DESIGN OF AN ERECTION PLANT
FOR
A TEN-STORY REINFORCED-CONCRETE
FACTORY BUILDING

BY

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COLLEGE OF ENGINEERING

I hereby recommend that the thesis prepared under my direction by HUBERT VINCENZ STEPHENSON entitled DESIGN OF AN ERECTION PLANT FOR A TEN-STORY REINFORCED CONCRETE FACTORY BUILDING be accepted as fulfilling this part of the requirements for the degree of Bachelor of Science in Civil Engineering.

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DESIGN OF AN ERECTION PLANT FOR A TEN-STORY REINFORCED-CONCRETE FACTORY BUILDING.

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I. INTRODUCTION.

The purpose of this paper is to consider the principles involved in deciding upon the methods and equipment to be used in the erection of a building of this type. In order to better illustrate these principles they will be applied to a particular building. In general, the method and equipment to be used is that whereby the work can be most economically done within the specified time.

II. DESCRIPTION AND LOCATION OF BUILDING.

The building to be erected is the ten-story reinforced-concrete factory building of the Loose—Wiles Biscuit Company, near the Pennsylvania Railroad Company's tracks at the end of the Queensboro bridge in Long Island City, New York. The building is 430 feet long by 200 feet wide. It is on a recent fill of earth and sand 17 feet deep extending to mean low-tide level. Below this is a layer of mud and sand extending to bed-rock. The minimum thickness of this layer is 32 feet, making a minimum depth of 49 feet from the surface to bed rock.

The building is supported on columns resting on concrete piers and footings. The footings cover approximately 80% of the
entire area of the site, and are supported on foundation piles projecting one foot into the concrete footings, or to mean low-tide level. The footings are five to six feet thick, heavily reinforced with two cross-layers of deformed bars. On account of the large amount of room that would be required for concrete columns, the interior columns to the seventh floor are made of structural steel and enclosed in concrete. The remaining length of these columns is reinforced concrete. The exterior columns, which are substantially wall-piers, are made of reinforced concrete, and are rectangular in cross-section. The maximum cross-section is 6 feet x 2.5 feet.

English ovens, two stories high, occupy a large part of the seventh floor and extend through the eighth floor. These ovens are built of brick of which more than 1,000,000 were used for their construction.

The side walls are supported directly on steel girders riveted to the columns and enclosed in solid masses of concrete.

All other floors and the roof are reinforced concrete slabs supported on beams and girders. The girders are supported by brackets on the interior steel columns. The floor live-loads vary from 150 pounds to 3000 pounds per square foot. There are six elevator and stair shafts through the entire ten stories. The stair shafts are provided with smoke-vestibules with concrete walls.

The panels between the exterior columns or wall piers
have large steel-framed windows. The spaces around these windows are filled in with brick masonry. The front walls are faced with white glazed tile. The side and rear walls are of brick.

Some of the quantities involved in the construction of the building are as follows:

- Reinforced concrete: 35,000 cubic yards
- Reinforcing bars: 2,500 tons
- Structural steel: 4,000 tons
- Cement: 80,000 barrels

There is a bulkhead 1000 feet from the site at which a large part of the material may be delivered. The Pennsylvania Railroad Company's tracks also may be utilized for delivering material to the grounds. The excavation material from the foundation, and other waste material may be loaded onto scows at the bulkhead.

III. EXCAVATION.

The first question to be considered is that of the excavation for the foundation. The footings extend to 1 foot below mean low-tide level or an average depth of 18 feet below the ground-level. The amount of excavation is \((430 \times 200 \times 18) \div 27 = 57,300\) cubic yards. This amount of earth can not be wasted near the site; and as it is only 1000 feet to the bulkhead, it will be hauled to the bulkhead, loaded onto scows, taken away to sea, and dumped.
The amount of material is too large to be handled by hand, and the haul is too great for scrapers to be used economically. The questions to be determined are (1) whether it shall be dug by steam shovel or by orange-peel buckets operated by locomotive cranes, and (2) whether it shall be hauled by teams, in dump-wagons or by contractors' dinkeys, in dump-cars. The choice between these methods will depend upon their relative cost and convenience. The several combinations will be discussed separately in the succeeding pages.

COST OF DIGGING BY STEAM SHOVEL WHEN HAULING BY DUMP-WAGONS.

When hauling in dump-wagons it is not desirable to use a steam shovel of more than 1 1/2 cubic yards capacity. In these computations a 55-ton steam-shovel with a 1 1/2 cubic yard dipper will be used. Its cost will be about $7200 and its maximum working rate is 180 cubic yards per hour. Assume that the shovel will actually be in operation only half the time, its average capacity will be 900 cubic yards per 10-hour day.

