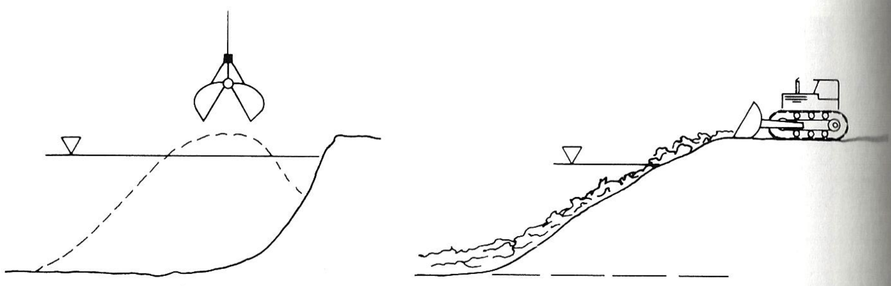

Figure 21.16 Backfill of slurry trench. (a) At start of trench, backfill is lowered into position with clamshell to prevent segregation of the backfill or pockets of undisplaced slurry. (b) After backfill breaks the surface, subsequent fill can be pushed into trench, sliding down the completed slope into its final position.

Backfill is mixed with slurry at the surface alongside the trench, using bulldozers or front end loaders. When starting the backfill, a preliminary mound (Fig. 21.16) is placed with a clamshell, lowering the bucket to the bottom of the trench before dumping, so that the material does not fall through slurry. When the preliminary mound is above the surface of the slurry, the material can be pushed with a dozer so that it rolls or slides down the slope.

To prevent sloughing of the trench walls the slurry level should be 3 ft (1 m) or more higher than the ground water table.

A variation in the slurry trench is the beam method (Fig. 21.17) wherein a narrow cavity is created in the ground by repeatedly driving or vibrating an I-beam section through pervious soils. As the beam is extracted, an impervious material is pumped into the cavity, usually a mixture of bentonite and cement. Asphalt has also been used. The successive penetrations of the beam are overlapped to ensure a continuous membrane.

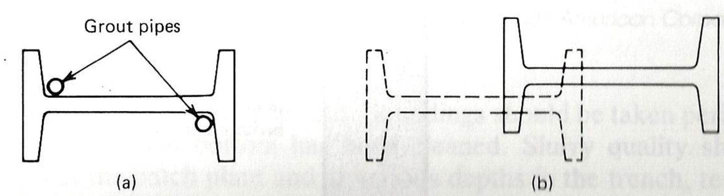

Figure 21.17 Beam method of constructing thin wall slurry cutoff. (a) Beam is vibrated to desired depth, and grout is pumped into the space created as the beam is extracted. (b) Subsequent penetrations of the beam are positioned to provide continuous cutoff.

21.5 TREMIE SEALS

The procedure of overexcavating and placing concrete under water to seal the bottom of the excavation is a very old one (Fig. 21.18). As always when working blind, quality control must be effective. The subgrade should be sounded to ensure that the design depth has been achieved. Soft sediments that always accumulate in underwater work can be removed by dredge pumping or airlifting. Where the subgrade meets the sheetpiling should get special attention, particularly at the corners. The webs of the sheeting can be cleaned with a water jet. If piles have been driven for bearing or anchorage, the tops should also be cleaned.

The concrete is placed in a continuous flow through the tremie tube, which is kept positioned so that its tip is always below the surface of the concrete. Because of these precautions, excavation, cleaning, and concreting are tedious, costly operations. But without the precautions leaks can develop, and repairing them can be extraordinarily expensive.

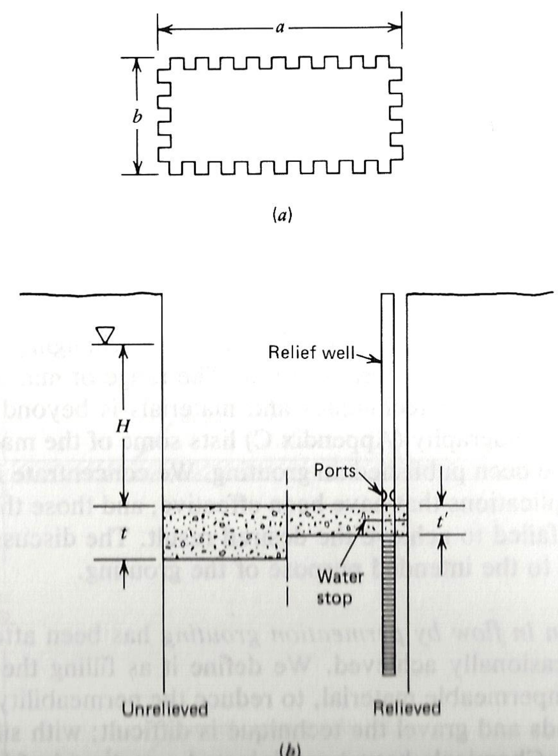

Figure 21.18 Cofferdam with tremie seal. (a) Plan. (b) Section.

