Sustainable Upcycling of Scape Tires for Environmental Cleanup and Construction

Jae K. (Jim) Park, Professor
Dept. of Civil and Environmental Engineering
University of Wisconsin-Madison

Permeation of Polybutylene Pipe and Gasket Material by Organic Chemicals

Jae K. Park, Laurent Bontoux, T.M. Holsen, D. Jenkins, and R.E. Selleck

The Effect of Soils on the Permeation of Plastic Pipes by Organic Chemicals

Thomas M. Holsen, Jae K. Park, Laurent Bontoux, David Jenkins, and Robert E. Selleck

1991-1992

American Water Works Association

Contamination of Potable Water by Permeation of Plastic Pipe

Thomas M. Holsen, Jae Kwang Park, David Jenkins, and Robert E. Selleck

Permeation of Organic Contaminants Through Gasketed Pipe Joints

Edward C. Glaza and Jae K. Park

290

ally!

EurekAlert! | AAAS

PUBLIC RELEASE: 10-NOV-2003

Golfing toward a greener environment

Golf courses are designed to improve playability, not environmental impact, says Jae (Jim) Park, a professor of civil and environmental engineering at UW-Madison and an avid golfer with a 6 handicap. But, as an environmentally conscientious person, Park is also aware of the unintentional side effects of the fertilizers and pesticides applied to the golf-course greens to keep them looking, well, green. These products contain chemicals that trickle into groundwater sources and contaminate the surrounding environment, he says.

Cayman Islands


West Bay
Water Cay
Governors Creek
Seven Mile Beach
North Sound Golf Course
Malportas Pond
Salina Reserve
Grand Cayman
Queen Elizabeth II Botanic Park
Clarinda Beach
Meagre Bay Pond
Sunrise Family Golf Center
George Town
Bodden Town
Caribbean Sea


TOURS DEPART
HOURLY

~2 million tires

CAYMAN iNEWS
OUR EYE, YOUR NEWS
January 22, 2014

Ironwood wants 2,000,000 tyres for unique 'Green Golf Course'

If no one is successful through the tender process this time, Ironwood's plan will not only remove existing tyres but recycle all future tyres.

Denise Gower, spokesperson for Ironwood said, "After approaching Arnold Palmer Design Group with the request to be part of the solution, senior designer Thad Layton responded saying that they would like the opportunity to showcase the recycling aspect and set Cayman atop the world stage in green golf design. The project would also seek *National Audubon Society accreditation."

Ironwood hopes this can spark momentum to resolving the other waste disposal issues by making recycling our primary solution to waste, and to design one of the most unique and environmentally-friendly golf courses in the world.

Consultant for Ironwood, Dr. Jim Park, who is a professor at the Department of Civil and Environmental Engineering at the University of Wisconsin-Madison said:

"I have reviewed many scientific publications to investigate the potential leaching of toxic chemicals. Actually I found that tyres are capable of adsorbing toxic chemicals when the concentrations in the surrounding environment are high. I can assure you there will be no environmental issues when ground tires are used for golf course construction. Actually, pesticides and fertilizers will be removed by ground tyres when they infiltrate through green and fairway grass."

Cayman Islands: $360 Million Mixed-Use Project Planning to Break Ground

January 16th, 2014 | 8:41 am

Caribbean Journal


IRONWOOD
GRAND CAYMAN
CAYMAN ISLANDS
OFFICE
PARK
58 Ac.
FUTURE 9 HOLE
GOLF COURSE
90.2 Ac.
FUTURE 9 HOLE
GOLF COURSE
82 Ac.
IRONWOOD
GRAND CAYMAN
CAYMAN ISLANDS
PHASE ONE
PARKVIEW
SPORTS
VILLAGE
TOWN
CENTRE
COMMERCIAL
PARKING
MULTI
FAMILY
MEADOW
POINT
PARK
PLANT
NURSERY
BOTANIC
PARK
(Not Included)
FUTURE
RESIDENTIAL
67 Ac.
EMPLOYEE PARKING,
MAINTENANCE,
CART STORAGE,
& TURF NURSERY
CAYMAN GOLF CLUB
AT IRONWOOD
Scale 1 Inch = 300 feet
FEET


PHARMACY
Future
Town Centre location
Ironwood
CAYMAN ISLANDS
Tel: (345) 936-4766 | www.ironwood.ky


