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ENGINEERING INSTRUCTION

NEW YORK STATE DEPARTMENT OF TRANSPORTATION

SUBJECT: SECTION 687 - THERMOPLASTIC REFLECTORIZED PAVEMENT MARKINGS: APPLICATION AND INSPECTION

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In July, 1979, Engineering Instruction EI 79-34 was issued. This instruction established a policy for the use of pavement marking materials. On new and existing bituminous concrete pavement surfaces hot extruded thermoplastic was designated as the primary material for pavement marking applications. The choice of thermoplastic was based on three factors; good durability, good nighttime reflectivity and favorable cost in comparison to other durable type pavement markings.

In the 1979 contract year, during which EI 79-34 was not in effect, approximately 700,000 LF of 4 inch thermoplastic line was included in Department contracts at an average price of just under $0.40/ft. In the 1980 contract year and under the present pavement marking policy, approximately 7,335,000 LF of thermoplastic pavement marking was let at a cost of about $0.41/ft. This represents a 1000% increase in the use of this item, and it is expected that similar quantities of thermoplastic will continue to be specified in the future. This vastly expanded use of thermoplastic necessitates a comparable increase in the level of inspection of thermoplastic application.

In conjunction with the issuance of EI 79-34 the specification requirements (Section 687) were up-dated to reflect the optimum conditions for the placement of thermoplastic materials. The major changes included stricter controls on applicating equipment; requirements for material marking thickness; and for materials, pavement surface, and air temperatures. These revisions were based on the latest technology and reflect the most important factors that influence a properly applied and adhered (bonded) thermoplastic pavement marking.

The revised Section 687 was prepared with the intent that it would account for and minimize field installation problems. In most instances, contractors have adhered to the specifications. However, during the 1980 construction season, problems did occur on some projects that have identified a need for additional clarification of the requirements of Section 687. The purpose of this instruction is to alert engineering personnel to the most important specification requirements and to set guidelines for the inspection of thermoplastic marking applications.

1. Striping Contractor. Applicators of thermoplastic pavement markings are dealing with a unique item. In general these contractors only work with the placement of pavement markings. To perform this work, a competent striping contractor has a large investment in his equipment (e.g. a mobile applicator is in the price range of $200,000 - $300,000). To obtain a return on his investment, the contractor must act as a "prime" or "sub" on several simultaneous on-going projects. To insure timely contract completion, striping applicators should be thoroughly checked as to their current commitments, work schedules, etc., and their ability to complete any additional work prior to their approval as a sub-contractor. In 1980, at least one striping contractor over-extended himself to the point where his work required completion by other applicators and several of his projects are still uncompleted.

2. Application Equipment. The Engineer is responsible for approving application equipment, both mobile and portable, prior to the start of work. In addition to thermoplastic applicators, any extra equipment for primer application and pavement cleaning should also be inspected and approved.

   The following is a listing of the minimum equipment components for approved thermoplastic applicators:

   a) Melting Kettle(s) - The melting kettle must be capable of heating the molten thermoplastic to temperatures above 400°F. The heating mechanism must employ a heat transfer medium (usually an oil bath or hot air); heating by direct flame is not allowed. A material temperature gauge must be visible on the kettle. Some melting kettles will also have a temperature gauge to record the temperature of the heat transfer medium. Do not confuse this with the material temperature gauge nor consider that it represents material temperatures - it does not.

   b) Mixing and Agitating Equipment - Melting kettles and portable applicators must be equipped with mixers (agitators). Most melting kettles are equipped with a continuously operating mixer, however, it should be checked periodically to insure that it is operational. Portable application equipment should be equipped with a hand or mechanical mixer - this is usually located on the top of the materials storage reservoir. If a portable applicator is not equipped with a mixing device, do not approve this equipment. If the portable applicator has a hand operated mixer, insure that it is used during marking operations. One purpose of the mixer is to maintain uniform material temperatures and these are most subject to change in the application of thermoplastic markings with portable equipment.

