



Office of the Auditor General

2010 Audit of the Mackenzie King Bridge Rehabilitation

Tabled at Audit Committee – November 26, 2015

Contents

Executive Summary	1
Introduction	1
Background	1
Audit Objectives	1
Audit Scope	2
Summary of Key Findings	3
Recommendations and Management Responses	13
Conclusion	16
Acknowledgement	17
Detailed Audit Report	19
1.1 Introduction	19
1.2 Background	19
1.3 Audit Scope	28
1.4 Audit Objectives	29
1.5 Findings	31
1.6 Conclusion	65
1.7 Acknowledgement	66

Executive Summary

Introduction

The Audit of the Mackenzie King Bridge Rehabilitation was undertaken as a result of a Fraud and Waste Hotline report, dated September 10, 2010, received from a member of the public.

Background

The Office of the Auditor General (OAG) carried out a preliminary assessment to examine the documentation relating to design and construction of the Mackenzie King Bridge rehabilitation.

Based on the findings of the Preliminary Assessment Report, the OAG decided to carry out an audit of the 2007 and 2009 Mackenzie King Bridge paving contracts.

Audit Objectives

Audit Objective No. 1

Examine the asphalt rehabilitation procedures used by the City for the Mackenzie King Bridge.

Criteria:

- Coordination of asphalt contracts with other structure renewal planning
- Input by Infrastructure Management structure specialists
- Asphalt rehabilitation procedures used in other structures, as background for procedures used in this bridge
- Use of waterproofing membrane in Ontario
- Comparison with other jurisdictions

Audit Objective No. 2

Examine and evaluate the studies, processes and methodologies used by the City to select the asphalt rehabilitation methods, including the selection of Rosphalt modified hot mix asphalt placed without waterproofing membrane.

Criteria:

- Pavement design criteria and procedures
- Mix design specifications, including selection of asphalt cement
- Mix design testing and verification, including inspection and testing

- Comparison with other methodologies
- Checking of Rosphalt references
- Testing

Audit Objective No. 3

Examine the scheduling of contracts for pavement rehabilitation, including coordination of work with structure renewal requirements.

Criteria:

- Program coordination with Infrastructure Management
- Timing of contract preparation in light of inspection results
- Frequency of resurfacing required
- Scheduling of design meetings

Audit Objective No. 4

Examine the qualifications of City staff and testing laboratory, and the use of consultants used to provide advice on the pavement rehabilitation.

Criteria:

- Review City staff qualifications in relation to complexity of decisions required
- Capabilities and certifications of City materials testing laboratory
- Review methodology used to decide between in-house vs. consultant design
- Review the involvement of pavement specialists on the project

Audit Scope

The scope of the audit comprised the maintenance procedure for the Mackenzie King Bridge, including the resurfacing and superstructure maintenance. The audit examined the scheduling of asphalt rehabilitation contracts for the bridge, the alternative solutions examined and the procedures used for selection of asphalt rehabilitation methods, including coordination with the structure renewal procedures.

The audit examined the investigations done by the City to resolve the problem of rutting and shoving of the asphalt and leakage into the NAC garage resulting in a need for a strategy that could deal with both; and the use of Rosphalt modified hot mix asphalt placed directly on the bridge concrete deck, including an assessment of this practice as a reasonable practice.

The audit encompassed the following tasks:

- Obtain and review all files for the project

Audit of the Mackenzie King Bridge Rehabilitation

- Review background data on the bridge and Rosphalt
- Review the City's policies, procedures, standards and practices
- Review industry procedures, standards and practices
- Conduct interviews with individuals involved in the 2007 and 2009 contracts and those responsible for inspection and maintenance of the bridge
- Conduct a site visit

Summary of Key Findings

1. The Mackenzie King Bridge (MKB) is located on the Central Transitway. The pavement on the bridge is subject to severe loading conditions, due to the number of buses using the bridge transit lanes, the slow operating speed of the buses on the bridge, and the number of bus stops and starts on the bridge.
2. When the MKB was transferred to the Regional Municipality of Ottawa-Carleton (RMOC) in 1996, the City accepted responsibility for maintaining the bridge above the National Arts Centre (NAC) parking garage. Leakage into the NAC parking garage has been a concern of the NAC and the City since at least early 2004; the City investigated the infiltration problems in 2005 and a report was completed in February 2006. The report concluded that the leakage problems were due to several factors; leakage through the deck was not one.
3. The City has had problems with the durability of the asphalt on the Mackenzie King Bridge (MKB) since about 2003. A list provided by the City of projects since 2001 shows that the City repaired the pavement on the bridge each year from 2004 to 2007; these repairs consisted of milling the existing asphalt in spots on the bus lanes and repaving.

