Tunnelling.

Thesis by

Edwd. A. W. Hammatt.

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Tunnelling.

I propose to treat this subject in the following order of subdivisions, namely; 1st Preliminary Work; 2d Sinking Shafts if there are to be any. 3d Transferring Levels and Line from the surface of the ground to the bottom of the shafts. 4th Driving the Headings; 5th Excavation, (and masonry if required) of Side Lengths. 6th Ditto of Shaft Lengths; 7th Ditto of Leading and Junction Lengths. 8th Centres, and then some remarks on Machine Drilling.

I shall illustrate my description of the first eight subdivisions, by drawings, principally showing the method of Construction followed at Blechingley Tunnel, Eng. as shown in Simms's work "On Practical Tunnelling."

1st Preliminary Work. Under this head I include the Ranging of the Line on the surface of the ground; the determination of one or more Distant Points on line; the erection of an Observatory or of Observatories, if they are to be used, and the Location of the places for the Shafts.

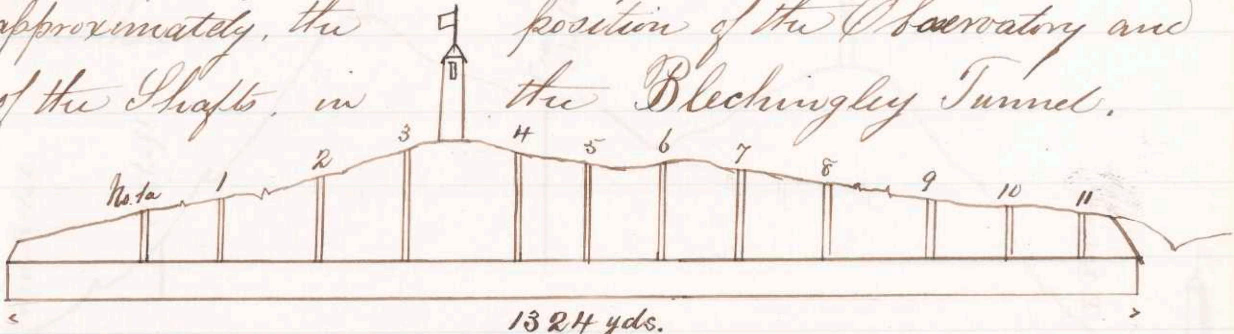
After running a preliminary line, in order to determine **about** the position of the intended tunnel; and having fixed upon the position of the entrances, the next thing is to get some intermediate station or stations on the centre line; upon which to erect the Observatories, or if they are not to be used, over which to "set up" the Transit.

The determination of these stations is an operation which usually requires great care, particularly if the tunnel is a long one, as it is very seldom that both ends can be seen from any one station.

When these stations have been determined upon, and before work upon the tunnel proper, has commenced, it is best, if possible, to erect distant marks, for reference, which shall be on the prolongation of the centre line of the tunnel, and some distance from the entrances.

Then when the Observatory is erected, the instrument is placed "on line" by means of these marks, and firmly fastened; and from this the locations of the Shafts are determined.

In the rough sketch below I have tried to show approximately, the position of the Observatory and of the Shafts, in the Blechingley Tunnel.



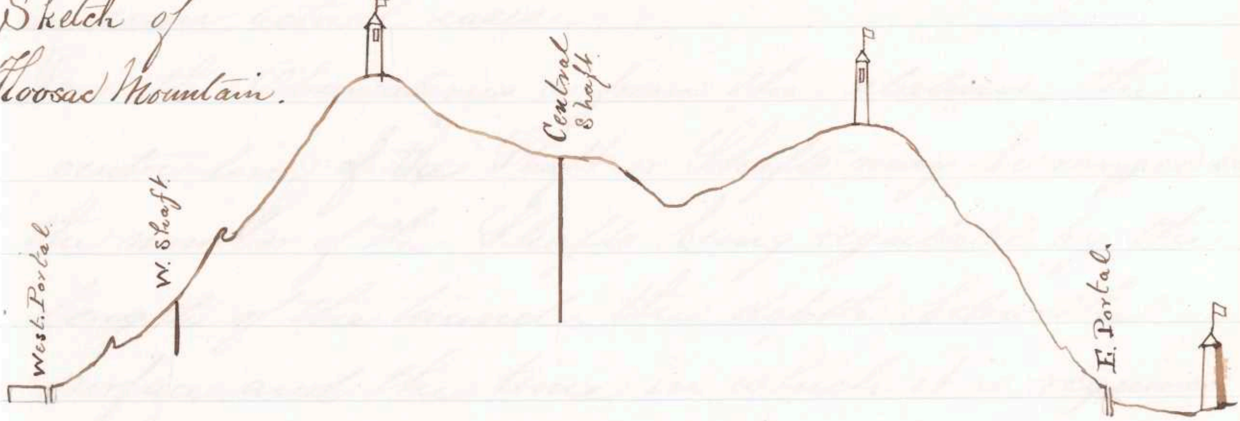
At this tunnel, the distant marks were erected at a distance of two miles from each entrance, and other marks were erected nearer, for use in thick weather; they were built of brick, painted black, with a white line which coincided with the centre line of the tunnel.

At the "Mont Cenis" Tunnel, an Observatory was built on the highest summit, from which two Observatories, one opposite and at some distance from, each entrance, could be seen.

The next sketch will show about the positions of the Observatories, erected at the Hoosac Tunnel.

