Towards Sustainable Winter Road Maintenance: Development of Ice-breaking Pavement

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0. CONTENT

Climate Change:

- ✓***Severe snowfall*** afflicted Russia;
- ✓Jerusalem was pounded by a ***blizzard***;
- ✓***The coldest winter*** in thirty years was recorded in eastern Asia;
- ✓Unusually low-pressure system known as a ***"bomb cyclone"*** snarled traffic in Japan

Moscow, Russia, 2012
http://www.afpbb.com/articles/-/2918054?pid=10025105

Jerusalem, 2013

1. INTRODUCTION

Anti-icing measures using chemicals:

- might accelerate aging of super structures
- tends to exhibit declining performance over time

Anti-freezing pavements :

- Assurance of Traffic safety,
- Minimization of road maintenance costs and
- Preservation of roadside environment

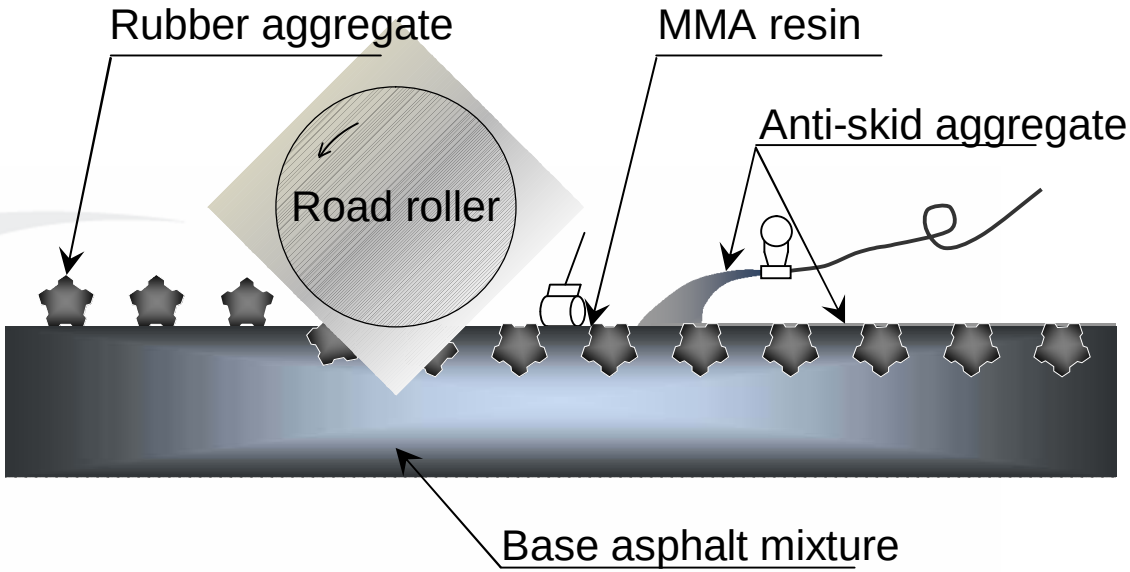
Factors affected

- Compactability of asphalt mixture;
- Durability of pavement

Development of Ice-breaking Pavement

2. Design - Ice-breaking Pavement -

- Anti-freezing pavement with physically flexible materials
- Utilising Hot Rolled Asphalt Technology
- Materials used:
  - Rubber aggregates, MMA resin, Anti-skid sands
  - Polymer Modified Asphalt for heavy traffic roads
  - Straight Asphalt 40/60 for light traffic roads



Base Asphalt Mixture

Quality standard of materials

Materials	Quality standard
Polymer-modified asphalt Type II Straight asphalt 40/60	Standard properties or quality standard described in the Handbook of Pavement Construction(the Japan Road Association)
Course aggregate□Fine Aggregate□filler	