Year	Rehabilitation Description	Approximate Area (m2)	Approximate Cost	Comments
2001	No work identified on MKB	n/a	n/a	n/a
2002	No work identified on MKB	n/a	n/a	n/a

Year	Rehabilitation Description	Approximate Area (m2)	Approximate Cost	Comments
2003	No work identified on MKB	n/a	n/a	n/a
2004	Eastbound and Westbound lanes	n/a	n/a	No details available
2005	Spot locations eastbound lane at QE Driveway overpass	720	\$16,000	Cost based on 6 areas of 4 m x 30 m
2006	Spot locations, Elgin Street to Waller	720	\$35,000	Strategy by former pavement engineer, cost based on 6 areas of 4 m x 30 m Removed waterproofing membrane at areas of repaving
2007	Spot locations, eastbound and westbound, west of Nicholas overpass	700	\$23,000	Cost based on 6 areas of 4 m x 30 m
2008	Remove waterproofing, Elgin to Waller, EB and WB transit lanes	4,000	\$625,000	Resurface using Rosphalt 50 modified hot mix asphalt, with no waterproofing membrane

Year	Rehabilitation Description	Approximate Area (m2)	Approximate Cost	Comments
2009	Remove RMHMA, install new waterproofing and paving, Elgin to Waller, EB and WB Transit lanes	4,000	\$718,000. Approximately \$80,000 to \$100,000 of this amount was for coordinated structural work and not resurfacing	Contract to repair work done in 2008; included bridge structural work coordinated within the same contract
2010	No work required on MKB	n/a	n/a	n/a

4. The City commissioned a pavement rehabilitation study in 2004 to investigate alternatives to the annual milling and paving of the bridge, which concluded that annual milling and paving was the most cost-efficient solution. The report recommended, based on life cycle cost financial analysis of the alternatives, to continue to mill and pave annually at an annual estimated cost of \$33,000 (2004\$), replace the entire surface course every 15 years at an estimated cost of \$169,400, including engineering (2004\$), and replace the waterproofing and asphalt every 30 years at an estimated cost of \$621,500, including engineering (2004\$). The report notes that the conclusions are based on annual repairs being required in the critical areas and a service life of 30 years for the existing waterproofing. Information provided by the City indicates that this \$51,548 report was commissioned by the former Structures and Transit division within Infrastructure Services. The Structures Engineer reporting to that unit, as well as the Pavement Engineer, were involved in the study.
5. Up to 2007, the City was following the recommendations of the 2004 Pavement Rehabilitation report
6. Information in correspondence provided by the City indicates that until 2006 the waterproofing on the bridge was working, although indications are that it had moved with load, and that the 2005 work possibly had resulted in some overmilling in spots, causing thinning of the waterproofing membrane, but not perforation of the same.

7. The City's former pavement engineer (2002-2008) believed that the instability of the asphalt on the MKB was caused by slippage of the asphalt in relation to the waterproofing membrane, caused by the waterproofing protection board acting as a slip plane. For the 2006 pavement repairs on the bridge, the resurfacing was scoped to include removal of the waterproofing membrane and placement of Stone Mastic Asphalt (SMA) directly on the concrete deck without a waterproofing membrane. Less than six months later the pavement was reported to be in good condition (i.e., no rutting or shoving). This supported the engineer's belief regarding stability of the hot mix asphalt. However, the leakage problems in the NAC parking garage were considerably worse than before the waterproofing membrane was removed, and there was evidence of water infiltration through the bridge concrete deck.
8. Rosphalt is a polymeric asphalt additive, manufactured by Royston Industries, a division of Chase Construction Products. The Rosphalt asphalt additive is applied to the hot mix asphalt (HMA) during the production of the asphalt concrete. In this audit, Rosphalt modified hot mix asphalt will be referred to as RMHMA.
9. According to Royston's marketing and product information, Rosphalt 50 is a dry mix asphalt additive that provides a waterproof wearing surface that will not rut or shove. The product information states that RMHMA is used as a single-system waterproofing and wearing course for bridge decks, in contrast with conventional asphalt and waterproofing installations, which consist of a waterproofing membrane placed on the bridge deck, covered with backer-board protection, covered with hot mix asphalt. The Rosphalt 50 additive is intended to reduce the permeability of the HMA, eliminating the need to place a waterproofing membrane and protection board.
10. Based on the results of the 2006 pavement rehabilitation work (which used SMA without a waterproofing membrane), the City decided to remove the waterproofing membrane and asphalt along the full length of both the eastbound and westbound bus lanes on the bridge, and to repave the bus lanes for the entire length of the bridge, using hot mix asphalt modified with Rosphalt 50 (RMHMA), placed directly on the bridge concrete deck, without a waterproofing layer. The premises for this decision were (a) the interface between the waterproofing membrane and the hot mix asphalt was considered to provide a slip plane which prevented the hot mix from adhering to the concrete deck, and permitted it to shove and rut; and (b) the RMHMA would be sufficiently impermeable to provide sufficient waterproofing of the concrete deck to permit removal of the standard waterproofing membrane without adverse effect to the concrete deck.
11. Standard practice for municipal and provincially owned bridges in Ontario is to use a waterproofing membrane and asphalt to protect the bridge decks. This is also the

