中国公路沥青路面冷再生技术与规范

Cold Recycling Practices and Specifications in China Mainland

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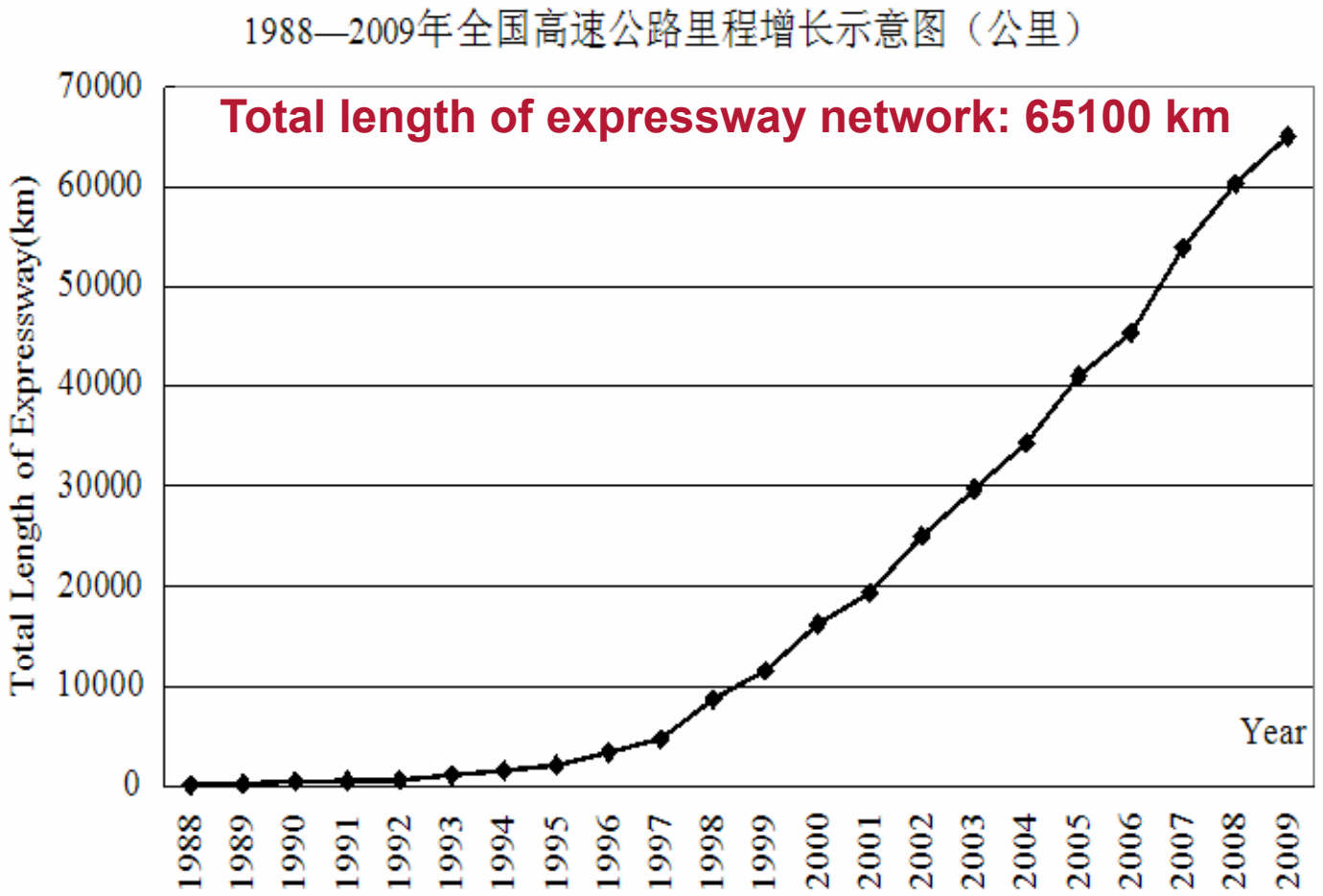
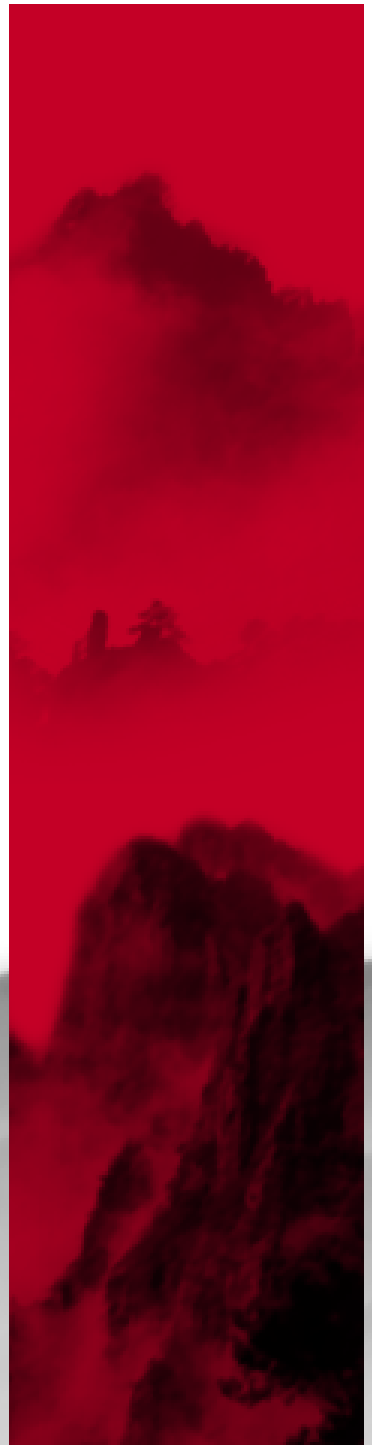
1、China Road Network





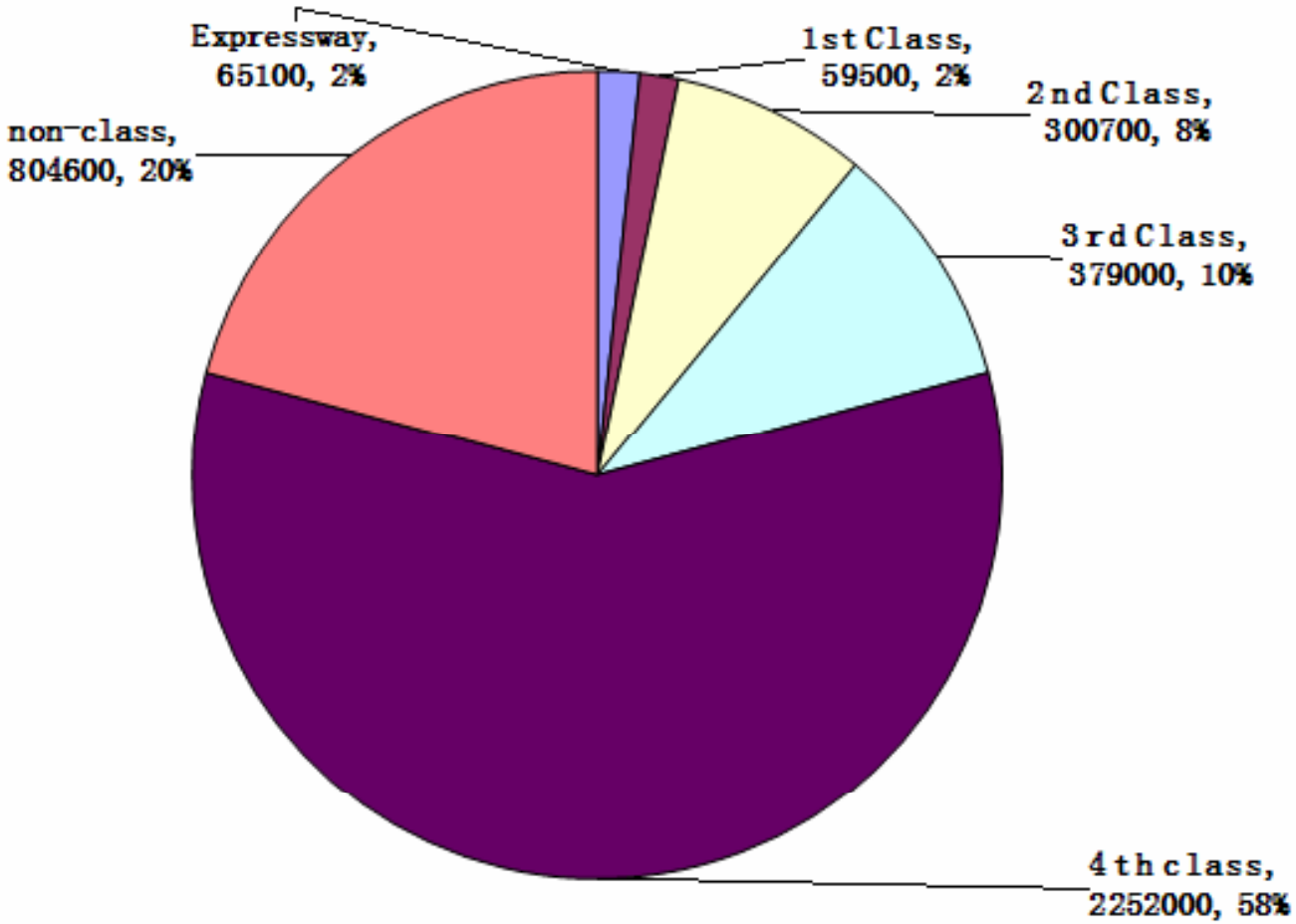
According to the plan issued by the central government in 2004, the total length of national expressway network will reach 85,000 km finally, nearly 25,000 km need newly construction.

按照国务院规划，中国国家高速公路网总规模将达到8.5万公里。


新蓝天钢构
正泰电气
玉柴机器
40

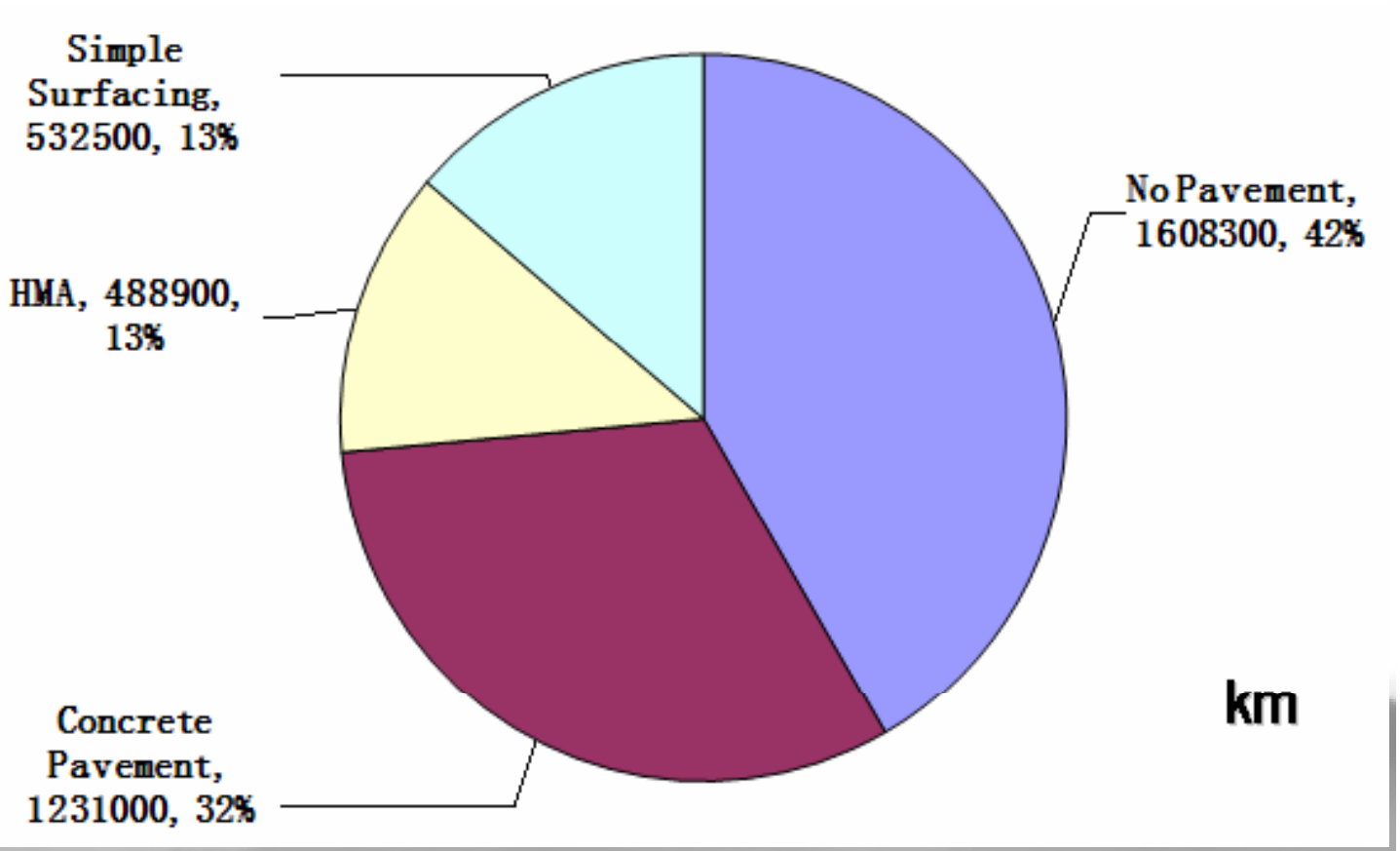
1、China Road Network

Total length of road network is 3.86million km



km

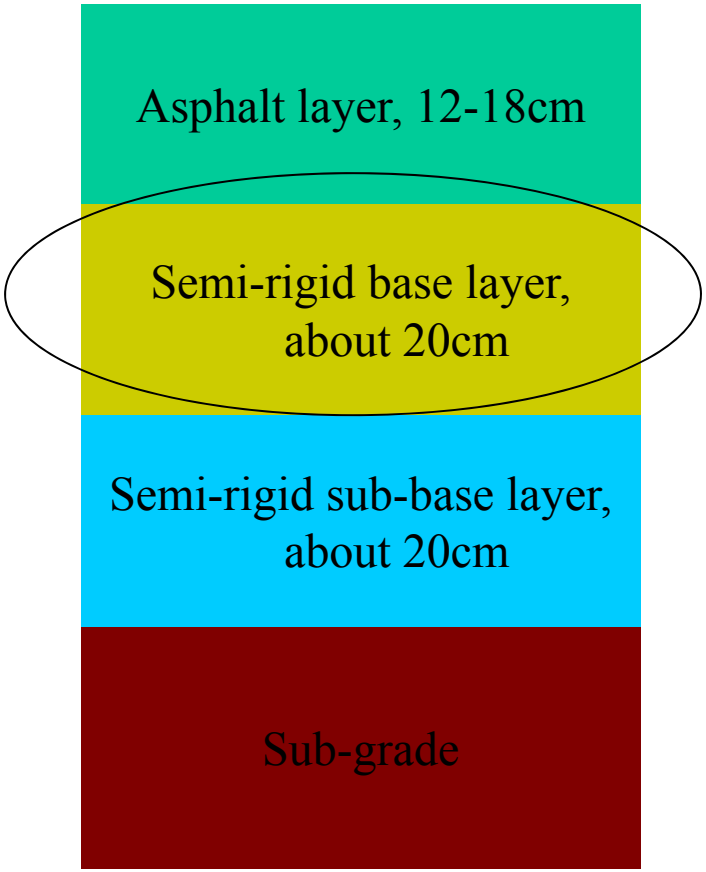
1、China Road Network



铺装公路225万km,其中48.9万km沥青混凝土，123.1万km水泥混凝土，53.3万km简易铺装。

1、China Road Network

About 80% of expressway has asphalt pavement, 20% has concrete pavement.



Typical cross section of asphalt pavement

2、Cold Recycling Practices

In the past 2 dacades, China put too many efforts, and funds into new road building, rather than maintenance and rehabilitation.

过去20年间，中国是全球最大的公路建设市场，这种趋势还将继续保持下去。接下来，中国公路的建设、养护、重建、升级改造任务将交织在一起。

2、Cold Recycling Practices

But the situation has been changing since the begining of this century, with more and more roads need maintenance, more low level roads need upgraded.

