TDA in Foundation Engineering

Foundation Engineering
CSU, Chico

Prepared for the CIWMB

Introduction

- Background
- Civil Engineering Applications
- Full Scale Test of TDA as Retaining Wall Backfill
- Case Study
- Conclusion

Basic Information

- Each year, the U.S. generated approximately 300 million scrap tires
- Historically, these scrap tires took up space in landfills or provided breeding grounds for mosquitoes and rodents when stockpiled or illegally dumped
- Fortunately, markets now exist for 82% of these scrap tires-up from about 17% in 1990
- These markets-both recycling and beneficial use-continue to grow
- The remaining scrap tires, however, are still stockpiled or landfilled

Whole Tires and Cut, Stamped, and Punched Products

- Scrap tires may be recycled by:
  - Cutting, punching, or stamping them into various rubber products after removal of the steel bead
- Recycled products include:
  - Floor mats, belts, gaskets, shoe soles, dock bumpers, seals, muffler hangers, shims, and washers
- Whole tires may be recycled or reused as:
  - Highway crash barriers, for boat bumpers at marine docks, and for a variety of agricultural purposes

Scrap Tire Markets

- The 3 largest scrap tire markets are:
  - Tire derived fuel
  - Civil engineering applications
  - Ground rubber applications/ rubberized asphalt concrete

- Both recycling and beneficial use of scrap tires has expanded greatly in the last decade through increased emphasis by state, local and Federal governments, industry, and other associations

- Unfortunately, even with all of the reuse and recycling efforts underway, not all scrap tires can be used beneficially

Tire Derived Fuel

- Tires can be used as fuel either in shredded form - known as tire derived fuel (TDF) - or whole, depending on the type of combustion device
- Scrap tires are typically used as a supplement to traditional fuels such as coal or wood
- In 2003, 130 million scrap tires were used as fuel (about 45% of all generated) - up from 25.9 million (10.7% of all generated) in 1991
- There are several advantages to using tires as fuel:
  - Tires produce the same amount of energy as oil and 25% more energy than coal
  - The ash residues from TDF may contain a lower heavy metals content than some coals
  - Results in lower NOx emissions when compared to many U.S. coals, particularly the high-sulfur coals

Civil Engineering Applications

- The civil engineering market encompasses a wide range of uses for scrap tires
- In almost all applications, scrap tire material replaces some other material currently used in construction such as lightweight fill materials, like expanded shale or polystyrene insulation blocks, drainage aggregate, or even soil fill
- A considerable amount of tire shreds for civil engineering applications come from stockpile abatement projects
- Tires that are reclaimed from stockpiles are usually dirtier than other sources of scrap tires and are typically rough shredded
- Rough tire shreds can be used as embankment fill and in landfill projects

Tire Derived Aggregate (TDA)

Definition:

Pieces of processed tires that have a consistent shape and are generally between 1 and 12 inches in size

Civil Engineering Applications

- Civil engineering applications include:
  - Subgrade Fill and Embankments
  - Backfill for Retaining Walls and Bridge Abutments
  - Subgrade Insulation and Lateral Edge Drains for Roads
  - Vibration Damping Layer Beneath Rail Lines
  - Landfill Applications
  - Septic System Drain Fields

Subgrade Fill and Embankments

- Tire shreds can be used to construct embankments on weak, compressible foundation soils
- Tire shreds are viable in this application due to their light weight
- For most projects, using tire shreds as a lightweight fill material is significantly cheaper than other alternatives
- Subgrade fill and embankment applications include: protecting roads from erosion, enhancing the stability of steep slopes along highways, and reinforcing shoulder areas

Backfill for Retaining Walls and Bridge Abutments

- The lower weight of the tire shreds reduces lateral earth pressures and allows for construction of thinner, less expensive walls
- Tire shreds can also reduce problems with water and frost build up behind walls because tire shreds are free draining and provide good thermal insulation

Subgrade Insulation for Roads

- In cold climates, excess water is released when subgrade soils thaw in the spring
- Placing a 6 to 12-inch thick tire shred layer under the road can prevent the subgrade soils from freezing
- In addition, the high permeability of tire shreds allows water to drain from beneath the roads, preventing damage to road surfaces

Landfills

- Landfill construction and operation is a growing market application for tire shreds
- Scrap tire shreds can replace other construction materials that would have to be purchased
- For Instance, scrap tires may be used as a lightweight backfill in gas venting/collection systems, in leachate collection systems, and in operational liners
- They may also be used in landfill capping and closures, and as a material for daily cover

