# Infrared Thermographic Inspection of De-bonding Between Layers of Airport Flexible Pavement

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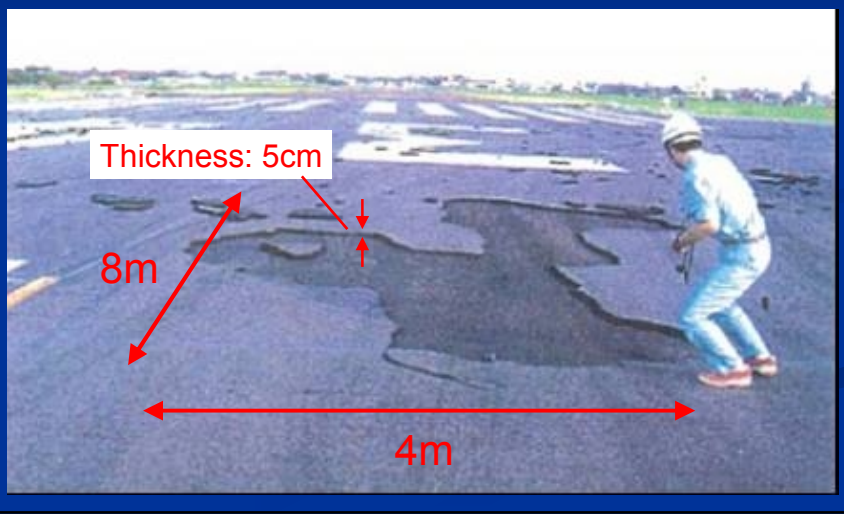
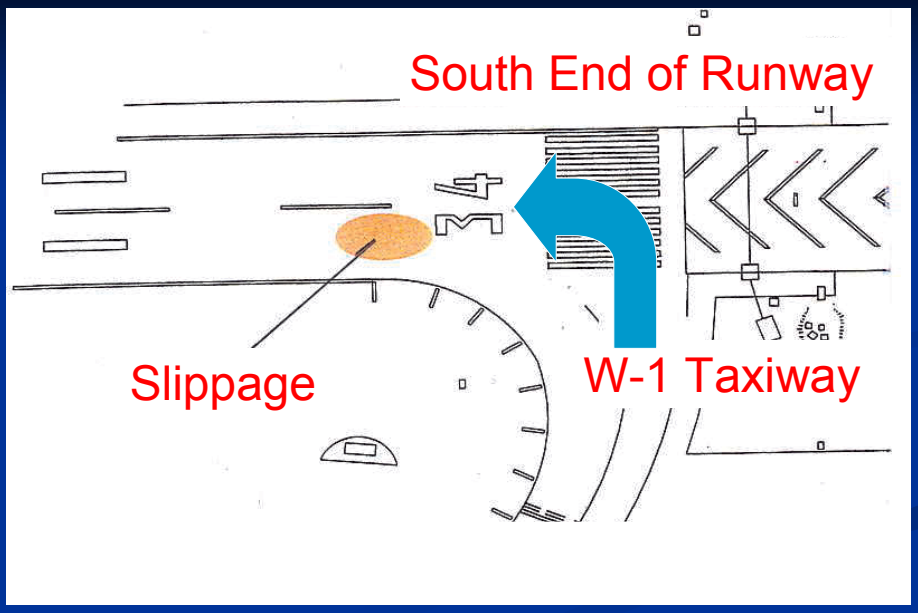
## Background and Objects