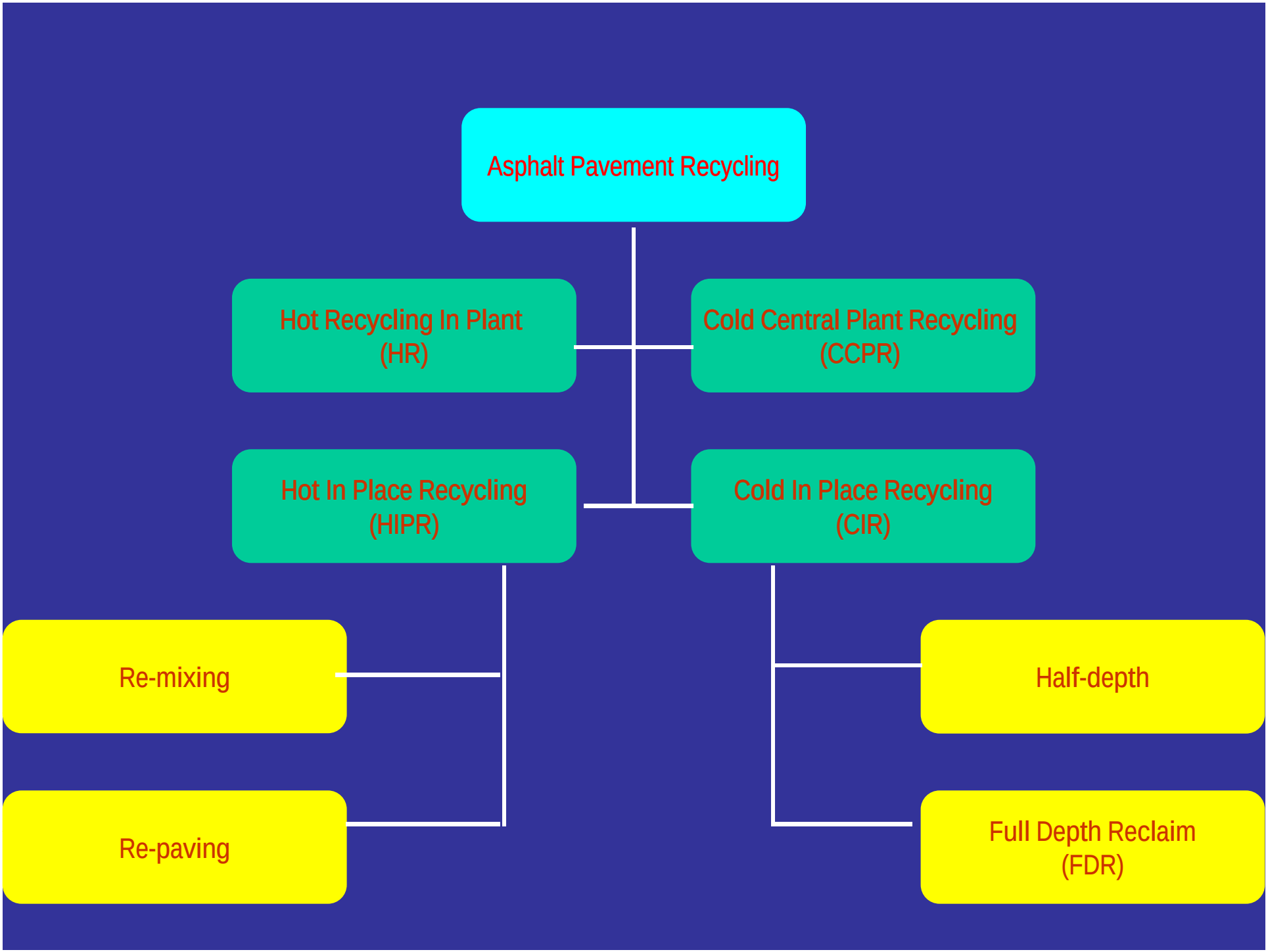
And especially with the concept of sustainable development being widely accepted, recycling has been becoming one of the hottest topics in road industry.

随着我国公路大量进入大中修养护期，随着可持续发展理念的深入人心，路面再生已经成为目前中国最热点的议题之一。

2、Cold Recycling Practices

The ministry level asphalt pavement recycling specifications, drafted by a team led by RIOH, was enacted by MOT on July 1, 2008. It gives a great push to the use of asphalt pavement recycling.

交通部于2008年7月1日颁布实施《公路沥青路面再生技术规范》，对再生技术在中国的应用起到积极推动作用。


Asphalt Pavement Recycling
Hot Recycling In Plant (HR)
Cold Central Plant Recycling (CCPR)
Hot In Place Recycling (HIPR)
Cold In Place Recycling (CIR)
Re-mixing
Re-paving
Half-depth
Full Depth Reclaim (FDR)

2、Cold Recycling Practices

We use all of these recycling approches,HIPR, HR, CCPR, CIR, etc.

➢2.1 Hot Recycling

(1) Hot-In-Place Recycling

HIRP began to be used in China from 1990s, it has seen a rapid increase. More than 8 million m2 HIPR has been done.

我们使用过所有的再生技术。就地热再生：中国从90年代开始使用，发展比较迅速,已累计实施就地热再生超过800万平方米。

2、Cold Recycling Practices

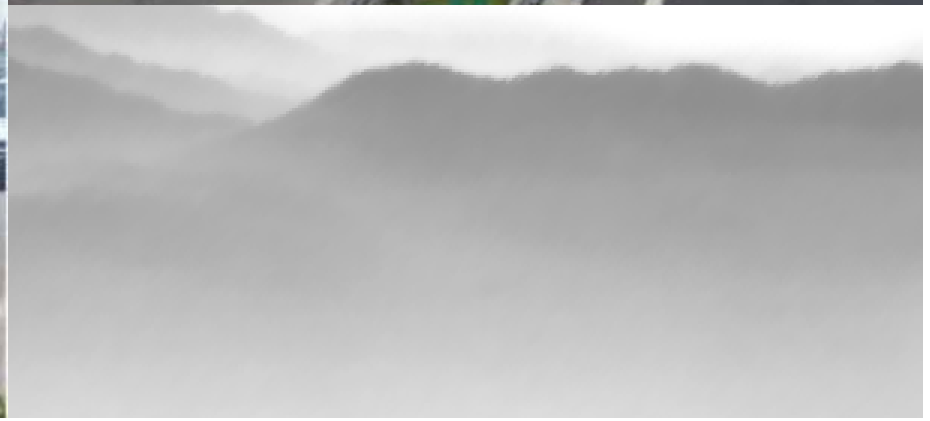
About 12 sets of HIPR machines, 8 WIRTGEN, 1 NIGATA, 1 KALOTTIKONE, 2 MATEC are working in China. Realizing that HIPR is a promising tech, Some local machinery companies have developed HIPR machines.

中国目前有12套就地热再生机组，8套德国维特根、1套日本新泻、1套芬兰卡龙、1套马太克。一些中国机械制造企业认识到就地热再生的发展潜力，也开始开发了就地热再生机组的样机。


Nestlé


2007/08/15


2004/04/29



2、Cold Recycling Practices

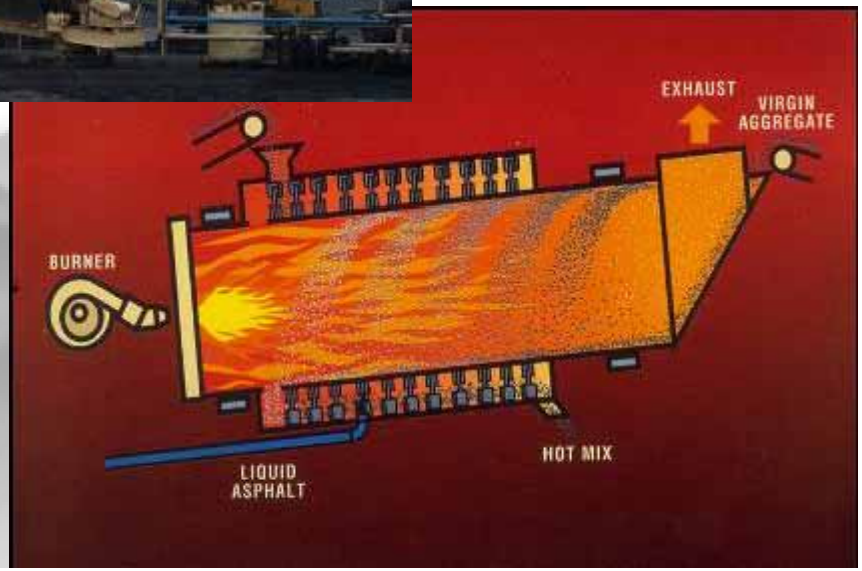
(2) Hot Recycling（In Plant）

Hot Recycling (In Plant) is not very popular for the time being, compared with other recycling approaches. The main hurdles are as follows:

- **1)Lack of confidence in this technology.**
- **2)Marginal capital benifits.**
- **3)Lack of policy supports and tax allures**

不同于国外，厂拌热再生目前在中国用量相当较小，主要原因：技术上缺乏信心；经济效益有限；政策引导不够。

Hot Recycling on Guang-Fo Expressway

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Hot recycling on Guang-Fo Expressway

Pavement structure

4cm SMA-13 with PMB

5cm AC -20 with PMB

6cm Hot-recycling AC-25I

Hot-recycling LSM-25 or concrete

Original base layer

Batch Plant with double drum in Beijing

2、Cold Recycling Practices

➢2.2 Cold Recycling

(1) Cold Central Plant Recycling (CCPR)

It has been used for about 5 years. About 800km has been paved on expressways by the end of 2009. Some examples:

Shi-Huang Exp. , Foamed Asphalt;

Xi-Yan Exp. , Foamed Asphalt.

Hu-Ning Exp. , Emulsion;

Chang-Jiu Exp. , Emulsion.

厂拌冷再生最近5年来开始在中国得到应用，如石黄高速（泡沫沥青）、沪宁高速（乳化沥青）、昌九高速（乳化沥青）、西阎高速（泡沫沥青）。

CCPR on Xi-Yan Expressway , Northwest China, Foamed Asphalt

CCPR on Hu-Ning Expressway, East China,Emulsion

CCPR on Chang-Jiu Expressway,Central China, Emulsion

CCPR on Shi-Huang Expressway,North China,Foam

2、Cold Recycling Practices

(4) Cold-In-Place Recycling (CIR)

CIR is one of the most popular recycling methods in China. There are about 150 sets of units working in China at present. The majority of CIR on expressways and first class roads use foamed asphalt or emulsion, but on low level roads, cement or lime are much more popular.

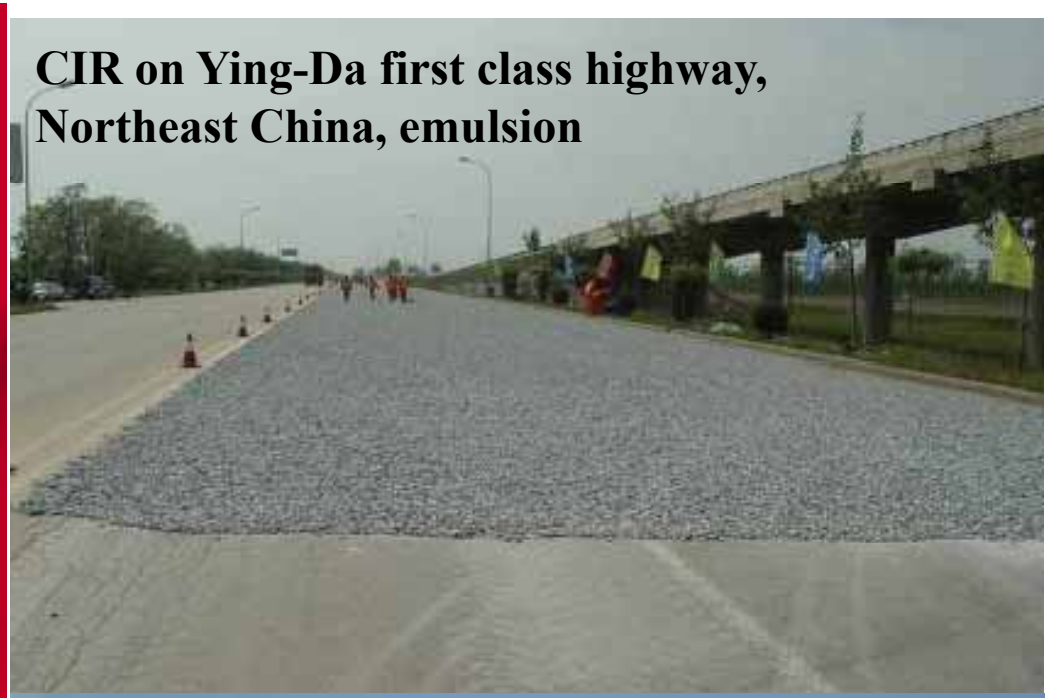
就地冷再生是目前中国应用最多的再生方式之一。绝大多数采用水泥、石灰作为结合料，最近5年应用泡沫沥青、乳化沥青多起来,尤其是在高速公路上。

CIR on Jing-Shen expressway, North China, Foam

CIR on Jing-Shen Expressway,North China, Foam

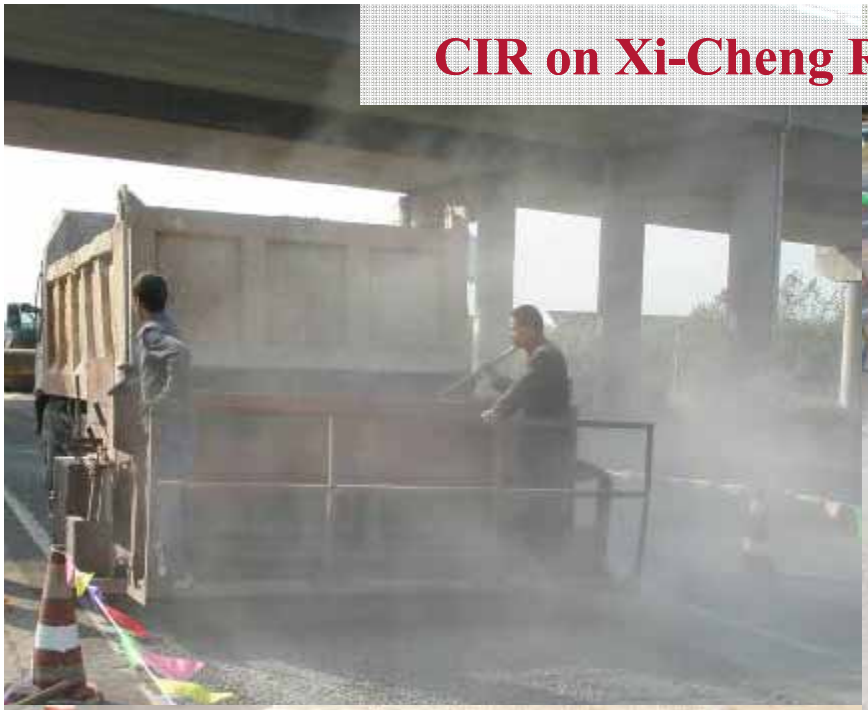

JAC

CIR on Ying-Da first class highway, Northeast China, emulsion



CIR on Ying-Da first class highway

CIR on Xi-Cheng Road,East China, emulsion



CIR on G320 in Zhejiang Province, East China, Foam

CIR in Heilongjiang Province, Northeast China, Lime

G109, Northwest China, Lime

Cement, North China

Chu-da Expressway, Southwest China, Foam

G106, North China, Foam

3、 Project Analysis and Thickness Design

➢3.1 Project Analysis

- **Visual assessment of the pavement surface**
- **Historical information review**
- **Pavement properties assessment**
- **Distress evaluation**
- **Preliminary rehabilitation selection**
- **Economic analysis**
- **Detailed project design**

3、 Project Analysis and Thickness Design

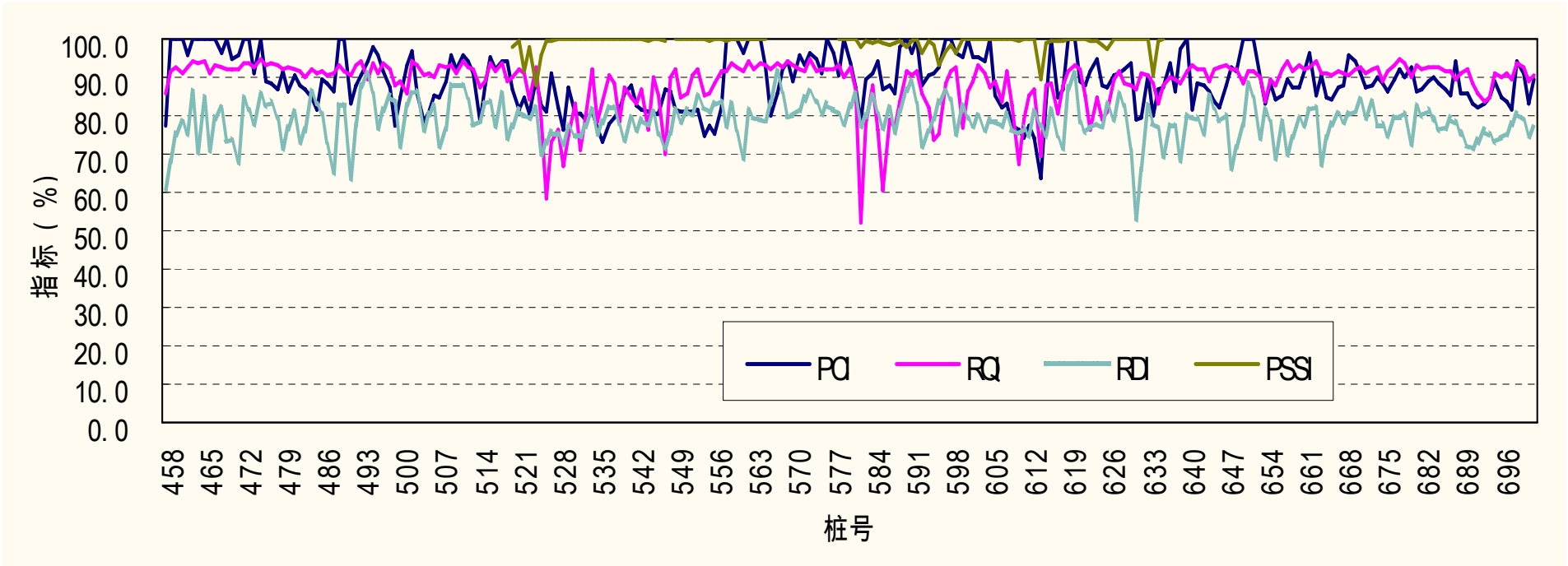
Example:

Items	Test Length	Equipment
Surface distresses	245km×2	CiCS
Deflection	245km	Deflectometer
Unevenness	245km×2	Laser section instrument
Rutting	245km×2	
Hidden distresses	100km	Geo-radar
Digging and Coring	100	

