THESIS

UTILITY AND ECONOMY

OF THE

REINFORCED CONCRETE

DWELLING HOUSE

For Degree oF C. E,

M. F. JOHNSON

1913

[illegible]
Title

The Utility and Economy of the Reinforced
Concrete Dwelling House.

Thesis

For

The Degree of Civil Engineer

at

The Michigan Agricultural College

1913

by

lower

Maurice F.Johnson.

THESIS

The Utility and Economy of the Reinforced Concrete Dwelling House.

The object of this thesis, is, as the title implies, to show the adaptability of reinforced concrete to modern dwelling house construction, to show some of the methods of designing and constructing, and to give a comparison of the cost of this with other house building materials.

Many of the so-called concrete houses have concrete side walls with roof, partitions and floors entirely of wood. Such buildings have few advantages over the frame structure and should not be classified as a reinforced concrete dwelling.

Experience and tests show that reinforced concrete is particularly well adapted to all kinds of construction. It is used for foundations, walls, columns, beams, floors, and for nearly every detail of construction. It is not only strong and durable but its plasticity lends it to ornamental purposes as well. It becomes harder with age, never decays, does not need repairs and be made water proof, and is practically fire proof. At present it seems to be the practical building material for nearly every requirement of building construction. It has a larger range of possibilities than any other building material. Materials for its construction are available in nearly every locality, and the fact that it can be cast into nearly every conceivable shape right on the job makes it a building material of many advantages.

For many years men have been making a study of the best and most economical house building material to secure permanency, durability, and comfort. Many materials have been tried with more or less satisfactory results but most of our house construction up to the present time has been more or less of the mushroom order and easily destroyed by fire and elements. Concrete, however, comes nearer the solution of the problem than any other material. When properly mixed and handled it should stand for hundreds of years and with each succeeding year it forms a more perfect bond the better to withstand fire, floods, earthquakes, and all conditions of the weather. Concrete is a nonconductor of heat, therefore houses built of this material will be warmer in the winter and cooler in the summer. They are also vermin proof and if properly built they come the nearest to being germ and dust proof, which should be no small item in deciding on a material for house construction. The initial cost of these houses leads one to believe that they are not the most economical. In some cases they are not, perhaps. In building houses to sell, a larger percent of profit would probably be realized from a wooden frame structure than from concrete. Where permanency is desired, however, there are several things to consider in determining the most economical material. Fire insurance, repairs, and painting should be nothing at all in a concrete dwelling, which in a few years would more than offset the actual difference in first cost. Besides this the safety of such a structure against all sorts of emergencies to one's family, furniture and valuables is a big item in its favor. There are very few, if any, disadvantages to be overcome in the use of concrete for house construction, unless perhaps it is the difficulty of securing competent and

experienced workmen, which is an item that should not be overlooked. When considered from all viewpoints, however, concrete seems to be the nearest to the ideal house building material.

Time alone can decide the style of architecture that will prevail. Concrete adapts itself to any form of plastic design and lends itself to almost every conceivable style. The more modest houses will undoubtedly follow the straight line patterns with few exterior decorations, except for vines, shrubs, etc., which lend a great deal to the beauty of concrete houses that might otherwise be plain and unattractive.

There is a wide range of possibilities in the finishimg of outside walls. Surfacing may be carried on by the use of a false partition of sheet steel held in place an inch away from the rough wall,and the space between filled with the finishing mixture. This operation is carried on at the same time that the wall is being constructed. By removing the partition before the wall sets the facing mixture adheres to the wall. The same results may be obtained by spading the concrete back from the front of the forms and introducing the finishing material which at once unites with the wall. These finishing mixtures, usually a 1 to 2 mixture, may be a plain or colored cement mortar or composed of cement and aggregates of broken stones, brick, or gravel, depending on the color and texture desired. After the forms are removed the joint marks and impressions of the grain of the wood will be retained on the wall. These disfigurements must be removed before an acceptable finish is obtained. This may be accomplished in different ways. The outer film of cement is scrubbed or brushed from the surface exposing some of the aggregate and leaving a very pleasing surface. This scrubbing or brushing must be undertaken within twenty-four hours of the time the concrete is poured into the forms, and while the concrete is still green. For this reason the walls cannot be carried to any considerable height at one operation and the forms must be so arranged that they can be readily removed. If for any reason the forms cannot be removed before the concrete is set and too hard to surface by scrubbing or brushing with a wire brush, some method of tooling the surface may be employed. Hammering, picking, and sand blasting are used to good effect. These methods require care and experience in using them. The aggregate may be disturbed by hammering or picking, while the sand blast will cut too deep in soft spots and not deep enough where the surface is harder, thus weakening the walls.