IRONWOOD
GRAND CAYMAN
CAYMAN ISLANDS

Key Design Concepts for Sustainability

Use of Scrap Tires

Sustainable Storm Water Management

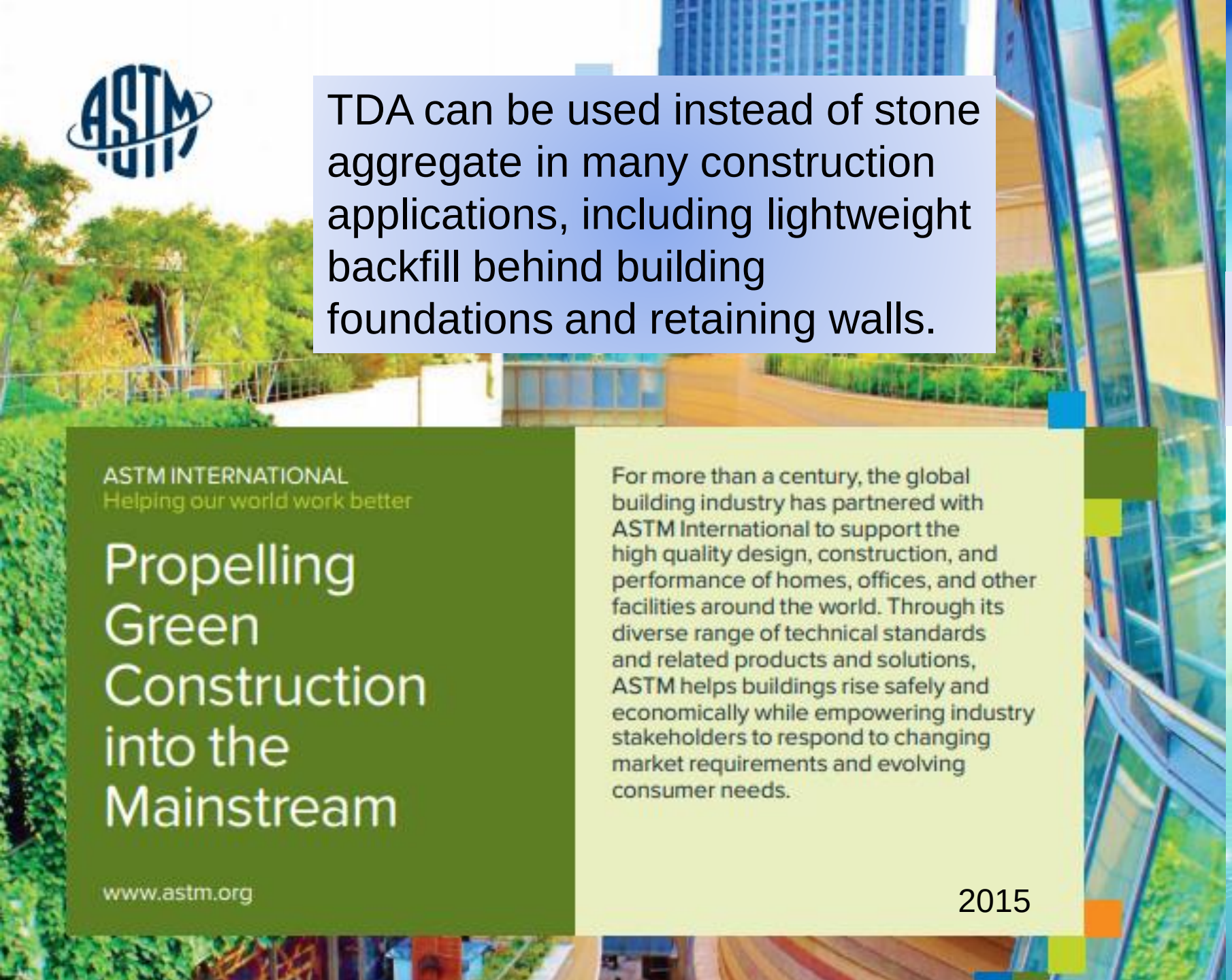
Two Million Tires in a Golf Course Guinness World Record

Prevention of Water Pollution

Eco-friendly landscaping and course management

TDA can be used instead of stone aggregate in many construction applications, including lightweight backfill behind building foundations and retaining walls.

Ten Key Properties of TDA



First State Tire Recycling & R-TEA Manufacturing

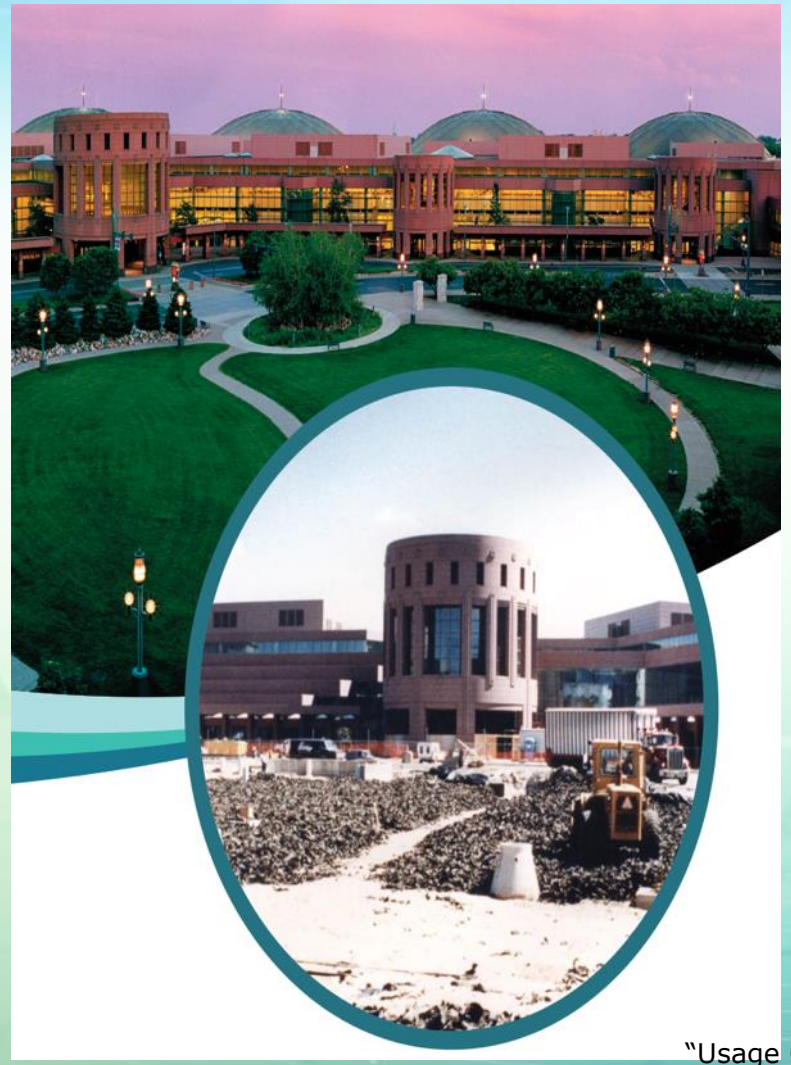
For ALL Your Tire Recycling Needs: 763-434-0578

https://www.firststatetire.com/

First State Tire Recycling & R.-T.E.A. Manufacturing
1500 278th Lane NE
Isanti, MN 55040

