article, the subject will be dealt with only so far as it lies within the province of the mining engineer, and it is not intended to enter into any discussion of the theory of foundations.

A foundation in its simplest form consists of an excavation in the ground of such form and dimensions as will give a firm base for the superstructure. Such a foundation is all that is required for comparatively light structures, not subject to sudden and severe strains. But for most structures about a colliery such a foundation is quite inadequate, and the excavation is partially or completely filled with some material which will form a firm and solid base. In many cases, as for example in the case of a pulley frame, the area of the base of the structure is small in comparison with the weight upon it, and the pressure per unit area is consequently great, greater often than simple earth foundations can resist. To reduce the pressure per unit area it is customary to form the excavation of sufficient size, and subsequently to fill it with some solid material as masonry, brickwork, or concrete, through which the pressure is distributed to any desired extent. Before proceeding with the construction of foundations, the first thing to be ascertained, after an acquaintance with the nature of the ground, is the approximate weight to be supported, and the foundations must be so designed that the pressure per unit area will be well within the limits of safety. The direction of the pressure must also be taken into account, and the base of the foundation should be formed as nearly as possible at right angles to the direction of pressure upon it. As a general rule also, the line of the resultant pressure on a foundation should pass through the centre of gravity of the foundation, or as near thereto as possible.

In some few cases a firm and sufficient foundation readily obtainable on rock, in which case all that is necessary to prepare it for the superstructure resting on it, is to cut away all loose or decayed parts, and to hew or dress the surface of the rock to suit the form and pressure of the structure to be erected. When the surface of the rock is irregular, it may be necessary to fill hollows in it with masonry or concrete. It is customary in engineering practice to allow for stone structures a factor of safety of not less than eight, and for foundations on rock the pressure should not exceed, at any point, one-eighth of the pressure required to crush the rock. Experiments on the crushing pressure of rocks have from time to time been made by various engineers of eminence, the average results of some of which are given in the subjoined table:—

TABLE OF THE STRENGTH OF ROCKS.

	Crushing Stress. Pounds per square inch.
Sandstone (strong)	5000 to 9000
do (weak)	2000
do (ordinary)	3000 to 5000
Limestone, compact (strong)	8000
do magnesian (strong)	7000
do do (weak)	3000
do granular	4000 to 4500
Chalk	300 to 400
Whinstone (basalt)	9000 to 17000
Granite	6000 to 11000

Where the rock surface is not accessible for forming the foundation, the base of the structure has to be rested on the earth above the rock, and the total pressure must be more or less distributed as the earth is softer or firmer. In firm earth, such as hard clay, clean sharp sand, or firm dry gravel, the greatest pressure in general engineering practice is from 2,500 to 3,500 pounds per square foot of bearing surface. For a superstructure that is in itself heavy, or that has to support a heavy load, or that is liable to severe strain, the foundation base must be made of such area that the pressure per square foot will not exceed the above limit. Usually the footings or lower courses of ordinary masonry or brickwork, as of an engine house, have an additional breadth or "spread" equal to one-and-a-half times the thickness of the body of the wall when built on compact gravel, or of twice that thickness when built on sand or stiff clay.

Before building on *soft* earth, additional precautions must be taken with regard to the foundations, and some other expedients must be adopted than those applicable to firm earth foundations. Of course there are degrees of softness, and no general rule can be laid down applicable to the variety of cases that may occur in practice. The simplest class of foundations on soft earth are those already referred to as applicable to firm earth, with this difference, that the base must be further increased to reduce the pressure per unit area. When softer earth, as peat moss, soft alluvial clay or silt, with, in some cases, a natural slope of one vertical to eight or ten horizontal, is met with, of considerable depth, other methods have to be adopted. These generally entail the use of timber or iron. Timber platforms are usually constructed by forming a grating of crossed beams of elm or oak which in turn is covered by planking on which the superstructure rests. The beams employed are usually from 10 to 12 inches square, and laid about 3 feet apart, the spaces between being filled with concrete.

