A Thesis on "Reinforced Concrete Construction" with Floor and Chimney Design for Power House.

by

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June 9th, 1909.

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W.T.H.

The Huntingdon Tablet

"Reinforced Concrete Construction"
with
Design for a Concrete Floor and Chimney
for the
Power House
at
Washington and Lee University.

Submitted to the
Faculty of the Engineering School,
Washington and Lee University
by
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Concrete Steel Construction.

Introduction.

In working up this thesis I used as reference books, Cambria Steel; Concrete Plain and Reinforced, Taylor and Thompson; Principles of Reinforced Concrete Construction, Turneaure and Maurer and several different issues of the Engineering Record. I also had drawings and specifications of concrete chimneys from the General Concrete Construction Co., Chicago, Ill. and from the Weber Chimney Company, Chicago, Ill.

Before going into the details of the construction of the concrete floor and chimney of the Power House I will give a brief history and discussion of cement and reinforced concrete.

Reinforced concrete has in the last few years come into quite an extended use as a buildmaterial, not only for floors and chimnies but for columns, beams, roofing, bridges, dams, arches, etc. The developement and progress made by this wonderful building material has of course been slow. Like wood has been replaced in bridge construction, etc. by iron and then iron by steel so reinforce concrete has to a great extent replaced them all. Although there are many places where concrete cannot be used it bids fair to become a standard and much used construction material.

The great advantages as a floor material over other materials are that it renders the room of the building fire proof from below as well as preventing the fire from decending to the next floor from the room. The floor itself is almost indestructible and the advantage of a continuous floor need not be discussed. The concrete takes care of the compressive strains while the steel reinforcement provides for the tensile stresses produced by shocks etc.

In chimney construction the advantages over other materials is the fact that it forms a structure of monolithic character resulting in greater certainty in stresses and economy in design. Concrete resists the heat as well if not better than common brick or stone and besides sustains the wind stress with more certainty than brick or stone put together with any mortar.

Concrete being the product resulting from an intimate mixture of cement mortar, with an aggregate of crushed stone, gravel, or similar material it would be well to give a brief history of the most important constituent, cement.

Cement made from valcanic ashes was used by the Romans several centuries before Christ but the art seems to have been lost until the Middle Ages. John Smeaton, an Englishman discovered, in 1750, the fact that limestone containing clay would slake very slowly but after slaking would set again even under water and form a very firm mass. This was called hydraulic lime and was much used in the construction of light houses, canals, etc, at that day.

James Parker, of England, in 1796 made what he called "Roman Cement" from argillacious limestone nodules by calcining and grinding. This process was patented and from it grew the Natural Cement industry which attained a marvelous use as a construction material until about 1890 when it was superceeded by a better and more uniform cement known as Portland Cement.

Portland cement was invented by Joseph Aspdin of Leeds, Eng. in 1824, by discovering that an artificial mixture of slaked lime and clay, highly calcined formed a hydraulic product. It was named "Portland Cement" on account of its hardness and color, ~~which~~ when set, to the Portland stone which was much used in Eng. at that time. About twenty years after ~~at~~ Aspdin's discovery the Portland cement industry was commenced by J. B. White and Sons. of Eng. who began its manufacture on a large scale. From that the industry rapidly grew in England and was extended to France and Germany about the middle of last century. In 1900 Germany produced more Portland cement than any other country.

The Natural cement was very extensively manufactured and used in the U.S., the cement rock being discovered, in 1818, by Canvass White an engineer connected with the construction of the Erie Canal.