Septic System Drain Fields

- Some states—Alabama, Florida, Georgia, South Carolina, and Virginia—allow tire shreds to be used in construction of drain fields for septic systems
- Tire-derived material replaces traditional stone backfill material, but reduces the expense and labor to build the drain fields
- Tire chips can also hold more water than stone and can be transported more easily due to their light weight

Other Civil Engineering Applications

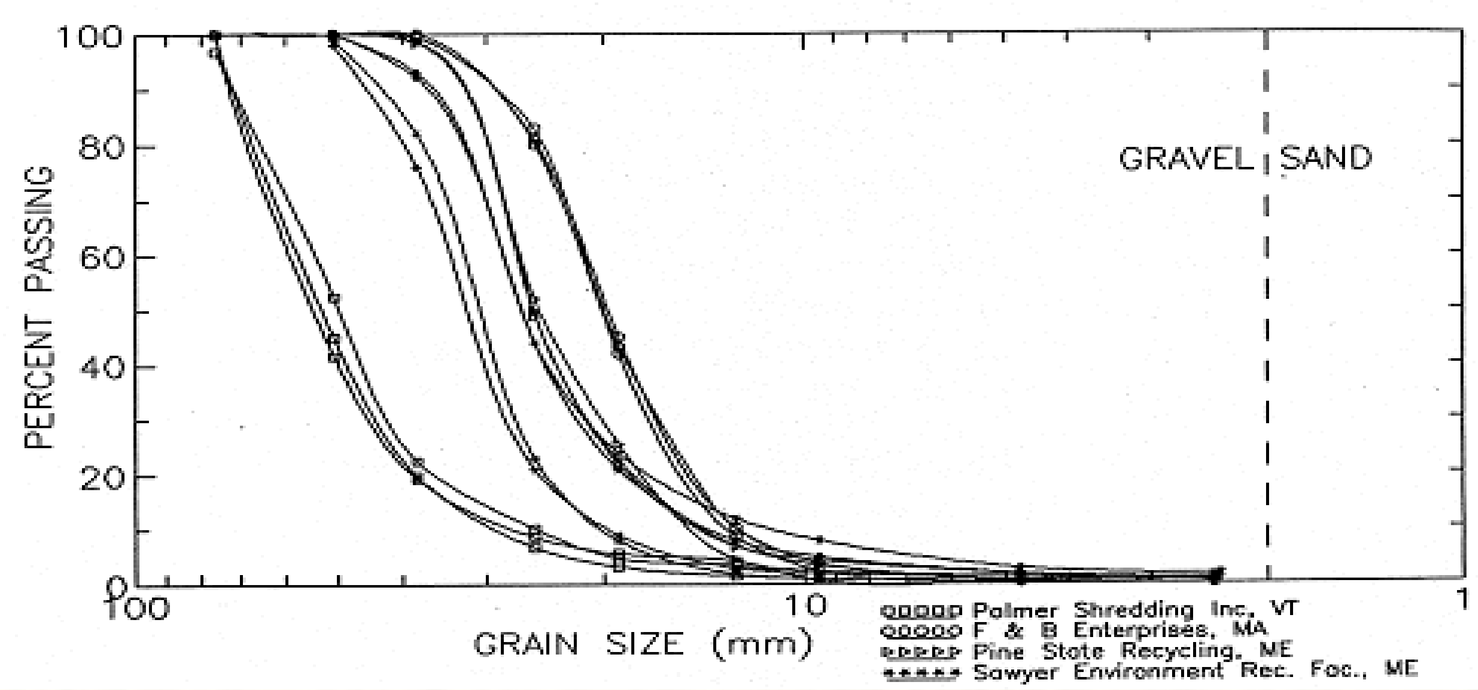
- Playground surface material
- Gravel substitute
- Drainage around building foundations and building foundation insulation
- Erosion control/rainwater runoff barriers (whole tires)
- Wetlands/marsh establishment (whole tires)
- Crash barriers around race tracks (whole tires)
- Boat bumpers at marinas (whole tires)

Engineering Properties of TDA
(After Humphrey, 2003)

1. Gradation
2. Specific Gravity and Absorption capacity
3. Compressibility
4. Resilient Modulus
5. Time Dependent Settlement of TDA Fills
6. Lateral Earth Pressure
7. Shear Strength
8. Hydraulic Conductivity (Permeability)
9. Thermal Conductivity

