双组分标线在全球使用情况介绍

双组分涂料已广泛应用于地坪、防水、防腐等工业和建筑领域，其主要种类有环氧、聚氨酯。近几年新兴的材料体系有丙烯酸反应型和聚脲喷涂体系。在道路标线领域，冷漆和热熔涂料占主导，双组分用量在持续增长，有丙烯酸反应型、环氧及少量的聚脲喷涂。环氧主要在美国使用——我国在上世纪 70 年代曾使用溶剂型环氧标线，后因干结时间慢、设备不配套而终止。丙烯酸反应型源于德国，因其干结时间快、耐候好的特点，在世界各地得到快速发展。

MMA 即甲基丙烯酸甲酯的英文简称，它是一种活性单体树脂。是丙烯酸树脂的基础原材料，同时大量应用在有机玻璃的制造上。赢创德固赛做为全球特种丙烯酸的主要供应商，全球第一个将 MMA 树脂用于有机玻璃的制造，即现在的亚克力板 PMMA。该公司在 MMA 树脂研究推广方面做了大量的前期工作，上世纪 70 年代便将 MMA 树脂做成反应型涂料用于地坪、防水和道路标线。德国的 Silikal 公司，Alteco-technik 公司，主要生产 MMA 地坪涂料；英国的 Stirlinglloyd 公司主要生产 MMA 桥面防水涂料。德国和瑞士上世纪 70 年代已开始使用 MMA 冷塑标线，美国上世纪 90 年代初在气候最恶劣的阿拉斯加州（Alaska）开始使用 MMA 冷塑型标线。MMA 冷塑标线应用已有 30 多年历史，在英国、瑞士、丹麦、德国和美国北方的气候寒冷的州大量使用（见美国 Aexcel 公司网站介绍）。在亚州、南

美州、非洲也开始逐步应用。现世界各地的一些大型标线涂料生产商纷纷开始研发制造 MMA 标线涂料——美国有 Ennis 公司、Aexcel 公司、Swarco-colorado paint 公司、Relly-Moore paint 公司等；英国有 Prismo 公司、Wjroadmarkings 公司以及 Irroadlines 公司；还有加拿大的 Lafrentz 公司，土尔其的 Rapaskimya 公司，泰国的 PPI 公司等。

1、双组分标线在各国的习惯称呼

常见的标线种类有冷漆、热熔、双组分。冷漆可分为溶剂漆、水性漆，热熔可分为石油树脂和松香树脂，双组分可分为环氧(Epoxy)、甲基丙烯酸甲酯（Methyl Methacrylate）、聚脲（Polyurea）等。此外，还有根据需要在工厂预制好的标线带，通常粘贴安装。

在欧洲国家即德、英、法等国，双组分标线只有一种即甲基丙烯酸甲酯 MMA 型，通常称为 Cold Plastic 即冷塑型标线。

在美国，双组分标线种类较多，有环氧(Epoxy)、聚脲(Polyurea)、甲基丙烯酸甲酯（MMA）类。美国和加拿大标线名称通常按主树脂类型称呼，如环氧型称为 Epoxy,甲基丙烯酸甲酯型称为 MMA，聚脲型称为 Polyurea，MMA 标线常见的英文有“MMA trafficpaint、MMA roadmarking、MMA laneline、MMA (2-Component)、MMA resin”等等。

在澳大利亚和新西兰，将标线材料分为 3 类，即 Paint、Thermoplastics 及 Cold Plastic，将 Cold Plastic 冷塑型标线称为 PMMA（见 www.nzta.govt.nz 网站）。

关于 MMA 树脂的称谓，德国 Silikal 公司网站解释如下：

MMA resins have different names on the market.Examples include methacrylic resins,acrylic resins,cold plastic resins,methacrylates,MMA,PMMA，etc.No matter the name,they are all of the same nature as described before.

译文：MMA 树脂市场上具有不同的名称，诸如甲基丙烯酸树脂、丙烯酸树脂、冷塑性树脂、甲基丙烯酸酯、甲基丙烯酸甲酯即 MMA、聚甲基丙烯酸甲酯即 PMMA，……无所谓名称，如前所述，它们都是相同的性质！（详细可上 www.silikal.avatos.com 查阅，见附件 1）

国内所说的双组分标线多数为丙烯酸型双组分标线，仅有少量企业生产聚酯双组分、环氧双组分。一般企业只介绍商品名称，而较少告知主要成膜物树脂种类。目前市场上叫 MMA 双组分的，叫 PMMA 双组分的，还有叫活性丙烯酸的，叫冷塑型的，都是一类即 MMA 甲基丙烯酸甲酯型。只有 MMA 树脂做为主要成膜树脂，才能和固化剂发生化学反应而固化。

通常标线采用的活性丙烯酸树脂并非纯的 MMA 单体，而是以 MMA 单体为主，还有 PMMA（粉体溶解于 MMA 单体溶液中）以及其它助剂等预聚合而成。涂料生产商在该树脂中加入必要的颜料、填料以及助

