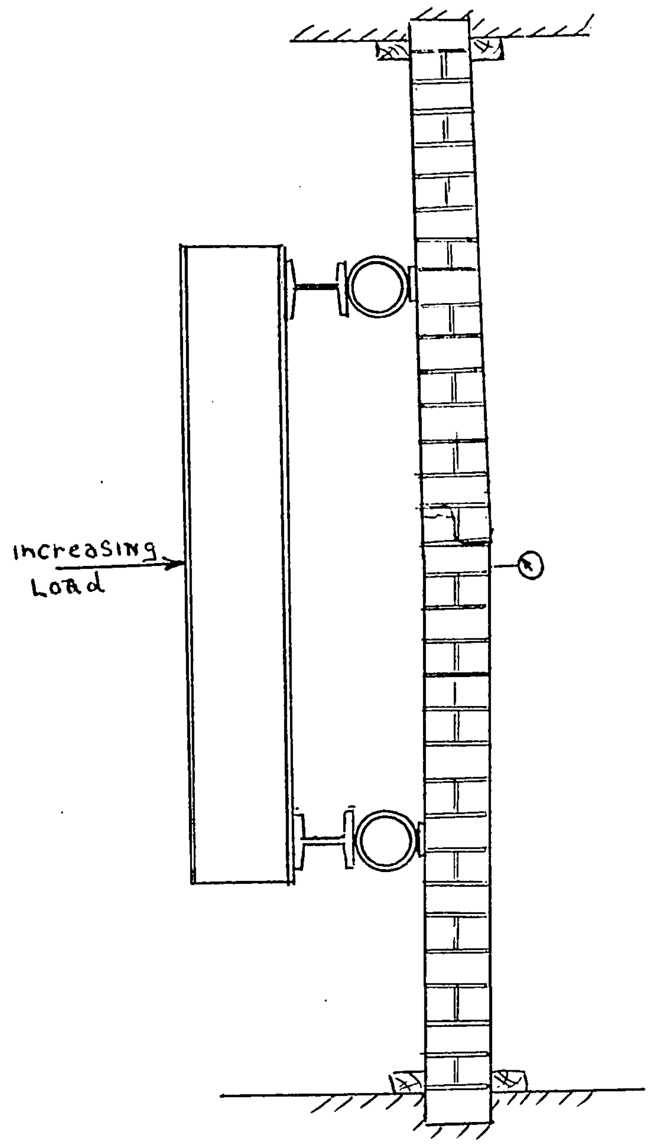


Fig.4 Typical Transverse Test Assembly

the Journal of the American Concrete Institute, indicates that the resistance of concrete block walls to lateral forces, when the bed joints are parallel to the span, is from three to four times the resistance of similar walls with bed joints normal to the span. Limited data on transverse strengths of brick and structural tile walls when tested, with bed joints parallel to the span, indicates similar relationship exists for these walls.[1]

6.5 Method of loading

The apparent transverse strength of masonry walls subjected to laboratory tests is affected by the method of loading. ASTM specifications E72 provide that the transverse test shall be conducted on walls 8ft. high and 4ft. wide, tested as simple beams on a 7ft.6in. span, and that transverse loads may be applied either as two equal concentrated loads,each at a distance of one quater of the span from the supports or, as a uniformly distributed load. Figure 4 shows a typical test assembly for quater point loading.The methos of applying the uniformly distributed load is known as the "Bag Method" and, consists of inserting plastic bags between the wall and a movable restraining framework by means of which a uniform pressure can be applied to the wall by inflating the begs with air.

C.B. Monk tested masonry walls by both mathods and, stated that: "Theoritically, the average shows that the uniform loading,depending on end conditions, will yield mean strengths 8.8% to 17.1% greater than the quater-point loading".Table 6 shows the mean strengths in both methods.

Table 6 Mean Strengths

Mortar	Mean strength lbs per sq.ft. quater-point loading	7ft. 6 in. span Uniform loading
1:$\frac{1}{4}$:3	32.8	87.0
1:$\frac{1}{2}$:4	62.4	86.5
1:1:6	26.1	68.5

As may be noted, the average apparent, tranverse strengths under uniform loading,reported hereabove, are approximately twice the average strengths reported for quater-point loading.

Mr. Monk states:"This difference can only be explained in part. The coefficient of variations of many specimens sets was above 16.8%.Undoubtedly stress concentration under rollers used in quater-point technique contributed to lower values".

The results of these tests indicate that substantially higher strengths are developed in masonry walls of structures than might be predicted from laboratory tests of similar specimens. This is undoubtedly due in part to the factors discussed previously in the location of lateral supports which may result in some plate action and method of applying loads.

6.6 Shearing Strength

The racking test, as described in ASTM standard method of conducting strength tests of panels for buildings construction E72 , is usually considered a measure of the shearing strength of brick masonry walls. The specimen used for this test is a wall 8 x 8 ft. which is tested by restraining it from sliding or rotating and applying a horizontal force near the upper end of the specimen. Failure of walls in the racking test, shown in Figure 5 , is usually in diagonal tension and the plan of failure extends from near the top corner, where the load is applied diagonally downward toward the bottom support.

Tests of wall sections as short span (7.5 ft.) beams were conducted by the Smith Emery Co. of Los Angeles, California, to determine shearing strength of unreinforced grouted brick masonry walls.

In Figure 6a , the applied load is comparable to a force applied in the plane of the wall parallel to the bed joints and in Figure 6b the applied load simulates the force applied normal to the bed joints.

Mortar used for the construction of these specimens consisted of 1 part cement , $\frac{1}{4}$ part lime putty and 3 parts sand by volume and grout consisted of 1 part cement, 0.15 part lime putty and 3 parts sand by volume.

Data included in the National Bureau of standards publications BMS5, structural properties of six masonry wall constructions, and BMS 136 properties of cavity walls, together with the data on "SRC BRICK" walls reported by the Structural Products Research Foundation are available.[1]

6.7 Heat Transfer

The thermal resistance of the wall itself is separate and distinct from the surface resistances. It is a property of the wall and is not influenced by the surroundings except in certain case of air leakage. Heat transfer through solid walls takes place only by conduction in the direction of temperature gradients.

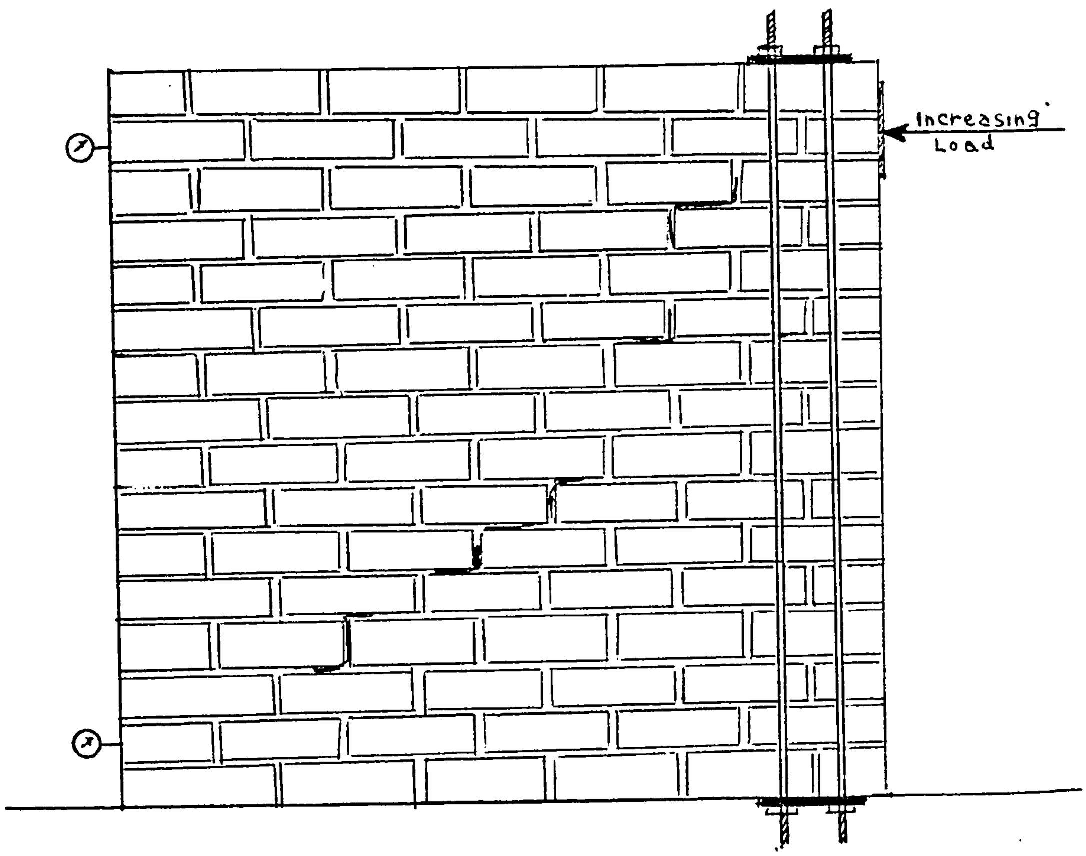
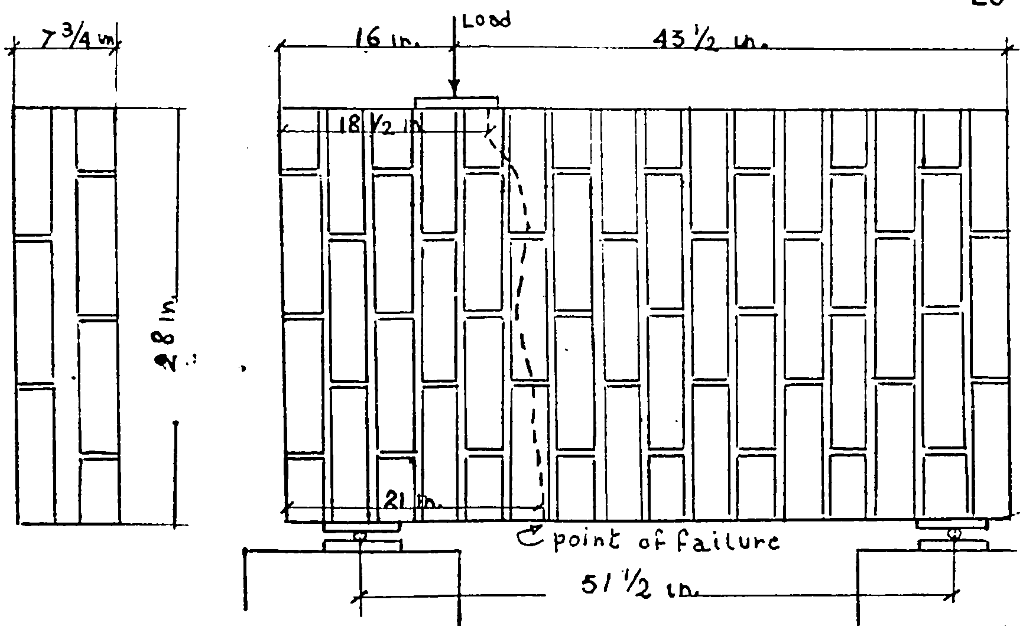
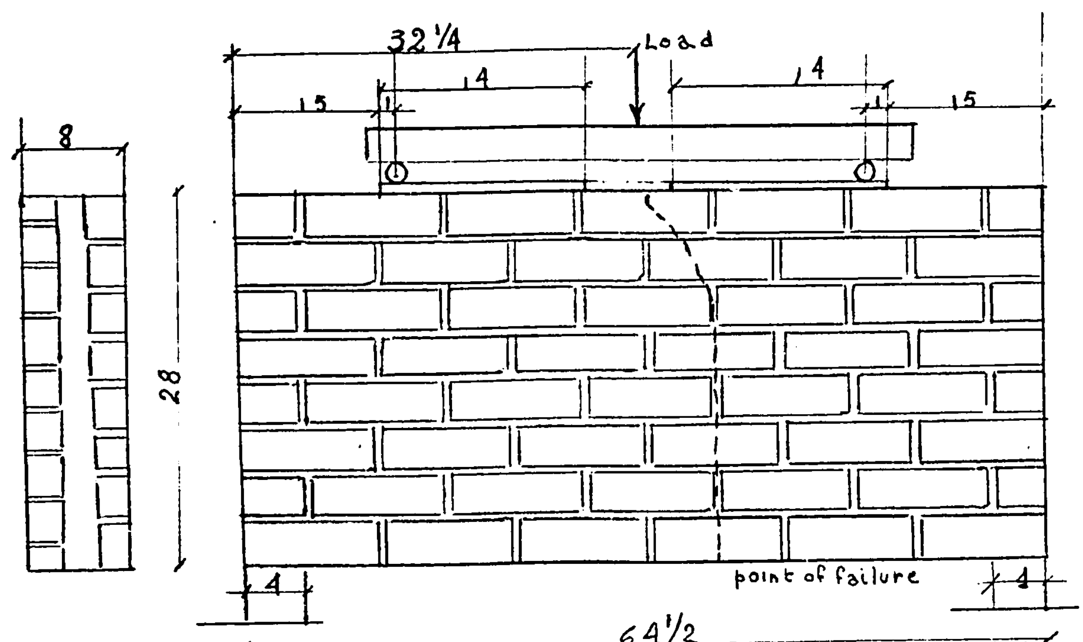


Fig.5 Typical Racking Test Assembly



a) Groutlock brick laid with grout only. Gravity grouted with slip forms. Offset joints horizontally, one side of column started and finished with half brick.



b) Groutlock brick laid up in the regular manner. Offset joints, one side of beam started and finished with half brick.

Fig. 6 Loads parallel and normal to the bed joints of the wall.

