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A Study of Thermal Effects on the Properties of the Asphalt Layer of Roads in Southern Libya

Anwar Hamed Mktar Basha

Higher Institute of Sciences and Technology, wadi Etba- Libya, Department of General Materials

ABSTRACT: Southern Libya's road infrastructure is particularly challenged by the region's severe desert climate, which is marked by sharp temperature swings. In order to improve road performance and durability, this case study explores the impacts of heat on the characteristics of asphalt road surfaces in the area. The study thoroughly examined a number of variables, such as temperature fluctuations, the characteristics of the asphalt material, and the effect on road performance. Data from several road lengths in Southern Libya were gathered for the study, which concentrated on various building methods, asphalt blends, and environmental factors. In order to comprehend the thermal stress that the asphalt layers were subjected to, temperature data were collected and examined over an extended period of time. The study was carried out to assess the dynamic modulus, fatigue behaviour, and resistance to rutting of asphalt, as well as how these parameters responded to temperature variations. This research indicates that asphalt road surfaces are significantly impacted by the intense heat in Southern Libya. Variations in temperature caused the asphalt to become more rigid during hot weather, which had an impact on the asphalt's resistance to rutting and dynamic modulus. On the other hand, when the temperature dropped, the asphalt grew more brittle, which could cause cracks. The study ends with a discussion of potential mitigating actions to increase the resilience and longevity of road surfaces in Southern Libya. These include better designs for asphalt mixtures, construction methods, and maintenance schedules. These observations will be extremely helpful to architects and designers of infrastructure in similar regions with harsh climates, making road networks safer and more dependable.

KEYWORDS: Asphalt properties; thermal effects; Road infrastructure; Southern Libya; Extreme climate; temperature fluctuations; Asphalt Mixture; Road Performance;

I. INTRODUCTION

The network of roads is a crucial part of contemporary infrastructure because it makes it easier to transport people, products, and services around, which promotes connectedness and economic growth. Due to its longevity, affordability, and ease of upkeep, asphalt roads have become the most popular and frequently utilised forms of roadways [1]. A road's asphalt layer, also referred to as the pavement, is crucial in creating a stable and smooth surface for vehicle movement [2]. It acts as the top architectural layer of the roadway, shielding the soil and lower layers from the damaging impacts of heavy traffic loads, the weathering process, and outside stresses. As temperature has a substantial impact on the behaviour and functionality of road constructions and materials, it is an important part of transportation engineering. Given the wide-ranging and frequently significant temperature changes observed in many countries and climates, thermal impacts play a crucial role in the planning, construction, and upkeep of roadways. Extreme temperature swings from bitter cold to sweltering heat can cause severe thermal strains in the road elements [3]. These stresses may cause a variety of negative outcomes, including cracking, ruts, and structural distortions, which eventually jeopardise the strength and lifespan of the road [4].

The growth of fractures and holes in layers of asphalt due to the periodic thaw and freeze of water in colder climes can speed up deterioration and diminish load-bearing capability. On the other hand, in hotter climates, too much heat can weaken the asphalt, resulting in ruts and distortion under the pressure of heavy traffic, reducing the smoothness and safety of the road [5]. Furthermore, internal pressures caused by the expanding and contracting of road materials as a result of temperature changes may result in cracking that is reflective and fatigue harm, especially in asphalt surfaces. Engineers use a variety of strategies, such as including temperature-resistant materials, installing appropriate drainage structures to avoid water accumulation, and using the right design practises to deal with thermal changes in temperature, in order to lessen the negative effects of fluctuations in temperature on roadways. In addition, mitigating temperature-induced discomfort and extending the useful life of roads depend on routine maintenance and quick fixes. To ensure the security, longevity, and long-term viability of transportation networks, it is crucial to comprehend and properly manage the impact of heat on roads [6]. This will help to promote effective and dependable roadways that can endure the difficulties presented by a variety of temperature circumstances.

The main component of this layer is asphalt, a thick, dark, and sticky material made from crude oil. It is made up of a variety of aggregates, such as dirt, gravel, sand, and crushed stone, that are joined by a substance called bitumen. Together, they provide a surface that is sturdy and durable and can bear the strains of continual use and changing weather conditions. The efficiency and durability of a road are greatly influenced by the calibre of the asphalt layer. The ability of the road to withstand enormous loads, resist stretching, and maintain its resistance to damage over time is substantially influenced by factors including the ingredients of the asphalt blend, the amount of thickness of the asphalt layer, and the use of proper building procedures. The strength and capabilities of the asphalt layer, which ensures the security and comfort of road users and the continued growth of the towns and economies linked by these crucial transportation arteries, must be ensured through effective planning and building practises, periodic upkeep, and recovery [7].

A vital artery for regional economic activity, transportation, and social connectivity is the road networks in Southern Libya [8]. High temperatures have a considerable impact on the resilience and functionality of the roadways, especially the asphalt layer, and present major infrastructural issues due to the region's peculiar environmental characteristics. Inducing heat stress on the asphalt causes a variety of distresses, including ruts, cracking, and premature ageing. These distresses are caused by the combination of searing heat during the day and a dramatic decrease in temperature at night, which is characteristic of the desert climate. Such consequences not only jeopardise the road's foundational reliability but also greatly increase the risk to the security and effectiveness of transportation systems. Researchers and professionals in the fields of construction engineering and materials research have been increasingly concerned with the effects of heat stress on asphalt qualities. In terms of rigidity, the viscosity fatigue resistance, and total strength, asphalt's reactivity to temperature changes can have a big impact [9]. Therefore, comprehending the complex interaction between thermal variations and the effectiveness of the asphalt layer is essential for putting into practise effective maintenance plans and creating durable road infrastructure that can withstand the challenging climate in Southern Libya [10].

