반강성포장에 대한 실험적 연구
An Experimental Study on Semi-Rigid Pavement

임승욱* 양성철** 윤경구**
Lim Seung Wook Yang Sung Chul Yun Kyong Ku

ABSTRACT

The dense graded asphalt concrete materials have been used for construction of pavement for a long time. The performance of asphalt concrete pavement, however, is influenced by various factors including high temperature and heavy axle loads which cause plastic deformation. The plastic deformation is one of the main functional disadvantages of flexible pavement.

In this study, the semi-rigid pavement is considered to solve the problem. A set of experimental evaluation on semi-rigid pavement material has been conducted in laboratory to obtain it's physical properties and serviceabilities.

The results of tests, including compressive strength, flexural strength, ravelling and wheel tracking, show that the semi-rigid pavement has a good mechanical properties and serviceabilities. Consequently, the semi-rigid pavement may be suitable to bridge deck, tunnel, slow lane and parking area pavements.

1. INTRODUCTION

Semi-rigid pavement is developed to supplement normal dense graded asphalt concrete pavement to eliminate plastic deformation, shoving in high temperature, dark color etc.. In 1954, it has been applied for the first time to a runway in France, which was named Salviacim method.

Construction procedure of semi-rigid pavement is relatively simple. Its first stage is to produce an open-graded asphalt concrete mixture, and next is placing and compacting it. The final stage is pouring cement paste into the asphalt concrete and curing it. Table 1 shows general properties of semi-rigid pavement which is compared to those of portland cement concrete, normal dense asphalt concrete and porous asphalt concrete. Followings are major objectives of this study which will be used in highway practice.

(1) Bridge deck pavement ; To solve the plastic deformation problem in bridge deck pavements.
(2) Tunnel pavement ; To gain a bright effect in the tunnel pavements.
(3) Slow lane pavement ; To resist to heavy traffic load.
(4) Practice and Specification ; Mix design and in-situ test.

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* 한국도로공사 도로연구소 연구원
** 한국도로공사 도로연구소 책임연구원

Table 1. General Properties of Semi-Rigid Pavement

Items	Porous Asphalt	Dense Asphalt	Semi-rigid Asphalt	Cement concrete
Strength Mechanism	.Aspahalt cohesion	.Aspahalt cohesion	.Aspahalt cohesion .Chemical cohesion of cement paste	.Chemical cohesion of cement paste
Relation	Greater ductility ← → Greater rigidity			
Advantages	.Porousability .Silence .Low potential of hydroplaning	.Good rideability .Easy to maintain .Stage construction	.Durability .Resistance to deformation	.Good durability .Load capacity .Low cost
Disadvatages	.Plastic deformation .Short service life	.Cost .Plastic deformation .Poor durability	.Cost .Complicacy in construction	.Maintenance .Driving noise .Poor rideability

properties of semi-rigid pavement are analized including strength, marshall stability, mix design, void ratio, paste penetration ratio, etc.. In addition, a set of laboratory tests related to serviceability, including ravelling, wheel tracking, abrasion, and skid resistance, has been conducted. Furthermore, a functional evaluation on semi-rigid pavement, and comparison with normal dense asphalt concrete pavement and portland cement concrete pavement also have been conducted.

2. RESEARCH SCHEME

2.1 General

Semi-rigid pavement could be classified into full impregnation and half impregnation type, with regard to the penetration ratio of cement paste into the asphalt concrete mixture. In this study, authors considered semi-rigid pavement of full impregnation type only.

Table 2. shows physical properties of semi-rigid asphalt concrete compared with dense and porous asphalt concrete.

Table 2. Properties of Pavements

Items		Semi-Rigid	Dense Asphalt	Porous Asphalt
Density		2.0	2.3	2.0-2.3
Max. Aggregate Size		19mm	25mm	19mm
Void Ratio		20-25%	3-5%	12-18%
Marshall Stability		over 250kg	over 750kg	over 500kg
Compaction Temperature (°C)	1st	130-140	120-140	130-140
	2nd	70-80	90-110	70-80
	3rd	40-60	60-70	40-60
AP Contents		3-5%	3-5%	3.5-5.5%

2.2 Laboratory Test

Conducted tests and analized items are listed below and summerized in Table 3. Materials used in the tests are summerized in Table 4.