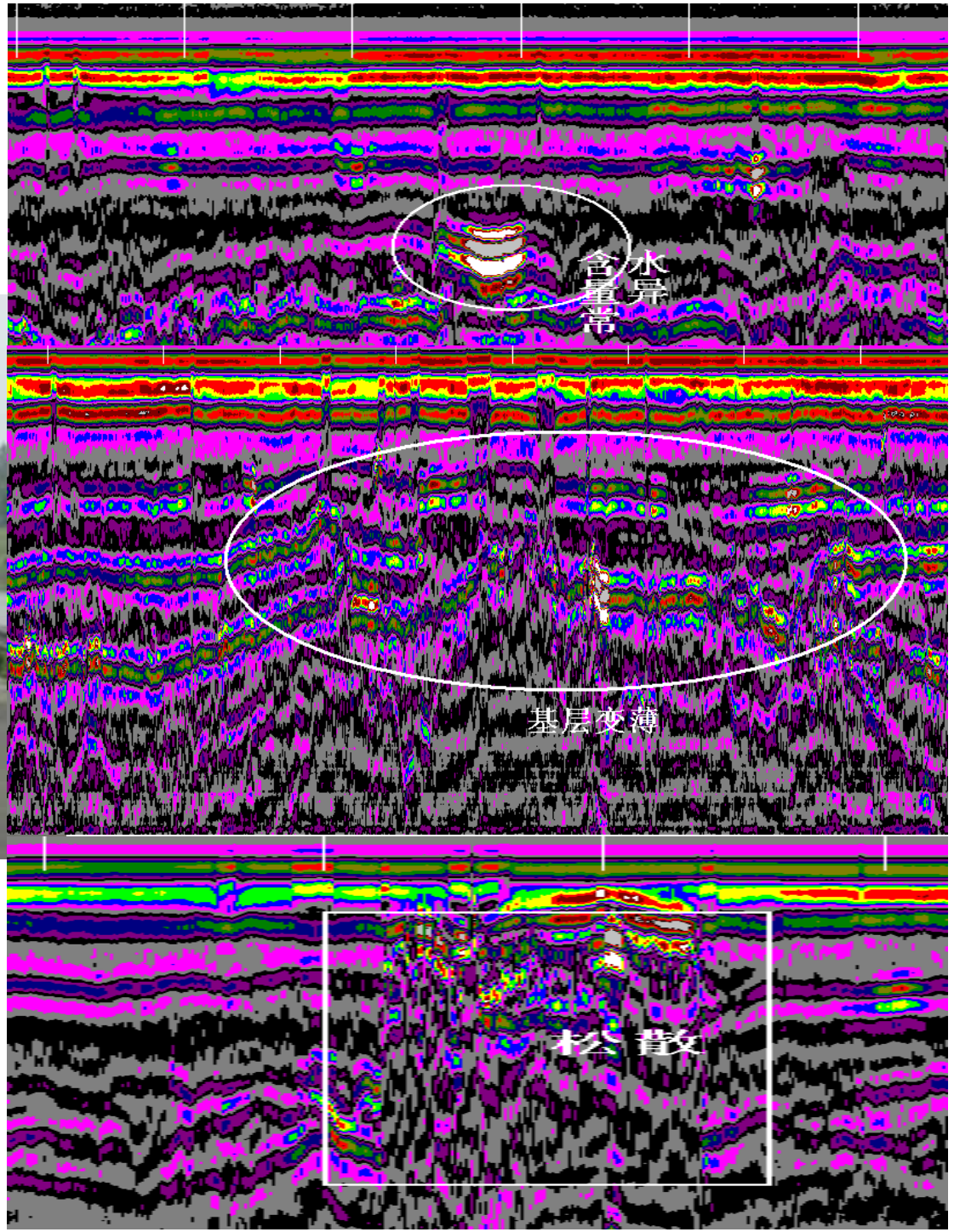
CiCS：Cracking image Collection System

Deflectometer

Classification	PCI		RQI		RDI		PSSI	
	Length (km)	Percentage(%)	Length (km)	Percentage(%)	Length (km)	Percentage(%)	Length (km)	Percentage(%)
Excellent	205	41.84%	322	65.7%	4	0.8%	213	98.61%
good	234	47.76%	125	25.6%	191	39.0%	2	0.93%
fair	48	9.80%	31	6.3%	263	53.7%	1	0.46%
poor	3	0.61%	9	1.8%	31	6.3%	0	0%
bad	0	0%	3	0.6%	1	0.2%	0	0%


100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
指标（%）
PCI
RQI
RDI
PSSI
458
465
472
479
486
493
500
507
514
521
528
535
542
549
556
563
570
577
584
591
598
605
612
619
626
633
640
647
654
661
668
675
682
689
696
桩号

Geo-radar tests:

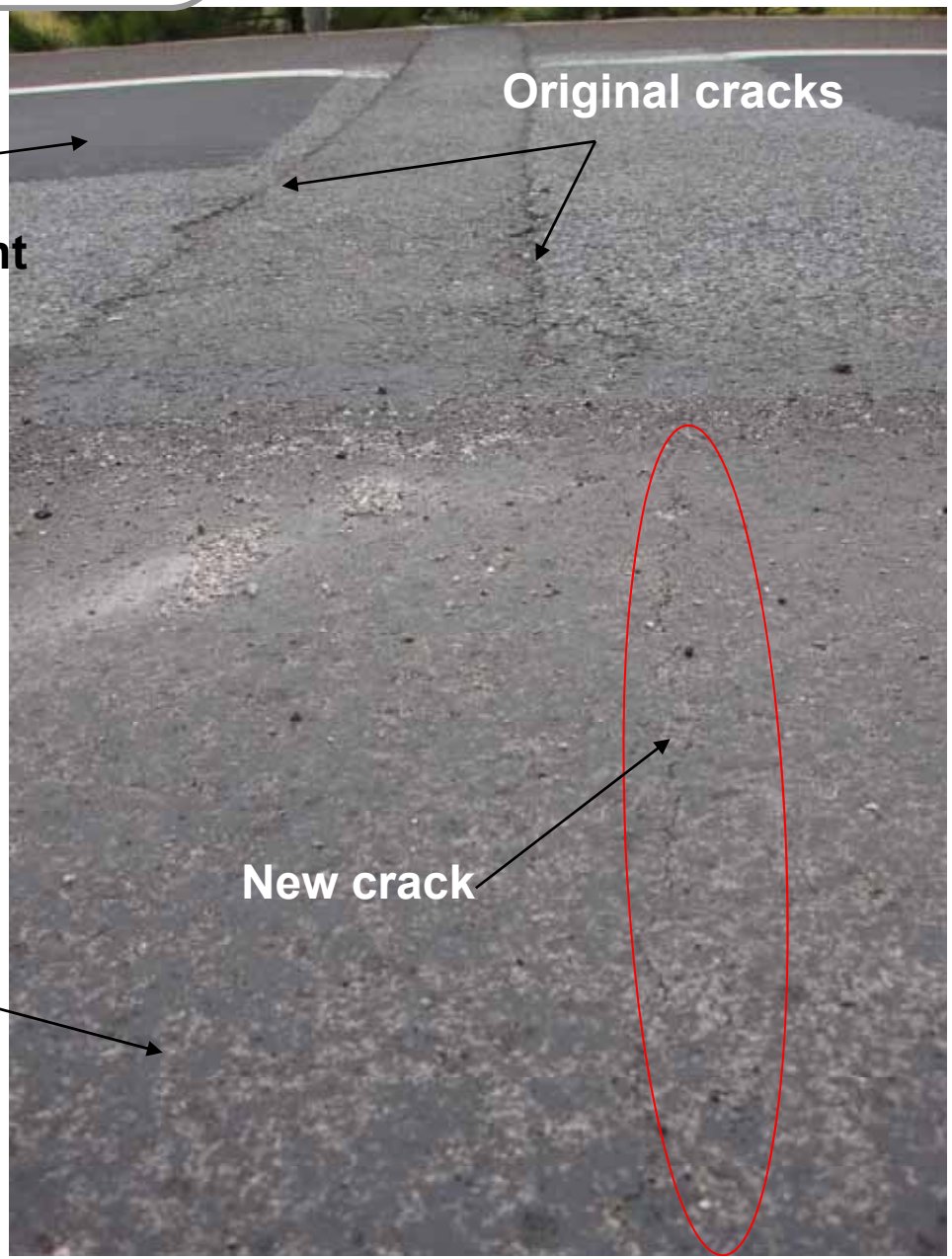


Digging test pits and taking cores:

Digging test pits and taking cores:

3、 Project Analysis and Thickness Design

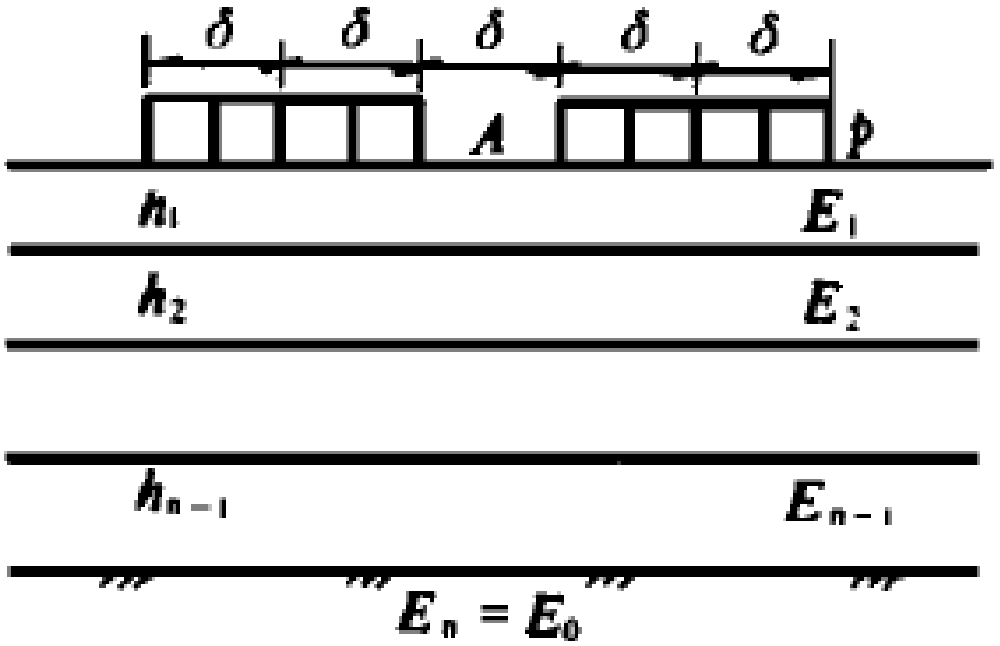
- It is not a good candidate for CIR if the strength of underneath layer is not sufficient, or there are structural failures –cracking, mix instability, wet or soft sub-grades, drainage issues, etc.

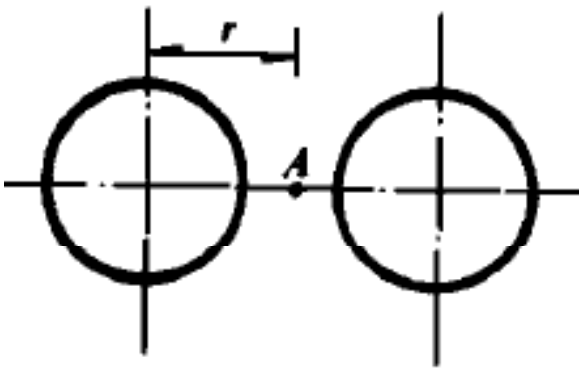


3、 Project Analysis and Thickness Design

➢3.2 Thickness Design

●Theory: The calculated surface deflection of elastic continual multi-layer system under the double circle uniformly distributed vertical loading should not exceed the designed deflection, and the tensile stress at the bottom of asphalt layers and base layers should not exceed the required stress.





3、 Project Analysis and Thickness Design

- Input: ESAL, Designed deflection, Elastic Modules of each layer, ITS of each layer material, thickness of base layer.
- Output: The thickness of designed layer (Asphalt layer).

3、 Project Analysis and Thickness Design

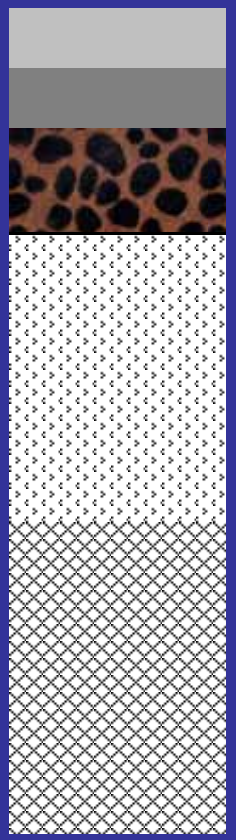
- Cold recycling layer must be overlayed. On expressway, the overlay thickness is suggested to be more than 100mm.
- The thickness of one CCPR layer should be more than 60mm and less than 160mm. The thickness of one CIR should be more than 80mm and less than 160mm. The thickness of FDR should be more than 150mm and less than 220mm.

CCPR approach and Pavement Structure, Xi-Yan Exp., Foam

Asphalt Layer

Base

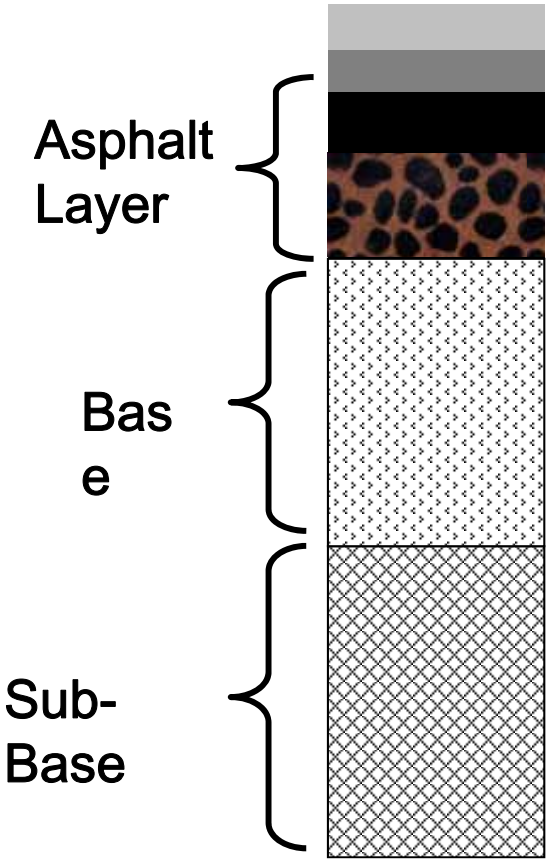
Sub-Base



Original		After Recycling	
AK-16	4cm	AC-13	4cm
AC-20	5cm	AC-20	6cm
AC-25	6cm	CR, foam	14cm
Semi-rigid base	20cm	Original base	20cm
Semi-rigid sub-base	28cm	Original sub-base	28cm

Normal

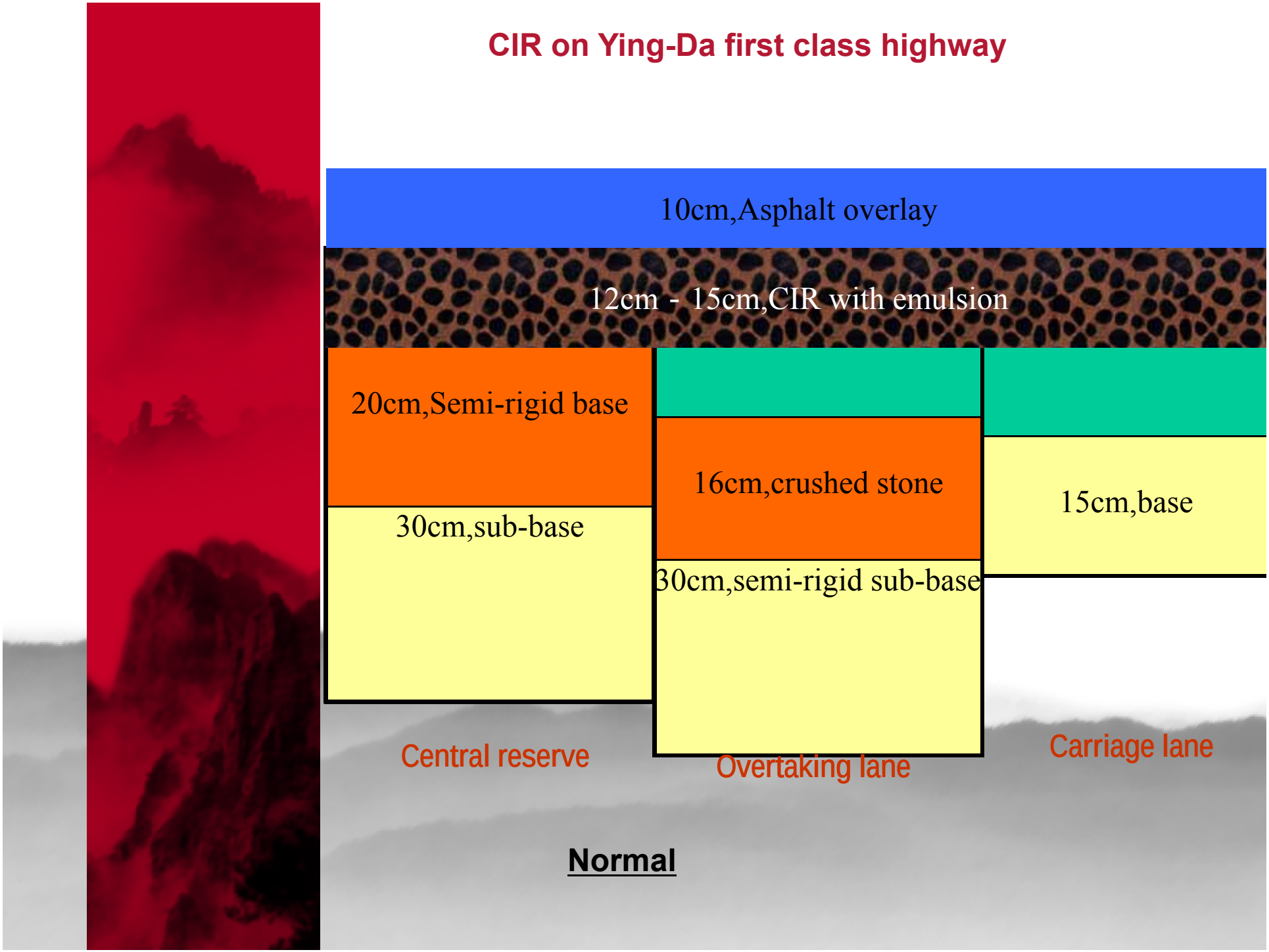
CCPR on Chang-Jiu Expressway, Emulsion



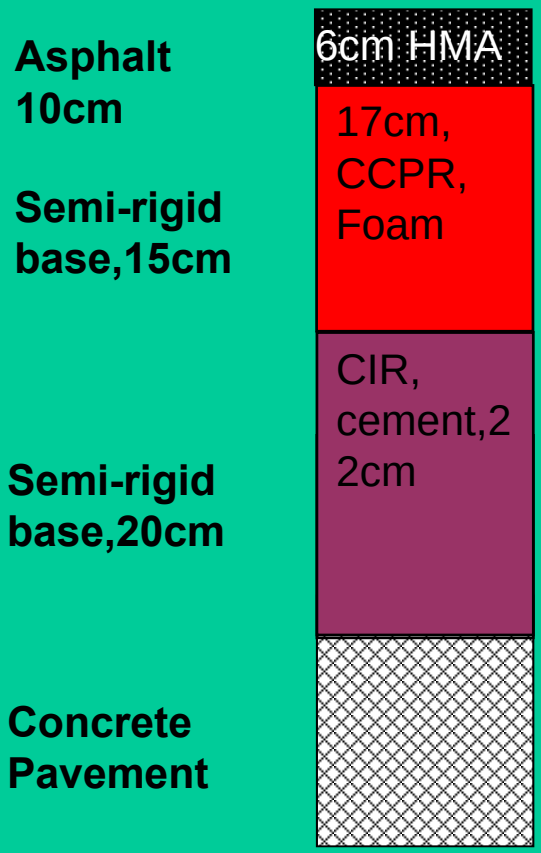
Original		After Recycling	
		PMB,AC13	4cm
Top asphalt	? cm	PMB,AC20	6cm
Second asphalt	4cm	AC20	6cm
3rd asphalt layer	6cm	CCPR	10-12cm
Semi-rigid base	22cm	Original base	20cm
Graded gravel	33cm	Original graded gravel	