R-TEA: Recycled-Tire Engineered Aggregate

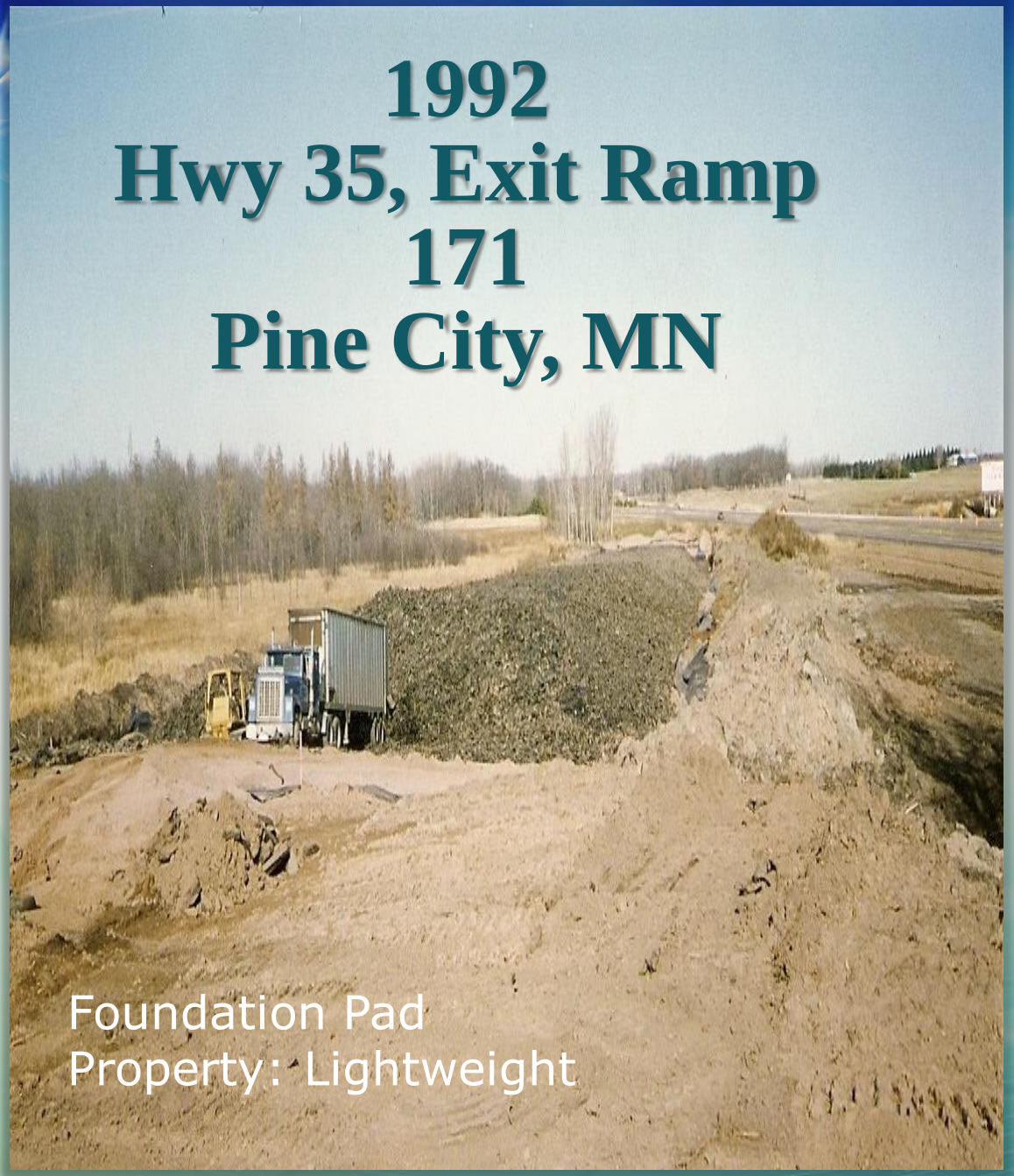
Property #1: Lightweight



- 356 kg/m^3 (600 lbs per loose volume cubic yard) = approximately 1/3 the weight of soil
- 1 ton = 1.65 cubic yards (in place)
- In-place density = 45-50 lb/ft^3
- Stockpile density = 25-35 lb/ft^3

"Usage Guide: Tire-Derived Aggregate (TDA)". CalRecycle, January 2016, Page 56.

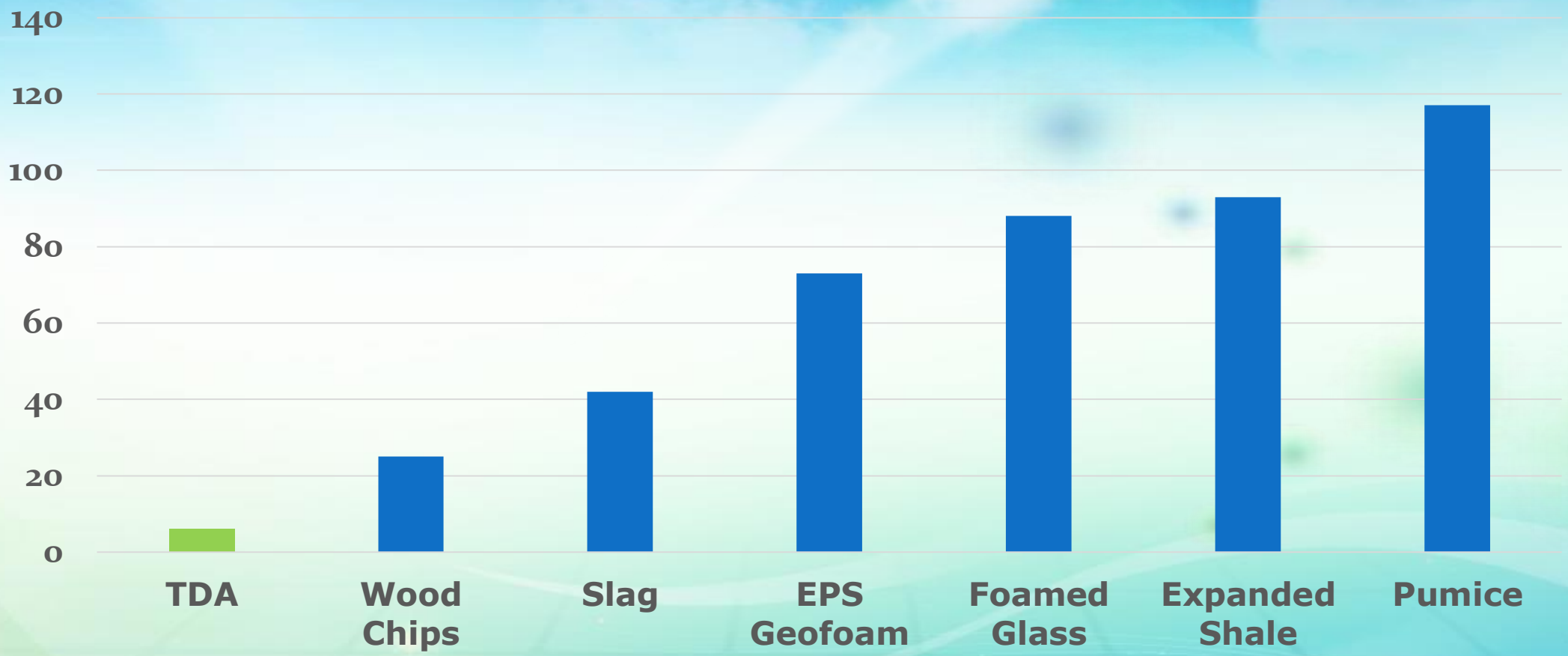
1992
Hwy 35, Exit Ramp
171
Pine City, MN