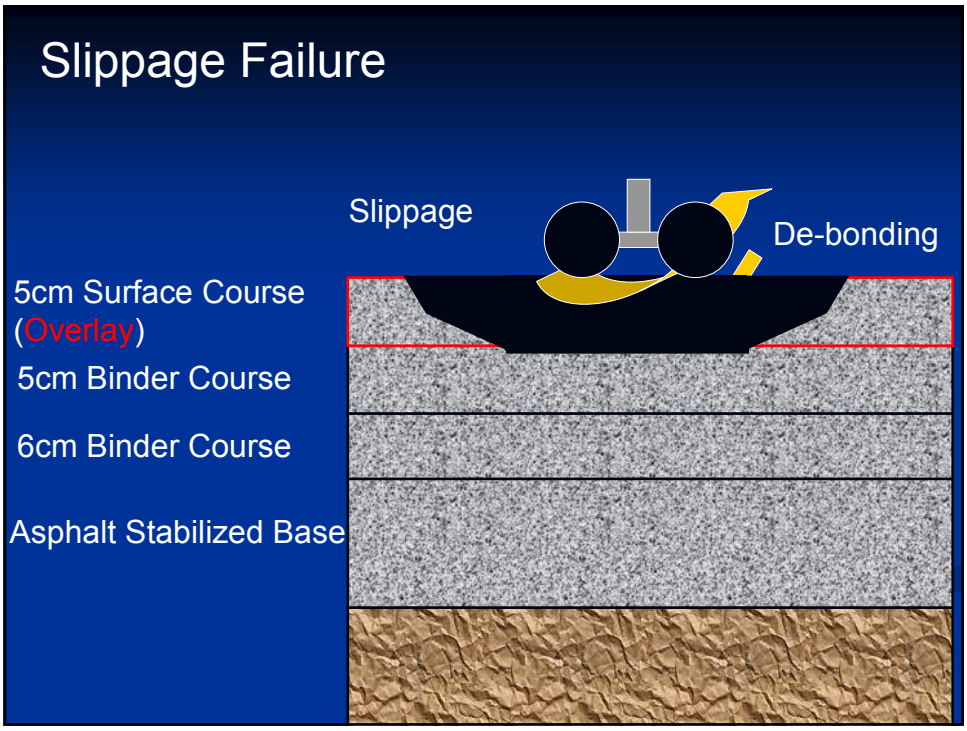
- Many de-bondings between lifts are found out in airport flexible pavement.
- Cause of de-bonding seems to be the failure of spraying and curing of tackcoat.
- Impact acoustic method is hard work to find out de-bonding between lifts.
- Final Goal is to verify Infrared thermographic method as more quick survey method in night time.

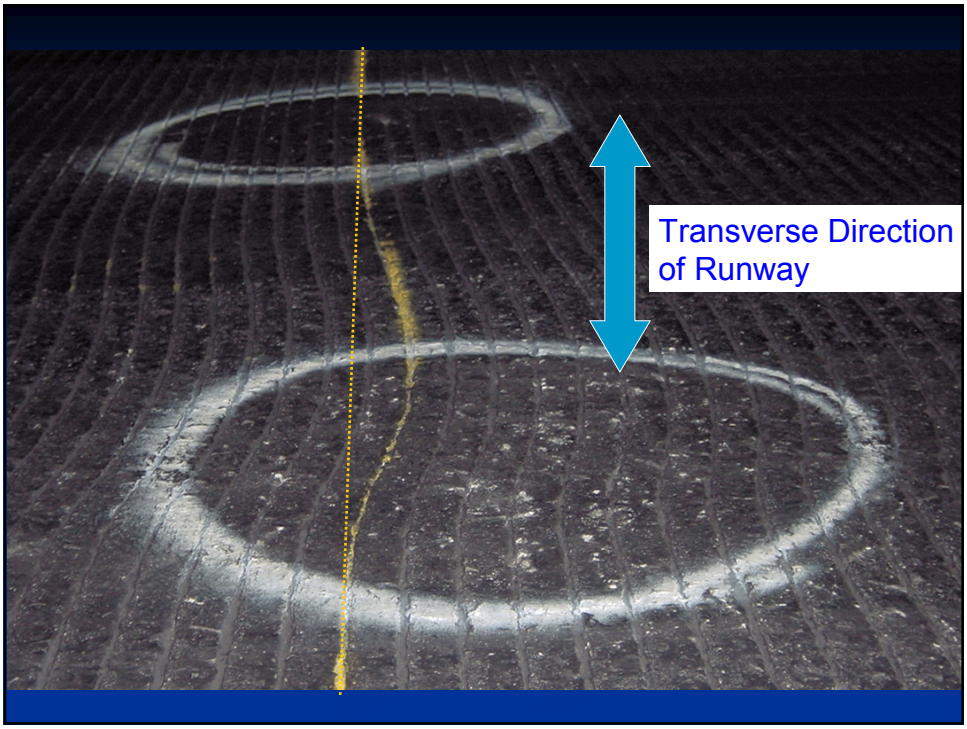
## Slippage Failure

Slippage Failure in Nagoya Airport (2000 Summer)





