

altitudes, and the direct rays of the sun make the balloon exceedingly hot. These experiments have been made chiefly by M. Hermite.

At an altitude of seventy miles the pressure of the air is but one millionth that of the atmosphere at the surface of the earth, and the older scientific books argued that the deeper we descend into the earth, the greater does the pressure of the air become; they argued that at a depth of forty miles the air would be as dense as mercury, but all that is now known to be wrong. The air has been compressed more than that by artificial means, and it is found that its density never exceeds  $1\frac{1}{2}$  times that of water; it comes to a limiting density, or, in other words, to a limiting volume. If the atmosphere be supposed to be in a state of convective equilibrium, then what takes place in compression will depend upon the nature of the gas. The presence of moisture in air has a great disturbing effect, because as it condenses there is such great evolution of heat, but in the case of dry air some of the facts can be easily ascertained by calculation. In rising in the atmosphere, for instance, at a height of twenty miles we should reach the absolute zero of temperature, but radiation and conduction of heat came into play, and there is no doubt that the upper regions of the air have a higher temperature than it is generally thought they ought to possess.

Solar radiation falls off a great deal at low elevations, and the constituents of the atmosphere exhibit complicated selective absorptions. Gladstone and others have observed the differences in atmospheric bands from sunrise to sunset, and shown that a large proportion of them are due to aqueous vapor, but oxygen and nitrogen have also their special absorptions, and in dealing with oxygen one wants a mile of the gas to study. Experiments are made in laboratories by taking a tube 60 ft. long, and getting in the gas under a pressure of 150 atmospheres. Professor Dewar here exhibited the absorption spectrum of compressed oxygen.

In the course of the lecture he drew attention to the following table of the variations at the surface of the earth of solar radiation :

Solar Radiation.		
Zenith distance. Deg.	Thickness of atmosphere.	Intensity of radiation. (Air Dry.)
0	1,000	2,403
10	1,016	2,401
20	1,065	2,395
30	1,155	2,383
40	1,305	2,364
50	1,555	2,331
60	2,000	2,275
70	2,930	2,164
80	5,700	1,868
90	35,000	0,359

#### THE CONSTRUCTION OF A WATER TIGHT MASONRY DAM.\*

By WALTER McCULLOH, Jun. Am. Soc. C.E.

In 1857-58 the Croton Aqueduct Department of New York City made a careful topographical survey of the Croton watershed above Croton Dam, with a view to locating all possible sites for dams and storage reservoirs, should such reservoirs be required as the city grew and the demand for water increased. The survey was made under the direction of the late Alfred W. Craven, chief engineer of that department, and covered some 338 square miles of the watershed. Fifteen sites were located as possibilities; but of these some have since been considered impractical for various reasons.

Dams were constructed on two of these sites a few years ago by the Department of Public Works, and one more is now under construction by the same department. Four more are in course of construction by the aqueduct commission, and two have recently been completed by the latter and are now in use; the latter being at "Double Reservoir I," which is familiarly known as Sodom and Bog Brook Reservoir.

This reservoir is termed double, as it is composed of two basins connected by a 10 ft. circular tunnel, 2,000

ft. long, through which the overflow of the larger passes into the smaller before any waste takes place over the spillway. The smaller, or Bog Brook basin, has an inadequate watershed of only  $3\frac{1}{2}$  square miles, while its storage capacity nearly equals that of the larger. The combined storage capacity of the two basins is practically nine and one-half billion gallons.

Sodom Dam, the one which impounds the water in the larger of the two parts of reservoir "I," is built of masonry throughout, but Bog Brook Dam is an earth embankment with a rubble core wall.

Sodom Dam is situated near the village of Brewsters, in Putnam County, New York, on the east branch of the Croton River, 18 miles above the present Croton Dam; is 54 miles from New York City, and 2 miles from the Connecticut State line. It spans a narrow gorge only 500 ft. wide at coping line, 78 ft. above the river bed, and has behind it 73.42 square miles of watershed.

The aqueduct commission, in August, 1886, sent a party into the field to sink test pits and make borings at the proposed site, to locate the underlying rock and to determine its character. Upon information thus obtained a location for the dam was fixed upon which

wall 8 ft. high and 500 ft. long, with the lip set at elevation 415.

The waste water, after passing over the overflow wall, flows to the old river course through a channel cut to bed rock and confined between curved retaining walls. (Fig. 1.)

The principal dimensions of Sodom Dam are (see Figs. 2 and 3) :

Length at coping.....	500	ft.
Length at top of foundation (elevation, 347).....	240	"
Thickness at foundation.....	253	"
Thickness at center elevation.....	23	"
Thickness under coping.....	12	"
Height at center, greatest.....	98	"
Height above ground line.....	78	"
Elevation of top of coping (New York datum).....	425.0	"
Elevation of flow line.....	415.0	"
Elevation of flood line.....	419.0	"

The greatest batter is on the lower face, changing at five points between elevation 347.0 and 424.0 and varying from a rate of 9.3 in 10 to 2.7 in 10; the total