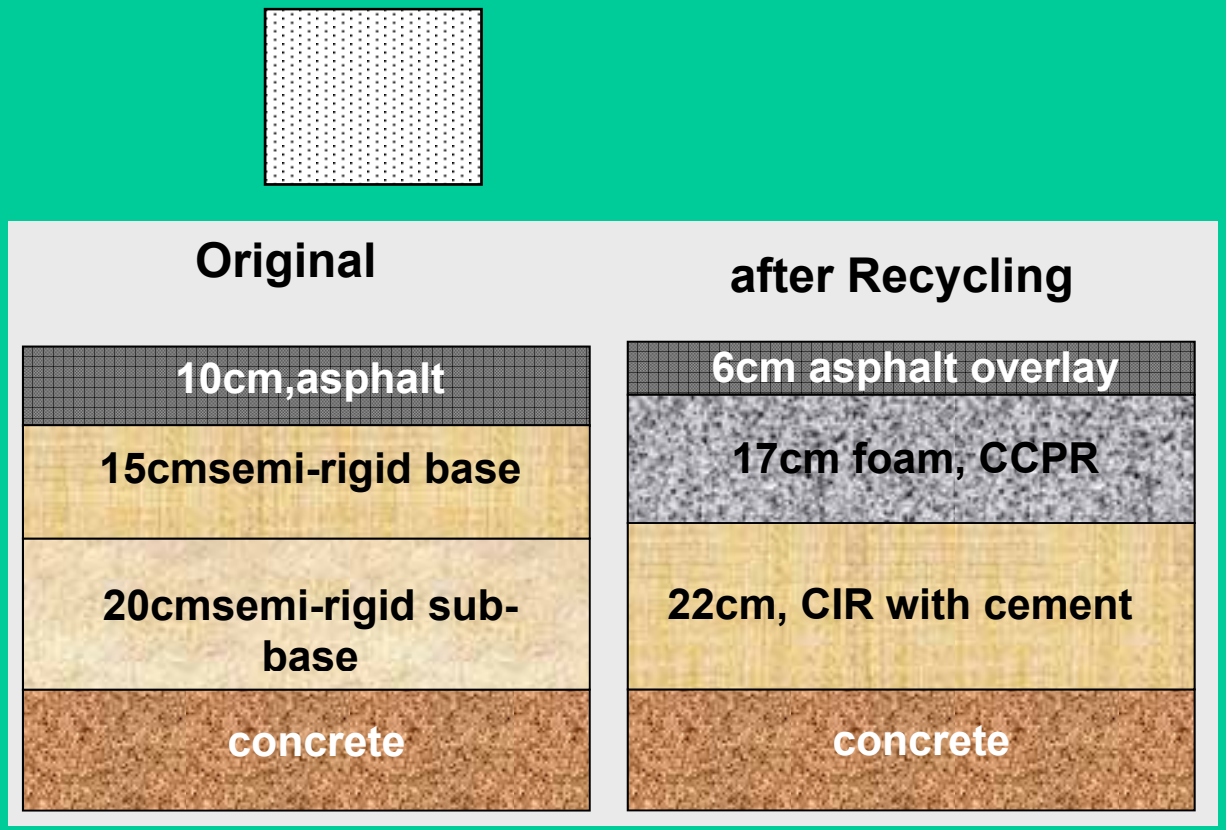
Normal

CIR on Ying-Da first class highway



CIR and CCPR on G320 Zhe-jiang Province





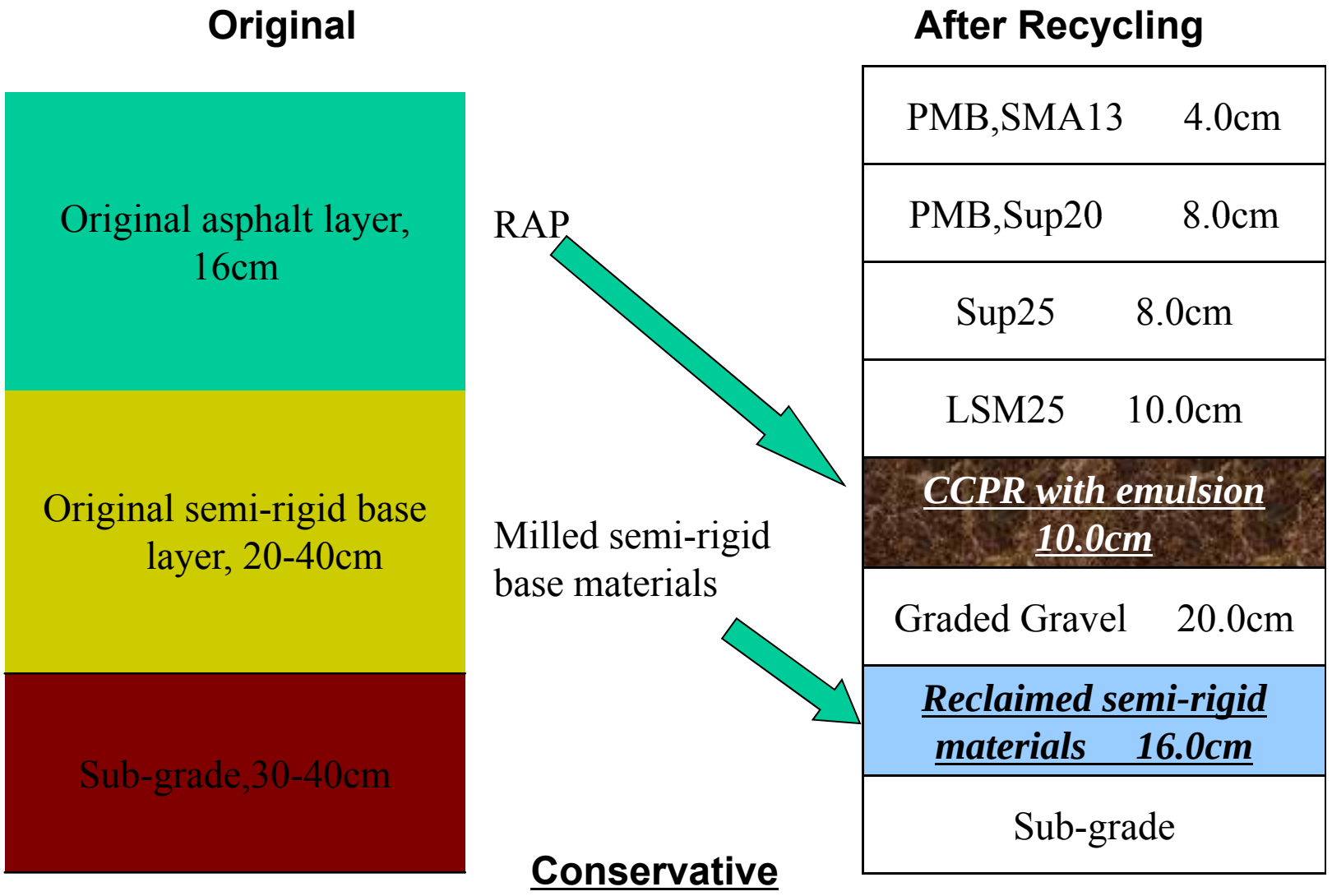
Normal

CCPR on Hu-Ning Expressway-Zhenjiang

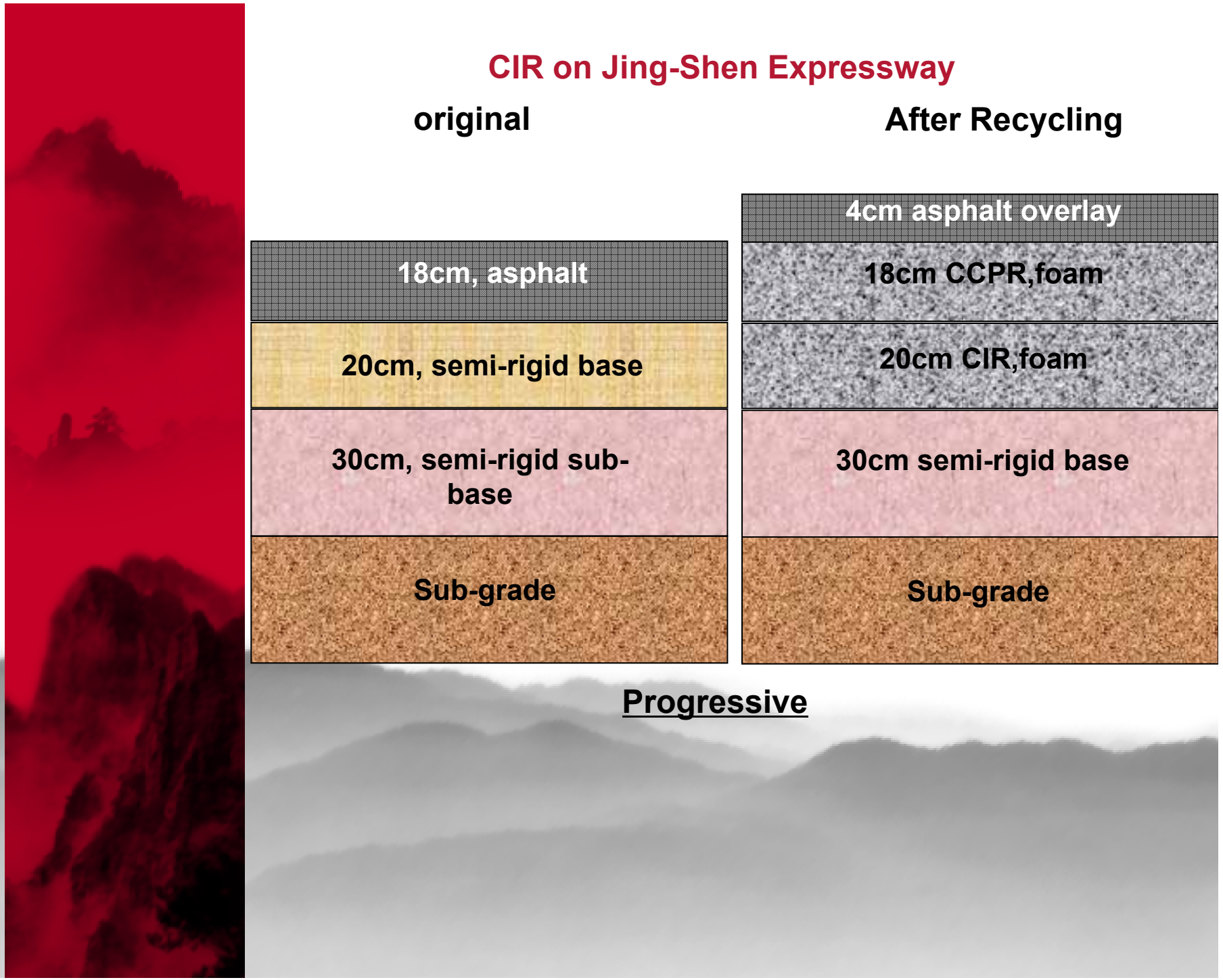
Asphalt layer（15cm）	4cm,PMB,AK-13A 8cm,SUP20 8cm,SUP20）
Semi-rigid Base（15cm ）	CCPR with emulsion(10cm)
Sub-grade	Sub-grade

Normal

CCPR approach and Pavement Structure, Hu-Ning Exp., Emulsion



CIR on Jing-Shen Expressway



Progressive

4、Mixture Design

- Mixture Design procedure

①Obtain Sample of RAP

②Material Selection

③Gradation Design

④Determine Optimal Moisture Content

⑤Test Trial Mixtures

⑥Establish Job Mix Formula

4、Mixture Design

➢4.1Obtain Samples from Field

●(1) RAP Sampling

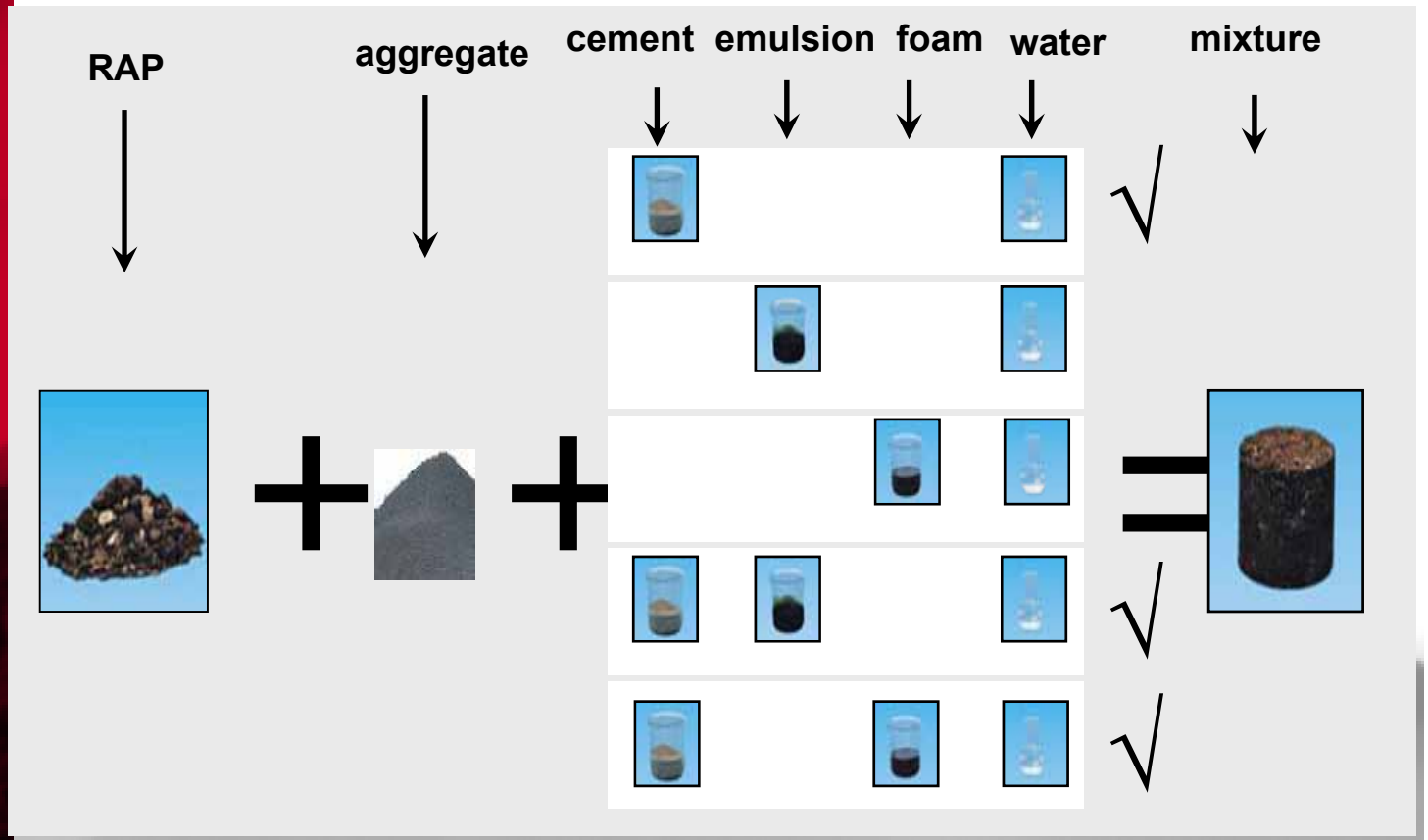
Method: Milling(CIR),

Stockpile sampling (CCPR)

Frequency: The CIR project is divided into sections based on pavement condition and mixture condition, and each section is suggested to be 500m -5000m long, or 5000 m^2- 50000m^2. Take one sample for each lane of each section.

4、Mixture Design

➢4.2 Material Requirements



4、Mixture Design

- **Foamed Asphalt**

Items	Requirement	Test methods
Expansion ratio	10	JTG F41 E
Half life（s）	8	JTG F41 E

●Emulsion: Solvent free, CSS or CMS type, Lower than 60℃.

Items			Reruirement	Test Method
Set speed			Slow or Medium	T 0658
Particle charge			positive(+)	T 0653
Sieve test(1.18mm)		%	≤0.1	T 0652
Viscosity	Engler, E_{25}		2-30	T 0622
	25℃,Saybolt Furol V_s	s	7-100	T 0621
Tests on residue	Residue content	%	≥62	T 0651
	Solubility in trichloroethylene	%	≤97.5	T 0607
	Penetration (25℃)	0.1mm	50-300	T 0604
	Ductility(15℃)	cm	≥40	T 0605
Coating ability			≥2/3	T 0654
mixing test			good	T 0659
Storage stability test,	1d 5d	%	≤1 ≤5	T 0655

- Asphalt used for foam and emulsion, Aggregates, filler, cement, lime, etc, should meet the same specifications as those used for HMA.
- Water should be drinkable water.

➢4.3 Aggregate gradation

●Cold recycling with emulsion.

