# Best Management Practices for using Tire Derived Aggregate (TDA) in Civil Engineering Applications

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Contractor's Report
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# Purpose

The purpose of this document is to provide general guidance for selecting and implementing Best Management Practices (BMPs) in using Tire Derived Aggregate (TDA) in civil engineering applications. The following provides the framework for an informed selection of BMPs. Due to the diversity in climate, construction site conditions, and local requirements across California, this document does not dictate the use of specific BMPs and therefore cannot guarantee compliance with NPDES permit requirements or local requirements specific to the user's site.

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# Acronyms and Abbreviations

| | |
|---|---|
| ASTM | American Society for Testing and Materials |
| BART | Bay Area Rapid Transit |
| BMP | Best Management Practice |
| CASQA | California Stormwater Quality Association |
| CE | Circular Economy |
| cf | cubic foot |
| cm/sec | centimeter per second |
| cy | cubic yard |
| ELT | End-of-Life Tire |
| EPA | Environmental Protection Agency |
| GHG | Greenhouse Gas Emissions |
| in/min | inches per minute |
| MM | Millimeter |
| MTA | Metropolitan Transportation Agency |
| pcf | pounds per cubic foot |
| PTE | Passenger Tire Equivalent |
| SMM | Sustainable Materials Management |
| TDA | Tire Derived Aggregate |
| TWP | Tire Wear Particles |

# What is Tire Derived Aggregate

Whole waste tires have been successfully used in slope stabilization and creek revetment projects in California since the late 1970's. Although successful as an engineering application, whole waste tire reuse resulted in very limited use. After the End-of-Life Tires (ELTs) stockpile fires that occurred in the late 1990s, the State of California developed and initiated the current program of investigating alternative uses and promoting markets for the ELTs of the State.

California, and its agency CalRecycle, is currently tasked with safely managing and diverting more than 40 million ELTs from landfills each year. That amounts to approximately one waste tire for every person in the state, every year *(CalRecycle 2022).*

One use for ELTs is Tire Derived Aggregate (TDA) which is essentially ELTs shredded to a specific gradation range and used as fill for engineering projects where the material characteristics bring benefits to the project that traditional materials cannot. Over the last 22 years, the CalRecycle TDA program has grown its library of knowledge and successful civil engineering applications to become the national recognized leader of civil engineering projects using TDA.

CalRecycle's goal is to divert ELTs from landfill disposal, prevent illegal tire dumping, provide engineering solutions, and promote markets for recycled-content tire products. Development in the waste tire market promotes a sustainable and diversified market for a variety of products using ELTs. TDA is an important component to accomplish that goal.

TDA is a sustainable, lightweight, free-draining engineering material. TDA not only helps California divert ELTs from landfills, but it also solves a variety of engineering problems, often with safer and more cost effective results.

TDA is considered an economical alternative when used as a lightweight fill in retaining walls, landslide stabilization, and embankment projects; a vibration mitigation solution in light rail projects; and an alternative gravel solution in landfill and infiltration gallery projects *(GHD 2015).*

Since 2000, research efforts and extensive material testing have enabled CalRecycle to successfully partner with both state and local governments to complete projects that have demonstrated its performance and cost-effectiveness. These efforts have ultimately resulted in the creation of numerous long-term, sustainable markets for TDA One of the most notable is the use of TDA as vibration mitigation in the expansion of the light rail systems for both the Bay Area Rapid Transit (BART) in the San Francisco Bay Area and the LA Metro Gold Line in Southern California. In addition to diverting more than 1,500,000 tires from our landfills, using TDA saved BART and MTA millions of dollars *(GHD 2017, January).*

## *Types of TDA*

TDA is used for a wide range of public works projects and other civil engineering applications. TDA is shredded ELTs that are categorized by a nominal particle size with a defined plus and minus variance. There are two recognized types of TDA gradations differentiated by their manufacturing techniques *(CSU 2016).*

Type A has a nominal size of 3 inches and is often utilized in landfill leachate and gas collection and removal systems, infiltration galleries, and applications where smaller material size particles are beneficial.

Type B has a nominal size of 8 inches and is often used as a lightweight backfill for embankments, road subgrade, mechanically stabilized, and cast in place retaining walls

One ton of TDA is made of approximately 100 tires (PTE, passenger tire equivalent) and has a volume of 1.4 cubic yards. The in-place density is 45-50 pcf and the permeability is 24 in/min (1 cm/sec) or greater.

Typical TDA Properties

- 1 ton = 1.4 cy
- 1 ton = 100 tires
- In place density: 45-50 lbs. per cf
- Permeability: >1 cm/sec

TDA Uses:

- Drainage material, septic leach fields
- Vibration dampening layer in light rail construction
- Gas collection media
- Leachate collection systems
- Lightweight and conventional fill for retaining walls, embankments, and slopes
- Lightweight backfill for road repairs
- Lightweight backfill for mechanically stabilized walls

*(CalRecycle 2015).*

### TDA Attributes

Direct shear tests were performed on TDA to measure the properties governing the internal shear strength as well as its interface shear strength with concrete. It was determined that TDA can be used as a replacement for soils in geotechnical engineering applications such as retaining walls and embankments do to their similar shear strength parameters, with significantly lower unit weight than granular soils *(UCSD 2016).*

Because it is lightweight and free draining, TDA it is often used as a cost-effective alternative to geofoam, pumice, and gravel.

## *Civil Engineering Standards*

ASTM International, formerly the American Society for Testing and Materials (ASTM) produces the largest voluntary standards development systems in the world. This not-for-profit organization publishes thousands of standards per year used around the world to improve product quality, enhance safety, facilitate market access and trade, and build consumer confidence. Working in an open and transparent process, ASTM producer, user, and consumer members participate in developing industry standards, test methods, specifications, guides and practices that support industries and governments worldwide TDA *(ASTM D6270-20).*

The ASTM standard that applies to TDA and ELTs used in civil engineering is:

> ASTM D6270-20
> "Standard Practice for Use of Scrap Tires in Civil Engineering Applications"

This standard provides guidance for testing the physical properties, design considerations, construction practices, and leachate generation potential of processed or whole scrap tires in lieu of conventional civil engineering materials, such as stone, gravel, soil, sand, lightweight aggregate, and other fill materials.

## *Sustainable Material*

TDA is made from ELTs discarded from cars and trucks. In the foreseeable future, the industry does not see a potential replacement for rubber tires. This means ELTs and TDA will always be available, and therefore are sustainable materials. With this knowledge, it is important to treat TDA as an alternative to virgin resources in appropriate applications.

**TDA as Economic, Environmental, and Social Assets**

- Cost effective: When compared to other fill products used in construction, such as soil, gravel, or stone, TDA generally costs less for the same volume of product.
- No mining required: The production of TDA does not require borrow source mining.
- Waste diversion: Turning used tires into TDA diverts a solid waste from landfills.
- Repurposed: Tires that are made into TDA become a sustainable redesigned material which contributes to California's Circular Economy by keeping materials in circulation as long as possible *(EPA CE 2022).*

The lightweight material requires less energy to transport to a construction site and is placed with readily available conventional construction equipment. A small construction project can repurpose hundreds of ELTs, and thousands for a larger project. TDA can bring engineering benefits, even on small projects, while simultaneously using a sustainable repurposed construction material (*CSU 2015).*

### TDA in a Circular Economy

A circular economy (CE) is a model involving sharing, leasing, repurposing, repairing, refurbishing, and recycling existing materials and products. This concept reduces material use by redesigning materials to be less resource intensive and promoting the repurposing of materials, keeping them in circulation for as long as possible. It is a change to the thinking in which resources are harvested, made into products, and then become waste.

Circularity is embraced within the Sustainable Materials Management (SMM) approach that EPA and other federal agencies have pursued since 2009*.* A CE approach under the SMM umbrella demonstrates an emphasis on reducing lifecycle impacts of materials, including climate impacts, reducing the use of harmful materials, and decoupling materials use from economic growth *(EPA CE 2022)*.


*Source: US Environmental Protection Agency, Sustainable Material Management's Lifecycle (EPA SMM 2022)*

***Figure 1 Sustainable Materials Lifecycle***

Repurposing of ELTs into TDA and using it in civil engineering applications promotes and supports the roadmap to a CE and follows the SMM approach.

Recycling and repurposing ELTs uses fewer natural resources than mined or other raw material. Recycling is fundamental to the state's recently enhanced efforts to reduce Greenhouse Gas Emissions (GHG). Recycling of all materials, including ELTs, creates jobs and helps grow a sustainable, circular economy.

## *TDA in Civil Engineering Applications*

The majority of civil engineering applications for TDA are occurring in the construction industry. Most prominent are TDA uses suitable for construction projects in road building and repair, transportation infrastructure, commercial and residential building and landfill design and construction. These uses are diverse and growing as contractors, engineers, designers, and architects in both the public and private sectors realize the engineering properties and the economic and environmental value TDA brings to a project. In addition, new case studies, educational videos, and monitoring data from full-scale instrumented projects are contributing to the expanded use of TDA *(CSU 2022)*.

There are five primary categories of civil engineering applications:

**Road Failure Landslide Repair**

- Landslide Stabilization: used as lightweight fill at the head of a landslide to reduce the weight pushing the slide downhill.
- Road Sub-grade: used as lightweight fill over weak soils.
- Thermal insulation to limit frost penetration: used as an aggregate layer in road beds in cold climates can help mitigate the depth of frost penetration and associated effects that contribute to frost heaves.

**Retaining Wall and Bridge Abutment Backfill**

- Used as backfill behind retaining walls and bridge abutment walls reduces lateral forces on the inside of the walls.

**Vibration Attenuation**

- TDA reduces ground borne vibrations transmitted away from the tracks on commuter rail lines. Typically, a 1-foot thick layer of TDA placed under the traditional stone ballast and gravel sub-ballast layers in light rail construction is effective in mitigating vibrations that transmit the noise of the passing train away from the tracks to adjacent homes and businesses.

**Embankment Fill**

- Used as lightweight fill over weak foundation soils to limit settlement and increase slope stability. Based on the requirements of the project, TDA can also be used to replace conventional fill in embankments.

**Infiltration Galleries**

- Used as an effective attached growth media for water treatment, while providing higher volume capacity infiltration galleries than most granular aggregate. TDA is unlikely to increase the concentrations of substances with primary drinking water standards above those naturally occurring in ground water *(Humphrey 2006).*

For each of these applications, a BMP has been created (see Appendix A Best Management Practices). The crosswalk between the applications and BMPs is shown in Table 1 below. Summary of the BMPs is presented in the following descriptions.

