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CONSTRUCTION OF THE ALASKA CENTRAL RAILWAY, WITH COST DATA.

By WM. G. ATWOOD.*

The Alaska Central Railway is projected to connect an ice-free harbor on the Pacific coast with the navigable waters of the Yukon River system. Its general location is shown in the map, Fig. 1. When completed this road will have a main line 467 miles in length, with a branch of 40 miles leaving the main line at Mile 149 and extending to the eastward into the coal fields of the Matanuska River.

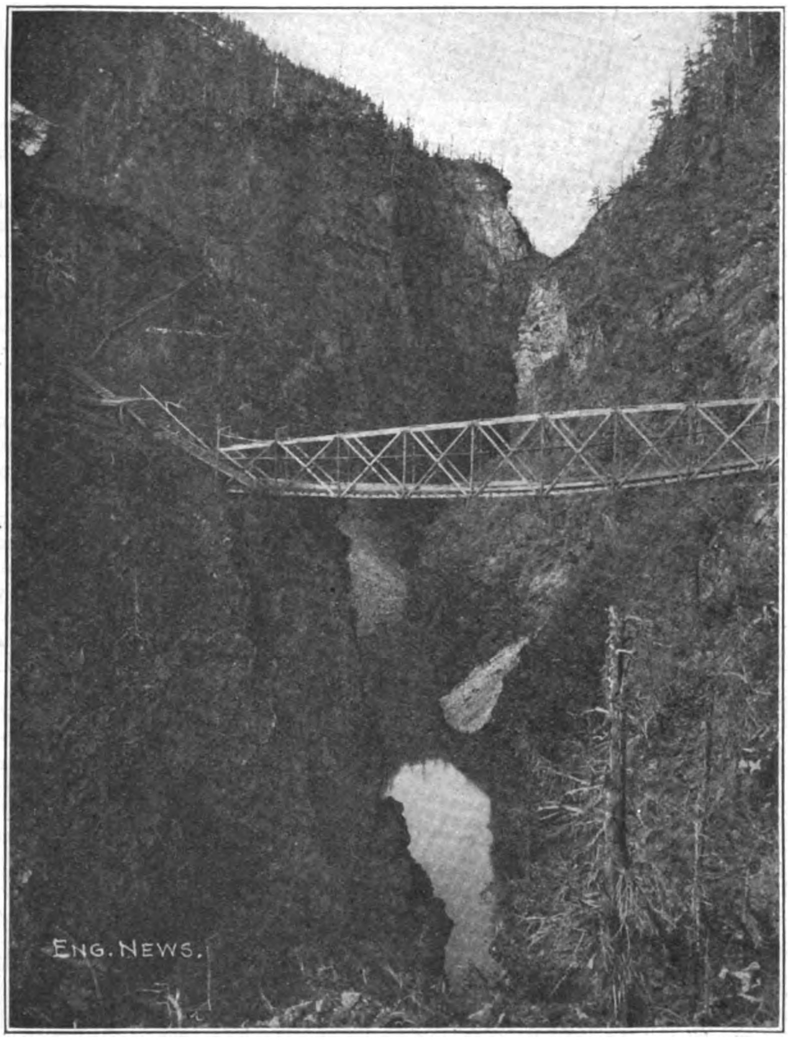
A satisfactory harbor was selected in Resurrection Bay, and a town called Seward was established at that point. The establishment of this town and the early construction work on the road were described in Engineering News, Sept. 8, 1904, but the ownership of the road changed hands about that time, and the character of the work and the methods used were materially altered. Only the work done since, January, 1905, will be considered in this paper.

Under the former owners the location surveys were carried only a short distance beyond the construction, but on the acquisition of the property by the new owners the force engaged on surveys was much augmented. A preliminary line was run over alternate routes from Mile 34 to Turnagain Arm of Cook Inlet. This work was done in the winter, when there was snow from 10 to 20 ft. deep on the mountain passes which were crossed. The parties consisted of about 14 men, exclusive of freighters driving dog teams, whose numbers depended on the distance of the parties from their base of supplies. All supplies had to be moved by dog teams, since the depth of snow precluded the use of horses, but owing to the scarcity of dogs it was often necessary for the survey work to be stopped and the supplies moved by the parties themselves on hand sleds.

The line selected crossed the watershed, between Kenai Lake and Turnagain Arm at an elevation of 1,050 ft. above sea level at the head of Placer River, a distance of 45 miles from Seward. The valley of Placer River furnished some very interesting location work and a great amount of heavy construction. This valley is of comparatively recent glacial formation, two of the glaciers which formed it being still in existence, though they have entirely receded from the main valley.

The established maximum grade of 2.2%, compensated for curvature, was easily obtained from the summit at Mile 45 to Mile 48 by following the water grade of Placer River. At this point there is an almost vertical descent in the general level of the valley of about 200 ft., marking the place where the now extinct glacier, coming from the mountains on either side of the pass, met the still existing (Bartlett) glacier. This combined glacier formerly extended about 1½ miles further north to the head of a box canyon 500 to 800 ft. in depth, which has been probably eroded by the melting waters of the glaciers. This canyon, 4,500 ft. in length, ends at the foot of the second (Placer River) glacier, which formerly extended to Turnagain Arm. The valley from this point to the head of Turnagain Arm is flat and swampy, with an elevation of 150 ft. at Mile 54, descending to sea level at Mile 67.