Such transfer is proportional to the temperature difference between the two surfaces of the wall and further, depends on the material composing the wall. The thermal conductivities of building materials in general , increase slightly with increasing temperature. Consequently, the resistance of the wall will decrease somewhat with increasing mean temperature of the wall. Heat transfer through walls containing voids, such as hollow tiles, frame or hollow types of brick walls, takes place by convention and radiation as well as conduction. [1]

7. LOAD DISTRIBUTIONS

7.1 Load Normal to the Surface

When a lateral load, such as wind, is applied to a wall, this load will be transmitted to horizontal and vertical edge supports if the wall does not fail. Edge supports may be pilasters, shear walls, roofs, floors, beams or columns. The proportion of the load transmitted vertically and horizontally will depend upon the flexural resistance and rigidity of the wall in both the vertical and horizontal spans, the fixity or restraint developed at the edges, the horizontal to vertical span ratio and the distribution of the loads applied to the wall panel.

Figures published by the National Concrete Masonry Association in 1960 shows the proportion of the uniform wind loads transmitted to supports. These curves are based on the assumption that the moments of inertia and modulus of elasticity will be the same in both the horizontal and vertical directions and that the walls either have no openings, or would be so located that the effect on the stiffness of the wall panel would be the same in both directions.

In view of the fact that the ultimate strength of common bond unit masonry walls, when the bed joints are parallel to the span, is up to four times the ultimate strength when the bed joints are normal to the span, it is questionable if the modulus of elasticity of such wall "will be the same in both the horizontal and the vertical directions". No data is available to substantiate the assumption, however, it seems probable that the modulus of elasticity in the horizontal direction would be greater than the modulus of elasticity in the vertical direction. (1)

7.2 Load Parallel to the Surface

Loads parallel to the surface of the wall which may be transmitted to the wall through connecting members by diaphram action induce shearing stresses in the wall. If various elements of a structure are connected to another common rigid element and that the element is deflected by a force, then, the various connecting units also move an equal amount , or failure occurs somewhere in the system. Assuming failure does not occur, the portion of the load carried by any of the connecting elements is proportional to its rigidity as compared to the sum of the rigidities of all connecting elements, or in proportion to its relative rigidity. Rigidity is defined as the recipricol of the deflection resulting from both moment and shear and is a function of the dimensions and modulus of elasticity of the wall, and the fixity or moment restraint provided by horizontal elements at the end of the wall. The deflection of a wall, of hight (h) depth (d) and width (t) fixed at both ends and subjected to a horizontal force (p) , is obtained from the following formula:

$$\Delta = \Delta_m + \Delta_v \tag{7.1}$$

Where $\Delta_m = (ph^3)/12 E_m I$ = Deflection(in.)due to moment.
$\Delta_v = 1.2\, Ph/E_v A$ = Deflection(in.)due to shear.
p = Horizontal force applied to the wall.
h = Height of the wall.
E_m = Modulus of Elasticity of the wall.
E_v = Modulus of Rigidity of the wall.
$I = (td^3)/12$ = Moment of Inertia of the wall.

Assuming that $E_m = 1 \times 10^6$ and $E_v = 0.4E_m$

Therefore: $\Delta = \dfrac{Ph^3}{12 \times 1 \times 10^6 \times \frac{td^3}{12}} + \dfrac{1.2\,Ph}{0.4 \times 10^6 \times td}$

$$\Delta = \frac{P}{10^6 \times t}\left[\left(\frac{h}{d}\right)^3 + 3\left(\frac{h}{d}\right)\right] \qquad (7.2)$$

Then for a force of one ton on a wall of one inch thickness

$$\Delta = 0.001\left[\left(\frac{h}{d}\right)^3 + 3\left(\frac{h}{d}\right)\right] \qquad (7.3)$$

For wall fixed at one end only and P = 1 ton, t = 1 in.

$$\Delta = 0.001\left[4\left(\frac{h}{d}\right)^3 + 3\left(\frac{h}{d}\right)\right] \qquad (7.4)$$

The rigidity of the wall is to $1/\Delta$

Relative values of the rigidity of walls of varying heights to width ratio are shown in figure 7. (1)

7.3 Diaphragms

Horizontal distribution of lateral forces to the various vertical elements at each storey may be done through horizontal bracing systems or trusses, by bending of local members from bent to bent or, by utilizing the inherent strength and rigidity of roof and floor constructions. The latter is the diaphragm method. Structural Engineers Association of California recommended the following: "Diaphrams for structural purposes must have sufficient strength and stiffness to redistribute shears and, at other points where vertical resisting elements may be discontinued". Rigid diaphrams are preferred, particularly for masonry buildings and for taller buildings. In masonry, this is to avoid deflections which can cause secondary failures in structural and non-structural walls. In taller buildings, say 13 storeys and

~~over, a ri~~gid diaphram construction is strongly recommended to distribute not only direct shear, but also calculated and accedental torsional shears. (1)

7.4 Concentrated Loads

Concentrated loads applied to masonry walls may safely be assumed to spread through a supporting pyramid of masonry, whose sides make an angle of 60 degrees with the horizontal.

It is recommended that allowable stresses under concentrated load be 50% greater than the allowable compressive strength; provided, the concentrated load bears on solid masonry whose thickness is greater. When a concentrated load results from a reaction of a beam or girder bearing directly on a masonry wall, the reaction, as a rule, will not be in the center of the bearing area, but due to the deflection of the member, will move toward the inner face of the support. In general, it may be assumed that the vertical reaction is at one third the bearing distance from the inner face of the support. (1)

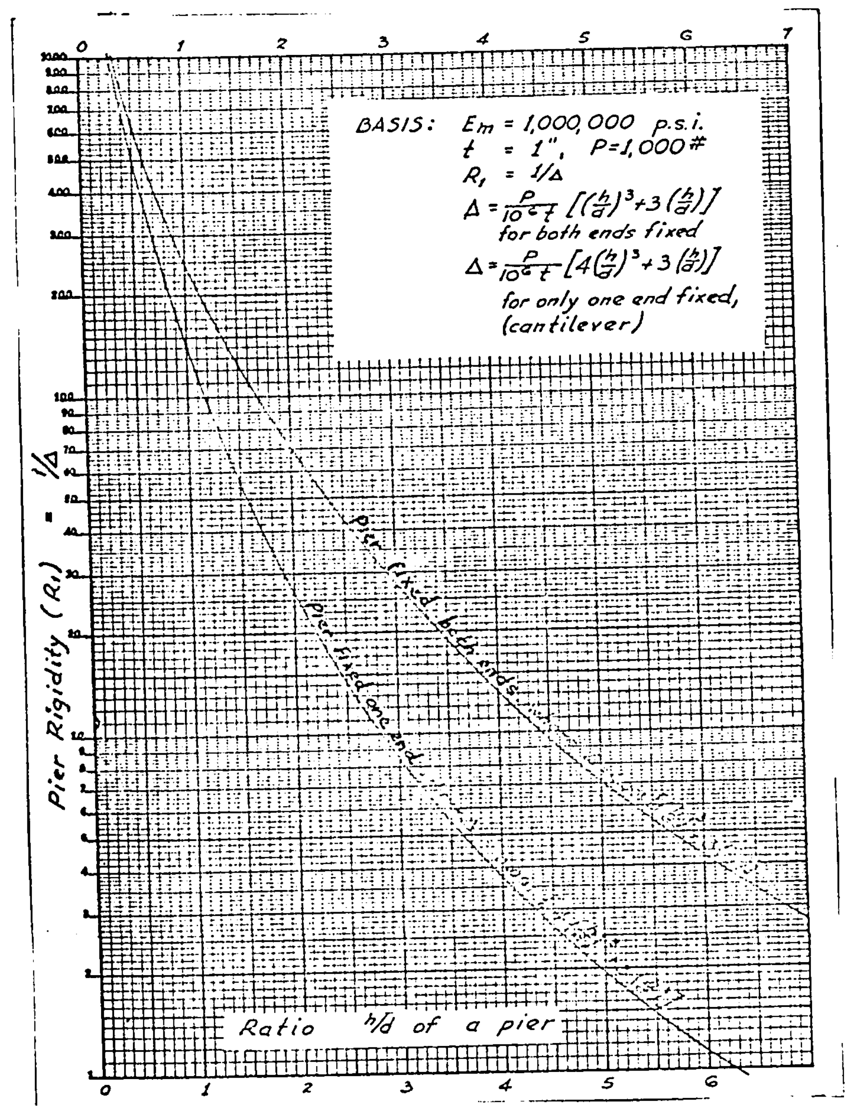


Fig 7 Relative Rigidity of walls

8. WORKING STRESSES

8.1 Evaluation of Working Stresses

The performance of brick and tile walls, pilasters and columns subjected to axial loading, both concentric and eccentric, can be predicted with reasonable accuracy by a rational analysis of the design inaccord with well known principles of mechanics and, from data obtained from laboratory tests on compressive and transverse strengths of masonry. However, no rational method has been developed which will explain the performance of non bearing walls in resisting lateral forces when the only axial load is the weight of the masonry.

It is believed that a rational design utilizing the recommended working stresses which follow will be safe. However, experience indicates that such a design to resist lateral forces will be unnecessarily conservative, unless all the factors contributing to lateral strength of masonry walls are taken into account.[1] Since, for many constructions, it is unpractical to do this, minimum requirements included in most building codes for wall thicknesses, unsupported hights and lengths are recommended as a basis for design of such structures.

8.2 Compressive Stress

The ultimate compressive strength is related closely to the compressive strength of the brick and to a lesser degree to the strength of the mortar. For this reason allowable compressive stresses included in most building codes are related to both brick and mortar strengths.

Recommended allowable compressive stresses for various wall constructions and brick strengths are similar to those included in the American Standard Building Code requirements for masonry A41-1-1953.[1]

8.3 Tensile and Shearing Stresses

Unlike compressive strength the tensile and shearing strengths of brick and tile masonry are affected only slightly by the compressive strength of the masonry unit, but most importantly by the bond between mortar and the masonry unit.[1]

9. LEADING EUROPEAN SYSTEMS

9.1 General Introduction

Only a small amount of European constructions is performed by industrialized methods. The proportion is higher in some countries than in another, going as 20% in France to a low of 4 to 5% in Switzerland. In Denmark and Sweden 7 to 8%, Germany and England between 5 and 6%. These figures include industrialized buildings of all types and, are not only representative of industrialized systems which utilize structural ceramics as principal material. The reasons underlying the need for industrialization of building processes are:

1) Throughout Europe there exists an accute shortage of buildings, particularly housing, schools and hospitals of various type.
2) A shortage man-power which, in every western Europe country, has precipitated the need for higher labour productivity in the building industry.

Industrialized building systems are of two main types:

a) Open systems
b) Closed systems

"Open systems" are those where the components are interchangeable within other systems with which they are dimentionally co-ordinated or, are available for use in traditional constructions. These may be applied to a variaty of plan forms and are not necessarily particular to one contracting organization.

"Closed systems" are those where the parts or components are peculiar to that system. These may be associated with specific plan forms and may be also particular to one contracting organization. Company officials strongly emphasized that industrialized building costs will not necessarily be less expensive but rather, ranged up to five per cent more than traditional buildings. There is one notable exception however. Officials of the"Fiorio" Company in France, said their costs ranged up to 18% less for a given structure than traditional buildings costs for an equivalent structure in France.

The trend in Europe appears to be away from "closed" systems and towards those which are more "open" systems. As long as this situation cȏntinues, the number of buildings constructed from prefabricated "open" system element will remain limited until future demands create a wider acceptance for "open" industrialized systems.

The applicability of European systems to Canadian requirements generally speaking, those systems which employ brick as an exterior facing, do not present as acceptable in appearance as modern Canadian brick work. Their appearance does compare favourably with traditional European brick work. The Fiorio system which employs very thin bearing wall(7¼ in. thick) is stated to be designed around a factor of safety of 5.

Insulation provision is adequate in the Montage-Tegl and Tegel-element elements,each of which include a 4 in. thickness of minral wool or fiberglass, sandwiched between the wythes. This gives a U value(Insulation coef.)of about 0.092. The Kornerup and H.S.S.B elements could be insulated by the addition of a pour-type insulating material such as expanded vermiculite.

The Costamagna, Fiorio and, Montage-Bau exterior elements rely on the air spaces of the tile cells to provide insulation. Each of these has an approximate U value of 0.13. (2)

9.2 The Costamagna system (France)

Costamagna is a large and diversified manufacturer and supplier of building materials and elements to the French construction industry. It produces a wide range of hollow tiles, precast tile and concrete panels, a variety of prestressed and precast concrete products, such as balconies, stairways and chimeneys. Costamagna have been involved in the construction of several thousand apartments in Sarcelles through a licensed contractor. The contractor operates a temporary on-site pre-fabrication plant, where wall elements for three apartment units per day are produced. Elements are cast within wooden or steel forms,on smooth horizontal concrete slabs, which, are situated in line to suit production flow.The forms are adjustable in both horizontal directions. Door and window frames are positioned within the forms in the preparation of an element. Plastic electrical conduits and copper pipes for plumbing may also be incorporated.(2)

A) Manufacture of Elements

The manufacture of a typical exterior element involves the following steps:

1) Adjust forms on slab and position openings,door and window frames

2) Place facade material, such as ceramic tiles.

3) Pour fine aggragate concrete layer and spread evenly.

4) Place structural tiles (one or two layers) in wet concrete.

5) Place reinforcing steel as necessary; also lifting-hooks conduits, plumbing fittings.

6) Pour afinish coat of concrete, and finish with gypsum plaster.

Load-bearing partition elements are similary made. Production steps are:

1) Spread a thin layer of plaster within the positioned form.

2) Place structural tiles.

3) Place lifting-bolts, conduits and plumbing fitting.

4) Pour concrete, scred and float.

5) Apply finish coat of plaster.