In 1875 Mr D.O. Saylor founded the Portland cement industry in the U.S. and located his factory in Lehigh Valley. His process was to mix rocks high in lime with those low in lime but high in clay and then to calcine them to almost vitrification. He then ground the mass to a very fine powder. The foreign Portland cements had been largely imported up to this time. These imported cements were made of an entirely different process which was to mix clay with pure limestone and after calcining grind the mass to a fine powder. Saylor's cement was much better and after a few years was very extensively used and has almost superceeded Natural cement altogether. The ~~to~~ comparison of the following figures will show the developement of Portland and the decrease of Natural cement. In 1890 the Portland cement manufactured was 335,500 bbls. against 7,082,204 bbls. of Natural cement. In 1903 the production of Portland cement was 22,342,973 bbls. while the Natural cement produced was 7,030,271 bbls. In 1904 there were only 4,870 000 bbls of Natural cement manufactured showing a decrease of 2,170,271 bbls. while the Portland increased several millions bbls.

There are several different materials that may be used in the manufacture of Portland cement but they must consist mainly of calcium carbonate and silicate of alumina. Their exact proportions are determined by their chemical composition. A ~~as~~ usual ratio is about 75% carbonate to 25% silicate. The two substances occur in nature in many different forms but the most common used in the U.S. are:

Cement rock and limestone.
Limestone " clay.
Limestone " shale.
Marl " clay.
Chalk " clay.
Alkali waste " clay.

The two materials needed are often found in the same locality and because of their great abundance and wide distribution of occurence it makes it possible to locate a cement plant where it is most needed thus reducing very much the cost of shipment of the finished product.

In the manufacture of cement there are two methods of mixing the materials, respectively the wet process and the dry process, before

introducing them into the kilns.
The wet process is employed with soft or wet materials, such as chalk and clay or marl and clay. The two substances are put into vats and agitators break up all large lumps and so finely reduce the particles that they are held in suspension in the water and flow off over the top of the vat. In another vat they are allowed to settle, the water drawn off and the "slurry" becoming hard enough to handle in barrows it is dried, and finally calcined in kilns. After being calcined almost to the melting point the product is taken from the kiln, cooled with water, and ground to a very fine powder after which it is placed in barrels and ready for shipment.
The dry process of mixing is best suited where cement rock and limestone are used. Rotary kilns

are merely used for this purpose into which the right proportions of the rocks are introduced, after being ground together, and the mixing goes on while the calcining is taking place. The rest of the manufacture is the same as in the wet process.

Nothing but a good even grade of cement should be used and it should be fine enough to pass through a no. 74. sieve. Impurities have some effect on cements and therefore care must be used in selecting the finest grades. All standard grades of cement are tested for, (a) Fineness, (b) Expansion, (c) Shrinkage, (d) Rate of hardening, (e) and Resistance to tension and compression.

The chemistry of the setting of cement is not fully understood but some think it is according to the formulae:

$$2Ca_3SiO_5 + 9H_2O + 9H_2O = (CaSiO_3)_2 5H_2O + 4Ca(OH)_2$$

The $Ca(OH)_2$ then further reacts upon the calcium aluminate of the cement forming hydrated basic calcium aluminate:

$$Ca_3Al_2O_6 + Ca(OH)_2 + 11H_2O + Ca_4Al_2O_7 \cdot 12H_2O.$$

The first reaction represents the hardening of the cement while the second represents the setting. Other theories are offered by chemists but this seems to be the most likely.

Historical Sketch of Reinforce Concrete.

The invention of reinforced concrete is usually credited to Joseph Monier but his first constructions are antedated by those of Lambot, who, in 1850, constructed a small boat of reinforced concrete and in 1855 exhibited the same at the Paris Exposition. In this latter year Lambot took out patents on this form of construction as he considered it especially well adapted to ship-building, reservoir walls etc.

In 1861 Monier, a Parisian gardener constructed tanks and tubs of concrete surrounding a frame work or skeleton of wire. In the same year Coignet announced his principles for reinforcing concrete, and proposed construction of beams, arches, pipes, etc. Both he and Monier exhibited some work in the new material at the Paris Exposition in 1867. In this year Monier took out patents on his reinforcement. It consisted of two sets of parallel bars one set at right angles to and lying upon the other thus forming a mesh of bars. This system, and slight modifications of it, are extensively used at present particularly for slab reinforcement.