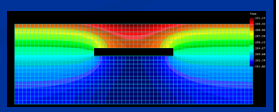
## Impact Acoustic Method (Hammer Method)

Hard Work !

## Inspection Method for de-bonding between lifts

Impact Acoustic Method (Hammer Method)

| | |
|---|---|
| Merit | Simple Method |
| Demerit | Long time, Many inspectors |



Infrared Themographic Method (IR Method)

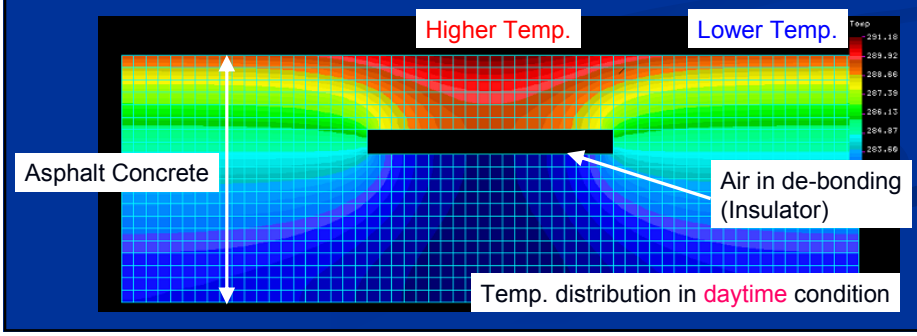
| | |
|---|---|
| Past Result | Defects within concrete piers of roads and railways |
| Problem | Night time survey?<br>Weather condition ?<br>Accuracy ? |

## Infrared Thermographic Method (IR Method)

The method is based on the surface temperature difference between bonded and de-bonded areas.

Since heat transfer is blocked between lifts
due to air in a de-bonding (which acts as an insulator)…

| | |
|---|---|
| In daytime | De-bonded Area Temp. > Bonded Area Temp. |
| In night | De-bonded Area Temp. < Bonded Area Temp. |




## Contents

1. Field Trial of IR Inspection in night time
   Verification of the applicability of IR Method

2. Weather Condition
   Verification of suitable weather condition for IR Method

## Field Trial of IR Method

Conditions

| | |
|---|---|
| Airport: | Naha Airport (Southeast of Japan) |
| Day: | Sep. 2005 12:30am～5:30am |
| Weather: | Fine / Occasionally Cloudy |
| Wind Velocity: | 1～5m/s, |
| Max. / Min. Air Temp.: | 33.0 / 26.2 °C (91.4 / 79.2 °F) |

Procedure:

1. Field was inspected by Impact Acoustic Method to detect the de-bonded area.
2. Infrared image was taken in every 30 minutes from a height of 10 m.
3. Core boring was carried out to confirm the depth of de-bonding.

## Infrared Thermography Camera

Both still image and movie can be taken.

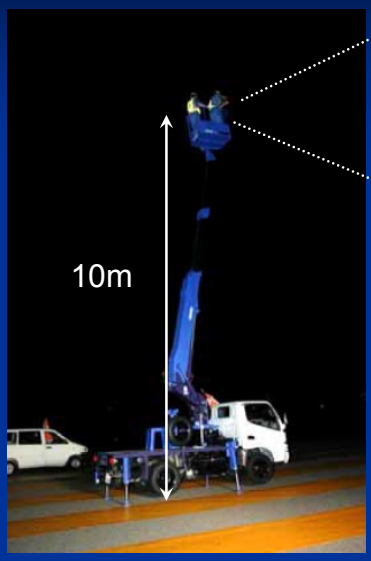
Measurement Temp. Range

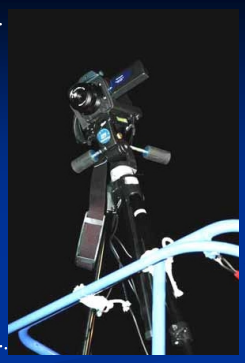
- 40 to 500 °C (- 40 to 932 °F)

