Innovative Field Method for Determining Site-Specific Mine Material Expansion and Compaction Characteristics

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Overview

- Basic Expansion/ Compaction Concepts
- Conventional Approaches
- Innovative Approach
- Additional Considerations
- Results

Typical Uses of Expansion/Compaction Factors

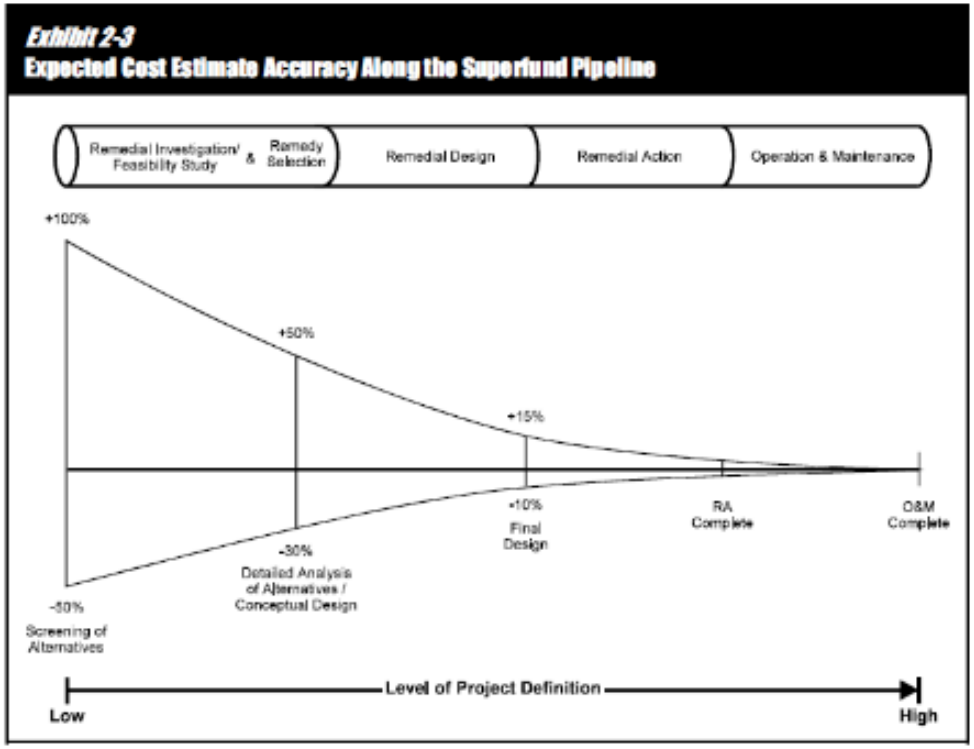
- Quantity Estimates
  - Excavation
  - Loading and Hauling
  - Placement
  - Borrow, Excess, and Amendment
- Cost Estimates
- Design of Repository (or Other Earthwork Features)

Problem Statements

Inadequate consideration of site-specific expansion/compaction factors results in:

- Inaccurate productivity, schedules, and cost estimates $\$\$\$$
- Oversized/undersized repositories (or other earthwork features)

Generic factors most problematic during design and construction phases!



Extracted from *A Guide to Developing and Documenting Cost Estimates during the Feasibility Study.* EPA 540-R-00-002, OSWER 9355.0-75.

Basic Expansion/Compaction Concepts

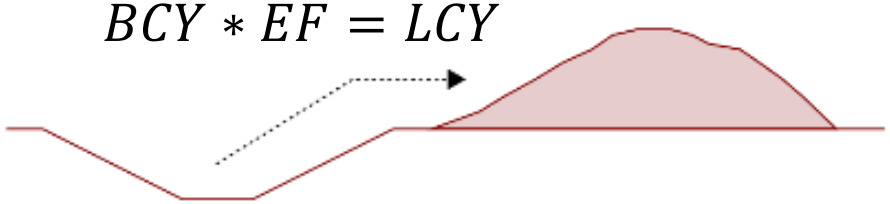
Bank Volume – The volume of material in its undisturbed state (in-place or in-situ).