剂制成标线材料。在标线施工时，该涂料与固化剂发生化学反应而固化成膜。

2、双组分标线应用方式和应用领域

环氧、聚脲双组分采用喷涂施工方式。因涂料粘度大，且随温度变化敏感。标线喷涂设备需要加热功能。美国 Minnesota 州较早采用喷涂环氧树脂，在《Cost of Pavement Marking Materials》明尼苏达州道路研究所 2000 年出版的一份研究报告中指出环氧施工时，两组分材料需分别加热到 43℃±1℃，施工时因干结慢，需撒布大量玻璃珠（见附件 2）。甲基丙烯酸型树脂由于粘度低，易喷且标线固化时间适中，通常不需对涂料加热。标线施工有喷涂、刮涂、甩涂等多种方式。

目前，MMA 双组分涂料使用的比例有 1:1 和 98:2 较多，有个别使用 4:1 的体系。使用的固化剂一般为过氧化物即 BPO。固化剂有粉体和液体状。施工用量比例如下：

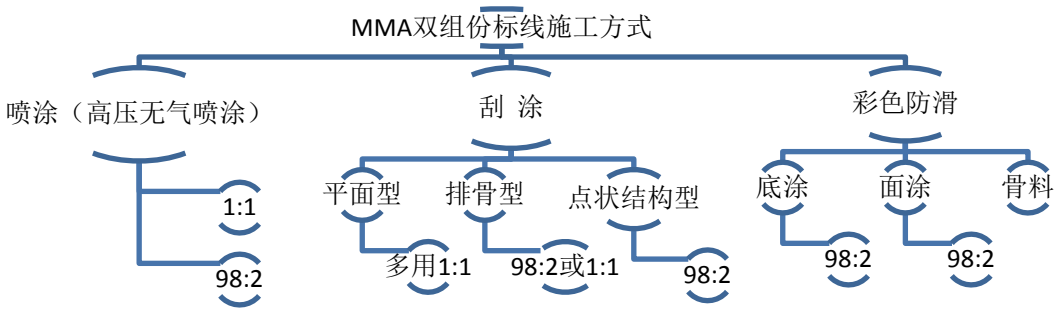
A 组份:B 组份+2-4%BPO=1:1

A 组份:固化剂 BPO=98:2

固化剂一般在施工现场提前加入，B 组份加入固化剂常温下可保持 1-2 天，加入固化剂的 B 组份一旦与 A 组份混合便很快发生反应而固化。

MMA 双组分标线施工方式有喷涂（膜厚 0.5-0.7mm）、刮涂以及彩色防滑标线，刮涂又分为平面型（膜厚 1-1.5mm）、排骨型（基线

1.2mm，排骨突起高 4-5mm），以及点状结构型（点状面积占 60%，高度 3-4mm）。



在德国，早期应用较多的是喷涂和平面刮涂型，喷涂施工效率高，可长距离连续作业，刮涂标线施工速度慢，多用在小型区域标线，如人行横道线及文字箭头符号。本世纪初，欧洲制定了新的标线标准，要求在国道等主干线采用 II 型标线（即要求雨夜反光的标线）。目前在欧洲国家采用 MMA 点状结构型标线较多，尤其在德国和瑞士用量很大，而在欧洲以外地区，采用较多的还是喷涂和少量的平面刮涂型。

3、各国政府对双组分标线的使用性能要求及标准

欧洲国家有统一的标线标准，适于英、法、德、丹麦、意大利、瑞士等国家。具体如下：

ISEN1436：Roadmarking matrial—Roadmarking performance for users —2007 年（标线的路用性能）

ISEN1871：Roadmarking matrials:physical prlperties—2000 年（标线的物理性能—试验室测试）

ISEN1824：Roadmarking：Road trials（道路试验）

在欧洲标线材料有三类：冷漆（含溶剂型和水基型）、热熔及冷塑型。冷塑型特指 MMA 双组分。

标线分为 I 型和 II 型标线。I 型标线为传统平面标线雨夜不反光。II 型标线指标线表面有纹理，可雨夜反光。

欧洲将标线的性能进行分级以供顾客选择。标线材料既要通过试验室测试其物理性能，同时也必须进行路试来测定其耐久性、反光性、颜色保持性等，并对其材料进行分级。

美国由于国土面积大并采用联邦制管理，标线并无统一的国家标准。国家建有道路标线测试中心并在全国建立几个试验场地，只出试验报告，不作判定。各州有权制定自己的标线材料规定和使用何种标线材料，并对合格的供应商建立备案制（可查阅 www.ntpep.org）。

加拿大的情况跟美国相似，Edmonton 市在 2000 年制定了 MMA spray plastic 的性能规定，主要指标有磨耗、白度、反光性、比重、硬度、对水泥的粘接力以及耐水、耐油等（见附件 3 MMA spray plastic—Edmonton 2768-2000）

