4.6 DESIGN CRITERIA FOR PROTECTIVE FILTERS:

When seepage water flows from a mass of relatively fine soil into a coarse material (e.g., filter), there is a possibility of fine soil particles to migrate in to the coarser material. If the migration of particles is allowed, it can lead to clogging of filters and drains, and in extreme cases, to piping failure. A filter therefore should consist of any porous material whose openings are small enough to prevent movement of soil particles and at the same time be sufficiently pervious to permit seepage to escape freely without build up of large hydrostatic pressure and seepage forces. The U.S. Bureau of Reclamation has developed design criteria for protective filters which must meet the following four requirements.

1 The filter material should be more pervious than the base material so as to avoid the build up of any hydrostatic pressure to disrupt the filter and adjacent structures.
2 The voids of the in-place filter material must be small enough to prevent base material particles from entering the filter and causing clogging and failure of the protective filter system.
3 The layer of the protective filter must be sufficiently thick to provide a good distribution of all particle sizes through the filter and also to provide adequate insulation for the base material where frost action is involved.
4 Filter material particles must be prevented from movement into drainage pipes by providing sufficiently small slot openings or perforations, or an additional coarser filter zone if necessary.

The soil to be protected by the filter is called base material.

4.7 TYPES OF FILTERS:

The following two types of filters are mostly used to prevent piping.

a- Graded filters (Fig: P-159-a.)
b- Loaded filters (Fig: P-159-b.)

