Subject: Construction of buildings

Synopsis of subject:

I. Determination of a form of tower having the greatest resistance to the pressure of the wind.
II. Determination of the required thickness of wall (two methods)
III. " an expression for the moment of stability of a tower, not vertical.

IV. Brick construction
   I. General principles
   II. Bond in brickwork
   III. American bond

V. Stone construction
   I. Kind of stone
   II. Block-in-coursed
   III. Combined rubble
   IV. Common rubble

VI. Foundation
   I. In rock
   II. Firm earth
   III. Soft

VII. Examination of the proposed centennial tower
I. Necessary thickness of wall
II. Conditions of stability when axis is vertical
III. Required foundation
I determine upon the form of Tower which has the most
resistance to the pressure of the wind.

Having examined the octagonal, hexagonal, etc.,
plan, I find that for the same dimensions, the oc-
tagonal plan resists more than the octagonal.
And these are the octagonal, hence I conclude
that the circular plan must be the plan
when the maximum amount of resistance will be
found.

Also from a second reasoning, I can prove
that the circular plan offers the most resistance
to the wind.

Having examined the square plan in two positions
I—wind acting directly against one side, II—wind
acting against sides at an angle of 45°.

I find in the first case, that the total wind pres-
sure on a strip 12" wide x 12" long, by dividing
the total wind pressure for the square strip 24" long to be 8.64 lbs. Hence,
we may say that the wind pressure of the cir-
cular plan, in the case of the square plan, one side of which pre-

To determine the required thickness of wall to
resist the wind pressure. For a square, I shall take
a brick column 100' high x 12" wide,
12 ft. of cubic foot of brick = 120 lbs,
100' = required thickness of wall in ft = 100'
W = 120 lbs of wall per cubic foot = 100 lbs.
P = pressure per square foot of wind = 40 lbs.

Then \( P \times \frac{X}{2} = \frac{(w \times h \times t)}{2} \) or \( P \times \frac{X}{2} = \frac{W \times h}{t} \) or \( t = \frac{P \times X \times h}{W} \)

Substituting values \( t = \frac{140 \times 100}{120} = \frac{14000}{120} = 116.66 \) feet.

If the mortar is of the best quality, according to the regulations by the Armored Tower of the U.S. army, the coke in this house or the resistance to a fire, with mortar may six months side in one hour per square foot, I use the mortars twice older, the resistance grows larger. Taking this into consideration will be as follows: when we are building a house, will be supported by walls as might appear, in practice, the thickness used for the necessary thickness of the wall required.

The following is Professor Richter's method.

\[ l = \text{length of wall in feet} \]
\[ X = \text{thickness} \]
\[ Z = \text{length of joint considered} \]
\[ W = \text{mixture of mortar per foot in height} \]
\[ P = \text{pressure of wind per foot in height} \]
\[ w = \text{set of one cu. foot of wall in pounds} \]

Considering one foot length of wall between buttresses.

The total pressure of the wind causing a strain at any point = the pressure above the joint \( = P \times (h - z) \)

Its live area \( = \frac{h - z}{2} \)

Consequently, \( \frac{1}{2} \) the total weight amount at any joint \( = \frac{P}{2} (h - z)^2 \)

II. Resistance of the weight of the wall may, the weight of wall above the joint would be the only weight that will act. Volume above joint \( = X (h - z), Wt = W \times (h - z) \)
II Resistance from tensile strength of mortar.

