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A Division of CMC

Sustainable Pavement Design Using Geosynthetics

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Agenda

- Geosynthetics and their use in enhanced pavement design
- Sustainability and resilience in pavement design
- FHWA Sustainable Pavements Program
- The role of design in sustainability analysis
- Design example

Types of Geosynthetics

Koerner, R. M. (2012). *Designing With Geosynthetics* (6th ed.). Xlibris Publishing Co., 914 pgs.

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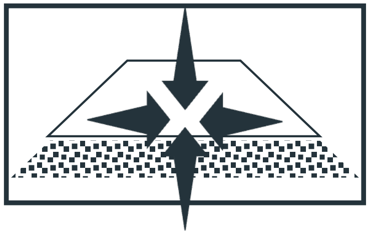
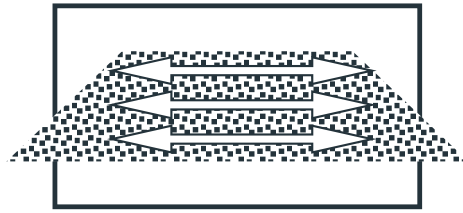
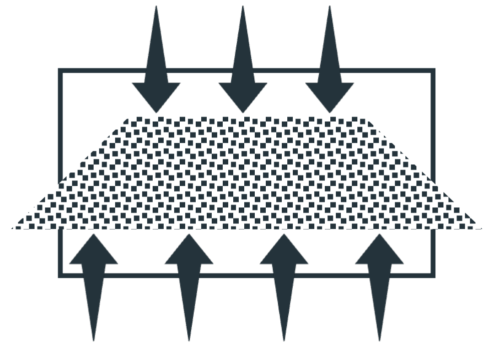
Geosynthetic Functions



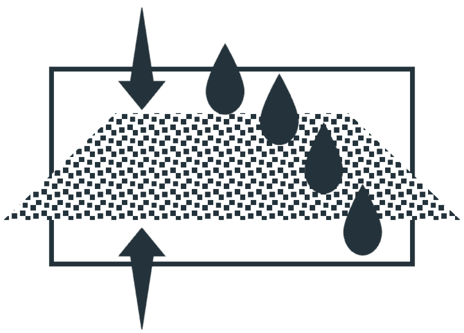
1 Stabilization



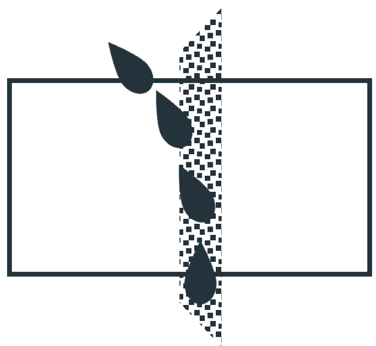
2 Reinforcement



3 Separation



4 Filtration



5 Drainage

6 Containment

Function: Stabilization

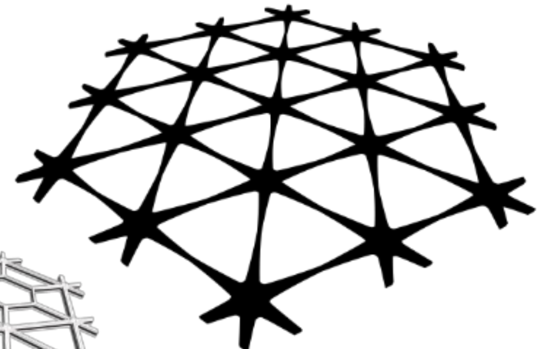
Definition:

- Improves the mechanical behavior of unbound granular materials, by interlocking and confining their particles to minimize deformations caused by traffic loading

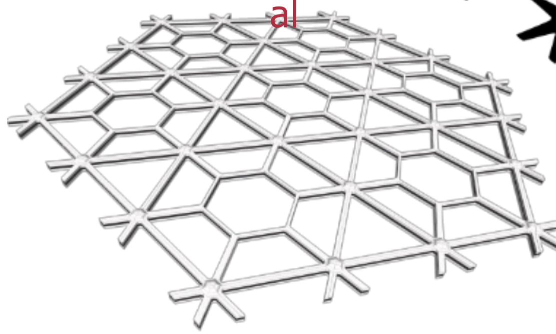
Types of Geosynthetics:

- Multiaxial Geogrids
- Geocells

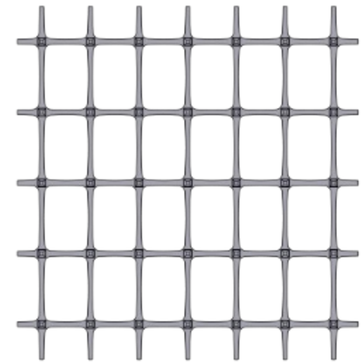
Triaxial



Multiaxi
al



Biaxial



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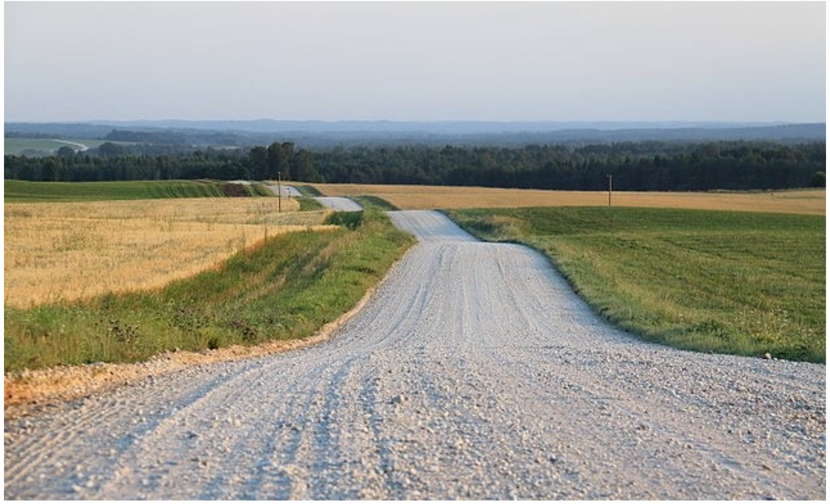
Function: Stabilization

Applications:

- Unpaved Haul/Access Roads
- Paved Roads
- Working Platforms



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What are Geogrids?