Audit of the Mackenzie King Bridge Rehabilitation

City of Ottawa practice. Not using a waterproofing membrane is very unusual. In the references provided by Royston for the use of the Rosphalt 50, only two bridges are located in Ontario, and those were done in the mid-1980s. The Ministry of Transportation of Ontario (MTO) has used Rosphalt 50 in three contracts in the last two years as a stop-gap measure and on a trial basis.

- The MTO generally uses waterproofing membrane and hot mix asphalt on bridge concrete decks.
 - The MTO has used Rosphalt 50 additive on a trial basis in three recent contracts, in situations where the MTO cannot use their normal waterproofing system. Rosphalt is being used temporarily until the bridge deck can be completely rehabilitated.
 - MTO structural staff is responsible for making the waterproofing decision. Normal waterproofing system is a hot applied rubberized asphalt waterproofing membrane, which cannot be used when the deck surface is rough.
 - The MTO contact indicated that the paving company had some problems with getting the correct aggregate gradation. Rosphalt in the US kept sending it back. If gradation is not right then asphalt will not have the correct density and will not be waterproof.
 - Municipalities in Ontario generally use waterproofing and asphalt on concrete decks. In some applications bridge decks are provided with a concrete overlay as the wearing surface, but this is not a common practice.
 - The Ontario Good Roads Association was contacted to enquire whether they are aware of municipalities in Ontario who may have used the Rosphalt additive, but they were not aware of the use of the product.
 - The auditor contacted the City of Guelph Engineering Department, as the City of Guelph's Edinburgh Street Bridge is listed in the reference provided by Royston for projects where the Rosphalt additive has been used, which is on a road used by buses. The City advised us that they do not have the files for this contract, as it was done in 1986.
 - It is notable that the product has not been used in either the City of Toronto or the City of Montreal, two cities with routes with significant bus loads.
12. There is no documentation in the files provided by the City to attest that the decision to use the RMHMA was preceded by appropriate tests, financial studies, and preparation of specifications. The review of references appears to have been limited to the New Brunswick Department of Transportation, who have used the Rosphalt 50 product on highway bridges, which have much different traffic and axle loading conditions than the Mackenzie King Bridge.

13. The grinding and resurfacing work done in 2006 suggested that the removal of the membrane helped to reduce the rutting and shoving; however, it resulted in a higher leakage rate. This resulted in the City's consideration of other waterproofing products, including Rosphalt, which was subsequently selected as it provided the opportunity to address both rutting and leakage concerns.
14. Review of the documentation on the asphalt stability problems on the bridge indicates that more advanced examination of the reasons for the instability of the hot mix could have been warranted. Tests that could have provided additional insight into the rutting, shoving, and shear forces between the asphalt mix and the waterproofing membrane, such as the Asphalt Pavement Analyzer, the Repeated Load Permanent Deformation test, Fatigue testing and the Superpave Shear Tester (SST), appear to have been warranted. There is no documentation on file attesting that any of these or equivalent tests were conducted prior to making the decision to use the RMHMA.
15. The decision to use RMHMA was made without documentation of evaluation of other options, such as waterproofing membranes not requiring a protection board, or higher grade performance graded asphalt cements. Management has indicated that the option of using other waterproofing systems was discussed and considered, but was not retained because of concerns that it would not address the root cause.
16. The decision to remove the waterproofing membrane and to place RMHMA was done by the former pavement engineer without formal approval by the Structures Section of Infrastructure Management (now Asset Management). Correspondence in the file indicates that the Structures Section had serious reservations about the removal of the waterproofing, but these were not communicated clearly and forcefully enough to the former pavement engineer.