If the walls are to be surfaced by scrubbing it is customary to pour about two feet of concrete at a time, removing the forms as soon as the concrete is stiff enough to stand alone.

The surfacing mixtures may vary in color from white, obtained by the use of white cement, to several shades of gray and slate, obtained by the use of coloring mixed as follows:- The ingredients should be mixed with the cement while dry. (Any concrete excepting that colored by crushed rock will fade with age.)

In the following table the mortar is a 1 to 2 mixture:-

Material	½# per 100# Cement	4# per 100# Cement
Lamp Black	Light slate	Dark Blue Slate
Prussian Blue	Light green slate	Bright blue slate
Ultra Marine Blue		Bright blue slate
Yellow Ocher	Light green	Light buff
Burnt Umber	Light pinkish slate	Chocolate
Venetian Red	Slate, pink tinge	Dull pink
Red Iron Ore	Pinkish slate	Light brick red.

A concrete made of granite screenings and mixed comparatively dry gives a good mortar to be used in the above mentioned method of surfacing.

Stucco may be applied directly to the concrete in surfacing the outer walls. In order to secure an even color, if coloring is used, a large amount should be mixed dry and water added to such quantities as will be immediately needed. This prevents unevenness of color caused by mixing small batches. Surfaces that are floated or troweled may show slight variations in color due to differences in troweling. Freezing will change the color of stucco, as will sunlight and cloudy wet weather. Stucco should not be applied in freezing weather. If the water freezes before the cement has set the stucco will not harden.

Stucco is not the most economical surfacing for concrete walls, as much the same effects may be obtained from other methods which require less time and material and are more durable.

The roof of a concrete house should be flat. The pitching of residence roofs at a steep angle was originally to make a shingle roof rain proof. Considering the preponderence of the shingle roofs over those of any other material it is not surprising that the pitched roof should become our standard. The concrete slab roof does not require such construction. It should be pitched enough to carry off the rain and if necessary add a parapet or other architectural features. This will make it possible to use the roof much as our porches are now used. Such a roof would not be feasible with timber, but with concrete it is simple and most economical.

The concrete house, whether it has block or monolithic walls should have, not only the reinforced roof, but reinforced walls and stairs as well, and these without the wooden surface. Such construction adds to the fire proof qualities of the house and is cleaner and more sanitary. By removing the rugs the house may be flushed out with the hose, removing the dirt more easily than in any other way.

Concrete conveys the sound quite readily, so if the floors are to be used without rugs over them it is better to construct the floor by combining the concrete with hollow tile. The hollow tile are laid in rows about four inches apart and in the space between are built reinforced concrete beams. A layer of concrete is then placed over the entire surface. If a wood floor is desired wooden sleepers are embedded in the top layer of concrete to which the flooring is nailed.

For interior non-supporting walls, plastering over metal lath is probably one of the most economical methods of construction, Companies manufacturing the metal lath also make a metal studding to be used with it so no wood need enter into the construction. Two rough and heavy coats of plaster, followed by a coat of hard plaster, makes a very good partition.

The expanded metal is also used in floor and roof construction but it is not as well adapted to stress analysis as some other methods.

The metal lath may also be used for outer wall construction, but it is generally so used in connection with wooden floors and a semi fire proof construction.

To overcome the cost of constructing forms for concrete beams and floor slabs, a method of casting these structural members in standard sizes has been devised. Concrete floor joists and slabs are made and delivered by the manufacturer and set and finished by the builder. After the joists are set in place the ceiling slabs are laid on the lower bevelled flanges and the joints filled with cement mortar. The floor slab is then placed on the top flanges. In many localities, however, the expense of delivering such members would be greater than the cost of building them on the job. When the slabs and beams are poured in position, wood forms are generally used. Steel forms are obtainable for such work but they are more economical where they can be taken down and used several times. The forms for floor slabs and beams must stay in place until the concrete is thoroughly set, and in many cases it would be desirable to build the forms and pour the second floor before the first floor had set sufficiently to carry the necessary load.

Concrete roofs are designed and laid in much the same manner as the floors. The forms are also very similar. In order to obtain a reasonably light roof, cinder concrete is often used. The roof may be made water proof by the use of a layer of rich concrete troweled to a smooth finish. The roof must not contain joints and must be finished by expert workmen. It is generally advisable, however, to cover the concrete roof with some water proofing material, as tar and gravel.

Concrete stairs may be built very conveniently with side girders which may be calculated as a beam with a longitudinal rod near the lower surface. A small rod should run from girder to girder near the foot of each riser so that each riser acts as a reinforced beam. If the stairs are very wide, one or two girders may be placed between the side girders to support the stairs in the middle.

There are various ways of constructing concrete walls. If concrete could be laid in thin walls as cheaply as in mass work it would be the least expensive material for permanent construction. The principle item of expense is the construction of forms,and this has led to the invention of several methods of constructing thin walls.

