END USE DEFINITIONS PROJECT

TIRE-DERIVED AGGREGATE

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INTRODUCTION

Worldwide, around one billion tires reach the end of their useful life every year. This underlines the importance of managing scrap tires in an environmentally responsible and productive manner so that they don't simply go to landfill sites where they put our environment and health at risk (Canadian Association of Tire Recycling Agencies, 2019).

Canada has well-established tire recycling programs through which 346,467 tonnes of scrap tires were collected and recycled into various products in 2019 (CATRA, 2019). Tire-derived aggregate (TDA) is one such product. According to a ranking of the United States Environmental Protection Agency (US EPA), using scrap tires to make TDA follows the best practical approach (US EPA, 2016). For every tonne of TDA that is processed - approximately 1.15 cubic meters - 100 tires are kept out of landfills (Eco Green Equipment, 2021).

HOW TDA IS MADE

TDA is mostly made from Passenger and Light truck tires (PLT), however Off-the-Road tires (OTR) are also used (Meles et al., 2014). In fact, OTR tires are sometimes preferred because the TDA from these thicker tires produce TDA that is more similar in particle size and shape to conventional aggregate (Meles et al., 2014).

Figure 1. *Whole tires before and after they are shredded into TDA* (Wanrooe, 2019).

Primary shredders are used to process scrap tires into TDA. Depending on the type, shredder equipment may be equipped with screening equipment and fitted with single or double shafts (Ningbo Sinobaler Machinery Co., Ltd., 2015).

Single Shaft Shredder

Scrap tires are fed into the hopper and pushed towards the cutting shaft by a hydraulic-driven arm to ensure they are properly shredded by the rotating cutting blades. The tires are continually shredded until the shreds are small enough to pass through the screen mesh, creating a TDA product that is even in size (Ningbo Sinobaler Machinery Co., Ltd., 2015). The single shaft shredder shown in Figure 2 is designed to process up to 12 tons of scrap tires per hour.

Figure 2. *A single shaft tire shredder*. Source: (Eco Green).

A short video, produced by Eco Green, is attached here to show a single shaft shredder in operation: https://youtu.be/rR60TNkeGN8

Double Shaft Shredder

Scrap tires are fed into the hopper and the two shafts of cutting blades slice them until they are fully shredded and discharged. Unlike the single shaft design, tire shreds do not pass through a screen, resulting in a product that is rough and unevenly sized (Ningbo Sinobaler Machinery Co., Ltd., 2015). The double shaft shredder shown in Figure 3 is designed to process up to 30 tons of scrap tires per hour.

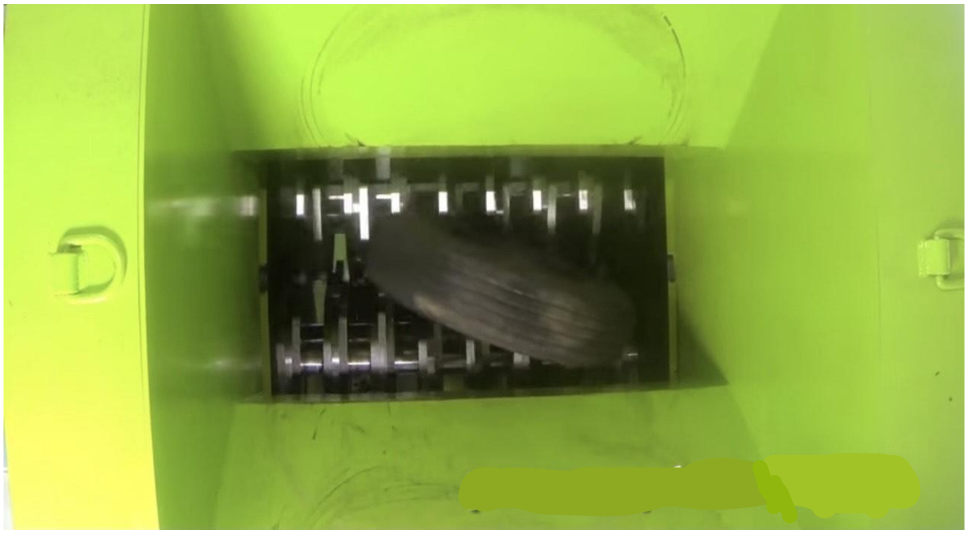

Figure 3. *A double shaft tire shredder.* Source: (Eco Green).

A short video, produced by Eco Green, is attached here to show a double shaft shredder in operation: https://youtu.be/fzhY7bHykF0

In addition to rubber, the shreds produced by each type of shredder typically contain steel and fibres. As part of the TDA processing operation, a machine is used to reduce the crumb size and remove the nylon fibre if necessary (Eco Green Equipment, 2021). The steel has value and, as such, is sold to steel manufacturing companies. Having no viable market, fibre is typically discarded.