- Unit: Bank Cubic Yard (BCY)
- Examples: Survey and Excavation Quantities

Basic Expansion/Compaction Concepts

Loose Volume – The volume of material that has been removed from the earth and moved or placed in a different location in an uncompacted state.

$$BCY * EF = LCY$$

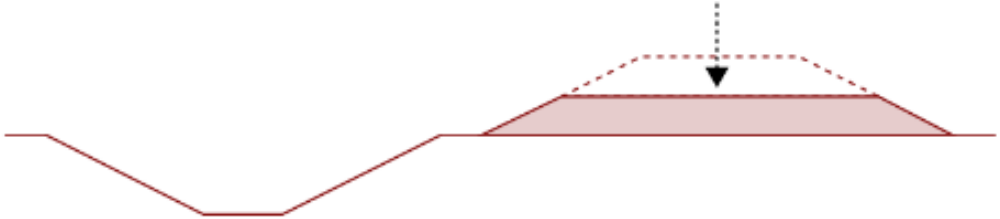


- Unit: Loose Cubic Yard (LCY)
- Examples: Loading and Haul Quantities

Basic Expansion/Compaction Concepts

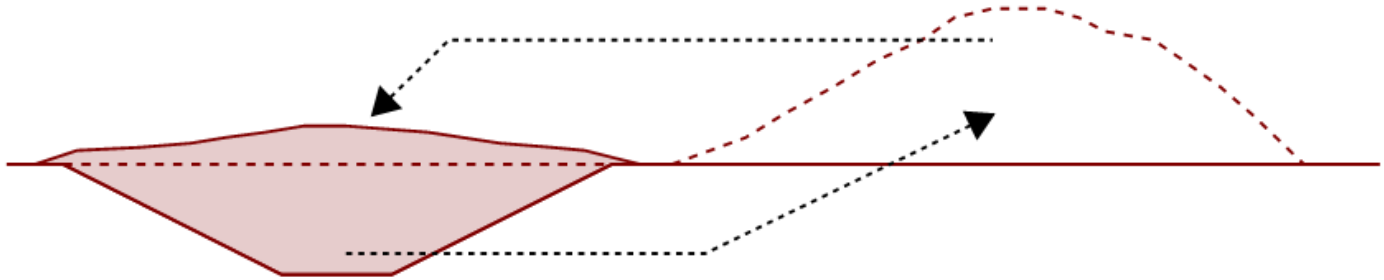
Compacted Volume – The volume of material measured after it is placed and compressed mechanically in a fill. Also known as the embankment volume.

$$LCY * CF = ECY$$

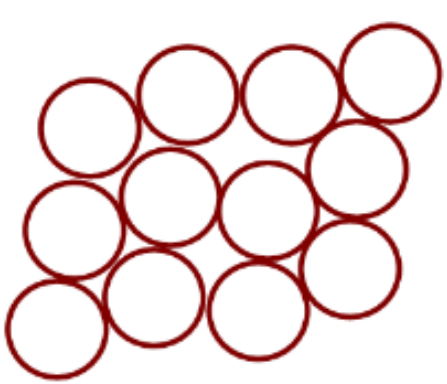


- Unit: Embankment Cubic Yard (ECY)
- Example: Placement Quantities

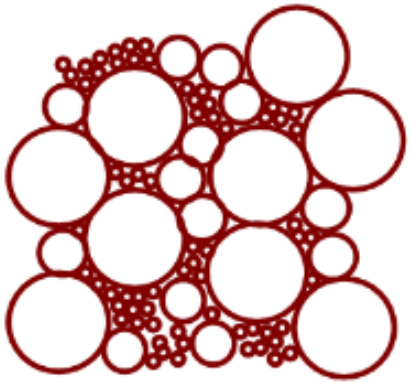
Bank Volume ≠ Loose Volume ≠ Compacted Volume



- Why is this the case?
  - Due to this process, the material occupies different volumes
- Typically LCY>ECY>BCY
- In cases of extreme compactive efforts, BCY>ECY!



