Why concrete racetracks race differently than asphalt: A literature review

Giovana Sofia de Souza Marques [a].

[a] Civil Engineering Department, State University of Londrina, Londrina, Brazil, giovanasmarques@outlook.com

Abstract. The choice of materials for constructing motorsport racetracks is crucial in optimizing vehicle performance. This paper explores the properties and characteristics of racetrack surfaces, with a primary focus on NASCAR racetracks. It delves into the differences between flexible and rigid pavements, comparing aspects such as skid resistance, temperature and heat effects, pavement texture, rubber friction theory, and surface degradation of asphalt and Portland cement concrete pavements. The study also reveals how factors like surface texture, composition, and temperature affect grip and racing dynamics. Understanding these nuances is essential for enhancing safety and performance in high-speed precision.

Keywords. Motorsport racetracks, skid resistance, asphalt pavement, concrete pavement.

1. Introduction

The primary objective of motorsport racetracks is to enable drivers to optimize their vehicle's performance while racing. The choice of materials for constructing a racetrack is very important in attaining these objectives. This decision hinges not only on the pavement surface but also on factors such as whether the track is a street circuit or a purpose-built circuit, its location, and even the prevailing weather conditions.

Enhancing our comprehension of racetrack surfaces and quantifying the differences between asphalt mixes and concrete would be highly advantageous for the entire motorsport industry. It has become apparent that a significant research gap exists when talking about properties and characteristics associated with these surfaces. So a comprehensive analysis was conducted, primarily focusing on NASCAR racetracks.

It is widely acknowledged that motorsport is a competitive and secretive sport. Information related to vehicle specifications, tire compositions, or racetrack surfaces is often challenging to access due to commercial confidentiality. Added to the lack of academic research concerning the materials used in the construction of racing circuits, the primary objective of this review paper is to demonstrate and summarize how the exising knowledge derived from roads and runway can be effectively applied to racetracks in general. At last, the structure of this paper is organized to discuss the following topics:

1. The differences between asphalt and concrete pavement composition;
2. Comparing skid resistance, temperature and heat, pavement texture, rubber friction theory and surface degradation between them.

2. Different types of racetracks surface

There are different types of track surfaces for different categories of racing. Formula 1 is the most popular motorsport category in the world. The racetracks, are designed and constructed to meet rigorous standards, so the surface of these circuits is typically paved with high-quality asphalt. Whether it's a purpose-built circuit or a temporary street circuit, the composition and quality of the pavement remain a crucial factor in the overall development. The precise mix of asphalt, its texture, and the meticulous construction process all contribute to creating the perfect racing surface that enables Formula 1 drivers to push the boundaries of speed.

Besides that, The National Association for Stock Car Auto Racing (NASCAR) circuits offer a unique contrast to the precision pavement of Formula 1 tracks. These oval tracks, often feature asphalt surfaces mixed with concrete or even entirely concrete in some cases. This choice of pavement is related to the style of stock car racing, where the focus is not just on high-speed precision but also on the physicality of the sport. It is also known as one of the few categories which races on concrete circuits and these tracks can be especially challenging for drivers, making each NASCAR circuit unique in its own way.

3. Rigid pavement and flexible pavement

Pavement is a multi-layered structure, constructed on the earthworks surface, designed technically and economically to withstand the forces from vehicle traffic and weather, and to provide users with improved rolling conditions, comfort, economy, and safety [1].

Pavements are classified into three main categories: flexible pavement, semi-rigid pavement, and rigid pavement. Flexible pavements are characterized by significant elastic deformation of all layers under load, distributing the load evenly among them. On the other hand, semi-rigid pavements consist of a base with cementitious properties, such as soil-cement, covered by an asphalt layer. Finally, rigid pavements have an extremely stiff surface compared to the lower layers, absorbing most of the stresses generated by the applied load [2].

Rigid pavements are commonly referred to as cement concrete pavements. These are pavements in which the surface is a Portland cement concrete slab. The cement concrete pavement slab can effectively function both as a wearing surface and as an efficient base course. Therefore, typically, the rigid pavement structure comprises a cement concrete slab, beneath which a granular base or subbase course may be included [3]. **Fig. 1.** illustrates this scenario.

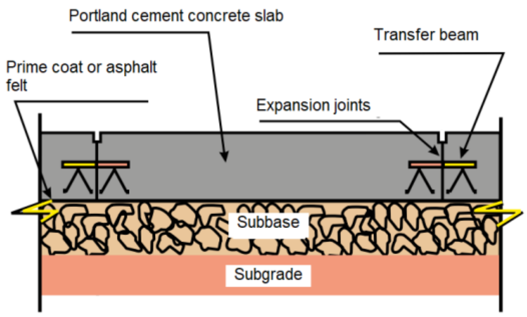

Fig. 1. Cross-section of a rigid pavement [1].

