Pavement Marking Technical Manual

Québec

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Preface

The *Pavement Marking Technical Manual* is part of a process undertaken to consolidate general knowledge and to harmonize practices. It is also aimed at improving the quality of longitudinal and special marking work and, by the same token, road safety. Its target audience primarily consists of technicians, engineers and various professionals in the field of pavement marking.

Based on various publications, standards and guides drafted by the Ministère des Transports concerning pavement marking, this manual covers, in particular, the legal framework, the departmental guidelines in force, the planning of marking work, the materials used and the supervision of marking operations.

The Ministère's technical and operational staff, service providers and those wanting to further their understanding of pavement marking are thus invited to read this manual.

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Sous-ministériat à l'ingénierie
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1 General provisions

Horizontal markings, or pavement markings, make it possible to:

- guide users on the roadway by establishing the use of the different traffic lanes; and
- provide road users with information, in addition to that provided by traffic signs.

The presence and visibility of pavement markings are linked to road safety. Indeed, the presence of visible lines ensures a safer network for road users. Unlike other signalling devices, pavement markings are subjected to significant wear from vehicle traffic and winter road maintenance. A good knowledge of the road network and implementation of a maintenance strategy are essential to ensuring the presence of markings throughout the year.

Pavement markings are divided into two elements: longitudinal markings, made up of the lines delineating the traffic lanes, and special markings, characterized by markings on the roadway such as lane-selection arrows, stop lines and pedestrian crosswalks.

1.1 Legal framework

In accordance with the provisions of the *Highway Safety Code* (CQLR, chapter C-24.2), longitudinal marking has legal force: generally, solid lines can be crossed only under certain conditions, while broken lines indicate where changing lanes is permitted. Special markings, meanwhile, aim to reinforce both the messages conveyed by signalling devices, in particular, traffic signs and lights, and the legal provisions provided for in the Code. Pedestrian crossing and lane-selection arrow markings, for example, remain elements that attract the attention of drivers and encourage safe manoeuvres.

Like other signalling devices, the marking on a roadway must comply with the provisions of *Volume V – Traffic Control Devices* from the collection Normes – Ouvrages routiers of the Ministère des Transports to ensure uniformity across the entire road network.

Section 289 of the Code also provides that every person responsible for the management or maintenance of public highways must comply with the standards set out in *Volume V – Traffic Control Devices* where a requirement to do so is indicated therein, to enable the attainment of this standardization objective and to facilitate road users' comprehension of the message transmitted.

Pavement markings must be present on public roads where the average traffic flow is greater than 500 vehicles per day. Each type of line and each symbol carries a specific message and must be used in the right place, according to the conditions provided for in the traffic control standard.

Lastly, with regard to Section 303 of the Code, any person carrying out work must erect traffic signs or signals in compliance with the provisions of *Volume V – Traffic Control Devices* for the duration of the work. Thus, for any intervention on a public highway, the traffic control standard becomes a reference.

1.2 Departmental guidelines and framework documents

Concerned about the environmental impact of the marking operations carried out on the 90000 km of pavement marking lines under its responsibility, the Ministère has developed new requirements to improve environmental performance while providing a safer network for users.

In the context of its re-marking operations, the Ministère, among other things, replaced alkyd paints by water-based paints, which are more durable and less harmful to the environment, and has eliminated the use of lead chromates. The glass microbeads added to the marking material, for their part, are made from fully recycled glass, and the containers used to store the marking materials and the glass microbeads are also recycled.

Marking operations have been optimized by better management of inventories, of the human resources assigned to the work and of the quantities of materials used. The pavement marking management system (MRG – Gestion du marquage routier), implemented in 2010, has resulted in better planning of operations as well as improved monitoring of marking work. The Ministère has also acquired tools to supervise operations related to horizontal marking, tools that it regularly updates and that include, in particular, standard specifications, norms, guides, training and departmental guidelines. The Ministère is also pursuing its efforts to innovate and improve ways of doing things by implementing pilot projects and research projects.

On its network, the Ministère mainly uses short service life materials to re-mark pavement markings, while medium and long service life materials are generally used on new surface courses to provide a durable base layer for marking.

1.2.1 Short service life materials

Short service life materials are basically water-based paint and alkyd paint. These materials need to be reapplied annually to maintain a good presence on the road surface.

- Water-based paint is used to annually re-mark all markings on the road network. This measure ensures the presence of lines until the following spring and restores the markings' night visibility (retroreflectivity).
- Alkyd paint is mainly used for road safety reasons. It is used for temporary marking work in cold weather, being the sole material that can be applied under such conditions. Alkyd paint can be used only between October 15 and May 1 for environmental reasons, in accordance with the *Volatile Organic Compound (VOC) Concentration Limits for Architectural Coatings Regulations* (SOR/2009-264). However, low-VOC (≤ 150 g/L) alkyd paint can be applied year-round.

1.2.2 Medium and long service life materials

Materials with an epoxy resin (epoxy) and methyl methacrylate (MMA) base are the main medium and long service life materials used on the network, offering greater durability than short service life materials. The Ministère's performance requirements are defined over two years for medium service life materials and over four years for long service life materials.

- Epoxy and MMA sprays are used on all new surface courses to give the marking a durable base coat. Epoxy alone is used for longitudinal marking, while both products can be used for special marking.

Source: Transports Québec

Figure 1 – Two-layer epoxy resin on concrete roadway

On heavily travelled networks used by more than 50000 vehicles per day, each year, the marking is inlaid. This method ensures better durability of the marking over time.

Marking for new concrete pavement is also inlaid and, to increase the contrast between the marking and the roadway surface, a two-layer (white on black) epoxy resin-based material is used for directional dividing lines and broken lines, as illustrated in Figure 1.

1.3 Marking colours

Pavement markings can be yellow, white, red, green, blue or orange. A marking's colour must comply with the specifications stipulated in the chapter, *Peintures et produits de marquage* of *Tome VII – Matériaux* of the Ministère's collection Normes – Ouvrages routiers, all to ensure uniformity throughout the province. Table 1 summarizes the intended use for each of these colours.

Table 1 – The different marking colours and their uses

Marking colour	Use
Yellow	Separates traffic flows in opposing directions
	Marks the left edge of the travel lane of divided public highways
	Marks the left edge of highway ramps
	Marks out pedestrian crossings where there are no traffic lights or "Stop" signs
	Increases the visibility of curbs
	Delineates alternate lanes, reserved opposing traffic lanes and left-turning lanes in both directions
	Delineates areas where parking is prohibited
White	Separates the lanes of a one-way roadway
	Delineates the right edge of a divided public roadway
	Delineates the two edges of a two-way roadway
	Indicates where vehicles must stop
	Indicates pedestrian crossings where there are traffic lights or "Stop" signs
	Delineates reserved lanes of traffic flows in the same direction
	Delineates areas where parking is permitted
Red	Indicates access to an emergency lane with arrester bed
	Delineates a reserved bus lane
Green	Indicates a bike box
	Increases the visibility of parking spaces for electric vehicles
Blue	Increases the visibility of parking spaces for mobility impaired persons
Orange	Delineates an area of road work being carried out on a highway which respects the established criteria

Markings applied in large quantities, on bus lanes and bike boxes, for example, must include an anti-skid/anti-slip product to avoid compromising the adherence of vehicle and bicycle tires coming to a stop or making a turn.

1.4 Types and dimensions of markings

Each type of line and each symbol have a specific use and must be used in the right place, according to the conditions set out in *Volume V – Traffic Control Devices*. Figure 2 shows examples of two types of markings.

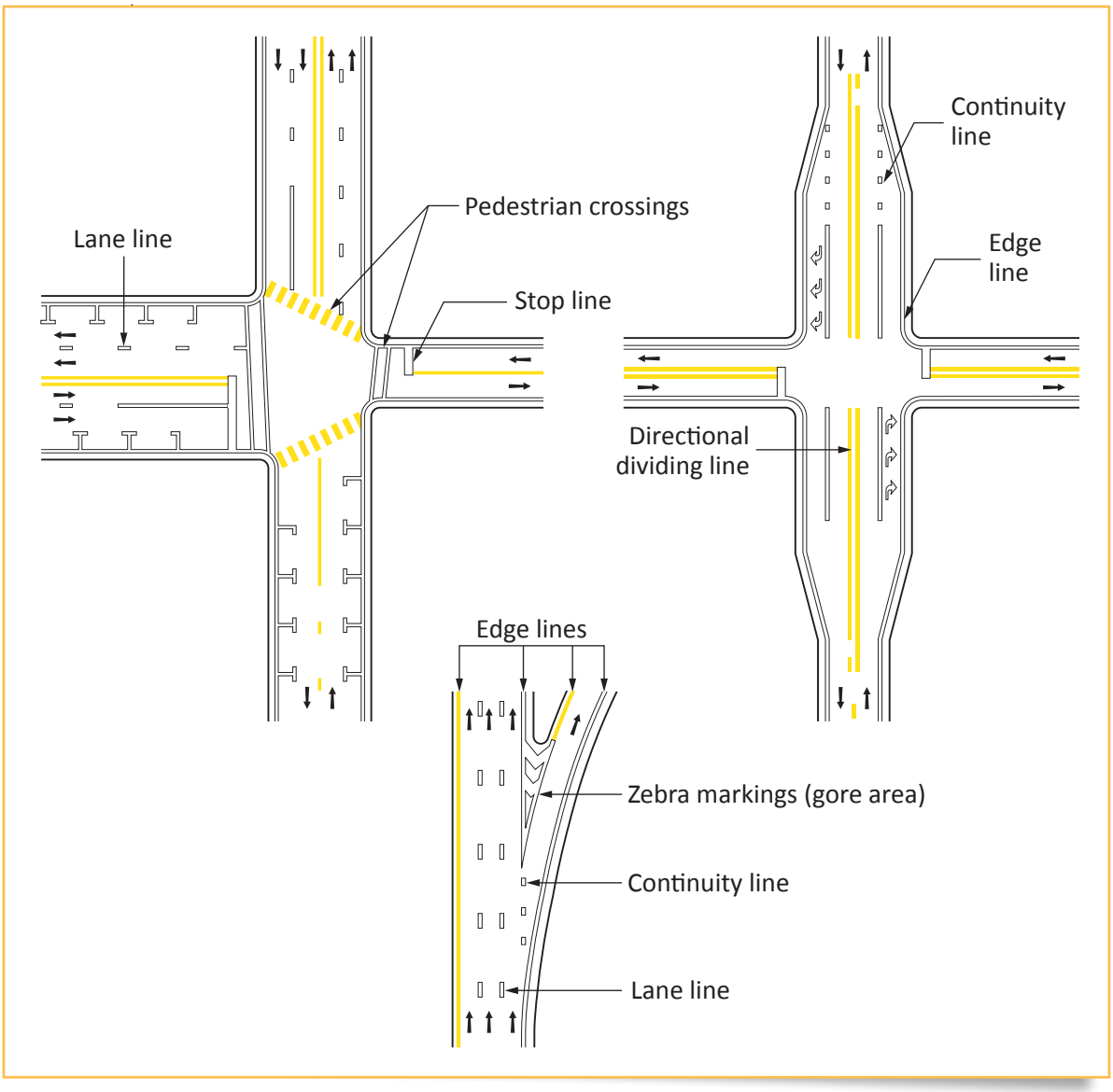


Figure 2 – Examples of types of markings

In *Volume V – Traffic Control Devices*, it can be seen that the dimensions of certain types of markings vary. For example, longitudinal lines must be between 100 mm and 150 mm wide, stop lines can be from 300 mm to 600 mm wide and the gap between broken lines can be from 6 m to 9 m.

However, on the Ministère's network, criteria for dimensions have been clearly set, for reasons of uniformity and visibility. All of these criteria are indicated in the contract documents. The main criteria are summarized below:

- A stop line consists of a 600-mm wide solid white line. The line must cover the full width of the traffic lane without encroaching on the opposing traffic lane
- Broken lane line segments must be 3 m in length with 6-m gaps
- A marking's length must not vary more than 25 mm from the required length
- Longitudinal line markings must be from 120 mm to 125 mm wide. When a longitudinal marking consists of two parallel lines, the latter must be 120 mm to 125 mm apart.

Always with a view to uniformity, the standardized drawings of different pavement markings are available on the website of the *Répertoire des dispositifs de signalisation routière du Québec*. They are accompanied by technical specifications for the different types of arrows used on the network, bikeway markings and certain symbols, such as vehicle detector, electric vehicle, wheelchair and pictograms of school children and pedestrians.

1.5 Marking work

Longitudinal marking is generally carried out using a line striping truck. Figure 3 shows one being used to apply water-based paints. For special marking, which consists of applying symbols on the pavement, a pressure gun and stencils are generally used, as shown in Figure 4.

Source: Transports Québec

Figure 3 – Striping truck used for longitudinal marking

Source: Transports Québec

Figure 4 – Application of special marking using a pressure gun and stencil

1.6 Caution

The application of pavement markings to create an art form that can incorporate different colours must not impair the visibility, legibility or understanding of a traffic control signal, essential to the safety of road users. As such, the traffic control signalling provided for in *Volume V – Traffic Control Devices* cannot be modified to put in place any art-form type of marking.

Not only can such a marking confuse and distract road users, it can also give pedestrians a false sense of security.

2 Planning the work

It is essential that marking work be well planned to ensure that it is executed in accordance with the specifications of the *Cahier des charges et devis généraux – Infrastructures routières – Construction et réparation* (CCDG), the Ministère's different standard specifications and standards. Adequate planning makes it possible to anticipate and prevent problematic situations and thereby ensure that the marking work goes smoothly.

The Ministère has also published the *Guide de surveillance – Chantiers d'infrastructures de transport*, covering the supervision of transportation infrastructure work sites. Stakeholders may wish to refer to that document for planning the work.

2.1 Roles and responsibilities of key stakeholders

Planning begins at the design phase of the project and continues with the supervision and completion of the work. The work may be carried out by a contractor or by one of the Ministère's marking crews.

2.1.1 Designer – Specifications

The designer's role is to design plans and specifications in accordance with the standards in force. As such, the designer needs to refer to the most recent versions of the CCDG and standard specifications concerning longitudinal and special marking. The standard specifications are updated regularly to integrate, where applicable, departmental guidelines and modify requirements. The standard specifications are available on the Ministère's website.

In addition, the designer must validate and approve the documents provided by the contractor and any requests for changes to the plans and specifications submitted by the contractor or supervisor.

2.1.2 Supervisor

The supervisor must refer to the contract documents and reference documents to ensure proper supervision of the work.

It is important for the supervisor to also, among other things:

- read the documents submitted by the contractor
- ensure compliance with contract documents
- send change requests to the design team
- carry out sampling, if applicable
- identify any non-conformities on site
- validate retroreflection following application
- document the progress of the work
- approve the work
- recommend payment for the work.

The frequency of monitoring depends, among other things, on the scope of the marking work, the number of people assigned to monitoring, the number of marking crews, the territory to be covered and the working hours. Depending on how the contract is progressing, in general, consideration should be given to adjusting the frequency of monitoring to ensure that the work is compliant.

2.1.3 Pavement marking contractor and marking crew

The role of the pavement marking contractor and marking crew is to do their utmost to ensure that the marking work is carried out in such a way as to ensure the safety of road users and workers. In addition, the work has to be carried out in accordance with the contract documents, the CCDG and the Ministère's various standards. The marking must meet the Ministère's requirements respecting durability and retroreflection; otherwise, penalties may be applied, if necessary.

The contractor must also:

- provide the documents and samples required in the contract documents
- cooperate with the supervisor
- comply with the marking material supplier's technical conditions of application
- comply with the conditions of application prescribed in the contract documents and the CCDG.

2.2 Site visit

The site visit before the arrival of the marking crew, whether the work is contracted or carried out by the Ministère, is a fundamental step to ensure that the condition of the site allows the marking to be carried out effectively. It is also during this visit that the supervisor determines where pre-marking and sweeping will be necessary, if applicable.

The section to be marked must be clean, and all pre-marking must have been completed so that the contractor or the department's marking crew can effectively perform their work without being delayed. It is therefore important to coordinate the sweeping and pre-marking operations.

2.3 Kick-off meeting

When the work is performed under contract, the kick-off meeting is the time to, among other things, establish a relationship between the marking contractor and the supervisor. In addition to setting up communication mechanisms and carrying out a review of the main clauses of the marking contract, the following subjects should be addressed during the meeting:

- presentation of the stakeholders and their respective roles
- communications and emergency response
- deadlines and order of work, the work schedule and the work timetable
- method and frequency of payment
- the sub-contractors and suppliers of materials
- quality control (certificate of compliance, safety data sheets and sampling)
- important, innovative, major or critical aspects of the plans and specifications
- road works signalling plans
- the documents provided by the Ministère and by the contractor
- the list of equipment and machinery
- the procedure for unforeseen works
- notices to the contractor
- occupational health and safety
- the claim procedure
- inspection and acceptance of work.

During the meeting, it is also important to remind the contractor of the documents that the latter must provide before the work begins. These documents aim, in particular, to ensure the conformity of the materials used and the methodology that the contractor intends to put in place for the work.

It should be noted that this list is not exhaustive and that other topics could be discussed during the kick-off meeting. To facilitate subsequent discussions, a report of the meeting must be written.

3 Pre-marking

Pre-marking is used to place indicating marks on the road for line striping so that the right type of line is applied in the right place. Pre-marking also guides road users until the final marking has been carried out.

Depending on whether it is carried out on a new surface layer or on an existing road surface, pre-marking can be done in different ways, which are presented in the following sections. During road rehabilitation work or when marking is no longer visible, pre-marking of the roadway must be carried out before the arrival of the marking crew, both for longitudinal marking and special marking.

- In the case of road repair, the project management team of the Direction générale territoriale is responsible for seeing to the completion of the pre-marking.
- When marking is no longer visible and a pre-marking operation is necessary, the service centre (e.g. annual line repainting) is responsible.

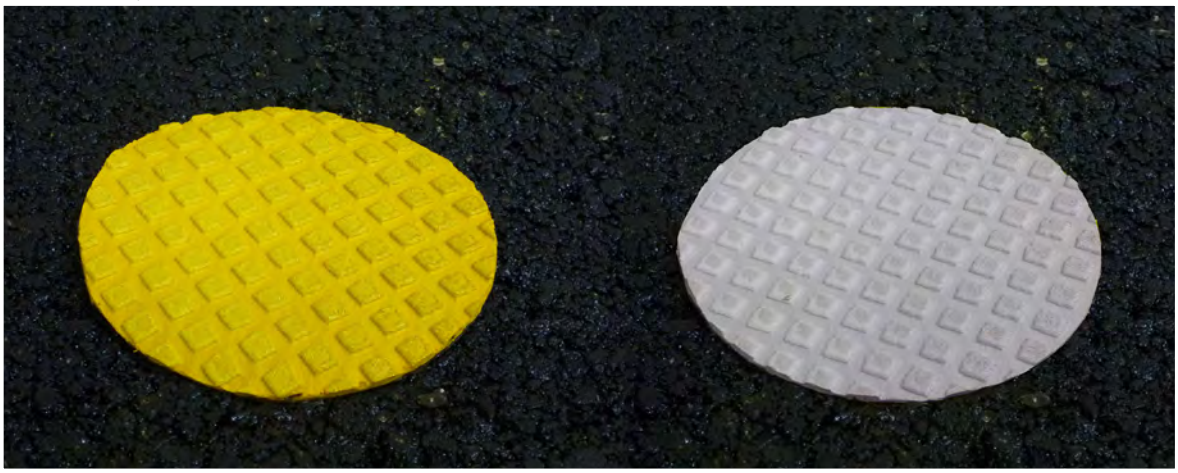
Pre-marking should always be based on a marking plan in order to ensure the effective transmission of the message to the road user while respecting established standards. When the marking is carried out under contract, the marking plans must be provided to the contractor, accompanied by descriptive specifications.

3.1 For marking applied to a new surface

On a new surface course, pre-marking made prior to the marking applied to the surface consists in applying reflective discs, temporary overlay markers and road surface symbols.

3.1.1 Reflective discs (pre-marking discs)

Reflective discs, or pre-marking discs, are used to determine the marking's alignment. They are primarily used by the marking crew and need to be set in place for all the types of lines. Figure 5 shows examples of pre-marking discs. Note that other types of pre-marking discs can be used.