Temperature Resolution

Better than 0.06 °C (0.108 °F) with averaging

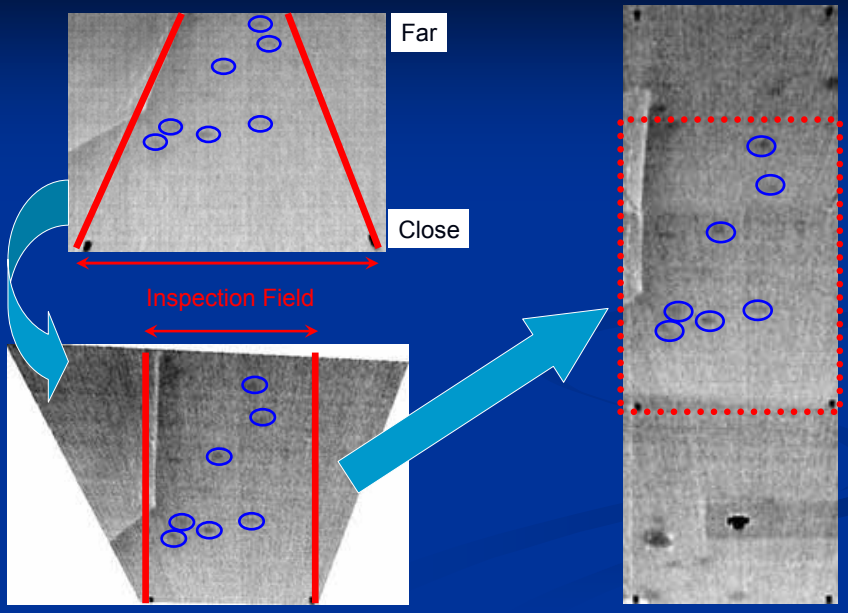
## How to take image



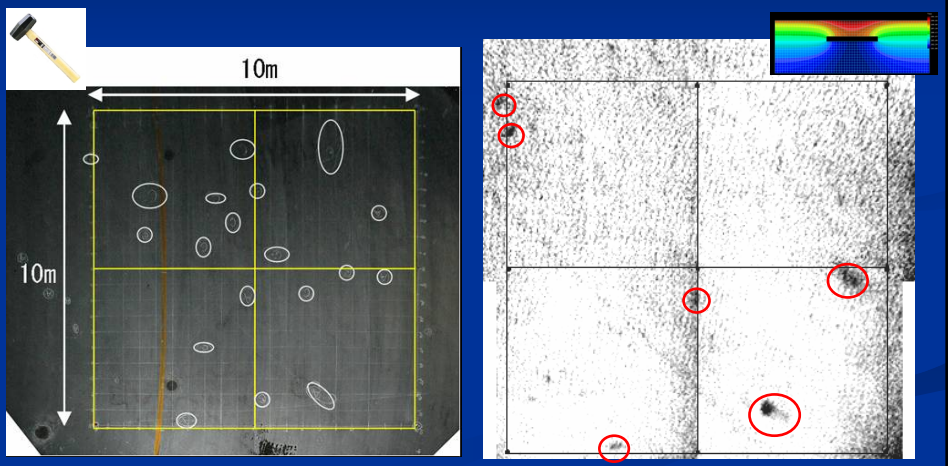
IR / Visible images were taken
from a height of 10m.

