

Road Concretisation and Urban Heat Island Intensification in Sangli-Miraj-Kupwad City Municipal Corporation Region: A Critical Assessment of Pavement Material, Surface Heat Storage, and Thermal Comfort Risk

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Abstract - Indian municipal corporations increasingly adopt road concretisation as a durable and low-maintenance infrastructure strategy. In hot-dry regions, however, large-scale conversion of asphaltic road surfaces to impervious concrete corridors can alter the urban surface energy balance when tree protection, permeable edges, water-sensitive design, and pedestrian shading are not incorporated. This paper examines the likely urban heat island implications of the proposed concretisation of roads in the Sangli-Miraj-Kupwad City Municipal Corporation region of Maharashtra, India. The SMK block estimate indicates that approximately 300397.00 sq. m. of road surface is proposed for concrete treatment across 11 corridors. The study uses IMD Miraj (Sangli) Station Index No. 43158 monthly climatological baseline and peer-reviewed literature on pavement albedo, heat storage, urban morphology, cool pavements, and outdoor thermal comfort. Scenario-based projection indicates that exposed road corridors may experience a local near-road air-temperature increase of approximately 0.5-1.2°C in daytime and 0.7-1.4°C at night by 2035. The study recommends climate-sensitive concrete-road design standards for the SMK region.

Key Words: road concretisation, urban heat island, concrete pavement, surface heat storage, thermal comfort, cool pavements.

1. INTRODUCTION

Urban roads are normally evaluated through engineering criteria such as strength, service life, drainage performance, maintenance cost, traffic capacity, and construction speed (Nwakaire et al., 2020; Sen et al., 2022). In many Indian municipal corporations, concrete roads are preferred because they are perceived as durable, clean, and less vulnerable to potholes than conventional bituminous roads; in the SMK case, this preference is reflected in the proposed concrete-road block estimate and public reporting on the 11-road concretisation proposal (Sakal News, 2026b; Sangli, Miraj and Kupwad City Municipal Corporation, 2026). From an urban-climate perspective, however, pavement material is not a neutral technical choice. Roads receive solar radiation, store heat, emit long-wave radiation, alter near-ground air temperature, and influence the thermal exposure of pedestrians, street vendors, traffic police, cyclists, two-wheeler users, street workers, bus-stop users, and residents (AzariJafari et al., 2021; Li et al., 2019; Nwakaire et al., 2020; Qin, 2015; Santamouris, 2013).

Figure 1 explains how concrete roads absorb solar radiation, store heat, emit long-wave radiation, and alter near-ground air temperature, collectively increasing human thermal exposure along municipal road corridors.

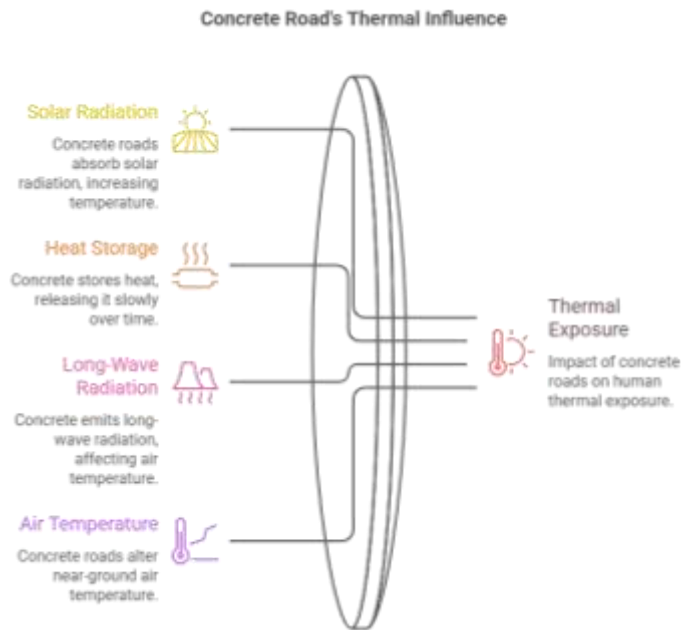


Fig. 1: Concrete Road's Thermal Influence on Near-Road Air Temperature and Human Thermal Exposure

Pavements are therefore part of the urban surface-energy system and influence urban heat island (UHI) formation through albedo, emissivity, thermal conductivity, heat capacity, permeability, surface moisture, and interaction with built form (Nwakaire et al., 2020; Qin, 2015;

Santamouris, 2013). Figure 2 shows how albedo, thermal conductivity, permeability, emissivity, heat capacity, surface moisture, and built-form interaction collectively determine pavement influence on urban heat island formation in road corridors.

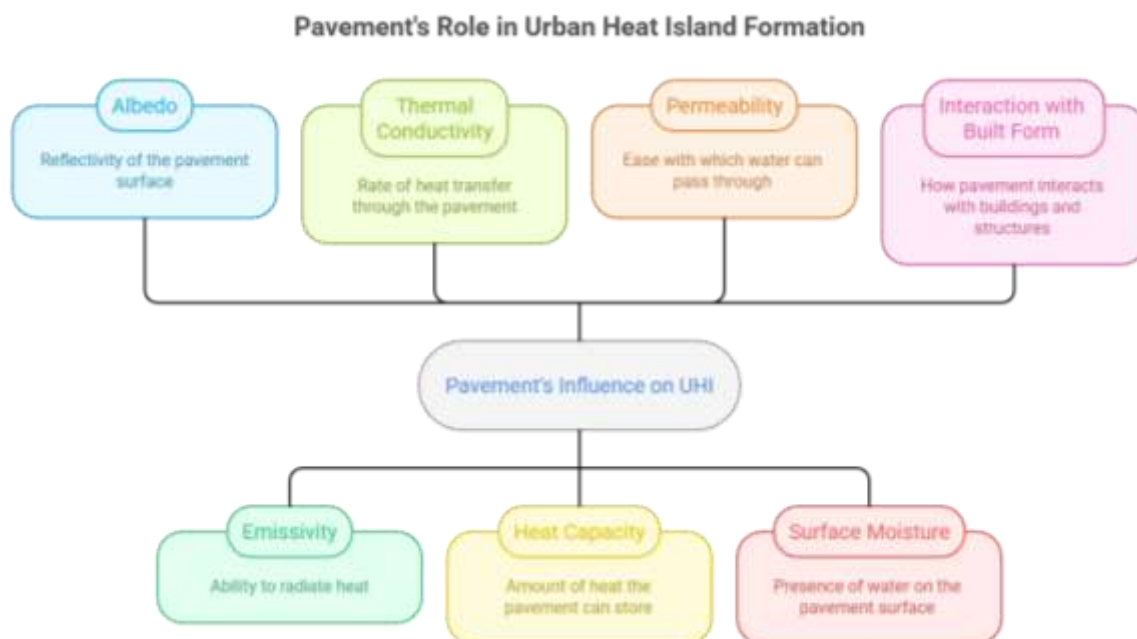


Fig. 2: Pavement Properties Influencing Urban Heat Island Formation

The proposed direction of developing major roads in the SMKC region as concrete roads, therefore, requires strict environmental scrutiny. A concrete road may perform well structurally, but if it is implemented as a wide, unshaded, impervious, high-thermal-mass corridor, it contributes to local heat storage and delayed night-time heat release. This concern is more serious because the available IMD climatological baseline for Miraj (Sangli)

Station Index No. 43158 already indicates strong hot-season exposure. April is the most thermally severe month in the baseline, with a mean maximum temperature of 38.50°C and a monthly average of 30.00°C. This high pre-monsoon background temperature makes the SMKC region sensitive to additional local heating caused by surface sealing, tree

loss, reduced evapotranspiration, and unshaded pavement expansion.

