DRIVING THE BIG SAVAGE RAILROAD TUNNEL WITH COMPRESSED AIR.

An Inrush of Soft Material Prevented Progress by Customary Methods and Necessitated the Use of Air Pressure for 200 Feet.

Compressed-air methods have been in use for several months in driving through soft, running material in a long section of the Big Savage tunnel on the new Western Maryland Railway extension between Cumberland, Md., and Connellsville, Pa. This tunnel is on the summit of the Allegheny Mountains, at an elevation of 2,350 ft. Construction was started on it about 14 months ago, the work being conducted from both portals in top headings in rock. The west heading had progressed about 640 ft. when on Dec.19, 1910, a rapid inflow of soft, wet material blocked it and prevented further progress until an air lock was installed and pneumatic methods introduced. These methods have coped with the situation successfully and the difficulty is practically past at the present time.

The early plan of construction- of the Big Savage tunnel was outlined in a general de-scription of the work on this railroad extension, given in the Engineering Record of Dec. I, 1910. The tunnel is a single-track structure, 17 ft. in width in the clear, with a full semicircular arch on a radius of 8 ft. 6 in., with the springing line I j ft. 3 in. above sub-grade. The length is 3275 ft. The rock en-countered in the first 60o ft. on the west and in all of the work on the east has been a hard gray sandstone, bedded in thick layers dipping toward the east at an inclination of about z to I. It was originally intended to drive both headings through to a meeting before starting the bench, these headings being the full arch section above the springing line.

INRUSH OF SOFT MATERIAL.

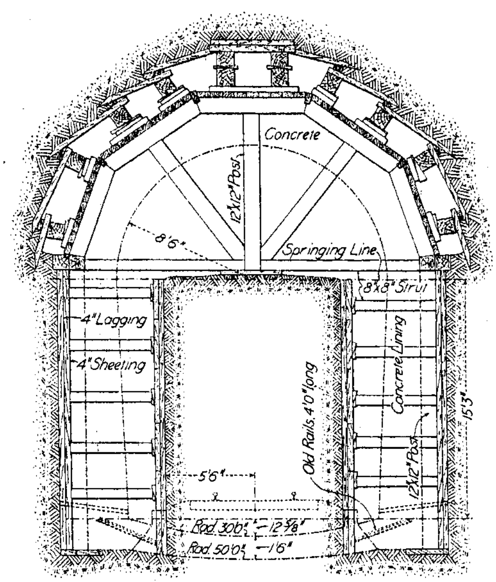
Just previous to the time of encountering the soft material, the west heading was in rock so hard that practically a full shift was required to drill a round of holes. On Dec. 19 the holes were drilled and loaded as usual, but following the shot, soft mud and sand rushed in from the top and flooded the heading back to a point about 200 ft. from the face. This material was a mixture of fine water-bearing sand and finely-divided disintegrated rock, which was accompanied by so much water as to make it flow very easily.

It was at first thought that a soft pocket had been struck, so the heading was cleared as far as possible and work was resumed in the soft material, a pilot drift being driven at the crown to ascertain the conditions ahead. This drift required full box timbering and breast boards with straw packing, and progress was very laborious. The soft material ran into the heading practically as fast as it was removed, and the pressure from above became so great as to displace and break the drift timbering. As soon as a small amount of headway was gained with this drift, it was enlarged and timbered closely with wooden voussoir~. After continued efforts to advance in this way, which netted only about I5 ft. total gain in a period of more than a month, it became apparent that satisfactory progress could not, be made by this procedure and pneumatic methods were determined upon. During this time the soft material and water continued to flow in and former springs on top of the mountain were observed to have ceased flowing. On Feb. I, at a time when the frost was beginning to leave the ground, a large cave-in occurred in the ground surface over the tunnel, a hole about 20 x 20 x 16 ft: appearing, with soft wet material at its bottom. This was at an elevation about zoo ft. above tunnel subgrade.

COMPRESSED-AIR METHODS.

During the early part of February, an O'Rourke air lock which had been used on the North River tunnels in New York was brought to the site and installed in the heading, its end being set in a 4-ft. concrete bulk-head wall about 40 ft. in front of the point where the roof had broken through. This lock was 7 ft. in diameter and 25 ft. long, equipped with a material track and small steel material cars. Air pressure was put on the heading on Feb. 23 and work was resumed at the face, which was then 10 ft. behind its position when the first break occurred. A pressure of 20 to 35 lb. per square inch was found to be neces-sary, and an average of about 25 lb. per square inch has been maintained throughout the work.

A new tunnel section, enlarged to provide space for a concrete lining and invert, was adopted for the soft ground. This section, together



Timbering of Heading and Wall Pits.

with the timbering used in its construction, is shown in the drawing on this page. The width of excavation for this section, upon resumption of work within the lock, was made 21 ft. between wall plates.

In proceeding with the excavation within the lock, a small crown drift was driven ahead as before and enlarged toward both sides by driv-ing poling boards outward and working down with temporary radial timbering. The vertical posts in the sides of the drift were 12 x 12-in. timbers, 2 ft. on centers, so in widening toward the sides, excavation was made between the posts and the first set of temporary I2 x 12-in. radial struts placed in the space thus gained. The posts were then removed while the struts tool: the roof load, and then a second set of struts was placed in a similar manner. This was continued down far enough to permit placing one angle segment of permanent timber and similar drifts were driven along the line and grade of the wall plates for setting the two lower angle segments and the wall plates. The segments consisted of 12 x 12-in. oak arch blocks, 2 ft. on centers with 4 x 8-in. oak lagging. Radial struts were provided to hold the blocks in place as the core was re-moved. All space behind the permanent tim-ber was packed tightly and grout was forced in through pipes in the arch blocks by means of a compressed-air jet.

