2018 Tailings and Mine Waste Conference

Improved Methodology for TSF Capacity Prediction

October 1, 2018

Gordan Gjerapic, Golder Associates, Inc.

Dobroslav Znidarcic, University of Colorado at Boulder

Outline

- Three-dimensional considerations of seepage and compression
- Large strain deformation during deposition and closure
- Variable production rate and complex geometries
- Robust numerical approach
- Mass balance and water balance errors

Numerical Models

HISTORICAL PERSPECTIVE

Gibson et al. (1967) – large strain consolidation theory

One-dimensional models

- Schiffman et al. (1992) – ACCUMV
- Yao and Znidarcic (1997) – CONDES
- Fox and Berles (1997) – CS2
- GWP Software (1999) – FSConsol

Numerical Models – 2D and 3D

COMMERCIAL MODELS USED FOR TSF CONSOLIDATION

Programs supporting large strain consolidation approach

- FLAC® and FLAC3D™- ITASCA Consulting Group
- PLAXIS, PLAXIS3D – Plaxis BV => Bentley Systems, Inc.
- SVOFFICE™5 – SVFLUX – SVSOLID, SoilVision => Bentley Systems, Inc.

Simplified Consolidation Approach – 3D

DOMINANT SEEPAGE AND COMPRESSION MECHANISMS

TSF modelling using a series of one –dimensional columns (Gjerapic et al. 2008)

- Consolidation dominated by seepage in vertical direction
- Applicable to most TSF geometries and boundary conditions

SoilVision => Pseudo 3D large-strain consolidation (under development as of May 2018)

Improved Methodology

PRACTICAL IMPLICATIONS

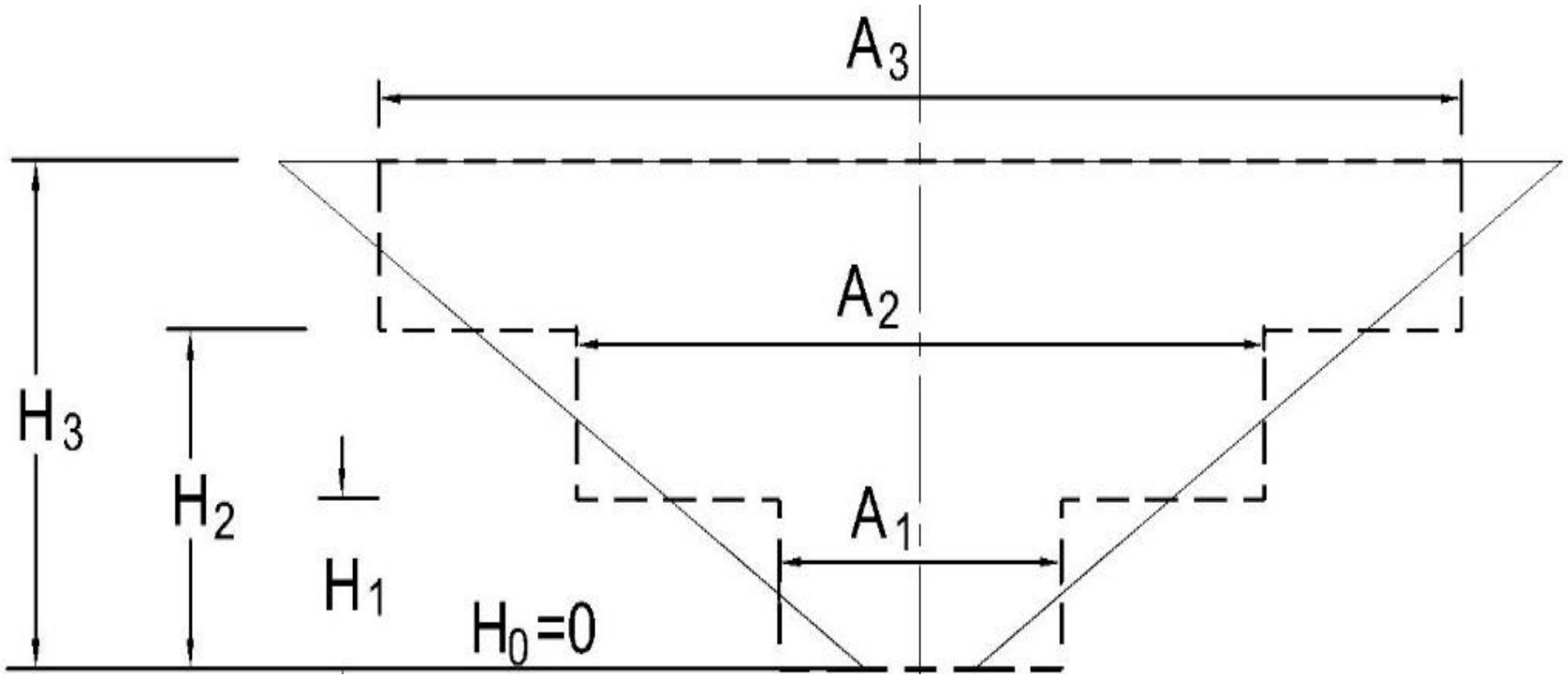
Develop solutions for rapid assessment of TSF capacity

- Negligible vertical strains during the filling process
- Fully consolidated tailings (apply analytical solutions)
- TSF filling starting with the deepest column and continuing by filling horizontal layers at higher elevation (e.g. FSConsol approach)
- TSF filling using a series of one-dimensional vertical columns (Gjerapic et al. 2008) => computationally efficient and relatively easy to implement