Typical cross-sections are shown in Figures 8,9,10 and 11. (2)

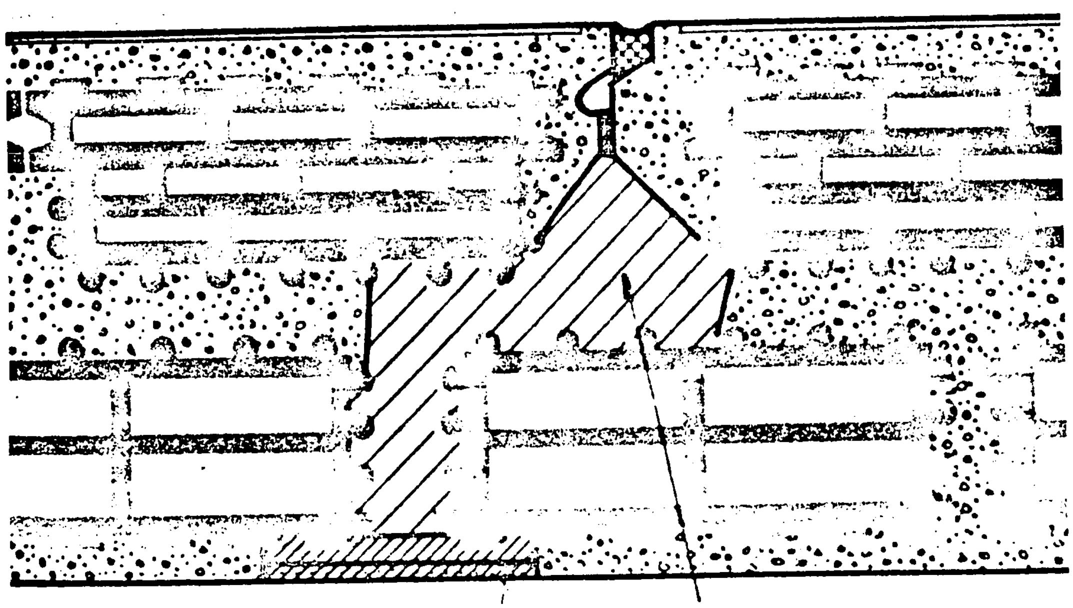


Fig.8 Double Tile Exterior Wall Element

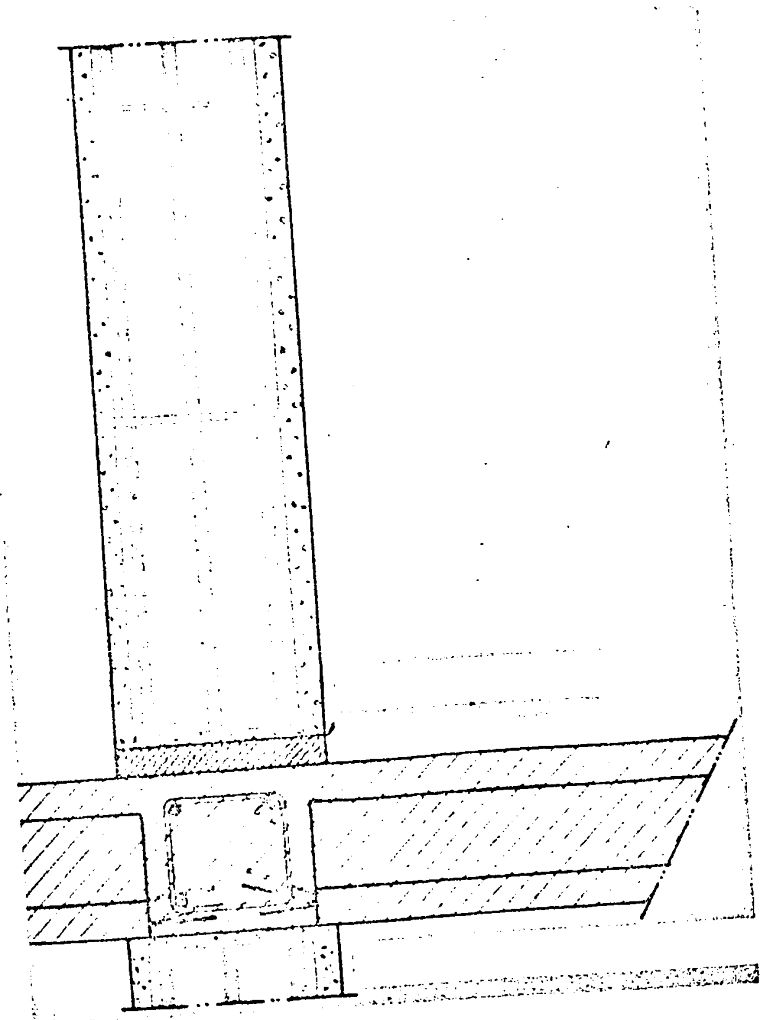


Fig.9 Sectional Elevation of Load Bearing Partition Element Showing Floor Junction Details

It will be noted that the structural tiles are so positioned that the cores are aligned vertically when the panel is in the wall.

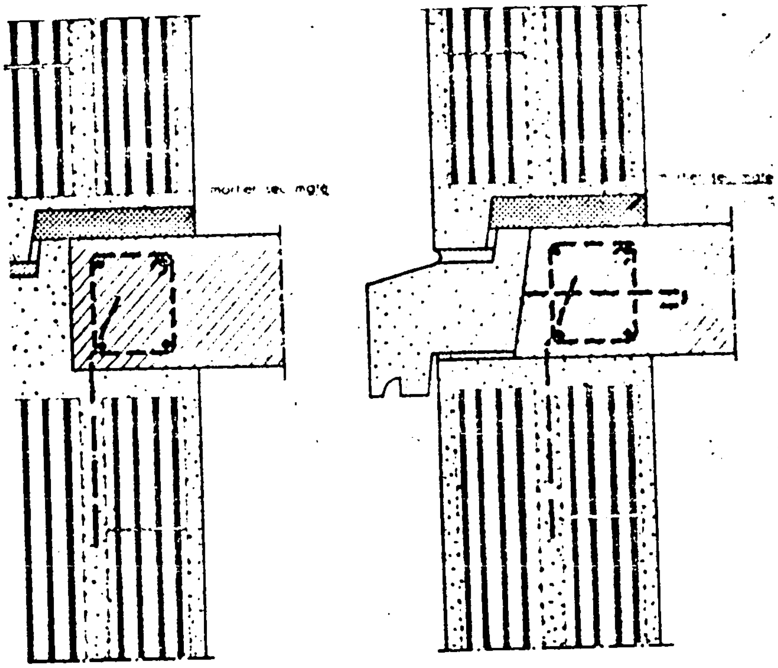


Fig.10 Sectional Elevation of a Double Tile Exterior Wall Element Showing Floor and Horizontal Joint Details

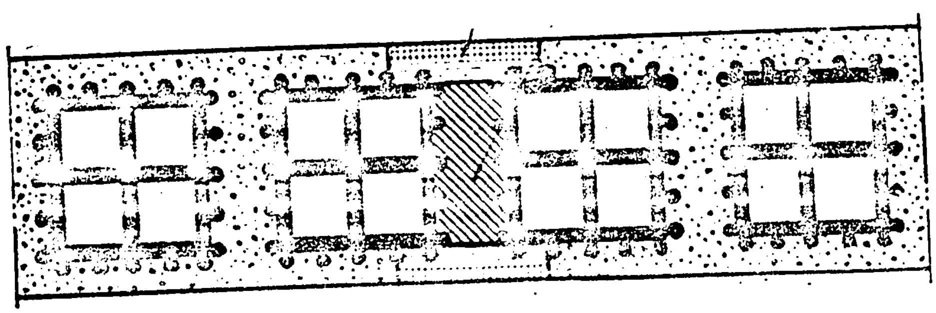


Fig.11 Plan Section of Load-Bearing Partition Element

The vertical joint illustrated in Figure 11 is made after the elements are positioned by clamping wood or sheet steel forms on each face of the wall at joint position. Concrete grout is then poured between the elements from the top. After the forms are removed, the area around the joint is touched up with gypsum or cement plaster.

Figure 12 shows a finished Costamagna element.

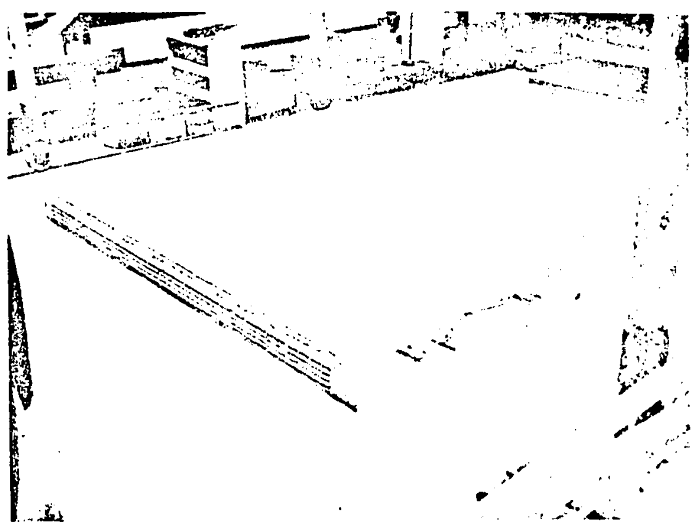


Fig.12 A Finished Costamagna Element

B) Partition Panel Factory at Cannes de Bocca

This is a highly efficient plant and lends itself well to detailed productivity studies. Storey-height planks measuring either 12 in. or 16 in. wide by about $2\frac{1}{2}$ in. thick are produced. They each weigh about 120 lbs and fit together tongue-and-groove fashion to form partition walls.

The planks are prepared by joining hollow tiles measuring $1\frac{3}{4}$ in. by 14 in. by 14 in. (7-core) together by means of fiberglass reinforced gypsum plaster.

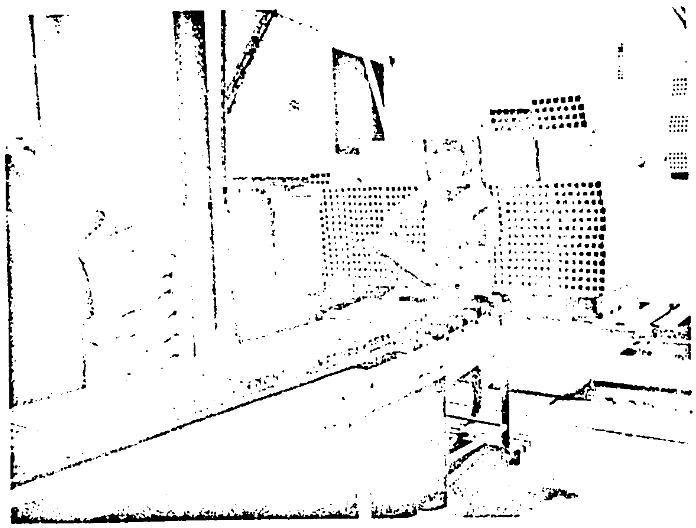


Fig.13 Preparation of "Beams"

"Beams" thus formed are flipped into a storage conveyor which indexes one unit forward in readiness for the next. At the exit of the conveyor, each tile beam is lifted at its third points and placed in a compartment of a magazine car. The beam is centered in the compartment by small plastic spacers.The magazine car holds 10 such beams.

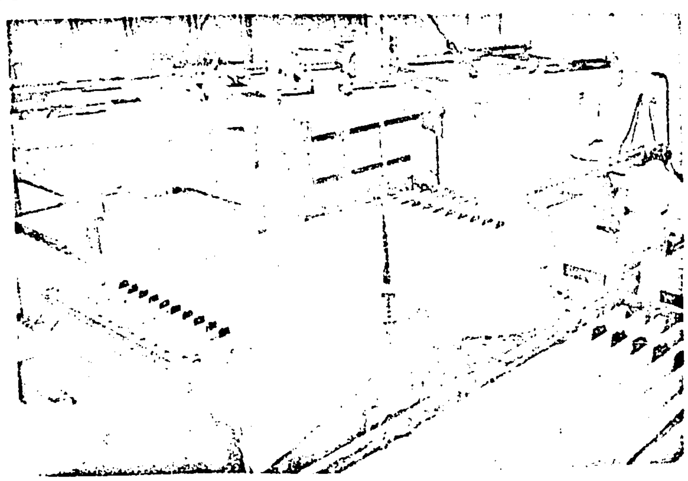


Fig.14 Magazine Car Showing Compartments in which Planks are formed

After positioning a top framework on the magazine car, the car is moved to a grouting station, where a water gypsum mix from a program-controlled mixer is flooded into the magazine and thus around the tile beams. This, in effect forms the planks. The bottom of each compartment and the top framework are so formed to provide the tongue-and-groove contours necessary for fitting the planks together to form walls.

After swinging,the ends of the car open, the planks are lifted with the aid of a harness and moved to a dryer. This operation to this point takes about fifteen minutes.The planks are cured in the dryer for six hours.(2)

Fig.15 Bundled Panels in Storage

9.3 The Montage-Bau System (West Germany)

The Montage-Bau system was developed be the "Institut fur Zeigelforschund" at Essen, Germany. This is a research intitute supported by the German Clay Products manufacturers, and is responsible for some of the more advanced work in Europe. Many new brick and tile shapes have also been developed.

In the development of the Montage-Bau system, flexibility appears to have been a prime consideration. The wall elements have a facade of full-size facing bricks, or brick-shaped tiles about 1¼ in. thick. Backup material is of structural tile, which is strong enough to take the design load of the wall. Floor elements consist of multi-cored structural tiles which are flanged to provide linear spaces in which reinforcing rods are placed and concrete is poured. Prestressing is sometimes employed in floor and roof elements.

A laboratory building at the Institute was constructed in 1962. The brick used in this construction was patterned in stack bond, which seems to be the most popular type. The building has a very good appearance and is said to have no maintenance problems. Mortar joints are smooth and even. Vertical joints between panels have been grouted and have had a rubber-like caulking compound applied on the outside. The joints are reported to be satisfactory in all repects.