APPLICATIONS OF TDA

While TDA can be consumed as a fuel, its highest product value is as a geotechnical material for civil engineering projects where TDA's higher permeability, thermal conductivity, shear strength, and compressibility – together with a lower unit weight - offer a cost-effective substitute for conventional materials such as stone, gravel, and soil (Scrap Tire News, 2020). Typically, TDA is used as a fill component by mixing or layering it with soil according to the project's specific needs. Given that TDA is so often mixed with soil, stockpiles of dirtier tires are generally considered acceptable as feedstock (U.S. EPA, 2016).

The following are common applications for TDA:

Building Foundations: Using TDA as a foundation wall backfill material for both residential and commercial buildings can be beneficial due to its thermal insulation qualities and its ability to allow easy drainage of water. As well, TDA's lighter weight reduces the pressure against the wall, resulting in a more cost-effective foundation wall design that requires less concrete or steel to withstand that pressure (Scrap Tire News, 2020).

Subgrade Fill and Embankments: TDA is applied as fill material, either alone or combined with soil, for roadway embankments and backfills behind retaining walls. In the case of embankments, the TDA is surrounded with geotextile fabric and a layer of natural soil is placed between the scrap tire layer and the roadway. Using

TDA to construct embankments on weak compressible foundation soils is beneficial due to its lighter weight and lower cost than conventional materials (Scrap Tire News, 2020).

Subgrade Insulation for Roads: A layer of TDA under a road can prevent the subgrade soils in northern climates from freezing in places where subgrade soils release excess water during spring. TDA's high permeability allows water to drain from beneath the roads, reducing the chance of damage to road surfaces (U.S. EPA, 2016).

Septic System Construction: TDA can be used as a substitute backfill for crushed gravel in constructing septic system leach fields (U.S. EPA, 2016). TDA's higher permeability and a lower unit weight can increase the drainage capacity of the field by 30 percent compared to stone (Eco Green Equipment, 2021).

Light-Rail Construction: TDA is used in light-rail construction to decrease vibrations that typically transmit the noise of passing trains, thus benefiting nearby homes and businesses. It is recommended to lay a one-foot thickness of TDA below the stone ballast railway base (Eco Green Equipment, 2021).

Landfill Construction: TDA is used as a drainage layer in leachate collection systems to provide drainage and prevent underlying clay barriers from freezing in a cold climate. It is also used as a backfill in leachate recirculation trenches that distribute the collected leachate back into the waste (Scrap Tire News, 2020). TDA's permeability also can help with the collection of landfill gas (Scrap Tire News, 2020). In Alberta, TDA is considered a preferred material for landfill leachate collection systems in that it provides a sustainable market for a tire-derived product that is enabled through their provincial stewardship program.

NOTABLE PROJECTS

TDA has been used in a wide range of civil engineering projects in many parts of the world and it has proven to be effective in those applications. Some of these projects includes:

CANADA

- **Halifax, Nova Scotia, 2016:** TDA was used as a cost-effective method to build a high-traffic off-ramp for the Ragged Lake Bus Depot, saving the municipality up to $140,000 (Moore, 2016). TDA was applied because of its effectiveness in road construction where there is a high groundwater table and poor soil condition.
- **Halifax, Nova Scotia, 2016:** TDA was used as a drainage system for the Shubenacadie Ball Field to allow overnight drainage. TDA was applied because it is more compressible than conventional soil (Moore, 2016).
- **Stettler County, Alberta, 2013**: The Alberta Recycling Management Authority (ARMA) and the County of Stettler used TDA as a lightweight fill in place of conventional clay fills in the embankment construction for a section of Range Road 184 between Township Road 360 and 361. Upon completion, it was observed that TDA's elasticity resulted in a less rigid fill that still provided the required structural strength and behaviour. (Parkland Geotechnical Consulting Ltd, 2016).
- **Edmonton, Alberta, 2013:** TDA was used as a fill to construct an 80-meter-long embankment connecting the Anthony Henday ring road to the Edmonton Waste Management Center. TDA was chosen because of its

light weight and greater permeability (Meles et al., 2014).

- **New Brunswick, 2007:** TDA was used as a lightweight fill in the first stage construction of the Route 1 highway embankment after it collapsed during construction due to underlying soft marine clay. TDA helped to reinforce the holding capacity of the foundation soil (Hoppe & Oman, 2013).
- **Winnipeg, Manitoba, 2000:** TDA was used to build a 305-meter long embankment above soft ground to act as a subgrade thermal insulator to limit frost penetration and prevent road damage (Hoppe & Oman, 2013).

UNITED STATES

- **Mankato, Minnesota, 2010:** TDA was used as a lightweight fill to stabilize the peat under the embankment area of the Blue Earth County Road 12 bridge that sustained cracks after construction (Hoppe & Oman, 2013).
- **Sonoma County, California, 2008:** TDA was applied as the subgrade layer for Geysers Road providing a lightweight fill to repair the landslide failure caused by the saturation of soil backfill during periods of heavy rain (Cheng, 2016).
- **Indiana, 2008:** A mixture of TDA and soil was used as lightweight backfill for the widening of SR-110 road in Marshall County and SR-19 road in Elkhart County where the grade needed to be raised over peat to minimize soil settlement (Hoppe & Oman, 2013).
- **Riverside, California, 2007:** TDA was used as lightweight fill material to exert less pressure behind the retaining Wall 207 project that was constructed to aid the widening of I-215/Route 60/Route 90 freeway interchange. TDA served as both the backfill and the drainage material. (Cheng, 2016).

