明道优术

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交通运输部公路科学研究院

“十二五”优秀论文集

人民交通出版社股份有限公司
China Communications Press Co.,Ltd.

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交通运输部公路科学研究院　组织编写

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内 容 提 要

“十二五”期间,交通运输部公路科学研究院以“提高自主创新能力、发展引领能力、科技服务能力,建设世界一流科研院”为目标,开展了卓有成效的科技创新活动,突破了一系列前沿与重大技术,取得了一批优秀科技成果,也在国内外学术期刊和国际学术会议上发表了大量学术论文。

本书为交通运输部公路科学研究院“十二五”期间发表的部分优秀论文,反映了该院在基础与前沿研究中获得的新突破和在重大应用技术研究领域取得的新进展。本论文集既是优秀论文的汇集,也是创新性研究理念的展示,可为广大科技人员开展科技创新活动提供启迪和参考。

本书可供从事公路工程管理、科研、设计、施工等工作的人员参考使用。

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Preface 序言

熠熠一甲子，艰苦创业60年！

交通运输部公路科学研究院自1956年10月10日正式成立，经过60年的发展，已成为集科研创新与产业开发于一体、公路交通运输行业最大的、国家级的综合性科研机构。

20世纪60、70年代，为解决公路“通”的问题，增加运输能力，我院科研人员刻苦攻关，取得了渣油路面、钻孔灌注桩和双曲拱桥等重大成果，被誉为公路建设的“三大法宝”。主持完成了冻土地区筑路技术研究课题，解决了青藏公路多年冻土、岛状冻土等技术难题，成果获国家科学技术进步一等奖。主导完成了公路桥梁单点顶推施工技术和新型刚架拱桥结构。这些成果对后来我国路面、桥梁技术的发展产生了深远的影响。

20世纪80年代初，为解决公路“畅”的问题，提升运输效率，交通部确立了“普及与提高相结合，以提高为主”的公路建设方针，高等级公路的修建成为重点，高速公路建设开始提上发展议程，公路现代化发展步入快车道。为解决公路建设的资金问题，我院牵头进行了车辆购置附加费征收研究，主持完成的《关于车辆购置附加费的建议》被国务院采纳，使我国公路建设有了长期稳定的资金来源。我院参与完成的国家“12个重要领域技术政策研究”，在“路面发展与材料问题”“解决混合交通问题”“汽车合理使用寿命”“汽车拖挂运输”“汽车合理轴重与车速”“降低汽车油耗与节油途径”以及“公路集装箱运输”等方面取得重要成果，填补了多项国内空白。主持完成了大跨径桥梁荷载试验方法研究，该成果在行业内得到广泛采用。在高速公路起步阶段，我院论证了在国内修建高速公路的可行性，又通过一系列样板工程的实施以及国家“六五”“七五”攻关项目研究，论证提出了高速公路交通工程及沿线设施和半刚性基层沥青路面设计方案，为高速公路交通安全设施和机电系统设计打下了坚实基础，深刻影响了我国高速公路技术的发展，至今仍被广泛使用。随着高等级公路的大规模兴建和公路总里程的增加，对在役公路和桥梁的养护管理提出了新的要求，我院对检测手段自动化、技术状况评定标准化、养护管理信息化、决策科学化以及维修养护工程技术开展了系统研究，取得了累累硕果，开启了我国公路养护技术现代化的新时代。

20世纪90年代，智能交通在国际上悄然起步，我院敏锐地抓住先机，及时设立了智能交通研究中心，开始谋划智能交通的发展，并在公路交通试验场建设实体化收费车道，开展

ETC试验等相关研究，为我国高速公路智能化奠定了基础。通过研究汽车排放对环境的影响及其防治技术，在国内最先界定了汽车污染分担率，提出的汽车排放源强纳入了公路环评导则，沿用至今。我院研究提出的路域生态系统的新理论，在路域生态保护中发挥了重要作用。这一时期，我院还主持完成了虎门悬索桥关键技术、道路通行能力等重要研究课题，取得了一系列成果，有力地支撑了我国公路大规模建设和高速发展。

