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FOUNDATIONS FOR TRANSMISSION LINE TOWERS AND TOWER ERECTION

I—Notes on Investigation of Types of Foundations—Digging Holes for Foundations—Concreting Foundations—Erect- ing Towers

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ABSTRACT OF PAPER

Concrete tower foundations of mushroom type, requiring no forms or back filling, as used in recent Baltimore-Holtwood transmission line, are found to be cheaper and stronger than steel tripod foundations previously used in a similar line alongside.

It was found that mushroom type concrete foundations could be built with a smaller construction force and at lower cost, and more rapidly, than certain types of concrete foundations requiring forms and back filling.

The procedure of digging holes and concreting of mushroom type foundations is described.

Method of erecting transmission towers by the use of a shear leg is described in some detail.

THE FOLLOWING notes relate to the transmission lines of the Pennsylvania Water & Power Company. On the first Holtwood-Baltimore Line (No. 12) the steel tripod stub, Fig. 1 was used with suspension towers and a concrete foundation, Fig. 2, with anchor towers.

On the Holtwood-Lancaster Line mushroom type concrete foundations were used for both suspension and anchor towers.

Lifting tests made on steel tripod stubs, steel single leg stubs, (with fins at top and bottom Fig. 4) and under-cut mushroom type concrete stubs (the lift being not vertical but inclined, and parallel to the direction of the tower leg, though in service the horizontal component would be somewhat greater than this) showed that the tripod type pulled out of fresh ground at about 32,000 pounds; the single leg at about 23,000 pounds; while the mushroom concrete type showed no signs of lifting or cracking of soil up to the limit of capacity of the testing outfit, *i. e.*, 70,000 pounds. The shifting of the single leg stub was more than one inch at 50 per cent of its ultimate loading; the tripod stub

Manuscript of this paper was received April 28, 1915.

movement at 50 per cent ultimate loading was $\frac{1}{4}$ in. in the vertical direction and $\frac{5}{16}$ in. in the lateral direction.

Experience in the field indicated greater difficulty in securing exact setting with the tripod stub than with the concrete stub, so in view of the greater strength of the concrete stub, its lesser liability to displacement when pivoting on it in tower raising, and the consequent lessened chance of unequal stressing of the tower legs, due to lack of fit of the tower shoes with the foundations, together with certain other construction advantages, determined the use of concrete stubs for both suspension and anchor towers on the second Holtwood-Baltimore Line (No. 56). The reason for the massive construction adopted, it should be explained, is that this latter line is a short and important trunk line

FIG. 1—STEEL TRIPOD TYPE FOUNDATION

of very heavy construction, *i. e.*, 15,000 pounds and 30,000 pounds breast pulls for suspension and anchor towers respectively carrying two circuits of 30,000 kw. per circuit and insulated for 110,000 volts.

Investigations were made on four types of concrete foundations to determine which type of foundation would best suit our conditions. Concreting was done with a hand mixer. The earth was hard red clay with a few small boulders.

The mushroom type, without forms, was constructed by digging a post hole, approximately 16 in. in diameter, 6 ft. in the ground and under-cut at the bottom of the hole as shown in Fig. 3. It was later found advisable to dig the post holes only 3 to 4 ft. deep and make a bell shaped expansion in the bottom by

the use of dynamite. The mushroom type, in good ground, is cheaper to build, can be built more quickly than the other types experimented with, and is especially satisfactory on account of not disturbing the adjacent ground or necessitating backfill.

FIG. 2—MUSHROOM TYPE CONCRETE FOUNDATION FOR HEAVY TOWERS

The next best type of foundation appeared to be the mushroom type using steel forms. Considerable difficulty was experienced at the start with the latter type owing to the difficulty

FIG. 3—MUSHROOM TYPE CONCRETE FOUNDATION

of keeping the forms properly lined up and vertical, since the form had a tendency to float and cant when the concrete is poured into it. It was found possible, to prevent this by backfilling, slightly before pouring the concrete, the backfilling not

being too much to prevent the withdrawal of the steel forms. In this type and the following types, excavating by dynamite did not prove successful.