Its moment of resistance = that of a rectangular beam,

\[ \frac{Wx^2}{2} \]

\[ s = \text{factor of tensile strength per sq. foot} \]

\[ b = 1 \]

\[ d = x \]

\[ \text{Moment of resistance} = \frac{vx^2}{6} \]

IV Resistance due to stiffness having in full of the wall, when supported horizontally at the ends,

\[ L = \text{factor of friction for the mortar joints}. \]

Resistance to slipping per sq. foot = \( SW(h-z) \)

At the top joint the resistance = \( \frac{SW}{k} \)

\[ H = \text{horizontal force per foot of } k \]

\[ \text{Resistance per foot} = \frac{5Wx^2}{6} \]

\[ b = \frac{1}{k} \]

\[ d = p \]

\[ H = \frac{5Wx^2}{3k^2} \]

Supposing \( H \) to remain uniform by clinch with towards the joint in question,

considering a vertical piece of wall one foot in being \( k \) of the center.

\[ \text{We have} \]

\[ H = \frac{H}{2} (h-z) = \frac{5Wx^2}{9k^2} (h-z)^2 \]

Thus for the total resistance at any horizontal joint in the center of the wall + 1 foot long.

\[ \text{We have,} \]

\[ \frac{L}{2} (h-z)^2 = \frac{Wx^2}{2} (h-z) + \frac{5x^2}{6} + \frac{5Wx^2}{3} (h-z)^2 \]

\[ 9kW^2 (h-z)^2 = 9kW^2 \]

\[ (h-z)^2 + 3kW^2 x^2 + 9kW^2 (h-z)^2 + 2SW (h-z)^2 = 9kW^2 (h-z)^2 \]
\[ x = \frac{98k \cdot \ln((h-z)^2)}{98k - W(h-z) + 36k \cdot t + 23 W(h-z)^2} \]

<table>
<thead>
<tr>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>( k )</td>
<td>15 ft</td>
</tr>
<tr>
<td>( W )</td>
<td>125 lb</td>
</tr>
<tr>
<td>( t )</td>
<td>2000</td>
</tr>
<tr>
<td>( f )</td>
<td>70</td>
</tr>
<tr>
<td>( h )</td>
<td>100 ft</td>
</tr>
<tr>
<td>( m )</td>
<td>5</td>
</tr>
<tr>
<td>( z )</td>
<td>2</td>
</tr>
<tr>
<td>( p )</td>
<td>40 lb</td>
</tr>
</tbody>
</table>

Substituting values:

\[ x = \sqrt{\frac{7 \times 140 \times 5^{-2}}{7 \times 13 \times 5 \times 125 \times 100 + 3 \times 13 \times 5^{-2} \times 2000 + 2 \times 73 \times 125 \times 100^2}} = 3.35 \text{ ft}^{-1} \]

Making \( z = 50 \text{ ft} \), \( x = 3.74 \text{ ft} \), \( h = 2 \), \( x = 0 \)

III Determination of a Formula, which expresses the conditions of stability of a tower.

As I have stated before, the total pressure of the wind against the surface of a cylinder is about one half the total pressure against the plane that is that of the cylinder. To include all forms of planes, I shall consider the circle and square planes, as the rectangular plane may be considered in practice as being circular without sensible error.

Let the figure represent a tower, square or circular in plan, \( D \) be required to determine the conditions of stability of the joint \( B \).
Let \( S \) denote the area of a discoidal portion of the part of the
part of the floor above the joint in question, and \( p \), the greatest
pressure of the wind per square foot of flat surface.

Then the total pressure of the wind against the floor
will be sensibly \( p = p_S \) for a square plan

and its resultant may, with tolerable approximation, be assumed
to act in a horizontal line through the center of gravity of
the vertical discoidal portions.

Let \( h \) denote the height of that center above the joint \( F_2 \)
and the moment of pressure is \( H_P = H_P S \) for a square plan

\[ H_P = H_P \frac{p}{2} \quad \text{circle} \]

If the joint is vertical, the moment of stability is the same in all directions.
But for towers having their axis exactly vertical, and the least
moment of stability, in the latter case, is obviously that which
takes a lateral pressure, acting in that direction towards which
the tower leans.

