SECTION 687 THERMOPLASTIC PAVEMENT MARKINGS

General
Thermoplastic is a durable-type pavement marking material that, when properly applied, can be expected to provide 3-5 years service on new bituminous concrete pavements. Thermoplastic markings are susceptible to damage from snowplows and should not be used in locations with significant plow activity. Thermoplastic adheres poorly and should not be used on portland cement concrete pavements.

Project Procedure
The specifications for thermoplastic (Section 687) were prepared with the intent that they would account for and minimize field installation problems. In most instances, contractors have adhered to the specifications. However, problems have occurred on some projects that have identified a need for additional clarification of the requirements of Section 687. The following is provided to alert engineering personnel to the most important specification requirements and to set guidelines for the inspection of thermoplastic applications.

A. 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/her equipment (e.g., a mobile applicator is in the price range of $200,000 - $300,000). To obtain a return on his/her investment, the contractor must act as a "prime" or "sub" on several simultaneous on-going projects. To ensure timely contract completion, striping applicators should be thoroughly checked as to their current commitments, work schedules, and their ability to complete any additional work prior to their approval as a sub-contractor.

B. 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:

1. Melting Kettle(s) - The melting kettle must be capable of heating the molten thermoplastic to temperatures above 204.5°C. 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.

2. 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 ensure 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, ensure 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.

3. Priming Equipment - When specified, primer material is to be sprayed on the pavement surface at the coverage noted in the manufacturer's instruction 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 ensure
that is operational.

4. 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 ensure uniform rates of bead application over the entire marking's surface. The Contractor is required to clean up the excess beads.

If application 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.

5. Extrusion Devices - All thermoplastic pavement markings are specified for application by the extrusion method using an approved extrusion device. Schematics of acceptable extrusion devices are shown in Exhibit 687-A. The first two schematics show devices which use an extrusion shoe riding directly on the pavement surface. 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. The third schematic depicts a device that extrudes a vertical ribbon of thermoplastic from a properly sized slot located approximately one inch above the pavement surface. The slot is surrounded by a heated jacket and air shroud. Line thickness is controlled by the operating speed of the applicating equipment and low pressure that is used to extrude the material. The air shroud and pavement surface do not act as a shaping die. Exhibit 687-B is a schematic of an unacceptable extrusion device that has been used by a contractor. A primary objection to this device is that in a cool weather striping, air is allowed to cool the bottom of the extruded line prior to its contacting the pavement. This type application will result in a poor mechanical bond.

Material temperature gauges shall be affixed or incorporated in all extrusion devices in such a manner as to be visible and capable of monitoring the composition temperature throughout the marking operation. Stripping work should not be allowed to start or continue unless the temperature gauge is affixed in the device. Some newer equipment may come equipped with a thermometer, etc. in the device; on older applicators it will be necessary for the contractor to determine an appropriate way to incorporate this.

C. 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 then 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 thermoplastic line by snowplows. This failure mode is common on the leading edge of skip line stripes where 50-203 millimeters (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:

1. **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 no apply edge line markings directly over the joint formed between the roadway and adjoining shoulder; no skip line markings over the longitudinal joint between travel lanes.

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

3. **Materials** - Materials for thermoplastic marking operations are covered under Section 727-01. Solid thermoplastic composition is supplied in the form of slabs, blocks of granular powder and should arrive at the job site pre-accepted. Material specifications and the MURK cover the requirements for acceptance of thermoplastic, reflective glass spheres and primer materials.

4. **Pavement Surface** - Pavement surfaces must be clean, dry and at a minimum temperature of 12.5°C (55°F). Each of these factors is critical to satisfactory bonding. New bituminous surfaces are often overlooked 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 the 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 pavement 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
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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 12.5°C (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 12.5°C (55°F), marking operations should be stopped.

5. Air temperature - The ambient (air) temperature is to be a minimum of 9.5°C (49°F) and rising at the time of marking operations. 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 9.5°C (49°F) and continual cooling is indicated, work should be stopped. Starting work at air temperatures lower than 9.5°C (49°F) should not be allowed.

6. Primer Applications - Primer is not used on "new" asphalt cement concrete pavement when the thermoplastic markings are applied within the same calendar year as the completion of the "new" asphalt paving.

When primers are used, they must be applied at the manufacturers recommended 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 the 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.

7. Thermoplastic Application - The thermoplastic must be extruded on the primed pavement at a material temperature no lower than 204.5°C (400°F), as measured in the extrusion device, 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 at a minimum of 204.5°C (400°F), or if glass spheres are not dispensed, marking operations are to be stopped.

The material temperature requirement (minimum 204.5°C or 400°F) is one the most important factors affecting bond. It should also be one of the easiest to inspect because the extrusion device 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 device 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 12°C 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 204.5°C (400°F), however, this material will not be well bonding to the pavement. It should also be noted that depending on the heat loss of the contractor's equipment between the kettle and the extrusion device, thermoplastic material in the kettle may require heating to temperatures greater than 204.5°C (400°F) to obtain the minimum specified temperature in the extrusion device. This is allowable provided that the
manufacturer's recommended maximum material temperature, normally 230°C (450°F), is not exceeded.

8. **Thermoplastic Thickness** - The specified thickness of the extruded thermoplastic marking is (3.2 mm minimum to 4.8 mm 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 a wet film gauge 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 application 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.

9. **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 markings 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 "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 of marking can be chipped from the pavement, the bond is satisfactory. If large pieces can be removed through the entire thickness of making 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 the inspection of thermoplastic reflectorized pavement markings should be referred to the Materials Bureau, (518) 457-4285.

**References**
MATERIALS METHOD NO. 2, BITUMINOUS PAVING INSPECTION, "SURFACE TEMPERATURES"

**Related Contract Provisions**
Standard Specification §727-01