

**PAVEMENT AND MATERIALS TECHNOLOGY REVIEW FOR
MUNICIPALITIES – INCLUDING A CASE STUDY**

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ABSTRACT

Advancements and improvements in technologies are continual in the pavement industry. Understanding and effectively implementing these methods can be a challenge. Identifying the appropriate improvements to integrate into current practices within a municipality may also be difficult. It is necessary to understand the current practices before new technologies and methods can be implemented. A careful Pavement and Materials Technology Review (PMTR) with an experienced pavement engineer is a method that can provide guidance in assessing improvements and advancements that are applicable to a specific municipality. A PMTR first involves an evaluation of typical pavement condition in the area and determining the current state-of-the-practice of pavement projects in a municipality. This includes thorough assessment of the current specifications, submittals from contractors, construction testing results; laboratory testing results that cover the span of multiple recent years; acceptance; and follow ups. With this information it is possible to identify practices that are working well and producing quality results and also highlight areas where improvements or changes are required.

Following the identification of typical pavement distresses and developing an understanding of the current industry practices for an area, appropriate actions must be considered. Actions to improve on the current practices and implement appropriate new technologies are discussed in this paper. Methods for implementing these actions within the municipality and to local consultants and contractors are recommended. Findings of a PMTR and action recommendations are specific to a particular area and may include any or all of the following: appropriate technology; modification to specifications; acceptance; enforcement of specifications; follow ups; staff training and education/workshops within the area including owners, contractors and consultants; and implementation of new technologies. The conclusion of a PMTR is intended to be the development of a clear system that can be routinely applied to projects within the municipality. The quality improvements of projects that are carried out using this system should be monitored and improved upon over time.

The City of Moncton retained Golder Associates Ltd. to perform a PMTR in 2009/2010. The City of Moncton PMTR is used as a case study in this paper to demonstrate the method of carrying out a PMTR. The findings of Moncton's PMTR will be presented as well as the recommendations for actions and implementation in the municipality.

INTRODUCTION

Advancements and improvements in technologies are continual in the pavement industry. Some of the current areas of advancement and growth include: materials including asphalt cements; mix designs; recycling; rehabilitation methods; pavement preservation; and pavement design methodologies. Various reasons lead to the advancement of pavement technology. Economics are generally a substantial contributor when there is a need to change the current method or materials. Other contributing factors include performance improvements and sustainability. Evaluating and understanding which of these is applicable for a particular municipality can be challenging. In order to effectively determine when and which method or technologies should be integrated it is necessary to understand the current state of the practice in the municipality. By understanding the current state of the practice it is possible to select new methods and technologies that will at least maintain the current quality of pavement or possibly lead to improvements in quality of pavements.

It is necessary to understand the current practices before new technologies and methods can be implemented. A Pavement and Materials Technology Review (PMTR) carried out by an experienced pavement engineer can provide guidance in assessing improvements and advancements that are applicable to a specific municipality. A PMTR involves pavement condition inspection and identifying typical pavement distresses in new, relatively new and older pavements and an evaluation of the current state-of-the-practice in a municipality. This includes a thorough assessment of the current specifications, submittals from contractors, construction testing results, laboratory testing results that covers the span of multiple recent years, acceptance, and follow ups. With this information it is possible to identify practices that are working well and producing quality results and also highlight areas where improvements or changes are required. A successful PMTR is a combined effort between the municipality technical staff members and the reviewing engineer, with the goal of both parties aiming to continually improve the quality of pavements in a municipality.

Many municipalities find premature distresses developing on pavements and the causes are often unclear. Figures 1 to 3 present examples of probably the most common premature distresses that are observed on pavements: poor longitudinal joint performance; early ravelling; and premature cracking. The purpose of a PMTR is to work with the municipality and identify areas in the current practice that could be improved and determine what improvements would be most effective, suitable and feasible.



Figure 1: Example of poor longitudinal joint in newly constructed pavement.



Figure 2: Example of early ravelling.



Figure 3: Premature cracking.