A locating party under Mr. Frank Bartlett, locating engineer, began work on this division in March, 1905, and completed the location in November of that year. The development had to be obtained between Miles 48 and 54, so this area was very carefully studied for a 3.1% grade as well as for a 2.2% grade. Seven preliminary and location lines were run and a 2.2% grade finally obtained, although it was necessary to exceed the 12° limit of curvature twice by inserting two 14° curves; one of these had a central angle of 238° and the other of 213°. This territory was covered with a very dense growth of alders. Many of the slopes were very steep, and in the canyon the men had to work on ropes or points had to be located by triangulation. An approximate plan of the development between Mile 47 and Mile 53 is shown in Fig. 2.



BRIDGE FOR PIPE LINE AND TRAIL.

Tunnel No. 1, 699 ft. long, is entered close to the P. C. of the first 14°-curve (on Mile 49), and from the tunnel the line passes out on a trestle about 1,600 ft. in length and from 40 to 90 ft. high on the center line. A portion of this trestle is on a side hill and has one leg 160 ft. long for a few bents. Near Mile Post 52 the line reaches the head of the canyon and crosses it on a Howe truss deck span of 120 ft. The road is located for the full length of the canyon from 150 to 200 ft. above the river. In this portion of the line there are six tunnels and several very heavy rock cuts, one of them being 150 ft. deep on the inside slope and from nothing to 30 ft. on the outside, with a total yardage of 28,000 cu. yds. in 300 ft. Fig. 3 is a view of this cut from the north portal of Tunnel No. 6; the men are standing at the level of the grade line, and the ladders (150 ft. high) reach to the trail above.

After passing out of the canyon the line follows the side hill for about a mile; then the terminal moraine of the Placer River glacier and the center of the low valley to Turnagain Arm. The north shore of Turnagain Arm is followed from Mile 67 to Mile 101, and aside from crossing the valleys of some small streams the line is on a steep side hill. Three locating parties were placed on this work as soon as navigation was open in Cook Inlet, in April, and they were not able to complete the work until November. The supplies for these parties were delivered to them by water, and in addition to the regular members of the party there were one or two boatmen, experienced on these waters. Turnagain Arm is a very dangerous body of water, since it has a tidal rise and fall estimated at 50 ft. and currents as high as 10 knots per hour, with several bad tide rips. The general elevation of grade is about 50 ft. above high tide, though in places it reaches 100 ft. The work of the sur-

*Late Assistant Engineer of Construction, Alaska Central Ry.

vey parties was very dangerous, much of it having to be done on ropes, and some of it triangulated.

From Mile 101 to Knik Junction, at Mile 149, the location along the shores of Knik Arm was made by one party in the winter of 1905-1906, while another party located the 40-mile branch up the valley of the Matanuska River to the coal fields.