**Table 1 TDA Civil Engineering Applications and Applicable BMP**

| Application | BMP |
|---|---|
| Road Failure Landslide Repair | BMP TDA-1A – TDA-1D |
| Retaining Wall Backfill | BMP TDA-2 |
| Vibration Mitigation | BMP TDA-3 |
| Embankment Fill | BMP TDA-4 |
| Stormwater Infiltration Galleries | BMP TDA-5 |

Through partnerships with Caltrans and numerous local agencies, CalRecycle is helping to educate engineers and decision makers about the beneficial engineering properties, and the cost savings of using TDA in our infrastructure projects. These efforts have saved local agencies substantial amounts of funds while building safe, durable and sustainable infrastructure projects which have diverted and repurposed large amounts of ELTs from the landfills *(CalRecycle 2022)*.

# Best Management Practices

Best Management Practices (BMPs) are created to implement successful measures to address specific areas of concern. BMPs are used in many different practices such as California Stormwater Quality Association (CASQA), Environmental Protection Agency (EPA), American Forest Foundation, and civil infrastructure projects. Furthermore, the EPA mandates that states provide BMPs for landowners engaged in activities that have the potential to impact downstream waterways and water bodies–anything from agriculture and forestry to the development of infrastructure *(CASQA 2003).*

Since the passing of SB 876 in 2000 CalRecycle has been tasked with developing and promoting environmentally safe beneficial reuses for the states ELTs. Over twenty years of research and pilot studies have helped CalRecycle develop these BMPs for the use of TDA in our states civil engineering and infrastructure projects. The BMPs are meant to be flexible, allowing the ability to tailor the BMP to meet the needs of the specific characteristics of each site *(EPA 2022)*. The following provides a summary of each BMP, with additional description for each included in Appendix A.

### *Road Failure, Landslide Repair (TDA-1)*

The following provides a summary of the BMPs related to the four engineering applications for the repair of road failures where a landslide has occurred.

**Gabion Basket (TDA-1A)**

Road failures are often caused by excessive hydrostatic pressures and weak subgrade material below the road or a combination of both, resulting in road surface failure. Mechanically stabilized TDA stabilizes fill material with plastic geo-grid that is attached to rock filled gabion baskets. The TDA along with the geogrid reinforcing and rock filled gabion baskets are combined to create a lightweight and highly permeable, backfill material effective in substantially reducing lateral loading on Gabion basket walls. This can result in road repair designs with reduced cost that effectively eliminate the potential for saturated conditions to develop. These benefits make TDA a good material choice for repairs of persistent road failures.

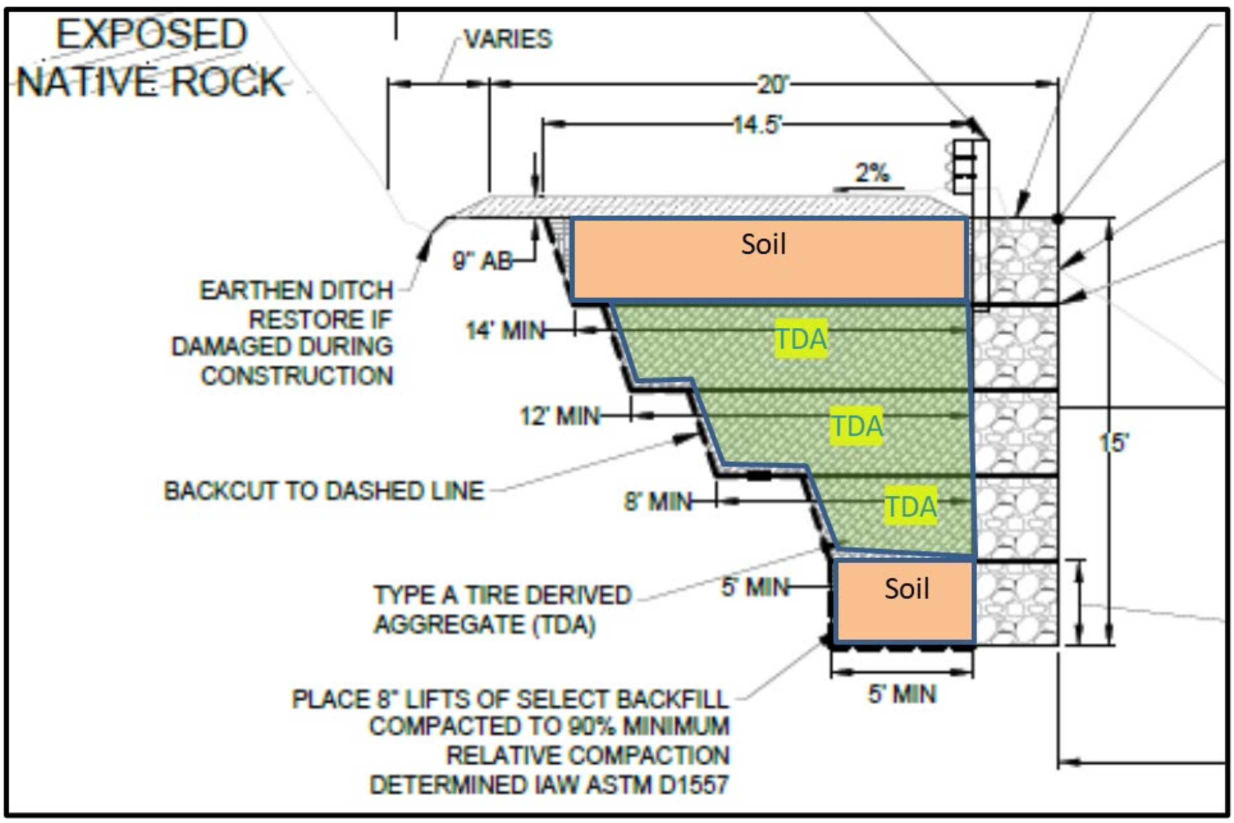



***Figure 2 Gabion Basket Diagram (TDA-1A)***

**Pile Walls (TDA-1B)**

Because TDA is lightweight and highly permeable, it is a backfill material effective in reducing lateral loading on pile walls. This can result in wall designs with reduced cost that effectively eliminate the potential for saturated conditions to develop in the future. These benefits make TDA a good material choice for pile wall road projects.

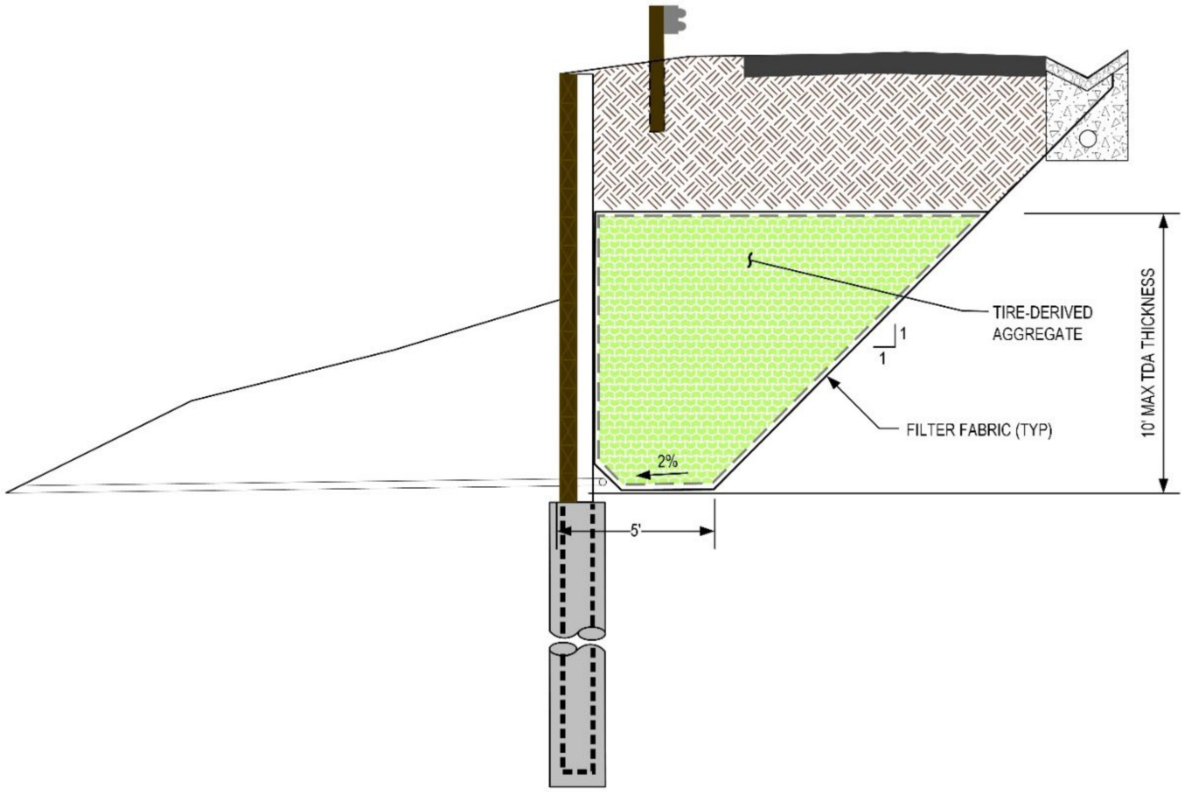



***Figure 3 Pile Wall Diagram (TDA-1B)***

## Mechanically Stabilized (TDA-1C)

Excessive hydrostatic pressures and weak subgrade material below the road or a combination of both, can result in road surface failure. Because TDA is lightweight, highly permeable, and has high internal strength, it is a backfill material that works well with mechanical stabilized design options (two shown below). This method can produce long term road repairs a with high factor of safety. This can result in long term road repair designs with reduced cost that effectively eliminate the potential for saturated conditions to develop. These benefits make TDA a good material choice for repairs of persistent road failures *(UCSD 2021).*