THE ECONOMICS OF TDA

Using TDA as a Geotechnical Material Can Reduce Project Costs:

Ton for ton, TDA costs less than conventional civil engineering materials while, at the same time, its comparative lightness reduces transportation costs. A cost-benefit assessment was performed for CalRecycle to evaluate projects where TDA was used in place of conventional soil fill materials. Findings showed that the material and transportation costs of TDA are much cheaper than all other studied materials that included crushed gravel, floating concrete slabs, pumice rock, expanded polystyrene, expanded shale clay, and wood chips. For example, in Sonoma County in California, where a mountain road has washed away every ten years, TDA helped bring the cost of repairs in at 50% of the county's estimate (Cheng, 2016).

TDA’s greater durability than conventional fill materials means that work is required less often to maintain civil engineering assets, leading to overall cost savings. In Santa Barbara County, also in California, TDA was used in the Palomino Road project where engineers predict that the TDA repairs will last four times longer than the road which uses conventional fill materials (California State University, 2021).

TDA’s higher permeability compared to gravel can also reduce the amount of labour and materials to achieve the required drainage rate that many projects require. (California State University, 2021).

The TDA Processing Industry Helps Local Economies:

Processing and using TDA for civil engineering projects contribute to a cleaner environment and stimulate the local economy through job creation. In places where many scrap tires are generated, there is the opportunity to build and operate a TDA processing facility that recycles scrap tires into TDA or other tire-derived products. The collection and haulage of tires to a processing facility can also support the economy. Currently, most provinces and territories with tire disposal regulations offer incentives for the above activities, helping these businesses get started and stay viable.

HEALTH & ENVIRONMENTAL IMPACT

Concerns have been raised about the potential for toxic compounds to leach from tires when placed in wet soils. One prominent study was undertaken by the Civil Engineering department at the University of Maine to assess the potential health and environmental impacts of various applications of TDS in drinking water quality, freshwater, and marine life. They found that while TDA is likely to increase the levels of iron and manganese in groundwater, the compounds would have limited ability to move beyond where the TDA was applied. It follows that any potential impact would then be highly dependent on local water and soil conditions. If the pH level of groundwater remains neutral, TDA is not expected to have any significant effect on groundwater quality (U.S. EPA, 2016).

ADVANCING THE OPPORTUNITIES FOR TDA

Despite the potentially beneficial properties of TDA, its adoption as a mainstream material in civil engineering projects has been slow (Scrap Tire News, 2020). This may be partly because of environmental concerns that persist even though findings show that, so long as TDA is made to accepted standards, negative environmental impacts are unlikely (Moore, 2016). The hesitancy is also because engineers prefer to use known products with established procedures rather than having to determine the exact specification of TDA to apply based on the needs of individual projects.

To address these barriers, governments and academia are taking measures to encourage the use of TDA. The State of California has been a leader in both research and deployment with the California Department of Resources Recycling and Recovery (CalRecycle) establishing the Tire Derived Aggregate Technology Center (TTC) out of California State University in 2012. TTC provides research and material testing services that support the acceptance of TDA by both private and public engineers, resulting in more opportunities for TDA projects (California State University, 2021). An important product of these combined resources is a first comprehensive Usage Guide for Tire-Derived Aggregate, published in 2016, that provides state-of-the-art design and construction practices for using TDA in civil engineering applications. Additionally, to reduce any financial barriers, CalRecycle offers grants to civil engineers to use TDA in their projects. While their initial focus has been on using TDA for road projects, CalRecycle/TTC has been conducting tests that show the potential benefits of using TDA in foundations and retaining walls, and in septic and stormwater applications.

Closer to home, Red River College in Manitoba collaborated with OTR Recycling Corp, Tire Stewardship Manitoba, and Manitoba Hydro to research the use of TDA to replace natural material in residential home basement construction. Their 2018 report showed that TDA has no negative effects and can perform better than conventional materials when used as backfill and underneath the slab of home basements (Rashwan, 2018). These findings led the Manitoba construction industry to recognize the value of TDA, with the City of Winnipeg Engineers approving the use of TDA so long as geotechnical reports accompany the construction permits (Rashwan, 2018).

CONCLUSION

Ongoing product development efforts, together with a strong track record of successful applications, show that TDA is a viable and safe substitute for conventional materials serving a range of civil engineering needs.

The use of TDA is projected to grow due to its performance and the increasing recognition that conventional aggregate has its challenges such as environmental concerns associated with gravel mining (Marshall, 2021). The economics of using TDA are supporting its uptake, at the same time that the early development of usage guidelines is helping engineers adopt a new material that they are less familiar with. In some locations, there may also be some form of incentive for engineers and project developers to use TDA and discover firsthand the benefits that it can offer both in cost savings and material performance. At the same time, the supply chain associated with scrap tire recycling supports local economies where TDA is produced.

As more research and projects are undertaken, it is anticipated that interest in using TDA across a wide range of applications will continue to grow among civil engineers around the world.

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