Management has indicated as follows: Discussion did take place at the staff level, including with the Structures section, before the decision to proceed with the RMHMA was made. The challenges with the Mackenzie King Bridge (MKB) structure were well understood. Similar rutting problems were encountered at Transit Stations and addressed by replacing the asphalt with a concrete resurfacing. This solution was not applied to MKB because it is a bridge with unique challenges and constraints. Had the Structures section not supported the proposed direction, this issue would have been escalated, to Management, which it was not.

17. As noted in Items No. 3 and 10, the City milled and repaved areas of the bridge in 2006, removing the waterproofing membrane and placing SMA directly on the concrete deck. Approximately seven months passed between the time when the City became aware that the deck was leaking at the location where the

Audit of the Mackenzie King Bridge Rehabilitation

waterproofing membrane was removed in 2006 and when the City moved to resurface the entire length of the bus lanes using RMHMA; however, there is no documentation of the reasons why there was such a long a time gap between the two events. A project of such magnitude would have warranted sufficient study and preparation of tender documents.

18. The decision to resurface the bus lanes, made in 2007 and implemented in 2008, appears to have not taken into consideration the previous reports commissioned by Infrastructure Management relating to evaluation of alternative pavement rehabilitation strategies.
19. Based on the 2004 pavement rehabilitation study and the rehabilitation work done from 2004 to 2007, both inclusive, the City could have continued to spend up to \$33,000 annually for another 15 years before milling and repaving the entire bus lanes. Instead, the City spent \$625,000 in a pavement rehabilitation scheme that was unsupported by adequate investigations, testing, and financial analysis.

Management has indicated as follows: The bridge was renewed in 1998 and it would be unreasonable to expect that it would be another 15 years beyond 2004 before resurfacing would be required. Because of the frequent repairs and the fact that shortly after the repairs were done the pavement started showing signs of failure, staff worked collaboratively to find an innovative solution. Based on the history of the bridge, its unique challenges and the premature pavement failures, staff concluded that the 2004 plan warranted a different approach.

As noted in Point 4 above, the 2004 report was reviewed and accepted by senior engineering staff within the City, so it would be expected that the assumptions in the report were vetted by them. Management has now stated that those assumptions are unreasonable. If the City was not in agreement with the assumptions made in the 2004 report, further discussion should have taken place to ensure that the report's assumptions were correct. If there was disagreement with the report, it should have been modified to address the revised assumptions regarding the useful life of the asphalt and waterproofing.

20. After making the decision to resurface using RMHMA, the City proceeded to request a quotation from the contractor who was undertaking the 2007 Transitway Rehabilitation Contract. The total cost was \$625,000.
21. Based on this information, the City requested quotations from three contractors, but without preparing a formal Request for Quotations.

The City proceeded on the basis that the work was urgent and time was limited due

to the impending closure of the asphalt plants.

Management has advised that Article 23 of the Purchasing By-law, Special Circumstance Purchases, delegates authority to the Director, or Deputy City Manager, as appropriate, to authorize the purchase of construction as is considered necessary to remedy the special circumstance without regards to the requirement for a bid solicitation. In this instance, the Department opted to solicit quotations and award the contract to the lowest responsive bidder. This is considered preferable to a non-competitive contract award, which is permitted under Article 23, as pricing was provided in a competitive, although informal, environment. Moreover, the award to the lowest responsive bidder was approved in accordance with the Purchasing By-Law.

22. The City did not prepare a Specification specifically for the application of the RMHMA, but used a Standard Specification for a new product application. This resulted in some confusion within the City during construction as to the warranty implications of controlling the RMHMA specifications.
23. The former pavement engineer who was responsible for the selection of the RMHMA strategy for the MKB left the City in early 2008. No other staff at the City had the experience or training to vet the decisions made by Royston and/or the contractor with respect to the RMHMA mix design.
24. As a result of the lack of experience with and training in the Rosphalt additive, the QA Section and Construction Services left it to Royston and the contractor to prepare the mix design, test it, and control it during construction. Quality assurance testing was performed on the asphalt cement content and aggregate gradation on production samples to confirm conformance with supplier mix formula.
25. The Royston literature indicates that they will use the PG grade specified by the owner. The asphalt grade (PG 70-34) specified in the contract was modified to a lower grade (PG 58-34) by Royston during the mix design. Approval of this change by the City is not documented.