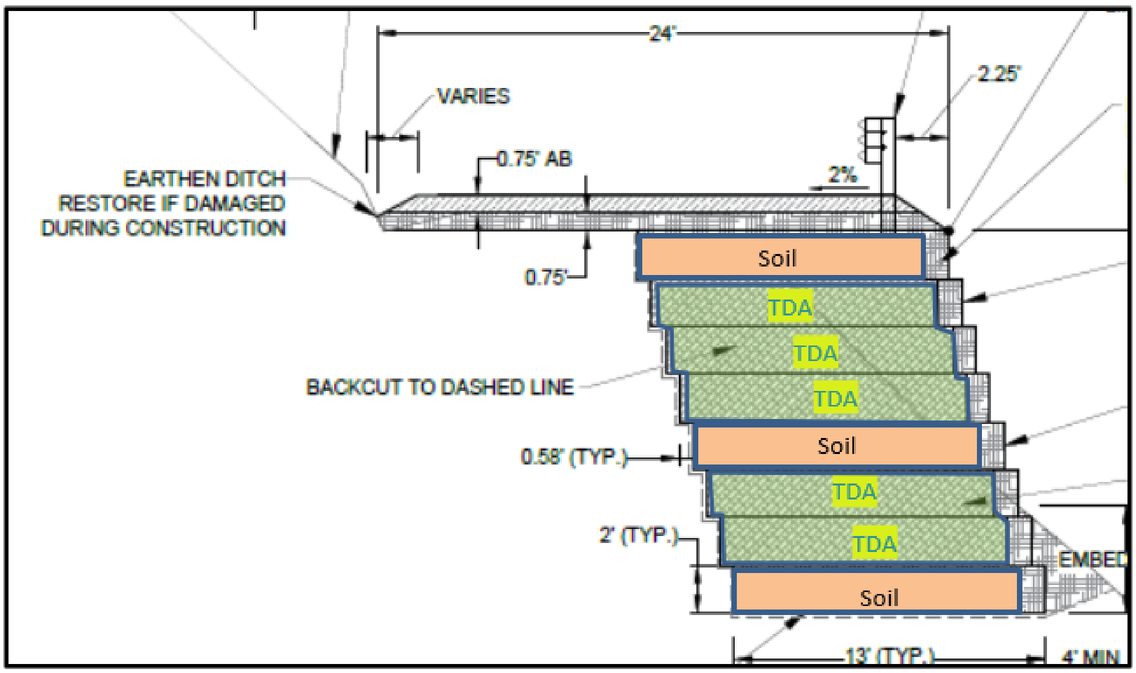



***Figure 4 Welded Wire Mechanically Stabilized Diagram #1 (TDA-1C)***

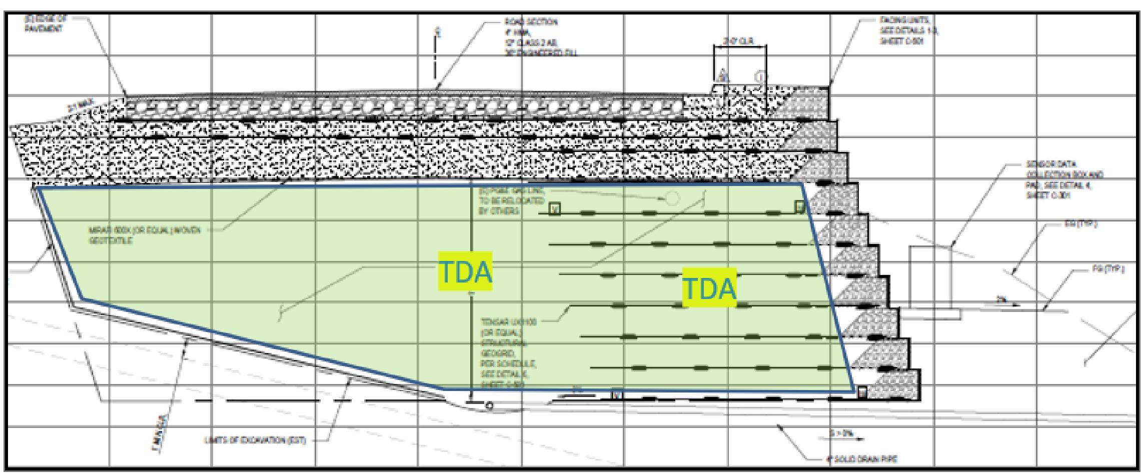
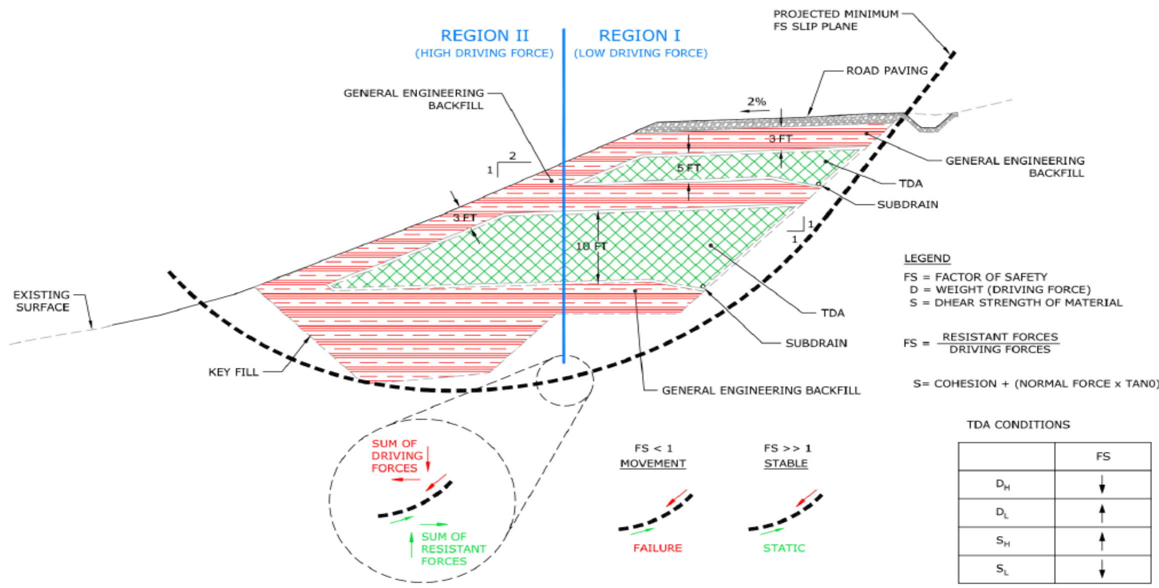



***Figure 5 Geogrid Mechanically Stabilized Diagram #2 (TDA-1C)***

## Lightweight Backfill (TDA-1D)

Road failures, slip-outs, and landslides are often caused by excessive hydrostatic pressures and weak subgrade material below the road or a combination of both, resulting in road surface failure. Because TDA is lightweight and highly permeable, it is a fill material both effective in reducing immediate loading on a slope and reducing the potential for future saturated conditions to develop. These benefits make TDA a good material choice for repairs of persistent road failures *(GHD 2017, June).*




GENERAL TDA SLIDE REPAIR SECTION

***Figure 6 Lightweight Backfill Diagram (TDA-1D)***

## *Retaining Wall Backfill (TDA-2)*

### Cast-in-Place Retaining Walls

Retaining walls are commonly used in civil engineering structures adjacent to roads and bridges and designed based on the material properties of the backfill. Properties such as unit weight and cohesion of backfill materials are important factors in determining the design characteristics of the retaining wall. Traditional backfill materials having higher unit weight and/or higher walls will require more robust structures. Replacing the backfill with TDA has advantages as an alternative to conventional soil mainly because it is significantly lighter and is free draining *(GHD 2020), (UCD 2014).*

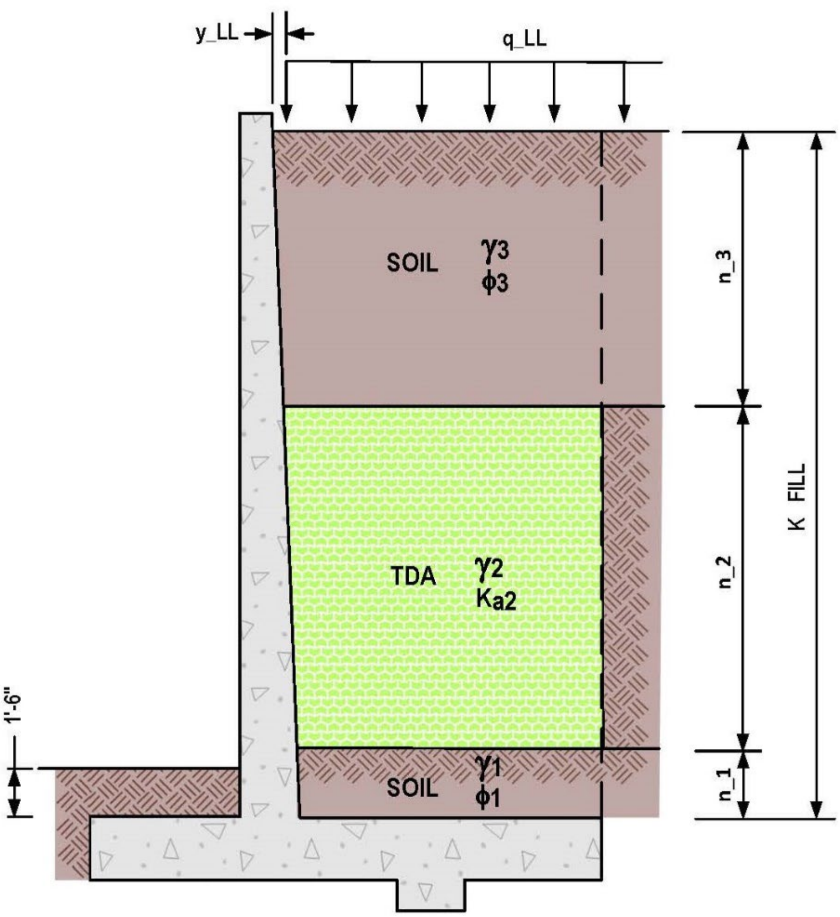
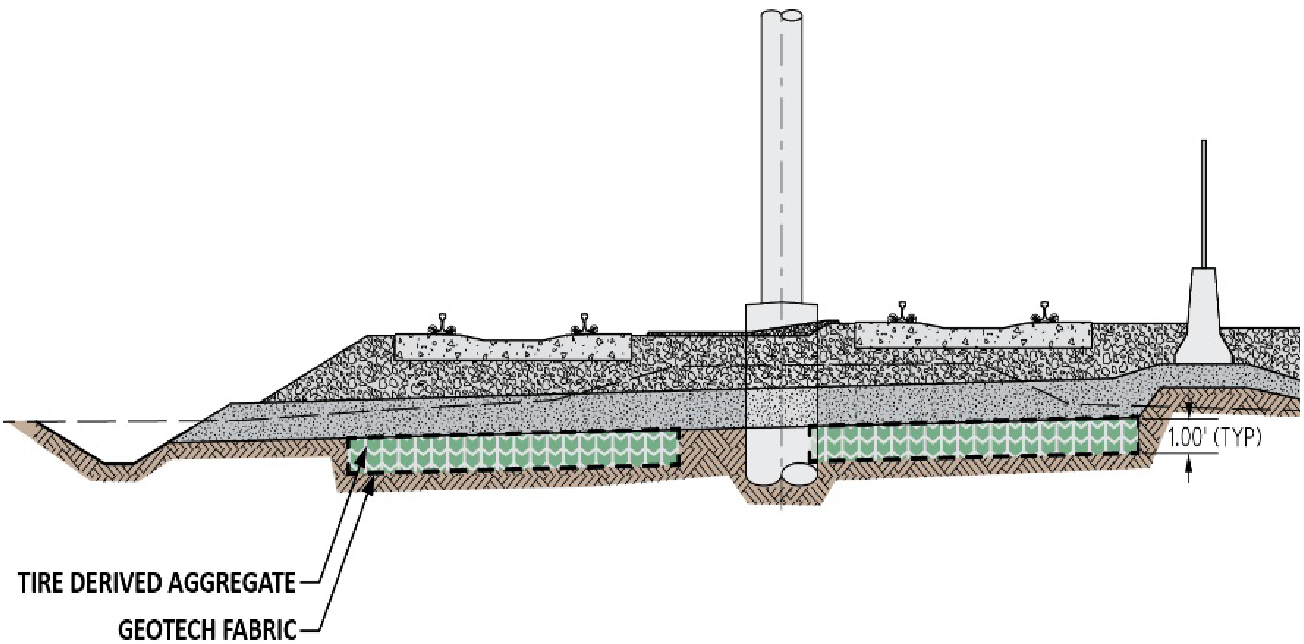