In 1884-5 the German and American ~~ca~~ rights of the Monier patents fell into the hands of German engineers. One of these G. A. Wayss and J. Bauschinger at once began an experimental investigation of the Monier system, and in 1887 they published their results. The investigation proved reinforced concrete a valuable means of construction, and furnished some formulas and methods of design. From this time on, the use of reinforced concrete in Austria spread rapidly, and a few years ago, the engineers of that country were credited with having done more to develop the new construction than those of any other country. Among these engineers should be mentioned Melan, who in the early 90's originated a system in which I or T beams are the principal element of strength, providing compressive as well as tensile strength. In Germany government regulations hindered the application of reinforced concrete construction for a time, but now it is widely used in that country and it is stated that over two hundred systems of reinforcement have been developed by the Germans alone.

France also made some advancement in reinforced concrete and claims to be the home of the "stirrups" and "bent-up" bars reinforcement which is quite widely used all over the world.

In England and America the first use of iron and steel with concrete arose in the effort to fire proof the former by means of the latter. Attempting to utilize also the strength of concrete, Hyatt built beams of concrete reinforced with metal in various ways and with Kirkaldy of London performed tests on such beams and published the results in 1877. The first reinforced-concrete work in the U.S. was done in 1875 by W.E. Ward, who constructed a building in N.Y. state in which walls, floor-beams, and roof were made of concrete reenforced with metal to provide tensile strength, but the Pacific Coast saw the actual early development of this form of construction. H.P. Jackson, G.W. Percy and E.L. Ransome were early workers. Jackson has been credited with reinforced constructions dating as far back as 1877, but Ransome executed the most notable early examples. Among these are a warehouse (1884), and a factory building a few years later. Percy was architect of the California Academy of Science (1888) and the museum building of Leland Stanford Junior University. These last two buildings named withstood the earthquake remarkably well compared with structures of other material.

F. von Emperger and Edwin Thacher were first to construct bridges and arches in this country using the Melan system. The first large reinforced-concrete bridge was built in 1896 and was without precedent here as in Europe.

America is the home of the "patent bar". Ransome and Thacher invented bars known by their respective names the patent feature of which is to furnish a "grip" between bar and concrete. There are also patented bars for supplying "shear reinforcement".

Discussion of Concrete in General.

The conditions to be met in reinforced-concrete construction require the use, generally, of a concrete of relatively high grade. In this type of construction the strength of the material is of much greater importance than it is in many forms of plain concrete design, as the dimensions of the structures are more directly dependent upon strength and less upon weight. A comparatively strong concrete is therefore found to be economical.

It is also very important, also, that the concrete be of uniform quality and free from voids, ~~that~~ as the sections are comparatively small and the stability of the structure, to a much greater extent than is the case with massive concrete, is dependent upon the integrity of every part. Thoroughly sound concrete is also required in order to insure good adhesion to the steel reinforcement and adequate protection of the steel from corrosion and from fire. These requirements call for great care in preparation and placing of the material.

In mixing concrete and choosing the materials for it there should be extreme care taken. Nothing but Portland cement should be used, and that of a standard quality, for reinforced concrete construction. A coarse sharp sand free from clay should be used. Broken stone or gravel may be used in making the concrete but should be free from clay and sand as well as being of a uniform size. The size depends upon the kind of structure is being made. The maximum ~~---~~ sizes should not be over 1¼ inches and where the rods are close together much smaller should be used. The best proportions used by scientific workmen is between 1:2:4 to 1:3:6 of cement, sand, and broken stone respectively. The tendency in all kinds of concrete construction is to use a wetter mixture than formerly. Relatively dry concrete well tamped will give slightly greater strength than a wet mixture, although a plastic mixture is not considered too wet as a rule.