新西兰在 2003 年制定了长寿命标线的使用性能规定（详见附件 4 Specification for long-life roadmarking materials）。该标准规定，在路试 300 万轮次后，MMA 冷塑型标线反光性不低于 100mcd，

黄线不低于80mcd，标线的完好率不低于8级。标线的颜色不大于4级。

以上可看出，标线材料不仅要满足一定的理化指标更主要是通过路试来测定其实际使用性能，厂家的标线材料不通过路试很难进入市场使用。

4、各国对双组分标线使用效果评价

MMA冷塑型标线发源于德国。德国联邦公路研究所（BAST）拥用全球第一个大型的环形道路标线模拟实验室，R keppler教授负责试验室工作，他从1989年到2004年，共收集1954份不同类型白色标线的材料的试验结果，发现冷塑型（喷涂、刮涂、挤压）标线的试验结果满意率最高，德国政府便积极推广该种标线，在欧洲新的标线标准中，专门增加了MMA冷塑型标线，为该标线在欧洲及以外的地区使用奠定了坚实的基础。2004年，MMA在德国标线市场占有率超过10%，瑞士几乎全部采用MMA标线。

英国过去以热熔标线为主（几乎占80%市场份额），现在很多标线企业开始推广该产品（上网可查阅英国标线公司的介绍）。

美国阿拉斯加州在美国最北部，气候极端寒冷，该州在1994年开始做MMA标线与热熔标线、标线带、冷漆的对比试验，该研究认为MMA适于寒冷气候效果最好（详见附件5），华盛顿州交通部门在2000

年开始采用 MMA 标线（详见附件 6）。在寒冷多雪地区，冬季降雪对标线破坏较大，原有的冷漆标线和热熔标线效果均不好，而 MMA 冷塑型标线强度高，耐磨，对玻璃珠附着力强，美国北方的一些州和加拿大都采用 MMA 冷塑标线（既有喷涂，也有刮涂标线），有些州使用环氧双组分标线。在美国西南部如加利福尼亚州也开始采用 MMA 双组分标线，已在洛杉矶国际机场和旧金山县采用 MMA 标线，该州已将 MMA 标线列入采购目录，并有 4 家合格的材料供应商，分别是 Ennis、Aecel、Swarco-Coloraolo Paint 和 Kelly-Moore Paint 公司（见附件 7）。

在中国尽管双组分标线推广已有近十年，但一直未能得到大量使用。过去五年是中国城市大发展的时期。由于北方城市大量采用热熔标线，但热熔标线易粘污变脏，雨水较少，造成北方城市标线不清。2008 年开始，MMA 双组分抗污标线在太原、哈尔滨、北京、乌鲁木齐等市做对比试验（和热熔标线对比），经过 1-2 年观测其抗污效果明显优于热熔标线，而二者标线寿命相当。北方城市的政府主管部门推荐使用该产品，多个城市都开始大量使用 MMA 双组分抗污标线。

另外在我国南方，如上海市采用 MMA 结构型标线可实现雨夜反光，在我国的高速公路和国道主干线上，MMA 双组分标线也开始应用，如纳黔高速、奎克高速等。

附件提示：

附件 1、Performance of cold plastics

附件 2、Expoxy traffic paint

附件 3、The specification for the supply of MMA spray plastic traffic marking material

附件 4、Specification for long-life roadmarking materials TNZ M/20:2003

附件 5、Performance of traffic markings in cold regions

附件 6、Washington Pavement Marking Material Selection Guide

附件 7、State of California,Authorized Materials List For MMA Traffic Paint

参考网站：

1、www.aecelcorp.com 该公司位于美国，生产“MMA traffic paint ”,其商标名为 Roadzilla

2、www.nzta.govt.nz 新西兰政府网站，有耐久性标线材料规定

3、www.silikal .avatos.com 德国公司主要生产 MMA 防水、地坪涂料，站内有文章专门介绍 MMA 标线的使用情况

4、www.ntpet.org 美国道路材料测试机构。在全美有几个实验场地，对标线材料进行室内物理测试和道路试验评估。出具试验报告，但不做合格判定，报告供各州管理部门参考。

5、www.dot.ca.gov 是加利福尼亚州政府网站，内有 MMA 标线漆的合格供应商名录

6、“performance traffic Markings in cold Resins”1995 Alaska 州研究报告

7、“MMA lanelines 15 Nisqually River Bridge to Gravelly Lake I/C”1996 年 Washington 州的研究报告

8、www.stirlinglloyd.com 该公司是英国大型的地坪、防水企业,基于 MMA 树脂生产桥梁防水材料 ，已成立 40 多年

9、www.Alteco-technik.eu 德国公司生产环氧、聚胺脂、MMA 地坪和防水涂料

10、www.roadtraffic-technology.com 该公司位于美国，专业生产各种标线涂料，已开始生产 Cold MMA plastic roadmarking 商品名 Nitesite MMA Roadmarking