The expense of building wooden forms to pour an entire wall at once is very great as compared to the amount of concrete to be placed in thin walls. Such construction also requires more expensive surfacing as the wall becomes hard before the forms may be removed. This method of form construction was designed for mass work and is not necessary in thin walls.

Portable forms are easily constructed to a height of about two or three feet and these may be raised with each layer of concrete. Such forms should be removed as soon as the concrete will sustain its own weight in order to allow surfacing while the concrete is still green. It is generally desirable to employ help enough to place a layer of concrete each day so the forms may be raised each morning.

For details of portable wooden forms see drawing No.10

Studding for wood forms should not be placed more than four feet apart and the sheeting used for the lining of the forms should be two inch planks dressed on one side. The forms should be thoroughly braced so they will be perfectly rigid during the operations of pouring and tamping the concrete.

Steel forms have been used for mass concrete and other engineering construction to some extent for several years. The application of these forms to house construction, however, has come quite slowly. These forms have many advantages over wooden forms, and, as the concrete house construction becomes more common, they will probably replace the wooden forms entirely.

These forms are constructed in panels of various sizes and must be designed to fit each different wall. There are especially designed lap corner panels, for inside corners, outside corner angles, special liners, ties and fasteners, all of which must be ordered special for any job. Enough forms are generally purchased to allow for a three or four foot layer of concrete entirely around the building and across each of the sustaining walls.

These forms are perfectly rigid and leave a smooth wall which requires no surfacing. They do not warp nor change their shape easily and may be used many times if properly cleaned and handled. Each job, however, would generally require a few special panels or pieces in order to do good work.

Steel forms complete with liner braces, etc., cost approximately forty-five cents per square foot of form surface, f. o. b. If they are owned by a contractor who could use them several times in a season the cost would not be excessive. The same forms may be loaned from the manufacturers for 30¢ per square foot of form surface, but even at that price would be too expensive for most work if they were to be used for only one building.

Another system of erecting side walls is known as the Aiken system. It is being used some by the U. S. government and its principle features are as follows: Foundation walls are first built to a level of the first floor, a platform is then built resting on jacks in the basement excavation and the front wall cast upon the platform. Door and window casings are put in place on the platform so when the wall is completed and raised to a vertical position they are ready for the insertion of the doors and windows. The surface finish may be obtained before the wall is raised. The wall being flat allows the workmen to operate from a bridge and in that way most any desired finish may be obtained. This also gives great opportunities for decorations which could not otherwise be obtained. After the front wall is anchored in position the rear wall is cast and raised in a similar manner, requiring merely another setting of the jacks beneath the platform. The side walls are made short enough to be raised from the inside between the two walls already in position. After the walls are all raised forms are placed and the corners poured.

Double walls are cast in this way by covering the first layer of concrete with a layer of dry sand. The outer wall is cast upon the sand and anchored to the inner wall. The sand is rodded out before the wall is raised to its final position.

The desired air space may be obtained in these walls by laying hollow tile on the platform and casting the outer wall on this and then plastering over the tile after the wall is in position.

These jacks are raised simultaneously by power, being connected by a tumbling rod. By the aid of these jacks the wall rotates about the rod or shaft as an axis and being very nearly balanced does not require very much power.

For house construction the machinery complete costs approximately $16.00 per linear foot of the longest wall to be raised, besides this a small gasoline engine would be required to furnish the power.

This system could be used economically only by contractors or companies where they had several jobs of construction on which the machines could be used.

Another system of wall construction is known as The VanGuilder System. The system consists of a hollow wall machine which is placed, filled with concrete, and tamped.

The machine is then released from the concrete by the means of a lever and moved along. It is similar to the construction of concrete blocks except that they are in position when moulded. This system is generally used with wooden floors and roofs and the walls are generally not reinforced. It is advertised, however, as being a fire proof construction, which is true only of the outer walls.

Owing to its great density concrete does not readily receive nails or screws, and any cutting or drilling can be done only with great difficulty and considerable expense. For this reason plans should indicate the location of plumbing and heating pipes, electric conduits, etc., as well as the position of any wood trimmings, so that all holes and blocks may be provided for during the construction of the building.

Window and door frames in position when walls are poured must be thoroughly braced so that they will not be warped when the concrete is tamped.

There are many and varied ways of decorating the exterior of monolithic concrete houses. The Old English panelled effect is obtained by planing furring strips in the concrete and to these are nailed the panel strips. When these strips are painted the color is slightly reflected by the concrete surface in such a way as to give a tinge to the surface which is very pleasing.

