Construction Dewatering

Introduction

The control of groundwater is one of the most common and complicated problems encountered on a construction site. Construction dewatering can become a costly issue if overlooked during project planning. In most contracts, dewatering is the responsibility of the contractor. The contractor selects the dewatering method and is responsible for its design and operation.

The purpose of construction dewatering is to control the surface and subsurface hydrologic environment in such a way as to permit the structure to be constructed “in the dry.” Dewatering means “the separation of water from the soil,” or perhaps “taking the water out of the particular construction problem completely.” This leads to concepts like pre-drainage of soil, control of ground water, and even the improvement of physical properties of soil. If ground water issues are addressed appropriately at the investigation and design stage, construction dewatering, which involves temporarily lowering the ground water table to permit excavation and construction within a relatively dry environment, is rarely a problem.

Construction dewatering has existed as a specialty industry for a long time. Consequently, a number of well-established techniques have been developed to lower the ground water table during excavation. The geology, ground water conditions, and type of excavation all influence the selection of dewatering technology. The most common methods for dewatering include sumps, wells and wellpoints.

- Sumps provide localized, very shallow dewatering (less than 3 feet) and consist of pumping from perforated drums or casings in a gravel-filled backhoe pit. Sumps work best in tight, fine grained soils, or very coarse, bouldery deposits.
- Wells are large-diameter (greater than 6 inches) holes, drilled relatively deep (greater than 10 feet), and contain slotted casings and downhole pumps. Wells work best in soils consisting of sand, or sand and gravel mixtures, and can dewater large areas to great depths.
- Wellpoints are small-diameter (less than 6 inches), shallow wells, and are closely spaced (2 to 10 feet apart). Wellpoints effectively dewater coarse sands and gravels, or silts and clays. They have a wide range of applications. However, wellpoints use a vacuum system and their depth is limited to about 25 feet. Wellpoint systems generally cost more than either sumps or wells, and require near-continual maintenance.

A number of other dewatering techniques are available including ground freezing and electro-osmosis. However, such techniques are very costly and used only for particularly difficult dewatering applications.

Underwater Excavations

In special cases where the soil is very pervious or when it is not possible or desirable to lower the groundwater table, underwater excavations can be considered. If underwater excavation is to be performed, the work area must be enclosed with an impervious structure. Once the impervious structure is in place, the excavation is performed within the structure. Once the desired excavation level is achieved within the structure, it is sealed with an impervious layer, such as concrete, in order to prevent water from sipping into the work area. After the impervious seal has been constructed, the water remaining within the structure is pumped out and construction is completed.
Caissons

Caisson is a structure that is constructed at location if the project site is on land, but if the project site is offshore, it is constructed on land and then floated to the site offshore. In the caisson method of construction, the excavation is performed from within the permanent structure. After the caisson is in position, excavation from within the caisson structure begins. As the excavation is carried out, the caisson structure starts to sink by its own weight, or if necessary, by imposed loads. This procedure continues until the desired foundation level is achieved. Figure 1 shows this process schematically.

By injecting bentonite clay slurry at the soil-structure interface, adding weight, or in case of cohesionless soils using jetting, the frictional resistance between the caisson and the surrounding ground may be significantly reduced.

When a pile, or in this case caisson, must be driven through dense and hard materials, several driving aids have been developed. The principal function of these driving aids is to speed the driving operation and to prevent damage to the structure that results from heavy driving. Jetting is applicable to those situations where structure must be driven through cohesionless soil materials to greater depths. Water jets can be used to displace granular soils from beneath the toe of a pile or caisson. Jetting is accomplished by pumping water through pipes attached to the side or center of the structure as it is driven. The flow of water creates a “quick” condition and thereby reduces skin friction along the sides of the driven structure. The result is that the structure drives more easily. Figure 2 illustrates a centrally-placed jetting pipe schematically.
During unwatering (pumping the water to outside of caisson) a caisson in cohesionless soils, the upward flow from the surrounding groundwater induces a quick condition, which results in loss of strength at the bottom of excavation. In other words, if the flow is upward then the water pressure tends to lift the soil element. If the upward water pressure is high enough the effective stresses in the soil disappear, no frictional strength can be mobilized and the soil behaves as a fluid. This is the quick condition and is associated with piping instabilities around excavations and with liquefaction events in or following earthquakes. Quick condition is shown in Figure 3.