11、www.swarco.com 该公司是一家全球大型交通设施企业，生产信号灯、玻璃珠、标线涂料，在其产品介绍中，生产 MMA(2-component)标线漆

12、www.Limburger Lackfarik.de 该公司是 Swarco 集团公司的德国子公司，是德国最大的标线涂料生产商，主要生产 MMA cold plastic

13、www.ppi.com 该公司位于泰国，是泰国及东亚地区最大的标线涂料安全产品生产商之一，生产热熔、冷漆、双组分材料（MMA）

14、www.rapaskimya.com 是一家土尔其公司，生产冷漆和 MMA 双组分漆

15、www.Lafrentz.ca 该公司是加拿大唯一可生产热熔涂料和 MMA 冷塑型标线涂料的企业

16、www.prismo.com 该公司位于英国， 是英国较大的标线材料生产企业，已生产 MMA 冷塑型材料

17、www.degarout.com 德国赢创公司，是全球最大的特种化工材料供应商，Degarout 是其道路标线材料的商标名称

Performance of cold plastics

Cold plastics adhere well to asphalt but not as good to concrete. We recommend using a suitable MMA concrete primer to improve the adhesion to concrete. Concrete primer is used to seal off the capillaries of the porous concrete in order to keep oxygen from interfering with the curing process. Oxygen and a surface temperature above +30 °C are the biggest sources of problems for MMA polymerisation. The marking film used on the surface offers protection thanks to the paraffin wax incorporated in the resin. Only a polymer film placed underneath the marking film as a primer can protect the cold plastic against curing problems. Sometimes concrete additives, such as emulsion resins or flow additives used in the fresh concrete, can affect the chemical hardening procedure, thereby causing tacky surfaces or poor adhesion.

Due to the flow tendency of bitumen, cold plastic resins must be designed to follow movements up to a certain extent. Hard resins, high shock temperature, high thickness and a high content of soft bitumen can create cracks at least on larger coating areas or long and wide marking lines.

Once the cold plastic has been mixed with hardener, the chemical reaction starts. After approx. twenty to forty minutes, the film is usually tack-free and ready for traffic. Just remember to wait 24 hours if you plan on checking the adhesion with a pull-off tester. The marking can be exposed to the hardest traffic immediately after tack-free time but the bitumen underneath is still saturated with monomer MMA which takes several hours for delayed curing. As a result, improperly placed lines can be removed shortly after curing with a scraper, leaving no white staining behind on the asphalt.

MMA cold plastic markings are very abrasion-resistant. With traffic under 10,000 vehicles per day, the average abrasion is approximately 0.2 mm per year. Shorter lifetimes sometimes result, not due to traffic, but rather because of improper application of the markings. If it rains during application, humidity and moisture will shorten the lifetime and result in delamination. Hot temperature during the curing phase will cause a higher residual monomer content, leading to soft marking lines which can absorb traffic dust and will darken very soon. Dust on pavement works like a release agent similar to flour used in the kitchen to stop dough from adhering to the worktop. Nowadays it is not common for damage to arise due to abrasion and wear. Occasionally damage does occur to cold plastic lines mainly because of delamination due to improper application.

MMA resins have different names on the market. Examples include methacrylic resins, acrylic resins, cold plastic resins, methacrylates, MMA, PMMA, etc. No matter the name, they are all of the same nature as described before. As described in many books and as you may know yourself, these resins are fully weather-resistant: UV radiation, heat, snow and ice as well as rain do not affect the properties. As a result, the line surface is sometimes improved due to the absence of these weather conditions. In countries located in the Near East and North Africa, where there is not much rainfall, road markings are usually not as white as they should be. Some countries use bitumen in pavements with a high crude oil content, meaning that in under intense sunshine, this oil can sometimes sweat out. Tyres transfer this grease onto the white lines and after months the road markings (all systems) are no longer visible.

Environmentally friendly

Since MMA resins do not contain solvents, they are VOC friendly according to ASTM 2369 test method. 99% of the monomers turn solid during the hardening procedure. Only a very small monomer amount can be identified by the typical odour of methacrylates.

During manufacturing, storage, transport and application, safety regulations must be considered. The MMA monomer and the resin made thereof are flammable liquids with a low flash point of more than +10 °C. Avoid open fire and sparks, and check the regulations for limited storage quantities, if you do not obtain permission by the authorities to keep flammable liquids in stock at your premises. The same applies to transport conditions of dangerous goods.

According to regulations for hazardous substances and mixtures, cold plastic compounds are usually classified as flammable (F) and irritant (Xi). When applying markings on outdoor surfaces, there are no health risks associated with the maximum MMA vapor concentrations. For indoor areas, such as line markings in warehouses or factory facilities, please refer to each product's Material Safety Data Sheet (MSDS). (Under special formulations, cold plastic compounds can be made without warning labels by using very low viscous resins and a very high filler content.)