Upper and Lower Bound

NUMERICAL MODELS

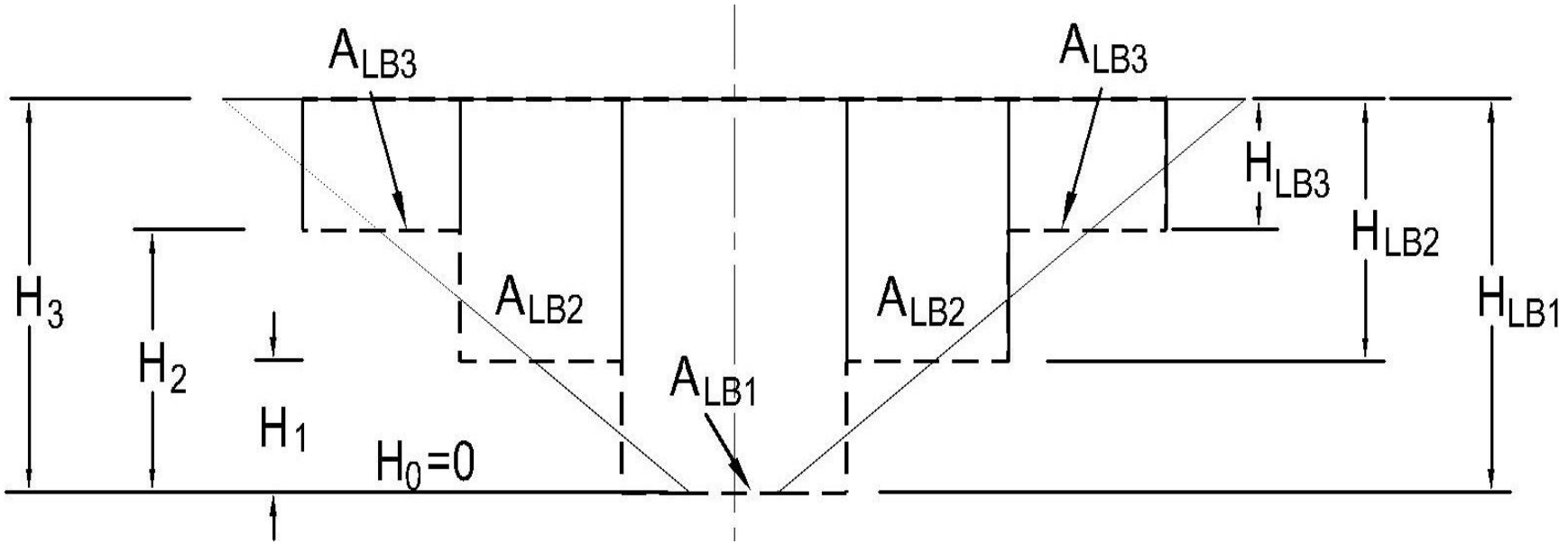
Horizontal Layers: $$V_{total} = \sum_{i=1}^{n} (H_i - H_{i-1})\ A_i$$