Foundation Pad
Property: Lightweight

Engineered by: MNDOT

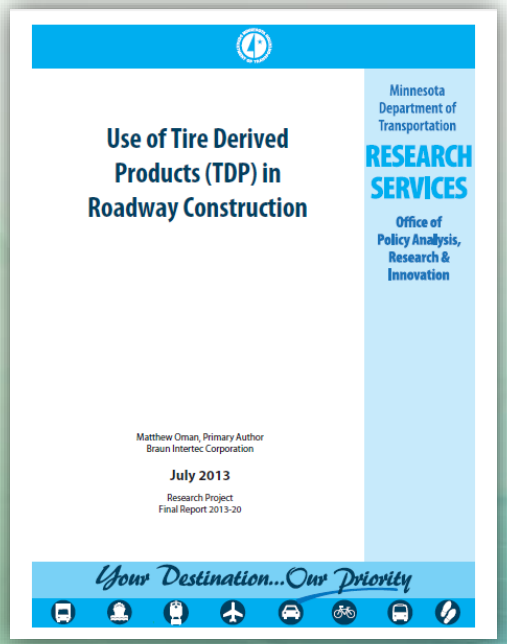
Commonly Used Lightweight Aggregate: Cost Comparison Per Cubic Yard ($US)



This cost comparison does not include freight charges**

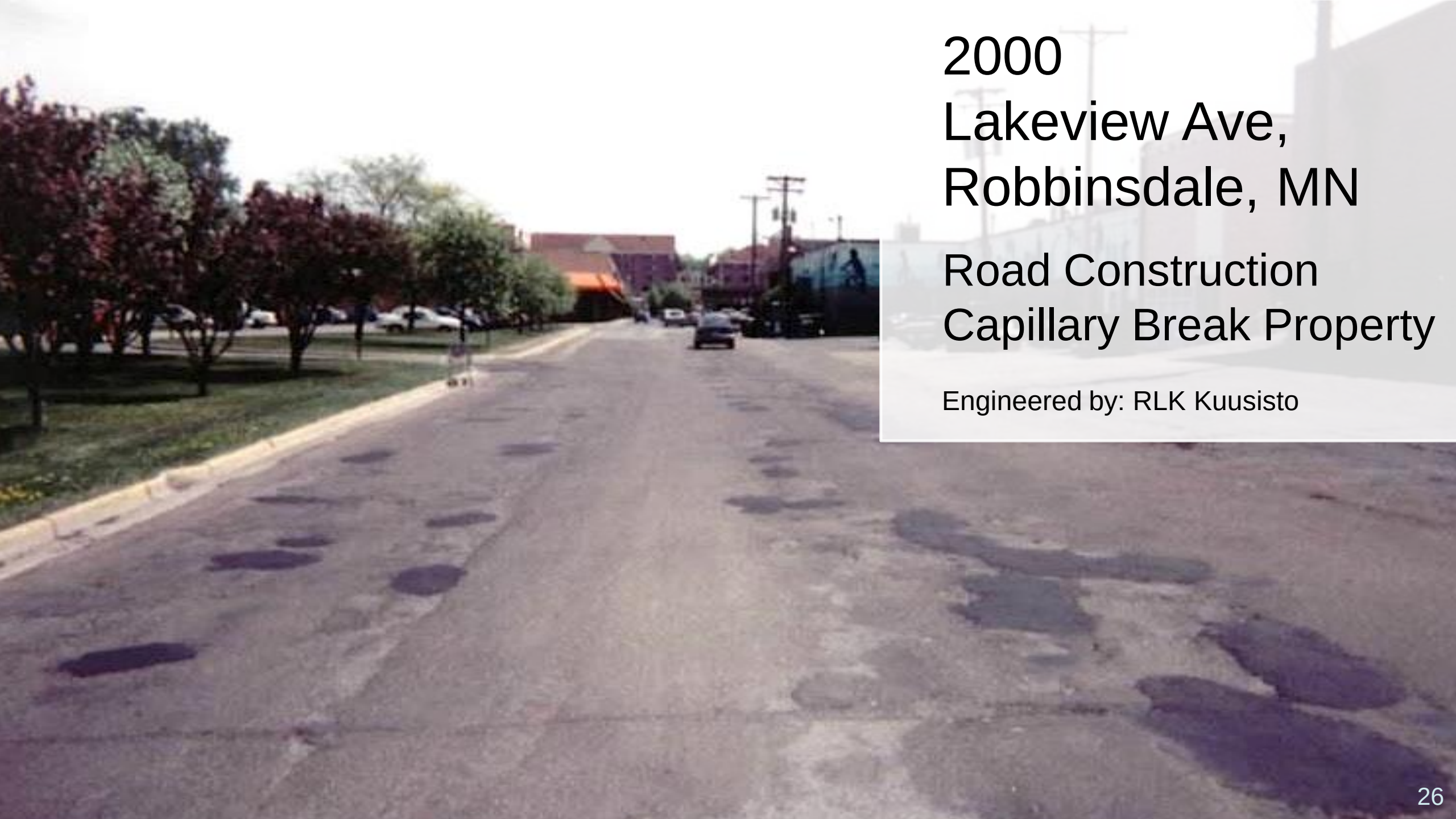
Property #2: Capillary Break

The high porosity of TDA and its hydrophobic properties prevent water from wicking towards the surface, eliminating frost heaving.



Reference

"Use of Tire Derived Products (TDP) in Roadway Construction" Matthew Oman, Braun Intertec Corp., MnDOT., page 9.



2000 Lakeview Ave, Robbinsdale, MN

Road Construction Capillary Break Property

Engineered by: RLK Kuusisto

24 inches of sand over fabric compresses TDA to desired elevation

Completed Project 2000

20 years later photo of Lakeview Ave. Project(2020)

Property #3: Shear Strength

TDA's physical characteristics provide better shear strength than conventional material.