In order to fully understand the heat effects on the characteristics of the asphalt layer under the roadways in Southern Libya, this study aims to undertake a thorough examination. The goal of the research is to provide important insights that can guide the creation of a reliable and durable roadway system in the area by examining the effects of temperature changes on asphalt performance. A thorough grasp of the particular difficulties presented by the particular environmental circumstances peculiar to Southern Libya will be made possible by the study's integration of empirical data gathered from fieldwork with an overview of previous research. This study aims to advance practical methods for the building and maintaining of roadways in drought-prone regions, ensuring the long-term sustainability and security of the regional transportation system by filling knowledge gaps regarding the connection between heat stress and concrete properties. The key contribution of this study is as follows:

1. Impact Assessment offers a thorough analysis of how heat variations affect the asphalt's characteristics in the arid climate of Southern Libya.

2. Realistic Suggestions provides doable recommendations for modifying asphalt mix layouts and construction methods to increase the region's roadway infrastructure's resiliency.

3. Increased Sturdiness makes practical recommendations for extending the life of asphalt roads, which will lower maintenance costs and increase traffic safety.

4. Research fusion adds to our understanding of asphalt performance by integrating findings with previously published literature in the fields of material sciences and civil engineering.

5. Promotion of Sustainability proponents of ecologically responsible road development, highlighting the significance of these approaches in areas with harsh climate conditions.

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The following is how the remaining sections of this research are arranged: In Section II of various approaches, they give an overview of pertinent research as well as the analysis of road construction and asphalt layers in southern Libya. These assertion mistakes are discussed in Section III. Section IV provides a detailed explanation of the general approach of the heat influence on the road's asphalt layers. To illustrate the temperature impacts of the road's asphalt layers, they give the experiment's findings and analyses in Section V. Section VI elucidates the model's discussion. Section VII brings the paper to a close by reviewing the research findings and suggesting future directions for this field of study.

II. BACKGROUND RESEARCH

Southern Libya, often referred to as the Fezzan region, occupies the southernmost territory of the country, characterized by its vast desert landscapes, arid climate, and unique cultural and geographical features. Figure 1 depicts the southern Libyan map. The region predominantly consists of the Sahara Desert, covering a significant portion of Libya's landmass with extensive stretches of arid, scarcely populated desert terrain, marked by striking sand dunes, rugged plateaus, and sporadic oases. The climate is exceedingly arid, with scorching daytime temperatures and cooler nights, and the region experiences significant temperature swings that influence infrastructure, such as road surfaces. Population density is lower compared to the more urbanized coastal areas, with traditional nomadic and semi-nomadic communities, particularly the Tuareg and Tebu people. These communities maintain unique cultural traditions and languages, adding to the region's cultural tapestry. Challenges in Southern Libya include the harsh desert environment, demanding climate, and challenges related to infrastructure development and maintenance, particularly in terms of road networks. Security concerns have been a persistent issue, often exacerbated by tribal conflicts and the presence of armed groups. The region also holds historical and cultural significance with ancient caravan routes, archaeological sites, and rock art, showcasing its rich heritage. The development and stability of Southern Libya are crucial factors in shaping Libya's broader economic and political landscape.

Figure 1: **Map of Southern Libya** [11]

III. UTILISATION OF ASPHALT IN SOUTHERN LIBYA

The investigation into thermal effects on the properties of the asphalt layer of roads in Southern Libya is a comprehensive and vital research endeavor, driven by the unique and challenging environmental conditions of this arid desert region. Southern Libya, nestled in the northern fringes of the Sahara Desert, is characterized by its dramatic temperature fluctuations. Daytime temperatures can soar to extremes, only to plummet to cooler levels during the night. It's against this backdrop that this study unfolds, aiming to unveil the intricate relationship between these temperature swings and the characteristics of asphalt road surfaces. Data collection forms the bedrock of this research, spanning a multitude of road segments dispersed across Southern Libya, with an extensive focus on temperature records meticulously documented over an extended time frame. These temperature records provide invaluable insights into the thermal stresses that the asphalt layers of the roads endure. Yet, the research doesn't halt at field data alone; it extends into the controlled environment of the laboratory. Here, a battery of tests is performed to scrutinize critical asphalt properties, including dynamic modulus, fatigue behavior, and rutting resistance. The dynamic modulus offers a window into the asphalt's stiffness under varying temperatures, a critical factor in assessing a road's capacity to withstand the rigors of traffic loads. The evaluation of fatigue behavior, on the other hand, provides insights into the asphalt's ability to resist damage under repeated loading, offering valuable indications of the road's long-term performance. Lastly, the study probes into rutting resistance, a measure of the asphalt's capability to endure deformation caused by traffic loads and high temperatures, which can lead to the formation of depressions or grooves on the road surface. With data from both the field and laboratory in hand, the researchers engage in a rigorous process of analysis, aiming to unravel patterns and correlations between temperature variations and the shifting properties of the asphalt. The ultimate goal is to discern how these thermal effects impact road surfaces in Southern Libya, providing a deep understanding of the challenges and vulnerabilities faced by the region's road infrastructure. The findings of this study can be profound, unveiling observations such as increased asphalt stiffness during high-temperature periods, which may affect its resistance to deformation, and heightened brittleness during low-temperature conditions, potentially leading to cracking. Moreover, the study is not merely a pursuit of academic knowledge; it carries significant practical implications. It serves as a compass for recommendations tailored to mitigate the effects of extreme temperature fluctuations on the asphalt layers of roads in Southern Libya. These recommendations may span improved asphalt mixture designs, innovative construction techniques, and strategic maintenance practices, all finely tuned to the region's unique climate conditions. Such insights and directives are not only of paramount importance for the efficient management of road infrastructure in Southern Libya but also hold broader relevance for regions around the world grappling with similar extreme climate challenges in their pursuit of enhancing road durability and performance.