Seive size (mm)	Percentage passing each seive (%)			
	Coarse	Medium	Fine-A	Fine-B
37.5	100			
26.5	80-100	100		
19		90-100	100	
13.2	60-80	-	90-100	100
9.5	-	60-80	60-80	90-100
4.75	25-60	35-65	45-75	60-80
2.36	15-45	20-50	25-55	35-65
0.3	3-20	3-21	6-25	6-25
0.075	1-7	2-8	2-9	2-10

●Aggregate gradation for Cold recycling with foam.

Sieve size (mm)	Percentage passing each sieve (%)		
	Coarse	Medium	Fine
37.5	100		
26.5	85-100	100	
19	-	90-100	100
13.2	60-85	-	90-100
9.5	-	60-85	-
4.75	25-65	35-65	45-75
2.36	30-55	30-55	30-55
0.3	10-30	10-30	10-30
0.075	6-20	6-20	6-20

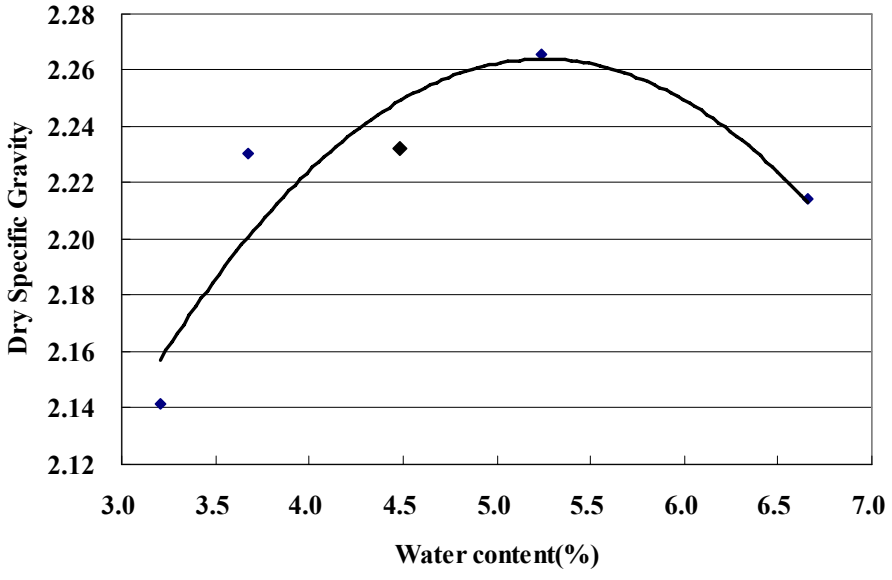
●Aggregate gradation for cold recycling stabilized with cement or lime

Sieve size（mm）	Percentage passing（%）		
	1	2	3
37.5		100	90-100
31.5	100		
26.5	90-100		66-100
19	72-89		54-100
9.5	47-67		39-100
4.75	29-49	50-100	28-84
2.36	17-35		20-70
1.18			14-57
0.6	8-22	17-100	8-47
0.075	0-7	0-30	0-30

4、Mixture Design

➢4.4 Determination of Optimal Moisture Content

- Modified proctor test is used to determine OMC in accordance with China's MOT JTG E40-2007 T0131, which is similar to the ASTM D 1557 "Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56000 ft-lbf/ft3 or 2700 kN-m/m3)."



4、Mixture Design

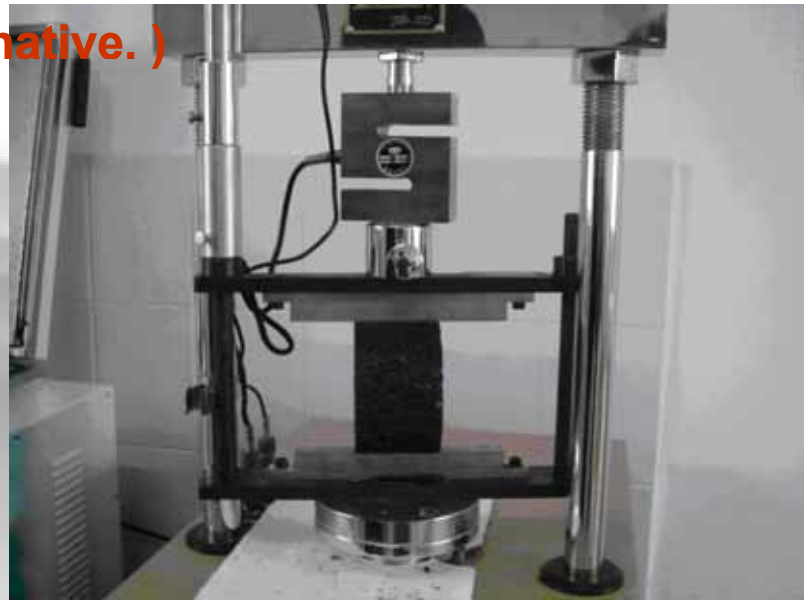
➢4.5 Specimen preparation

- 101.6 mm diameter Marshall specimens.
- Emulsion mixture: 50 blows on each side of the specimens at ambient temperature, 48h curing in 60℃ oven, 25 blows further on each side at 60℃, cooling down and extruding.
- Foam mixture: 75 blows each side at ambient temperature, 48h curing in 60℃ oven, and then cooling down and extruding.

4、Mixture Design

➢4.6 Laboratory Tests

- VV
- ITS_{dry} at 15℃
- ITS_{wet} at 15℃. Specimens are immersed in a 25℃ water bath for 23 hours and then placed in a 15℃ water bath for an additional 1 hour prior to the ITS test.(40 ℃ Marshall stability tests are the alternative.)
- Freeze-thaw TSR.



➢4.7 Requirements for cold recycling mixture

●Emulsion

Items		requirements
Air voids		9% ~ 14%
ITS/ 15℃	ITS at 15 ℃, MPa	≥0.50（base） ≥ 0.40（sub-surface）
	Retained ITS after soaking 24h, %	≥ 75
Marshal stability/ 40℃	Marshal stability, kN	≥ 6.0（base/sub-base） ≥ 5.0（sub-surface）
	Retained Marshal stability after 24h soaking,%	≥ 75
Freeze-thaw TSR %		≥ 70

● Foam

Items		requirements
ITS/ 15℃	ITS at 15 ℃, MPa	≥0.50（base） ≥ 0.40（sub-surface）
	Retained ITS after soaking 24h, %	≥ 75
Marshal stability/ 40℃	Marshal stability, kN	≥ 6.0（base） ≥ 5.0（sub-surface）
	Retained Marshal stability after 24h soaking,%	≥ 75
Freeze-thaw TSR %		≥ 70

- **Typical mixture formula:**

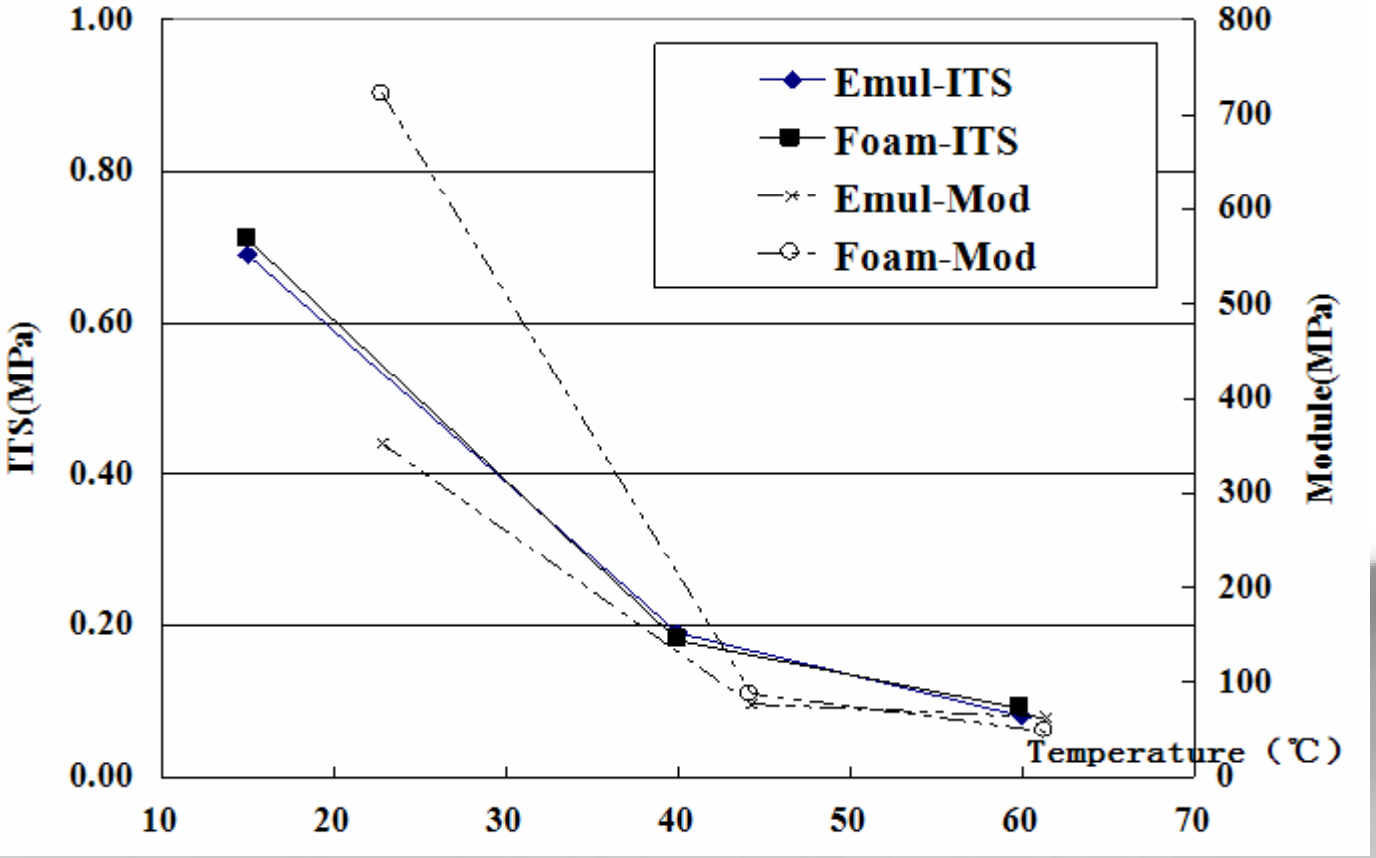
1. RAP: 75%-80%
2. Virgin aggregates:20%-25%
3. Foam Asphalt: 2.2%-2.5%

   (or Emulsion: 3.5-4.5%, 62% residue)
4. Cement:1.2%-1.5%
5. Water: 3%-5%

5、CR Mixture Characteristics

- **(1)Mechanical Nature**

It's visco-elastic material, rather than rigid material

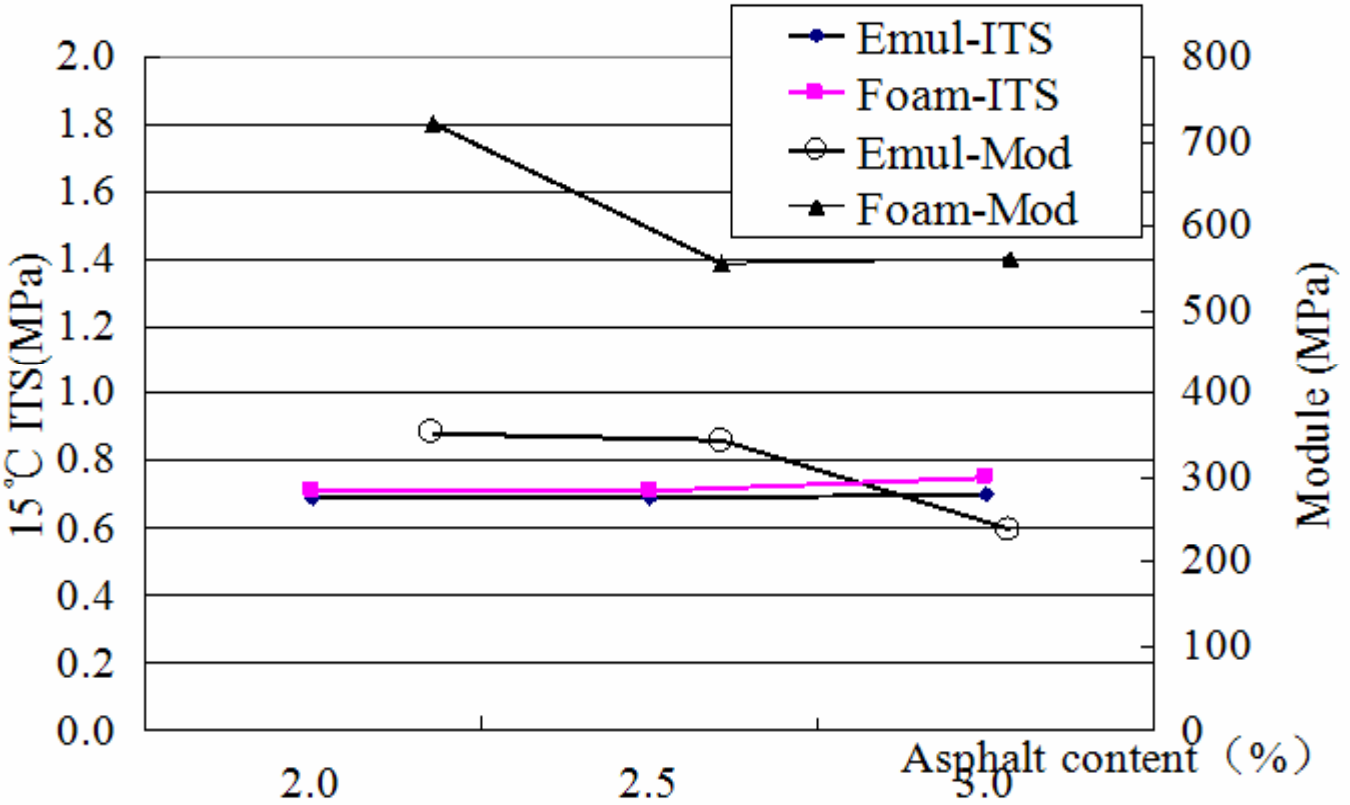


Cores from foam stablized recycling mixtures

It is really different to tell the difference between foam or emulsion stablized cold recycling mixtures and HMA.

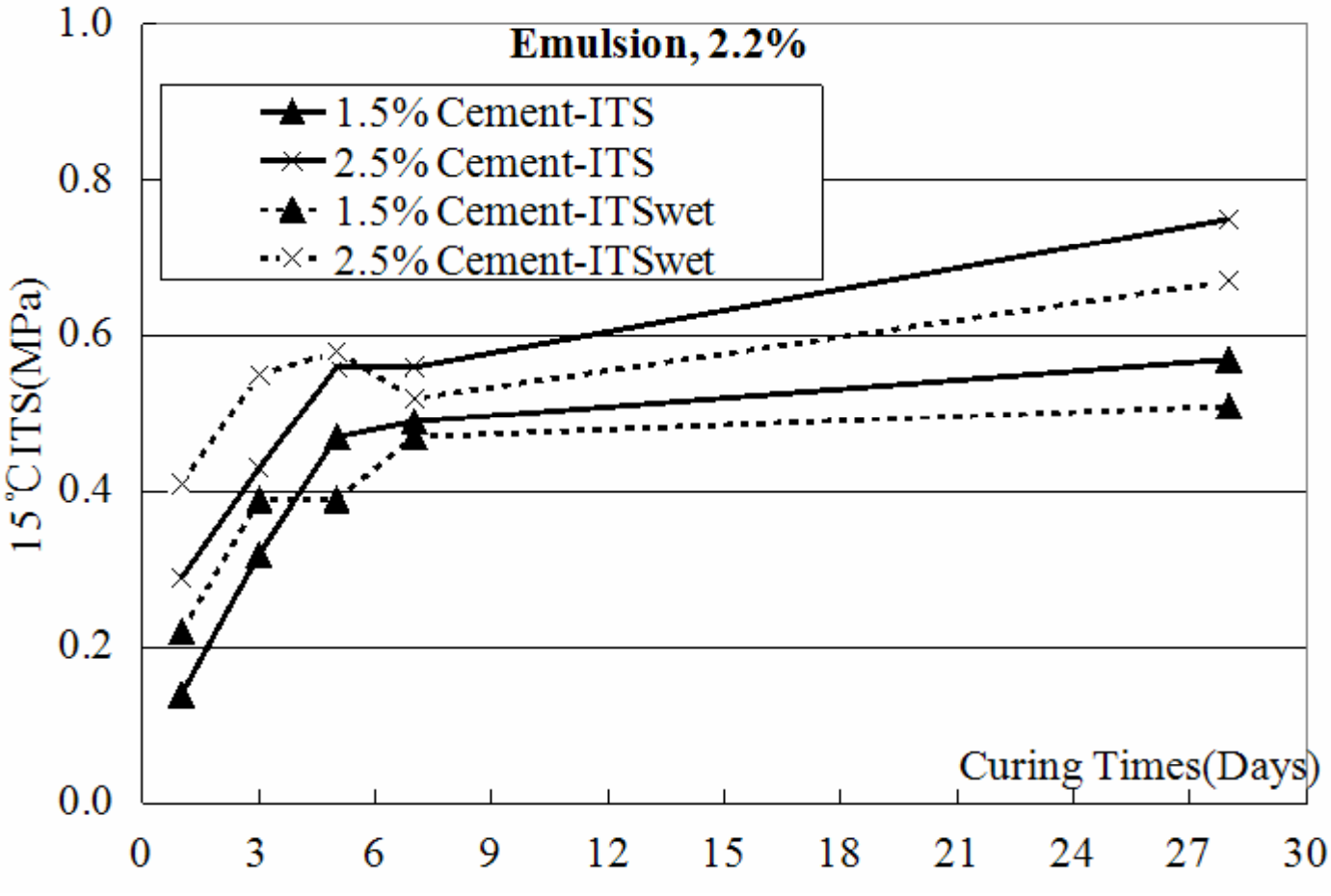
●(2) Asphalt Content

ITS values don't change significantly with the asphalt content changing in the range of 2.0-3.0%, but the modules drop significantly with the increase of asphalt content.The lower limit of asphalt content is around 1.8%.