Poorly Graded



Well Graded

Conventional Approaches for Estimating Expansion/Compaction Factors

Literature Values:

Generic factors obtained from reference sources for common soil/rock types

- Advantage
  - Readily available
- Disadvantage
  - Limited number of categories
  - Not representative of heterogeneity
  - Lack of site-specific data
  - May not meet design specifications

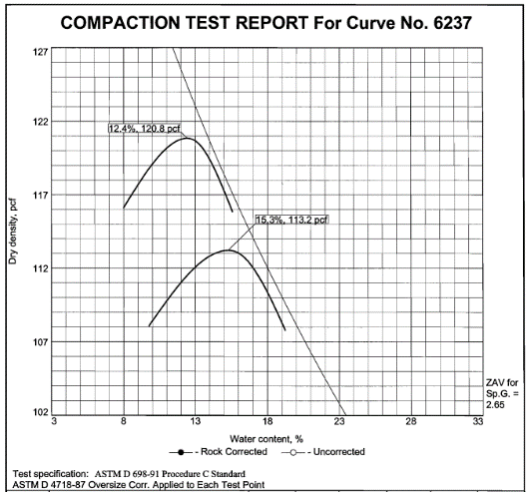
Safety Note: This was a spare hard hat. Always wear your hard hat!

Conventional Approaches for Estimating Expansion/Compaction Factors

<u>Laboratory Geotechnical Data:</u>

Proctor density testing

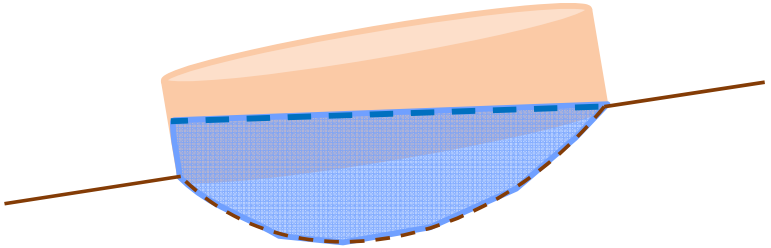
- Advantage
  - Wide variety of soil/ gravel can be tested
  - Site-specific data



- Disadvantage
  - Limited by size
  - Narrow range of compaction effort
  - Delays in obtaining laboratory test data
  - Shipping/disposal of contaminated materials by lab

Starting Basis for Innovative Field Test Method

- ASTM D5030-04 – Standard Test Method for Density of Soil and Rock in Place by the Water Replacement Method in a Test Pit
- Addressed 1 of 3 states of material volumes (i.e. bank volume)
- Innovation is a simplified approach eliminating template
- Also includes method for loose and embankment volume