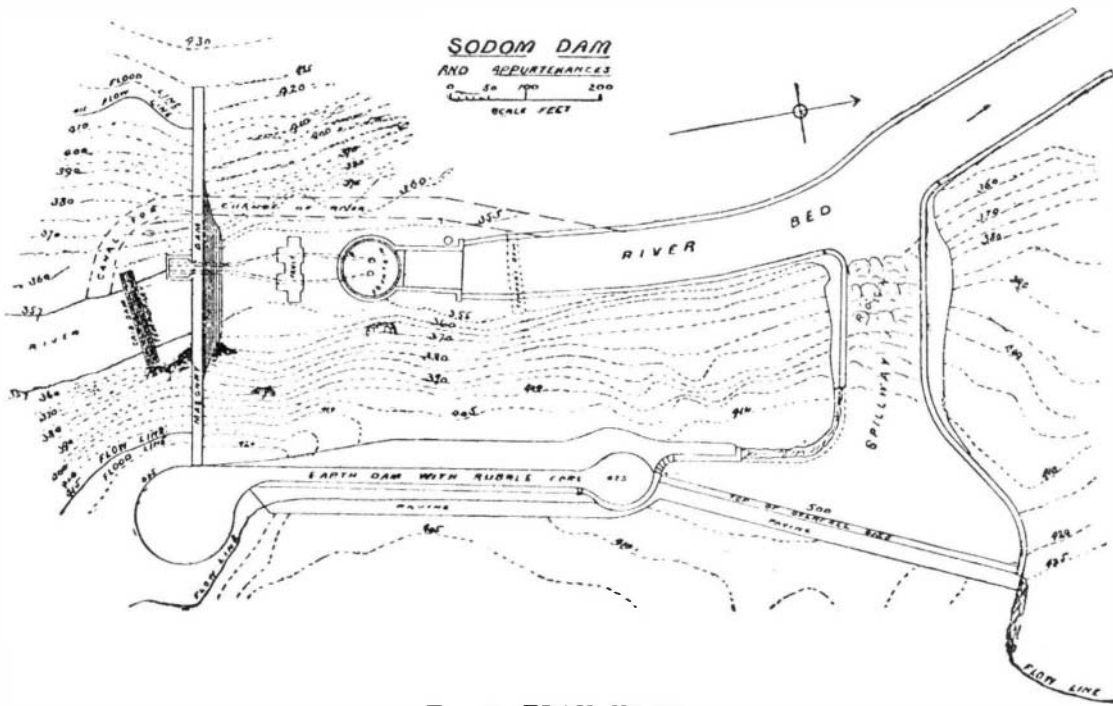


FIG. 1.—PLAN VIEW.

crossed the valley at about right angles to the stream (see Fig. 1) and which differed but slightly from that contemplated in previous surveys made by the Croton Aqueduct Department and the Department of Public Works.

On the site adopted, the hill east of the river (the stream flowing north at this point) showed an outcrop of hard gneiss rock which rose quite abruptly for about 30 ft. above the water and at the foot of which were large boulders, gravel and river drift. The slope back from the top of this outcrop was much flatter, rising 40 ft. in 100, and the rock was covered with but a few feet of soil. On the west side the slope of the hill starts from the river at a rate of 35 in 100, and gradually flattens to about 5 in 100 at the elevation of the top of the dam. The rock on this side was from 4 to 10 ft. below the surface, and was rotten and shaly for a depth of about 15 ft. The river bed was rock, quite solid, with a light deposit of sand and gravel overlying it. (See Fig. 2.)

The hill on the east side of the river is simply a ridge parallel to and averaging 75 ft. above it, which begins about 400 ft. behind the dam, and at the lowest point north of the dam is 9 ft. below the flow line of the reservoir. On top of the ridge an earth dam was constructed, 600 ft. long, with its top at the same elevation as the masonry dam. At the north end of the earth dam is the overflow or spillway dam, a masonry

batter is 37.0 ft. The rate of batter on the back face is 1 in 10 between elevation 347.0 and 387.0; from the latter point the wall is plumb to the coping.

Near the center of the structure at the back is the gate house, 37 x 42 ft., upon which a superstructure stands, rising 23 ft. above the dam. In this gate house are the sluice gates, stop-planks, etc., for controlling the discharge through two 48 in. pipes inclosed in, and passing through, the body of the dam.

After the work had been commenced, the cross section of the dam was modified, as shown in Fig. 3, by the addition of 6 ft. in width at the foundation, 3 ft. at center elevation and 2 ft. at elevation 407.0, the top remaining unchanged. This change was thought advisable by the aqueduct commissioners and the engineers as an extra assurance of safety, and was made at the time when the sad details of the terrible disaster at Johnstown, Penn., were fresh in the minds of every one. The change was also a great help to construction in making it easier to hold the facing stones in their places when laid upon a sloping bed of fresh mortar.

The contract for Sodom Dam and its appurtenances was awarded to Sullivan, Rider & Dougherty, December 30, 1887, and ground was broken by them February 22, 1888.

The first problem of importance to be solved was the care of the river during construction. Croton River usually appeared a very calm and modest stream, but in the spring time, or after a heavy rain, the water would rush through this narrow gorge at an astonishing rate, sometimes as high as 250,000 cu. ft. per minute.

The floods always came suddenly, raised for about twenty-four hours, and then slowly receded.

Several plans of flumes were submitted by the contractors (the specifications putting upon them the responsibility of handling the water), but were not approved by the engineers, being considered inadequate to the necessity. The plan adopted was the suggestion of the engineer in charge, and consisted in throwing a timber crib dam across the river about 80 ft. back of the dam site, and from this cutting a canal, 26 ft. wide and about 15 ft. deep, into the west side hill, and entering the river again 500 ft. below the dam. Before the completion of the work this plan proved itself to be the proper mode of meeting the situation.