(1) Mix design and plant of base asphalt concrete.
(2) Mix design and basic properties of cement paste.
(3) Test on physical properties and serviceability of base asphalt concrete and semi-rigid pavement.
(4) Performence of semi-rigid pavement related to asphalt modifier, acryl and cement paste.

3. SERVICEABILITY

3.1 Physical Properties

The semi-rigid asphalt concrete pavement requires high void ratio and proper stability. In this study, authors selected a target void ratio of 18-25%, and acceptable results were obtained. Stability of base asphalt concrete was obtained over 300kg, which satisfies standard limit of 250kg. In case of using an asphalt modifier, CHEMCRETE, stability range of 400-480kg was obtained.

For strength test of semi-rigid asphalt

Table 4. Materials

Items	Characteristics	Remarks
Coarse Aggregates	Crushed Stone	Max. size= 19mm
Fine Aggregates	River Sand	
Cement	Rapid Hardening	ASTM type III
Acryl Resin	Water Soluble Polymerized	H.K.Polymer Co.
Asphalt	Penetration 85-100	AP-3
Asphalt Modifier	Liquified Organic Compound	CHEMCRETE

Table 3. Test and Analysis Items

Items	Subjects	Tests	Analysis
Physical Properties	Material	Aggregate	Grade, Specific Gravity, Water Absorbtion
		Asphalt	Penetration
	Base Asphalt	Marshall	Void Ratio, Stability, Flow
	Cement Paste	Flow	Workability
		Strength	Compressive, Flexural
	Semi-Rigid	Strength	Compressive, Flexural
Serviceability	Semi-Rigid Pavement	Ravelling	Resistance to traffic load at low temperature
		Wheel Tracking	Resistance to traffic load at high temperature
		Abrasion	Surface Property
		Skid	Skid Resistance

concrete, authors cut out the specimen for ravelling test in a size of 5X5X5cm for compression test, 5X5X25cm for flexure test. The compressive and flexural strength of semi-rigid asphalt concrete mixture were compared and evaluated with cement paste in terms of paste penetration ratio.

Plain cement paste resulted in slightly higher strength than acryl cement paste. However, semi-rigid asphalt concrete with acryl cement paste resulted in higher compressive strength than plain paste. It may be caused by higher penetration ratio of acryl paste, because of its better flowability. Namely, strength of semi-rigid asphalt concrete is largely influenced by paste penetration ratio. Table 5. shows results of compressive test on semi-rigid asphalt concrete.

3.2 Serviceabilities

3.2.1 Ravelling Test

Ravelling test is widely used to analize pavement serviceability at low temperature. Test was conducted in a specific test machine refregerated at $-10\pm2^{\circ}C$, by revolving a steel tire, suspended with a set of chain, on the surface of specimen. Test result is expressed by wearing area(cm^2) of exposed surface. The result was compared with dense asphalt concrete and PCC, and it is presented in Fig. 1.

As shown in Fig. 1, wearing of semi-rigid asphalt concrete is similar to PCC and is lower than 50% of dense asphalt concrete. Therefore, the resistance of semi-rigid asphalt concrete to wearing at low temperature is as good as that of PCC. Resistance to wearing is also estimated and it shows that it is strongly influenced by void ratio of base asphalt concrete and paste penetration ratio. Fig. 2 shows how paste penetration ratio affects test result.

