

Skid Happens: Managing Friction in Asphalt

Tisha Reynolds

Sarfaraz Uddin

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1

Why Measure Pavement Friction?



ARDOT's Vision



Improve safety & maintain skid resistance of asphalt pavements

Pavement friction plays a critical role in **accidents** by directly affecting a vehicle's ability to maintain control, especially during **braking and steering**.

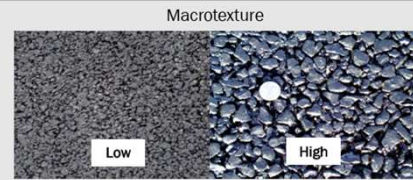
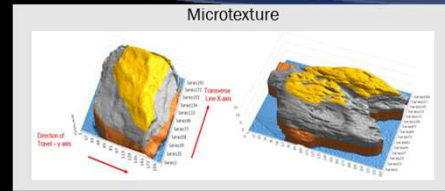
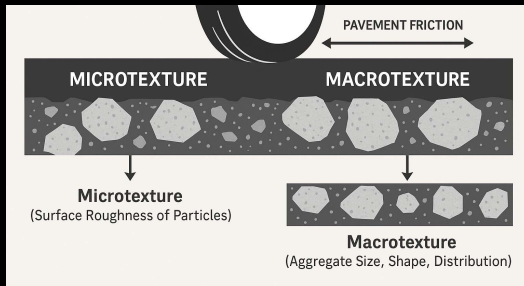
Inadequate or **reduced friction** can increase the risk of **skidding, hydroplaning,** and other hazardous maneuvers, resulting in higher crash rates.

Objectives and Scope

- Determine **friction** and absorption values for all aggregate sources.
- Evaluate **combinations** of different **aggregates** for friction in asphalt mixtures.
- Develop performance-based specifications for the friction of asphalt mixtures.
- Develop **guidelines** or **safety standards** for asphalt mixtures regarding roadway friction.
- **Comparison** testing of **lab** application vs **field** application.



What is Pavement Friction?



Property	Wavelength (mm)	Controls	Typical Measurement	Key Effect
Microtexture	< 0.5	Low-speed friction	DFT, BPT	Adhesion (skid resistance)
Macrottexture	0.5 – 50	High-speed friction, drainage	CTM, Sand Patch	Hysteresis, drainage
Megatexture	50 – 500	Ride quality, noise	Profiler, PSD analysis	Comfort, durability

Pavement friction is the result of a complex interplay between **two** principal **frictional force** components: **adhesion and hysteresis**.

Adhesion is the friction that results from the small-scale bonding/**interlocking** of the vehicle **tire rubber** and the **pavement surface**.

The **hysteresis** component of the frictional forces results from the **energy loss** created within the **tire** when a rubber material is **repeatedly stretched and compressed**.

Microtexture is the fine-scale texture (**below 0.5mm**) on the surface of the aggregate that **interacts** directly with the **tire rubber**. The **adhesion force** is influenced by the micro-texture of aggregate particles, enabling vehicles to maneuver and **stop properly at any speed**.

The **gradual loss** of microtexture due to the effects of traffic **over time** is described as **“polishing.”**

Macrottexture is the larger-scale texture (**0.5 to 50 mm**) on the pavement formed by the **individual aggregate** particles in the surface. The **hysteresis force** within

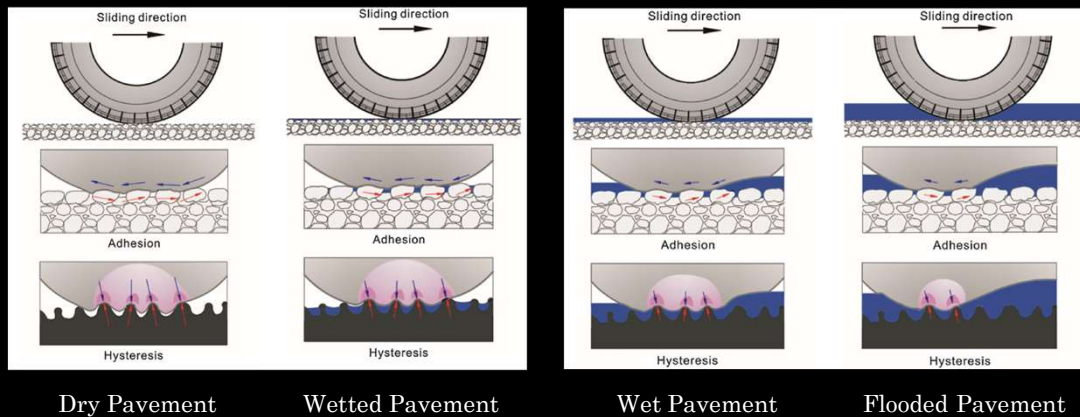
the tire relates to the macro-texture of the pavement surface. Macrotexture is **influenced** by either the **aggregate shape, size, and gradation** of asphalt pavements.