Upper and Lower Bound

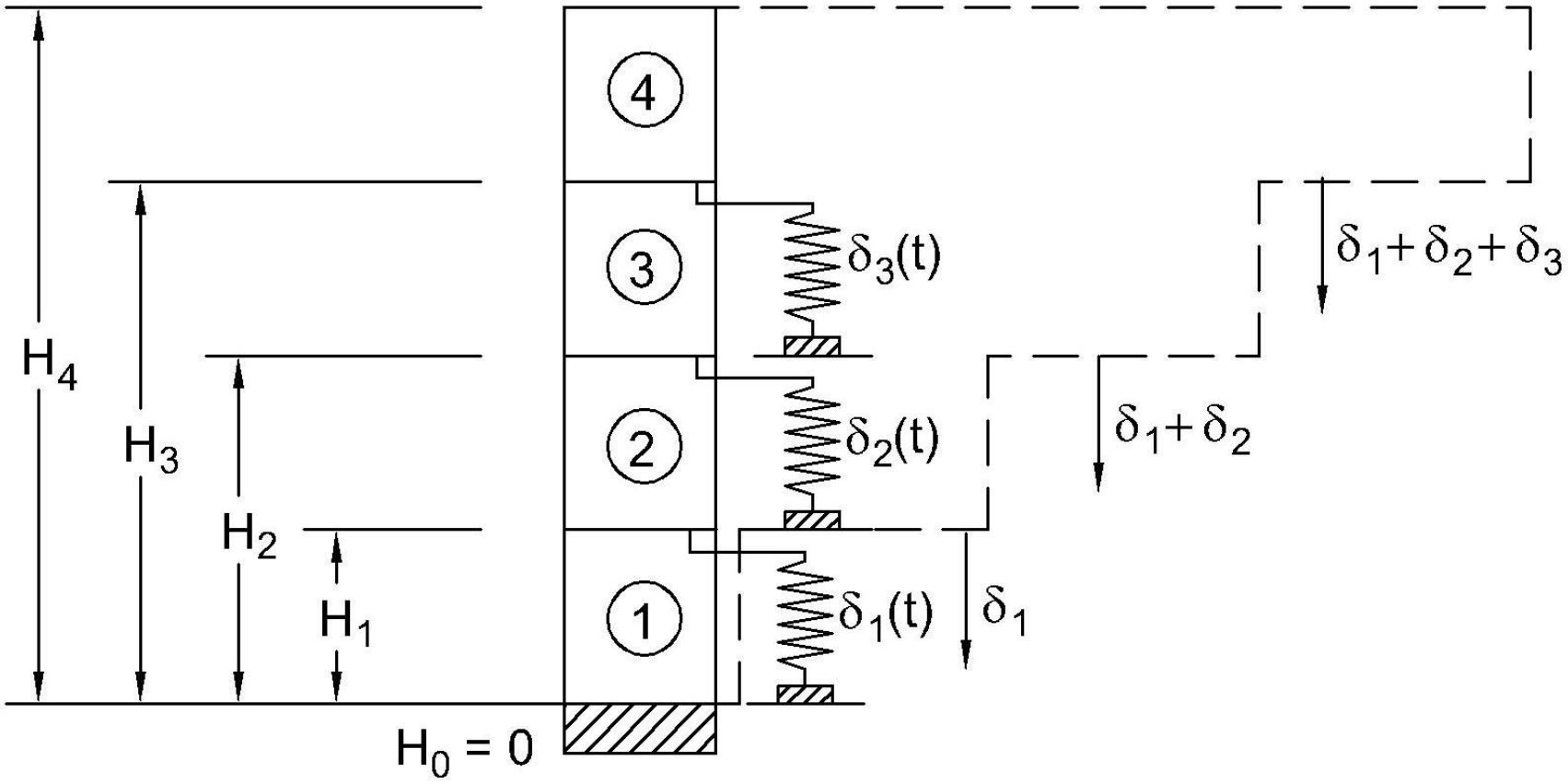
NUMERICAL MODELS

Vertical Columns: $$V_{total} = \sum_{i=1}^{n} A_{LBi} H_{LBi}$$



Does it Matter ?

TAILINGS VS. FOUNDATION COMPRESSIBILITY



How to Determine Calculation Errors ?

MASS CONSERVATION

$$\int_0^t Q_s(\tau)d\tau = \rho_{dry,avg} \times V_{TSF}(t)$$

Total Mass of Solids = Avg. Dry Density of Tails x TSF Volume

$$\int_0^t Q_s(\tau)d\tau = G_s\rho_w \sum_{i=1}^{n} A_{LBi}\, H_i^{solids}$$

Total Mass of Solids =

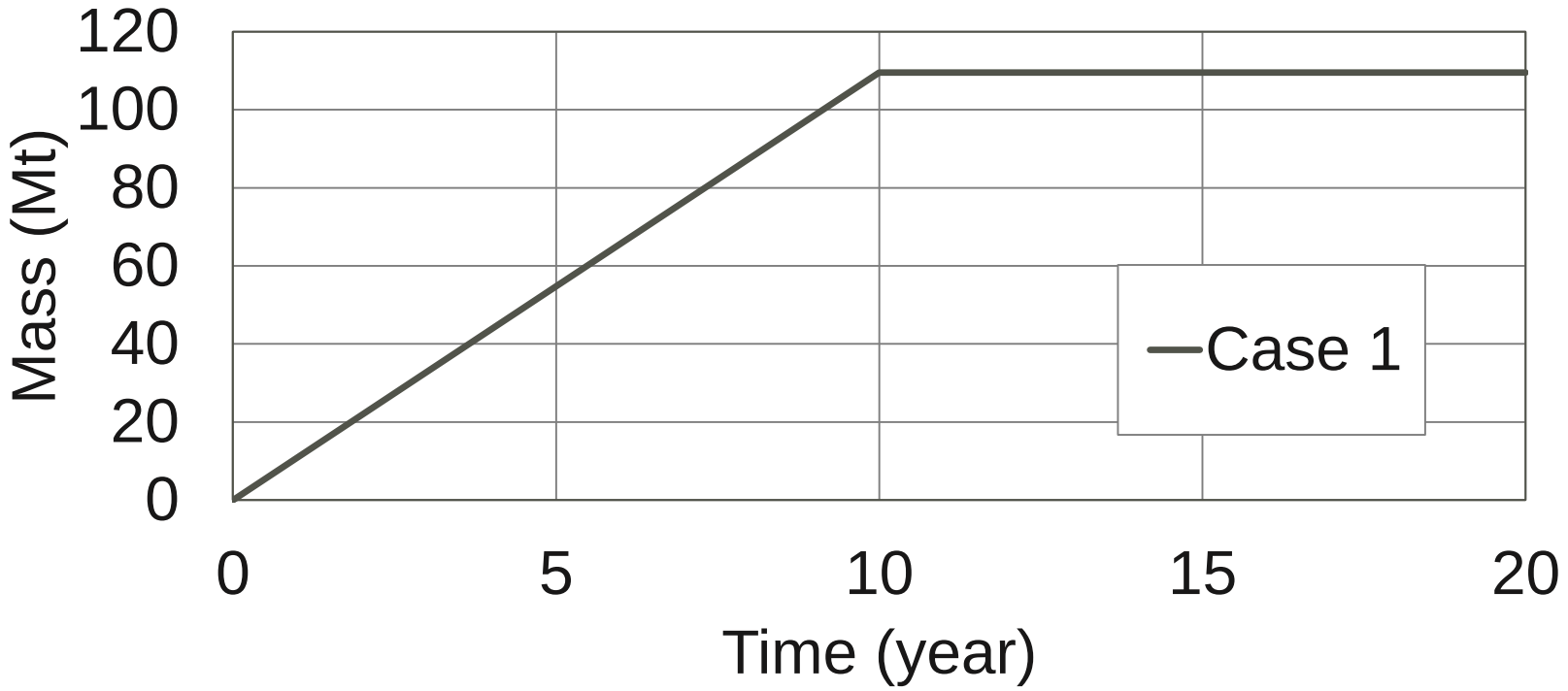
Mass Density of Solids x Volume of Solids in Individual Columns