To prevent quick condition, the head difference causing flow, i.e. the difference between the groundwater table level and the standing water level within the caisson, should be kept low. Caissons should not be used in the vicinity of existing structures that can be damaged due to loss of ground from beneath their foundations.
At the desired excavation level, an impervious seal is placed, usually by using tremie concrete (refer to Lesson 3). Once the Tremie concrete seal is in place, the dewatering of the caisson can begin.

**Permeability and Seepage - Flow of Water in Soil**

Soils have interconnected voids through which water can flow from points of high energy to points of low energy. It is necessary to estimate the quantity of underground seepage for investigating problems involving the pumping of water for underground construction, and making stability analysis of earth dams and earth-retaining structures that are subjected to seepage forces. Range of permeability for various soils is shown in Table 1:

<table>
<thead>
<tr>
<th>Soil</th>
<th>Permeability Coefficient, $k$ (cm/sec)</th>
<th>Relative Permeability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse gravel</td>
<td>Exceeds $10^{-1}$</td>
<td>High</td>
</tr>
<tr>
<td>Sand, clean</td>
<td>$10^{-1}$ to $10^{-3}$</td>
<td>Medium</td>
</tr>
<tr>
<td>Sand, dirty</td>
<td>$10^{-3}$ to $10^{-5}$</td>
<td>Low</td>
</tr>
<tr>
<td>Silt</td>
<td>$10^{-5}$ to $10^{-7}$</td>
<td>Very low</td>
</tr>
<tr>
<td>Clay</td>
<td>Less than $10^{-7}$</td>
<td>Impervious</td>
</tr>
</tbody>
</table>

Gravels are 1 million times more pervious than clays

**Permeability in the Field by Pumping from Wells**

When a well is pumped, the groundwater surface in the surrounding area is lowered which depends on the pumping rate, the size of the well, the permeability of the soil, and the distance from the well. In the field, the average hydraulic conductivity of a soil deposit in the direction of flow can be determined by performing pumping tests from the well. Figure 4 shows a well in an open aquifer being pumped at a pumping rate of $q$. (An aquifer is a permeable geological stratum or formation that can both store and transmit water in significant quantities).

![Figure 4](image-url) – Pumping in a well which is fully penetrating an open aquifer
The basic mathematical relationships concerning flow in soils assume that aquifers extend horizontally in all directions beyond the area of interest and its thickness is uniform throughout and it is isotropic, i.e., permeability in the horizontal and vertical directions is the same. The pumping rate from a well in an open aquifer is (Figure 3):

\[
q = \frac{\pi k(H_2^2 - H_1^2)}{\ln\left(\frac{R_2}{R_1}\right)}
\]

where \(q\) = Water flowing through the soil at a constant rate
\(k\) = the coefficient of permeability (aka: Hydraulic conductivity, a material’s constant)
\(R_1\) and \(R_2\) = distances of observation wells from the well where pumping is performed
\(H_1\) and \(H_2\) = drawdowns in the observation wells caused by pumping

If there are no observation wells, then \(q\) can be estimated by the following equation:

\[
q = \frac{\pi k(H_2^2 - H_w^2)}{\ln\left(\frac{R}{R_w}\right)}
\]

where \(H, H_w, R\) and \(R_w\) are as shown in Figure 3.