Management has stated that the City recognized that it was dealing with a proprietary product and wanted to ensure that the responsibility for the warranty remained with Royston. Without knowing the proprietary composition of the Rosphalt additive, staff followed Royston's recommendation regarding the PG grade since staff could not confirm the reaction between the Rosphalt additive and the polymer in the PG 70-34.

26. Although the Quality Assurance (QA) Section had valid concerns and offered what would have been helpful suggestions to the contractor regarding the mix design tests, these were not addressed. The City indicated that they did this to avoid nullifying the contract warranty, but we believe that the lack of experience with Rosphalt and the lack of a specific specification made it practically impossible for the City to test and verify the material.
27. The City staff responsible for the design of the 2007 contract appear to have had the necessary qualifications.
28. The City Quality Assurance staff consists of engineers with substantial experience in testing of materials, but they are not certified either by the Canadian Standards Association (CSA) or the Canadian Council of Independent Laboratories (CCIL). The City Quality Assurance lab does not have the required CCIL certification.
29. CCIL certification is voluntary, but the certification program ensures that materials testing labs meet correlation and proficiency requirements. The Ontario Provincial Standard Specifications for Municipal and Provincial contracts require that testing of materials be done in CCIL-certified labs. MTO requires that all their testing be done in CCIL (or equivalent) certified labs.
30. The lack of CCIL or equivalent certification places the City's lab at a disadvantage in relation to labs that are CCIL-certified, particularly in cases of disputes. In cases of disputes, testing is referred to an independent lab.
31. The City's Quality Assurance lab has a total of 7.98 FTEs, a 2011 budget of \$871,594, and anticipates recovering \$803,022 from the Capital Works program by way of services. The QA lab currently outsources up to 80% of the City's bulk asphalt testing and 100% of the structural concrete testing to certified laboratories.
32. In the absence of the former pavement engineer, or someone with similar qualifications, the City did not involve a consultant to assist with the pavement mix design and quality control issues, although it became clear after 2008 that the City staff did not have the required training and experience to be able to manage the results [for the City] of the new pavement technology.
33. Correspondence and other documentation provided by the City shows that the RMHMA was breaking up significantly and that leakage through the bridge deck had become a serious concern for the NAC parking garage, other users of the space under the bridge, and the bridge deck.
34. In 2009, the City decided to remove the RMHMA from the bus lanes, install a new waterproofing membrane and resurface using Superpave asphalt based on the

City's standard specifications. The 2009 contract in the amount of \$718,000 included approximately \$100,000 for bridge structural work as well as the cost of removing the RMHMA placed in 2008, concrete deck preparation, installation of waterproofing, and placing the new asphalt. This contract was tendered in accordance with the City's Purchasing By-law, using the City's standard tender documents format.

35. No spot milling and repaving is currently programmed in 2011 for the asphalt placed in 2009, but it is recognized that it will require annual spot milling and repaving, in a similar manner as the asphalt placed in 1998 needed maintenance a few years after being placed. Management has indicated that the 2011 program will only be confirmed after field verification as it is too early to confirm that no repairs will be undertaken in 2011.
36. The City is currently planning to undertake a study of alternative pavement and waterproofing options for the MKB, to determine what options may be available to resurface the bridge bus lanes to provide a stable, durable and appropriate solution to the asphalt rutting and shoving and leakage problems.
37. The various investigations and the peer review indicate that the RMHMA did not perform as intended. In October 2010, the City indicated that the matter had been referred to the City's Legal Services, with the intention of determining what legal recourse is available to the City for damages.

Legal Services were first consulted concerning a possible claim against the contractor or manufacturer in June of 2010. At that time, an initial expert report on the causes of the problems with the RMHMA was obtained and reviewed by Infrastructure Services. Subsequently, a second expert report was obtained in the form of a peer review of the first report. Management considers that currently the results are inconclusive. To preserve the City's legal rights, a claim was issued on March 1, 2011 in order to ensure that the limitation period did not expire. The claim has not been served pending the acquisition of an expert report (prior to mid-August 2011).

