

# Foamed Asphalt Recycling In CHINA Experience

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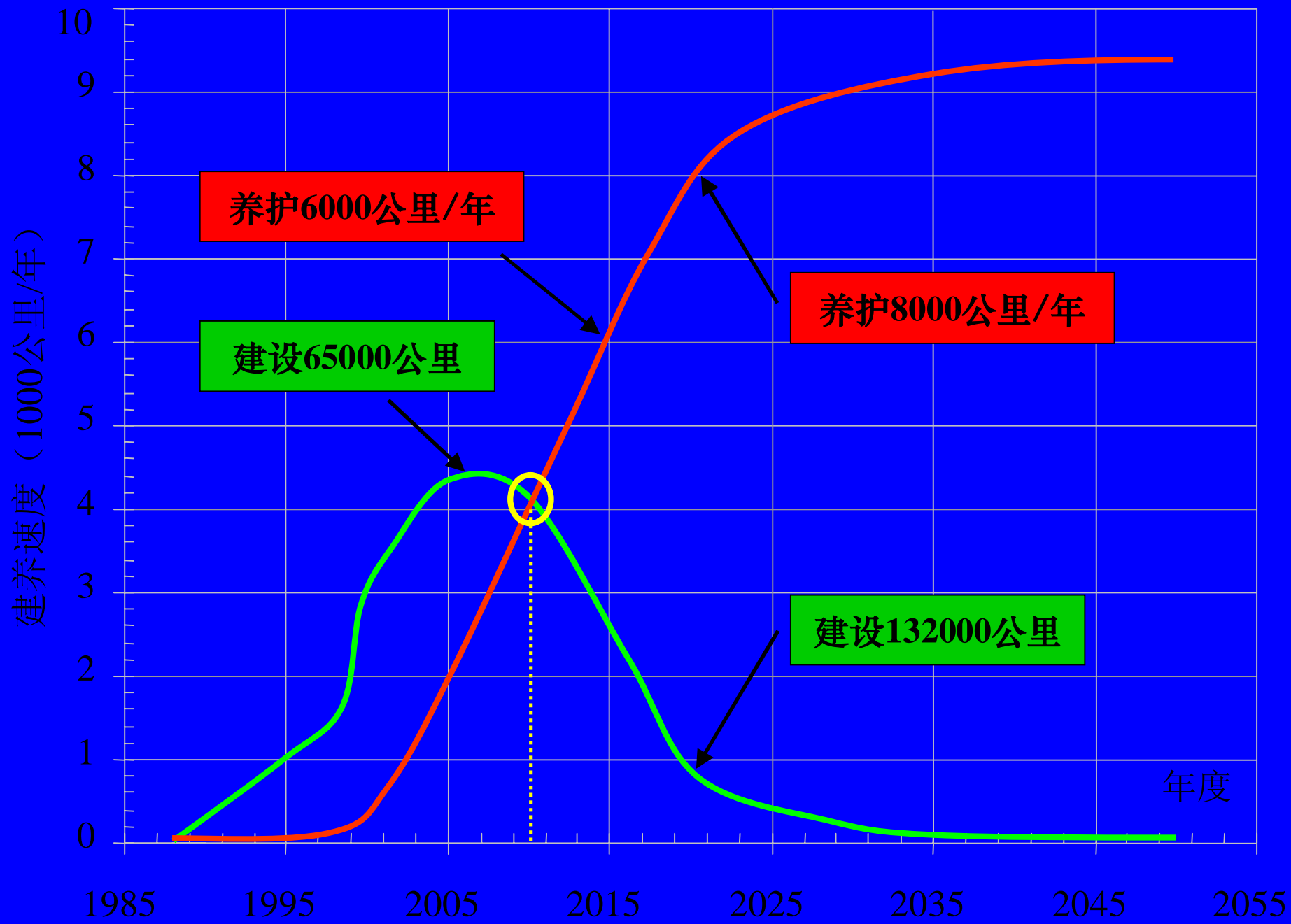
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**Chang'an University**  
**JUN 2010**

# Contents

- **Introduction**
- **Laboratory Test Results**
- **Rehabilitating Highways**
- **Conclusion**

# Introduction

- Xi 'an , Foam asphalt in plant (Express highway) ,in 2004;
- About 500 KM rebuild ; about100KM /per year increasing
- Foam asphalt mixture as Asphalt base coures.
- Structure design method based on experience
- Mixture design method is relative simple (ITS)



## 公路沥青路面再生技术规范

Technical Specifications for Highway Asphalt Pavement Recycling

2008-04-01 发布

2008-07-01 实施

中华人民共和国交通运输部发布

表 4.9.2-2 厂拌冷再生和沥青层就地冷再生时 RAP 检测项目与质量要求

材 料	检测项目	技术要求	试验方法
RAP	含水率	实测	本规范附录 A
	RAP 级配	实测	
	沥青含量	实测	
	砂当量(%)	>50	
RAP 中的沥青	针入度	实测	抽提,《公路工程沥青及沥青混合料试验规程》(JTJ 052)
	60℃黏度	实测	
	软化点	实测	
	15℃延度	实测	
RAP 中的粗集料	针片状颗粒含量、压碎值	实测	抽提,《公路工程集料试验规程》(JTG E42)
RAP 中的细集料	棱角性	实测	

表 5.4.3 乳化沥青冷再生混合料设计技术要求

试验项目			技术要求
空隙率(%)			9~14
劈裂试验(15℃)	劈裂强度(MPa)	不小于	0.40(基层、底基层),0.50(下面层)
	干湿劈裂强度比(%)	不小于	75
马歇尔稳定度试验(40℃)	马歇尔稳定度(kN)	不小于	5.0(基层、底基层),6.0(下面层)
	浸水马歇尔残留稳定度(%)	不小于	75
冻融劈裂强度比 TSR(%)		不小于	70

注:(1)任选劈裂试验和马歇尔稳定度试验之一作为设计要求,推荐使用劈裂试验。

(2)空隙率宜控制在 12% 以内。

# Why Cold In-Place (or Plant) Recycling

Asphalt pavements eventually will develop distress such as:

- ❖ Cracking
- ❖ Raveling
- ❖ Pot holes
- ❖ Poor Ride Quality

Traffic, weather and hardening of the asphalt binder all contribute to these problems.







2001 5 24







# Typical Pavement Structure in China



4 cm surfacing

14 cm binder course

25-36 cm cement treated aggregate course

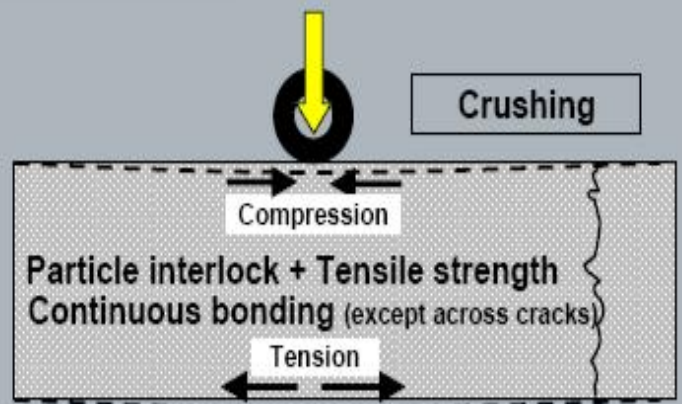


Typical pavement structures in china



# Pavement Failure in China

- Shrinkage cracking
- 1. Fatigue cracking
- 2. Permanent deformation



# Pavement State in China

- **China 's road network is ageing(1988Y)**
- **Many designs use cement stabilized stone(95%above)**
- **Need to rehabilitate with available materials**
- **Use of foam and emulsion bitumen are appropriate solutions for many cases**



# Laboratory Tests

- **Materials**
- **Testing program**
- **Mechanical tests**

# Materials

- **Shaan'xi**
  - Xi' an-Bao'ji Expressway
  - Old cement treated base, with old surfacing and some subbase
  - Poor quality base (lime fly ash basecourse)
- **Untreated materials obtained from behind recycler during road construction**
  - Treated in laboratory
  - Foamed bitumen and cement

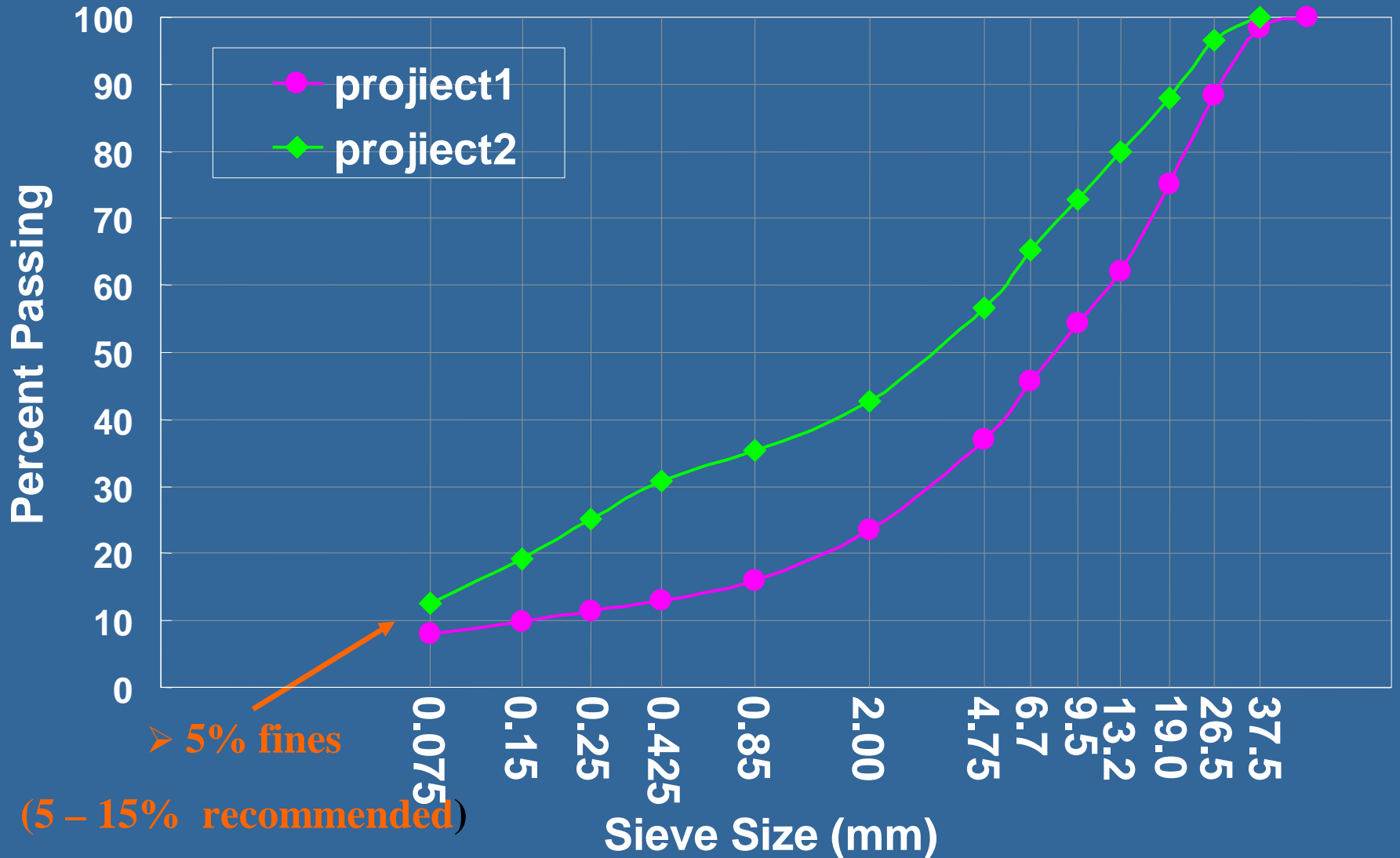
# Lab Mixers

- Foam mixing using high speed twin shaft pugmill mixer
  - Results more comparable with field mixes



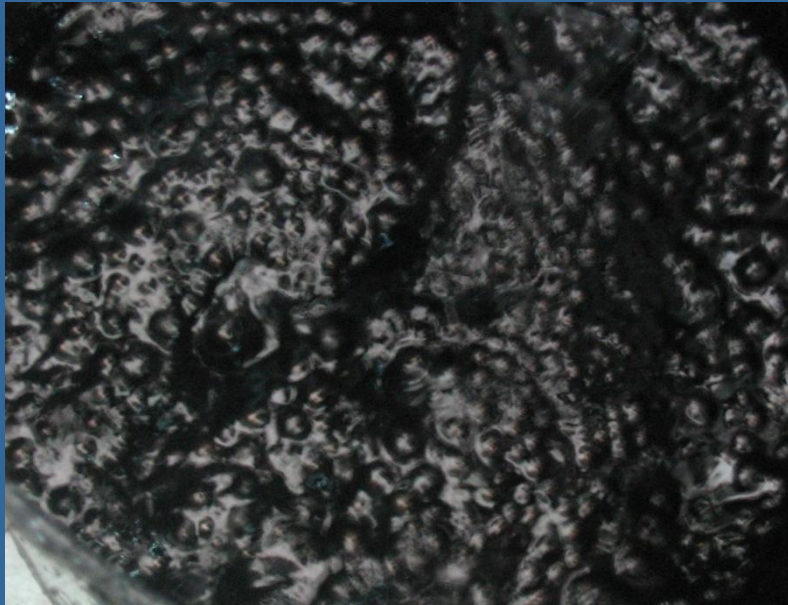


# Materials: Gradation

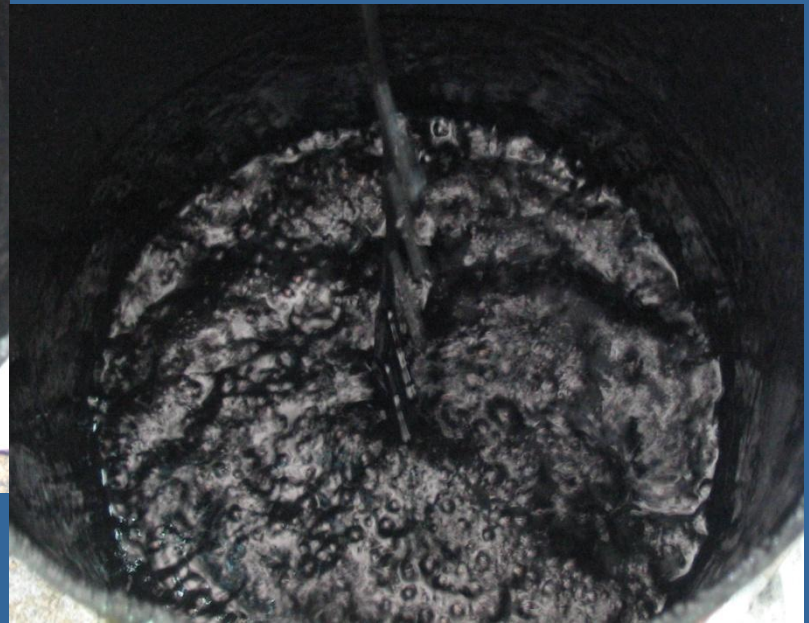
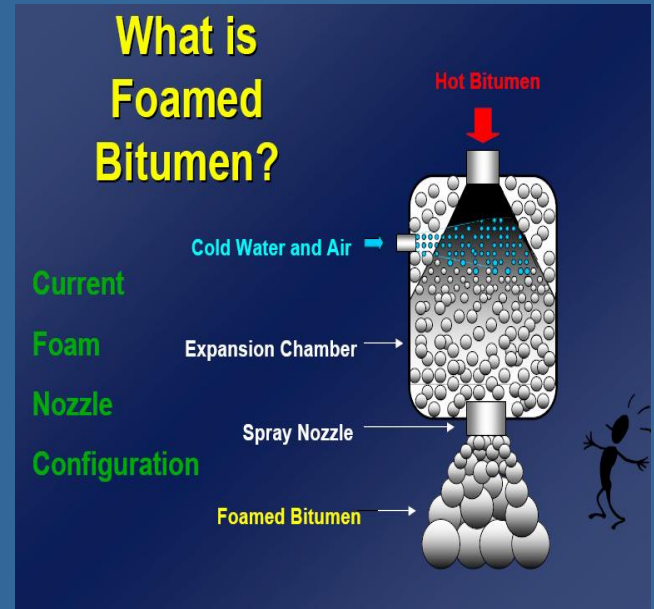


# Lab testing Program

- **Material passing the 19mm sieve was used in all lab tests**
  - **UCS**
  - **ITS**
  - **Creep**
  - **Fatigue**