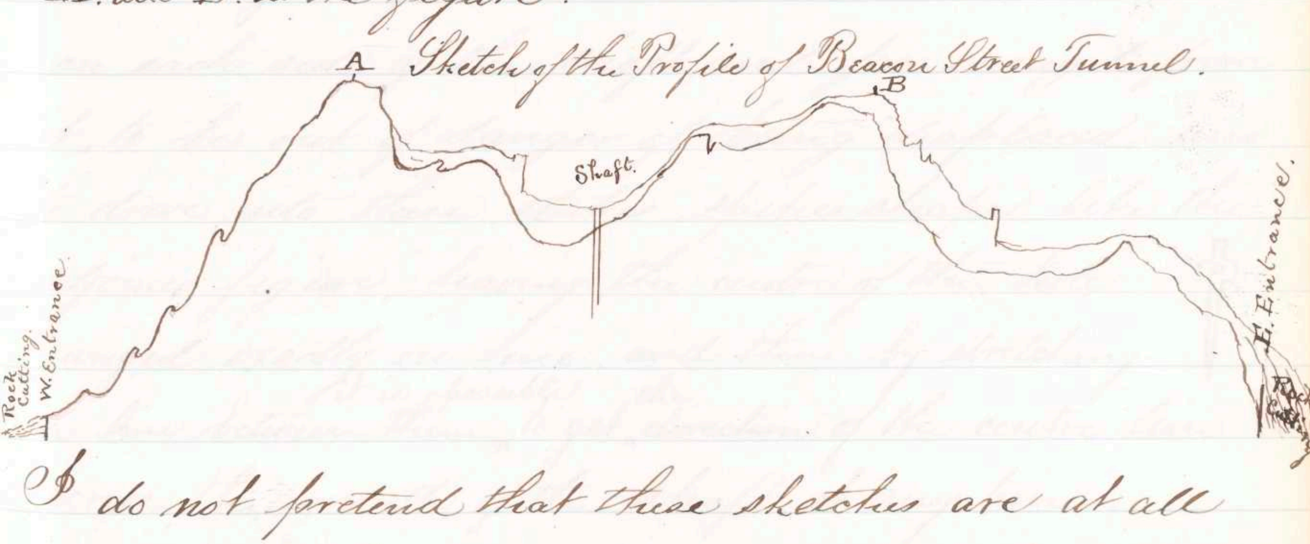
It took, all one summer to locate these points, working only early in the morning or at night in order to avoid refraction; and repeating each observation a number of times.

Sketch of Hoosac Mountain.



At the tunnel for the Boston Water Works, at Newton Centre, Mass. and which is designated "The Beacon Street Tunnel", no Observatories were erected, but stations were fixed at the points A. and B. in the figure.

Sketch of the Profile of Beacon Street Tunnel.



I do not pretend that these sketches are at all accurate, either in outline, or in relative proportions, but I give them in order to give some idea of the positions of the stations, which were selected in in some actual cases.

From the Observatories or from the stations, the centre line of the Shaft or Shafts may be ranged out; the number of the Shafts being regulated by the length of the tunnel, the depth below the surface, and the time in which it is required to be completed.

At Blechingley, they had a great many shafts. in order to hasten the completion of the works; and at Mont Cenis they had no shafts owing to the great depth of the tunnel below the surface.

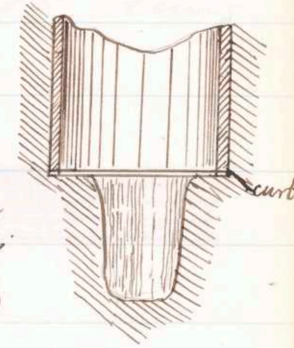
It is a good plan to drive a stout stake on line on each side of the shaft, and far enough from it, to be out of danger of being displaced, and to drive into these stakes, spikes shaped like the adjoined figure, having the centre of the hole ranged exactly on line, and then by stretching a line between them, it is possible to get the direction of the centre line across the mouth of the shaft, at any time.

2d Sinking Shafts.

This may be done in either of two ways - by a Drum Curb or by Propping and Underpinning. The latter mode is usually followed where the ground is good, and solid enough to sustain the pressure on the props.

The Drum Curb consists of a ring to carry the brickwork, and below it a cylinder or drum, having its lower edge beveled; then after excavating as far as the earth will stand, the curb is lowered, and the brickwork built up regularly, upon it, then the earth under it is loosened, and this with the weight of masonry upon it, causes the curb to sink; the brickwork being built up as fast as the curb sinks. Great care must be taken to see that the shaft sinks vertically -

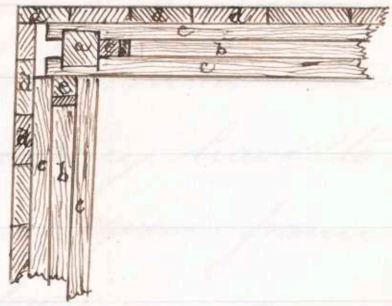
In the other process of shaft sinking, the process is as follows; Excavate the shaft as far as the earth will stand vertical, and then place a curb of oak or elm plank, on the bottom, and set it level; then build up the brickwork or stonework to the surface, this is now supported by the earth; then excavate in the middle as shown in the figure, and next cut out a slice up to the brickwork or rather to the curb, and insert a prop; in this way insert a number of props, and then cut away the rest of the earth and insert a new curb, on which build up brickwork to meet the upper curb.