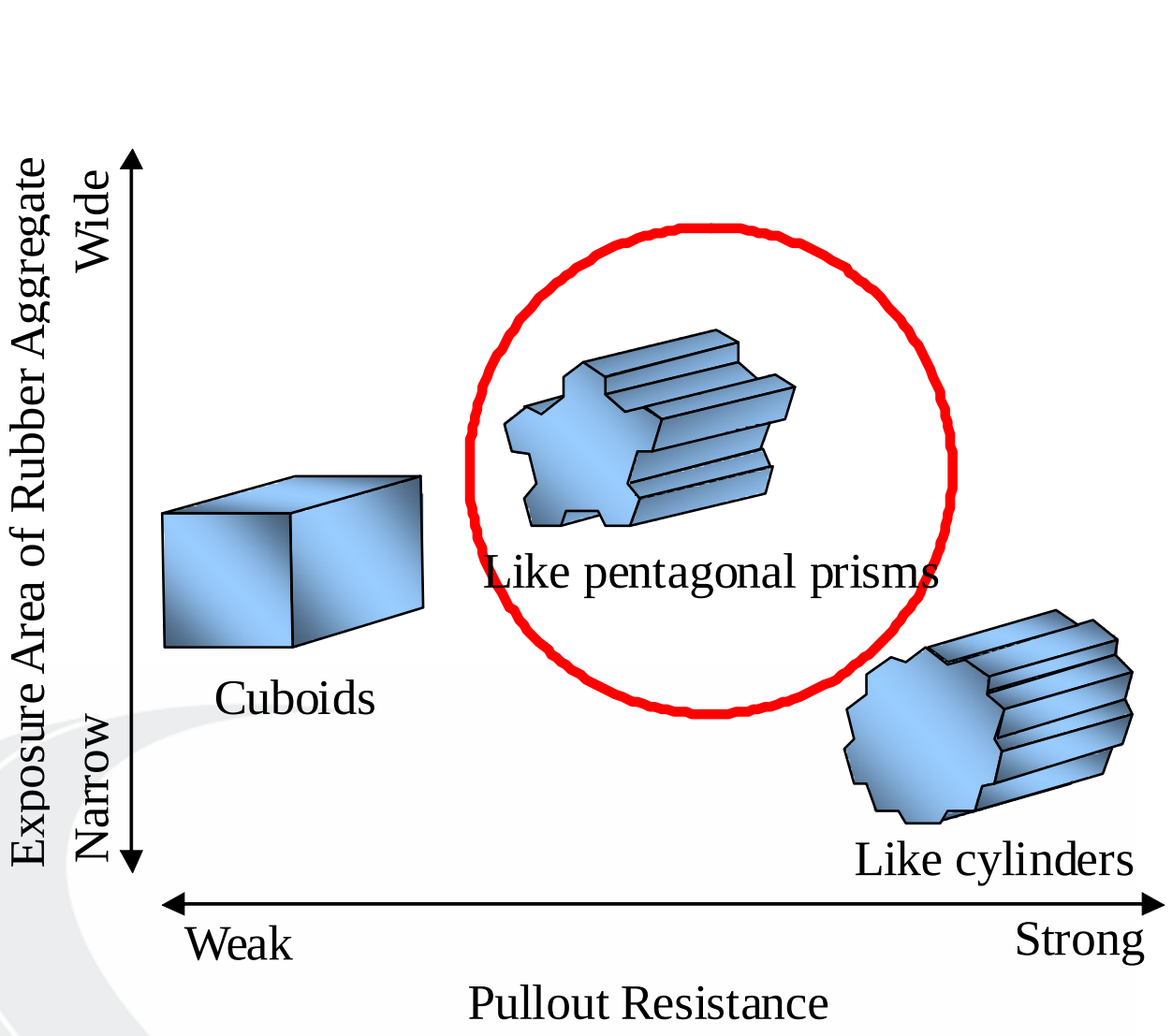
Mixing example of base asphalt mixture

Materials	Design Ration (%)
Single-sized crushed Stone S-20(grade-6)	20
Single-sized crushed Stone S-13(grade-5)	20
Fine sand	50
Mineral filler	10
Asphalt	7.0-9.0