OBJECTIVE

The intent and objective of a PMTR is described in the following section. The objective of this paper is to describe the basics of PMTR and describe a case study. A PMTR was completed for the City of Moncton (City) in 2009 and will be presented in this paper to demonstrate the various aspects of the PMTR. The objective of carrying out the PMTR in the City was to identify problems with pavement performance and to evaluate the current state of the practice of the pavement industry in the City. After identifying and understanding the current state of the practice the intent was to build on the successful aspects and identify those that could be improved or changed.

PAVEMENT AND MATERIALS TECHNOLOGY

A PMTR is an objective method of evaluating the current state of the practice of the pavement industry in a particular municipality. It is a tool that can assist a municipality in effectively managing its pavement assets. A PMTR can be carried out in municipalities of various sizes and is highly dependent on the involvement of municipal staff members. A PMTR includes the following steps, each of which will be discussed in the following sections:

- Document and results review from current and previous years;
- Field visits and condition evaluation of new, relatively new and older pavements;
- Specification review;
- Evaluation of current state of the practice;
- Identification of effective aspects;
- Identification of possible areas of improvement;
- Implementation, including staff training;

- Monitoring; and
- Updating.

Figure 4 presents a flowchart describing a PMTR.

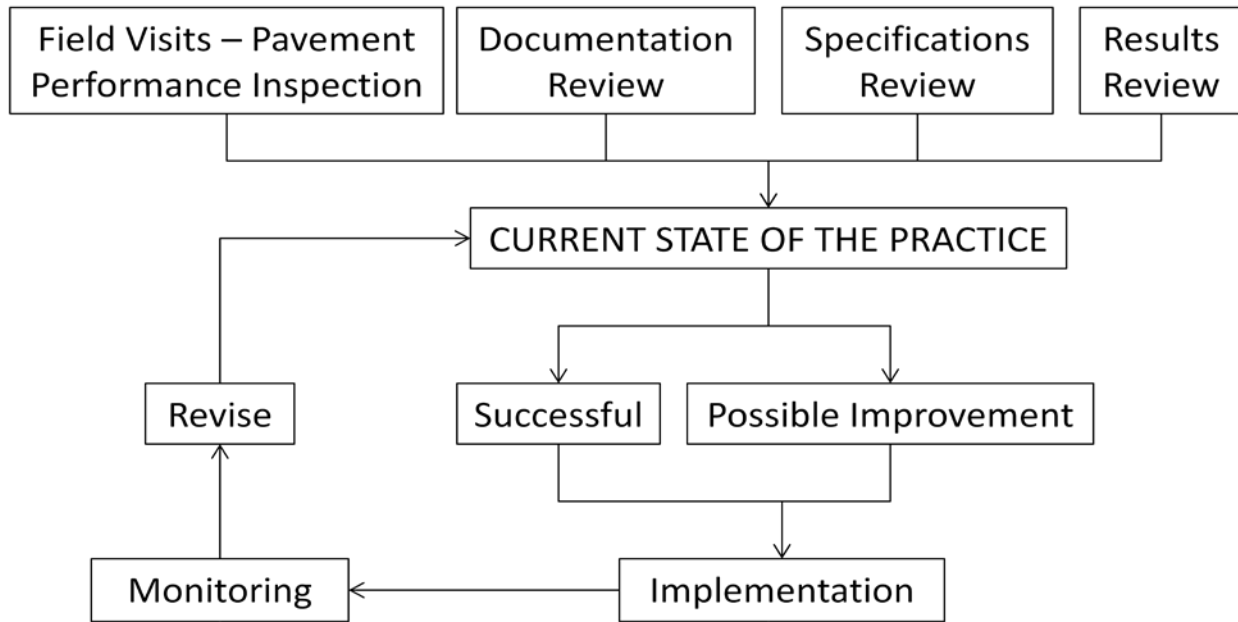


Figure 4: Flowchart describing PMTR

Figure 4 shows the connections between various aspects of a PMTR. The terms referenced in Figure 4 generally represent aspects of a PMTR and change slightly depending on the specific municipality. The ability to link these various aspects within a municipality is one of the key reasons that PMTR are successful. Municipalities vary in size and many have multiple departments that all contribute to work with the paving industry, such as tenders and contracts, design, field inspection and maintenance. It can be challenging to connect the work from various departments together and objectively assess the effectiveness of the final outcome: short and long term quality of pavement. In a PMTR an objective review is undertaken with the assistance and involvement of the municipal staff. The outcome is an understanding of the current state of the practice in a municipality, that bridges across all involved groups.