**Example**

Consider the case of pumping from a well in an unconfined permeable layer underlain by an impermeable stratum. Given:

\(q = 26\ \text{ft}^3/\text{min}\)
\(H_1 = 15.7\ \text{ft at} \ R_1 = 100\ \text{ft}\)
\(H_2 = 18.0\ \text{ft at} \ R_2 = 200\ \text{ft}\)

Calculate the hydraulic conductivity (in \(\text{ft}/\text{min}\)) of the permeable layer.

\[
k = \frac{q}{\pi(H_2^2 - H_1^2)} \ln\left(\frac{R_2}{R_1}\right) = \frac{26}{\pi(18^2 - 15.7^2)} \ln\left(\frac{200}{100}\right) = 0.074\ \text{ft}/\text{min}
\]

**Dewatering Methods - Wellpoints**

The wellpoint consists of a slotted or perforated pipe which is covered with a screen mesh. At the foot of this pipe is an orifice which permits jetting of the pipe into the ground during installation. A well-point dewatering system consists of a series of closely placed small-diameter wells installed to shallow depths. These wells are connected to a pipe or header that surrounds the excavation and is attached to a vacuum pump. The construction steps in the wellpoint system are:

1. the wellpoints are jetted into the ground;
2. the annulars void is filled with filter media;
3. the wellpoints are connected to a header pipe by means of a riser;
4. the header pipe is connected to suction pumps for pumping.
Figure 5 shows small pipes, up to 2.5 inches in diameter, connected to screens at the bottom and to a vacuum header pipe at the surface, which constitute a wellpoint system.

Wellpoints typically have capacities ranging from a fraction of a gallon a minute to 100 gallons per minute and they may be used in single stages or in multiple stages to accomplish deep dewatering.

Single stage wellpoint systems have an effective suction lift of 15 feet at sea level, and under certain circumstances, lifts can be increased to as much as 22 feet, as shown in Figure 6.

If the total required drawdown is substantially more than 22 feet, it is usually necessary to use a multistage wellpoint system (Figure 7), or a combination of deep wells and a single stage of wellpoints. It consists of the installation of wellpoints at two or more levels. It is important the lowest wellpoint stage be located at an elevation within reasonable suction lift or the desired final water level.
The normal range of wellpoint spacing is from 3 to 12 feet. The wellpoint depth is based on adequate information on the soil conditions. Figure 8 shows the recommended wellpoint depth under the following conditions:

(a) In uniform soil, place top of screen 3-5 ft (minimum) below subgrade
(b) with clay at or above the grade, place top of screen ± 6 in. above top of clay, and
(c) with deep coarse layer below grade, place screen in coarse layer.

Wellpoint Pumps, Header and Discharge Piping

Once the total flow, $Q$, the required vacuum, the distance to the point of discharge, and the discharge elevation has been determined, a suitable mechanical system should be selected for those conditions. When selecting wellpoint pumps, they must have adequate water and air capacity at the necessary vacuum and must be capable of developing the required total dynamic head in order to be able to deliver the water to the discharge point.
Single pump or multiple pumps may be used, depending on availability of equipment and job conditions. If multiple pumps are used, they should be spaced along the header, or they can be grouped into one single pump station. In a single pump station only one discharge line is used, but in this case large header pipes are used to bring the water to the central pump station without excessive friction. Redundant or standby pumps must be provided, installed and be ready to operate in case of malfunction of the regular pumps or during maintenance or repair of those pumps.

For high volume pumping a suction manifold may be used, which reduces the water velocity in the header line at the pump. The manifold also causes smooth flow in the critical approach to the pump entrance, reducing cavitation, which will increase the capacity of the pump.

Header lines are sized to keep friction at acceptable levels. Valves are used to facilitate installation, trouble shouting, repair and removal. The discharge lines should be braced and strapped, where pressure is moderate to high. The arrangement and location of header lines, pumps and discharge should be selected in accordance with the plan and schedule of construction sequence and activities so that it is convenient during excavation, but also will not interfere with construction and backfill operations, in order to prevent relocation and modifications during the course of the project. Figure 9 shows a typical dewatering system using wellpoints.

![Figure 9 – A typical well point system dewatering](image-url)