The roof was made from prefabricated tile elements which were constructed in the same manner as the floors. However, lighter tiles were used in this instance.[2]

A) Manufacture of the Elements

Elements are constructed upon any flat horizontal surface. In the case of brick-faced wall panels, a grid of rubber for spacing the bricks is first fixed to the platform. A form frame of appro-

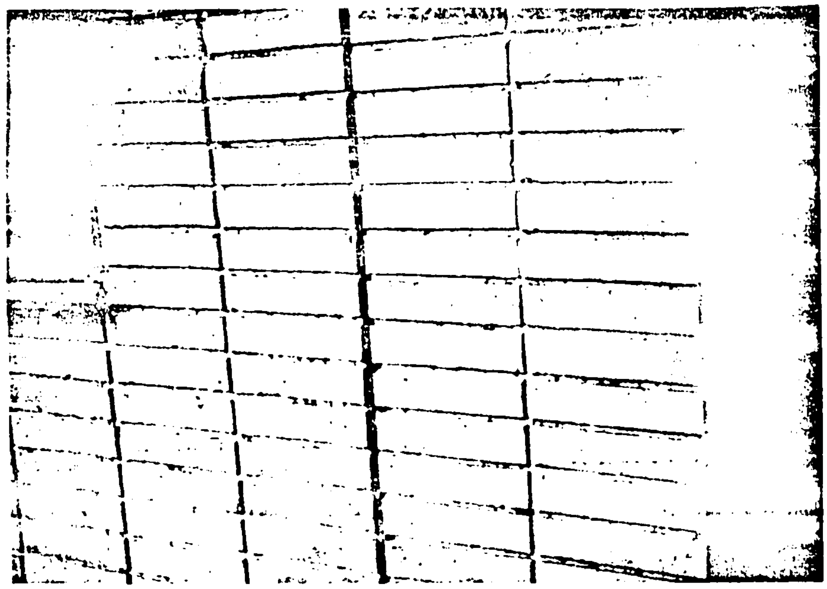


Fig. 16 Montage-Bau Element, Showing Vertical Joints

priate dimensions is then positioned and brick laying can begin. Window and door frames are installed if necessary. After placing the bricks a 1:3 cement sand grout is poured and spread by brushing to fill in the spaces. A sufficient amount of grout is applied to cover the backs of the brick to a depth of about ½ in. the structural tiles are then placed in this wet grout, which, when dry, bonds the brick facade and tile backup together. Reinforcing is then placed in both directions in the spaces between tiles,and a fine aggregate concrete is poured and screeded level is the uppermost tile surface. This is contrast to the Costamagna elements in which reinforcing is generally used. To finish the panel, a coat of plaster may be applied. The size of Montage-Bau wall elements is limited only by the size of the crane which will handle them after prefabrication. Some panels are of 100 sq.ft., and are as much as 15 in.thick. Floor elements are also made on any convenient flat surface within a form frame. The process is simple. The flanged multi-cored tiles are placed within the frame so that the flanges abut one another. A net work of spaces to receive reinforcing and concrete is thus fashioned. Reinforcing is placed and concrete is poured to the level of the tops of the tiles.

After the floor sections are installed in the building, a layer of concrete up to 2 in. thick is poured and finished.

It should be noted that double shellsection of tile are designed to provide extra compressive strength.

Should a plaster or smooth concrete ceiling be called for, a layer of either material is first placed, the tiles are then layed in the wet substance and the procedure continued.

All openings for ducts and pipes are allowed in the floor and wall elements. Electrical conduit and service piping may be installed during prefabrication. All elements are of good appearance , however, structural tiles used as backup are in inferior appearance and quality by Canadian standards.

Both brick-shade quarry, tiles and brick soaps are being used as facade material.(2)

B) Atrium Houses Project

The architect who designed the project of Atrium houses (using Montage-Bau elements) favoured industrialized construction for his work because of the rapidity by which the job could be completed. This is an important consideration in Europe, where traditional construction of detached houses is very slow. Up to 18 months might be required to complete one house,depending on the number of men employed on the project. It is thus impossible to guarantee contract prices as wages and materials costs can increa-se during thelong construction period. With prefabricated elements similar detached houses can be completed in three weeks. While the price of the house is not normally lower, it has the advantage of being fixed for the duration of the profect.(2)

B) Methods of Prefabrication

The factory employs two methods of prefabricating wall elements. The terms used for designating these methods are "negative" and "positive" methods.

In the positive system the breaks are placed in the rubber grid within the form frame and the other materials placed in order.

In the negative system, the interior face of the wall, which may be concrete or plater, is cast or poured first and, after the structural tiles have been placed, the facade material, usually brick-shaped flats, is placed last. Load-bearing exterior wall elements 12 in. thick,manufactured by the positive method, are produced at a rate of approximately 7.8 sq.ft. per man-hour. Productivity for similar elements using the negative method is said to be 5.1 sq. ft. per man-hour.

The cost of a 12 in. thick element, erected, was given as $1.87 per sq.ft., compared with a 9½ in. thick wall built traditionally at $2.13 per sq.ft. The largest element manufactured for the Atrium Houses measured 8 ft. 9 in. wide by 8 ft. 6 in. high and weighed 7,500 lbs.

Floor elements 8 in. thick, 16 ft. long and 7 ft. wide were manufactured and erected at the rate of 7.7 sq.ft. per man-hour. The comparative cost of a similar floor using traditional mathods was said to be $1.00 per sq.ft. including form work, installation and removal.(2)

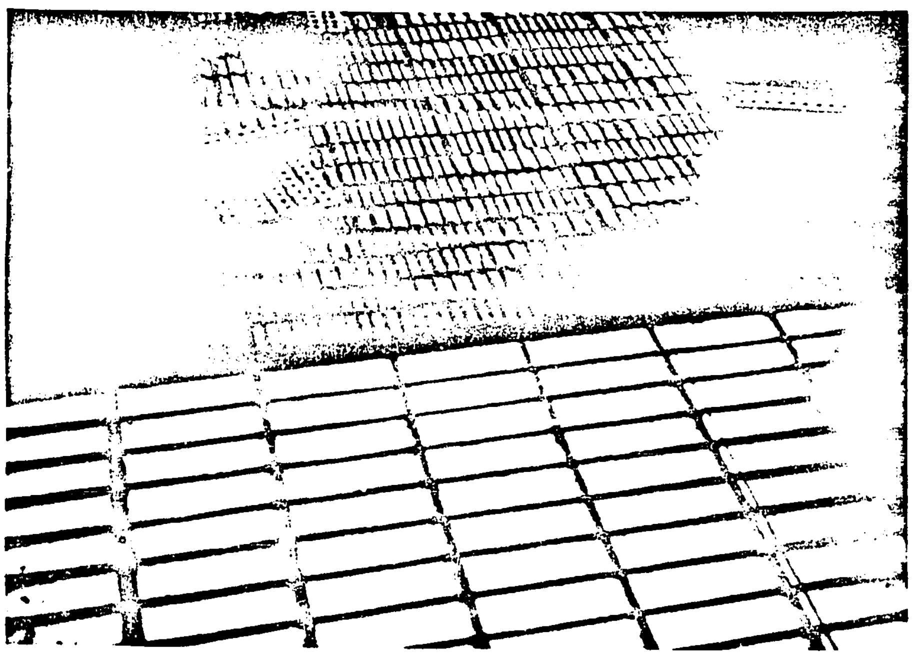


Fig.17 Manufature of Montage-Bau Element by Positive System

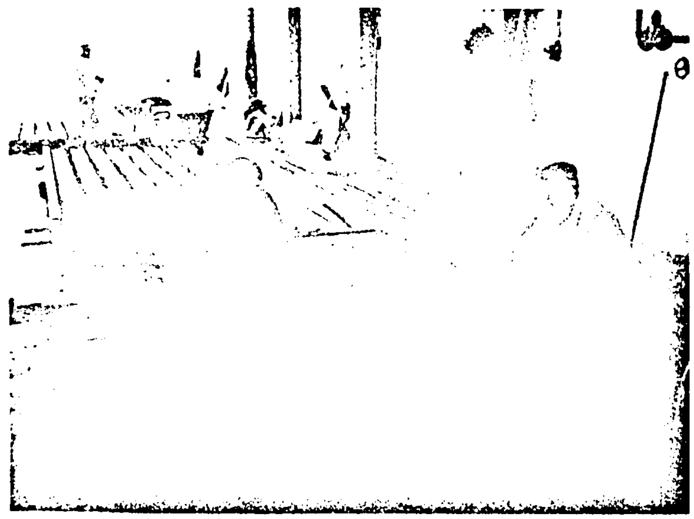


Fig.18 Manufacture of Montage-Bau Element by Negative System

9.4 The Montage-Tegl System (Denmark)

The Montage-tegl system was developed on the initiative of a consortium of five Danish brick manufacturers in the south Zealand area. The consortium supplied the capital, engineering and technical knowledge for the design and establishment of a plant to produce load-bearing brick-faced elements.

Montage-tegl elements consist of an exterior wythe of brick and, an interior wythe of reinforced concrete which may be dense or semi-leightweight. Fiberglass insulation batts are sandwiched between the two wythes.

Brick for the panels is specially made having a central U-shaped groove at the back. The access of groove is at right angle to the length of the brick. The purpose of the groove is to allow for the installation of the ladder-type reinforcing wall ties which bond the brick wythe to the concrete wythe. It is interesting that the cross ties of the reinforcing are of stainless steel. The fiberglass batts are specially cut to fit between the ties.

The elements may be from one brick width to a maximum of 6 ft. wide. The heights vary according to design requirements, the common size being $8\frac{1}{2}$ ft. high. Elements 30 ft. high have been produced. The overall thickness is standard at $7\frac{1}{4}$ in.
Brick spacing is facilitated by means of a wooden grid which may be hydraulically lowered on to the table. After placing the bricks the grid is raised to allow the table to be moved to the mortar grouting station.

A) Manufature of Elements

Montage-tegl elements are made in a series of steps as follows:

1) Remove any extranious matter from table deck.
2) Sprinkle a sawdust-oil mixture on the deck to prevent mortar adhesion.
3) Move table forward to brick placing station.
4) Lower guide grid and place bricks. Stack bond is the predominant type but, other bond patterns are possible.
5) Move table to mortar grouting station.
6) Place measured amount of mortar grout and level to a depth of about one quater inch over back of bricks.
7) Place ladder-type reinforcing wall ties in the wet mortar.
8) Lay fiberglass batts between wall ties.
9) Pour concrete directly on fiberglass, inserting lifting-bolts and reinforcing rods as pour is made.
10) Level concrete and finish float. The top of the sides of the table are used as guides in this operation.

11) Transfer table to steam chamber.

    The elements remain in the steam chamber for a minimum of 4 hours at 140 degrees F and 100% relative humidity.

12) Remove table from steam chamber and tip element to A-frame.

13) Clean excess or overflow mortar from elemant and place in storage.

The mortar used is a straight 1:3 cement-sand and water mixture of the consistency of thick cream. The concrete has a strength of about 2,500 psi and contains 3/8 in. aggragates.

Elements have generally fair appearance but, because of the flush untooled joints and, some variation in brick size, they are not considered as acceptable be Canadian Standards. It would seem that this difficulty could readily overcome by the use of a rubber grid or other spacing device.[2]

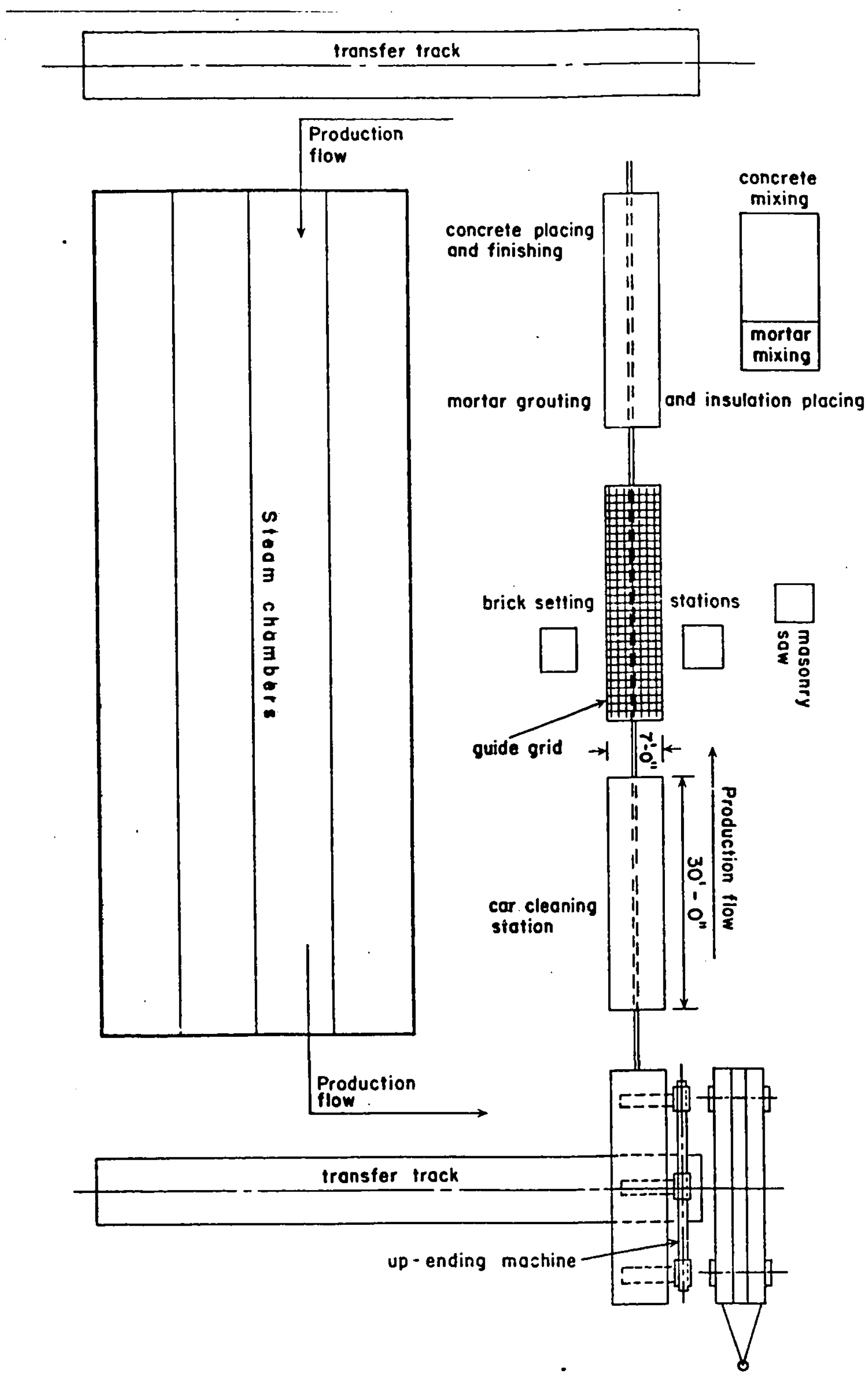


Fig. 19 Production Flowsheet and Schematic Layout of a Plant for Montage-tegl Elements.