***Figure 7 Cast-in-Place Diagram (TDA-2)***

### *Vibration Mitigation (TDA-3)*

Historically, vibration damping for light rail tracks has been achieved by either the use of special “elastic” track fasteners or through the construction of a vibration isolation system. This isolation system can be part of the track structure or built beneath the supporting base and is expensive to install. To implement TDA as a vibration mitigation layer, a 12-inch layer is installed beneath the sub-ballast rock. This has proven to be a effective in the attenuation of groundborne vibrations, and a cost-effective solution. Groundborne vibration mitigation is often called for when light rail (commuter) installations come close to sensitive areas such as residential neighborhoods. As the demand for light rail transportation increases, the generation of vibrations and their associated noise can affect public health and safety. TDA offers a unique solution that is long term and cost effective. Using TDA as an underlayment under the traditional track system reduces vibration in an equivalent manner to a traditional application, but at a lower cost *(GHD 2017, January)*.




*Source: Cross Section Provided by Kiewit – Parsons, March 2021*

***Figure 8 Vibration Mitigation Diagram (TDA-3)***

## *Embankment Fill (TDA-4)*

Constructing embankments on weak foundation soils can provide numerous challenges such as slope instability and excessive settlement. This is primarily due to the weak foundation soils not being able to support the weight of the overlying soil fill. One solution is to use lightweight fill. TDA is lightweight and has beneficial characteristics that will limit settlement and increase stability. TDA additionally has proven to be a cost-effective alternative to other lightweight materials.

TDA is highly permeable and won't retain water like soil. Additionally, using TDA can increase the stability of steep slopes on roadways, reinforce roadway shoulders, and providing an insulating layer against frost penetration due to its thermal resistance properties *(ASTM D6270-20), (UCSD 2016).*

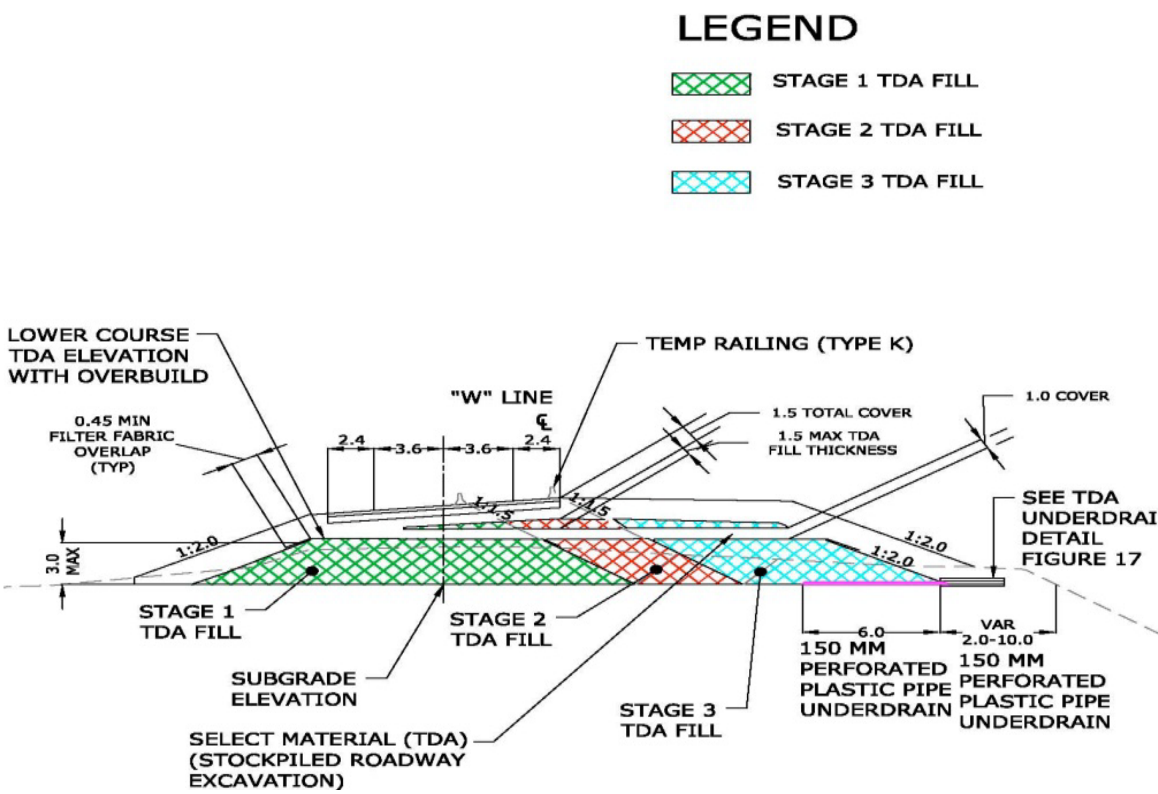



***Figure 9 Embankment Fill Diagram (TDA-4)***

### *Stormwater Infiltration Gallery (TDA-5)*

Use of a TDA infiltration gallery feature helps clean road surface runoff while it is being directed towards the ground water setting.

TDA particles have been shown to serve as an excellent attached growth media for water treatment. The attached microorganism communities clean the water of many storm water constituents of concern.

The soil below the TDA media captures storm water constituents and microparticles that have passed by the microorganism communities, as well as any heavy metals that might come from the TDA media itself.

TDA is an excellent choice as a media in storm water treatment and infiltration features. There is no evidence that any nutrient, metal, or VOC leached from the TDA poses any risk of impairing water quality. *(HSU 2016)*.

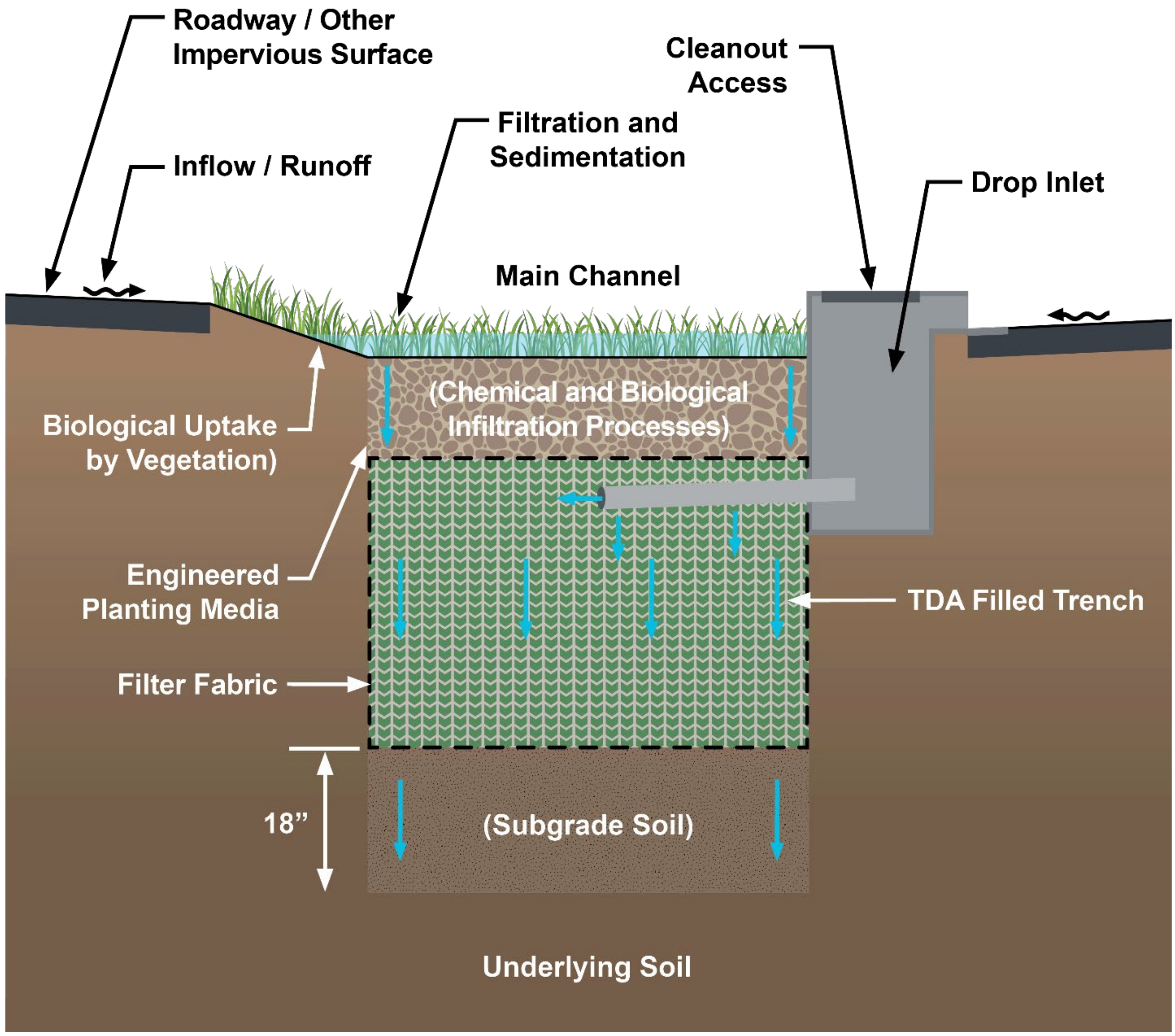



***Figure 10 Stormwater Infiltration Gallery Diagram (TDA-5)***

# Summary

California generates over 40 million ELTs every year. Some of the ELTs are repurposed into TDA, which can be used as a construction material to bring engineering and environmental benefits to a variety of infrastructure projects.