Asphalt, also known as bitumen, plays a pivotal role in Libya's infrastructure and construction sector, serving as a foundational material for a multitude of applications. Perhaps most notably, it is the cornerstone of the country's extensive road network. Given Libya's vast geographical expanse, a well-maintained and robust road system is imperative for national connectivity, facilitating transportation, trade, and overall economic development. Asphalt's popularity in road construction stems from its exceptional durability, ability to withstand heavy traffic loads, and its resilience in the face of the region's extreme and fluctuating weather conditions, characterized by scorching daytime heat and cooler nights. Furthermore, Libya's airports feature asphalt runways, ensuring safe and efficient takeoffs and landings for both domestic and international flights, underlining the material's importance in the aviation sector. Asphalt also finds applications in more localized settings, such as the construction of parking lots, driveways, and other vehicular surfaces, thanks to its strength and smooth finish. Moreover, it is a fundamental component of various infrastructure projects, including bridges, tunnels, and public transportation facilities, contributing to the overall development and modernization of the country. The ongoing maintenance and rehabilitation of existing roads and infrastructure also heavily rely on asphalt, with resurfacing and repair work playing an essential role in preserving the longevity and functionality of these critical assets. In sum, the widespread and versatile use of asphalt underscores its significance in Libya's construction and transportation sectors, as it not only facilitates essential infrastructure but also stands as a resilient solution in a challenging desert environment.

Libya's current asphalt binder specifications rely on penetration grades, which are determined through empirical tests like penetration and softening point tests. These specifications are mainly based on practical experience and observations, lacking a solid foundation in pavement performance theory and long-term binder aging considerations. Asphalt cement grade 60/70 is exclusively used in constructing asphalt pavements across Libya. However, it's worth noting that pavement performance varies across regions. The coastal areas in the north generally exhibit satisfactory performance, while the central and southern desert regions often experience unsatisfactory results. This is primarily attributed to premature thermal cracking caused by rapid binder aging and significant temperature fluctuations in the central and southern regions. Asphalt, a thick, black, high-viscosity oil, is extracted through the distillation of crude oil at high temperatures (up to 300 °C) and pressure. It varies in terms of its liquidity, concentration, and melting and freezing points. One of its primary applications is as an adhesive that binds small building stones (aggregate) together to create a durable material suitable for paving streets and airport surfaces, commonly referred to as "asphalt mix." Various types of asphalt mixtures are employed in road construction, including:

- **Cold Bituminous Mix:** This kind of asphalt mixture is made for certain uses on roads where high temperatures are not necessary. In some cases, it's a more practical and energy-efficient choice for building requirements.
- **Penetration Macadam:** This technique of building roads combines asphalt with coarse aggregate, which is then compacted to provide a strong road surface. It's an affordable method of constructing traffic-resistant roadways.
- **Mastic Asphalt:** Roadway paving and other applications requiring waterproofing frequently employ mastic asphalt, a dense and durable material. It offers exceptional resilience against deterioration and wear and tear.
- **Sheet Asphalt or Rolled Asphalt:** This kind of asphalt is usually provided in rolls and is used for surfaces such as pavements and roofs. It provides a practical and reasonably quick method for covering bigger regions.
- **Sand Asphalt:** Sand asphalt is a mixture of sand and asphalt that is mainly utilised in certain situations where skid resistance is crucial. This mixture is frequently utilised in locations where slipperiness may be an issue since it offers high grip.
- **Hot Mix Asphaltic Concrete:** This popular and incredibly resilient asphalt combination is made and poured at a high temperature. It's a flexible option that works well on different types of roads and provides durability and strength even under extreme traffic and weather conditions.

3.1 Common Types of Asphalt Mixtures Utilized in Road Construction in Libya

To meet diverse needs and circumstances, numerous kinds of asphalt mixtures are utilised in Libya when building roads and other infrastructure. The following are the most popular kinds of asphalt mixtures employed in Libya:

3.1.1. Hot Mix Asphalt (HMA)

Hot Mix Asphalt (HMA), sometimes referred to as Hot Mix Asphaltic Concrete, is a popular and incredibly resilient asphalt mixture. The high temperatures involved in the production and application process of HMA are what distinguish it. Because of its high temperature, HMA is incredibly adaptable to a variety of road conditions. Notable for its robustness, durability, and resilience to severe weather and traffic, it is widely recognised for its strength. Before the asphalt binder is combined with aggregates, it is usually heated to a high temperature in order to produce HMA. After that, the heated mixture is spread across the road surfaces, giving it time to condense and take on the shape of a durable, smooth pavement. HMA is a recommended material for road construction in a variety of climates and traffic situations due to its ability to withstand large loads, withstand deterioration, and maintain structural integrity in the face of extreme weather. The ability of the asphalt industry to produce road surfaces that can hold up over time without losing their integrity or functionality is demonstrated by HMA, assuring the resilience and longevity of road infrastructure.

3.1.2. Mastic Asphalt

A unique type of asphalt combination called mastic asphalt is renowned for its exceptional durability and density. Its main uses are in surface and waterproofing projects. This dense asphalt combination is the best option for road surfaces that require a high level of durability because of its remarkable wear resistance. Mastic asphalt is widely used in construction because of its ability to form an impenetrable seal, which makes it perfect for waterproofing bridges, flat roofs, and other buildings. Because of its excellent bonding qualities and resilience to wear, it's also a recommended surfacing material for high traffic or high usage areas. Mastic Asphalt is the preferred choice for projects where long-lasting performance and resistance to water penetration are critical because to its resilience and toughness.

3.1.3. Penetration Macadam

A durable road surface is created by compacting a mixture made of asphalt and coarse particles, a process known as penetration macadam. This method produces a strong road surface that can handle heavy traffic and is widely used in road construction since it is affordable. Asphalt is used in the Penetration Macadam process to hold coarse materials, like stones or gravel, together. It produces a long-lasting and reasonably priced road surface once it is applied and compacted. This approach works especially well on roadways that must withstand considerable vehicle wear and tear and heavy traffic volumes. Penetration Macadam is a popular option in many projects since it provides a cost-effective yet durable solution for road construction.

IV. DATA COLLECTION

Engineers and contractors facing the challenge of constructing pavements in Libya encounter particular difficulties when dealing with desert or sand dune environments, common in the hot desert regions of North Africa and the Arabian areas. Adding to the complexity is the unpredictability of traffic growth in Libya due to limited access to annual road traffic data from road agencies and the volatile economic conditions in the country. Moreover, Libya lacks a comprehensive development strategy for roads, along with plans for services, funding sources, and land use. The construction of Hot Mix Asphalt (HMA) pavements in this context is a multifaceted process, influenced by numerous critical factors that are often not adequately considered during the mix design phase. This has resulted in the construction of pavements in Libya with suboptimal quality, leading to distresses such as rutting, shoving, and depressions appearing within the initial years of operation [12].