3.2.2 Wheel Tracking Test

Wheel tracking test is one of the most important tests to evaluate pavements serviceability regarding resistance to plastic deformation at high temperature. For wheel tracking test, void ratio of base asphalt concrete was obtained 18-20%, and paste penetration ratio was 50-80%. Test results are presented in Fig 3. and Fig 4. and show that the paste penetration ratio affects test results. As shown in Fig 3, the resistance of semi-rigid asphalt concrete to plastic deformation is better than that of normal dense asphalt concrete. Especially in case of semi-rigid

Table 5. Compressive Strength of Semi-Rigid Pavement

Specimen	Penetration Ratio (%)	Compressive Strength(kg/cm^2)		Remarks
		Measured	Average	
With Plain Paste	81.7	87.2	94.8	
		104.2		
		93.1		
With Acryl Paste	87.3	112.5	130.3	
		155.1		
		123.3		

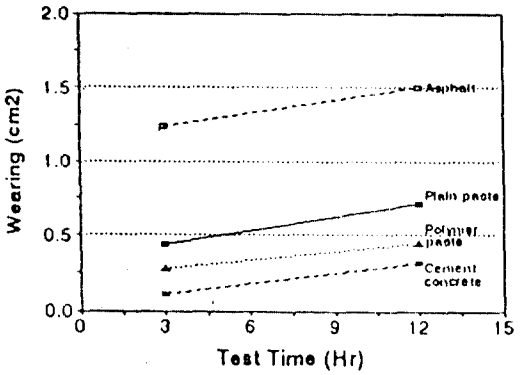

Fig 1. Comparison of Ravelling Test Results

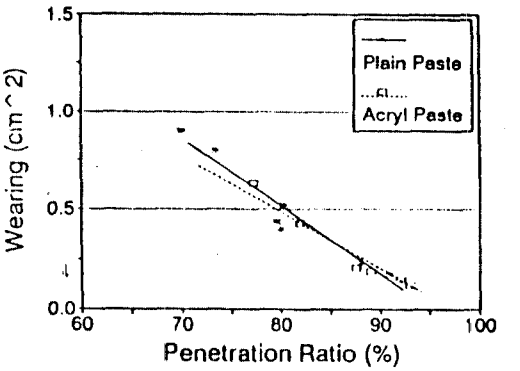

Fig 2. Wearing Area to Paste Penetration Ratio

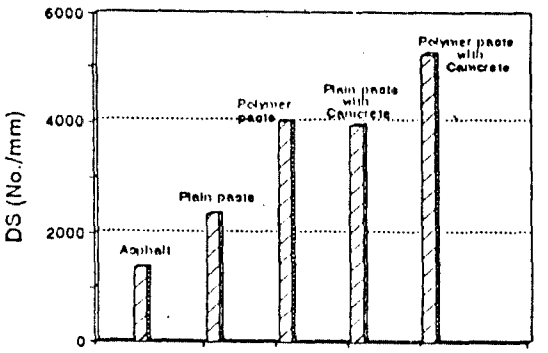

Fig 3. Comparison of Wheel Tracking Test Results

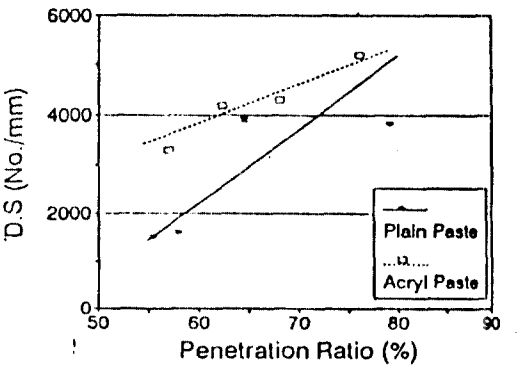

Fig 4. Dynamic Stability to Paste Penetration Ratio

asphalt concrete with asphalt modifier, CHEMCRETE, its resistance to plastic deformation increased more than two times compared to that of dense asphalt concrete.

Generally, dynamic stability (DS) of full impregnation type of semi-rigid asphalt concrete is reported over 5,000-10,000 (No./mm), and normal dense asphalt concrete 1,500-2,000 (No./mm). In this test, most of specimen were obtained at half impregnation type semi-rigid asphalt concrete, and its dynamic stability was 2,000-5,000 (NO./mm). But, if void ratio of base asphalt concrete and paste penetration ratio are improved to full impregnation type, the DS, the resistance to plastic deformation will be greatly higher.

