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# Use of Solar Heat-blocking Pavement Technology for Mitigation of Urban Heat

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NIPPO

# Outline of Presentation

- Background
- Solar Heat-blocking Pavement
  - Basic concept & properties
- Laboratory evaluation
- Application to various sites
- Thermal sensation & Environmental effect
- Conclusions

# Background

# Background

## Urban areas and pavements in Japan

- Air temperature during summer has been increasing due to global warming
- Surface temperatures of asphalt pavement **reach 60°C or higher** in summer
- Asphalt surfaces cover approx. **20%** of urban areas
- Pavement is a source of heat, similar to concrete structures

# Environmental issues

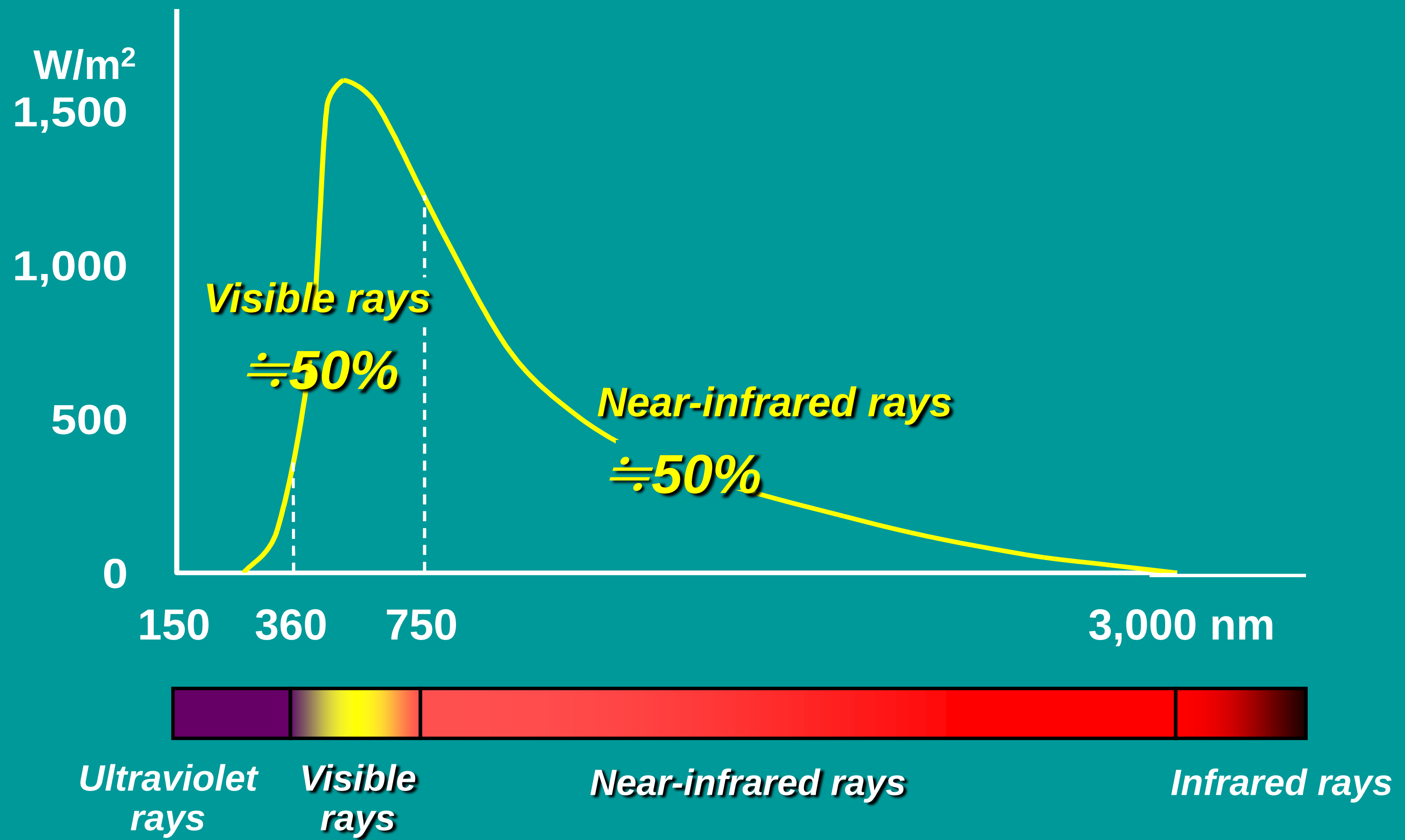
**Hotter pavement:**

- a factor in the “***urban heat island*** “phenomenon,
- may affect the heath of pedestrians due to the much higher temperatures

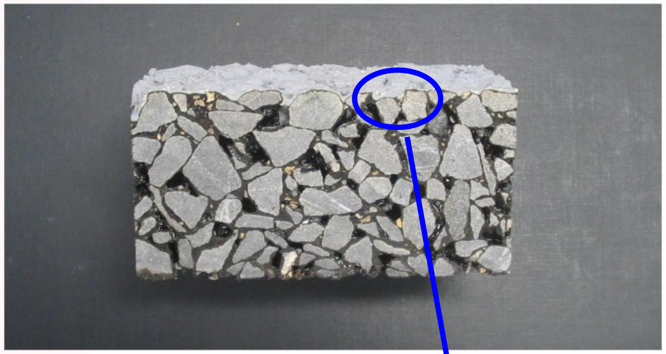
**Public demand to reduce the temperature of road pavement**

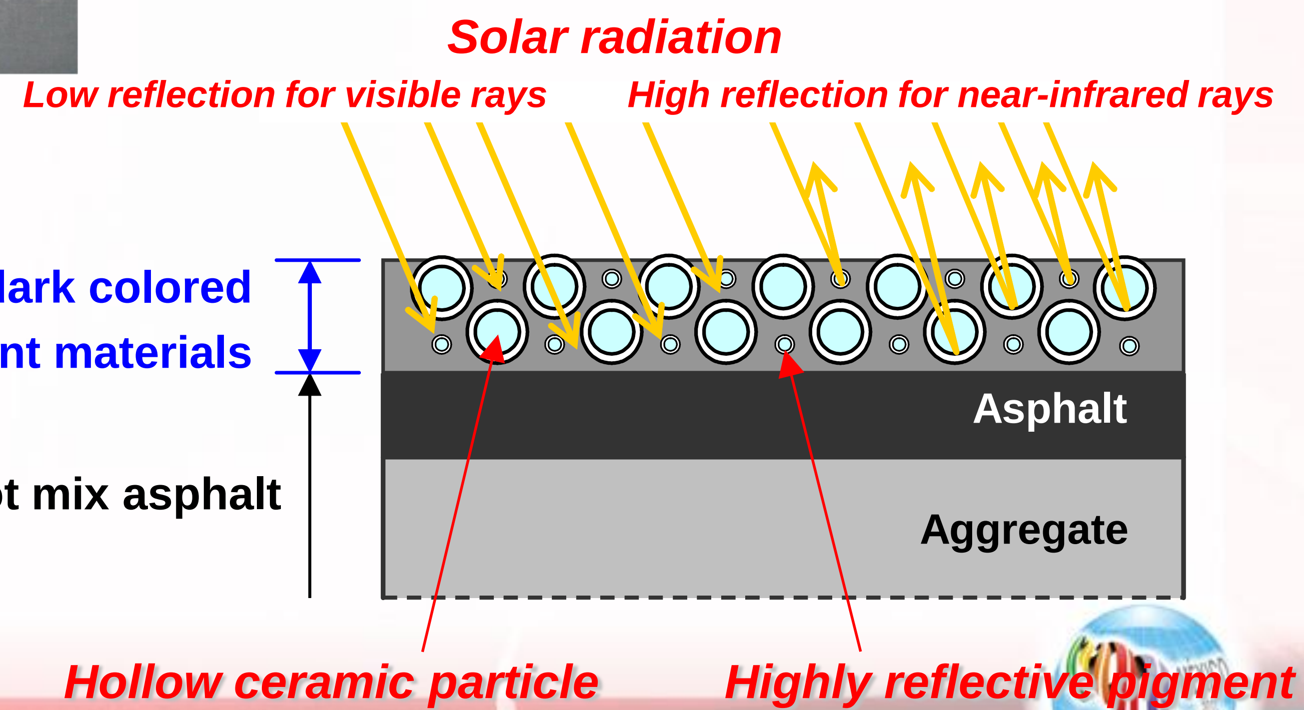
# What is solar radiation?