By adaptation of the table of costs of operating a steam shovel given in Gillette's "Handbook of Cost-Data", pages 134-139, we find the charges per day against the steam shovel to be as follows:

<table>
<thead>
<tr>
<th>Crew</th>
<th>Cost per day.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Engineman</td>
<td>$5.00</td>
</tr>
<tr>
<td>1 Craneman</td>
<td>4.00</td>
</tr>
<tr>
<td>1 Fireman</td>
<td>3.00</td>
</tr>
<tr>
<td>6 Pitmen</td>
<td>2.50</td>
</tr>
<tr>
<td>Total (for Crew)</td>
<td>27.00</td>
</tr>
<tr>
<td>Coal 1 1/4 tons</td>
<td>4.00</td>
</tr>
<tr>
<td>Oil and Waste</td>
<td>1.00</td>
</tr>
</tbody>
</table>
Interest and Depreciation on $7200 (shovel) at 
12% per year + 100 days per season $8.00
Repairs, 3% per month of 22 days on $7200 10.00
Housing shovel at $200 per year 2.00
Total charge $53.00

In addition to the above charge there should be added the cost of moving the shovel to and from the job. It will be sufficiently accurate to assume this to be $100. As the track required for the steam shovel will be used later in the erection, the only charge which should be made for the track is for handling it. This is provided for in the item for the six pitmen.

COST OF WAGON-HAULING.

In Gillette's *Earthwork and Its Cost*, page 40, it is stated that a team hauling a heavy load in one direction and returning empty will make an average speed of 220 feet per minute. With this statement as a working basis and the 1000 foot haul given, it is found that one team using a 1 1/3 cubic yard dump wagon will haul about 100 cubic yards per ten-hour day. The average capacity of the shovel is 900 cubic yards per ten-hour day, with a maximum running capacity of 1800 cubic yards per ten-hour day. Eighteen teams would have to be provided to haul away the earth at this maximum rate. It will be cheaper, however, to provide only about twelve teams and allow the steam shovel to work at less than its maximum rate while running. The shovel will then have an average capacity of 720 cubic yards per ten-hour day.

When hauling by teams, the scow will be brought along side the bulkhead and by throwing a light platform bridge from the bulkhead to the scow at each end, the teams may be driven onto the scow
at one end, along the scow to the required point, the wagons dumped, and the teams driven off at the other end, thus making a complete circuit without turning around and with but little or no loss of time in dumping.

With the foregoing as a basis, the cost of wagon hauling is estimated as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost per day.</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 teams</td>
<td>$78.00</td>
</tr>
<tr>
<td>2 dumpmen on scow</td>
<td>5.00</td>
</tr>
<tr>
<td>Interest and depreciation on 12 dump wagons</td>
<td>3.00</td>
</tr>
<tr>
<td>Repairs on 12 wagons, 2% per month of 22 days</td>
<td>1.40</td>
</tr>
<tr>
<td>Total (720 yds. @ $0.121)</td>
<td>$87.40</td>
</tr>
</tbody>
</table>

In addition to this a charge of $10 per wagon should be added for transportation.

COST OF JOB BY ABOVE METHOD.

The steam shovel works on the lower level, therefore an inclined roadway to the pit will have to be excavated. This will require the excavation of about 3,500 cubic yards additional material. This will be dumped near the site and used to refill the roadway. The total amount of material to be handled will be 57,300 cubic yards plus 2 x 3,500 cubic yards = 64,300 cubic yards. The cost of digging is $53.60 \div 720 = $0.074 per cubic yard. The final estimate of the cost by this method is as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Amount.</th>
</tr>
</thead>
<tbody>
<tr>
<td>64,300 cu.yds. steam shovel work @ $0.079 =</td>
<td>$4,758</td>
</tr>
<tr>
<td>Transportation on shovel</td>
<td>100</td>
</tr>
<tr>
<td>64,300 cu.yds. of wagon-haul (1000') @ $0.121</td>
<td>7,780</td>
</tr>
<tr>
<td>Transportation on wagons</td>
<td>120</td>
</tr>
<tr>
<td>Total for 64,300 cu. yds. =</td>
<td>$12,758</td>
</tr>
</tbody>
</table>
As the above outfit is a complete unit in itself, very little if any saving could be affected by using two or more steam shovels instead of one.