Example

FILLING SCENARIO

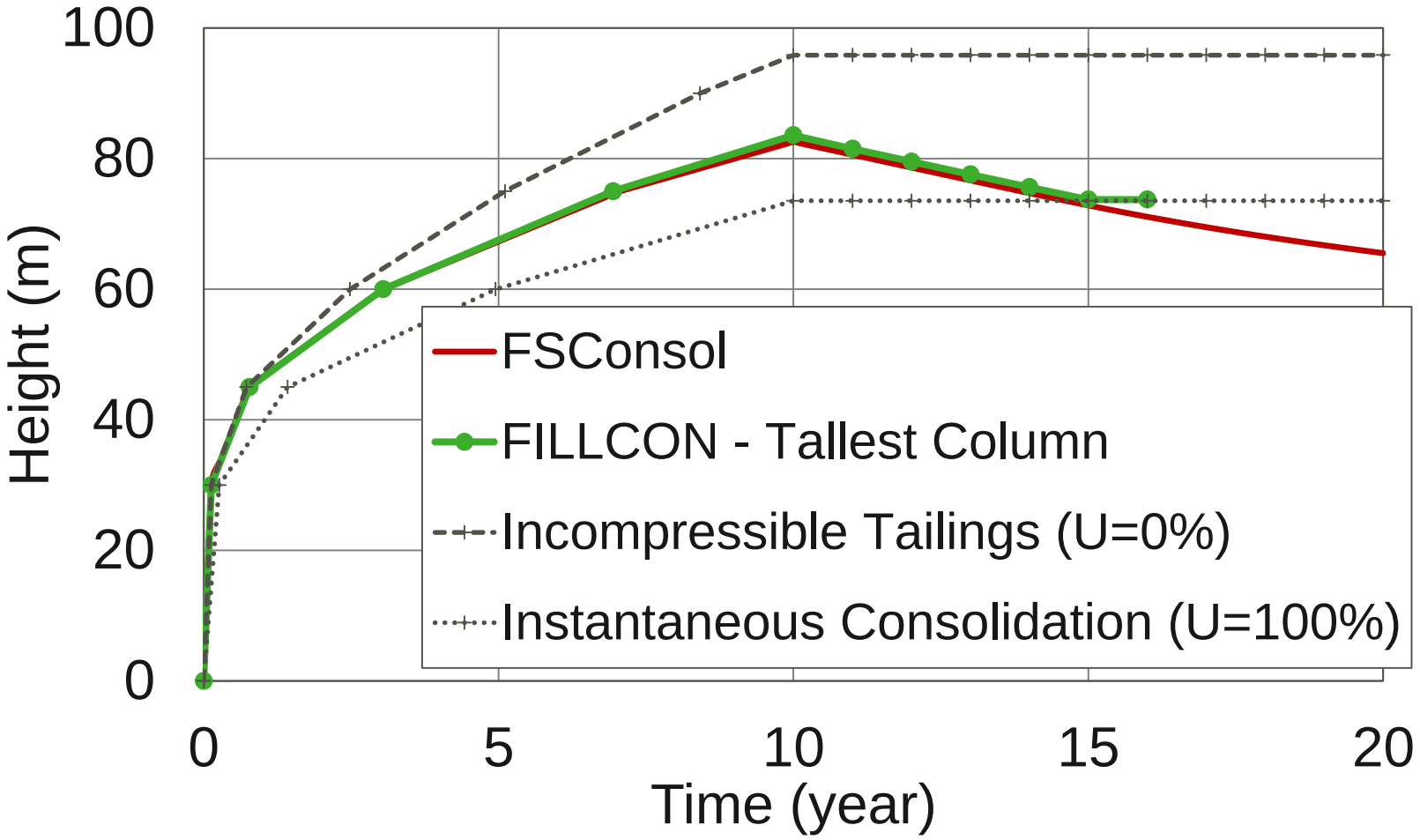
Case 1 => 30,000 t/day for 10 years

Case 2 => On-off filling (1yr + 1yr) – see paper

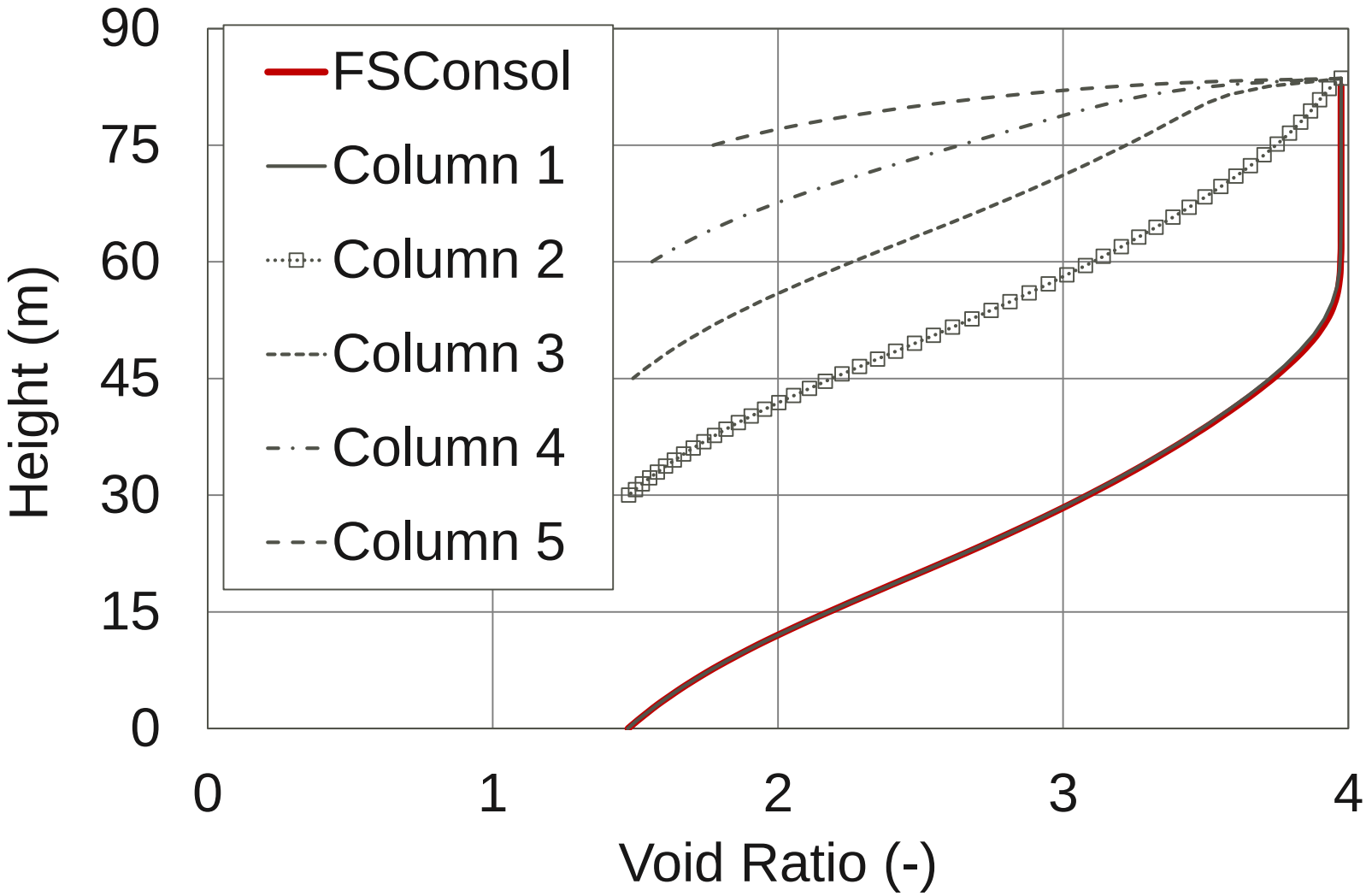


Case 1 Results – Time Settlement

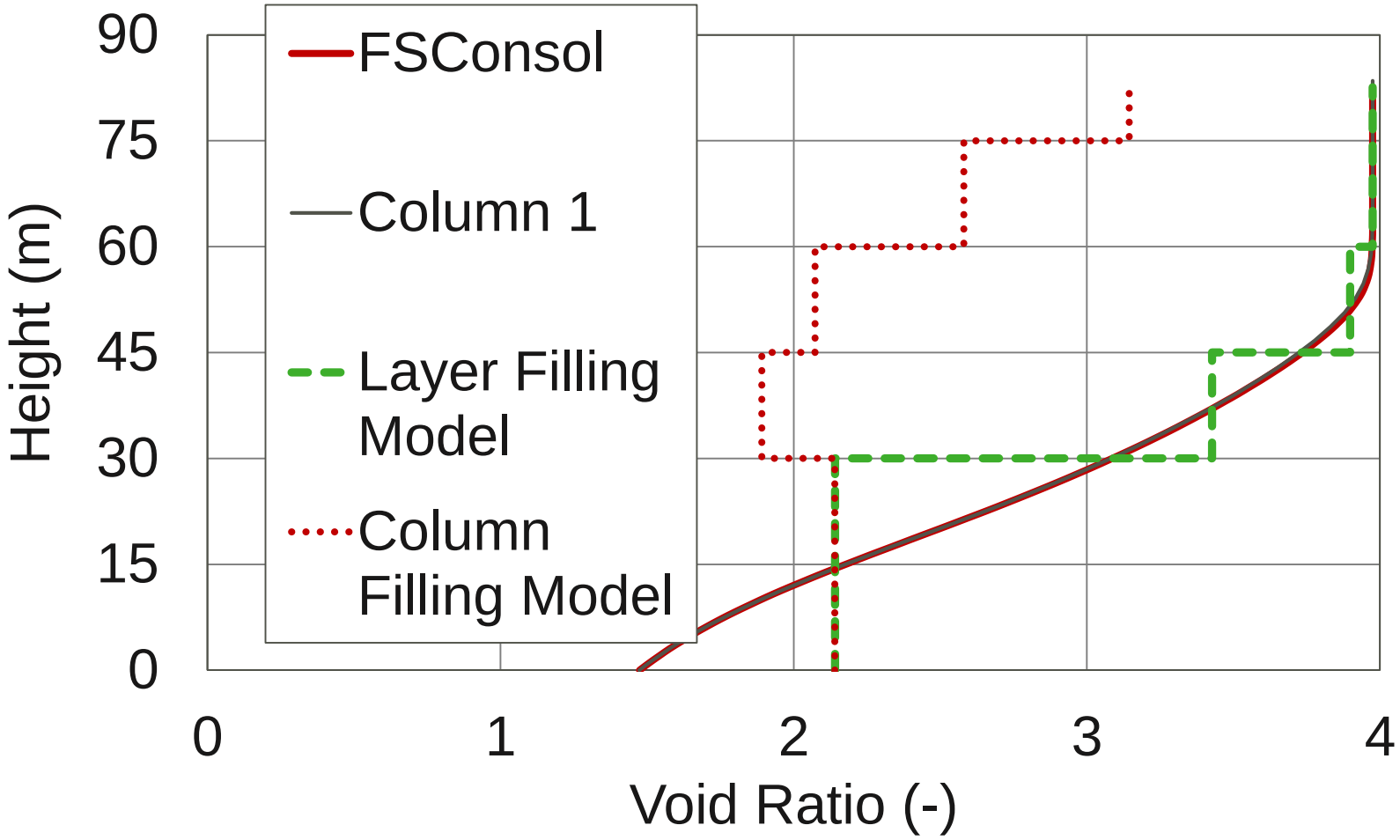