- Solar radiation mainly consists of visible rays and near-infrared rays; plus some ultraviolet rays.
- 50% of solar energy is in the visible spectrum; the rest is in the near-infrared spectrum.



# Basic concept



# Basic concept

***Highly reflective pigment***

Highly reflective for near-infrared rays

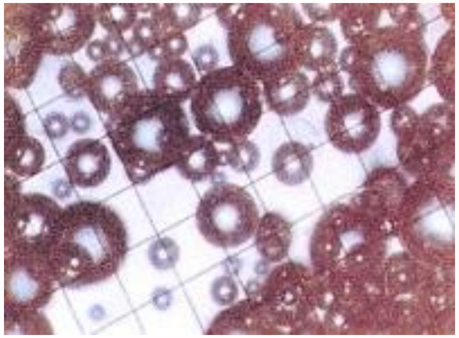
→ **Prevention of heating**

Low reflectivity for visible rays

→ **Enables various colors to be selected**

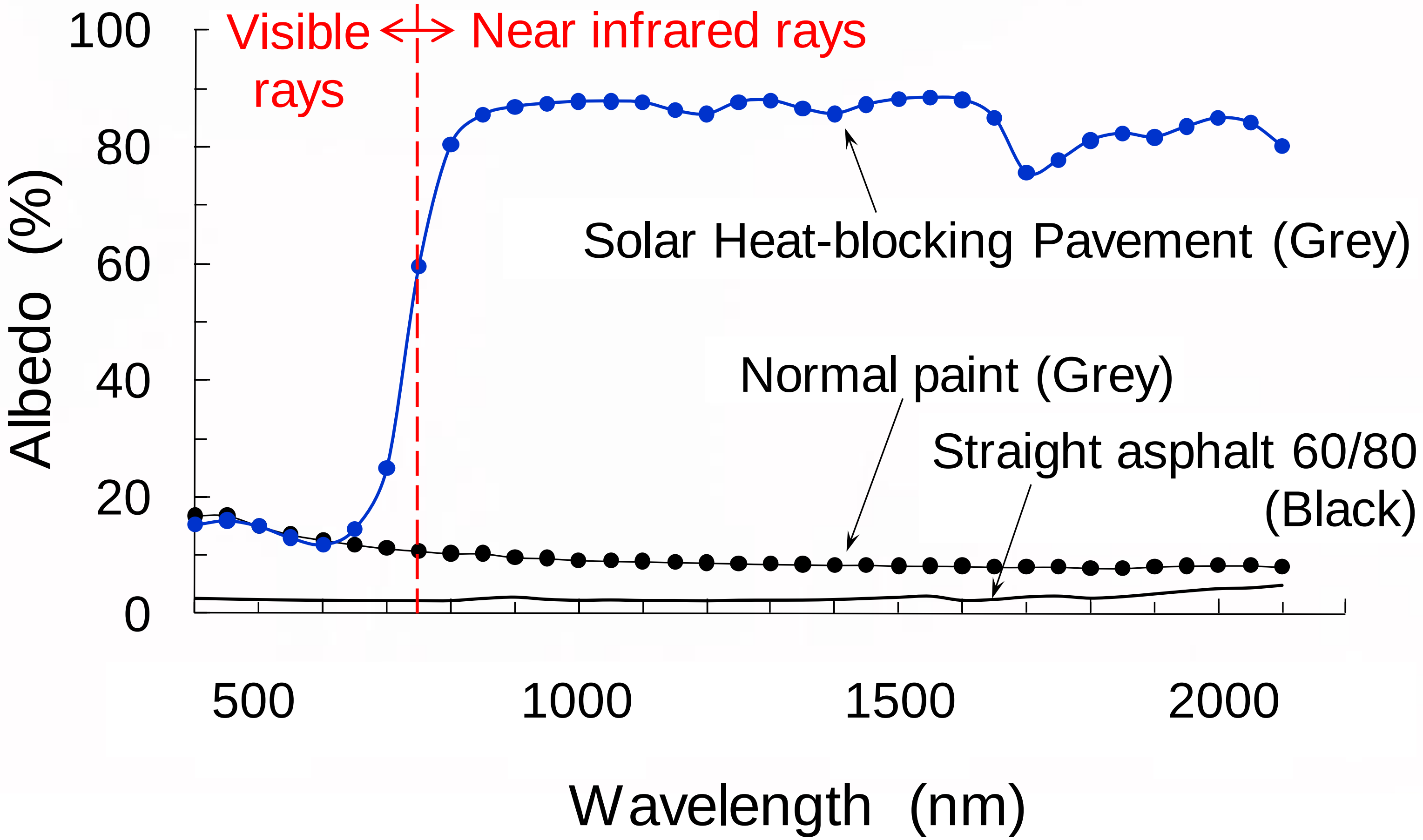
***Hollow ceramic particles***

- **Reflects solar radiation back into the atmosphere**



Hollow ceramic particles
(5~150 μm)

# Albedo characteristics

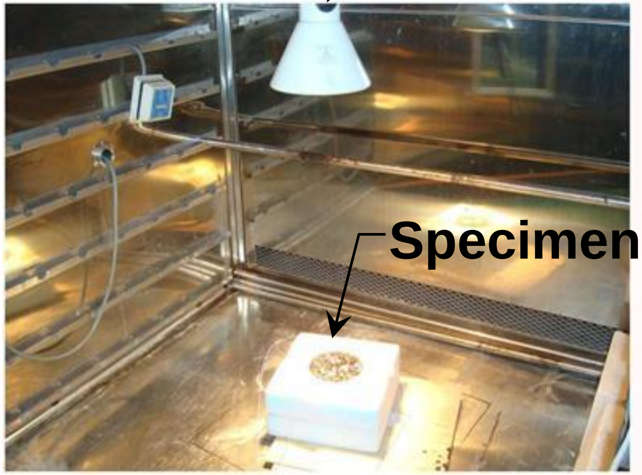



- Straight asphalt has a **very low albedo**
- Dark-gray treatment materials have a **low albedo for visible rays,** but **a very high albedo (about 90%) for near-infrared rays**