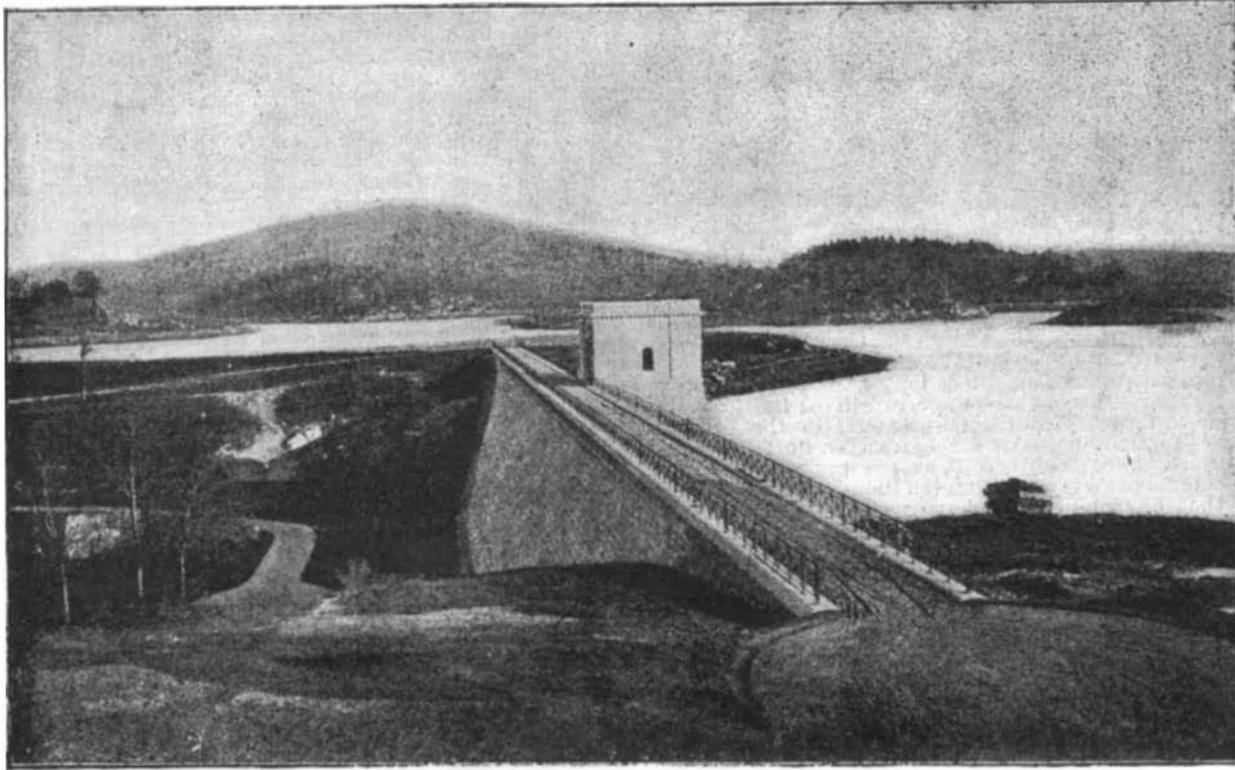
With the river flowing through this new channel the gatehouse and the eastern half of the dam were built to from 25 to 30 ft. above the discharge pipes, and when conditions seemed favorable in the dry season of 1889, the water was turned from the canal and through the pipes, and the remaining half of the dam was then started.

Excavations for the foundation were well under way in April, 1888, and the center 200 ft. section was ready for masonry by the end of August.

In preparing the foundation, drilling was done, both by steam and hand, and light charges of 40 and 60 per cent. dynamite used in blasting till the rock appeared firm. Then all loose seams or shakes were followed up with block holes and black powder blasting and by barring out, until a solid and practically tight bottom was secured. All excavation made in the latter manner was classified as "deep rock," for which an extra price of 50 cents per cubic yard was paid.

The foundation thus prepared was swept with wire stable brooms and washed clean with streams from hose pipes, to insure a perfect union between the rubble masonry and the rock.

When the bottom was ready for the masonry, the



THE SODOM DAM.

plan first used was to fill the pockets, or holes, with a rich Portland cement concrete, forming a series of small level beds upon which to begin the rubble. Concrete beds were discontinued after a two days' trial, because it was found that a surer and tighter bed could be formed of rubble made with small stones.

A large quantity of water made its way through the loose rock above the bottom, and in a number of places through seams in the bottom itself; but in these cases, where the rock was solid, the seams were not followed any deeper. The springs in the bottom would wash the mortar out of the concrete, and in many cases render it worthless; but in making the rubble beds the water could be led round and prevented from doing damage. These streams were nursed about from place to place till finally a small well, 2 ft. in diameter and 1 to 2 ft. deep, would be formed just around the point where the water boiled up. When the mortar about

The largest quantity of masonry laid in one month was 3,000 cubic yards, with 12 masons and three derricks. The average progress per month was about 1,700 cubic yards.