The macrotexture creates **drainage channels** for water to flow away from the tire and pavement, enhancing **tire-pavement contact** and improving friction, which helps prevent **hydroplaning**, especially at **high speeds**.

Megatexture represents the even larger-scale irregularities (**50 to 500 mm**) of the pavement surface, between macrotexture and roughness.

Excessive megatexture increases **rolling** resistance and **tire wear**.

Pavement Skid Resistance Generation.



Friction **slows down** the rotation of the wheels, ultimately bringing the vehicle to a **stop**. If there is **insufficient friction**, the tires can **skid**, resulting in **longer stopping distances** and a potential **loss of control**.

As illustrated in Fig., on a **dry pavement** free of contaminants, **cohesion force F_c** and **drag force F_d** are absent. Its **skid resistance** is derived from rubber **adhesion** and **hysteresis** (i.e., **F_a** and **F_h**).

The same is **true** on a **wetted** pavement, except that the **presence of moisture** on the surface and water in the surface voids acts to **weaken** the rubber **adhesion** force F_a and the **hysteresis** force F_h . This explains the abrupt **reduction of skid resistance** when a dry pavement is **wetted**.

On a **wet or flooded** pavement where there is a **layer of water** on the pavement surface, the presence of free water not only changes the tire pavement contact mechanism but also introduces an additional **hydrodynamic-induced mechanism** that causes **tire deformations** and interferes with the skid resistance generation mechanisms of **adhesion** and **hysteresis force** (F_a and F_h)

The **magnitude** of interference **increases** as the vehicle speed is **raised**. The interaction between a moving tire and the surface water develops **hydrodynamic** pressures that **deform the tire** wall and reduce the tire-pavement contact area, thereby reducing the magnitudes of F_a and F_h .

Aggregate Properties & Friction



Property	Definition	Role in Pavement Friction	Key Characteristics / Tests	Effect on Performance
Microtexture	Small-scale surface texture affecting tire-surface contact.	Initial skid resistance , especially in wet , low-speed conditions.	Aggregate performance depends on its mineral composition and texture. Hard , angular types like quartzite and sandstone are the most effective.	Rough microtexture improves early-life friction, while smoother aggregates like limestone polish quickly.
Macrottexture	Surface profile shaped by aggregate gradation and mix structure .	Governs water drainage , hydroplaning resistance, and high-speed friction.	Determined by shape, size, gradation, and mix type (open-, gap-, or dense-graded).	Coarser , angular aggregates create higher macrottexture, while dense-graded mixes yield a smoother surface and faster polishing .

Aggregate Properties & Friction



Property	Definition	Role in Pavement Friction	Key Characteristics / Tests	Effect on Performance
Polish Resistance	Aggregate's ability to maintain texture under traffic wear .	Ensures long-term skid resistance after polishing or aging .	Depends on hardness and mineral composition: High: quartz, granite, slag; Low: some limestones, dolomites.	High polish resistance maintains friction durability over service life.
Hardness & Abrasion Resistance	Aggregates' ability to resist wear and impact .	Prevents raveling and loss of texture, maintaining structural and frictional integrity.	Measured by L.A. Abrasion and Micro-Deval tests.	Harder aggregates retain texture longer; softer ones wear smooth, reducing friction.
Absorption & Porosity	Measure of the aggregate's ability to absorb water or binder.	Affects binder coating and exposure of texture to tires.	Related to pore structure and binder film retention.	High absorption → thicker binder films → less texture. Low absorption → cleaner, sharper surface.






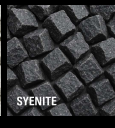




Aggregate Properties - FAA & SE



Property	Main Influence	Role in Friction	ARDOT Spec
Fine Aggregate Angularity (FAA)	Microtexture	<p>High FAA → better initial & long-term friction.</p> <p>Low FAA → smoother, polish-prone surface.</p>	Minimum FAA ≥ 45 for surface mixes.
Sand Equivalent (SE)	Microtexture & durability (clean vs. dirty fines)	<p>High SE → clean, durable fines.</p> <p>Low SE → clay/silt fines reduce texture & polish faster.</p>	Minimum SE ≥ 45.
Coarse Aggregate Properties	Macrottexture & long-term polish resistance	<p>Angular, polish-resistant coarse aggregates ensure durable friction.</p> <p>Rounded, polish-prone ones reduce skid resistance.</p>	Use blended coarse aggregates from QPL-approved sources.