It will be easier to get this last curb into place, if the props are slightly raking, and they should be taken out, as the brickwork between them is made good to the upper curb.

The centre is again dug out, the props inserted, a new curb put in position vertically under the others and the brickwork built up as before; in this was the shaft is carried to the required depth. Of course in a shaft through rock, unless it was quite soft and likely to tumble in, little or no brickwork would be required, and the same thing may be said of the tunnel itself, in such cases. In some cases, timbering only, is used to line the shafts, one method of timbering for a square shaft being represented in the adjoining figure.

(a) is about nine inch scantling in lengths of about six feet; scarfed at the ends and placed vertically in the angles - it is kept in place by horizontal pieces (b) and (c) (c),

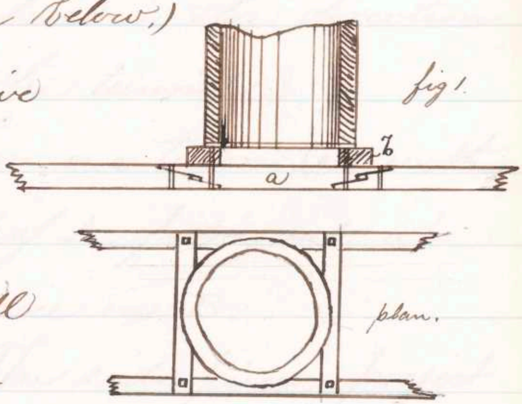


nine, by four and one half inches, bolted together; the pieces (c) (c) are notched fore and aft to the vertical piece (a). Behind these comes thick planking (d) (d) and the whole is tightened by wedges (e) (e). The object of scarfing the pieces (a) is; that they may be easily lengthened as the work proceeds.

In the case of the Brick lined shafts, the brickwork is carried down to within a few feet of the intended top of the tunnel, and from there down, timber is used, and planked close against the sides. This is shown in the middle part of Fig. 2. of the drawings accompanying these pages.

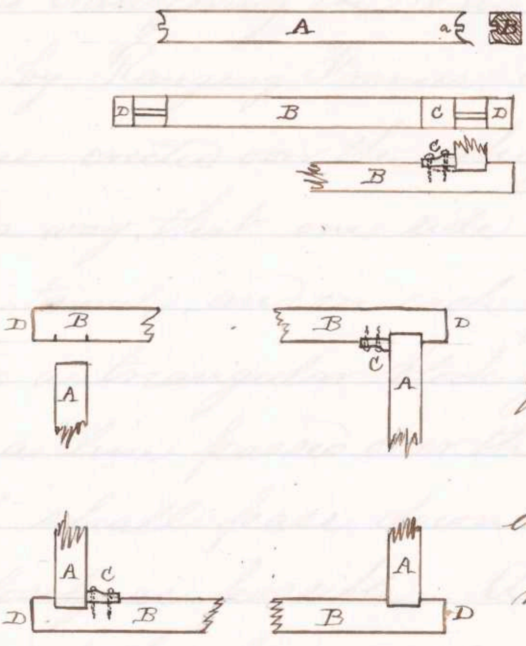
The Shaft may be supported either from below or from above -

If the shaft is supported from below, a small heading is driven in which to insert a pair of sills, represented at A. in the accompanying figure, at right angles to the direction of the tunnel and directly under the shaft; their dimensions will depend on the weight which they have to support. On these sills is placed a square frame (shown at b fig. 1 and shewn in plan below,) of the same kind of timber, to receive the bottom curb.



This is also shown in Fig. 2 of the drawings, where (a) is a sill and (b) the frame; and below the sills, square settings of timber were (at Blechingley) placed at intervals of about six feet, and propped with rough timber as seen in fig. 2 above referred to. This setting is to be placed vertically under the shaft and square with the line of the tunnel: then excavate enough earth to insert the poling boards, driven close, and if there is much water comes between the cracks, bringing the earth with it, they should be packed with straw; insert the rough props and proceed as in sinking the shaft.

The method of framing these square settings is shown below.

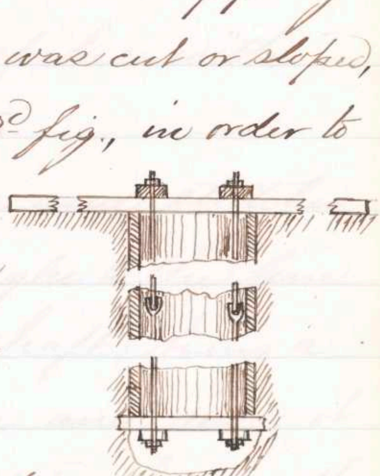


A. is a stretching timber placed at right angles to the line of the tunnel.

B. is the side timber placed in the direction of the tunnel.

There is a tenon (a) in the end of A. fitting into a mortice in B.

The side pieces project beyond the stretchers, forming a kind of shoulder as at D. which prevents A from slipping outwards, while the blocks C prevented them from slipping inwards. A portion of the side piece B. was cut or sloped, as shown by the dotted line under C in 3rd fig., in order to let the tenon slip into its mortice



One method of supporting a shaft from above, is shown in the adjoining sketch; it rests on a square frame as before. Chains may be substituted for the tie rods.

When the shafts have been sunk to the depth required, it is necessary to transfer the line and levels to the bottom.