# Laboratory evaluation

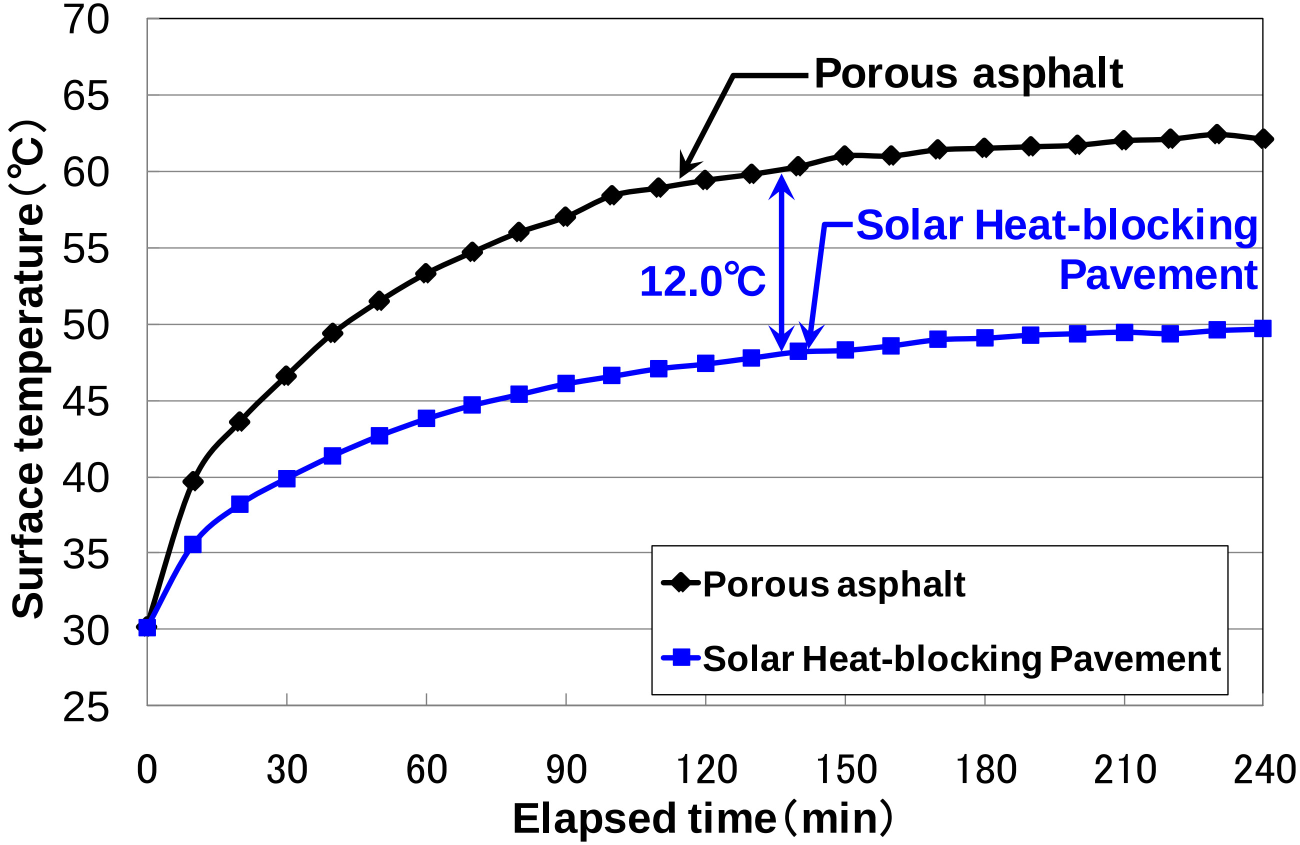
# Laboratory lamp test

- Experimental temp.: 30°C
- Lamp height: A height at which the surface temperature of a conventional specimen reaches 60°C in about three hours
- Measurement method: Thermocouples




**Inside of Temperature control cabinet**

# Laboratory lamp test




- Laboratory lamp tests are useful for predicting on-site performance

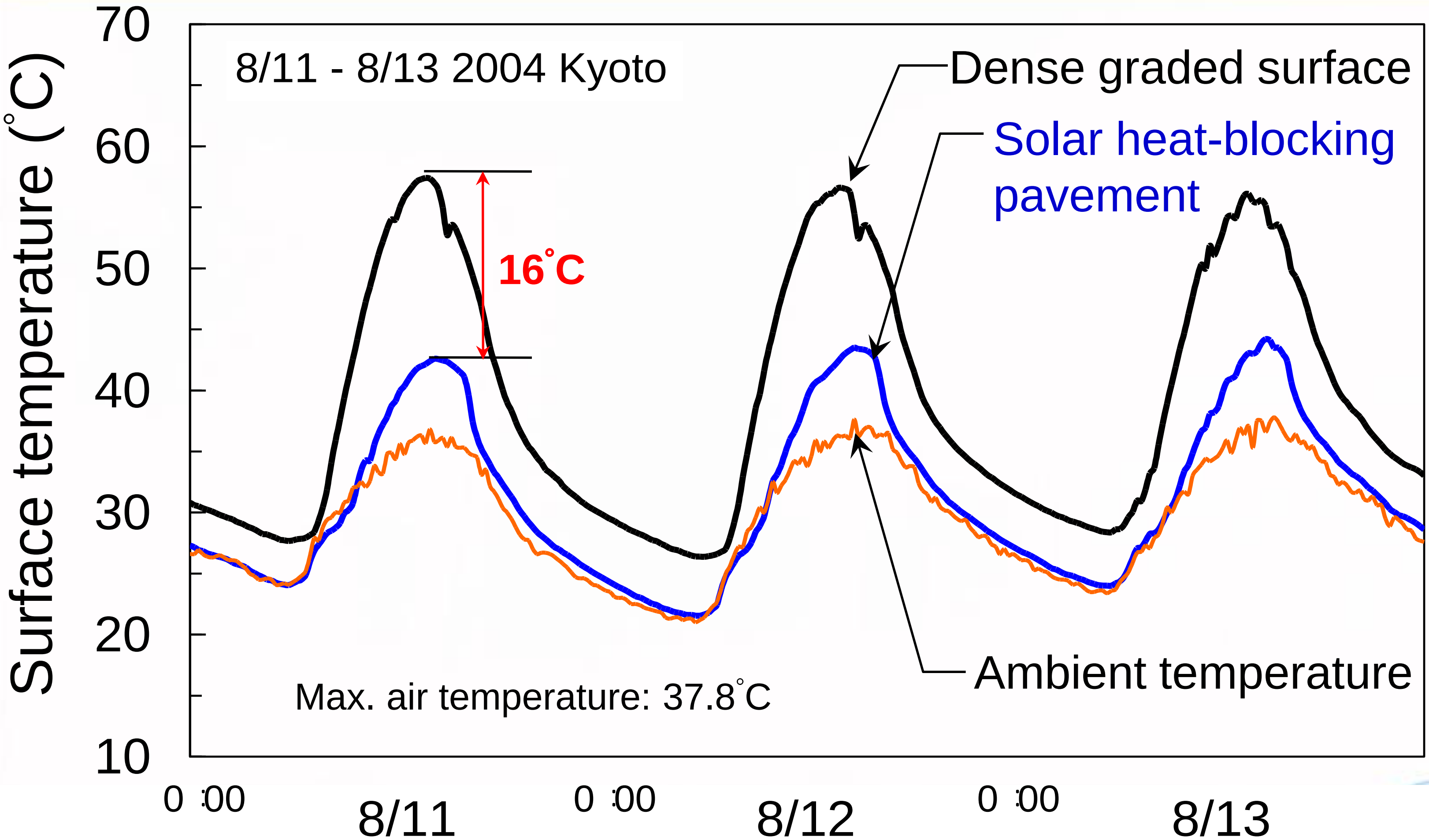
# Skid resistance & permeability

| | | Porous Asphalt | Porous Asphalt with Solar Heat-blocking Pavement |
|---|---|---|---|
| Skid resistance Dynamic Friction (μ) | 40 km/h | 0.60 | 0.62 |
| | 60 km/h | 0.55 | 0.56 |
| Permeability (cc/15 sec) | | 1,222 | 1,210 |