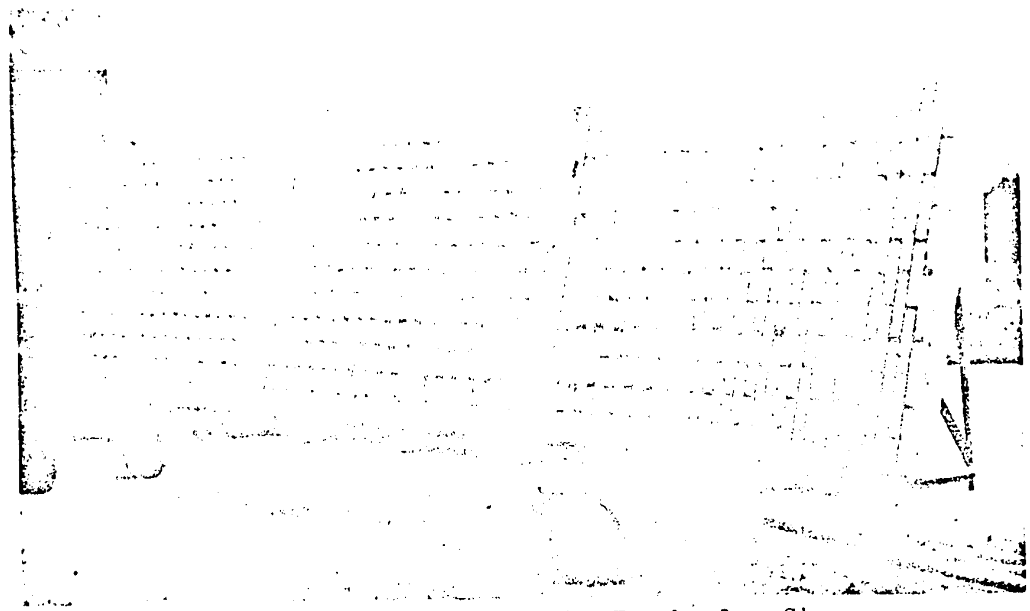


Fig.20 Montage-tegl Elements Ready for Storage

9.5 The Kornerup System (Denmark)

The aim of the Kornerup system is in part to move the process of bricklaying from the exposed work environment of the construction site to the controlled environment of a factory building.

Kornerup elements are of the cavity wall type. They are not insulated, although a poured-in-place type of insulation could be used effectively and without difficulty. Standard bricks, used for both wythes and for the returned ends, are built by skilled masons upon a precast concrete sill. This sill remains an integral part of the element. An angle-iron jig, ressembling the corner pole type jigs in common use in North America, is used to facilitate the bricklaying process.Figure 21 shows the elevation and plan of ornerup panel.

The approximate dimensions of the element are as much as 6 ft.6 in.

by 8 ft.6 in. high by 10 in.thick. They conform to the widely accepted 10 centimeter module, both in brick size and in over all dimensions.

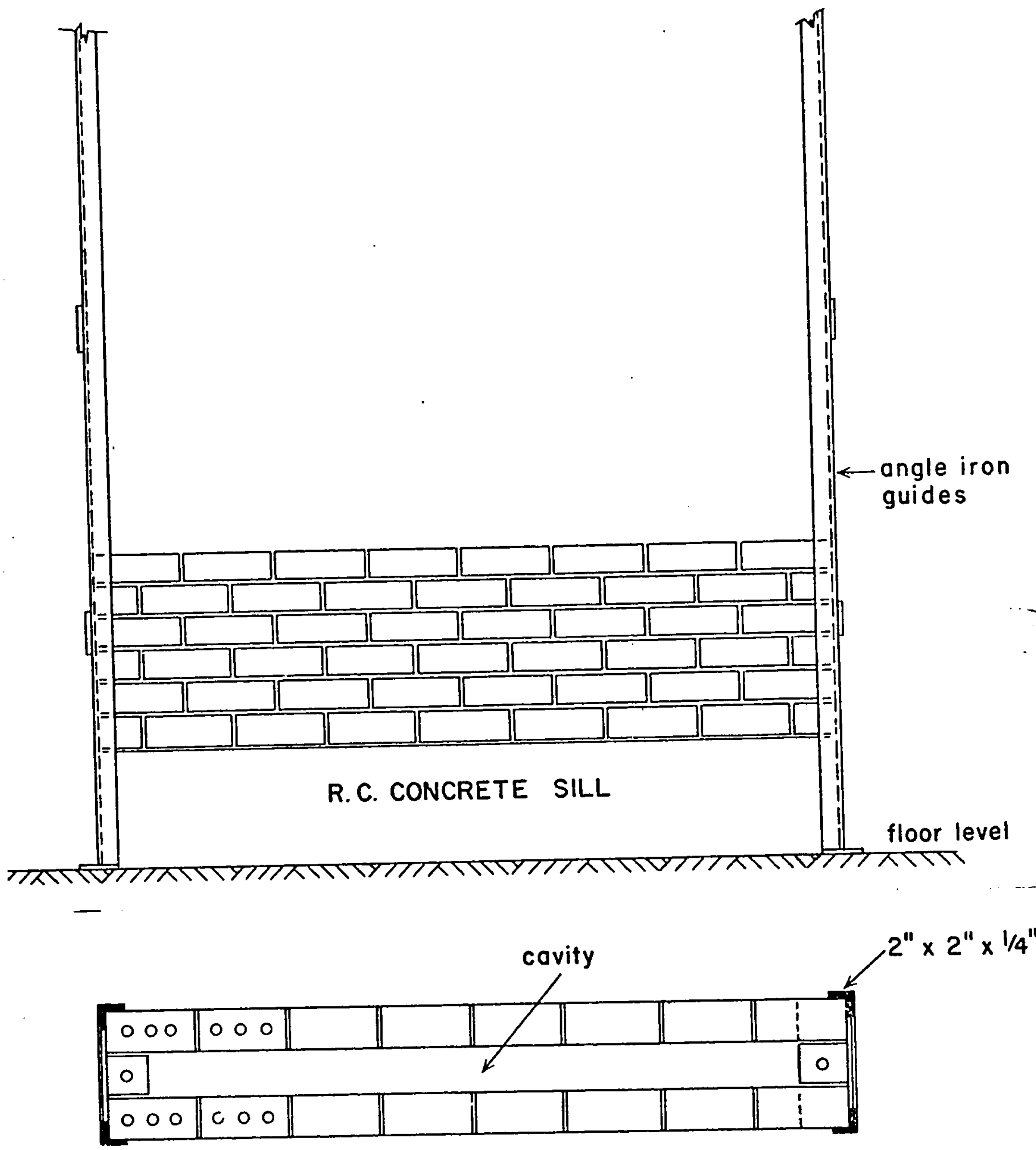


Fig.21 Elevation and Plan of The Kornerup Panel
Showing the Guide Frame.

Installation of Kornerup elements should, for their greatest exploitation, conform to a system where window frames are of the same height as the panels, i.e. storey height. If so planned, elements of appropriate height could be installed underneath smaller windows, in such case, the width of the window should conform to the width of the element. The utilization of the kornerup system is more convenient when the building is designed to conform to a modular grid and to incorporate modular components. The kornerup system requires little in the way of expensive equipment for its efficient utilization. Apart from elevating scaffolds the normal building site material-handling facilities are all that is necessary. Capital expenditure can thus be kept to a minimum.

The Kornerup system has been used on two large housing projects and a large children's hospital near Copenhagen.

In the production process, the mason is continiously supplied with brick and mortar. A scaffold, which moves vertically, maintains his relative position to the work at about bench height, so that a minimum amount of bending and lifting is involved. In this way, a high productivity can be acheived. Plumbing, heating and electrical facilities are incorporated in the elements during fabrication. The elements are lifted to storage or to final location by a tower ceane. A special rigid angle-iron frame is used for this purpose. Paint can be applied to the brick on the inside of the walls.

The elements are joined together simply by butting and grouting, with a wall plate beam being used to tie the elements together at the top. This method appears to leave something to desire,since some cracking has taken place in structures constructed by this system. The cracking was not extensive however, and only a few of the joints were so damaged. The damage is more pronouced at the corners.(2)

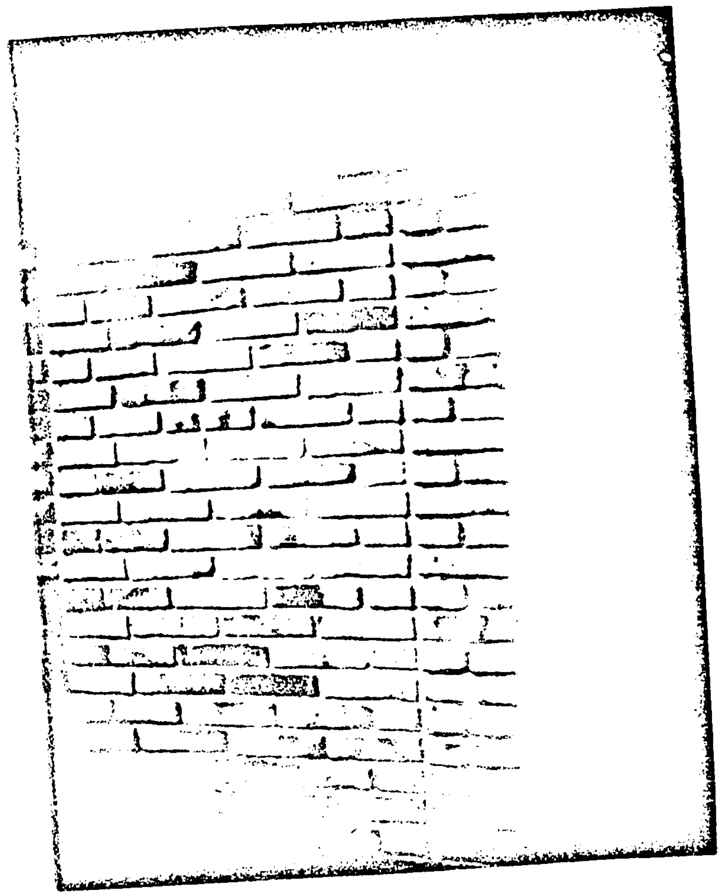


Fig.22 Exterior Corner Details in the Kornerup System

9.6 The Tegelelement System (Sweden)

The tegelelement elements, also called Tecab elements, are of the "sandwich"insulated type, having an exterior wythe of facing bricks and an interior wythe of structural tiles and a layer of fiberglass insulation in between. They are similar in many respects to the montage-tegl elements, but because of the use of structural tile they contain a greater amount of structural ceramic products.

Up to the present time, the elements have only been made experimentally, but the concept has been employed in the production of very large elements at an on-site factory near Uppsala. Some of these measured 26 ft. by 9 ft. Window and door frames may be installed and provisions for service installation are normally made in the tecab system.

The overall tecab system also utilizes prefabricated structural tile partition walls and, prefabricated brick and tile chimneys. Prefabricated floors of tile and concrete will be a feature when the system is fully developed.

Apart from the Uppsala project, which involves the construction of a large number of four-storey apartment buildings, elements produced in a laboratory have been used in the construction of six houses near Stockholm.

Brick used in the tecab system are specially formed having a U-shape groove across the back at right angles to, and the mid-point of the length, and with the back corners so formed that the bricks are placed, additional U-shaped grooves are formed at the vertical joints. This facilitates the development of almost any bond pattern in the element. During the experimental development, a number of methods of spacing the brick prior to grouting have been used.[2]

A)Method of Spacing the Bricks

1) The bricks are placed in a soft foam latex in the desired pattern. When the late stiffens it forms a mould for positioning of bricks in subsequent elements.

2) The bricks are placed in a warm liquid parafin wax. The wax is allowed to harden and, the bricks are thus held in position for grouting. The wax is removed from the finished element by scraping and washing with hot water and steam. A novel convex mortar joint, attravtive appearance are produced in this way.
3) Bricks are placed in a rubber grid which is fastened to the deck of the bench car. The pattern of the grid determine the bond pattern of the bricks.[2]

B) Method of Manufacture of Tecab Elements

The method of manufacture is essentially similar to the montage-tegl method. Briefly the program is:

1) Bricks are placed on the deck of the hinge-sided table in the desired bond pattern and grouted with 1:3 cement-sand mortar.
2) Ladder-type reinfircing wall-tie material is placed in the wet grout now filling the U-shaped grooves at the back of the bricks
3) Fiberglass batts,precut to size, are laid between the wall ties. This fiberglas is sufficiently rigid to sustain the weight of the tile and cement wythe.
4) Structural tile, usually lightweight from sawdust burn-out, is laid on the fiberglass in such a way that the reinforcing wall ties enter into the vertical joints between the tiles. The tiles are spaced about one inch apart in both directions.
5) The tiles are grouted in place with cemnt-sand grout, which is leveled and floated.
6) After a suitable period, a thin coat of finish plaster may be

applied.

It is noted that the longitudonal side of the bench car have small holes (5/16 in. diameter) situated opposite each other, and at the correct dimension from the tops of the sides. A $\frac{1}{4}$ in. pencil rod is inserted through these and underneath the top tie of the ladder reinforcing. This has the effect of holding the reinforcing in place while the batts are laid and the tiles placed. The pencil rods are withdrawn immediately after the grouting of the tile.[2]

C) Joining of Elements and Production.

The method of joining tecab elements is interesting. When they are side-butted on the foundation beam, the interior wythe of the elements are designed to be in close contact. The exterior wythe should be the thickness of a mortar joint apart. Special glue is used to join the interior wythe. Mortar grout is applied in the exterior joint. These joints appear to be very satisfactory and quite precise on the inside of the wall. The wall plate beam effectively holds the tops of the elements in alignment.

