ing down the dotted line (*cc*), leaving the earth at (cc) to support the curb *(a).* Timber props (*d*) may also be set up for further support, if thought necessary.

When the ground again shows signs of weakness, exca­vate inwards, as at *(a),* and filling up with another curb, pro­ceed as before, according to the nature of the ground, fak­ing out one fourth, one sixth, or one eight of the circum­ference, and putting in the same quantity of the curb, brick it up to the curb nbove, and then take out another portion of the earth ; or, if possible, proceed in pairs.

When it is found expedient to use the gin, two pulleys must be fixed, as shown in the drawing, fig. 13, for the rope to run over, and the supports or standards made proportion­ally stronger. Having in this way completed the working shafts, the next process is to sink down to the bottom of the tunnel : it is of no consequence whether enough is taken out for the invert or not. The excavation should then be com­menced at the top of the tunnel, first running a heading at the upper part, a little exceeding the length intended to be put in. This length must depend entirely on the nature of the ground, varying from three to fifteen feet up to rock, which wants no brick-work. The excavating is then conti­nued downwards from the heading ; and when got out, the earth is propped up by the mining centres, mostly composed of round timber, as shown in Plate CCCCXLIV. All this propping is above the centring ; it is composed of two cills (*aa*), fig. 10, close to the face of the tunnel, between which are the props (*bb*). These cills might be fastened by an earth-screw (c), fig. 16, worming into the face of the tunnel. The crown and side bars *(dd)* are then introduced : the two upper ones are called crown-bars, and all the rest side-bars. The thick end of the bars rests on the props, and the smaller end on the last length of brick-work in the tunnel. From each cill stretchers *(ee),* fig. 16 and 10, are fixed, the other end taking the last brick-work ; also raking stretchers or rakers (*ff*)*,* figs. 10 and 16, the ends of which are let in so as to have a firm hold on the last brick-work. The cills may be from twelve to fourteen inches square when the ground is bad ; the crown-bars fourteen inches diameter at the thick end, the stretchers, rakers, and props, being in proportion ; and their thickest ends placed as shown in the drawing, reducing their sizes in better ground. It is advis­able to buy the timber whole, and cut it up according as the strain is found to vary.

The number of side-bars depends entirely on the nature of the ground. Sometimes they will only be required down to the top cill, and in other grounds they must be carried down to the invert. Sometimes, when, from the weight of the face, it is seen that many stretchers must be used, three cills are put in. The props also to the crown and side bars vary with the pressure ; and for this purpose, they are made to radiate to a point, which changes accordingly. Thus the prop (*g*), fig. 10, would in rock be perpendicular; and if the ground at the prop (*h*) was bad, and likely to come in, the prop (*h*) would be inclined in the position of the dotted line. The props between and under the cills are all perpendicular ; between each crown and side bar there are stretchers to keep them apart at the proper distance. When the prop­ping is completed, the next object is to get up the centring for the brick-work (which is formed in the manner shown in fig. 15), of the required shape for the tunnel, leaving a space just enough to take the brick-work and laggins be­tween the centring and the propping apparatus. The in­vert is the first thing built, then the side-walls, by means of the leading frame (*ff*), which goes up to the springing, hav­ing supports *(gg).* This leading frame, which is in fact a template, is set up next the face of the tunnel, and from it the bricklayers string their lines; and when finished, the leading frame takes to pieces, and is got out till a new length of the work is excavated, and it is then put together as before.

When the side-walls are raised to the springing of the arch, acill(e), fig. 15, is built in with them ; then the centring, which, with its cill (i), is all fixed together, is got up and wedged to the required height. The laggins *(kk)* are pieces of quar­tering which go from centre to centre, and on them the bricks are laid ; (*cc*) are the queen-posts, *(d)* is the straining-piece, (*aa*) principal beams butting against *(b), (mm)* are the ribs on which the laggins lie; and if the centring is large, these may be joined over the queen-posts and struts.

In some rare cases the cill (*e*) is not laid on the side-walls and bricked in, as leaving a hole would, if the weight was great, be dangerous. Whenever this happens, trestles are set up from the bottom to support the cill (e).

Sometimes in quicksands or other bad ground, a slip will happen, in spite of all exertions to the contrary. This occur­rence will perhaps take place, if the rakers are not got up, although the crown-bars, side-bars, anil cills are up. It arises principally from a pressure on the face, throwing the cill back and letting the bars down. When it does happen, a shaft must be sunk from above, and the ground beaten perfectly firm and solid from bottom to top, and the work then proceeded with as in any other new length. The slip will often extend to the surface, and will then take the ap­pearance of a hollow dome.

In the upper portion of the arch, where the bars cannot be withdrawn, and the vacancy between the brick-work and the excavation filled up and rammed in till the completion of the brick-work, it should invariably be done at the very earliest possible period, which will be when the next length of excavation has proceeded far enough to let the workmen have sufficient space to perform it with soundness ; and whenever the material through which the tunnel is making is of so bad a nature as not to admit the withdrawal of the bars and planking, without a risk of disturbing either the form or stability of the brick-work, they must be left in, according to the judgment of the engineer ; consequent­ly their value should invariably form an item in tire sche­dule of prices under which the contractor is constructing his work.

Tunnelling under rivers presents considerable difficulty, as has been experienced in that under the Thames. the first tunnel was commenced at Gravesend in the year 1799, but the scheme was speedily abandoned. In 1804 another was commenced from Rotherhithe to Limehouse ; but after sinking an eleven-feet shaft forty-two feet, the difficulties were such that the work was suspended. The diameter was then reduced to eight feet, and at seventy-six feet deep a drift was carried 923 feet under the river, which was only 150 feet from the opposite shore: the engineer then report­ed that farther progress was impracticable. Several other plans were devised, till in 1823 Mr Brunel proposed his for a double tunnel between Rotherhithe and Wapping, the soil there being a tenacious blue clay. The Rotherhithe shaft is fifty feet diameter 150 feet distant from the river, being forty-two feet high and three thick, built on the sur­face and excavated afterwards; the earth and water being drawn out by a steam-engine on the top. It was thus sunk in its place in a body, and by this means passed through a bed of gravel and sand twenty-six feet deep, which had caused great inconvenience in the former attempt. Sec fig. 11.

The fifty-feet shaft was sunk sixty-five feet, and from the lower level a twenty-five feet shaft was sunk to eighty feet for drainage. At sixty-three feet the tunnel commences dipping two and a quarter feet per 100 feet. The excavation was thirty-eight feet wide and twenty-two and a half high, or a sectional area of 850 feet ; and the bottom, at the deepest part of the river, is seventy-six feet below high water. The excavation was effected by a shield composed of twelveframes close together, having each three cells above one another for the miners (fig. 18) : 400 feet were bricked