Mechanisms of Geogrids

1

Aggregate Confinement

2

Improved Bearing Capacity

3

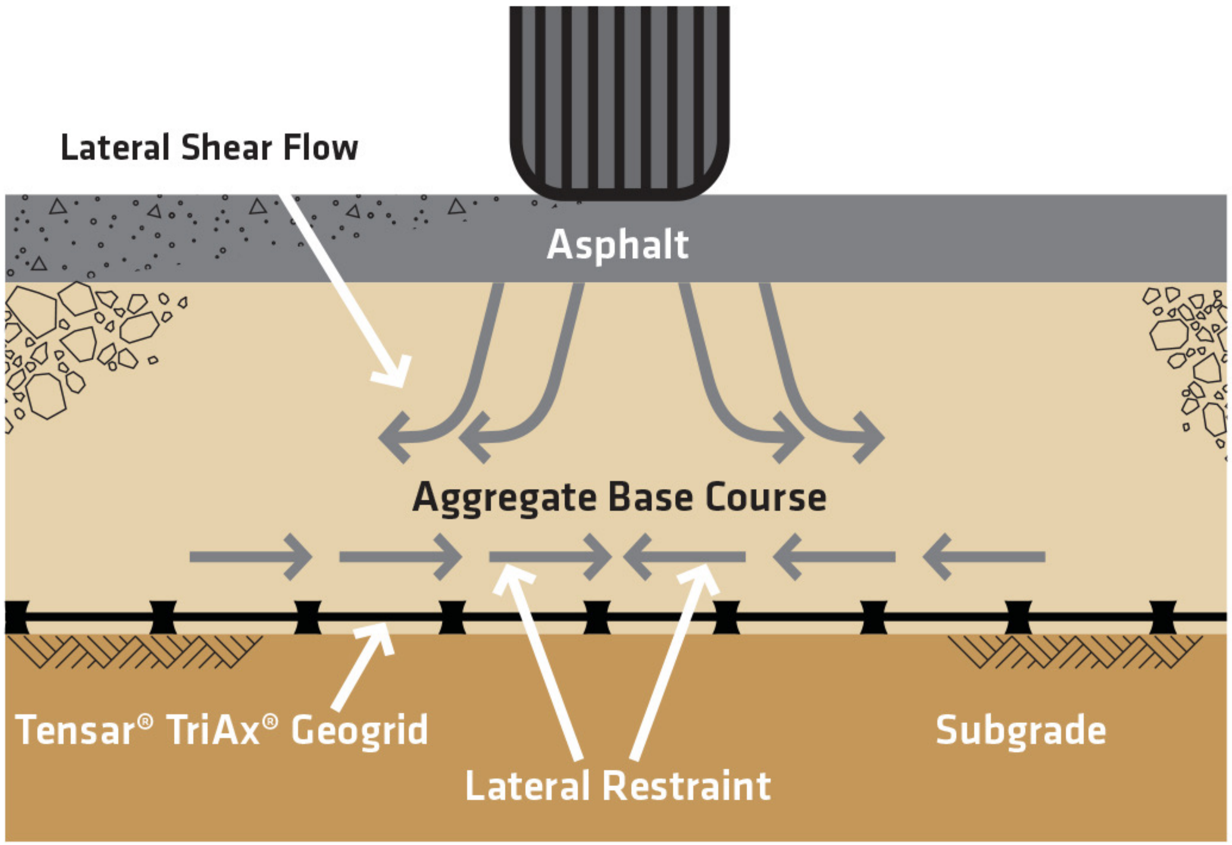
Tension Membrane Effect

All mechanisms act together to

MAKE STONE PERFORM BETTER

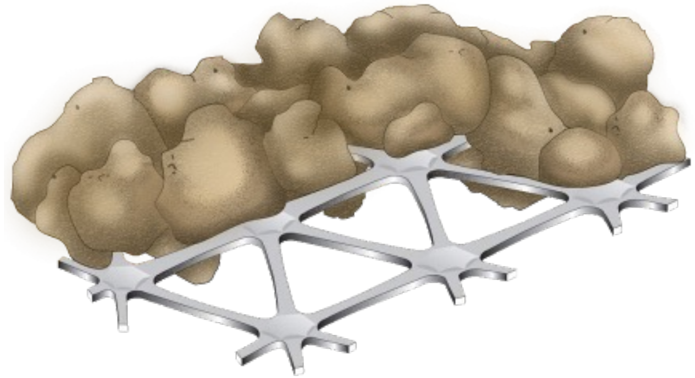
These mechanisms were identified and defined by
ACE USACOE, Tngle & Webster (2003)