Source: Transports Québec

Figure 5 – Examples of pre-marking discs

Pre-marking discs are installed by the contractor when the asphalt is laid and just before the finishing roller passes. The discs need to be spaced approximately 10 m apart for straight lines and 5 m apart for curved lines. The precision of the discs' alignment must be 100 mm longitudinally and 10 mm transversely to ensure precise alignment of the marking lines which will then be painted.

Pre-marking discs are to be made from prefabricated strips, consisting of rot-proof polymer, non-absorbent, chemically stable and unalterable by sodium and calcium chlorides.

The pre-marking discs must be white or yellow, pressure-sensitive, flexible and free of cracks, 1.5 mm to 2 mm thick (excluding the protective backing), between 90 mm to 100 mm in diameter, and have a removable film backing to protect the adhesive.

Despite their name, reflective discs are not very retroreflective and do not provide adequate guidance for road users, especially in darkness. Consequently, temporary overlay markers must be installed to increase the pre-marking's night visibility.

3.1.2 Temporary overlay marker

Temporary Overlay Markers (TOMs) with their retroreflective band, shown in Figure 6, are used to indicate the different lanes of traffic at night.

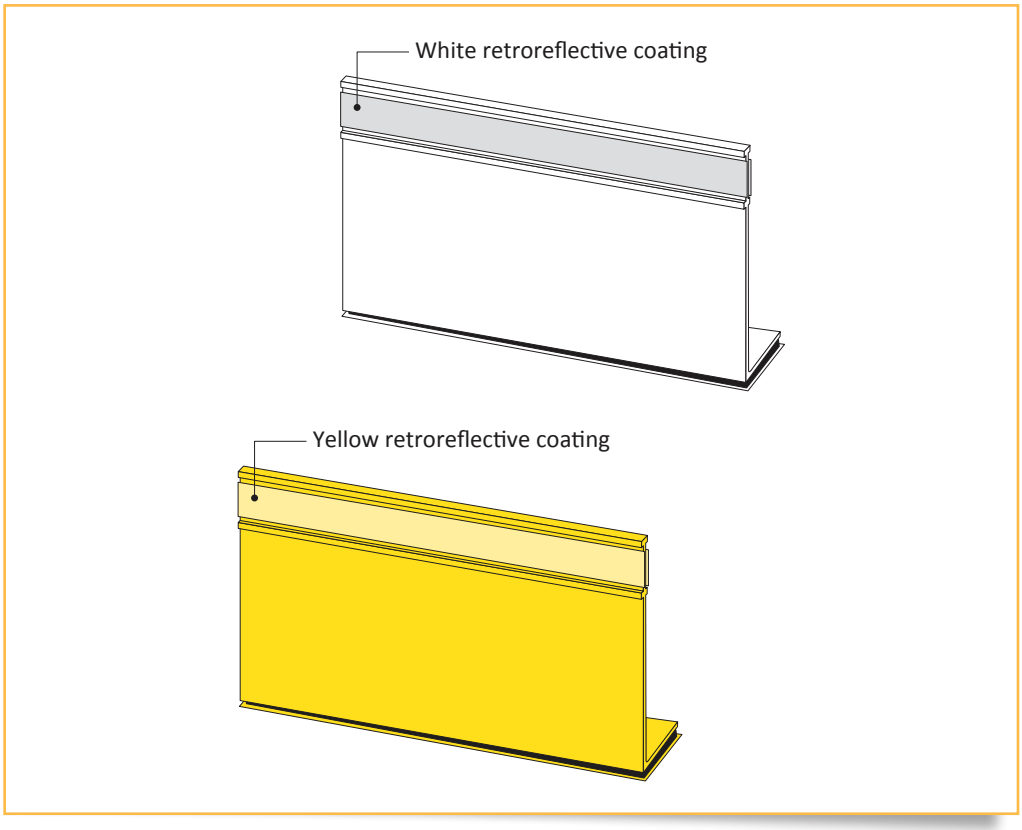


Figure 6 – Temporary Overlay Markers

It is important for TOMs to be installed according to the manufacturer's instructions. The use of a mechanical anchoring device with one or more nails is prohibited for reasons of road safety.

The spacing of the TOMs must be approximately 20 m in straight sections and 10 m in curves. This works out to one TOM every two pre-marking discs. They have to be installed before restoring traffic and replaced if necessary before the final markings are carried out. TOMs' service life varies from a few days to about two weeks, depending on where they are installed (curve, lane line, etc.) and the average annual daily traffic (AADT). TOMs do not have to be removed before proceeding with the marking work.

Temporary overlay markers must comply with the requirements of *Volume V – Traffic Control Devices* and *Tome VII – Matériaux* for retroreflective film. Generally, they must be white or yellow, pressure-sensitive, flexible and free of cracks, with a removable film that protects the adhesive, and have a retroreflective band.

3.1.3 Road surface symbols

The symbols on the road surface either indicate the type of line to be drawn or delineate the zones for changing the type of marking material. The symbols supplement the pre-marking made with pre-marking discs and TOMs.

The symbols must be produced in accordance with the specifications of *Tome VI – Entretien* of the collection Normes – Ouvrages routiers of the Ministère des Transports, which defines the symbol to be applied according to the type of mark. Figure 7 presents examples of pre-marking symbols.

Change of line	Pre-marking symbol[1]
Double solid to double broken 3-6 (3 m line - 6 m gap)	
Double solid to single 3-6	
Double solid to broken 3-6 right	
Double solid to broken 3-6 left	
Single broken to double broken 3-6 left	
Single broken to double broken 3-6 left	
Single solid to single broken 1-3 (1 m line - 3 m gap)	
Start of continuity line 1-3	
End of double line	
End of single line	
Start of approach nose	

1. The gap ratio of broken lines (1-3 or 3-6) can be indicated on the pavement when necessary.

Figure 7 – Examples of pre-marking symbols

Figure 8 clearly shows that, without the presence of symbols on the road surface, it is difficult to differentiate the types of lines to be painted based solely on the presence of pre-marking discs. The discs make it possible to align the marking lines, while the pre-marking symbols specify the type of line or mark to be applied. They are essential for the marking crew to do their job effectively.

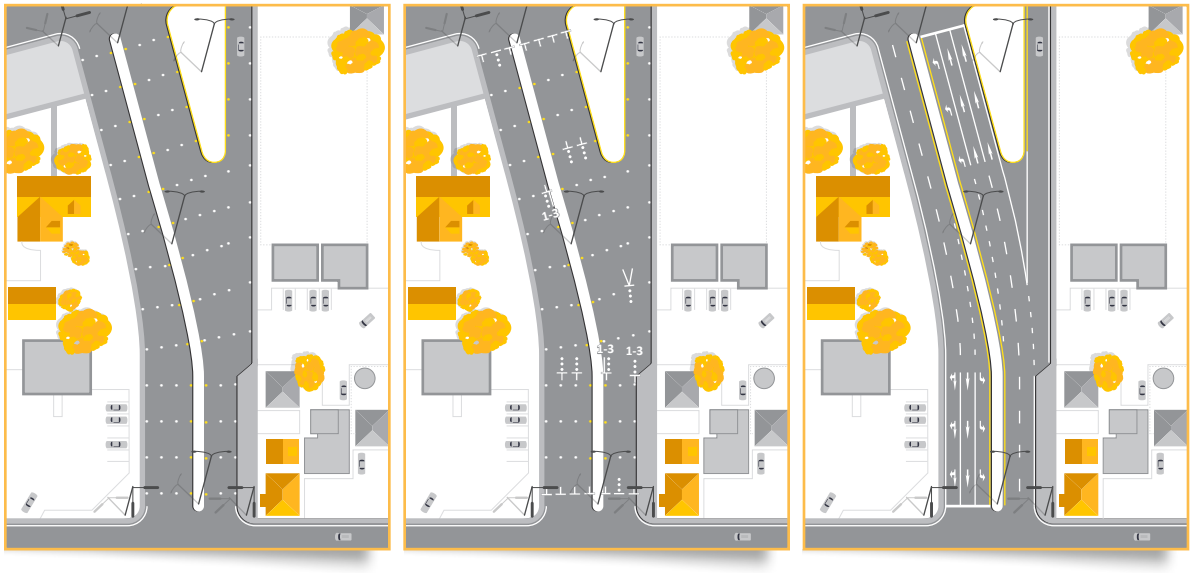


Figure 8 – Use of pre-marking symbols

Pre-marking symbols are made with white spray paint.

3.2 For inlaid marking on a new surface

On a new surface, the type of pre-marking done before the inlaid marking is determined according to the roadway on which the inlay is made.

3.2.1 Positioning of pre-marking

Regardless of the type of roadway, pre-marking must be carried out according to the marking plans in the same places as the inlaid marking. Pre-marking is therefore to be removed at the time of the inlay.

Figure 9 shows an example of misaligned pre-marking and inlaid marking. After the marking work, the yellow edge lines are double and the broken lines do not meet the required dimensions in terms of width, length and spacing.

Source: Transports Québec

Figure 9 – Example of misalignment of pre-marking and inlaid marking

3.2.2 Asphalt pavement

Following the laying of the plant mix, pre-marking can be done with pre-marking discs, temporary overlay markers and symbols on the road surface, as described above.

The service life of temporary overlay markers is very limited on high-traffic road networks. Pre-marking with a certified, water-based paint must be carried out within 72 hours after the plant mix has been laid.

Pre-marking lines are to be drawn according to the contract specifications. The contractor must also comply with the retroreflective requirements set out in the documents.

The marking material used must be a certified water-based paint that meets the requirements of *Tome VII – Matériaux*.

3.2.3 Concrete pavement

On concrete pavement, pre-marking is carried out with an epoxy resin-based material since the short service life materials have a very limited durability on this type of surface. The markings must be produced in accordance with the specifications of the contract documents. The contractor also needs to meet the retroreflectance requirements set out in the contract documents.

The marking material used needs to be epoxy resin-based and meet the requirements of *Tome VII – Matériaux*.

3.3 For re-marking existing pavement

On pre-existing pavement, pre-marking is necessary when markings are no longer clearly distinguishable and thus need to be re-marked. It is therefore the marking's degree of traffic wear on the pavement that determines the need for pre-marking.

The evaluation of the marking's degree of wear, or percentage of presence, consists of an analysis of the condition of the pavement marking, based on standardized photos and a functional classification developed in 2003 and based on the ASTM D913 standard, *Standard Practice for Evaluating Degree of Traffic Marking Line Wear*. The complete methodology of the marking's percentage of presence is described in the *Guide d'inspection de la durabilité du marquage*. Table 2 presents the functional classification.

Table 2 – Functional classification of the durability of pavement marking

Class	Percentage of presence (%)	Colour
1	96 to 100	
2	75 to 95	
3	50 to 74	
4	15 to 49	
5	0 to 14	

Pre-marking is necessary when the existing marking is class 5, that is, when the percentage of presence on the road surface is less than 15%. Below this percentage, it becomes difficult, if not impossible, for the striping truck to ensure the correct location or alignment to re-apply the marking at the same place.

3.3.1 Materials

Pre-marking on the existing pavement is done with white spray paint. The symbols are drawn on the road surface, as presented above, as well as small dashes to indicate the alignment of the marking lines.

3.3.2 Pre-marking plates

Pre-marking plates make it possible to determine the type of line to be drawn. They have a colour code indicating the type of line separating two contiguous lanes. Figure 10, which illustrates the possible configurations for the pre-marking plates, is taken from *Tome VI – Entretien*. The yellow indicates a broken line, while the blue indicates a solid line.

Figure 10 – Pre-marking plates

Pre-marking plates are installed one behind the other (recto verso) on one side of the adjacent road. Figures 11 and 12 show, respectively, the front and back of a roadside pre-marking plate on the edge of a road.

Source: Transports Québec

Figure 11 – Example of yellow/yellow pre-marking plate (recto)

Source: Transports Québec

Figure 12 – Example of yellow/blue pre-marking plate (verso)

4 Marking materials

In addition to winter road maintenance, other factors will directly influence markings' durability. These elements need to be taken into account when selecting materials and developing a maintenance strategy:

- **the material used:** For the same category of material, each has its own characteristics. Some materials are more durable than others, but each has its limitations.
- **the quality of the work:** A non-uniform or too thin a layer of paint directly affects durability.
- **compliance with the installation conditions:** Weather and road conditions will directly influence a material's drying or curing time.
- **the condition of the road surface:** Marking applied on a new plant mix will be more durable than when applied on a degraded or cracked asphalt. Marking must be applied to a clean surface.

4.1 Certification of pavement marking materials

Since each material has its own level of performance, a given material's durability cannot be predicted based solely on its formulation or simply by carrying out laboratory tests. Road tests are therefore essential to determining a material's actual performance.

The pavement marking material certification program aims to validate the performance of materials before use and to ensure that they meet the Ministère's requirements. Laboratory tests supplement the roadway tests and make it possible to characterize each of the materials submitted in order to validate, thereafter, that it is indeed the certified materials that are applied to the network.

The roadway tests consist in applying, for each material evaluated, six parallel lines, 3 metres long, according to a well-defined marking plan (Figure 13). Subsequently, monitoring of durability (degree of traffic marking line wear) and retroreflection is carried out twice a year on each of the materials applied.

Source: Transports Québec

Figure 13 – Example of field test deck

The materials meeting road and laboratory requirements are listed in one of the certified materials lists. These lists are available on the website of the Ministère.

Table 3 presents the durability and retroreflection requirements that must be met by short, medium and long service life products to be approved, as well as the skid resistance requirements for anti-skid/anti-slip products for large areas.

Table 3 – Short, medium and long service life pavement marking material performance criteria

		Pavement marking material performance criteria[1]		Anti-skid/anti-slip marking materials for large areas
		Durability (%)[2][3]	**Retroreflectivity** (mcd·m^{-2}·lux^{-1})	**Skid resistance** (BPN)[4]
Short service life	Autumn (around 2 weeks after application)	100	≥ 250 (white) ≥ 175 (yellow)	–
	Following spring (around 8 months)	65 (water-based paint) 55 (low VOC alkyd paint)	–	–
Medium service life	Autumn (around 2 weeks after application)	100	≥ 250 (white) ≥ 175 (yellow)	≥ 45
	After 1 year	85	–	≥ 45
	After 2 years	75	–	≥ 45
Long service life	Autumn (around 2 weeks after application)	100	≥ 250 (white) ≥ 175 (yellow)	≥ 45
	After 1 year	95	–	≥ 45
	After 2 years	85	–	≥ 45
	After 3 years	80	–	≥ 45
	After 4 years	75	–	≥ 45

1. All the other colours (green, blue, red, orange and black) must comply with the durability criteria and, where applicable, possess at least the retroreflection value of yellow.
2. The percentage of presence of pavement markings is calculated using photographs, taking as reference the moment the product is applied (100%). The ASTM D913 method *Standard Practice for Evaluating Degree of Traffic Marking Line Wear* is used.
3. The Ministère accepts a margin of error of ± 1% on the durability value at the time of the evaluation.
4. This criterion applies specifically to marking materials applied on large areas that must be skid-resistant for road safety reasons, in particular. The test is carried out according to the specifications of the method ASTM E303 *Standard Test Method for Measuring Surface Frictional Properties Using the British Pendulum Tester*. Three measurements are taken, two in the wheel paths and another between them. All three measurements must be greater than a British Pendulum Number (BPN) of 45.

The minimum marking retroreflection threshold is 100 $mcd \cdot m^{-2} \cdot lux^{-1}$. Retroreflection in the spring is often much lower than this value due to winter maintenance operations, which tear off or break the glass microbeads added to the marking materials to provide night visibility. This is why retroreflection requirements cover only the period following the application of pavement markings.

The durability requirement for medium service life materials after two years is the same as that after four years for long service life materials.

A second certification program is reserved exclusively for alkyd paints. As alkyd paints can be used only between October 15 and May 1, for environmental reasons, and very often the application conditions are not favourable, the concept of road performance has been excluded from the program. Thus, this program essentially consists in carrying out laboratory tests to determine the physico-chemical conformity of the alkyd paint.

4.1.1 Evolution of marking materials used at the Ministère

The use of pavement marking materials at the Ministère has evolved considerably since 2006. These changes have largely been dictated by departmental guidelines, with the on-going objective of improving the presence of lines. The departmental guidelines, for their part, are based on in-house experience, on the review of literature as well as on data collected from the certification bench and pilot projects. Figure 14 shows the evolution of the main pavement marking materials that have been used at the Ministère since 2006.

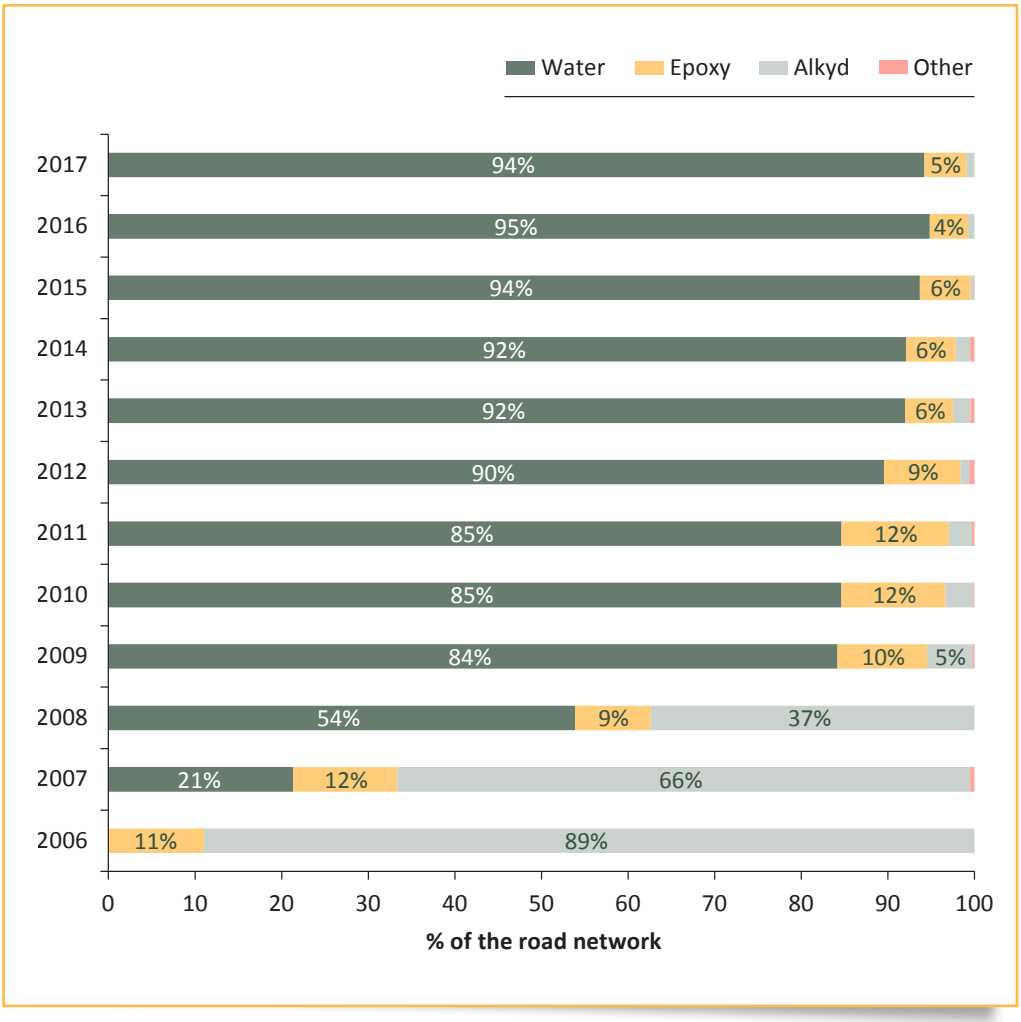


Figure 14 – Evolution of the marking products used at the Ministère

The three highlights of the years since 2006 are:

- the transition, between 2006 and 2009, from alkyd paint to water-based paint
- the application, since 2009, of the *Volatile Organic Compound (VOC) Concentration Limits for Architectural Coatings Regulations* (SOR/2009-264)
- the decrease, in 2012-2013, of systematic re-marking using an epoxy resin-based material.