- **Internal shear strength angle = 35-40°**

Shear Resistance of Tire-Derived Aggregate Using Large-Scale Direct Shear Tests

Ming Xiao, M.ASCE[1]; Martin Ledezma[2]; and Corbin Hartman[3]

Abstract: This paper presents a large-scale direct shear testing of tire-derived aggregate (TDA) of large sizes (25–75 mm). The objective of this research is to obtain and compare the shear resistances of large-sized TDA and TDA in contact with sand, concrete, and geosynthetics. TDAs are pieces of processed and shredded waste tires that can be used as lightweight and quick fills for embankments, subgrades, and retaining walls. A large-scale direct shear apparatus was designed and constructed. The shear box dimensions were 79 cm wide, 80 cm long, and 122 cm tall. The lower shear box was driven by a hydraulic piston, while the upper shear box remained stationary. The horizontal shear forces, shear displacements, and vertical forces were recorded by an automatic data acquisition system. Three normal loads were applied on the TDA to simulate overburden pressures of 24, 48, and 96 kPa (or 500, 1,000, and 2,000 lb/ft^2). Duplicate tests were performed to verify the repeatability. The control tests using sand proved that the equipment could obtain comparable and slightly conservative shear strength. The Mohr-Coulomb failure criterion was used to obtain the cohesion (or adhesion) and friction angles of the TDA. The shear testing revealed the difference of failure mechanisms of TDA and sand. For TDA, no peak shear resistance was observed during the entire shearing, and shear resistance continued to increase until the test was terminated at sufficient shear displacement. Further analysis revealed that the shear strength parameters of TDA increase with shear deformation; this represents a challenge in selecting the design parameters of TDAs. The shear strengths of TDA and TDA in contact with other materials are dictated primarily by friction. The friction angles of TDA, TDA on sand, and TDA on concrete are very similar (in a range of 35–39°). **DOI:** 10.1061/(ASCE)MT.1943-5533.0001007. © 2014 American Society of Civil Engineers.

Author keywords: Tire-derived aggregate (TDA); Shear strength; Large-scale direct shear test.

Introduction

The U.S. Federal Highway Administration (FHWA) has estimated that approximately 280 million tires were discarded each year by American motorists, 40% of which were disposed in landfills, stockpiles, or illegal dumps (FHWA 1997). In California, for example, approximately 44.8 million reusable and waste tires were generated annually, with nearly 250,000 waste tires remaining in stockpiles throughout California (CalRecycle 2010). These stockpiles pose a potential threat to public health, safety, and environment. Tire shreds, also known as tire-derived aggregate (TDA), are pieces of processed and shredded waste tires that have a "basic geometrical shape and range between 2 in. (50 mm) and 12 in. (305 mm) in size and are intended for use in civil engineering applications" [ASTM D6270-08 (ASTM 2012)]. Some of the applications include lightweight and quick fills for embankments and subgrades and retaining wall backfills.

Two types of TDA are commonly categorized in the practice: Type A, with a maximum size of 75 mm (3 in.), and Type B, with a maximum size of 305 mm (12 in.). TDA of different sizes has been widely studied as alternative backfills in the past 20 years, and a large body of literature is available (e.g., Humphrey and Manion 1992; Bosscher et al. 1992; Tweedie et al. 1998; Strenk et al. 2007; Tandon et al. 2007). These studies have expanded the knowledge on the mechanical characteristics and in situ performances of embankments and retaining walls using tire shreds or chips. In a recent study, Pando and Garcia (2011) summarized the shear strengths of tire crumbs (2–13 mm or 0.08–0.5 in.) under various confining pressures obtained by previous researchers. Moreover, they reported the ranges of effective cohesion (0–11.4 kPa) and effective friction angle (8.2–14.9°) of crumbs of maximum size of 4.5 mm (0.18 in.) at 20% strain when the material was subjected to confining pressures ranging from 25 to 100 kPa. A mixture of shredded tires and sand is another backfill alternative, and its static responses (stress, deformation, strength) have also been investigated (e.g., Tatlisoz et al. 1998; Bosscher et al. 1997; Lee et al. 1999; Wartman et al. 2007).

Large-scale direct shear tests were also conducted on TDA and TDA–sand mixtures. Table 1 summarizes a few notable TDA shear testing studies in the literature. These studies provided comparable shear resistances of TDA of large sizes. Bernal et al. (1997) noted that the rubber–sand and tire shred specimens did not develop well-defined peak shear resistance within the allowable shear displacement of 6 cm. A shear device with larger dimension and larger displacement may provide a better understanding of the shear resistance developments of TDA of large sizes (25–75 mm) under a wide range of vertical overburden stresses (e.g., 20–100 kPa). Moreover, in civil engineering applications involving TDA, the TDA may be in contact with other civil engineering materials, such as soil, concrete, and geosynthetics. A comprehensive experimental study of the relative shear resistances of TDA and TDA with other materials may provide a useful reference for the practice. Therefore, the objective of this research is to obtain and compare the

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[3]Staff Engineer, LGC Geotech, San Clemente, CA 92672.

Note. This manuscript was submitted on July 10, 2013; approved on December 16, 2013; published online on December 18, 2013. Discussion period open until December 8, 2014; separate discussions must be submitted for individual papers. This paper is part of the *Journal of Materials in Civil Engineering*, © ASCE, ISSN 0899-1561/04014110(8)/$25.00.

Reference

"Shear Resistance of Tire-Derived Aggregate Using Large-Scale Direct Shear Tests"
Ming Xiao, M.ASCE1; Martin Ledezma2; and Corbin Hartman3