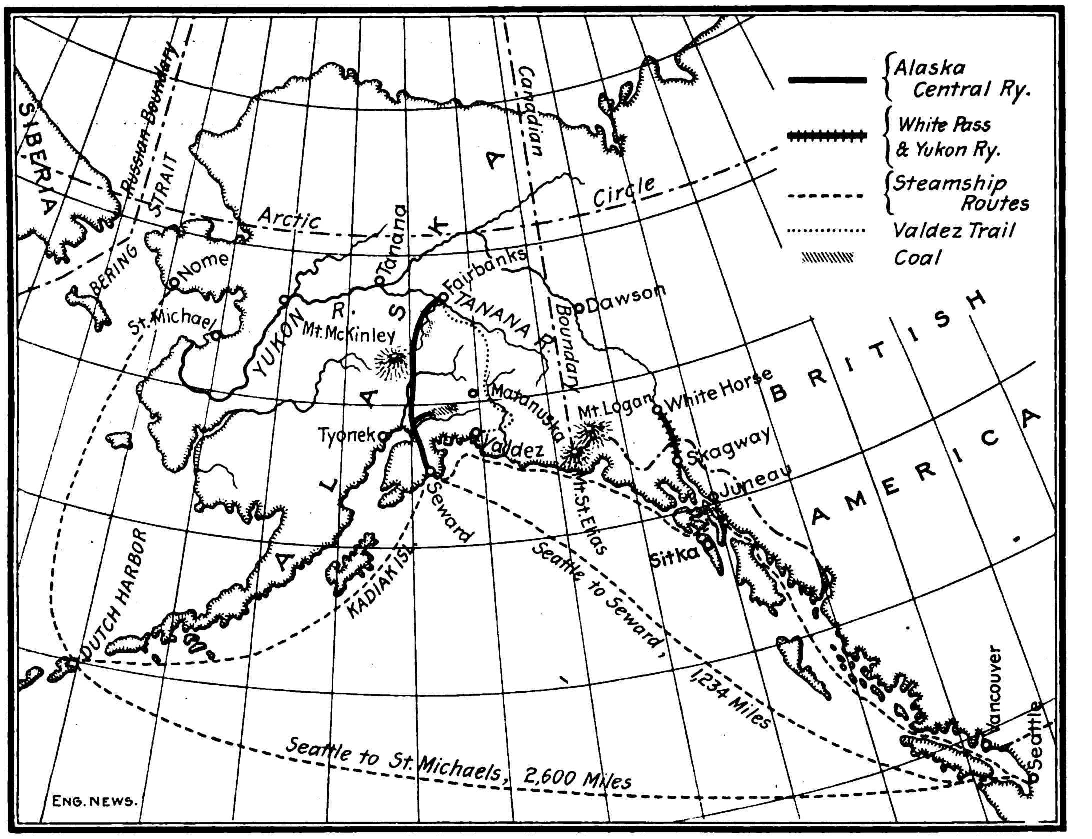


FIG. 1. MAP OF THE ALASKA CENTRAL RY. (467 MILES.)

During the summer of 1905 a preliminary line was run from Knik Junction to Mile 206, on the Sushitna River, and the following winter two parties made a stadia survey from that point to the northern terminus of the road, at Fairbanks, on the Tanana River, Mile 467. These parties began work in January, one at Mile 206, the other at Fairbanks, and connected their lines in May near Broad Pass, in the Alaskan Range. They carried with them supplies enough to complete their work and return to the coast. They were furnished with four dog teams of four dogs each as their sole means of transportation. Such a team of good native dogs can haul about 400 lbs. on a fair trail about 25 miles per day. The average cost of the survey parties was about $2,000 per month for salary, subsistence and transportation.

New construction work was started on Mile 18 in April, 1905. The work was supervised by the resident engineers, to whom the foremen in charge of camps reported. Residencies Nos. 2, 3 and 4 were all in the valleys of Kenai Lake and its tributary Trail Creek, which has its source on Mile 45.

The pile trestles on residency No. 3 were built with four-pile bents, 12-ft. span, and an average length of piles of 22 ft. The floor system consisted of six 8 × 14-in. stringers per span, with 7 × 8-in. ties, 10 ft. long, spaced 14 ins. c. to c., and guard rails 5½ × 8 ins. The 12 × 14-in. caps were hewed, and they, as well as the piles, were cut as close to the bridge sites as possible and floated to place. The sawed timber was furnished by the company's mill at Seward. There were 3,514 lin. ft. of trestle built on residency No. 3, at a cost of $6.40 per lin. ft., including the cost of moving the pile-driver between bridges.

On Mile 35 a rock fill containing 4,524 cu. yds. was made from borrow, with an average haul of 700 ft., made in Peteler cars of 1 cu. yd. capacity. A 3⅛-in. steam drill, supplied with steam by a 10-HP. vertical boiler, was used in the borrow pit, and the rock (a hard slate) was moved for $1.06 per yd. On Mile 36 a fill of 4,488 cu. yds. was made in a swamp with Peteler cars from an earth borrow-pit 3 ft. deep, after a haul averaging 3,522 ft. down a 1%-grade. Cars of 1 yd. capacity, in 10-car trains, hauled by two horses per train, were used. The cars were loaded by hand, and the fill cost 38.6 cts. per yd. On Mile 38 a similar fill was made with the same equipment and methods, except that the pit was only 2 ft. deep, and the haul was 4,133 ft. down a grade of 0.6%. This fill contained 5,283 yds. and cost 46.1 cts. per yd. The material in both cases was a fine slate gravel. No steam shovels were used on the work, all excavation being done by hand labor.

Miles 44 and 45 were not completed until January, after there had been a heavy snowfall, which required a large amount of snow-shoveling. Then, too, in December in this latitude (60° North) the days are only about six hours long; and while the men worked eight hours for ten hours' pay, their work was very inefficient for a part of the time. These conditions increased the cost of the rock excavation (which amounted to 14,871 yds. on Mile 44 and 19,411 yds. on Mile 45) by about 75% over that of work done under more favorable conditions. The material on both Miles 44 and 45 was a hard syenite, and on Mile 44 required 1.3 lbs. of powder, while 2 lbs. were used on Mile 45, owing to the fact that the weather was so cold during a part of the time when work was in progress on Mile 45 that it was impossible to load the holes without a portion of the powder being frozen.