Example properties of Marshall test

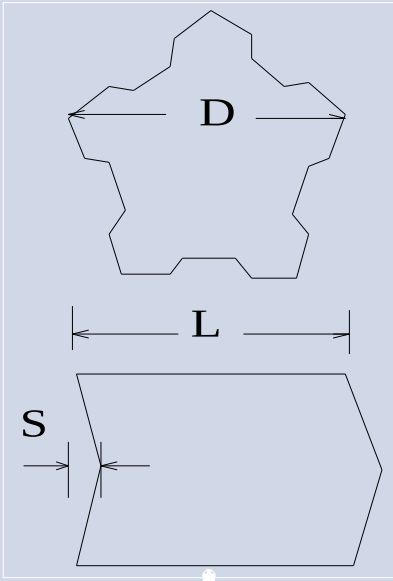
Density (g/cm^3)	Air Void (%)	Degree of saturation (%)	Stability (kN)	Flow value (1/100cm)
2.320	3.7(3-7)	82.0(70-85)	9.73 (4.9 or more)	47(20-50)

Shape of Rubber Aggregate



Specification of Rubber Aggregate

Specification of rubber aggregate

Item	Specification	Remarks
Shape	Special pentagonal prism	
Diagonal length *D* (mm)	20.0±2.0	
Length *L* (mm)	22.0±5.0	
Ruggedness Length *S* (mm)	2.0±1.0	
Material	SBR special rubber Recycled rubber powder is partly used.	
Hardness of rubber	70-90 JIS K 6301(A Sclerometer)	

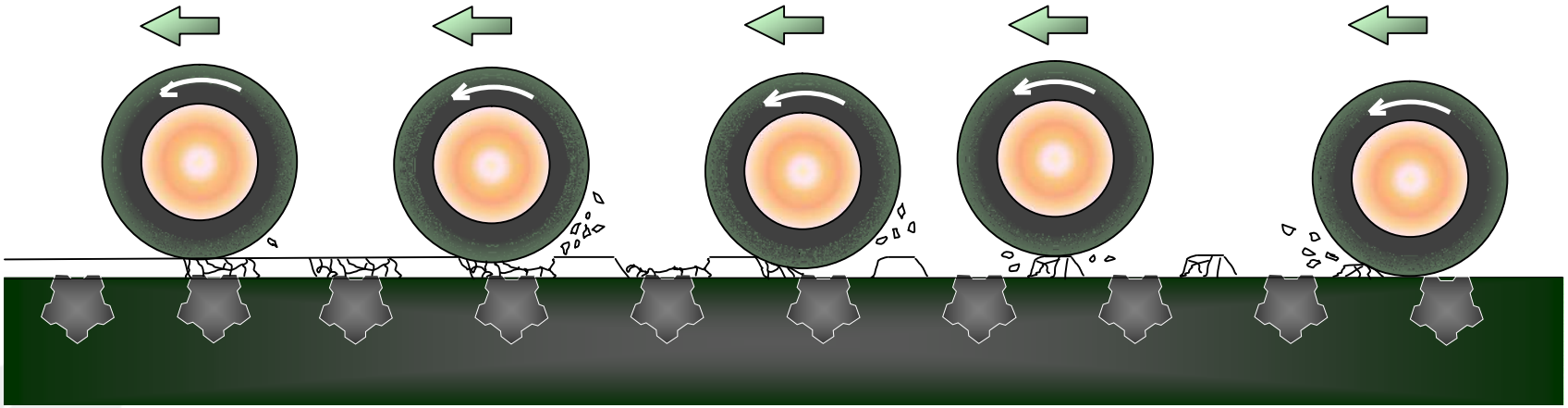
Material of Rubber Aggregate

Comparison table of rubber material

Main raw material		EPDM	SBR	Test methods
Specific gravity		1.30	**1.35**	JIS K6301
Hardness		84-88	**80-86**	JIS Hardness(A) JIS Hardness Meter
Modulus of Elasticity (Theory value)		About 5MPa	**About 4MPa**	Calculated from Hardness
Performance embedded		Good	**Good**	Practice
Remarks	Wear resistance	Better	**Good**	JIS K6264
	Weather proofing	Good	**Better**	JIS K6266