Let \( C \) denote the center of gravity of the portion of the
floor above the joint \( F_2 \) and \( B \) a point in the joint \( F_2 \), releasing
the wind \( B \), and let the line \( F_2 = \frac{1}{2} \) which denotes the geometric of the
joint which contains \( B \), let \( \gamma \) = the ratio which the deviation of
\( B \) from the middle of the diameter \( F_2 \), bears to the length \( e \) of
the diameter, then the least moment of stability is
denoted thus:

\[ M = \frac{1}{2} (\gamma - \frac{1}{2}) W \]

The value of the coefficient \( \gamma \) is determined by
considering the manner in which floors are known to give
way to the pressure of the wind. This is generally noticed to commence
by the opening of one of the hill joints such as \( F_2 \), at
the windward side of the tower.

A crack thus begins which extends itself in a
zigzag, from diagonally slanting rows of cracks.
The final destruction of the chimney takes place, either by
the diagonal shifting of the upper division until it loses its m.

The fire, therefore, will not be
This causes the tissue to burst.
put from below, or by the crushing of a portion of the brick work, at
the base. And, since there is too great a concentration of pressure
at that point or by both those causes combined.

And in other cases the upper portion of the tower faces in
a slant of the ground, partly into the interior of the portion left
standing and partly on the ground inside its base.

It is obvious that in order that the sta-

bility of the tower may be secured, no hole joint should tend to
open at its inner wall edge, that is to say there ought to be
some pressure at every point of each hole joint, except the
inner inner wall edge, where the intensity may diminish
To nothing, and this condition is fully filled with sufficient
accuracy, for practical purposes, to assume the pressure to
be a uniformly varying pressure, as dividing the edge of pressure
and that the intensity at the lowest edge shall
be double the mean intensity.

Towers in general consist of a hollow shell of brick
or stone work, whose thickness is small compared with its di-
cameter, and in such case it is sufficient for practical
purposes to give to the following values

For square plan \( v = \frac{3}{4} \) \( \text{IV} \)

\[ \text{circle} \quad v = \frac{3}{4} \]

The following general equations determine the moment
of stability of the tower, \( M \)

\[ H P = (y - y') W t \] \( \text{V} \)

This becomes when applied to square towers

\[ H P s = (y - y') W t \]

and when applied to circular towers

\[ H P s = \left( \frac{3}{4} - y' \right) W t \] \( \text{VI} \).
Brick construction

I. Annual rains expose—

The following rains expose one to be on sure when building
with bricks.

I. All the cracks in the brick are to be repaired
II. To place the brick in the brick, proper cooler or as near
as possible to the direction of the house which they have
must get to make the bricks break joints with each other
above and below by the over laying to the extent of from 3/4 of
the length of a brick
III. To chase the surface of each brick, and cut it
throughly before laying, so that it will not absorb the mo-
in the bricks
IV. To fill each strong joint with mortar, taking care
that these joints do not exceed more than 1/2 of an inch in thick-
ness.

In order to prevent the use of too great a thickness of
mortar it would be well to specify in the specifications the
space, which is certain number of bricks in the wall is
to occupy, as for 150 square 7 bricks each 2 1/2" thick, and each
layer one upon the other, shall not occupy a space more
than 24 1/2" in height.

This shall be especially notified where any
stone work comes in the wall, as for at angle corners, for
the joints in the brick work, in so much more numerous,
then those of the bricks that any superfluous thickness
of the mortar in the corner case will accent the brick work
to settle more than the stone, thus causing cracks—
the wall, & sometimes ministration of the building.

If to saw no slats or pieces of bricks unless abso-
letly necessary, as in making a closing that is to fin-
ish the corner of a wall, a opening, and even thin nothing else.
than a half brick should be used.

The volume of the mortar in some brick work
should be about 3 the volume of the brick.

II Brick in brick work

The bricks used in a given building, being of nearly
uniform size, are laid according to a uniform sys-
tem, which is to make the bond of the brick work
The header in brick work over those bricks
which are laid with their length perpendicular to the
face of the wall, and a stretcher in one where the length
is laid parallel, to the face of the wall,
and on the length of a brick is just double its breadth.
A stretcher will occupy a space in the wall just equal to
the space occupied by two headers.