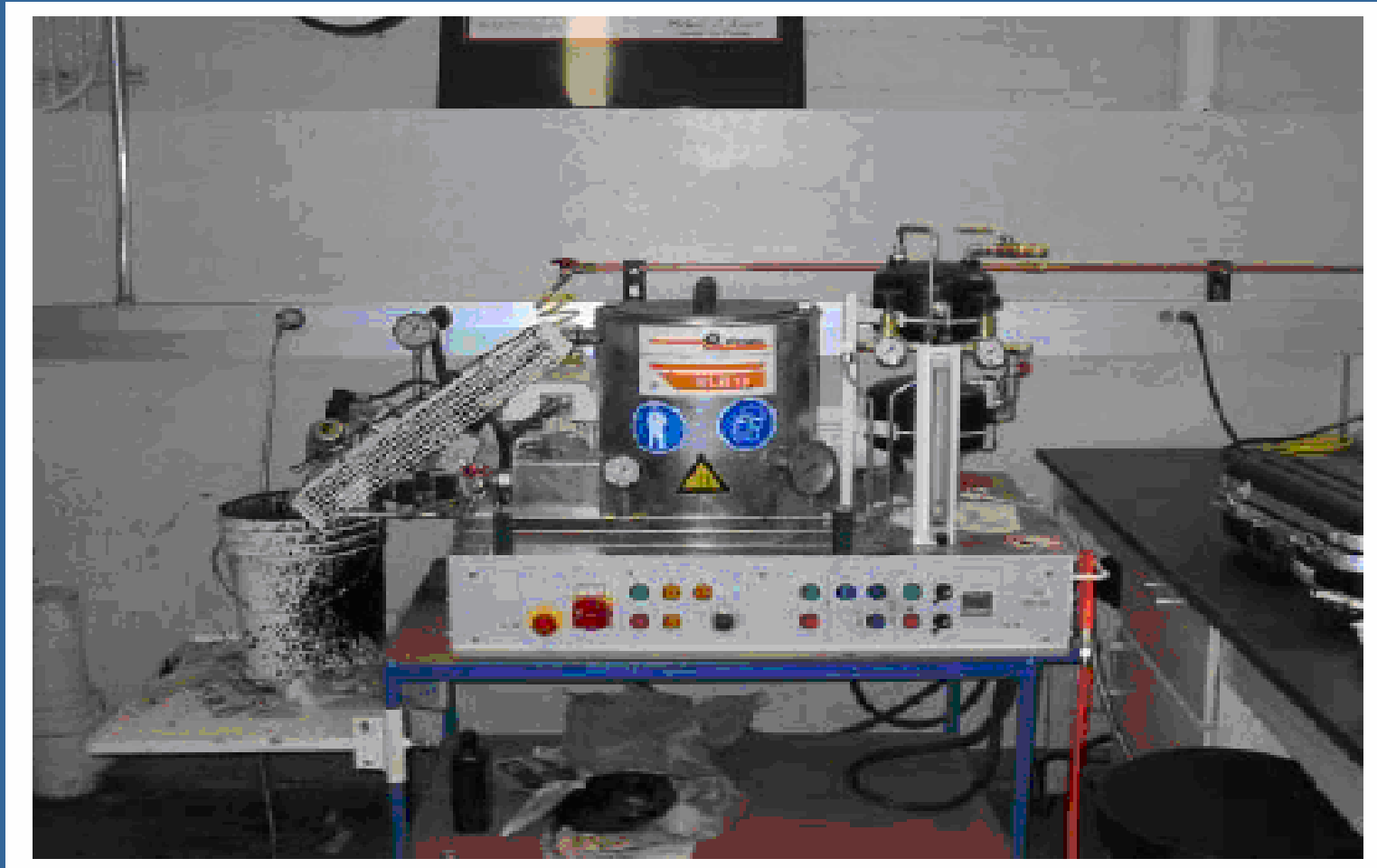


Foam disappear



Foam form





WLB10 Foaming Equipment

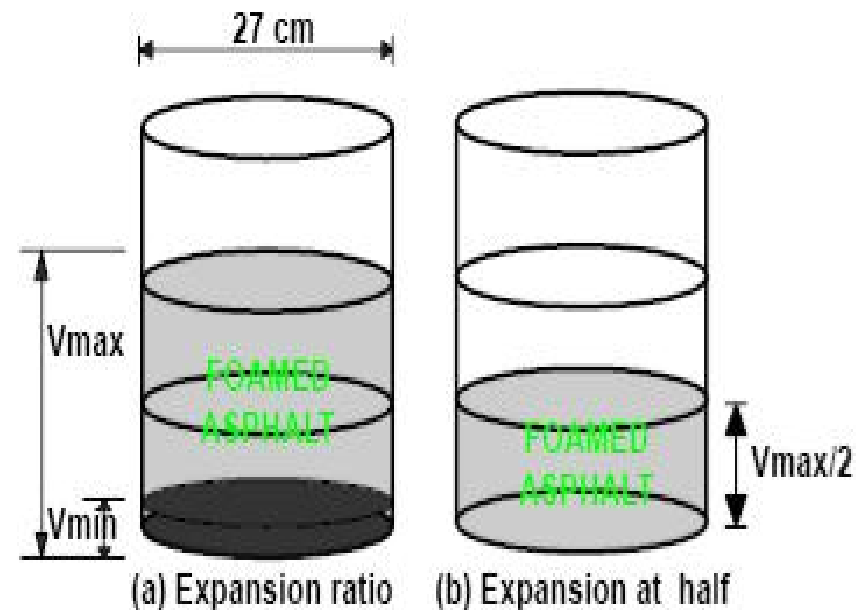
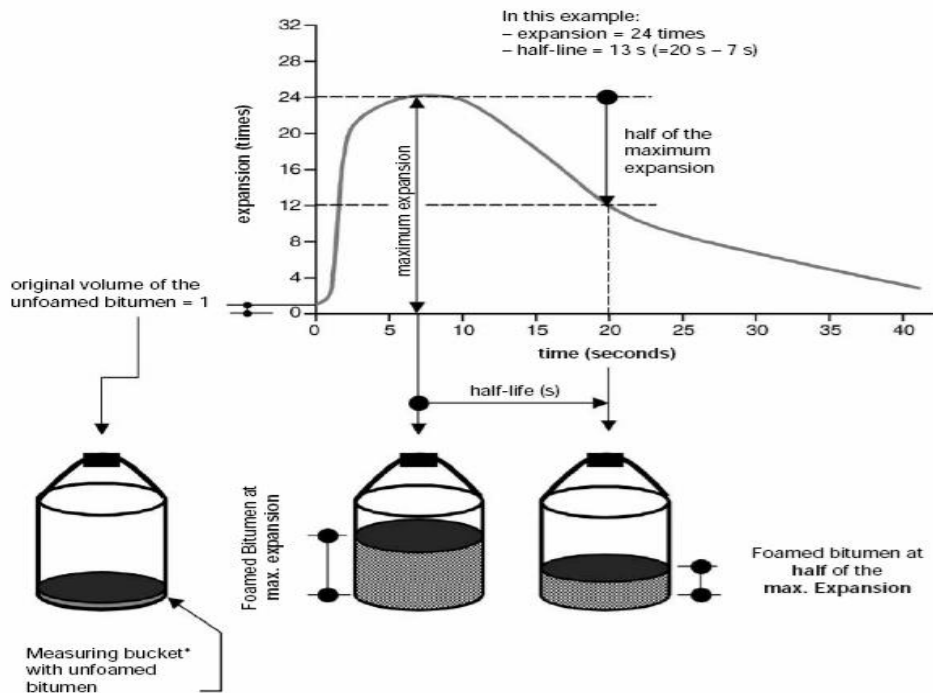


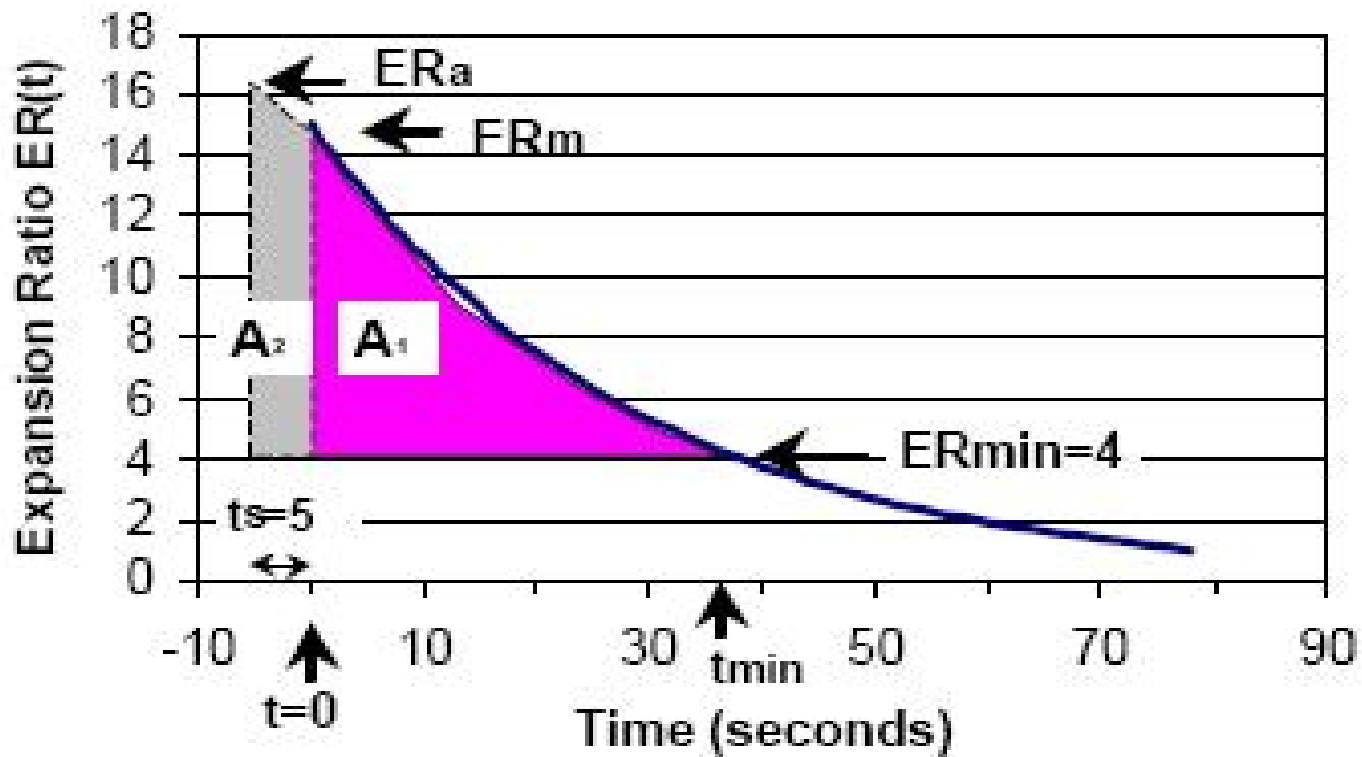
# Foamed Asphalt Characteristics

## Foamed asphalt evaluation indicators

Expansion Ratio that is a measure of the viscosity of the foam and will determine how well it will disperse in the mix. It is calculated as the ratio of the maximum volume of foam relative to its original volume; and

Half-Life is a measure of the stability of the foam and provides an indication of the rate of collapse of the foam. It is calculated as the time taken in seconds for the foam to collapse to half of its maximum volume.





$$FI = \frac{-\tau_{1/2}}{\ln 2} \times \left( 4 - ER - 4 \times \ln\left(\frac{4}{ER}\right) \right) + \left( \frac{1+c}{2c} \right) \times ER \times t_s$$



# Foaming Test for Different Asphalts

Asphalts

Temperature

Water content

ZH90#

SK90#

LH90#

XSH90#

HXL70#

ESS070#

150 °C

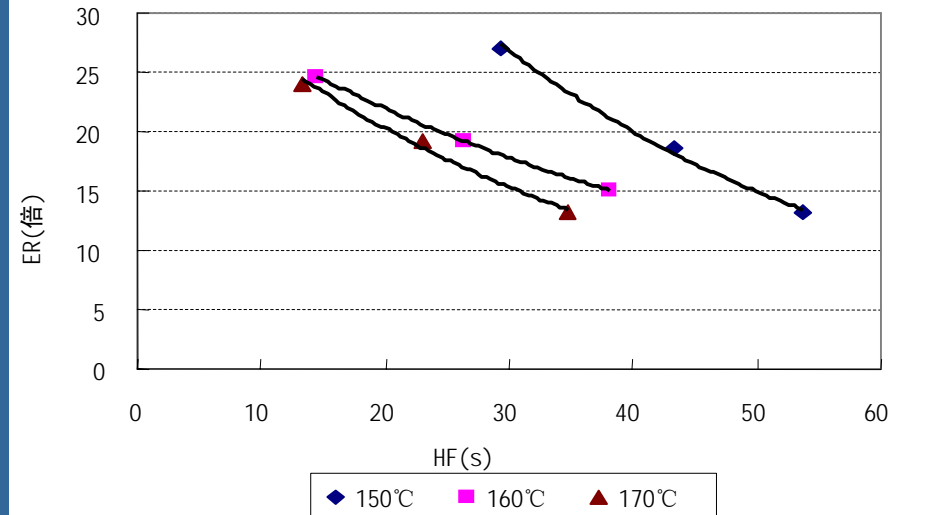
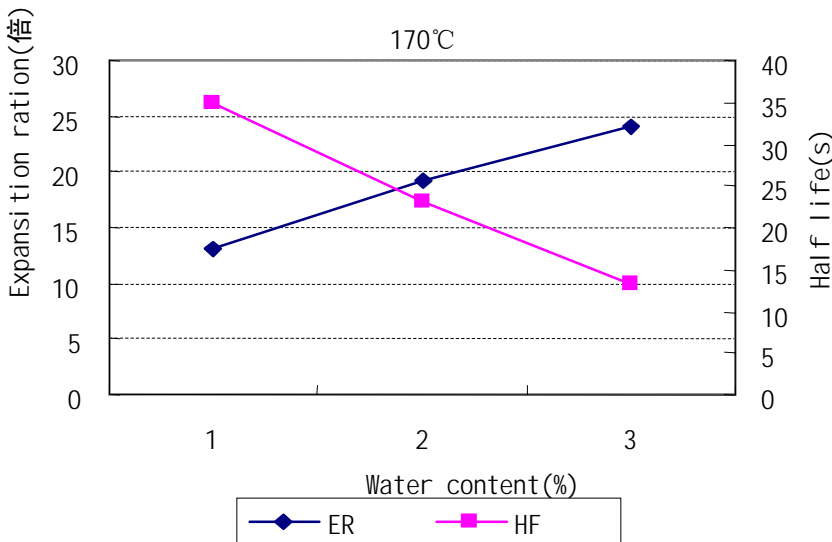
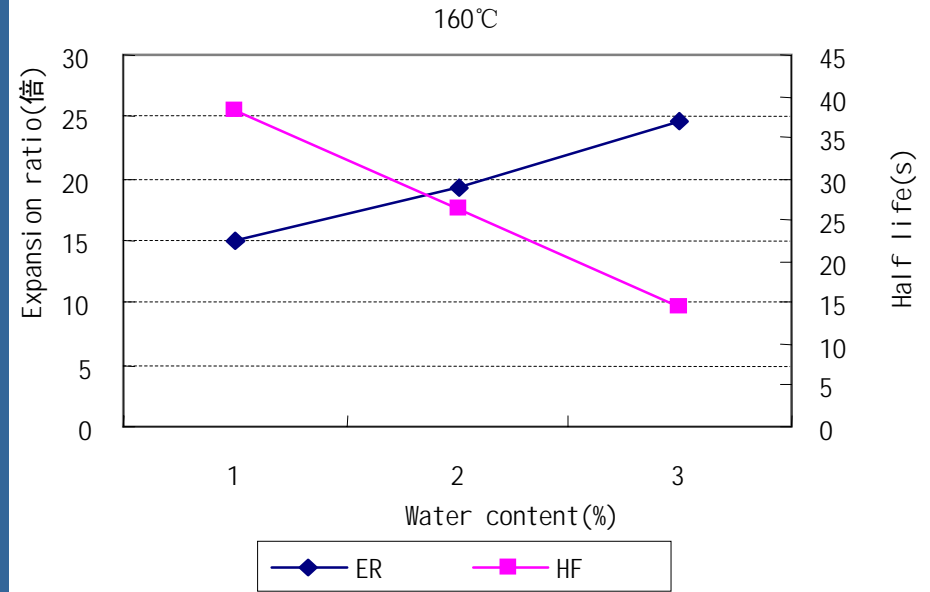
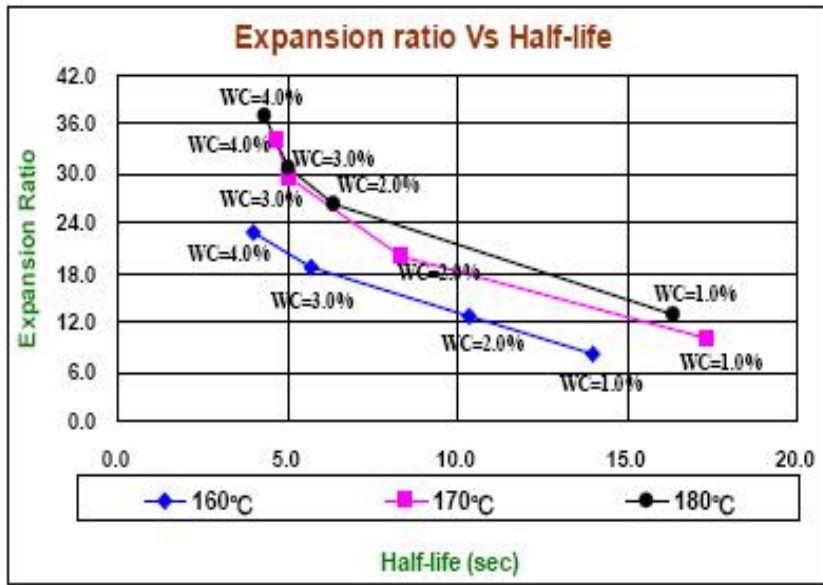
160 °C