CalRecycle has developed these BMPs for a collection of TDA uses in civil engineering projects. Knowledge about TDA material properties and interactions have been compiled through project lessons learned and University research. The knowledge gained through these efforts are incorporated in ASTM D6270-20. The data and knowledge developed has been used to create these BMPs to help TDA users reap the many benefits that the material offers.

# References


ASTM International. (ASTM). *D6270-20 Standard Practice for Use of Scrap Tires in Civil Engineering Applications. 2022.* https://webstore.ansi.org/standards/astm/astmd627020.

California Stormwater Quality Association. (CASQA 2003) *Stormwater Best Management Practice Handbook, New Development and Redevelopment*.

CalRecycle. (CalRecycle 2015). *Tire Derived Aggregate (TDA) – Type A and Type B Material Specification.*

CalRecycle. (CalRecycle 2022). *Tire-Derived Aggregate (TDA).* Accessed August 15, 2022. Copyright © 2022. https://Calrecycle.ca.gov/Tires/TDA.

Chico State University. (CSU 2015). Cheng, DigXin. *Usage Guide: Tire Derived Aggregate* (TDA). CalRecycle.

Chico State University. (CSU 2016). Cheng, DingXin et.al. *California TDA Gradation Specification Analysis*. CalRecycle.

Chico State University. (CSU 2022). *Tire Engineering Research Center.* Accessed August 2, 2022. Copyright © 2022. https://www.csuchico.edu/cp2c/terc/index.shtml.

Environmental Protection Agency, US. (EPA 2022). *Environmental Protection Agency, US (EPA 2022). National Menu of Best Management Practices (BMPs) for Stormwater-Construction.* Accessed October 4, 2022. Updated September 14, 2022. https://www.epa.gov/npdes/national-menu-best-management-practices-bmps-stormwater-construction.

Environmental Protection Agency. (EPA CE 2022). *What is a Circular Economy?* Accessed October 4, 2022. Updated September 29, 2022. https://www.epa.gov/recyclingstrategy/what-circular-economy.

Environmental Protection Agency. (EPA SMM 2022). *Sustainable Material Management's Life-cycle Perspective.* Accessed July 2022. Updated February 24, 2022. https://www.epa.gov/smm/sustainable-materials-management-basics#lifecycle

GHD. (2012). Wright, Joaquin. *TDA Slide Repair Monitoring Report for Marina Drive, Geysers Road, Sonoma Mountain Road, and Palomino Road Repair Projects.*

GHD. (2015). Wright, Joaquin. *Cost Benefit Assessment, Evaluation of Tire Derived Aggregate Against Alternate Fill Options for Civil Engineering Applications.*

GHD. (2017, January). GHD. Wright, Joaquin. *VTA/Bart Berryessa Extension Project.* CalRecycle.

GHD. (2017, June). GHD. Wright, Joaquin*. TDA Slide Repair Survey.* CalRecycle.

GHD (2020) Wright, Joaquin. *TDA Type 1A Retaining Wall Draft Design Report.* Caltrans.

Humboldt State University. (HSU 2013). Finney, Brad. *Properties of Tire Derived Aggregate for Civil Engineering Applications.* CalRecycle.

Humboldt State University. (HSU 2016). Finney, Brad. *Evaluation of Tire Derived Aggregate as a Media for Stormwater Treatment.* CalRecycle.

Humphrey, et.al. (2006). *Literature Review of the Water Quality Effects of Tire Derived Aggregate and Rubber Modified Asphalt Pavement.*

University of California, Davis. (UCD 2014). Cheng, Lijuan. *Retaining Wall Shake Table Test and Design Using Tire Derived Aggregate as Backfill*. CalRecycle.

University of California, San Diego. (UCSD 2016). McCartney, John. *Large Scale Measurement of Internal and Interface Shear Strength of Tire Derived Aggregate – Phase II*. CalRecycle.

University of California, San Diego. (UCSD 2021). McCartney, John. *Design of Mechanically Stabilized Tire Derived Aggregate (MSTDA) Retaining Walls*.

# Appendix A

## Best Management Practice's

TDA-1 Road Failure Landslide Repair

- A Gabion Basket
- B Pile Walls
- C Mechanically Stabilized
- D Lightweight Backfill

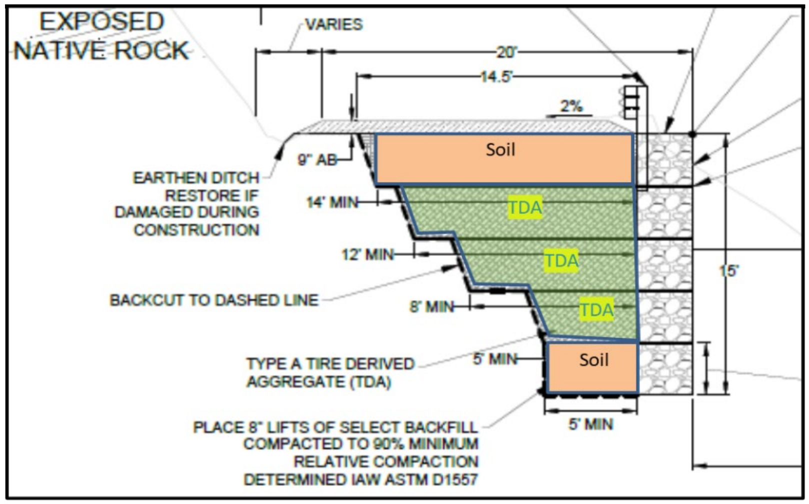
TDA-2 Retaining Wall Backfill

TDA-3 Vibration Mitigation

TDA-4 Embankment Fill

TDA-5 Stormwater Infiltration Gallery

Road Failure Repair, Gabion-Basket TDA-1A




## *Description*

Road Failures, slip-outs, and landslides are often caused by excessive hydrostatic pressures and weak subgrade material below the road or a combination of both, resulting in road surface failure. Because Tire Derived Aggregate (TDA) is lightweight and highly permeable, it is a backfill material effective in substantially reducing lateral loading on Gabion basket walls. This can result in road repair designs with reduced cost that effectively eliminate the potential for saturated conditions to develop. These benefits make TDA a good material choice for repairs of persistent road failures.

### Key Design Features

When a road edge failure occurs, it is often necessary to excavate the subgrade soils until a more stable soil is found. The road is then reconstructed with rock filled gabion basket walls and TDA backfill.

Since TDA is lightweight, free draining, and has high internal strength it allows engineers to design road repairs cost effectively, with increased factor of safety, and reduced future failure risk. Surface water rerouting and subgrade drainage are typically installed so that potential hydrostatic pressure conditions cannot develop. By using TDA as a lightweight backfill material, less excavation is possible and potential future failures can be mitigated.

### Advantages

- Lightweight, TDA is 45-50lbs/cf about 1/3 that of soil and/or rock.
- Strength of TDA, Type B TDA has Phi values of 35-40 degrees.
- Using lightweight backfill can result in reduced excavation.
- Increased factor of safety due to internal shear strength and lightweight.
- Constructability on a variety of poor subgrade conditions.
- Method specification for compaction efforts increases placement productivity.
- Sustainable recycled material.
- Highly permeable and does not “wick” water.
- Cost effective.

**Limitations**

- Historically used above water table.
- TDA fill wrapped in geotextile fabric soil separator.
- Requires overbuild consideration.

## *Construction Considerations*

A road repair feature depth, width, and length are developed based on constructability and the hydrology of each site.

Communication between all parties is important for the success of any project. This is accomplished by holding pre-construction meetings where TDA material properties can be introduced to all project stakeholders. Quality assurance reviews should be performed regularly

The following areas should be addressed by the project manager prior to construction:

- Design configuration.
- Factor of safety analysis.
- Delivery supplier(s), schedule, rates, and route.
- Stockpiling and delivery rate considerations.
- TDA compaction methodology and density specification.
- TDA placement methods and education of the onsite contractors.

Since TDA is much lighter than soil or gravel, contractors should become familiar with the basic properties of TDA before it arrives at the site. The following areas should be addressed by the contractor prior to receiving TDA at the project site:

- Volume of delivery.
- Project stockpile and configuration.
- Placement and compaction methodology.

## *Maintenance and Inspection*

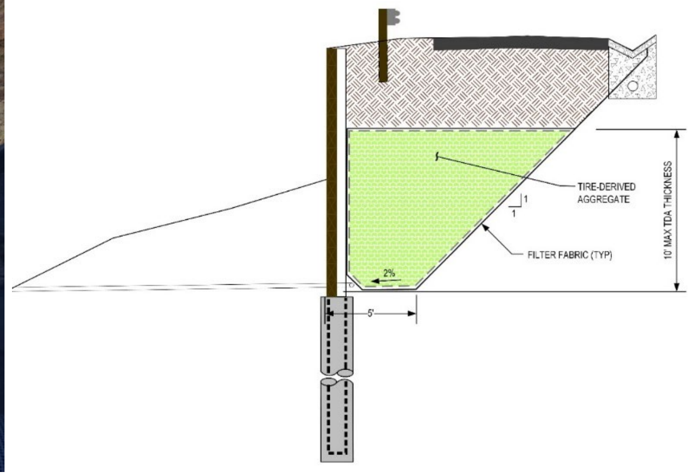
| Activities | Maintenance Frequency | Inspection Frequency |
|---|---|---|
| Review road surface for cracking, fill cracks | Annual | Annual |
| Review drainage, remove trash and debris | Quarterly | Annual |
| Survey road surface and slope | As needed | As needed |

## *Additional Resources*

ASTM International. (ASTM). *D6270-20 Standard Practice for Use of Scrap Tires in Civil Engineering Applications. 2022.* https://webstore.ansi.org/standards/astm/astmd627020.