1st As to transferring the Line; This used to be done by Ranging Frames; which are triangular frames erected over the shafts, and supported in such a way that one side is parallel to the line of the tunnel, and on each of the other sides is spiked a triangular block of wood, in such a way, that a line passed over the projecting angle "on line" shall pass down the side of the shaft as closely as possible. A heavy plumb bob is hung at the lower end in a pail of water. The great objection to this method is; that the line is easily blown by the wind, and hence can only work on calm days.

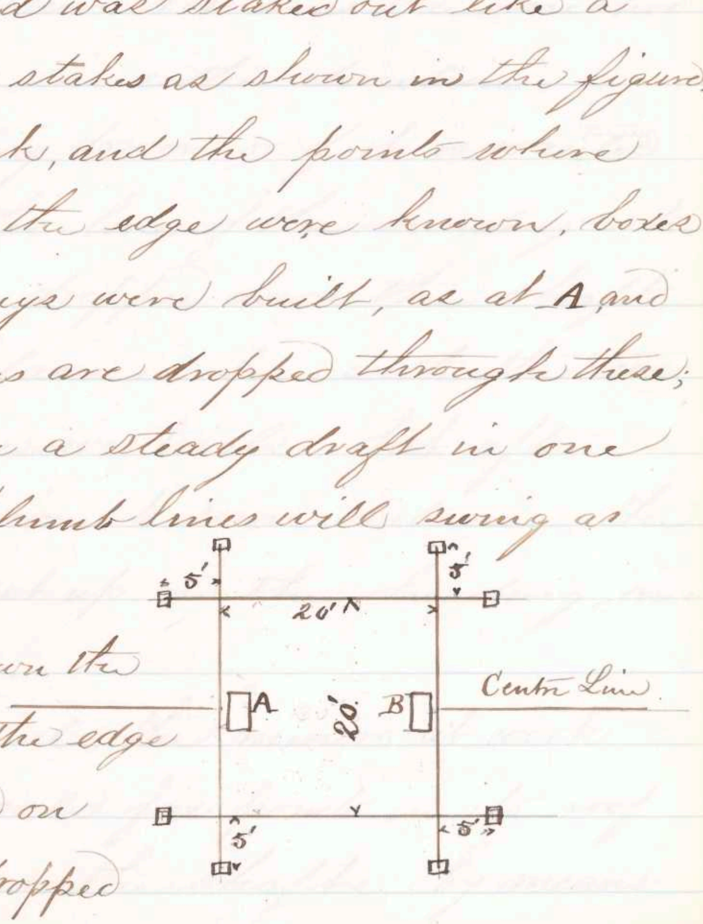
Another way is by means of the spikes with holes in them mentioned on page 5.

A line is passed through the holes and stretched taut; then put a plank at right angles to the line, and projecting over the edge of the shaft; hang a line with a plumb bob over its edge, and move it until it is just under the line stretched between the spikes; then drive a nail in the plank, and suspend the plumb bob from this, down the shaft; letting it hang in a pail of water.

By means of this line, nails may be ranged in the square timbering of the shaft, from which the workmen can suspend plumb bobs, if required.

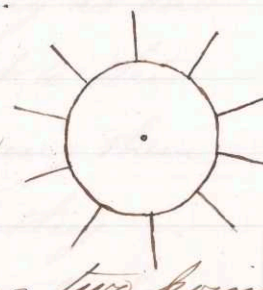
This method was followed at Blechingley Tunnel, where the shafts were circular and nine feet in diameter.

The shaft at the Beacon Street Tunnel is twenty feet square, and was staked out like a house lot, by putting in stakes as shown in the figure. After the shaft was sunk, and the points where the centre line crossed the edge were known, boxes or rather wooden chimneys were built, as at A and B, and the plumb lines are dropped through these; the object being to have a steady draft in one direction, so that the plumb lines will swing as little as possible.



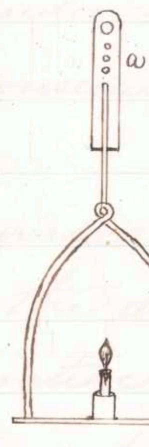
Now when line is wanted down the shaft, a plank is laid over the edge of the box, a point is found on line; and the plumb line dropped

from it, the weight hanging in a pail of water.
Fine copper wire is used for the line and the weight attached to get it plumb looks like the following sketch in plan, the projections stopping the vibrations to a great extent.
The form is that of a short cylinder and the projections are pieces of tin.



Having given a method of getting two points down the shaft, on line, there remains the method of prolonging the line in either direction.
If there is no heading driven or if it is wanted to fix points where the line of the heading is to be, the lines being dropped down the shaft, the instrument is placed in line with the two plumb lines, by successive trials, but after the headings are driven to some distance, the instrument can be set up in the heading, and then placed in line.
At Blechingley Tunnel, the miners at work on the headings, would fix points in its roof as the work receded from the shafts, by means

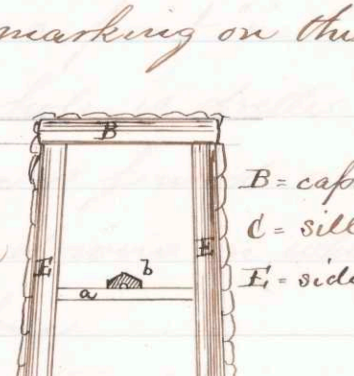
of the lines at the shaft, but after these headings had been drawn to some distance; it was necessary to test their work, and instead of having a man hold a candle at each line, a candle holder was devised, similar to the sketch.