The method usually adopted, however, for securing a good foundation in very soft ground is by piling. Piles are usually of square or round timber from 6 to 9 inches diameter for piles from 6 to 12 feet long, and larger in proportion to the length, the ratio of diameter to length being in general about one to twenty. In setting the piles they are placed as close together as practicable. When piles are driven to form a rectangular or circular foundation, the outer circuit of piles should always be driven first. The work being finished at the centre. The piles may be surmounted by a platform as above described, or simply by a layer of concrete. The most suitable timber for making piles is elm. In general practice the limits of pressure on pile foundations may be taken at 1,000 pounds per square inch of head are.. when the piles are driven till they reach firm ground, or 200 pounds per square inch of head area when the frictional resistance between the timber and the earth is the only support. In all cases where timber is thus employed in foundations, care should be taken to keep it entirely removed from the influence of the atmosphere, and to keep it wet, otherwise it will soon decay.

Engine foundations, as a rule, require to be raised sufficiently high above the surrounding ground to give clearance for the fly-wheel, drum, or gearing, or for other purpose, as also to form a sufficient weight to which to fix the engine. Engine foundations may be constructed of timber, brickwork, masonry or concrete. For permanent work timber foundations are not to be recommended, as they are liable to early decay, but for temporary winding or pumping engines at a sinking shaft they form a convenient, simple and cheap foundation. They are easily built and easily removed, and the material may subsequently be used for similar or other purposes.

One form of engine foundation, now almost obsolete, was built of ashlar masonry, the stones being of large size, each measuring about 10 cubic feet, the usual dimensions being 4 feet by 2 feet by 15 inches thick. Stones of larger size are more expensive, and were consequently seldom, if ever, used. Undoubtedly this makes a very good foundation, but it is costly, and it is now generally superseded by brickwork or concrete.

Brickwork built with Portland cement mortar is in very general favor, and forms an excellent foundation. The bricks should be tightly built, the joints not exceeding quarter of an inch in thickness, and the whole structure well bonded together so as to form, as nearly as possible, one solid block. The cost of this kind of engine foundation is considerably less than one of ashlar masonry.

For engine foundations, and, indeed, for all sorts of foundations about a colliery, there is much to recommend the use of concrete. It forms the best foundation, and is less costly than either ashlar masonry or brickwork. Concrete is essentially a species of rubble building, the stones of which are cemented together by a mortar, usually of Portland cement and sand or fine gravel. About a colliery where, as a rule, a plentiful supply of sandstone is readily obtainable, especially during sinking operations, it may with advantage be used in the manufacture of concrete. A quantity of stone is broken to about the size of ordinary road metal, or from 1½ to 2½ inches diameter. This is mixed with certain proportions of clean sand and of Portland cement, the proportions of the various ingredients varying with the purposes for which the concrete is to be employed. For ordinary foundations the proportions are generally about four parts by measure of broken stones, one part of sand, and one part of cement. These, after being thoroughly mixed, have sufficient water added to make the whole a plastic mass, which is forthwith transferred to the excavation or other receptacle previously provided for it. At the same time, a number of large stones may with advantage be thrown in, care being taken that they are thoroughly bedded in the concrete, which should also fill all interstices between them. When using sandstone for making concrete, it is not generally necessary to add sand, as in breaking the stone a quantity of sand is produced, unless the stone be very hard. By a little experience one can readily estimate whether there is a sufficient quantity of sand among the broken stones, and it becomes unnecessary to measure them out separately. Broken bricks, blast furnace slag, limestone and other materials are frequently used for making concrete. It should be noted that the concrete occupies only about two-thirds of the volume of the ingredients when unmixed.

When concrete foundations have to be raised above the level of the surface, a casing, usually formed of planks, has to to be erected, of the form and height of the monolith, into which casing the plastic concrete is placed. After it has sufficiently set to permit of the casing being taken away, this should be done.