V. EXTREME CLIMATE CONDITIONS IN LIBYA

Libya's climate falls within the hot-arid region, situated between 15° and 45° north and south latitudes. It's characterized by arid and dry conditions with high temperatures and low humidity, especially during the summer. The desert climate, in particular, can be extremely harsh during both summer and winter. Sunshine is abundant, with an average of about 11 hours per day annually, resulting in high solar radiation. Temperatures soar, with the mercury often exceeding 25°C for approximately seven months each year. The ambient temperature regularly surpasses 40°C, and even the average daily temperature in the hottest month remains above 20°C. The summertime sees extreme highs of over 52°C, while winter can bring temperatures below freezing, dropping as low as -6°C. Libya holds the record for the highest temperature ever recorded on Earth, a scorching 58°C in Azizia, located at approximately 32.53°N and 13.02°E, with an elevation of about 112 meters (367 feet) and proximity to the coast. Rainfall in the Libyan Desert is a sporadic and minor occurrence, with short-lived rainstorms resulting in annual averages as low as 0 to 10 millimetres, making it practically negligible in this arid environment. The annual average relative humidity falls within the range of 30% to 50%. The region is significantly affected by harsh dry winds and intense dust storms, and these weather conditions have discernible impacts on both structures and the well-being of people.

In this region, a well-known scorching wind called the "gibli" is a common occurrence. This hot, extremely dry wind, laden with sand, can swiftly elevate temperatures, often reaching between 40°C and 50°C within a matter of hours. The road sections under examination traverse a hot-arid climate zone that experiences extended periods of scorching summer weather, often spanning over 100 days annually. This climate, apart from causing discomfort to humans, also leads to the deterioration of building materials. The challenging hot-arid environmental conditions have a significant impact on asphalt pavement mixtures. They result in accelerated hardening and aging due to the repeated cycles of temperature fluctuations. As the asphalt pavement binder ages, characterized by the oxidation of organic components and the sublimation of volatile fractions, the pavement gradually loses its durability. It becomes less flexible and behaves more like a rigid pavement, primarily relying on the friction between its mineral components. The swift aging of the asphalt pavement, driven by the daily temperature fluctuations and intense solar radiation, can induce low-temperature thermal cracking, a phenomenon typically associated with colder regions. This deterioration process initiates cracks that later propagate downward, eventually affecting the full depth of the pavement. The deterioration and eventual failure of Libyan roads, primarily attributed to problems like cracking and uneven surfaces, have rendered the asphalt pavement structures incapable of fulfilling their designated function. They can no longer bear the imposed loads without causing discomfort for both road users and vehicles. This, in turn, creates a hazardous, unsafe, and unpleasant riding experience.

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Table 1: **Monthly Summary of Temperature**

Month	Monthly Minimum Temperature (°C)	Monthly Maximum Temperature (°C)
January	-9°C	30°C
February	-4.5°C	34°C
March	-1.2°C	40°C
April	-1°C	44.5°C
May	4.5°C	46°C
June	3.5°C	50°C
July	13.5°C	51.5°C
August	10°C	49.5°C
September	11°C	46.5°C
October	5°C	42.5°C
November	0°C	40°C
December	-4.5°C	30°C

A thorough monthly summary of temperature data for a particular area or region, expressed in degrees Celsius, is provided in table 1. It contains the monthly minimum and maximum temperatures for each of the twelve months, with January having the lowest temperature at -9°C and December having the highest temperature at 30°C. This data offers a clear picture of the seasonal variations and temperature swings in the area, which is helpful information for comprehending the climate and weather patterns all year round. A graphical representation of the monthly temperature range in southern Libya is presented in Figure 2.

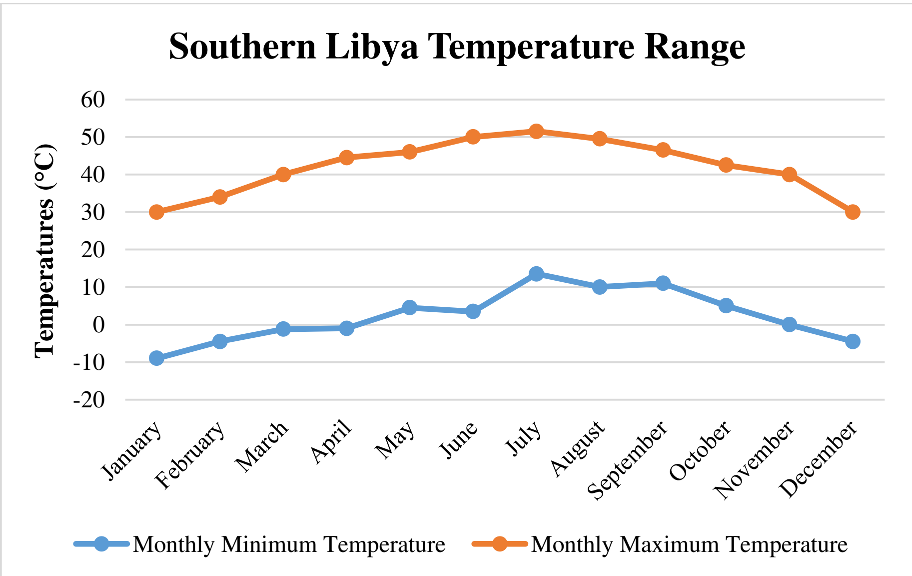

Figure 2: **Temperature fluctuations in Libya's southern region**

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VI. SIMULATION OF SOLAR RADIATION ON ASPHALT PAVEMENT

Heat transfer occurs in various forms, including conduction, convection, and radiation. Conduction, for instance, is the process of heat moving through solids, liquids, and gases, where heat energy travels from regions of high temperature to low temperature due to molecular vibration and collisions. In the context of asphalt pavement, heat is primarily transferred through conduction. The mathematical description of this phenomenon, the Fourier Law (heat equation, Equation 1), was applied to model and simulate temperature variations in the layers of asphalt pavement in Libya using the Schmidt procedure. This simulation was then validated by comparing the actual air and pavement temperatures with the results obtained. The study also used the data in Table 2 to estimate solar radiation on the asphalt pavement, taking into account the specific climate conditions in Libya.