Anti-Freezing Mechanism

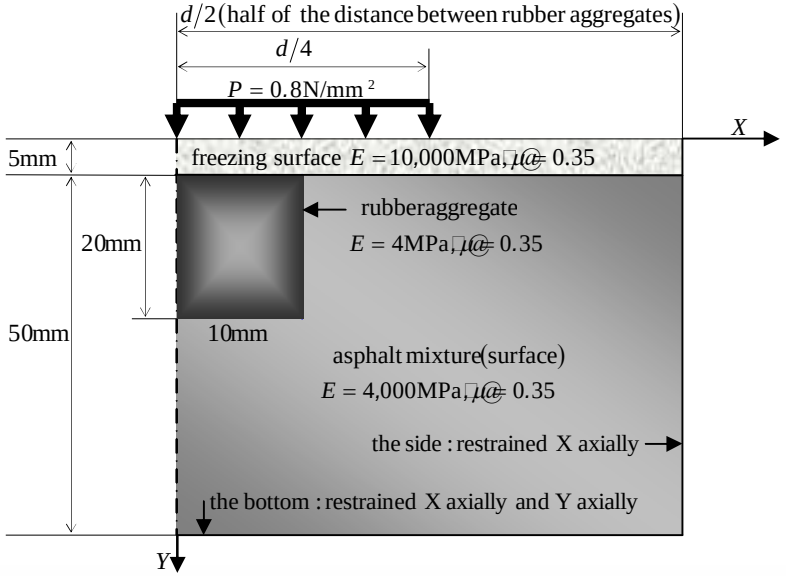
- The amount of rubber aggregate chipping: 1.6 – **2.0** kg/m^2