- The coating layer did not significantly affect the porosity of the asphalt surface
- Solar Heat-blocking Pavement can be applied to porous asphalt pavement without affecting its function

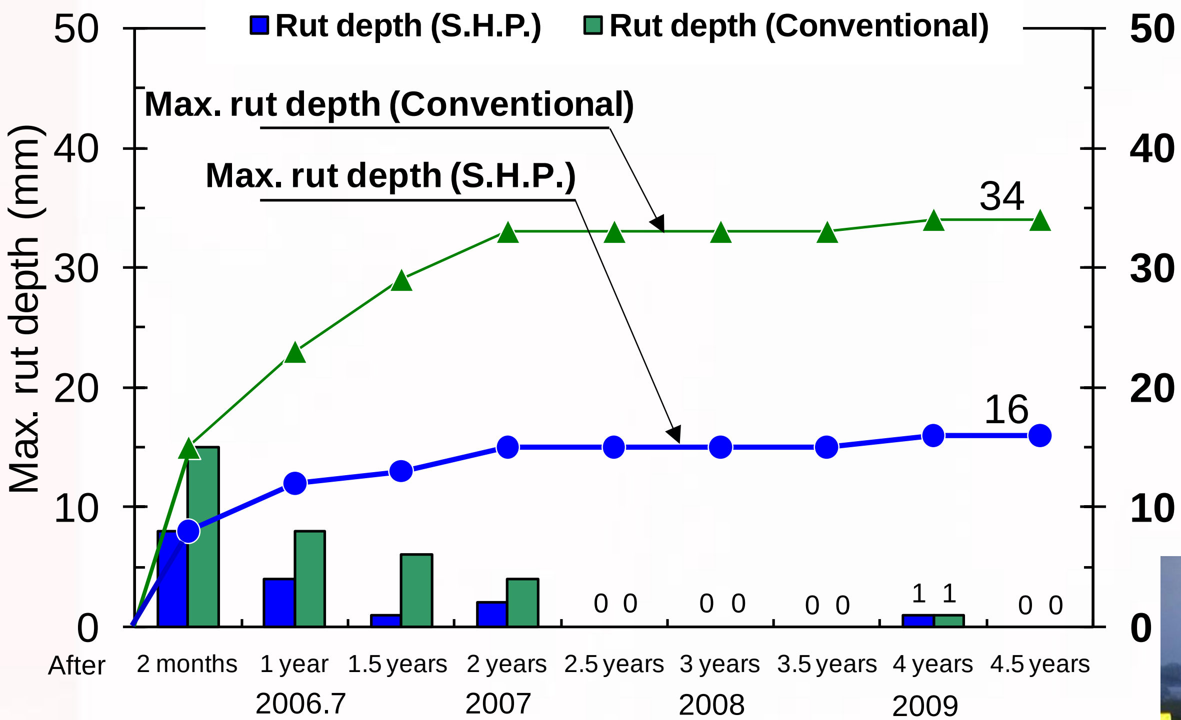
# Application

# Effect of temperature reduction




- The maximum temperature of the conventional pavement **rose to 57.4°C**
- The temperature of the treated surface was **reduced by about 16°C**

# Mitigation of rut depth -Application to a taxiway-



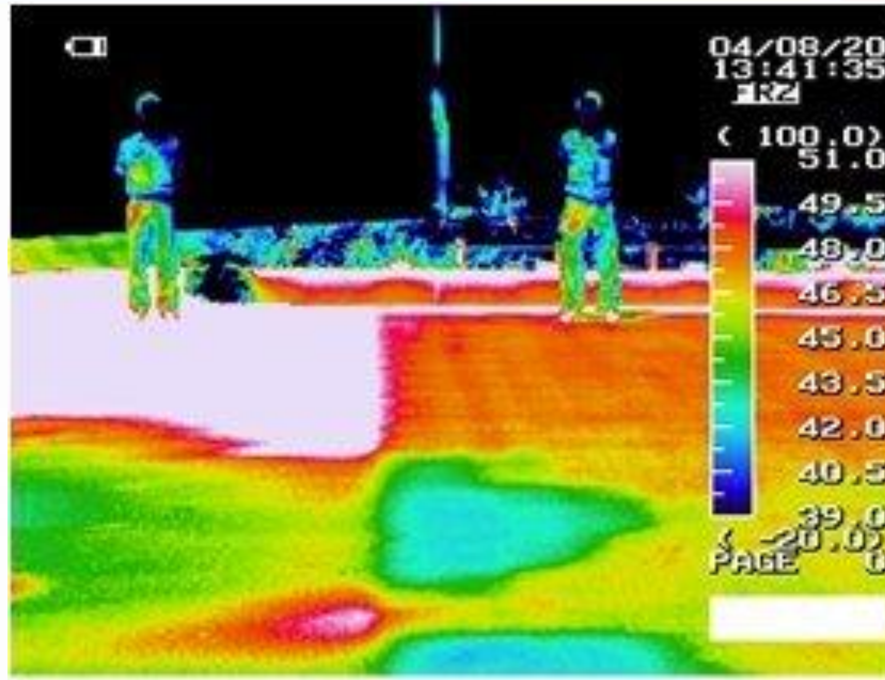

Examine long-term performances such as:

- rut depth
- surface temperature
- surface state

- Solar Heat-blocking Pavement can reduce the maximum rut depth **by half**, compared to that of conventional pavement

# Thermal sensation for pedestrians
# &
# Environmental effect

# Thermal sensation - Thermographic image -




Conventional Pavement | Solar Heat-blocking Pavement | Conventional Pavement | Solar Heat-blocking Pavement

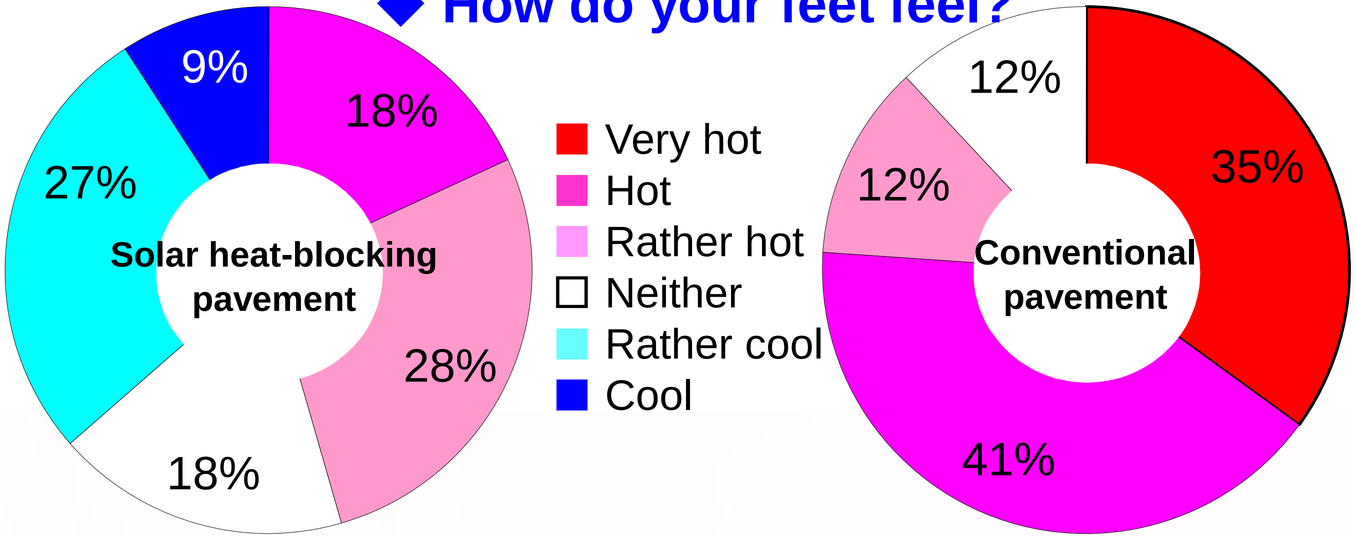
- The surface temperature of the two pavements were significantly different