4.1.2 Regulations respecting volatile organic compounds

In September 2009, Environment Canada published the *Volatile Organic Compound (VOC) Concentration Limits for Architectural Coatings Regulations* (SOR/2009-264). These regulations apply to manufacturers, importers, seller and users. During the period beginning on May 1 and ending on October 15, they prohibit the use of marking paints in which the VOC concentration exceeds 150 g/L. In addition, the regulations limit the VOC concentration to 450 g/L for paints that can be used between October 15 and May 1.

This new federal regulatory requirement included a three-year implementation period to allow the industry and governments to adapt. Since September 2012, alkyd paints have been prohibited from being used in the summer, with the exception of low-VOC alkyd paints.

VOCs are substances formed from at least one carbon atom and one hydrogen atom in a gaseous state in the atmosphere. Many of these compounds react through photo-chemical processes (sunlight) and contribute to the formation of ground-level ozone and the particles that make up smog.

In marking paints, the VOCs result from the use of solvents. As these paints dry, these solvents are released into the atmosphere through evaporation. However, not all solvents present in marking paints are considered VOCs. Thus, the compounds excluded from section 65 of Schedule 1 to the *Canadian Environmental Protection Act* (1999) and tert-butyl acetate ($C_6H_{12}O_2$) are not taken into account in calculating the VOC content, as their photochemical reactivity is negligible and since, theoretically, they do not contribute to the formation of smog.

4.2 Water-based paint

Water-based paint is the marking material most used by the Ministère and by North American administrations. Annually, almost all of the 90000 km of lines making up the Ministère's network are re-marked with this short life service material to restore night visibility to markings and ensure the presence of lines until the following spring. Before a water-based paint may be used by crews under contract or by the Ministère's crews, it must be certified.

Water-based paint consists of a binder (emulsion resin in water) solvents, pigments, pulverulent materials and various additives. In total, a water-based paint can consist of more than 10 products. Table 4 describes the roles of the main components.

Table 4 – Components of water-based paint

Component	Definition	Role
Binder	The binder is composed of a resin and plasticized emulsion.	The binder holds the pigments and the pulverulent materials together when the paint film hardens. In addition to ensuring that the paint adheres to the road surface, the binder has a major impact on the paint's durability and on its physico-chemical properties.
Solvent	The solvent is a volatile liquid in which the binder and the other constituents are dispersed. In water-based paint, the main solvent is water, but it can also be made up of a small amount of alcohol (methanol). The solvent evaporates when the paint dries.	The solvent regularizes the paint viscosity to make it applicable on the road. Solvent also promotes the formation of the paint film.
Pigments	Pigments are mineral or organic substances found in the form of a powder in suspension in the liquid phase. The most important pigment is titanium dioxide (TiO_2).	Pigments influence paint opacity and colour.
Pulverulent materials	Pulverulent materials are mineral substances in the form of powder suspended in the liquid phase which serve as inert fillers. They are much less expensive than the other constituents.	Pulverulent materials can improve the properties of a paint, to a certain extent. However, their effects on opacity and colour are very minimal. Pulverulent materials, notably, make it possible to reduce production cost.
Additives	Additives are products added in small amounts to paint. They can be: • wetting agents • coalescing agents • thixotropic agents • defoamers • anti-fungals.	Additives play very specific roles in improving a paint's properties or characteristics during its manufacture, storage or application.

Source: Centre de recherches routières

The water-based paint used on the Ministère's network is quick-drying. In favourable conditions, the paint is considered to be dry to the touch 5 minutes after application and does not splash onto vehicles driving over the marking line. However, after 5 minutes, the paint is not completely dry since the evaporation process can take up to 14 days. Its ammonia component (e.g. ammonium hydroxide), which evaporates very quickly, results in the water-based paint gelling after a few minutes.

Figure 15 describes the stages in the drying process of water-based paint, up to the formation of a durable film. At 24°C and 50% relative humidity, a durable film of paint can take up to 2 hours to form (for a thickness of 400 µm). However, the drying time can increase exponentially when the relative humidity is very high and the ambient temperature is very low. In addition, if a thunderstorm occurs 30 to 45 minutes after application, the water-based paint could be completely washed off if it rains long enough. Though brief periods of bad weather do not seem to affect the appearance of water-based paint, they could compromise the paint film's cohesion with the roadway surface and thus reduce its long-term durability. If the marking is altered by the weather, work must be redone to ensure that the pavement markings meet the requirements.

Adapted from: Ennis-Flint

Figure 15 – Stages of how water-based pavement marking paint dries

The two most important elements during pavement marking operations are the concepts of “dry to touch” and “water resistance”.

More precisely, the factors that influence the drying time of water-based paint are:

- the relative humidity (RH), which must be below **80%**
- the ambient temperature (T°), which must be higher than **10°C**
- the temperature of the road surface, which must be higher than the calculated **dew point** temperature
- the humidity of the road surface
- sunshine
- wind speed
- bad weather.

The dew point is the lowest temperature to which a mass of air can be subjected, at a given pressure and humidity, without the formation of liquid water by saturation. When the road surface temperature reaches the calculated dew point temperature, condensation forms on the surface. The pavement marking carried out under these conditions will not be durable, because of the layer of moisture between the coating and the paint applied. A minimum spread of 2°C between the road surface temperature and the calculated dew point temperature must be observed.

4.3 Alkyd paint

Alkyd paint can be used only between October 15 and May 1 when weather and road conditions allow. It is applied for end-of-service-life markings, especially in the winter or during paving contracts that end late in the fall, since no other materials can be used in colder weather conditions. The use of alkyd paint should be considered only when weather conditions prevent the application of more durable certified products, such as water-based paints, epoxy resin-based products or methyl methacrylates.

Alkyd paint consists of a binder (alkyd resin), solvents, pigments, pulverulent materials and various additives. The solvent used in the formulation is a light naptha, which means that alkyd paint is a flammable product, requiring specific provisions.

Alkyd paint also dries by evaporation, but is much less dependent than water-based paint on weather conditions. The risks of leaching after a downpour are therefore less likely. While the drying time of alkyd paint is less affected than that of water-based paint, it is also influenced by:

- the relative humidity (RH)
- the ambient temperature (T°)
- the road surface temperature
- the road surface humidity
- the dew point
- sunshine
- wind speed.

4.4 Low-VOC alkyd paint

Legislative changes limiting the concentration of VOCs in marking materials have resulted in manufacturers developing a new line of alkyd paints with VOCs below 150 g/L. Low-VOC alkyd paint can therefore be used year round.

Low-VOC alkyd paint consists of a binder (alkyd resin), solvents, pigments, pulverulent materials and various additives. The solvent used in the formulation is acetone (mostly), which makes low-VOC alkyd paint a flammable product. As regards the drying process, the same evaporation principle applies.

Though, technically, low-VOC alkyd paint can be used without restrictions between May 1 and October 15, the Ministère does not intend to replace the use of water-based paints by this type of short service life paint in the summer for the following reasons:

- Its durability is lower than water-based paint (lower requirement during certification).
- Its VOC content is higher (almost double) than that of water-based paint.
- The release of organic solvent through evaporation can have an impact on health and on the environment.
- Low-VOC alkyd paint is flammable.
- Specific provisions are required for handling hazardous materials.

4.5 Epoxy resin-based materials

At the Ministère, epoxy resin-based materials are applied to new surface courses. On concrete roadways, these materials offer the best durability among all the materials used by the Ministère.

Epoxy resin-based materials are also used for re-marking pavement marking lines in high-traffic sectors. However, it should be noted that the superimposing of layers of medium or long service life epoxy resin-based materials must be minimized. The creation of tensile stresses during the hardening of each application of this material can lead to premature removal of the marking. Thus, a marking must not be re-marked more than twice with an epoxy resin-based material. As for the use of a water-based paint to re-mark a line marked with an epoxy resin-based material, there is no limit to the number of subsequent re-markings.

To avoid problems of premature removal of the marking, an epoxy resin-based material must never be applied over a short service life product whose percentage of presence is greater than 50%. Indeed, premature removal can occur due to poor adhesion of the epoxy resin-based material to the road surface.

Regarding the two-layer (white on black) marking carried out on concrete roadways, standard specifications require that the two layers of epoxy resin-based products be applied in the context of a single closing operation, with the black marking being followed by the white marking. It is important for the maximum delay of 24 hours between the two applications to be respected, so as to ensure good cohesion between the two coats of marking.

Epoxy resin-based materials are made up of two components: a resin and a catalyst (hardener). They do not contain solvents but instead harden by chemical reaction after mixing the components in a precise volume ratio of 2:1 (resin/catalyst). The resin consists of several organic compounds, including epoxy, ether and phenol groups, inorganic or organic pigments (yellow colour) and additives. The catalyst, for its part, consists of several organic compounds, including phenolic, amino and ether groups.

To ensure the proper mix of components, and thereby achieve the expected durability, each component must be heated to a different temperature so that its viscosity is similar in the applicator gun's mixing chamber. However, the fact of having to heat the components involves logistics that can cause additional challenges for special marking.

The mixing of the resin with the catalyst results in a polymerization process that hardens the mix. Since there is no evaporation process, epoxy resin-based materials do not emit VOCs into the atmosphere when hardening.

The hardening time of epoxy resin-based materials can vary, depending on the components used, the ambient temperature and the road surface temperature. It can range from 20 minutes to 60 minutes. The following application conditions must be observed to ensure the best possible durability:

- There must be no risk of bad weather before the material has hardened.
- The ambient temperature (T°) must be above **10°C**.
- The road surface temperature must be higher than the calculated **dew point** temperature.

4.6 Methyl methacrylate

Methyl methacrylate (MMA) is a marking material that can be applied either manually or by spraying. MMA spray is used by the Ministère for special marking. However, in order to obtain results comparable to epoxy resin-based materials, this material must be applied more thickly.

MMA spray comes in two different types of systems.

- The first is a two-component system consisting of a resin A and a resin B. A solid benzoyl peroxide based (BPO) catalyst is added to resin B. The two resins are then mixed in a 1:1 volume ratio.
- The second type is also a two-component system consisting of a resin A and a liquid benzoyl peroxide based (BPO) catalyst. Each component is then mixed in a 98:2 volume ratio (A/BPO).

MMA hardens by chemical reaction (polymerization) when resin A contacts the liquid BPO or with resin B supplemented by solid BPO. Unlike epoxy resin-based materials, the components of MMA do not need to be heated to adjust their viscosity, which reduces the risk of poor mixing. Generally, MMA is formulated to harden in approximately 10 minutes. However, this time can be adjusted by changing the BPO content. Since no evaporation process is involved, MMA does not emit VOCs into the atmosphere during the hardening process.

As with epoxy resin-based materials, MMA's hardening time is largely influenced by the ambient temperature and the road surface temperature. The application conditions required are the same as those for epoxy resin-based materials though, theoretically, MMA can be applied at 0°C.

4.7 Other marking materials

There are other marking materials on the market and they can meet specific needs. The Ministère remains on the lookout for new technologies available in the area of pavement marking and generally accepts the application of all types of materials on the test deck as part of the certification process.

4.8 Anti-skid/anti-slip material for large areas

To reinforce the signalling of reserved bus-lanes, a red mark, with the word BUS stenciled on in, can be added, as shown in Figure 16. The marking and its use must conform with the specifications of *Volume V – Traffic Control Devices*. For road safety reasons, an anti-skid/anti-slip mixture must be added to the marking material to make the surface less slippery.

Source: Transports Québec

Figure 16 – Red band for reserved bus lane

5 Sampling

Sampling is essential to establishing pavement marking material conformity and thereby ensuring that a given material has not been modified by the person responsible for applying it or by the supplier. Since the analysis results are always compared with those obtained during the Ministère's certification process, the sampler must ensure that the marking materials are homogeneous before taking samples. This representativeness is essential in order not to bias the conclusions made with respect to the conformity of the samples taken.

The main sampling procedures are described in the *Guide d'échantillonnage des produits de marquage et de mesure de l'épaisseur du film humide*, published by the Ministère. However, the following section presents alternative methods that can be carried out on-site during marking work.

5.1 Production batch

A production batch corresponds to a determined quantity of a material having the same physico-chemical characteristics and manufactured using the same formula, from the same source of supply and during a period of uninterrupted production.

Thus, if the mixture is not modified by the person applying it and the material is homogeneous, the same production batch will produce laboratory test results similar to those obtained during certification. The results entered on the certificate of conformity supplied by the manufacturer's laboratory relate only to a given production batch, and it is normal for them to differ slightly from one batch to another. Therefore, as far as possible, it is best to avoid sampling when several production batches are mixed.

The production batch number is listed on the certificate of conformity, not on the data sheet. The first gives information about the production batch, while the second gives general information about the material.

5.2 Sampling frequency

When marking with water-based paint, the contractor must provide samples at the start of work. Thereafter, the sampling frequency can be very variable from one contract to another, in particular due to the scope of the pavement marking contract and its overall progress.

For large-scale contracts with a water-based paint that span several weeks, weekly sampling would be adequate.

The water-based paint must be sampled throughout the contract work, because it can easily be diluted before application, and its formulation can be modified by substituting certain raw materials for other, less expensive ones. These modifications can have significant consequences on the paint's physico-chemical properties (e.g. drying time) and performance (durability and retroreflection).

Due to their complexity and stability, epoxy resin-based materials are difficult to alter between the time they are sampled and the time they are applied by the contractor. Consequently, source sampling, that is to say, directly from the distributor, is carried out in order to draw a portrait of the materials applied in Québec and especially to limit redundant analyses. If major non-conformities were to be detected during sampling, the materials cannot be used for the Ministère's contracts.

If the site supervisor has any doubts about material conformity, he or she must contact the chemist in charge at the Direction des matériaux d'infrastructures (DMI). In addition, if a particular problem is observed during the work, an additional sampling of each component (resin and catalyst) must be carried out.

Source: Transports Québec

Figure 17 – Example of enameled container

5.3 Sample amount

Regardless of the type of marking material and the method used during sampling, two 1-L samples of the material must be taken from the same production lot. In addition, samples are to be collected in a 1-L airtight metal container with an enamel coating inside (Figure 17).

It should be noted that to prevent solvents from evaporating, the use of plastic containers is prohibited, because even if these containers seem airtight, certain solvents could evaporate through their walls.

5.4 Sampling procedure (general principles)

Before sampling, the person taking the samples (sampler) must read the safety data sheet and wear the necessary protective equipment. Once the sample has been taken, regardless of the method used, the container must be hermetically sealed immediately to prevent skin formation and evaporation. Too long a delay in sealing can modify the material's physico-chemical properties. In addition, the amount of air in the containers must be minimized, hence, the need to ensure that they are filled to 1 cm from the rim.

Source: Transports Québec

Figure 18 – Example of container insufficiently filled

Source: Transports Québec

Figure 19 – Example of container properly filled

Failure to comply with the general principles and sampling methods described below could lead to non-conformities in the samples taken and thus lead to the application of unjustified penalties. Even minimal evaporation can significantly modify material properties (viscosity, density, etc.).

Always with the goal of preserving the sample's integrity, it is important to avoid exposing the sample to extreme temperatures between the time it is taken and received in the laboratory for analysis. Samples must be sent within one week of collection.

5.4.1 Procedures described in the *Guide d'échantillonnage des produits de marquage et de mesure de l'épaisseur du film humide*

The sampling procedures, detailed in the Guide, can be performed **before the marking work**. It involves the:

- sampling from a tank (outlet valve)
- sampling from a tank (sampling tube)
- sampling from a 20-L container
- sampling when loading the striping truck
- sampling of glass microbeads.

These procedures are the preferred procedures since they are generally carried out off-site and make it possible for a homogenous sample to be taken.

5.4.2 Alternative on-site sampling procedures

In the context of monitoring pavement marking work, it is sometimes impossible to use one of the methods described in the *Guide d'échantillonnage des produits de marquage et de mesure de l'épaisseur du film humide*, especially when the marking material is already in the striping truck at the time of sampling. An alternative on-site method must then be used for taking representative samples from the tank's content.

Whichever method is used, the sampler must ensure that the sites are suitable and safe for sampling.

5.4.2.1 Sampling from an applicator gun

Sampling from an applicator gun is appropriate only for water-based or alkyd paints. Before taking the sample, it is important to ensure that there is no residual water used for washing (or solvent) in the pipe between the truck's tank and the gun. Also before taking any samples, the contractor must first install a few kilometres of lines.

Thereafter, the application pressure should be reduced to a minimum and the gun nozzle removed to allow filling at low pressure, thus preventing splashing. In addition, the sampler needs to take special care to prevent debris from falling into the sampling container.

In the case of special marking, the same procedure is used, again, after the contractor has installed a few markings on the road surface.

Material sampling should never be carried out directly after filling the tanks. In the case of water-based paint, water inevitably needs to be pumped after loading to clean the pumping system and prevent it from becoming clogged. A maximum of 10 L of water can be added for each filling, because beyond this amount, the physico-chemical properties could be modified considerably and influence the performance.

5.4.2.2 Sampling via a diverter valve

Some striping trucks are equipped with a diverter valve for sampling the marking material. However, since all trucks are different, it is hard to establish a general procedure.

If the striping truck is fitted with a diverter valve, the sampler should first ensure that the location of the valve is such that the sample taken is representative of the tank's contents and that the marking material is thoroughly homogenized. In some cases, the valve location may result in the sample being diluted with wash water, for example. If the integrity of the sample is not guaranteed, an alternative sampling method must be considered.

5.5 Shipping

For the requirements of the DMI laboratory, a label (Figure 20) containing the following information must be affixed to each container.

V-1037	
Supplier	
Type of material	
Colour	
Product code	
Batch number	
Date of manufacture	
Date of receipt	
Date of sampling	
Name of sampler	
Recipient's name (if different)	

Figure 20 – Example of a shipping label

On the label, the recipient's name is the name of the person to whom the analysis report should be sent. When sending for the first time, it is important to write the email address on the label or to add a business card to the package.

The parcel must be accompanied by the shipping form V-1037. The *Guide d'échantillonnage des produits de marquage et de mesure de l'épaisseur du film humide* or the *Guide de l'usager* specifies the sections to be completed and the information required to help process the samples at the DMI.

6 Supervision of marking work

To ensure the durability of the marking, the supervisor must check certain aspects during the work, but also before and after.

6.1 Before and during the marking work

6.1.1 Conditions of application

The conditions for applying the marking material must be respected. In addition, the pavement marking work is not to be performed when:

- the roadway is damp or wet
- it could rain before the material has dried or hardened
- the roadway is contaminated with various dirt and debris that can affect the marking material's adhesion.

After a rain shower, sufficient time must be allowed for the roadway to completely dry before the marking material can be applied.

Roadway condition affects the marking's durability. Indeed, since marking materials do not adhere properly to the road surface if the latter is covered with dirt and debris, it must be adequately cleaned before marking.

For water-based paints, special attention should be paid to temperature and humidity, which can have a major impact on drying time. Certain wetter areas need to be more closely monitored during marking work. In extreme cases, the drying time can extend over several hours and require the installation of additional signalling, such as cones, to protect the marking.

6.1.2 Pre-marking

In order to not cause additional delays for the marking crew, it is important to ensure that the pre-marking is done and compliant. Before the crew arrives, the pre-marking discs or paint marks, where applicable, need to be checked to ensure that they are correctly applied for proper alignment of the marking lines. Pre-marking symbols also need to be checked to ensure that they have been completed, indicating the type of line to be marked and the type of material to apply, where applicable.

6.1.3 Location and alignment

When it comes to re-marking pavement markings, the marking crew must apply the material at the exact same place as the existing marks.

When a marking plan is provided by the Ministère, the contractor must accurately implement it. The plan is to clearly indicate the location of marking lines as well as the other types of markings (approach noses, arrows, etc.).

- The longitudinal alignment of the marking must not deviate transversally by more than 25 mm from the marking plan.
- The position of a marking under 3 m in length must not deviate longitudinally more than 25 mm from the marking plan.
- For a marking longer than 3 m, this tolerance is 50 mm.

In the event that there is no marking and if no marking plan is provided in the contract, the contractor is to follow the pre-marking on the road surface carried out by the supervisor or the supervisor's representative.

6.1.4 Marking quality, dimension and definition

The marking material must be applied uniformly, homogenously, clearly and precisely. For special marking, the contractor is to apply the marking material using a pressure gun. Rigid stencils are to be used to trace the symbols on the road surface, must be in good condition and not interfere with meeting the specific requirements. Adhesive tape cannot, under any circumstances, be used to delimit shapes on the road surface. If another method is considered, the contractor must submit a written request to the supervisor.