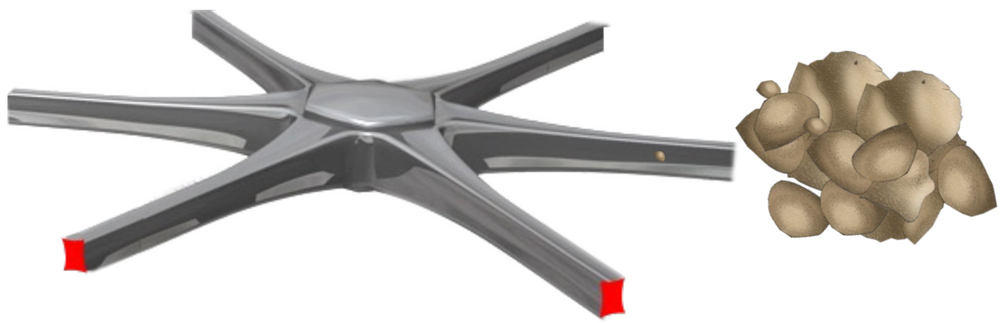
Mechanisms – Aggregate Confinement



Source: USACOE ETL 1110-1-189

Mechanisms – Aggregate Confinement





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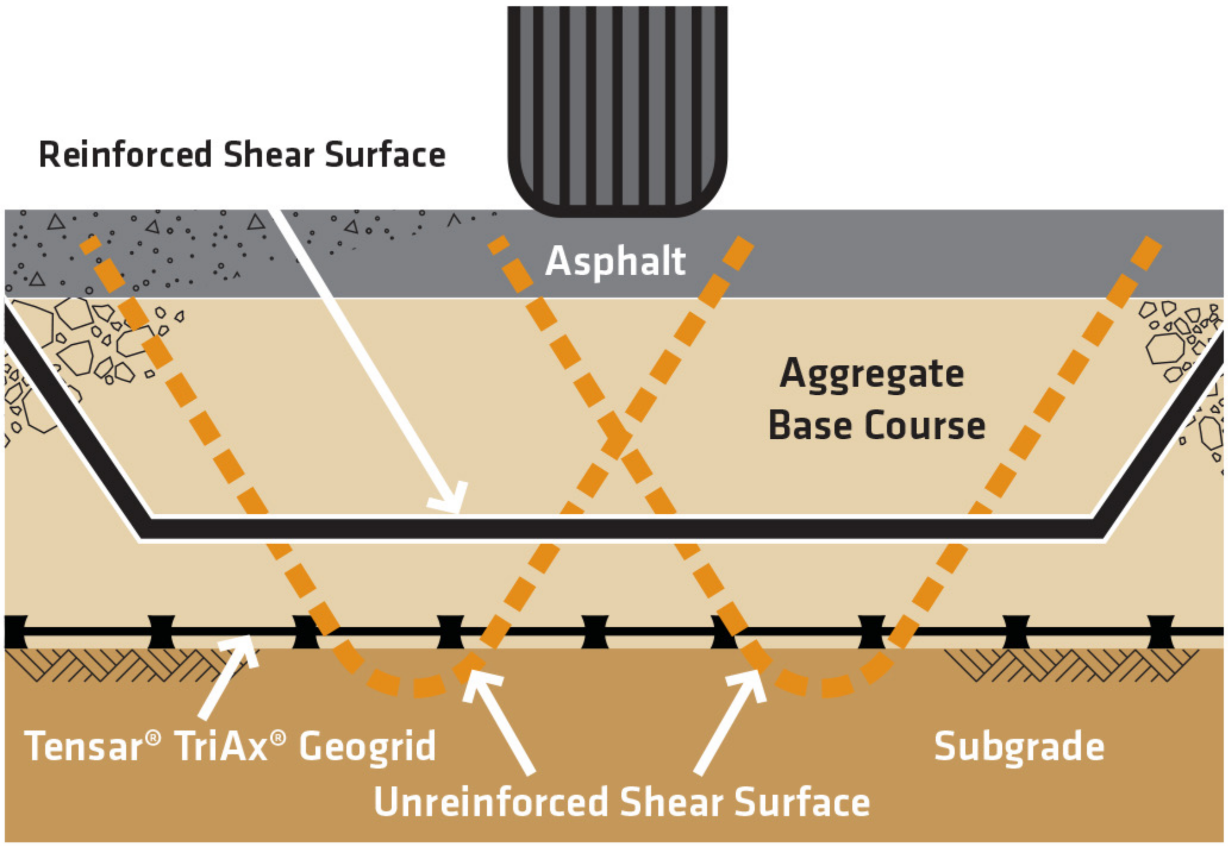
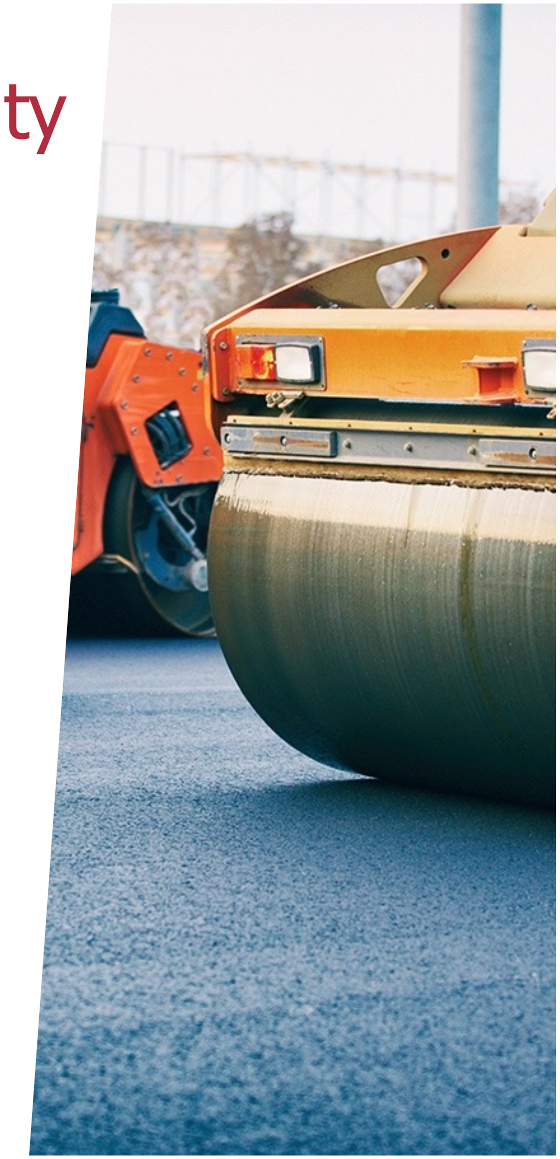
Mechanisms - Improved Bearing Capacity



Source: USACOE ETL 1110-1-189



Small Scale Trafficking Tests

Unstabilized
3,000 passes

Biaxial Geogrid
10,000 passes

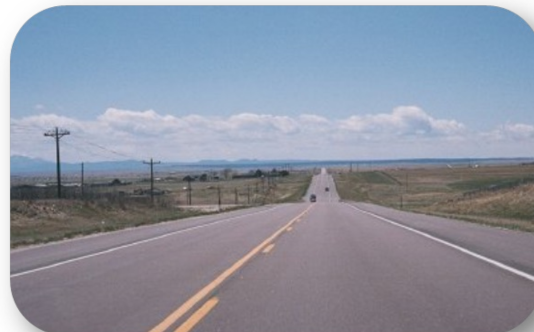
Triaxial Geogrid
10,000 passes

Common Geogrid Applications for Roadways

Subgrade Stabilization

- Bridge over soft soils
- Establish working surface
- Reduce fill thickness
- Reduce or eliminate undercut
- Replace mechanical mixing
- Replace chemical stabilization
- Provide uniform support condition
- Reduce maintenance

Pavement Optimization



- Stiffen aggregate base material
- Reduce aggregate/asphalt thickness
- Replace mechanical mixing
- Provide increased reliability
- Reduce maintenance
- Extend roadway life

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Options for Addressing Weak Subgrades

Excavate and Replace – remove the poor-quality soil and replace it with better material

Thicker Base or Sub-Base Layer – Use more granular material on top of the poor subgrade

Augment the Subgrade Soil – Use lime or other chemical treatments to improve the soil's strength