3.2.3 Abrasion & Skid Resistance

Wearing course of pavement structure is demanded a good resistance to skid and abrasion against continuous traffic loads. Especially, it is more important properties to heavy traffic roads like highway. Specimens for wheel tracking test were also used for abrasion test, and skid resistance was measured with the specimens, which were used for ravelling test, by British Pendulum Tester (BPT).

Result of abrasion test is compared with PCC in Fig. 5. It shows that semi-rigid

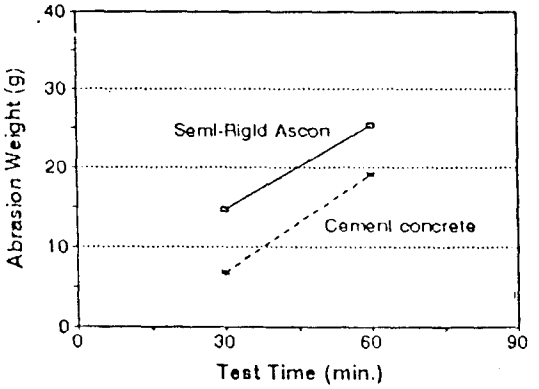

Fig 5. Comparison of Abrasion Test Results

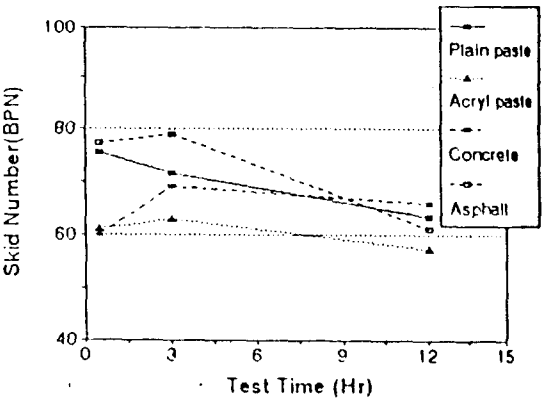

Fig 6. Comparison of Measured Skid Resistance

asphalt concrete has lower abrasion characteristic than PCC. Measured skid resistance is compared to PCC and dense asphalt concrete in Fig. 6. As shown in Fig. 6, dense asphalt concrete is recorded the highest initial skid number, but its decreasing rate with test time is also highest. However, the decreasing rate of skid number with time for semi-rigid asphalt concrete is similar with PCC.

3.3 Summary

(1) Void ratio of base asphalt concrete was obtained 20-25%, using asphalt contents of 3.5-4.5%.
(2) Standard limit for stability of base asphalt concrete is over 250kg, and more than 300-350kg was obtained.
(3) In case of using asphalt modifier, CHEMCRETE, Marshall stability was improved to over 400kg.
(4) Plain cement paste was more reconmendable for semi-rigid asphalt concrete in terms of increasing strength than acryl cement paste, and in case of using plain cement paste, traffic opening time should be more than 3 days for curing.
(5) Strength and serviceability of semi-rigid pavement are directly related to paste penetration ratio.
(6) As the results of laboratory test, semi-rigid pavement is similar to normal asphalt concrete pavement in terms of physical properties, but its performance is similar to PCC pavement.

4. CONCLUSIONS

In this study, semi-rigid pavement is estimated as an effective method to gain and maintain a good rideability. Also, its durability and serviceability, including resistance to plastic deformation and shoving, load carrying capacity, brightness of surface, etc., are improved.

(1) Semi-rigid pavement is suitable to bridge deck pavement, slow lane, parking area, and toll gate area since it has better rideability and resistance to plastic deformation.
(2) Semi-rigid pavement has more bright surface than normal asphalt concrete pavement. Thus, it is also suitable to tunnels pavement.

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