170 °C

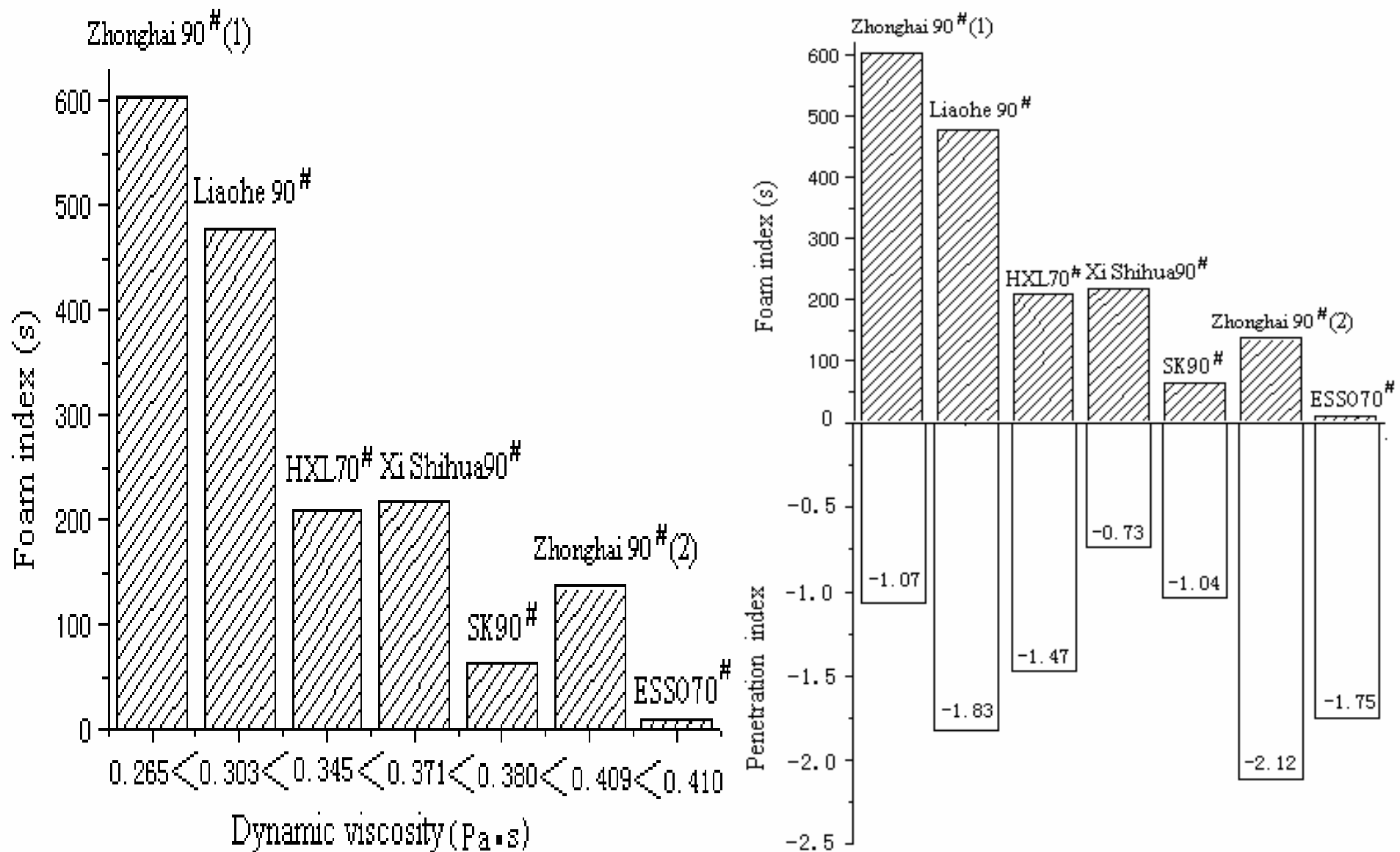
1%

2%

3%

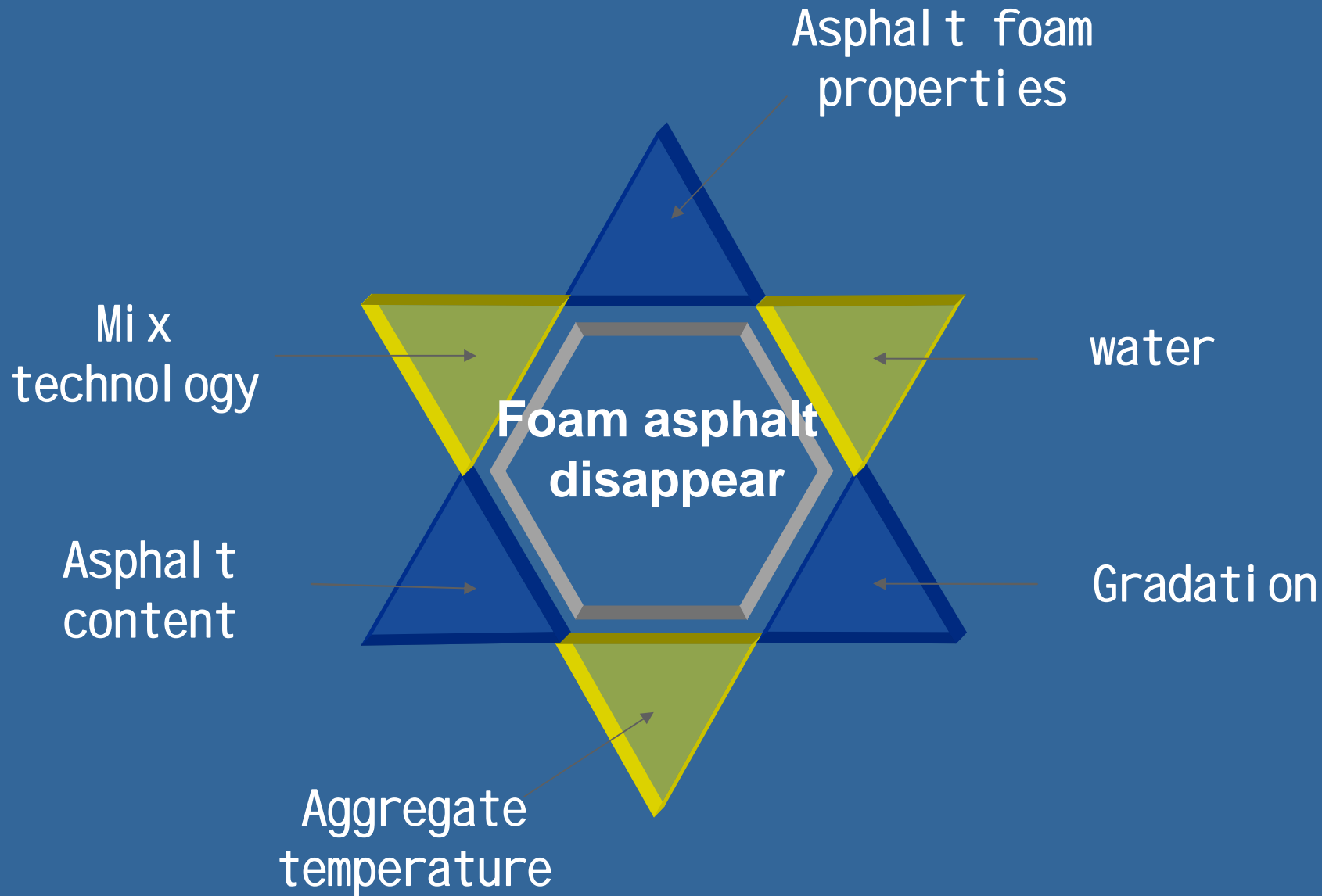


Test results of ZH foamed asphalt



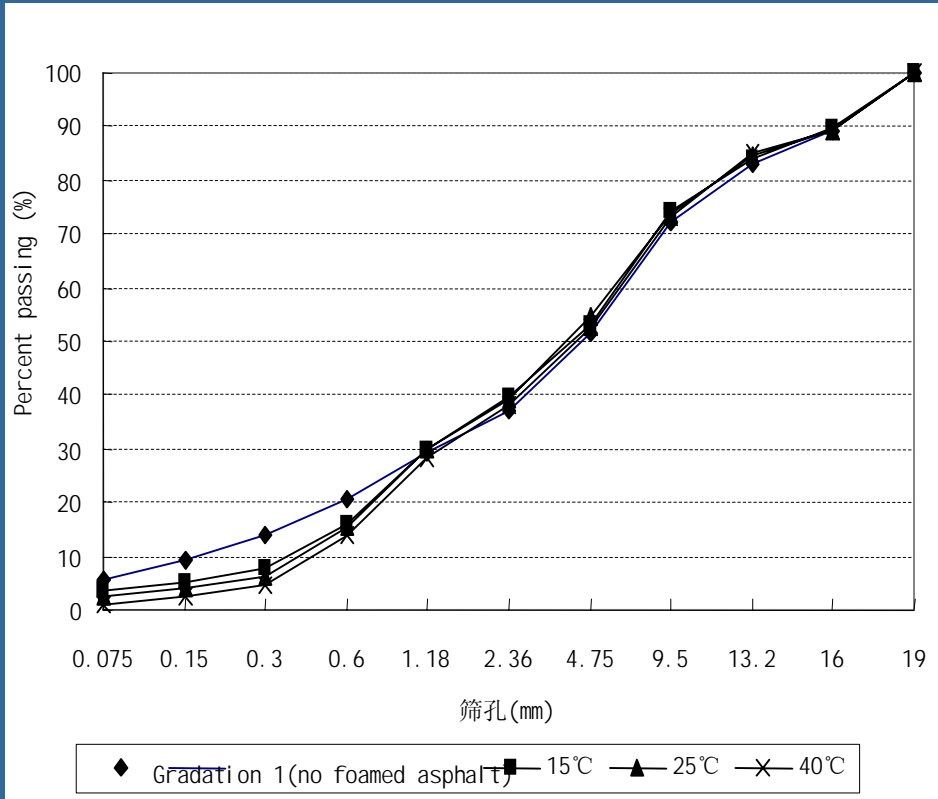
**FI and Viscosity or PI**





# Foamed Asphalt Disappear Test

## 1. Effect of asphalt foaming and RAP temperature:



# 2.Effect of RAP gradation :



SK90#与G2 ( fine less )



ZH90# (1) 与G2 (fine less)



Foamed asphalt mastic



### 3.Effect of mixing moisture:



100%OMC



50%OMC



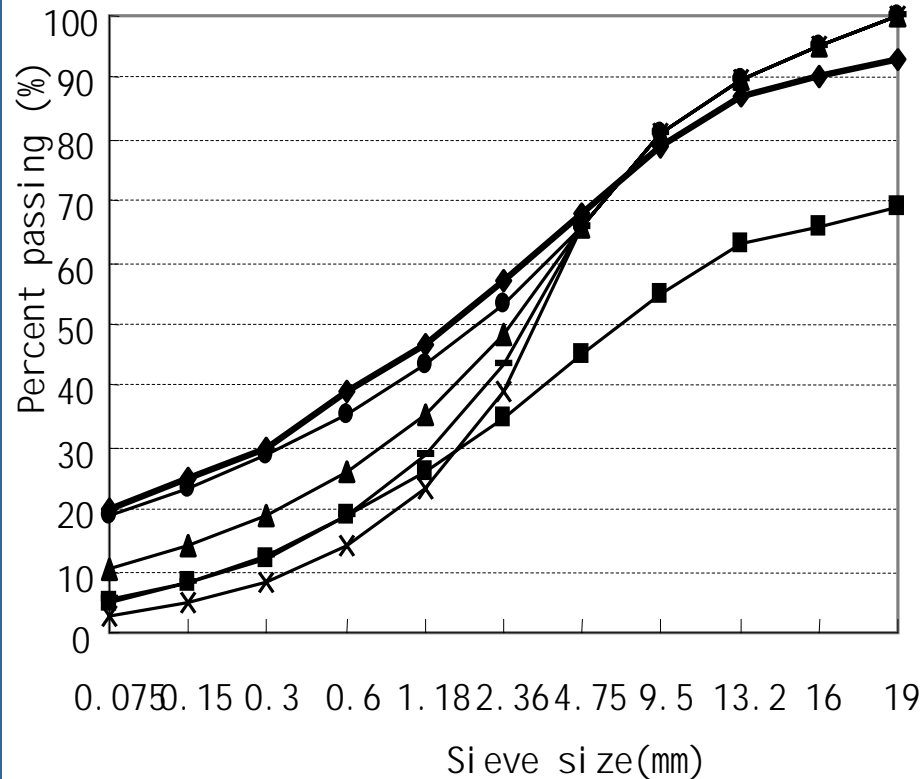
Aggregate with foamed asphalt mastic





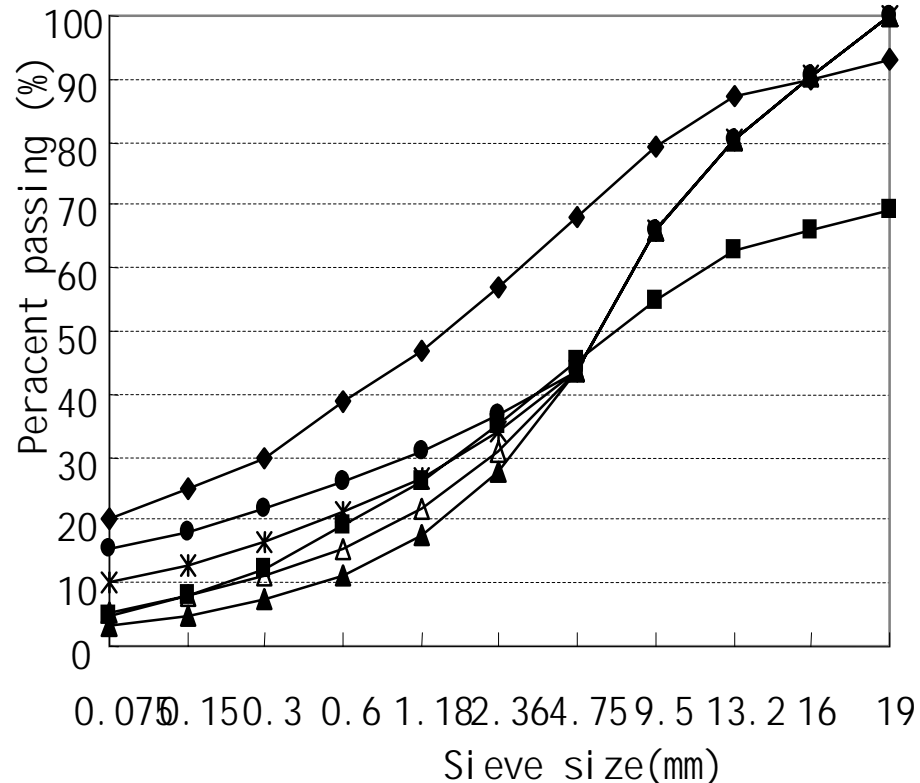
# Gradation of foamed asphalt mixtures

## 1. Effect of fine aggregate on mixture gradations



◆ Wirtgen up    ■ Wirtgen down    × Gradation 1  
— Gradation 2    ▲ Gradation 3    ● Gradation 4

G1~G4 ( $n_{CA}=0.3$ )

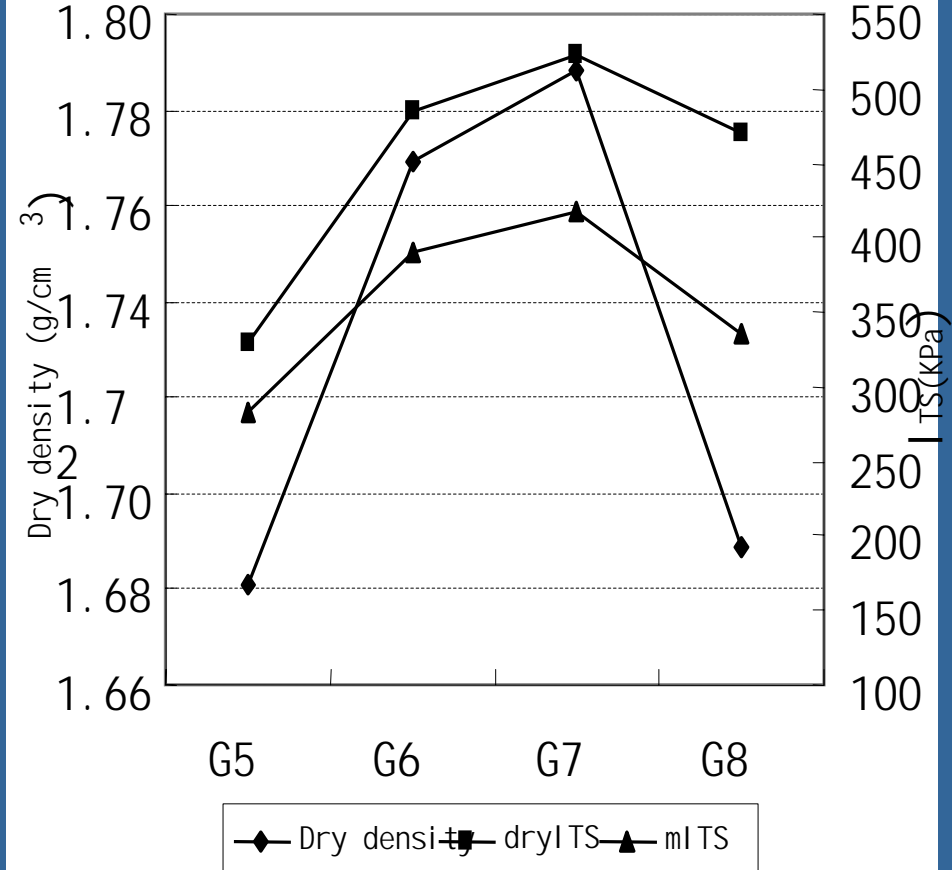
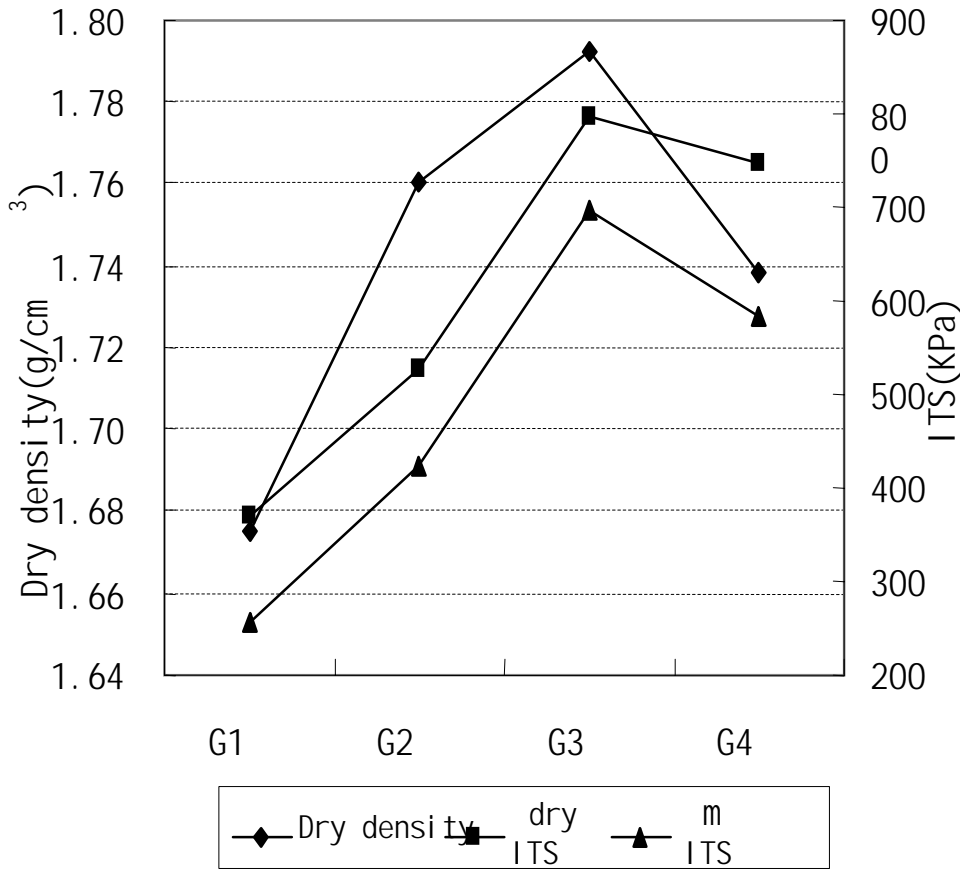


◆ Wirtgen up    ■ Wirtgen down    ▲ Gradation 5  
— Gradation 6    × Gradation 7    ● Gradation 8