In mixing the mortar for all classes of masonry, the practice was to mix the sand and cement dry and to wet it on the wall only as fast as it was required. The "dry mixing" was done in large boxes on the ground at the east end of the dam in batches containing three barrels of cement, and when thoroughly mixed, the dry mixture was carried in these boxes to the mortar beds on the dam, and there divided into smaller batches and wet according to the rate at which it could be used up. By following this course the best results from the cement were obtained, as the mortar would be in the work before its first set had taken place, and the necessity of "tempering up" was avoided.

The cement used was "Burham" (English) and

cured from pits on reservoir lands about one mile from the dam; each load had to pass inspection, and all containing any loam were condemned and rejected.

The quarries from which the rubble stone was obtained were about a mile and a quarter from the dam. The stone was transported on double team trucks carrying from 1 to 1½ cubic yards at a load, and making from six to eight trips a day. The rock was a hard and tight-grained gneiss of irregular cleavage.

The facing stones were quarried and cut at a quarry opened especially for the Sodom work, at Towner's, New York, 7 miles away; were brought on cars over the New York and New England Railroad and unloaded at the dam, from which a switch was laid to and connected with the railroad.

These stones, a light bluish gray limestone, were cut rectangular, with "rock face" on exposed face, stretchers being from 3 to 6 ft. in length and 30 in. deep and head-

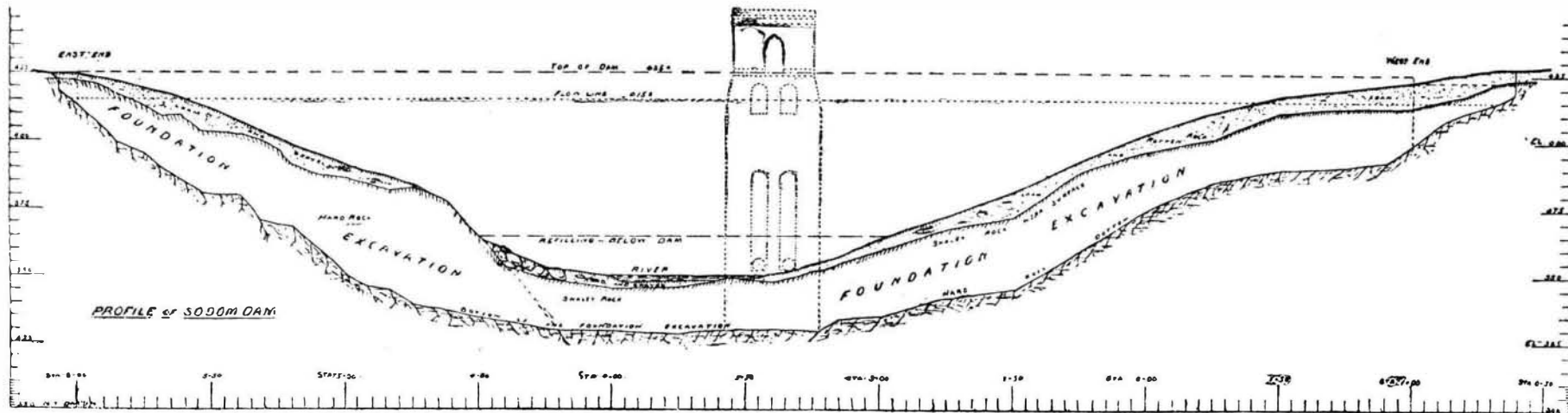


FIG. 2.—SODOM DAM PROFILE.

each little well had thoroughly set, the water was bailed out, the well quickly filled with dry mortar, a bed of stiff, wet mortar put on top of this, and on top of all a large rubble stone was placed, and the spring would be successfully squelched.

This process was followed over the entire bottom wherever water had to be contended with, and gave much better satisfaction than could be obtained with the concrete. After the first 6 ft. of the rubble foundation had been placed, it was plain sailing, and the masonry proceeded without further difficulty.

Below elevation 357.0 the entire wall was composed of rubble masonry in 2 to 1 Portland cement mortar; but above 357.0 on the back and 364.0 on the face, it was faced with "facing stone" 30 in. deep and backed with rubble.

Rubble stones varied from a cubic foot to cubic yard in bulk, and in placing them the beds of mortar were made very full and the stone thoroughly shaken to a firm position. The rubble was not carried on in level courses, but was broken as much horizontally as possible, so as to avoid having a straight joint of mortar through the wall.

In filling the interstices the rule invariably followed was to put the mortar in first, then force into it all the spalls it would take, thus insuring perfectly filled joints, and as much stone in the work as possible. Grouting was not permitted at all.

All stones, of whatever size, were thoroughly washed before going on the wall, and were usually wet when placed in the work.

Of the entire bulk of rubble, the larger part was in 1 to 2 Portland cement mortar, the remainder being in 1 to 3 Portland, and a small amount of 1 to 2 American natural cement. All the facing stone and dimension stone masonry is laid in 1 to 2 Portland cement mortar.

"Giant" (American) Portland cements, and "Union" (American) Rosendale cement.

Of the total Portland cement used, only 15 per cent. was Burham.