2009
River Road
Bismarck, ND

Slope Stabilization
Shear Strength Property

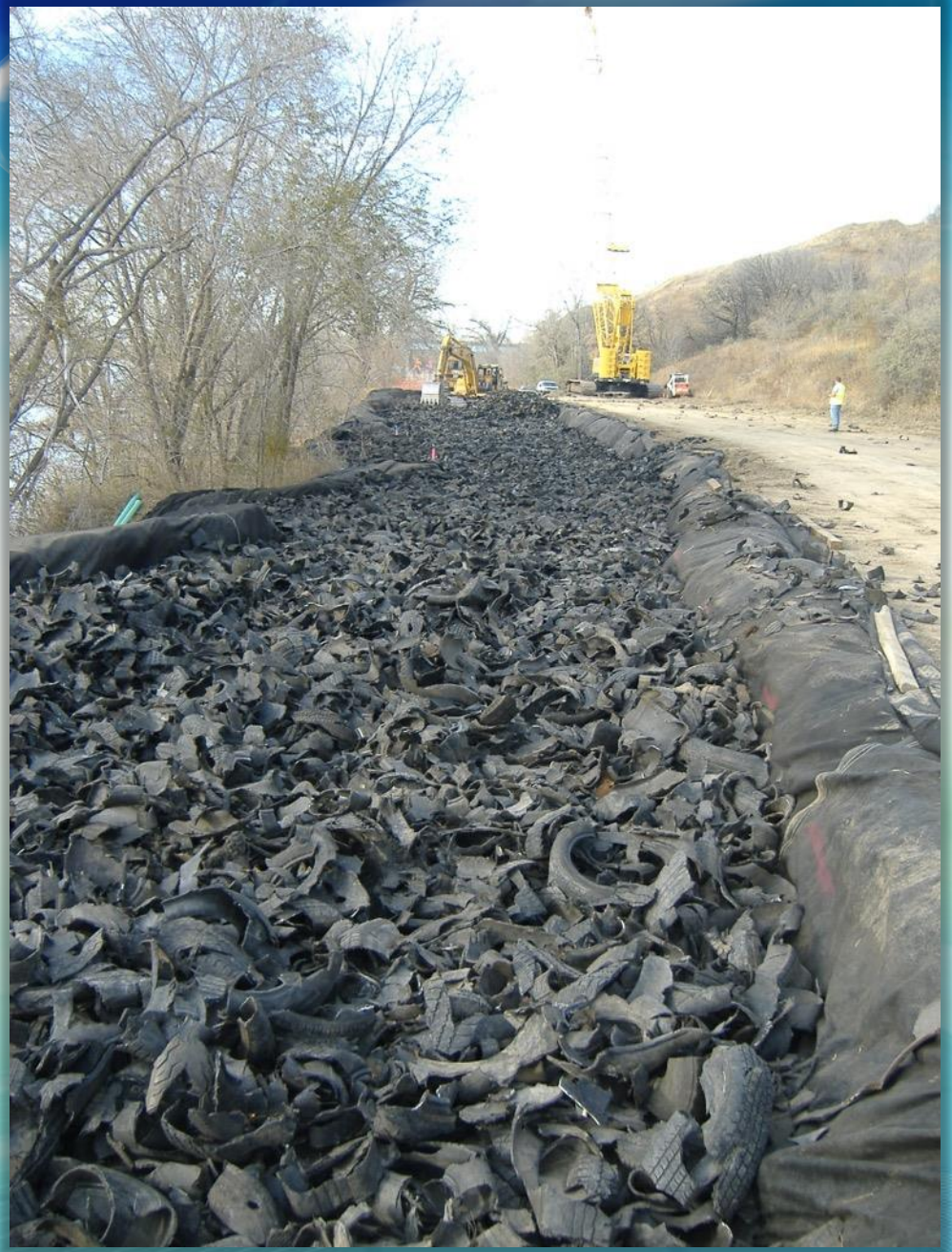
Engineered by: Braun Intertec
Contractor: Sand Creek Corporation

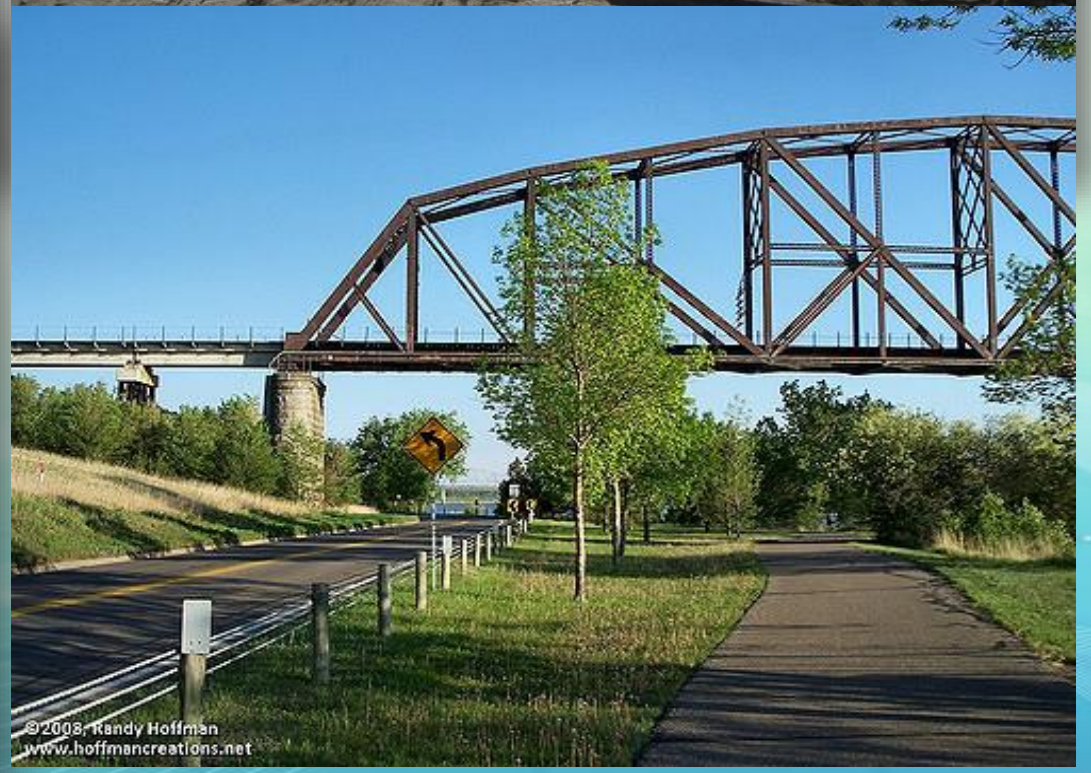
- Internal shear strength angle = 35-40˚

- TDA's physical characteristics provide better shear strength than conventional material.

The road subsided 2-3 feet in two months.