Field Visits – Pavement Performance Inspection

Site visits typically start with a meeting with municipal technical staff to discuss their concerns and observations about pavement performance, pavement design methodology, types of materials used including granular materials and asphalt and concrete mixes and their quality, concern about specifications and quality of construction, effectiveness of Quality Control (QC) and Quality Assurance (QA), capability of local contractor in delivering quality products, suggestions about technology improvements including rehabilitation methods, pavement preservation and maintenance. The technical people have often years of experience and deep knowledge of local sources of material and potential problems with technology currently being used. Their input is particularly important to achieving better quality, longer lasting pavements.

During the PMTR it is important to complete field visits on a variety of roads throughout the municipality. At minimum this should include those currently under construction or just completed (less than one year old), roads two to five years old and roads more than five years old. Visits should also be made to construction sites to evaluate the construction practice. Also, if there are issues with the quality of aggregates and granular materials, a visit to aggregate quarries or pits can be arranged, if feasible. Staff members are typically directly involved in the projects since they are very familiar with the roads in the municipality. These individuals will be able to highlight pavements that are performing well and any that are deemed to be under performing. Comments and experiences shared by the municipal staff is critical in fully assessing the current state of the practice in a municipality.

The quality of the construction of a pavement will be one of the ultimate factors in the long term performance. The combination of pavement design, materials, construction and maintenance will determine the long term performance. However, if one of the three initial items is insufficient then maintenance will typically not be able to correct it. Observations made during construction field visits can be very useful to municipal staff members as well. Findings should be shared with staff members, especially during the implementation stage and with management. It is unfair to expect staff members to be able to adequately inspect construction practices if they have not had the opportunity to learn about the methods themselves.

Properly carried out pavement condition inspections by an experienced pavement engineer will not only identify the types, severity and density of the distresses but will also help in identifying their causes, such as deficient pavement design, poor materials, poor construction practice or environmental impact. The most commonly observed pavement distresses can be grouped as follows:

- Structural - including alligator cracking on rutting in the wheel path. They occur mainly due to insufficient pavement structure to support the traffic loading. They should be addressed by proper design including necessary geotechnical/soil information, anticipated traffic loading calculation and using proper design methodology;
- Materials – including polished aggregate, shoving and swelling. These distresses occur due to the characteristics of the materials throughout the pavement structure. The maintenance or repair to address these distresses varies dependent on the distress. Proper selection of the materials and laboratory testing should eliminate these distresses.
- Construction – including ravelling, bleeding, bumps, sags, depressions, edge cracking, longitudinal cracking, joint opening and slippage cracking. These distresses develop due to the practices that were used during construction. Depending on the severity of the distress is maybe possible to apply maintenance such as crack sealing. Otherwise the material that was poorly constructed would need to be replaced. The major objective here is to make sure that proper construction practice is followed so that premature distresses can be avoided.
- Environmental – including transverse cracking, frost heaves and block cracking. These distresses develop due to an inability for the pavement structure to perform under changing climatic conditions, particularly freeze-thaw cycling.

Although it is impossible to eliminate the impact of the environment on the pavement, the potential for environmental distresses can be reduced or minimized by using proper design, particularly rehabilitation of existing pavements, and good quality materials.

Document Review

Available documentation is provided to the pavement engineer carrying out the review. The documentation would typically include annual paving plans, pavement designs, contract documents, specification requirements, QC/QA, reports, municipality inspection reports and maintenance plans.

Additionally, information about the current pavement design practices in the municipality would be provided for review. Municipalities are often responsible for a wide range of roadways and it is understood that having simple templates or a design matrix is often considered to be a feasible solution. The templates or matrices should consider relevant design inputs, such as, soil and water conditions, traffic and pavement materials characteristics. It is also important to ensure that adequate design information is used for the new construction, reconstruction or rehabilitation design for at least major roads in the municipality. Pavements will begin to deteriorate immediately following construction but sufficient pavement structure, materials and construction will decrease the rate of deterioration. Suitable maintenance throughout the life of the pavement is necessary as well to achieve the optimum performance.