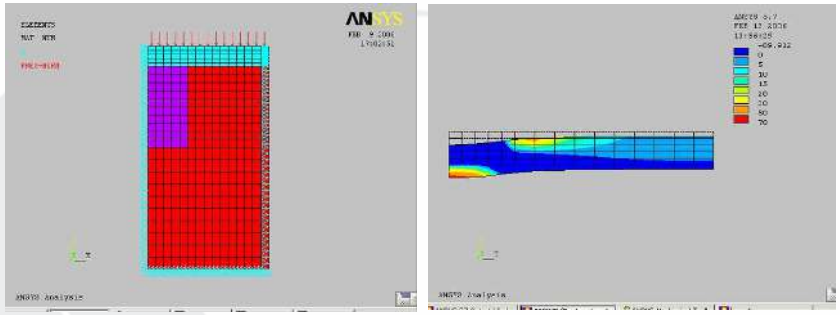


1.Bending Failure 2. Partially Exposed 3. Compression Failure 4. Exposed

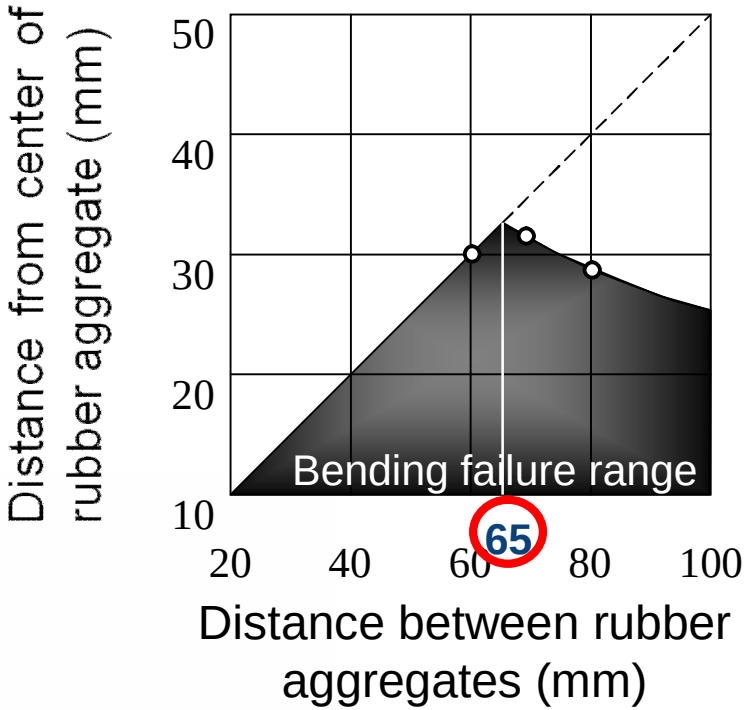
Anti-Freezing Mechanism

Bending: Failure by Finite Element Analysis





Analytical FEM model



Range of freezing bending failure

Anti-Freezing Mechanism

- **Compression:** Failure & Conclusion

  Case of a passenger car:

  Mass of a wheel 2.500 kN

  Compression failure stress 6,000 kN

The ice area >= 2.500kN÷ 6,000kN/m^2 ≒ φ23mm

Chipping Amount of Rubber Aggregates:

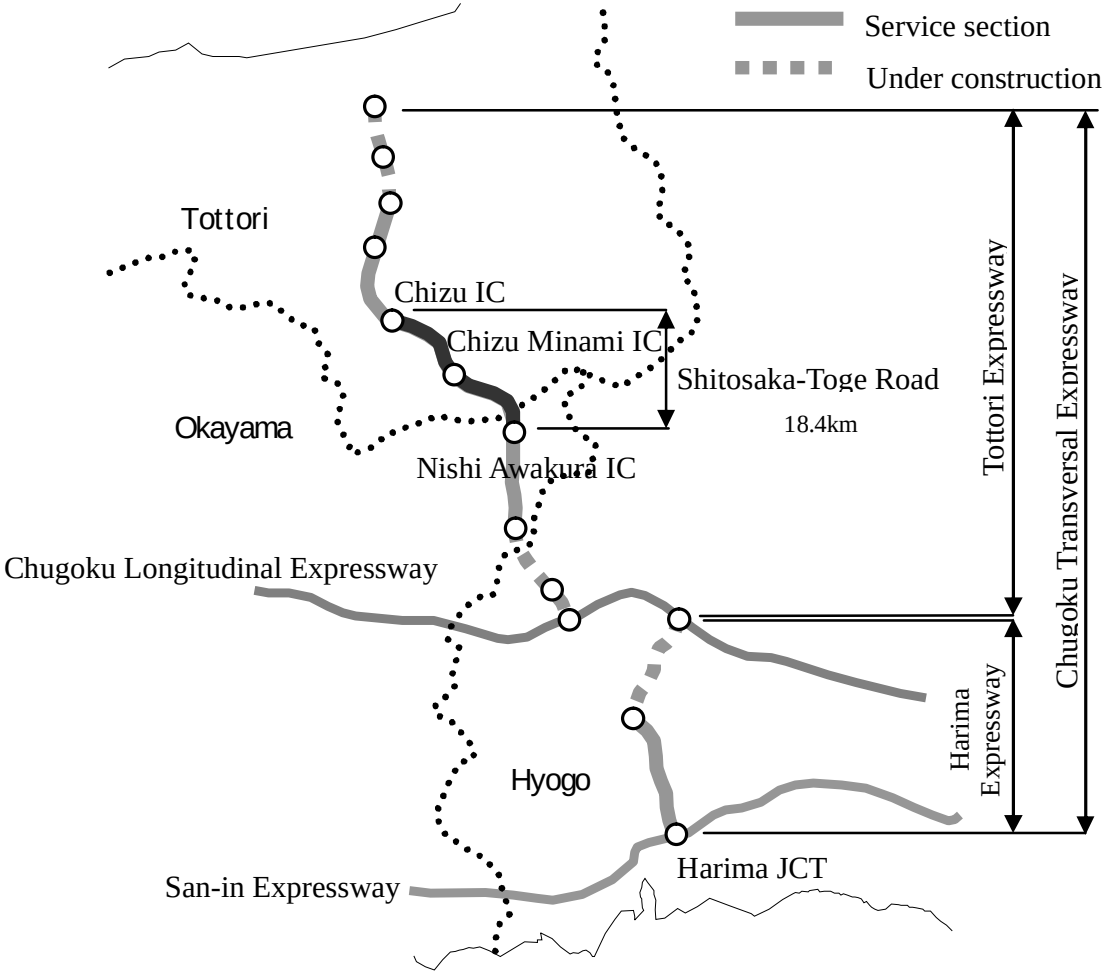
Distance=65mm+23mm>85mm□1.6-1.8kg/m^2

Design Amount = **1.8-2.0kg/m^2**

Characteristics

- Anti-freezing surface
- Continued effectiveness
- High durability
- Protecting the environment

4. Case study


Service section
Under construction
Tottori
Chizu IC
Chizu Minami IC
Shitosaka-Toge Road
18.4km
Okayama
Nishi Awakura IC
Chugoku Longitudinal Expressway
Tottori Expressway
Chugoku Transversal Expressway
Harima Expressway
Hyogo
Harima JCT
San-in Expressway

Case study

Construction overview

Name of Works		Chizu Pavement Works	Chizu 2 Pavement Works
Construction Period		16.3.2007 - 22.12.2007	26.6.2007.6.26 - 13.3.2008
Ice-breaking Pavement Area	Total	12,410 m^2	9,820 m^2
	Earthwork	Main line & ramp: 9,320 m^2	Main line & access: 5,480 m^2
	Bridge	Main line : 3,090 m^2	Main line & access : 4,340 m^2
Width		Pavement width =7 m(3.5m x 2)	