The size of the markings must comply with the provisions of *Volume V – Traffic Control Devices* and to the specifications in the contract documents. Figure 21 shows a double line where the lines are too wide and not spaced far enough apart.

Source: Transports Québec

Figure 21 – Example of double solid lines that are too wide and not spaced far enough apart

6.1.5 Field test deck

At the start of the work, the contractor is to make a field test deck so that the marking method can be approved by the supervisor. For longitudinal marking, the test deck can be made in the same place as where the work is planned.

For special marking, it is recommended that a field test deck be made at a control site. The site needs to be at a spot where traffic is more limited, because the test deck may have to be referred to in the event of a dispute or non-compliance. When building the sample control site, the contractor and the supervisor must agree on the visual aspect of one or two symbols deemed to be in conformity by both parties. It is also recommended that the wet film thickness be measured at this time and that photos be taken to document it.

6.1.6 Rate of application

Monitoring during application is essential to ensure the quality of the work and ultimately the marking's durability. Indeed, a material applied in too small a quantity risks having poorer durability than if the application rate is respected. In addition, the thickness of material applied after the marking work cannot be verified with any degree of certainty.

6.1.6.1 Application rate and thickness required

For short service life materials, the application rates must be adhered to. For the application rates of glass microbeads and medium or long service life materials, the indicated rates are for guidance and information purposes. Contracts are instead based on performance values relative to retroreflection and durability. For longitudinal marking, the application rates are specified in tables 5 and 6, depending on the type

of material applied. In the case where two marking lines of the same colour requiring different dosages are applied at the same time, the higher dosage should be applied. Finally, for special marking, the thickness is specified in Table 7.

Table 5 – Application rate for epoxy resin-based materials for longitudinal marking

Epoxy resin-based material			Glass microbeads
New asphalt (< 2 months' use)	Asphalt and concrete	Re-marking	
66 L/km	60 L/km	39 L/km	2 kg/L

Table 6 – Application rate for alkyd paint and water-based paint for longitudinal marking

Alkyd paint and water-based paint			Glass microbeads
New asphalt	Re-marking Presence on road surface < 50%	Re-marking Presence on road surface ≥ 50%	
48 L/km	48 L/km	35 L/km[1]	0.6 kg/L

1. This rate of application applies only to the Ministère's marking crews. Based on the AADT, the decision may be made to retain a rate of 48 L/km for remarking.

Table 7 – Thickness to apply according to the type of material used for special marking

Type of material	Thickness to apply (µm)
Spray MMA	Between 600 and 800
Epoxy resin-based material	550
Water-based paint or alkyd paint	400

6.1.6.2 Methods to verify the application rate used

There are two main methods for verifying the application rates of longitudinal marking on-site:

- validation of quantities from the tanks of the striping truck
- measurement of the wet film thickness.

6.1.6.2.1 Validation of quantities from the tanks

The method involving validation of quantities from the tanks makes it possible to establish the application rate by calculating the quantity of paint applied according to the number of kilometres of lines striped.

With this method, the contractor must provide the Ministère with a means of knowing the precise amount of paint and glass microbeads in the striping truck's tanks. Generally, a schematic plan of the tanks is submitted.

Before starting work, the level of the marking material in the tanks (initial paint level) must be measured. Thereafter, measurements must be taken during the work and before any of the tanks are refilled to determine, using the tank diagram provided, the number of liters of paint applied (the difference between the second measurement and the initial measurement). Using the number of kilometres travelled between the two measurements, the application rate (L/km) can be calculated.

The measurements can be taken using a ruler or a laser device. However, it is important to ensure that all measurements are taken using the same reference point. Figure 22 indicates the chosen reference point, which is located around the edge of the tank opening. In Figure 23, it can be seen that the person about to measure the quantity of marking material in the tank is positioned according to the chosen reference point.

Source: Transports Québec

Figure 22 – Example of reference point for taking measurements

Source: Transports Québec

Figure 23 – Taking measurements, using the reference point

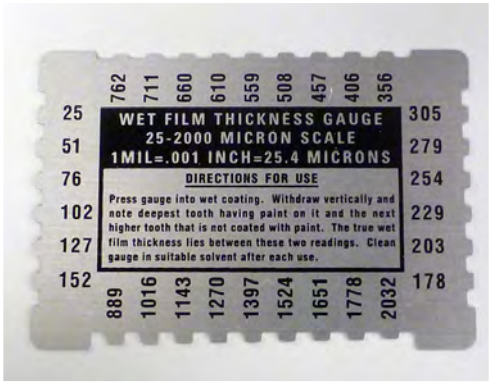
To determine the number of kilometres of lines striped, the odometer of the striping truck or any other vehicle can be used. It must be checked to ensure that it is calibrated. Standard kilometre checks on the Ministère's network can be used to carry out this verification. The section for calibrating a vehicle's odometer is indicated by the "Km étalon" sign (Figure 24).

Figure 24 – "Km étalon" sign

6.1.6.2.2 Measurement of wet film thickness

The use of a thickness gauge gives a very good indication of the actual thickness of the wet film. It can be used for any material and for both longitudinal and special markings. However, this method remains less precise than the method involving the validation of quantities from the tanks. It is therefore important to follow a rigorous procedure to obtain the most accurate measurements possible.

The gauges measure the thickness, either in micrometres (µm) (Figure 25), or in thousandths of an inch (mil) (Figure 26), or both.



Source: Transports Québec

Figure 25 – Thickness gauge (µm)

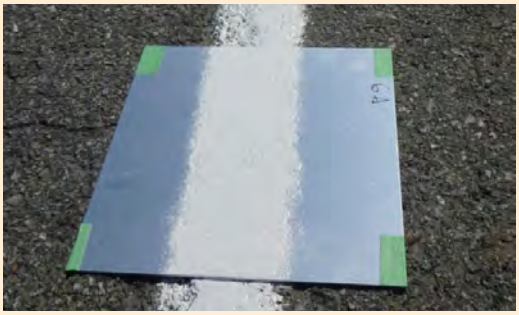
Source: Transports Québec

Figure 26 – Thickness gauge (mil)

The procedure that follows explains how to use a thickness gauge to adequately measure the thickness of the wet film.

1. Place a smooth, rigid support on the ground on which the marking material will be applied. Microbeads are not involved so as to avoid biasing the results.

- Use a Plexiglas or aluminum plate or any other smooth surface as a support.
- Never measure wet film thickness directly on the road, as its surface is irregular.

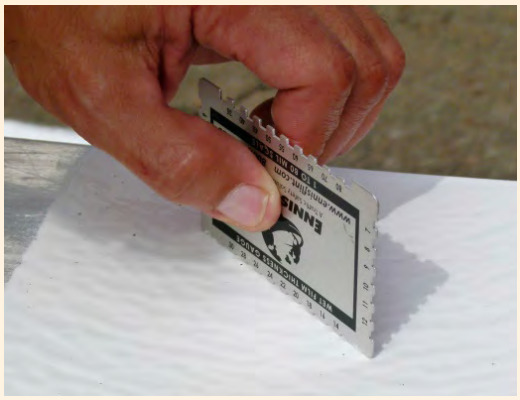


Source: Transports Québec

Figure 27 – Plate on the ground with marking

2. Push the gauge into the wet film at a 90-degree angle to the plate.

- Insert the gauge as soon as possible after application of the marking material to prevent a skin from forming which could distort the measurement.
- Ensure that both ends of the gauge are firmly bearing on the surface of the plate.
- Do not take measurements on the sides of the line, because the thickness may be different from that of its centre.



Source: Transports Québec

Figure 28 – Taking a measurement

3. Remove the gauge from the wet film and locate the last tooth on which the material is visible.

- The actual thickness of the wet film is between the last tooth on which the material is visible and the following unmarked tooth (calculate the average of the two measurements). Figure 29 illustrates an example of the calculation.

4. Quickly clean the gauge after each use.

- Be sure to thoroughly clean the ends of the gauge and each tooth.
- Use a cloth and a suitable cleaning solvent, if necessary.

5. Take three measurements to obtain a more representative average of the thickness applied.

In the following example, the measurement indicated on the last tooth is 406 µm and that of the next unmarked tooth is 457 µm. Based on the average of the two measurements, the actual thickness of the wet film is 432 µm or 17 mils ((406 µm + 457 µm)/2).

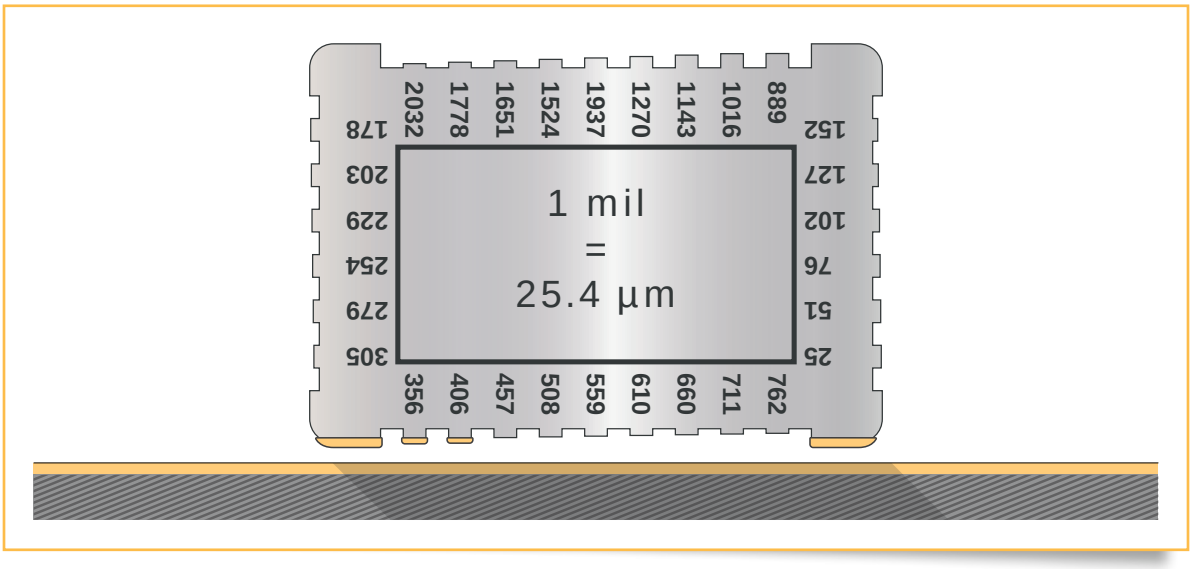


Figure 29 – Example of calculation of the wet film thickness

The "wavy" aspect of the paint film is the primary source of error when measuring. Taking multiple measurements, as shown in Figure 30, helps mitigate this error.

To further reduce the error related to thickness measurement, the gauge needs to be applied and removed in a continuous movement without leaving it in the marking material too long. It should be noted that some types of materials tend to be "attracted" to the thickness gauge (over-evaluation), while others tend to be "repelled" (under-evaluated). An experienced user generally obtains an accuracy of around ±10%.

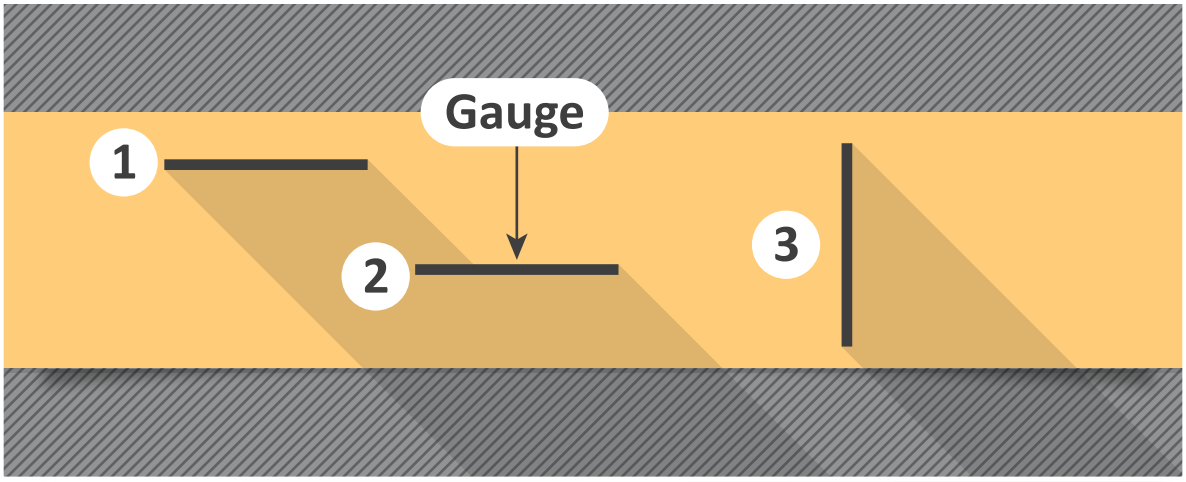


Figure 30 – Example of a measurement being taken (plan view)

Table 8 shows different thicknesses according to the primary application rate used at the Ministère, based on a 120-mm wide line.

Table 8 – Wet film thickness calculated according to the application rate

Application rate (L/km)	35	48	60	66
Thickness in µm[1]	292	400	500	550
Thickness in mil[2]	11.50	15.75	19.70	21.65

1. Theoretical wet thickness for a 120-mm wide line.
2. Mathematical conversion based on the thickness in µm (**25.4 µm = 1 mil**).

6.1.6.3 Longitudinal marking

For both water-based and alkyd paint, the marking crew is responsible for respecting the application rate. It must at all times have a system for monitoring the quantities of materials applied, and take the necessary measurements to validate the application rate of the marking material and glass microbeads applied. However, it is good practice for the supervisor to carry out certain checks during the marking work, using one of the two methods described earlier.

For an epoxy resin-based material, verification of the application rate is not mandatory, since the contractor is normally subject to performance requirements. However, for verification purposes, the supervisor can check the application rate using the wet film measurement method. The validation method based on the quantities in the tanks is more complex, since there are two tanks on the striping truck, one for each of the components of the marking material.

In order to ensure that the application rates are actually applied by its own striping trucks, the Ministère has developed two procedures for verifying the calibration of trucks for paint and glass microbead application rates. These procedures are presented in the accompanying annex.

6.1.6.4 Special marking

The only applicable method for determining the application rate on a special marking symbol is that of measuring the thickness of the wet film. However, since the application is generally made in several successive passes with a pressure gun, the supervisor must take care to ensure that the thickness applied to the plate remains representative of that applied to the road surface.

6.1.7 Inlay work

Inlay work consists in mechanically grooving the roadway (asphalt or concrete) only at the places where the marking lines will be applied. The marking applied in these grooves is better protected from snow removal operations and traffic, thus increasing its durability.

The inlaid marking is carried out on new wearing courses where more than 50000 vehicles per day circulate annually and on new concrete roadways. In all cases, the groove depth is 3 mm to 5 mm. The inlaid marking can also prove to be a solution to recurring problems of durability in a particular location. In that case, the depth of the groove is generally 1 mm to 2 mm.

6.1.7.1 General elements for all the types of roadways

Regardless of the type of roadway, the groove must have a smooth, clean finish before the marking product is applied. The supervisor therefore needs to pay particular attention to these elements since they will directly impact on the durability of the marking lines. Figures 31 to 34 show examples of compliant and non-compliant finishes, for supervisors' reference.

Source: Transports Québec

Figure 31 – Example of compliant smooth-finish groove

Source: Transports Québec

Figure 32 – Example of compliant smooth-finish groove (close-up)

Source: Transports Québec

Figure 33 – Example of an irregular finish groove with ridges (non-compliant)

Source: Transports Québec

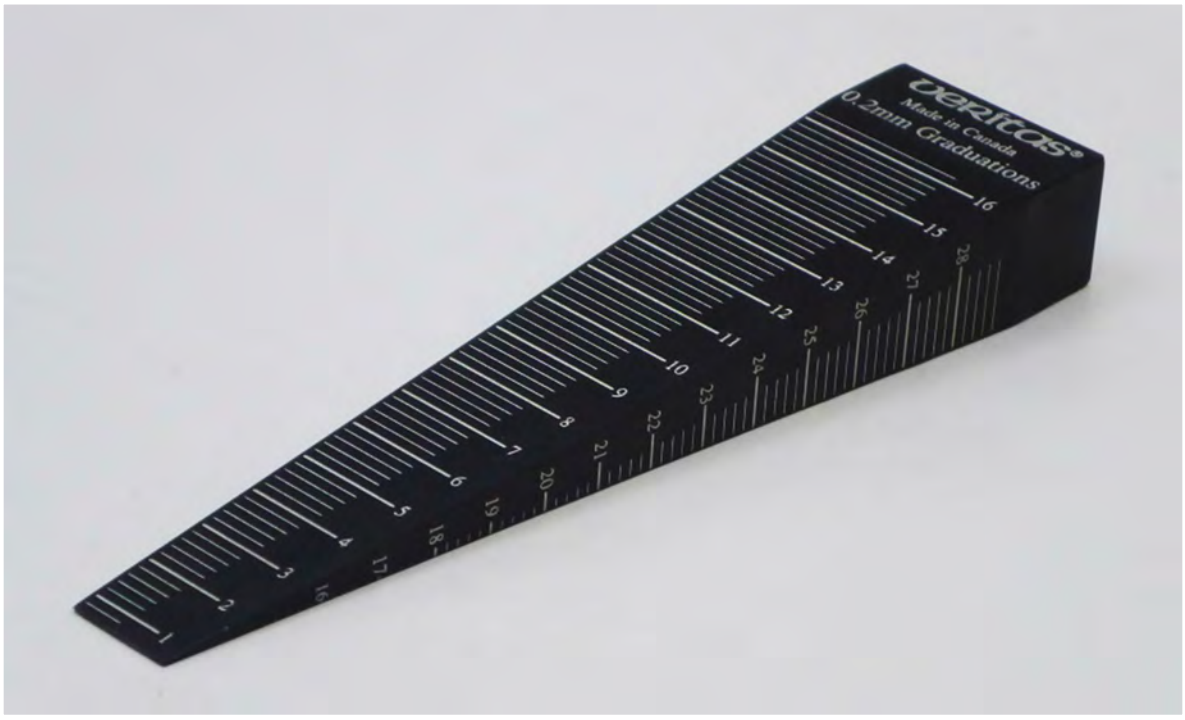
Figure 34 – Example of a rough finish groove (non-compliant)

6.1.7.2 Test deck prior to inlay work

At the start of the work, the contractor must carry out a 50-m test deck to have the grooving method approved by the supervisor. During the field test, the supervisor must document and validate the following elements, among others:

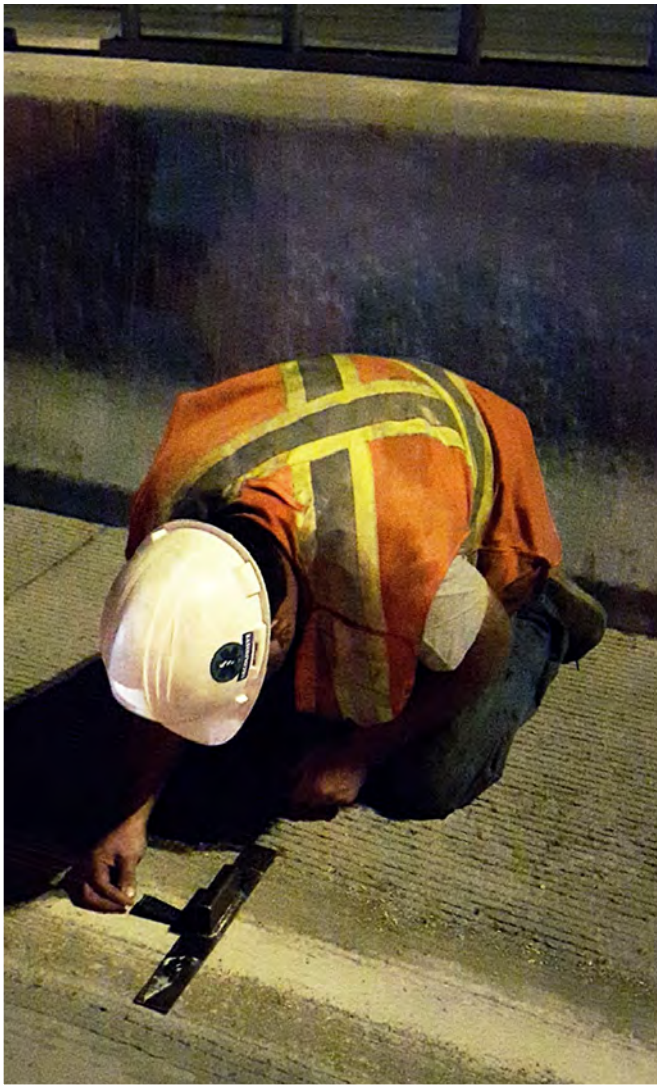
- the dimensions of the groove
  - the width
  - the depth
  - the length (broken line)
- the finish
- the cleanliness.