Next in order in point of cost and rapidity of construction was the mushroom type with wooden forms. Here 24 sets of forms are required, which are heavy and difficult to assemble.

The least satisfactory type of base was the truncated pier with wooden forms. This pier had a square base 2 ft. 6 inches each way and a square top 12 in. each way. Like the others it was six feet high. The wooden forms are heavy and hard to assemble in the field, although a little less difficult to assemble than the forms for the preceding type of base. As with the preceding type of foundation, a three days' supply of forms is required for a gang, *i. e.* 24 sets of forms involving, as extra men, a carpenter, a foreman, and three helpers with team to provide steady work for the concrete gang.

The type adopted on Transmission Line No. 56 was that shown in Fig. 3 and the actual cost of this type on the line averaged per tower, as follows:

Hauling materials.....	\$13.20
Grading.....	2.27
Digging.....	4.92
Materials and concreting.....	28.50
	<u>\$48.89</u>

The type used on Transmission Line No. 12 shown in Figs. 1 and 2, averaged per tower, as follows (3 steel foundations to one concrete foundation):

Hauling materials.....	\$8.03
Grading.....	4.80
Digging.....	11.34
Materials and concrete.....	30.08
	<u>\$54.25</u>

DIGGING HOLES

Tools. Each man in the digging gang is provided with the following tools:

- 1 Long Handle Shovel,
- 1 Digging spoon with 8 ft. Handle,
- 1 one inch by 8 ft. telegraph digging bar,
- 1 Post Hole Digging Bar 6 ft.

FIG. 4—STEEL SINGLE LEG STUB

ERECTING SHOE

[WALLS]

ARRANGEMENT OF HEAD PINS

[WALLS]

SIDE GUY TACKLE

[WALLS]

The foreman is provided with 40 per cent dynamite, exploders and battery.

The foreman lays out and stakes the center of each hole. In order to avoid the transportation of a templet, the laying out is done as follows:

The engineer stakes the center of the tower and marks the tower height on the reference stake; in addition to this two stakes are put down in the direction of the line and two stakes across the line. These four stakes give the center line of the base. A cord is strung across two of the stakes and the distance from the center stake to a line through the center of two holes on the same side measured by means of a stick cut to length. The point arrived to is marked with a pin and the operation is repeated on the other side of the center. By swinging the cord 90 degrees to the other stakes two more points are located. By laying out two

sticks of a length equal to half the base width of the tower from two adjacent points found in the first operation, and then swinging them till their ends meet, the center of one corner is located. The operation is best understood from the accompanying sketch.

In this way two men can lay the base out in less than five minutes and no heavy tools are required. One man is provided for each hole, and the foreman is able to take care of three

to four gangs. When a man starts a new hole he first makes a circle, approximately 16 in. diam. around the pin, and the foreman sees to it that he keeps his hole inside this circle.

The hole is dug about three feet deep using the post hole bars to loosen up the soil, and a long handle shovel to scoop it out. If the soil at this depth is too hard to scoop out with a spoon a hole about two feet is punched in the center and the hole shot with about one half stick of dynamite. The dynamite will loosen up the soil and works down and sideways so as to form the bell. After the shooting, the loose dirt is scooped out with a spoon. Under ordinary conditions one man can dig from two to three holes a day in this manner, In some places rock has been encountered. Sometimes this rock is soft enough to be dug out with a bar, in other places it has to be drilled and dynamited. Three to four shots generally opens

the hole. It has been tried to blow holes open with dynamite in the following way:

A hole is punched about four feet deep by means of a bull point and one half stick of 60 per cent dynamite lowered to the bottom of the hole. One half stick of 40 per cent dynamite is suspended in the hole about 8 inches above the bottom stick and another half stick of 40 per cent with a fuse cap about 20 inches from the top. By this method one man has been able to open a hole in 45 minutes, but due to unfavorable soil encountered, this method was not generally followed.