# Thermal sensation - Questionnaire -

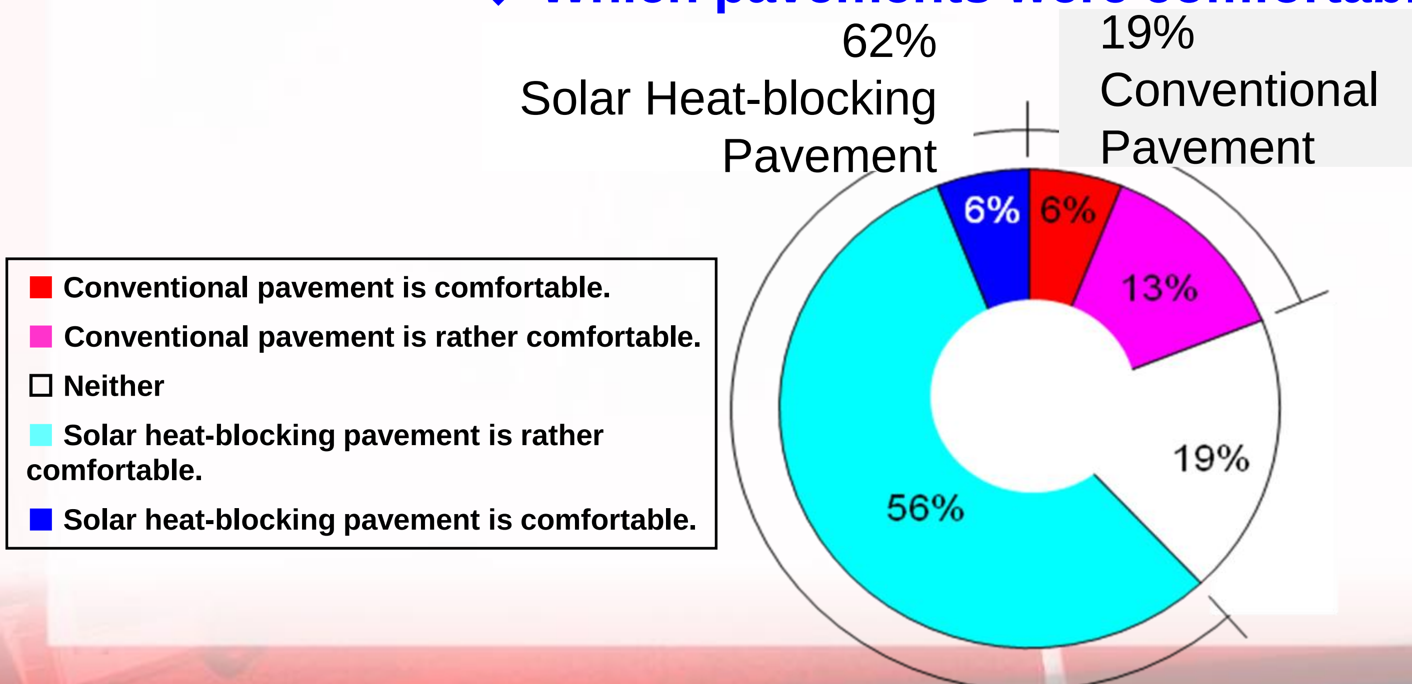
Experimental state

- Six assessors
  (i.e. three males and females in their 20's to 30's, respectively)
- Standing on both Conventional and Solar Heat-blocking Pavement for three minutes
- Ambient temperature: approx. 35°C

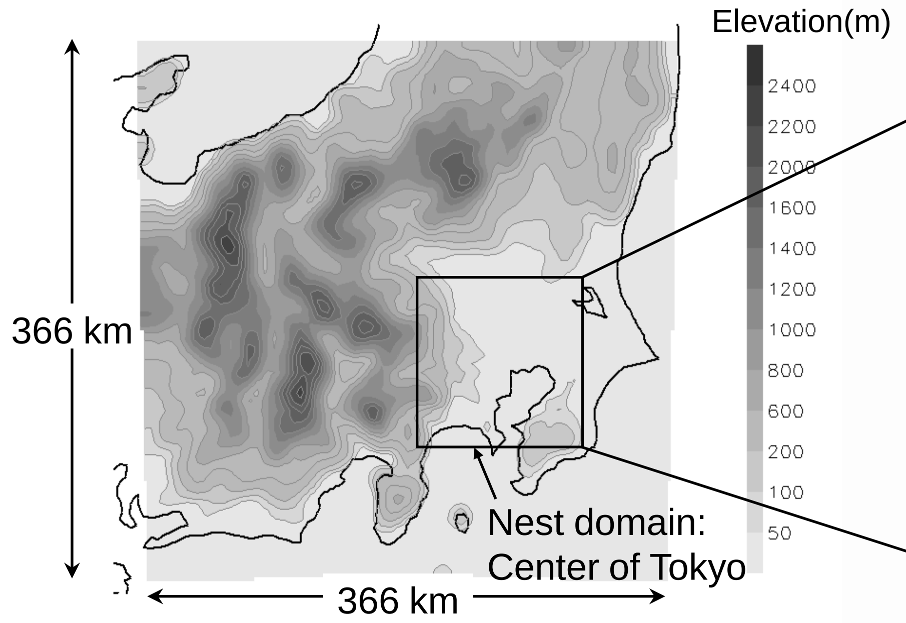
## ◆ How do your feet feel?