$$\gamma = \frac{d^2t}{ds^2} = \rho A \frac{dt}{dm} \tag{1}$$

Where ,

- $\gamma = Thermal\ Conductivity\ \left(\frac{W}{m}.k\right)$
- $A = Heat\ capacity\ \left(\frac{J}{Kg}.k\right)$
- $\rho = Material\ Density\ \left(\frac{Kg}{m^3}\right)$
- $m = Time\ in\ Seconds$
- $t = Temperature\,(°C)$
- $s = Depth\ (m)$

Table 2: **Properties of Thermodynamics**

Quantity of Solving Components	**Depth (m)**	$\boldsymbol{Heat\ capacity\ \left(\frac{J}{Kg}.k\right)}$	$\boldsymbol{Thermal\ Conductivity\ \left(\frac{W}{m}.k\right)}$	$\boldsymbol{Material\ Density\ \left(\frac{Kg}{m^3}\right)}$
20	0.1	880	2.1	2234
3	0.2	855	2.2	1789
3	0.5	848	2.1	1789
1	5.0	848	2.1	2100

A comprehensive summary of the characteristics of a thermodynamic system is given in Table 2, which includes the number of solute components, measurement depths, heat capacity, thermal conductivity, and material density. The number of compounds in the system is described in the "Quantity of Solvent Components" column, which ranges from 20 to 1, indicating the complexity of the system. The depths of measurement, which range from 0.1 to 5.0 metres, are specified in the " Depth (m)" column. The temperature needed to increase a single degree Kelvin is shown by the " $Heat\ capacity\ \left(\frac{J}{Kg}.k\right)$" number, which varies depending on how sensitive a material is to temperature changes. " $Thermal\ Conductivity\left(\frac{W}{m}.k\right)$" displays various conductive qualities and represents the rate of heat transmission. With values ranging from 1789 to 2234 $\left(\frac{Kg}{m^3}\right)$, "Material Density $\left(\frac{Kg}{m^3}\right)$" provides information on the mass per unit volume and offers insights on material compactness at varied depths and solute component quantities. comprehension the makeup and behaviour of the system under various circumstances requires a comprehension of this data.

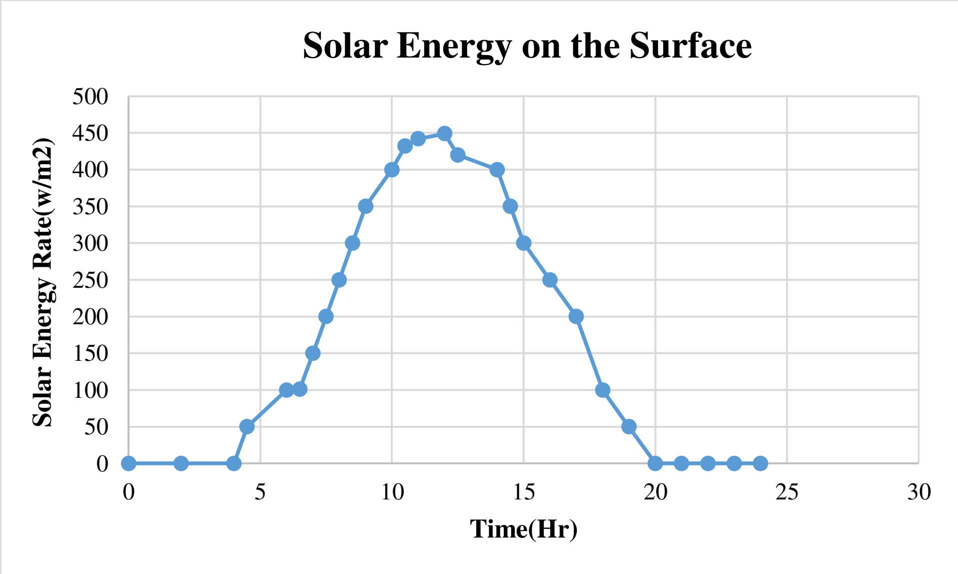

Figure 3: **Simulation of solar radiation in the Libyan environment**

The solar energy received at the surface is shown in the table as a 24-hour cycle, with time intervals expressed in hours and solar energy expressed in arbitrary units. Beginning at time 0 with zero solar energy, the data shows a progressive increase in solar energy that peaks at 449 units at 12 hours (noon) and reaches 100 units at 6 hours. The amount of solar energy decreases after noon, peaking at 100 units after 18 hours after steep declines at 12.5 and 14 hours. The amount of solar energy decreases further until it reaches zero units after a full day, signifying the end of the day or night. The diurnal pattern of solar energy is depicted in Figure 3, wherein the maximum values occur in the middle of the morning, fall as the day goes on towards evening, and finally return to zero during the night.

6.1 Influence of Temperature Variations and Solar Radiation on Aging

Libya is exposed to a hot, dry desert environment due to its unusual geographic location, which is marked by large temperature changes and strong sun radiation. The study aims to investigate in detail the ways in which these environmental conditions accelerate the ageing of road materials, especially asphalt, which is essential to the nation's road system. Road surfaces are subjected to significant stress from extreme temperature fluctuations, which can reach both freezing lows and searing highs. This can result in changes to the structural composition and material qualities. Furthermore, constant sun exposure can hasten the ageing process of asphalt by encouraging the loss of volatile components. Road performance and durability are directly impacted by decreased penetration, higher softening points, and an elevated penetration index that follow. It is anticipated that the study would examine two types of ageing: long-term ageing, which takes place over the course of the pavement's service life, and short-term ageing, which happens during the bitumen's laying, mixing, and storing operations. Given the influence of environmental factors on road pavements, long-term aging—also known as on-road hardening—is particularly relevant in this context. It is noteworthy that the impacts of ageing are typically more noticeable near the pavement's surface due to the oxygen content and the larger temperature fluctuations that occur there. The bitumen composition, air holes in the pavement structure, and the kind or source of bitumen used in road construction all have an impact on this aspect of ageing.