The physical scale of the proposed concretisation is central to the present study. As per the SMKC block estimate, approximately 300397.00 sq. m. of road surface is proposed for concrete treatment across 11 major municipal road corridors. This footprint should not be treated merely as a construction quantity. In urban-climate terms, it represents a large heat-exchanging surface capable of modifying local surface temperature, radiant exposure, evaporative cooling potential, and night-time heat release. Pavement-related UHI studies show that road surfaces influence urban heating through albedo, surface moisture, thermal storage, permeability, and interaction with surrounding built form (Li et al., 2019; Nwakaire et al., 2020).

The present study frames road concretisation through three linked mechanisms: (a) pavement material

properties, including albedo, emissivity, conductivity, heat capacity, permeability, colour, age, and texture; (b) surface heat storage, referring to the amount of heat stored during the day and slowly released after sunset; and (c) human thermal comfort risk, referring to the social distribution of outdoor thermal stress. The study does not argue that concrete roads are inherently unacceptable. The critical concern is that large-scale concretisation without compensatory cooling design intensifies urban heat island conditions in the municipal region (Qin, 2015; Santamouris, 2013).

Figure 3 illustrates how pavement material properties, surface heat storage, and human thermal comfort risk interact to explain road concretisation's contribution to urban heat island intensification in municipal road corridors.

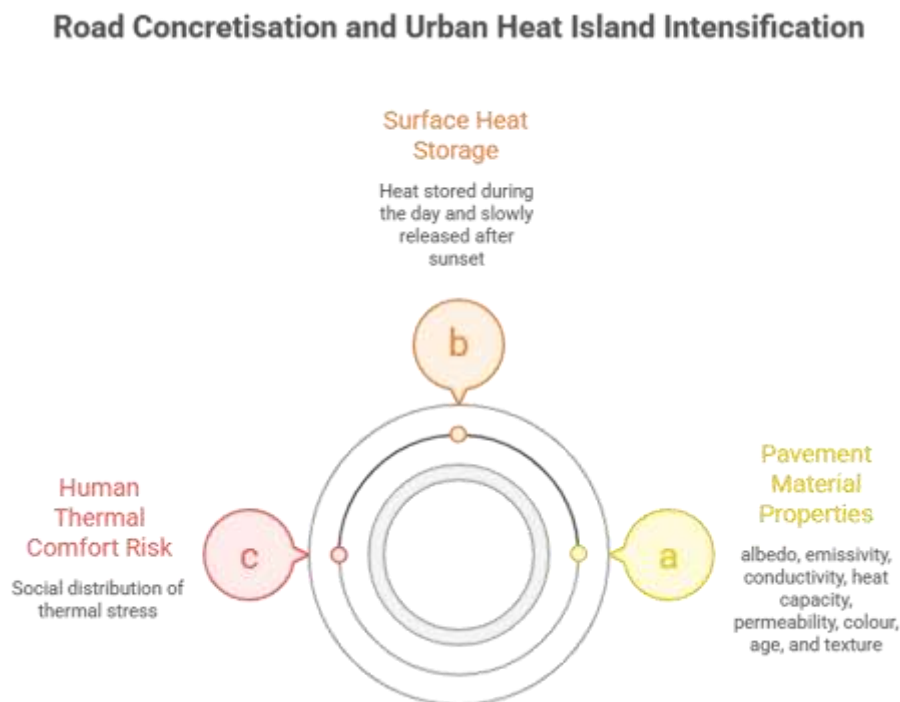


Fig. 3: Conceptual Framework Linking Road Concretisation, Surface Heat Storage, and Urban Heat Island Intensification

2. RESEARCH PROBLEM AND OBJECTIVES

The research problem is that municipal road concretisation is often treated as a civil-engineering upgrade rather than a microclimatic intervention. If major roads are converted into continuous concrete surfaces without integrating shade, permeability, surface reflectance optimisation, and local temperature monitoring, the policy increases urban heat island intensity and reduces outdoor thermal comfort. This is especially important in cities such as Sangli-Miraj-

Kupwad, where public life depends heavily on outdoor mobility, street vending, two-wheeler movement, pedestrian commuting, and open roadside commercial activity.

The objectives of the present study are fivefold: (a) to establish the preliminary thermal sensitivity of the SMKC region using the available IMD Miraj (Sangli) baseline; (b) to review pavement-related UHI mechanisms; (c) to develop a conceptual framework linking road concretisation with surface-energy balance

and comfort risk; (d) to provide a scenario-based 10-year projection of possible near-road temperature increase; and (e) to recommend climate-sensitive design safeguards for municipal road development.

Figure 4 summarises the study objectives through five linked components.