There are several kinds of bonds in use,

1. English Bond
    This form of bond is considered the strongest
    and most stable arrangement.
    It consists in laying an entire course of headers
    and stretchers periodically, for example:
    The stretchers three tying the wall lengthwise to the headers tying it
    otherwise, sometimes there is only a course of headers for
    every 2 or 3 courses of stretchers.

2. Flemish Bond
    In this case a header & stretcher is laid altern-
    ately in the same course time and so laid that the
    middle point of each course also coincides with the middle
    point of the stretcher above & below it. This form presents a more
    uniform appearance than the first case, but is not considered as
    strong.

III American Bond
    In this case there is a course of headers for each
IV. American Gretel Bond.

In this case the headers are not visible in any part of the wall. The construction is said due to this that it is a very poor form as the outer wall is held together only by the cohesion of the mortar & its own weight. This bond is breaking jointless between objects.

To distribute the vertical load which rests on each brick or row or stone of the bricks below it, it is more readily produce a new form distribution of the load than would otherwise take place.

If to enable the structure to resist forces that tend to break it by shearing, or by the sliding of one part on another in the vertical plane.

It is not able to resist forces tending to tear it as one horizontally.

V. Stone Construction.

The general principles are the same as just for brickwork.

I. Kind of Masonry.

There are an indefinite number of different kinds of masonry, from the "prepared ashes" (in which every stone is furnace to an exact figure, & filled to the joinery above) to the common rubble, in which the stones are laid nearly as they come from the quarry, the great irregularities in figure being alone taken off by means of the hammer.

For building purposes masonry may be classified under four principal kinds:

I. Ashlar. II. Block in course. III. Course of Rubble.

IV. Common Rubble.
Ashlar masonry, or stone masonry, consists of blocks of stone cut to regular figures, generally rectangular, and built in courses of a uniform depth, which is seldom less than one foot.

In order that the stones may not be broken across, one stone of a weaker material such as the softer kinds of sandstone, should have a length twice as long as their depth. For quarry stone the length should not be grater than three times the depth. In harder materials the length may be four or five times the depth.

The breadth in soft materials may range from 1/2 to 2, double the depth, in harder materials it may be three times the depth.

The true and false joints should be chased with care, that every point of these surfaces should be in the same plane, for if the false points should be concave, thus giving a perpendicular view upon the entire surface, the block point in any course should be directly above the point of the course below, but should overlap to the amount of one to one and a half the depth of a course.

The thickness of the mortar in the joints of stone is usually one inch, and for blocks should be kept to one inch. In any case, the mortar should not exceed one inch in thickness, and should be kept to one inch in thickness in all cases.

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The thickness of the mortar in the joints of stone should not exceed one inch.
III In concrete masonry, the wall consists of a mix of horizontal courses, where each course is laid one foot in depth, each of which is accurately levelled before an other is built upon it. But the side joints are not necessarily critical.

IV Every part of least of the surface of the wall should consist of headers or course stone, and each of which is to be of the future depth of the wall.

V Compress rubble, differing from the concrete rubble by not being built in course, the plaster being left as it comes from the quarry. The resistance of concrete is not much more than that of the mortar which it contains, hence it must not be used where great strength is required.

VI Formations.

The formation of a work of masonry consists in the first place of an excavation in the ground. It precisely required a structure at the bottom of that excavation sufficient to form a firm base for the masonry. Ordinary formations are of three classes.

I Formations in rock or material whose stability is not impaired by the saturation of water.

II Formations in firm earth, such as sandy gravel, and

III Formations in soft earth.