At least four of these were hung at one time, and the lights brought to the same level by raising or lowering them in the racks (a); then see that they all cover, and range other points by means of these. The racks were made of sheet iron, the rest of strong iron wire.

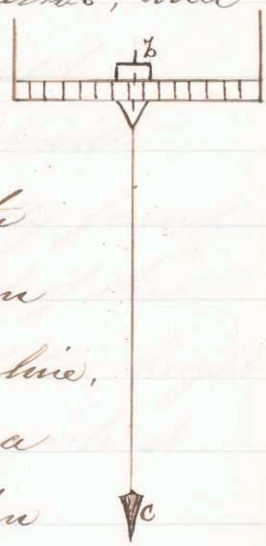
When the headings had been driven from end to end, permanent marks "on line" were fixed.

A cross piece (a) (see figure below) was fixed to a setting or heading frame, and after marking on this where the intended centre line of the tunnel crosses it, a block (b) with a hole in it which is placed to coincide with the centre line mark; is screwed down; then by stretching a line through several of these (they were placed at intervals of thirty or fourty feet) it gives the



centre line of the tunnel.
The positions of the points on the cross bars (a) were determined by stretching a line very tightly in the headings, and having it pass under the plumb lines passed down two or more consecutive shafts.
At the Beacon Street Tunnel, the material being rock, and the tunnel small, the driving of the heading and tunnel is one operation.
Line is given by setting up the instrument in a heading, placing it (by trials) in line with the plumb lines dropped down the shaft, and reversing, correcting the error of the instrument by turning around 180° and reversing again, and taking the mean of the two as a point "in line"; this point is found in the roof, a hole is drilled and a wooden plug inserted; line is found on this plug, and a small hook is driven on which the miners can hang a plumb line.
Lately an arrangement has been used to give a means of knowing where the line passes, every time it is given; which consists of a scale,

shown in the figure, graduated to hundredths, and inverted in the roof of the tunnel.



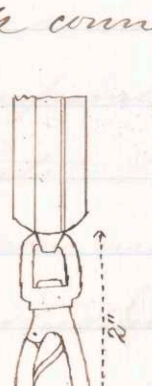
There is a kind of a cap, shown at (b), which is free to slide along the top edge of the scale and from which a plumb bob (c) can be suspended; this having been placed on line, the position of the cap is noted, and from a number of readings the mean is to be taken as most probably the true line.

There are two of these scales in the East Heading, the first about 75 feet from the entrance, and the second 1000 ft. further on; two in the headings on each side of the shaft; one on one side about 100 ft. and on the other side about 150 ft. from the shaft, and the second one somewhere about 500 ft. from these first. Now by hanging the plumb lines from these points and setting the instrument between, they have two points 250. ft. apart instead of 20 ft. to get the line from.

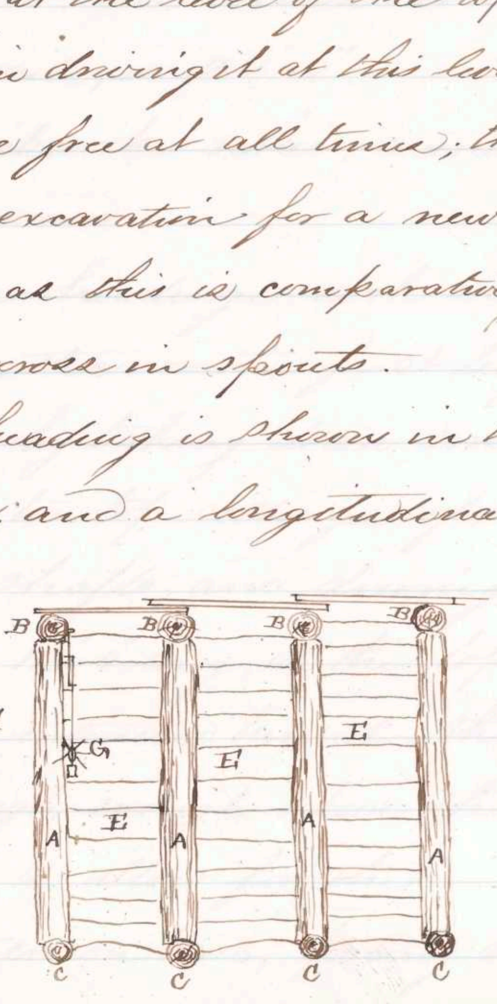
The depth of the shaft here at the Beacon Street Tunnel is only about 57 ft. and most of the tunnel so far as excavated, is through the conglomerate rock commonly known as "Pudding Stone".

Levels: A permanent bench mark should be established near each shaft; its height with reference to the standard datum carefully found and recorded; then knowing the height of the formation level at any shaft, the relative height of any point in the tunnel to the bench mark at that shaft, can easily be found.