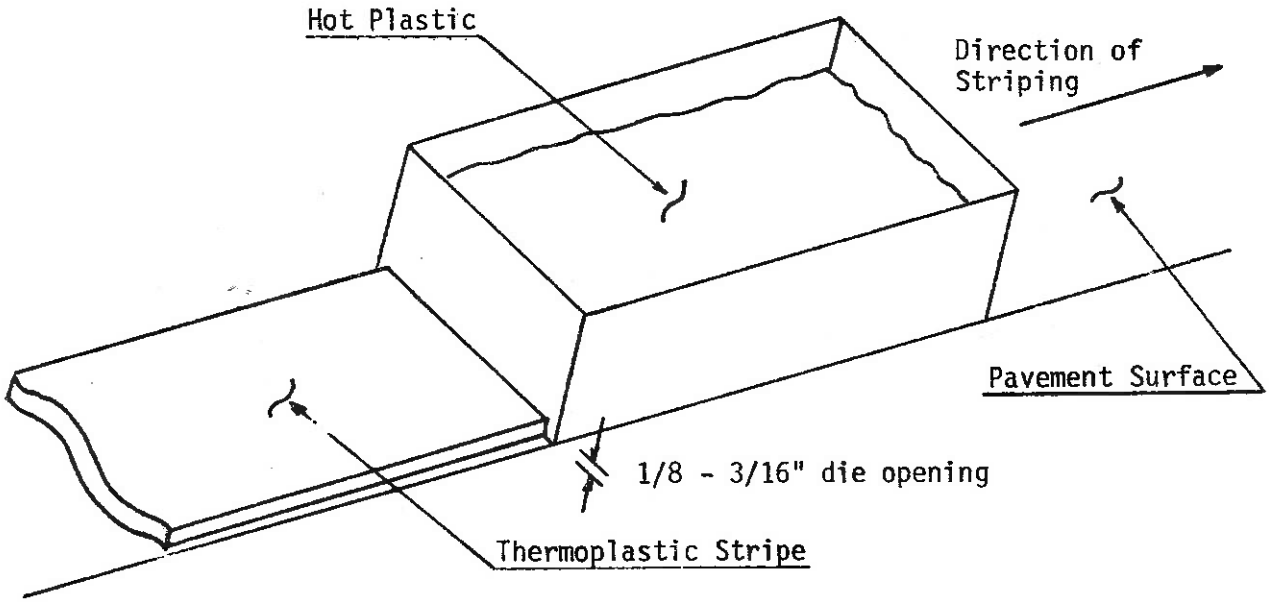
   c) Priming Equipment - All pavement surfaces are to be primed prior to the application of thermoplastic markings. The primer material is to be sprayed on the pavement surface at the specification rates or at the coverages noted in the manufacturer's instructions for use. Spray equipment for primer application may be mounted directly on a mobile type thermoplastic applicator or may be a separate push or mobile type spray machine. Priming equipment should be checked to insure that it is operational.

d) Glass Bead Dispensers - Both mobile and portable thermoplastic application equipment are required to be equipped with a drop-on type bead dispenser. The glass beads are to be dropped onto the hot thermoplastic stripe immediately after its application. The purpose of the glass spheres is to provide initial nighttime reflectivity of the pavement marking - without them the newly placed line would be barely visible to the motorist under night driving conditions. The bead dispenser should be checked for proper operation and to insure uniform rates of bead application over the entire marking's surface.

If applicating equipment is not equipped with a bead-dispenser or if it is non-operable during marking applications, work is to be stopped until the problem is corrected. Do not allow contractors to apply glass beads by hand or other unapproved methods.

e) Extrusion Shoe - All thermoplastic pavement markings are specified for application by the extrusion method using an extrusion shoe that rides directly on the pavement surface and uses the underlying pavement as part of the shaping die. Schematics of acceptable extrusion shoes are shown in Figure 1. The shoe is designed to hold and extrude a mass of hot molten thermoplastic onto the pavement surface in the form of a stripe of specified width and thickness. Figure 2 is a schematic of an unacceptable extrusion device that has been used by a contractor. This is not acceptable because it does not provide a shaping die wherein one side is the pavement, as required by the specifications. A primary objection to this device is that in cool weather striping, air is allowed to cool the bottom of the extruded line prior to its contacting the pavement. This type of application will result in a poor mechanical bond.

