On the whole it would seem that the method of driving a top heading is not the best for any tunnel where machine drills are used for the rapid completion of the work.

Pressure of Rock.—Where the rock is of a gravelly nature, so that it exercises great pressure, but is not itself compressible both theory and practice show that if the Belgian method be adopted, and the arch put in without abutments, a sinking and crushing in of the arch cannot be prevented. The same is yet more certain where the rock is of a clayey or plastic nature, as has been shown on the line from Foggia to Naples, and also in the "pressure length" of the St. Gothard tunnel. Here it was found in many places impossible to complete the arch at all on the Belgian method, it was absolutely necessary to begin with the abutments and invert. In wet earth the Belgian method is clearly quite inapplicable.

Herr Bridel has drawn the following conclusions on this subject:—

a. The Belgian method is not safe where there is great pressure, and especially where the rock is plastic.

b. Even where all possible precautions are taken, the work is extremely difficult, slow, and expensive, and the success always doubtful.

c. With a top heading, the English method of completing the tunnel is possible indeed but exceedingly costly, difficult, and slow.

d. With a bottom heading, this method is capable of any amount of development, and renders possible a much more rapid advance.

e. In a long tunnel it is impossible to tell whether plastic strata, or others exercising great pressure, will be met with, through which it would be necessary to drive a bottom heading. But it is exceedingly difficult to pass from working by a top heading to working by a bottom heading.

All the above conclusions point to the superiority of the bottom-heading system.

Cost of Construction.—The experience gained on this head leads to the following conclusions, as drawn up by Herr Bridel:—

a. With forced working (*i.e.* where the progress is to be as rapid as possible), when the conditions as to ventilation and drying the tunnel are the same, the general cost of blasting is nearly the same whether the leading heading is at the top or at the bottom.

b. The drying and ample ventilation of the working places are however much more difficult with a top heading than with a bottom heading, so that the latter system is really superior in these respects.

c. The removal, loading, and transport of the spoil is done much more easily, quickly, and cheaply with the bottom heading than with the top heading.

d. The formation of drains, and the laying of roads and of air and waterpipes, are extensive and costly works with a top heading, but are a small matter with a bottom heading.

It follows that, where rapid progress is necessary, the bottom-heading system is to be preferred to the other.

At the Arlberg tunnel the contract price at 3 to 4 kilometres from each portal (which is about the average distance at the St. Gothard), and where walling is thinnest, is as follows.—

	Ft. per metre.
Bottom or leading heading	374
Top heading, following it..................	242
Completion, except masonry to trains........	1430
Masonry to drains........................	57
Total......	2103
Add 3½ per cent. for extras....................	73
Add interest on cost of plant, &c., supplied by the railway company (taking this as the same as at the St Gothard)............................	470
Grand Total......................	2646
	(say £96 per yard.)

On the other hand the contract price at the St. Gothard tunnel was as follows:—

	Fr. per metre.
Total except masonry....	2800
Masonry, minimum thickness. .	830
Total........	3630
	(say £132 per yard.)

There is thus a difference *in favour of the Arlberg tunnel* of 984 fr. per metre (£36 per yard). This difference is certainly *more that can be* accounted for by the somewhat harder character of the rock at the St. Gothard: and thus confirms the conclusion that, at least with force working, the bottom-heading system is the cheaper of the two

THE DESIGN AND CONSTRUCTION OF BRIDGES.

(*See page 208.*)

The structure shown in our illustration page, represents the bridge constructed at Grenoble, over the Isere, by M. Berthier engineer-in-chief. As will be seen, it comprises three arches, segments of circles. The centre arch has an opening of 25·10 m., and a rise of 3.30m., the side arches are each 23·10m. span, and 3m. rise. These arcs correspond to an angle in the centre of 60°; in other words, the chord is equal to the radius or side of the inscribed *hexagon. Many engineers rightly consider* this proportion of arc as the most graceful. M. Debauve, whose description we are quoting, says, the thickness of the keystone of the middle vault is 1·20m., and that of the side vaults 1·10m. The fronts of the "pierres de taille" (ashlar voussoirs) are dressed to spring from a skewback, the masonry is formed in steps, and the front portions of the piers or cutwaters are also of ashlar masonry. The filling of the spandrel is in masonry covered by a layer, and the infiltrated water which collects is carried to the centre of piers, where it percolates through a heap of rubble or stones before being discharged by the inclined pipe seen in the section. The longitudinal and transverse sections illustrate the construction of the spandrel, and show the filling and masonry *through the axis of the* pier. The piers and quay walls have a slight batter, the former one of $\frac{1}{25}$ and the latter of $\frac{1}{16}$. The width between the parapets is 12 metres, and there is a slight set-off from the arch-face to the tympana. The widths of roadway and footways and parapets are figured *in the cross section; the footways* have gutters. The convex contour of the bridge is favourable to the carrying off of the water, and also to the architectural effect. The plan and elevation show that the bridge is turned by quarter circles or quadrants into the approaches or quays, which angles are rounded off by a corbelling of masonry a plan favourable for the easy passage of traffic. We give a plan of the end of bridge showing this arrangement We also give a plan and side view of the "organeaux," or rings, for mooring vessels. These are fixed in the piers. All bridges built on navigable rivers ought to be provided with these appliances, which are placed at different heights The piers, as will be seen, are built on a mass of beton submerged in an inclosure of piling. The scouring of the river is *prevented* by the rubble aprons seen in the section The bed of foundation is an incompressible gravel.

Our other illustration shows the railway bridge of Plessis-les-Tours, over the Loire. We only give one arch and pier of this fine structure which is composed of 15 arches of elliptical shape of 24 metres span each, and of 7 10m rise or versed sine, separated by piers of 3 metres in width, and terminated by abutments of 8 metres. The width of the bridge is 8 metres between the parapets. The thickness of the keystone is 1.20m., and the line of extrados springs from the summit of the head of the pier, which gives, at this part, a joint of 1·50m. for the vault. The small discharging or relief vaults have only a thickness of 0·70m. at the keystone. A dotted line *on the elevation* shows the backing. The foundations consist of masses of beton inclosed by piles and planks. The conveyance of the water which passes through the ballast, and which arrives at the surface of the masonry, is effected by a covering or layer, which is shaped to the profile shown in the sections, or inclined from the axis of pier to the summit of vault, where the discharge takes place. By this means, the surface drainage is carried to the summit of each vault, where they are met by vertical pipes, the superior orifice of which is protected by a head or rose covered by a mass of stones, forming a filter. The covering of the vault is composed of three layers, the lowest of concrete, the intervening of cement, and the upper of asphalte. Between the covering and masonry in the spandrels of bridge, the vaults have been filled with a very thin beton or rubble, which constitutes an incompressible material.

The parapets are built in terracotta, which, M Debauve observes, is less costly than ashlar, and is preferable to iron railings. The "voussoirs des têtes" are alternately in two or three pieces, but the keystone is formed of a single block, the