Thermosets are becoming increasingly popular as their durability becomes known. Thermosets are a durable pavement marking material that typically is in the form of an epoxy or polyester. Epoxy is the more common material, and as a result is the one that will be discussed in greater detail in this section.

Epoxy is often referred to as "epoxy paint" because of its superficial resemblance to paint. Epoxy is a durable pavement marking material that is made up of two components. One component is the pigment and the second component is a hardener.

Application of epoxy requires specialized equipment and well-trained operators. As with the conventional materials, the air and pavement temperature should be at least 50^{o} F, and the pavement surface should be cleaned prior to the application. Each component of the epoxy is heated separately and then thoroughly mixed and applied at a temperature of $43^{o} \pm 1^{o}$ C ($110^{o} \pm 30^{o}$ F). Following the application of the epoxy, glass beads are added to give the marking its retroreflectivity. One of the drawbacks to using epoxy is the large number of glass beads that are dropped on top of it. Epoxy generally requires three times the number of beads as do the conventional materials. In part, such a large number of beads are needed to prevent cars from tracking the epoxy before it sets.

Epoxy comes in two forms, fast-dry and slow-dry. The fast-dry (also known as Type I) is a fast-curing material suitable for line applications. Under ideal conditions, application of this product may not require coning. The slow-dry (also known as Type II) is a slow-curing material suitable for all applications of pavement markings. This material always requires controlled traffic conditions (i.e., coning and/or flagging).

Epoxy is initially more retroreflective than the conventional pavement marking materials. Studies conducted by the Minnesota Department of Transportation indicate the initial retroreflectivity is around 300 mcd/m^2/lux for white and around 220 mcd/m^2/lux for yellow. The number of beads that are dropped on top of the marking as the material is applied may skew the initial retroreflectivity. As mentioned above, three times the number of beads are applied to epoxy as there are to the paints. Some organizations have found that the retroreflectivity of the epoxy does not last as long as the marking on the pavement. One way to address the long-term

1. GENERAL

This section provides the specification for the supply of MMA spray plastic traffic marking material.

2. PRODUCT

MMA spray plastic shall conform to the following specification

Tests	Minimum Requirements	Maximum Requirements	Test Method A.S.T.M.
Abrasion Resistance * (maximum loss /grams)	-	0.45g	D4060
Reflectance White - Yellow -	 75% 45%	 - -	E1347
Retroreflectance (with proper bead application)	200 millicandelas per square metre per lux		
Specific Gravity @ 25° C (77°F)	1.8	-	D792
Hardness	A-2 Shore 70		D2240
Water Absorption		0.5%	D570
Chemical resistance to anti-freeze brake fluid motor oil diesel fuel, gasoline calcium chloride sodium chloride transmission fluid	No signs of degradation after 7 days immersion		
Adhesion ** (to Portland Cement)	200 psi		
Skid Resistance (Field Base)	45 units		E303

* Abrasion resistance, maximum weight loss when subjected to 200 revolutions on Taber Abrader at 25° C using H-22 Calibrade wheels weighted to 500 grams with sample kept continuously wet with distilled water. Prepare test sample with representative material placed on 100mm square plate, 2 ±0.1 mm thickness.

** Adhesion to asphalt is dependent on the tensile failure strength of the substrate. This compound shall be resistant to the effect of ultra-violet light.

3. GLASS BEADS

Glass Beads shall conform to specification Section 02761.

END OF SECTION

TNZ M/20: 2003

SPECIFICATION FOR LONG-LIFE ROADMARKING MATERIALS

1. SCOPE

This specification sets out requirements for marking materials which have a long service life and which are typically applied at thicknesses of about 0.9 mm or more. The specification is applicable to these markings when applied over bituminous or concrete road surfaces.

The specification particularly applies to thermoplastic roadmarkings. For materials other than thermoplastic, test procedures need to be agreed with the testing agency.

2. MATERIAL REQUIREMENTS

2.1 Markings of Materials Other Than Thermoplastic

Markings of materials other than thermoplastic shall meet the field test requirements of clause 3 below. The packaging/labelling requirements shall meet the requirements of clauses 9 and 10. Additionally, when used, they must meet the requirements of TNZ P/12 for maximum thickness of markings.

Specific requirements for these materials will be defined as part of the Approval.

2.2 Markings of Thermoplastic Materials

Markings of thermoplastic materials must meet all clauses of this specification, with the exception of 2.1 above.

3. FIELD TESTING

3.1 General

Beaded test lines shall be applied in accordance with Appendix B, in a lane which is subjected to 1,500,000 vehicle passes within a period of more than three but less than nine months, and be assessed for skid resistance, retroreflectivity, degree of wear and colour after the stated numbers of vehicle passes.

3.2 Skid Resistance

When tested in the wheelpath in accordance with Roadnote 27 of Transport Road Research Laboratory at 1 hour after application and at any time thereafter, the skid resistance on a test line shall be not less than 50 BPN and no greater than 65 BPN.