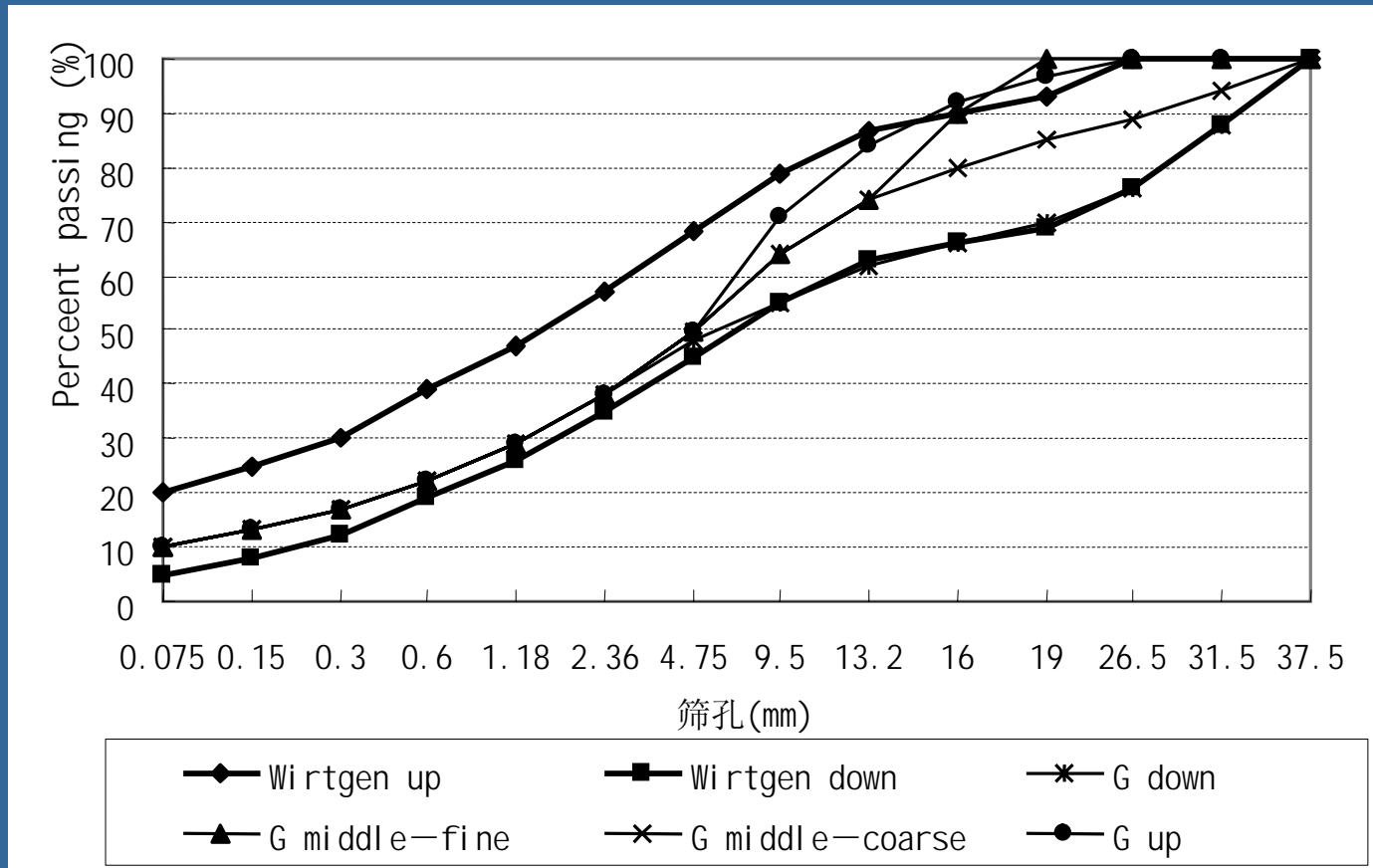
G5~G8 ( $n_{CA}=0.6$ )

<b>Filler contents (%)</b>	<b>Optimum foamed asphalt content (%)</b>	<b>Filler to asphalt</b>
<b>3~5</b>	<b>3.0~3.5</b>	<b>0.9~1.7</b>
<b>5~10</b>	<b>3.5~4.0</b>	<b>1.5~2.9</b>
<b>10~20</b>	<b>4.0~4.5</b>	<b>2.2~5.0</b>

# Gradation and ITS

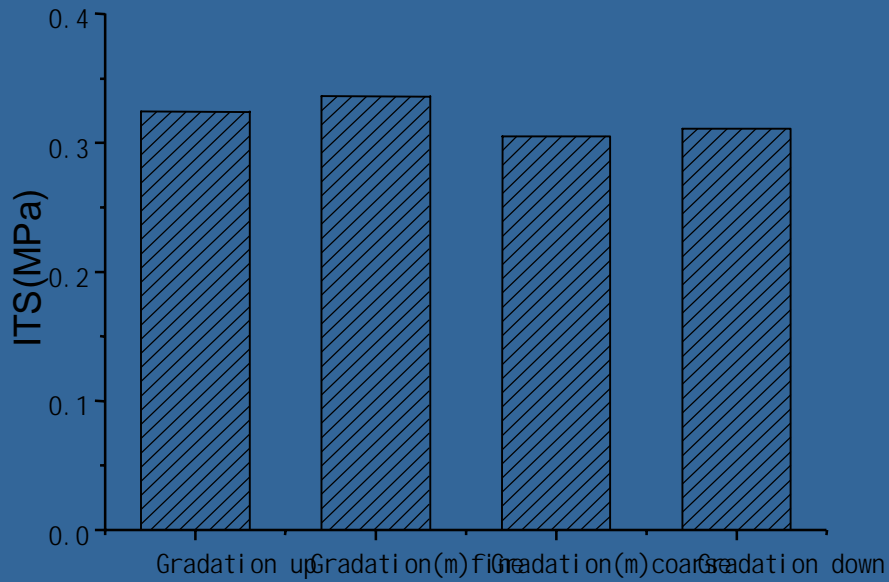


## 2.Effect of aggregate :

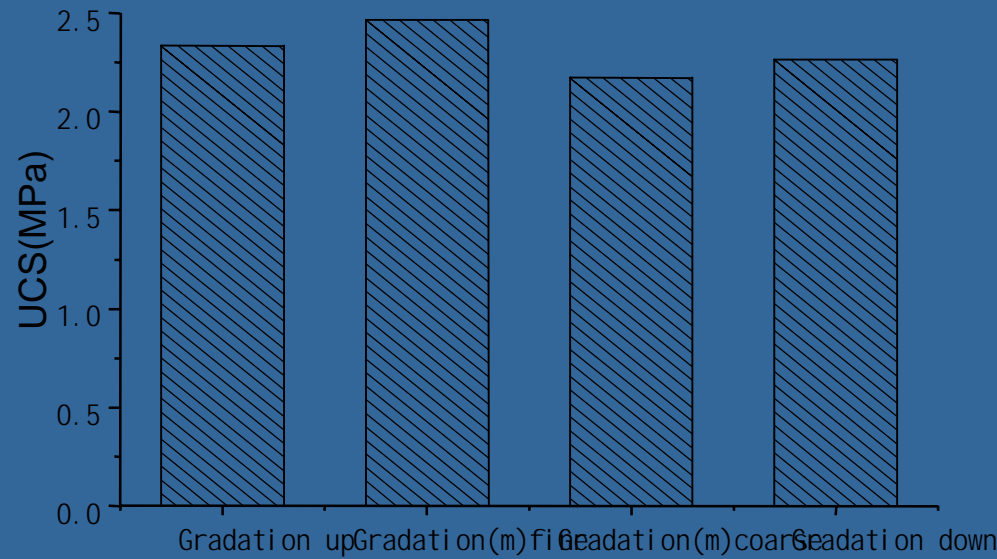


Gradation





**Effect of four coarse aggregates on ITS**



**Effect of four coarse aggregates on UCS**

## Gradation requirement of foamed asphalt mixture

Sieve Size (mm)	Percent passing (%)													
	37.5	31.5	26.5	19	16	13.2	9.5	4.75	2.36	1.18	0.6	0.3	0.15	0.075
Up limit	100	100	100	93	90	87	79	68	57	47	39	30	25	20
Down limit	100	88	76	69	66	63	55	43	31	22	16	11	7	5

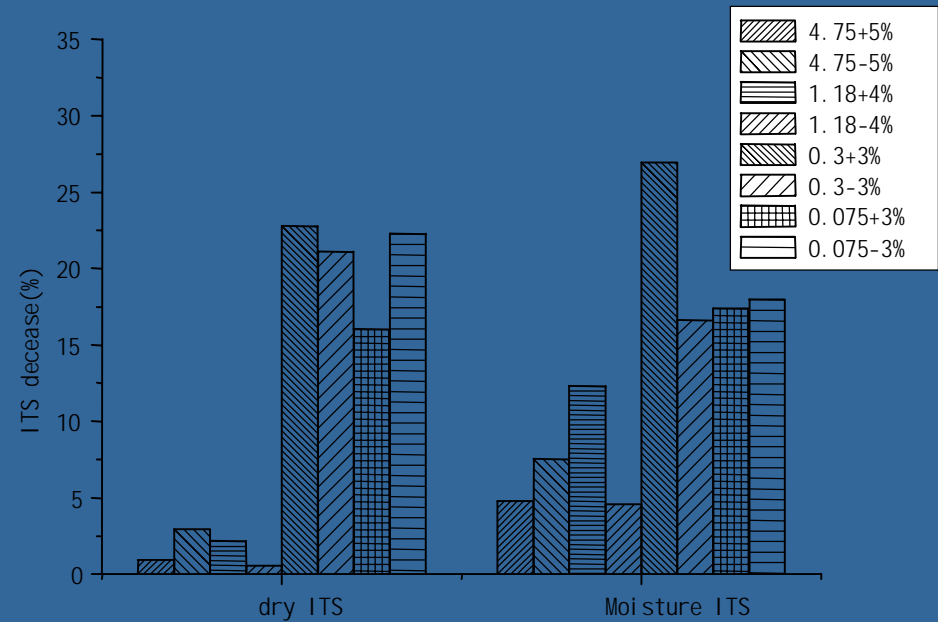
# 4. Gradation error :

## Test methods

<b>Sieve size (mm)</b>	<b>4.75</b>	<b>1.18</b>	<b>0.3</b>	<b>0.075</b>
<b>Percent passing error (%)</b>	<b>± 5</b>	<b>± 4</b>	<b>± 3</b>	<b>± 3</b>

## Allow error Based on construction

<b>Key size (mm)</b>	<b>4.75</b>	<b>1.18</b>	<b>0.3</b>	<b>0.075</b>
<b>Allow error range (%)</b>	<b>± 8</b>	<b>± 7</b>	<b>± 3</b>	<b>± 2</b>



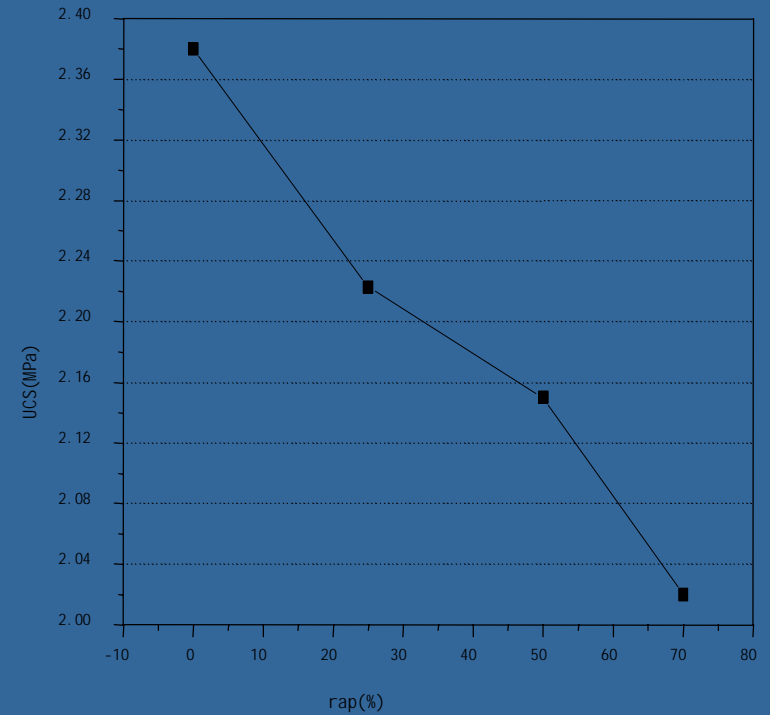
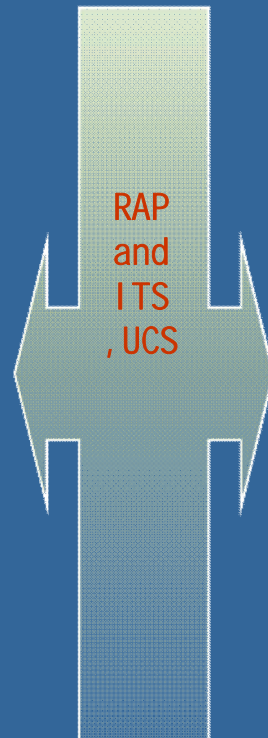
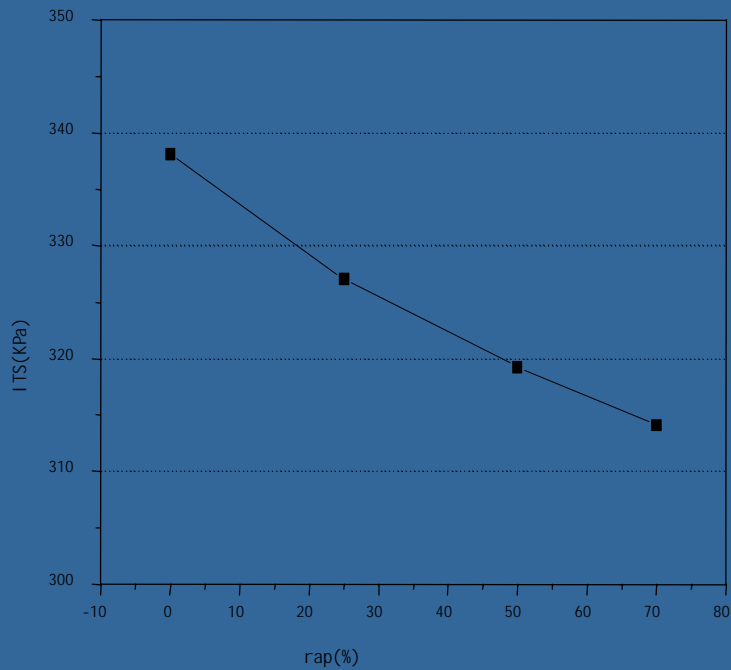
ITS decreasing percent based gradations error





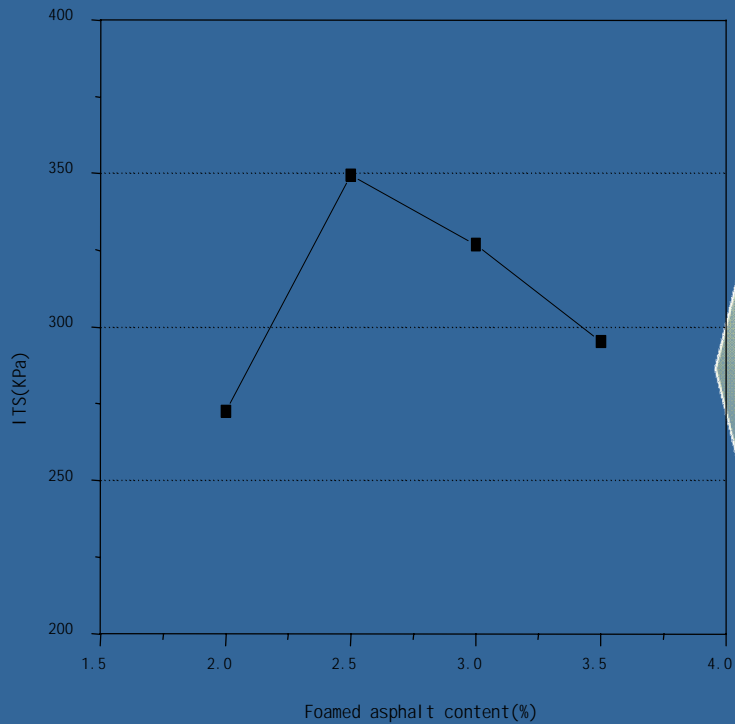
# 1.Effect of RAP content :

Test plan : two different RAP, four RAP (0%、25%、50%、70%)

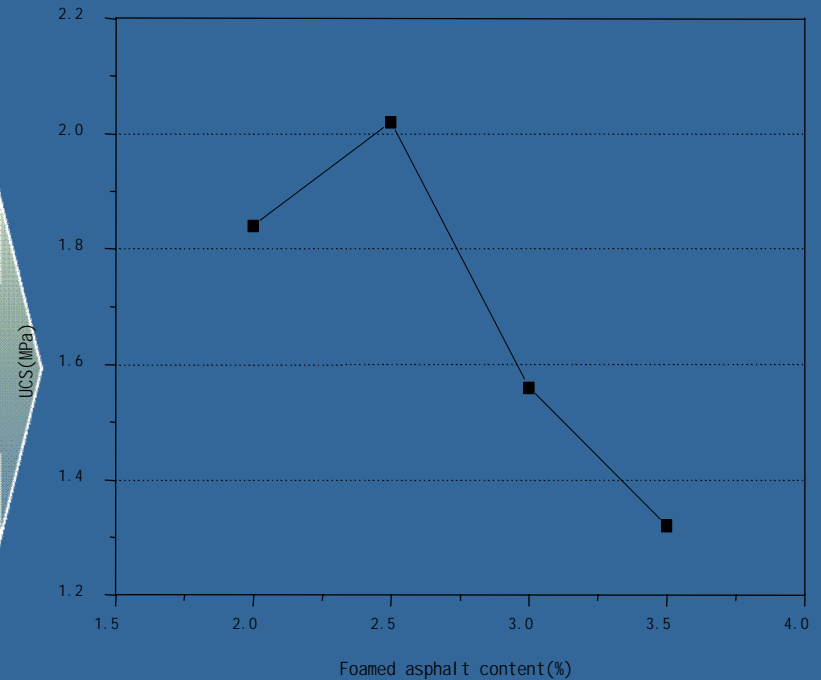


## 2.Effect of foamed asphalt content :

Test : two kinds of RAP content (0%、70%) ,  
3~4 kinds of foamed asphalt contents