Mobile or portable applicating equipment without extrusion shoes are not to be approved for Department work. In addition, effective with Addenda No. 2 to the Standard Specifications of January 3, 1978, material temperature gauges visible to the inspector during application must be incorporated in the extrusion shoe (contracts let on or after Feb. 28, 1980). This requirement was added to give the inspector the capability of monitoring the temperature of the thermoplastic composition throughout marking operations. Striping work should not be allowed to start or continue unless the temperature gauge is affixed in the shoe. Some newer equipment may come equipped with a thermometer, etc. in the shoe; on older applicators it will be necessary for the contractor to determine an appropriate way to incorporate this.



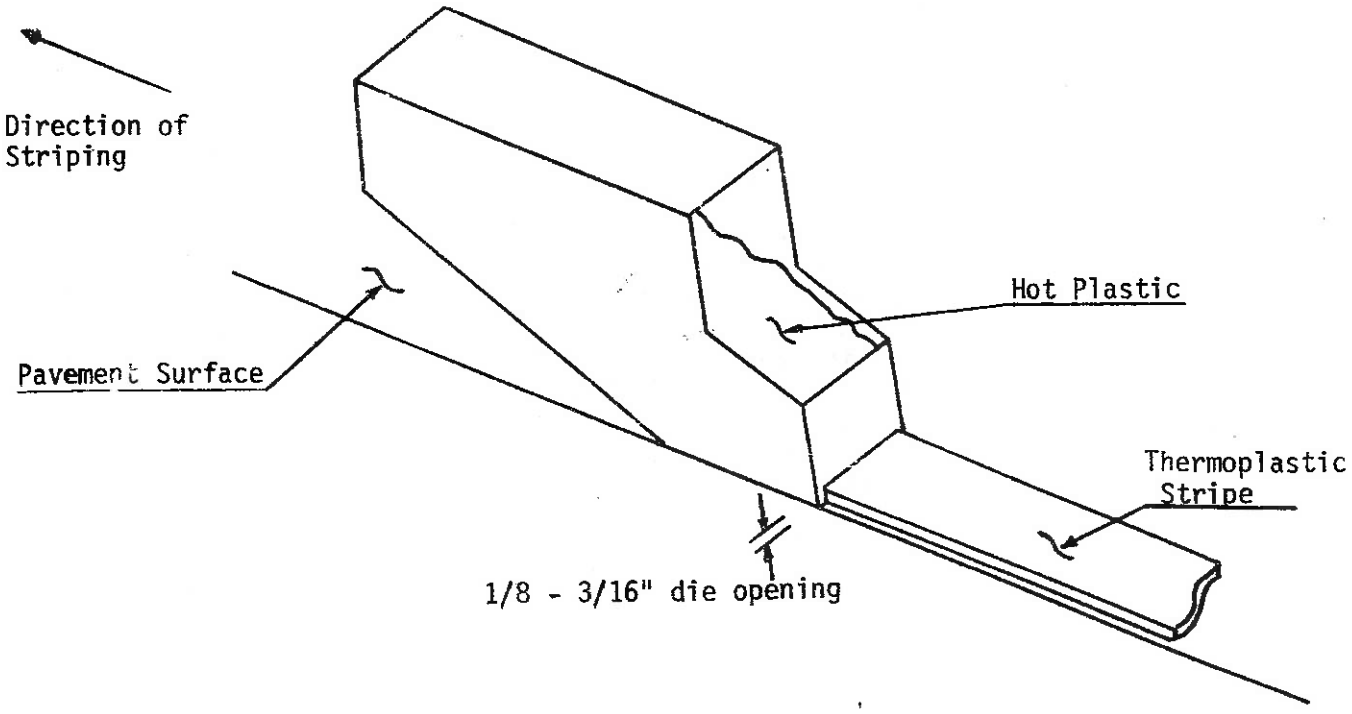


Figure 1 - Acceptable Extrusion Shoes

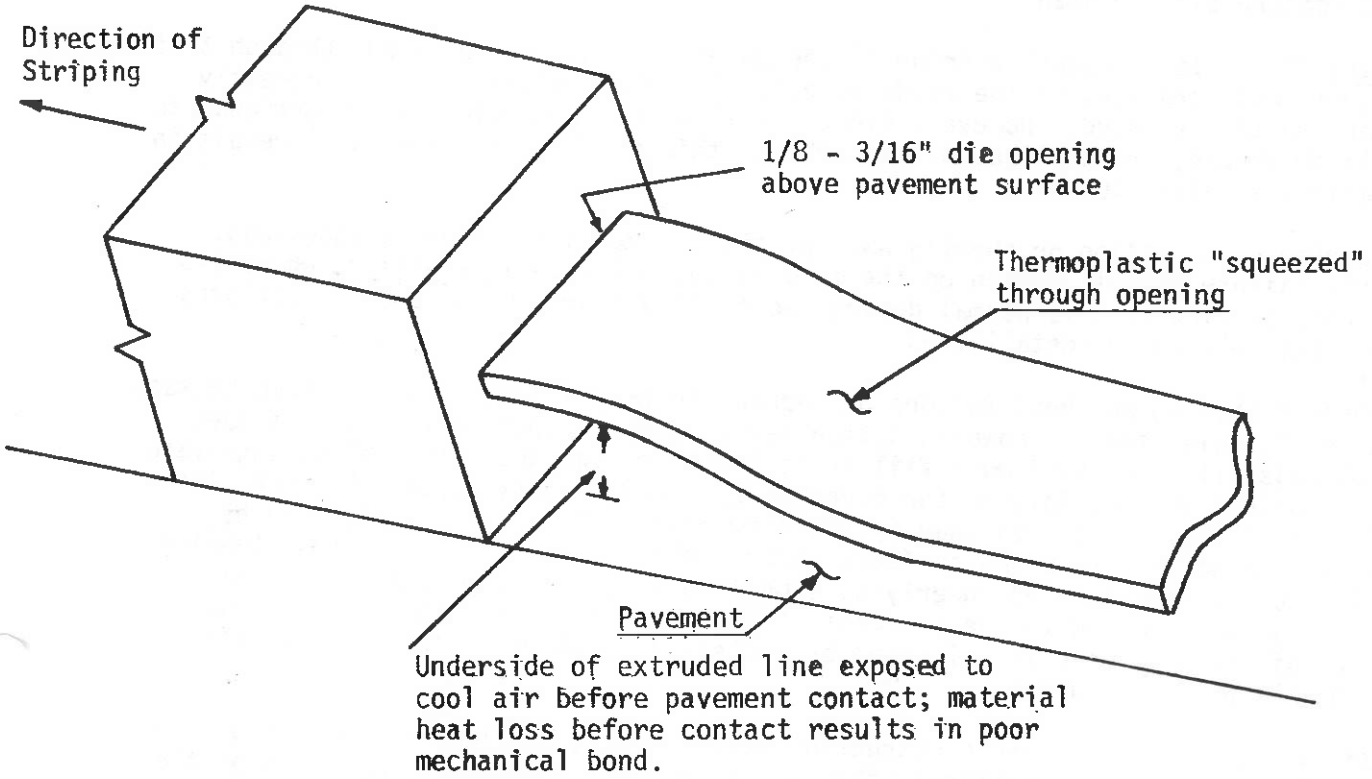


Figure 2 - Unacceptable Extrusion Device

3. Inspection of Thermoplastic Marking Work. After contractor and equipment approval requirements are satisfied, marking operations may begin. The basic work consists of pavement cleaning; primer application; melting and extruding the thermoplastic material on the pavement in a molten state at elevated temperatures; and an immediate drop-on application of glass beads.

   A thermoplastic line that is properly placed within the specification requirements will soften (melt) and fuse with the underlying asphalt to form a mechanical bond (interlock) with the aggregate portion of the bituminous mix. If the bituminous pavement is unclean or wet; if air, surface and material temperatures are lower than specified; if other requirements are not met; this mechanical bonding will not be accomplished. If this occurs, the full service-life of the marking will not be realized.

   Three basic modes of thermoplastic failure can be identified -- bond, abrasion and shaving.