Numerous tests are applied to reinforced concrete and especially have these tests been carried on for beams and columns, cubes, etc. for compressive strength, tensil strength, shearing strength, elastic properties, adhesive properties of concrete to steel, etc.

These tests have been carried on to

a great extent in the laboratories of the Universities of Pennsylvania, Columbia, Chicago and many schools of technology.

This last winter I saw a very interesting test going on at the University of Pennsylvania under the supervision of Mr. A.T. Goldbeck, Instructor in Civil Engineering. The tests were carried out on beams 13 ft. long but of different cross-sectional area and with different moods of reinforcements. The testing apparatus was arranged so that the repeated loads could be applied at any point along the beam or at several points at the same time. The loading arrangement was run by the power engine of the University and applied the load, of any desire, about 10 times per minute for any length of time. The beams were given several thousand applications of the loads and then examined. After several million applications the beams were taken out and broken up to be examined for other things as well as for examining the reinforcement.

The following conclusions have been reached by H.C. Berry who has written a phamphlet on this series of experiments.

1. "That the ultimate strength of a reinforced concrete beam is not materially affected by one million repetitions of high working stresses."

2. "That the maximum deflection is not affected."

3. "That hairline cracks become visible for such loads at intervals of 6 to 8 inches and grow deeper as the number of repetitions is increased, but that for one million repetitions no crack extended beyond the neutral axis."

4. "That the bond between the steel and the concrete is not appreciably affected as shown by the difficulty with which the steel was

removed in breaking up the beams."

5. "That the position of the neutral axis is not changed by repetitions of the load."

6. "That the greater part of the set in deformation in the plane of steel occurs in the first few thousand applications of the load".

7. That the set in the deformation on the compressive side of the beam is also relatively large for the first few thousand repetitions, and that it increases with the stress applied and the number of repetitions."

Design of the Concrete Floor for the Power House at Washington and Lee University.

Drawings will accompany this to show dimensions and details of construction.

Specifications:

Materials. The cement used in this construction shall be a Portland cement fulfilling the U.S. standard specifications.

The sand used shall be a coarse grained angular, clean sand.

The stone used shall not be larger than 1 inch and shall be crushed stone and not gravel.

Construction. The concrete shall be mixed in the proportion of 1: 2½ : 5.

The materials shall be well mixed and put into the forms wet enough to flow from the shovel.

The concrete shall be well

tamped around the reinforcement and into the forms.
The floor shall have a smooth wearing surface of granolithic finish which shall be given to it before the lower part is set.
The floor shall rest upon I beams as indicated in the drawings and shall be reinforced by wire cloth. The I beams and reinforcement shall be of sufficient strength to support an uniform load of 150 lbs per sq. ft., besides the weight of the concrete floor.
There shall be steel wall plates for the I beams to rest upon where ever they come in contact with the wall.

Design.

area of floor surface = 30 x 60 = 1800 sq. ft.
Cu. feet of concrete = 30 x 60 x $\frac{1}{3}$ = 600 cu. ft.
Weight per cu. ft. of concrete = 150 lbs.
Total weight of concrete = 150 x 600 = 90000 lbs.
Wt. per sq. ft. of concrete = 1 x 1 x $\frac{1}{3}$ x 150 = 50 lbs

Uniform live load allowed per sq. ft. = 150 lbs
Total load per sq. ft. = 150 + 50 = 200 lbs.
Safe load for slab of 6 ft. span per sq. ft. = 200 lbs. for 4 in. slab with steel 3 in. deep and .490 sq. in. area in 1 ft of slab.

Design of Small I Beams.