## Geometry Correction



## Visible / IR Image of Inspection Field

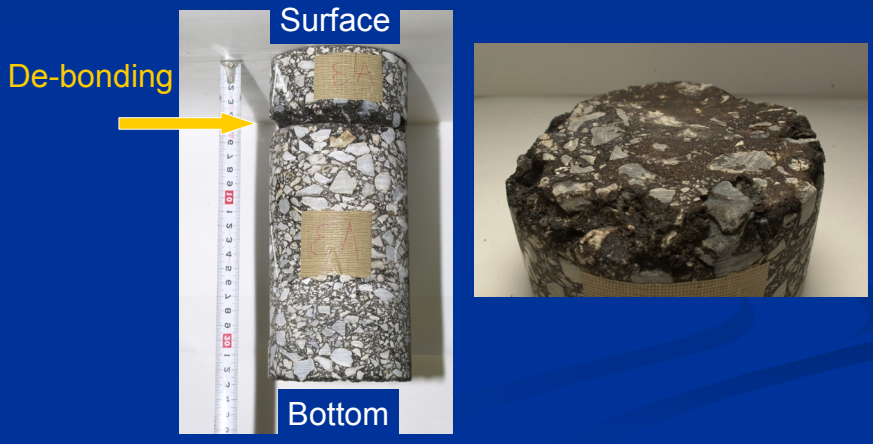
Low-temperature areas generally match the de-bonded areas found by hammer….. However, not perfect.




Hammer Result IR Result

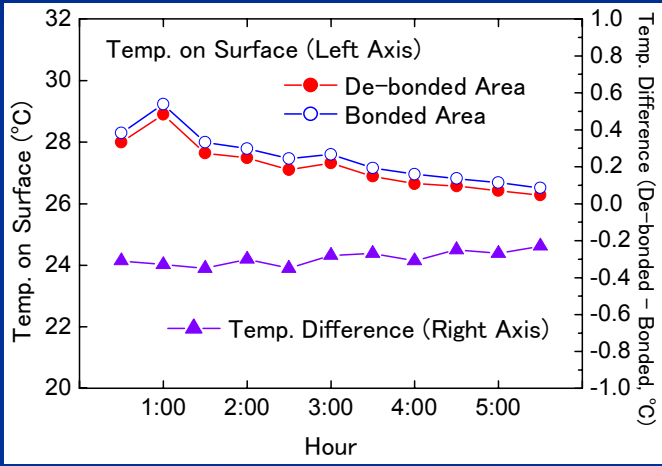
## Core boring

De-bondings were confirmed in the depth of 40 – 70 mm at all low temperature areas.



## Temperature Difference on Surface

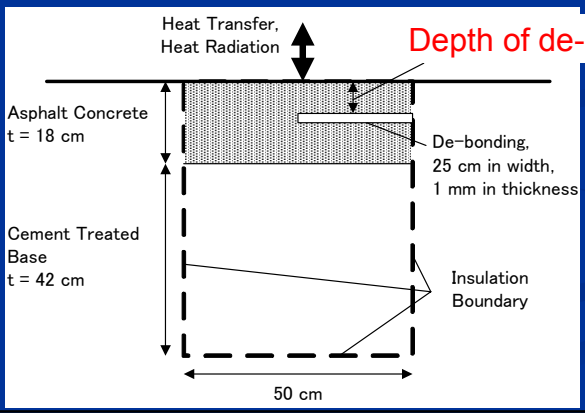
Temp. Difference (De-bonded – Bonded)
was 0.20 to 0.35 °C (0.36 to 0.63 °F)



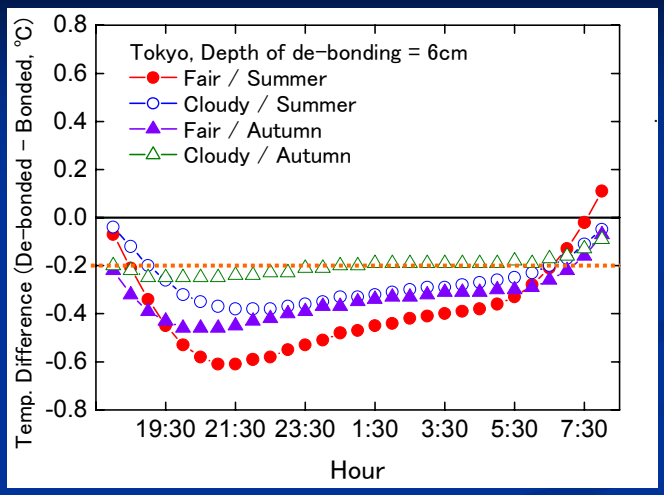

## Effects of Weather Conditions

Unsteady-state Thermal Analysis was performed by using 2D-FEM
to calculate max. temp. difference by using several weather conditions.