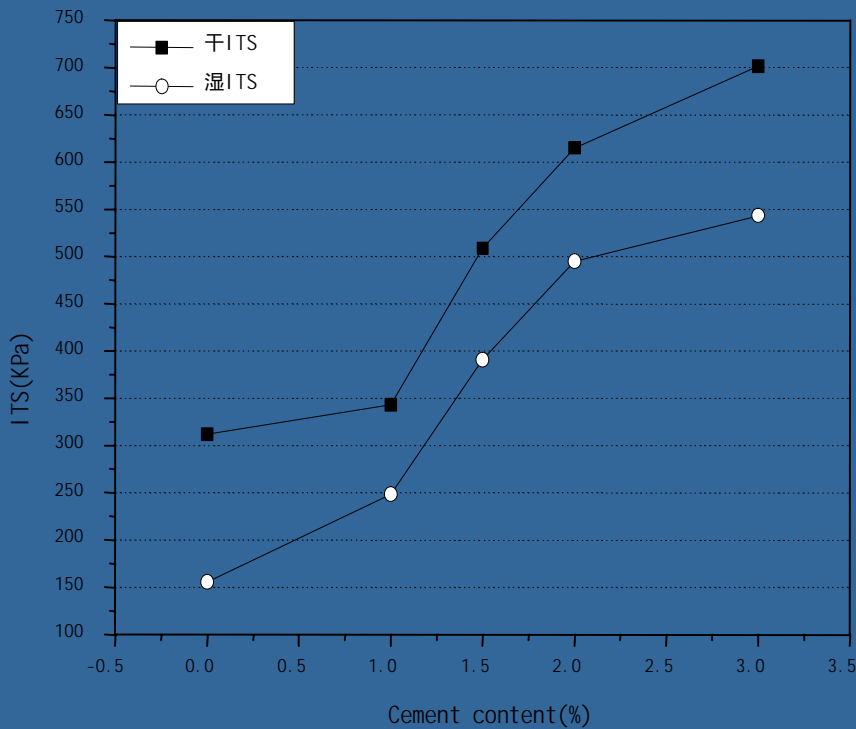
ITS and  
foamed  
asphalt  
content



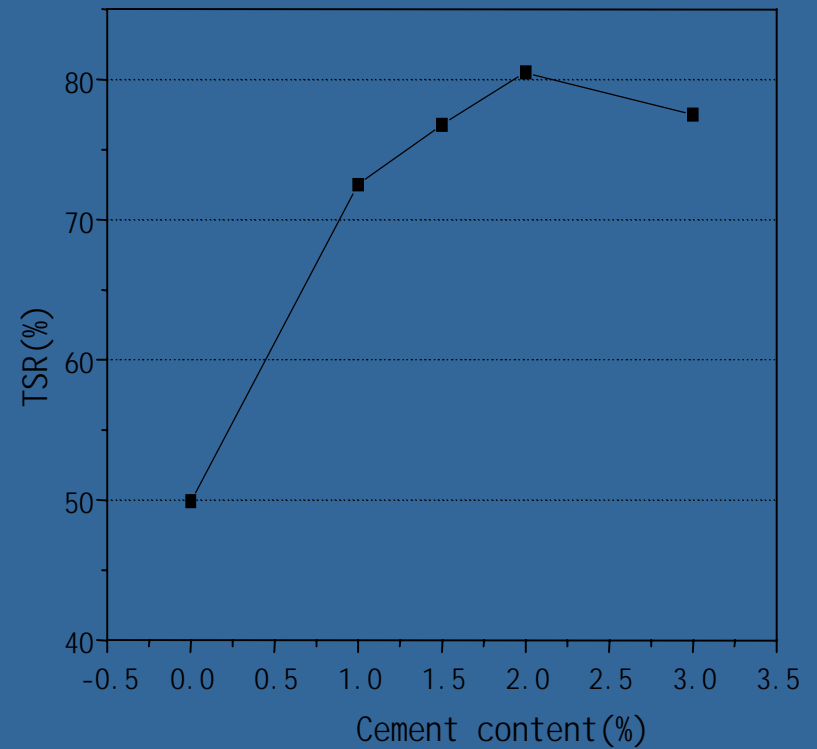
70%RAP test results

### 3.Effect of cement content:

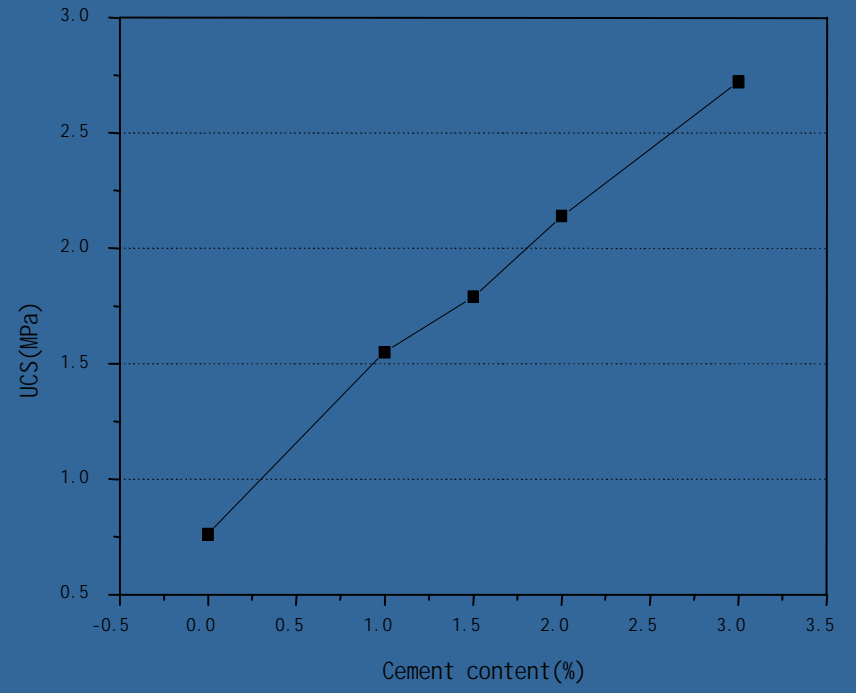
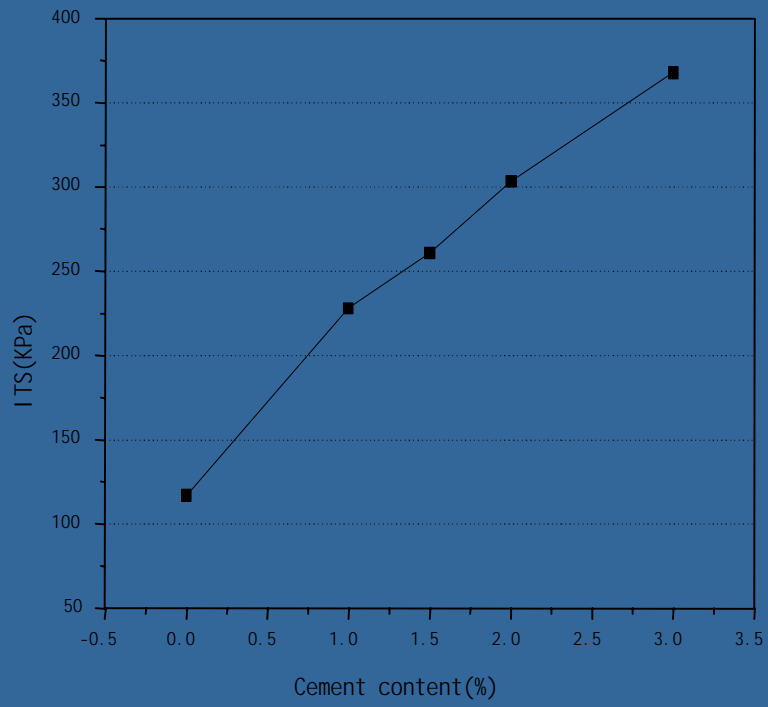
Test : five kinds of cement content (0%、1%、1.5%、2%、3%)



Strength increasing rule



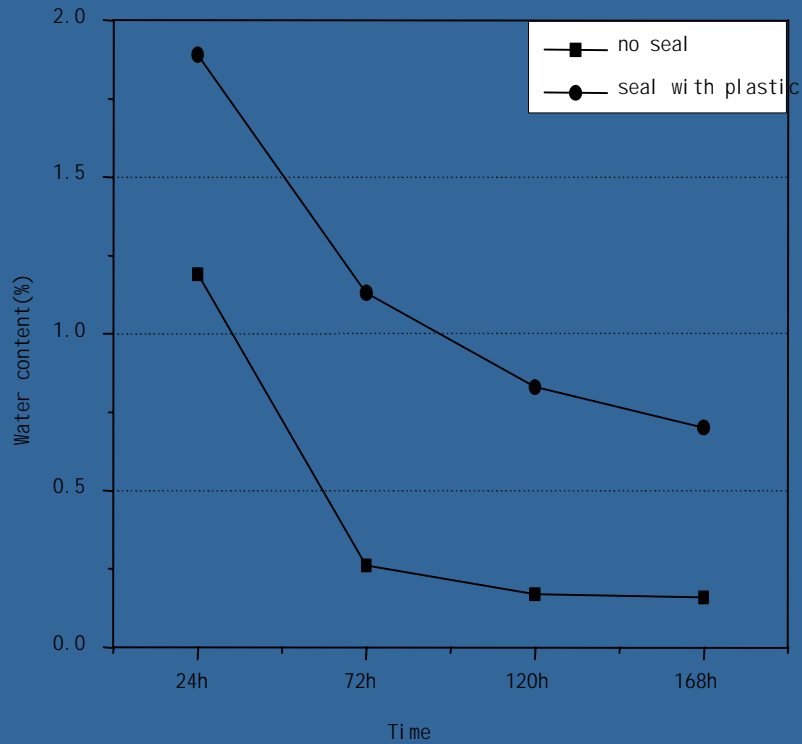
Water stability



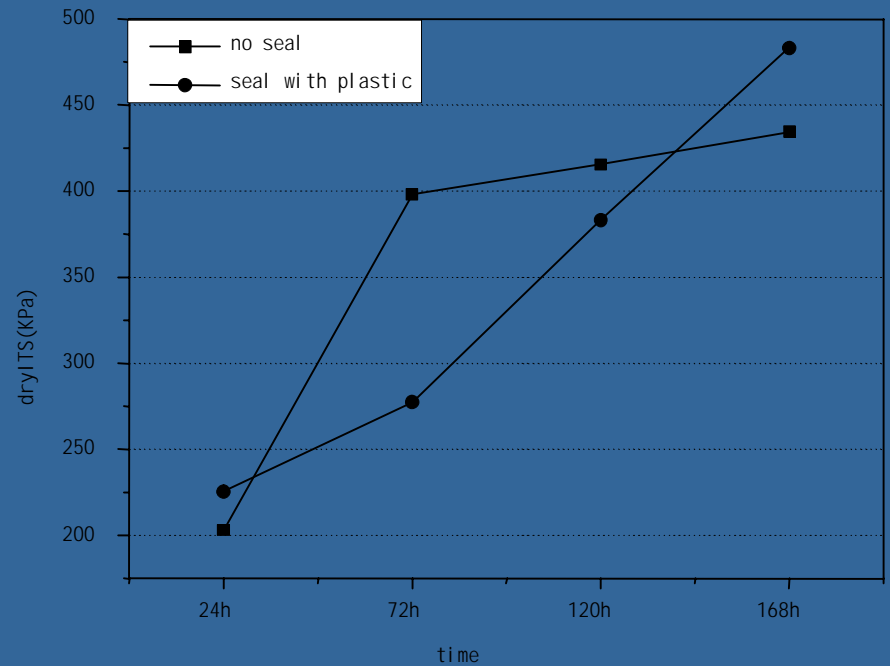
**ITS and cement content**

## 4. Effect of curing method :

Test : seal with plastic bag and no seal



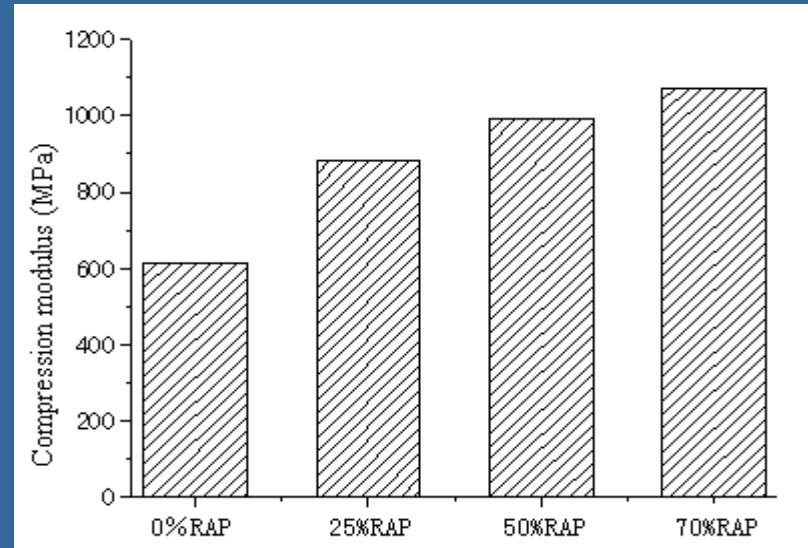
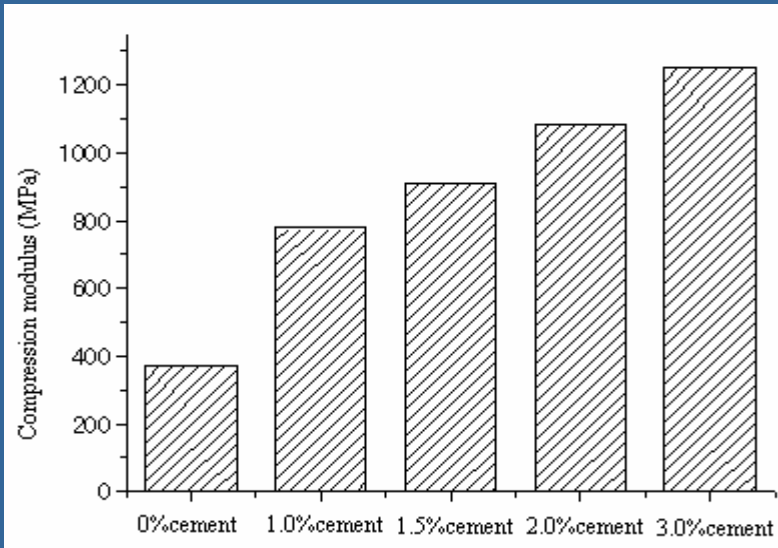
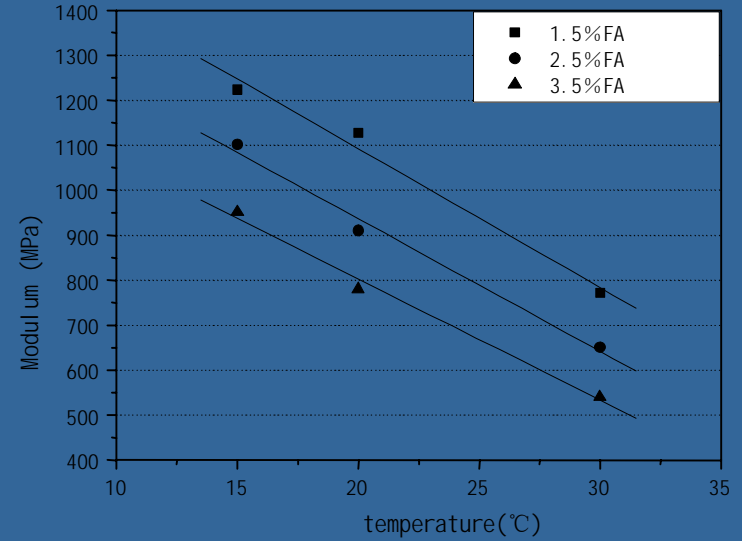
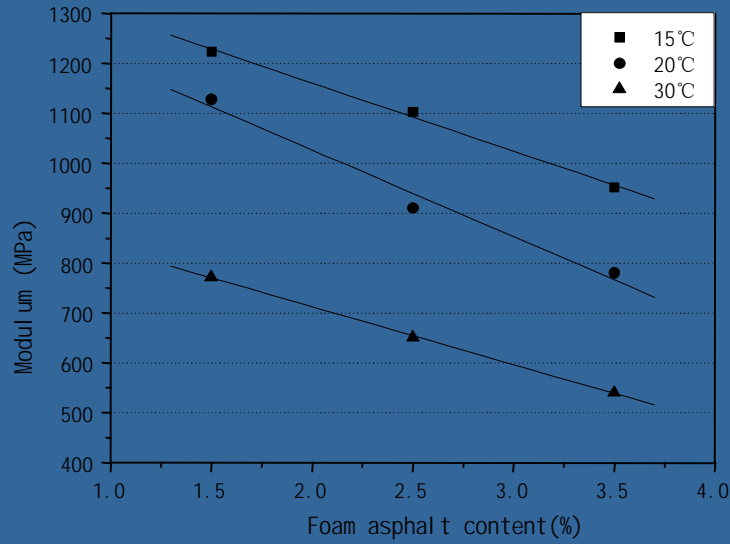
No seal



Seal with plastic bag



# Modulus of foamed asphalt mixtures



<b>Compact degree (%)</b>	<b>Modulus (MPa)</b>	<b>Compact change based on 100% compact degree</b>
97	733.8	Decrease 19.4%
100	910.5	1
103	1060.9	Increase 23.2%

<b>Curing method</b>	<b>modulus (MPa)</b>	<b>STV (MPa)</b>	<b>Water content (%)</b>	<b>Modulus percent based on dry curing (%)</b>
<b>Seal with plastic 48h (40°C)</b>	<b>910.5</b>	<b>37.3</b>	<b>2.18</b>	<b>26.8</b>
<b>Dry curing 48h (40°C)</b>	<b>1243.1</b>	<b>150.9</b>	<b>0.73</b>	<b>/</b>
<b>Dry curing 48h (40°C) soak 24h (25°C)</b>	<b>953.1</b>	<b>44.2</b>	<b>/</b>	<b>23.3</b>



