Assessment of Filter Compatibility in Earth Dams Using Empirical and Experimental Methods

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INTRODUCTION

Erosion boundaries were proposed by Foster and Fell in 1999 to indicate whether the characteristics of dam core and filter material, would result in No Erosion (NE), Some Erosion (SE), Excessive Erosion (EE) or Continuous Erosion (CE). If the filter and core were compatible they would fall into the No Erosion category while soils that were in the Continuous Erosion category would be highly likely to erode completely..

In this study filter-core compatibility was explored for a pre existing New Zealand earth dam. Filter designs used in this study were adapted from international literature, specifically the Foster and Fell (1999) paper. The empirical equations, derived by Foster and Fell during their research, were applied to core material. This material was sampled from a borrow site used in the construction of a New Zealand dam. This gave the expected performance categories for the five different filter gradations considered in this study.

Following the empirical designation of the material, Continuing Erosion Filter (CEF) testing was performed. This provided lab based results as to how the different filter designs performed. The results were integrated into the erosion boundary frame using mass loss of core material during the test.

EMPERICAL EQUATIONS + FILTER SELECTION

Foster and Fell's empirical equations were derived from a series of erosion tests performed by them in a CEF chamber and from pre-existing erosion test results. The derivation of the equations took into account: fines content of core material, core gradation, previous design criteria and their experimental results. The equations contributed to current filter design criteria for new filters and are used to assess expected compatibility of existing filters.

The boundaries are expressed in terms of the D_{15} value of filter material. This is the diameter (in mm) that 15% of the filter soil particles are smaller than in the gradation.

Applying the equations to the New Zealand dam core, the following empirical boundaries were produced: 0.7 mm (NE), 2.36 mm (EE_{av}), 6 mm (EE_{coarse}) and 36 mm (CE).

The filters selected were based on filters previously tested in Foster and Fell's work. Filters, based on field informed data, had previously been tested by Katie Vincent and Petra Garratt in an earlier stage of the study, hence the decision to use literature based filter designs. Below are both the literature informed filters tested in this study and the field informed filters tested in the previous study.

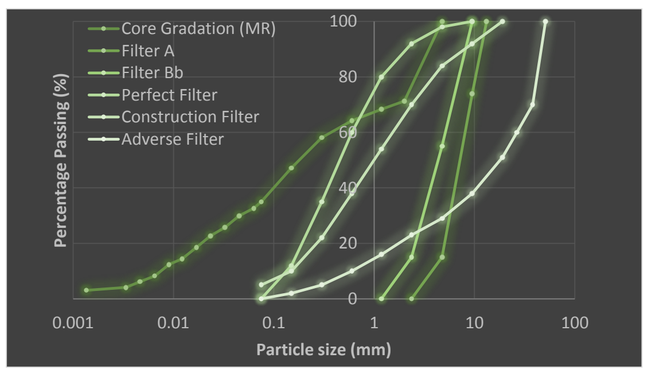


Figure 1: Five different filter gradations used in CEF tests and the core gradation filters were being tested against

Table 1: D_{15} for filters

Filter variant	D_{15} (mm)
Perfect	0.16 mm
Construction	0.2 mm
Adverse	1.1 mm
A	2.36 mm
B	4.75 mm

DISCUSSION

- A range of filter designs, from a D_{15} of 0.5mm to a D_{15} of 4.75 mm were tested against the same core material.
- As was expected, the finer filters were more compatible with the core material from the dam. Greater compatibility was demonstrated by less erosion (mass loss).
- The results for the empirical equations and CEF tests did not match for every filter gradation.
    - This was particularly the case with the coarser filter designs.
- Due to the empirical nature of the erosion boundary relationships commonly used in practice, caution should be taken when applying them. This study demonstrates that some filter-core interfaces may perform with more or less erosion than expected.
- The empirical equations are a highly valuable tool to use in earth dam design and assessment however, where feasible, it would be beneficial to use other tools alongside the relationships to get the best possible results or design.

Further Research

A couple of interesting points came out of the study and results that would involve further research:

- The effect of moisture content during compaction of the core material on the filter-core compatibility and core behaviour.
- The extent of variation across core material within the dam and therefore how accurate or relevant this study is to the dam as a whole.

WHY?

A large number of New Zealand dams are Medium to High Potential Impact dams (after NZSOLD 2015); implying that if failure were to occur it would have considerable consequences. Large dams pose a threat to communities and the environment downstream of the dam as well as being an essential piece of infrastructure for water storage, sustainable energy, flood control and irrigation purposes.