Mechanical Stabilization – Use geogrid to stabilize the subgrade

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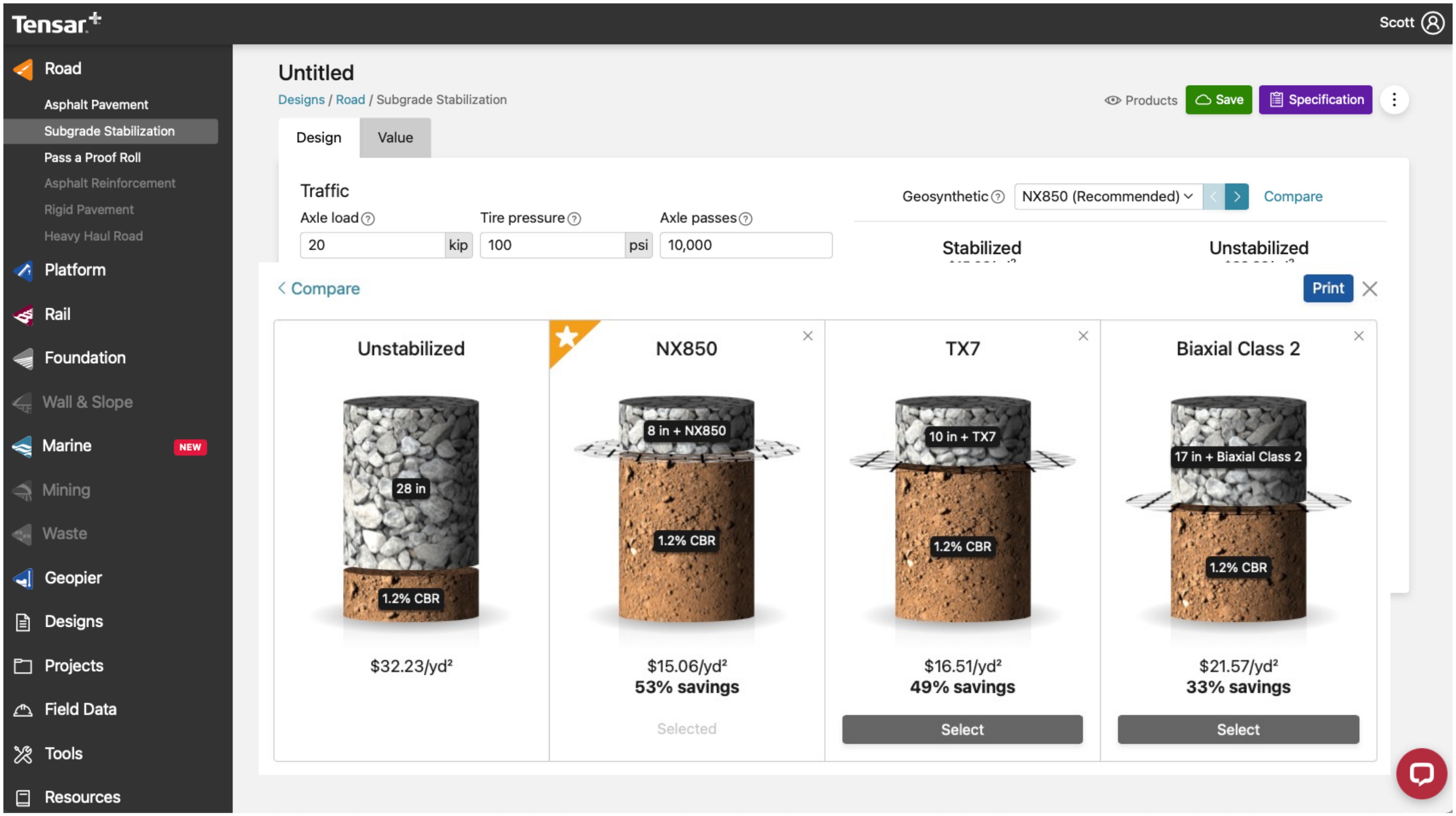
Subgrade Stabilization Design



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Pavement Design Using AASHTO93

$$\log_{10}(W_{18}) = Z_R S_o + 9.36\log_{10}(SN+1) - 0.20 + \frac{\log_{10}\left[\frac{\Delta PSI}{4.2-1.5}\right]}{0.40 + \frac{1094}{(SN+1)^{5.19}}} + 2.32\log_{10} M_R - 8.07$$

W_{18} = Allowable ESALs

Z_R = Standard normal deviate

S_o = Standard deviation

SN = Structural number

ΔPSI = Change in serviceability

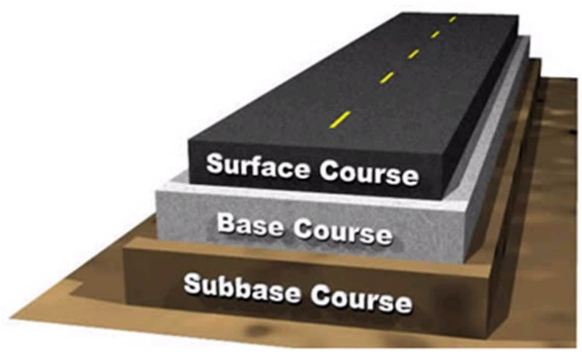
M_R = Subgrade resilient modulus

- Converted to a layer depth using coefficients.
  - SN = a_1D_1 + $\mathbf{a_2}$*D_2m_2 + $a_3D_3m_3$ + …

a = **ENHANCED (base)** structural layer coefficient

D = layer thickness (inches)

m = layer drainage coefficient (typ. 1.0)



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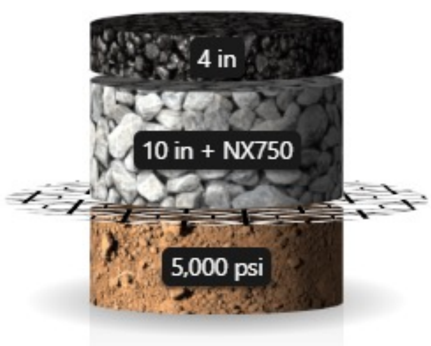
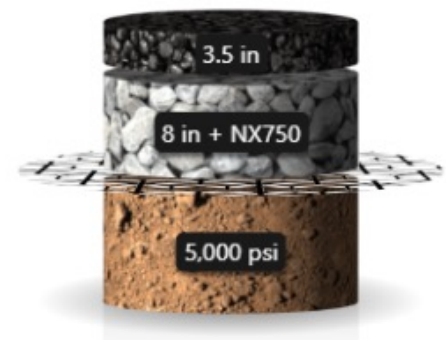
Pavement Optimization

Conventional Design	Stabilized Option 1	Stabilized Option 2	Stabilized Option 3
			
116,900 ESALs	**1,041,300 ESALs**	**116,900 ESALs**	**372,500 ESALs**
Conventional Design	**Maximum Life**	**Minimum Construction Cost**	**Equivalent Cost**

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Sustainability and Resilience

- **Resilience or Resiliency**: the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions (FHWA)

- **Sustainability**: to create and maintain conditions, under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic, and other requirements of present and future generations (NEPA)

Resilience supports sustainability in infrastructure in almost every case, both by minimizing required inputs and supporting broader goals for humans and nature.