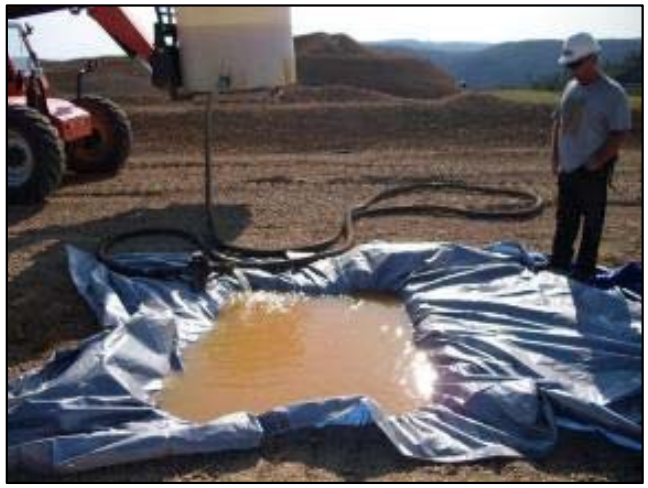


Innovative Field Method Procedure: Bank Volume

1. Excavate Material for Test Pit

2. Line Excavated Test Pit

3. Measure Volume of Test Pit with Water

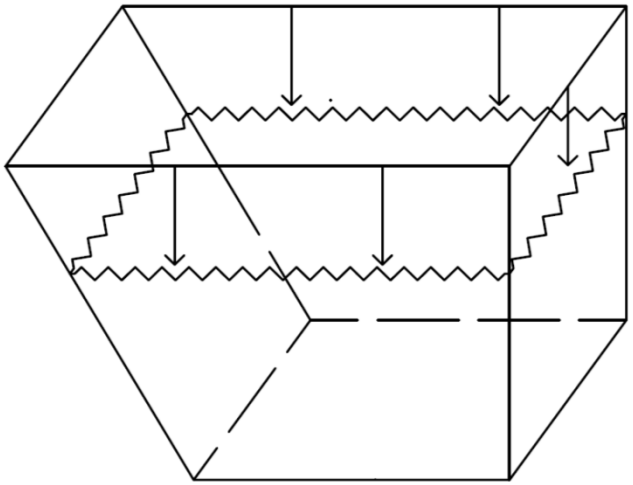


Innovative Field Method Procedure: Loose Volume

1. Place Loose Material in Container

2. Measure Depth to Loose Material

3. Repeat!

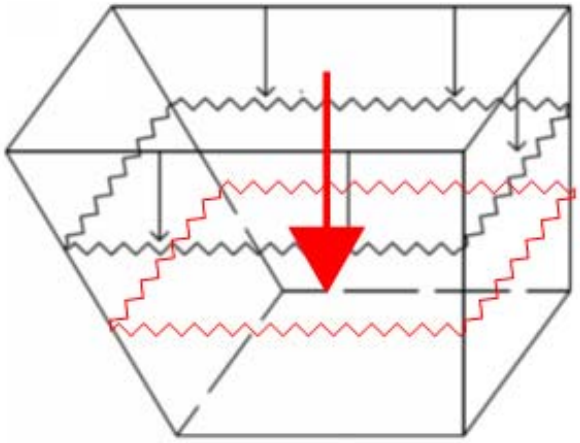


Field Method Procedure: Compacted Volume

1. Compact Loose Volume in Container

2. Measure Depth to Compacted Material

3. Repeat!



Additional Considerations

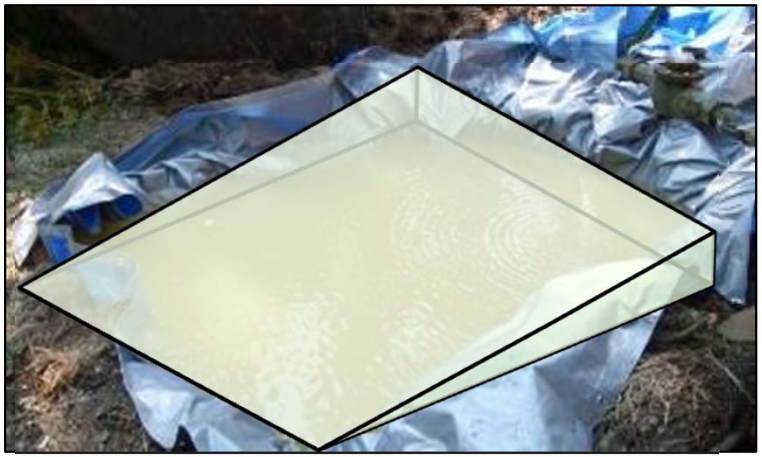
- Test Pit Freeboard

- Container Volume Dimensions
  - Size and Shape
  - Volume Confirmation

Calculations

Volume Calculations

- Bank Volume: Convert gallons of water to cubic yards
  - Freeboard Correction



- Loose and Embankment Volume: Cubic yards calculated from dimension measurements