在交通瓶颈得到初步缓解之后，从20世纪末开始，我院又将关注点转向交通运输全面协调、可持续发展，全方位加大各学科专业建设力度，结合行业发展和工程建设的问题和需求，积极行动，开展了路面早期损坏、复杂地质和气候条件下筑路技术、长大桥梁建设技术，以及智能交通、环境保护、交通安全等方面卓有成效的研究，在信息技术应用、生态环保、交通安全等领域取得了一系列具有自主知识产权和影响深远的科研成果，培养了一批国内顶尖的科研团队，拥有一流的科研平台和设备，成长为能够有力助推中国交通运输现代化发展的科技"主引擎"，提升了科技支撑能力和水平。

"十二五"期间，我院贯彻落实交通运输部党组的决策、部署和要求，以"提高自主创新能力、发展引领能力、科技服务能力，建设世界一流科研院"为目标，以实现"为部服务再上新水平、科学研究再上新档次、产业开发再上新台阶"为抓手，统筹推进全院各项工作，突破了一系列前沿与重大技术，取得了一批优秀科技成果，为行业发展提供了重要支撑。

基础前沿研究取得新突破。一是形成了宽刚度域长寿命沥青路面协调设计模型、基于下一代互联网的国家干线公路网管理与服务等15项前瞻性技术。二是构建了新一代国家交通控制网、在役混凝土桥梁可靠性检测评估等32项前沿技术。引领了行业技术发展。

重大应用技术研究取得新进展。一是打造了桥梁耐久性、公路基础设施维护、公路甩挂运输等12项交通运输行业重大共性关键技术。二是完成了湖北沪蓉西、山西忻阜、江西庐西等6项高速公路科技示范工程。三是在高性能材料、新型结构、无损检测、监测控制、路网运行、安全评估、运输服务、交通物流、交通信息化等方面取得了一系列创新与突破，推动了行业共性技术的进步。五年间共获得国家科学技术进步二等奖7项。

政策规划研究取得新成果。一是完成了深化出租汽车行业改革、公路养护、绿色公路、跨省道路危险品运输、安全风险防控、交通运输治理现代化等86项政策规划研究；二是依托《科技创新与现代交通运输业发展》专刊，研究提出了"关于创新公路网运行监管与服务体系建设及运营方式的建议""公路交通行业治理体系现代化思考"等政策建议68项，其中5篇专报和12条建议得到部领导批示，为深化交通运输行业改革、制定产业和技术政策提供了决策支持。

标准规范创制取得新成绩。主持或参与制修订了《公路工程技术标准》《公路工程质量检验评定标准》《公路通行能力手册》等技术标准规范300余项，制定团体标准49项。通过发挥标委会桥梁纽带作用，凝聚行业智慧、成果和经验，在行业标准规范方面发挥了主导和支撑作用。

科技服务能力得到新提升。一是形成了以科研活动为先导、科技服务为主体的成果转移转化体系。技术服务、开发、咨询、转让成为我院科研成果转移转化的重要方式。二是在公路、桥梁建设与养护，路网运营与管理，智能交通与运输服务，工程检测与设备，工程诊断与评估，事故调查与鉴定，安全与环境评价，生态保护，节能减排与循环利用，工程材料与制品等领域，形成了较强的科技服务能力。

本书收录了我院"十二五"期间发表的部分优秀论文，反映了公路院在基础与前沿研究中取得的新突破和在重大应用技术研究领域取得的新进展。这本论文集既是我院优秀论文的汇集，也是我院创新性研究理念的展示。真诚希望这本论文集能够为公路科技创新活动提供一些启迪和参考，共同为引领和支撑我国公路交通运输发展做出更大的贡献。

张劲泉

交通运输部公路科学研究院院长

2016年8月

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明道优术

交通运输部公路科学研究院"十二五"优秀论文集

2013年

优秀论文

Effect of Linear Low Density-Polyethylene grafted with Maleic Anhydride(LLDPE-g-MAH) on Properties of High Density-Polyethylene/Styrene-Butadiene-Styrene (HDPE/SBS) modified asphalt