Chico State University. (CSU 2022). *Tire Engineering Research Center. Accessed August 2, 2022*. Copyright © 2022. https://www.csuchico.edu/cp2c/terc/index.shtml.

# Road Failure Repair, Pile Walls TDA-1B




## *Description*

Road failures, slip-outs, and landslides are often caused by excessive hydrostatic pressures and weak subgrade material below the road or a combination of both, resulting in road surface failure. Because Tire Derived Aggregate (TDA) is lightweight and highly permeable, it is a backfill material effective in reducing lateral loading on pile walls. This can result in wall designs with reduced cost that effectively eliminate the potential for saturated conditions to develop. These benefits make TDA a good material choice for repairs of persistent road failures.

### Key Design Features

When a road landslide occurs, it is often necessary to excavate the failed saturated subgrade soils down to more stable soil. The roadway is then reconstructed by placing a soldier pile wall on the outside road edge and placing compacted layers of TDA behind it. A road section is considered stable when the shear strength of the subgrade fill is greater by a factor of safety than the driving force (weight of the backfill and surface loading). Since TDA is lightweight, free draining, and has high internal strength it allows engineers to design road repairs cost effectively, with increased factor of safety, and reduced future failure risk. Surface water rerouting and subgrade drainage are typically installed so that potential hydrostatic pressure conditions cannot develop. By using TDA as a lightweight backfill material, smaller soldier pile walls are possible and future potential failures can be mitigated.

### Advantages

- Lightweight, TDA is 45-50lbs/cf about 1/3 that of soil and/or rock.
- Strength of TDA, Type B TDA has Phi values of 35-40 degrees.
- Using lightweight backfill can result in reduced excavation.
- Increased factor of safety due to internal shear strength and lightweight.
- Constructability on a variety of poor subgrade conditions.
- Method specification for compaction efforts increases placement productivity.

- Sustainable recycled material.
- Highly permeable and does not “wick” water.
- Cost effective.

**Limitations**

- Historically used above water table.
- TDA fill wrapped in geotextile fabric soil separator.
- Requires overbuild consideration.

## *Construction Considerations*

The road repair feature depth, width, and length are developed based on constructability and the hydrology of each site.

Communication between all parties is important for the success of any project. This is accomplished by holding pre-construction meetings where TDA material properties can be introduced to all project stakeholders. Quality assurance reviews should be performed regularly

The following areas should be addressed by the project manager prior to construction:

- Design configuration.
- Factor of safety analysis.
- Delivery supplier(s), schedule, rates, and route.
- Stockpiling and delivery rate considerations.
- TDA compaction methodology and density specification.
- TDA placement methods and education of the onsite contractors.

Since TDA is much lighter than soil or gravel, contractors should become familiar with the basic properties of TDA before it arrives at the site. The following areas should be addressed by the contractor prior to receiving TDA at the project site:

- Volume of delivery.
- Project stockpile and configuration.
- Placement and compaction methodology.

## *Maintenance and Inspection*

| Activities | Maintenance Frequency | Inspection Frequency |
|---|---|---|
| Review road surface for cracking, fill cracks | Annual | Annual |
| Review drainage, remove trash and debris | Quarterly | Annual |
| Survey road surface and slope | As needed | As needed |

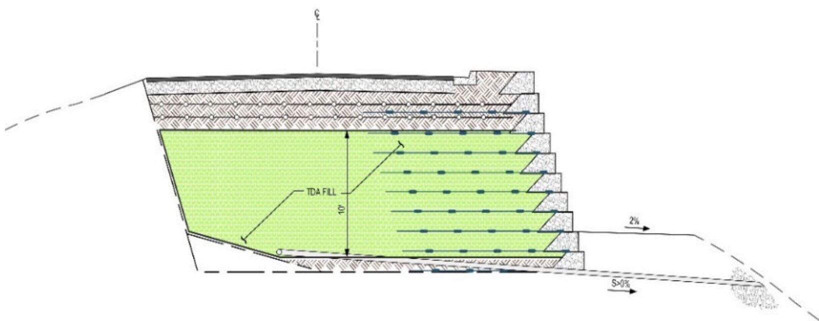
## *Additional Resources*

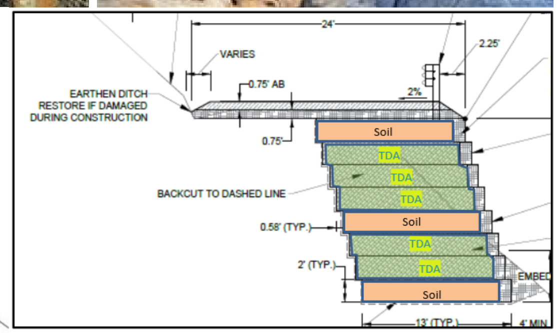
ASTM International. (ASTM). *D6270-20 Standard Practice for Use of Scrap Tires in Civil Engineering Applications. 2022.* https://webstore.ansi.org/standards/astm/astmd627020.

Chico State University. (CSU 2022). *Tire Engineering Research Center. Accessed August 2, 2022*. Copyright © 2022. https://www.csuchico.edu/cp2c/terc/index.shtml.

CalRecycle

# Road Failure Repair, Mechanically Stabilized TDA-1C




## *Description*

Road Failures, slip-outs, and landslides are often caused by excessive hydrostatic pressures and weak subgrade material below the road or a combination of both, resulting in road surface failure. Because Tire Derived Aggregate (TDA) is lightweight, highly permeable, and has high internal strength, it is a backfill material that works well with mechanical stabilized design options, producing long term road repairs with high factors of safety. This can result in longer term road repair designs with reduced cost that effectively eliminate the potential for saturated conditions to develop. These benefits make TDA a good material choice for repairs of persistent road failures.

### Key Design Features

When a road landslide occurs, it is often necessary to excavate the failed saturated subgrade soils down to more stable soil. The slope is then reconstructed in compacted layers of TDA and covered with a soil veneer. A slope is considered stable when the shear strength of the subgrade fill is greater by a factor of safety than the driving force (weight of the backfill and surface loading). Since TDA is lightweight, free draining, and has high internal strength it allows engineers to design road repairs cost effectively, with increased factor of safety, and reduced future failure risk. Surface water rerouting and subgrade drainage are typically installed so that potential hydrostatic pressure conditions cannot develop. By using TDA as a lightweight backfill material, less excavation is possible and future potential failures can be mitigated.

**Advantages**

- Lightweight, TDA is 45-50lbs/cf about 1/3 that of soil and/or rock.
- Strength of TDA, Type B TDA has Phi values of 35-40 degrees.
- Using lightweight backfill can result in reduced excavation.
- Increased factor of safety due to internal shear strength and lightweight.
- Constructability on a variety of poor subgrade conditions.
- Method specification for compaction efforts increases placement productivity.
- Sustainable recycled material.
- Highly permeable and does not “wick” water,
- Cost effective.

**Limitations**

- Historically used above water table.
- TDA fill wrapped in geotextile fabric soil separator.
- Requires overbuild consideration.

## *Construction Considerations*

The Road Repair feature depth, width, and length are developed based on constructability and the hydrology of each site. Detailed calculations and considerations are outlined in the MSTDA summary guide.

Communication between all parties is important for the success of any project. This is accomplished by holding pre-construction meetings where TDA can be introduced to all project stakeholders. Quality assurance reviews should be performed regularly

The following areas should be addressed by the project manager prior to construction:

- Design configuration,
- Factor of safety analysis,
- Delivery supplier(s), schedule, rates, and route,
- Stockpiling and delivery rate considerations,
- TDA compaction methodology and density specification.
- TDA placement methods and education of the onsite contractors.

Since TDA is much lighter than soil or gravel, contractors should become familiar with the basic properties of TDA before it arrives at the site. The following areas should be addressed by the contractor prior to receiving TDA at the project site:

- Volume of delivery.
- Project stockpile and configuration.
- Placement and compaction methodology.

## *Maintenance and Inspection*

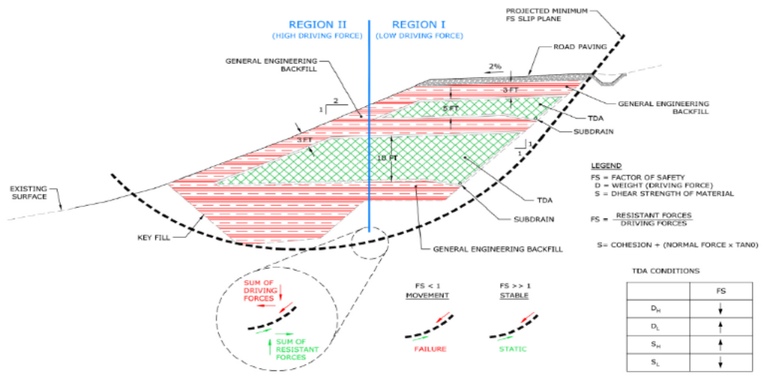
| Activities | Maintenance Frequency | Inspection Frequency |
|---|---|---|
| Review road surface for cracking, fill cracks | Annual | Annual |
| Review drainage, remove trash and debris | Quarterly | Annual |
| Survey road surface and slope | As needed | As needed |

## *Additional Resources*

ASTM International. (ASTM). *D6270-20 Standard Practice for Use of Scrap Tires in Civil Engineering Applications. 2022.* https://webstore.ansi.org/standards/astm/astmd627020.

Chico State University. (CSU 2022). *Tire Engineering Research Center. Accessed August 2, 2022*. Copyright © 2022. https://www.csuchico.edu/cp2c/terc/index.shtml.

# Road Failure Repair, Lightweight Subgrade Fill TDA-1D



GENERAL TDA SLIDE REPAIR SECTION

## *Description*

Road Failures, slip-outs, and landslides are often caused by excessive hydrostatic pressures and weak subgrade material below the road or a combination of both, resulting in road surface failure. Because Tire Derived Aggregate (TDA) is lightweight and highly permeable, it is a fill material both effective in reducing immediate loading on a slope and reducing the potential for future saturated conditions to develop. These benefits make TDA a good material choice for repairs of persistent road failures.

### Key Design Features

When a road landslide occurs, it is often necessary to excavate the failed saturated subgrade soils down to more stable soil. The slope is then reconstructed in compacted layers of TDA and covered with a soil veneer. A slope is considered stable when the shear strength of the subgrade fill is greater by a factor of safety than the driving force (weight of the backfill and surface loading). Since TDA is lightweight, free draining, and has high internal strength it allows engineers to design road repairs cost effectively, with increased factor of safety, and reduced future failure risk. Surface water rerouting and subgrade drainage are typically installed so that potential hydrostatic pressure conditions cannot develop. By using TDA as a lightweight backfill material, less excavation is possible and future potential failures can be mitigated.