At Blechingley after the shaft was bricked, a horse-shoe shaped staple was driven into the side of the shaft, and the level of its upper surface relatively to the outside bench mark found, then the levels were "dropped" by means of rods connected as shown in the figure and 10 ft. long from the inner edge of the loop at one end as (a), to the inner edge of the hook at the other; these rods were passed through the staple in the side of the shaft, and kept at the right height by a clamp on the rod whose lower edge is at the required height and which cannot pass through the staple. At Hoosac and at the Beacon Street Tunnels; the levels were got by



measureing down the timbering of the shaft with a steel tape.
As the operations in tunneling through rock consist mostly of blasting and quarrying, and very little or no timbering is required unless the rock is quite soft; I shall confine my descriptions of the methods of working, to those of tunneling through earth, as at Blechingley.
After the shafts were completed, a heading was driven between each shaft, at the level of the top of the invert; the object in driving it at this level being to keep the drainage free at all times; the only obstruction being the excavation for a new length of brickwork, and as this is comparatively short, the water is carried across in spouts.
A transverse section of a heading is shown in the lower figure on 14th page; and a longitudinal section is shown below.
The clear dimensions were height 4'-8". breadth 3'-0" at bottom and 2'-7" at top.
The sides A 5" or 6" in diameter tenoned into mortices in caps B,



also 5" or 6" in diameter, and into the sills C, 4" in diameter. These frames set 2' or 3' apart and the sides closed by poling boards E. from 3/4" to 1" thick; the top with boards not less than 1" thick.

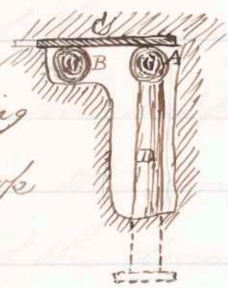
One of the candle holders is shown at G.

The form of this tunnel is shown at figure 1. of the drawings; the rise of the invert is 3'.0"; the level of the rails 1'-0" higher, and the clear height above the rails 21-0"; the width at a height of 5'-0" above the rails, is 24'-0".

The thickness of the brickwork varied, according to the character of the ground.

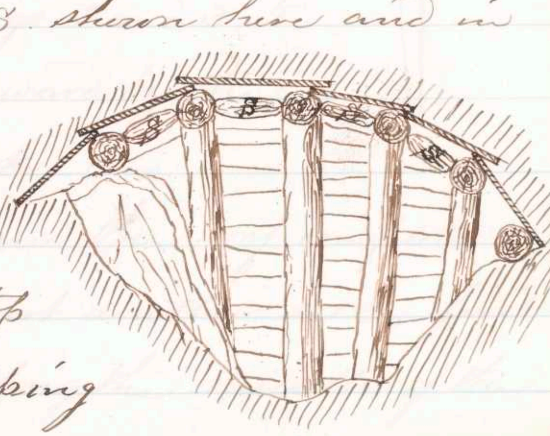
On the completion of the headings, work was begun on the Side Lengths, or the first lengths on each side of a shaft; by taking down some polings from behind the two top settings of the square timbering of the shafts, and driving a narrow heading, about 12'-0" long, at the top, and in the middle of the intended tunnel; the top of the heading being high enough above the intended soffit of the arch to allow for the thickness of the brickwork, crown bars, poling boards and several inches for settlement.

5th. After the heading has been driven, it is widened at the top along one side to form a shelf upon which to place a crown bar lengthwise, as shown at B in figure, then put the centre crown bar A. along the top of the heading and support its further end by the prop D, and its near end upon the square timbering of the shaft; then arrange poling boards C, to carry the weight of the earth above the bars.



Next get in a crown bar on the opposite side, in the same way, and then remove a slice of earth from under their further ends, and insert props as shown at the centre crown bar; then remove the rest of the earth, which leaves the heading much wider. A complete arched roof is formed in this manner, partly shown in figure below; the crown bars being kept apart by short struts, S.S. shown here and in figure 3 of the drawings.

Relieve the square timbering of this extra weight as soon as posible by inserting the top sill, next the shaft, and propping



every bar from this; previous to its insertion, the timbering may be partly relieved by laying a stick of timber on the ground and propping from that. This top sill is shown at D fig. 2, of the drawings. The forward ends of the crown bars are supported by props, resting at first on foot blocks on the ground, then upon the sill A, figs 2 and 3 of the drawings. The crown bars are longer than the length of the brickwork is intended to be, so that the sill may be placed in front of the advance props G, fig. 2; when the sill is in place it is set level, and the permanent props H (fig. 2.) inserted and wedged; and to prevent their moving brobs are driven round them; these brobs show in several of the sections. F is a crown bar.

A Brob.

The dimensions of the sills will depend on the weight or pressure they are to sustain or resist. Next insert the stretchers M. figs. 2 and 3. to prevent the sills being forced inward by the pressure on the face of the work.

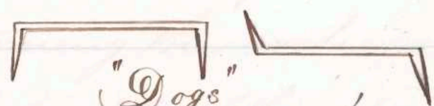
After the top sills are in place and the roof completed, excavate downward so as to insert another sill; first making a narrow passage along the middle of the length, corresponding to the heading, and at the forward end temporary raking props K, K fig. 2 are inserted, then get in the sill, directly under A and insert the permanent props P.P' At the end next the shaft we can insert props raking inward, or if the square timbering can be depended upon, the sill E' can be temporarily supported from this, as at L fig. 2. After getting in the props P. P'. remove the rest of the earth to the level of the second sills and insert polings, bars and props to support the earth, and stretchers M. figs 2 and 3. to prevent sills being forced inward.

Figure 3 shows the arrangement of all the timbers mentioned, as used at Blechingley. If the soil is wet sand, if the poling boards are packed with straw it will prevent, in a great measure, the sand from running through. If the ground should be very heavy and more sills needed, they would be inserted in the same manner.