Bitumen aging is a complex process involving changes in its properties, structure, and composition. This aging is accelerated by various factors, including exposure to oxygen, ultraviolet radiation, temperature variations, and dry wind storms. These environmental stressors lead to the rapid loss of volatile components in the bitumen, resulting in reduced penetration, increased softening point, and a higher penetration index (PI). The short-term aging of bitumen is influenced by factors such as the source of the bitumen, its chemical composition, the type of mixture it's used in, and the temperature and time during the mixing process. Long-term aging, known as on-road hardening, is primarily attributed to the environmental conditions affecting the road surface, particularly the presence of oxygen and surface temperatures. Deeper layers of the pavement experience less aging. In-service aging, which occurs as bitumen reacts with atmospheric oxygen through oxidation, is further influenced by factors like air voids, bitumen content, and the source or type of bitumen used. The performance of pavements is significantly affected by the aging of bitumen, which

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undergoes changes due to exposure to a wide spectrum of temperatures. This aging process occurs both in the short term, encompassing storage, mixing, and laying phases, and in the long term, during the service life of the pavement.

6.2 Key Influential Factors Shaping Pavement Properties

Table 3 provides a comprehensive understanding of the several aspects that significantly impact pavement performance in Libya. The influence percentages of these criteria show how important they are in determining the overall efficacy, longevity, and quality of the nation's road infrastructure. Primarily, the "Type of Asphalt Binder" has a noteworthy 93% influence rating, highlighting the crucial importance that the selection of asphalt binder plays in determining the characteristics of pavement. The attributes of the binder, such as composition and characteristics, have a major effect on how well the road endures the severe weather patterns typical of Libya. With a 92% rating, the " Insufficient Data Gathering " category follows closely, highlighting the difficulties caused by restricted access to crucial information about road performance and conditions. Optimising pavement maintenance plans and making well-informed decisions require access to current and accurate information. Furthermore, " Name of Owner and Experience " receives an 87% influence rating, making it stand out as a strong factor. This section explores the history and methodology of the organisations in charge of managing and owning Libya's road infrastructure. It is essential to comprehend their priorities and tactics in order to evaluate and improve pavement performance.

Table 3: **Elements influencing Libyan asphalt quality**

Elements	Indicators
Name of Owner and Experience	85%
Modernising Asphalt Mix Design Techniques	86%
Different Kind of Binder for Asphalt	94%
Insufficient Data Gathering	91%
Contractor workforce and equipment proficiency	82%
Building Management	76%

With an 84% rating, the " Modernising Asphalt Mix Design Techniques " factor highlights how crucial it is to use cutting-edge mix design strategies to make sure that asphalt pavements are built to withstand the changing demands and difficulties brought on by Libya's traffic and climate. Given its 80% effect rating, " Contractor workforce and equipment proficiency" plays an important function that should not be undervalued. Building and maintaining high-quality pavements successfully depends on having skilled contractors with the appropriate staff and tools. The final category, " Building Management," received a 78% grade and emphasises the need of efficient management and quality control during the building stage. This element contributes to pavement qualities that last over time by guaranteeing that the materials and methods used meet the necessary standards and specifications. To sum up, the aforementioned table highlights the intricate relationship between several elements that affect pavement performance in Libya. These elements work together to influence the nation's road system and highlight the necessity of a thorough approach to road management, building, and upkeep to guarantee that Libya's pavements are robust and able to withstand the particular difficulties brought about by the country's environment and usage patterns. The graphic representation of the factors affecting the quality of Libyan asphalt is displayed in Figure 4.

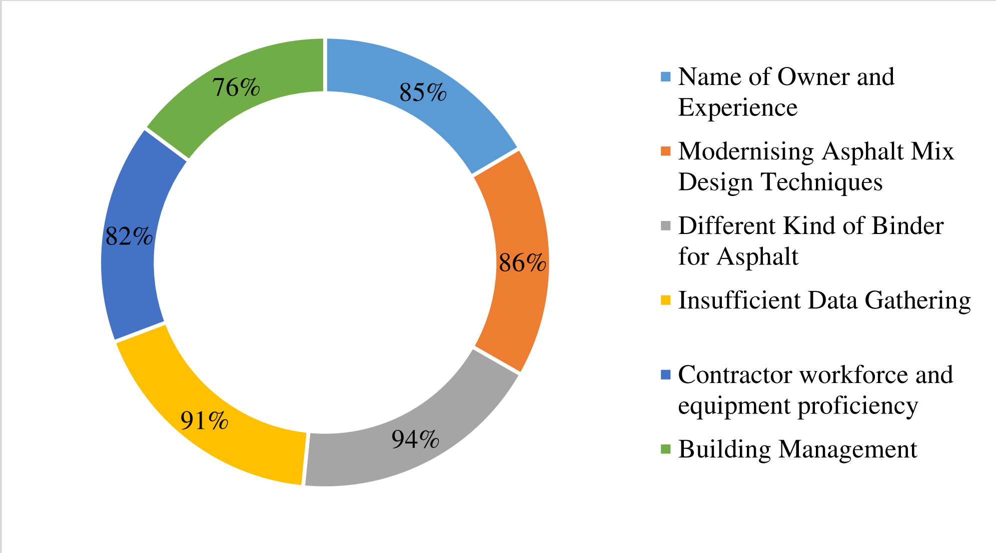

Figure 4: **Graphical Representation of the Elements influencing Libyan asphalt quality**

VII. CONSTRUCTION SUPERVISION

The supervision of mix design components, which include the aggregate skeleton, Optimum Bitumen Content (OBC), mixing temperature, and compaction method, plays a substantial role, accounting for 78% of the impact. The mixing process significantly influences the viscosity of the asphalt binder and the behaviour of the final product during paving. Precise control of asphalt quantity and mixing temperature within the mix design phase holds paramount importance for achieving a satisfactory mixture. This not only mitigates the aging of the asphalt binder due to oxidation but also ensures the creation of a uniform coated mixture. Maintaining the correct asphalt content is essential for attaining the desired void content in the compacted mixture. The volume of air voids, in turn, affects various pavement properties, encompassing durability, flexibility, stability, and resistance to moisture-induced damage. Any deviation in asphalt content can result in an overly dry mixture, leading to premature ravelling and cracking, or excessively rich mixtures, which may cause permanent deformation [13].