MASS CONSERVATION



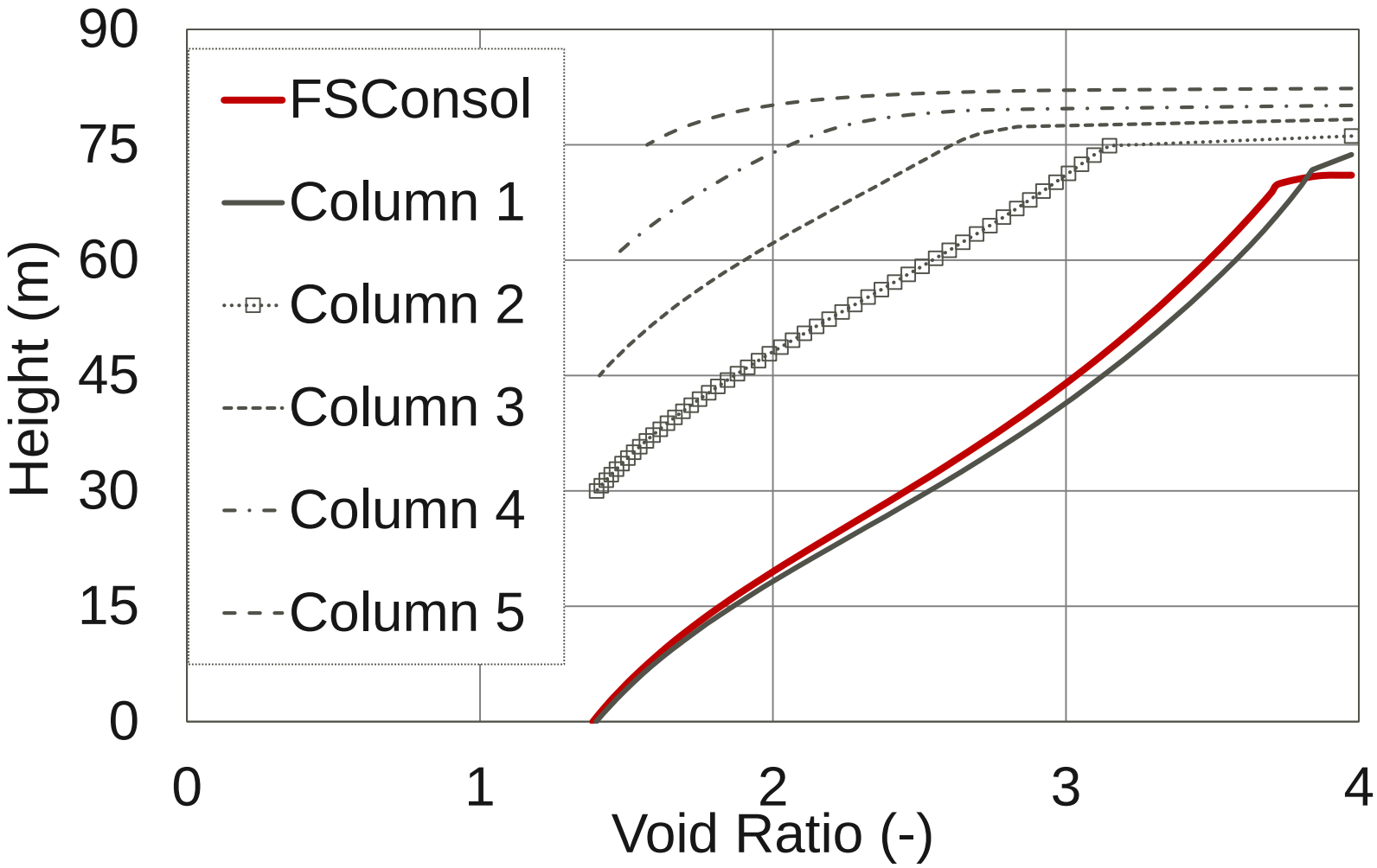
Case 1 – Void Ratio Profiles at 10 years