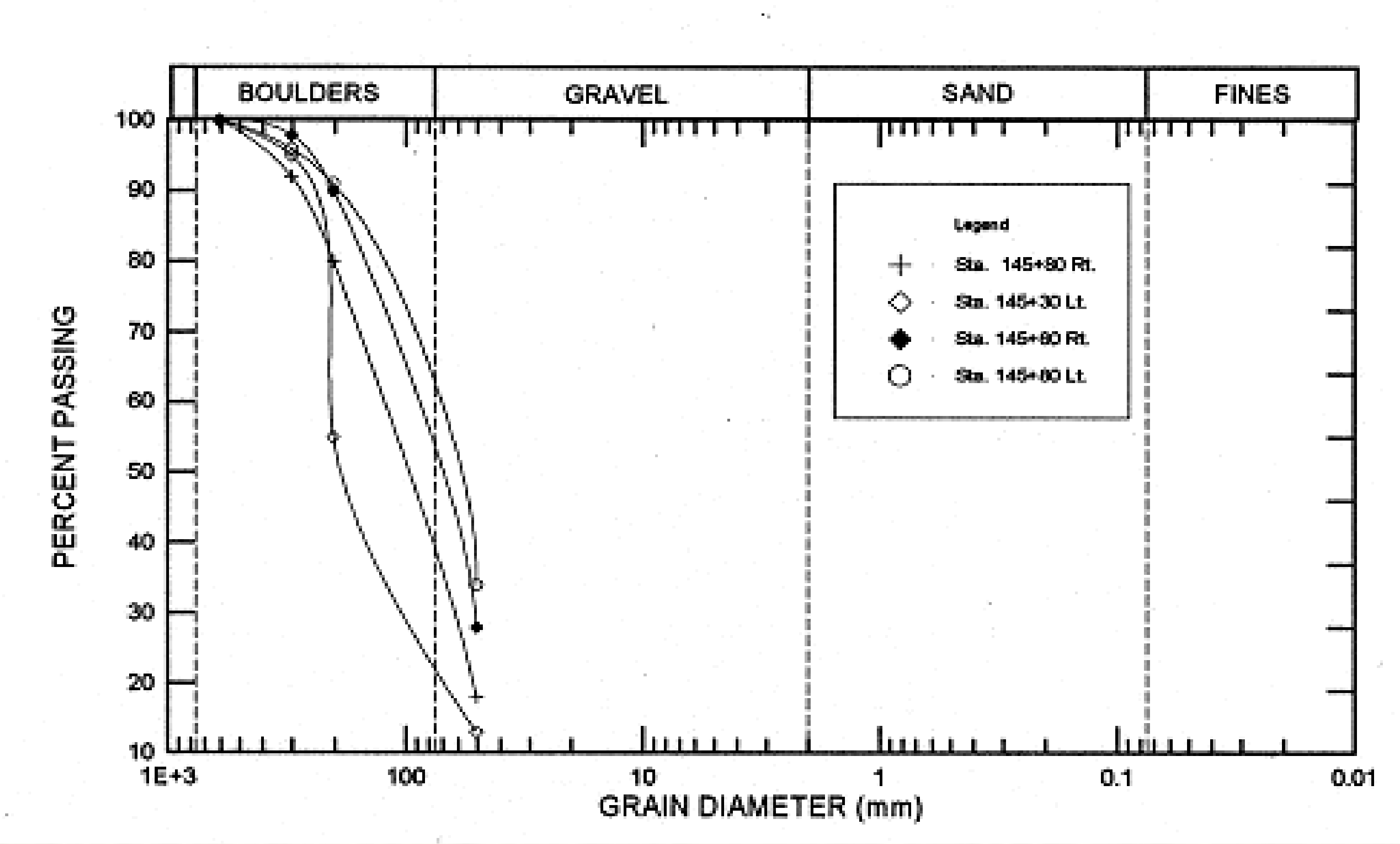
Gradation

- Generally uniformly graded (same size)
- Max size varies according to manufacturing
- Test according to ASTM D 422