A very careful test was made of all cements used, under the following requirements:

Tensile strength required in pounds.	One day.	One week.
Portland cement, neat.	110	300
American natural cement, neat.	35	85

Fineness.  
Portland 80 percent. must pass through a sieve of 10,000 meshes per sq. in.  
Am. nat'l 92 " " " 2,500 " "

Following are some of the results obtained from these tests:

AVERAGE TENSILE STRENGTH IN POUNDS.								
BRAND.	Fineness. Average.	TIME SET IN WATER.						
		One day.	One week.	One month.	One year.	Two years.	Three years.	Four years.
Portland.	10,000 mesh.							
Burham, neat.	80 pr. ct.	167	429	615	798	700	764	782
" 1 to 2 mortar.			141	258	468	532	632	658
" 1 to 3 mortar.			169	224	404	520	552	
Giant, neat.	82 pr. ct.	140	348	422	682	694	736	771
" 1 to 2.			168	230	490	564	630	674
" 1 to 3.			140	234	420	512	572	
Natural.	2,500 mesh.							
Union, neat.	96 pr. ct.	160	240	228	510	542	650	654
" 1 to 2.			34	94	394	430	514	522

An excellent quality of coarse, sharp sand was se-

lers 4 ft. deep. They were laid in regular courses gradually decreasing in rise from the bottom up. The face of the stone is square with the bed, and set with bed normal to the batter.

At first considerable trouble was experienced in holding the stone up to line when set on the inclined bed, but this difficulty was overcome by building the rubble backing up first to about the height of the course, which, when set, could be braced against with wooden blocks and wedges, and the stone held perfectly in place. When the stone had been set for twenty-four hours or more, the blocking was removed and the space immediately filled with rubble backing.

All dimension stone came by rail from quarries on the Brandywine River, at Wilmington, Del., and was an excellent quality of dark bluish granite of a very hard, tight grain.

The plant used by the contractors in building the dam was, with but two exceptions, the "cable" and the "traveler," without novel or especially interesting features.

Three stiff-leg boom derricks with double-drum steam hoisters and two stiff-leg derricks with double-drum horse powers were used, which were shifted from place to place as required.

The "cable," which the writer believes was here used for the first time as part of a construction plant, consisted of a 2 in. steel wire cable weighing 7 lb. per ft., stretched over two towers, one erected at each end of the dam 667 ft. apart and anchored into the bed rock behind the towers. Upon this cable a trolley or car ran which was entirely controlled by a double-drum reversible engine situated back of the west tower.

The cable was swung over the length of the dam, parallel to the center line, and 10 ft. from the back face, and at such an elevation that a car at the center of span loaded to 10 tons would sag the cable to 25 ft.,