VIII. LITERATURE SURVEY

Amhadi and Assaf [14] explains The qualities of the soil are crucial for designing pavements and determining if a road is financially viable. The extremely poor soil quality in arid regions, like that of southern Libya, causes significant pavement degradation, including cracks, ruts, potholes and horizontal shear damage on the margins. An inventive method of using manufactured sand, regular Portland cement (OPC), and fly ash (FA) as a glue is suggested to increase the strength of desert sand. The properties of mixes containing natural desert sand (NDS) and crushed fine aggregates (CFA) are enhanced by OPC and FA. These findings are based on X-ray fluorescence (XRF) analysis of the particle arrangement and grading of two sand sources to ascertain the chemical and physical qualities from the particles, respectively. This study evaluates the impact of fly ash and concrete on the geological behaviour of two blends of produced and fine desert sand (30:70% and 50:50%). The mixture with 26% CFA, 62% NDS, 5% OPC, and 7% FA yields the best outcomes in terms of capacity for bearing, compaction, and strength. This method can be problematic for nations who produce coal because they have a lot of fly ash to get rid of and don't have enough calcareous materials to make cement.

Omar et al.[15] was conducted to look into how bitumen ages prior to as well as following modification. After introducing nano-clay (NC) to 60/70 penetrating grade bitumen, nano-clay altered bitumen (NCMB) was created. The binder's properties, including penetration, softening point, and viscosity, were then assessed using standard testing methods. The modified binder was subjected to these tests both before and after it aged. For the modified binder, short-term ageing (STA) was simulated using a rolling lightweight oven (RTFO) and long-term ageing (LTA) was simulated using a pressure-controlled ageing vessel (PAV). Infrared spectroscopy with a Fourier transform (was used to continue the experiment after preliminary findings about the modified bitumen's improved ageing properties. FTIR allowed researchers to observe the changed binder's microstructure distribution both before and after ageing. Ultimately, it was apparent that further research on the impact of ageing on mixes was necessary. The indirect tension strength (ITS) test was used for this phase because it illustrates the strength variations that the mixes undergo with age. In good accordance with the findings of earlier binder experiments, the tensile strength of mixes prepared with modified bitumen demonstrated greater resistance towards ageing when NC was added. The study's findings demonstrate that bitumen can be modified by adding nano-clay to increase the binder's resistance to ageing, which in turn increases the durability of the asphalt mixture. The observed decrease in fluidity and rise in viscosity is one possible negative that can affect the asphalt mixtures' functionality and compacted during building.

Selecting the right asphalt binder requires accurately determining the highest and lowest temperatures of the pavement. Pavement design temperatures can now be determined with the use of temperature prediction models. Therefore, proper pavement overlay design and the construction of climate-resilient pavements depend on precise temperature predictions. Studies have indicated that a number of factors, including complexity of the model's input variables, and geographic location, might impact how accurate temperatures prediction models are. Additionally, calibrating has been shown to increase the anticipated temperature's accuracy. Lekea and Steyn [16], explains Using a sample of substances, particularly asphalt, the effectiveness of three pavement temperatures forecasting algorithms was investigated. Additionally, a calibration's impact on the model's precision was assessed. The models were tested and calibrated using temperature data that came from Pretoria. It was also evaluated how well the calibration and uncalibrated algorithms performed in a different region. Data on asphalt temperature were gathered from two Ghanaian locations. In the investigation, the statistical techniques of determination coefficient (R 2), variance taken into account (VAF), maximal relative error (MRE), and the root mean square error (RMSE) were applied. The models were shown to be more accurate at predicting maximum temperatures, but they were less accurate at predicting lowest temperatures. According to the substance, different models performed differently when predicting the highest temperature. The models' precision was increased by calibration, however for calibrating to be successful, test data pertinent to each location must be used. Additionally, data from different continents must be used to evaluate the models. A possible limitation is the dependence on temperature data mostly from Africa, indicating the need to evaluate the models with data from different continents for a more thorough assessment of their effectiveness.

One of the main variables affecting the efficiency and bearing capacity of temperatures-sensitive asphalt products is air temperature. In order to forecast the temperature of asphalt pavement and assess asphalt performance, this study looks into the connection among air temperatures at various depths and time. Milad et al. [17]discusses Four models of regression constructed using deep learning are used to determine the temperature of asphalt pavement depending on time, thickness from the asphalt surface, and air temperature. In the area known as Gaza, the temperature of the pavement was measured. Temperatures of the air and asphalt surface were recorded at various depths and periods using monitoring stations. Using manual measurements, the data were gathered between March 2012 and February 2013. Convolutional neural networks (CNNs), long short-term memories (LSTMs), bidirectional long-term memories (Bi-LSTMs), and gated recurrent units (GRUs) are used to train and validate the data. With an R2 of 0.9555 for the created dataset, Bi-LSTM performs better than other algorithms due to its supremacy in multifunctional information processing and extraction of features. Bi-LSTM has shown exceptional stability and intriguing potential for forecasting asphalt pavement temperatures through deep learning approaches. A possible disadvantage is the omission of some environmental factors, which may have led to a more thorough and precise estimation of the temperature of asphalt pavement, including air temperature, sun radiation, velocity of the wind, and relative humidity.