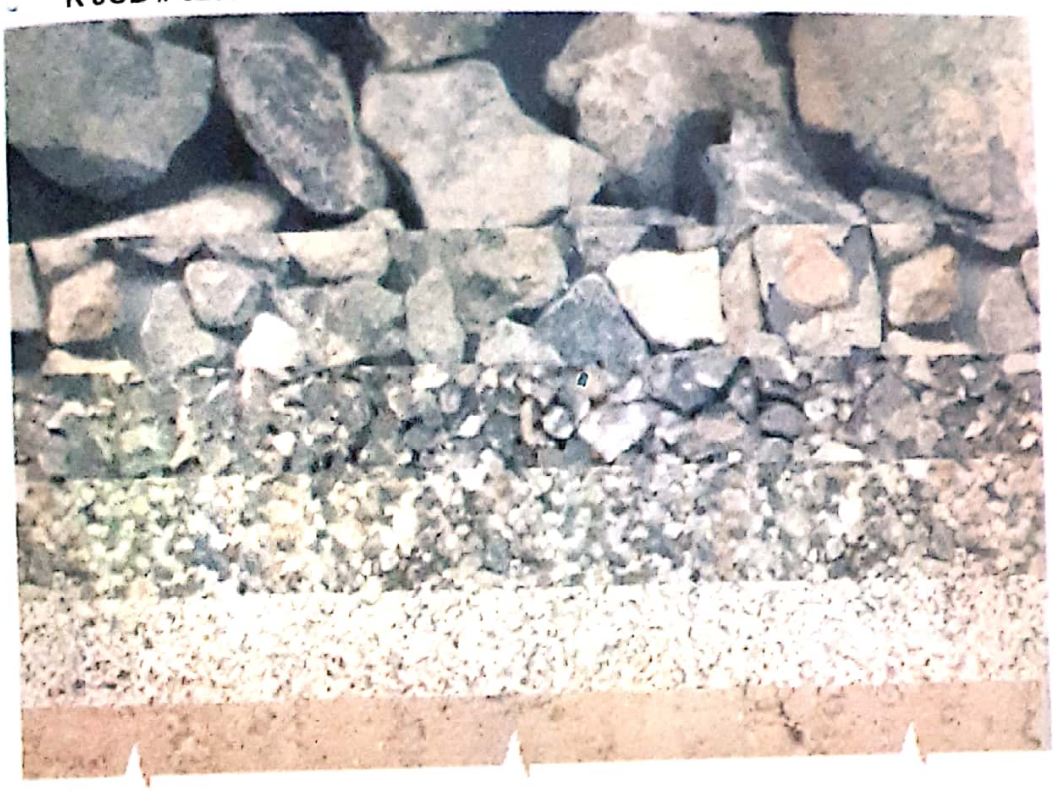

Fig: P-159-a. Graded filter

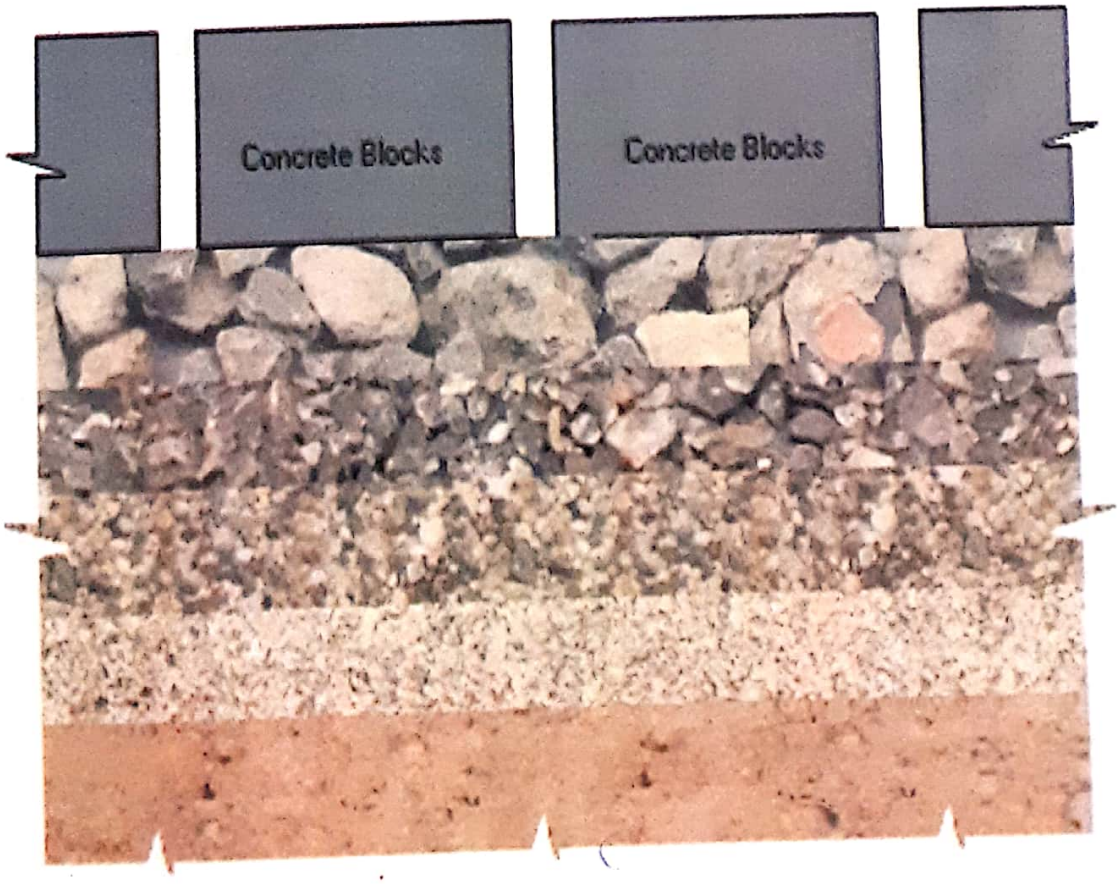

Fig: P-159-b. Loaded filter

4.7.a Graded Filters

A filter that consists of multiple layers of pervious material which permit the flow of water but prevent the movement of soil particles is known as graded filter. The number of the layers depends on the size (gradation) of the base material and the openings of the perforated drainage pipes. Finer the base material greater will be the number of layers. The particle size in any layer should be coarser than that in the preceding layer. However, the difference of sizes of particles in the two consecutive layers should not be excessive otherwise the particles of the preceding layer will move into the next layer. The particle sizes of different layers of the filter are fixed according to the design criteria as discussed in section-4.6. According to the design criteria, the following requirements are to be satisfied.

1- The filter material should be pervious enough such that the seepage water escapes freely without any build up of hydrostatic pressure in the base material or in any layer of the filter.