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What is an EPD?

An Environmental Product Declaration (EPD) is defined by ISO as a declaration that "**quantifies environmental information on the life cycle of a product to enable comparisons between products fulfilling the same function**".

Environmental Product Declaration

Tensar InterAx™ Geogrids

Tensar InterAx™ NX750 and NX850 Geogrids

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Tensar is committed to investing in research, industry collaboration, and product development that supports sustainable and resilient infrastructure. Our corporate mission is to advance and improve sustainable and resilient infrastructure by optimizing the construction and performance of roadways, building foundations and other structures while significantly reducing the environmental footprint associated with these activities. Our solutions allow customers and stakeholders to use natural resources sustainably and address climate change with urgency. Tensar recognizes the threats that global climate change has on our business and the communities in which we operate. This is the catalyst that drives our constant innovation, improvement, and the development of new products and operating technologies to significantly reduce our energy, resource consumption and waste.

Headquartered in Alpharetta, Georgia our workforce services stakeholders across the globe and are supported by operations from our production facilities in the US, Europe and Asia. We believe our sustainable foundation is a key differentiator that sets us apart from our competitors.

Highest performing geogrid for soil stabilization that combines advanced material science and optimized geometry to solve civil and site construction challenges.

CERTIFIED

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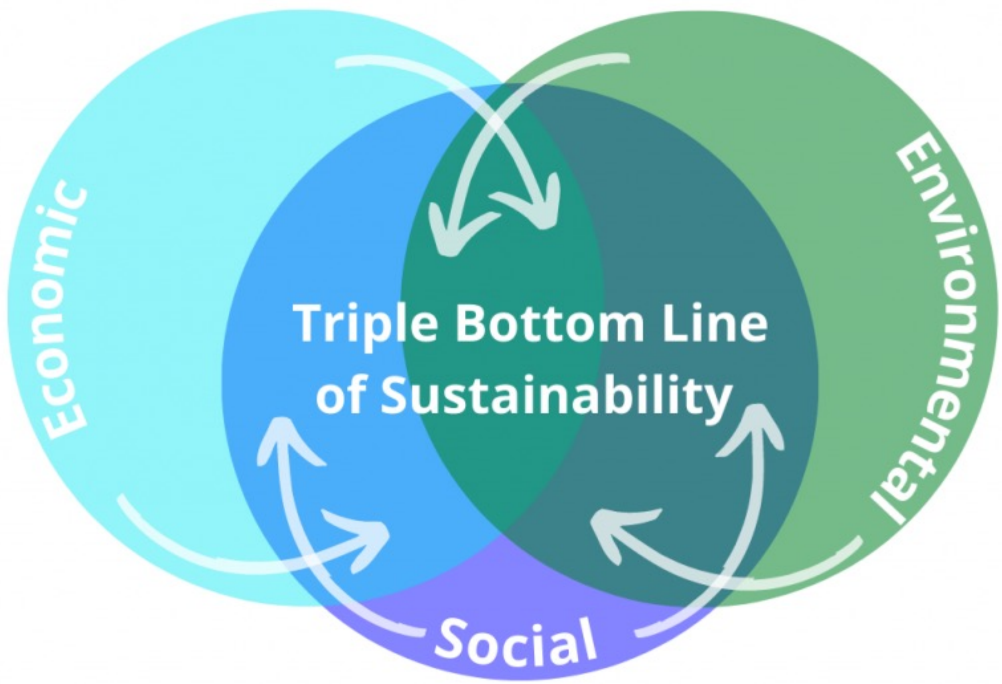
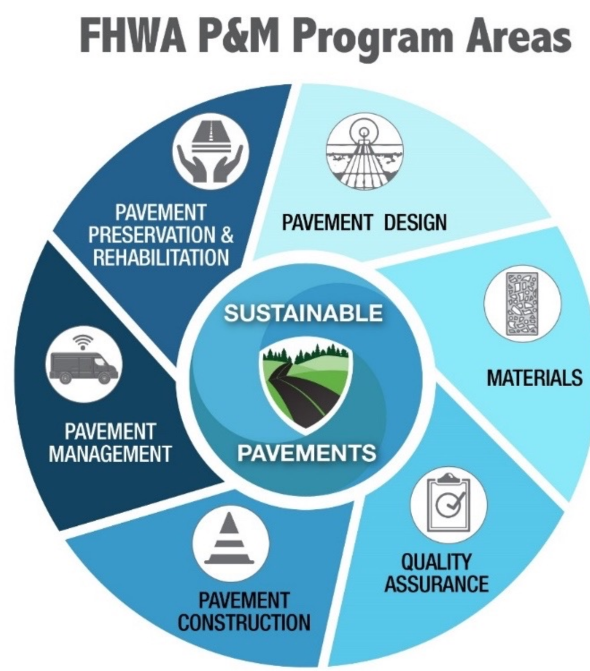
Triple Bottom Line



FHWA Pavement & Materials Program

Ensure that pavements are designed, constructed, preserved, and maintained to accommodate current and predicted traffic needs and consider economic, environmental, and social impacts and needs throughout the pavement's life cycle.



Source: FHWA

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Sustainable Pavements

1. Achieve the engineering goals (performance).
2. Preserve and (ideally) restore surrounding ecosystems.
3. Use financial, human, and environmental resources wisely.
4. Meet basic human needs such as health, safety, equity, employment, comfort, and happiness.

FHWA Sustainable Pavements Program

Advance the knowledge and practice of designing, constructing, and maintaining more sustainable pavements through:

- Stakeholder engagement
- Education
- Development of guidance and tools

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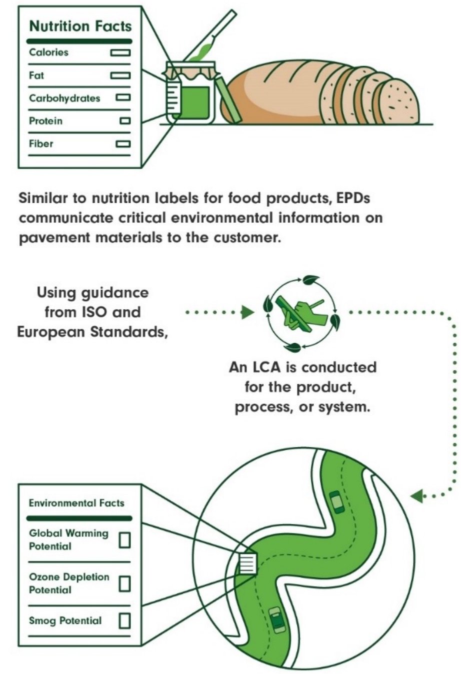
Quantification Methods