Size of slab supported by one small I beam = 6'×15' = 90 sq. ft. (Floor 4" thick)
$1 \times 1 \times \frac{1}{3} = \frac{1}{3}$ cu. ft. = concrete to one sq. ft. of floor surface.
$90 \times \frac{1}{3}$ = 30 cu. ft. = concrete carried by one small I beam.
150 lbs = weight per cu. ft. of concrete.
30 × 150 = 4500 lbs = weight of one concrete slab supported by one small beam.
150 lbs = Uniform live load per sq. ft.
150 × 90 = 13500 lbs = Total live load on one small beam.
∴ 13,500 + 4,500 = 18000 lbs. = Total load carried by one small I beam.
From Cambria a 10" I 25# 15 ft. long the safe uniform load is 17,360 lbs.
∴ as the uniform live load of 150 lbs. per sq. ft. is taken rather high ~~there~~ it will

be seldom if ever that as much as the total load (18000 lbs) calculated will come upon the floor. Therefore it seems that the <u>10" I 25#</u> beam will be large enough.

Design for large I-beams.

15 x 16.5 = 247.5 sq. ft. = floor carried by one large I beam.

247.5 x 30 = 7,425 lbs = weight of concrete carried by one beam.

247.5 x 150 = 37,125 lbs = Uniform live load carried by one beam.

∴ 37,125 + 7,425 = <u>44,550</u> = Total uniform load on one I beam.

As the uniform live load is taken higher than it will actually be for this floor the total load is too much. This being the case a <u>15" I 42#</u> beam carrying a safe load of 39,270 lbs. (from Cambria) may be used.

Design for small I beams used as lentals over the doors in the wall.

6' x 15 = 90 sq. ft. = Floor supported by one lental.

90 x $\frac{1}{3}$ = 30 cu. ft. = Concrete carried by lental.

30 × 150 = <u>4,500</u> lbs = weight of concrete carried by one lintel.
90 × 150 = 13 500 lbs = uniform live load.
13500 + 4,500 = <u>18000</u> lbs. = Total load carried by lintel.
From Cambria a 6" I 12.25# 6" long the safe uniform load is <u>17,050</u> lbs.
∴ as ~~as~~ the uniform live load of 150 lbs per sq. ft. is taken too large the 6" I beam is strong enough.

Design for the steel wall plates.
In designing these plates we use the formula from Cambria;

$$t = .00685(l-b)\sqrt{\frac{R}{b'l}}$$ in which,

t = thickness of plate. (in inches.
l = length of plate in direction ⊥ to axis of beam
b = breadth of flange of beam in inches.
R = Reaction at pt. of support in lbs.
b' = width of plate in direction of axis of beam.

For small beams.
8" = l ; b = 4.33" ; b' = 6", R = 9000 lbs.

$$\therefore t = .00685(8-4.33)\sqrt{\frac{9000}{6\times 8}} = \underline{\underline{.351}} \text{ in. about.}$$

.351 in. is not a standard thickness for plates so the nearest commercial thickness is 3/8. ∴ plates for small I beams must be $6'' \times 8'' \times 3/8''$.
Weight per plate $= 490 \times \frac{1}{2} \times \frac{2}{3} \times \frac{.5}{12} = \underline{12.09}$ lbs.
(490 lbs = wt. per cu. ft. of steel.)
If concrete is used in the proportion of 1:2½:5 for the masonry for support the allowable pressure per sq. in. being 350 lbs. the safe bearing value of this plate is $350 \times (6 \times 8) = \underline{16800}$ lbs
This gives a plate of size enough to well support 9000 lbs.

<u>Plates for large I beams.</u>
Thickness found by same method to be about 3/4"
∴ Plate used $12'' \times 12'' \times 3/4''$. wt. = 30.62 lbs.

<u>Plates for lintels.</u>
Thickness found by same method to be about ½".
∴ Plate used $6'' \times 9'' \times \frac{1}{2}''$; wt. = 9.72 lbs. and two others for door lintel are $12'' \times 16'' \times \frac{1}{2}''$, weight = 10.2 lbs.

Plates for top and bottom of column.
$14'' \times 14'' \times 1\frac{1}{2}''$ weight = 85.6 lbs.