Flower baskets are often built into the walls of houses, or along the top of the parapet walls and in warm weather the vines and flowers give some very beautiful effects. Wrought iron lends itself very beautifully in decorating concrete houses and is used considerably. It is often used in the form of window and door grilles where iron contrasts well with a wall of almost any color and texture. Wrought iron receptacles fashioned to receive and hold flower boxes are particularly pleasing, and when employed for window balconies combine nicely with casement windows.

It is believed by some that concrete can not be used economically in house construction unless the owner intends to spend from $20,000.00 to $25,000.00. This is not true, however, as houses have been constructed of concrete at a much more reasonable figure.

In order to show some of the methods of designing a concrete house, I shall present here the drawings together with the formulas for designing the members of a medium sized house. I shall also give approximately the cost of such a structure.

A close approximation to the cost of a building can not be given for all localities, owing to the fact that the cost of labor and materials vary greatly in the different localities.

The outer walls will be reinforced and hollow. The inner supporting wall will be a 7" wall with wooden strips embedded vertically 2 ft. on centers to which one inch furring strips are nailed, lathed and plastered for finished surface. The floors, beams, columns, stairs and roof of reinforced concrete. Doors, door and window casings of wood.

The minimum live load for which floors should be designed is 30 pounds per square foot of floor area. The maximum need not exceed 100# per square foot. In the following the

maximum load will be considered:

The cellar wall 10 inches thick, the concrete should be mixed in the proportions of 1:2½:5. For beams, girders, walls and floors, the mixture should be 1:2:4.

In the following, formulas will be given for the design of floor slabs, beams, etc., which will be used in the design of the parts of the accompanying house drawings.

"The straight line theory" will be used because it is most easily understood and is the simplest method of design. This theory assumes the following hypothesis as a basis of design. (See Taylor & Thompson's Concrete, Plain and Reinforced)

1. A plane section before the bending remains plane after bending.
2. Tension is borne entirely by the steel.
3. Initial tension or compression is absent in the steel.
4. Adhesion of concrete to steel is perfect within working limits.
5. Modulus of elasticity of concrete within the usual limits of stress is constant.

Further reasons for the use of this theory are as follows:

(a) Beams designed by it and properly built will be unquestionably safe.

(b) Fine cracks are formed in the tension portion of the beam at an early stage in the loading which actually destroy nearly all of the tensil resistance of the concrete

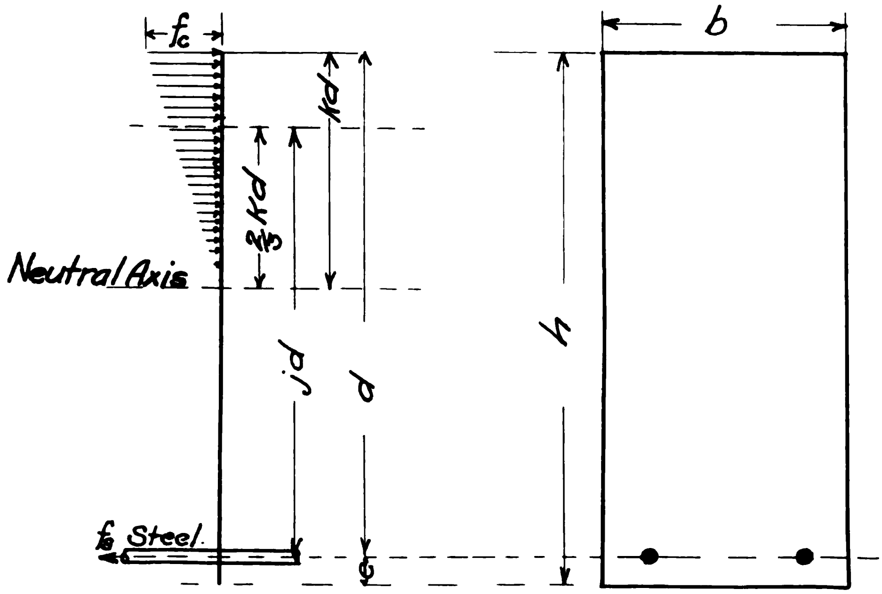
(c) The modulus of elasticity in many tests has been shown to be approximately a constant within working loads.

(d) This theory has been adopted by the highest authorities in America and Europe.

(e) The results from it may be readily compared with other theories.

The following formulas are used with these assumptions:

Design of a Rectangular Beam.



In a simple rectangular beam the stresses may be represented as in the above diagram. In any vertical section the upper portion of the concrete resists the forces which tend to compress it, while the steel in the lower part resists the forces which tend to stretch and break it in tension.

The safe resisting moment of the beam must be equal to or greater than the bending moment. This resisting moment is equal to the product of the moment arm (distance between centers of compression and tension) times either the total safe pressure or total safe pull. The minimum valve of resisting moment must be considered.

In the following let

d = depth of beam from compressed surface to center of steel in inches.