To determine the depth of the groove, the supervisor must use a conical gauge (Figure 35) and a ruler. The conical gauge is simply placed in the groove and then is slid under a ruler placed across the trench, resting on both sides of it, as shown in Figure 36.



Source: Transports Québec

Figure 35 – Example of a conical gauge



Source : Transports Québec

Figure 36 – Example of measuring with a conical gauge

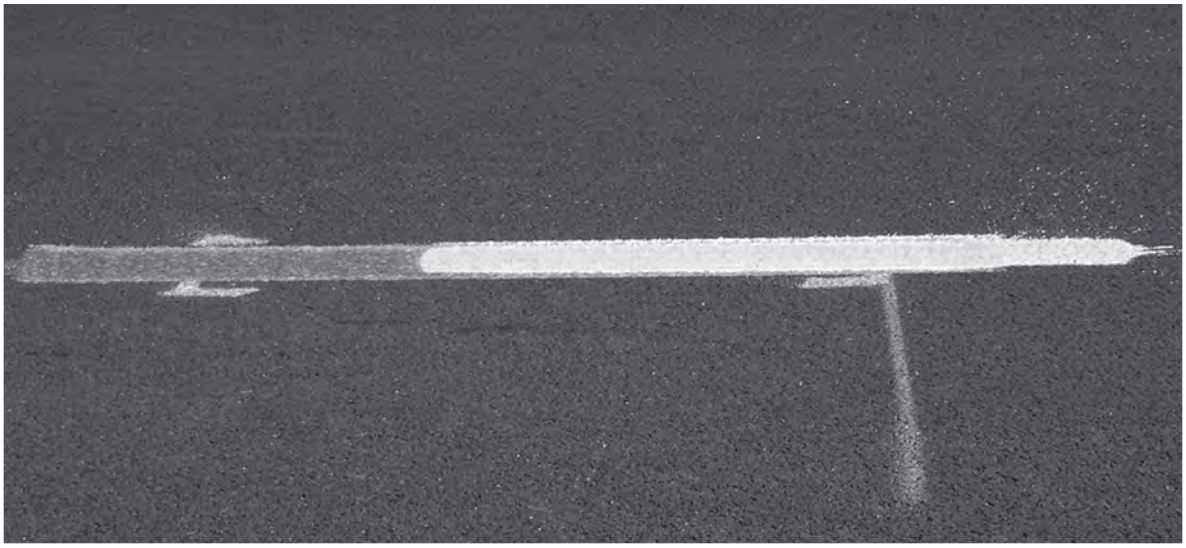
If the grooving technique is found to be non-compliant, the contractor must take corrective measures and carry out another 50-m test deck. The test decks can be made at the location provided for the marking.

6.1.7.3 Carrying out inlay work

During the work, the groove depth must be checked before marking work begins. Measurements should be taken in several places and across the full width of the groove to ensure that the depth requirements are met. To do this, the contractor must take measurements at the intervals stipulated in the documents, record the results of these measurements in writing and transmit them to the supervisor. Throughout the work, the supervisor should randomly validate the dimensions, finish and cleanliness of the groove in order to advise on any need of corrective measures. It is impossible to measure groove depth after the marking work has been done.

At the end of the work, the supervisor must ensure that the groove grindings are eliminated as per the requirements of the contract documents. The marking material is then applied entirely inside the groove.

Figure 37 illustrates two cases of non-compliance: failure to follow the pre-markings (groove offset) and application of the marking material outside the groove.



Source: Transports Québec

Figure 37 – Example of non-compliant alignment

6.1.7.4 Grooving on asphalt pavement

In addition to the general elements described above, other elements need to be monitored during inlay work on asphalt pavement. In fact, to ensure that the new pavement remains unaltered, a minimum period of seven days must be respected between the laying of the asphalt mix and the grooving work.

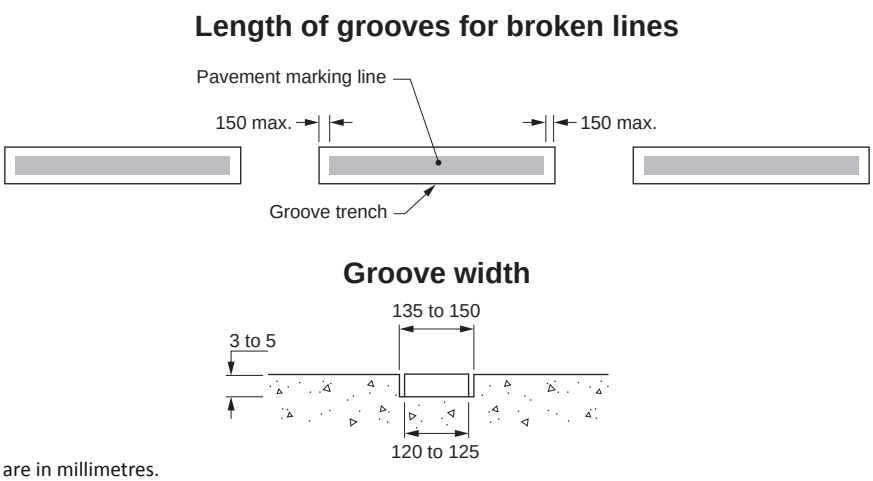
Inlay work must be carried out only in the places where the marking is done, while respecting the marking plans. For example, for a broken line, the groove must also be broken. Figure 38 presents an example of a non-compliant broken line in a solid line groove.

Source: Transports Québec

Figure 38 – Example of broken line in a solid line groove (non-compliant)

The dimensions of the groove (Figure 39) must be the following:

- the groove width is to be from 135 mm to 150 mm
- the groove length for a broken line may exceed the marking by a maximum of 150 mm at each end
- the groove depth is to be from 3 mm to 5 mm across the entire width.



Note:

– Dimensions are in millimetres.

Figure 39 – Dimensions of groove on asphalt pavement

6.1.7.5 Grooving on concrete pavement

In addition to the general elements, other elements need to be monitored during inlay work on concrete pavement. To ensure adequate curing of the concrete, inlay work cannot be carried out until one year after the construction of the concrete pavement, hence the need for adequate temporary marking with an epoxy resin-based material.

Inlay work must be conducted in a single operation while respecting the marking plans. In addition, for technical reasons, inlay work is not to be carried out on a wet surface.

The distance between the edge of the groove and the longitudinal joint must be at least 35 mm in order to avoid spalling. The recommended distance is 50 mm, with a tolerance of 15 mm. When the joint line has a fractured geometry, the contractor must adjust to ensure good visual alignment of the marking line with respect to the road configuration. Unless otherwise specified by the designer, the groove needs to be located on the right side of the longitudinal joint (Figure 40).

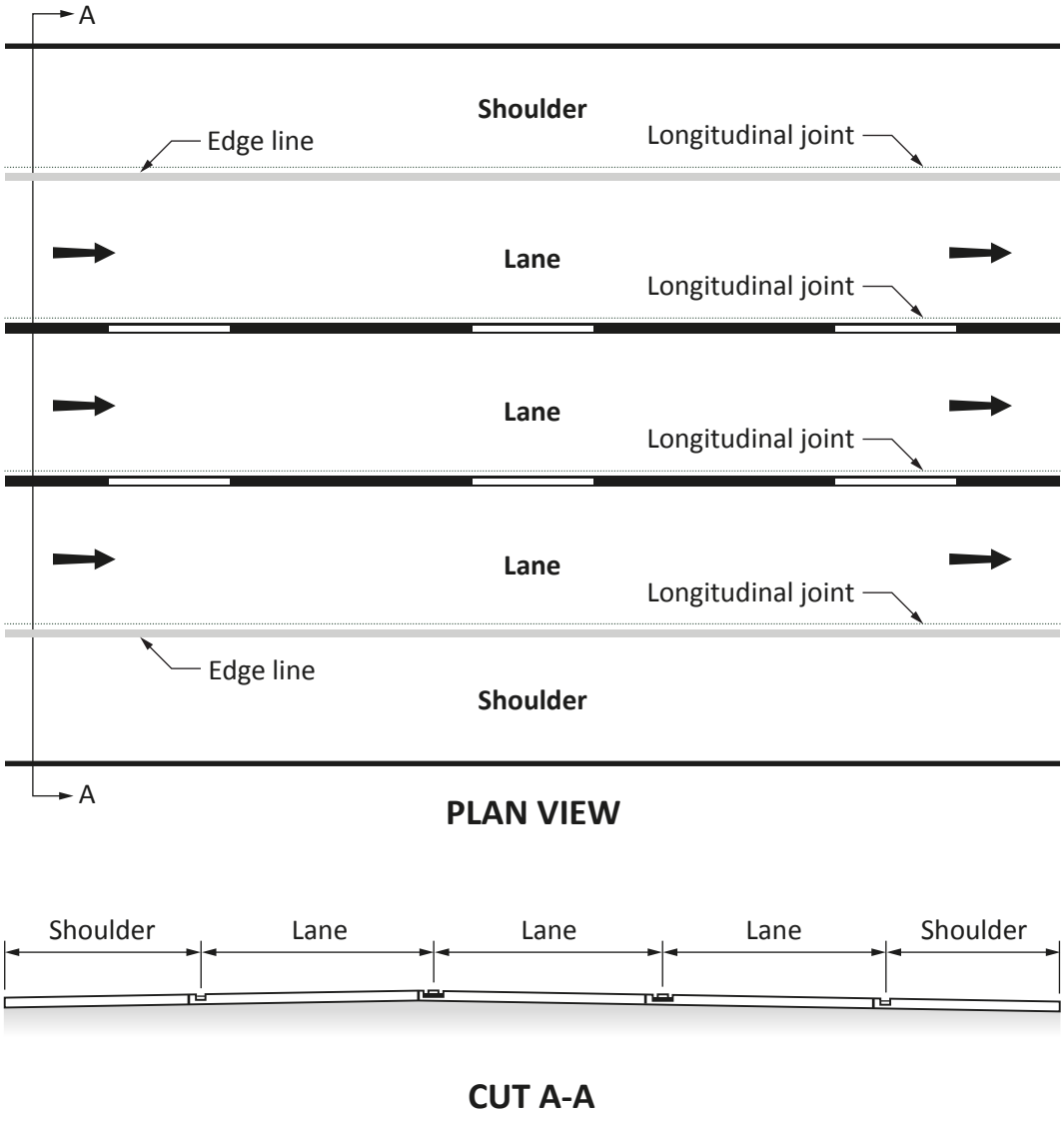


Figure 40 – Example of the location of inlaid markings

The dimensions of the groove (Figure 41) must be the following:

- for edge and solid lines, the groove width is to be from 135 mm to 150 mm
- for lane lines, the groove width must be from 250 mm to 265 mm
- the groove depth is to be from 3 mm to 5 mm across the entire width.

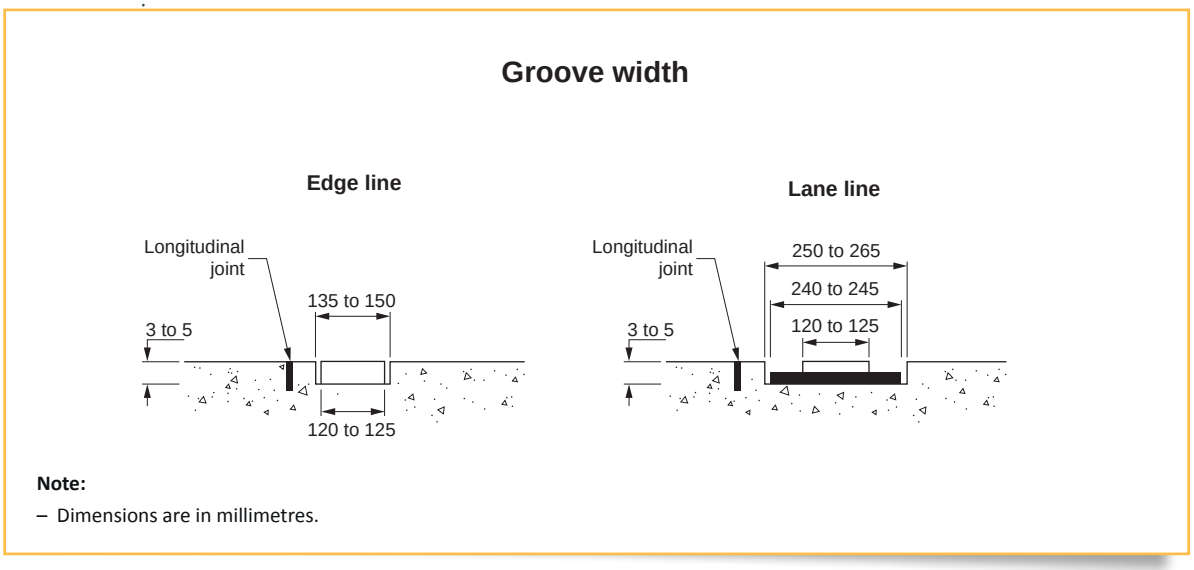
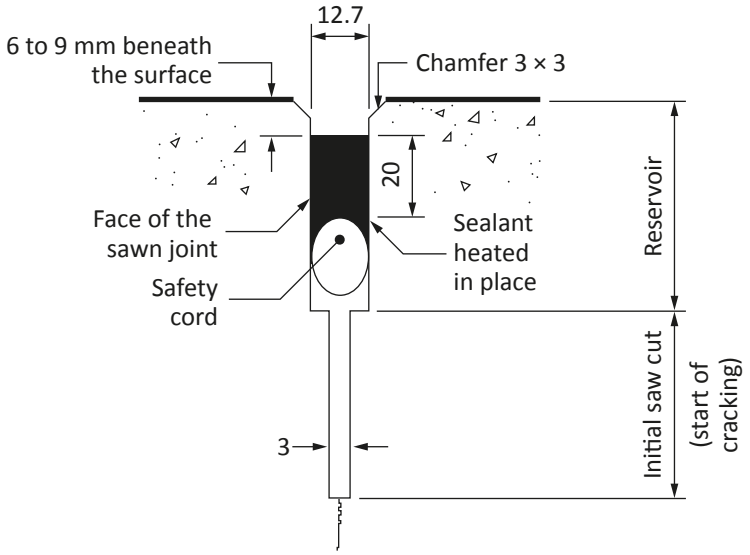


Figure 41 – Dimensions of groove on concrete pavement

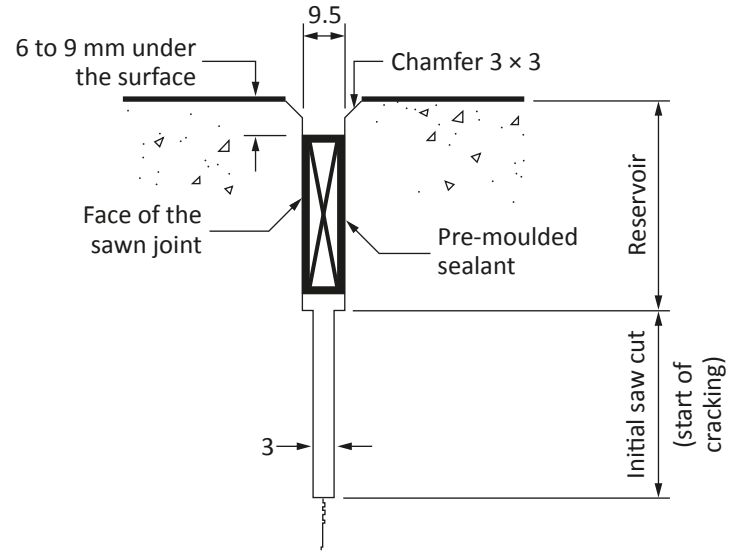
When the work is carried out near the transverse joints of the slab, the supervisor needs to pay particular attention to groove depth so that the sealing material (Figures 42 to 44) used for sealing joints is not torn off by mechanical equipment. Since the sealant is generally between 6 mm and 9 mm beneath the surface, groove depth must not exceed 5 mm.



Note:

– Dimensions are in millimetres.

Figure 42 – Sealant heated in place



Note:

– Dimensions are in millimetres.

Figure 43 – Pre-moulded sealant

Source: Transports Québec

Figure 44 – Tearing off of pre-moulded sealant

6.1.8 Site restoration

The contractor must return the roadway to the same condition as before the start of the work. Equipment cleaning is prohibited on traffic lanes and in the Ministère's right-of-way.

For special marking, when the paint is completely dry, the contractor must blow the excess glass microbeads from the pavement using a powerful jet of air. This step is essential because the glass microbeads make the road very slippery.

6.2 After marking work

In the days after the marking work has been completed, the supervisor needs to pay particular attention to retroreflection (for all the types of materials or paints) and to the phenomenon of darkening of epoxy resin-based materials.

6.2.1 Retroreflection

The retroreflection check must be performed using a portable retroreflectometer or a manual device that meets the requirements of standard ASTM E1710 *Standard Test Method for Measurement of Retroreflective Pavement Marking Materials with CEN-Prescribed Geometry Using a Portable Retroreflectometer*.

The text that follows is taken from the *Guide sur la rétroréflexion du marquage routier – Principes et évaluation*, published by the Ministère, which deals with the basic principles of night visibility of pavement markings as well as assessment methods. It may be used to further the supervisor's knowledge of retroreflection.

6.2.1.1 Basic principles of retroreflection

Retroreflection, which refers to the night visibility of pavement markings, is the most important element concerning the safety of road users who travel in the evening or night (low light). In the absence of an outdoor light source (street lights), the visibility of a marking line is ensured by the light from the headlights of the vehicle which is retroreflected back toward the driver's eyes.

Retroreflection of the light from headlights is largely ensured by the addition of spherical glass microbeads on and in the marking material when the latter is applied. The microbeads are added by pressure jet or by gravity (drop-on) using applicator guns (Figure 45) located directly behind the gun used to apply the marking material.

The glass microbeads act as small mirrors that reflect back light emanating from the headlights toward the driver's eyes, making the marking lines brighter.

Source: Transports Québec

Figure 45 – Example of glass microbead applicator guns

Retroreflection is expressed by the coefficient of retroreflected luminance (R_L). This is measured by the ratio of the marking line's luminance (L) in the direction of observation, divided by the normal luminance (E_L) measured with respect to the roadway.

$$R_L = L/E_L$$

This coefficient of retroreflected luminance (R_L) is expressed in millicandelas per square metre per lux ($mcd \cdot m^{-2} \cdot lux^{-1}$).

As mentioned previously, retroreflection is governed by geometric parameters defined by international standards (CEN EN 1436 and ASTM E1710). These geometric parameters simulate the visibility, by the driver, of the marking at a distance of 30 m when lit by the headlights of an automobile (standard) located at 0.65 m in height and that the observer (eyes) is 1.20 m high, as shown in Figure 46.