Aggregate Types



Aggregate Type	General Characteristics	Effect on Surface Friction & Performance	Aggregate Images	
Limestone / Dolomite / Dolostone	Smoother, polish-prone surface texture under traffic.	Loses microtexture quickly, reducing long-term skid resistance ; suitable when blended with harder aggregates.		
Sandstone / Novaculite / Syenite	Hard , angular, and rough-textured materials with durable surfaces .	Provide strong, long-term skid resistance; resist polishing effectively. Preferred for high-friction surfaces.		
Gravel	Rounded particles with low angularity and FAA .	Lower microtexture and initial friction unless blended with crushed or angular materials.		
Slag / Tuff	Angular, high-hardness industrial or volcanic materials.	Exhibit excellent polish resistance and durability with improved surface texture retention.		
Sand (Natural or Manufactured)	Fine aggregate impacts workability and surface texture.	Rounded natural sands reduce friction , while manufactured angular sands enhance FAA and microtexture.		

Aggregate Properties – Mix Design



- Friction is about **proportions**
- ARDOT often needs a mix of polish-resistant coarse aggregate with economical local materials
- Balanced Mix Design (BMD) - optimize cracking/rutting resistance without sacrificing surface friction

Sample Job Mix of ARDOT:

Mix Type	Natural Sand	Sand	Limestone	Sandstone	Dolomite	Dolostone	Gravel	Tuff	Slag	Syenite	Novaculite	Donnafill	RAP	RAC	RAS	TOTAL
9.5	12	10	56	22												100
12.5		18			82											100
12.5		7			60		33									100
12.5		13		87												100
12.5		22								20	58					100
12.5		8		77									15			100
12.5		5	45				28		22							100
9.5										90		10				100
12.5		5	6		21	43							25			100
12.5	8	13	10	25	11	8							15	10		100
9.5	7	18		52										20	3	100
12.5		7			38	24		16					15			100



Friction Measurement Equipment

APA Jr. Friction Tester
Dynamic Friction Tester (DFT)
Circular Track Meter (CTM)

APA Jr. Friction/Polishing



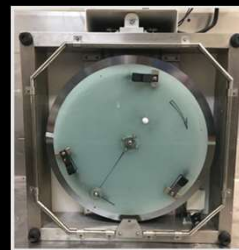
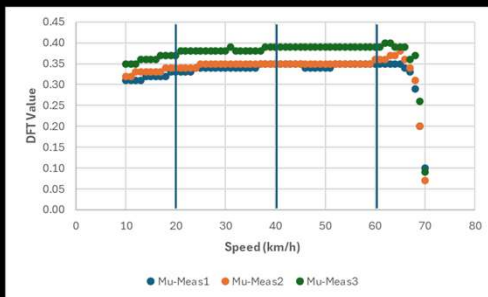
- To measure pad wear thickness
- Wheel Load Pressure 30 psi
- Rubber Hardness 60 Durometer
- Rubber Thickness 8 mm
- Test Temperature 66.5 °F
- Related references AASHTO T340 and NCHRP 508

APA Cycles	Approximate Equivalent	Field Interpretation
8,000	≈ 0.1–0.2 million ESALs	Early-life / 1–2 years traffic
40,000	≈ 0.6–0.8 million ESALs	Mid-life rutting condition (~5–7 years)
60,000	≈ 1–1.5 million ESALs	Design-life (~10+ years)

APA Jr measures **pad wear** thickness.

Dynamic Friction Tester

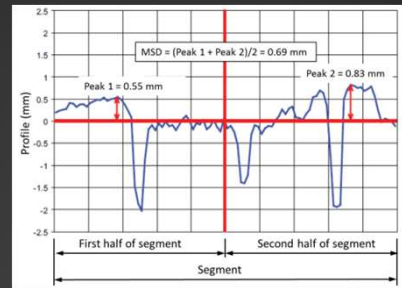
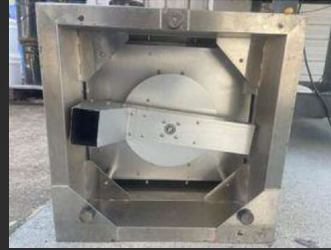
- To measure the coefficient of friction (sliding resistance) of a pavement surface under wet conditions at different speeds
- It uses an ASTM standardized procedure (E1911) and measures friction over a range of speeds
- Dynamic friction at 20, 40, 60 km/h respectively denoted as DF20, DF40, DF60.
- Commonly paired with the **Circular Track Meter (CTM)** to compute the **International Friction Index (IFI)**.