### Advantages

- Lightweight, TDA is 45-50lbs/cf about 1/3 that of soil and/or rock.
- Strength of TDA, Type B TDA has Phi values of 35-40 degrees.
- Using lightweight backfill can result in reduced excavation.
- Increased factor of safety due to internal shear strength and lightweight.
- Constructability on a variety of poor subgrade conditions.
- Method specification for compaction efforts increases placement productivity.
- Sustainable recycled material.
- Highly permeable and does not “wick” water.
- Cost effective.

**Limitations**

- Historically used above water table.
- TDA fill wrapped in geotextile fabric soil separator.
- Requires overbuild consideration and initial settlement period.

## *Construction Considerations*

The road repair feature depth, width, and length are developed based on constructability and the hydrology of each site.

Communication between all parties is important for the success of any project. This is accomplished by holding pre-construction meetings where TDA can be introduced to all project stakeholders. Quality assurance reviews should be performed regularly

The following areas should be addressed by the project manager prior to construction:

- Design configuration.
- Factor of safety analysis.
- Delivery supplier(s), schedule, rates, and route.
- Stockpiling and delivery rate considerations.
- TDA compaction methodology and density specification.
- TDA placement methods and education of the onsite contractors.

Since TDA is much lighter than soil or gravel, contractors should become familiar with the basic properties of TDA before it arrives at the site. The following areas should be addressed by the contractor prior to receiving TDA at the project site:

- Volume of delivery.
- Project stockpile and configuration.
- Placement and compaction methodology.

## *Maintenance and Inspection*

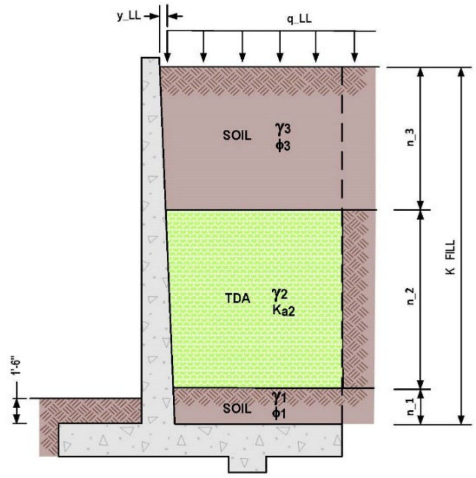
| Activities | Maintenance Frequency | Inspection Frequency |
|---|---|---|
| Review road surface for cracking, fill cracks | Annual | Annual |
| Review drainage, remove trash and debris | Quarterly | Annual |
| Survey road surface and slope | As needed | As needed |

## *Additional Resources*

ASTM International. (ASTM). *D6270-20 Standard Practice for Use of Scrap Tires in Civil Engineering Applications. 2022.* https://webstore.ansi.org/standards/astm/astmd627020.

Chico State University. (CSU 2022). *Tire Engineering Research Center. Accessed August 2, 2022*. Copyright © 2022. https://www.csuchico.edu/cp2c/terc/index.shtml.

# Retaining Wall Backfill TDA-2




## *Description*

Retaining Walls are commonly used in civil engineering structures adjacent to roads and bridges and designed based on the material properties of the soil backfill. Properties such as unit weight and cohesion of a soil in addition to the height of the soil backfill are important factors in determining the design characteristics of the retaining wall. Generally, materials having higher unit weight will require more robust structures to retain them due to the increase in the lateral forces applied to the structure by the soil. Tire Derived Aggregate (TDA) has advantages as an alternative to conventional soil backfill because it is significantly lighter than soil, is free-draining and acts as a seismic dampener.

### Key Design Features

Since the in-place unit weight of TDA typically ranges between 45 and 50 $lbs/ft^3$ (approximately one-third of the unit weight of most soils), it is very effective in reducing the lateral forces applied to the wall. Using TDA as a retaining wall backfill can result in wall designs that use less steel and/or concrete and require less excavation, which can result in significant cost savings over typical soil backfill retaining walls.

### Advantages

- Lightweight TDA Reduces loading stress on subgrade/existing conditions.
- Strength of TDA increases resistance against driving force (hillside sliding and overturning).
- Can be constructed on a variety of poor subgrade conditions.
- Sustainable recycled, lightweight, free draining, recycled material.
- Cost effective.
- Reduced supplies, i.e., concrete and steel.
- Reduced excavation.
- Increased factor of safety.
- Is a seismic dampener.

**Limitations**

- Historically used above water table.
- TDA fill wrapped in geotextile fabric soil separator.
- Requires overbuild consideration.

## *Construction Considerations*

Retaining Wall feature depth, width, and length are developed based on constructability and site conditions. Good communication and proper training will assure the smooth and problem-free construction process when using TDA.

While communication between all parties is important for the success of any project, it is even more so when introducing an unfamiliar material like TDA to the designers and/or contractors. Team member education is accomplished by holding pre-construction meetings where TDA can be introduced to all project stakeholders. Quality assurance reviews should be performed regularly.

The following areas should be addressed by the project manager prior to construction:

- Delivery supplier(s), schedule, rates, and route,
- Stockpiling locations, and
- TDA education of the contractors on-site representative.

Since TDA is lighter and stronger than soil or gravel, contractors should become familiar with the basic properties of TDA before it arrives at the site. The following areas should be addressed by the contractor prior to receiving TDA at the project site:

- Volume of delivery.
- Project stockpile and configuration.
- Placement methodology.
- Proper equipment for placement.

## *Maintenance and Inspection*

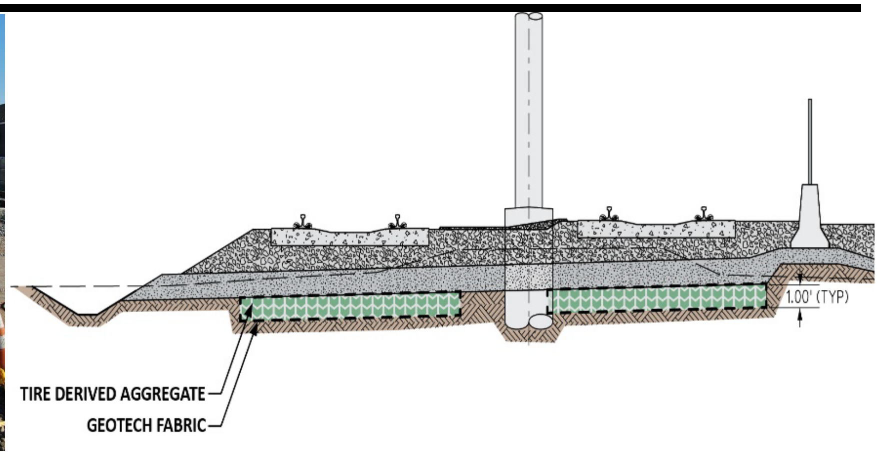
| Activities | Maintenance Frequency | Inspection Frequency |
|---|---|---|
| Review road surface for cracking, fill cracks | Annual | Annual |
| Review drainage, remove trash and debris | Bi-annual | Annual |
| Survey road surface and slope | As needed | As needed |

## *Additional Resources*

ASTM International. (ASTM). *D6270-20 Standard Practice for Use of Scrap Tires in Civil Engineering Applications. 2022.* https://webstore.ansi.org/standards/astm/astmd627020.

Chico State University. (CSU 2022). *Tire Engineering Research Center. Accessed August 2, 2022*. Copyright © 2022. https://www.csuchico.edu/cp2c/terc/index.shtml.

# Vibration Mitigation TDA-3




## *Description*

Historically, vibration damping for light rail tracks has been achieved by either the use of special "elastic" track fasteners or through the construction of a vibration isolation system. This isolation system can be part of the track structure or built beneath the supporting base, and can be extremely expensive to install. In the year 2000, Tire Derived Aggregate (TDA) began being implemented as vibration mitigation layer under light rail. A 12-inch layer of Type A TDA beneath the ballast rock, and sub-ballast layers. It has been shown to be effective in the attenuation of groundborne vibrations. Groundborne vibration mitigation is often called for when light rail installations come close to sensitive areas such as residential neighborhoods. As the demand for light rail transportation increases, the generation of vibrations and their associated noise can affect public health and safety. TDA offers a unique solution that is long term, cost effective, uses recycled material and is sustainable. Using TDA as an underlayment under the traditional track system reduces the issue through the use of vibration-mitigating materials.

## *Key Design Features*

In general, rubber is a type of viscoelastic damping material that is commonly used in engineering and is widely used for reduction of vibration and noise. The basic principle is that TDA (a rubber material) is effective in mitigating the vibration frequencies generated by moving trains.

When evaluating vibration mitigation techniques, the frequency levels of the source vibration define the types of mitigation techniques that will work. TDA used as a damping material performs as well as or better than most available alternatives for the most commonly mitigated frequency levels.

### Advantages

- Reduces loading stress on subgrade/existing conditions.
- Constructability on a variety of poor subgrade conditions.
- Sustainable recycled, light weight, free draining, recycled material.
- Allows for vibration mitigation of frequencies above 16 Hz.
- Highly cost effective when compared to alternatives.

### Limitations

- Does not mitigate all frequency levels.

## *Construction Considerations*

When rail construction projects call for vibration-damping measures to reduce ground-borne vibrations, there are several options that the designer may consider. TDA is often the least expensive option, and the cost benefit compared to the most common alternatives is substantial.

Type A TDA is placed in a layer 12 inches thick, which is then covered with a 1-foot thick layer of sub-ballast, which is below a 1-foot layer of ballast material. This in turn supports the track structure. Tire-derived aggregate is effective in mitigating midrange vibrations (above 16 Hz). TDA performs better than that of a ballast mat technology where reduction of frequency vibration is necessary.