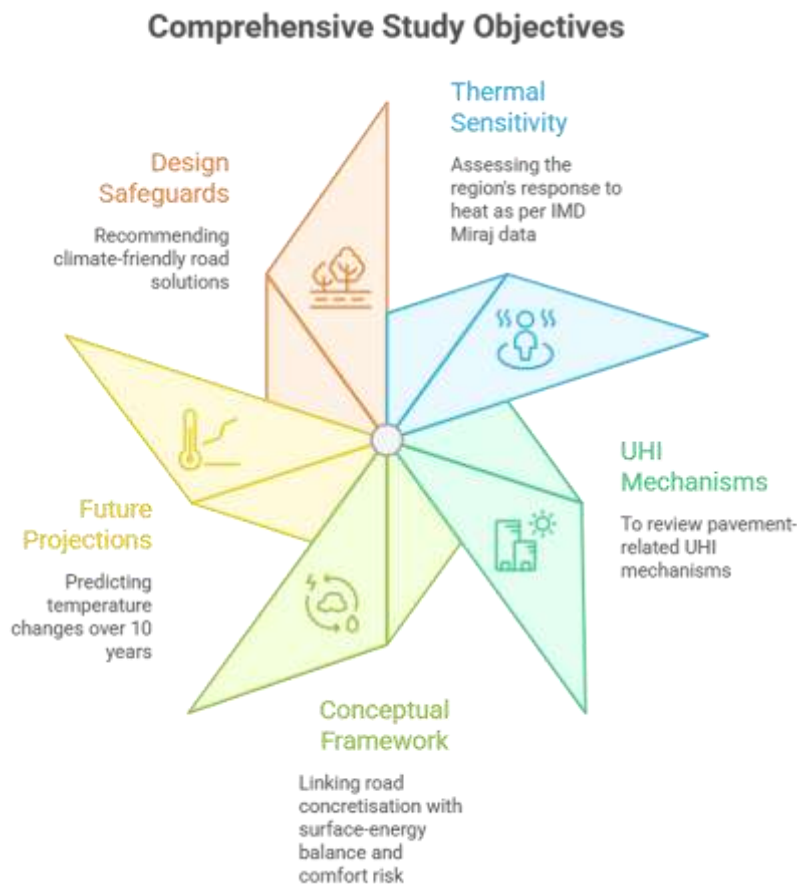


Fig. 4: Comprehensive Study Objectives for Assessing Road Concretisation and Urban Heat Island Risk in the SMKC Region

Four research questions guide the present study:

How can road concretisation alter the urban thermal environment in the SMKC region?

Which pavement mechanisms are most relevant to UHI formation?

What level of local temperature increase is plausible over a 10-year horizon under ordinary unmitigated concrete-road development?

What design measures can reduce the thermal burden of concrete-road infrastructure?

Figure 5 emphasises problem focus and policy-oriented investigation.

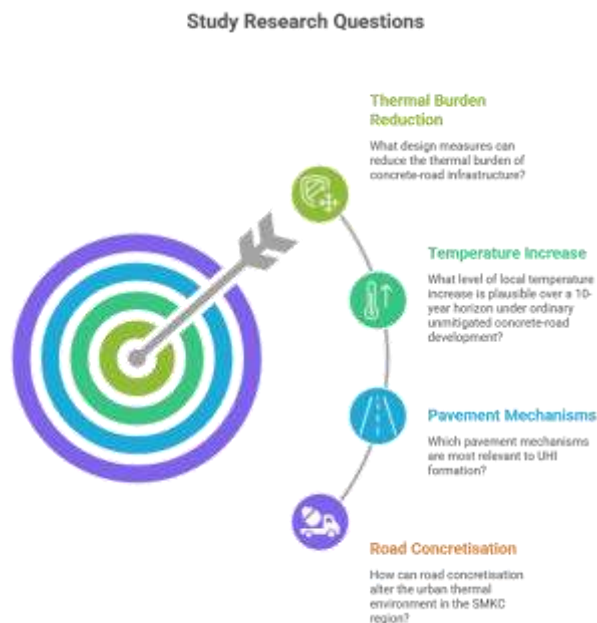


Fig. 5: Study Research Questions Framing Road Concretisation, Pavement Mechanisms, Temperature Increase, and Thermal Burden Reduction

The present study is based on the proposition that unmitigated road concretisation increases local near-road heat exposure, particularly where concrete corridors are wide, unshaded, traffic-intensive, poorly ventilated, and constructed with sealed edges. Conversely, climate-sensitive concretisation with high-albedo low-glare surfaces, tree protection, permeable shoulders, bioswales, and shaded footpaths reduces this risk.

3. LITERATURE REVIEW

Urban heat islands arise when dense, impervious, heat-retaining materials replace natural or vegetated surfaces. Roads, parking areas, walls, roofs, and compact building forms alter the surface-energy balance by modifying albedo, evapotranspiration, air movement, heat storage, and anthropogenic heat release. Li et al. (2019) showed that imperviousness and urban aerodynamics both contribute to UHI formation, indicating that surface cover and urban morphology must be analysed together. This is important for road concretisation because roads do not operate as isolated pavement strips; they interact with adjacent buildings, traffic, tree canopy, wind flow, and drainage conditions.

Pavement-related UHI research identifies albedo as a key thermal property. Santamouris (2013) reviewed cool pavement development and showed that reflective pavements mitigate urban heat islands by increasing solar reflectance. Qin (2015) similarly concluded that cool pavements are a significant mitigation strategy, although performance depends on surface material, colour, ageing, moisture, and local climate. Akbari et al. (2009) argued

that increasing urban albedo through lighter roofs and pavements produces climate-cooling benefits at larger scales, although such benefits must be evaluated in relation to the local urban context. Xu et al. (2020) further demonstrated that pavement-albedo effects are location-specific, meaning that albedo-based mitigation should be evaluated through climatic and urban-morphological conditions rather than through generic assumptions.

AzariJafari et al. (2021) demonstrated that cool pavement impacts are context-sensitive because albedo change influences urban air temperature, building energy demand, reflected radiation, transport emissions, and global warming potential. Gilbert et al. (2017) similarly showed that cool pavement campaigns have both energy and environmental consequences, implying that pavement material selection must be assessed through an integrated framework rather than a single surface-temperature indicator. These findings are particularly relevant to the SMKC region because reflective or concrete surfaces reduce absorption compared with dark asphalt, but they also influence glare, reflected radiation, pedestrian radiant exposure, and adjacent building heat gain.

The literature does not support a simplistic claim that concrete is always hotter than asphalt. Conventional Portland cement concrete is often lighter than asphalt and has higher solar reflectance. Ibrahim et al. (2018) found that asphalt produced higher surface temperatures than concrete in the studied setting, while permeable and lighter surfaces retained less heat. Their work also

showed that pavement type, albedo, density, moisture, and permeability all affect surface heating. However, this does not mean that mass concretisation is automatically climate-safe. Ordinary concrete roads remain impervious and heat-storing surfaces. Their thermal impact depends on surface finish, surrounding shade, pavement width, moisture availability, traffic, and built-form geometry.

Permeability is equally important, particularly because it governs surface moisture retention, evaporation potential, drainage behaviour, and pavement-related cooling capacity. Dense sealed pavements reduce evaporative cooling by limiting water exchange at the surface and road edge. Permeable pavements show lower temperatures where moisture is available because evaporation consumes part of the incoming net radiation. Nwakaire et al. (2020) reviewed urban pavement effects and emphasised that pavement design must consider material properties and environmental performance, not only structural durability. This is relevant to the SMKC region because full-width concrete roads with sealed shoulders remove the limited cooling contribution of soil strips, tree pits, and vegetated edges.