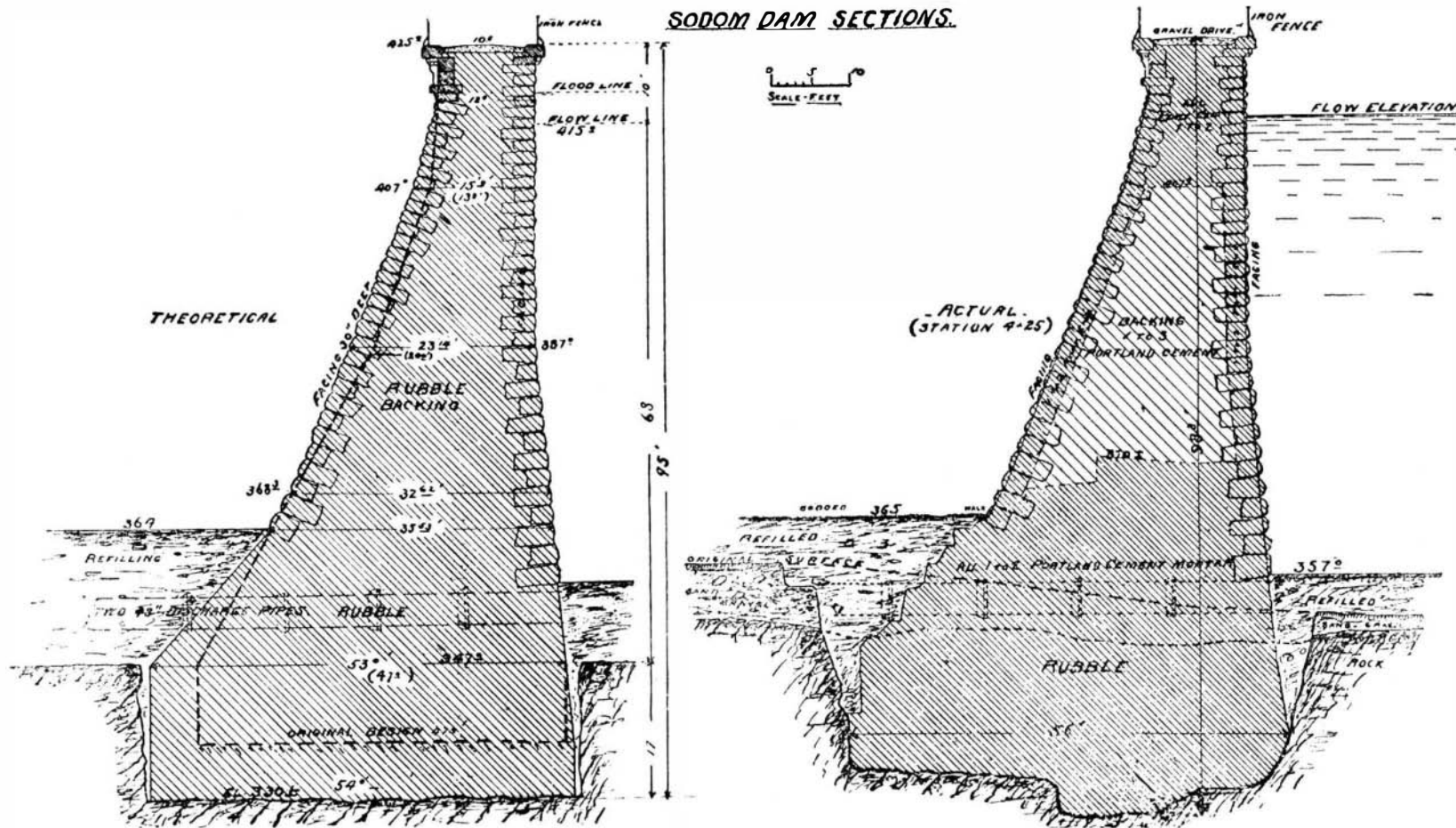


FIG. 3.—SODOM DAM SECTIONS.



and still clear the coping by 5 ft. when the work should reach that point.

The engine was so constructed that it controlled both the movement of the trolley from tower to tower and the raising or lowering of the load. The load could be held at any desired distance below the trolley, and run forward or back, or the trolley could be kept stationary while raising or lowering the load.

With this appliance nearly the whole of the excavated rock was removed, and all material for the masonry was delivered upon the wall. In raising the cable it was drawn up till the sag at the center was about 20 ft. below the supports at the towers. A load would add from 3 to 5 ft. to the sag.

The prime cost of the cable plant complete and erected was \$3,750.

In July, 1888, the first cable was raised, from which time it was in constant use till October 29, 1889, when, without warning, it parted at a point 50 ft. from the east tower and fell upon the wall. At the time of the break the trolley was running out from the west end with a load of only 6 tons, and was one-third of the distance across. No satisfactory conclusion was ever reached as to the cause of the failure. In the writer's opinion it was due to unequal wear at that point, for it parted directly over the place where stone and cement boxes were loaded and taken up by the cable. A new cable was immediately secured, and at the same time the towers were raised about 10 ft., so that it would not be necessary to draw the cable so tight, but allow a deeper sag.

No further trouble was experienced and this second cable was kept constantly busy till the completion of the dam. When taken down in the middle of August, 1892, the cable was found to be in an excellent condition, except for a reasonable amount of wear showing on the outside wires; but no broken wires were discovered.

When the wall had reached elevation 395.0, the derricks standing upon the ground were replaced by the "traveler," a traveling derrick mounted upon a 30 ft. trestle and running upon a track of 36 ft. gauge. A 55 ft. boom derrick was erected at the center of the front of the traveling platform and secured by two stiff legs to the back corners of the same, and was operated by a double-drum steam hoisting engine. With this traveler the dam was completed between the points that could be reached by derricks placed upon the side hills.

From start to finish the work seemed destined to delays of all kinds. The celebrated blizzard of March, 1888, was the first serious setback received. Then followed two unusually wet summers, causing a great deal of broken time and consequent loss.

In November, 1889, the most serious of the floods came upon us, and a shutdown for the season was the consequence. All the month of November had been rainy, but on the 28th the climax was reached when in 18 hours the rainfall was 3.8 in., bringing the total fall for the month up to 8.7 in. Eight hours after the rain had ceased, the water behind the dam had raised 10 ft., and in 12 hours had raised 15 ft. and was pouring over the top of the wall in a perfect torrent, notwithstanding the fact that both 48 in. pipes were open and discharging at their full capacity all the while.

Provision had been made for such an emergency by always keeping that portion of the dam directly over the new river channel from 4 to 5 ft. lower than the remainder.

A most serious loss was met with in January, 1889, when John Sullivan, the head of the contracting firm, was removed by death after but a few days' illness. To him had been left entirely the organization of the work and the planning for its future conduct. After Mr. Sullivan's death his interest in the contract was cared for by his executor, Clinton Stephens; P. J. Dougherty, another member of the firm, assuming the superintendence of the work till its completion.

Many other delays, such as strikes at the granite quarry and on the railroads, failure of the railroads to deliver cement and other materials on time, the exhausting of materials, etc., occurred from time to time, so that instead of the contract being completed on December 31, 1889, the specified time, it was not finally finished and accepted till October 31, 1892.

Only one fatal accident occurred during the whole course of construction, and that was caused by the breaking of the cable on October 29, 1889. An Italian mortar carrier was struck on the head by a piece of the trolley and killed. Three minor accidents occurred in which the sufferers required hospital attention.

Labor employed was for the most part foreign, at prices ranging from \$1.25 for laborers to \$3.50 for stone masons.

The following is a partial list of the quantities of materials handled in the excavation for, and masonry in the construction of, Sodom Dam and the gate house, and the contract price paid for the same:

Quantity. Cubic Yards.		Price.
5,986.	Earth excavation.....	\$0.35
16,200.	Rock excavation.....	1.50
3,600.	Deep rock excavation.....	2.00
300.	Rubble masonry, 1 to 2 Am. cement.....	3.75
23,280.	Rubble masonry, 1 to 2 Portland cement.....	4.50
6,260.	Rubble masonry, 1 to 3 Portland cement.....	4.25
530.	Brick masonry, 1 to 2 Portland cement.....	10.25
776.	Granite dimension stone ma- sonry, 1 to 2 Portland cement.	35.73
4,287.	Facing stone masonry, 1 to 2 Portland cement.....	10.75

The total bulk of masonry of all classes in the dam is 35,887 cubic yards.