## *Maintenance and Inspection*

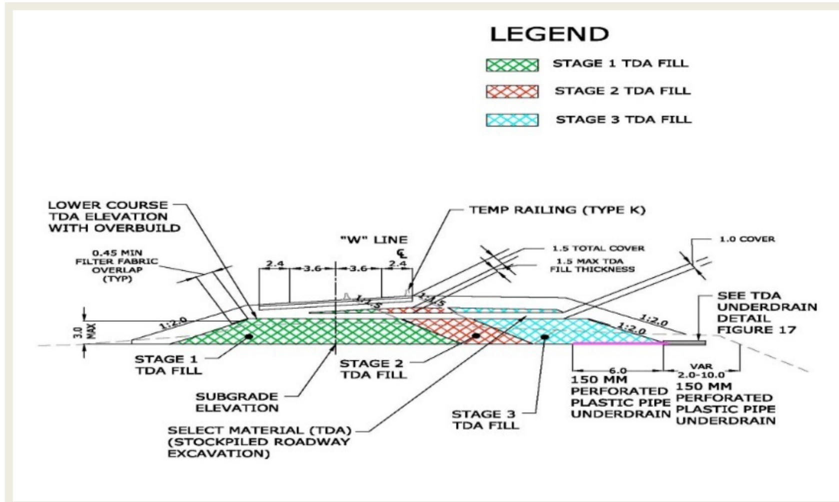
| Activities | Maintenance Frequency | Inspection Frequency |
|---|---|---|
| Survey track surface | Annual | Annual |

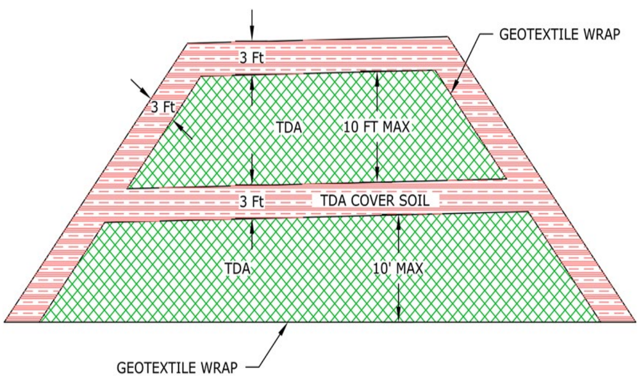
## *Additional Resources*

ASTM International. (ASTM). *D6270-20 Standard Practice for Use of Scrap Tires in Civil Engineering Applications. 2022.* https://webstore.ansi.org/standards/astm/astmd627020.

Chico State University. (CSU 2022). *Tire Engineering Research Center. Accessed August 2, 2022*. Copyright © 2022. https://www.csuchico.edu/cp2c/terc/index.shtml.

# Embankment Construction TDA-4


## *Description*

Constructing embankments on weak foundation soils can provide numerous challenges such as slope instability and excessive settlement. This is primarily due to the weak foundation soils not being able to support the weight of the overlying soil fill. One solution is to use lightweight fill. Tire Derived Aggregate (TDA) is lightweight and has beneficial characteristics that will limit settlement and increase stability. TDA additionally has proven to be a cost-effective alternative to other materials like volcanic pumice or geofoam.

TDA is highly permeable and therefore will not create saturated conditions. Benefits of TDA in road fill and embankment applications may include increasing the stability of steep slopes along roadways, reinforcing roadway shoulders, and providing an insulating layer against frost penetration due to its thermal resistance properties.

### Key Design Features

When designing an embankment with TDA, there are several aspects that are important for consideration. These include expected surface loading, overlying soil cover thickness, slope stability, geotextile separator, TDA overbuild, and time-dependent settlement.

**Advantages**

- Lightweight, TDA is 45-50lbs/cf about 1/3 that of soil and/or rock.
- Strength of TDA, Type B TDA has Phi values of 35-40 degrees.
- Using lightweight backfill can result in reduced excavation.
- Increased factor of safety due to internal shear strength and lightweight.
- Constructability on a variety of poor subgrade conditions.
- Method specification for compaction efforts increases placement productivity.
- Sustainable recycled material.
- Highly permeable and does not “wick” water.
- Insulates against frost penetration.
- Cost effective.

**Limitations**

- Historically used above water table.
- TDA fill wrapped in geotextile fabric soil separator.
- Requires overbuild consideration and settlement period.

## *Construction Considerations*

The Embankment feature depth, width, and length are developed based on design need, constructability, and the hydrology of each site.

Communication between all parties is important for the success of any project. This is accomplished by holding pre-construction meetings where TDA can be introduced to all project stakeholders. Quality assurance reviews should be performed regularly.

The following areas should be addressed by the design team and project manager prior to construction:

- Design configuration.
- Factor of safety analysis.
- Delivery supplier(s), schedule, rates, and route.
- Stockpiling and delivery rate considerations.
- TDA compaction methodology and density specification.
- TDA placement methods and education of the onsite contractors.

Since TDA is much lighter than soil or gravel, contractors should become familiar with the basic properties of TDA before it arrives at the site. The following areas should be addressed by the contractor prior to receiving TDA at the project site:

- Volume of delivery.
- Project stockpile and configuration.
- Placement and compaction methodology.

## *Maintenance and Inspection*

| Activities | Maintenance Frequency | Inspection Frequency |
|---|---|---|
| Review Road surface for cracking, fill cracks | Annual | Annual |
| Survey road surface and slope | As needed | As needed |

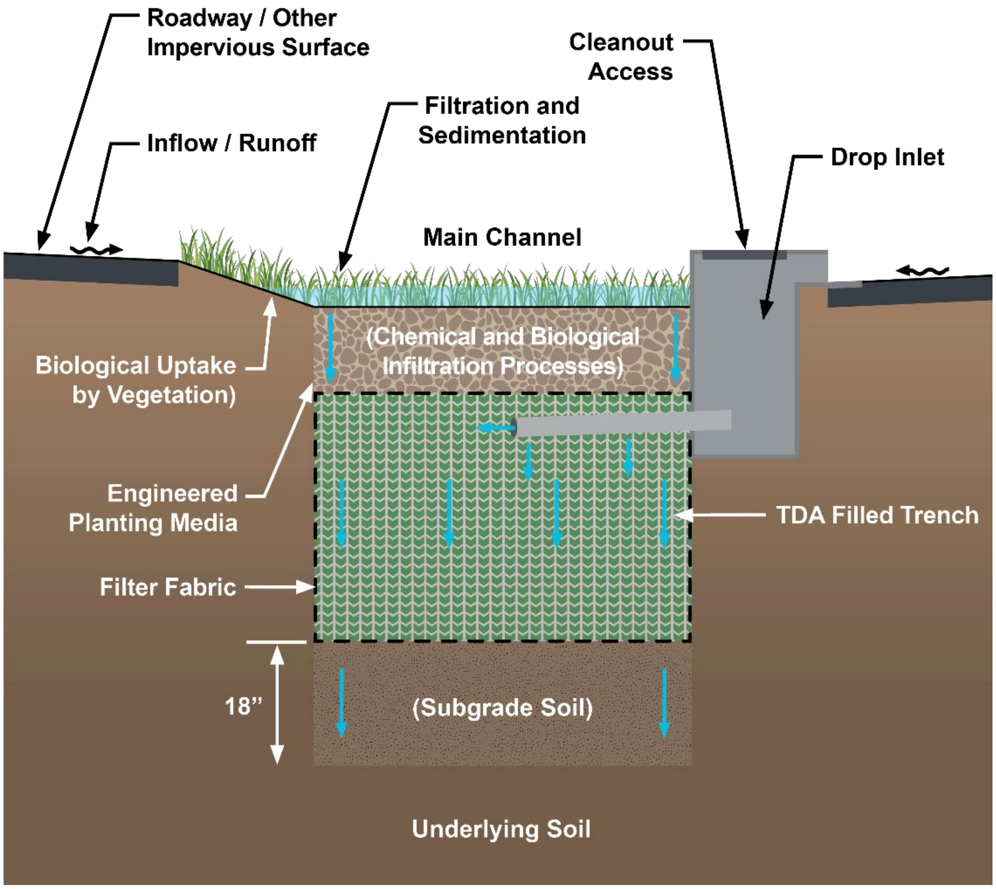
## *Additional Resources*

ASTM International. (ASTM). *D6270-20 Standard Practice for Use of Scrap Tires in Civil Engineering Applications. 2022.* https://webstore.ansi.org/standards/astm/astmd627020.

Chico State University. (CSU 2022). *Tire Engineering Research Center. Accessed August 2, 2022*. Copyright © 2022. https://www.csuchico.edu/cp2c/terc/index.shtml.

CalRecycle

# Storm Water Infiltration Gallery TDA-5




## Targeted Constituents

| | |
|---|---|
| Sediment | High |
| Phosphorus | Medium |
| Nitrates | Medium |
| Trash | High |
| Metals | High |
| Bacteria | Medium |
| Oil and Grease | High |
| Microplastic particles | High |
| Tire wear particles | High |

**Legend**
(Removal Effectiveness)
Low Medium High

## *Description*

Tire Derived Aggregate (TDA) Vegetated Bioswale uses recycled End of Life Tires (ELT) material to help clean and direct water towards the ground water setting. The swale allows for the catchment and eventual removal of road surface microplastics and other water quality contaminants before they can enter the waterways. This directly influences the amount of potential Tire Wear and Road Particles (TWRP) surface area exposed to water and the consequent potential loading of constituents released from TWP in stormwater to the adjacent water environments.

### Key Design Features

By design, the storm water infiltration gallery diverts storm water runoff towards the ground water setting through infiltration. The features need little maintenance and can be incorporated into a variety of landscapes. They are especially effective in areas where first flush roadway runoff should be captured and filtered locally.

### Advantages

- Increased uptake of nutrient loads due to micro-organism growth on TDA particles.
- Capture and concentrate road surface particles from the first precipitation events of the season.
- Filtration of stormwater runoff, reducing microplastics, contaminants, and suspended solids.
- Reduce sedimentation.
- Infiltration: allows groundwater table to recharge.
- Reduce constituent loads.
- Can be used to filtrate both stormwater and wastewater.

### Limitations

- Needs to be above groundwater table.
- Custom designs based on rainfall and site locations.

## *Construction Considerations*

### Sizing Design – Goal and Requirements

The infiltration gallery depth, width, and length are developed based on constructability and the hydrology of each site.  The soil type and resulting infiltration rate is another important engineering variable. The storm water volume and constituent loading are also important variables in the design specifications for infiltration galleries.

## *Maintenance and Inspection*

| Activities | Likelihood | Maintenance Frequency | Inspection Frequency |
|---|---|---|---|
| Remove trash and debris | | As needed | As needed |

## *Additional Resources*

ASTM International. (ASTM). *D6270-20 Standard Practice for Use of Scrap Tires in Civil Engineering Applications. 2022.* https://webstore.ansi.org/standards/astm/astmd627020.

Chico State University. (CSU 2022).  *Tire Engineering Research Center. Accessed August 2, 2022*. Copyright © 2022. https://www.csuchico.edu/cp2c/terc/index.shtml