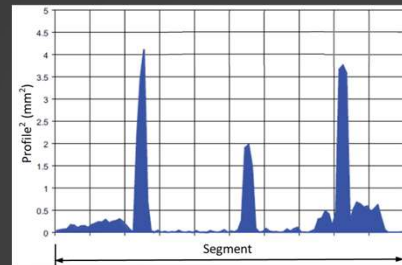
A Dynamic Friction Tester (DFT) is a **portable** device designed to measure the **coefficient of friction** (μ) of a surface.

It **simulates** the **dynamic** conditions of a tire interacting with a **wet surface** at a specific **sliding speed**. The DFT measures both the **horizontal** and **vertical forces** acting on a test tire as it slides with controlled slip on a wetted surface at a constant speed. This data is essential for evaluating pavement safety and assessing friction properties.

Circular Track Meter



- To measure the macrotexture profile of a pavement surface
- It uses an ASTM standardized procedure (E2157) and measure Mean Profile Depth (MPD) and Root Mean Square (RMS)
- Used for laboratory and field investigations, and in conjunction with the DFT, it provides data to calculate the International Friction Index (IFI).



Circular texture meters are **laser-based** devices for measuring the mean profile depth (**MPD**) of a pavement at a given location.

MPD values are **highly** correlated with mean texture depth (**MTD**) values and can replace

Volumetric measurement methods often used to determine MTD.

IFI Calculation:

- We tested the CTM and DFT on the same circular track allowing identical physical surface.
- **ASTM E1960** used for the IFI calculation

$$S_p = 14.2 + 89.7 \text{ MPD} \quad (1)$$

$$FR60 = FRS \times EXP [(S - 60)/S_p] \quad (2)$$

S_p = speed constant

FR60 = the adjusted value of friction from a slip speed of S to 60 km/h

FRS = the friction measured by the equipment at slip speed S

S = the slip speed

SN40 Calculation:

- Compared the field friction with the skid truck friction or skid number (SN)

$$F60 = 0.081 + 0.732 \times FRS \times EXP [-(60 - S)/S_p] \quad (3)$$

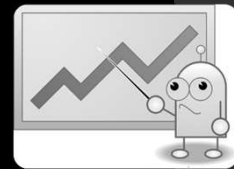
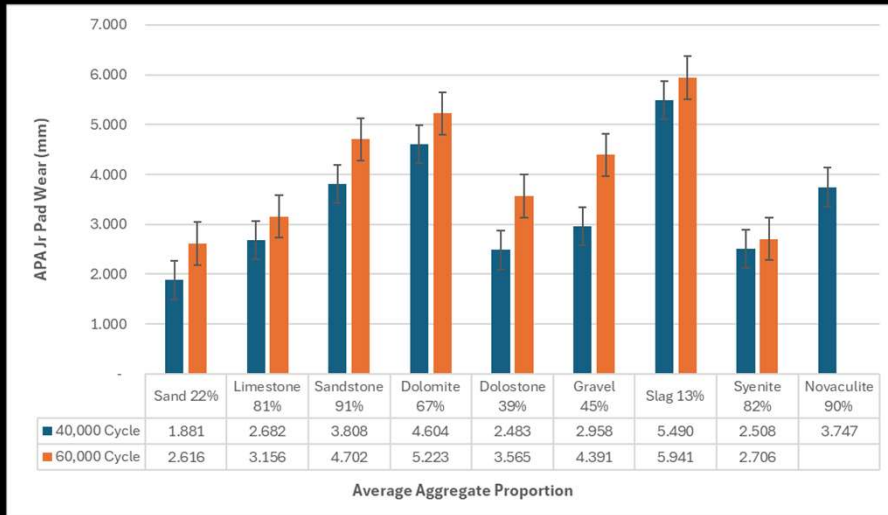


Figure 1: Aggregate Proportion VS APA Pad Wear

Hard/abrasion-resistant aggregates (slag, novaculite, syenite) show positive influence

Soft or polish-prone aggregates (natural sand, gravel, some limestones) show negative influence.