Factor Calculations

- Expansion Factor:

$$EF = \frac{LCY}{BCY}$$

Water + Freeboard

- Compaction Factor:

$$CF = \frac{ECY}{LCY}$$

- Calculation repeated for each type of material tested

Innovative Approach for Estimating Expansion/Compaction Factors

Field Test Method:
Water replacement and container measurement

- Advantage
  - Wide variety of soil/rock can be tested
  - Larger size fractions (e.g. cobbles, small boulders)
  - Site-specific results
  - Wide range of compaction effort
  - Real-time results
- Potential Disadvantages
  - Additional equipment
  - Limited suitable test locations (e.g. slope)
  - Large volume of materials to manage

Summary of Expansion and Compaction Factors at Gilt Edge Mine Superfund Site, Operable Unit 1 (OU1)

Mine Material Category	Expansion Factor (BCY to LCY)		
	Site-Specific	Professional Judgement	Standard Book Factor[1]
General Fills	**1.27**	1.15 **-10.4%**	1.25 **-1.60%**
Reclamation Fill	**1.18**	1.15 **-2.61%**	1.25 **5.60%**
Onsite Topsoil/Subsoil Stockpile	**1.33**	1.15 **-15.7%**	1.25 **-6.40%**
Onsite Soil Borrow	**1.11**	1.15 **3.48%**	1.25 **11.2%**

[1] Common Earth Factor from *Figure A.9: Weights and Characteristics of Materials, Means Heavy Construction Handbook*

Mine materials have variable expansion characteristics!

Compaction Factor (LCY to ECY)
Standard Book Factor[1]: 0.90
Variability **-2.22%** to **4.44%**

Comparison of Loose Volume Calculations

Estimated Loose Volume for Loading and Hauling

Mine Material Category	Estimated Volume (BCY)	Estimated Volume (LCY)	Difference (LCY)	
		Site-Specific	Professional Judgement	Standard Book Factor Volume[1]
General Fills	4,745,000	6,027,000	(570,000)	(95,000)
Reclamation Fill	968,000	1,143,000	(29,000)	67,000
Onsite Topsoil/Subsoil Stockpile	219,000	292,000	(40,000)	(18,000)
Onsite Soil Borrow	350,000	389,000	14,000	49,000

[1] Common Earth Factor from *Figure A.9: Weights and Characteristics of Materials, Means Heavy Construction Handbook*

Small changes in factors for large volumes equals large differences!

Cost Impact Due to Differing Conversion Factors

Assumed Average Unit Cost for Hauling = **$2.50 per LCY**

Mine Material Category	Estimated Hauling Cost	Difference in Estimated Hauling Cost	
	Site-Specific	Professional Judgement	Standard Book Factor[1]
General Fill	$15,068,000	($1,425,000)	($238,000)
Reclamation Fill	$2,858,000	($73,000)	$167,000
Onsite Topsoil/Subsoil Stockpile	$730,000	($100,000)	($45,000)
Onsite Soil Borrow	$973,000	$35,000	$122,000

[1] Common Earth Factor from *Figure A.9: Weights and Characteristics of Materials, Means Heavy Construction Handbook*

Small changes in factors for large volumes can make major cost differences!

Comparison of Compacted Volume Calculations

Estimated Compacted Volume for Placement

Mine Material Category	Estimated Volume (LCY)	Estimated Volume (ECY)	Difference (ECY)
		Site-Specific	Standard Book Factor Volume[1]
General Fills	6,027,000	5,425,000	0
Reclamation Fill	1,143,000	1,052,000	-23,000
Onsite Topsoil/Subsoil Stockpile	292,000	252,000	11,000
Onsite Soil Borrow	389,000	335,000	16,000

[1] Common Earth Factor from *Figure A.9: Weights and Characteristics of Materials, Means Heavy Construction Handbook*

Small changes in factors for large volumes impact design considerations!

Conclusions

Innovative Field Test Method Results in:

- Improvement in schedules
- Refined accuracy for cost estimates
- Appropriate sizing of repositories and other earthwork features during design
- Additional considerations:
  - Greater impact on large volumes
  - Best use is for large earthwork remediation projects

Acknowledgements

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