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Abstract: A kind of modifier composed of high density-Polyethylene (HDPE) and Styrene-butadiene-styrene (SBS) was prepared by melt blending with different contents of linear low density-Polyethylene grafted with maleic anhydride (LLDPE-g-MAH). HDPE/SBS modified asphalt composites were prepared.. Effects of LLDPE-g-MAH on classical performance, hot storage stability, and dynamic rheological behaviors of HDPE/SBS modified asphalt were investigated. Compared with samples without LLDPE-g-MAH, penetration and ductility of HDPE/SBS modified asphalt were both increased, in the meantime, softening point and the maximum failure temperature were decreased. The research results showed that low-temperature performance was improved, while LLDPE-MAH had no positive effect on high-temperature property. In addition, softening point difference between the top and bottom sections of samples was sharply reduced. A fairly homogeneous dispersion system of the modifiers in the asphalt matrix was observed by microscope. A conclusion that LLDPE-g-MAH had no significant effect on high-temperature property and rheological character can be drawn from the rheological studies.

Keywords: High density-Polyethylene (HDPE); Linear low density-Polyethylene grafted with maleic anhydride (LLDPE-g-MAH); modified asphalt; properties

0 Introduction

In recent years, with the increasing volume of traffic, larger-scaled vehicles and the increasing proportion of overloading vehicles, the quality requirement for the road surface of modern transportation is higher and higher. Ideal performance demands that the binder must be able to withstand low temperatures and the resulting thermal stresses that develop pavement shrinks, resist repeated loading and unloading without exhibiting fatigue failure, withstand loading to prevent permanent deformation, and be capable of being compacted, transported, and stored at safe temperatures[1,2].

From this perspective, application properties of ordinary oil asphalt can not accommodate the increasing traffic intensity, axle loads and meet the demand for comfort, because of its severe temperature susceptibility. Therefore, it is essential to modify asphalt[3,4]. Polymer modified bitumen (PMB) has been growing rapidly in road paving applications over the last decade[5]. Polyethylene (PE) has been found to be one of the most effective polymer additives with reducing the rutting under heavy loads. Unfortunately, the high crystalline nature of PE makes badly compatible with asphalt. PE particles separate from the asphalt when stored at high temperature, which further limits the application of PE modified asphalts in paving[1].

From previous studies, we can know that the compatibility between polymer and asphalts and stability of modified asphalt depend on many factors, such as asphalt composition, polymer characteristics, preparation processes and so on. In order to resolve this problem, many researchers have been trying to find effective methods, such as adding of sulfur[6], incorporating silica into LDPE[4], chemical reactive blending[7], steric stabilizers[8]. On the basis of the common physical modification of the asphalt, the chemical reactive blending and adding the graft copolymer were valuable to obtain better performance[9,10].

It is well known that plastomeric polymers can improve rut resistance, but they are inferior to elastomers[11,12]. In addition, plastomeric polymers can not improve low-temperature performance of asphalt. Elastomers can improve fatigue resistance and cracking resistance, but it is limited to improve heat resistance. Thus, combining the advantages of plastomeric polymer such as PE, EVA and elastomers such as SBS, SBR and incorporation of these materials into PMA would be an effective method of recycling polymer to enhance the properties of asphalt pavement[13-17].

In the present work, high density-Polyethylene (HDPE) modified asphalts with good high-temperature storage stability were prepared by blending SBS and graft copolymer into HDPE and mixing into asphalt. We selected tentatively LLDPE-g-MAH as the graft copolymer to improve the compatibility between asphalt and HDPE, and to enhance interaction between modifiers. The effects of LLDPE-g-MAH on the classical properties, high-temperature storage stability, rheological properties of HDPE/SBS modified asphalt were analyzed.

1 Experiment

1.1 Materials

Base asphalt, with 60/80 penetration grade, was obtained from the Shenghua refinery in Shan Dong province, China. The base properties and chemical composition of base asphalt are shown in Table 1.

Basic Properties and chemical composition of base asphalt Table 1

Properties	Value	Chemical composition	Value
penetration 25℃, dmm	67.1	Asphaltenes, %	12.13
Softening point, ℃	50.1	Resins, %	22.82
ductility 10℃, cm	21.1	Saturates, %	11.93
density 15℃, g/cm^3	1.004	Aromatics, %	53.12

HDPE, Grade 5000S, was produced by Yanshan Petrochemical Company. SBS, Grade 791H, was provided by Baling Petro-Chemical Company of Sinopec Corp. Co.. LLDPE-g-MAH was obtained from the market; its graft level is 0.9%.