The required thickness t of a gravity tremie is given by the relationship

$$t = \frac{H \gamma_w}{\gamma_c - \gamma_w} \tag{21.1}$$

where H = head above the top of the tremie
γ_w = specific gravity of water
γ_c = specific gravity of concrete

The required thickness t can be reduced if, for example, it is safe to make an allowance for the resistance of the steel sheeting to pulling out. In the case of sands the pullout resistance is very high, with soft organic silts it may be quite low. Where piles have been driven inside the cofferdam the thickness t can be reduced by their anchoring capacity. In areas of acute seismic activity, the soils should be evaluated for their tendency to liquefy, which reduces the holding ability. Where allowance is to be made for hold-down, attention should be given to the shear connection between the slab and the sheeting or piles. The analysis is on the basis of total weight rather than the unit area approach of Eq. (21.1).

In deep cofferdams where the required thickness t is uneconomically great, it may be advisable to use a partially relieved tremie slab as shown on the right hand side of Fig. 21.18. Usually the relief wells are pumped, but outlet ports should be placed immediately above the top of the tremie. If there is a pump failure the cofferdam will be flooded but it will not be otherwise damaged.

21.6 GROUTING

A number of techniques have been developed for changing the characteristics of soil by injecting materials into it. The range of materials available is broad. Describing the techniques and materials is beyond the scope of this book; the bibliography (Appendix C) lists some of the many books and papers that have been published on grouting. We concentrate in this section on grouting applications that have been effective, and those that only partly succeeded, or failed to achieve the desired result. The discussion is organized according to the intended purpose of the grouting.

1. *Reduction in flow by permeation grouting* has been attempted many times, and occasionally achieved. We define it as filling the pores of the soils with an impermeable material, to reduce the permeability of the mass. With clean sands and gravel the technique is difficult; with silty sands it is rarely feasible. Chemicals have been injected as a liquid of low viscosity, to form a gel when accelerators are added, or from reaction with the ground water. Woodward Clyde (82) discusses the difficulties encountered with hy-

drofracturing, when the liquid splits the ground instead of permeating it grout has been observed to travel tens of feet (10 m or more) along the fracture planes it creates. Without permeation, no advance is made toward the goal.

Where permeation grouting has succeeded, it can be ascribed to meticulous work by skilled specialists. Manchette pipes (32) are used, so that repeated injections can be made in each hole. Pressure and rate of flow are monitored and analyzed with sophisticated computer programs that can detect when hydrofracturing rather than permeation is taking place. The deductions are subtle. Unless periodic tests of the impregnation are feasible a favorable result can be elusive.

The simple flow regime of Fig. 21.19 illustrates the difficulty of the task. It has been analyzed by FLOWPATH (38). A constant head source exists at the top and a line of pumping wells at the bottom. Initially, the pumping rate for 10 ft (3 m) of drawdown is 460 gpm/100 ft length of the well line (1700 liters/min/30 m).

A grout curtain 8 ft (2.5 m) wide is created by permeation grouting. The average permeability at the curtain is reduced to 10% of the original value no small achievement. The flow for the same drawdown drops to 364 gpm (1370 liters/min). A 90% effective grout curtain produces a flow reduction of only 21%.

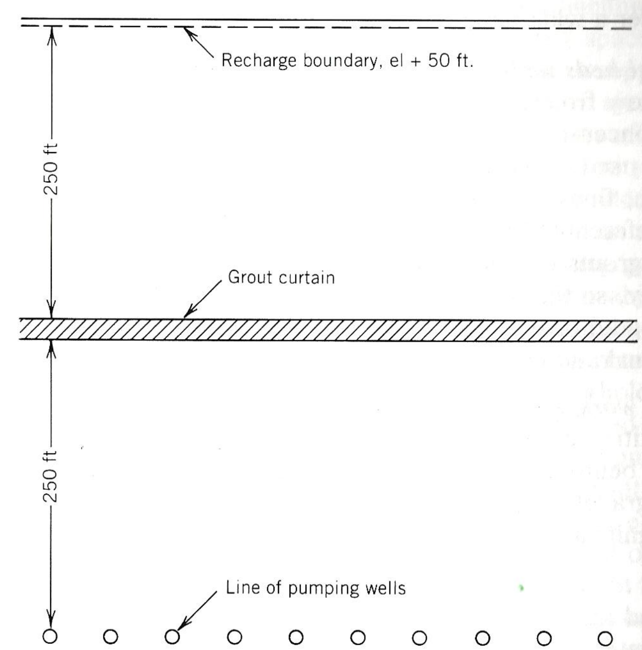

Figure 21.19 *Effectiveness of a curtain formed by permeation grouting. Plan view.*