The documentation should also include all documents associated with submitted mix designs. The submitted documents for each mix would be compiled and reviewed to evaluate if all required information was being submitted to the municipality prior to the initiation of construction of a project. These submittals should be complete for each project.

Specification Review

Specifications are very important to a municipality as they are one of the steps in ensuring that the pavement that is constructed is as intended. As with many of the aspects of a PMTR, the specifications do not alone ensure that a quality pavement will be constructed, they need to be updated periodically and need to be understood between various areas in the municipality. A PMTR goes through the existing specifications in detail and provides an objective interpretation of them. Some of the key considerations when reading a municipality's specifications include:

- Clarity;
- Do they reflect current practices being used in the municipality and by the industry;
- Are requirements for acceptance payment outlined; and
- Are consequences of failure to meet requirements described.

Although municipality's specifications are a critical tool in achieving quality pavement, they are often large documents and can be intimidating and challenging to work with. An objective review can be helpful as it will assist in the interpretation of the existing specifications and identify if areas exist that should be improved or changed to reflect the municipality's goals and affordable budgets. The state of the specifications will be reflected in the quality of pavement that is produced in a municipality.

Results Review

All results from years in consideration should be provided to the pavement engineer carrying out the review for compilation and analysis. Results will be analyzed in consideration of a variety of aspects, such as type, year, specific mix design, construction, QC/QA and acceptance. Analysis of the available results, generally construction QA can identify aspects of the current practices that are effective; and lead to success as well as those that are not meeting the acceptance criteria. The analysis of the results combined with the field visits can help to identify which particular distress or scenario is occurring. Figure 5 shows an example of the analysis of asphalt cement content variance in QA sample results for a municipality.