**COST OF DIGGING BY STEAM SHOVEL WHEN HAULING IN DUMP-CARS.**

When hauling by dump-cars the capacity of the steam shovel dipper may be 2 cubic yards. In the previous estimate it was assumed that the shovel actually worked but half of the time, with the larger dipper the shovel would not be in operation quite half of the time. Assuming that the same amount of material is excavated per move, it is found by proportion that the capacity of the steam shovel equipped with the two-yard bucket is 1,030 cubic yards per ten-hour day. The operating cost per day will be as before very nearly the same so the price per cubic yard becomes

\[
\frac{53.60}{1,030} = 0.052.
\]

**COST OF HAULING BY DUMP-CARS.**

The cost of hauling by dinkeys and dump cars depends more upon the output of the shovel than upon the distance hauled, because the capacity of the hauling outfit, especially on a short haul, is very much greater than that of the excavating outfit. The track to be used for the dirt train will be used for hauling materials to the building during construction so only about half of the cost of laying and maintaining the track should be charged to excavation. The cost of operating a dirt train consisting of 11" x 16" contractors' dinkeys with 3-yard dump cars, based on the table of costs given in Gillette's, "Handbook of Cost Data", page 139, is as follows:
Crew

2 Enginemen on 2 dinkeys @ $4.00 = $8.00
2 trainmen @ 2.50 = 5.00
6 dumpmen @ 2.50 = 15.00
Total for Crew = 28.00

Coal for two dinkeys 0.0 ton @ 4.00 = 2.40
Oil and waste = 1.00
Interest and depreciation on $8000 (2 engines, 24 cars) @ 14% + 100 days per season = 11.20
Repairs 1/2% per month of 22 days on $8000 = 5.45
Total charge on train (1030 yds. @ $0.047) = 48.05
Transportation on engines and cars $100.

A dumping trestle with an inclined platform to the scows and an approach on about 3% grade will have to be built for dumping the earth onto the scows. This will cost about $750.

COST FOR JOB BY ABOVE METHOD.

The cost of the job by the above method is as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>64,300 cu. yds. steam shovel work @ $0.052</td>
<td>$3,344</td>
</tr>
<tr>
<td>Transportation on shovel</td>
<td>100</td>
</tr>
<tr>
<td>64,300 cu. yds. hauled 1,000 ft. by cars @ $0.047</td>
<td>3,022</td>
</tr>
<tr>
<td>Transportation on engines and cars</td>
<td>100</td>
</tr>
<tr>
<td>Track</td>
<td>100</td>
</tr>
<tr>
<td>Dumping trestle</td>
<td>750</td>
</tr>
<tr>
<td>Total for 64,300 cu. yds.</td>
<td>$7,316</td>
</tr>
</tbody>
</table>

COST OF DIGGING BY ORANGE-PEEL DREDGE WHEN HAULING BY DUMP CARS.

It is not necessary to consider hauling by wagons in this case as it has already been shown to be much more expensive than hauling in dump cars. The capacity of a 1 cubic yard orange-peel dredge-bucket operated by a 15 ton locomotive crane is 900 cubic yards per 10-hour day, according to Gillette's "Earthwork and Its Cost", page 95. The cranes cost $6,000 each and the buckets cost $1,000 each. Two such excavating outfits will be
used on this job. As this machine works from the original ground level, no inclined approach will be required so the amount to be excavated will be 57,300 cubic yards.

The cost of operating the two machines will be about as follows:

<table>
<thead>
<tr>
<th>Crew</th>
<th>Cost per day.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Enginemen @ $5.00</td>
<td>$10.00</td>
</tr>
<tr>
<td>2 Firemen @ $3.00</td>
<td>$6.00</td>
</tr>
<tr>
<td>8 Laborers @ $2.50</td>
<td>$15.00</td>
</tr>
<tr>
<td><strong>Total for crew</strong></td>
<td>$41.00</td>
</tr>
<tr>
<td>Interest and depreciation on $14,000 at 12%, 100 days per season</td>
<td>$10.80</td>
</tr>
<tr>
<td>Repairs, 2% per month of 22 days on $14,000</td>
<td>$12.70</td>
</tr>
<tr>
<td><strong>Total charge (1,200 yds.@ 0.059)</strong></td>
<td><strong>$70.50</strong></td>
</tr>
</tbody>
</table>

As the locomotive cranes will be used for other work in the erection of the building $100 will be a sufficient charge for transportation.