CONCRETING

The concrete mixture used for the foundations is made in proportions varying from 1:2:4 to 1:3:5. The cement is good quality Portland cement. Test samples taken from various lots show that the cements meet the specifications of the American Society for Testing Materials. Three-quarter-inch stone and sand were shipped in carload lots to various stations along the line. Four head teams were used for hauling the material from the railroad stations, each team being capable of hauling from $\frac{3}{4}$ yard on bad roads to 1.5 yards on good roads. The distribution was kept well ahead of the concreting gang, 1.5 yards of stone and 3.4 yards of sand being dumped at each tower site. This amount was increased about 50 per cent at every fifth tower, so as to make up for occasional shortages. The cement was delivered in bags, and had to be distributed as the work proceeded. In most cases no storage room was available at the railroad stations and, therefore, the cement had to be stored in farmer's barns along the line, 100 to 200 bags being stored at each place. A team following the concreting gang could pick up the cement at these barns and could distribute the bags directly ahead of the work. This procedure kept the loss due to wet weather at a minimum.

The equipment for a gang of men engaged in transmission line work must necessarily be made as light as possible on account of the small amount of work to be done at each place. This is especially true of the concreting gang, as those men invariably spend more time in moving than in concreting.

The time required for mixing and pouring the concrete is about three quarters of an hour, while moving and setting up takes about one hour. The move from tower No. 312 to No. 313 at Big Gun Powder crossing may be given as an ex-

aggregated example of the time required for moving. The teams had to make a detour of about five miles at this place and it required eight hours to move the concreting outfit between the two towers, a distance of 1100 feet.

A 2.5-cu. ft. hand mixer had done excellent work on the Lancaster transmission line and such a mixer was, therefore, purchased for the work on line No. 56. This mixer runs on two wheels and weighs about 1000 lb. with loading platform. The wheels are provided with separate axles and a few days work showed the necessity of strengthening these axles, which was done with a heavy flatiron strap on each side of the mixer. This mixer is still in good condition after being hauled 40 miles over rough ground. Water was hauled in a steel tank mounted on a two horse wagon. The tank was made of $\frac{1}{4}$ -in. steel plate, which proved to be unnecessarily heavy.

Water was taken from small streams and creeks and was drawn up by means of a 4-in. boat pump. A more efficient way would be to mount a small lever suction pump equipped with 10 to 15 feet of hose on the tank wagon. With such a pump the water could be reached without driving the wagon too close to the soft banks of the stream.

Smaller tools needed by the concreting gang are:

- 4 wheelbarrows
- 4 concrete buckets
- 4 barrels for water
- 2 digging spoons
- 3 shovels
- 1 digging bar
- 1 concrete chute for the mixer
- 1 level board
- 1 24-in. carpenters level
- 1 cross cut saw
- 1 maul hammer
- 1 set of carpenters tools

In addition to this, a small amount of blocking and running boards must be carried.

The smallest number of men needed for efficient handling of this work is one foreman with nine men, with from one to three teams depending on the length of haul of water and cement. The men would be distributed as follows:

- One man wheeling stone
- “ “ “ sand
- Two men wheeling concrete

One man hauling water and cement
Two men turning mixer
One man loading wheelbarrow with concrete
One man tamping
The teams hauling water, cement and assisting in moving.

Two or three additional men can and have been used to advantage in this gang. When placing concrete these additional men seem unnecessary being mostly occupied with loading sand and stone in wheel-barrows and bailing water from one barrel to another, this latter operation being necessary on account of the difficulty in moving the water wagon or a full barrel. The real benefit of these men is, however, shown when moving. Let us consider, a case where two teams are available for moving. As soon as the last batch of concrete is mixed a number of men will start loading the tools on the wagon. But before this, two men have been sent ahead to set the forms and place supports for the templet. Ten men are needed to move the templet and this leaves one man in a gang of thirteen to help the teamsters clean up the place and unload at the next tower. At the new set up the foreman will use four men or five men in lining up the templet. One man handles the level board and four men move and block up the templet in position and then place the anchor bolts. In the meantime the other men have completed the unloading, blocked up the mixer to such a height to permit a wheelbarrow to be placed under the chute and laid out the running board so as to make everything ready for the placing of concrete.