Coutu Jr et al.[18] explains the two most common substances used to build motor vehicle highways, bicycle lanes, and runways for airports are concrete as well as asphalt. As a substitute material and power source, Solar Roadways®, Inc. (SR) presented a revolutionary solar pavement technology, namely solar road panels (SRP). In order to employ SRPs in not critical situations like parking lots, SR carried out impact, traction, and load tests. Engineering tests, such as freeze/thaw, absorption of moisture, heavy automobile, and shear testing, were completed on "SR3" prototypes in order to deploy SRP on public roads. Testing was done at Marquette's campus in the areas of the SR Pilot Project and the School of Engineering's Materials and Structures Testing Laboratory. Tests for absorbing moisture and freeze/thaw demonstrated that "SR3" is resistant to harsh weather and damp conditions. Testing with heavy vehicles showed that the "SR3" was not physically damaged even after 989,457 comparable single axle weights were continually rolled across a prototype pavement. The properties of the "SR3" composite structure were investigated through shear testing. Electrical failure was always characterised by the "SR3" photovoltaic voltage falling to 0 volts. For "SR3" (S/N's Paver 1, 002B, 007C, and 004B), the highest shear stress and applied torque were, respectively, 1756 kPa, 1835 kPa, 1643 kPa, and 2023 kPa; and 121.2 kN·m, 131.3 kN·m, 117.6 kN·m, and 144.8 kN·m. Furthermore, during the whole shear testing process, the "SR3" "heartbeat" LED (light-emitting diode) continued to function, i.e., to signal computer bus communication. When "real-world" test circumstances are applied to "SR3" prototypes, the overall findings demonstrate their resilience, robustness, and functionality. The existence of process uncertainty and flaws during the production of SRPs is one possible disadvantage that could have an effect on the products' dependability and performance in real-world scenarios.

Table 4: **Comprehensive Summary of Various Research Studies**

Reference	Technique	Advantages	Drawbacks
Amhadi and Assaf [14]	Utilising FA, OPC, and produced sand as glue.	Strengthened desert sand and better-quality pavement.	Environmental issues arising from the utilisation of fly ash
Omar et al.[15]	Bitumen is introduced with nano-clay.	Increased resistance to bitumen aging, enhanced asphalt mixture durability	Potential impact on asphalt mix fluidity and compaction
Lekea and Steyn [16]	Examining theories for predicting temperature.	Improved accuracy in predicting maximum temperatures, calibration enhances model precision	Less accuracy in predicting minimum temperatures, model performance varies by region
Milad et al. [17]	Deep learning algorithms to forecast the temperature of asphalt	High accuracy in predicting asphalt pavement temperatures, superior performance with Bi-LSTM	Limited environmental factors considered in the models, potential for a more comprehensive approach
Coutu Jr et al.[18]	Solar-powered Road panel testing (SRP).	Resilience and robustness of SRP demonstrated under various tests, including heavy vehicles	Possible process uncertainties and flaws in SRP production, affecting reliability and performance

Amhadi and Assaf [14] investigated the novel strategy of fortifying desert sand for pavement construction with manufactured sand, fly ash (FA), and ordinary Portland cement (OPC). The pavement quality improved as a consequence of this procedure. However, there were environmental issues highlighted by the utilisation of fly ash. In order to improve bitumen's ageing resistance and asphalt mixes' durability, Omar et al.[15] added nano-clay to bitumen. This method showed promise, but it also brought up questions about the asphalt mixtures' compaction and fluidity. In order to increase the precision of temperature forecasts for pavements, Lekea and Steyn [16] concentrated on researching temperature prediction models. These models showed limits in predicting minimum temperatures and inconsistent performance across different regions, even though they performed well in predicting maximum temperatures and benefited from calibration. In order to accurately estimate the temperatures of asphalt pavement, Milad et al. [17] investigated the use of deep learning models. Better results were obtained when the Bidirectional Long

Short-Term Memory (Bi-LSTM) model was used. There may be space for a more thorough approach, nevertheless, given that some environmental aspects were not taken into account by the simulations. Solar road panels (SRP) were extensively tested by Coutu Jr et al.[18] to determine their robustness and durability in a variety of scenarios, including exposure to heavy cars. The research revealed significant process uncertainties and defects in SRP production, which could affect their dependability and performance, but the results also showed that SRP is viable for such applications. As a whole, table 4 provides an insightful overview of these research, highlighting their methods, the advantages they offer the pavement engineering community, and any potential drawbacks or difficulties. Every study advances the knowledge of the components and techniques used in the building of durable and sustainable pavements.

Thus, in this case study on how heat affects the characteristics of the asphalt layer on Southern Libyan highways aims to achieve a number of important goals. Its primary goal is to evaluate the significant effects of Southern Libya's severe desert climate, which is marked by high temperatures and low humidity, on the characteristics and functionality of asphalt pavements. The goal of the research is to better understand how the asphalt layer and asphalt binders react to the large temperature swings that occur in this area. Additionally, the study aims to explore the ageing mechanisms of asphalt binders and the ensuing impacts on pavement performance, specifically concerning thermal cracking. In order to comprehend how important elements like mixing temperature, compaction techniques, and asphalt binder quantity affect the longevity and toughness of asphalt pavements in arid climates, the study will also look at these elements.

IX. CONCLUSION

In this harsh desert climate, road infrastructure has particular problems, as demonstrated by the case study on the impact of heat on asphalt road surfaces in Southern Libya. The thorough examination of temperature swings, the characteristics of asphalt, and how these affect road performance in the study offers insightful information for improving the resilience and longevity of roads in the area. The findings of the study show that the severe heat waves that Southern Libya experiences have a significant effect on asphalt road surfaces. Low temperatures can make the asphalt more brittle, increasing the chance of cracking, while high temperatures enhance the stiffness of the asphalt, impacting its resistance to rutting and its dynamic modulus. Road planners and engineers working in this climate must take these impacts of thermal stress into account. Several recommendations are made by the report to address these issues. These include using building methods that increase the longevity of road surfaces, designing asphalt mixtures with optimal temperature tolerance, and putting proactive maintenance plans in place to deal with and avoid thermally related distress. The study's conclusions have wider ramifications for infrastructure engineering and planning in other areas of the world with equally severe climates. Road networks can be made safer and more dependable by putting the recommended solutions into practise. This could improve the quality of transport and support the general growth and well-being of the communities they serve.

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+91 99405 72462 +91 63819 07438 ijmrsetm@gmail.com