# Deformation characteristics of foamed asphalt mixture

## Research plans :

1) dynamic creep test, 30°C

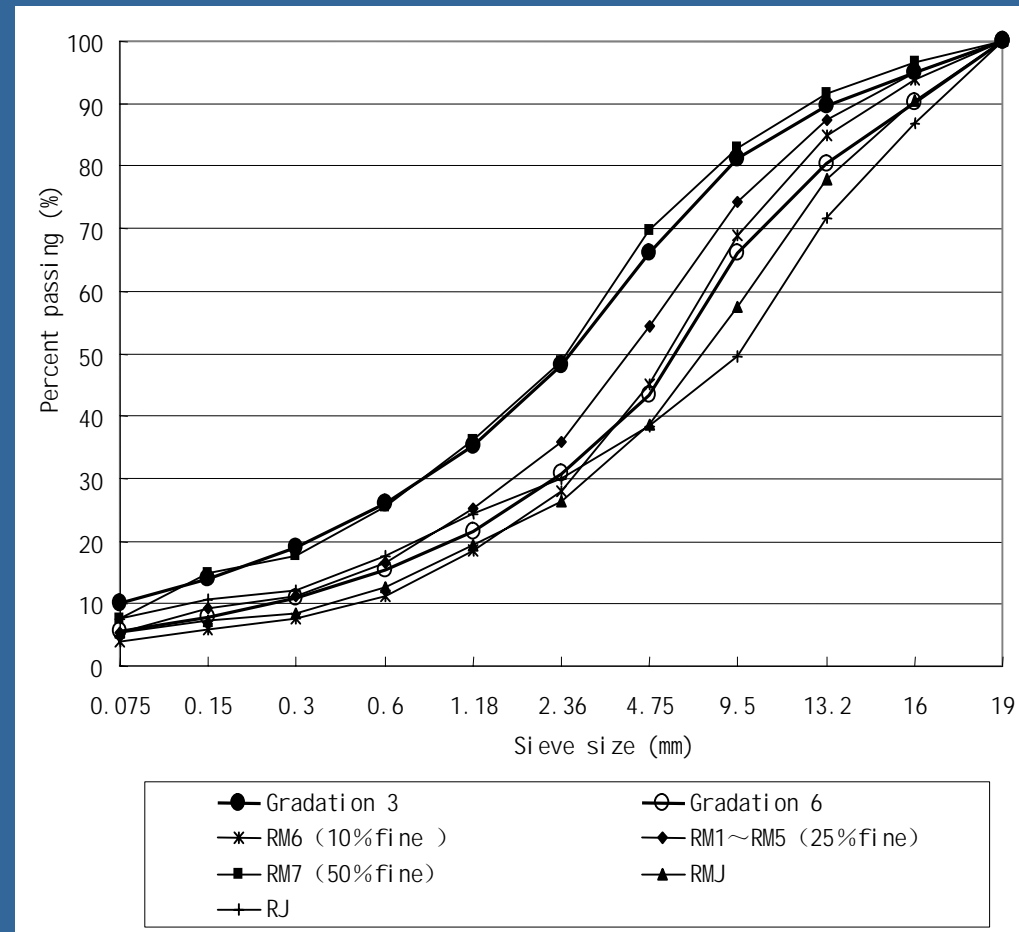
2) factors

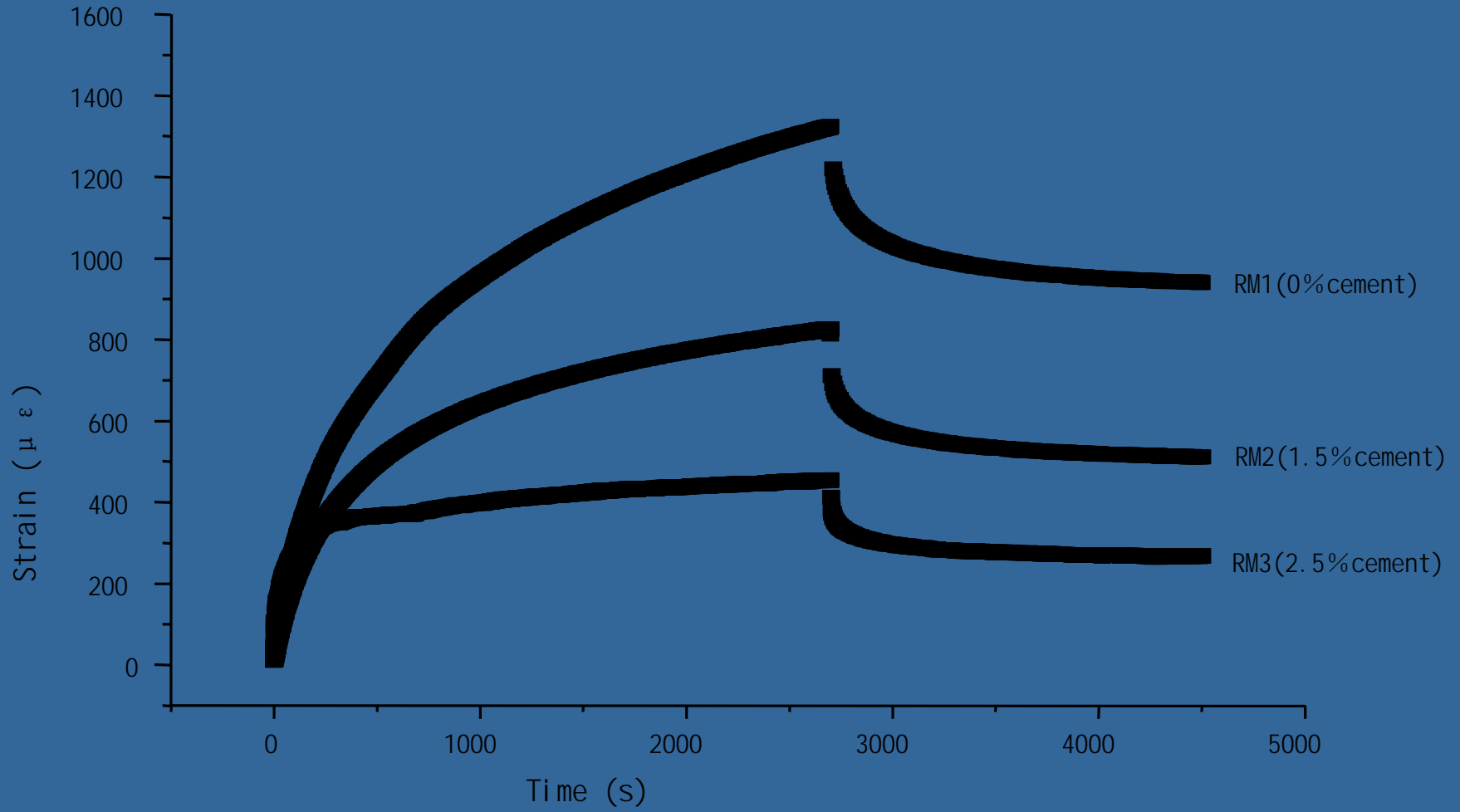
➤ Cement

➤ Foamed asphalt

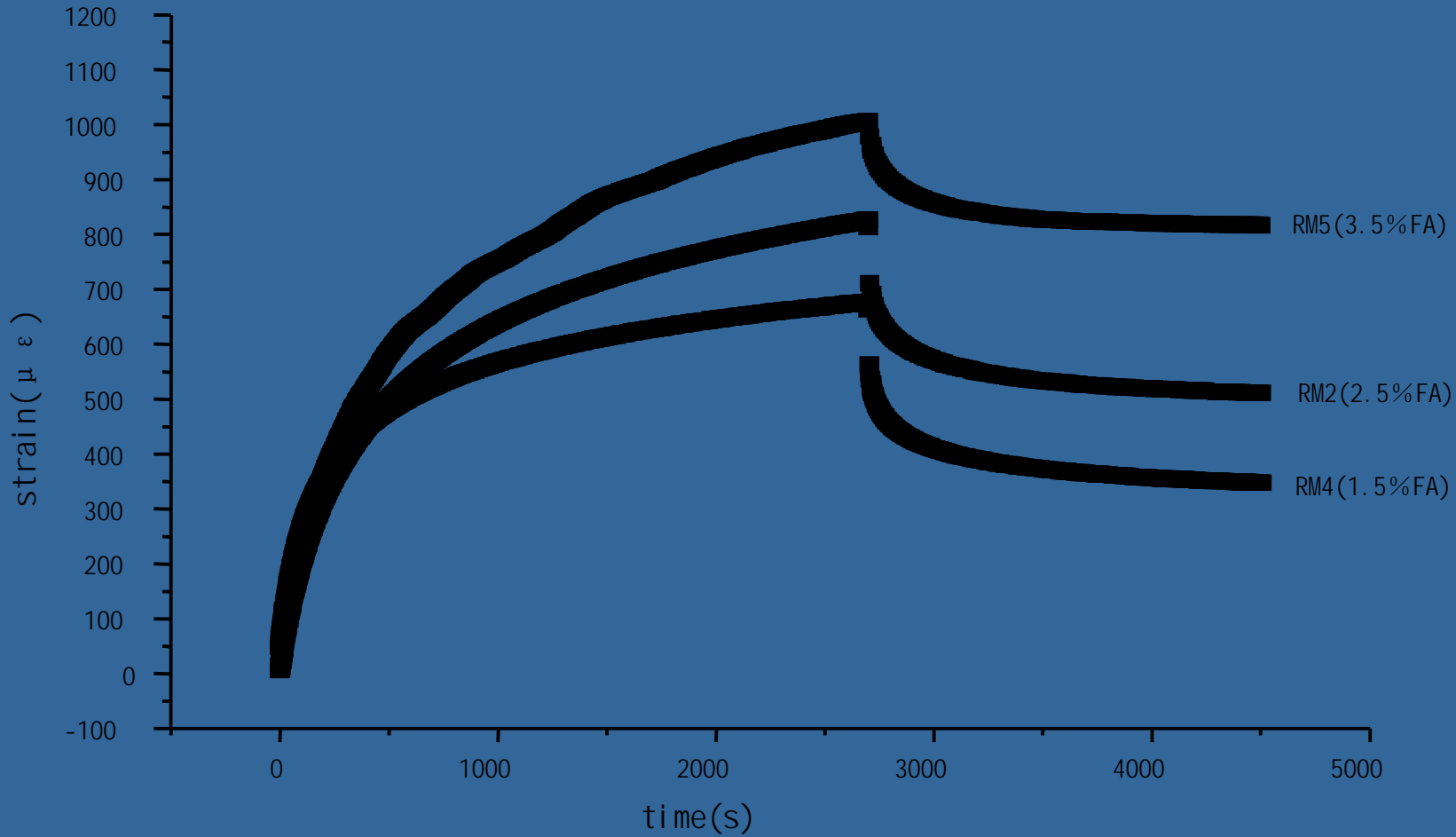
➤ Gradation

➤ Different materials

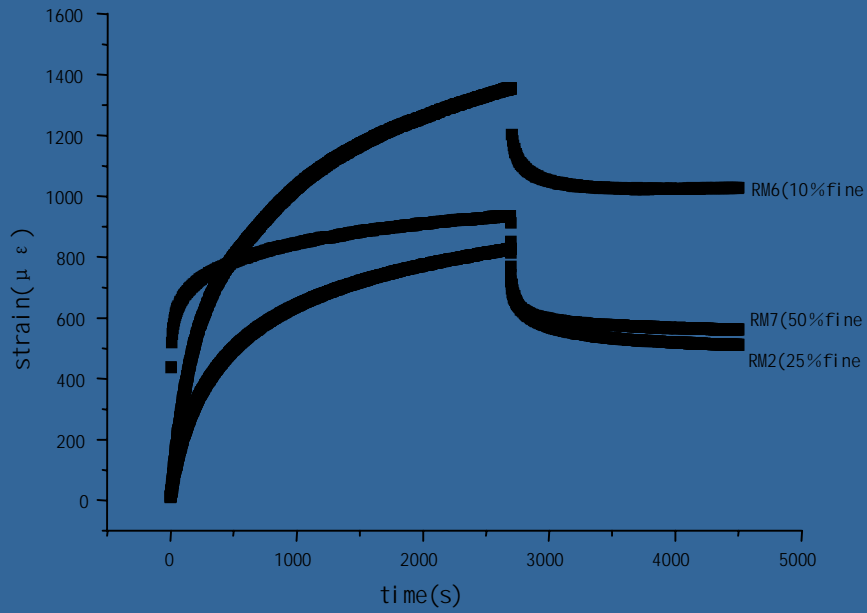




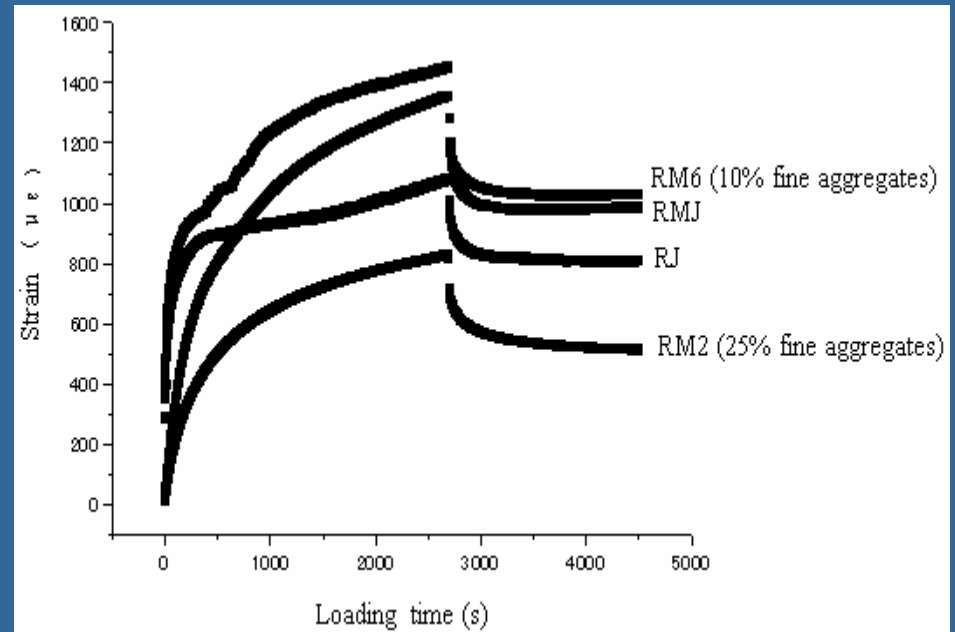
**Deformation of foamed asphalt mixture with different cement content**



**Deformation of foamed asphalt mixture  
with different foam asphalt content**



Deformation of different gradation foamed asphalt mixture



Deformation of differentt mixture



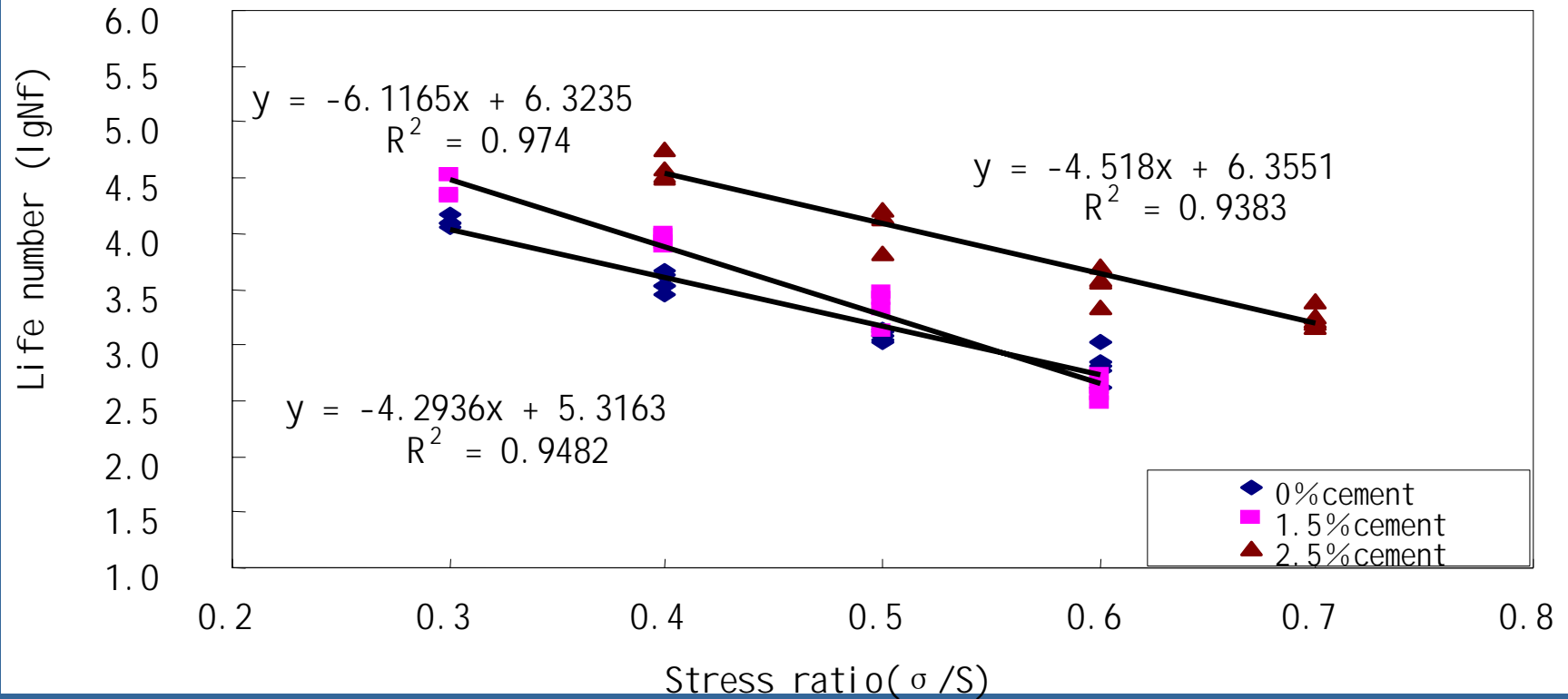


# Fatigue properties of foamed asphalt recycling mixtures

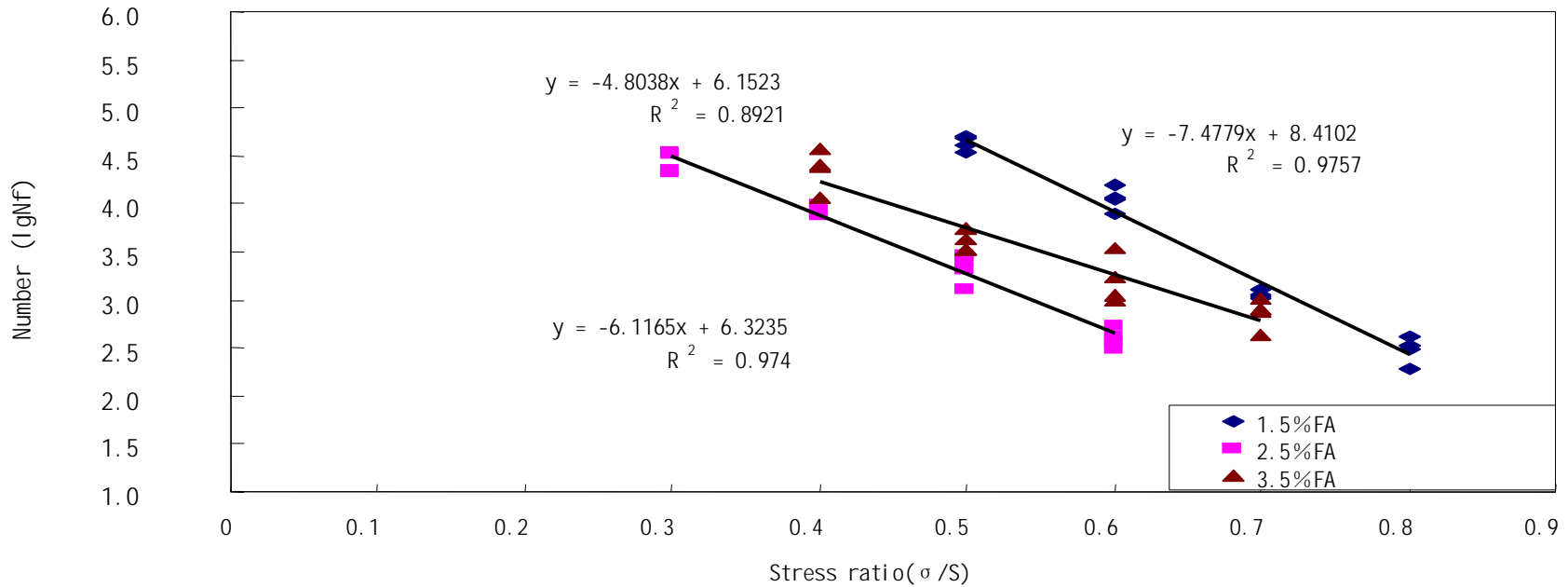
## Research plans

- 1) ITS TEST, 15°C, STRESS CONTROL MODEL ;
- 2) EFFECT OF CEMENT ON fatigue
  - Effect of Foamed asphalt content on fatigue
  - Effect of Foamed asphalt properties on fatigue
  - Effect of Different materials on fatigue