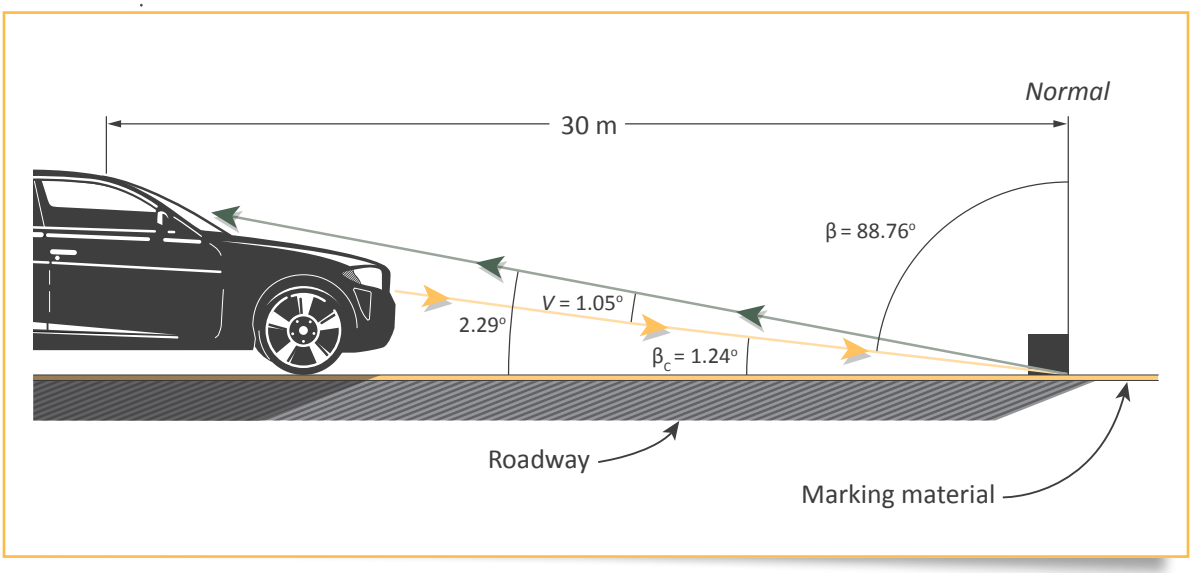


Figure 46 – Geometry of retroreflection

6.2.1.2 Glass microbeads

The glass microbeads used by the Ministère are not certified, but must meet the technical specifications set out in *Tome VII – Matériaux*. In addition to the requirements relating to roundness, imperfections, granularity, refractive index, surface coatings (moisture-proof and adhesion) and the maximum contaminant content, the standard obliges manufacturers to include a minimum of 90% of glass residue from an industrial process (pre-consumption) or recycled glass which would normally have been disposed of as waste (post-consumption).

6.2.1.3 Factors influencing retroreflection

The factors influencing retroreflection are directly linked to either the glass microbeads or external causes.

For the return of light to be optimal, the glass microbeads must have seven intrinsic characteristics:

- They must be perfectly round and free from imperfections (**quality**).
- They must have a refractive index of at least 1.50 (**refractive index**).
- Their embedment depth in the marking material must be between 40% and 60% (**level of embedment**).
- They must be present in sufficient quantity (but not in excess) to ensure optimal return of light (**quantity**).
- They must be adequately dispersed in the marking material to ensure retention of the retroreflection (**dispersion**).
- They must be covered with two coatings prescribed by the Ministère to ensure retention of retroreflection (**coating**).
- The quality of the pigment (colour) also affects retroreflection, because this is what plays the role of the "mirror" in the glass microbeads to retroreflect light (**pigment quality**).

In addition to the factors directly linked to glass microbeads, several external factors can also greatly influence retroreflection. Generally, retroreflection decreases substantially when the glass microbeads are covered with a "foreign body".

- The element that most contributes to reducing retroreflection is the **winter season**. In addition to snow and abrasives (sand and others) that can cover the glass microbeads, the salt applied on the road has a direct effect on night visibility (sometimes even during the day), since, when the roadway dries, the salt in solution is deposited on the surface of the glass microbeads and masks them. Snow removal operations will also break or pluck the glass microbeads, causing loss of retroreflection.
- **Rain** also acts directly on the level of retroreflection. Even a light drizzle decreases retroreflection. When the glass microbeads are covered with a thin layer of water, the light coming from headlights undergoes a diffuse reflection on contact with the water.
- **Other substances** that mask microbeads also influence retroreflection. When the glass microbeads are masked by another substance (debris, dirt, braking marks, oil, etc.), the light emanating from the headlights does not reach the glass microbeads and, as such, cannot be retroreflected toward the driver's eyes.

- The **technique used to project** microbeads also has an impact on retro-reflection, since a light mist of paint might be sprayed onto the surface of the glass microbeads at the time of application and hide them. The technique to project microbeads can also make it so that they roll in contact with the marking material and thus create a slight rib on the microbeads.
- An **irregular road surface** means that shadowing can reduce retroreflection.

6.2.1.4 Visual assessment

To quickly assess the retroreflection of a new marking or an existing marking, a visual assessment can be carried out day or night. The visual assessment is used only to establish an order of magnitude and cannot be used to establish the conformity of the retroreflection.

Conducting a visual assessment during the day makes it possible to quickly assess the quality of the installation of the glass microbeads and to determine any problematic sections (dark). The principle is to simulate night-time retroreflection by replacing the headlights of a vehicle with sunlight (Figure 47).

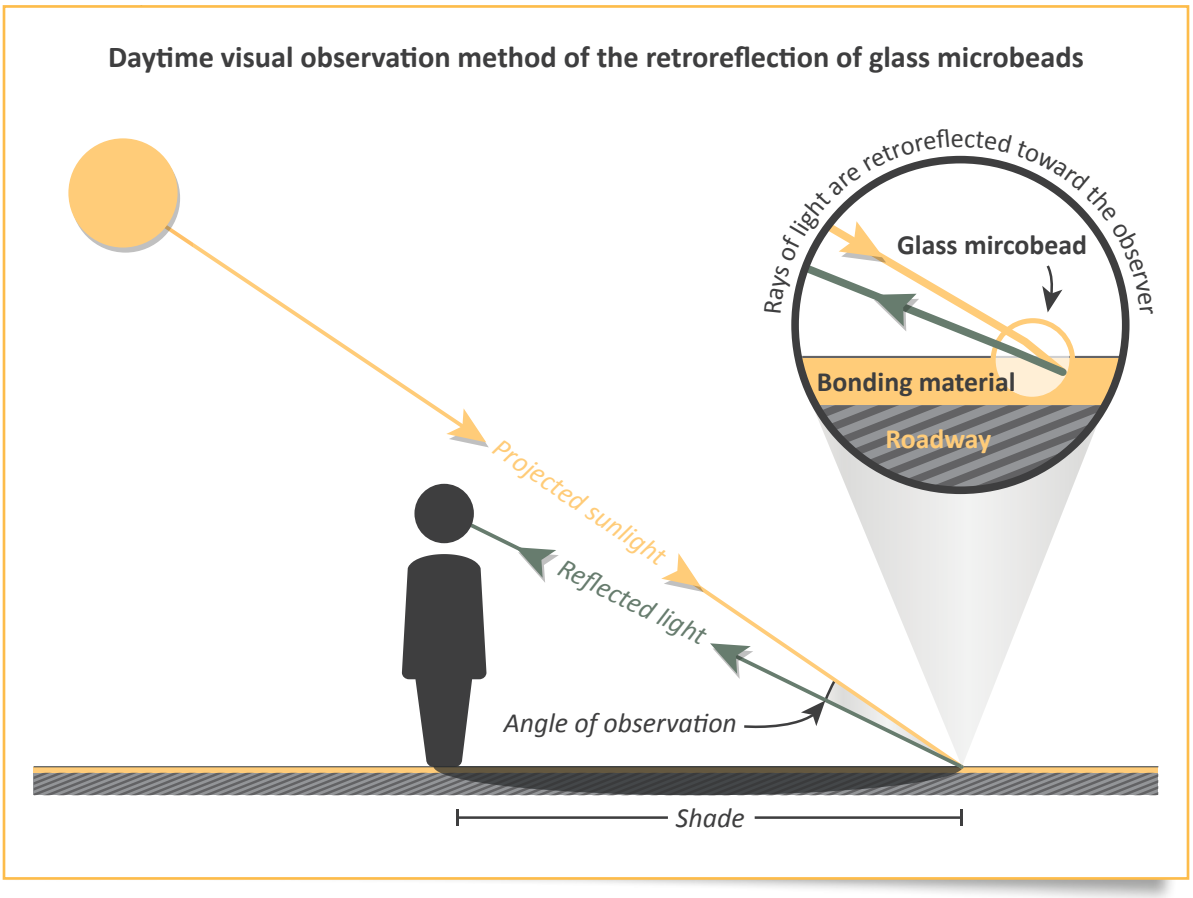


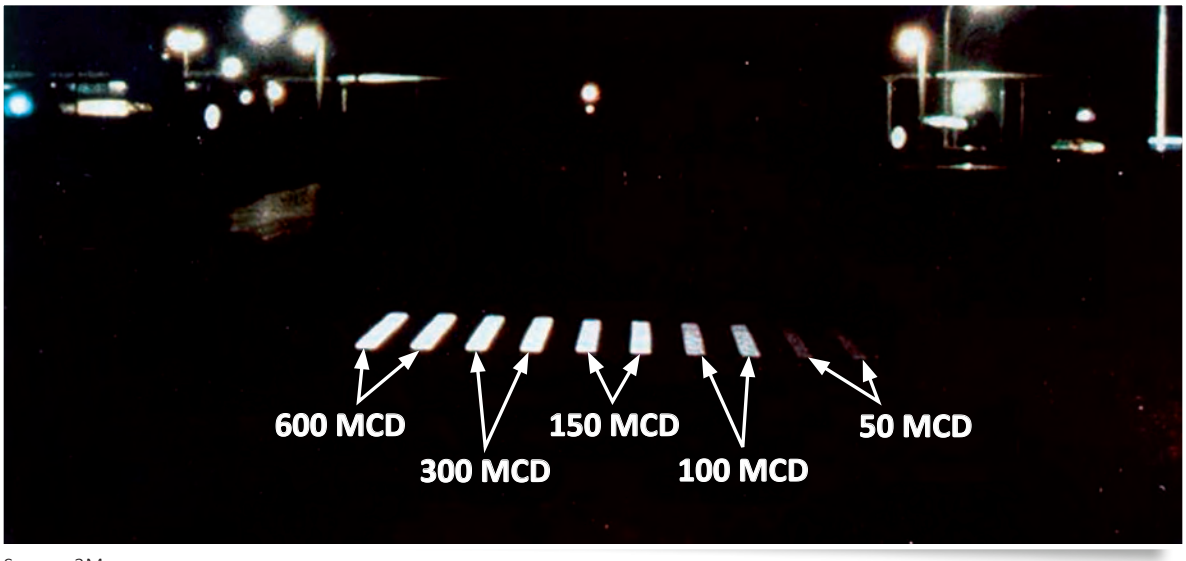
Figure 47 – Visual determination of retroreflection

For a better assessment, the check should be conducted when the sun is lowest, either early in the morning or at the end of the day. If the glass microbeads are correctly embedded (level of embedment) and dispersed, the marking line, directly above the shadow, will then throw off uniform, bright rays (Figure 48).

Source: Transports Québec

Figure 48 – Example of adequate dispersion of glass microbeads

The visual assessment at night-time also makes it possible to quickly identify any problematic sections. However, this method cannot be used to precisely establish the retroreflection measurement. Figure 49 illustrates that beyond 150 $mcd \cdot m^{-2} \cdot lux^{-1}$, it is difficult to distinguish between different levels of retroreflection.



Source: 3M

Figure 49 – Visual determination of retroreflection

When the retroreflection value is below 100 $mcd \cdot m^{-2} \cdot lux^{-1}$, road users have difficulty detecting marking lines. Consequently, that value is the minimum visibility threshold.

6.2.1.5 Assessment with a portable or mobile device

To determine the conformity of the retroreflection, a portable or mobile retroreflectometer must be used (shown, respectively, in figures 50 and 51). The evaluation procedure, using both types of retroreflectometers, is described in the *Guide sur la rétroréflexion du marquage routier – Principes et évaluation*.

Source: Transports Québec

Figure 50 – Portable retroreflectometer

Source: Transports Québec

Figure 51 – Vehicle-mounted mobile retroreflectometer

When assessing newly applied marking, it is recommended to wait approximately two weeks before taking measurements, but no more than six weeks after application. This waiting period is necessary to limit external factors (microbeads that have not adhered or paint film covering them) that can lead to erroneous values. In addition, the first 50 metres of newly applied marking should be avoided because they may not be representative of the entire contract. Indeed, the marking crew often has adjustments to make on the striping truck to achieve the target application rates.

Whether in the case of an assessment of a new marking or of an existing marking, it is absolutely essential that the marking line be dry when measuring retroreflection. This means that measurements must be stopped as soon as the first raindrops appear, since the water on the surface of the marking line has a very negative effect on retroreflection. If the measurements must be taken early in the spring, it is important to wait until there have been at least two periods of heavy rain to thoroughly clean the road surface (de-icing salt, abrasives, etc.).

6.2.2 Quality of work carried out with an epoxy resin-based material

After carrying out the marking work with an epoxy resin-based material, the supervisor must pay particular attention to the phenomenon of darkening of the lines (Figure 52), since this has a direct impact on the marking's durability.

Source: Transports Québec

Figure 52 – Phenomenon of darkening

As mentioned earlier, an epoxy resin-based material is composed of a resin and a catalyst which must be mixed in a ratio of 2:1 (resin/catalyst) to obtain good physico-chemical properties and the anticipated durability with this type of material. To do this, each component must be heated to a different temperature so that it has the same viscosity in the mixing chamber of the applicator gun. Poor mixing of components or too much of either of the two components can affect the hardening of the marking by leaving sticky sections. Surrounding dirt can then adhere to the line, causing dark sections to appear.

It should be noted that this phenomenon usually appears within 24 to 72 hours after applying the material. The speed at which darkening occurs is highly dependent on the road environment and traffic flow, since the darkening is due to ambient dirt and debris that settle on the surface of the line that remains sticky (not hardened). Figure 53 shows a marking line immediately after application, while Figure 54 shows the same marking line a few days later. On the latter, the phenomenon of darkening can be seen.

Source: Transports Québec

Figure 53 – Marking line immediately after the work

Source: Transports Québec

Figure 54 – Same marking line a few days after the work

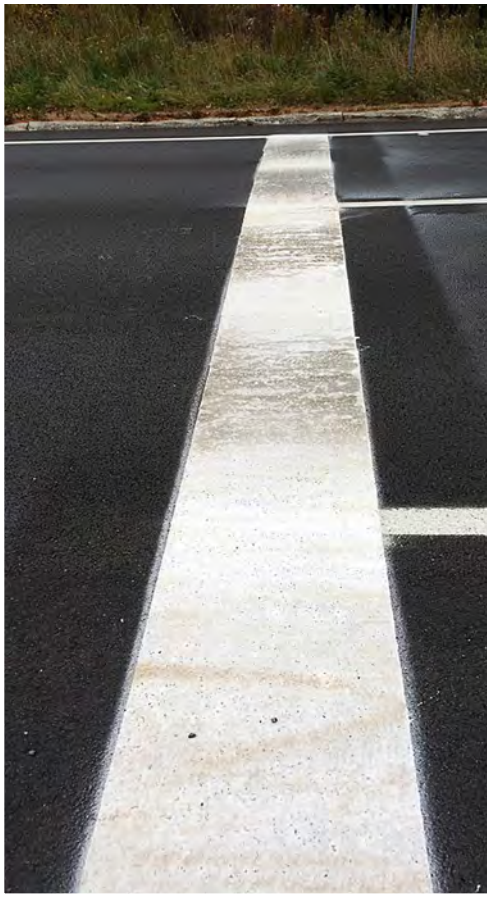
For longitudinal marking, darkening often appears at the start of the contract over a very short distance due to the adjustments made on the truck to reach the target application rate. Consequently, it has very little impact on the entire contract. However, in some cases, the phenomenon is more extensive and requires corrections (Figure 55). A follow-up must therefore be done in the days following the work to document the problem areas and require the contractor to make any necessary corrections.

Source: Transports Québec

Figure 55 – Recurring problem of poor mixing (pump stroke of the striping truck)

The supervisor may sometimes be able to spot a potential problem because sections have a different appearance (colour and opacity) or hardening time. In this case, if the work is still in progress at the time of the observations, the marking crew must establish the cause of the problem and make the necessary corrections.

The phenomenon of darkening is more likely to occur during special marking work. Since the work is static and often interspersed with waiting periods, it is more difficult to obtain a perfect mixture of components. As in the case of longitudinal marking, darkening appears within 24 to 72 hours after the end of the work. Most often, darkening is generalized throughout the entire symbol (Figures 56 and 57).



Source: Transports Québec

Figure 56 – Darkening of a stop line (example 1)

Source: Transports Québec

Figure 57 – Darkening of a stop line (example 2)

In certain cases, the phenomenon can even lead to the disappearance of a portion of the symbol in the days following completion of the work (Figures 58 and 59).

Source: Transports Québec

Figure 58 – Disappearance of a portion of a symbol (example 1)

Source: Transports Québec

Figure 59 – Disappearance of a portion of a symbol (example 2)

6.2.2.1 Consequence of the darkening of marking lines

As previously mentioned, darkening is visual evidence of inadequate hardening of the epoxy resin-based material. This has a direct impact on material durability, since the poor hardening weakens the bond between the road surface and the material. The marking will thus be more easily removed by snow removal equipment and will wear prematurely.

Even if the darkening seems minor, it can be a sign of a significant problem of durability. Figure 60 shows a stop line a few days after it was applied and Figure 61 shows the same stop line a few months later. It should be noted that no action was taken to correct the situation following the appearance of the darkening.

Source: Transports Québec

Figure 60 – Darkening phenomenon (after a few days)

Source: Transports Québec

Figure 61 – Darkening phenomenon (after a few months)

6.2.2.2 Corrections to be made when darkening has been observed

Darkening indicates that the adhesion between the road surface and the material is not optimal and, in the vast majority of cases, this will result in the marking being worn off over the course of the winter. Thus, the only possible solution to correct these defective works is to remove the problematic sections and to reapply an epoxy resin-based material.

In any case, the application of a material, whatever its nature, must not be carried out on problematic sections without first removing the marking. Figure 62 shows the results of applying an epoxy resin-based material to another unhardened material: neither has acceptable durability.

Source: Transports Québec

Figure 62 – Application of an epoxy resin-based material on a product that has not hardened

However, if the darkening is localized over a very short distance at the start of the marking line and if removal of the marking at this location does not have any consequences on road safety, the marking may be accepted with no correction being made.

7 Marking removal

Marking removal work consists in mechanically removing the marking lines, either by abrasion or with high-pressure water blasting. Removal is mainly carried out in the work zone during a change of phase, at the end of the work or when the existing marking lines are no longer applicable (e.g. change of geometry). The existing marking must be removed when repainting and when three layers of medium or long service life materials have been superimposed.

In all cases, the removal method must minimize damage to the road surface.

7.1 Field test deck

Before carrying out the work, it is important to know which method will be used to remove the old markings. Different methods can be used, but the main ones are abrasion and high-pressure water blasting.

At the start of the removal work, a 50-m test deck must be made to validate the methodology used and the results obtained, so as to be able to make the necessary corrections for the work to be done. In the context of the test deck, the following elements must be validated:

- the percentage of the material remaining
- the surface condition
- whether free of debris and dirt.

If the technique is not considered to be compliant, corrective measures are to be taken and another 50-m test deck established. The test decks can be made where the marking removal work is planned.

7.2 General elements regarding removal

Throughout the work, it is important to continue monitoring the elements validated during the test deck and to make any necessary corrections. Particular attention must be paid to the percentage of material remaining, the surface condition and proper cleaning, since these will impact on the durability of the marking lines restriped in the same place as the removal.

Removal of an inlaid marking is allowed only when it must be completely redone or when problems with application of the marking material have been noted. In this case, the groove created by the removal must remain less than 5 mm.

Under no circumstances can black paint be used to hide markings.

If the section being removed cannot be marked before the traffic lanes are reopened, the contractor must pre-mark.

At the end of the work, the supervisor must ensure that debris from removal is eliminated in accordance with contract requirements.

7.3 Authorized removal methods

The two removal methods primarily used by the Ministère are removal by mechanical abrasion and by high-pressure water blast. Each method has its own advantages and disadvantages which are detailed in the following sections.

7.3.1 Removal by mechanical abrasion

The mechanical abrasion method of removal is the most frequently used on the Ministère's network. This technique can be carried out with a removal truck or with a small manual device for smaller jobs.

The removal truck (Figures 63 and 64) offers a very good return on the number of metres removed as a function of time and allows better control of the depth of the marking (groove) left on the road. In addition, most removal trucks have a residue vacuum system that leaves the surface cleaner than does manual removal. However, before carrying out marking, special attention must be paid to the presence of debris on the road surface and, if necessary, carry out additional cleaning.