Flexible pavements, also known as asphalt pavements, are those in which the surface is composed of a mixture of aggregates, filler, and asphalt binders. The main layers that make up this type of pavement include the surface layer, base layer, sub-base layer, subgrade reinforcement, all placed on top of prepared natural ground [1].

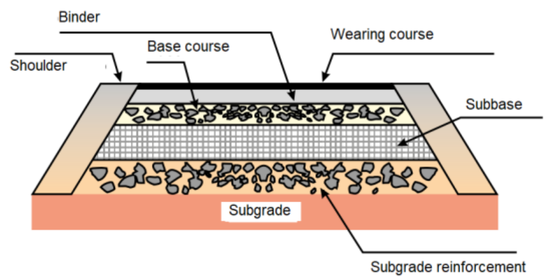

Fig. 2. Cross-section of a flexible pavement [1].

3.1 Asphalt pavement composition

The precise composition of asphalt pavement can vary depending on factors such as the intended use, local climate conditions, and engineering specifications. But it primaly consists of aggregate, asphalt binder, air voids and filler materials.

Aggregate is a mixture of various-sized crushed stones, gravel, sand, or even recycled materials which provides strength, stability, and durability to the pavement structure. Asphalt Binder, also known as asphalt cement, is a viscous substance derived from crude oil refining. It is the compound that holds the aggregate particles together, creating a solid pavement. The spaces between the aggregate particles are necessary in asphalt pavement because of the thermal expansion and contraction due to temperature variation, it prevents cracking and ensure the pavement's longevity. Sometimes, filler materials are added to the asphalt mixture to improve workability, increase durability, and reduce voids in the mix.

In general, the asphalt mixtures used in surface or even in base layers must undergo a precise selection process to meet project requirements for proper mix design, including the correct dosage of additives. Which plays a crucial role in optimizing the performance of these surfaces, providing essential characteristics such as adhesion, wear resistance, durability, drainage capacity and other things. **Fig. 3.** shows the Daytona circuit, an asphalt racetrack.

Fig. 3. Daytona International Speedway asphalt racetrack.

3.2 Portland cement concrete pavement composition

The composition of concrete pavement can vary significantly, particularly based on factors such as its purpose and local climate conditions, among others. It is a carefully balanced combination of cement, aggregate, water, and optional additives, tailored to meet specific project requirements.

Cement acts as the binding agent in concrete, holding the aggregate particles together. It undergoes a chemical reaction with water, known as hydration, which forms a strong and durable solid structure. Added to that, the choice of aggregate size and type can influence the concrete's performance and appearance. Additives, sometimes are included in the concrete mixture to enhance it.

At last, concrete pavement may or may not incorporate reinforcements. For each situation, the determination is made to assess what is more viable and which type of concrete pavement is most suitable. The Dover International Speedway is an example of concrete racetrack, it is made of portland cement concrete pavement and it is laid down in sections, so it has joints between the slabs to prevent crackings from temperature variation. In **Fig. 4.** It is apparent the individuals slabs of concrete on the Dover circuit.

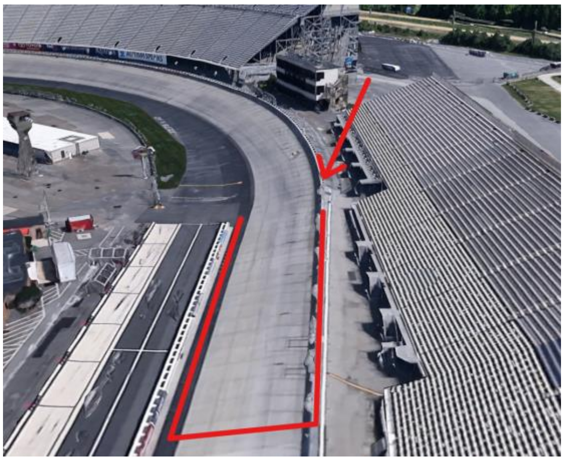

Fig. 4. Dover International Speedway concrete racetrack.

4. Comparative analysis

The primary difference between asphalt and concrete is the rigidity of the two materials and how they distribute the load over the base on which they are laid. The more rigid the pavement, the more the load is distributed over the surface when something like a car move over it. It was decided to analyse pavement characteristics based on NASCAR's circuits, because in contrary to Formula 1 - which all racetracks are made of asphalt - NASCAR has a few circuits that uses concrete pavement, so the comparisons will be more coherent.