Weather Conditions: Temp., Wind, Solar Radiation in 5 cities.
Season: Summer (June, Jul. and Aug.)
Autumn (Sep., Oct. and Nov.)
Fine / Cloudy

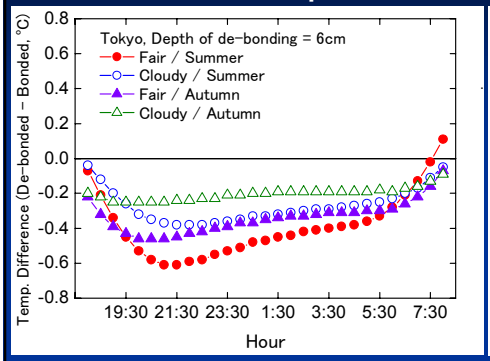


## Effects of Weather Conditions

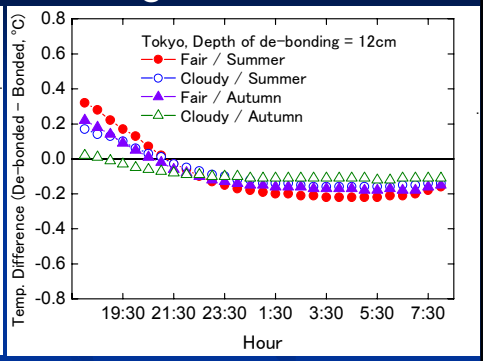



Max. Temp. Difference is
Fine > Cloudy
Summer > Autumn

## Effects of Depth of De-bonding




Depth of de-bonding : 6cm




Depth of de-bonding : 12cm

Max. Temp. Difference is
6cm > 12cm

## Multiple Linear Regression Analysis

To clarify the weather conditions under which the infrared thermographic inspection method can be used.

- Based on the results of FEM thermal analysis
  Weather condition in five cities
- Dependent variable
  Surface temperature difference (°C)
  calculated by FEM thermal analysis
- Independent variables
  Maximum difference of air temperature in a day (°C)
  Amount of solar radiation in a day (kWh/m²)

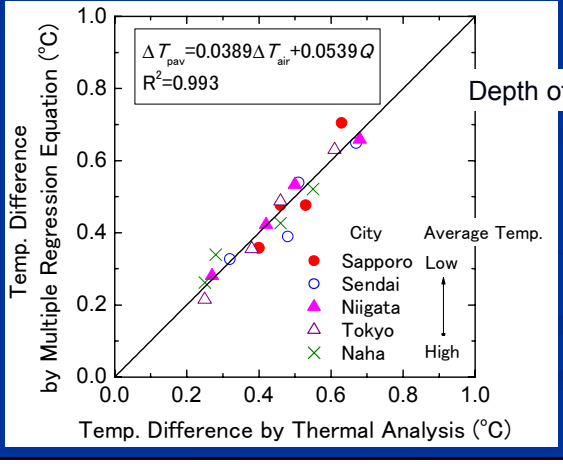
## Max. Temp. Difference and Weather Conditions

$\Delta Tpav = 0.0389\ \Delta Tair + 0.0539\ Q$

$\Delta Tpav$ : max. temp. Difference (°C)

$\Delta Tair$ : max. difference of air temp. in a day (°C)

$Q$ : amount of solar radiation in a day (kWh/m²)




Depth of de-bonding = 6cm

## Conclusions

(1)
De-bonding at a depth of, at least, 70 mm can be found by IR method.
However, the depth of de-bonding which can be detected by the IR method changes with the weather conditions.

(2)
The amount of solar radiation and the air temperature difference between day and night affect the surface temperature difference due to the existence of de-bonding.

Thank you for your attention !

Question ?
(Would you ask me slowly?)