Source: Transports Québec

Figure 63 – Example of removal truck

Source: Transports Québec

Figure 64 – Example of removal truck (close-up view)

Source: Transports Québec

Figure 65 – Blade assembly for removal by mechanical abrasion

The operating principle of a removal truck involves several serrated blades aligned on a drive shaft, as shown in Figure 65, which rotates at a set speed. The width of the removal can then be established by the number of blades added, while the groove depth is generally set by the removal truck operator.

The type of blade added to the assembly may vary depending on the surface involved and the contractor's method.

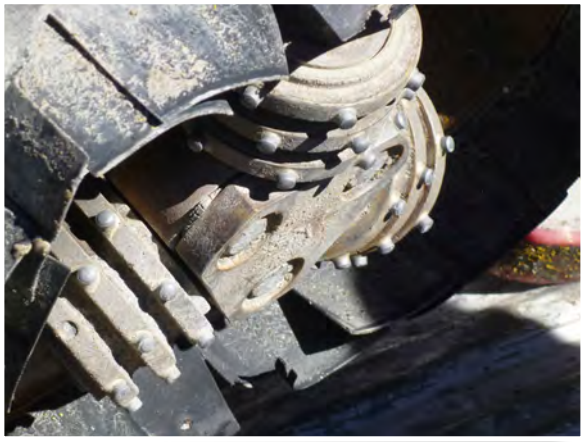
Removal using a hand unit (Figure 66) is not as effective as that obtained using a removal truck and makes it more difficult to control the depth of removal. Operator experience therefore directly impacts on the final result of the removal. In addition, as this type of device does not have a vacuum system to remove debris, an additional step is required to clear the roadway of dirt and debris and ensure that it is clean enough not to compromise the durability of the marking to be carried out. For that reason, vigilance needs to be exercised with respect to surface debris; additional cleaning may be required before the marking work can be authorized.

Source: Transports Québec

Figure 66 – Example of hand removal unit

Though its performance is not as good as that of a removal truck, the ease of operation of the hand removal unit makes it an ideal device for removing special marking.

The operating principle of a hand removal unit differs slightly from that of a removal truck. The hand unit contains fewer blades (Figure 67) and they rotate both on themselves and on another axis (head with blades). The type of blade that is added to the assembly can also vary depending on the surface to be removed and the contractor's method.



Source: Transports Québec

Figure 67 – Blades on the bottom of a hand removal unit

7.3.1.1 Advantages of removal by mechanical abrasion

The main advantages of removal by mechanical abrasion are:

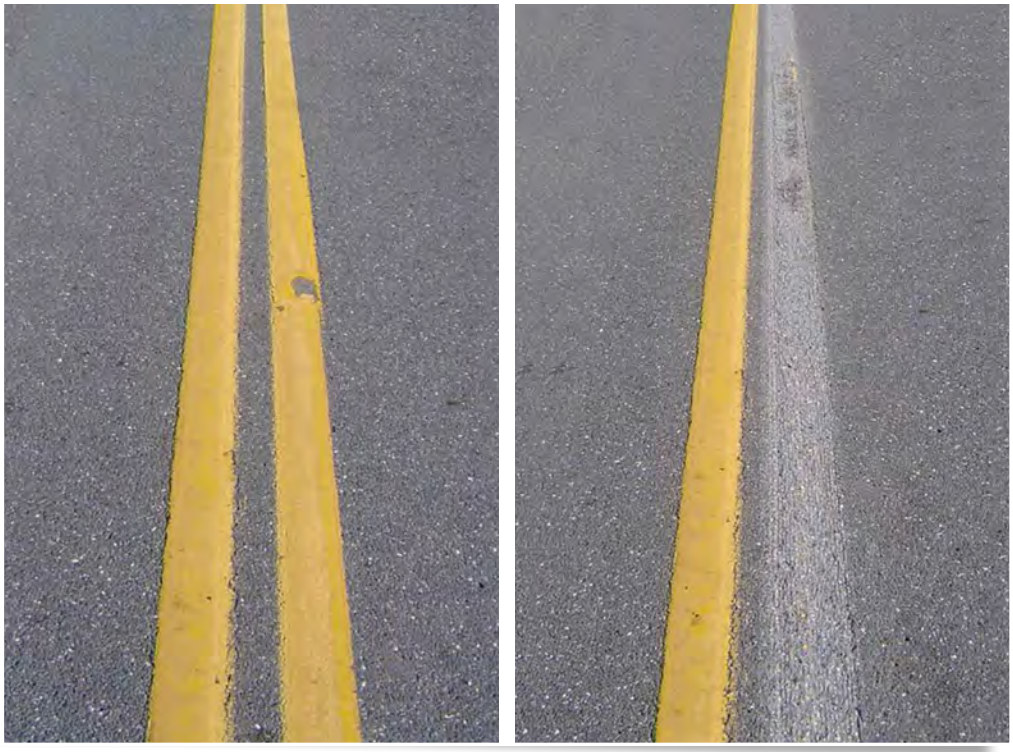
- It is a frequently used and well-mastered method.
- Marking can be carried out at the same place as removal.
- With a clean and dry roadway, no wait time is needed before the marking can be carried out.

7.3.1.2 Disadvantages of removal by mechanical abrasion

The main disadvantages of removal by mechanical abrasion are:

- A mark (groove) on the roadway which may be more or less deep (Figure 68).
- The presence of marking residues if the road surface is very coarse.
- When a hand removal unit is used: the presence of debris on the roadway that depends on the efficiency of the vacuum system and cleaning after its use.

Particularly during precipitation, the scarring left by removal may give the road user the impression that it is a marking line and result in difficulty in determining the right path. It is therefore important to pay particular attention to the removal depth in the work area when the purpose of the removal is to change traffic lane alignment. In the latter case, a small percentage of residual marking is acceptable.



Source: Transports Québec

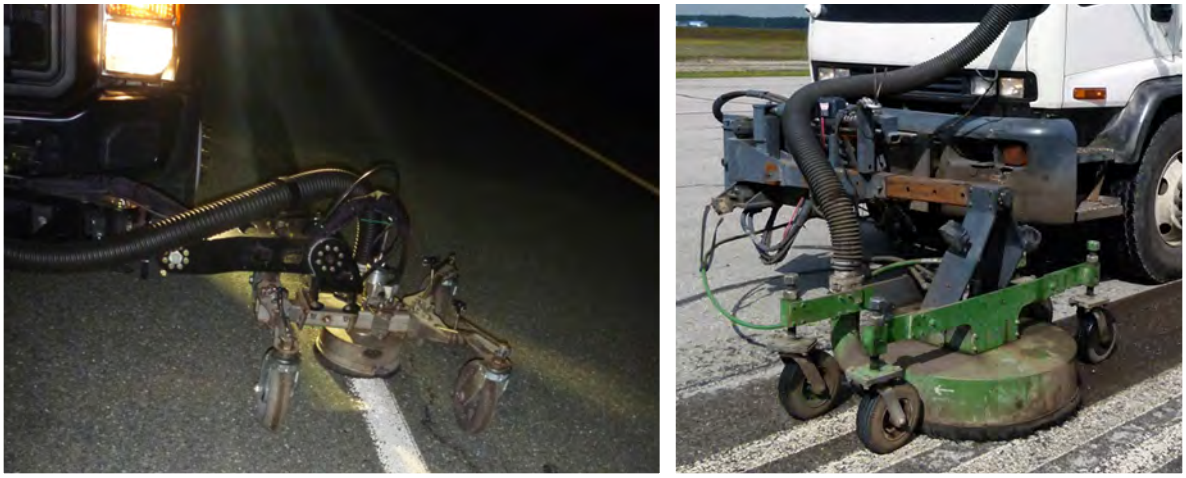
Figure 68 – Example of removal work by mechanical abrasion (before and after)

7.3.2 Removal using high-pressure water blasting

High-pressure water blasting is a removal method that relatively recently began being used at the Ministère's work sites. It is done with a removal truck of variable size and capacity (water tank).

A removal truck equipped with high-pressure water (Figure 69) also offers very good performance with respect to the number of metres removed as a function of time. High-pressure water blasting leaves fewer scars than does removal by abrasion. However, it removes the surface layer of asphalt binders and polishes the surface of the aggregate. The degree of stripping depends on the water pressure and the forward speed of the removal truck. The supervisor must therefore pay particular attention to ensure that removal is made only over the required width. Consequently, this technique is preferred when marking is not carried out in the same place as the removal, in the roadway work zone, for example.

Truck-mounted mobile high-pressure water blasting systems have a water and debris vacuum suction system that leaves the surface cleaner than does the abrasion method. However, special attention must always be given to the presence of dirt and debris on the surface; additional cleaning may be required before authorizing the marking of the lines. As well, in order for the pavement to dry completely, a reasonable period of time—at least 12 hours—must be allowed between removal and marking work.



Source: Transports Québec

Figure 69 – Examples of removal with high-pressure water blasting

The principle of operation of this type of removal truck consists in spraying water under high pressure (up to approximately 40 000 psi), as shown in Figure 70, using a rotating head on which jets are aligned.

Source: Transports Québec

Figure 70 – High-pressure water blasting

On some models of trucks, the width of removal can easily be adjusted by opening or closing jets (Figure 71).

Source: Transports Québec

Figure 71 – Heads with high-pressure water jets

7.3.2.1 Advantages of removal using high-pressure water blasting

The main advantages of removal using high-pressure water blasting are:

- It does not leave marks (grooves) in the road surface.
- It does not leave debris on the road surface.
- There is no residual scarring even if the surface is very coarse.

7.3.2.2 Disadvantages of removal using high-pressure water blasting

The main disadvantages of removal using high-pressure water blasting are:

- The polishing and stripping of aggregates. Figures 72 and 73, respectively, show the road surface condition before and after removal using high-pressure water blasting.
- The resulting wait time for carrying out marking (12 hours).
- Marking cannot immediately be carried out in the same place as the removal. Figure 74 shows a premature degradation of marking that was applied shortly after removal work using high-pressure water blasting.

Source: Transports Québec

Figure 72 – Example of road surface prior to removal

Source: Transports Québec

Figure 73 – Example of road surface after removal

Source: Transports Québec

Figure 74 – Premature degradation of the marking occurring directly on the area removed using high-pressure water blasting (top of the photo)

Source: Transports Québec

Figure 75 – Example of black pavement marking tape

7.3.3 Masking with black pavement marking tape

The masking of lines is authorized only in work areas where the existing marking is inlaid. Masking must be carried out with a black pavement marking tape, as shown in Figure 75. The surface of the black pavement marking tape must be matt so as not to reflect light.

The only drawback with using black pavement marking tapes to mask lines is that if the tapes are left on the road surface for too long and vehicles pass over them, they can be difficult to remove. To prevent this situation, the black pavement marking tapes need to be changed more or less regularly according to the manufacturer's instructions.

Plans must also be made to replace the black pavement marking tapes that are torn off by passing traffic, since unmasked lines may be confusing for the road user.

Figures 76 and 77, respectively, show a good example of the use of black pavement marking tapes and an example of them having been torn off and requiring replacement.

Source: Transports Québec

Figure 76 – Proper use of black pavement marking tapes

Source: Transports Québec

Figure 77 – Tearing off of black pavement marking tapes

7.4 Unauthorized removal methods

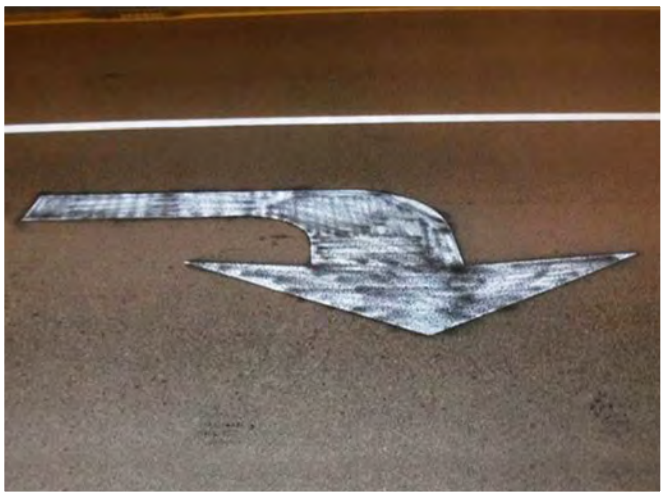
Use of the removal methods described below is, in all cases, prohibited on the Ministère's network.

7.4.1 Masking with black paint

As mentioned earlier, the masking of lines with black paint is prohibited because the marking paint underneath almost always remains visible at night (Figures 78 and 79). More precisely, as the black paint wears off, the glass microbeads become exposed on the road surface, resulting in retroreflection. Depending on the characteristics of the black paint used, this phenomenon can occur very quickly. Given that it can compromise road safety, this method is strictly prohibited.

Source: Transports Québec

Figure 78 – Example of masking with black paint, daytime (non-compliant)



Source: Transports Québec

Figure 79 – Example of masking with black paint, night-time (non-compliant)

7.4.2 Removal using a grinder

No matter which removal method is chosen, it should have the least possible negative impact on the road surface. For this reason, the supervisor must ban the use of unrecognized alternative methods, even for small areas (Figures 80 and 81).

Source: Transports Québec

Figure 80 – Example of non-compliant removal using a grinder

Source: Transports Québec

Figure 81 – Example of non-compliant removal using a grinder (close-up)

7.4.3 Chemical-based removal

The Ministère has conducted a few tests with chemicals (Figure 82) for research purposes, which have not produced very good results. There is also the aspect of potential damage to the roadway. Use of this method is therefore prohibited on the Ministère's network.

Source: Transports Québec

Figure 82 – Example of removal with a chemical stripper (non-compliant)

7.5 Removal on asphalt pavement containing chrysotile asbestos fibres

When removal work is planned on asphalt pavement containing chrysotile asbestos fibres, the Ministère is responsible for informing the contractor who will be carrying out the work. Consequently, very strict rules must be observed to ensure worker safety and the proper management of debris. Work planning thus needs to include putting in place the means necessary to ensure that the work is executed in accordance with the various regulations and laws in force.

At any time, should one of the regulatory requirements not be met, the removal work must be suspended until the necessary measures have been put in place to resolve the problematic situation.

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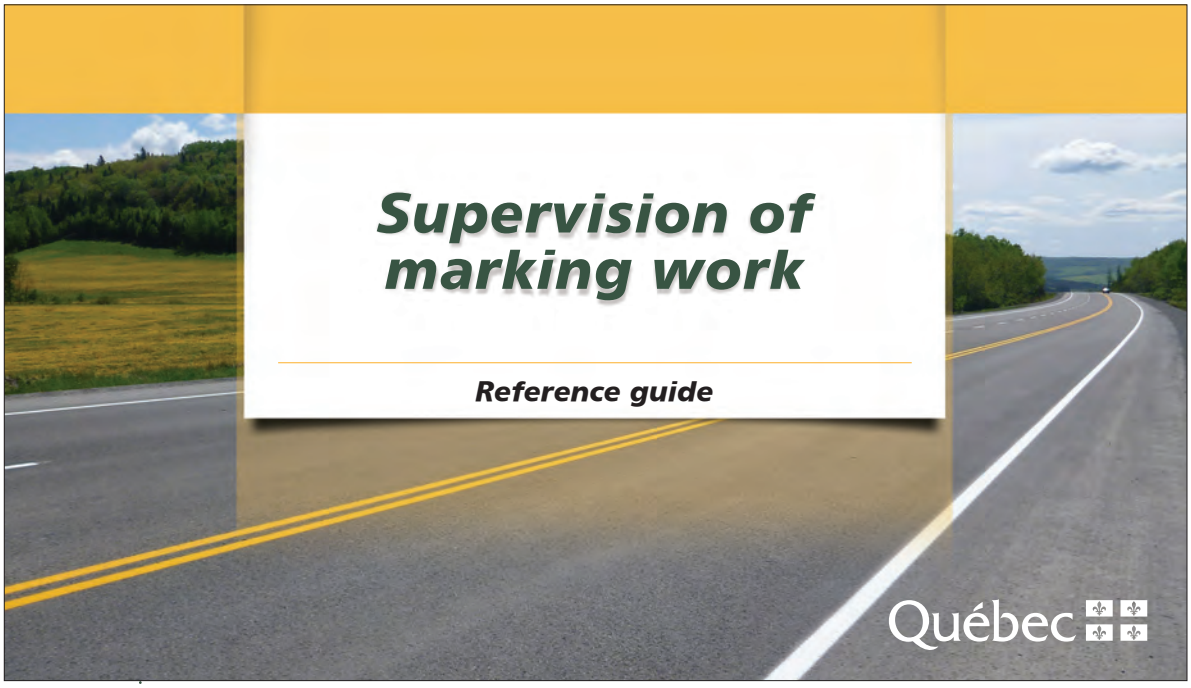
Annex A
Reference guide



This publication has been prepared by the Direction de l'encadrement et de l'expertise en exploitation and the Direction des matériaux d'infrastructures and edited by the Direction des normes et des documents d'ingénierie of the Ministère des Transports.

November 2019

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Pre-marking on a new surface (with no groove)

Responsible unit: Service des projets	
Element to verify	**Requirement**
Marking plan	Respect the marking plan
Pre-marking discs *(apply at same time as surface mix)*	Spacing • 10 m in straight line • 5 m in curves Accuracy required • 100 mm longitudinally • 10 mm transversally
Temporary overlay marker	Spacing • 20 m in straight line • 10 m in the curves
Pre-marking symbols	For each type of line: • use the appropriate symbol (see Figure 1, page 13) • specify the type of broken line, where applicable (see Figure 1, page 13) • specify the type of material (water or epoxy).

Note: Pre-marking discs and temporary overlay marker must be installed alternately in the alignment of future marking lines. The temporary overlay markers are not to be removed before marking.

Pre-marking 3

Pre-marking 4

Temporary marking prior to inlay work a new surface

Unit responsible: Service des projets	
Element to verify	**Requirement**
Marking plan	Respect the marking plan Temporary marking must be carried out at the same spot as the inlaid marking.
Marking material used for temporary marking *(prior to inlay work)*	Asphalt pavement • Certified water-based paint Concrete pavement • Certified epoxy resin-based product
Dimension of temporary marking *(prior to inlay work)*	Asphalt pavement • See Table 1, page 17 Concrete pavement • See Table 2, page 17

Pre-marking on existing road surface

Degree of traffic marking line presence ≤ 15%

Unit responsible: Centre de services	
Element to verify	**Requirement**
Longitudinal and special marking	Spray-painted marks on the roadway, indicating: • the position of marking lines (longitudinal marking) • the position of marking on the roadway (special marking)
Pre-marking symbols	For each type of line: • use the appropriate symbol (see Figure 1, page 13) • specify the type of broken line, where applicable (see Figure 1, page 13) • specify the type of material (water or epoxy)
Pre-marking plates	Respect the pre-marking plates (see Figure 2, page 14)

Pre-marking 5

Longitudinal marking 6

Longitudinal marking with water-based paint

Re-marking the existing marking

Element to verify	Requirement
During application	Respect of road and meteorological conditions • Roadway clean and dry • No risk of rain before the paint dries • Relative humidity ≤ 80% • Temperature ≥ 10°C • Surface T° ≥ (dew point T° + 2°C)
	Respect of pre-marking, where applicable
	Alignment of the marking with the existing marking (re-marking of the marking)
	Dimension of the marking lines (see Table 3, page 18)
	Quality of work, including the uniformity of the wet film and definition of lines
	Application rate used (measurements taken in the tanks) – 48 L/km
	Sampling (if necessary)
Two weeks after application	Retroreflection of marking • White ≥ 250 mcd·m^{-2}·lux^{-1} • Yellow ≥ 175 mcd·m^{-2}·lux^{-1}

Longitudinal marking with an epoxy resin-based material

Element to verify	Requirement
During application	Respect of road and meteorological conditions • Roadway clean and dry • No risk of rain before the material dries • Temperature ≥ 10°C • Surface T° ≥ (dew point T° + 2°C)
	Respect of pre-marking
	Alignment of marking
	Dimension of marking lines (see Table 3, page 18)
	Quality of work, including uniformity of the wet film and definition of lines
Two weeks after application	Retroreflection of marking • White ≥ 250 mcd·m^{-2}·lux^{-1} • Yellow ≥ 175 mcd·m^{-2}·lux^{-1}
After one year and two years	Measure the marking's degree of wear and validate if it meets the requirements set out in the specifications

Longitudinal marking 7

Longitudinal marking 8

Longitudinal marking with an inlaid epoxy resin-based material

Element to verify		Requirement
During application	**Inlay work**	Dimension of the groove • 3 mm to 5 mm deep across the width of the groove • Width and length respecting specification requirements (see Figures 3 + 4, pages 15 + 16)
		Inlay carried out only where there will be marking
	Marking	Respect of road and meteorological conditions • Roadway clean and dry • No risk of rain before the material dries • Temperature ≥ 10°C • Surface T° ≥ (dew point T° + 2°C)
		Dimension of marking lines (see Table 3, page 18)
		Quality of work, including the uniformity of wet film and definition of lines
		Inlaid marking
Two weeks after application		Retroreflection of marking • White ≥ 250 mcd·m^{-2}·lux^{-1} • Yellow ≥ 175 mcd·m^{-2}·lux^{-1}
After one year, two years, three years and four years		Measure the marking lines' degree of wear and validate whether it meets the requirements set out in the specifications

Longitudinal marking with alkyd paint

Between October 15 and May 1

Element to check	Requirement
During application	Respect of road and meteorological conditions • Roadway clean and dry • No risk of rain before the paint dries • Temperature ≥ 0°C • Surface T° ≥ (dew point T° + 2°C)
	Respect of pre-marking, where applicable
	Alignment of marking with respect to existing marking, where applicable
	Dimension of marking lines (see Table 3, page 18)
	Quality of work, including uniformity of wet film and definition of lines
	Application rate used (measurements taken in the tanks) – 48 L/km
	Sampling (if necessary)
Two weeks after application	Retroreflection of marking • White ≥ 250 mcd·m^{-2}·lux^{-1} • Yellow ≥ 175 mcd·m^{-2}·lux^{-1}

Longitudinal marking **9**

Special marking **10**

Special marking with water-based paint

Re-marking of existing marking

Element to check	Requirement
During application	Respect of road and meteorological conditions • Roadway clean and dry • No risk of rain before the paint dries • Relative humidity ≤ 80% • Temperature ≥ 10°C • Surface T° ≥ (dew point T° + 2°C)
	Alignment of the marking with respect to existing marking (re-marking of marking)
	Dimension of marks • References: contract documents and technical specifications available at www.rsr.transports.gouv.qc.ca
	Quality of work, including uniformity of the wet film and definition of lines
	Application rate used – 400 microns
	Sampling (if necessary)
Two weeks after application	Retroreflection of marking • White ≥ 250 mcd·m^{-2}·lux^{-1} • Yellow ≥ 175 mcd·m^{-2}·lux^{-1}
	Uniformity of glass microbead dispersion

Note: A control site at the start of work is recommended to validate the quality of the work carried out.