A new factory which employs the tegelelement system have been constructed and, produces about 10,000,000 sq.ft of elements of all types per year. Exterior elements are produced up to three storeys high and, up to ten ton in weight. Partition, floor and chimney elements are also produced. The factory is highly automated; all brick placings are done by mechanized means. Mortar mixing is programmed and material handling and flow are carefully controlled.[2]

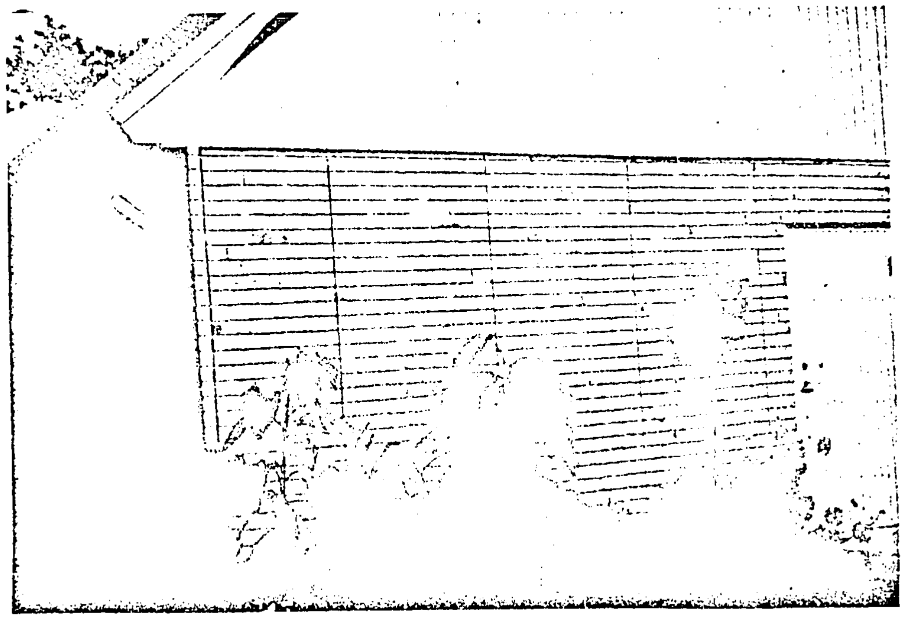


Fig.23 House Built with Tecab Elements
Note Thin Vertical Joints Between Elements

9.7 The Preton System (Switzerland)

The ease and flexibility of the production of the elements and their application to a single house project or,to a group of houses or apartments make the Preton system an interesting one. In addition, the full strength characteristics of the structural ceramic product are utilized and a minimum amount of reinforcing steel is required. Chimney sections and components are also made by Preton.

Equipment in any Preton factory consists of flat, almost vertical surfaces of concrete or asbestos board, about fifty feet long by ten feet high. These easel-type surfaces are marked with courses lines to facilitate the laying of the brick. The height of the element is thus determined according to its number of courses. The width is established by movable vertical wooden forms, which are clamped to the easel at the appropriate position. All elements are made to shop drawings. Electrical conduits, plumbing pipes and windows, doors or other openings may be incorporated, but window and door frames are not normally installed at the factory.(2)

A). Description of Elements and their Manufacture

Preton elements have been made at Paradies to a maximum length of 5 metres by 3 meters high. Longer ones have been made in a new plant.

The bricks, from which Preton elements are made, are specially designed to suit the system. They are multi-cored, having a large center core measuring 2 in. by 1½ in. and, a slot at each end measuring 1 in. by 1½ in. When the bricks are laid in common bond the cores and slots form vertical chases suitable for pipe runs and conduits.

Manufacture of elements is essentially a manual operation. To commence, a course of bricks is laid at the base of the easel on a right-angled ledge. A cement mortar grout is poured on top of the bricks by one labourer while another places the course of bricks, and so the process continues to the completion of the element. Mortar is placed on the bed joints only; the vertical joints remain "dry". The elements are reinforced by two ¼ in.pencil rods between the first and second courses. Lifting bolts, situated at the third points, extend from the top to the base of the element through the vertical course and are grouted in position. The lifting bolts which are $\frac{1}{2}$ in. in diameter, may be considered as vertical reinforcement. Stirups necessary for joining the panels in the building are installed during the prefabrication process. Portable scaffolds, moved into place manually, are used to place bricks above the five foot level.

Elements are moved into storage about 12 hours after completion. Overhead cranes will be employed in a new plant for this purpose, but the operation is presently performed by forklifts having a special lifting harness.

Preton elements are not usually plastered or otherwise finished in the factory. They are generally used as load-bearing elements and, are finished in place.(2)

Figures 24 and 25 show front and rear view of finished elements.

B) Productivity

It was reported, that a productivity of 25 sq.ft. per man-hour had been acheived in the prefabrication of a sizable number of large elements. Productivity is naturally related to the number and size of the elements to be made against an order. If, for example, a large number of small elements is required, productivity will tend to be low. Conversely, the manufacture of a sizable number of large ones will a lightly higher rate of productivity.

The preton system has been used to construc all types of dwellings from single and two storey houses to, ten storey apartment blocks. The system is often augmented by the "Stahlton" system for floors. It is reported that preton elements have been used in the construction of high-rise buildings, which embody the concept of engineered load-bearing masonry. In this connection, the cost of panelized load-bearin walls is about five per cent higher than traditionally built walls. Erection of the building, of course, is considerably faster.(2)

9.8 High Speed System Building Ltd. (England)

The Sir Lindsay Parkinson organization is the principal licensee in England od the H.S.S.B. system. Under the name of S.L.P. Industrialized Building ltd.,a new factory capable of producing elements for 1500 apartments or single houses per day have been built.

This sytem originated in England during the late1930's. In 1945 rights to it were acquired by N.V. Nederlandsch Bouwsyndicaat, Brinkhorstlaan 309, Gravenhage. The system has been re-imported to England through the agency of Mr.Eugen Spier, who maneges the the overseas licencing of the system for the Dutch Parent Co. H.S.S.B. incorporates elements of several types. For example, precast stairway elemets and load-bearing partitions are made from reinforced dense concrete. Non-load-bearing elements utilize bricks. These are of the cavity wall type; the exterior wythe is of brick and the interior of semi-lightweight reinforced concrete.(2)

A) Description of H.S.S.B.Elements and their Manufacture

Full size H.S.S.B.elements are of half storey height and are of ten feet six inch in length. The usual bond pattern is"Half-stretcher" but any desired bond pattern may be acheived by modi-

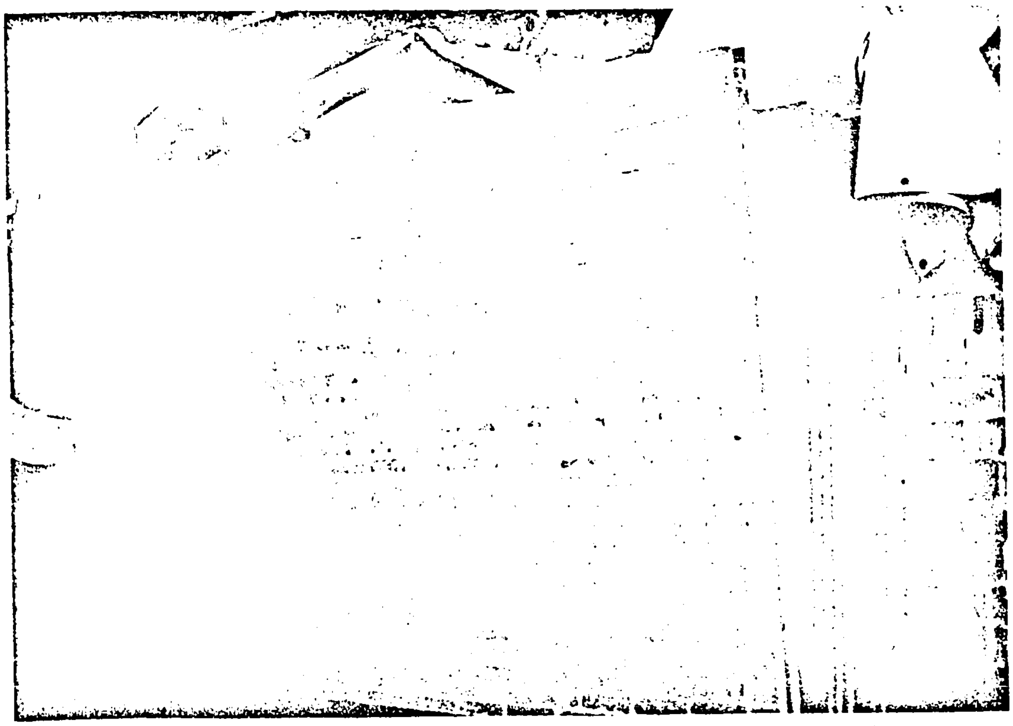


Fig.24 Front View Of Face-Brick Preton Element

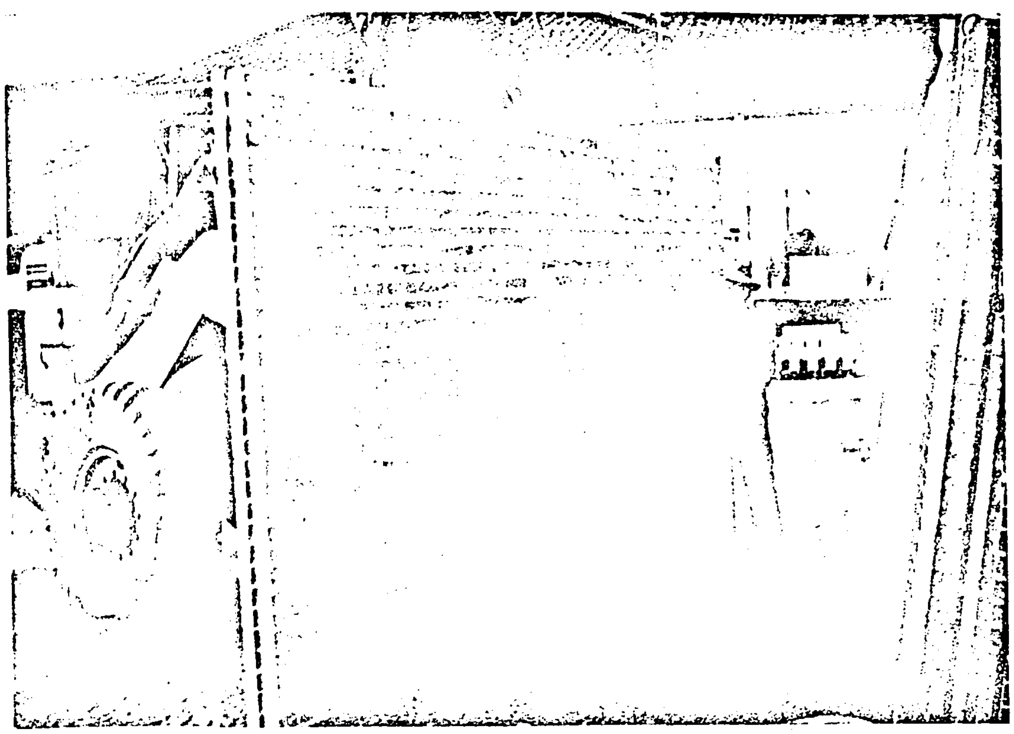


Fig.25 Rear View of Face-Brick Preton Element

fication of the bench car grid upon which the elements are manufactured. Smaller sizes are produced by blanking-off part of the bench car as shown in Figure 26.

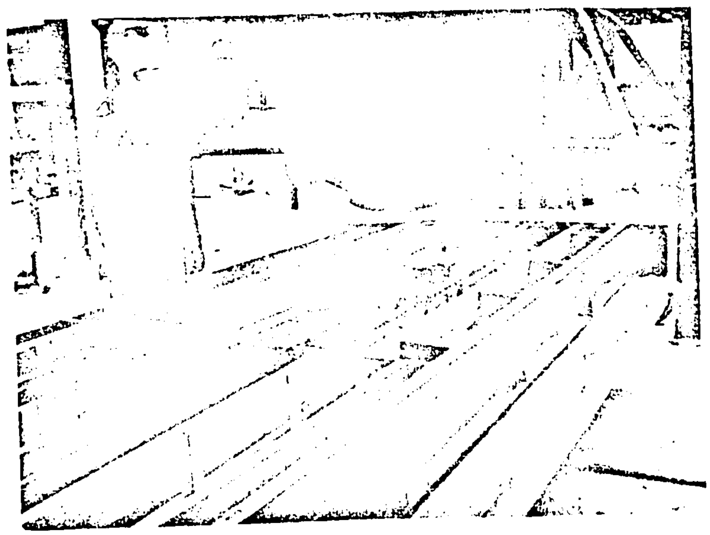


Fig.26 Bench Car with Blanked-off Sections to Porduce Special Size Elements

The bench car are of the size conforming to a full size element. They have a grid deck of cast iron, which incorporates individual spaces, into which the bricks are placed, as shown in Figure 27

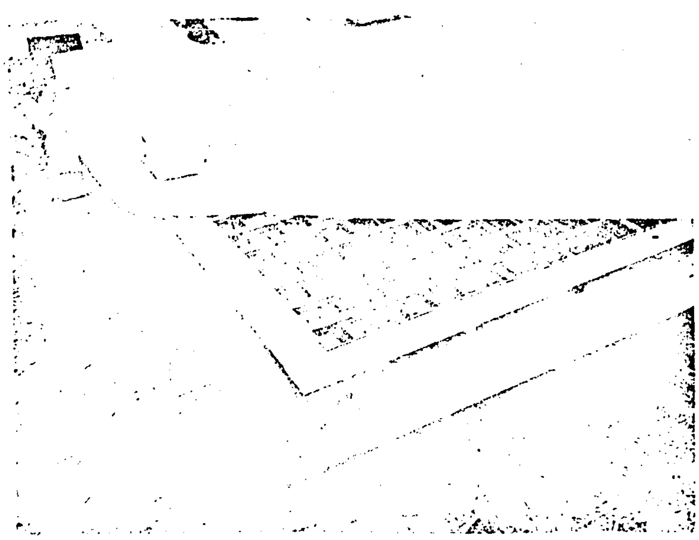


Fig.27 Detail of Grid Deck of Bench Car

The depth of the cars sides conforms to the thickness of the element. They are easily separated from the car deck to facilitate removal. The sides also have narrow ledges which support the temporary form work upon which the interior wythe of concrete is poured.(2)

B) Steps in the manufacture of an element

1) Clean bench car of all adhering mortar.
2) Place bricks in individual spaces of grid.
3) Pour a measured amount of mortar over the backs of the bricks and spread evenly.
4) Move car to vibrating table and vibrate mortar into place.
5) Move car to concrete placing station.
6) Position wall ties (3/16 in. by 1 in. galvanized steel).
7) Place formwork on side ledges and place reinforcing steel.
8) Pour non-slump semi-lightweight concrete and spread level.
9) Finish by rolling to the depth of the car side. The tops of the car are used as guide in this operation.
10) Transfer car to open steam chamber for curring.
11) After curring, tip car into upright position, open sides, remove forms and lift panel free.
12) Wash panel with mariatic acid and place in storage.