38. The consultant retained by the City to review the possible reasons for the failure of the RMHMA is headed in Ottawa by the former City Pavement Engineer. We consider that in cases where a project has had a problem, the City should not retain the engineer responsible for the original design to provide advice on the possible solutions to the problem. Management has stated that staff retained the former Pavement Engineer based on his unique skill set and in-depth knowledge of the file. An independent consultant conducted a peer review of the report completed by the former City staff member.

Recommendations and Management Responses

Recommendation 1

That the City modify its procedures to ensure that pavement work on structures be scoped with the specific agreement and approval by the Structures Section of Asset Management.

Management Response

Management agrees with this recommendation, and it has been implemented.

The Asset Management branch has documented procedures related to resurfacing on structures and associated approval processes. This information was provided to the auditor during the audit review process.

Recommendation 2

That the City modify its procedures to ensure that application of new technologies be preceded by a sufficiently detailed, tested and documented investigation of alternatives and costs, and that application receives specific management approval.

Management Response

Management agrees with this recommendation.

In May 2011, the General Manager, Infrastructure Services issued a departmental directive outlining requirements to be followed when piloting new technologies. Management will monitor amendments that may be required to further clarify the directive. The audit recommendation will be reflected in the next amendment, which is expected in Q4 2011.

Recommendation 3

That the City ensure that the specifications for application of new technologies be vetted by management in the same or more strict manner than the production of standard specifications.

Management Response

Management agrees with this recommendation.

In May 2011, the General Manager, Infrastructure Services issued a departmental directive outlining requirements to be followed when piloting new technologies. Management will monitor amendments that may be required to further clarify the directive. The audit recommendation will be reflected in the next amendment, which is expected in Q4 2011.

Recommendation 4

That the City modify its procedures when applying a new technology to ensure that all departments who will be involved in the implementation have proper training on the new technology.

Management Response

Management agrees with this recommendation.

In May 2011, the General Manager, Infrastructure Services issued a departmental directive outlining requirements to be followed when piloting new technologies. Management will monitor amendments that may be required to further clarify the directive. The audit recommendation will be reflected in the next amendment, which is expected in Q4 2011.

Recommendation 5

That the City ensure that the application of new technologies be preceded by a documented investigation of references, including an assessment of whether the referenced applications had similar conditions as those known or anticipated in the City's site.

Management Response

Management agrees with this recommendation.

In May 2011, the General Manager, Infrastructure Services issued a departmental directive outlining requirements to be followed when piloting new technologies. Management will monitor amendments that may be required to further clarify the directive. The audit recommendation will be reflected in the next amendment, which is expected in Q4 2011.

Recommendation 6

That the City modify its procedures to include all major rehabilitation work on structures, including major resurfacing work, in its guidelines for renewal options.

Management Response

Management agrees with this recommendation, and it has been implemented.

This requirement has already been reflected in the Asset Management branch's Structures Best Practice Guide.

Recommendation 7

That the City review its requirement for a Quality Assurance lab, including staff requirements.

Management Response

Management agrees with this recommendation.

The services provided by the Quality Assurance section have been previously reviewed with a change in focus from a high dependence on materials testing towards specialty services. A further review will be conducted regarding the lab testing services. This review will be completed by Q3 2012.

Recommendation 8

That the City develop guidelines for the engagement of consultants to assist with unusual or new situations in construction projects where the required expertise or experience is not available within the City.

Management Response

Management agrees with this recommendation.

This is consistent with the procurement processes already in place through the Standing Offer, Request for Qualification and Request for Proposal processes.

Recommendation 9

That the City modify its procedures for situations in which projects have presented problems to ensure that the reviewing engineer is different from the design engineer; and that this procedure applies to both individual engineers and engineering firms.

Management Response

Management agrees with this recommendation.

For future projects that require further review or investigation after project completion, the engineering firm and engineer assigned for review will be different than the firm/engineer who originally undertook the work. This will be reflected in a departmental directive by Q4 2011.

Recommendation 10

That the City modify its procedures so that in cases where a project is found to have a design problem, the City retain an engineer different from the one responsible for the original design to provide advice on the possible solutions to the problem.

Management Response

Management agrees with this recommendation.