The base of every formation should be as nearly as possible perpendicular to the direction of the pressure which has to be sustained, and of sufficient area to sustain that pressure with safety. The method of determining the area of a formation for a given wall is as follows. Taking the thickness of a square foot of stone, to be one and one half times, we proceed as follows:
Calculate the weight of a section of the wall having the same height and depth as prescribed for the wall, but may take one foot of the length: "Taking the weight of one cubic foot of brick at 230 lbs. 36, the weight of one cubic foot of stone at 150 lbs." Then divide the total weight by one pound per half ton, the dividend will be the number of square feet for the foundation of the section of wall in question.

To prepare a rock foundation, the following are the following one in general all the operations necessary:

I. To cut away all the loose & decaying parts of the rock.

II. To cut & cover the rock to a plain surface or to a sort of plain surface like those of steps, or in a circular to the profile which they object system,

III. To fill of necessary the hollows in the rock with cement, or rubble measuring. The intensity of the pressure in a rock foundation should not be more than we eight the amount which would crush it.

II. Earth foundations,

When a foundation is to be made in such earth as hard clay, gravel or clean chalk &c. &c., "that is to say in earth which has considerable frictional stability, and is not liable to have that stability diminished by becoming saturated with water," it is rarely necessary to prepare any further earth for the foundation bed, than the excavation for, & leveling of the same. The depth of the bed of a good foundation should not be less than three feet below the surface of the ground.

Because for any loose distance from this it liable to be affected by the actions of the earth.

III. Foundations in soft earth.

The area of the foundation should be at large as possible when it is to be placed upon such soil,
so as to distribute the weight over as much surface as possible.

If practicable the ground should be well drained before the laying of the foundation commences, in order to increase the firmness of the earth. Sometimes in order to secure a good foundation, after the foundation trench has been excavated, the bottom of the trench is filled with a layer of sand. About 3" deep in this is then laid a layer of concrete to the depth of about six inches, from the top of this the foundations walls are started. When this earth is too soft to allow this, the method of driving piles is used.

\[ H^{1/2} = \left( \frac{1}{4} - 0 \right) \frac{W}{2} \]

or

\[ 1000 \times 40 \times 200000 = \frac{320000000}{4} = 320000 \times 200 \times 18 \times 6 \]

II Conclusions of stability when arch is vertical - in which case \( q = 0 \) then by formula VI

\[ \text{or} \]

\[ 320000 \times 200000 = 4,000,000,000,000, \text{and the internal pressure is} \]

\[ 4000 \times 40 \times 200000 = 8,000,000,000,000, \text{and the external pressure on masonry is} \]

\[ 220,000,000 \times 5 = 960,000,000 \text{; thus showing the masonry to be over 200\% firm as the force tending to turn the structure over} \]

But this masonry is assisted by diminishing the wall towards the top.
III Required foundation.

The required depth for the bed of foundation, when the furnace is covered over with good strong concrete, is determined as follows:

\[ x = \frac{x}{w} \]

\[ w = \text{wt of one cubic ft of the earth on which the foundation rests} = 150 \text{ lb} \cdot \text{ft}^3 \]

\[ w' = \text{wt of one cubic ft of the concrete foundation} = 180 \text{ lb} \cdot \text{ft}^3 \]

\[ P = \text{the pressure per square foot in the foundation} = 10,000 \text{ lb} \cdot \text{ft}^2 \]

\[ k = \text{The function of the angle of repose} \]

Thus \[ x = \frac{P}{W - W'k} \]

Substituting values:

\[ x = \frac{10,000}{180 - 150} = \frac{25 - 04}{118} = 21.7 \text{ ft} \]

from this

The area of foundation must = \[ 48,064.96 \times 1000 \div 10,000 = 2403.2423 \text{ square ft} \]

or radius = 275 ft.

The weight of the structure is divided by 2 since the wt calculated is the wt of four, supposing it to have the same diameter & thickness of wall throughout.

In addition, the wall is to decrease, towards the top, both in diameter & section of wall, the wt of column will only be one half as shown.