The grading on residency No. 5, which extended from Mile 45 to Mile 52, did not offer any serious problems until Tunnel No. 1 was reached on Mile 49. This tunnel is 699 ft. long, in a hard, blocky slate, which gave considerable overbreak in some parts. Fig. 4 is a view of the north portal of this tunnel, and shows the character of the rock. The plant used in driving this tunnel consisted of a 40-HP. boiler of locomotive type, an air compressor with a rated capacity of three drills, and a 10-HP. vertical boiler and boiler feed pump for delivering water to the compressor plant at the north portal of the tunnel. This tunnel was driven entirely from the north portal, to take advantage of the favorable grade for hauling spoil, and because there was a large snow-slide over the south portal, which made work at that point dangerous. For about 300 ft. this tunnel was driven by using steam in the drills instead of air. The drills were connected with the boiler in the usual way, and the exhaust carried from them in a 2-in. steam hose to a 12-in. square wooden box with a vent outside the tunnel. This method was a success until the heading had been driven about 300 ft., when the heat became excessive. Driving a tunnel with steam drills is practical and economical in a short tunnel, where the freight on machinery is very high, and it is impossible to obtain a sufficient number of competent hand drillers, although the amount of steam hose consumed is very large. In this tunnel it would have been more economical to have installed the compressor at the beginning, and so saved this large expenditure.

The standard tunnel section is 21 ft. high above sub-grade and 14 ft. wide in the clear on tangents; it is widened to 16 ft. on 12° and 14° curves, and the center line of the track so located with reference to the center of the tunnel as to give the maximum clearance. Tunnel No. 1 is so located that all supplies had to be hauled two miles from the end of the track by freight team and about ⅜-mile up a trail too steep and crooked for the four-horse teams. A single horse on a sled or "stone-boat" was used here.

The distribution of costs in this tunnel is set forth for the month of May, 1906, which month is a fair type of the whole work:

Yardage moved during month	2,109 cu. yds.
Labor, and tool depreciation	$5,346.26
Explosives	842.32
Lighting	165.20
Coal	285.00
Bonus	281.10
Total	$6,919.88

A bonus of 50 cts. per ft. was paid each man who worked a full week in this tunnel, regardless of his rate of pay, for every foot progress beyond 24 ft. This same system was followed in the other tunnels, with a different amount of progress required in each.

There is a great amount of timber trestle in this division, and owing to the fact that there was no suitable timber for the work available in the Placer River Valley, the span of 12 ft., which had been standard on other portions of the road, was changed to 20 ft., with the result that the stringers had to be increased in size and number. The stringers were increased from six 8 × 14 ins. per span to eight 9 × 18 ins. All posts were round timber, mud sills were hewed, and all other timber in the sub-structure was sawed in the company's mill at Seward. This bridge work was contracted to a firm in the State of Washington, who cut all the round and hewed timber, hauled it to the track, loaded it on cars, unloaded it at the end of the track, and hauled it to the bridge site. The company furnished all iron and sawed timber f. o. b. cars at the end of the track, and the contractors had to haul it

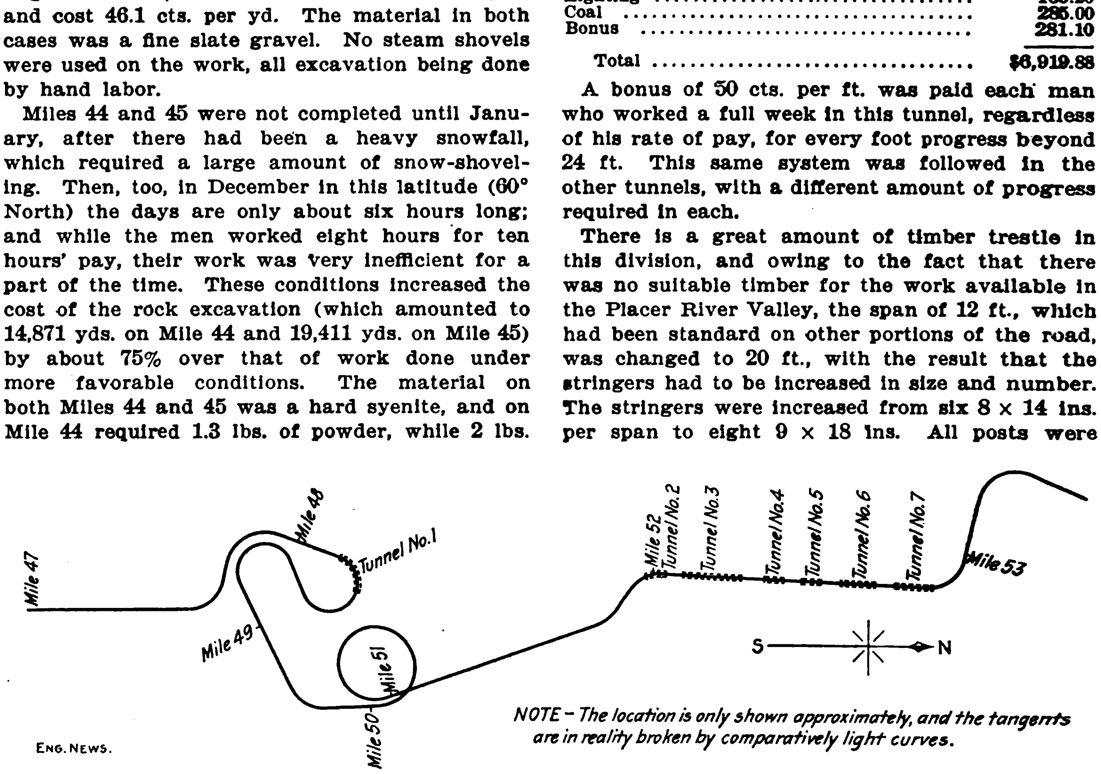


FIG. 2. LOCATION OF THE ALASKA CENTRAL RY. FROM MILE 47 TO MILE 53.

from that point. Fig. 5 shows a high trestle on Mile 48, with a 40-ft. span over a stream; a set of A-frames above this opening support the intercepted bent in the upper panels.