**COST OF HAULING BY DUMP CARS.**

Three engines and 30 cars will be required; one engine and 12 cars at each machine and one engine and 12 cars dumping. The cost will be about as follows:

<table>
<thead>
<tr>
<th>Crew</th>
<th>Cost per day.</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 Enginemen @ $4.00</td>
<td>$12.00</td>
</tr>
<tr>
<td>3 Trainmen @ $2.50</td>
<td>$7.50</td>
</tr>
<tr>
<td>6 Dumpmen @ $2.50</td>
<td>$15.00</td>
</tr>
<tr>
<td><strong>Total for Crew</strong></td>
<td>$34.50</td>
</tr>
<tr>
<td>Coal for three dinkeys, 1 ton @ $4.00</td>
<td>$4.00</td>
</tr>
<tr>
<td>Oil and waste</td>
<td>$1.50</td>
</tr>
<tr>
<td>Interest and depreciation, 14% on $12,000 (3 engines and 30 cars) 100 days per season</td>
<td>$10.80</td>
</tr>
<tr>
<td>Repairs 11% per month of 22 days on $12,000</td>
<td>$8.20</td>
</tr>
<tr>
<td><strong>Total charge on train (1,200 yds.@ 0.040)</strong></td>
<td><strong>$55.00</strong></td>
</tr>
</tbody>
</table>

Charges to be added to the job are the same as for the steam shovel except transportation which is $150.
Figure 1
Bottom View of Orange-Peel Bucket.
Figure 2
Orange-Peel Buckets in Operation
COST FOR JOB BY ABOVE METHOD.

<table>
<thead>
<tr>
<th>Item</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>57,300 cu. yds. digging @ $0.059</td>
<td>$3,381</td>
</tr>
<tr>
<td>Transportation on Orange-peels</td>
<td>150</td>
</tr>
<tr>
<td>57,300 cu.yds. hauled 1,000 feet by dump cars @ $0.046</td>
<td>2,638</td>
</tr>
<tr>
<td>Dumping trestle</td>
<td>750</td>
</tr>
<tr>
<td>Transportation</td>
<td>150</td>
</tr>
<tr>
<td>Track</td>
<td>100</td>
</tr>
<tr>
<td><strong>Total for 57,300 cu. yds.</strong></td>
<td><strong>7,019</strong></td>
</tr>
</tbody>
</table>

EQUIPMENT ADOPTED.

The above figures show that there is very little difference between the cost of excavating with a steam shovel and with two orange-peel dredges hauling, in either case, by dump cars. The cost of doing the work might be reduced a little by using two steam shovels instead of one, but they could not be used for anything except the excavation. The locomotive cranes operating the orange-peel dredges are a very convenient size and can be used for several purposes after the excavation is completed, e.g. Unloading steel-work, operating a clam shell for unloading sand and gravel, etc. Considering these advantages it probably would be better to use the orange-peel dredges.

METHOD OF WORKING.

The excavating will be commenced as soon as the frost is out of the ground. Begin in the middle of one end and work backward and toward the sides. The driving of the sheeting should be begun at the same time as the excavation and carried on so that by the time the excavation is close enough to the sides to require
the sheeting it will all be in place. Excavate to grade as close to the sheeting as is practicable without putting in the bracing. This will leave a bank of earth next the sheeting all around the pit. As only 80% of the bottom of the pit is covered by footings, this bank may be taken out by shovels and wheelbarrows and put into the spaces between the footings after they are poured. In this way it will not be necessary to operate the orange-peel dredge between the braces.

IV. SHEET PILING.

It will be assumed that the sheeting projects far enough below the level of the excavation to require no bracing at the bottom and that it will be left four feet above the natural ground level to allow for the construction of the concrete wall without removing the top bracing. A brace will be put in at the top and one 9 feet above the bottom, or half way to the top of the natural ground. Assuming that the materials stored along the edge of the excavation will equal four feet of surcharge and that the ground pressure is equivalent to that of a liquid weighing 25 pounds per cubic foot, the maximum bending moment is 6,100 pound feet per foot of length. It is also assumed that the sheeting acts as if it were hinged at the point of application of the middle brace. Assuming a fibre stress of 1,000 pounds per square inch for timber, a 6" wood sheeting is required. For steel sheeting, assuming a fibre stress of 16,000 pounds per square inch the section-modulus required is .38 per lineal inch. The lightest section having this section-modulus is the Lackawanna 14"x 3/8" arched web
sheet piling which has a section-modulus of .543 per lineal inch, and weighs 35 pounds per square foot of surface.

According to the assumptions made, the sheeting will have to be 25 feet long. The amount of surface is 25 x the perimeter of the building excavation, 1,260 feet, or 31,500 square feet. For wood sheeting the number of board feet required is 31,500 x 6 = 189 M feet B. M. At $25 per M this will cost $4,725.