For future projects that require further review or investigation after project completion, the engineering firm and engineer assigned for review will be different than the firm/engineer who originally undertook the work. This will be reflected in a departmental directive by Q4 2011.

Recommendation 11

That the City request Legal Services to consider recovering the costs associated with both the 2008 and 2009 resurfacing contracts.

Management Response

Management agrees with this recommendation, and it has been implemented.

As acknowledged in the audit report, this has already been initiated. The contract information was submitted to Legal Services prior to the date the audit was initiated. Management considers that no further action by Infrastructure Services is required.

Conclusion

The Mackenzie King Bridge is part of the OC Transpo Central Transitway, with large volume of bus traffic, operating at slow speeds and making frequent starts and stops. The MKB is also part of the NAC parking garage where leakage has been a chronic problem. These are onerous conditions on the pavement, and the City has had to mill and repave portions of the bridge annually due to deformation such as rutting and shoving in the most severe portions. A 2004 study of options for pavement rehabilitation concluded that annual pavement repairs were the most economical solution: spend an average of \$33,000 (2004\$) annually for 30 years, mill and repave the entire surface course every 15 years at an estimated cost of \$169,400, including engineering (2004\$), and replace the waterproofing and asphalt every 30 years at an estimated cost of \$621,500, including engineering (2004\$). The City could have continued to spend \$33,000 until 2019. It is noted that the assumptions in the 2004 report were vetted by the City.

Although the 2004 report was vetted by senior engineers, management now states that the bridge was renewed in 1998 and that it would be unreasonable to expect that it would be another 15 years beyond 2004 before resurfacing would be required. Management indicates that because of the frequent repairs and the fact that shortly after the repairs were done the pavement started showing signs of failure, staff worked collaboratively to find an innovative solution; based on the history of the bridge, its unique challenges and the premature pavement failures, staff concluded that the 2004 plan warranted a different approach.

The decision to remove the waterproofing and asphalt, and repave using Rosphalt modified hot mix asphalt did not heed the previous study result, was made without

Audit of the Mackenzie King Bridge Rehabilitation

proper design and testing, and without following alternative evaluation methods that were formalized in the guidelines for structure renewal. Management indicates that the decision was made in consultation with affected parties, including the Structures section, and recognizing the complexities of this structure to address both rutting and leakage issues. The total cost of removing the waterproofing on the bus lanes for the entire length of the bridge and repaving using Rosphalt 50 modified hot mix asphalt was \$625,000 in 2008.

The decision to remove the badly damaged Rosphalt modified hot mix asphalt and repaving using conventional waterproofing and asphalt appears to be justified based on the amount of damage to the RMHMA and the leakage to the NAC parking garage. The cost of this work in 2009 was \$718,000, including approximately \$100,000 in structural bridge work that was coordinated with the resurfacing contract.

A portion of the cost of the 2008 and 2009 repaving contracts (a total of \$1,243,000) could have been avoided if the City had continued with the program of milling and repaving only those sections of the bridge pavement requiring repair in accordance with the recommendations of the 2004 Pavement Rehabilitation Report. It is expected that the annual spot milling and repaving will need to resume within a few years, as the asphalt placed in 2009 will require maintenance. This strategy did not address the leakage concerns in the NAC parking garage, which the 2005 report concluded originated from sources other than infiltration through the bridge deck.

Acknowledgement

We wish to express our appreciation for the cooperation and assistance afforded the audit team by management.

The section that follows is the detailed audit report.

Detailed Audit Report

1.1 Introduction

The Audit of the Mackenzie King Bridge Rehabilitation was undertaken as a result of a Fraud and Waste Hotline report, dated September 10, 2010, received from a member of the public.

1.2 Background

The Office of the Auditor General (OAG) carried out a preliminary assessment to examine the documentation relating to design and construction of the Mackenzie King Bridge rehabilitation.

Based on the findings of the Preliminary Assessment Report, the OAG decided to carry out an audit of the 2007 and 2009 Mackenzie King Bridge paving contracts.

1.2.1 Bridge Characteristics

The Mackenzie King Bridge (MKB) was constructed in 1950, and was transferred to the Regional Municipality of Ottawa-Carleton in 1996. It is owned by the City of Ottawa.

The bridge is 575 m long and carries four lanes of traffic between Nicholas Street in the east and Elgin Street in the west. The structure also has two sidewalks and a raised median. The bridge spans the Rideau Canal, Colonel By and Queen Elizabeth Drives, and several parking structures. The bridge is located over the National Arts Centre, Rideau Centre, and Department of National Defence.