As soon as the excavation is completed, a ground mould is to be set up at each end, to guide the bricklayers in laying the invert; shown at O. O fig 2 and at D fig. 3. It forms a part of a leading frame, of which E. E' fig. 3 are the moulds for the side

walls; F and G are stretchers or cross bars, both connecting and keeping at the proper distance the parts of the frame. The invert is built in front of, or against the ground mould; the ends of which are formed as at I (fig. 3) and form the skewback.
It may be noticed that the ground mould does not rest on the ground in the side lengths, as the brickwork was to be thicker; this is usually done as these lengths have to sustain a greater strain, particularly when first constructed.
I, I, are two upright pieces fitted between G and D, by mortices and tenons, to give stability. The centre line was marked on G and D by a saw kerf, so as to place it centrally under the ranging line; these mould were set at required level by wedging or by excavating more, set in line by bringing saw kerf under the ranging line, and set at right angles to centre line by measuring from each end (after setting it perpendicular by plumb lines attached at I, I.) to a nail driven in some timber at the shaft end of the length, exactly in the centre line; if both measurements are the same, all is well; if not the same, try again.

The moulds or rather the frame was kept in position by strips of board nailed from one to the other, and by "dogs" driven into the frame and adjoining timbers. Two leading frames are required in each side length, afterward only require one and the brickwork of the back length. The sidewalls are built outside the moulds and the timber (bars &c) removed as the brickwork is carried up.



"Dogs"

After completing the excavation, the operations are as follows. 1st Fix mould furthest from the shaft. 2d It must be upright. (plumb bobs) 3d Its centre must coincide with centre of tunnel (saw kerf.) 4th Each end must be at the required level, making allowance for change of grade if any; 5th It must be at right angles to the line of the tunnel.
6th The two moulds must be equidistant.

Upon the face of the ground and side moulds, was marked every course of bricks, in order to keep the courses regular.

The invert was built in concentric half brick rings, bonded where the joints became flush, except for about 6'-6" on each side from the springing at the angle of the skewback, which was built in English bond.

At Bleckingley the bricks were made on purpose; but sometimes cut the common bricks and sometimes use stone, for the skewback. When the invert and skewback were finished; the side moulds were set up. The brickwork of the sidewalls up to the springing, was constructed in English bond; and when up to this height; the centres were set for turning the arch; seen in the transverse section at figs 8 & 9. although the figure is really a section of shaft length. Fig. 2 represents a Side Length, the right hand portion, the timbering; and the left hand, the brickwork. Brickwork of the arch consists of concentric half brick rings, bonded at flush joints; and keep true form of the arch in every ring. Brickwork brought up equally on each side until it has the appearance of fig. 10. then place the laggins c.c, which are rabbeted on the top of their inner edges on the centres; in these rabbets place cross laggins (d) about 18" wide and the bricklayer, standing with head and shoulders between the walls A, A. keys in the arch over (d); inserts another cross laggin; keys that in, and so on until the length is completed. I accidentally

represented the brickwork in fig. 2. with a 4" side up.
6th. Upon the completion of the two side lengths the excavation of earth for the shaft length should be carried on as quickly as possible and yet take proper care for the shaft. As in doing this all the square timbering must come out, the shaft is supported only by the shaft sills or by the hanging rods or whatever is used; but we can get temporary support, by propping from the projecting ends of the crown bars of the side lengths; and from the upper bars of the shaft length, as they are inserted. Mode of timbering is simple; place bars with their ends resting back of the brickwork of the side lengths, and prop between them; then put poling boards behind these; shown in fig. 4. B, B are the bars; S, S the props; C. C the ends of the crown bars of the side lengths a. a. props from them and a', a', props from B'. Transverse section shown in fig. 8. During the excavation for the shaft length, the centres under the side lengths A and A'. should remain undisturbed with the timbering connected with them; but the miners sills D and E' fig. 2. and the stretchers M. must be removed, but before removing them, to secure the face of the work, insert raking props D fig. 4. the top, cut

birds mouth to take the angle of the sill, and hooped to prevent splitting, and the bottom wedged in a hole left in the invert for the purpose.
If there is a sump at bottom of shaft, it is to be filled with earth or concrete; after the side walls were built the arch was turned on four centres a, a, a, a, fig. 5; the three ribs under each side length being left undisturbed until the shaft length and first leading length were completed.
When the arch is turned, the shaft is permanently connected with it by a brick or cast iron curb; if it is to be a permanent shaft; the former was used here and is shown at figs 5 and 9. The mode of constructing the skewback is shown at E fig. 9.
The use of 10 centre ribs (as here), or of 6 (a single set) is to be determined by the consideration of whether the extra cost will more than counterbalance the risk incurred in using the 6.
Longitudinal sections of shaft length shown in figures 4 and 5; cross section in figure 9.

7th. Leading and Junction Lengths.

After completing the shaft length, inserting the curb and making the brickwork good to the shaft; the centre ribs and lagging may be removed, but those under the side lengths should remain.

Before commencing the leading lengths, a platform should be built over the part of the invert which is completed, to make a level way on which to run the skips for removing the earth, and to allow a free passage for the water.

The process of driving these lengths is similar to that of the side lengths, except that now the crown bars require props only at one end, the rear end being supported by the brickwork of the side lengths.

All the crown bars which were used in the side lengths which it is possible to draw forward, are used in the leading length; those which cannot be drawn are built in: care being taken when a bar is drawn to pack the space left with earth.

The settlement in the side lengths should be noted, in order to regulate how much above the intended top of the tunnel the crown bars should be placed.