Concrete pavement performance itself is affected by heat. Sen et al. (2022) found that climate change and UHI increase concrete pavement deterioration because thermal gradients through slabs influence stress development and fatigue cracking. This indicates that concrete roads are not thermally inert assets. Their durability and environmental behaviour are both conditioned by the local climate. A road that is structurally durable under conventional engineering assumptions still creates heat-related environmental burdens if surface-energy behaviour is not considered.

Urban vegetation remains a primary mitigation measure because it provides shade and evapotranspirative cooling. Yan et al. (2020) quantified the cooling role of vegetation at the local scale, while Yuan et al. (2020) emphasised the need to understand urban morphology and

anthropogenic heat dispersion. For road policy, this means that concrete surfaces must be designed together with trees, setbacks, wind flow, shaded paths, and stormwater-sensitive edges. The literature gap, therefore, is not whether pavements affect urban heat. The gap is how such evidence should be translated into municipal road-concretisation policy for specific Indian urban regions, such as the SMKC region.

4. STUDY AREA AND CLIMATIC BASELINE

Sangli, Miraj, and Kupwad form a continuous municipal corporation region in western Maharashtra, India. The region contains old city fabrics, commercial roads, institutional zones, residential neighbourhoods, transport junctions, and expanding peri-urban edges. The available temperature baseline identifies the IMD Miraj (Sangli) Station Index No. 43158 as the relevant public meteorological reference for the corporation region. Separate long-term public climatological station datasets for Sangli and Kupwad city limits are not available presently; therefore, the Miraj (Sangli) station data are used as the SMKC region meteorological baseline.

The available station dataset is treated in the present study as a monthly climatological temperature summary for the SMKC region based on IMD Station Index No. 43158. It is suitable for preliminary climate-risk framing and scenario interpretation. Table 1 shows that March, April, and May form the critical pre-monsoon thermal period. April records the highest mean maximum temperature, while May records the highest mean minimum temperature. From a thermal-comfort perspective, this is significant because high night-time minimum temperature reduces physiological recovery and increases indoor heat carry-over. Concretised road corridors store and release heat slowly after sunset; therefore, the night-time heat burden becomes more important than the daytime maximum-temperature value alone.

Table -1: Monthly Climatological Temperature Baseline for the Sangli-Miraj-Kupwad Municipal Corporation Region, 2006-2025 IMD Station Index No. 43158 Data

Month	Mean Minimum Temperature (°C)	Mean Maximum Temperature (°C)	Monthly Average Temperature (°C)
January	14.40	31.80	23.10
February	15.70	34.10	24.90
March	18.80	36.80	27.80
April	21.50	38.50	30.00
May	22.40	37.30	29.90
June	22.20	31.50	26.90
July	21.60	28.90	25.30

Month	Mean Minimum Temperature (°C)	Mean Maximum Temperature (°C)	Monthly Average Temperature (°C)
August	21.20	28.40	24.80
September	20.90	30.50	25.70
October	20.30	32.10	26.20
November	17.40	31.70	24.60
December	14.70	31.00	22.90
Annual	19.20	32.70	26.00

Note: Mean minimum and mean maximum temperature values are adapted from publicly available India Meteorological Department climatological reference information for Sangli/Miraj Station Index No. 43158 (India Meteorological Department, n.d.-a).

4.1 PROPOSED ROAD-CONCRETISATION FOOTPRINT

The proposed concrete road programme has a substantial spatial footprint within the SMKC region. The estimated data indicate 11 road corridors with a combined length of approximately 19612.00 m and an estimated concrete surface area of approximately 300397.00 sq. m., equivalent to 30.04 ha or 0.300 sq. km. The estimated project cost is approximately Rs. 226.89 crore. The public report in Sakal News also identifies 11 concrete roads, approximately 19.6 km in length, and a project cost of about Rs. 227 crore, while recording the political claim that the long-term financial burden may reach about Rs. 350 crore under the HAM model (Sakal News, 2026b; Sangli, Miraj and Kupwad City Municipal Corporation, 2026).

This area-based quantification is important because UHI risk is related not only to material type but also to the total exposed surface area, continuity of impervious cover, street width, vegetation loss, moisture availability, traffic exposure, and urban ventilation. Imperviousness and urban aerodynamics jointly influence UHI formation (Li et al., 2019), while pavement-related heating depends on albedo, thermal storage, permeability, moisture, and road-edge conditions (Nwakaire et al., 2020; Qin, 2015). Therefore, the proposed concrete-road footprint is used as a thermal exposure variable in the present study, not merely as a civil-cost variable.

Table 2 summarises corridor-wise estimates of concrete road length for the SMKC region, including proposed road lengths, calculated concrete surface areas, area shares, and estimated costs across 11 corridors.

Table -2: Proposed Concrete Road Corridors and Estimated Concrete Surface Area in the SMKC Region

Sr. No.	Proposed Road Corridor	Length (m)	Estimated Concrete Surface Area (sq. m.)	Estimated Cost (Rs. crore)
1	Tilak Chowk-SMKC Main Building-Azad Chowk-Amrai Garden/Ram Mandir	2140.00	38520.00	27.25
2	ST Stand-Dilip Tyres-100 ft Road	3330.00	59940.00	42.94
3	College Corner-Patel Chowk-Rajwada Chowk-Karnal Road-Madhavnagar Bypass	2510.00	35140.00	27.90
4	Chivate Hospital-Pujari Hospital-Station Road, Miraj	1215.00	21870.00	15.75
5	Bharat Sutgirni Chowk-Kupwad Concrete Road	1060.00	19080.00	13.76
6	Laxmi Market Chowk-Guruwar Peth-Ambedkar Statue	1195.00	16730.00	12.93
7	Laxmi Market-Bombay Bakery-Gandhi Statue	1300.00	18200.00	13.95
8	Sphurti Chowk-Dhamani Road Approach	560.00	6720.00	9.42
9	ST Stand-SMKC Office-Shivaji Market and Pratapsinh Garden/ST Stand Chowk	1521.00	21294.00	15.60
10	White House-Wellness-Dhamani Chowk-Kolhapur Chowk	4031.00	52403.00	34.00
11	Swami Vivekanand Chowk-Miraj-Madhavnagar Road	750.00	10500.00	13.39
	Total	19612.00	300397.00	226.89

4.2 REPORTED 2026 HOT-DAY OBSERVATION AND RELEVANCE TO ROAD-CONCRETISATION RISK

A local newspaper reported that Sangli recorded a maximum temperature of 42.00°C on 17 May 2026. This value is substantially higher than the May mean maximum temperature of 37.30°C shown in the monthly climatological baseline, indicating a hot-day excess of approximately 4.70°C above the May baseline maximum. This observation is treated as a reported local hot-day event and should be verified with certified IMD Station Index No. 43158 daily data before it is used as an official meteorological record (Sakal News, 2026a).