- Environmental Product Declarations (EPD)
  - LCA-based, transparent and verified report of environmental impacts of a product
- Life Cycle Assessment (LCA)
  - Method to quantify environmental impacts of products and processes over life cycle



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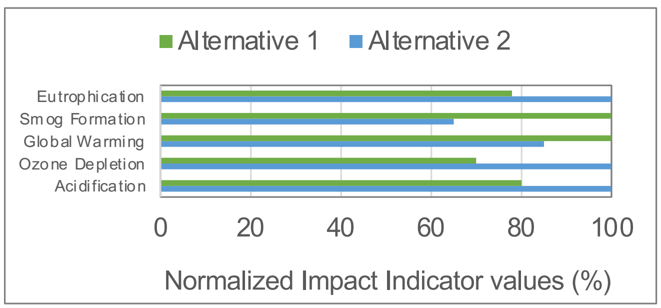
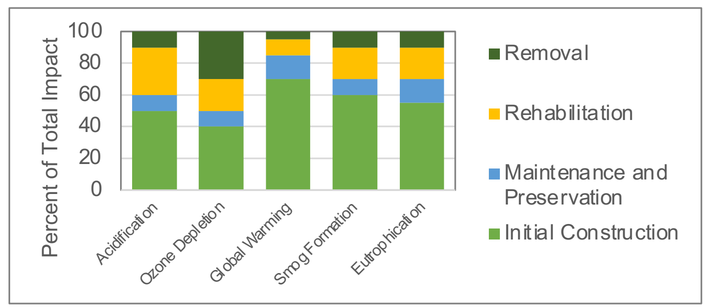
LCA Benchmarking Tool

- Created with stakeholder input
- Use the identified background datasets
- Incorporate material EPDs





Available at: https://www.fhwa.dot.gov/pavement/lcatool/

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Inflation Reduction Act of 2022

Section No.	Agency	Funding	Title	Expiration Date
60112	EPA	$250M	Environmental Product Declaration Assistance	Sept. 30, 2031
60116	EPA	$100M	Low-Embodied Carbon Labeling for Construction Materials • Identify and label construction materials with lower embodied GHG • Production, Use, and Disposal	Sept. 30, 2026
60503	GSA Federal Buildings Fund	$2.15B	Use of Low-Carbon Materials	Sept. 30, 2026
60506	DOT FHWA	$2B	Low-Carbon Transportation Materials Grants • Use of construction materials and products that have substantially lower embodied GHG Production, Use, and Disposal	Sept. 30, 2026

Carbon Reduction Program

- Purpose: To reduce transportation emissions through the development of State carbon reduction strategies and by funding projects designed to reduce transportation emissions (IIJA Pub. L. 117-58)

- Sustainable pavements and construction materials

  "Sustainable pavements technologies that reduce embodied carbon during the manufacture and/or construction of highway projects could be eligible for CRP if a lifecycle assessment (LCA) demonstrates substantial reductions in CO_2 compared to the implementing Agency's typical pavement-related practices. The LCA Pave Tool can be used to assess the CO_2 impacts of pavement material and design decisions."

  (From Program Guidance https://www.fhwa.dot.gov/environment/sustainability/energy/policy/crp_guidance.pdf)

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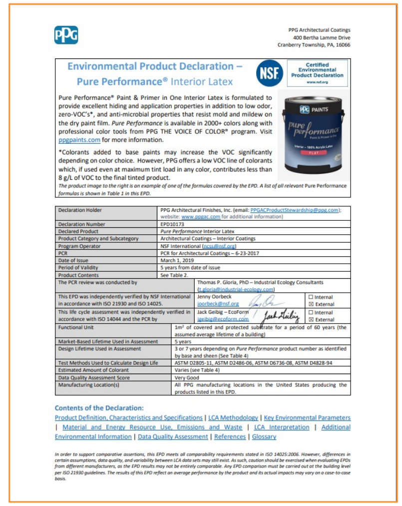
Understanding the Role of Design

- Alternative design approaches often use products from different categories to achieve the desired result
- If the design approach changes, a simple comparison of EPDs will yield flawed results
- Operational and maintenance differences may also come into play with different designs
- A valid analysis must cover both the proper **scope** and the proper **time frame**


PPG Architectural Coatings
400 Bertha Lamme Drive
Cranberry Township, PA, 16066

Environmental Product Declaration – Pure Performance® Interior Latex

Certified Environmental Product Declaration www.nsf.org

Pure Performance® Paint & Primer in One Interior Latex is formulated to provide excellent hiding and application properties in addition to low odor, zero-VOC's*, and anti-microbial properties that resist mold and mildew on the dry paint film. *Pure Performance* is available in 2000+ colors along with professional color tools from PPG THE VOICE OF COLOR® program. Visit ppgpaints.com for more information.

*Colorants added to base paints may increase the VOC significantly depending on color choice. However, PPG offers a low VOC line of colorants which, if used even at maximum tint load in any color, contributes less than 8 g/L of VOC to the final tinted product.

The product image to the right is an example of one of the formulas covered by the EPD. A list of all relevant Pure Performance *formulas is shown in Table 1 in this EPD.*

Declaration Holder	PPG Architectural Finishes, Inc. (email: PPGACProductStewardship@ppg.com); website: www.ppgac.com for additional information)	
Declaration Number	EPD10173	
Declared Product	*Pure Performance* Interior Latex	
Product Category and Subcategory	Architectural Coatings – Interior Coatings	
Program Operator	NSF International (ncss@nsf.org)	
PCR	PCR for Architectural Coatings – 6-23-2017	
Date of Issue	March 1, 2019	
Period of Validity	5 years from date of issue	
Product Contents	See Table 2.	
The PCR review was conducted by	Thomas P. Gloria, PhD – Industrial Ecology Consultants (t.gloria@industrial-ecology.com)	
This EPD was independently verified by NSF International in accordance with ISO 21930 and ISO 14025.	Jenny Oorbeck joorbeck@nsf.org	☐ Internal ☒ External
This life cycle assessment was independently verified in accordance with ISO 14044 and the PCR by	Jack Geibig – EcoForm jgeibig@ecoform.com	☐ Internal ☒ External
Functional Unit	1m² of covered and protected substrate for a period of 60 years (the assumed average lifetime of a building)	
Market-Based Lifetime Used in Assessment	5 years	
Design Lifetime Used in Assessment	3 or 7 years depending on *Pure Performance* product number as identified by base and sheen (See Table 4)	
Test Methods Used to Calculate Design Life	ASTM D2805-11, ASTM D2486-06, ASTM D6736-08, ASTM D4828-94	
Estimated Amount of Colorant	Varies (see Table 4)	
Data Quality Assessment Score	Very Good	
Manufacturing Location(s)	All PPG manufacturing locations in the United States producing the products listed in this EPD.	