The power plant for driving the series of tunnels in the Placer River canyon had to be located about 400 ft. south of the south portal of the No. 2 tunnel, and on the opposite side of the canyon, so that coal and other supplies could be delivered to the plant by the regular four-horse freight teams. This location forced the use of about 7,000 ft. of air pipe to reach the north portal of the No. 7 tunnel. This plant consisted of four 40-HP. boilers and two compressors with a rated capacity of about 600 ft. of free air per minute, which was slightly increased owing to the excess of boiler power.

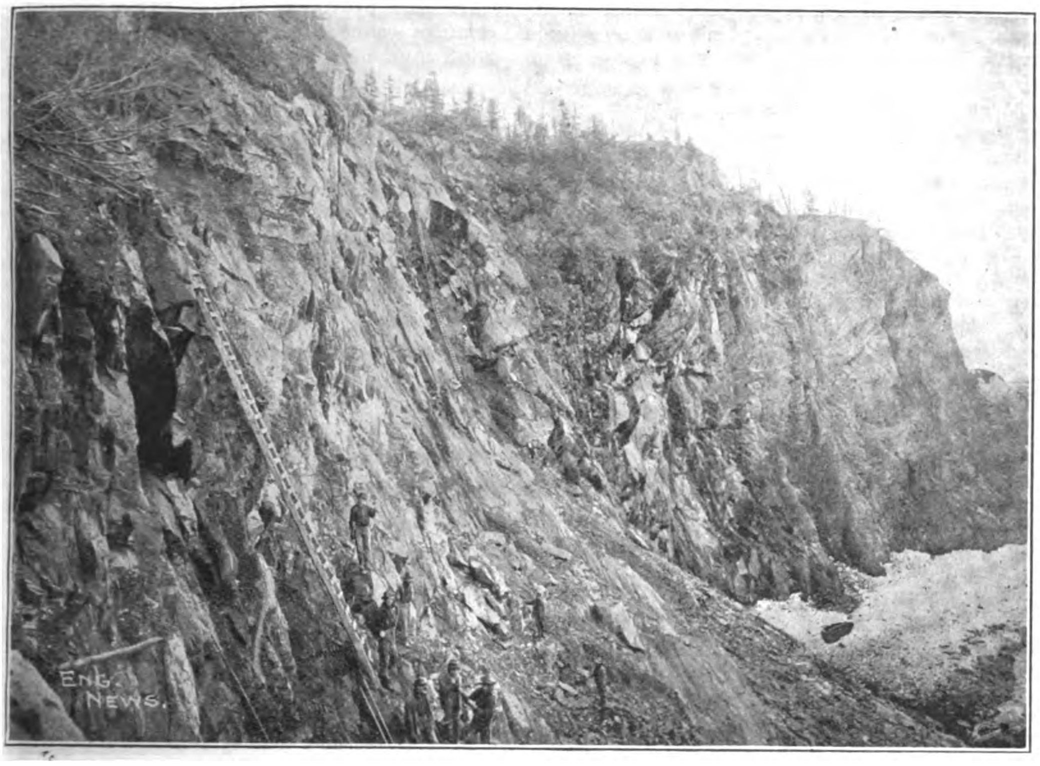


FIG. 3. A 150-FT. SIDEHILL CUT; NORTH OF TUNNEL NO. 6.

Fig. 4. North Portal of Tunnel No 1; Alaska Central Ry.

It was necessary to build a temporary bridge across the canyon to carry the air pipe line and to serve as a foot-bridge for the men. This bridge was suspended on four ¾-in. steel cables, with a stiffening truss made of 2 x 4-in. and 2 x 6-in. timbers, bolted at the joints. This structure was so stiff that no leaks were developed in the pipe line, even though horses and dump-cars passed over the bridge. The labor and material for the structure cost about $1,300. The photogravure on page 199 is a view of this structure, and along the left wall of the canyon, near the top, may be distinguished the line of the trail.

A pack-trail for horses was built over the tunnels, in some places being blasted out of the canyon wall. This trail became impassable for horses during the winter, owing to the frequent snow-slides, and all materials and supplies had to be delivered to the tunnels by packing on men's backs, except that by a detour of about seven miles over the Placer River glacier, a portion of the road being on a 12% grade, it was possible to reach a point about 1,000 ft. from the north portal of the No. 7 tunnel with four-horse teams.