The relevance of this 42.00°C event lies in its urban-climate implications. During such hot-day conditions, concrete roads intensify citizens' thermal discomfort

through increased surface heat storage, higher mean radiant temperature, long-wave heat release, reduced evaporative cooling from sealed surfaces, and delayed night-time cooling. Pavement-related UHI studies show that road materials influence urban heating through albedo, permeability, thermal storage, moisture availability, and interaction with surrounding built form (Nwakaire et al., 2020; Qin, 2015; Santamouris, 2013). Urban heat intensity also varies with imperviousness and urban aerodynamics, meaning that wide, unshaded, poorly ventilated concrete corridors expose pedestrians and outdoor workers to higher local heat stress than indicated by station-level air temperature alone (Li et al., 2019). Table 3 presents the reported 42.00°C hot-day observation for Sangli on 17 May 2026 and compares it with scenario-based 2035 near-road projections under alternative concrete-road design conditions.

Table -3: Reported 2026 Hot-Day Temperature and Scenario-Based 2035 Near-Road Projection for the SMKC Region

Indicator	Value / Calculation	Interpretation
May baseline mean maximum temperature	37.30°C	Monthly climatological reference for May
Reported maximum temperature on 17 May 2026	42.00°C	Reported hot-day observation from a local newspaper clipping
Difference from the May baseline maximum	+4.70°C	Indicates a severe hot-day departure from the monthly baseline
Low-risk climate-sensitive 2035 scenario	42.20-42.50°C	Assumes shade, permeable edges, water-sensitive design, and low-glare high-albedo surface treatment
Moderate ordinary-concretisation 2035 scenario	42.50-43.20°C	Represents ordinary concrete-road development with limited shade and partial sealing of shoulders
Moderate central estimate for 2035	43.10°C	Calculated as 42.00°C + 1.10°C, consistent with the moderate May projection increment
High-risk unshaded 2035 scenario	43.00-43.80°C	Represents wide unshaded concrete corridors, high traffic, sealed edges, poor ventilation, and tree loss

Note: The 42.00°C value is based on the reported hot-day observation published in Daily Sakal, Sangli edition on 18 May 2026 and should be verified with certified IMD Miraj (Sangli) Station Index No. 43158 daily maximum temperature data before being treated as an official meteorological extreme. The 2035 values are scenario-based near-road estimates and do not represent official IMD forecasts. The moderate central estimate was calculated as: reported 2026 hot-day maximum temperature + moderate May scenario increment = 42.00°C + 1.10°C = 43.10°C.

5. CONCEPTUAL FRAMEWORK

The proposed framework links road concretisation to UHI intensification through five pathways, each of which explains how changes in pavement material, surface exposure, moisture exchange, urban form, and human outdoor activity can convert a road-upgrading intervention into a measurable microclimatic stressor within dense municipal corridors, particularly where

compensatory cooling measures such as shade, permeability, and ventilation are absent or insufficiently integrated locally.

First, surface reflectance and absorption shape how much solar radiation is absorbed or reflected by the road surface. A pavement with low albedo absorbs more solar radiation, while a higher-albedo pavement reflects more. However, high reflectance also increases glare and

reflected radiation toward pedestrians and adjacent buildings. Therefore, albedo must be optimised, not increased mechanically. This balance is important because the environmental benefit of cool pavements depends on local context, building interaction, and radiative exchange (AzariJafari et al., 2021; Gilbert et al., 2017; Xu et al., 2020).

Second, heat storage and delayed release explain why dense urban materials remain thermally active after sunset. Concrete and other dense urban materials store heat during the day and release it after sunset. This reduces night-time cooling and raises minimum temperatures in road corridors. Pavement heat storage is a central UHI mechanism because built surfaces retain thermal energy and later release it to the surrounding urban canopy (Li et al., 2019; Nwakaire et al., 2020; Santamouris, 2013).

Third, loss of evapotranspiration occurs when permeable edges, soil strips, tree pits, and vegetated shoulders are replaced by continuous concrete. Under such conditions, the road corridor loses moisture-based cooling capacity. Permeable pavements and vegetated surfaces reduce heating when moisture is available because evaporation consumes part of the incoming net radiation (Ibrahim et al., 2018; Nwakaire et al., 2020).

Fourth, urban geometry and ventilation influence how stored heat is dispersed or trapped. A road in an open, ventilated, tree-lined setting behaves differently from a road in a narrow street canyon. Street width, building height, edge density, sky-view factor, and ventilation potential influence the degree to which stored heat is dispersed or trapped (Li et al., 2019; Yuan et al., 2020).

Fifth, thermal comfort exposure links physical heating mechanisms to human experience. Even a small near-road air-temperature increase becomes physiologically significant when combined with high mean radiant temperature, low wind speed, traffic heat, direct solar exposure, and long exposure duration. In road corridors, pedestrians and street-dependent workers experience not only air temperature but also radiant heat from road surfaces and adjacent façades. Vegetation and shade are therefore central to outdoor thermal comfort protection (Yan et al., 2020; Yuan et al., 2020).

Figure 6 illustrates five interconnected pathways through which road concretisation intensifies UHI: surface reflectance and absorption, heat storage and delayed release, loss of evapotranspiration, urban geometry and ventilation, and thermal comfort exposure. The chain format emphasises their combined effect on corridor-level heat retention, radiant stress, and citizen vulnerability.

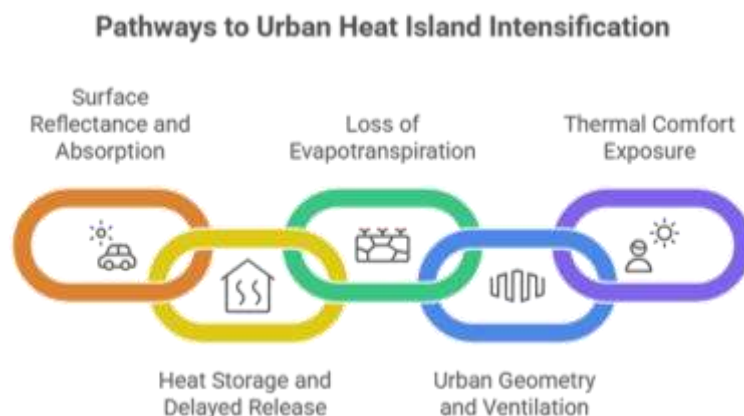


Fig. 6: Pathways to Urban Heat Island Intensification through Road Concretisation

6. METHODOLOGY FOR SCENARIO PROJECTION

One continuous meteorological station record, from the Miraj (Sangli) IMD temperature series, was available for the present analysis. The present study, therefore, adopts a scenario-based projection method rather than a deterministic city-wise forecast for Sangli, Miraj, and Kupwad separately. A single meteorological station represents the regional background climate, but it cannot capture intra-urban thermal variation produced by

pavement type, impervious surface cover, vegetation loss, street geometry, ventilation, traffic intensity, and local heat storage. UHI intensity is known to vary with imperviousness and urban aerodynamics (Li et al., 2019), while pavement-related heating depends on albedo, permeability, material composition, surface moisture, and surrounding built form (Nwakaire et al., 2020; Qin, 2015). Cool-pavement and albedo impacts are also context-sensitive across neighbourhoods and road segments (AzariJafari et al., 2021; Xu et al., 2020).

