Chapter 1. Introduction

1.1. Background

Since Terzaghi (1922) developed grain size criteria for granular soils in dam filters, many researchers have studied embankment dam filters. The major function of the filter is to prevent erosion and piping. In order to have this ability, filters must restrain the particles of the protected soil (the base soil) and allow water to pass freely out of the base soil. Sherard et al. (1984) modified these criteria for cohesive soils, and developed the concept of “critical filters,” that can prevent erosion even under the severe condition where the base soil is cracked, and where concentrated flow occurs through the crack.

In addition to grain size criteria that ensure restraint of the base soil while allowing free passage of water, a filter must also be graded so that the filter itself will not crack. To ensure that filters will not support cracks, most current filter gradation criteria require that no more than 5% of the filter material should be finer than the #200 sieve, and that the fines within the filter should be non-plastic. However, it is not clear that this criterion is sufficient. At Ochoco Dam shown in Figure 1.1, a sinkhole developed in a filter that was designed to have a maximum of 3% passing the #200 sieve. This incident at Ochoco Dam gave rise to renewed interest in filter criteria, and resulted in sponsorship of the research described in this dissertation. This research was designed to investigate the crack-preventing and crack-stopping abilities of filters, and to develop criteria that can be relied upon to ensure that a filter will perform its essential function even when subjected to deformations that cause cracks in the adjacent core.

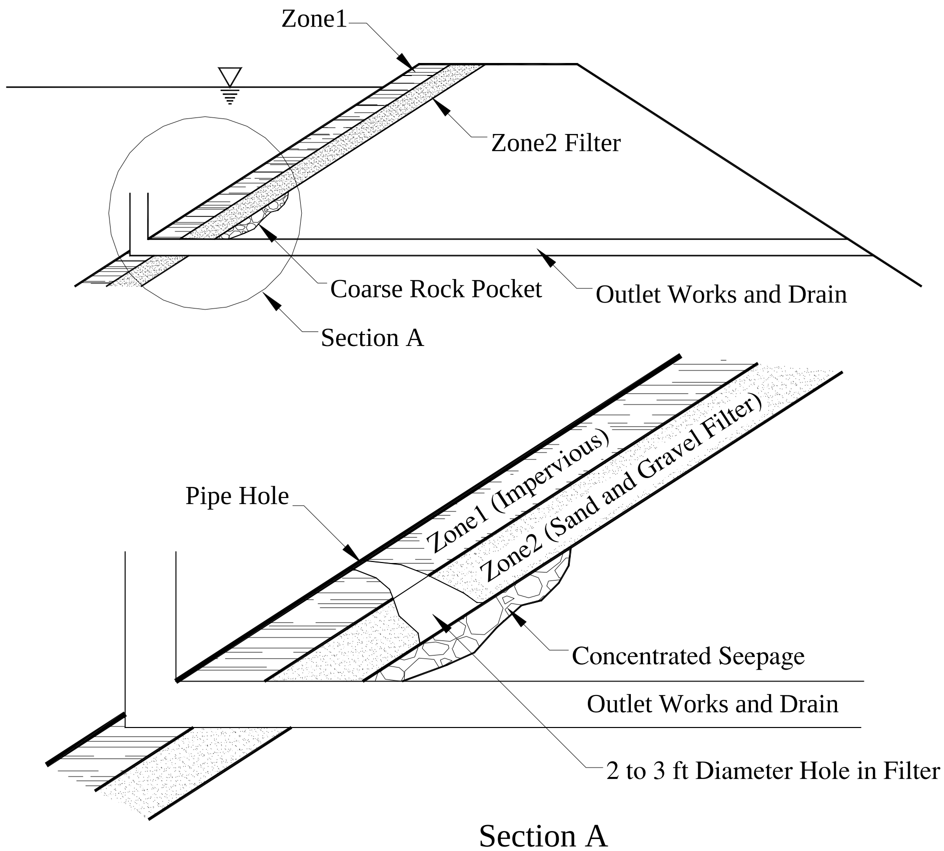

Figure 1.1 Ochoco Dam Piping Problem

1.2. Transverse Cracks in Dams

Transverse cracks in embankment dams can develop as a result of post-construction settlement (Hsu, 1981) or earthquake deformations (USCOLD, 1992). These cracks result from differential settlements or deformations. A related and equally serious problem can occur where settlements or earthquake - induced deformations cause separation between an embankment dam and an adjacent concrete structure.

Hsu (1981) reported that piping through settlement–induced transverse cracks has occurred in Apishapa Dam (1923), Stockton Dam (1950), Cougar Dam (1963), Round Butte Dam (1964), Yard's Creek Dam (1963), Matahina Dam (1966), and Viddalsvatn Dam (1971). In Yard's Creek Dam, Matahina Dam, and Viddalsvatn Dam, the cracks extended through the filters as well as the core, because the filters contained excessive amounts of fines (Hsu, 1981).

USCOLD (1992) reported two instances of transverse cracks in dams resulting from earthquake deformations. Matahina Dam (New Zealand) suffered settlements and cracking as a result of the Magnitude 6.3 Edgecumbe Earthquake on May 2, 1987. Trenching showed that the cracks were shallow, and that they did not extend across the core. The trenching exposed a large cavity which was thought to be related to earlier core cracking, seepage and internal erosion. The rate of seepage through the dam increased as a result of the earthquake. Austrian Dam (California) suffered deformations and cracking as a result of the Magnitude 7.1 Loma Prieta Earthquake on October 17, 1989. A transverse crack was traced 30 ft down the left abutment, and transverse cracking and separation of the embankment from the spillway occurred to a depth of 23 ft on the right abutment. Water levels in the embankment, measured in open well piezometers, increased as a result of the earthquake.

1.3. Filters and Crack-Stoppers

It is commonly assumed that filters downstream of the cores in dams will prevent erosion and piping through transverse cracks in dams (Sherard and Dunnigan, 1989). This assumption is based on the concept that the filter will be cohesionless, and that it will not support a crack. However, as shown by observations at Yard's Creek, Matahina, and Viddalsvatn Dams, this is not always the case.

The ability of a filter to provide a reliable line of defense against erosion and piping depends on the cohesionless nature of the filter material, and its own inability to support a crack. The same is true of upstream crack-stoppers – zones of sand upstream from the core, designed to wash into and fill cracks. If they crack and do not wash into the crack in the core, they will not perform their intended function.

1.4. Objectives of the Research

This research to investigate the ability of filters to stop cracks has four principal elements:

- A review of the literature concerned with filters, and particularly the crack-stopping ability of filters.
- Development of a laboratory filter test device for testing composite specimens with cracks formed through both the filter and the base coarse material.
- Development of procedures for processing base and filter materials, in order to have precise control over their grain-size distribution.
- Performing tests on composite specimen to explore (1) the effect of the compaction water content, (2) the effects of the density to which the filter material is compacted, (3) the effect of the width of the crack that extends through the base and filter material, and (4) the effects of the percentage of fines in the filter material.