Figure 28 shows a finished H.S.S.B. element.

At the end of the manufacturing process, the elements are ready for placing in the wall. The interior of the element has a surface smooth enough for wallpapering. If a painted wall is required, a thin skin of gypsum plaster is applied on site.

Fig.28 Cleaning and Touching-up Finished H.S.S.B.Element

This entire process is of the production circuit type. The cars run on rails, and are moved manually and, return on trackage to the starting point. Great care is taken in the quality control of mortar and concrete in the manufacturing process. Automatic mixing equipment of sophisticated nature is usually employed.[2]
The relatively heavy wall ties have a three-fold purpose. First, to tie the two wythes together; second, to maintain the relative position of the wythes,should these be subject to oblique stresses such as might be substained in placing the element on an uneven surface; and third, to act as suitably strong bars by which the element may be lifted.
The low pressure steam chambers are maintained at a temperature of between 100 degrees F and 120 degrees F, at relative humidity of 100%. Element remains in the chamber from six to twelve hours. H.S.S.B. factories, being integrated facilities where the various system components are produced, do not lend themselves to produc-

tivity study to one componet only. Under conditions of full production, it is claimed that 9.5 sq.ft. of finished exterior wall elements can be produced per man-hour. It is reported that a 88.8 man-minutes are required to place such an element in the wall. A crane, crane-driver and three semi-skilled workers normally make up the team for the positioning of elements.

In assembly, the elements are positioned upon a bed of cement mor- tar, and the vertical joints are made by grouting. Vertical groo- ves are somtimes provided in the ends of both interior and exte- rior wythes of the facade elements, to recieve the grout and, also for the installation fo reinforcing which ties into the joints between the floor and load-bearing partition elements.

Mortar joints and brick disposition compare favourably with good quality Canadian brickwork. The cavity wall construction widely used in Great Britain does not appear to possess sufficient heat insulation quality to meet Canadian requirements. This could be readily corrected by the application od a "pour" type insulation on site.

Figure 29 shows a typical section of a room.

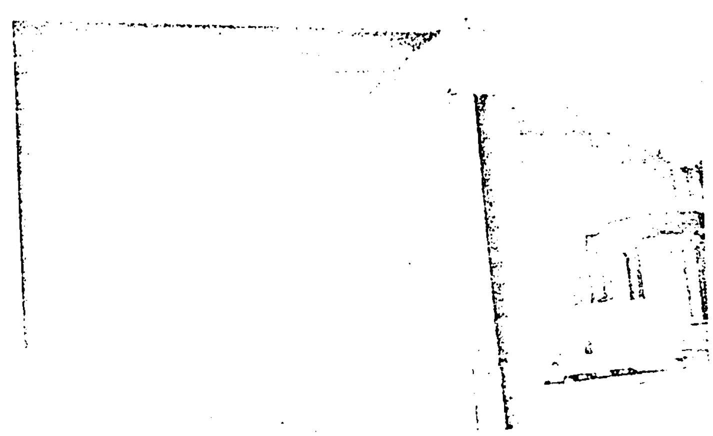


Fig.29 A Typical Section of a Room

10. CANADIAN AND AMERICAN SYSTEMS

Prefabricated masonry panels were introduced four years ago by the firm of L.E.Shaw in Halifax. The Canadian Structural Clay Association and the Department of Industry have for the last five years been involved in a joint research program to develop a system of prefabricated brick walls.(4)
The system is a prototype stage and is being patented and evaluated for adoption by some manufacturers.

10.1 The CSCA/PAIT Project

The Canadian Structural Clay Association has developed a viable system of prefabricating structural wall panels in 1970. The manufacturing technique makes use of horizontal casting on a tilting table designed to roll off the panel in a vertical position. while the mortar is still fresh, before reaching initial set. High productivity has been acheived by developing a mechanized setting station for loading the casting table. This consists of a movable table which supports the panel form or jig in which the bricks are set. The whole form is then transferred to the casting table by a motor driven pusher. The form or jig consists of a frame made of structural tubing which can be assembled very quickly. The bottom consists of a steel sheet on which a spacing grid is attached. This grid consists of closed cell neoprene sponge strips, 3/8 in.wide, cemented to the sheet to form the bond pattern desired. The steel plate and grid are peeled off the face of the panel as it is rolled off the casting table and to the curing rack.

It is considered to standardize on a modular panel, either four or five sheet wide. The height may be varied as required. The basic panel is 4 in. thick with a 3/8 in. recessed joint and a maximum of 3/8 in. mortar finish on the back side of the panel.

All panels are load-bearing, and may be made of any modular brick with a nominal thickness of 3 in., 4 in., 6 in.,or 8 in.

Steel reinforcing, lifting rods, and inserts for structural connections, are installed as required bythe structural design of the building.

Corner panels and also panels with ribs for lateral support have been developed.

The investigation and development work on this project indicates that the initial introduction of a Brick Masonry Wall Panel in Canada should be limited to a standard modular elements in assembling a buildint or other structure.

It is also important to take advantage of the high strength of prefabricated brick panels and to use them as load-bearing walls.[4]

A) Panel Design and Engineering

The basic panel is modular in size, 4 in. thick and nominally 4 ft. wide by 8 ft. high, less the thickness of one mortar joint.

With the present equipment , this size may be varied to make 5 ft. wide and any length up to 10 ft. 6 in.

Uniformity and size control is obtained by placing the brick in a grid of the desired pattern. This grid forms the bottom of the jig and consists of sponge neoprene strips cemented to a 26 gauge steel sheet.

The brick must first be wetted to give the optimum rate of suction to suit the type of mortar that will be used. The bricks are then placed face down, in the grid, spaced approximately 3/8 in. apart. This arrangement forms a recessed 3/8 in. joint. A semi-dry or damp mortar is first placed into the joints to a depth of 1/4 in. to 1/2 in. Steel reinforcing is then placed running through the core holes of the brick. Two 3/8 in. bars and three 1/4 in. bars are used in each panel as vertical reinforcing. Half inch threaded ferrule inserts are welded to the 3/8 in. roads as connections for lifting the panel in storage and for erection on the job site.

The joints are filled with a type "S" mortar grout, while the table is vibrated, in a horizontal position. This ensures that all core holes as well as joints are completely filled. The back side of the panel is finished with 1/4 in. to 3/8 in. of mortar, to give a plain surface suitable for insulation and/or interior finishes.

Ferrule inserts of the same type that are used for lifting the panel may be placed on the back side. These inserts have a loop that goes around the 3/8 in. bars and therefore make a very strong connection for supporting the panel and fastening to other elements in the structure.[4]

Figure 30 shows a Typical Modular Panel.

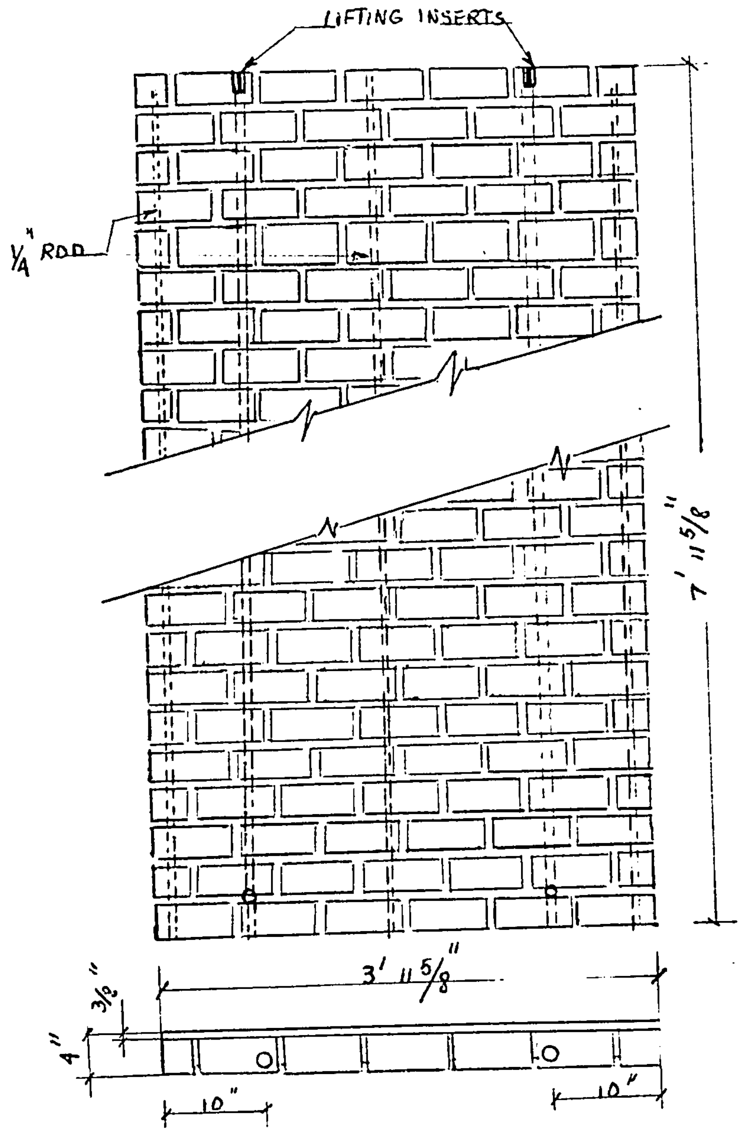


Fig.30 Typical 4x8 ft. Modular Panel in Running Bond and 3/8 in. Strip joint

B) Mortar

The mortar used in this development work has been standard mixes of Portland Cement, Hydrated Lime and Sand.

The system is not limited, however, to any type of mortar, although tests have indicated that it is desirable to use a mortar that will develop a relatively high bond strength with the brick used. "Sarabond" mortar additive may be used where very high strengths are required.

The semi-dry or damp mix first packed into the joints is type "M" mortar.

The proportions by volume are:

Portland Cement	1 part
Hydrated Lime	¼ part
Sand	3 parts

A typical batch, by weight, required for one 4 ft. x 8 ft. panel is as follows:

Portland Cement	5.0 lbs
Hydrated Lime	0.75lbs
Sand	15.0 lbs
Water (approx.)	2.5 lbs

Approximately 3/4 lbs of damp mix is required per sq.ft. of panel.

The grout is a type "S" mortar. The proportions by volume are:

Portland Cement	1 part
Hydrated Lime	½ part
Sand	4 parts

A typical batch by weight, required for one 4 ft. x 8 ft. panel is as follows:

Portland Cement	100.0 lbs
Hydrated Lime	22.5 lbs
Sand	366.0 lbs
Water (approx.)	84.0 lbs

The previous quantity is sufficient to include a 3/8 in thickness of mortar on the back of the panel.

The flow or viscosity of the grout must be adjusted to suit the suction rate or I.R.A. of the bricks. This relationship must be carefully controlled if maximum possible productivity is to be acheived. There are two ways of controlling this relationship:

1) If the bricks have a high rate of suction, they should be wetted to reduce the I.R.A. to the optimum of 15 to 20 grams, or approximately 2/3 of the 24 hour absorption. When the suction of the bricks has been adjusted in this way, the grout should have a thick creamy consistency with a water content as given in the previous typical mortar batch.
2) If the bricks have a medium rate of suction, no wetting is required, but, a light spray of water may be applied on the back side of the panel before pouring the grout.

Bricks that are vitrous with I.R.A of less than 5, require a mortar with a flow equivalent to the consistency of that used for hand laid masonry.

These relationship of brick suction and mortar grout viscisity must be determined experimentally for whatever brick is used.(4)

C) Reinforcing

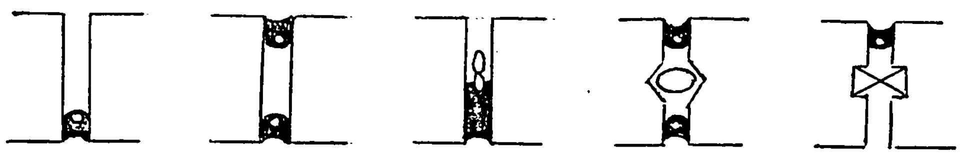
Reinforcing in the standard panel is limited to the requirement for handling and wind load design. The 4 ft. wide panel have vertical reinforcing consisting of two 3/8 in. steel bars running the full height of the panel. A 1/2 in. treated ferrule insert is welded to the top end of the 3/8 in. bar and set flush with the top of the panel. A suitable lifting device is fastened to the ferrule insert, using a 1/2 in. bolt, which then forms a convenient and safe mean of lifting the panel in storage and during erection on job site. In addition to the 3/8 in. reinforcing bars that serve as lifting rods, there are three 1/4 in. pencil rods; one in the first core nearest each side of the panel and one at approximately the mid point.

Threaded ferrule inserts welded to a heavy wire loop, which goes around the vertical reinforcing, may be placed flush with the back side of the panel at any elevation desired for the purpose of fastening the panel to the foundation or other structural members.