Therefore, in the absence of separate long-term station datasets for Sangli and Kupwad city, scenario-based projection provides a transparent planning estimate. The projected values should be interpreted as local near-road UHI-risk scenarios and should be validated through future street-level measurements.

The baseline monthly minimum and maximum temperatures were taken from the available IMD Miraj (Sangli) climatological station data. The monthly average temperature was calculated as the midpoint of the mean minimum and mean maximum temperatures. The projection estimates the possible 2035 near-road urban air temperature under ordinary concrete-road expansion. It separates baseline regional climate from local road-corridor intensification:

Projected near-road temperature = baseline IMD temperature + background warming component + local concretisation component.

In the present study, the background warming component and the local concretisation component are not estimated as two independently measured variables. Instead, both are combined into a total scenario increment because separate long-term station data for the SMKC region and pre-concretisation field measurements are not yet available. The background warming component represents general climatic and urban warming, while the local concretisation component represents additional corridor-level heat exposure associated with impervious concrete surfaces, surface heat storage, reduced evapotranspiration, sealed shoulders, and delayed night-time heat release. Thus, the projected 2035 values should be read as scenario-based near-road thermal-risk estimates, not as official IMD forecasts.

The 2026 hot-day scenario was calculated using the same additive planning logic. The reported maximum temperature of 42.00°C on 17 May 2026 was treated as a hot-day reference condition. The 2035 near-road hot-day estimate was then calculated by adding the assumed local

concretisation-related increment under each road-design scenario from the previous research. For the moderate ordinary-concretisation condition, the May increment used in the main projection is approximately +1.10°C. Therefore, the comparable 2035 hot-day near-road maximum is estimated as 42.00°C + 1.10°C = 43.10°C. This calculation is interpreted as a corridor-level thermal-risk estimate, not as a deterministic meteorological forecast.

The spatial footprint informs the local concretisation component of the proposed concrete-road intervention. The estimate indicates approximately 300397.00 sq. m. of proposed concrete road surface. This area is treated as a proposed impervious pavement exposure zone for scenario interpretation. The projection does not assume that the entire municipal region will warm uniformly. Rather, it assumes that near-road air temperature, surface temperature, radiant exposure, and pedestrian thermal stress will be more affected along and around these concrete corridors, especially where roads are wide, unshaded, traffic-intensive, and poorly ventilated. This interpretation is consistent with urban-scale cool pavement studies showing that pavement albedo and road-segment effects are context-sensitive and vary by neighbourhood morphology, traffic, and adjacent built form (AzariJafari et al., 2021; Xu et al., 2020).

Table 4 presents a scenario-based framework for estimating local near-road temperature effects associated with alternative concrete road-corridor conditions by 2035. The scenarios distinguish climate-sensitive, ordinary, and high-risk forms of road concretisation based on albedo, shading, permeability, drainage, traffic exposure, vegetation retention, and ventilation context. This framework helps compare how design choices either reduce or intensify heat accumulation, radiant exposure, night-time heat release, and pedestrian thermal discomfort along major municipal road corridors.

Table -4: Scenario-Based Projection of Local Temperature Effects under Alternative Road-Concretisation Conditions by 2035

Scenario	Road-Corridor Condition	Assumed Local Temperature Effect by 2035
Low-risk climate-sensitive concretisation	High-albedo low-glare concrete, shaded footpaths, tree retention, permeable edges, bioswales, and water-sensitive design	+0.2 to +0.5°C near-road air temperature

Scenario	Road-Corridor Condition	Assumed Local Temperature Effect by 2035
Moderate ordinary concretisation	Ordinary concrete roads, limited tree shade, partial sealing of shoulders, moderate traffic, and conventional drainage	+0.5 to +1.2°C daytime; +0.7 to +1.4°C night-time
High-risk unshaded concretisation	Wide unshaded concrete corridors, tree loss, high traffic, dense built edges, sealed shoulders, and poor ventilation	+1.0 to +1.8°C near-road air temperature; higher surface-temperature rise possible

Note: These increments represent local near-road scenario estimates derived from pavement UHI literature and applied as an interpretive municipal planning framework. Actual local outcomes must be validated through pre-concretisation field measurements of air temperature, surface temperature, humidity, air speed, radiant heat, pavement type, shading, traffic, and adjacent built form.

7. TEN-YEAR PROJECTION TO 2035

The following projection estimates near-road urban air temperature for the SMKC region under the moderate ordinary-concretisation scenario. Increments are larger during March-May because of stronger solar load and higher pre-monsoon temperatures. Night-time minimum-temperature increments are slightly higher than daytime increments because heat stored in pavements and adjacent urban surfaces is expected to delay cooling after sunset.

The projected values are interpreted as road-corridor exposure estimates. Their role is to demonstrate the plausible magnitude of municipal-scale heat risk if road

concretisation proceeds without shade, permeability, reflective optimisation, and field monitoring.

Table 5 presents a scenario-based comparison between the preliminary monthly climatological baseline and projected 2035 near-road temperatures for the SMKC region under moderate ordinary road-concretisation conditions. The projection indicates an increase in monthly minimum, maximum, and average temperatures, with higher thermal risk during March, April, and May. April remains the most critical month, with the projected maximum temperature rising from 38.50°C to 39.70°C.

Table -5: Scenario-Based Projection of Monthly Near-Road Temperature Conditions for Sangli-Miraj-Kupwad under Moderate Road-Concretisation Conditions by 2035

Month	Base Min °C	Base Max °C	Base Avg °C	2035 Min °C	2035 Max °C	2035 Avg °C
January	14.40	31.80	23.10	15.20	32.40	23.80
February	15.70	34.10	24.90	16.60	34.80	25.70
March	18.80	36.80	27.80	20.00	37.80	28.90
April	21.50	38.50	30.00	22.90	39.70	31.30
May	22.40	37.30	29.90	23.70	38.40	31.00
June	22.20	31.50	26.90	23.10	32.20	27.70
July	21.60	28.90	25.30	22.30	29.40	25.90
August	21.20	28.40	24.80	21.90	28.90	25.40
September	20.90	30.50	25.70	21.70	31.10	26.40
October	20.30	32.10	26.20	21.30	32.90	27.10
November	17.40	31.70	24.60	18.30	32.40	25.40
December	14.70	31.00	22.90	15.50	31.60	23.60
Annual	19.20	32.70	26.00	20.20	33.50	26.80

Note: The annual near-road average increases from approximately 26.00°C to 26.80°C under this moderate scenario. April remains the most critical month, with projected mean maximum near-road air temperature approaching 39.70°C. All temperature values are in °C. These values are local road-corridor estimates and should not be interpreted as official IMD station forecasts.