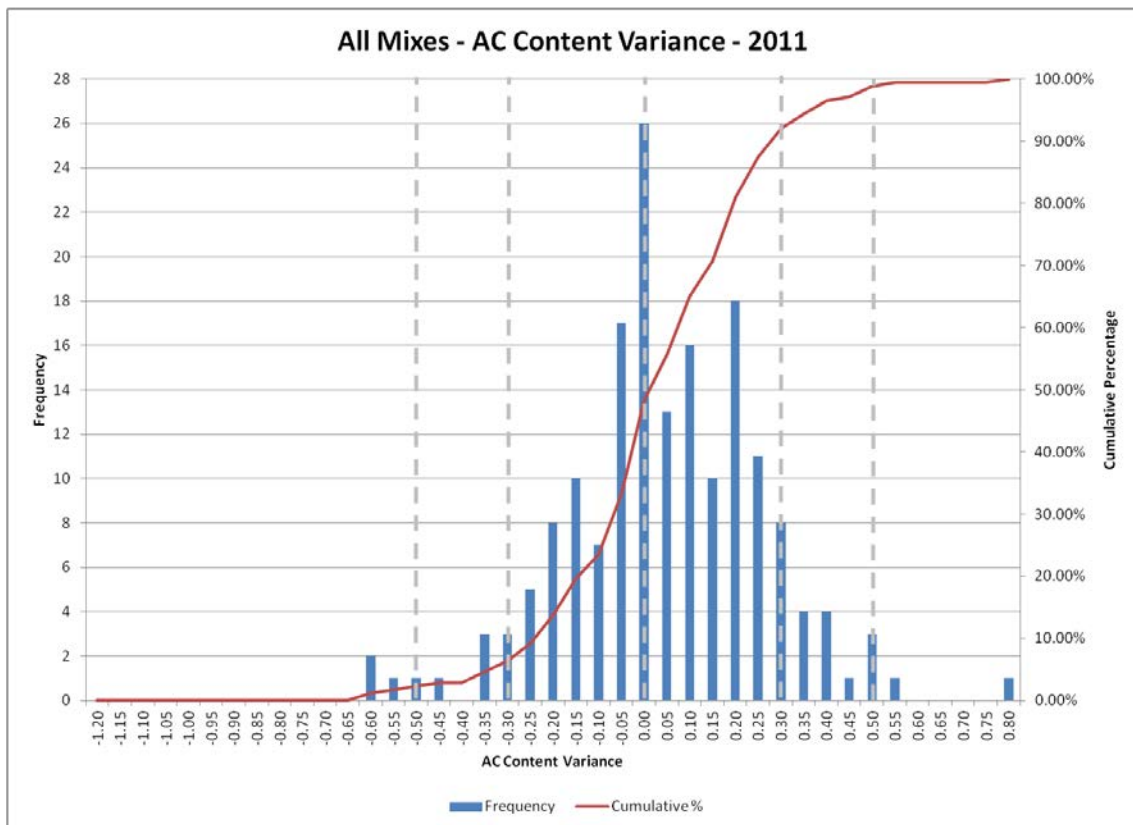


Figure 5: Asphalt cement content variance results compiled for a municipality.

Figure 5 shows the asphalt cement content variance from the JMF results from all projects in a municipality in 2011. Figure 5 presents a clear picture of the asphalt cement content variance results that are experienced in this municipality and it would be challenging to appreciate this data without it being compiled in this manner. The dashed vertical lines represent the acceptable, borderline and rejectable result limits. Figure 5 shows that although the majority of the results are in the acceptable zone of the designed asphalt cement content ($\pm 0.3\%$ tolerance), there are a number of results within the borderline zone ($\pm 0.3\%$ to $\pm 0.5\%$) and a few results in the rejectable zone ($> \pm 0.5\%$). Comparing asphalt cement content variance in a few subsequent years will show what the trend is. In some cases tightening the specification tolerance limits may be effective in getting much closer to the designed value.

Evaluation of Current State of the Practice

By compiling the four previously discussed areas: field visits; documentation review; specification review; and results review then the current state of the practice in the municipality can be evaluated. This is one of the largest aspects of the PMTR. During this evaluation, the intent is to draw links between the four noted areas. In general, identify a pavement that showed good and poor performance in the field visit and then examine the specifications that were used as well as the associated documentation. By compiling all of this information for both good and poor performing pavements it will be possible to identify trends within the municipality.

In addition to looking at specific projects, all data is also analyzed. The available data is typically examined based on year and type. As an example, the asphalt cement content results from 2011, would be compiled and plotted to evaluate if trends existed, such as routinely lower asphalt cement content within borderline or rejectable limits for one particular mix type. Analysis of the data in this manner allows for repeat occurrences to be highlighted that may not have been evident in the evaluation of specific projects.

Evaluation of the current state of the practice is a relatively cumbersome process; however, is one of the most effective aspects of a PMTR. The conclusions drawn from this evaluation are applied in the following steps.

Identification of Effective Aspects

Using the conclusions and findings from the evaluation of the current state of the practice it is possible to identify aspects that are effective. Effective aspects would be those that lead to quality pavement performance. These include effective specifications, suitable materials and quality construction practices.

Identification of Possible Areas of Improvement

Through analysis of all results and field visits, areas that are inadequate will be identified. The analysis of all results can clearly highlight aspects that are being missed or not performed sufficiently, such as mix design verification or implementing consequences if there are unacceptable results in quality assurance testing. Observations during field site visits will trigger areas that may require improvement. Distresses observed in the field that are typically caused by unsuitable mix designs can reinforce the need to evaluate the mix designs and acceptance method. Observations in the field and in analysis of all results may also identify a weakness in the specifications that needs to be revised. Practical experience with pavement and material technology reviews shows that poor specifications and lack of specification enforcement are the major reasons for poor quality pavement.

Implementation

After evaluating the current state of the practice in the municipality and identifying both effective and not effective aspects it is important to discuss what, if any changes, should be made

for future projects. Results of the PMTR to this point and possible revisions to current practices would initially be discussed with management at the municipality. Following discussions, agreed upon revisions would be carried out where necessary. These revisions would typically be covered in two aspects, modifications to current specifications and supplementary education for staff members.