Jd = moment arm or distance between centers of tension and compression.

b = breadth of beam.

p = ratio of cross section of steel to cross section of beam above the center of gravity of the steel.

As = area of cross section of steel in sq. in.

M = moment of resistance or bending moment, in general in inch pounds.

C = a constant for a given steel and a given concrete.

650 lbs. per sq. in. will be used for a working compression in concrete and 16,000 lbs. per sq. in a working pull in steel. The ratio of the modulus of steel to concrete of 15 will be used.

Using the above we have the following formulas:

$$d = \frac{1}{10} \frac{M}{b}$$

$$As = .0077\ bd$$

In using the above the bending moment is calculated for the required loads, b is assumed, and from this d and As are calculated.

These formulas will be used in calculating the depth of the floor slabs. A section will be taken transverse to the floor beams 12 inches wide.

Design of slab 8'-4" long (For floor and ceiling of living room.)

Assumed dead load 50# per sq. ft.

" live " 100# " " "

M = moment

W = load per running foot

l = length of beam.

b = breadth = 12"

$$M = \frac{wl^2}{12} = \frac{150 \times 8\ 1/3 \times 8\ 1/3 \times 12}{12} = 10350 \text{ inch pounds.}$$

$$d = \frac{1}{10} \frac{10350}{12} = 2.9$$

$$As = .0077 \times 3 \times 12 = .28$$

Allowing ¾ inches of concrete to cover steel

h = 3 3/4 inches.

Use one round rod 5/8" diameter. 3/4" from bottom.

" " short " " " 4 ft. long 3/4" from surface to take negative moment over beams.

For slab 6 ft. long for kitchen and floor above and roof.

Loads as above.

$$M = \frac{wl^2}{12} = \frac{150 \times 6 \times 6 \times 12}{12} = 5400 \text{ in pounds}$$

$$d = \frac{1}{10} \cdot \frac{5400}{12} = 2\tfrac{1}{4} \text{ inches.}$$

$$As = .0077 \times 12 \times 2\tfrac{1}{4} = .20$$

Use h = 3"

" 1 rod 9/16" diameter. 3/4" from bottom

Also one short rod (4'-0") 9/16" in diameter 3/4" from top to lap over support, and take tension due to negative moment.

For slab 8'06" long. Diningroom floor and floor above.

$l = 8'\text{-}6"$

$$M = \frac{wl^2}{12} = \frac{150 \times 8.5 \times 8.5 \times 12}{12} = 10{,}800 \text{ inch pounds}$$

$$d = \frac{1}{10} \cdot \frac{10{,}800}{12} = 3"$$

allowing 3/4" to cover steel h = 3 3/4"

$$As = .0077 \times 3 \times 12 = .28$$

use one rod 5/8" diameter

Insert short one same size near surface over supports.

Roof slab 9' - 0" span above dining room.

$$M = \frac{wl}{12} = \frac{150 \times 9 \times 9 \times 12}{12} = 120,000$$

$$c = \frac{1}{10} = \frac{12000}{12} = 3.1$$

allowing 3/4" for e h = 3 3/4"

As = .077 X 3 X 12 = .28

Use 1 rod 5/8" in diameter.

Insert short one over support near top.

Because of embedding metal, concrete floors should be limited to a thickness of 3".

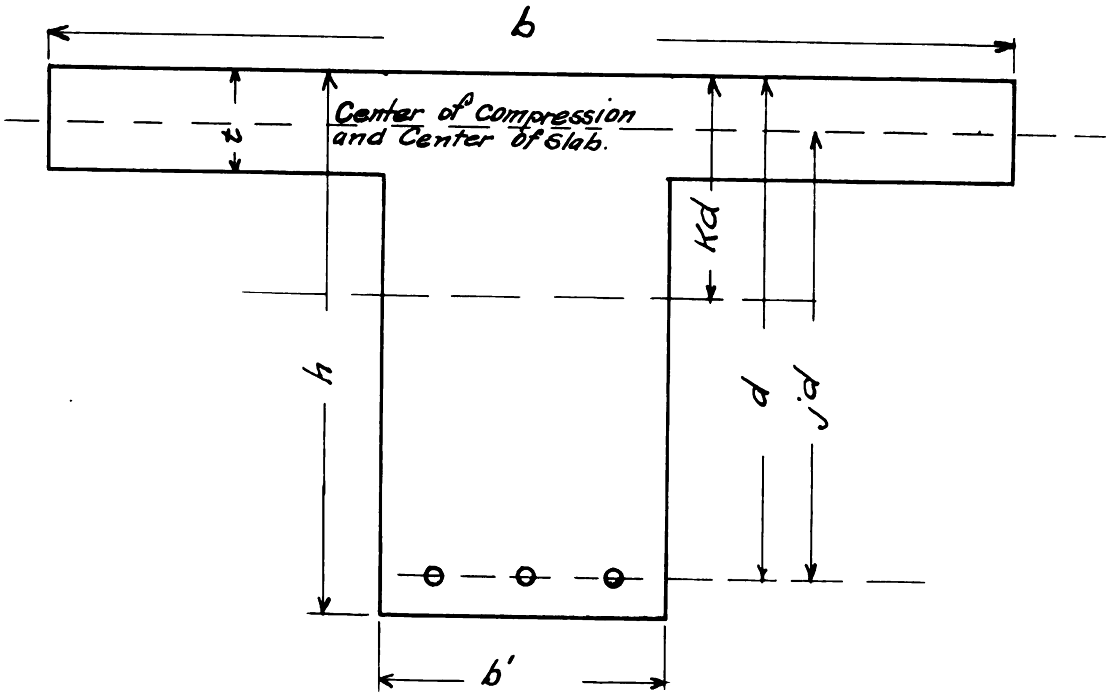
Concrete for floors and beams should be mixed wet enough so the mortar will flow around the metal and entirely coat and protect it from rust and fire. It should be wet enough so if not handled quickly it will run off the shovel.