Gradation

- **12” Maximum Size:**



Specific Gravity and Absorption Capacity

Tire shred type	Specific gravity			Water Absorption capacity (%)	Reference
	Bulk	Sat. surf. dry	Apparent		
Glass belted	----	----	1.14	3.8	(1)
Glass belted	0.98	1.02	1.02	4	(2)
Steel belted	1.06	1.01	1.10	4	(2)
Mixture	1.06	1.16	1.18	9.5	(3)
Mixture (Pine State)	----	----	1.24	2	(1)
Mixture (Palmer)	----	----	1.27	2	(1)
Mixture (Sawyer)	----	----	1.23	4.3	(1)
Mixture	1.01	1.05	1.05	4	(2)
Mixture	----	0.88 to 1.13	----	----	(4)

Compacted Unit Weight

- Loose 21.3 to 30.9 pcf (no compaction)
- 50 to 60% of Standard 38.3 to 40.1 pcf
- Standard 39.5 to 40.7 pcf
- Modified 41.2 to 42.7 pcf
- Range of dry compacted = 38 to 43 pcf
- Soil typically 125 pcf
- Data also available for TDA/Soil mixtures

Compressibility (3 Reasons)

1. Settlement that will occur during and in the first month or two after placement of fill
2. In-place unit weight of fill varies with compaction effort
3. Deflections caused by temporary loading (e.g. wheel loads) may need to be considered

Compressibility

Definition: The susceptibility of a material to volume change due to changes in stress

Due to its porosity and high rubber content, TDA is highly compressible under loaded conditions.
TDA can compress by as much as 50% under high normal loads.

Lateral Earth Pressure

- Lateral earth pressure is the pressure exerted by a fill material on the wall of a structure like a retaining wall
- It can be determined by coefficients of lateral earth pressure, which are calculated by dividing horizontal stress by vertical stress
- Poisson's ratio, μ, relates horizontal deformation to vertical deformation
- The following table lists values for the coefficient of lateral earth pressure and Poisson's ratio:

Lateral Earth Pressure

Particle size range (in.)	Tire shred type	Source of tire shreds	K_o	μ	Reference
2	Mixed	Sawyer Environmental	0.44	0.30	(1)
3	Mixed	Palmer Shredding	0.26	0.20	(2)
2	Mixed	Pine State Recycling	0.41	0.28	(2)
1	Glass	F & B Enterprises	0.47	0.32	(2)
----	----	----	----	0.3 to 0.17	(3)
2	Mixed	Maust Tire Recycles	0.4[a]	0.3	(4)

Notes: a. For vertical stress less than 25 psi.

References:

(1) Manion and Humphrey (1992); Humphrey and Manion (1992)
(2) Humphrey, et al. (1992, 1993); Humphrey and Sandford (1993)
(3) Edil and Bosscher (1992, 1994)
(4) Drescher and Newcomb (1994)

Shear Strength

- A direct shear apparatus and ASTM D 3080 or a triaxial shear apparatus can be used to measure the shear strength of tire shreds
- When testing tire shreds, larger sample sizes have to be used than are necessary for other soils. This is due to the larger particle size of tire shreds
- Large triaxial shear apparatuses only have limited availability, so tests are generally completed on 1-in or smaller tire shreds
- The triaxial shear apparatus also shouldn't be used for tire shreds with protruding steel belts

Permeability

The permeability of tire shreds is much greater than most granular soils, with experimental values ranging from 0.58 cm/s to 23.5 cm/s. Often times the permeability of TDA exceeds the flow capacity of the test equipment!

The table in the next slide lists hydraulic conductivity (permeability) values for tire shreds:

Summary of reported hydraulic conductivities of TDA

Particle size (in.)	Void ratio	Dry density (pcf)	Hydraulic conductivity (cm/sec)	Reference
2.5		29.0	5.3 to 23.5	Bressette (1984)
2.5		37.9	2.9 to 10.9	
2		29.3	4.9 to 59.3	
2		38.1	3.8 to 22.0	
1.5	----	----	1.4 to 2.6	Hall (1990)
0.75	----	----	0.8 to 2.6	
2	0.925	40.2	7.7	Humphrey, et al. (1992, 1993)
2	0.488	52.0	2.1	
3	1.114	37.5	15.4	
3	0.583	50.1	4.8	
1.5	0.833	38.8	6.9	
1.5	0.414	50.4	1.5	
1.5		0.653	0.58	Ahmed (1993)
1.5	0.693	42.0	7.6	Lawrence, et al. (1998)
1.5	0.328	53.6	1.5	
3	0.857	41.7	16.3	
3	0.546	50.1	5.6	