8. DISCUSSION

The projection supports three interpretations, clarifying how road concretisation influences local heat exposure, planning priorities, and climate-sensitive municipal design decisions within the study area.

First, the thermal effect of concretisation must be evaluated locally. The IMD station establishes the background climate, while unshaded concrete corridors produce higher pedestrian-level heat exposure. This is why local measurement of surface temperature, near-ground air temperature, humidity, wind speed, pavement type, pavement colour, tree shading, road width, traffic exposure, and adjacent built form is necessary. Pavement-related UHI studies show that road materials and urban morphology jointly affect urban thermal conditions; therefore, station-level climate data alone cannot capture microclimatic exposure along individual corridors (Li et al., 2019; Nwakaire et al., 2020).

The proposed concrete surface area of 300397.00 sq. m. strengthens the local UHI-risk argument. Even if concrete has higher reflectance than asphalt under certain conditions, a large continuous impervious surface still increases the urban heat burden when implemented without shade, permeability, water-sensitive edges, and thermal monitoring. Corridors with a greater area share should be prioritised for surface-temperature measurement, pedestrian-level air-temperature monitoring, tree-canopy assessment, and mean radiant-temperature study. This is important because the thermal outcome of pavement material is shaped by albedo, urban geometry, moisture, traffic, and surrounding building form rather than material type alone (AzariJafari et al., 2021; Nwakaire et al., 2020; Santamouris, 2013).

Second, the issue cannot be reduced to a simple concrete-versus-asphalt comparison. Asphalt is often darker and records higher surface temperatures than conventional concrete. Ibrahim et al. (2018) found that concrete, permeable pavement, and stormwater-retaining pavement retained less heat than asphalt in the studied case. However, the policy question in the SMKC region is whether converting large road networks into continuous impervious concrete corridors, while removing shade and sealing edges, will increase the total heat load experienced by the city. A lighter material can still become problematic if it expands into an impervious area, increases the exposed radiant surface, reduces evapotranspiration, and weakens walkability.

Third, nighttime temperature deserves special attention. Many road projects focus on daytime visibility, traffic

movement, and drainage, but UHI risk often becomes more serious after sunset because urban materials release stored heat slowly. Raised night-time minimum temperature reduces physiological recovery, increases indoor heat carry-over, and intensifies health stress for residents without mechanical cooling. Dense urban materials and paved surfaces contribute to delayed heat release, while vegetation and permeable surfaces moderate local thermal stress (Nwakaire et al., 2020; Santamouris, 2013; Yan et al., 2020).

The reported 42.00°C hot-day condition sharpens the public-health relevance of the study. At such temperatures, citizens do not experience heat only as air temperature; they experience combined thermal stress from direct solar radiation, hot pavement surfaces, reflected radiation from concrete, low wind movement, traffic heat, and long exposure duration. Large concrete surfaces increase mean radiant temperature and reduce pedestrian thermal comfort even when air temperature changes appear numerically modest. This is especially relevant for street vendors, two-wheeler users, traffic police, sanitation workers, pedestrians, school children, elderly citizens, and low-income groups who spend more time in exposed road environments. Peer-reviewed evidence shows that impervious urban surfaces and urban aerodynamics jointly influence UHI intensity (Li et al., 2019), while pavement materials affect surface heating through albedo, thermal storage, moisture, and permeability (Nwakaire et al., 2020; Qin, 2015; Santamouris, 2013). Vegetation and shade remain critical because they reduce local radiant exposure and improve pedestrian-scale cooling (Yan et al., 2020).

The social implications are significant because road-related heat exposure affects vulnerable street users, outdoor workers, pedestrians, vendors, commuters, and low-income urban populations disproportionately. Street vendors, traffic police, sanitation workers, construction workers, pedestrians, bus commuters, school children, older persons, and two-wheeler users are more exposed than residents travelling in air-conditioned vehicles or working indoors. Ikechukwu (2015) found that pavement-related urban heat affected residents through increased hotness, reduced ambient comfort, sleeplessness, restlessness, and other heat-related discomforts. This supports the argument that road-surface decisions have social and public-health consequences, not only engineering consequences. Road concretisation, therefore, creates unequal heat burdens.

9. POLICY AND DESIGN RECOMMENDATIONS

The SMKC should convert road concretisation into a climate-sensitive road programme through the following measures.

First, every major concrete road proposal should include a thermal-impact checklist recording pavement material, surface colour, albedo, road width, existing tree cover, proposed tree removal, pedestrian shade, building-edge condition, traffic load, and drainage permeability. Since pavement-albedo effects are context-specific, this checklist should be applied corridor by corridor rather than through one uniform design rule (AzariJafari et al., 2021; Xu et al., 2020).

Second, tree protection should be part of road design approval. Mature trees provide direct shade and reduce radiant exposure. Tree loss should not be compensated only through plantation numbers; canopy maturity, survival, spacing, and shade geometry should be considered. Local-scale vegetation cooling has been documented in urban-climate research; therefore, tree canopy should be treated as thermal infrastructure (Yan et al., 2020).

Third, concrete specifications should include heat-performance criteria. High-albedo surfaces may reduce heat absorption, but glare and reflected radiation should be controlled through surface texture, aggregate selection, and low-glare finishing. Cool pavement literature shows that reflective pavements reduce absorbed radiation, but the overall effect depends on surface ageing, urban form, and adjacent building interactions (Gilbert et al., 2017; Qin, 2015; Santamouris, 2013).

Fourth, road edges should not be fully sealed. Permeable shoulders, bioswales, vegetated medians, stormwater trenches, and tree pits should be incorporated wherever feasible. Permeable pavements and moisture-supporting edge systems reduce local heat by enabling evaporation and reducing full-surface heat storage (Ibrahim et al., 2018; Nwakaire et al., 2020).

Fifth, shaded pedestrian infrastructure should be mandatory on major roads, especially near schools, hospitals, markets, bus stops, government offices, and high-footfall commercial streets. Road improvement should not only increase vehicular durability; it should also protect the thermal comfort of people who use the street without mechanical cooling.

Sixth, the corporation should establish pre- and post-concretisation thermal monitoring during the summer months. Measurements should include road-surface temperature, near-ground air temperature at pedestrian height, relative humidity, wind speed, mean radiant temperature or globe temperature, traffic intensity, percentage of shaded area, pavement colour, pavement age, and adjacent built-form characteristics. These data should be collected before construction, immediately after construction, and during subsequent hot seasons.