The engineering properties of the HDPE and SBS are presented in Table 2.

Properties of HDPE and SBS Table 2

polymer	Density(g/cm^3)	melt flow rate(g/10min)	elongation at break(%)	Tensile strength(MPa)
HDPE	0.95	0.9	800	23
SBS	0.94	0.5	750	18

1.2 Preparation of composite modifier

The composite modifier, with HDPE and SBS as the matrix, LLDPE-g-MAH as the compatibilizer with different content, carbon black (CB) as the filler in definite proportion by weight, was prepared by melt blending. HDPE, SBS, LLDPE-g-MAH and CB were transferred into the twin-screw extruder preheated at 165℃ first, extruding grain at a constant mixing speed of 30 r/min, then composite modifier was obtained and can be used in the following step.

1.3 Preparation of HDPE/SBS modified asphalt

The HDPE/SBS modified asphalts were prepared by three steps. First, the base asphalt was heated to 160℃ and melted in an iron container, the composite modifier of HDPE/SBS was added into the asphalt and stirred at a moderate or low speed at 160℃ for 0.5 h to obtain a finely dispersed minor phase. Then, the sample was heated to 180℃ and sheared at the rate of 4000r/min for 40min. During this process, a little sulfide was added into HDPE/SBS modified asphalt. Last, the sample was stirred at 140℃ for 20min.

1.4 performance measurements

Conventional performance was mainly composed of softening point, penetration, ductility measured according to Standard Test Methods of Bitumen and Bituminous Mixtures for Highway Engineering[18].

The storage stability of the modified asphalts was measured as following steps: the sample (50g) was poured into an aluminum toothpaste tube (25-mm in diameter and 140-mm in height). The tube was sealed and stored vertically in an oven at 163℃ for 48h, then cut horizontally into three equal sections, after it cooled to room temperature. The samples from the top and bottom sections were melted and placed in small molds labeled A and B to evaluate storage stability by measuring the softening points of them, respectively. If the difference of the softening points between A and B were less than 2.5℃, the sample will be regarded to have good storage stability.

A drop of bitumen was first sandwiched between a slide, and a cover slip, and then put onto sample heater. Bitumen was heated and slowly pressed into a thin layer between slide and cover slip. Its distribution behavior was observed by using optical microscopy and micrographs were taken using a photo camera.

A dynamic shear rheometer (Anton paar made in Austria, Type. H-PTD120) was used for dynamic mechanical analysis of asphalt binders. The viscous and elastic behavior of asphalt binders was characterized at intermediate and high service temperatures at a rate of 10rad/s. The samples were "sandwiched" between two parallel plates with a diameter of 25mm and a gap of 1 mm. The test temperature was raised by ramping rate of 6℃ one cycle, and the test was terminated when the $G*/\sin\delta$ was equal to 1. Temperature sweeps were applied at a fixed frequency of 10rad/s and variable strain. The rheological parameters were measured for calculating viscoelastic parameters such as complex modulus ($G*$), phase angle (δ), and rut factor ($G*/\sin\delta$).

2 Results and discussion

2.1 Effects of LLDPE-MAH on classical properties of HDPE/SBS modified asphalt

In technical specifications for construction of highway asphalt pavements, penetration and low temperature ductility are usually used to evaluate the low-temperature performance of asphalt. The effects of LLDPE-MAH on low-temperature properties of HDPE/SBS modified asphalt were illustrated in Table 3.

Low-temperature Properties of HDPE/SBS compound modified asphalt Table 3

Sample[a] ID	Mass ratio[a]	Low-temperature performance of modified asphalt	
	(HDPE/SBS/ LLDPE-g-MAH)	penetration (25℃,0.1mm)	ductility(10℃,cm)
A	4/1.3/0.13	51.1	10.6
B	4/1.3/0.27	58	14.7
C	4/1.3/0.4	67	18.1
D	4/1.3/0	50.8	10.3

[a]The percentage contents of HDPE, SBS, LLDPE-g-MAH were calculated based upon the weight of base asphalt

Compared with those modified asphalts in absence of LLDPE-g-MAH, such as sample D, penetration and ductility of the asphalt became higher after the addition of LLDPE-g-MAH, and the changes are more obvious