In **Fig. 5.** the concrete spreads out the stress over a larger area, while the asphalt transmits stress to a narrows area. The narrower area and the same load means that the stress is more concentrated. Because concrete is stronger, asphalt has to be thicker to get the same rigidity. However, asphalt does have an advantage, its flexibility allows it to expand and contract with temperature changes with less cracking so it can be laid down continuously.

Fig. 5. Rigid and flexible pavement load distribution.

In this section, we will compare skid resistance, temperature and heat, pavement texture, friction theory and surface degradation characteristics between asphalt and concrete pavement based on NASCAR's racetracks.

4.1 Skid resistance

The skid resistance, also known as grip level, can be very different between asphalt and concrete, It depends primarily - but not entirely - on surface roughness. Concrete surfaces are much more grainy and denser than asphalt, which provides race car tires with better traction when patterned to create more grip. However, it is important to remember that the type of concrete or asphalt used, the age and condition of the surface, and environmental factors such as temperature and moisture also affects the skid resistance of the racetrack surface.

Additionally, while concrete may provide higher grip in dry conditions, it can become slicker than asphalt when wet, making asphalt tracks preferable in rainy or damp conditions. Also, the different surface texture scales provided depending on the circumstances can make rough asphalt pavement have a higher grip than smooth concrete pavement and vice versa.

It is important to say that asphalt tracks are not initially sticky, specially before the binder has fully cured. From a systems perspective, the asphalt binder protects the road, and the aggregate particles protect the binder, but for various reasons, the bitumen may migrate to the surface of the aggregate making the surface slippery, this situation is called bleeding [8]. If a racetrack is fighting this condition the fastest solution for getting rid of it is just drive. The tires degradation means it loses rubber, this rubber will be ground into the track surface by the sheer force of the car. This build-up of rubber creates a hot and sticky film, when the cars races on the line, the rubber on the pavement will be sticking to the rubber on the tyres, increasing the grip, so the longer the weekend goes on the faster every car gets.

4.2 Temperature and heat

The sun emits light across a broad spectrum of wavelengths, encompassing ultraviolet (UV) and infrared radiation (IR). While the human eye cannot perceive either of these types of radiation, we are capable of sensing infrared radiation as heat.

Measuring the temperature of a racetrack during the course of a race can vary by a lot of degrees, influenced not only by weather conditions but also by the properties of the track surface. The color of tracks surface, in particular, plays a crucial role in it because the sun's IR emissions impacts more on asphalt compared to concrete, specially due to differences in coloration.

Asphalt, being predominantly black, absorbs a substantial amount of radiation. In contrast, concrete surfaces don't absorb as much radiation as asphalt does, so they stay relatively cooler – it interferes on tyres management –. The end result is that in terms of temperature, a concrete track doesn't change over the course of a race in the same way as asphalt tracks do.

4.3 Pavement Texture

Surface texture impacts on vehicle wear, rideability, noise, friction and rowing resistance, specially in wet conditions. Therefore, several factors will affect surface texture of racetracks, including aggregates, binder properties (bitumen, cement, etc.), void content, paving techniques, among others [4].

Racing in wet conditions is influenced by various properties across different texture levels. Moreover, different pavement types, such as asphalt or concrete, are made of distinct compounds that result in varying texture scales. There are two texture levels affecting the performance while racing – microtexture and macrotexture. In summary, microtexture is a result of aggregate mineralogy and roughness of the aggregate particles itself, while macrotexture is a result of asphalt mixture properties and placement method [5]

Many researchers investigated the relation between skid resistance and surface texture levels with a general conclusion that microtexture impacts at all speeds, but it is more prevalent in the tyre/surface interaction at lower speeds. However, macrotexture becomes increasingly important at higher speeds in order to dissipate water in wet conditions [6].

Besides surface texture levels, asphalt pavement texture can be classified into smooth or bumpy. When the surface is smooth it helps with the tyre management, because the drivers won't be bouncing around as much, but the downside of it is there is less resistance for the tyres, so it means less grip. On the other hand, bumby surface has imperfections that can be beneficial to the amount of grip the car can have, specifically in corners, but unlike smooth surfaces it will fasten the tyre degradation.

4.4 Rubber friction theory

Four primary factors influence rubber friction analysis, namely: adhesion, cohesion, viscous friction, and hysteresis [9]. Researchs indicates that the friction between rubber and pavement is primarily a result of adhesion and hysteresis, both of which are highly influenced by surface properties and tyre-pavement performance.