Contents of the Declaration:
Product Definition, Characteristics and Specifications | LCA Methodology | Key Environmental Parameters | Material and Energy Resource Use, Emissions and Waste | LCA Interpretation | Additional Environmental Information | Data Quality Assessment | References | Glossary

In order to support comparative assertions, this EPD meets all comparability requirements stated in ISO 14025:2006. However, differences in certain assumptions, data quality, and variability between LCA data sets may still exist. As such, caution should be exercised when evaluating EPDs from different manufacturers, as the EPD results may not be entirely comparable. Any EPD comparison must be carried out at the building level per ISO 21930 guidelines. The results of this EPD reflect an average performance by the product and its actual impacts may vary on a case-to-case basis.


SHERWIN-WILLIAMS.

Environmental Product Declaration – Duration Home® Interior Acrylic[1]

Certified Environmental Product Declaration www.nsf.org

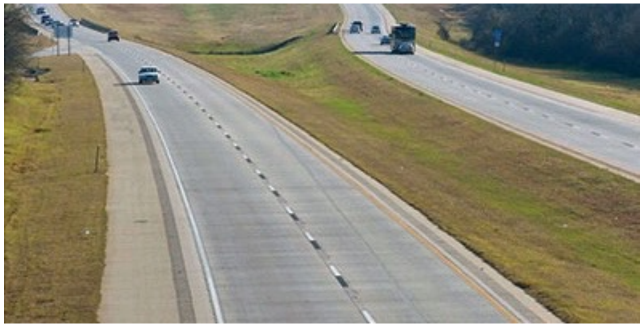
Duration Home® keeps your busiest spaces protected. This paint and primer in one provides outstanding coverage in fewer coats. It contains anti-microbial agents* that inhibit the growth of mold and mildew on the paint surface and its' advanced stain-blocking technology helps hide old stains and allows most new ones to be wiped clean with water. Whether it's a playroom or kitchen, Duration Home® paint or paint and primer in one makes high-traffic areas easier to maintain. For additional information, please visit www.sherwin.com.

*This product contains agents which inhibit the growth of mold and mildew on the surface of this paint film.

The product image to the right is an example of one of the formulas covered by the EPD. A list of all relevant Duration Home® Interior Acrylic formulas is shown in Table 1 on page 2 of the EPD.

Program Operator	NSF Certification LLC
Declaration Holder	The Sherwin-Williams Company
Declaration Prepared by	April Morris (sustainability@sherwin.com)
Declaration Number	EPD10613
Declared Product	Duration Home® Interior Acrylic
Product Category and Subcategory	Architectural Coatings – Interior Coatings
Program Operator	NSF Certification LLC ncss@nsf.org
Reference PCR	PCR for Architectural Coatings
Date of Issue	July 30, 2021
Period of Validity	5 Years
Contents of the Declaration	– Product definition and material characteristics – Overview of manufacturing process – Information about in-use conditions – Life cycle assessment results – Testing verifications
The PCR review was conducted by	Thomas P. Gloria, Ph. D. Industrial Ecology Consultants t.gloria@industrial-ecology.com
This EPD was independently verified by NSF Certification LLC in accordance with ISO 21930 and ISO 14025. ☐ Internal ☒ External	Tony Favilla afavilla@nsf.org
This life cycle assessment was independently verified in accordance with ISO 14044 and the reference PCR by	Jack Geibig – EcoForm jgeibig@ecoform.com
Functional Unit:	1m² of covered and protected substrate for a period of 60 years (the assumed average lifetime of a building)
LCA Software Used	GaBi (Most Recent Version)
Market-Based Lifetime Used in Assessment	5 years
Design Lifetime Used in Assessment	7, 15 years depending on base.
Test Methods Used to Calculate Design Life	ASTM D2805-11, ASTM D2486-06, ASTM D6736-08, ASTM D4828-94
Estimated Amount of Colorant	Varies (see Table 3)
Data Quality Assessment Score	Very Good
Manufacturing Location(s)	Various Plants Throughout the United States

[1] *In order to support comparative assertions, this EPD meets all comparability requirements stated in ISO 14025:2006. However, differences in certain assumptions, data quality, and variability between LCA data sets may still exist. As such, caution should be exercised when evaluating EPDs from different manufacturers, as the EPD results may not be entirely comparable. Any EPD comparison must be carried out at the building level per ISO 21930 guidelines. The results of this EPD reflect an average performance by the product and its actual impacts may vary on a case-to-case basis.*