3.3 Retroreflectivity Testing

When tested in accordance with Appendix C, the retroreflectivity of a test line, at any time in the period from 24 hours after application until 3,000,000 vehicle passes, shall be not less than 100 $mcd.m^{-2}.lux^{-1}$ for white material and not less than 80 $mcd.m^{-2}.lux^{-1}$ for yellow material, as assessed by a retroreflectometer which has equivalent characteristics to the "Mirolux 12", and which is referenced to a common base as described in Appendix 3 of TNZ P/20.

Note: drop-on beads may be required to achieve initial values

3.4 Degree of Wear

When assessed for degree of wear on a test line using the photographic scale of Appendix B after 3,000,000 vehicle passes the photographic rating shall not be less than 8.

3.5 Retention of Colour

When assessed in accordance with Appendix D, the colour of the marking after 3,000,000 vehicle passes shall not be more than 4.

3.6 Luminance Factor

When tested in accordance with Appendix H, after 3,000,000 vehicle passes the luminance factor of a test strip shall not be less than 45%.

4. REFERENCED DOCUMENTS

A list of documents referred to in this specification is given in Appendix A.

5. DEFINITIONS RELEVANT TO THERMOPLASTIC MATERIALS

For the purpose of this specification, the definitions below apply.

Materials

- Paint is a liquid product containing solids suspended in an organic solvent or in water. It can be supplied in single or multi-component systems. When applied by brush, roller, spray or any other appropriate method it produces a cohesive film by the process of solvent evaporation and/or by a chemical process.
- Thermoplastics is a solvent-free marking substance supplied in block, granular or powder forms. It is heated to a molten state and then applied with an appropriate hand or mechanical applicator. It forms a cohesive film by cooling.

- Cold Plastics is a marking substance which is supplied in single or multi-component forms. Depending on the type of system the components are mixed together in various ratios and applied with an appropriate applicator. It forms a cohesive film only by a chemical process.

Performance

- Retroreflectivity is the ability of a roadmarking to reflect back to a vehicle the light produced from the headlights making roadmarking visible at night. This retroreflective property is produced by incorporating solid glass beads in roadmarking materials.
- Luminance Factor is the ratio of the luminance of a reflecting surface in a given direction to that of an ideal white diffusing surface when viewed in the same direction and illuminated in the same way, expressed as a percentage.

Thermoplastic Components

- Aggregates comprise calcite, quartz and calcined flint.
- Calcite is a naturally occurring form of crystalline calcium carbonate.
- Quartz is a naturally occurring form of crystalline silica.
- Calcined Flint is a prepared material made by heating pure flints to a sufficiently high temperature to enable a change to the crystalline state, with an accompanying colour change from black to white.
- Pigment is a fine powder added primarily to impart colour and opacity to the mixture.
- Extender is a powder added to assist the dispersion of the pigment and impart body to the mixture.
- Binder is a thermoplastic resinous material, which, with any included oils or other plasticisers, provides adhesion to the road surface and cohesion between the other components (i.e. extender, pigment, aggregate and solid glass beads).
- Synthetic Hydrocarbon Resin is a synthetic product, resembling in some ways natural resin, used as a binding material.
- Modified Resin Esters are synthetic maleic modified ester of resin used as a binding material. Normally it is only recommended for use in thermoplastics other than sprayable grades.
- Maximum Safe Heating Temperature is the temperature specified by the manufacturer, above which the material is not to be heated at any time.

Cold-Applied Plastic Definitions and Components

- Cold-Applied Plastic is a cold hardening 2-part methyl methacrylate (PMMA) resin material. The material may be either water or solvent based and applied using a variety of methods.
- Products are covered by patents and licensing agreements
- Poly methyl methacrylate (PMMA) resin
- Typically virtually 100percent volume solids

CHAPTER 8. CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This study evaluated the performance of traffic markings used in Alaska and other northwestern states, including Washington, Idaho, and Oregon States. Primarily, this study was conducted by reviewing existing reports, past studies, and information databases; conducting a field survey that subjectively rated existing traffic markings in Alaska's central region; conducting field measurements of retro-reflectivity of traffic markings using a reflectometer in Alaska's central region; and conducting a subjective opinion survey about the performance of traffic markings, including preformed tapes, thermoplastics, Methyl Methacrylate (MMA), and traffic paints.

One of the main functions of traffic markings is guiding the traveling public. It has been proven that marking patterns affect drivers' behavior, in items of vehicle speed, vehicle lateral position and placement, and number of encroachments any given vehicle might make. Traffic markings that perform adequately, therefore, are necessary to maintaining roadways safety performance.

Reflectivity, the most important performance quality of a traffic marking, can be measured by a reflectometer. Currently, no standard specifications have been made to require minimum reflectivity for markings. However, a minimum reflectivity of 100 $mcd/m^2/lx$ has been recognized by many researchers and transportation engineers. If a traffic marking has a reflectivity lower than 100 $mcd/m^2/lx$, generally, it is considered unacceptable in the field and should be replaced.