As seen in fig. 6 the timbering does not extend to the bottom, but if the earth is loose it must be carried

way down. Should try to have the different lengths as nearly of the same length as possible.
The work on Junction Lengths is the same, except that no props are required to support the ends of the crown bars, they resting on the brickwork of the preceding lengths, and are built in. The side walls and arch built in the same way as usual, together with the keying in of the crown, until the space gets so small that the workman cannot get his head and shoulders into it; then he turns the top ring of the arch as best he can, wedges the brick tight and bonds into the next lower course by some brick put in as headers and proceeds in this way until the opening can be closed by one brick put in endwise and if necessary wedged with wooden or iron wedges.

8th Centres.

At Blechingley there was required at each shaft, 10 centre ribs, 4 sets of laggins, 6 centre sills, 16 half timbers, 40 props and 40 pairs of wedges. One half of these were used at each side of the shaft, thus making 5 centre ribs in each heading, and the two end ribs could have no tie bar at the bottom on account of the raking props. The construction and dimensions of these ribs is shown in fig. 11; they are made in two parts, joined along the line a, b. and by the movable tie c. and are quite strong. If thought best a movable tie could be put in at the bottom.

The other three centres are made as shown in fig. 12 they would not answer as well at the ends, as the tie would interfere with the raking props and they do not stand side shocks very well, to which they would be subjected if they were used as leading ribs, from blasting &c.

Frazer's Patent Centres. Sections of these are shown in figs. 14, 15 and 16. A is leading rib. B is middle rib and C is back rib; they are made of elm timber, in 4 pieces, scarfed together as shown in fig. 13.

The leading rib has the radius of its outer edge 12½" longer, and of its inner edge 3½" shorter, than the radius of the intrados of the arch.

The edges are covered with ½" iron plate, bolted through as shown in fig. 14; where (a, a) are the plates, (b. b) the bolts; the plate on the under side is 6" wide, and projects 2" on one side, forming a flange for the ends of the laggins (which are 3" thick) to rest on.

The ribs B and C stand on trestles, which run on rollers as seen at [m] fig 13. The under side of B is covered with $\frac{1}{2}$" plate iron bolted through; see fig. 15. which takes the place of the struts in centre of ordinary construction; this rib has the radius of its outer edge just 3", (the thickness of the laggins) shorter than the radius of the intrados of the arch.

C is strengthened in the same way, but the iron is fastened by patent screws for every alternate bolt. (cheaper). Between each bolt and screw, holes are made to recieve the stem of a bearing iron, n, n fig 16 and also shown at fig 17; there are as many of these as there are laggins, which rest on them. The laggins are adjusted by means of the screws o, o, tapped into the iron plate and acting on the bearing irons; by this means each laggin can be eased separately.

The ribs B and C are firmly fixed to the trestles, D figs 1, 15 & 16: which move upon rollers, m, fig. 1. and upon the half timbers I. I, fig. 1. which are kept in place by bricks or blocks let into the invert for the purpose.

Machine Drills.

One of the greatest, if not the greatest drawback to the use of machine drills in tunnelling, and especially in the case of long tunnels, has been the inability of getting a motive power that could be successfully used; but the problem was solved by Mr. Sommeiller, one of the chief engineers at the "Mont Cenis" tunnel, by the use of compressed air. Air is compressed to a certain degree, admitted to receivers, and from them conveyed by pipes to the place where it is wanted.

It is found that the air loses little or none of its force in traversing long distances through the pipes. At Mont Cenis, the air was compressed by means of water power, and also at the Hoosac Tunnel; but at the Beacon Street Tunnel, steam power is used.

I have been unable to get any information as yet, in regard to the construction of any of the drills in use in this part of the country, but perhaps among those best known may be placed the "Burleigh" and "Ingersoll". A drill has recently come out, which bids fair to excell either of them however; known as the "Winchester Drill" invented I believe by Mr. C. S. Winchester.

The "Ingersoll" is ranked rather superior to the "Burleigh" I think, but is an infringement of the Burleigh patent.

The following information in regard to the rate of progress by the "Ingersoll" and "Winchester" drills, and also by hand labor at the Beacon Street Tunnel, I received through the kindness of Mr. Rice; who has charge of the work there.

Drill used.	Time of working.	Total Progress.	Average rate per month.	Place of Working.
Ingersoll.	4 1/3 months	235. ft.	54. ft.	E. H. of Shaft.
Winchester.	5 2/3 "	585. ft.	103.2 ft.	" " " "
Ingersoll	11 "	810. ft.	73.63 ft.	E. Heading.
Winchester	5 "	513. ft.	102.6 ft.	" "
Hand Labor.	16 "	649. ft.	40.5 ft.	W. H. of Shaft.
" "	14 "	687. ft.	49.05 ft.	W. Heading.

Mr. Rice says that the comparison between the working of the two drills at the East Heading of the Shaft, is really the fairer one of the two, as the rock is more homogeneous here than in the East Heading.

I think that the rock was a little softer the last month that I have counted for the "Winchester" drill and yet if we throw out this months progress (140 ft.) it still leaves the average rate 95.4 ft. against 54. ft. for the Ingersoll.

The rock has been mostly the conglomerate known as the Roxbury Pudding stone, though a very little was met with in the west heading of a slaty character; I think that the length of the tunnel including about 600 ft. of conduit is just one mile, leaving for the tunnel proper, about 4680. ft. and there is to be a fall of one foot, in the grade; for the whole length. I am unable at present, to give any results of the comparative cost of hand and machine labor, in drilling; or of the construction of any of the drills, but if I can obtain the information in season, I will insert it as an appendix.