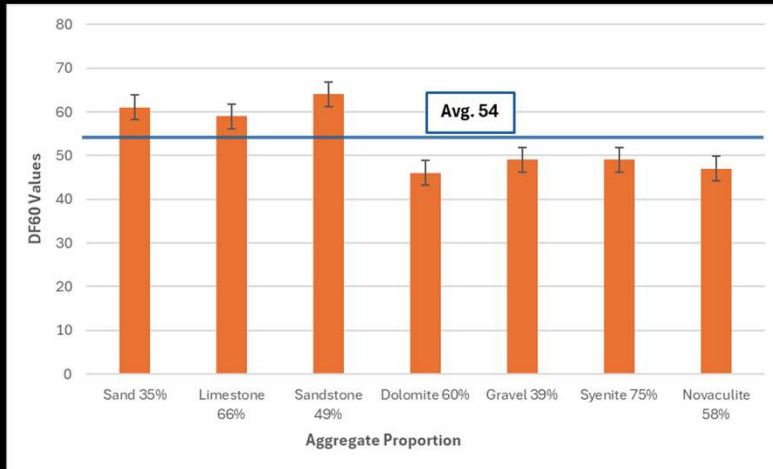


Figure 2: Aggregate Proportion VS DF60 Values

Hard/abrasion-resistant aggregates (slag, novaculite, syenite) show positive influence
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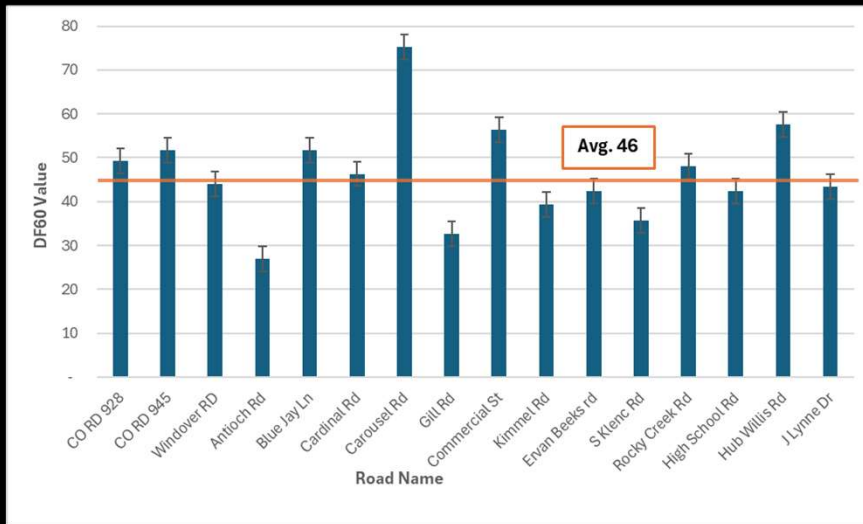


Figure 3: DF60 Values for 100% Limestone Roads

Hard/abrasion-resistant aggregates (slag, novaculite, syenite) show positive influence
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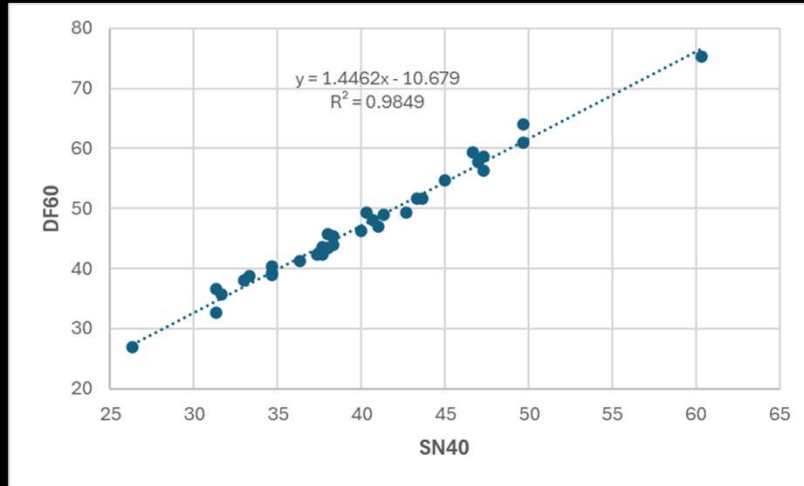


