Technical Brief NO15/Slow Sand Filter Design

Sand Filter Design

Slow sand filtration is a simple and effective technique for purifying surface water. It will remove practically all the turbidity from water, together with virtually all harmful eggs, protozoa, bacteria and viruses without the addition of chemicals and may frequently be constructed largely with local materials.

A slow sand filter consists basically of three different layers within a filter-box. These layers are from bottom to top: the underdrainage system, the gravel layer and the sand. It is only the sand which plays any part in the treatment process.

The underdrainage may consist of:

- perforated pipes of asbestos cement
- porous or perforated unglazed pipes
- perforated pipes of PVC

If pipes are employed, a series of lateral drains (80mm diameter) are connected to a main drain.

Perforations of 2 to 4mm diameter are made on the underside of the lateral drains at intervals of 150mm. Cross-sectional area of main drain = sum of cross-sectional areas of all lateral drains.

Standard bricks.

Concrete tiles - whole tiles are set on quarter-tiles as illustrated.

Large gravel (40 - 100mm).

The underdrainage should not be closer to the wall than 0.6m.
The Gravel Layer

The gravel layer is arranged in four graded levels. All gravel must be clean.

The gravel layer should not be closer than 0.6m to the walls. This means that any water which runs quickly down the walls and does not filter through the sand layers (i.e., it 'short-circuits' the system) must pass through some depth of sand before entering the gravel and underdrainage.

The Sand Layer

is characterized by:

Effective Size (E.S.) - mesh diameter (mm) of a sieve which retains 90 per cent of the sand.

Uniformity Coefficient (U.C.) - mesh diameter (mm) of a sieve which retains 60 per cent of the sand, divided by the effective size.

E.S. - between 0.2mm and 0.4mm

U.C. - less than 3.0, preferably less than 2.0

Suitable sand is usually easy to find locally. If any grading is necessary, it is normally sufficient to remove only the coarsest grains and the very finest grains.

Filter Box

The filter box may be constructed either with vertical sides or with sloping sides.

If designed to have vertical sides it may be constructed of either:

- mass-concrete
- ferroconcrete
- masonry
- reinforced concrete

During construction the wall must be roughened where it will be in contact with the sand in order to prevent short-circuiting (see section on the gravel layer).

If the filter box is designed to have sloping sides it may be constructed either of:

- mass-concrete
- masonry
- puddled clay
- rip-rap

Commonly, masonry will be employed and the system made watertight by adding a layer of puddled clay.

Sloping walls are simpler to construct and can usually be made with locally available material but cannot be guaranteed to be always watertight.
Inlet Arrangements

There are two main types of inlet arrangement.

The concrete tile is a splash tile to prevent water falling directly onto the sand-bed and eroding it.

The inlet is controlled either by a hand-operated gate valve or by a float-controlled butterfly valve.

Water Reservoir

This is normally maintained at a constant depth of between 1.0m and 1.5m.

Outlet Arrangement

The outlet flow is maintained at the design flow rate by a hand-operated gate valve which is adjusted every day. It is essential to provide an outlet weir which is above the height of the sand bed.
The size of the filter

The size of a slow sand filter is determined by several factors.

For example:

Population of 1000 with water consumption of 100 litres/capita day. Wasteage can be assumed to be 30 per cent of production. Therefore - total daily production needs to be: 

\[
1000 \times 100 \times 100 = 143,000 \text{ litres/day} \\
(100 - 30) = 143 \text{ m}^3/\text{day}
\]

The rate of filtration is \( 2.4 \text{m}^3/\text{m}^2\cdot\text{d} \) (\( \approx 0.1 \text{m/h} \))

Therefore - the filter tank needs to have an area of: 

\[
\frac{143}{2.4} = 56 \text{m}^2 \\
(7 \times 8 \text{m})
\]

Two parallel filters are required, each 7m x 4m, with a common divide wall.

Overall height:

<table>
<thead>
<tr>
<th>Component</th>
<th>Height (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above level of water</td>
<td>0.3</td>
</tr>
<tr>
<td>Water</td>
<td>1.0</td>
</tr>
<tr>
<td>Sand</td>
<td>1.2</td>
</tr>
<tr>
<td>Gravel</td>
<td>0.3</td>
</tr>
<tr>
<td>Underdrainage</td>
<td>0.15</td>
</tr>
<tr>
<td>Foundations</td>
<td>0.15</td>
</tr>
</tbody>
</table>

\[ \text{Total height} = 3.10 \text{ metres} \]

The Final Design

![Diagram of a slow sand filter system]

(The operation and maintenance of slow sand filters will be dealt with in a later Technical Brief.)

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