Bond - A loss of the entire thickness of stripe because of its failure to adhere or bond to the pavement. This failure mode is normally due to some sort of improper installation technique such as low temperatures, dirty pavement, etc. This failure is construction related.

Abrasion - Is a gradual wearing of the material from the top down, through traffic, debris and abrasives on the roadway, etc. Abrasion failures are not directly construction related. However, since the life of the marking is proportional to its thickness, the application of markings thinner than specified will result in earlier abrasion losses.

Shaving - A cutting or shaving away of the thermoplastic line by snowplows. This failure mode is common on the leading edge of skip line stripes where 2-8 inches of line loss is normal during the first winter's use. Shaving failures are not related to installation.

Because shaving and bond failure may appear to be similar, a point should be made to distinguish them. Snowplow action may accelerate bond failure but it does not cause it. The bond must fail or at least be weakened before plows aggravate it. With a shaving failure the pavement bond may be very strong, but the plastic is actually cut or shaved away by the plow blade. This can be evidenced by closely examining pavement surfaces under a skip-line stripe that shows leading edge loss - the textured underlying asphalt will show thermoplastic material that is still bonded to the pavement if the markings were adequately bonded. Lack of adequate bond is evidenced by a clean separation of the thermoplastic from the pavement surface.

Because bond failures are construction related, they can be minimized by proper engineering controls; primarily through correct and increased inspection at the project site. The following guidelines are intended to direct the Engineer in the inspection of thermoplastic marking operations:

a) Marking Location - To minimize damage from plow blades and from bituminous substrate failures, thermoplastic markings must be placed directly on the bituminous pavement and slightly offset from shoulder and construction joints. Do not apply edge line markings directly over the joint formed between the roadway and adjoining shoulder; nor skip line markings over the longitudinal joint between travel lanes.

b) Equipment - Daily inspections of the contractor's equipment should be made to insure that it is operable and within the specification requirements.

c) Materials - Materials for thermoplastic marking operations are covered under Section 727-01.01. Solid thermoplastic composition is supplied in the form of slabs, blocks or granular powder and should arrive at the job site pre-accepted. MURK and the material specifications cover the requirements for acceptance of thermoplastic, reflective glass spheres and primer materials.

d) Pavement Surface - Pavement surfaces must be clean, dry and at a minimum temperature of 55°F. Each of these factors is critical to satisfactory bonding.

New bituminous surfaces are often over-looked but should be inspected for cleanliness. Dirt from construction traffic, wind blown debris, etc. may be present and the contractor should be required to remove these contaminants in the location of the marking applications. Existing bituminous surfaces should be carefully inspected for cleanliness. Heavy deposits of existing pavement markings, built-up roadside accumulations of dirt, etc. will all require removal. In some cases an air blast will be sufficient to clean the surface - in others more effort or different methods will be needed. Regardless, the contractor should not be allowed to apply thermoplastic markings until the pavement is inspected and cleaned to the Engineer's satisfaction.

Pavement surfaces must be dry. At the minimum all pavements should be visibly dry. However, even with a surface dry appearance sub-surface moisture can be present in amounts sufficient to affect proper bonding. If excess pavement moisture exists, it will usually result in blistering of the hot applied marking. Blisters will form as surface "bubbles" that may or may not have burst. They are easily spotted and if the condition occurs marking operations should be stopped until the pavement dries out.

The pavement surface temperature must be a minimum of 55°F. at the time of marking applications. Surface temperature should be verified at the start of each day's work. In cool weather conditions, the surface temperature should be checked periodically throughout the work day. Materials Method No. 20, BITUMINOUS PAVING INSPECTION, "SURFACE TEMPERATURES" describes a suitable procedure for determining pavement temperature. If at any time during work, the surface temperature falls below 55°F., marking operations should be stopped.

e) Air Temperature - The ambient (air) temperature is to be a minimum of 49°F. and rising at the time of marking operations (effective with Addendum No. 2 to the Standard Specifications of January 3, 1978). Air temperature is to be verified at the start of each day's work and monitored as necessary during marking applications. If work has started and air temperatures fall below 49°F and continual cooling is indicated, work should be stopped. In cool weather conditions, temporary drops down to 45°F can be tolerated, providing temperatures also vary upwards. Sustained striping (greater than one hour) at 45°F should not be allowed; starting work at air temperatures lower than 49°F should not be allowed.