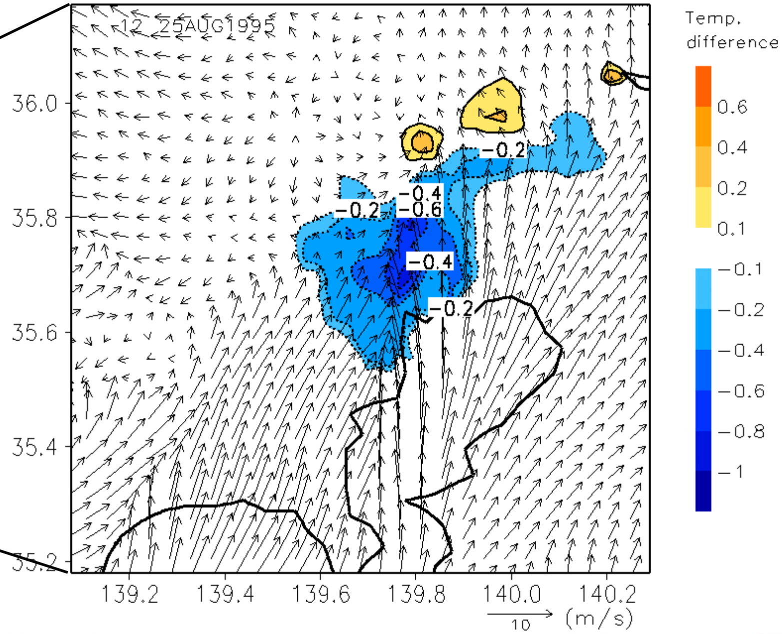



## ◆ Which pavements were comfortable?



# Environmental effect -Computer simulation-



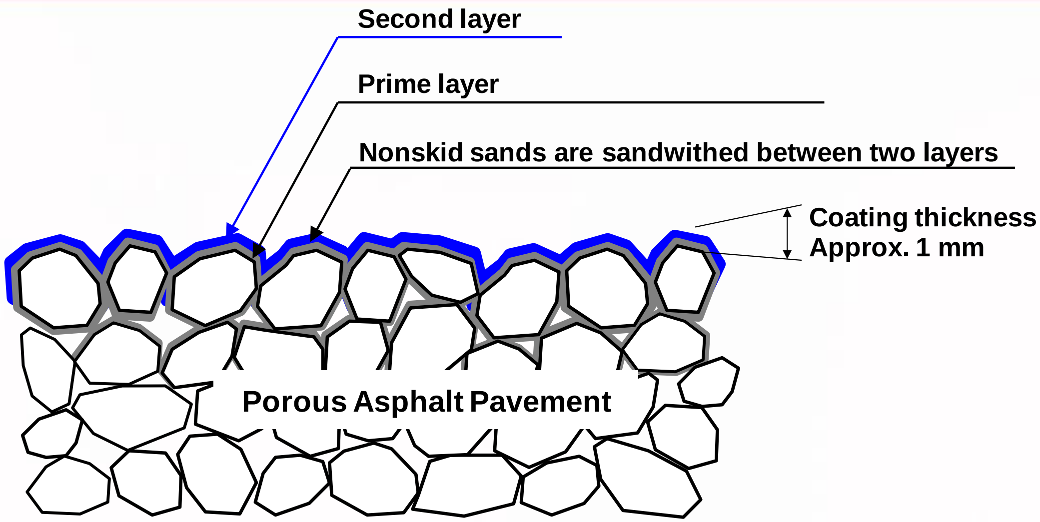

- The result indicates that air temperatures in central Tokyo tend to decrease. Also, the air temperature is reduced by more than 0.8˚C
- The technology is highly effective for mitigating urban heat islands.

# Conclusions

- The reduction in surface temperatures for solar heat-blocking pavement is approximately **16° C**.
- This technology can effectively reduce rutting, as the rate was **approximately half** compared to the dense-graded asphalt surface.
- It contributes to improving the **thermal sensation** around people's feet.
- Solar heat-blocking pavement is likely to be useful in mitigating the "urban heat island" effect, since atmospheric temperatures can be reduced by **0.8° C**.

# Thank you

# Application procedure





**Prime layer**

Density:
0.4 – 0.6 kg/m2

**Non-skid sand**

Density:
0.5 kg/m2

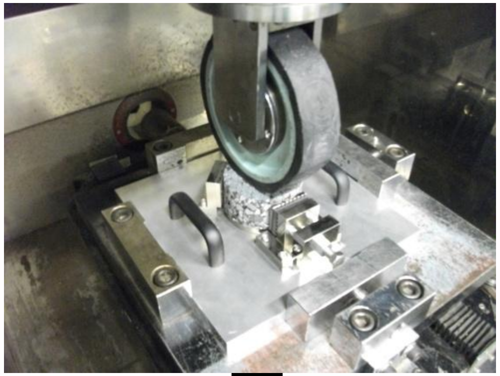
**Second layer**

Density:
0.4 – 0.6 kg/m2

**Open to traffic**

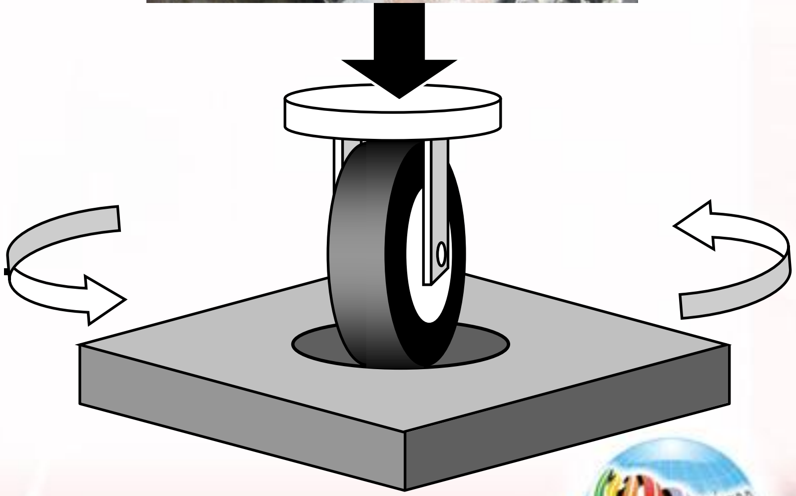
# Stripping resistance test - test method -

**Examines the adhesion between treatment materials and existing surface**



- Loading condition:

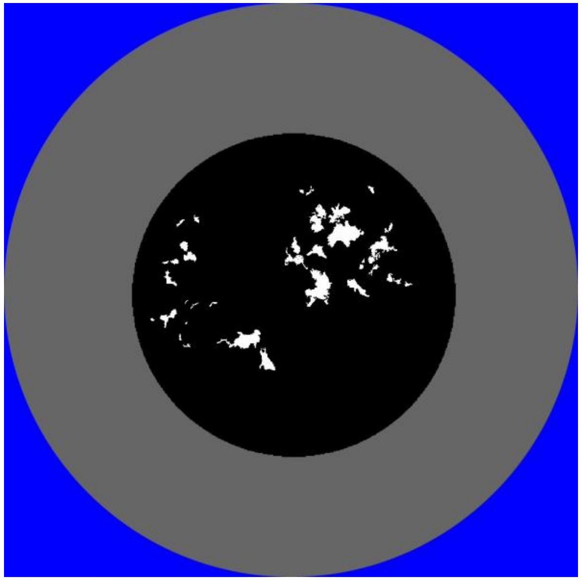
  Steering the front tires of a car to the **left** and **right**;



- Test temperature: **20**° C
- Total load: **686** N;
- Number of cycles: **650** times.

# Stripping resistance tests

Image analysis



Photo

Computer

| Stripping area rate (%) | |
|---|---|
| Performance requirement | Less than 40% |
| Solar Heat-blocking Pavement | **9.9%** |

Note: Stripping area rate = (stripping area/tire contact area) x 100

# Weather resistance: QUV test

## QUV test simulates sunshine and rainfall

- Test duration:
  400 hours/time;
- Temperature:
  $60 \pm 3^{\circ}C$;
- Time for water sprinkling:
  18 min./120 hours ;
- Water pressure:
  $1.0\ kgf/m^3$


QUV test cabinet

# QUV test results

| | Test Time (h) | Solar Reflective Ratio (%) | Ratio of Weather Resistance (%) | Remarks |
|---|---|---|---|---|
| QUV | 0 | 51.2 | - | Initial Condition |
| | 3,000 | 48.1 | 93.9 | After Required Exposure |

Note : QUV is in conformity to ASTM G-53

Solar reflective ratio is based on JIS A 5759

- QUV for 3,000 hours is equal to exposure time of the 12 years and its weather resistance keeps approx. **94%** of initial condition

# Noise reduction

- Measures the **noise from tires and road surfaces**
- Uses **microphone**
- The measurement was conducted at a speed of **50 km/h**