Adhesion results from the molecular interactions between the rubber tyre and the pavement surface during sliding but can be significantly reduced by lubrication at the interface. Meanwhile, the hysteresis component is linked to energy dissipation caused by the tyre's deformation during sliding. In simpler terms, when the drivers are racing, the grip that tyres provide not only depends on how well the rubber sticks to the road but also how the tire flexes and deforms as it moves. **Fig. 6.** Illustrates this.

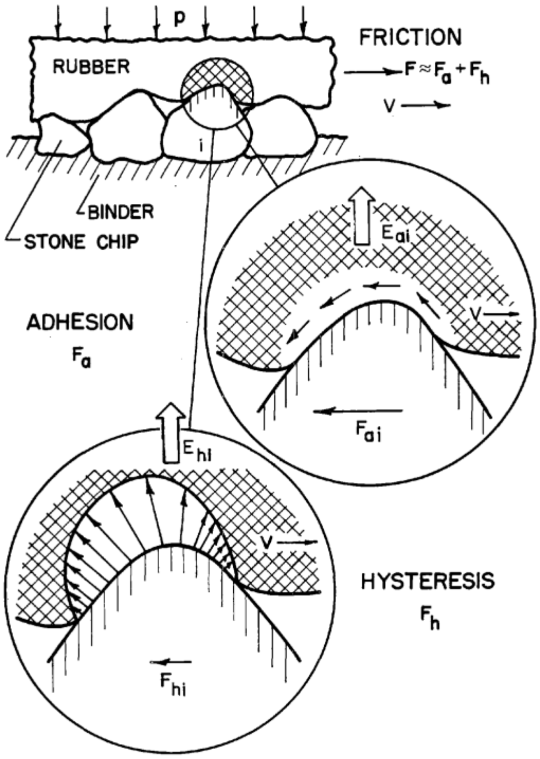

Fig. 6. Principal component of rubber friction. [9]

4.5 Surface degradation

No matter how well the pavement is built, it will deteriorate over time for several reasons. Concrete pavements distresses are mainly from cracks from temperature variation. Asphalt, while being a flexible pavement, suffers from surface deformation and disintegration, so if it is not repaired in early stages, a complete reconstruction of the pavement may be needed.

When a fresh layer of asphalt is first applied to a track, it starts out very smooth and flat. However, as time goes by and the bitumen on the surface begins to wear away, the aggregates in the asphalt start to show. Eventually, when enough of the bitumen has worn off, these aggregates are exposed, making the track weaker and leading to the need for a complete re-pave. Concrete, on the other hand, doesn't wear out as quickly as asphalt. It can last two to four times longer. While the initial cost of concrete can be higher, it doesn't require as much ongoing maintenance as asphalt surfaces, so when you factor in the cost of having to re-pave asphalt every few years, in the end, concrete can potentially be a cost-effective option.

5. Conclusion

In conclusion, this literature review has provided valuable understanding into the differences between asphalt and concrete racetracks. While concrete racetracks offer distinct advantages in terms of grip level and heat dissipation, they exhibit unique challenges, such as variations in pavement texture. In contrast, asphalt racetracks, while less durable, can offer superior grip in wet conditions due to its surface texture. This review has highlighted that there are still research gaps on the material science of concrete and asphalt when it comes to motorsport racetracks. It is crucial for researchers to fill these gaps through further investigation and analysis.

6. References

[1] Bernucci LB, Motta LMG, Ceratti JAP, Soares JB. Pavimentação Asfáltica. Rio de Janeiro; 2022.

[2] Manual de pavimentos rígidos. Departamento Nacional de Infra-Estrutura de Transportes. 2005.

[3] Mohod MV, Kadam KN. A Comparative Study on Rigid and Flexible Pavement: A Review. IOSR J Mech Civ Eng. 2016;13(3):84–8.

[4] Miller T, Swiertz D, Tashman L, Tabatabaee N, Bahia HU. Characterization of asphalt pavement surface texture. Transp Res Rec. 2012;2295(3):19–26.

[5] Kogbara RB, Masad EA, Kassem E, Scarpas A (Tom), Anupam K. A state-of-the-art review of parameters influencing measurement and modeling of skid resistance of asphalt pavements. Constr Build Mater. 1º de julho de 2016;114:602–17.

[6] James Waddell C. The Grip of Motorsport Surfaces. 2019.

[8] Lawson WD, Senadheera S. Chip seal maintenance: Solutions for bleeding and flushed pavement surfaces. Transp Res Rec. 2009;(2108):61–8.

[9] Kummer, H. (1966) Unified Theory of Rubber and Tire Friction. Engineering Research Bulletin B - 94, The Pennsylvania State University, 100-101.