Various traffic marking materials (including preformed tapes, thermoplastics, MMA, and traffic paints) have been applied in the northwestern states. The MMA is a new product recently introduced. This product has been well recognized by transportation engineers due to its good reflectivity performance, long service life, reasonable cost, and low application temperature. Based on results from the general evaluation of traffic markings, the following general performance can be concluded:

Traffic paints, preformed tapes, and MMA are suitable for severe winter conditions. Thermoplastics are not suitable for cold regions.

Traffic paints have the shortest service lives (4 months to 1 year). The other materials (preformed tapes, MMA, and thermoplastics) have about the same service life range. In addition to material type, other factors such as installation procedure, traffic volume, winter snow removal operations, and studded tires contribute to service lives.

Based on the cost analysis, high initial costs accompany preformed tapes and extruded MMA; medium to high initial costs for thermoplastics; medium initial costs for sprayed MMA; and low initial costs for traffic paints. However, if a seven-year life cycle is considered, preformed tapes have the highest life cycle costs, and the others have relatively similar costs.

MMA can be installed in the field at a temperature as low as -1 °C (30 °F). Other traffic marking materials require more moderate temperatures. MMA can be applied during the cold season in cold regions, such as Alaska.

Two field subjective surveys were conducted to evaluate traffic marking performance in Alaska. In the first survey, conducted in May, 1994 to evaluate MMA traffic markings, MMA traffic markings installed in 9 sites were subjectively surveyed by engineers from AKDOT&PF. The surveyors concluded that MMA had provided good performance quality and still presented good visibility and appearance during the survey time. The second survey, planned in this study and conducted in October, 1994 and April, 1995, evaluated preformed tapes, MMA, and traffic paints that were installed to form edge (white) and central (yellow) lines. Five subjective ratings (very poor, poor, fair, good, and excellent) were used in the survey. Appearance and reflectivity were used as the basis for the subjective rating. The results and comments made by field staff during the survey in October, 1994 indicated that the preformed tapes and MMA provided the best results in terms of appearance and reflectivity. The subjective rating of traffic paints was lowest. However, the survey results obtained in April, 1995 indicated that the preformed tapes deteriorated faster, compared with MMA. One important comment made by field staff was that the MMA traffic marking provided the brightest reflectivity, even on wet pavement surfaces.

A four-year reflectivity data set was analyzed in this study. This data set included reflectivity data on preformed tapes, thermoplastics, MMA, and traffic paints. Analysis results indicated that preformed tapes presented the best initial reflectivity performance. However, MMA reflected as well as preformed tapes and presented much better reflectivity performance than thermoplastics and traffic paints. The reflectivity of preformed tapes dropped faster in the first three years, compared with MMA. In general, preformed tapes and MMA presented satisfactory reflectivity performances in the first four years.

A reflectometer also gathered data on preformed tapes, MMA, and traffic paints in Alaska's central region in October 1994 and April 1995. Most traffic markings evaluated were installed in the summer of 1994. Data analysis indicated that preformed tapes and MMA presented very good initial reflectivity, compared with traffic paints. However, the reflectivity of preformed tapes

dropped much faster than MMA. The data obtained in April 1995 indicated that the reflectivity performance of yellow preformed tapes, MMA, and traffic paints reduced 65%, 8%, and 21%, respectively, and the reflectivity performance of white preformed tapes, MMA, and traffic paints dropped 69%, 13%, and 62%, respectively, compared with the reflectivity performance measured in October 1994. According to this data, the MMA had a better reflectivity performance and a longer service life in terms of reflectivity requirement.

One of the key elements of this study was the subjective opinion survey on the performance of preformed tapes, thermoplastics, MMA, and traffic paints. The survey covered three question categories: performance, applications, and installation. The performance category was most useful in reaching a conclusion about performance of traffic markings surveyed. The second and third categories resulted in helpful information on the use and installation of these traffic marking materials. Based on scores from summarized performance and overall rating, the following ranks were obtained:

Summarized Performance Rank	Overall Rating Rank	Rank
Sprayed MMA	Sprayed and Extruded MMA	1 (best)
Extruded MMA	Extruded Thermoplastics	2
Extruded Thermoplastics	Preformed Tapes	3
Preformed Tapes	Traffic Paints	4
Sprayed Thermoplastics	Sprayed Thermoplastics	5
Traffic Paints		6 (worst)

In conclusion, sprayed and extruded MMA are well recognized by transportation engineers in cold regions and can be successfully applied in Alaska.

Recommendations

Results from this research project indicate that MMA showed satisfactory performance in the field. MMA will be a suitable traffic marking material in Alaska. To effectively adopt this new product in Alaska, field trials and experiments of MMA should be continued.