Seventh, the corporation should adopt an area-priority thermal monitoring strategy. Road corridors with the largest proposed concrete surface area should be monitored first because their contribution to heat storage, radiant exposure, runoff, and pedestrian discomfort is likely to be greater. Based on the block estimate, the highest-priority corridors are ST Stand-Dilip Tyres-100 ft Road, White House-Wellness-Dhamani Chowk-Kolhapur Chowk, Tilak Chowk-SMKC Main Building-Azad Chowk-Amrai Garden/Ram Mandir, and College Corner-Patel Chowk-Rajwada Chowk-Karnal Road-Madhavnagar Bypass. These corridors should be assessed before and after concretisation using surface temperature, near-road air temperature, relative humidity, air speed, shade percentage, road width, traffic exposure, and adjacent built-form indicators.

Eighth, the corporation should introduce a hot-weather road-use safety protocol for days when the maximum temperature reaches or exceeds 40°C. On such days, exposed concrete road corridors should be treated as thermal-risk zones. Priority measures should include temporary shaded waiting areas at bus stops and markets, drinking-water points, reduced outdoor work during peak afternoon hours, misting or cooling support at high-footfall locations, tree-canopy protection, and public advisories for pedestrians, vendors, elderly citizens, and traffic police. Concrete-road design should therefore integrate public-health safeguards, not only pavement durability criteria.

Figure 7 summarises the proposed policy and design pathway for climate-sensitive road concretisation. It highlights thermal-impact checklists, tree-canopy protection, permeable edge systems, cool-pavement research, urban-form assessment, heat-island monitoring, pre- and post-concretisation measurements, ongoing thermal monitoring, and hot-weather safety protocols to protect citizens' outdoor thermal comfort.

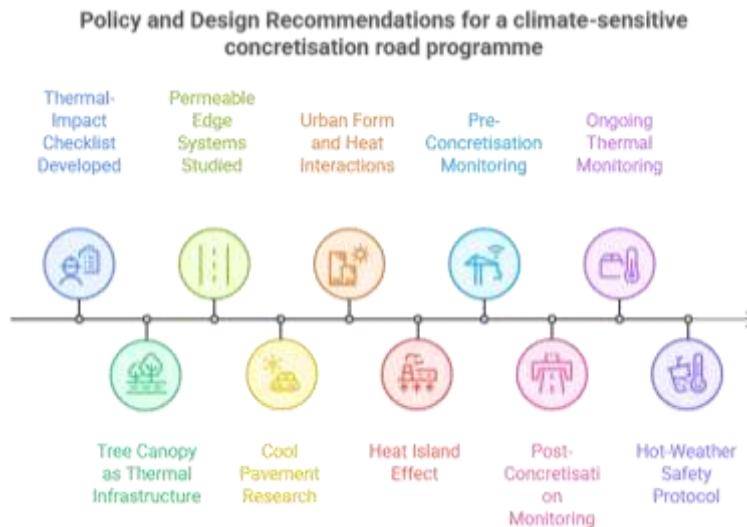


Fig. 7: Policy and Design Recommendations for a Climate-Sensitive Concrete Road Programme

10. LIMITATIONS

The present study is based on a preliminary monthly climatological baseline and a concrete road block estimate. Therefore, the 2035 projection is a scenario-based estimate of local near-road thermal risk, not an official meteorological forecast. A final statistical study should include certified daily maximum and minimum temperature data from the relevant IMD station, year-wise monthly aggregation, Mann-Kendall trend testing, Sen slope estimation, monthly anomaly analysis, heat-wave frequency analysis, and regression modelling of air temperature against land cover, road surface, and urban morphology variables.

Remote sensing of land surface temperature may also be used, but it should be validated through ground measurement because satellite land surface temperature and pedestrian-level air temperature are not identical. Field measurements before and after concretisation are necessary to isolate pavement effects from background climate change, traffic growth, land-use change, tree loss, and built-form densification.

The road-surface estimate provides a useful exposure variable, but it is still based on available estimate data rather than post-construction measurement. Actual thermal impact will depend on the final constructed width, surface finish, pavement colour, curing quality, shoulder treatment, tree retention, drainage design, and traffic intensity. Therefore, the 300397.00 sq. m. value used as a proposed pavement-exposure estimate should be verified against final tender drawings, as-built drawings, and post-construction field measurements.

The reported 42.00°C value used in the hot-day scenario is based on a local newspaper clipping and should be

verified through certified IMD daily maximum temperature data for Station Index No. 43158. Until such verification is completed, the value should be described as a reported hot-day observation rather than an official IMD extreme record. The scenario increments used in the study should be treated as indicative values for risk assessment, not as deterministic predictions.

11. CONCLUSIONS

Road concretisation in the SMKC region is not merely a road-engineering decision; it is an urban-climate and public-health decision. The available IMD baseline already shows high pre-monsoon temperatures, especially in April and May, and the reported 42.00°C maximum temperature on 17 May 2026 further demonstrates the region's vulnerability to extreme hot-day exposure. Against this climatic background, large-scale ordinary concrete-road development may intensify near-road thermal stress if implemented without shade, permeability, reflective optimisation, tree-canopy protection, and microclimate monitoring. Pavement-related UHI studies confirm that road surfaces influence urban heating through albedo, thermal storage, permeability, moisture availability, and interaction with surrounding built form (Nwakaire et al., 2020; Qin, 2015; Santamouris, 2013).

The scenario projection suggests that ordinary unmitigated road concretisation raises near-road annual average temperature by approximately 0.80°C by 2035. More critically, if a 42.00°C hot-day condition similar to 17 May 2026 occurs under moderate ordinary-concretisation conditions, the comparable near-road temperature may reach approximately 43.10°C by 2035. Under high-risk unshaded corridor conditions, the value

may plausibly rise toward 43.80°C. These projected values are not official IMD forecasts; they are corridor-level thermal-risk estimates. Their significance lies in the fact that citizens experience heat not only through air temperature, but also through pavement radiation, surface heat storage, low wind movement, reduced evaporative cooling, and delayed night-time heat release.

The proposed concrete-road footprint of 300397.00 sq. m. confirms that the intervention is large enough to require corridor-level thermal assessment, especially because the largest four corridors account for more than 61% of the estimated concrete surface area. The present study, therefore, concludes that the SMK region should adopt a thermal-performance-based road policy. Concrete roads should be permitted only with integrated shade, permeable edges, water-sensitive drainage, low-glare high-albedo material selection, tree-canopy protection, and pedestrian thermal-comfort safeguards. A road that lasts longer should not make the city hotter; durable infrastructure must also be thermally responsible, public-health sensitive, and socially equitable.

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