Thermal Conductivity

- The thermal conductivity of tire shreds is lower than typical soils and varies depending on the size of the tire shreds
- As particle size increases, and more air can circulate in the voids, thermal conductivity increases, and the tire shreds become less effective as insulators
- For insulation projects, tire shreds with a maximum size of 3 inches should be used
- The following slide gives thermal conductivity as a function of density and void ratio:

Apparent thermal conductivities of air dried tire shreds

Sample	Density (pcf)	Density (Mg / m³)	Void Ratio	Apparent thermal conductivity (Btu / hr-ft-°F)	Apparent thermal conductivity (W / m-°C)	Surcharge
gravel	117.6	1.88	0.41	0.295	0.510	none
	121.6	1.95	0.36	0.326	0.563	half
	123.0	1.97	0.34	0.345	0.596	full
F&B-g	38.5	0.62	0.85	0.120	0.207	none
	43.3	0.69	0.64	0.113	0.195	half
	45.4	0.73	0.56	0.114	0.197	full
F&B-s	39.1	0.63	0.85	0.145	0.251	none
	42.8	0.69	0.69	0.130	0.225	half
	45.3	0.73	0.60	0.134	0.232	full
Palmer	39.7	0.64	0.998	0.159	0.275	none
	45.1	0.72	0.76	0.119	0.206	half
	48.5	0.78	0.63	0.125	0.216	full
Pine State	39.2	0.63	0.97	0.158	0.273	none
	45.4	0.73	0.7	0.139	0.240	half
	49.6	0.79	0.56	0.114	0.197	full
Sawyer	36.0	0.58	1.13	0.184	0.318	none
	41.0	0.66	0.87	0.148	0.256	half
	43.7	0.70	0.76	0.156	0.270	full

Why Use TDA

- Tire Derived Aggregate (TDA) has properties that civil engineers, public works directors & contractors need
  - ✓Light weight
  - ✓High permeability
  - ✓Low earth pressure
  - ✓Good thermal insulation
  - ✓Durable
  - ✓Compressible
  - ✓May be cost effective
- Help solve significant environmental problem
- Conserve natural aggregate resources

What is Type A TDA?

Type A TDA - Typical, Three inch minus,
1 Ton = 1.4 cubic yards
1 Ton = 100 tires (PTE)
In Place Density = 45-58 lb/ft³
Permeability › 1 cm/sec

Uses - Drainage material, septic leach fields, vibrations dampening layers under light rail tracks, gas collection media, leachate collection material

What is Type B TDA?

Type B TDA - Typical, 12 inch minus,

- 1 Ton = 1.5 cubic yards
- 1 Ton = 100 tires (PTE)
- In Place Density = 45-50 lb/ft^3
- Permeability › 1 cm/sec for many applications

Uses - Lightweight fill for embankments, lightweight fill behind retaining walls

Dana Humphrey, 2005

ASTM D 6270 Fill Types

Class I Fills:

-TDA placed in layers less than 1m (~3’) thick.
Have a maximum of 50% (by weight) passing the 38 mm (~1.5”) sieve.

Have a maximum of 5% (by weight) passing the 4.75 mm (~.19”) sieve.

Sample Applications of Class I Fills are typically utilized in landfill leachate and gas control applications.

ASTM D 6270-98 Fill Types

Class II Fills:

-TDA placed in layers ranging from 1m (~3’) to 3m (~10’) thick.

Have a maximum of 25% (by weight) passing the 38 mm (1.5”) sieve.