Special marking with an epoxy resin-based material

Element to check	Requirement
During application	Respect of road and meteorological conditions • Roadway clean and dry • No risk of rain before the material dries • Temperature ≥ 10°C • Surface T° ≥ (dew point T° + 2°C)
	Dimension of markings • References: contract documents and technical specifications available at www.rsr.transports.gouv.qc.ca
	Location of markings
	Quality of work, including uniformity of wet film and definition of lines
Two weeks after application	Retroreflection of marking • White ≥ 250 mcd·m^{-2}·lux^{-1} • Yellow ≥ 175 mcd·m^{-2}·lux^{-1}
	Uniformity of glass microbead dispersion
After one year and two years	Measure the marking lines' degree of wear and validate whether it meets the requirements set out in the specifications

Special marking 11

Special marking 12

Special marking with alkyd paint

Element to verify	Requirement
During application	Respect of road and meteorological conditions • Roadway clean and dry • No risk of rain before the paint dries • Temperature ≥ 0°C • Surface T° ≥ (dew point T° + 2°C)
	Dimension of markings • References: contract documents and technical specifications available at www.rsr.transports.gouv.qc.ca
	Positioning of markings
	Quality of work
	Application rate used – 400 microns
	Sampling (if necessary)
Two weeks after application	Retroreflection of marking • White ≥ 250 mcd·m^{-2}·lux^{-1} • Yellow ≥ 175 mcd·m^{-2}·lux^{-1}
	Uniformity of glass microbead dispersion

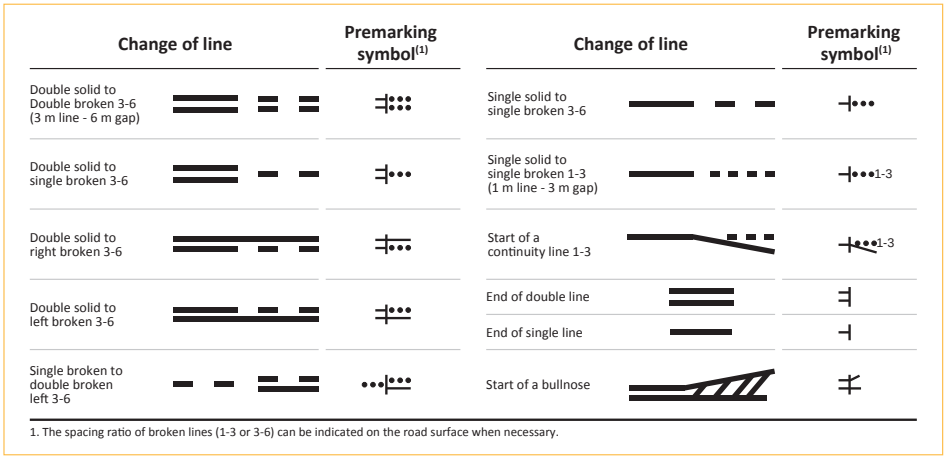


Figure 1 – Pre-marking symbols

13

14

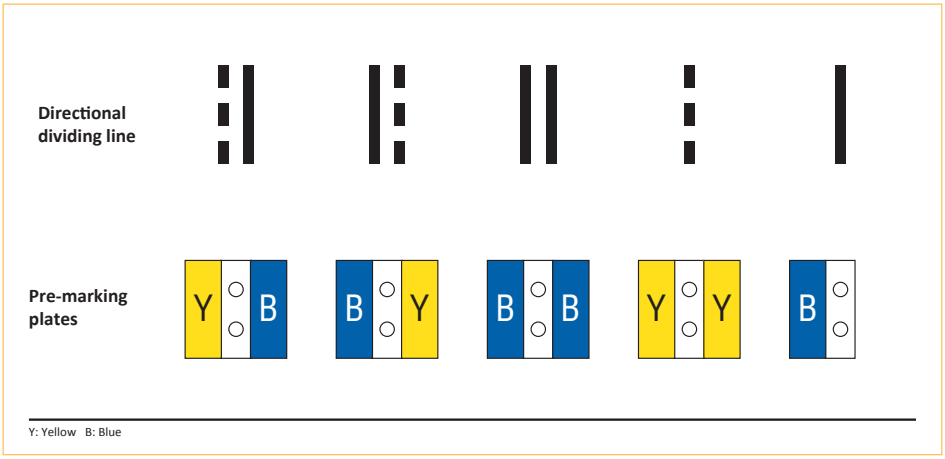
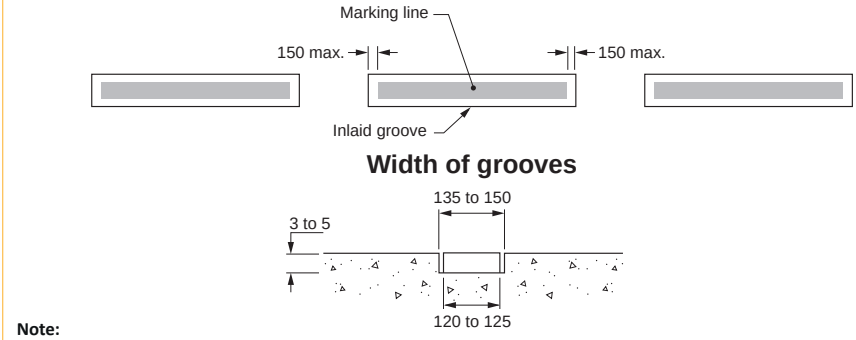


Figure 2 – Pre-marking plates



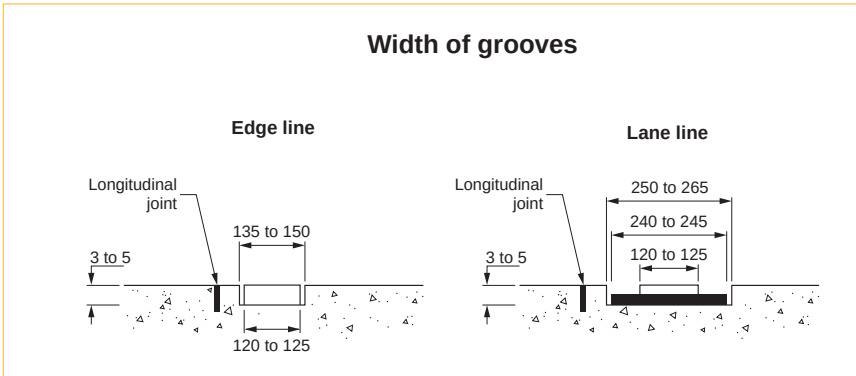
Note:

– Dimensions are in millimetres.

Figure 3 – Inlaid marking on asphalt roadway

15

16



Note:

– Dimensions are in millimetres.

Figure 4 – Inlaid marking on concrete roadway

Table 1 – Temporary marking before inlay on asphalt roadway

Type of line	Width	Length	Spacing
Solid line	90 to 100 mm	—	—
Lane line		1.5 m	7.5 m
Continuity line		0.75 m	3.25 m

Table 2 – Temporary marking before inlay on concrete roadway

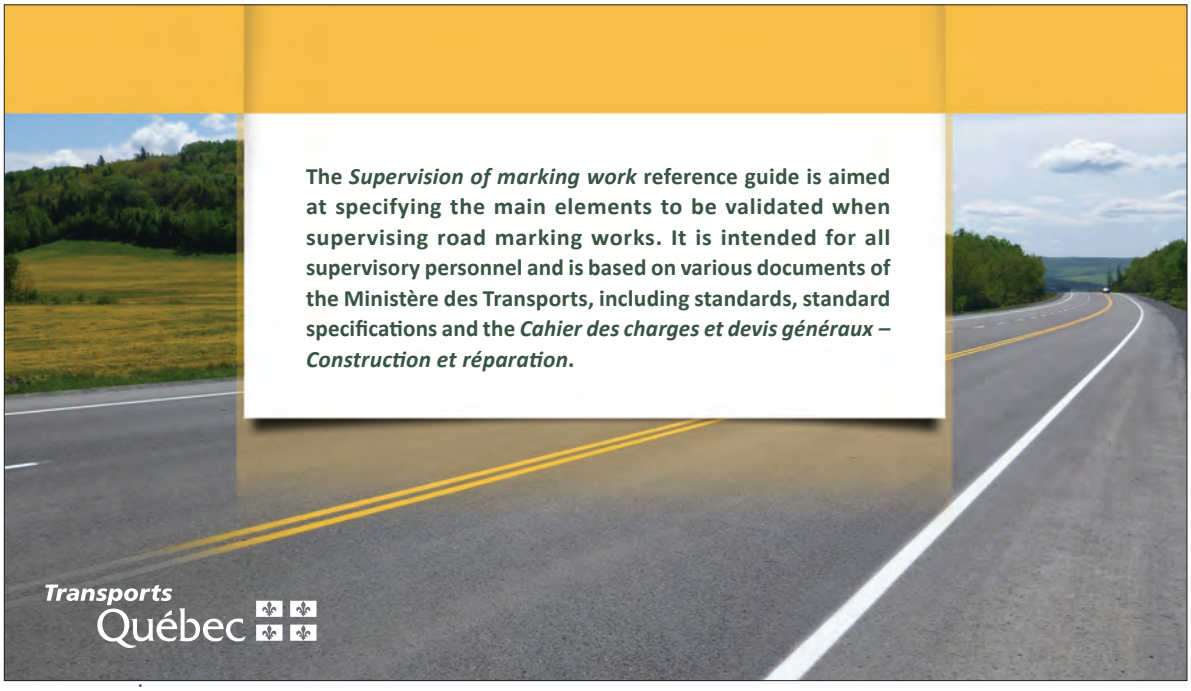
Type of line	Width	Length	Spacing
Solid line	120 to 125 mm	—	—
Lane line		3 m	6 m
Continuity line		1 m	3 m

17

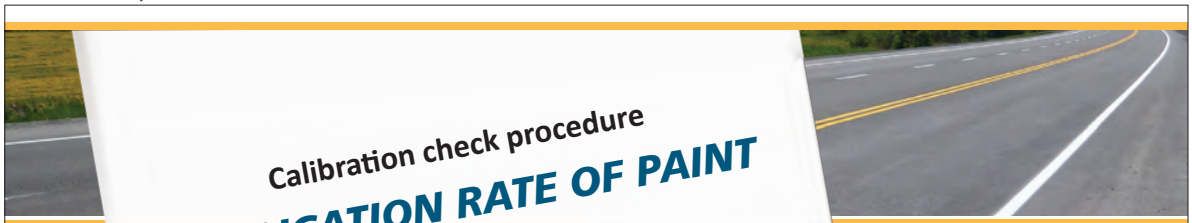
18

Table 3 – Dimension of marking lines

Type of line	Width	Length	Spacing
Solid line	120 to 125 mm	—	—
Lane line		3 m	6 m
Continuity line		1 m	3 m
Guide line		0.5 m	1 m


The *Supervision of marking work* reference guide is aimed at specifying the main elements to be validated when supervising road marking works. It is intended for all supervisory personnel and is based on various documents of the Ministère des Transports, including standards, standard specifications and the *Cahier des charges et devis généraux – Construction et réparation*.
Transports
Québec

Annex B
Calibration check procedure



Calibration check procedure

APPLICATION RATE OF PAINT

Material needed

- ☐ Scale with a precision of ± 0.1 g
- ☐ 9 smooth and rigid plates per application rate evaluated (e.g. aluminum or Plexiglas plates, 30 cm × 30 cm)
- ☐ Calibration check Excel file
- ☐ Spray paint

Frequency of calibration

- ☐ At the start of the season
- ☐ Following the calibration of the truck by the Centre de gestion de l'équipement roulant (CGER)
- ☐ Once per month
- ☐ When a problem is detected

Checking the application rate of paint is a simple procedure aimed at determining the rate of paint applied as well as discrepancies between the application rate entered in the striping trucks' control systems and the rate actually applied to the road surface.

Calibration check procedure

Important elements to be considered

– The calibration check must be carried out for each applicator gun:
  - For all paint application rates
  - For each marking speed

– The crew must plan for adequate signalling to ensure work safety. **It is strongly recommended to carry out the check procedure on a low traffic-volume road.**

Before

Numbering and weighing the plates

1. Number the plates that will be used for the calibration check. This numbering will be used to enter the information in the calibration check Excel file. **To ensure representative results, three different plates are to be used for each gun applicator per test.**
2. Weigh each plate separately, with no paint applied, being sure to reset the scale to zero (tare) before each weighing.
3. Mark the weight (in grams) on the back of each plate.

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During

Application of the paint on to the plates

1. Place the 3 plates at least 1 km beyond the start of the marking work. They need to be spaced around 50 cm apart.

2. Spray paint a line on the road surface a few metres before the first plate to indicate where to stop applying microbeads.
   - Stripe at least 1 km of each colour and, in the same operation, stripe the section with the plates.
   - It is important to maintain a constant striping speed throughout the operation.
   - In the case of a double line, place two plates side by side so as to have a single line on each.

3. Note, for each colour, the application rate indicated in the lane dividing line system at the time the plates were striped.

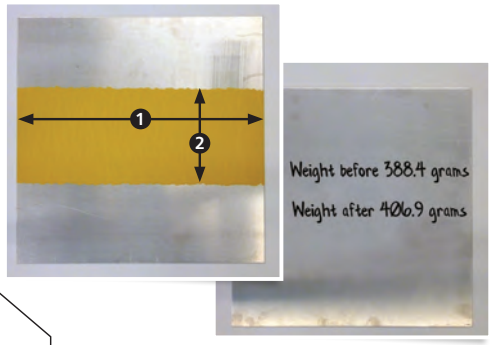
4. Let the plates dry, flat, for at least 24 hours before carrying out the following steps.

Two plates must be used for directional dividing lines.

After

Weighing of plates and determination of application rate

After the minimum drying period of 24 hours, the application rate is determined by taking the necessary measurements and entering them in the calibration check Excel file (dimension of marking lines and weight of plates with paint).



2 Width (cm) of marking on the plate
Three width measurements must be taken. The average of the three is entered in the Excel file.

1 Length (cm) of the plate

	C	D	E	G	H	I	J	K	L
23	Plate number	Plate weight without microbeads		Marking line dimensions			Application rate	Application rate in the control system	Difference
24									
25		without paint (g)	with paint (g)	length (cm)	width (cm)				
26							(L/km)	(L/km)	(%)
27	1								
28	2								
29	3								

Weight of plates before application of the paint

Weight of plates with the dried paint

Application rate entered in the control system during application

Note: The application rate used and the difference in weight are calculated based on the data entered in the Excel file.

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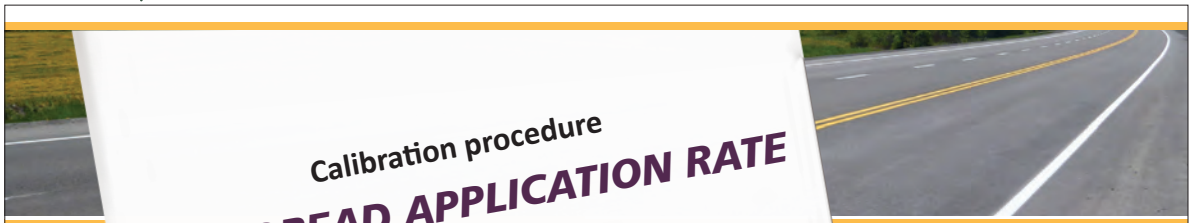
Annex C
Calibration procedure



Calibration procedure

MICROBEAD APPLICATION RATE

Materials needed

- Chronometer
- 1 graduated 4-L container
- Excel calibration check file

Frequency of calibration

- At the start of the season
- Once per week
- When a problem is detected

Glass microbead calibration is a simple procedure aimed at ensuring a compliant application rate. This rate is not checked during calibration at the start of the year by the Centre de gestion de l'équipement roulant (CGER).

Microbead flow time

The first step consists in determining the target flow time for microbeads to fill the 2-L container. To do this, use the table below or the Excel calibration check file.

Flow time for a target of 2 L (in seconds)			
Striping truck speed (km/h)	Microbead application rate (kg/L)		
	0.3	0.6	0.8
16	49	25	18
18	44	22	16
20	39	20	15
22	36	18	13
24	33	16	12
26	30	15	11
28	28	14	11
30	26	13	10

	A	B	C	D	E	F	G
1	MICROBEAD APPLICATION RATE CHECK						
2							
3	Application rate – glass microbeads (kg/L)					0,6	
4	Application rate – paint (L/km)					48	
5	Striping truck speed (km/h)					20	
6							
14	Flow time for the target (2 L)					20	

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Calibration procedure

Calibration of the microbead application rate requires at least two people.

The verification must be conducted for each microbead gun.

Steps to follow for each gun

1. Ensure that the pressure in the microbead tank indicated on the dial is stable.
2. Place the collection container under the microbead gun.
3. Open and close the microbead gun twice to ensure that the supply hose is completely filled.
4. Empty the collection container and place it under the microbead gun again.
5. Open the microbead gun and, at the same time, start the timer.
6. **Stop the microbead gun when the timer sounds.**
7. Shake the collection container to level the microbeads.
8. If the quantity of 2 L has not been reached, increase the microbead flow, then start the test over.
9. If the quantity of 2 L has been exceeded, reduce the microbead flow, then start the test over. A difference of ± 200 ml is acceptable.

The microbead application rate must be adjusted when a change is made to the striping speed or paint application rate.

If the required application rate cannot be obtained, contact the CGER.

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The *Pavement Marking Technical Manual* is a tool aimed at consolidating general knowledge and harmonizing practices related to pavement marking operations. It is based on various works, standards and guides written by the Ministère des Transports on this subject. The *Pavement Marking Technical Manual* addresses, in particular, the legal framework, the departmental guidelines in effect, work planning, the materials used and the supervision of marking operations. Its primary target audience consists of technicians, engineers and various professionals in the field of pavement marking.

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