Tunnels Nos. 4 and 5 and a portion of No. 6 were driven by station men doing hand drilling. No. 2 was built by the company, being driven from the north end, as was No. 7, while No. 3 was driven from both portals. A contract for all six tunnels was let, but after a small amount of work had been done the construction was taken over by the company. The costs for Tunnels Nos. 2 and 3, given below, are for labor and material used by the company on the tunnels, and do not include the cost of the plant, the expenditures of the contractor or the engineering expense. Tunnel No. 2 is 300 ft. long, of which 75 ft. was driven by the contractor and the remainder by the company, with cost distribution as shown in the accompanying table.

COST OF TUNNEL WORK.

	Tunnel No. 2 Per cu. yd.	Tunnel No. 2 Per lin. ft.	Tunnel No. 3 Per cu. yd.	Tunnel No. 3 Per lin ft.
Labor, and tool depreciation	$3.17	$38.26	$3.57	$38.39
Light	.13	1.57	.14	1.57
Explosives	.62	7.48	.85	9.20
Compressor, labor, fuel, etc.	.65	7.85	.57	6.10
Total	$4.57	$55.16	$5.13	$55.26

Yardage moved: Tunnel No. 2—2,717 cu. yds. in 225.1 ft.; Tunnel No. 3—9,078 cu. yds. in 844 ft.

About 3.1 lbs. of powder and 69 lbs. of coal per yd. were used in Tunnel No. 2. The rock was a hard, blocky slate, with a great number of quartz seams, and in places gave a rather poor roof.

Tunnel No. 3 is 955 ft. long, and is in a hard slate, with a definite plane of cleavage at right angles to the axis of the tunnel. This formation required the use of a considerable amount of powder, but broke almost exactly at the drill holes. Eight hundred and forty-four ft. of this tunnel was driven by the company, with a cost distribution as shown in the table. About 4.2 lbs. of powder and 58 lbs. of coal per yd. were used in this tunnel.

The cost of driving Tunnels No. 6 and No. 7 was about the same per yard as that of No. 2, and with about the same distribution, except that the expense of the compressor plant was slightly heavier, owing to the distance of the drills from the compressor. The tunnel timbering consisted of 12 x 12-in. sills, 12 x 12-in. posts 14 ft. long, a 12 x 12-in, plate, five segment timbers 12 x 12 ins., and lagging of 3-in. or 4-in. plank. Timber sets are 4 ft. c. to c. The timbering in Tunnel No. 1 cost about $21 per 1,000 ft. B. M.

Wages paid labor on this work were as follows, being per day of 10 hours:

Foremen of tie, grading and logging camps	$5.00
Sub-foremen in all branches	$3.50 to 4.50
Machine drillers in tunnels, and blacksmiths	4.00
Teamsters, hand drillers, tool dressers, firemen in the compressor plants	3.00
All common labor	2.75

Horses were figured at $1.50 per day, including forage, shoeing, etc.

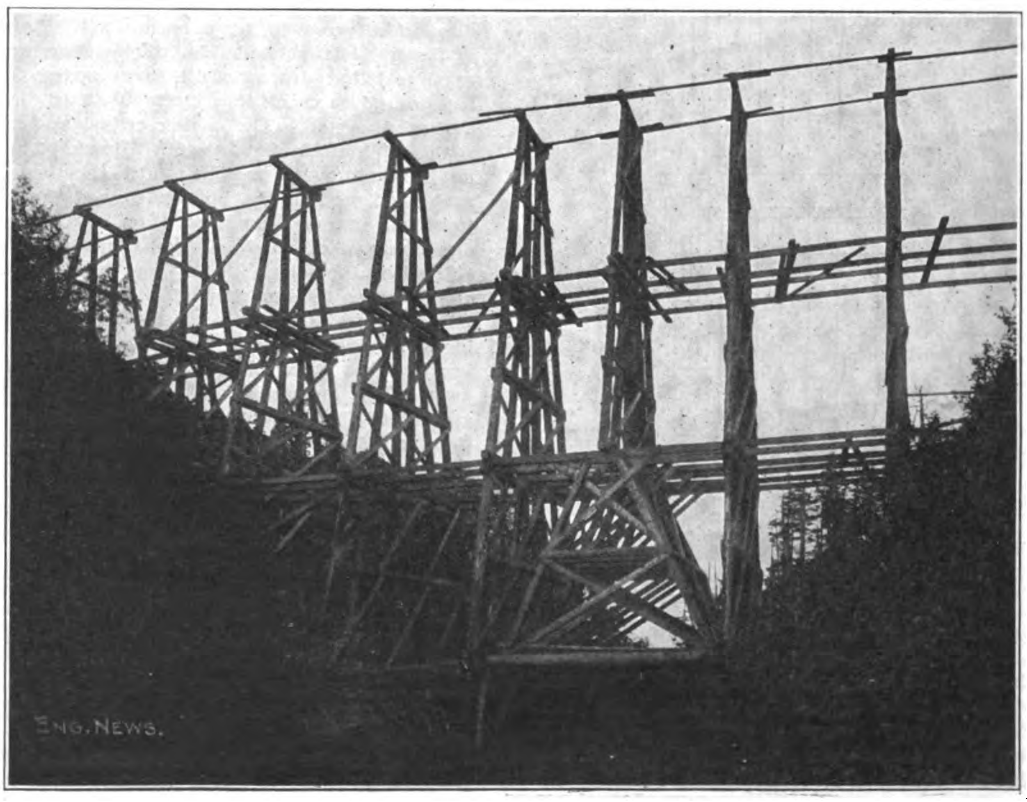


FIG. 5. HIGH TRESTLE WITH A-FRAME SUPPORTING A BENT OVER A 40-FT. OPENING.