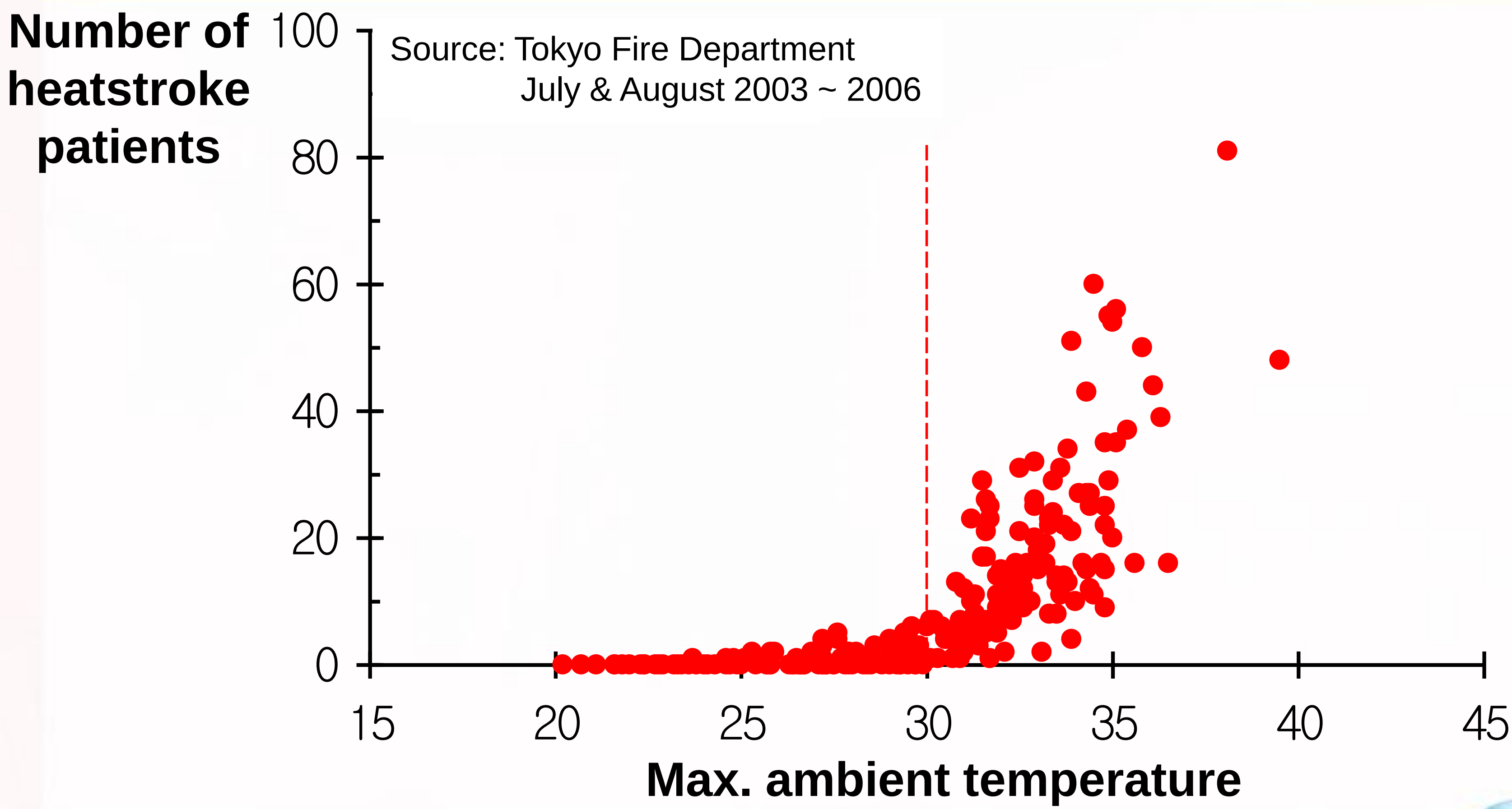

Noise measurement vehicle

# Noise measurement results

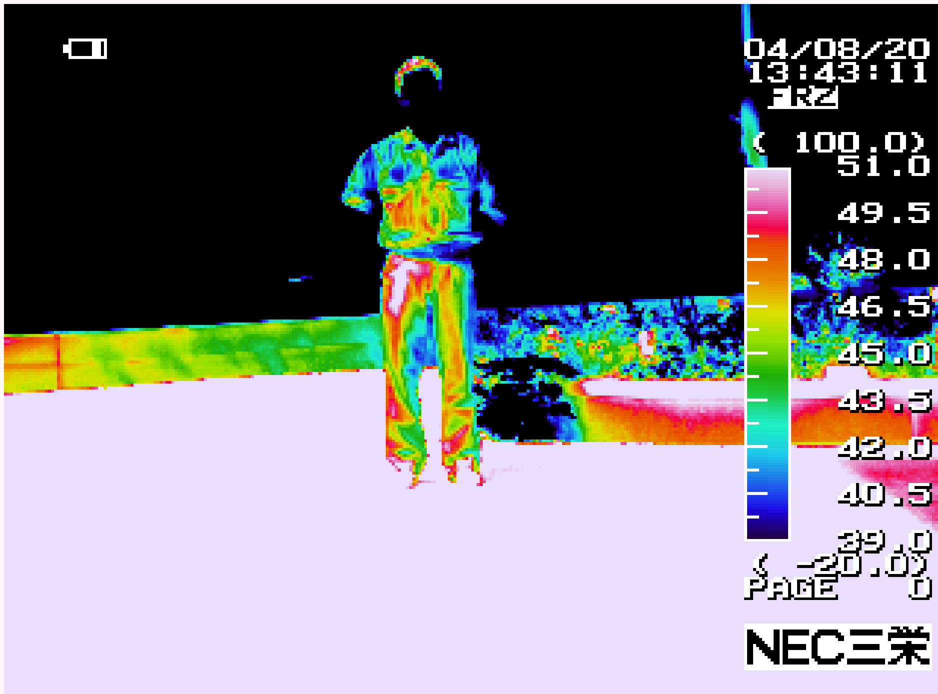
| Noise level on Porous asphalt surface | | Level (Iwama *et al.*) | Level (Tomonaga *et al.*) |
|---|---|---|---|
| Specific Tire Noise dB (A) | Before coating | 88.3 | 91 |
| | After coating | 87.9 | 90 |
| | A year after coating | - | 91 |

- Porous asphalt surfaces with solar heat-blocking material retains its original performance level, despite the materials being coated on top of the existing porous asphalt surface.

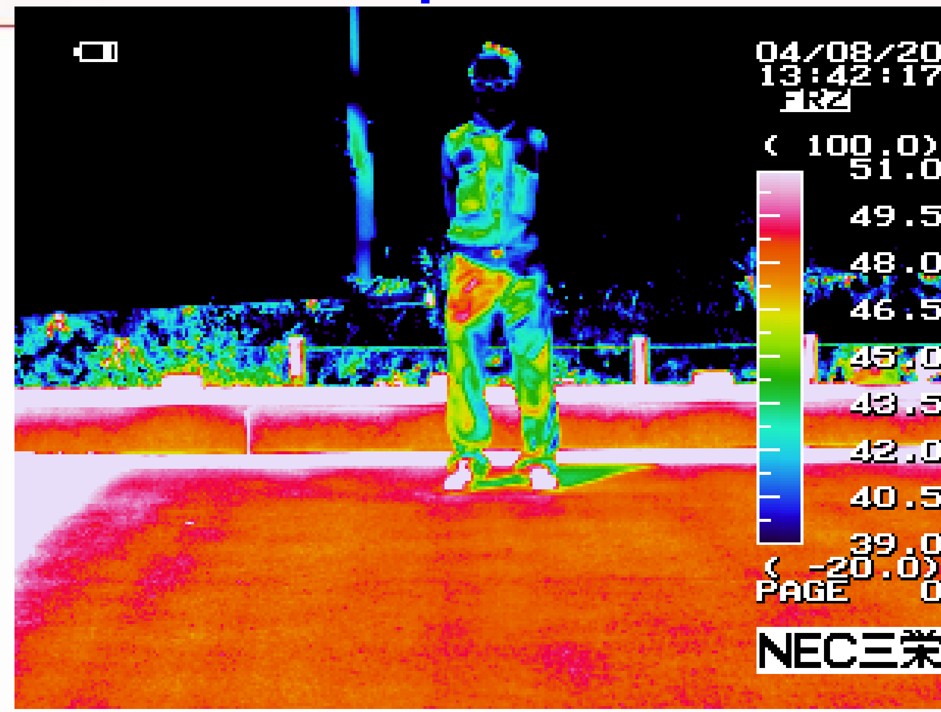
# Increase in patients suffering heatstroke