TDA Installation

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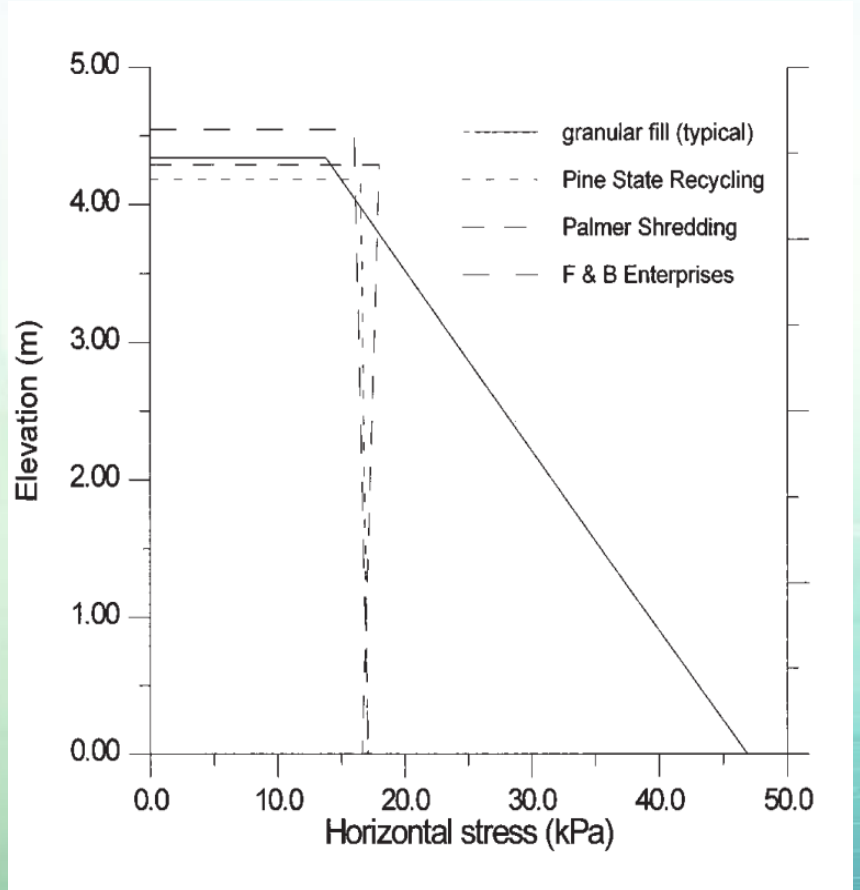
www.hoffmancreations.net

Property #4: Reduced Lateral Load

TDA reduces the lateral load against adjoining structures by approximately 50%.



Lake Jonathan Flats, 2018
Retaining wall backfill using TDA

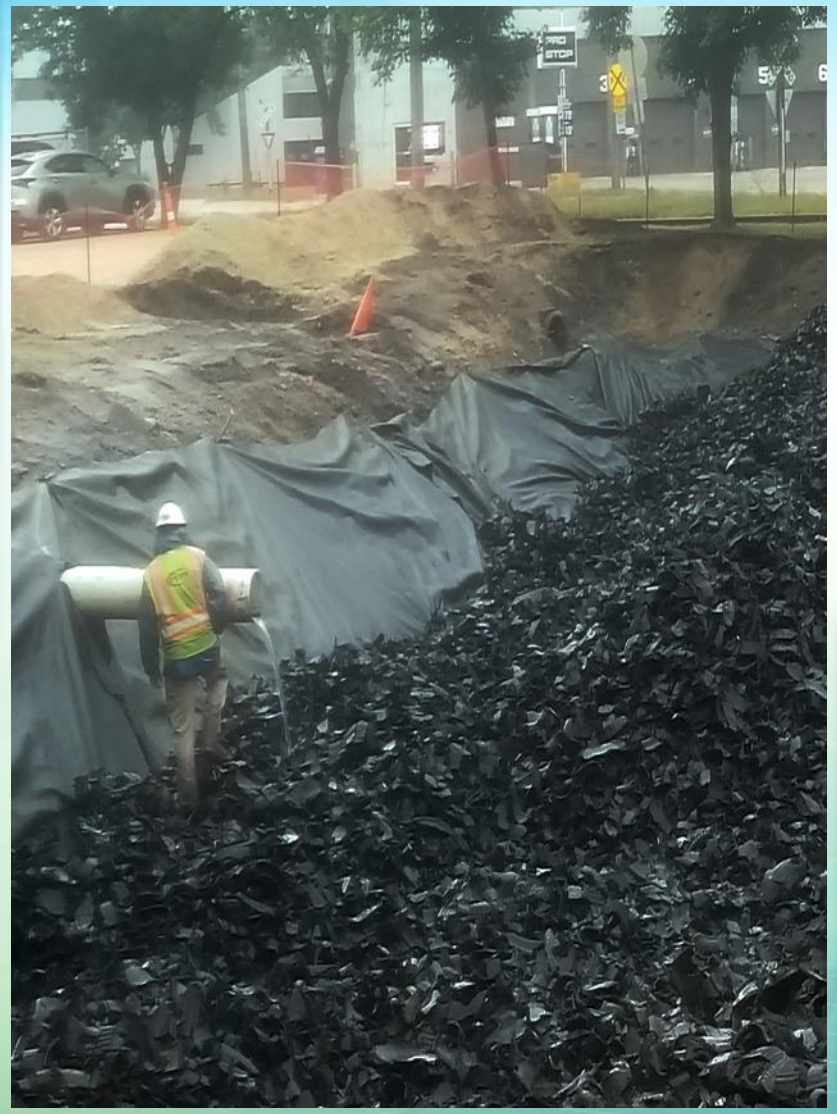
Lake Jonathan Flats

TDA is placed in 2-foot lifts

Property #5: Interlocking

The irregular individual pieces of TDA produces internal reinforcement, creating a "Snowshoe Effect" which prevents differential settlement and adds global support to an overlying structure.

Property #6: Permeability



TDA is a free draining material with high permeability.

TDA's permeability ranges from 30 to 51 cm/s.

Designation: D6270 - 17

Standard Practice for
Use of Scrap Tires in Civil Engineering Applications

Reference
ASTM D 6270-B 20

Drainage Trench

Road Edge Drain

Septic Drain Field

Road Drain Tile Application

TDA can be designed to replace stone in Edge or French drains.

Replacing sand with TDA enhances runoff permeation significantly through the road tile.