Floor forms should be so designed that they may be easily removed and used a second time where possible.

Beams and small colum forms may be held by clamps thus avoiding nailing them.

Forms for floor beams and slabs should not be removed for at least one week and should generally be left in place for two or three weeks if the floor is to be subjected to any load.

Design of T Beam.



When beam and slab are built at the same time so there is no crack between them, a portion of the slab may be considered as acting with the upper portion of the beam in compression. In this way the quantity of concrete necessary for safety may be very much reduced.

The theory of design is similar to that of the rectangular beam, that is, the upper portion takes the compression and the lower portion takes the tension.

In the design of a T beam the thickness of the flange is determined by the thickness of slab required to to support its load and the width of flange to use is selected in accordance with empirical rules. The width is limited on either side to four times the depth of the slab, for heavy work, for house construction, however, this ratio might be slightly increased and still be within safe limits.

In the following let

d = depth of T beam from compressed surface to center of steel in inches

t = thickness of flange in inches

b = breadth of stem in inches

$d - \frac{t}{2}$ = moment arm, the depth from center of slab to steel.

V = total vertical shear

M = bending moment in inch pounds

F_s = allowable unit tension in steel in pounds per sq. inch.

r = ratio of unit cost of steel in place to unit cost of concrete in place.

A_s = cross section of steel in square inches.

Using the given notation the following formula determines the cross section of the web for shear.

$$b' \left(d - \frac{t}{2}\right) = \frac{V}{120}$$

(120 = Max. allowable unit shear)

Formula for determining the economical depth of a T beam

$$\left(d - \frac{t}{2}\right) = \frac{rM}{f_s\, b'}$$

In using this formula different widths are assumed and d calculated. (The ratio of $\frac{d}{b}$ should never be less than 2.

Formula for determining sectional area of steel in a T beam

$$As = \frac{M}{Fs\left(d - \frac{t}{2}\right)}$$

In solid concrete beams horizontal shear need not be considered.

Design of T Beam for ceiling of living room to support wall above.

Span 16' - 3"

Distance between beams 8' - 4" C to C.

Live load 150# per sq. ft.

Assumed dead load 50# per sq. ft.

" " " of beam 200# per ft.

Total load per running foot of beam, 2200#

Using same notation as in preceding work.

$$M = \frac{wl^2}{12} = \frac{2200 \times 16.25 \times 16.25 \times 12}{12} = 560,000$$

Reaction at supports = V = 17,500.

To find breadth of flange take 8 times the thickness of slab plus breadth of stem of beam (assumed 10 inches).

b =(8 X 4) 10 = 42 in.

fcbt =650 X 42 X 4 = 109 200

Assumed ratio $\frac{d}{t} = 3$

Using these valves with table on page 225 of Taylor and Thompson's Reinforced concrete the minimum depth is 10 inches.

Using formula for most economical depth.

$$(d - \frac{t}{2} = \frac{rM}{fsb'}$$

Using $r = 70$

$M = 560,000$

$fs = 16,000$

$b' = 10"$

$t = 3\frac{3}{4}"$

$$(d - \frac{t}{2} = \frac{70 \times 560,000}{16,000 \times 10}$$

$$d = 16\frac{3}{4}"$$

Cross section determined by shear.

$$b'(d - \frac{t}{2} = \frac{}{120} = \frac{17,500}{120} = 148$$

$$d = 16\frac{1}{2}"$$

make $e = 1"$ (covering for steel)

$$h = 17\frac{1}{2}"$$

Sectioned area of steel $As = \frac{M}{fs(d-\frac{t}{2})}$

$$= \frac{560,000}{16,000 \times 15\frac{1}{2}} = 23$$

Use 4 rods 7/8" in diameter two bent up to lap over top of support.