In Gillette's "Handbook of Cost Data" page 1741, a cost of 0.8 cents per square foot is given for driving steel sheeting with a steam pile-driver, labor at $2.00 per day. At $2.50 per day this would be about 8.2 cents per square foot. On page 1740 the statement is given that steel sheeting averages 25% less for driving than wood-sheeting. From these two statements the cost of driving the wood sheeting is 10.9 cents per square foot. The cost of driving wood sheeting for this job would be 31,500 x 10.9 = $3,434, making a total cost of $8,159 for wood sheeting in place.

The average cost of steel sheet-piling delivered on the site is 2 cents per pound or 70 cents per square foot for the sheeting required. The cost is 31,500 x .70 = $22,050. As the steel sheeting can be used over several times, and its value as scrap is about one third of the cost new, the salvage runs very high. Assuming a salvage of 85%, which is conservative, the amount chargeable to the job for the sheeting is $3,310. The cost of driving at 8.2 cents per square foot as given above is $2,583.

The steel sheet-piling will, of course, have to be pulled, straightened, cleaned, and repainted before it can be used again. Gillette's "Handbook of Cost Data" page 1731 gives an instance
Typical section of wall of Lackawanna Arched-Web (15-inch) Steel Sheet Piling, showing the ample bearing surface for interior bracing or externally tied waling timbers.

Figure 3
of doing this on a small job at 4 cents per square foot. As this sheathing will be almost entirely dug out on one side and as it is quite a large job, the above price is probably ample. The cost of pulling at this rate is: $1,500 \times 0.04 = 60$; making a total cost for steel sheet-piling of $7,153.

The cost, as computed, for wood sheeting does not include anything for sawing off below the ground-level, and it is even likely that pulling the sheet-piling would be required, so that the advantage in favor of the use of steel sheet-piling is probably greater than the above figures would indicate. If the contractor doing the work has any place to use this amount of sheet-piling again or can sell it, the $14''x 3/8''$ arched web steel sheet-piling as shown in figure 3 should be used on this job.

**BRACING THE SHEETING.**

The wood and steel sheet-piling have been designed for the same number and location of braces so the cost of the bracing will be the same in either case. With the thrust as computed from the assumptions used in designing the sheathing, and with a $10''x 12''$ wale at the middle brace as shown in Plate I, the required spacing of the shores is 8 feet. With this spacing of shores it is found that a $6''x 8''$ timber is required for the upper wale.

The lower shore (about 15 feet long) must carry a load of 45,000 pounds. From the table of strength of wood-columns, in the Cambria Handbook, it is found that for a factor of safety of three, an $8''x 8''$ timber is required. The upper brace is about 30 feet long but the thrust is so small that it need be designed only for stiffness. It will be braced in three places as shown.
in Plate I. With a limiting value of 30, for the factor $\frac{1}{d}$, a 4" x 12" timber must be used.

With the bracing, or shores, spaced 8 feet center to center, as designed, 160 bents of the bracing shown in Plate I will be required. The amount of timber per bent is about 300 feet B.M. or, 48,000 feet B. M. for the 160 bents. The wales will require 1,260 linear feet of 10" x 12" and 1,260 linear feet of 6" x 8" timbers or 17,640 feet B. M. The total amount of timber required for the bracing is 65,640 feet B. M. Assuming a first cost of $25 per M, with 50% salvage, and a cost of $10 per M for framing and taking down, the bracing will cost $1,477.

V. FOUNDATION PILES.

The footings cover about 80% of the area of the site and are supported on bearing piles at an average of 2.5 feet center to center. The number of piles required is $430 \times 200 \times \frac{.80}{6.25}$ or about 11,000. Assuming an average length of 20 feet for these piles, the amount of piling required is 220,000 lineal feet.

VI. PILE DRIVING MACHINERY.

The choosing of a pile-driving outfit does not depend so much upon the speed with which the hammer will drive the pile, as upon the portion of the time the hammer can be actually driving. The great quantity of piling to be driven makes this a matter of considerable importance, for if this part of the work is not completed promptly, it may seriously delay the erection of the building.
SWIVELLING PILE DRIVER

No. 1 TURNTABLE
FOR SWIVEL PILE DRIVER LATEST FORM RAIL CIRCLE

Figure 4
If a drop hammer operated by a hoisting engine is used, the hammer must stand idle after a pile has been driven, while the next pile is being put into position for driving. With a steam pile-hammer the hoisting engine is not used for driving, so the next pile may be brought from the supply and placed in a vertical position beside the leads while the hammer is driving the pile already in place. When this first pile is driven, all that remains to be done is to shift the driver to the new position and place the pile between the leads. This feature of the operation of a steam pile-hammer affects a considerable saving in time over the drop-hammer.