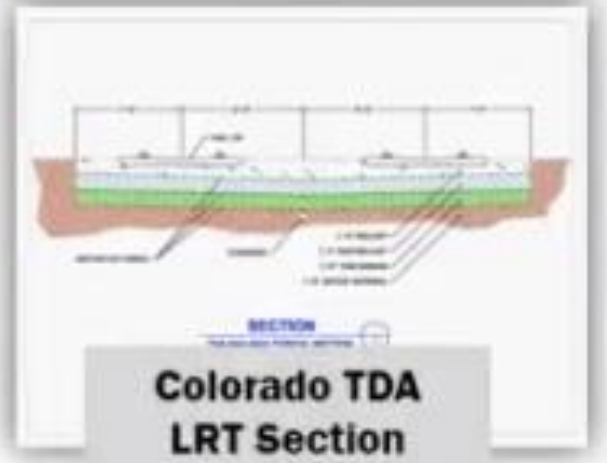
Underground Drainage, Prior Lake High School, MN 2005

Property #7:Vibration Mitigation

- TDA absorbs vibration that minimizes noise.

Reference – “Use of TDA Underlayment to Reduce Groundborne Vibration from Rail Transit Systems”.


Vasona Light Rail, Cal.


Colorado TDA LRT Section

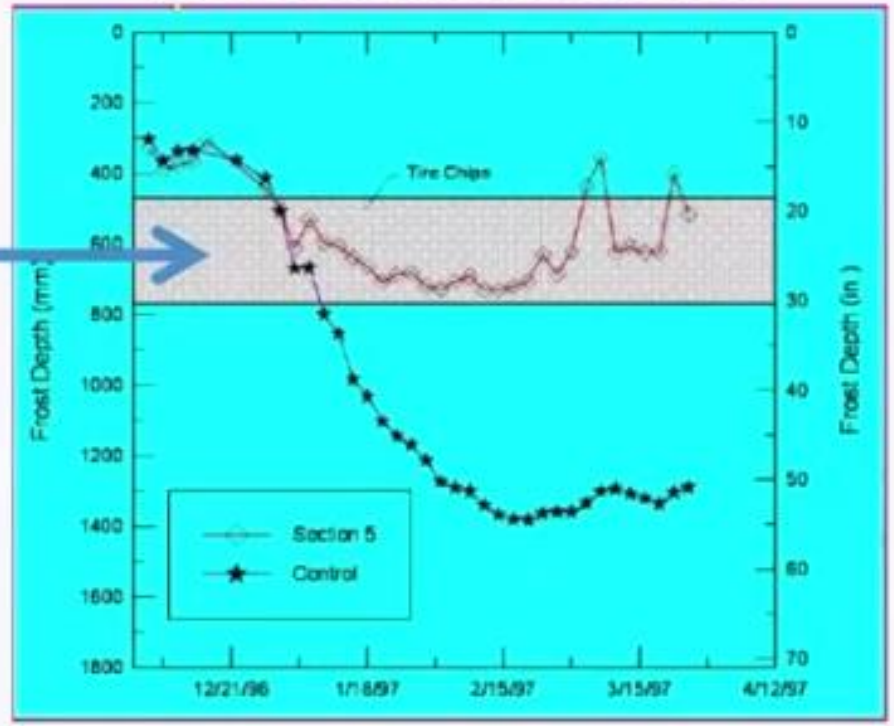
Texas Light Rail Vibration TDA Marketing


PLATFORM 4

Property #8 – Thermal Insulation

- Eight times better thermal insulation than soil.

"Civil Engineering Applications of Tire Derived Aggregate" Dana Humphrey, Ph.D. P.E. Professor of Civil Engineering



TDA Layer

TDA creating a thermal barrier & preventing frost penetration.

Reference – "Usage Guide: Tire-Derived Aggregate".

Property #9: Void Space

TDA has approximately 50% void space after compaction.

TDA has a very large storage capacity for liquids and gases.

TDA: Approx. 50%

Stone: Approx. 25%

Stormwater Management

These vaults are typically backfilled with stone, which has approx. 30-35% void space, and costs $20-40 per cubic yard + delivery.

Using **TDA in place of stone** can **double** water storage capacity and reduce aggregate costs by **75%.**

Property #10 – Filtration Factor

- Removes pesticides, nitrates, and phosphorus.

ECO-FRIENDLY FILTER ZONE

Improve Water Quality

Advances in Recycling & Waste Management: Open Access
Jae K. Park and Changqing Ye
2016

Conclusion:

"..tire rubber is capable of adsorbing toxic organic and inorganic compounds when the concentrations in the surrounding environment are high."

"Out of 51 pesticides, 37 pesticides were estimated to be removed with the tire rubber layer thickness of < 20 cm under a typical scenario."

Reference – Jim Park, University of Wisconsin-Madison

Removal of Emerging Contaminants by TDA

- **PFAS-related chemicals**: (1) defluoridation as a reducing agent, (2) biomass growth medium, (3) sorption, and (4) chemical precipitation
- **6PPD-related chemicals**: sorption
- **Micro/nano-plastics**: sorption and filtration
- **Heavy metals**: sorption.
- **Nitrate**: sorption and biodegradation
- **Phosphorus**: sorption
- **Oil/grease**: sorption, i.e., a non-polar (hydrophobic) rubber attracting non-polar organic compounds
- **Synthetic organic compounds**: sorption, i.e., a non-polar (hydrophobic) rubber attraction non-polar (hydrophobic) synthetic organic compounds

Is TDA Safe to Use?

Tire Derived Aggregate - ASTM D 6270
Environmental Conclusions

Above Groundwater:

TDA does not cause primary drinking water standards for metals to be exceeded.

Below Groundwater:

"For water that is collected directly from the TDA fill below the groundwater table, it is likely that the concentrations of manganese and iron will exceed their secondary drinking water standards. The concentrations decrease to near background levels by flowing only a short distance through soil (0.6 to 3.3 m)"


“TDA placed below the water table would be expected to have a negligible off-site effect on water quality.”
ASTM D 6270, Page 7

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This special issue is aimed to compile research activities that occurred all over the world on water and wastewater management and to provide future research directions.

The scope of the special issue is as follows:

1.Water quality management in rivers, lakes, and ocean

2.Decision making for infrastructure investment

3.Water treatment plant operation and optimization

4.Wastewater treatment plant operation and optimization

5.Energy management in water and wastewater management

Big Data and Artificial Intelligence in Sustainable Water and Wastewater Management

Guest Editor

Prof. Dr. Jae Kwang (Jim) Park

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