The contract prices for the largest and most important items on the whole work were extremely low, considering the situation and the requirements, and this made it hard upon both the contractors and the engineers to secure a first-class quality of work under such unfavorable circumstances, but it must be said to their credit that the contractors faithfully lived up to their contract, even if at a loss.

The dam now stands in testimony of the accomplishment of the desired result in every respect.

It is impossible to give exact figures upon the cost to the contractor of the different classes of work, owing

to accounts not having been kept with this end in view.

The following are some figures on the costs, estimated from such data as could be obtained:

Cement in shed at dam, per barrel:	
"Burham," Portland.....	\$2.51½
"Giant," ".....	2.31½
"Union," Natural.....	1.00½
Rubble stone from quarry on work, including 5 cents royalty, per cubic yard.....	1.97
Rubble stone and spalls from excavation waste banks.....	.67
Rubble stone, average from all sources.....	1.26
Facing stone on work, including 15 cents royalty, per cubic yard.....	9.75
Dimension stone on work, including dressing, per cubic yard.....	30.08
Rubble masonry, 1 to 2 Portland cement, per cubic yard.....	4.45
Facing stone masonry, per cubic yard.....	10.97

The dam was far enough advanced by the winter of 1890-91 to admit of storing water behind it to elevation 390.0, and by the following winter to elevation 415.0. The extra storage supply was absolutely necessary to meet the demand in the summer, since the new aqueduct had been brought into use by this time and the daily allowance to the city had been greatly increased. This early use of the dam caused some inconvenience to construction, and was also a premature test upon the green masonry, but no evil results came from it.

Sodom Dam was finally completed on October 29, 1892, and formally accepted by the aqueduct commissioners on December 28, 1892. The final estimate for dam and appurtenances amounted to \$436,499.05.

When the bids upon this work were received on December 7, 1887, Sullivan, Rider & Dougherty's bid was \$366,990, they being the lowest. The highest bidder was Miles Tierney, at \$584,315, and the engineer's estimate was \$540,030; all figured upon the same basis.

The difference between the amount bid and the final estimate is due to modifications made from time to time in the original plans.

As to the water-tightness of Sodom Dam, it is perfect. When the reservoir is filled (with 68 ft. of water behind the wall) many careful examinations have failed to disclose any leaks whatever, either through the wall or under it, or through the rock around the ends in the side hill. "Sweating" at the joints in the facing stone appears at several points only, but not in sufficient quantity to produce a trickle. What moisture there is will wholly disappear on a dry, clear day; but if the day be humid, dampness is visible upon the face of the stone as well as at the joints.

To the question, "Upon what did the successful construction of Sodom Dam as a water-tight structure depend?" the writer's reply is: 1st, upon the excellent quality of the material used and the methods adopted in using them, viz., the securing and preparing a solid, tight foundation, the care to have every stone perfectly cleaned with water, the prompt use of mortar after wetting, the perfect filling of every joint with mortar, and the placing of stones so as to always break joints both horizontally and vertically; 2d, upon the careful study and close attention given by the engineers in direct charge to every detail to see that the above methods were faithfully carried into effect; and 3d, upon the desire and endeavor on the part of the contractors to do good work and the existence of a proper relationship between them and the engineers, which the writer thinks is a most important factor in securing thoroughly satisfactory work.

From start to finish the engineers had ever before their minds the fact that they were building to resist water, one of the most subtle and persistent enemies that our profession has to cope with, and they permitted no defects in construction, however trivial they might appear at the time, to pass unremedied.

The engineers to whom was intrusted the direction of the work by the chief engineer, A. Fteley, were George B. Burbank, division engineer, and the writer as assistant engineer in charge, from the commencement until June 17, 1891, when, upon Mr. Burbank's resignation, the writer became division engineer, and assumed charge, with Frank N. Speyer as his assistant.

In conclusion, the writer feels safe in saying that for water-tightness Sodom Dam rivals all masonry dams previously constructed in this country, and stands in the front rank with, if not ahead of, those built abroad.

In answer to questions put by members of the Society after the presentation of the paper, the following additional information was given by Mr. McCulloh:

**Cements.**—The American natural cement used was the "Union" brand from Egypt, Pennsylvania, and was delivered in heavy duck bags containing 100 lb. each, three bags constituting a barrel. The "Giant" Portland cement came from the same mill as the "Union," in bags of 100 lb. each, four bags to the barrel.

The purchaser of the cement was charged with the price of the bags, which, if returned, he was given credit for upon his next order.

No greater loss or damage to the cement was sustained in using bags than had casks been used.

Testing samples were taken at random from about ten per cent. of the bags in each lot received, and, if any question arose about the test, a second and independent set of samples was taken, and a new test made. In the average tensile strains given in the table of tests, some figures are the result of over 1,000 breaks. The lowest number of breaks is probably about 15 or 20, but the average is over 100.