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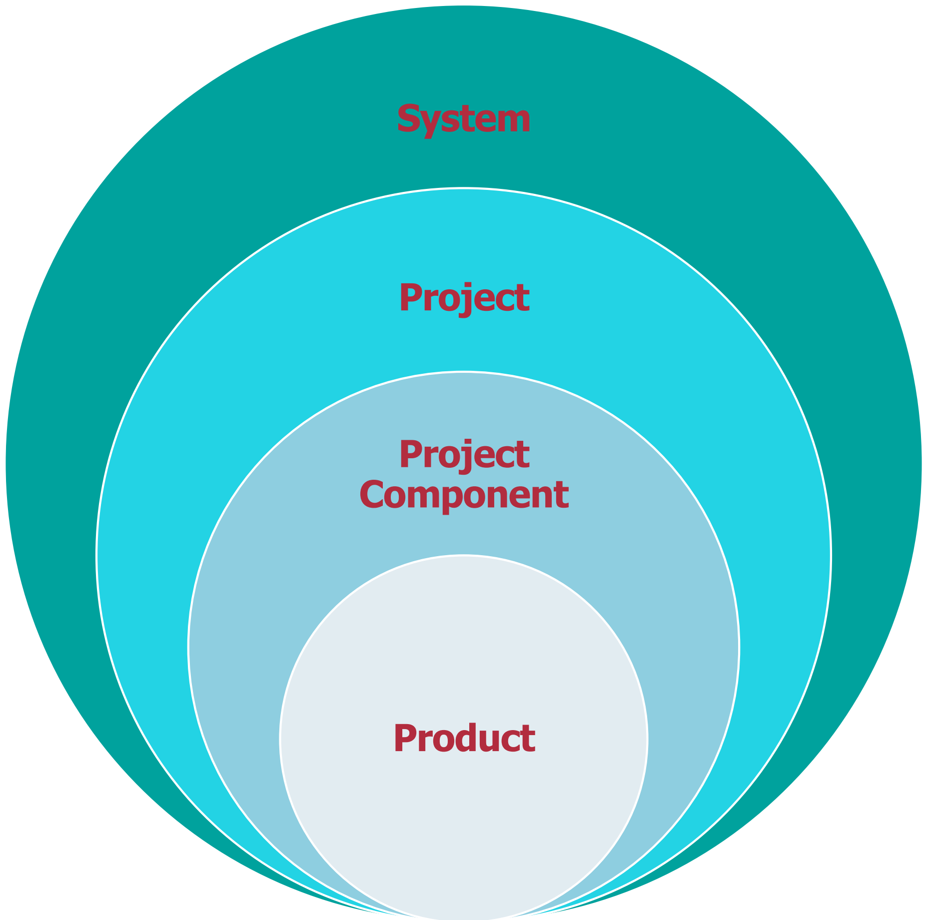
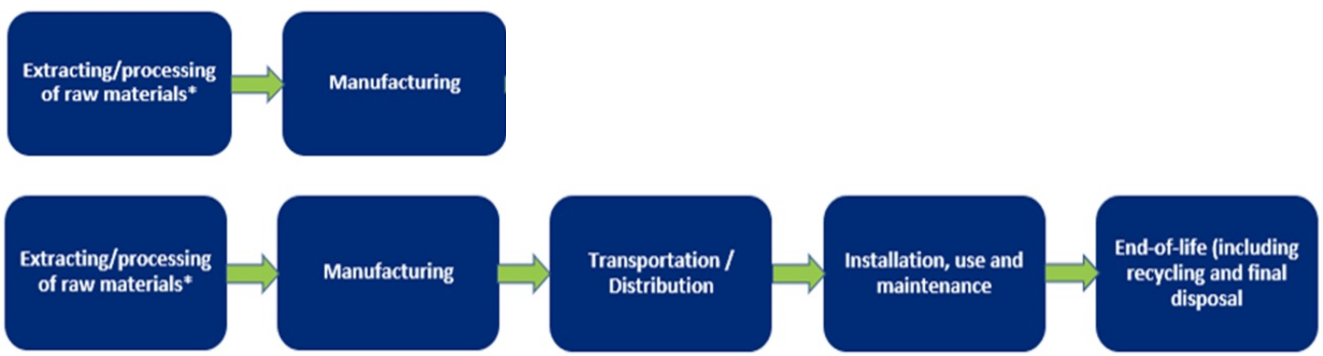
Scope of Consideration



Assumptions and Limitations

- **Scope of Consideration** is critical to valid results
  - Material/design scope
  - Temporal scope
- Understand the data you have, and the **data you don't have**
- For infrastructure projects, **construction is only the first part of the story**
  - **Cradle to Gate** tells a different story than **Cradle to Grave**
  - Maintenance is a major factor, but often unknown/unaccounted for



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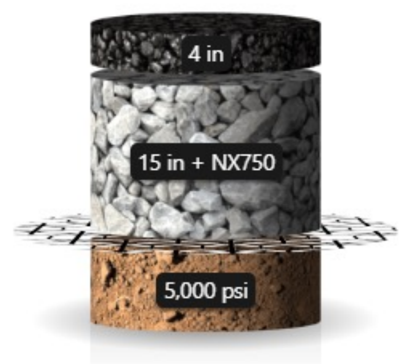
Example – Pavement Design

- 1 mile pavement, 30 feet wide
- AASHTO 1993 design
- Assumptions covering distances to project for asphalt, aggregate, geogrid
- Cradle to Gate + construction analysis

AASHTO 1993 Design Parameter	Value
Asphalt Layer Coefficient	0.42
Unbound Aggregate Layer Coefficient	0.14
Initial Serviceability	4.2
Terminal Serviceability	2.0
Aggregate Drainage Factor	1.0
Reliability	95%
Standard Deviation	0.49

Conventional Design

552,700 ESALs



MSL Used for Life Extension

4,055,500 ESALs

Design Optimized for Minimum Cost

625,000 ESALs

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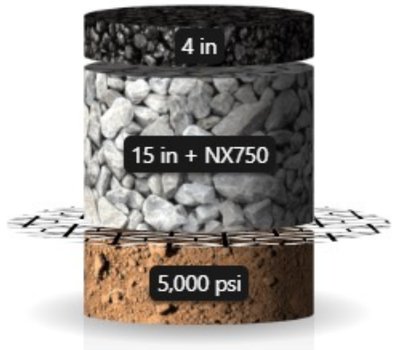
Example – Pavement Design

Conventional Design



MSL Used for Life Extension

Design Optimized for Minimum Cost

- **Scope of Consideration** – a design change must be considered as a whole
- Understand the data you have, and the **data you don't have** – which inputs require assumptions, and what is their sensitivity?
- For infrastructure projects, **construction is only the first part of the story** – lifespan and maintenance requirements can exceed construction inputs

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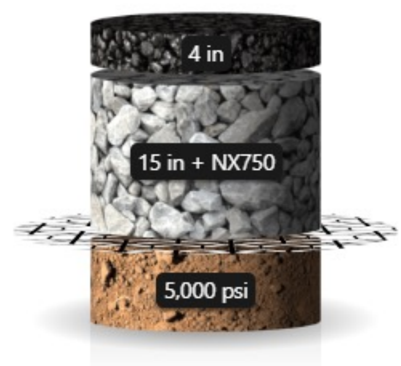
Example – Pavement Design

Pavement Section	Calculated Traffic Capacity (ESALs)	GWP Through Initial Construction (kgCO_2e)
Conventional Design, 4 in / 15 in	552,700	228,000
MSL Design, 4 in / 15 in	4,055,500	235,000
MSL Design, 4 in / 8 in	625,000	197,000

Conventional Design



MSL Used for Life Extension

Design Optimized for Minimum Cost

Summary and Key Points

- Mechanical aggregate stabilization using geogrid offers significant benefits for pavements:
    - Performance
    - Life cycle cost
    - Sustainability
    - Resilience

- **Environmental Product Declarations (EPDs)**, when properly used in construction, provide information necessary to perform **Life Cycle Analysis (LCA)** for project sustainability

- **Pavement sustainability and resilience** are a primary focus at FHWA through the Sustainable Pavement Program and other funding programs in the BIL and IRA

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Summary and Key Points

- **Design is a complicating factor**
- **Scope of Consideration** is critical to obtaining valid results
  - What's included?
  - Over what timeframe?
- The ideal scope of consideration would be set where design changes do not affect results at the next level
- As engineers, we are responsible for **asking and answering the big questions**, and doing so in a rigorous, clear-eyed, and ethical manner
- Are we considering the proper scope when we consider sustainability?

Thank You

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