With only one team available, two trips must be made for the tools, and with a smaller number of men, one part of the job must wait for the other. It is, however, to be noted that the records do not show any saving in money, but the speed is increased. Naturally the larger gang will make a better showing in rough country where the moving is hard, than on a level stretch with good going. Two men and a team were sent back occasionally to strip forms, bringing them ahead, distributing them where needed.

Originally buckets were used for removing the concrete from the mixer, but this proved to be inefficient as concrete could be mixed faster than it could be removed. A portable inclined runway was, therefore, made by means of which the mixer could be elevated enough to permit the placing of a wheelbarrow under the chute. When water was found in the

BACK GUY TAKING WEIGHT

[WALLS]

ERECTING TOWER WITH GIN POLE RIG

[WALLS]

holes it was removed with a boat pump. This worked all right in such places where the holes filled slowly, but in a few instances the water would fill in very fast and the holes could not be kept dry. It would be well to carry a short length of six-in. sheet iron pipe for such cases. The concrete could then be poured through the pipe without draining the holes and there would be no chance for the water to wash the cement out of the mixture. At the last end of the job a broken boat pump was used for this.

No bed plates were on the job when the work was started, and it was, therefore, tried to finish the first group of piers with help of dummy plates. This proved to be a very slow process and did not provide a very good seat for the plates. The dummies were then abandoned and until the plates arrived, piers were left about eight inches below the final grade. As soon as the plates arrived, an instrument man with his rod man and one laborer were sent back to finish the foundations, the bond between new and old concrete being obtained by means of toxement.

When bedplates are on hand at time of making the piers, the concrete is poured to within an inch of the top of the bolts and the instrument man gets his grade by hammering the plates down in the soft concrete, and is relieved from carrying cement and mixing concrete.

All material used for concreting during cold weather was heated, the piers were built up to ground line only and covered with sand to prevent freezing. When warm weather arrived men were sent back to finish these piers.

ERECTING TOWERS

Whenever possible the towers are assembled on the ground in a horizontal position. A rigging gang follows the assemblers and erects the towers. This rigging gang consists of a foreman with 11 men and a four-head mule team. The general scheme of erection is to pivot the lower tower legs to the foundations and then lift the head of the tower by means of a tackle running from a point below the cross arms over a shear leg to a dead end at a convenient distance ahead of the tower. The lifting is done by hitching the mule team to the lead line.

Dead Ends. In average soil the dead end consists of heavy iron pins, 2.5 in. diam., about 5 ft. long. Five of these pins are used for the main tackle, three for the back guy, and one

for the side guy. The pins are driven about three feet apart and connected with a chain, as shown in the accompanying sketch. The tackle is hooked in the front edge of the wedge.

Tackle. The main tackle consists of two 12 in. three-sheave blocks reeved with 600 ft. of 1.25-in. hemp rope. Both the side and the back guy tackles consist of 8-in. two-sheave blocks reeved with $\frac{3}{4}$ -in. rope. The side guy tackle need only be a short one, but the back guy tackle is of the same length as the main, so as to reach out to the shear leg.

Shear Leg. The shear leg is made of two 45-ft. spruce timbers, measuring about six in. at the top. The height of the lift is less than 43 feet as the timbers are bolted two feet from the top and the butts are spread about 16 feet. The pole tops are shod on both sides with heavy steel plates, so as to prevent splitting. The butts are grooved for kick lines.