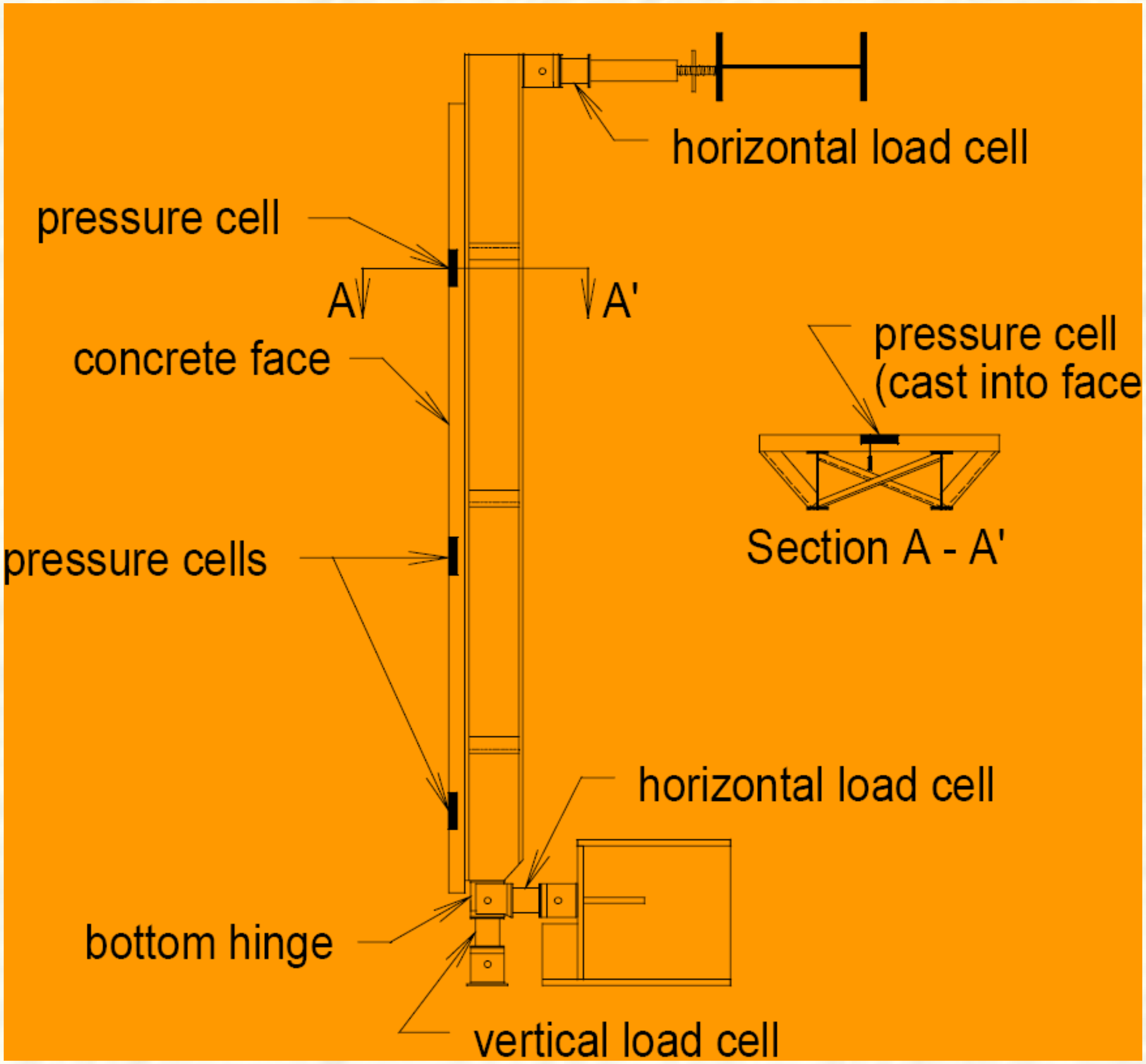
Have a maximum of 1% (by weight) passing the 4.75 mm (~.19”) sieve.

Sample applications of Class II Fills are retaining wall back fills, embankment fills, and slope repairs.

UMaine Test Wall- Introduction

- World's 2nd largest retaining wall test facility (16 ft high, 15 by 15 ft plan area, surcharge of 750 psf)
- Used tire shreds that were 3-in. max and had no removal of steel belts and 1.5-in. max and had most of the steel belts removed
- Tire shreds placed in 8-in. lifts and compacted with 2300-lb roller