# Cement content



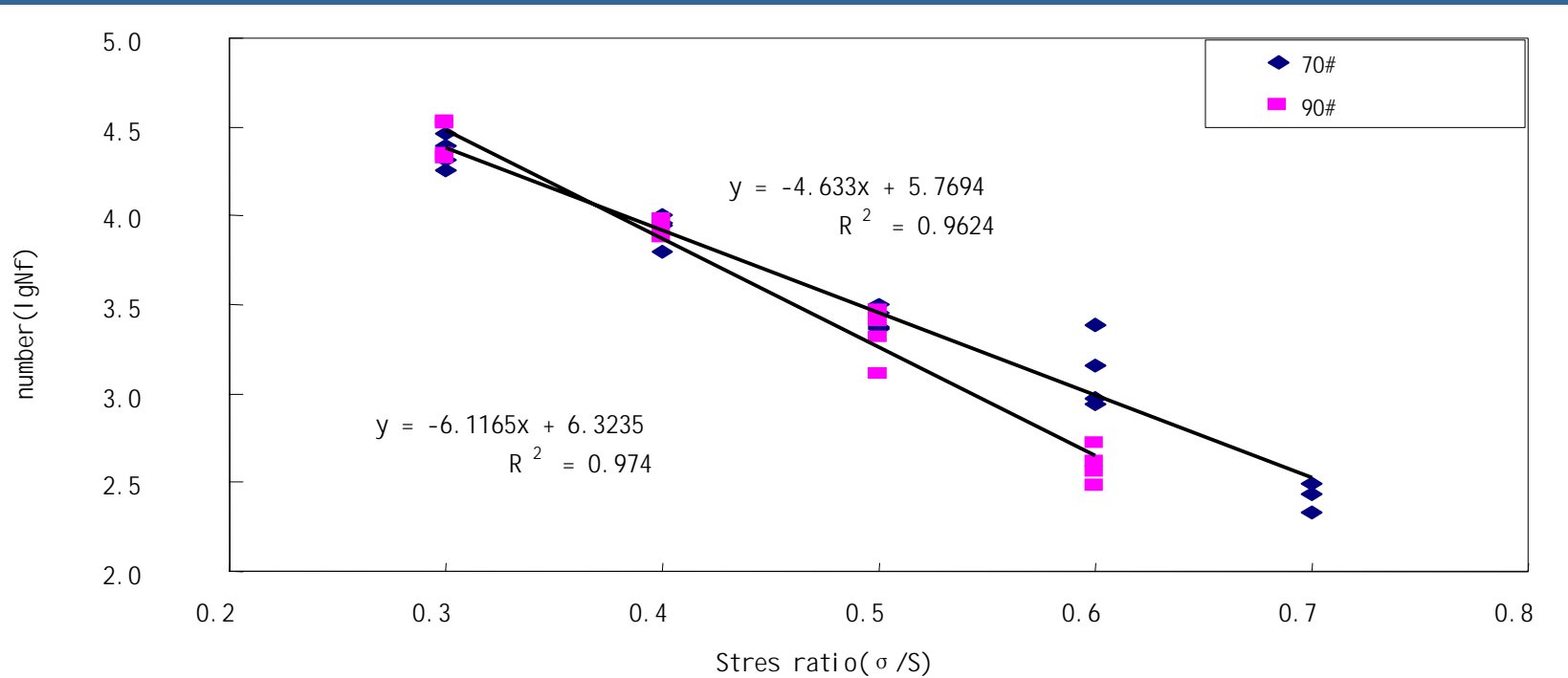
Fatigue life and stress ratio



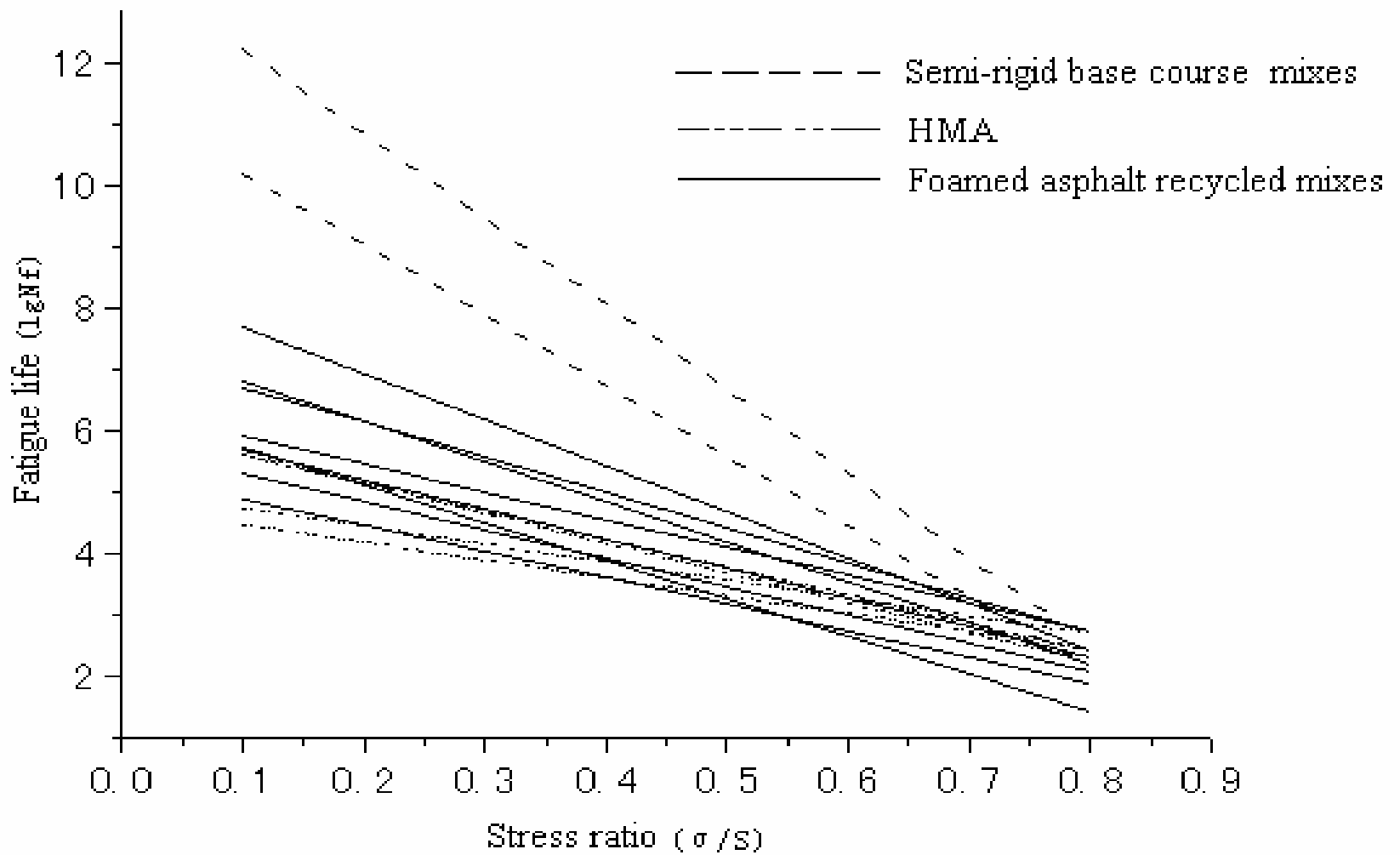
Fatigue life and stress ratio

Foamed  
asphalt  
content

# Effect of foaming property



Fatigue life and stress ratio



$\sigma/S$ - $\lg N_f$  with different materials



# **Foamed Asphalt in Plant Recycling Construction**

# Foamed Asphalt Cold Recycling Rehabilitating Highways Project in China

Old pavement struction	Tradition method	Cold recycling method
	4cm surfacing	4cm surfacing
4cm surfacing	6cm binder course	6cm binder course
8cm binder course	6cm binder course	26cm Foamed asphalt recycling course
20cm cement treated base	22cm new cement treated base	
22cm lime treated subbase	20cm lime treated subbase	20cm lime treated subbase