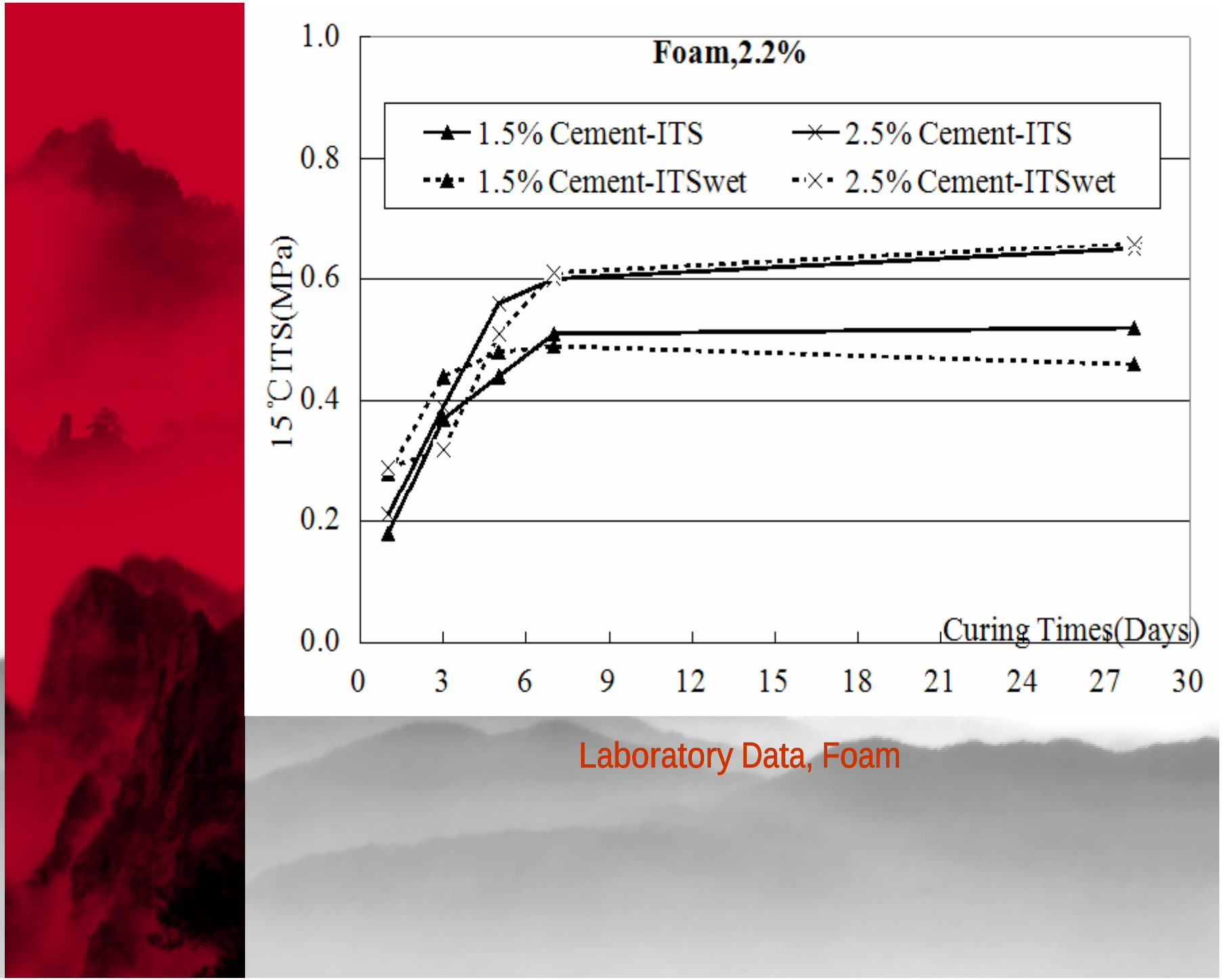


●(3)Strength Gaining

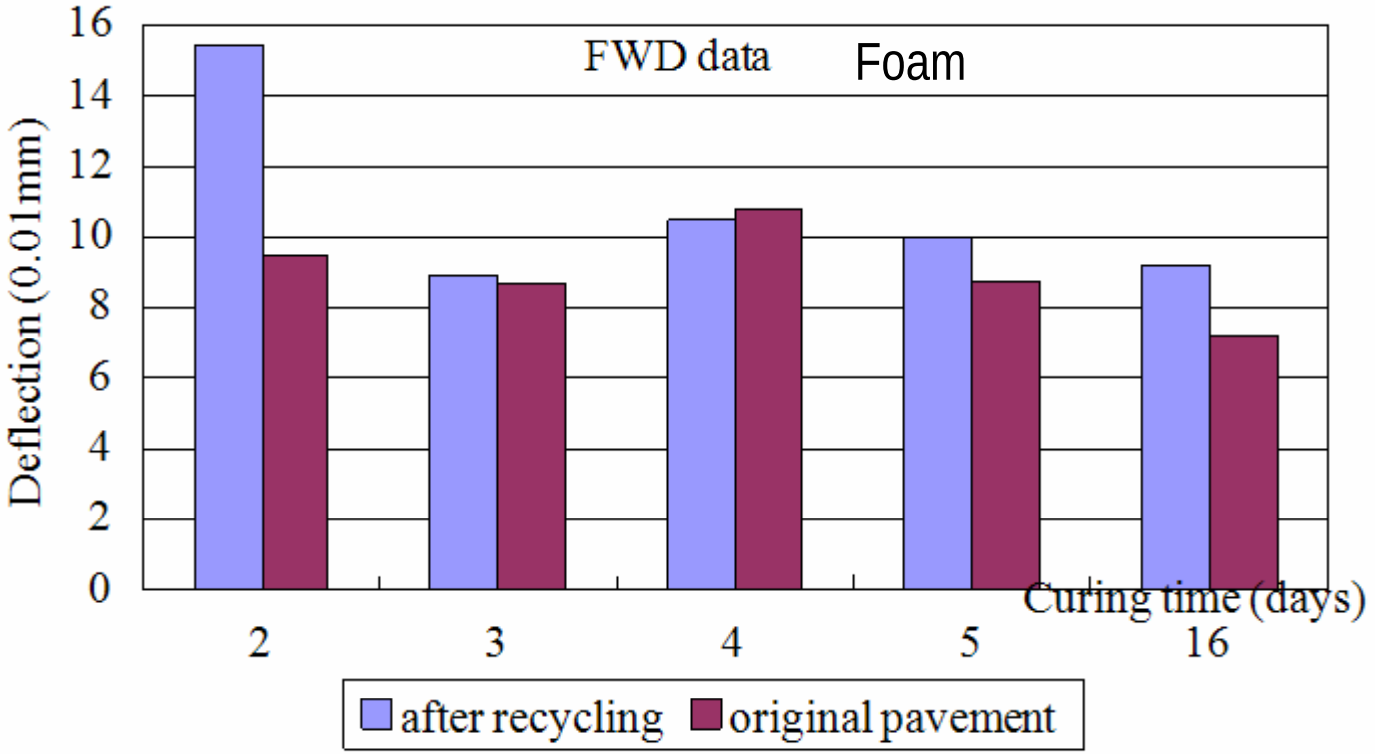
CR mixture gains most of its strength in the first 7 days.



Laboratory Data, Emulsion

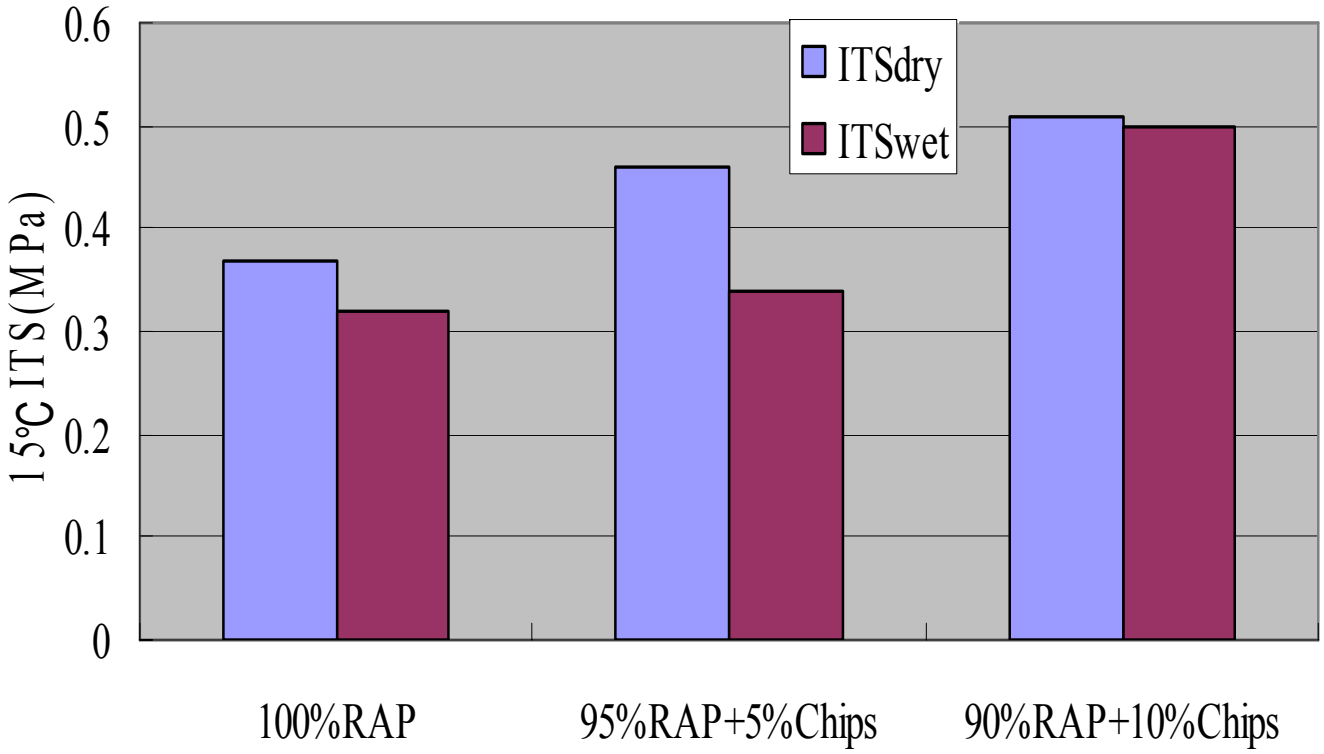


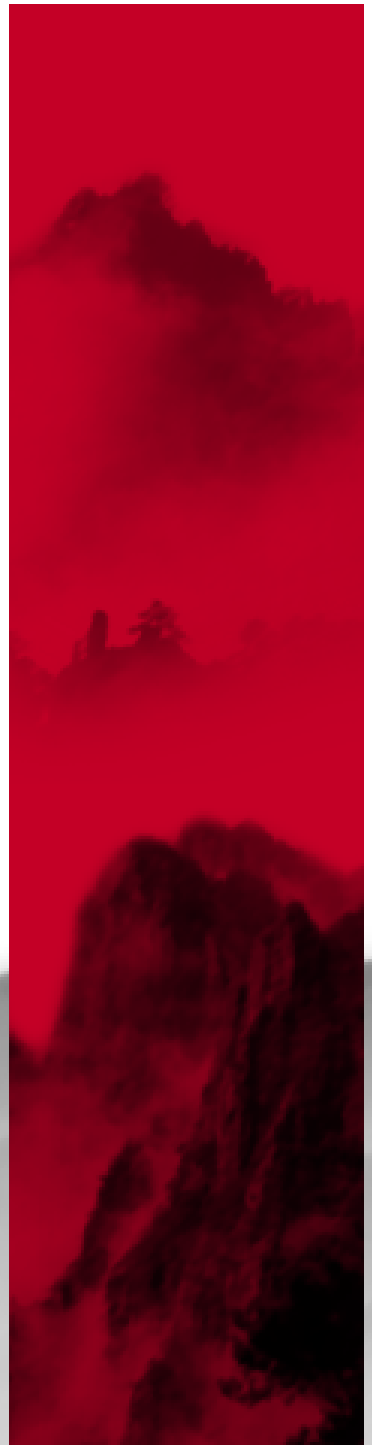
Laboratory Data, Foam



These Data were get from different spot along the same road recycling project

●(4)Virgin aggregates are helpful to enhance strength

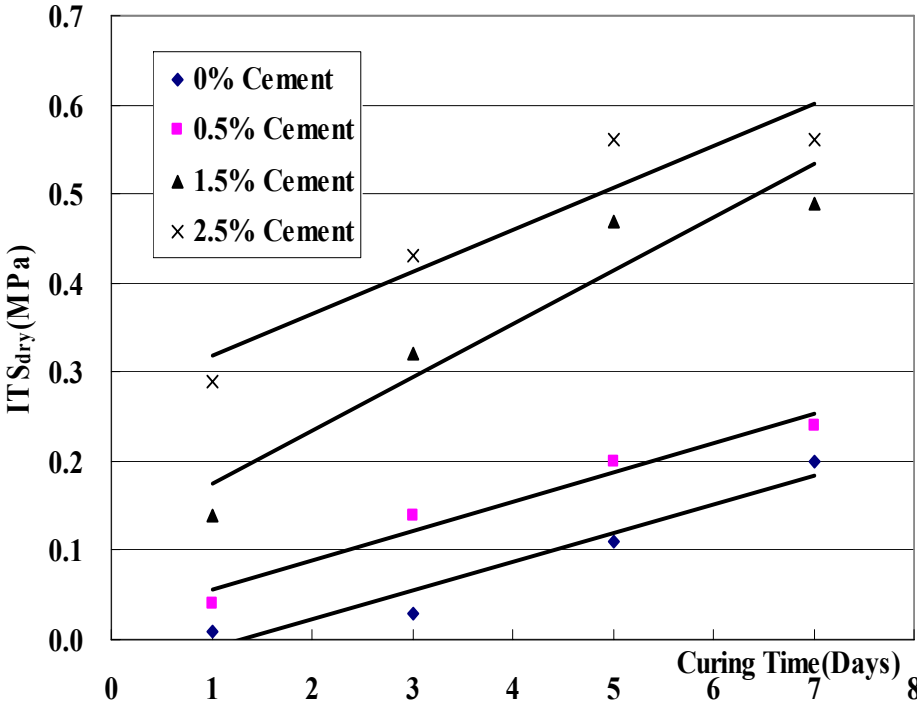


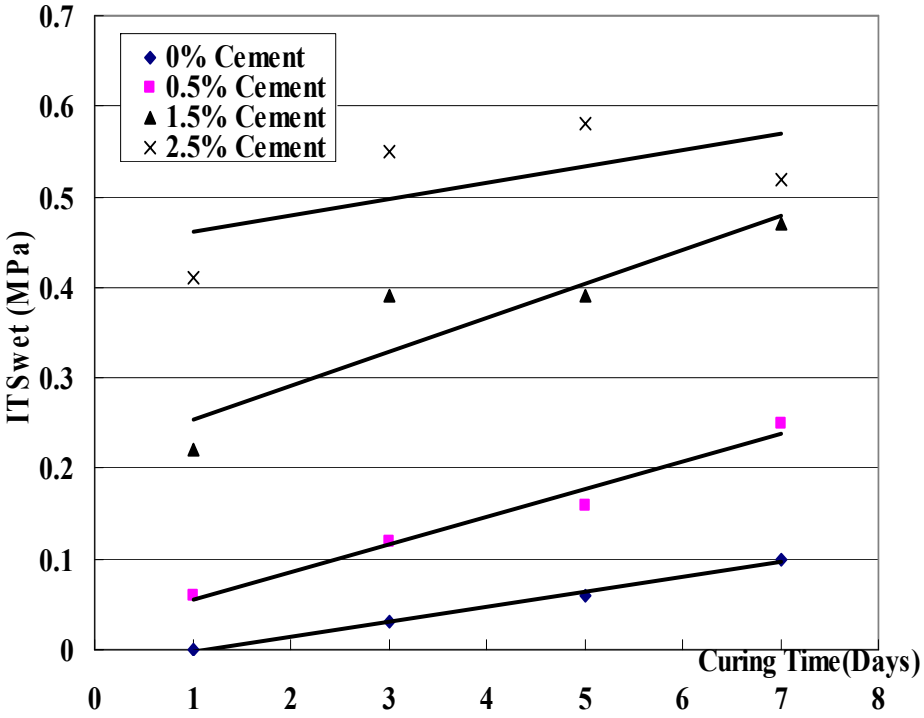


●(5)Cement content

Portland cement is absolutely necessary in CR mixtures. The point is, correct amount of cement optimizes mixture than too much or too little cement. The optimal cement content for CR mixture is around 1.5%。

(5.1)Cement and initial strength.