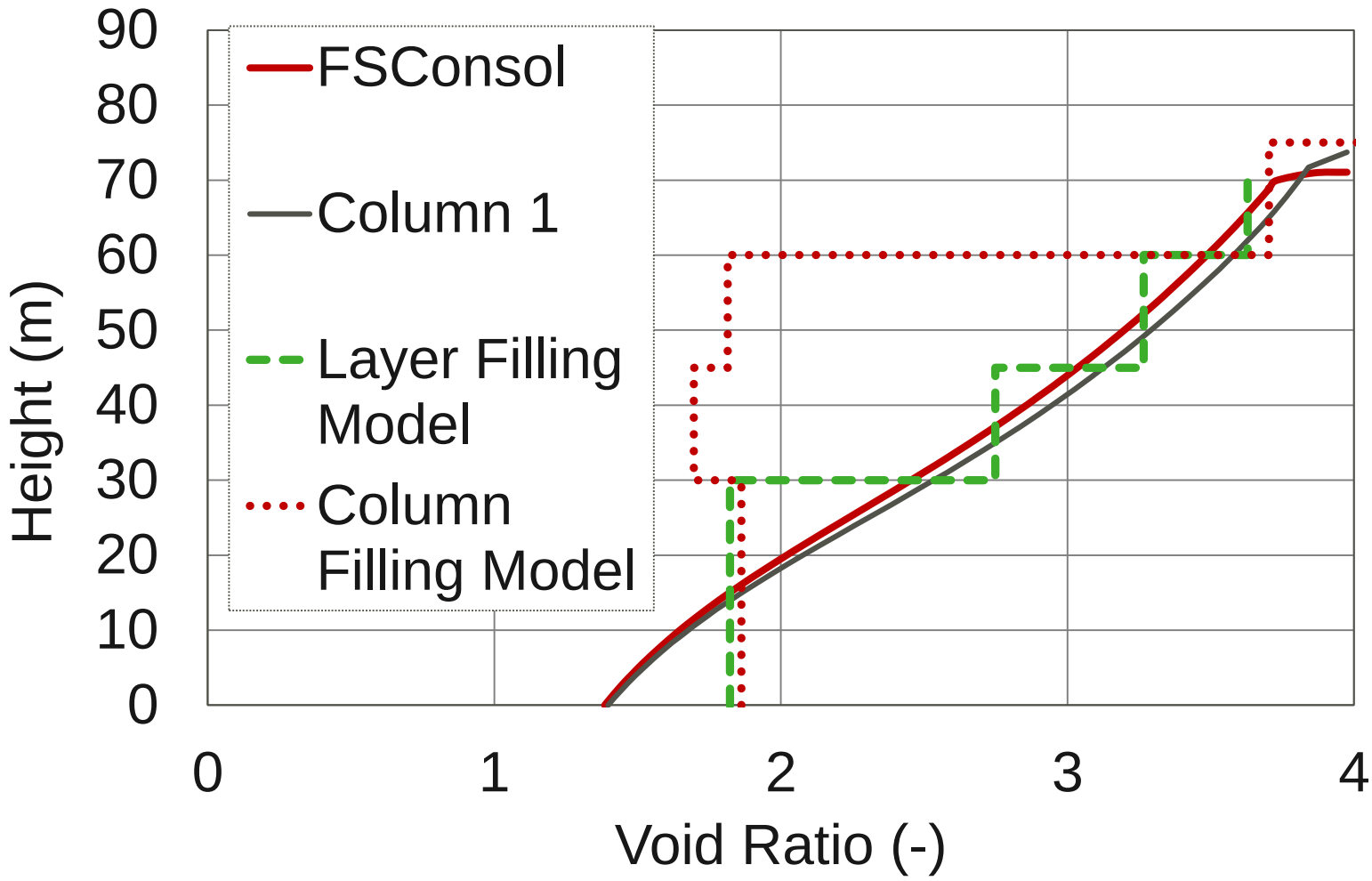
Case 1 – Avg. Void Ratio Profiles at 10 years



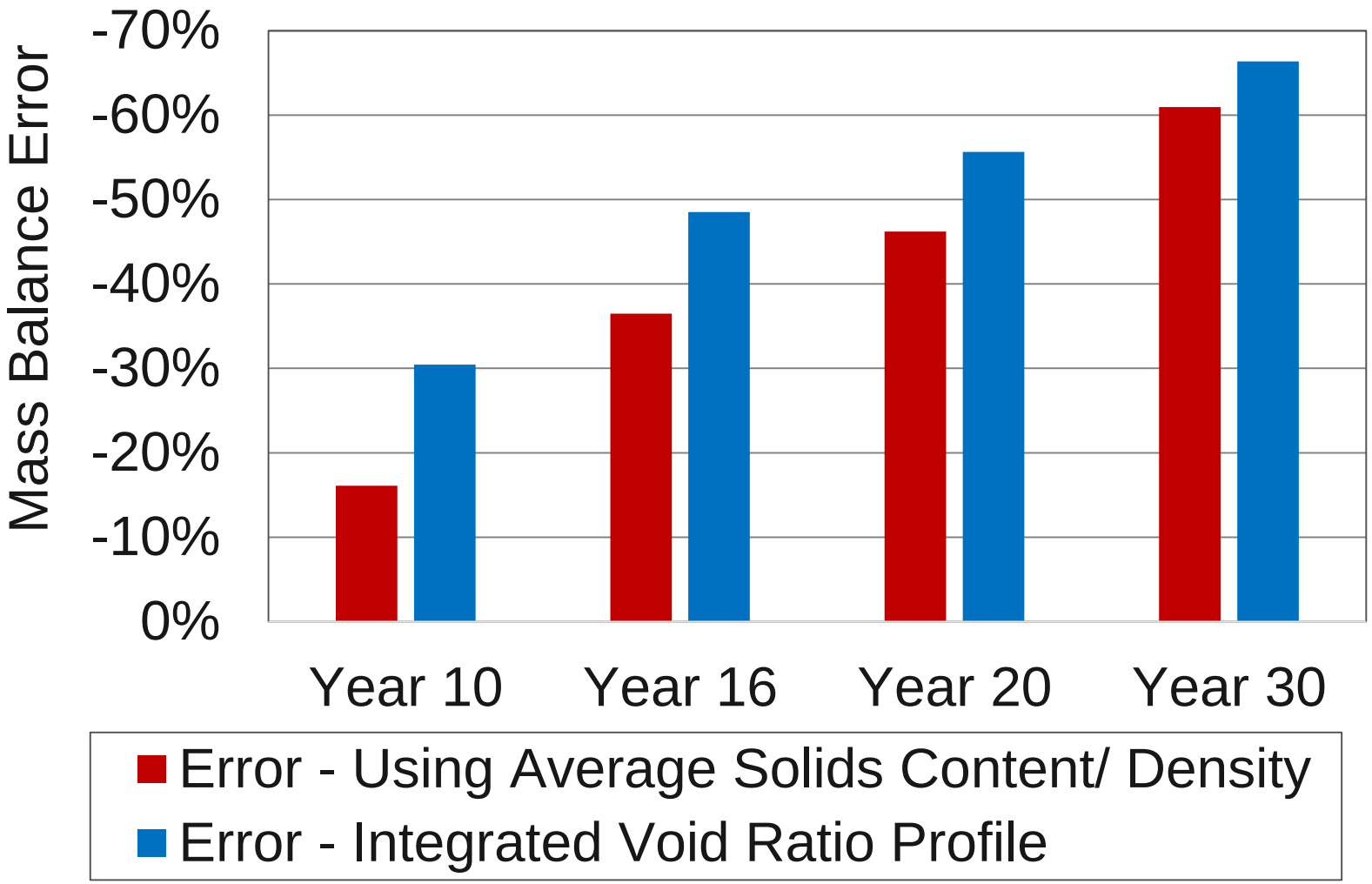
Case 1 – Void Ratio Profiles at 16 years