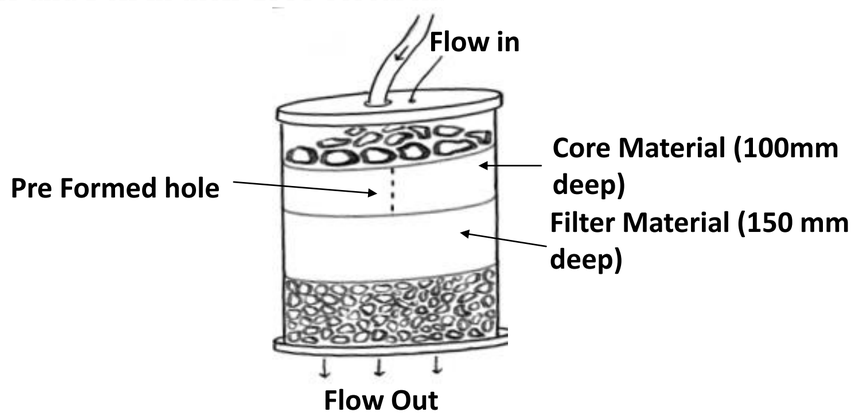
Over the course of dams being constructed in New Zealand, and overseas, the knowledge and designs improved greatly. This led to large amounts of variability between dams and a lot of uncertainty in how they will perform in the future. This difficulty is exacerbated by the variable nature of New Zealand geology, from which local soils make up the primary building material for these dams.

One of the most common failure modes of earth dams is internal erosion. A filter is incorporated into dam design to reduce the risk of internal erosion leading to failure. This is where the filter-core interface comes into play; if the core begins to erode, a compatible filter catches the core and forms a seal at the interface.

Due to the current lack of information and variability in NZ, this study was trying to get a better understanding of this interface performance through empirical and experimental methods for a specific New Zealand dam.

CEF TESTING

The continuing erosion filter testing investigated the filter-core interface behaviour within a controlled laboratory space. The set up used was an adaptation to the one used by Foster and Fell in their 1999 research.

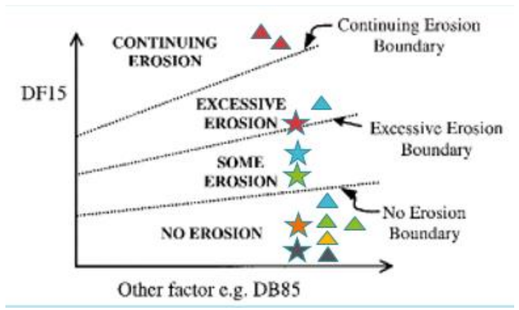


Pressure and flow data were recorded during the testing and all the material was weighed and processed through sieves after testing. This allowed the quantification of total mass loss from the core. The location where that mass loss ended up within the set up was obtained through analysis of the gradations before and after testing

RESULTS

Table 2: Mass loss results and erosion boundary categories for CEF tests

		Filter	Mass Lost	Erosion Category	D15	Expected category (empirical result)
Field informed (pre-existing data)	CEF1	Perfect Filter	0g	NE	0.16mm	D15<NE
	CEF2	Design Filter	0g	NE	0.2mm	D15<NE
	CEF3	Adverse Filter	3.25g	NE	1.1mm	NE<D15<EE
Literature informed (data collected in our testing)	CEF7	Filter "A"	512.61g	CE	4.75mm	EE_{Av}<D15<EE_{Coarse}
	CEF8	Filter "B"	187.75g	EE	2.36mm	NE<D15<EE



- Expected boundary determined using empirical formulas
- Foster and Fell defined categories based on mass lost
- Colour indicates different filters i.e. red – filter "A"

- Finer filters, including design filter, were compatible with core from New Zealand dam.
- Coarser filters were not compatible, exhibiting high levels of erosion and in filter "A" continuous erosion occurred

Figure2: Significant erosion in CEF7 core

- With the compatible filters the empirical equations held true, there was significantly more error between experimental and empirical results for the coarser, literature informed, filters.

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Vincent K. A., Garrat P. J., (2019). Experimental Assessment of Filter Core Compatibility of Embankment dams, Dept. Civil and Natural Resources Engineering, University of Canterbury.

Foster, M., and R. Fell (1999), Assessing embankment dam filters which do not satisfy design criteria, UNICIV Report No. R-376, The University of New South Wales, Australia.