**Masonry in Freezing Weather.**—A small portion of the dam was built in freezing weather, in December and early January of two winters. This was considered necessary, as it was desired to store water behind the dam to a certain elevation, and to do it the back half for a height of 4 or 5 ft., and 200 ft. long, was built in this way. Hot brine (5 lb. salt to 1 bbl. of water) and heated sand were used in making the mortar, and the rubble stones were also treated. Work was only allowed to proceed when the temperature was above 20° Fahr. To protect the fresh mortar at night, salt would be scattered over it, and if the conditions indicated a severe night in prospect, a layer of sand was spread over it also. No straw was used to protect masonry.

In the spring the masonry laid in winter showed only slight damage on the surface. A thin crust or scale  $\frac{1}{8}$  to  $\frac{1}{4}$  in. deep could be scraped off and would disintegrate. Under this scale the mortar was in good condition and set hard.

Each spring the old mortar was gone over with sharp picks, chisel edged, to remove the scale and secure a clean, fresh surface for the new mortar to fasten to.

It was not observed that the use of hot brine and sand caused the mortar to set more rapidly than usual.

**Freezing Tests of Cements.**—Certain tests were made at the laboratory, both with and without using brine, to observe the effects of freezing; but they were not complete enough to draw any positive conclusions from them. The results obtained were slightly in favor of the use of salt. Mortar frozen immediately after mixing would crumble, but, upon thawing, the mass would then set very satisfactorily, the freezing simply suspending the setting. Briquettes broken after a week's exposure to frost showed slight falling off of strength, but the difference was no greater than was often observed between two sets of samples under ordinary tests.

Portland and native cements acted practically the same under the same conditions of freezing.

**Cable.**—The main cable was 2 in. in diameter, made of seven strands of 19 wires each, or 133 wires in all. The total length between anchors was 990 ft. The anchors, back of the towers, were oak "deadmen," 10 ft. long, 2 ft. diameter, in trenches cut 6 ft. into solid rock. Near one anchor was a turnbuckle used to take up the "stretch" due to constant use and variations in temperature—the total stretch was about 3 ft. No twisting motion in the cable was observed as a load was run out upon it. The greatest indication of wear was in the cast iron trolley wheels, which would be cut in regular spiral grooves corresponding to the strands of the cable.

**Cable Failure.**—The break that occurred in the first cable took place between towers, 50 ft. from the one farthest from the power house, and at the time the load was slowly moving from the power end toward the center. It parted directly over the point where the rubble stones were lifted from the trucks by the trolley. When observed, after the break, both ends were found frayed for about 10 ft., and each wire showed a contraction at the point of parting, as is the case in testing samples.

Both cables were made by Cooper, Hewitt & Co., and were of the same dimensions. The original plant was furnished by the Lidgerwood Manufacturing Co.

**Preserving Batter Lines.**—As each course of facing stone was completed, the true batter points for that course were established upon it by the engineers every 20 ft., using the instruments. These points were cut into the stone, and the foreman was required to work from them for each succeeding course. At each change of batter, short profiles were set by the engineers 50 ft. apart, to insure the correct setting of the first course at the new rate of batter.

## THE UTILIZATION OF COAL MINES.\*

THE manufacture and utilization of steam power in any large city like Kansas City is an interesting study. From the huge steam engines with their boilers and immense stacks of the manufactories down to the printing presses and elevators, there are scattered everywhere these prime movers. They take up valuable space, they require a large force of skilled mechanics, and a constant bringing of fuel to them, and this transportation of fuel is really the bringing of power from the coal mines over the railroads and roads where, ultimately, in the cities, only a low per cent. of it can be obtained.

It has always been a favorite thought with engineers to distribute these powers from some central station, and so various attempts have been made with compressed air and underground steam pipes to deliver power thus to subscribers. But the areas have been limited and the space expensive. Still, in New York and Boston, even these methods have met with commercial success.

Of course, electricians have looked upon the problem and planned methods, and even tried them with success, of bringing the power of waterfalls for such distribution in the cities. In Italy, Switzerland, and France 400 or 500 horse power is already being transported every day, and in our own country there are in operation at Ouray, in Colorado, and at Telluride and at Portland, Oregon, electrical plants which are delivering power where previously it was not a commercial success, and the source of power is a dozen miles or so away.

The first noteworthy attempt was at Frankfort, in Germany, in 1891, where 300 horse power was transmitted 112 miles, over three small wires, and delivered at 72 per cent. efficiency, lighting 10,060 lamps and running one 20 horse power motor.

Every one is watching with interest now the development of the scheme for transmitting power from Niagara Falls to Buffalo, twenty miles away, and already the shafts and tunnels at Niagara are complete, and the turbines will be put in place to operate 20,000 horse power in units of 5,000 horse power each. It is proposed to deliver this power at \$36 per horse power per year at the motor in Buffalo. These items are encouraging to the electrician, and suggest the desirability of producing power outside our cities, and then bringing it there for distribution. But Kansas City is not in the vicinity of any sufficiently large water power.

The proposition seems not unfeasible to utilize some of the coal mines which lie so favorably within fifty miles of Kansas City. Here coal for boilers can be obtained at less than one-tenth the price delivered in cities for similar purposes.

In considering this fascinating problem, one must think of the various conditions to be fulfilled. The desirability is one thing, and its practical accomplishment another. I have determined, after considerable trouble—for it has never been done before—and with the kind assistance of the city boiler inspector, the amount of power used daily in Kansas City at present. I find it to be, according to the following list:

\* Abstract of a lecture delivered in Kansas City, Mo., April 15, 1893, by Professor Blake, of Kansas State University.