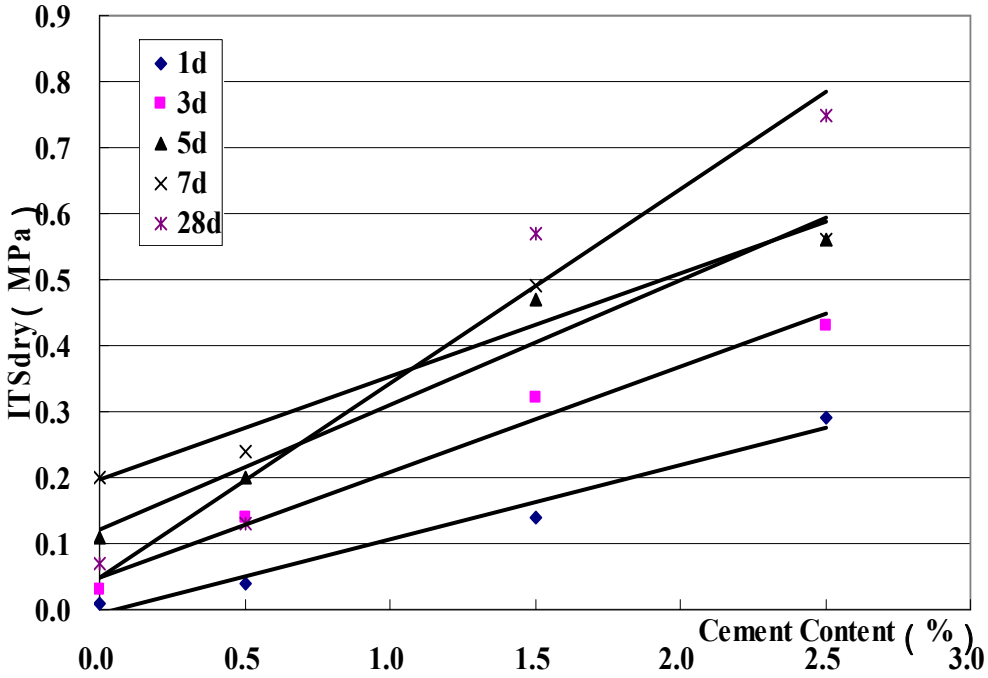


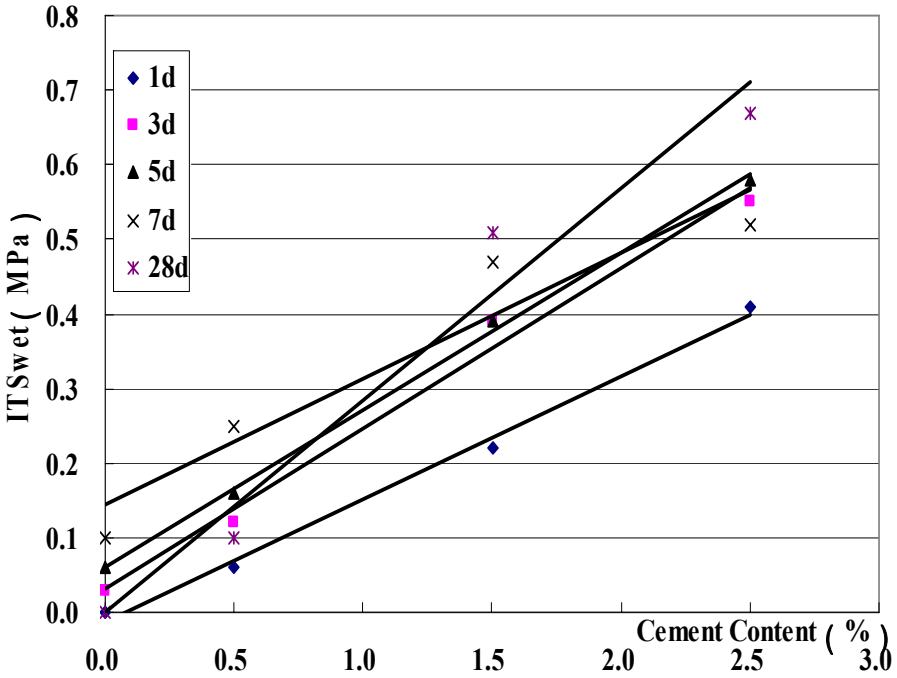


Cement Content	Linear Regression	Coefficient of Determination, R^2	Note
0.0%	y = 0.0325x - 0.0425	0.9399	y- ITS_{dry} x-Curing time
0.5%	y = 0.033x + 0.023	0.9595	
1.5%	y = 0.06x + 0.115	0.9125	
2.5%	y = 0.047x + 0.272	0.8871	

Cement Content	Linear Regression	Coefficient of Determination, R^2	Note
0.0%	y = 0.0165x - 0.0185	0.9945	y- ITS_{wet} x-Curing time
0.5%	y = 0.0305x + 0.0255	0.9754	
1.5%	y = 0.0375x + 0.2175	0.8452	
2.5%	y = 0.018x + 0.443	0.3927	

- (5.2) Cement and moisture resistance properties
- ITSwet is more significantly affected by cement content than ITSdry.
- Cement is indispensable to CR mixtures considering moisture resistance.



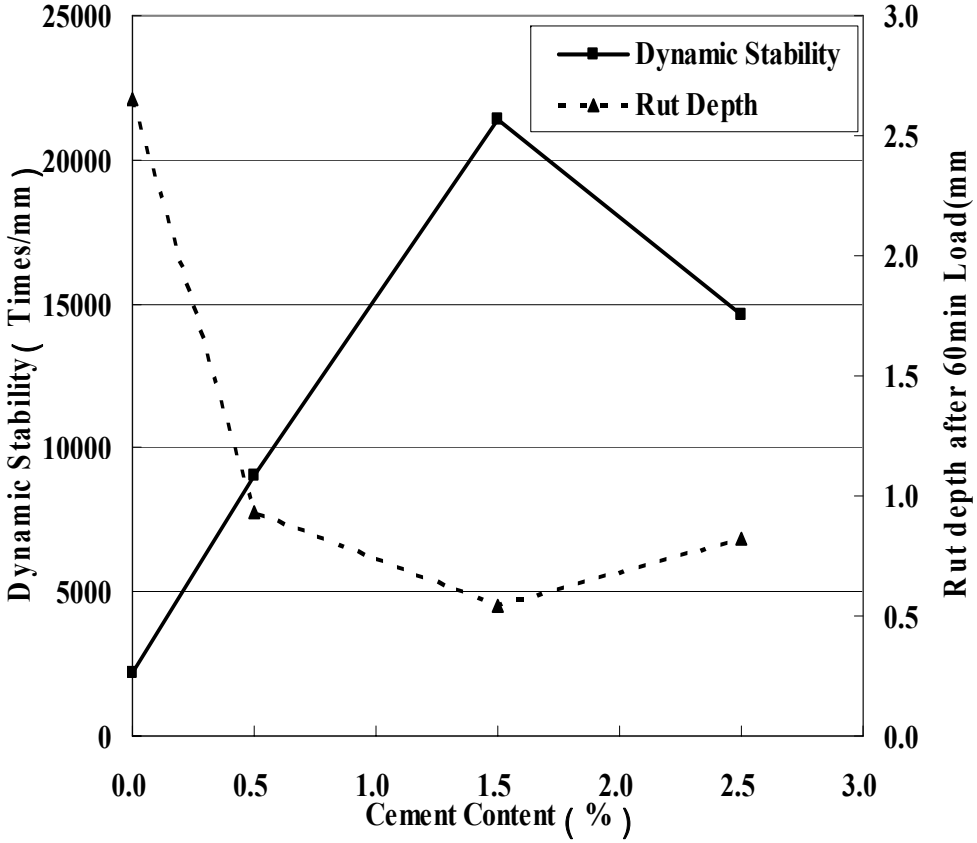


Curing Times	Linear Regression	Coefficient of Determination, R^2	Note
1 day	y = 0.1125x - 0.0066	0.9771	y- ITS_{dry} x-Cement Content
3 days	y = 0.16x + 0.05	0.9813	
5 days	y = 0.1892x + 0.1222	0.9581	
7 days	y = 0.1569x + 0.1959	0.9435	
28 days	y = 0.2942x + 0.049	0.9627	

Curing Times	Linear Regression	R^2	Note
1 day	y = 0.1651x - 0.0132	0.9973	y- ITS_{wet} x-Cement Content
3 days	y = 0.2153x + 0.0303	0.9883	
5 days	y = 0.2105x + 0.0607	0.9984	
7 days	y = 0.1688x + 0.1451	0.9146	
28 days	y = 0.2847x - 0.0003	0.9663	

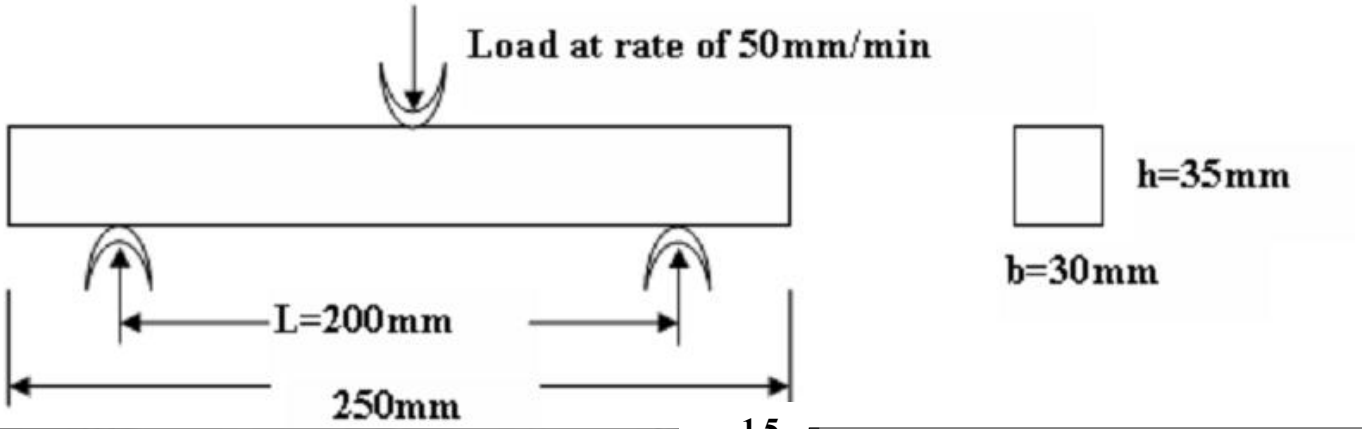
(5.3) Cement and rut-resistance properties

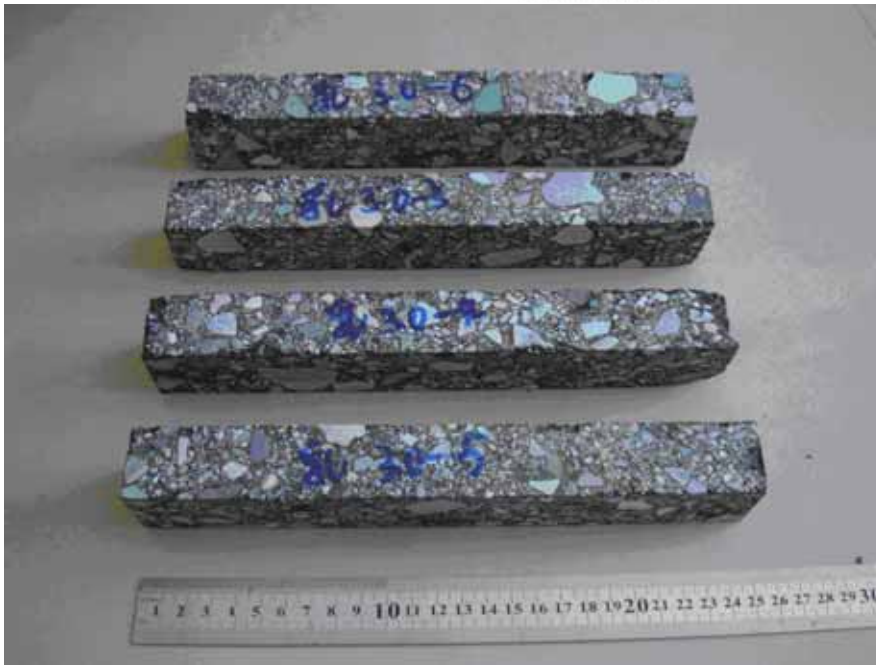
Adding cement enhances the rut resistant properties. However, when the cement content exceeds 1.5%, there is no further improvement.

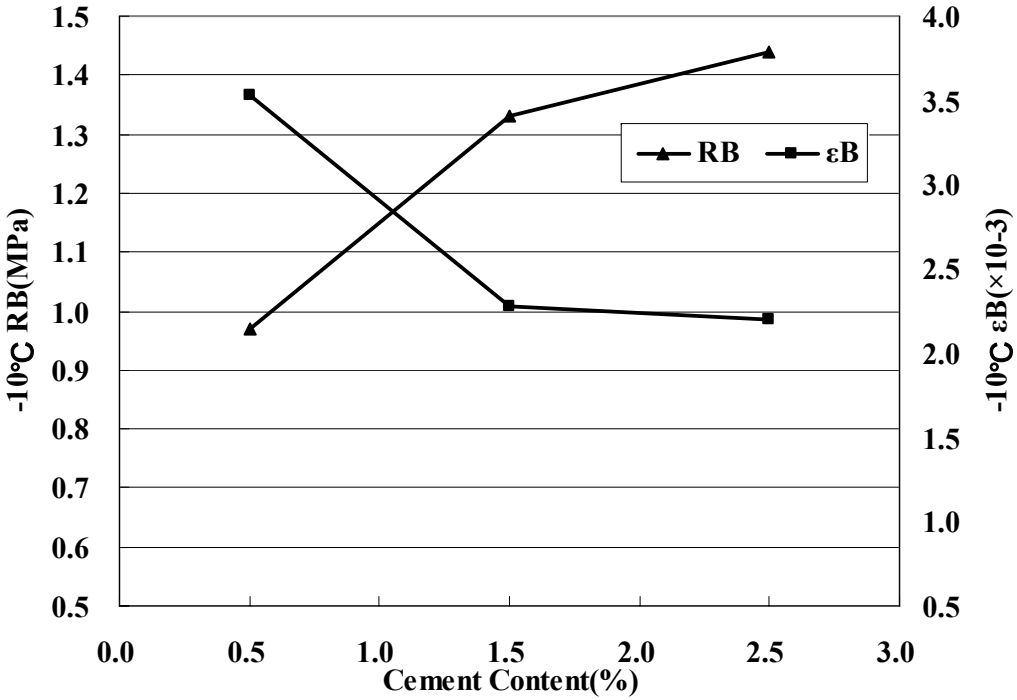


(5.4) Cement and crack-resistance properties

Increasing the cement content lead to a higher maximum bending strength and lower maximum bending strain at low temperatures(-10℃).

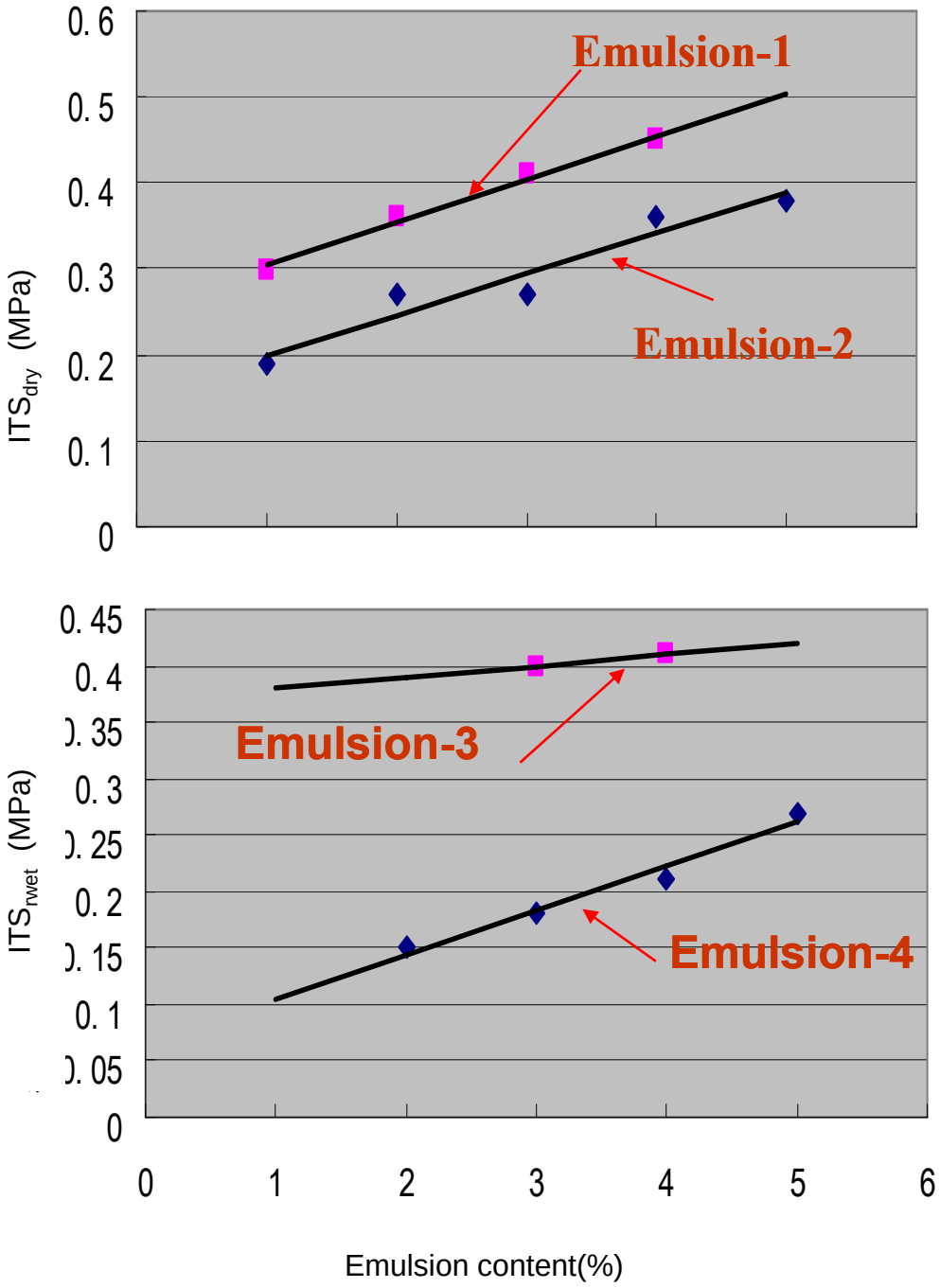






●(6)Emulsion design

Carefully designed Emulsion leads to better properties.



6、Construction

6.1Compaction

- Moisture content of mixture on the jobsite should be about 1% less than the OMC determined by lab test.
- Heavy pneumatic roller and vibration roller are recommended.