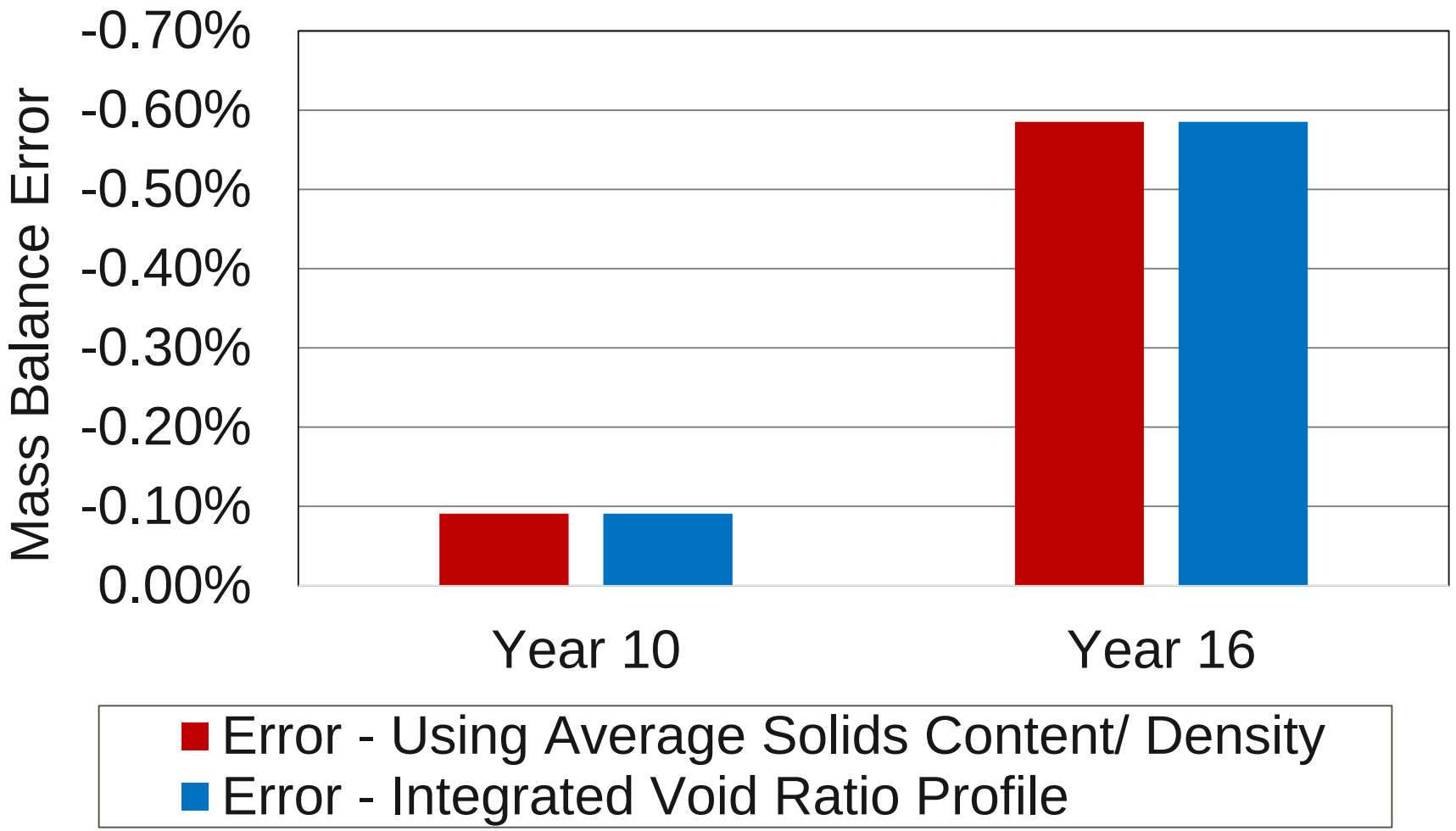
Case 1 – Avg. Void Ratio Profiles at 16 years



Mass Balance Errors – Horizontal Layer Approach



Mass Balance Errors – Vertical Column Model



More things should not be used than are necessary

William of Ockham

Everything should be made as simple as possible, but not simpler

Albert Einstein


GOLDER