The Warrington No. 2 steam pile-hammer, with moving parts weighing 1,800 pounds, is the commercial size best suited for driving the 14" x 3/8" arched-web steel sheet-piling. As the same hammer can be used for driving the foundation piles, only one hammer will have to be provided with each machine. The hammers will have to be equipped with two driving-caps, one for the steel sheet-piling, and one for the foundation-piles.

With the ordinary contractor's pile-driver, considerable time is lost while shifting the driver. With a swivelling pile-driver on a turntable, as shown in figure 4, the only movement required for shifting to the next pile is a backward or forward movement on the rollers and a turning movement on the turntable. With this driver, the piling in a strip about 25 feet wide can be driven without shifting the machine sideways. This sideways movement of the driver can be done very easily, because the cross-sills
are flush with the side-sills so it will not be necessary to block
the machine up and put in auxiliary cross-sills for the rollers to
work on.

The piling will be unloaded from scows at the bulkhead,
onto industrial cars, taken to the site, and dumped on skids into
the pit, as near to the driver as possible. The distance of pil-
ing from the driver need never be more than one hundred feet.

The swivelling pile-driver on turntable, as shown in
figure 4, with No. 2 Warrington steam pile-hammer will be used.
There should be enough of these machines to drive the foundation
piles and the sheeting in very little more time than is required
for the excavation. As soon as the excavation is begun, or a
little before, driving the sheeting should be commenced. As soon
as the sheeting is driven, the pile-drivers should be moved to the
part of the pit which has been excavated to grade, and driving the
foundation piling begun. The motion of the machine, when shifting
position, should be from the piles already driven, so they will not
have to be sawed off before the machine is moved. When the pile-
driving is completed the hoisting-engines on the drivers will be
used for operating derricks.

VII. POURING FOOTINGS AND PEDESTALS.

As soon as any considerable portion of the foundation
piles has been driven, work should be commenced on the concrete
footings and pedestals which support the interior steel columns.
The footings and pedestals are of rectangular cross-section, so
the forms may be made in panels, in the same manner as for the
Steel Guy Derrick for Building Construction

Figure 5
IX. ERECTING THE STEEL WORK.

The derricks used for erecting the steel can not sit directly upon the steel as is ordinarily done, because there are no beams or girders except in the seventh floor. The columns are in three-story lengths except the first length which is only one story. By building 6 platforms at the level of the fourth floor, and working 75 foot mast and boom derricks from these, all the steel below this level can be erected. These platforms are located as shown in Plate II (the dotted circles indicate the reach of the derricks), and are supported on timber trusses, resting on top of the columns. The trusses running the long way of the tower are 6 feet deep with 10" x 12" timber chords. The timbers used for the lower wales on the sheeting can be used for building these trusses. About 1,000 feet B. M. is required for each truss. Twelve trusses will be required for the six towers. Ordinary king-post trusses of the same depth may be used for the cross beams of these platforms.

Two 15-ton steel guy derricks with 90 foot mast and 75 foot booms, as shown in figure 5, will be used for erecting the steel. First erect the four columns, on which the working platform shown in Plate II is to be built, from the ground. Brace them with horizontal timber struts and diagonal wire-rope braces, then erect the platform on the columns. With the mast as a gin-pole, set the boom on the platform, then with the boom as a gin-pole set the mast in its proper position on the platform. The boom will then be connected to the mast and the derrick will be ready for operation.
When the steel within the working radius of this platform has been erected, lower the derrick by the reverse of the process described above. This process will be repeated for four of the six towers.

When all the steel below the fourth floor is in place, erect a tower consisting of the columns, beams and girders to the seventh floor, between the two platforms, on which the derricks remain. Raise the derricks to the level of the seventh floor, by the process described in the preceding paragraph. The remainder of the steel may then be erected by the derricks, sitting on the steel girders, in the ordinary manner.

X. CONCRETE MIXING AND DISTRIBUTING PLANTS.

Two mixing plants, one located at the center of each side of the building, as shown in Plate II, will be used. There are ten floors and the roof of the building, in which there are 35,000 cubic yards of concrete, or about 3,000 cubic yards per floor. The capacity of these mixing plants should be such that by continuous pouring, the part of one floor on which the pouring was begun will be set hard enough to support the forms for the next floor, by the time the first is finished. Plants of such capacity can be run at full-capacity all the time. In good weather, concrete will set so that the forms may be removed in five or six days, at which time it will be hard enough to begin erecting forms on it for the next floor. The gangs erecting forms and placing steel should be two or three days ahead of the concreting gang in order that a delay in their work would not stop concreting. This gives about 8 days in which to pour a floor. One plant will have
to furnish only half the concrete for each floor, therefore its capacity should be 190 cubic yards per day. This will require a 1 cubic yard mixer with a 12 or 15 horsepower engine to operate it.