6、Construction

6.2 Curing

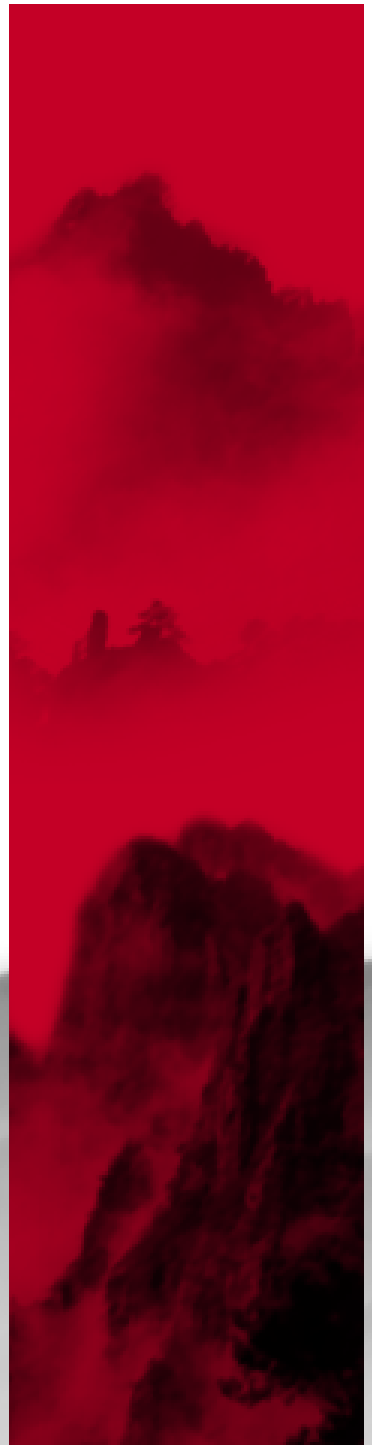
- It should be cured for at least 7 days before overlay, or reaching the following two circumstances: An integrated core can be taken from the recycling layer; the moisture content is less than 2%.
- It is prohibited to open to traffic within 24h after construction.
- If It has to open to traffic after 24h, heavy trucks are prohibited, and it is desirable to spray a fog seal beforehand (0.05～0.2kg/m2 diluted asphalt emulsion).

6.3 Quality Contral

Items		Requirements	Frequency	Test method
Emulsion	Compaction ratio（％）	≥90（Exp. And first class） ≥88（second class and below）	Once/ one lane km	T0924 orT0921
	Air voids（％）	≤10（ Exp. And first class ）≤12（second class and below）		
Foam	Compaction ratio （％）	≥98 （ Exp. And first class ） ≥97(second class and below）	Once/ one lane km	T0924 or T0921

15℃ ITS（MPa）	Meet the design requirement	Once / day	T0716
ITS loss after 24h soaking（%）	Meet the design requirement		T0716
Marshal stability（kN）	Meet the design requirement		T0709
Retained Marshal stability（%）	Meet the design requirement		T0709
TSR（%）	≥70	Once / 3 days	T0729
Water content	Meet the design requirement	Aperiodically	T0801
Asphalt content and aggregate gradation	Meet the design requirement	Aperiodically	Extraction and sieving

Items		Requirements	Frequency	Test method
Unevenness（mm）		10	2 times/200 m	T0931
Vertical highness（mm）		±10	1 time / 20 m	T0911
Thickness（mm）	average	-10	1 time / 10 m lane	-
	Each data	-20		
Width（mm）		Wider than design	Once / 40 m	T0911
Slope（％）		±0.3	3 times / 100 m	T0911
Appearance		No exterior defects	Aperiodically	eyeballing



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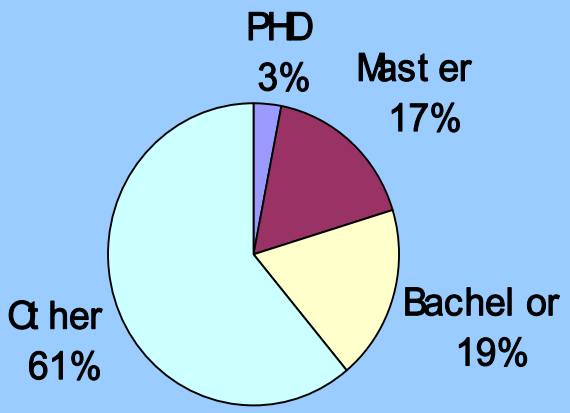
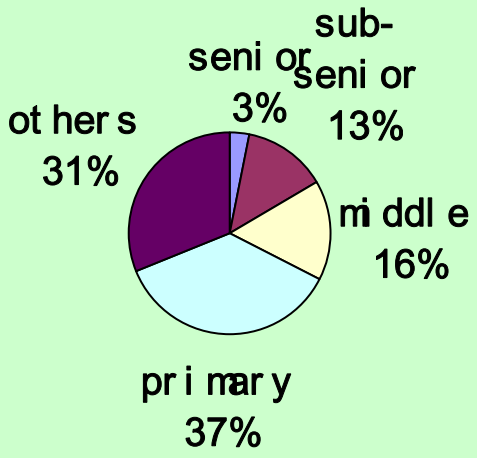




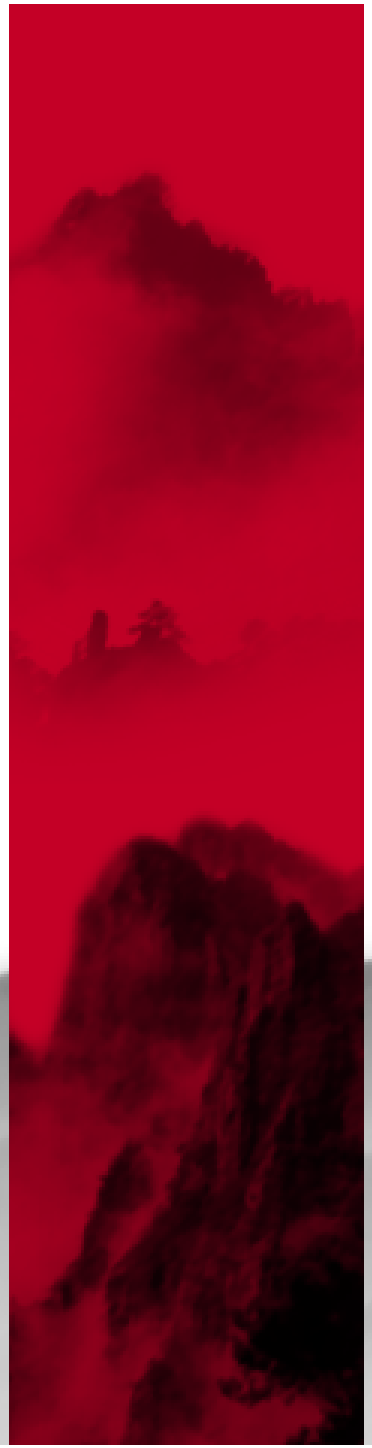
Nearly 1600 employees. Our MISSION:

(1)Establishing the Ministry level standards, specifications and guidelines

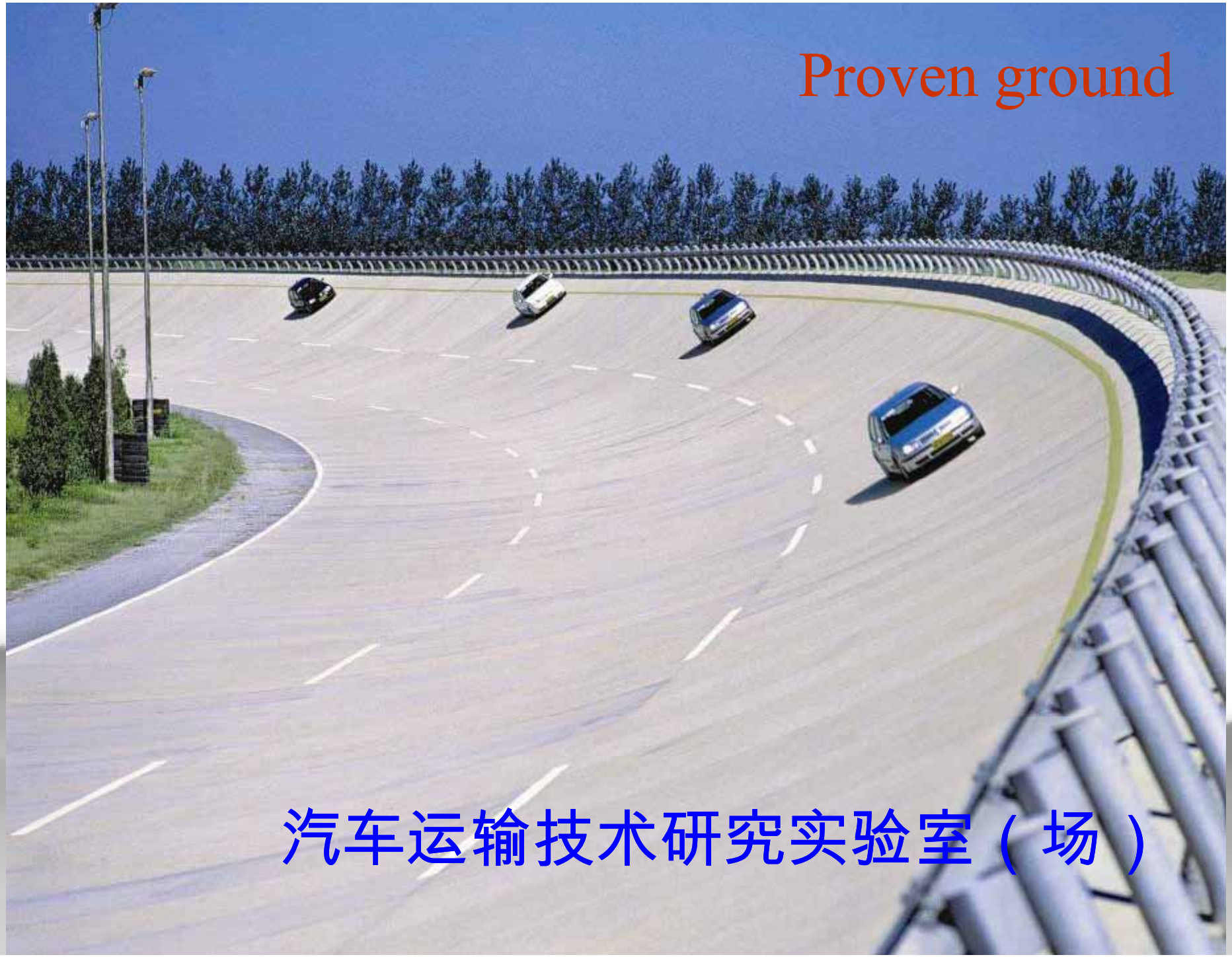
(2)Doing research on innovative road techniques

(3)Providing Technical services (Consultation, Road tests, and material tests)

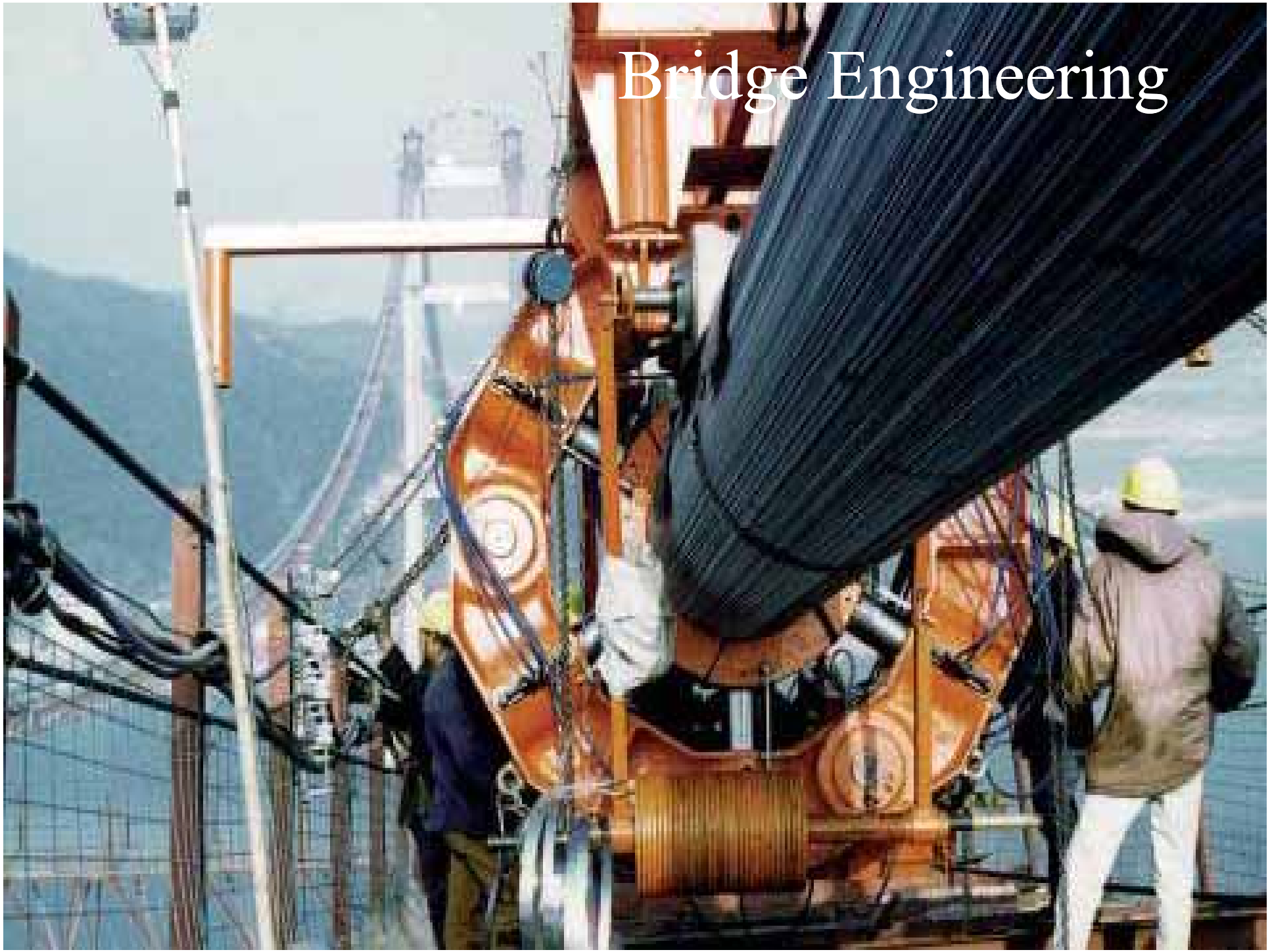
(4)Education and Training



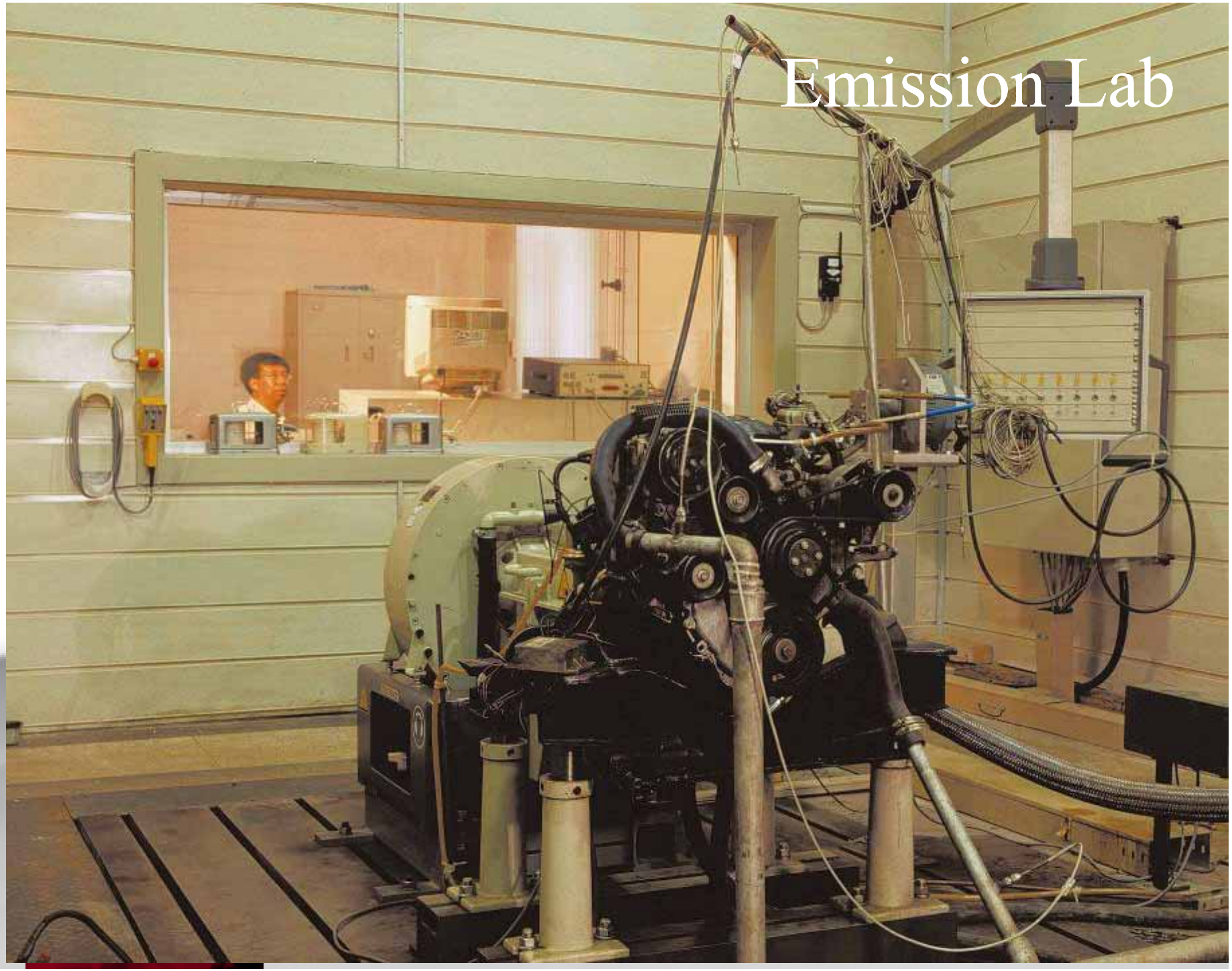
- Road Engineering RC
- Traffic safety RC
- ITS RC
- Automobile RC
- Environment RC
- Traffic economy RC
- Logistic RC
- Pavement management RC


Proven ground
汽车运输技术研究实验室（场）


ALF


Bridge Engineering

Emission Lab



Collision Facility

Thank You

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