In conclusion it may be useful to compare the cost of building engine foundations of the three classes referred to. For a set of coupled winding engines, each foundation will contain about 40 cubic yards, or say 80 cubic yards in the two, and the total cost will be approximately as under:—

80 cubic yards ashlar masonry	@	55/- =	£220	0	0
80 " brickwork in cement	@	16 - =	64	0	0
80 " concrete (5 to 1)	@	9/- =	36	0	0

Water Power Applied by Electticity to Gold Dredging.*

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In many mining districts there are deposits of gold which cannot be worked owing to the difficulties of transport and the dearth of fuel. The application of water power transmitted to a distance by electricity is, therefore, a subject which may well command attention in well-watered countries like New Zealand, where a plentiful supply of power is obtainable; for intervening hills and valleys form no obstacle to its transmission, there being few districts through which light wires and poles cannot be easily carried. The plant described in this paper is the first of its kind constructed in New Zealand. It was designed by the author for gold dredging on the River Shotover, at a point about thirty miles from its confluence with the Kawarau River and twenty-five miles from Queenstown, a small town situated on Lake Wakatipu, which lies about 1,000 ft. above sea-level. The Shotover runs through rugged and inhospitable country, generally in precipitous rocky gorges, and is only accessible by tracks cut down the leading spurs and gullies. Since the dredge commenced operations, however, a mountain road has been constructed at a considerable elevation above the river, and extends some twenty miles towards the upper Shotover dredging ground, opening up to some extent the interior of that part of the country. All the bucket, grab and suction dredges hitherto employed in New Zealand have been actuated by steam power, bituminous coal, lignite or firewood usually being fairly plentiful, and accordingly moderate in cost. In the case referred to, however, fuel could only be obtained at prohibitive prices, as it would have been necessary to transport it to the dredge for long distances over the mountain tracks on the backs of horses. Water power in a convenient form was found to be available at a branch creek, but for many reasons it could not be applied directly to dredging. It was therefore decided to transmit the water power by electricity to the dredge in whatever part of the river it might be working. The water was obtained from a creek one and a-half miles, and was brought, by a race cut in the side of the hill, or, through places where the ground was too precipitous or loose to carry the race, by a timber flume, to a pressure tank situated at a point 524 ft. above the generator house. The race is 2 ft. 6 in. deep, and 3 ft. wide at the bottom, and the sides are cut with slopes of 2 in 1. The flume is rectangular in cross-section, 2 ft. deep and 3 ft. wide, and in places where it could not be wholly set in, a cutting along the side of the hill, is carried, partly upon trestles standing about 6 ft. apart. The pressure tank is 20 ft. long and 12 ft. wide at the bottom, and has sides with slopes of 1 in 1 and 2 in 1. The water passes from the pressure tank through a bell-mouth covered by a wrought iron grid, and is carried in steel pipes to the generator house. The pipes are of rolled steel of 16 and 11 Birmingham wire-gauge, with double-riveted longitudinal seams and single-riveted circular seams with 1½ in. lap. The pipes are each 19 ft. 6 in. long over all, and are jointed with wrought iron flanges riveted to the pipes. The internal diameter of the main pipe is 14 3/8 in. The quantity of water available in ordinary seasons is 240 cubic feet per minute; but in dry weather after a fine winter, when the snowfall has been light, the supply falls to about half that quantity. This, however, is sufficient to develop the necessary power. The generator-house is situated about midway between the ends of the portion of the river to be worked, which is about four miles long. The prime mover of the generator-house is a 4 ft. Pelton water wheel, on the buckets of which the water impinges from a 1½ in. nozzle at a pressure, in the pipes outside the station, of 228 lb. per square inch. The Pelton wheel drives by belts, two Brush-Victoria, series-wound dynamos, which, when working at their normal speed of 700 revolutions per minute, give each an electromotive force of 650 volts and a current of 40 amperes, or together a total electrical output of nearly 70 horse power. The two dynamos are coupled in series. A Buss-Sombart tachometer, driven from the armature shaft of one one of the dynamos, indicates their speed, while a Soames-Nalder ampere-meter and a Cardew voltmeter (the latter reading up to 1,400 volts) indicate the current and electromotive force respectively. The Pelton wheel has no automatic regular, as the work required of it is fairly constant. It was necessary, however, to provide against the possibility of an abnormal increase of current, due either to accidental short circuiting of the line wires

*A paper read before the Institution of Civil Engineers in conjunction with the paper on "Electrical Haulage at Earnock Colliery."