The plant should be so arranged as to avoid all moving of materials by hand, if this can be done at a reasonable cost. The sand and gravel will be delivered to the bulkhead on scows, loaded onto dump-cars with a clam-shell bucket, hauled to the site and dumped into long trough-like bins located on each side of the mixing plant, along the tracks, as shown in Plate II. From these troughs it flows through gates onto a belt-conveyor, by which it is carried to chain-and-bucket elevators which lift it to small auxiliary hoppers from which it flows, by gravity, to the measuring bins. The material is dumped from the measuring bins into the charging-hopper of the machine. The cement will be stored in bags in a shed on the level of the mixer platform on which the measuring bins are placed, and will be taken from the shed to the charging-bin by hand. The mixer discharges into an auxiliary bin under the industrial track, from which it is discharged into the elevator-bucket.

In distributing, as well as in mixing, the aim is to avoid hand work as much as possible. An elevator tower will have to be built for any system of distribution, so it will be advisable to use chutes as far as practicable. It is impossible to use chutes entirely on account of the steel columns being in the way of swinging them. What can be done very conveniently, is to run a chute from the concrete-bin on the elevator-tower to a second concrete-bin located on the platforms, used for erecting the steel,
or clamped onto one of the steel columns. A short chute, 40 or 50 feet in length, can be handled fairly easily by taking it down and passing it around the columns. The concrete can be carted in two-wheeled carts to the areas beyond the reach of these chutes. The maximum carting distance will be about 30 feet. The carts will be run on tracks made of two inch planking in sections short enough to be handled by two or three men. These tracks, or runways, will be supported on horses about 6 feet center to center, resting on the forms, as nearly over the shores as possible. The horses must be very substantial and the legs must be so made that they need not interfere with the reinforcing-bars when in use. With this method of distribution, the concrete bin on the tower, and support for the tower end of the chute should be movable up and down along the tower. Commence pouring at one end and proceed along the building to the other end. By a proper manipulation of the chutes and carts, the carts will never be required to take away more than about one third of the output of the plant.

XI. HANDLING AND ERECTING FORMS.

Building forms in place is more expensive than building them in a shop. Therefore, the forms will be built in units, as much as practicable, as described later in this paper, at the form shop located at one end of the building. The forms will be stored in the form-yard near the form shop. When forms are wanted they will be loaded onto cars by a locomotive crane. A light derrick clamped to one of the steel columns will lift these forms from the cars to the required floor-level and place them on trucks for
distribution over the floor. For erecting the forms adjustable horses will be set up at the required height and the forms lifted onto them by a light derrick clamped to a steel column. When the forms are properly placed and fastened together the shores will be put in and wedged up and the horses removed. Only a few sets of horses will be required for erecting the forms.

XII. TAKING DOWN FORMS.

When taking down forms, lowering them from their original elevation to some form of a carriage or truck is quite a problem, especially if the units used are very heavy. A carriage with a platform that can be moved up and down along four posts which are supported on casters, will be used for this purpose. The carriage is run under the unit of form work to be removed, and the platform raised until it bears against the forms. The supports are then taken from under the form-unit thus transferring it to the carriage. The platform is then lowered so that the carriage can be wheeled out. When the carriage is loaded, it is pushed out onto an overhanging platform on the side of the building, and the forms lifted, by a derrick to trucks on the floor where they are to be re-erected.

XIII. BENDING AND PLACING STEEL.

It is not practicable to bend reinforcing bars in place, and bending them and wiring them together in units in a shop requires extra steel, makes considerable extra work in fastening them together, and they are very awkward to handle. The method explained below has the advantages of the latter method with but
very few disadvantages of any kind. The reinforcing bars for any unit are first cut to their proper length, and the rods required for the unit are tied in a bundle and labelled with the mark for the particular unit to which they belong. From the shearing machine these rods are taken to the bending machine where they are all bent and again tied into a bundle with the unit mark on it. These bundles are then stored in convenient manner in the space near the rod bending shop which is at one end of the building. When required for use these bundles of rods will be taken to their proper locations, and the rods put into place in the forms. This avoids any danger of leaving out any of the rods, or of getting the wrong ones, and makes it unnecessary to sort out rods when they are being placed.

The rods for slabs, beams, etc., should be held up to the required elevation above the forms by small concrete blocks. These may be moulded in groups in a standard form. This should be done near the mixing plant. All spacers within the forms for beams, girders, etc., should be concrete. By using concrete for these spacers they do not need to be removed; thus the danger of disturbing the position of reinforcing-bars and forms is avoided.