Since the filter has to provide free drainage, it should be much more previous than the base material. Experiments have shown that free drainage is achieved if the coefficient of permeability of the filter material is 25 times or more than the coefficient of permeability of the soil to be protected i.e., base material. Since the coefficient of permeability varies as square of the particle size, the effective diameter of the filter material should be 5 times or more than that of the base material. Therefore the first criterion for the design of filters is

$$\frac{D_{15}(filter)}{D_{15}(base)} \geq 5 \qquad (4.4)$$

2- The openings of the filter should be small enough i.e., the filter material should be fine enough such that the particles of the base material are not washed through the filter.

Experimental investigations have shown that it is not necessary for a filter to screen out all the particles of the base material. Rather the filter opening need to restrain only the coarsest 15 percent i.e., D_{85} size

of the base material. These 15% coarser particles (i.e., D_{85} and larger) of the base material will collect over the filter opening as shown in the Fig: P-161.

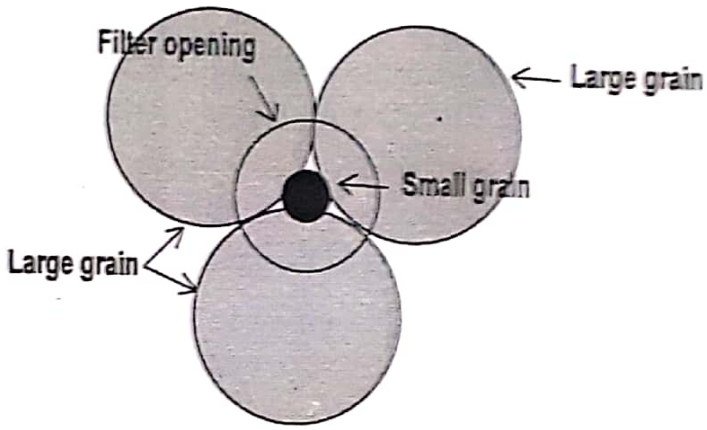

Fig: P-161. Large grain of base material screen small grains at filter opening

Their voids will form smaller openings to trap even smaller particles (i.e. remaining 85 percent) of the base material. Therefore the diameter of the openings of the filter must be less than D_{85} of the base material. Since the effective pore diameter is approximately one fifth of D_{15}, therefore the second criterion for filter design is

$$\frac{D_{15}(filter)}{D_{85}(base)} \leq 5 \tag{4.5}$$

The above two criteria can be combined together as under

$$\frac{D_{15}(f)}{D_{85}(b)} \leq 5 \leq \frac{D_{15}(f)}{D_{15}(b)} \tag{4.6}$$

The U.S. corps of engineers also recommends that the ratio of the D_{50} filter and base material should be as follows.

$$\frac{D_{50}(filter)}{D_{50}(base)} \leq 25 \tag{4.7}$$

For the graded filter, each layer is designed considering it as a filter and the preceding layer as a base material. The particle size in a layer increases in the direction of flow (Fig: P-159-a & 159-b).

If the seepage water is to be collected and disposed away by the perforated drainage pipes, then the material of the last layer should be coarse enough not be washed away through the openings of the pipe. According to U.S. Bureau of Reclamation the following criterion should be met to avoid movement of filter material into the drain pipes.

$$\frac{D_{85}(filter)}{Dia\ of\ perforation} \geq 2 \qquad (4.8)$$

The U.S. Army Corps of Engineers uses the following criteria for gradation of filter materials in relation to slots and holes:

For slots

$$\frac{85\%\ size\ of\ filter\ material}{slot\ width} > 1.2 \qquad (4.9)$$

For circular holes

$$\frac{85\%\ size\ of\ filter\ material}{hole\ diameter} > 1.0 \qquad (4.10)$$

For an efficient filter material in addition to the above design criteria the following grading characteristics must also be satisfied.

1- The grain size curve of the filter material should be roughly parallel to that of the base material.
2- To avoid segregating, filter should not contain the particles of size larger than 80mm.
3- The filter material should not contain more than 5 percent of fines passing 75 μm sieve.
4- The thickness and area of the filter should be sufficient to safely allow the seepage discharge.

4.7-b Loaded Filters:

Filters that are covered with surcharge weight to prevent uplifting by seepage forces are called loaded filters (Fig: P-159-b).