Pivots. The light section 40-ft. towers are pivoted on a $\frac{5}{8}$ -in. case hardened machine bolt on each side, the bolts running through the leg angle and standard foundation shoe. One tower was dropped and slightly damaged on account of a faulty foundation shoe breaking. This led to the ordering of one pair of shoes made of extra heavy angles and of such a height that the tower leg cleared the foundation plate by more than $\frac{1}{2}$ in., while the tower was being raised.

All extension and heavy towers are bolted to a hinge turning on a 1.25-in. bolt. The hinge and bolt are supported by means of a $\frac{3}{4}$ -in. plate bent in channel shape with the web resting on the foundation.

Setting up Rigging. Two men each at the main lift and back guy select a spot in line with the tower and drive their pins for the dead ends. Twenty pounds sledge hammers are used for driving the pins. If the ground is too soft to hold the pins, a dead man is buried. One man rigs up the side guy, two men put the shear leg in place, fix the kick lines and fit the shoes on the tower, while two more men put spreaders between the tower legs and attach the chains for the lifting tackle and a sling for the back guy. The main lift is hooked to the corner angles at the point where the braces in the first and second panel below the cross arm meet. This brings almost the full weight of the tower on the tackle. It was found un-

necessary to use any spreaders in the chains. The spreaders used in the tower legs consist of two by four-inch green oak bolted together so as to form four by four-inch. Two pieces bolted together make a more elastic strut, less liable to break if it falls down.

Lifting Shear Leg. With pins driven, shoes fitted, and the shear leg in place, everything is ready to lift the shear leg. A wooden cross piece, usually four by four inches, is placed over the upper tower legs so as to give the shear leg a start. The back guy tackle is hooked to a wire cable, running over the cross piece to the top of the shear leg and a pair of mules in the lead line lift the shear leg with main tackle and all. The main tackle is used for steadying the rig as the lifting cable is made to such a length that the shear leg must be pulled a little ahead before the chains can be hooked. The block of the main tackle is placed right at the top of the poles. As soon as the chains are hooked the tackle is slacked back and unhooked. The wire cable used for this lift is then lashed to the tower, so as to prevent the shear leg from falling when the main tackle lets go. Lifting the shear leg this way, besides being the most convenient method, gives a good test on the pins in the back guy.

Hoisting Tower. The shear leg being up and all rigging in place, the four-head mule team is hitched to the main lead line. Two men are stationed at each set of pins and no strain is taken before these men have reported everything o. k. On the first start the team goes just far enough to put full stress on the pins, and then stops. If everything proves all right, the team is ordered ahead and proceeds slowly until the men at the back guy commence to feel the weight of the tower on their tackle, when the team is stopped. This is the most critical point of the erection as the tackles on both sides of the tower must be kept taut. In case of a line fouling, one step too many by the team, is liable to pull the pins out or break a tackle, and the tower will fall. The team is, therefore, moved a step at a time only, at this stage until the weight of the shear leg is sufficient to pull the tower over when the team is unhitched and the tower let down with the back guy alone. The front leg being about six inches from the foundation, the tower is held until the spreaders are moved and one foundation shoe fitted to each side. When the tower is lowered the remaining six inches, these shoes are guided over the foundation bolts. In case the

special erecting shoe is used the tower is rocked ahead by means of the main tackle and these shoes exchanged for standard ones.

The side guy is used for emergency only, and is kept taut enough to take out the slack while the tower is going up, but it is not allowed to take any stress. In case something breaks this guy prevents the tower from falling onto line No. 12.

Moving. As soon as the main tackle is unhooked it is stretched by the team so as to be ready for the next lift. The tackle being stretched, a chain is slung around the shear leg and the team drags it to the next tower. In the meantime, the respective men coil up their tackles and load them on a wagon, together with pins, hammers, spreaders, and the like. While this is being done, one man has put all the foundation shoes on the tower with one bolt in each shoe. The final bolting up of these shoes is done by two men behind the rigging gang and counted as members of the same crew.