In the past, no reflectivity data and other performance ratings of traffic markings have been well documented in Alaska. To objectively and correctly evaluate the long term performance of various traffic markings, necessary information on traffic marking performance should be regularly measured and recorded to form a useful database. This database will help decision makers to correctly select a cost-effective material for traffic markings in Alaska.

Ice Chisel Snow Removal Areas					
Roadway Classification	Marking Type				
	Center Lines	Lane Lines	Edge Lines	Wide Lines	Special Markings
Interstate	N.A.	Plastic Insets	Paint	Paint	Paint
Major Arterial	Paint and RRPMs	Paint	Paint	Paint	Paint
Minor Arterial	Paint	Paint	Paint	Paint	Paint
Collector	Paint	Paint	Paint	Paint	Paint
Steel Blade Snow Removal Areas					
Roadway Classification	Marking Type				
	Center Lines	Lane Lines	Edge Lines	Wide Lines	Special Markings
Interstate-Urban	N.A.	Plastic	Paint or Plastic	Paint or Plastic	Paint or Plastic
Interstate-Rural	N.A.	Paint	Paint or Plastic	Paint or Plastic	Paint or Plastic
Major Arterial	Paint and RRPMs or Plastic	Paint	Paint or Plastic	Paint or Plastic	Paint or Plastic
Minor Arterial	Paint	Paint	Paint	Paint or Plastic	Paint or Plastic
Collector	Paint	Paint	Paint	Paint or Plastic	Paint or Plastic
Rubber Blade Snow Removal Areas					
Roadway Classification	Marking Type				
	Center Lines	Lane Lines	Edge Lines	Wide Lines	Special Markings
Interstate-Urban	N.A.	RPMs only or Plastic and RPMs	Paint or Plastic	Plastic	Plastic
Interstate-Rural	N.A.	RPMs only or Plastic and RPMs	Paint	Plastic	Plastic
Major Arterial	Paint and RPMs or Plastic and RPMs	Paint and RPMs	Paint	Plastic	Plastic
Minor Arterial	Paint and RPMs	Paint and RPMs	Paint	Plastic	Plastic
Collector	Paint and RPMs	Paint	Paint	Plastic	Plastic

Notes

1. Insets are grooves ground into the pavement and filled with material, usually methyl methacrylate.
2. Plastic refers to methyl methacrylate, thermoplastic, or preformed tape.
3. See Standard Plan H-5d for RPM substitute applications.
4. See Standard Plan H-3 and H-3a for RPM applications with paint or plastic.
5. Special Markings include arrows, symbols, letters, channelizing lines, and transverse markings.
6. RRPMs refers to RPMs installed in a groove ground into the pavement.
7. Type 2 RPMs are not required with painted or plastic center or lane line in continuously illuminated sections. See Section 830.03(2).

FIGURE D7 Washington State Department of Transportation Pavement Marking Material Selection Guide. (*Source*: Washington State DOT 2000.)

State of California, Authorized Materials List
For
Methyl Methacrylate Traffic Paint

Methyl Methacrylate (MMA) traffic paints are two-component liquid pavement marking/traffic striping materials that consist of a MMA resin (pigmented) and a catalyst. The two components are mixed as they are applied and generally cure in less than 15 minutes (at 77°F). Specialized application equipment is required to apply these materials. Post applied glass beads shall meet the requirements of AASHTO Designation M247 (Type 0 or 1). The glass beads shall have a coating recommended by the MMA paint manufacturer.

The Authorized Materials List below is organized into categories of products with the same mix ratio and same suggested application thickness range.

CATEGORY 1: Application thickness: 25 to 60-mils, Mix ratio 98:2

Ennis Traffic Safety Solutions (Phone: 800-331-8118)
HPS-6 Spray, product #999775W (white) and product #999775Y (yellow). Catalyst: product #999460LV (NOTE: for up to ~60-mil application).
HPS-6 Spray, product #999675W (white) and product #999675Y (yellow). Catalyst: product #999460LV (NOTE: for up to ~30-mil application).

Aexcel Corporation (Phone: 440-974-3800)
Roadzilla Thin-Film Spray MMA, product #25W-G019 (white) and product #25Y-G023 (yellow). Catalyst: product #95W-D016 (Benox L-40LV).
Roadzilla Thick-Film Spray MMA, product #25W-G023 (white) and product #25Y-G024 (yellow). Catalyst: product #95W-D016 (Benox L-40LV).

Swarco-Colorado Paint (Phone: 303-388-9265)
Swarcoplast Thin-Film MMA, product #5090 (white) and product #5096 (yellow). Catalyst: product #5035

Kelly-Moore Paints (Phone: 650-610-4146)
Smooth, Wide-Area MMA, product #X207-100 (white) and product #X207-131 (yellow). Catalyst: product #X207B (Benox L-40LV).

CATEGORY 2: Application thickness: ~ 250-mils (recessed), Mix ratio 4:1

This product category is currently being developed.

For more information about this site contact Mitch Gipson: Phone; (916) 227-7919, E-mail;
mitch_gipson@dot.ca.gov
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