f) Primer Application - Primer must be applied to all pavement surfaces at the specified application rate and allowed to "set" for the specified cure time prior to the placement of thermoplastic. Rates of primer application should be checked to insure proper coverage (thickness). Primed pavement surfaces must be striped with thermoplastic within the specified set time or within the same working day. Primed surfaces that are not striped over within these time limits must be reprimed prior to the application of thermoplastic markings.

g) Thermoplastic Application - The thermoplastic must be extruded on the primed pavement at a material temperature of from 400^{0} - 425^{0}F, as measured in the extrusion shoe, i.e. at the point of deposition. Immediately after placement, "drop-on" glass spheres are mechanically applied.

If the thermoplastic marking is not being applied within the temperature limits, or if glass spheres are not dispensed, marking operations are to be stopped.

The material temperature requirement (400^{0} - 425^{0}F) is one of the most important factors affecting bond. It should also be one of the easiest to inspect because the extrusion shoe on approved equipment should contain a visible thermometer, or temperature recording device. This gauge allows for continuous monitoring of temperatures during marking work. The contractor's gauge in the shoe must be checked for accuracy. This can be done by comparing it with temperatures recorded on a stem-type thermometer that is commonly used to determine bituminous mix temperatures. Depending on the accuracy of the thermometer(s) variances of up to 10^{0}F may occur. This degree of accuracy is satisfactory.

Strict attention must be paid to material temperatures. Time spent in melting and heating the thermoplastic material is non-productive time to the contractor. It is possible to extrude a "good looking" marking at temperatures much lower than 400^{0}F, however, this material will not be well bonded to the pavement It should also be noted that depending on the heat loss of the contractor's equipment between the kettle and the shoe, thermoplastic material in the kettle may require heating to temperatures greater than 425^{0}F, to obtain a minimum 400^{0}F in the extrusion shoe. This is allowable. The temperature range in the specification only pertains to the material temperature in the "shoe".

h) Thermoplastic Thickness - The specified thickness of the extruded thermoplastic marking is 1/8" minimum to 3/16" maximum. The service life of a thermoplastic marking is directly related to its thickness; e.g., a thin line will wear out faster. To insure that the proper thickness is being applied, both the wet and dry thickness of the line should be routinely checked. Wet thickness is inspected immediately after the line is extruded by inserting a thin, graduated machinists rule or similar instrument into the molten (liquid) plastic to the depth of the pavement substrate. The thickness of the line is simply determined by visually noting the depth of penetration. Dry thickness can be determined by various methods. One is to take a panel of known thickness, such as a piece of sheet metal, and place it in the path of the applicating equipment. After the thermoplastic has been deposited and has hardened on the panel, the total thickness should be measured with a micrometer and the panel thickness subtracted to indicate the line thickness.

i) Applied Marking - The applied markings should be inspected continually for overall workmanship. Markings should be of the specified width, with clean-cut edges. White and yellow colors should appear distinct. The drop-on application of glass spheres should appear uniform on the entire markings surface. The hardened thermoplastic should resist deformation, dirt pick-up, etc. by traffic. The marking should be firmly bonded to the pavement surface. Pavement bond of the hardened marking can be inspected by taking a stiff bladed putty knife and attempting to "shock" the thermoplastic from the pavement. The putty knife should be positioned as parallel to the pavement as possible and pushed or hammered against the bottom edge of the marking, at the pavement interface. If only small pieces of marking can be chipped from the pavement, the bond is satisfactory. If large pieces can be removed through the entire thickness of marking and there is little visible evidence of the thermoplastic having melted or fused with the bituminous pavement, the bond is poor. Evidence of fusion (melting) will be visible in the form of bituminous material remaining on the underside of the removed marking. If the thermoplastic has melted and bonded with the underlying asphalt the majority of its underside will be coated with bitumen; if not only minor and "spotty" deposits of bituminous material will be present.

Questions concerning the application and inspection of thermoplastic reflectorized pavement markings should be referred to the Materials Bureau, (518 - 457-4285).