Design of column used to support large I beams.
Total weight on column = 101,482 lbs
From Cambria for a cast iron hollow round column it gives a safe load of 122,000 lbs. for a column 11' long, 8" outside diameter and 3/4 in. thick.
Weight of column = 587.4 lbs.
Column to have square ends.

Bill of Steel used in Floor.

No.	Name of pieces and Description	Wt.	Total Wt. lbs.
18	Steel wall plates 6"x 8"x 1/2"	6.8 lbs	124.40
2	" " " 12"x 12"x 3/4"	30.62	61.24
5	" " " 6"x 12"x 1/2"	10.20	51.00
1	" " " 6"x 9"x 1/2"	9.74	9.74
2	Steel column plates 14"x 14"x 1 1/2"	85.60	171.20
1.	Column (8" Round Hollow Cast Iron Pipe 11' long 3/4" thick	587.40	587.40
2	15" I 42# 16'6" long	672.00	1344.00
18	10" I 25# 15'0" "	375.00	6750.00
20	Standard connections, 6"x 4"x 3/8" angle - 5" long	5.12	102.40

(Steel) Total = 9,201.38 lbs.

Estimate of Cost of Floor.

Concrete: 22.22 cu. yds. at $5.00	= $111.10
Labor in constructing forms	= 20.00
Lumber for forms	= 25.00
I beams, wall plates, columns, etc. 9201.38 lbs at $.02	= 184.03
Reinforcing wire cloth about	20.00
Other probable expenses	5.00
Making total of - - - -	$365.13

Concrete Chimney Construction

In discussing the chimney construction I will quote Mr. Sanford E. Thompson, at times, who is a well known authority on reinforced concrete and especially chimney construction.

After making a thorough investigation of concrete chimney construction for the American Portland Cement Manufacturers reaches the following general conclusions.

1. "Reinforced concrete is a suitable material for chimney construction".

2. "Reinforced chimneys must be designed and built on the same principles and by the same methods which have proved essential in other types of reinforced concrete construction".

3. "The defects and failures which have occurred in chimneys thus far built have been due to poor workmanship or faulty design or use of the wrong concrete mixtures or all three".

4. "The methods of construction at present being followed are defective in many cases and liable to lead to subsequent failures, and they should be radically modified."

Following these conclusions Mr. Thompson gives a few general specifications, or requirements by which concrete chimneys should be constructed.

1. "Design the foundation according to the best engineering practice."

The best type of foundation seems to be the one known as the "spread" type and is to be the one used for the chimney to be constructed. It has a shallow depth, with the stresses distributed to the other edges by reinforcing bars.

2. "Compute the dimensions and reinforcement in the chimney with conservative units of stress, providing a factor of safty in the concrete of not less than 4 or 5."

A clean fine ~~sand~~ gravel as well as clean sand should be used for the outer shell.

"In designing a chimney, the thickness of the outside shell must be sufficient to bear, with the steel imbedded in it, the pressure due to the weight of the chimney and to the wind."

The concrete to be used in this chimney is to be 1 : 2½ : 3, which makes a mixture of exceedingly dense concrete and can be relied on to develop an ultimate crushing strength between two and three thousand lbs. per sq. in.

3. "Provide enough vertical steel to take all of the pull without exceeding 14000 lbs., or at the most 16000 lbs. per sq. in."

Sufficient reinforcing steel must be used to absorb all the tension that might be caused by a wind pressure of 50 lbs. per sq. ft.

4. "Provide enough horizontal or circular steel to take the vertical shear and to resist the tendency to expansion

due to the interior heat."
The horizontal reinforcing used should be a wire net which is to be wired to the vertical bars one inch from the outer shell.
5. "Distribute the vertical steel by numerous small rods in preference to larger rods spaced farther apart."
About five-eighths in square or 3/4 inch round steel bars should be used.
6. "Specially reinforce sections where the thickness of the wall of the chimney is changed or which is liable to marked changes in temperature.
In the chimney to be constructed there shall be no offsets of any kind to cause undue stresses and there shall be a lining composed of a hard shale brick which is to take the heat before it reaches the concrete. There shall be an air space between brick and concrete and with the lining running about 1/3 way up the chimney there are no stresses in the concrete caused from heat.