Paving of Ice-breaking Pavement

1.Spreading

2.Chipping and breakdown rolling

3.Intermediate rolling

Surface dressing using MMA resin

Undercoat

MMA: 0.3 kg/m^2

Top coating

MMA: 0.2 kg/m^2

Non-skid Sand:0.6 kg/m^2

Surface state after construction

Snow on Pavement

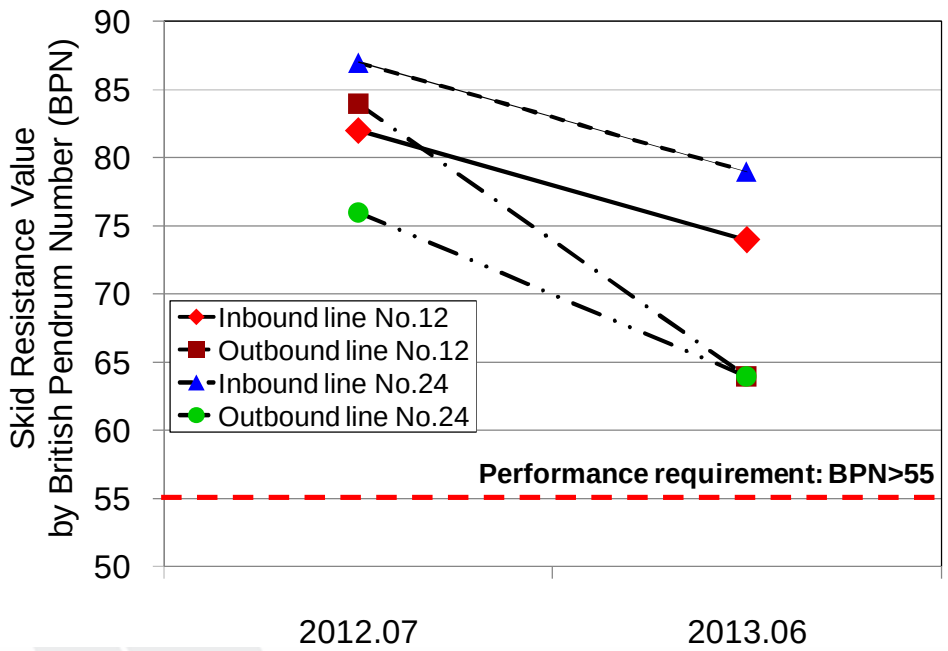
Ice-breaking Pavement

Surface after snowing

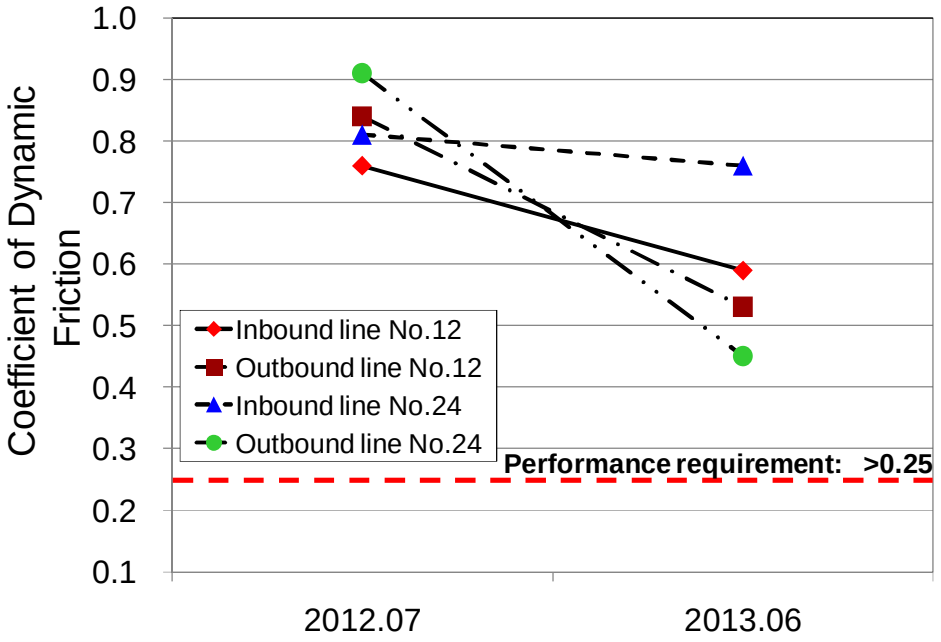
Dense-graded asphalt

5. Driving Comfort

- Skid resistance
  - BPN scored of **more than 60**
  - Coefficient of Dynamic Friction showed **more than 0.40**