Full Scale Testing – UMain Test Wall



Construction of UMain Test Wall

Interior of UMaine Test Wall

Loading TDA Fill

Compacting TDA

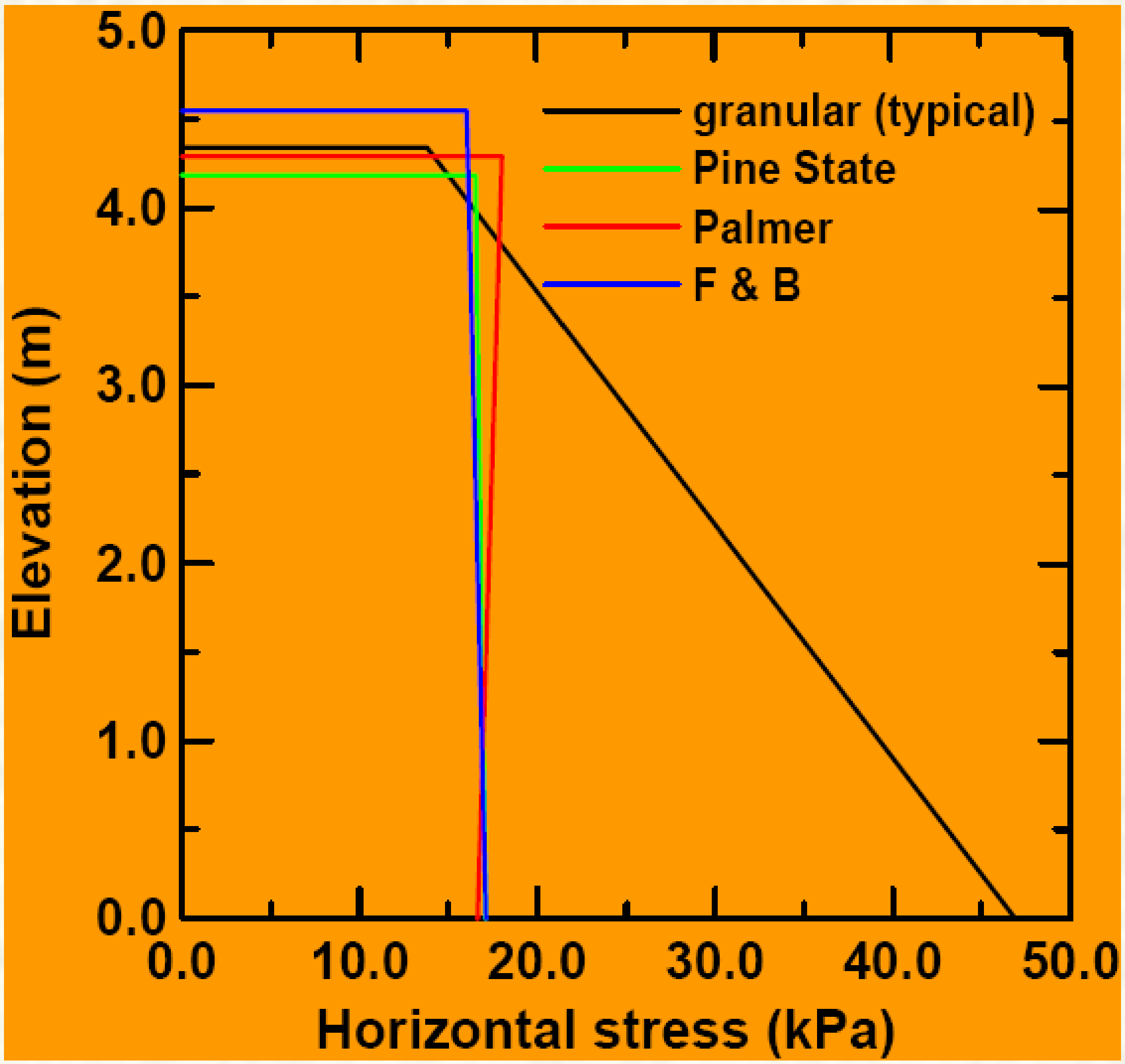
Surcharge Blocks

Fully Loaded Facility

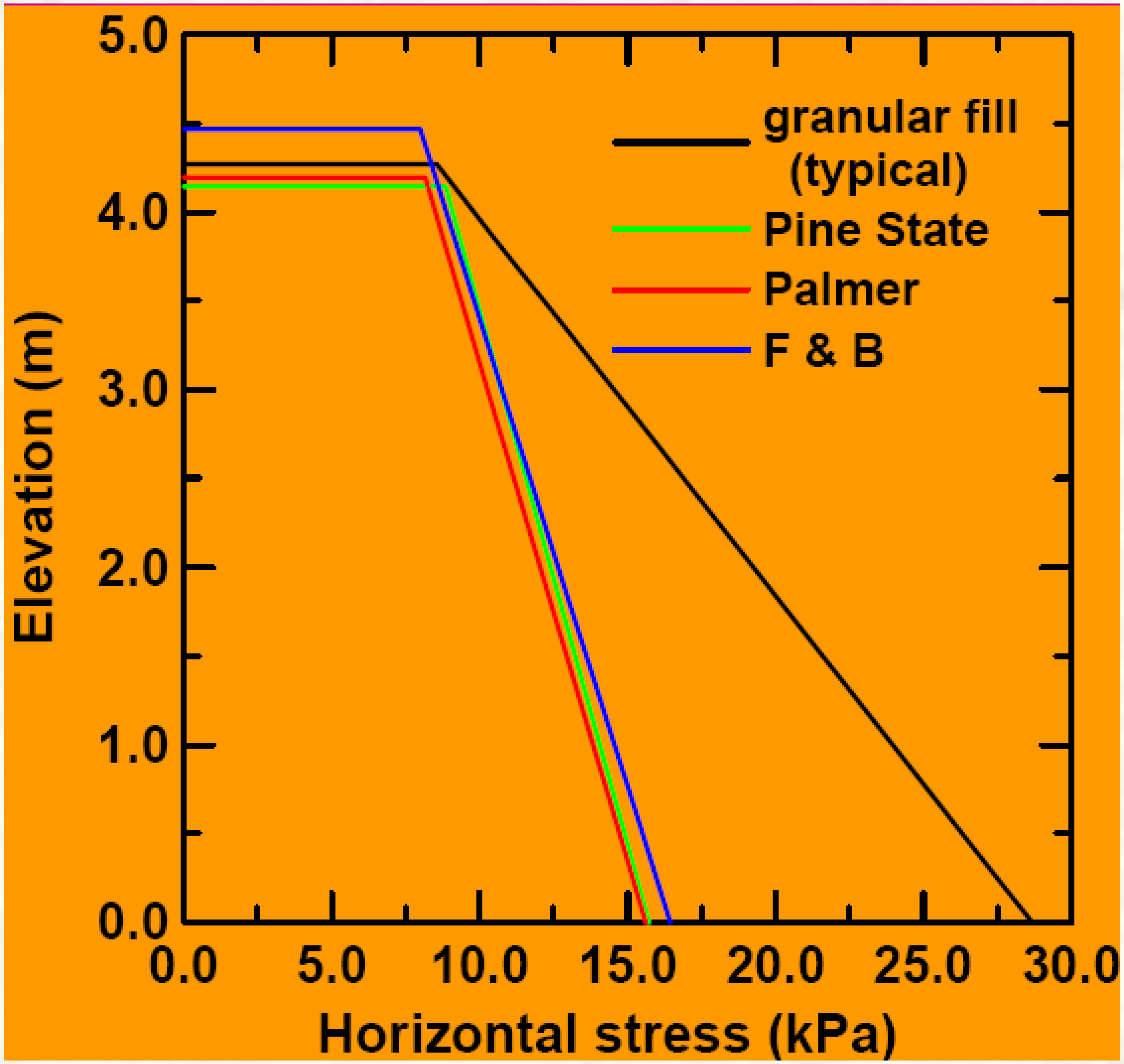
Surcharge blocks

Removable backwall

At-rest stress distribution at 35.9 KPa surcharge



Stress at 35.9 KPa surcharge and 0.01H rotation



After removed backwall

Close-up of TDA

Removing TDA after Test

Benefits of TDA as Backfill

- Lower pressure on wall
- Lateral earth pressure coefficient is not constant, but varies with depth
- Results in nearly constant at rest lateral earth pressure as seen in previous slide
- Less rebar and/or thinner retaining wall
- Get rid of waste tires

TDA Applications

Lightweight Backfill Behind Retaining Walls, Riverside, CA

Case Study for Retaining Wall Backfill

Wall 119, Riverside, CA

- PROBLEM: Widening the westbound side of Route 91 using TDA, is it as effective as typical backfill soil?

Case History Route 91 Retaining Wall

Ding6

- **Retaining Wall 12' tall, with 9.8' of TDA enclosed in a geotextile membrane to prevent soil intrusion**

Slide 51

Ding6 Add a picture
DingXin Cheng, 7/22/2008

Testing

Measurement: Installation of four types of gauges, strain gauges, pressure cells, temperature sensor, and a tilt meter

Wall 119, Retaining Wall Construction

Wall 119, Strain Gauge Installation

Wall 119, Pressure Cell Installation

Wall 119, Temperature Sensor Installation

Wall 119, Tilt Meter Installation

Wall 119, TDA Placement

Wall 119, TDA Compaction

Wall 119, Completed

Project Summary

- Used 1130 cubic yards of type B tire shreds for 262 foot long fill.
- This equates to 76,500 PTE (passenger tire equivalents)
- Find more data at www.usetda.com

Summary

- Background
- TDA has properties that engineers need
- Full scale testing wall with TDA as backfill material
- Case studies
- Can use a lot of waste tires

THANK YOU

QUESTIONS?

http://www.cp2info.org/center