If modifications to existing specifications are needed they would be carried out with the intent of updating any out of date specifications and providing clarity where current requirements may lead to confusion. One method of revising specifications that can be effective for both material suppliers, contractors and owners (the municipality) is to develop special provisions to the currently existing provincial specifications. An example of this would be for a city in the province of Ontario. An outcome of the PMTR would be a set of Special Provisions for the city, to the Ontario Provincial Standard Specifications (OPSS) (1).

After agreed upon revisions have been completed it is critical to share the findings of the PMTR with the current staff of the municipality. If the staff members are not included in the findings then it will not be possible to implement changes in the current practices effectively as these individuals who are involved in the day to day activities. The results of the PMTR should be made available to staff members and clearly explained, which can be effectively carried out through a training and open question and answer session. If new technologies or methods have been implemented in the municipality given the findings of the PMTR then it is critical to educate associated staff members on these new areas.

Monitoring

Following the implementation of the proposed revisions from the PMTR results it is important to monitor if the improvement or changes are effective. Initially some challenges may exist if transitions in technologies or methods are being carried out, such as for example moving from Marshall mix design to Superpave mix design. Challenges during transitions are common and expected. Part of the PMTR is the involvement of the review engineer in finding solutions to these challenges, should they arise. In many cases the solution is to provide explanation and education to not only municipality staff members but also common suppliers and contractors. Explanation of changes to prior specifications can be extremely beneficial to everyone involved as this can reduce unneeded expenses and delays in the future and lead to improved performance of the pavements in some areas.

Changes may also be incremental in a municipality, such as trialing a new method on lower volume roads before implementing it on all projects. Monitoring these types of initiatives is important to achieving success on projects in the future.

Updating

The final step of a PMTR is updating the findings of the initial evaluation of the current state of the practice. Through monitoring the implementation of new methods and technologies and revisions to the specifications, areas maybe identified that should still be updated. Additionally, results from subsequent years after the initial PMTR should be compiled and analyzed as was

done previously, to evaluate the effects of the implemented changes. It is anticipated that deficiencies in the initial PMTR will have been addressed; however, if they remain then further investigation will be required to determine the continuing cause of these challenges.

CITY OF MONCTON CASE STUDY

The City of Moncton (the City) in New Brunswick worked with Golder Associates Ltd. (Golder) to carry out a PMTR in 2008. The City retained Golder to carry out a PMTR in order to improve the state of pavement technology in the City. The PMTR involved the following tasks:

- Meeting with the City's technical staff to get an understanding of the current state of the practice;
- Review of the current City and New Brunswick Department of Transportation (NBDOT) specifications and pavement design methodologies;
- Pavement visual condition inspection of selected roads and streets;
- Site visits to suppliers of aggregates typically used in the City;
- Review of laboratory and field testing results from consultants and contractors/suppliers;
- Site visits to construction sites to review the current construction practice and QC/QA procedures;
- Review of the City's current subdrain installation practice;
- Recommendations for improvements in pavement and materials technology; and
- Training of City's technical staff.

The following sections describe the findings of each of above noted tasks in the project.

Meeting with City's Technical Staff

Two meetings were arranged with key staff from the City of Moncton to gain an appreciation for the current practices in the City. The discussion included:

- Pavement design methodologies – the City was concerned that the pavement designs used in Moncton were outdated and did not take into account all necessary aspects;
- The type of asphalt cements used such as Penetration Grade or Viscosity Grade;
- The quality of granular materials and aggregates – some of the quarries were known to supply materials that generally did not meet the specified requirements (mainly freeze-thaw); how, if at all, could the substandard quality be compensated in the pavement designs and construction;
- The type and range of asphalt mixes – what kind of improvement would be necessary;
- The quality of construction with particular emphases on the effectiveness of the QA system used by the City;
- The capability of the local contractors in terms of constructing quality pavements, techniques used to rehabilitate existing pavements; and
- Construction specifications including the clarity of the QA system used.

These factors were discussed as particularly important to achieving better quality, longer lasting flexible pavements. The subjects discussed at the meetings formed the basis for the pavement and materials technology review.

Review of City Specifications and Pavement Design Procedures

The City's specifications related to pavement and materials were reviewed and the following is a summary of the findings:

- Requirements for QC/QA testing were generally not specified;
- Mix design details in terms of type and required documentation were unclear; and
- Work acceptance criteria and corrective action for inadequate results were not determined.