In a continuous beam the negative moment over posts is the same as the positive moment at the middle. The allowable compression of concrete at the support may be 17% greater than at the middle.

Short T beams for floor of living room.

Span 8' - 2"

Dead plus live load per running foot 1660 lbs.

$$M = \frac{1660 \times 8.2 \times 8.2 \times 12}{12} = 107{,}000 \text{ inch pounds.}$$

Min. depth as per above, for b = 8", is 5".

$$V = \frac{1660 \times 8.2}{2} = 6200.$$

Cross section determined by shear With b = 8"

$$b'\left(d - \frac{t}{2}\right) = \frac{6200}{120} = 51.7$$

$$d = 8\tfrac{1}{2}"$$

allowing e = 1" to cover steel.

$$h = 9\tfrac{1}{2}"$$

$$As = \frac{M}{fs\left(d - \frac{I}{2}\right)} = \frac{107000}{16000\ (6\frac{1}{2})} = 1.03$$

Use 2 $\frac{13}{16}$" diameter rods.

Use two short ones same size and bent down over support for negative moment.

Diningroom floor beams.

l = 6' - 6"

Total load per ft 1350 lbs.

$$M = \frac{wl^2}{12} = \frac{1350 \times 6.5 \times 6.5 \times 12}{12} = 57000 \text{ inch pounds}$$

Economical depth = $5\frac{1}{2}$ inches

Cross section by shear

$$V = \frac{1350 \times 6.5}{2} = 4370$$

$$b'(d-\frac{t}{2}) = \frac{4370}{120} = 36.4$$

When b = 8"

d = $6\frac{1}{2}$"

allowing 1" for e to cover steel

h = $7\frac{1}{2}$"

$$As = \frac{M}{fs(d-\frac{H}{2})} = \frac{57000}{16\ 000 \times 4.5} = .81$$

Use 2 rods $\frac{3}{4}$ in diameter.

Insert on short one over support.

Dining room ceiling beams and roof above.

Span 13' - 0".

Distance between beams 8' - 6"

Dead plus live loads per running ft. of beam is

8.5 X 150 = 1275#

Assumed dead load of stem 175#

Total load 1450# per ft.

$$M = \frac{wl^2}{12} = \frac{1450 \times 13^2 \times 12}{12} = 245\ 000 \text{ inch pounds}$$

$$\text{Reaction at support} = V = \frac{1450 \times 13}{2} = 9420$$

Breadth of flange = (8 X 4) 10 = 42"

Min. depth from table = 7"

Cross section determined by shear.

V = 9420

$$b'(d-\frac{t}{2}) = \frac{9420}{120} = 78.$$

Using $b = 10"$. $t = 3\frac{3}{4}"$

$d = 9\frac{3}{4}$

allowing $e = 1"$ to cover steel

$h = 10\frac{3}{4}"$

$$As = \frac{M}{fs(d-\frac{t}{2})} = \frac{245,000}{16,000 \times 7.75} = 1.95"$$

Use 2 rods 7/8" diameter

and 2 " 3/4" "

Kitchen floor beams also same for one above

Span = 6' - 6"

distance between beams 5' -9"

Total load = 362#. (loads assumed as above)

$$M = \frac{wl^2}{12} = \frac{862 \times 6.5 \times 6.5 \times 12}{12} = 36,400 \text{ inch pounds.}$$

$$V = \frac{862 \times 6.5}{2} = 2800$$

$b = (8 \times 3)\ 6 = 30"$

Using $b' = 6"$

By shear

$$b'(d-\frac{t}{2}) = \frac{2800}{120} = 23.3$$

$d = 5\frac{1}{2}"$

With $e = 1"$

$h = 6\frac{1}{2}"$

$$As = \frac{M}{fs(d-\frac{t}{2})} = \frac{36,400}{16,000 \times 4} = .553$$

Use 2 rods 5/8" diameter.
One short one near surface over support.

Columns of short length as shown in the accompanying drawings need not be reinforced. The columns in the walls should be reinforced with a rod in each corner. In the monolithic construction a part of the adjacent wall acts with the column in sustaining the loads, and for house construction columns need not generally be thicker than the wall itself.

The following will show approximately the cost of such a structure as is herein shown. Wooden forms and portable will be considered for the walls.