PLACING THE SIDE WALLS

As the work progressed, the dip of the rock toward the east caused the hard rock floor of the heading to run out about 15 ft. beyond the first break, so that provision had to be made for the construction of the side walls below the wall-plate elevation to a footing on the solid rock. The method followed was to sink sheeted pits downward from the bench level along the lines of the wall plates, these pits being worked back to the outside line of the excavation so as to permit the vertical side posts to be placed within them. The location of these pits and the plan of timbering them are shown in the drawing on this page. The general procedure was to work them in 8 x 8-ft. sections, a set of 16-ft. timbering braced in the middle serving to form two such pockets. Tight 4-in., sheeting was used in sinking these pockets, the row next to the wall plates being driven on a batter so as to bring it eventually behind the lines of timbering. Pits of this size were as large as the material would permit, and in some cases the dimensions had to be re-duced to even less than 8 x 8 ft. Considerable difficulty was experienced in gaining headway against the soft material in the bottom, and if the pressure was released, it would boil up rapidly. .

As soon as a short section of trench had been opened along one of the side walls, vertical 12 X 12-in. side posts were set under the wall plates, 2 ft. apart on centers, and the spaces between posts filled with a solid 12-inch, wall of 1:3:6 concrete. This work was all behind the back lines of the finished tunnel side wall. When a section had been made tight on both sides in this manner, the tunnel core was removed as far down as the solid rock floor.

With the further advance of the working face, the floor continued to dip away and the. depth of the pits and the length of the side wall posts continued to increase correspondingly until, at a point about 40 ft. beyond the start of the soft material, the rock dipped entirely out of the bottom, placing the whole tunnel section in soft material. It then became necessary to place wall footings in the bottoms of the side trenches and to provide for the concrete invert, This involved the sinking of the pits to a level about 2 ft. below subgrade and placing a 2-ft. concrete footing about 6 ft. wide in sections 8 ft. in length, the walls being built as before. Concrete for all of the work within the lock was mixed by hand on a board inside.

DRAINAGE AND SPOIL HANDLING.

Drainage of the wet heading during these operations was effected by drawing the water to sumps in the ends of the side trenches and ejecting it by an air jet through a 4-in. pipe, equipped with a 3-in, wire-reinforced suction hose. A large amount of the soft material was also removed through this pipe with the water. The pipe discharged into a sump on top of the bench outside of the lock, where a force-pump threw the water to the outside. drain and laborers shoveled the sediment into spoil cars. The gritty character of the ma-terial passing through the pipe caused very rapid wear, some of the valves and fittings lasting only a couple of days.

Outside of the air lock, material tracks ran along the top of the rock bench and then, at the point where work had been started by the steam shovel on the removal of the bench, a timber gallery was built at the springing line of the arch. The spoil cars ran along this gallery to a chute from which they dumped into 1 1/2-yd. cars on the steam-shovel track below. An incline at the end of the gallery served to bring up the cement and other lock materials.

The labor problem for compressed-air work at this point in the mountains was a source of some difficulty. About 75 men for this class of work were required practically continuously, there being three shifts of about 25 men each. Most of the labor familiar with this class of work is found around the large cities, and the air men or "sand hogs" engaged on this work came mostly from New York. About three-quarters of these were negroes. The nearest Southern States also supplied a few. During the times when the pressure was high, the working shifts were reduced to two 3-hour periods, with a 3-hour rest period in between.

POWER PLANT CHANGES.

A considerable addition to the power plant equipment was necessitated by the introduction of compressed-aid methods. Originally there were two Class AA_2 Ingersoll-Rand compressors, each giving 1250 cu. ft, of air per minute. These were driven by three 100-hp Brownell boilers. Au additional compressor of the same type was installed, with capacity of 165o cu. ft. of air per minute, and two 125-hp Pennsylvania boilers were added to the steam plant. This plant compressed the air at 110 lb. per square inch for all tunnel service, and that for use in the lock was reduced to the required low pressure by a Westinghouse automatic reducer valve. Electricity for lighting the tunnel and lock was supplied by a 25-kw, 120-volt Port Wayne generator ill the main power house. At the time these notes were made, hard rock had been reached again in the top of the heading and the inclination of the rock indicated that the entire section will again run into firm material. This is at a point about 195 ft. from that where the soft material first ran in. About 250 ft. still intervened between the west and the east headings. The later has progressed favorably in hard rock of a character similar to that first encountered in the west heading.

On Oct. 25 the concrete lining was completed in all of the soft-ground section which was water-bearing, and from all indications it seemed safe to release the air and go ahead with ordinary soft-ground methods. This was done four days later, and for several hours there were no signs of undue pressure or of water breaking in, but in the evening of that day, the bottom of the tunnel bulged up ahead of the concrete invert and water came through in large quantities. Accordingly pressured was again applied so that a further advance of 50 to 60 ft. could be made before finally releasing the pressure.

Geological conditions somewhat similar to those in the tunnel have been found in a large cut about 1 mile farther west. The cut is 2400 ft. long, 90 ft. deep and contains about 250,000 cubic yards. It is at the summit point of the main Allegheny Mountain ridge of which the ridged pierced by the tunnel is a spur. Wide seams of soft material between hard layers of rock were encountered in this cut and a large amount of water was present.

The Big Savage tunnel is being built for the Western Maryland Railway under the direction of Mr. H. R. Pratt, chief engineer, and Mr. G. H. Friend, principal assistant engineer. The Carter Construction Company, of New York, is the contractor. Mr. A. W. Jones, chief engineer of that company, is in charge of the work at Big Savage. Details of the compressed-air working methods were developed under his direction by Mr. E. E. Evans, superintendent at the tunnel.