One problem of considerable importance in the carrying on of work in a cold climate, that of thawing dynamite, was solved by a method which the writer believes to be new. The common method of thawing by open fires is dangerous, and the hot-water method by immersing a vessel containing the dynamite in hot water is too slow where a quantity of power is needed. Thawing dynamite in a house containing a stove is very dangerous, because the house so often becomes overheated. On this work several houses, with a greater or less amount of powder, had been lost by explosion and fire, when Mr. J. B. Cameron, Engineer of Construction, put a new system in use. Two small houses were built about 12 ft. to 18 ft. apart and connected by two air ducts, one at the floor level and the other in the gable. These ducts were made of 1-in. lumber and both ducts and houses were covered with so-called fireproof roofing. The stove was placed in one house and the dynamite on racks in the other. With this method there is no danger of the powder becoming overheated and no difficulty in keeping a sufficient supply of thawed powder on hand. After the system of double houses was put in use only one house was burned, although several times the house containing the stove became ignited and the fire was extinguished before serious damage was done.

SINKING A SHAFT WITH STEEL AND CONCRETE LINING IN SOFT GROUND.

By W. E. WAGNER.*

The waterproofing of concrete has ever proved one of the most vexing difficulties that an engineer has to encounter, especially if the nature of the work is such that the surface in contact with the water cannot be coated with a waterproof paint or a coal tar pitch and felt covering. If added to this it proves impossible to exclude the water while laying concrete, the problem becomes one to cause many an anxious moment during construction and often a never ceasing worry and vexation afterwards.

The following should prove interesting as an illustration of such a case in which the waterproofing under a heavy pressure, at first almost despaired of, proved successful in the end beyond the utmost anticipation.

The work in question was the sinking of a shaft for a shot tower by the Equitable Powder Mfg. Co., of East Alton, Ill. The shaft was required to be 6 ft. in diameter and 80 ft. deep,

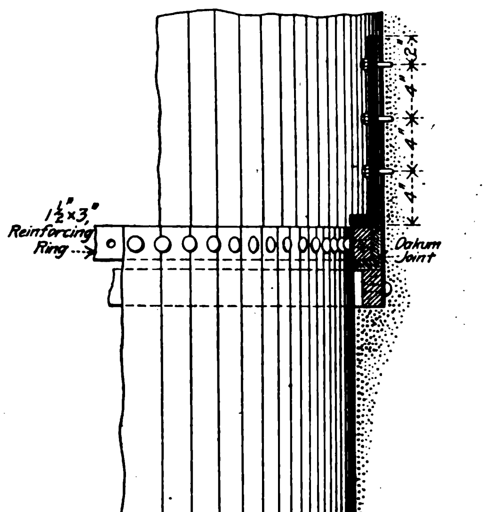


Fig. 1. Method of Connecting Adjoining Sections of Casing in Sinking a Well Through Water-Bearing Sand and Clay, at Alton, Ill.

necessitating a hole 7 ft. 6 ins. in diameter to allow for a 9-in. wall of concrete. A test hole showed that the ground consisted of successive strata of moist sand and clay overlaying a base under a very heavy pressure of water. The works are located about two miles from the Mississippi River and close to a sand deposit, which it is claimed at one time formed the course of the river, and this was verified by finding branches of trees in perfect condition, though spongy from age, at the depth of 80 ft. from the surface. This will account for the many and varied strata of clay and sand encountered in excavation.

*1247 Main St., Alton, Ill.

Owing to the nature of the soil and the facilities at hand it was thought impossible to force down a casing of uniform diameter in one piece. It was decided, therefore, to build the casing in eight sections, each of uniform diameter, varying in size from 10 ft. 6 ins. for the top to 7 ft. 6 ins. for the bottom, each section being 5 ins. less diameter than the one above it. The sections were built of 5-16-in. steel with a reinforcing ring 1½ ins. by 3 ins., riveted, as shown in Fig. 1, to the top of the outside and the bottom of the inside of each casing. The joints between these rings were stuffed with oakum when the lower casing reached its final position. Angle pieces, also shown in Fig. 1, of 1½ × 3-in. iron were bolted to the casings, to connect the adjoining sections and prevent the upper one from slipping.

The well was started by excavating the earth so that the casing sank of its own accord. As the material became stiffer, eight jacks applied around the rim were used. By this method the hole was driven with no extraordinary difficulty until at a depth of about 30 ft. the water pressure began to give trouble. From this time on the joints between sections would occasionally break loose and pour large volumes of water together with sand and clay into the well. It was these joints that caused the writer most uneasiness as they could be caulked only with great difficulty. They could not be tightened up enough to pour with lead and by no other means could they be made dry enough to deposit concrete against them, for even the smallest leak would create a pressure that would wash through green cement. The plan was tried of bolting iron above the oakum to hold it in place, but it was found that when the oakum became old and softened it leaked very freely and fresh oakum had to be forced into the joint so that any obstruction was more of a hindrance than a help.