BPN



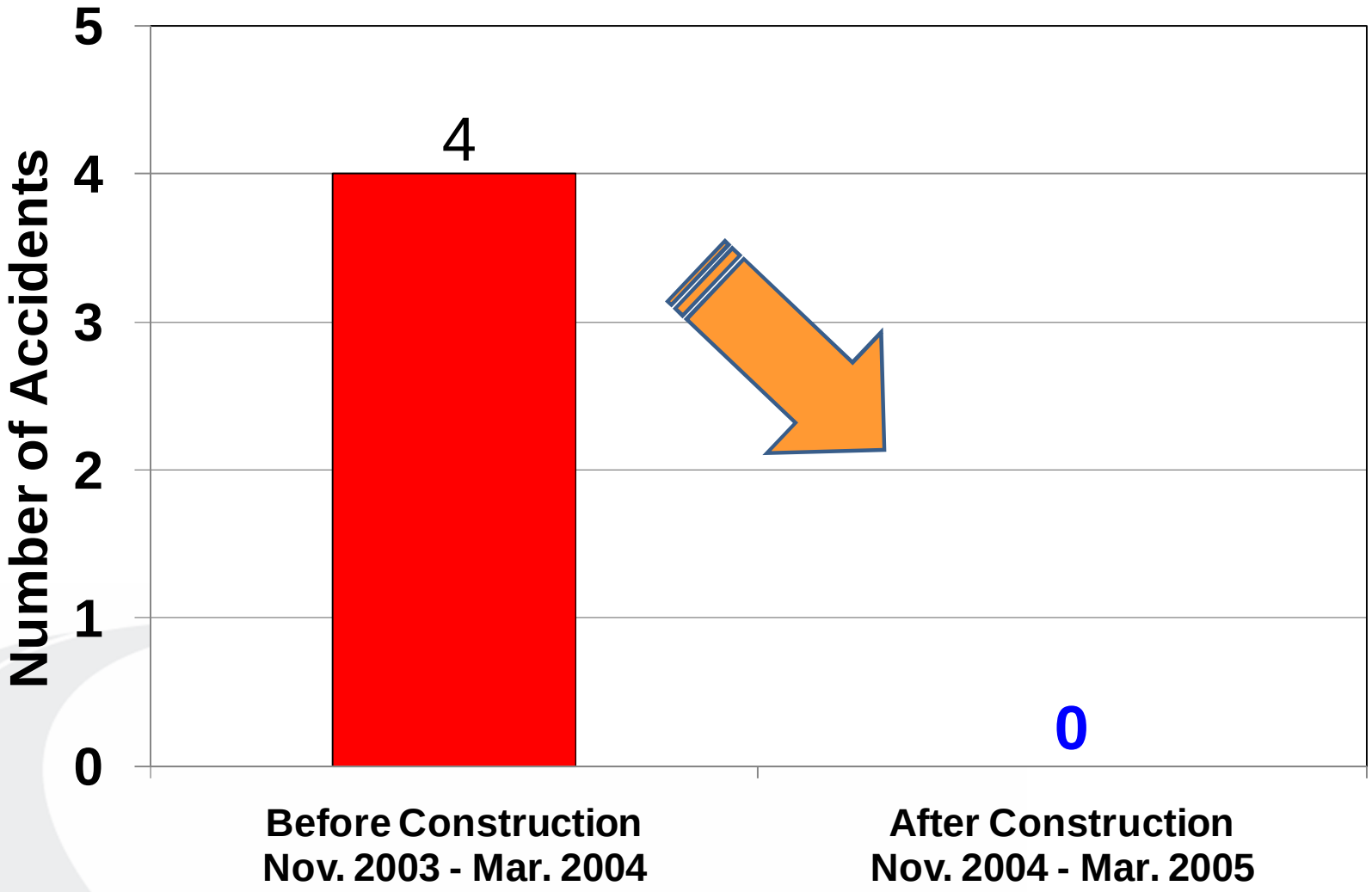
Dynamic Friction

5. Driving Comfort

- Roughness
  - Four sites meet the standard requirement (2.4 mm in standard deviation)

Job site	Roughness σ (mm)	Performance requirement
Site A	1.60 – 1.90	Less than 2.40
Site B	1.72	
Site C	1.50	
Site D	1.40 – 1.60	

5. Driving Comfort -Traffic accidents-



- Construction result shows dramatic reduction in traffic accidents

6. Conclusions

- A computer simulation using Finite Element analysis explains the mechanism for **fracturing the ice layer** and the design details, such as the appropriate amount of rubber aggregate to use.
- Field monitoring reveals that the ice-breaking pavement retains good surface condition and performance even after a year; and it is likely to be useful in **mitigating environmental damage**, as **no chemicals** are applied to the road surface.
- This technology may be effective in **minimising traffic accidents** during winter, as the number of traffic accidents was reduced, when compared to conventional asphalt pavement in the local region.

Thank you