Figure 4: Correlation Between SN40 and DF60



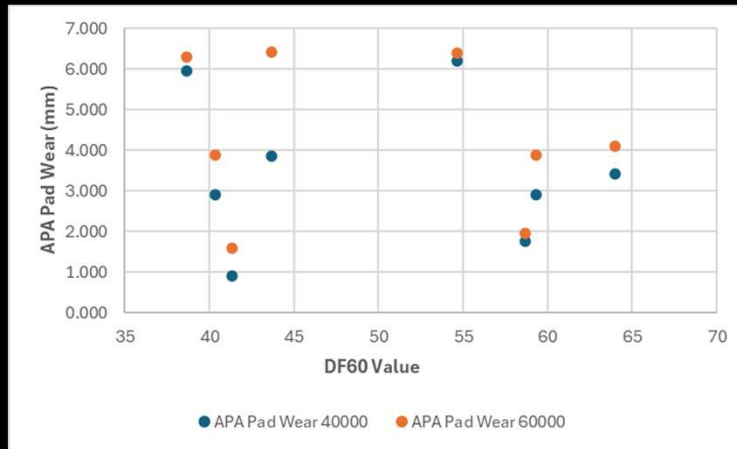
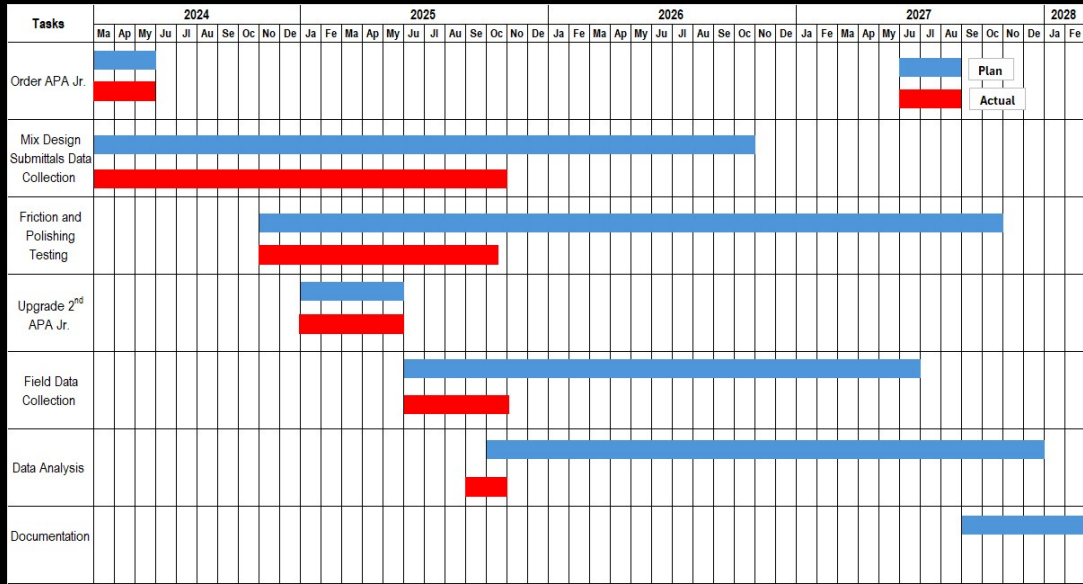


Figure 5: Correlation Between DF60 and APA Pad Wear

Hard/abrasion-resistant aggregates (slag, novaculite, syenite) show positive influence
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Project Status



References



1. Wambold, J. C., Antle, C. E., Henry, J. J., and Rado, Z., *International PIARC Experiment to Compare and Harmonize Texture and Skid Resistance Measurements*, Final report, Permanent International Association of Road Congresses (PIARC), Paris, 1995.
2. AASHTO: T 340-10, *Determining Rutting Susceptibility of Hot Mix Asphalt (HMA) Using the Asphalt Pavement Analyzer (APA)*, 2013
3. NCHRP REPORT 508, *Accelerated Laboratory Rutting Tests: Evaluation of the Asphalt Pavement Analyzer*, TRB, 2003.
4. ASTM E1911-19, *Standard Test Method for Measuring Surface Frictional Properties Using the Dynamic Friction Tester*, 2024.
5. ASTM E2157-15, *Standard Test Method for Measuring Pavement Macrottexture Properties Using the Circular Track Meter*, 2015.
6. ASTM E1960-07. *Standard Practice for Calculating International Friction Index of a Pavement Surface*, 2023.

THANK YOU!!

Questions 