7. "Select first class materials ~~thorou~~ thoroughly test them before and during the progress of work".
8. "Mix the concrete thoroughly and provide enough water to produce a quaking concrete."
The concrete should be mixed in "one bag batches" in order to insure it being placed in the forms before the cement has taken its initial set.
9. "Bond the layers of concrete together".
Before fresh concrete is to be added to that of the day before the surface shall be scraped, brushed clean, and covered with pure cement grout in order to bond the two sections.
10. "Accurately place the steel."
11. "Place the concrete around the steel carefully, ramming it so thoroughly that it will shrink against the steel and adhere to every point".
12. "Keep the forms rigid."

Stress in Chimney due to Wind.
Velocity of wind being 100 mi. per hour causing pressure of 50 lbs. per sq. ft.
To find compression stress on concrete at the base on leward side of chimney and tension in steel op windward.

$$S = \frac{Mc}{I} \ldots$$

M = Bending moment $= \frac{1}{2} w x^2$
$= \frac{1}{2} \times 385 \times 10000 = 1,925,000$
$Mc = 1,925,000 \times 3.85 = 7411250$
I = Moment of inertia for section.
$= \frac{1}{64} \pi (d_1^4 - d_2)$. d_1 = outside diameter.
d_2 = inside " .

$$I = \frac{1}{64} \pi ((7.7)^4 - (6.2)^4) = 100$$

$$\therefore S = \frac{7,411,250}{100} = 74,112.5$$ = Compression on leward side per sq. ft.

$$S = \frac{74,112.5}{144} = 514.68$$ = Compression per sq. in.

Allowable compression on concrete per sq. in. = 367 lbs.
$\therefore 514.68 - 367 = 147.68$ lbs. = Pull on steel on windward side for every sq. in. of concrete on leward side.

area of $\frac{1}{2}$ base of chimney = 1185.84 sq. in.
1185.84 x 147.68 = 175124.85 = total stress on steel on wind side.
100 sq. in. = Steel in half of base of chimney.
$\therefore \frac{175124.85}{100} = 1,751.2485$ lbs. = $P/a = S$ = Unit stress in steel on wind side due to wind blowing at 100 mi. per hr.

Weight of Concrete in Chimney.