XIV. FORMS.

For economy in form-construction all beams and girders should, as far as possible, be of the same width. The variation in floor live-loads will be provided for by varying the depth of the members. It will be assumed that this building has been
designed in this way, making all the floor panels the same size. Plate III shows sketches of the various units used in the form construction for this building.

SLAB AND BEAM FORMS:

The slab and beam form consists of an inverted box without ends, the sides of the box forming the sides of the beams. These sides have a batter of a quarter of an inch to the foot to prevent them from binding while being removed. The form has 2" x 6" horizontal cross-pieces four feet apart nailed to the 2" x 4" battens on the sides. These 2" x 4" battens rest on 2" x 6" brackets which are in turn bolted to the 6" x 6" shores. The forms are leveled up by wedges driven between the brackets and the battens, and are held in place by one inch strips nailed onto the bracket and batten. The bottom of the beam form is made by placing a two inch plank between the sides and wedging it up to the proper height. The lagging is 1 3/4 inch material planed on one side and both edges. When the forms are in place, a moulding strip is tacked into the corners and the sides of the beam form spiked into the bottom.

To remove these forms the spikes through the lagging into the two inch bottom are drawn, then the carriage previously described, is placed under the form, and the wedges and brackets taken out. When the platform of the carriage is lowered, the entire unit will come down by its own weight.

GIRDERR FORMS:

The bottom of the girder form is made of two inch material
and spiked to the sides the same as the beams. The sides of the girder-form have spaces cut into them for the beams. The sides of these spaces are provided with 2" x 4" cleats against which the beam-forms bear. The lagging of the girder is cut off 1\(\frac{1}{2}\) inches from the edge of this 2" x 4" strip. The depth of these openings is adjusted to the depth of the beam by putting in short horizontal strips of the proper width. The junction of the beam and girder form is finished off with a quarter-round strip tacked into the corner left behind the 2" x 4" cleat.

COLUMN FORMS:

The column forms are made in four panels, with narrow lagging strips at the sides which may be taken off to diminish the size of the columns. An opening should be made in the bottom for cleaning out before pouring the column. The junctions of beams and girders with the columns is provided for in the same way that the junctions of beams with the girders were provided for in the girder-forms.

The slab and beam, and girder forms are supported on brackets and shores as shown in the sketches on Plate III. These forms can be taken down, with the exception of the bottoms of the beams and girders, as soon as the concrete has set, without disturbing the shores. The forms can be taken down in about a week after the concrete is poured. Enough forms will be required for two complete floors. The shores should be left in about three weeks, so that enough for about four complete floors will be required. Building the forms so that they may be removed without
disturbing the snores affects a great saving in the amount of lumber required.

XV. TRACK ARRANGEMENT.

The track arrangement is shown by the sketch on Plate II. All the tracks are standard gauge and the material track has heavy rails for switching cars from the main line. As the building is for factory use, shipping tracks near the building will be required for the operation of the factory. Any of these tracks which are near those shown on the diagram should be put in with heavy rails, used for the construction and thrown to their proper position when the construction is finished. All other tracks will be built with light rails as ordinary industrial track, but the rails should, in most cases be heavy enough for a locomotive crane or a railroad car to run upon.

By using standard gauge dinkeys and industrial cars, making all tracks standard gauge, cars can be taken to or from either the bulkhead or the railroad track, to any point on the site where they may be unloaded and the materials in them stored in the spaces along the track left for that purpose.

XVI. GENERAL.

Material may be stored along any of the tracks or, if it is liable to be damaged by weather, it may be stored in the lower floors of the building, or sheds may be built along the track for it. The brick to be used for the English ovens in the seventh floor, and for the outside walls should be stored between the
tracks and the building.

The interior elevators will be used for raising the brick, and the materials for interior work as far as it is practicable. When this is not practicable, the material will be raised by derricks and brought in through the large windows in the exterior walls.

XVII. CONCLUSION.

The writer's intention, in preparing this paper, has been to work out the larger or more difficult problems to be dealt with in the construction of this building. There are many things which are entirely within the ordinary and would be done in the ordinary manner. On the other hand there are several problems; such as the number of men to work in each gang, the time and manner of doing certain lesser details, etc., which can be determined only as the work progresses or by trial.
PLAN OF BRACING FOR SHEETING
Scale: 1" = 50'

ELEVATION OR BENT OF BRACING
Scale 4" = 1'-0"

DESIGN OF AN ERECTION-PLANT
FOR A
TEN-STORY REINFORCED CONCRETE
FACTORY BUILDING
SHEET-PILING BRACING
H.D. Stephenson Thesis June 1914
UNIVERSITY OF ILLINOIS
PLATE I