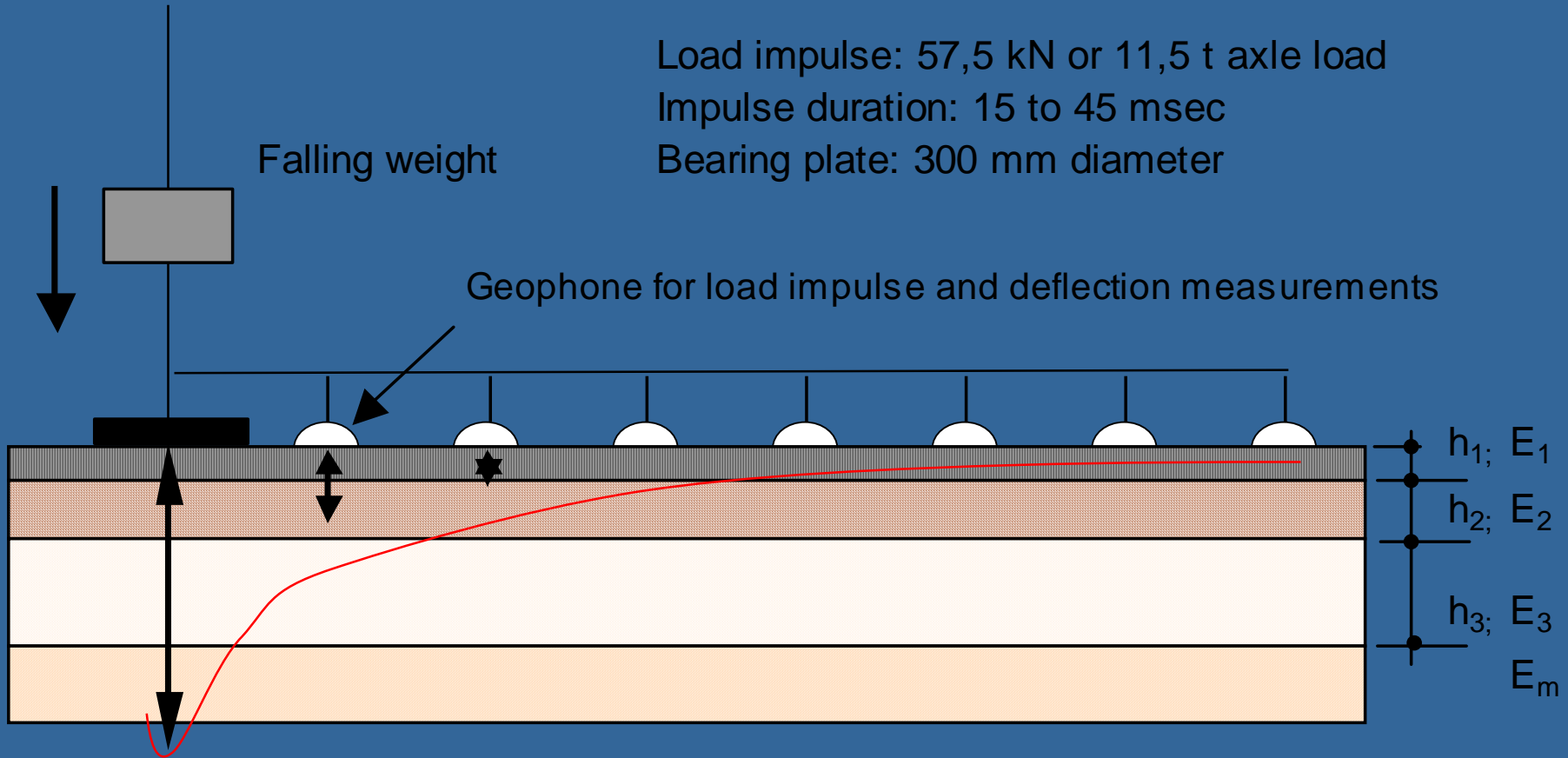


# DEFLECTION SURVEYS

Load impulse: 57,5 kN or 11,5 t axle load

Impulse duration: 15 to 45 msec

Bearing plate: 300 mm diameter

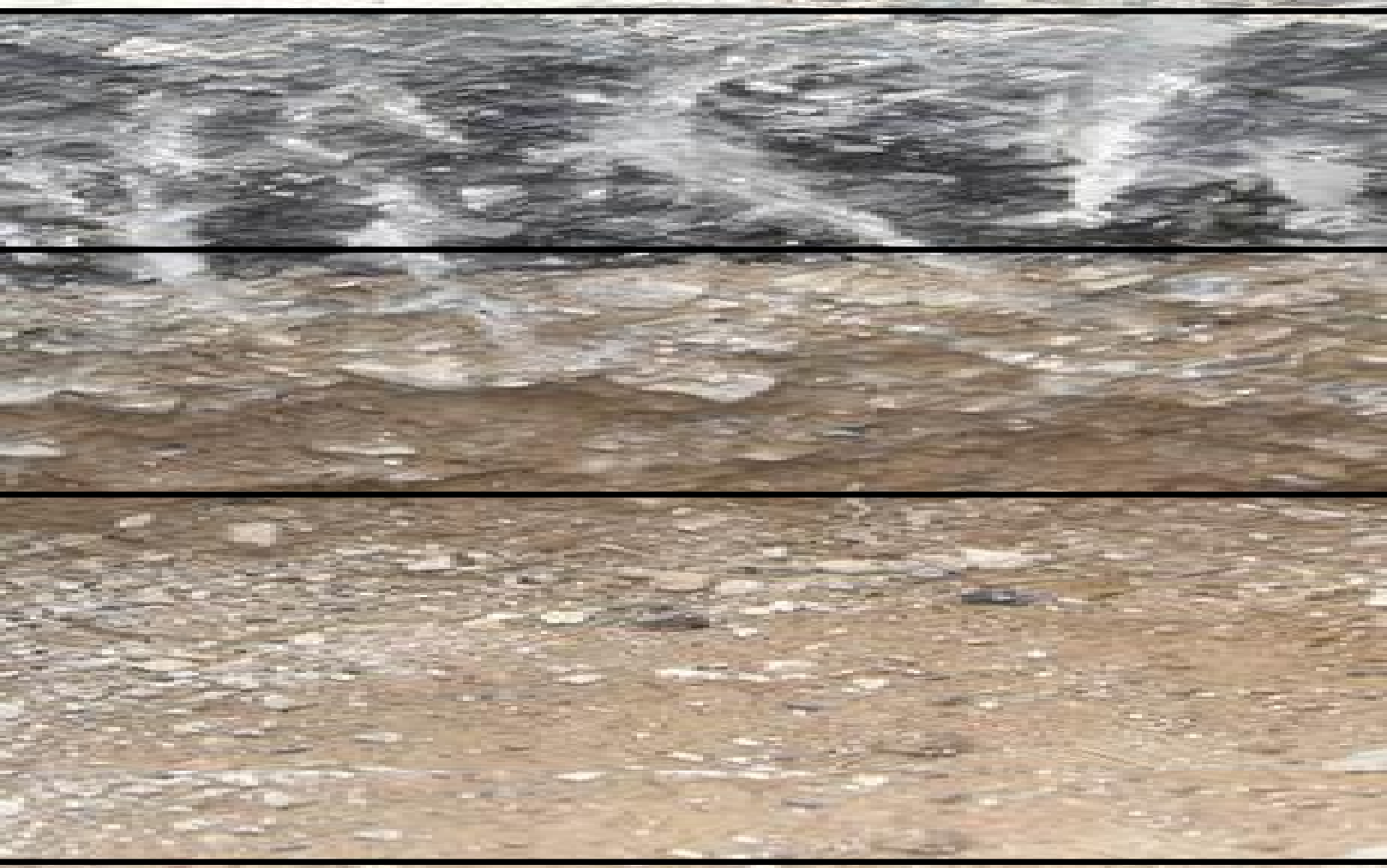


# Core extraction





# Cut pit





Existing pavement

Step 1  
milling and  
preshape

Step 2  
FA  
Recycle  
and  
stabilise

Step 3  
Apply  
asphalt

Asphalt

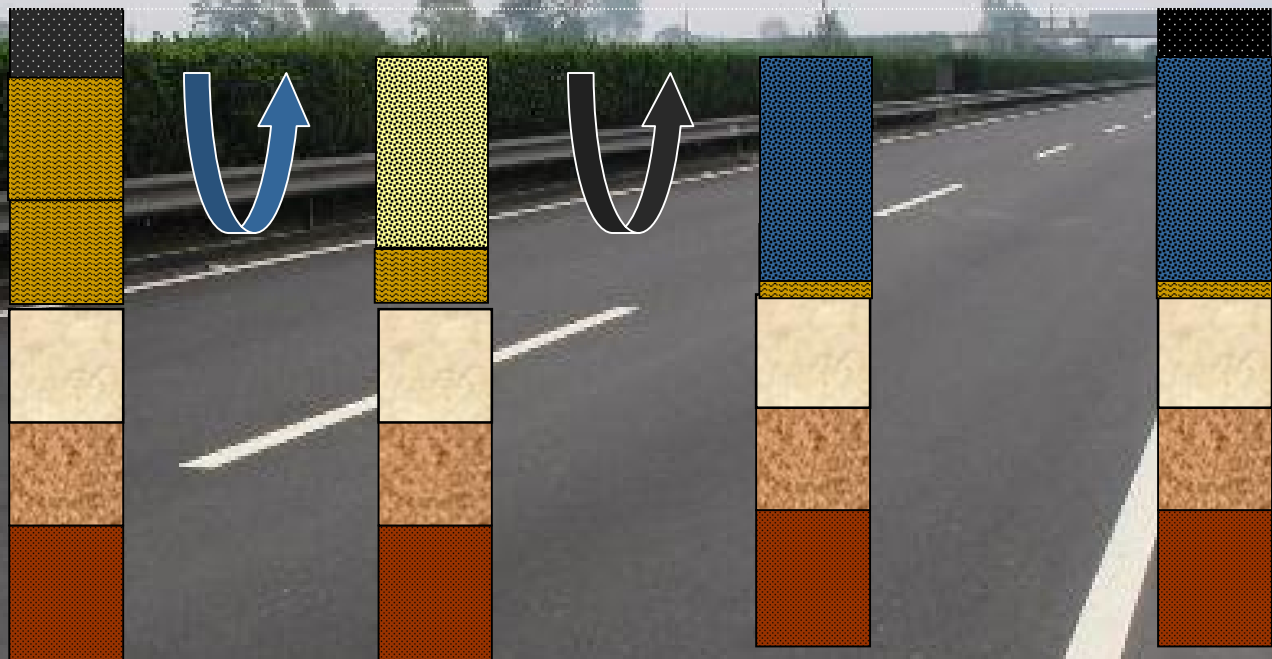
CTB

CTB

S/base

S/base

In situ



# Mixture Gradation Design

## 1. asphalt

foamed temperatures : 160 °C、170 °C

foamed water content: 1%、1.5%、2%、2.5%、3%

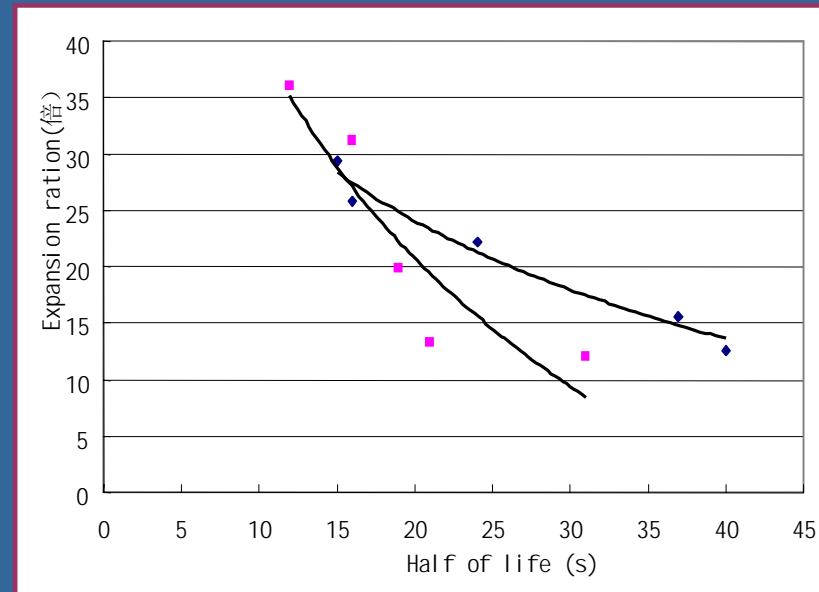
based on LAB test :

optimum foamed temperature : 160 °C

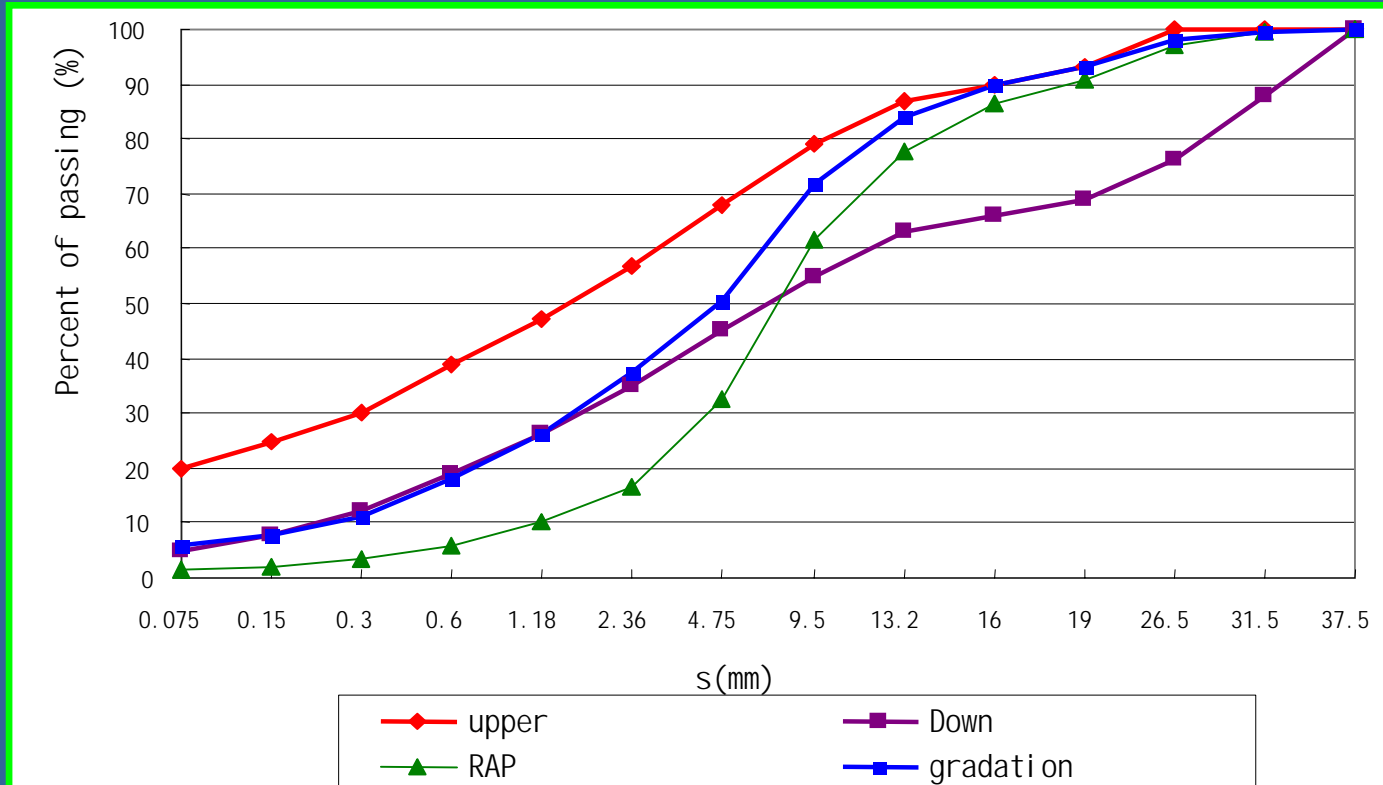
optimum foamed water content : 2%

expensive ratio: 22

hafe life : 24s

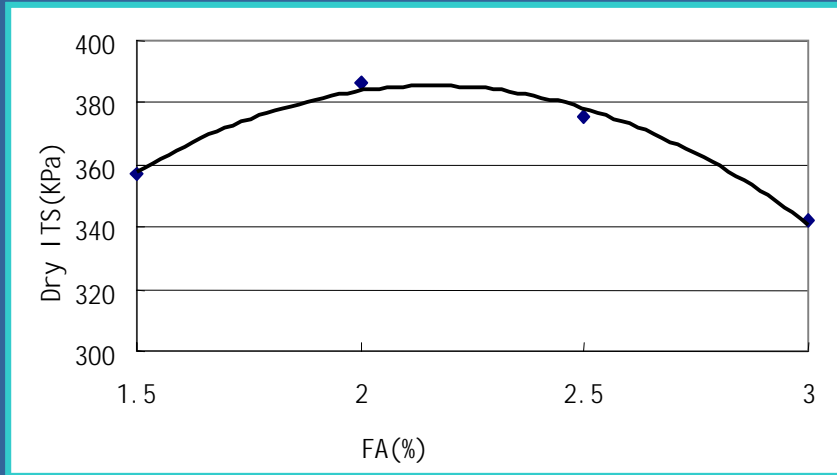


## 2.RAP and mix gradations

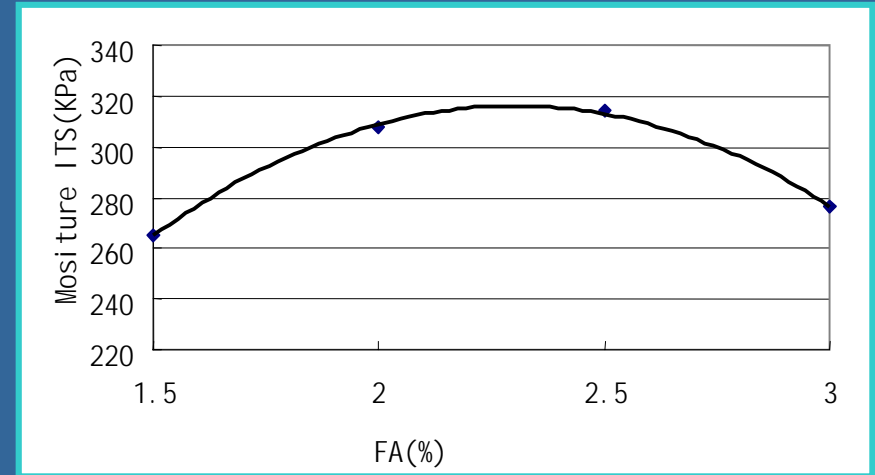


**Mix gradation : 73%RAP+25.5%fine+1.5%cement**

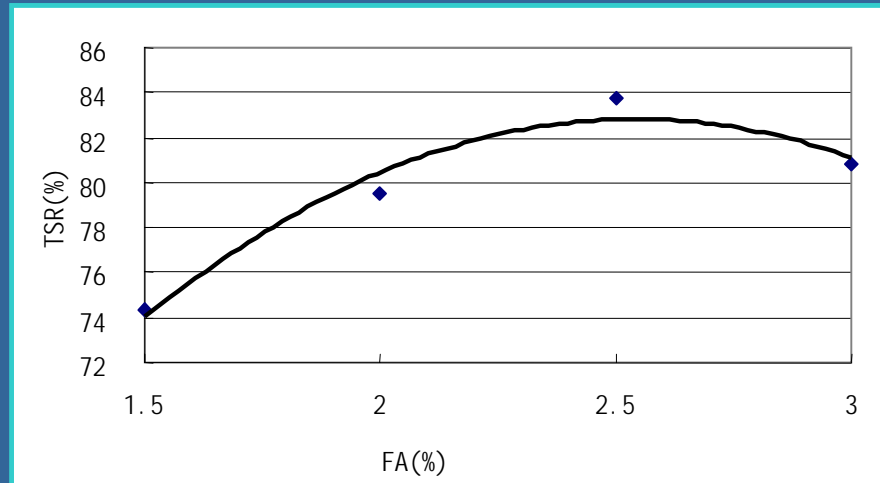
# 3.ITS Test Results



Dry ITS and FA



Moisture ITS and FA



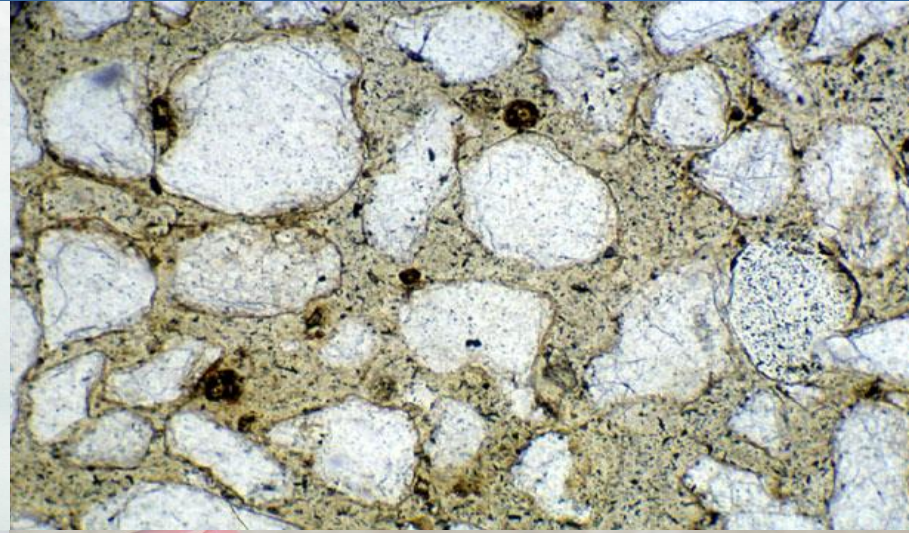
TSR and FA

# Final Design Results

Foam conditions		Mix gradation			Foam asphalt content /%	Water content /%
TEM/ °C	Water/ %	RAP /%	Fine /%	Cement/ %	Optimum content : 2.3	5.1
160	2.0	73	25.5	1.5	Error range: ± 0.3	



# Test Samples





# KMA200 Plant



**Foaming Process : RAP (+ additional aggregate if necessary) will be mixed with foamed bitumen**



# Paving of Recycling Course



26cm foamed  
asphalt recycling  
courses , paving  
divided into 13CM  
each.

**WR2000 Pavers**

# Roll of Recycling Courses





# Finishing







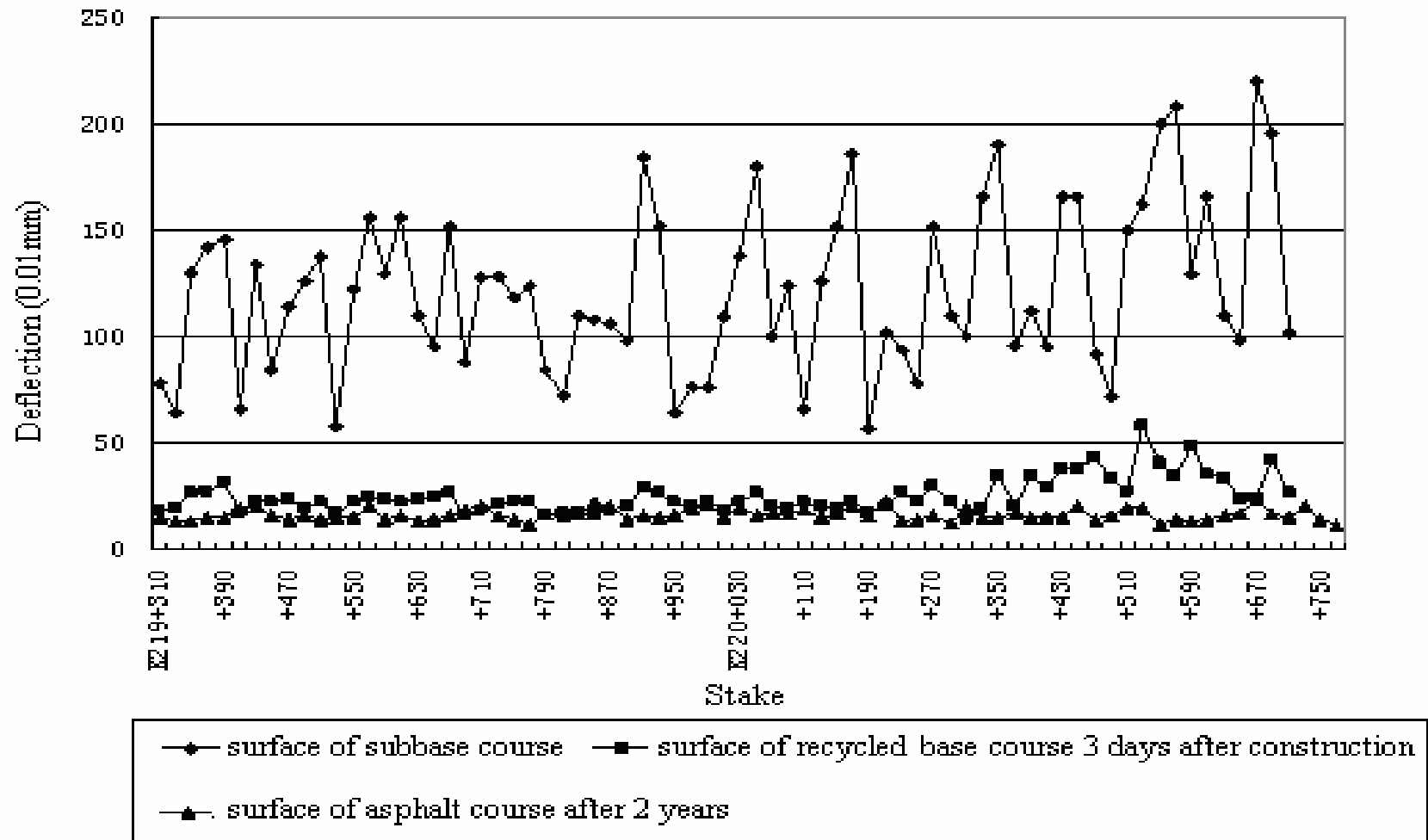
Test road core



## Test results of trial section

Marshall (60°C)		USC/(MPa)	Modulus/(MPa)
Stability/(KN)	Flow/(0.1mm)		
5.48	22.2	3.28	974

# Deflections test results



# Economic and effective analysis

Base types	Semi -rigid	Foamed asphalt recycling	Flexible base
Pavement structure	AC-13 4cm AC-20 6cm AC-25 6cm CTB 22cm LFB 22cm	AC-13 4cm AC-20 6cm FARB 26cm LFB 22cm	AC-13 4cm AC-20 6cm ATB 26cm LFB 22cm
Cost	86.91YUAN/m <sup>2</sup> (6cm AC-25+22cmCTB)	82.27YUAN/m <sup>2</sup> (26cmFARB)	130YUAN/m <sup>2</sup> (26cmATB)

FARB than Semi-rigid: 1kmSaving 18560YUAN/m<sup>2</sup>  
 ATB: 1kmSaving190920YUAN/m<sup>2</sup>





# Conclusions

- The use of foamed asphalt is growing in popularity and general acceptance both in China and throughout the world as a results of recent research and extensive trials
- Rehabilitation using foamed asphalt has proved to be successful because of its ease and speed of constructions ,its compatibility with wide range of aggregate type and its relative immunity to the effects of weather.
- Foamed asphalt has the potential to be used throughout China and provides another useful tool for the rehabilitation of heavily trafficked asphalt pavement or airport pavement

# Future consider

- RAP using in mixtures , as black aggregate, and other effect on different aging , asphalt content ect; micro-structure research ;
- Mixture design method need consider the middle and long-term performance ;
- Structure design method based on cold recycling course
- APT test
- Quality control method include binder content and cement content, and gradation

**cold recycling  
for better  
roads ...**