Excavating 150 yds. @ 30¢	$45.00
Grading	15.00
	$60.00

Forms

2 inch planks for floor forms, stairs, studding facing of wall forms and runways 8000 ft. @ $20.00 per	160.00
2 X 4 for studding and bracing, 1000 ft.@ $20.00	20.00
1 X 6 " " for portable forms Mixing boards, etc., 1500 ft. @ $18.00	27.00
Nails, bolts, etc., for forms	15.00
Construction and raising forms, runways, etc.	300.00
	$522.00

Concrete

Floors, cellar, columns, and roof	38	cu. yds.
Inner walls and stairs	25	" "
Cellar walls and floors	38	" "
Outer walls (2" air space)	47	" "
Porch complete	5	" "
Pantry and roof and parapet	$1\frac{1}{2}$	" "
Fire place, chimney & parapet	$14\frac{1}{2}$	" "
Total	169	cu. yds.

Allowing materials for a 1:2:4 mixture the concrete would cost as follows:

265 bbls. cement @ $1.60		$424.00	
75 yds. sand @ .50		37.50	
150 " gravel or stone @ .80		120.00	
			$581.00
Mixing and placing concrete			
169 yds. @ $3.50		591.50	591.50
Steel in place @ 3¢ per pound			
2900 ft. 5/8" round	3025# @ 3¢	90.75	
825 " 3/4" "	1240" @ 3¢	37.20	
2210 " 1/2" "	1470" @ 3¢	43.10	
360 " 9/10" "	305" @ 3¢	9.15	
			180.20
Plastering including materials and labor @ 35¢			
610 sq. yds. @ 35¢		213.50	213.50
Metal lath 106 yds. @ $3.00		318.00	318.00
Finishing outer surface		50.00	50.00
Doors and windows complete in place including frames		500.00	500.00
Plumbing and heating		1000.00	1000.00
Wiring and light fixtures		100.00	100.00
Total			$4176.20
Allowing 10% for profit			417.60
			$4593.80

Inexperienced labor and variations in the cost of materials and labor would cause a variation of several hundred dollars. Such a house could, under ordinary conditions, be built well within the limit given.

The cost of the same house built by the usual methods of frame construction would depend very largely on the materials and finish desired. Such a house built as the average man could afford would come within the $3000.00 limit.

The best authorities claim that a house built of concrete throughout costs from 15 to 50 per cent, more than a similarly designed frame house. This theory is shown to be true by houses that have actually been constructed.

When the demand for the concrete house is sufficient to warrant contractors a reasonable amount of work in this line, they will undoubtedly supply themselves with steel forms or other patent devices for wall construction and the initial cost of these dwellings will be greatly reduced.

A complete set of steel forms for the house shown in the drawings would cost @ 45¢ per sq. ft. of form about $515.00. The same forms could be rented for $345.00. Not including freight in either case.

Machinery necessary for the construction of the same house by the Aiken system would cost as follows:

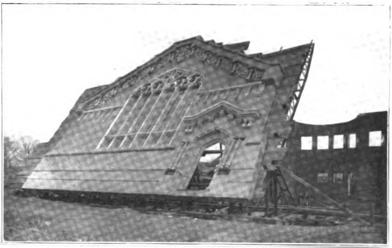
5 Pony Jacks @ $90.00	$450.00
30 ft. Hexigon Shafting @ 20¢	6.00
1 Main Drive Head	20.00
Total	$476. 00

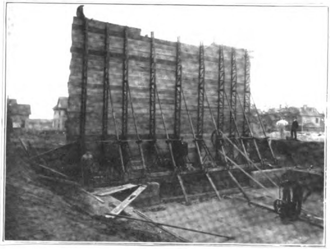
This does not include the rent of the engine for power in raising walls.

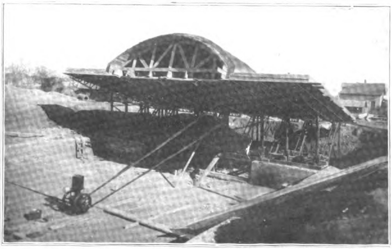
The VanGuilder Hollow Wall concrete machines and attachments for the house shown would cost approximately $300.00

Clippings are shown in the following pages of the above patent wall devices, in use:

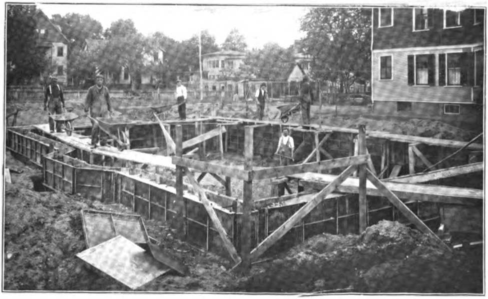
Also of houses constructed of concrete throughout and from which it can be seen that concrete is being used for the cheap or laboring man's cottage as well as the better class of houses.







The cuts show the Aiken System of raising walls.



The above cut shows the steel forms in use for a house foundation.

The above cut shows factory employees' cottages erected at Racine, Wis.