At about 60 ft. depth a new difficulty arose; the great pressure on the outside suddenly caused a boiling up of sand and water, piling up 3 ft. or 4 ft. of sand within the casing. By removing this sand carefully and forcing down the casing with all the power that could be exerted a foot or two could be gained before another rush of sand and water temporarily suspended the work. The leaks through the joints already referred to, by carrying with them clay and sand, left voids behind the casing, and the earth settling down to fill these spaces caused the ground to crack in a circle 40 ft. in diameter around the well. The casing tripod and ground within this circle slowly settled down. This was not thought very serious until the heavy inrushes of sand in the bottom caused the ground to sink 2 ins. or 3 ins. at a time, and these sudden changes of such a great mass of earth shifted the sections of casing, tearing off the angle braces by shearing off the bolts.

It was decided at this point to abandon any ideas of sinking lower, for though the last casing had not been put down, an extra 7 ft. was gained by the cracking and settling of the ground to that extent. However before preparations could be made for concreting, a heavy flow broke through between casings 4 and 5 and the subsequent movement of earth squeezed the shell into an egg shape. Fearing that the whole casing would collapse if the flow of clay continued, the well was allowed to fill up to relieve the pressure. Subsequent soundings showed that the hole filled up 20 ft. with clay and sand before the flow stopped. As winter was now on and the work in the water could only be carried on at great disadvantage it was thought best to let it stand till spring and allow the ground to settle and become firm.

During all the previous operations the well had been emptied by a pump hanging from adjustable cables at the clear bottom of the shaft. In addition to being constantly in the way of the workmen this pump would be submerged when for any reason the steam plant had to shut down. When the work was resumed in the spring the pumping was carried on by means of a deep well pump, steam driven, which was set up on cross timbers over the top of the well. This was provided with a brass slotted tube strainer connected to the drop pipe by a slip joint, thus allowing the strainer to remain on the

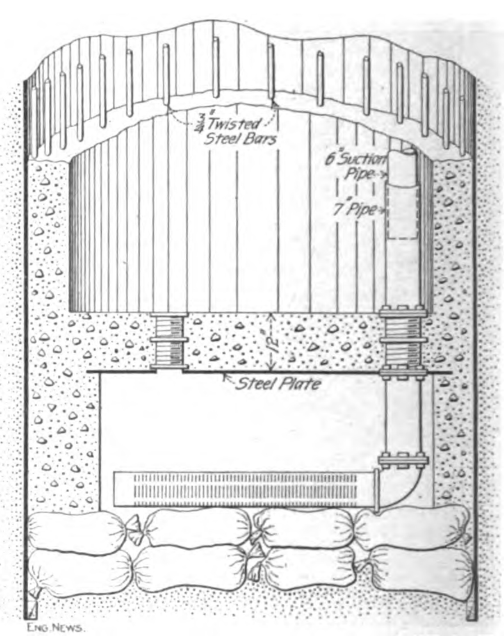


Fig. 2. Section Through Bottom of a Waterproof Shaft, Showing Method of Holding Sand Bottom from Blowing in, by Use of Concrete in Bags.

bottom of the hole and lower by its own weight with the excavation.

Although a great advantage was gained in having the additional room and in having all the steam pipes and working parts above ground in reach of the engineer, by far the greatest advantage was found to be the manner in which the water was kept down at all times. With the duplex pump the suction had to be kept submerged requiring the men to dig for most of the time with hands under the water, whereas with the deep well pump it was found to be an advantage to keep it running fast enough to hold the water below the top of the strainer. By doing this a certain amount of water would slush back after each stroke and clean the strainer, which on account of lying on the bottom would clog up if completely submerged. It was thus found that the pump was self-governed and would hold the water down to a few inches in depth all day without attendance.

It was recognized that the oval shape of the casings greatly weakened their natural strength, but the writer did not anticipate any danger with proper bracing provided the flow of clay and sand through the joints could be prevented. To accomplish this a quantity of dried white pine wedges, tongued and grooved, were procured and as each joint was uncovered it was well caulked with fresh oakum and the wedges driven in with a sledge. The angle braces which had not already sheared off were removed, as it was seen that they could not prevent the casings adjusting themselves to the flow of earth and the dropping of these pieces of iron endangered the lives of men at the bottom. So soon as the 20 ft. of filled in material had been excavated and the weight removed from the bottom the sand again began to flow up from the outside causing the casing and surrounding earth to sink, but bags of concrete were held ready and two layers were quickly spread over the bottom and the water then allowed to rise to remove the pressure and prevent the washing out of cement until the concrete had set.

The brass strainer of the deep well drainage pump was allowed to rest on top of the concrete bags and the next step was to build a concrete bottom 30 ins. high leaving a rectangular compartment around the strainer. Steel plates were then laid over this opening and a 12-in. floor of