# Influence of Thermal Impact




**Porous asphalt pavement**




**Solar heat-blocking pavement**

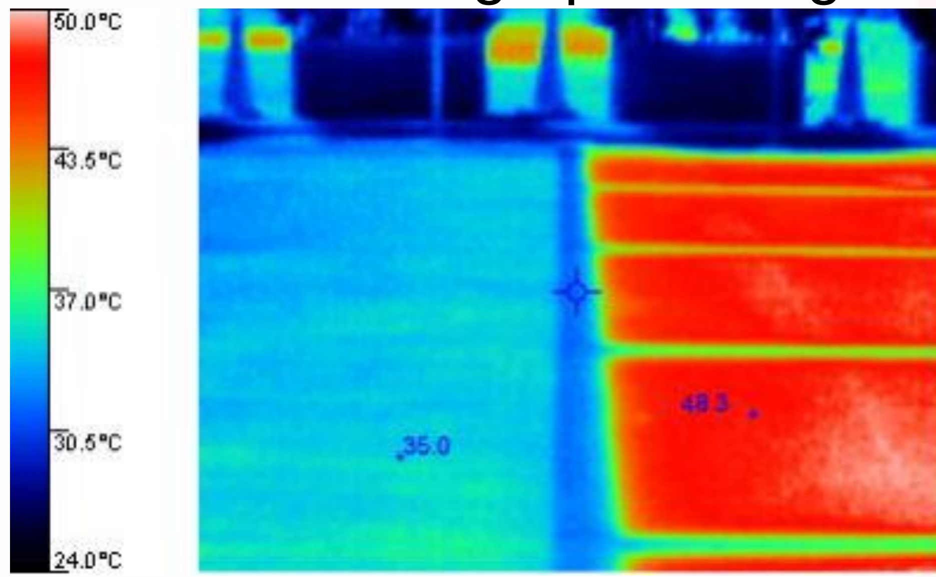
- Porous asphalt surface measured more than **51° C** whereas solar heat-blocking pavement had a surface temperature of about **46.5° C**.

# Thermal sensation - Surface temperature -

Original Image

Solar Heat-blocking Pavement | Conventional

Thermographic Image

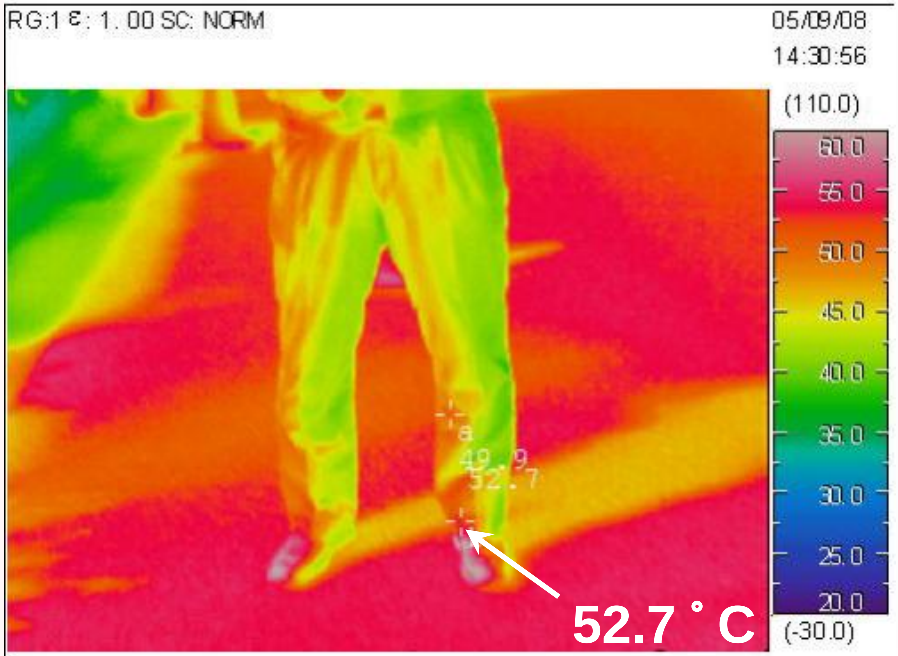



Solar Heat-blocking Pavement | Conventional

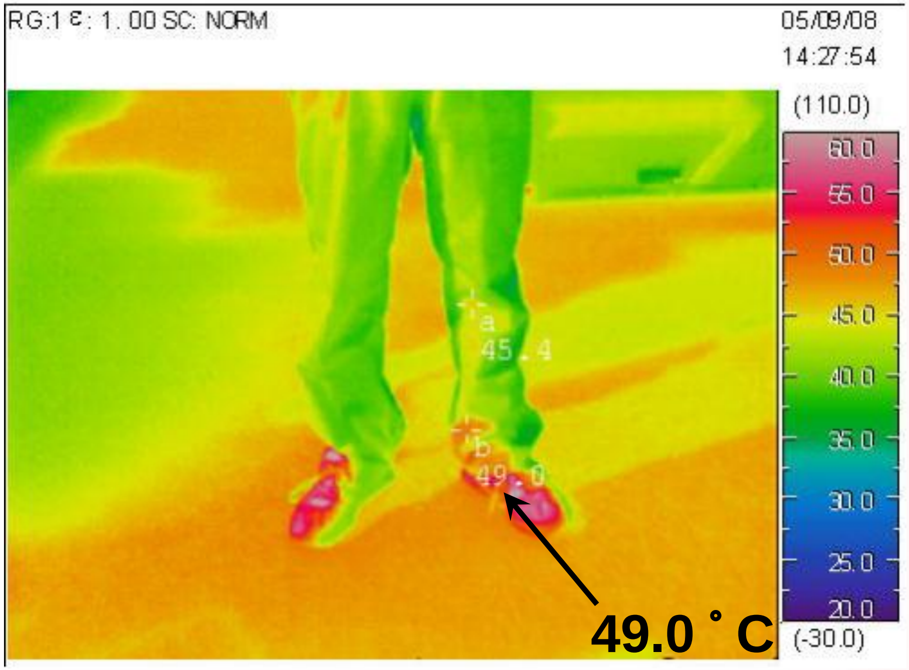
**35.0 ° C** **48.3 ° C**

# Thermal sensation - Temperature around feet-

**Porous asphalt pavement**




**Solar Heat-blocking Pavement**




Toyonaka *et al.* (2008): Journal of Hoso, Vol. 43, No. 6, pp. 31~36

- Toyonaka *et al.* concluded that S.H.P. can improve thermal comfort around our feet