It has been found that horizontal reinforcing in the joints is not necessary nor desirable for several reasons. Firstly, when using the standard modular brick laid so that three courses equal eight inches, we are restricted to a 3/8 in. mortar joint. This does not allow for sufficient mortar coverage around a 1/4 inch pencil rod to give effective bond. Secondly, they have found, in the compression tests of full size panels, that a stress concentration occurs at a reinforced horizontal mortar joint which precipitates initial failure at this point.[4]

D) Joints

It is anticipated that the rain resistance of prefabricated brick panel within the panel itself will be much more effective than average in situ brick work, because all joints in the panel are completely filled with mortar. In as much as we are here dealing with single wythe panels and not necessarily a cavity wall construction, it is unlikely that a butt mortar joint, made on site between two adjacent panels, will be adequate. We must therfore, provide for a more positive rain barrier. The sketches,in Figure 31, indicate some proven methods of doing this.[4]

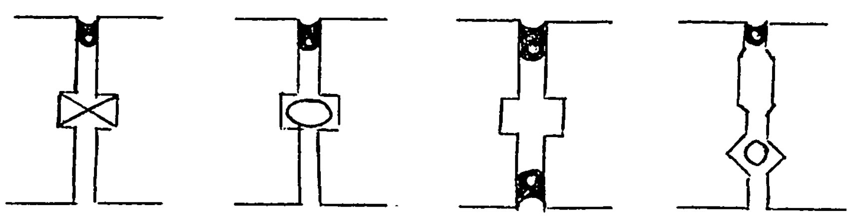


1 2 3 4 5

Suggested Vertical Joints 4 in. Brick

1 Mortar-Polyethylene (closed cell) Rod-Acrylic Terpolymer sealant
2 Mastic-Rod-Air Space-Rod A.T.Sealant
3 Neoprene Tube- A.T.Sealant
4 Mastic-Rod-Vinyl Tube in Groove Rod A.T.Sealant
5 Masic-Rod-Cruciform (Neoprene) Hold in 1/8 in. Groove

All joints employing air chamber (2,3,4,5) should be vented for pressure equilization.



1 2 3 4

Suggested Vertical Joints 6 in.Brick

1 Mastic-Rod-Airspace - Cruciform
2 Mastic-Rod-Airspace - Vinyl Tube
3 Mastic-Rod-Airspace - Rod A.T.Sealant
4 Mastic-Rod-Decompression Chamber - Vinyl Tube

All Joints Vented.

Fig. 31 Suggested Vertical Joints

E) Panel Casting Procedure

1) A first crew will place the steel sheet and spacing grid on the setting station table and, assemble the form or jig around the grid.

2) Brick are supplied to the setting station by either conveyor or on a pallet. This first crew places bricks in the grid; when all the bricks have been set up,activate the pusher on the setting station to push the loaded form on to the casting table, then return pusher and move the setting station to position No 2. The crew will repeat this procedure until seven panels have been assembled and pushed into position on casting Table No 1.

3) Setting station table is then returned to position No 1.The same crew move to Table No 2, and commence the previous procedure on Table 2.

4) Two men will follow this first crew and spread a damp mortar mix on top of the assembled bricks in each form. It is rushed into the joints between bricks, then tamped firmly into all joints.

5) A third crew follows the two men. They will move the top bulkhead rail of the jig and place the steel reinforcing and lifting rods as well as fastening inserts where required.

6) A fourth crew will have the mortar grout mixed in the surge tank ready to pump to the casting table.

7) Spread grout, vibrate the table, screed and finish the back side of the panel.[4]

IO.2 Denver Brick and Pipe Co. Manufaturing System (U.S.A.)
This company were the firt firm to make brick panels in the U.S.A. They cooperate with the Dow Chemical Co. to use Sarabond high bond mortar in the panels. Having made many conventional panels, they realized that labor-saving devices had to be developed.

After experimenting with many different existing systems both vertical and horizontal, they created a new horizontal casting system.

A mould of synthetic rubber-like material, with the desired pattern embedded in its surface, is held securely to a horizontal steel casting bed. The depressions are smaller than the actual size of the brick so that when the bricks are forced into the mould, a tight gasket-like seal is created around each brick, holding it firmly in place as well as forming the mortar joint. Reinforcing rods are placed in the holes of the brick and the mortar joints at prescribed spacings, and the grout is poured from above. Since grout is stronger than regular mortar, these panels are stronger, have better bond and are more watertight . The reinforcing rods give the necessary ductility and strength in bending that the panels require. Since the panel is open on the back or topside, conventional mortar joints can be formed on the backside simply by tooling this top surface and cleaning the excess mortar off.

The factory building is very large with a large overhead crane that services many casting beds. With this crane, the finished panels are moved to the cleaning area where an ingenious method cleans both sides of the panel simultaneously. The panels are then moved from this area to the storage area and are stacked horizontally to await delivery. The manufacturing facility at this plant has great potential in its expansion capabilities, its handling equipment and efficient layout. The company is experimenting with new mortars as well as conventional mortars and Sarabond mortar.

Two-hundred and sixty-one channel-shaped panels, 4 ft. wide by 20 ft. high by 4 in. thick, and fourty-nine curved panels, were used in the company's new factory.

The legs of the channel extend 8 in., and were reinforced to resist bending in position and mishandling during erection. These panels were designed and thoroughly tested before use.The panels were curtain or enclosure walls so that the building could be expanded at a later date re-using the panels. To create an interesting texture, the concave side of the channel-spahed panel alternated inward and outward. The panels are set on Neoprene pads and bolted to the building.

The curved panels of this project, 8 ft. wide by 20 ft high by 4 in. thick, are curved in the shape of a full sine wave with the ends flattened. These curved panels were made in a horizontal attitude by first making a curved bed lined with the same pliable mould. Because of the drastic sloping shape of the curve, another curved form was clamped on top of the bricks just prior to grouting.

This system has great potential because it can give the construction industry almost any shape and size that can be conceived and handled. It also allows a great variety of patterns, textures and shapes to be built into new walls.(3)&(5)

10.3 Summit Pressed Brick & Tile Co., (Pueblo, Colorado).
The manufacturing facility involves the use of flat-bed steel cars with wheels that roll on steel track in an endless loop. The bricks are led onto the flat bed of these cars, held in place by a vertical press reinforced with standard deformed reinforcing rods through the holes and the mortar joints and are pressure drouted. The mortar joints have the appearance of a hand-tool brick work. The panels are transported on the cars to the curing area and then to the storage yard where they are tipped up on end, and stored in a vertical position. The empty cars are then returned in the casting area to repeat the cycle again. This system is extremely new, so before the plant can go into full production, some changes are anticipated.(5)

10.4 Robinson Bricksand Tile Co.,
The panel consist of a reinforced-concrete backing with a facing of brick. Floor brick or paving brick is held in a desired position and patterned by a suitable grid and the specified thickness of reinforced concrete is poured on top of the brick slabs. After the panel is cured, it is stood up and the brick faces are cleaned of any mortar that seeped onto.(5)

10.5 Lakewood Brick and Tile Co., (Colorado)

Under the menagement of James R. Murray, this Company has developed a unique system known as "Inside out reinforced brick panel". A new type of panel utilizing unskilled labour was conceived, and, Sarabond mortar has been used. To reduce the cost of the material, very thin mortar joints, (1/8 to 3/16 in.)were used. The panels are built in vertical position using labour-saving devices and forms to eliminate the need for skilled bricklayers. The mortar is pumped through a hose and applied to each course and to the head joints through a specially designed nozzle. The bricks are then laid conventionally but more rapidly. Using special forms, different bondings and patterns can be created. The use of Sarabond mortar and high strength bricks enables relatively large panels to be made, but whenever, the structural use of the panel dictates more bending strength, a steel picture frame is placed around the panel. This is made of light-gauge steel channels or angles wraped around with brick pilaster and attached to the edges of the panel. By placing the steel on the exterior of the pilaster, it is being used to its greatest efficiency. The steel channels can be painted to create a pleasant effect of the exterior.[5]

Table 7 Production Throughout The World[5]

Country	Production 1000 sq. yd.
Bulgaria	10
Czechkoslovakia	350
Denmark	100
Finland	less than 5
France	2000
Germany	200
Holland	60
Hungary	10
Italy	50
Sweden	50
Switzerland	220
United Kingdom	10
Canada	less than 50
U.S.A.	100

11. CONCLUSIONS AND RECOMMENDATIONS

The develpmental concept of most European systems would appear to be acceptable in Canada. Significant differences could arise in the structural requirements of masonry elements for a Canadian system, since these wouls require to conform to Canadian National Building Code Standards, or to acceptable modifications or addition to the code.

European systems would benefit the Canadian construction industry in the following ways:

1)By increasing the productivity of construction labour and by utilizing this labour more effectively.

The scarcity of labour has been a mafor factor contributing to the development of industrialization of buildings in North America. In some areas od Canada, similar labour shortages are cause for serious concern and will continue to become increasingly so as the building tempo increases if the situation does not improve.The development of industrialized system buildings based upon prefabricated masonty element would permit masonry construction to become essentially a factory-based activity. Because of this, adverse effects of weather would be reduced, an important economic consideration in Canada and Europe. Moreover, the work environment would generally improved particularly from the stand-point of worker's safety.

2)By taking full advantage of the superior structural characteristics of structural clay products.

3) By meeting the increasing demand for large masonry components in comtemporary building design.(2)

A survey made in 1971 and,based on reports produced by 240 large business firms universities and governments, shows a 1½% decline in nonresidential constructions this year. According to statistics this decline will continue up to 1976.This is not the only problem facing the construction industry; fundamental problems are still to be solved.

Almost by tradition, construction has suffered from its cyclical nature and the effects have been severe.In simple labor-menagement terms, the cycles have produced instability, a frantic scrambing to recruit in times of demand and extensive layoffs in times of slack.Figure 32 shows the construction employment cycle. (6)

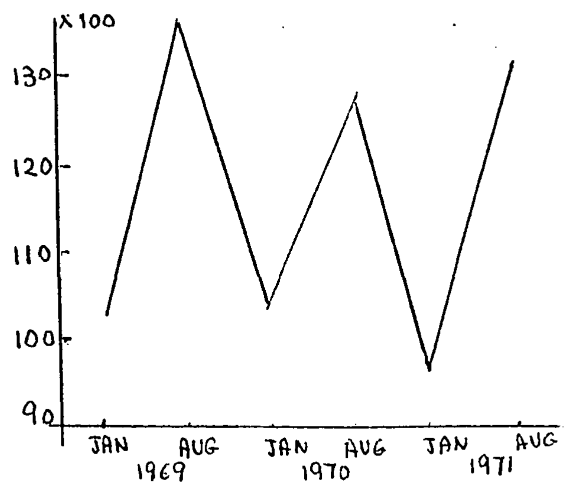


Fig.32 Construction Employment Cycle

Most of the problems concerning time,labour-shortage, workers' safety, weather conditions and variety of designs will be solved by the prefabricated brick panels.

The rapidity by which the constructions could be erected will compensate the about 18 per cent rise in the costs.

In the development of any system or systems,structural requirements should be provided for, by the application of sound engineering principle, supplemented by adequate physical testing. In this way, the restrictions of existing masonry codes could be overcome. This implies that the system and its elements would be judged on performance criteria. It also implies the establishment in Canada of large-scale test facilities, such as E.M.P.A. (The Swiss Federal Material Testing and Research Institute) in Switzerland or Centre Scientifique et Technique du Batiment de France.

The following list suggests that a Canadian industrialized building system should incorporate four functionally different types of masonry elements

1) Elements for exterior location in which the masonry units are exposed in the interior surface of the wall. These elements may be either load-bearing or non-load-bearing.

   Load-bearing elements of this type should incorporate the following features:

   a) Cost and quality of elements should be, in all respects, competitive with other panelized systems.
   b) Elements should be esthetically appealing
   c) The elements themselves and the joints between them in the structure should be weatherproof.
   d) Elements should be as thin and light as is commensurate with structural requirements.

e) Modular dimensional standard should be incorporated.

f) Elements should conform to Canadian standards for insulation fire rating and sound transmission.

g) The interior finish should be ready for decorating.

h) Design of elements should allow for the convenient installation of window and door frames, service ducts, electrical conduits and plumbing accessories.

Non-load-bearing elements for exterior purposes should have similar characteristics, but may not require insulation or have to conform to a specified fire rating. The interior finish need not be suitable for decorating.

2) Elements for exterior purposes in which masonry units are not exposed at the facade: In this type of elements,the exterior would feature a covering stucco, ceramic wall tile, glass mosaic, or other suitable material. The features of these elements would also conform to the foregoing list. They would normally utilize structural tile units to form the load-bearing medium.

3) Elements for interior partitions: These may be load-bearing or non-load-bearing.

Load-bearing partition element should, in general, possess similar features to the exterior load-bearing element. It should, however, has both surfaces suitably finished for decoration if required. It needs not be weatherproof.

Non-load-bearing partition element may incorporate these additional characteristics:

a) Lightness of weight.

b) Mobility.

4) Elements for use in floor and roof systems: These would normally use structural tile type units as the major components. The tile type units would be joint together with concrete in the same manner as the once popular tile and concrete floor systems.

The elements could be either reinforced or prestressed. They should, if possible, be room or bay sized.[2]

REFERENCES

1 Brick and Tile Engineering, H.C.Plummer, The Structural Clay Products Institute, Washington D.C., 1962.

2 Report of the Canadian Technical Mission on the Use of Prefabricated Structural Ceramics in Industrialized Building in Europe, Department of Industry, Ottawa, 1966.

3 Construction Methods and Equipments, McGraw-Hill, Vol. 52 N9, September 1970, P 116 - 118.

4 CSCA/PAIT, Structural Clay Products, Y.R.Anderson, Final Report, December 15th, 1970.

5 Sibmac Proceedings, Second International Brick Masonry Conferences held in Stoke-on-Trent, England, April 1970.

6 The Financial Post Magazine, P c.1, March 11, 1972.

7 Heavy Construstion News, Anonymous, April 19th, 1971, P 12.