From the earlier meeting with the City's technical staff it was apparent that there was interest throughout to update the specifications to achieve quality, better performing pavements.

The existing pavement design procedure used in the City was reviewed by Golder. The procedure was found to be overly generalized and over simplified and did not consider traffic volumes.

Review of Laboratory and Field Results

The City provided Golder with available laboratory and field testing results for analysis purposes. Golder reviewed the results and found that often the results were outside the acceptable criteria but no corrective action was recorded as having been carried out. This was found in the results of aggregate and granular materials and during construction. A limited number of mix designs had been provided to the City. In general only a part of the supplied information for each mix met the requirements in the City's specifications. However, only a small amount of the required documentation was provided to the City for each mix.

Construction and Existing Pavement Site Visits

Representatives of Golder visited construction sites and existing pavements in the City. During the construction visits, Golder was able to observe the techniques commonly used in the City. Having observed the current techniques, appropriate recommendations were made for specification revisions and inspector training.

Pavements of varying ages were visited (from newly constructed to more than five years since construction). The most commonly observed distresses were fatigue cracking, rutting, premature longitudinal and transverse cracking, joint failure and material segregation. The premature distresses were likely due to a combination of factors: inadequate pavement design; poor quality granular materials; poor quality mixes and mix ingredients; poor construction practices; poor QC/QA system; insufficient inspection; lack of specification enforcement and follow ups and unclear specifications. Figure 2 and 3 show examples on the pavement observed during the field site visits.

Recommendations

The conclusions of the PMTR were the following recommendations to advance the state of the practice in the City:

- Revise current specifications to meet NBDOT requirements where feasible;
- Include requirements for asphalt mix designs, aggregate materials and granular materials in revised specifications;
- Revised specifications should include acceptance criteria and corrective actions that will be required in criteria is not met and clear methods of enforcing them;
- Updating of pavement design matrix for future projects to include traffic loading and soil type;
- Avoidance of cold joint construction by using infrared joint heaters or paving in echelon, using good quality construction methods if it is necessary to construct cold joints (2);
- Adequate inspection during construction;
- Development and implementation of effective QC/QA program;
- Training of the City's technical staff;
- Implementing new feasible methods of pavement rehabilitation; and
- Implementing pavement preservation (3).

Prior to the initiation of the PMTR with the City, their current state of the practice was not reflecting currently available methods and technologies. The PMTR was a combined effort by the City and Golder. The conclusion was a thorough evaluation of the current practices and the development of simple guidelines for updating the current practices in the City. Golder provided an objective review of the practices in the City and worked closely with staff members to identify potential areas of improvement that would ultimately increase the quality of pavement in the City.

CONCLUSIONS

Pavement materials and technology reviews are an objective method of evaluating the current state of the practice in a municipality. An experienced pavement and materials engineer meets with the municipality technical staff to discuss their concerns and observations about pavement performance, pavement design methodology, types of materials used including granular materials and asphalt and concrete mixes and their quality, concern about specifications and quality of construction, effectiveness of Quality Control and Quality Assurance, capability of local contractor in delivering quality products, suggestions about technology improvements including rehabilitation methods, pavement preservation and maintenance. Field visits are then completed to assess the typical condition of pavements of various ages. A thorough review of documentation, specifications and results is completed to determine the reasons for the performance observed in the field visits. All of these aspects are compiled to evaluate the current practices in a municipality and determine where areas exist that could be improved or changed. Following this the pavement engineer works closely with the municipality to implement recommended changes, such as modifications to current specifications, training for technical

staff members and integration of new methods and technologies. This is later followed by monitoring if the improvements or changes were effective and making any updates, if necessary.

The City of Moncton retained Golder to carry out a pavement materials and technology review in 2008. The current practices in the City were evaluated and it was identified that improvements could be made in aspects of the pavement designs, specifications, required documentation, quality assurance testing, specification enforcement and construction practices. Recommendations were provided to the City for these various improvements and training was provided to technical staff members. The completion of the pavement materials and technology review enabled the City to understand the current practices being carried out and direct efforts to the most important aspects, with the intent of improving the quality of their pavements.

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