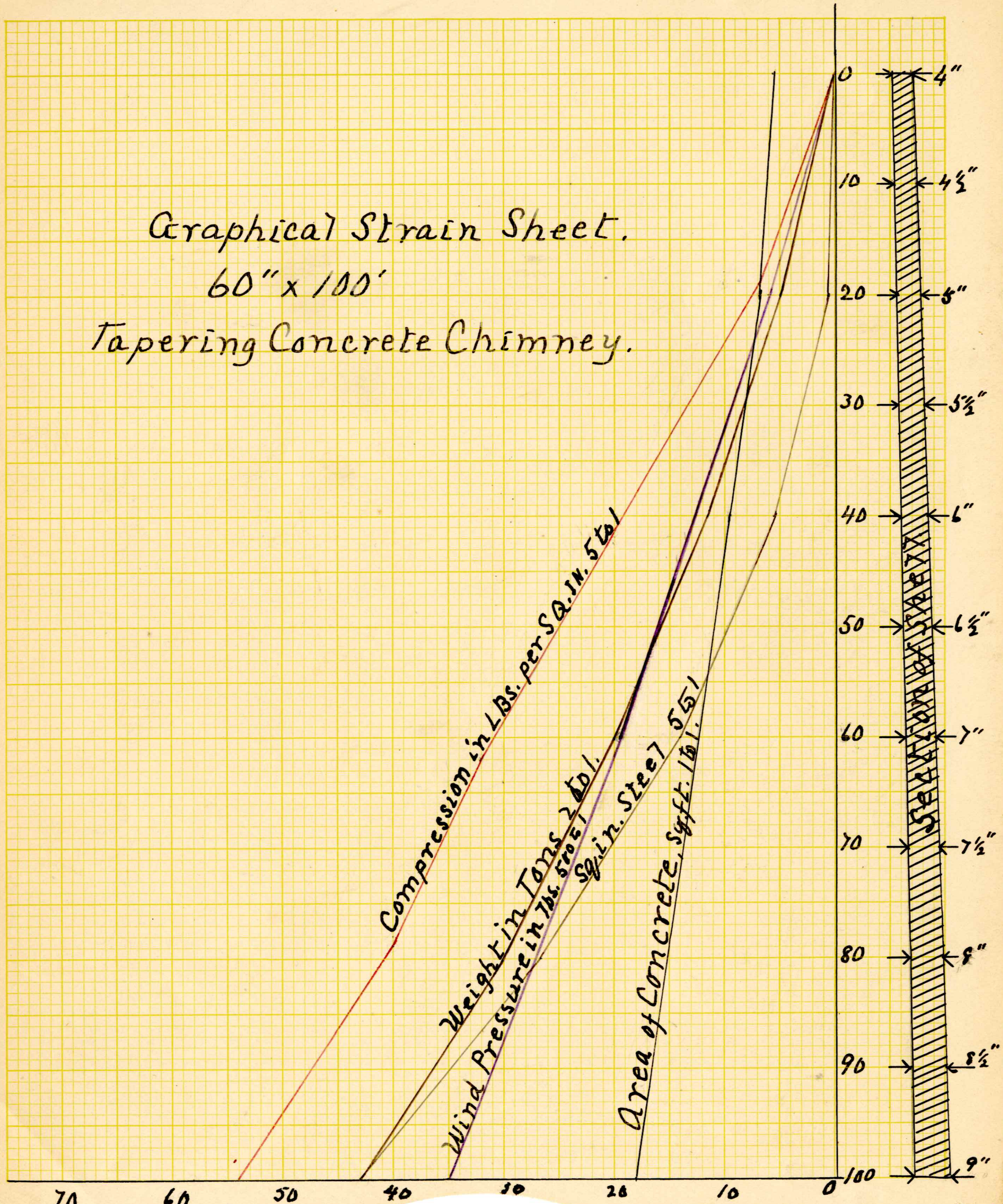
A_1 = 16.47 sq. ft. = area at base.
A_2 = 5.5 sq. ft. = " " top.
$A = \frac{21.97}{2}$ sq. ft. = 10.98 sq. ft. = average area.

10.98 x 100 = 1098 cu. ft. = Volume of concrete in chimney.

1098 x 150 = 164,700 lbs = Weight of Chimney or 164,700 ÷ 2000 = 80.5 tons. = Weight of Concrete in chimney.

Compression in concrete due to Weight of Chimney. (Com. = $\frac{W}{A_1}$ = C)
164,700 ÷ 1185.84 = 139 lbs. per sq. in.

Stresses are plotted on page 37.


Graphical Strain Sheet.
60" x 100'
Tapering Concrete Chimney.
Compression in LBs. per SQ. IN. 5 to 1
Weight in Tons 2 to 1.
Wind Pressure in lbs. 5 to 1
Sq. in. Steel 5 to 1
Area of Concrete, Sq. ft. 1 to 1.
Section of Shell
0
10
20
30
40
50
60
70
80
90
100
4"
4½"
5"
5½"
6"
6½"
7"
7½"
8"
8½"
9"
70
60
50
40
30
20
10
0

Cost of Chimney.

The cost of the chimney as bid on by the General Concrete Construction CO., Chicago. was $1,750.

Respectfully submitted,
J. J. Forrer

June 9, 1909.