The bridge consists of four structures: The National Arts Centre (NAC) structure, the Rideau Canal structure, the Steel Viaduct structure, and the Nicholas Street structure.

The two outside lanes of the bridge form part of the Central Transitway, and are used exclusively by buses. The two inside lanes are used by other vehicles. Because of the location of the bridge within the Transitway, the bus traffic on the bridge operates at low speeds, with numerous stops and starts. In addition, the bridge rises from its approaches to the centre of the bridge; this means that a large part of the bus stop and start operations occur on a down slope.

The City undertook a major rehabilitation of the bridge in 1998. The rehabilitation included repairs to the deck surface, application of hot applied rubberized asphalt waterproofing and placement of a high performance hot mix asphalt. It is reported that by 2004 repairs had been constructed in the eastbound and westbound bus lanes, with performance graded and stone mastic asphalts; the original waterproofing membrane was maintained.

Experience with the pavement of the bridge is that the City has had to carry out repairs to the asphalt at the bus stops and turns rather frequently. Information provided by the City indicates the work was done on this bridge every year from 2004 to 2007, at an estimated average cost of \$33,000 per occurrence.

The City has indicated that the asphalt and waterproofing on other bridges having normal vehicle distributions (i.e., combination of cars, buses, and trucks) at normal operating speeds do not present the same problems as the MKB and also tend to require much lower frequency maintenance. Asphalt in those bridges tends to last longer than 5 years and in many cases up to 12 years before requiring rehabilitation.

1.2.2 Bridge Investigations

The City provided the reports regarding the Mackenzie King Bridge pavement and leakage problems, as listed below:

- A) Mackenzie King Bridge (Structure No. 220) Pavement Rehabilitation, Investigation and Recommended Rehabilitation Report, McCormick Rankin Corporation, July 2004
- B) Mackenzie King Bridge (Structure No. 220) Investigation of NAC Parking Garage Structure, McCormick Rankin Corporation, February 2006
- C) Mackenzie King Bridge NAC Parking Garage Ceiling, Investigation Report, LG Building Group Inc., November 2008 (for the National Arts Centre)
- D) Mackenzie King Bridge (Structure No. 012200) NAC Structure Condition Assessment, McCormick Rankin Corporation, May 2009
- E) Mackenzie King Bridge Steel Viaduct Structure (Structure No. 012200-3) Deck Underside and Expansion Joint Investigations Report, McCormick Rankin Corporation, October 2010

The following report was also provided by the City, as it provides the results of a forensic evaluation conducted in 2009 to determine the possible cause for the premature failure of the RMHMA.

- F) Forensic Evaluation Rosphalt (Asphalt) Mix on Mackenzie King Bridge, AME Materials Engineering, January 2010

The following paragraphs provide a brief summary of each report listed above:

- A) Mackenzie King Bridge (Structure No. 220) Pavement Rehabilitation, Investigation and Recommended Rehabilitation Report, McCormick Rankin Corporation, July 2004

Audit of the Mackenzie King Bridge Rehabilitation

The report was commissioned as a result of the deterioration of the asphalt wearing surface of the bridge. The study included a visual inspection, sawn asphalt samples, and examination of rehabilitation alternatives. The alternatives examined included maintaining the existing waterproofing and milling and paving annually; placing a concrete overlay of either 20 or 30 year service life; and combinations of the three alternatives.

The report recommended, based on life cycle cost financial analysis of the alternatives, to continue to mill and pave annually at an annual estimated cost of \$33,000 (2004\$), replace the entire surface course every 15 years at an estimated cost of \$169,400, including engineering (2004\$), and replace the waterproofing and asphalt every 30 years at an estimated cost of \$621,500, including engineering (2004\$).

The report notes that the conclusions are based on annual repairs being required in the critical areas and a service life of 30 years for the existing waterproofing.

B) Mackenzie King Bridge (Structure No. 220) Investigation of NAC Parking Garage Structure, McCormick Rankin Corporation, February 2006

This investigation started in June 2005 due to infiltration of water into the NAC parking garage. As reported by NAC staff infiltration was occurring primarily in the mechanical room, the parking garage entrance on Elgin Street and the archives vault. MRC undertook visual examination of the asphalt drains, expansion joints, plus a limited sawn asphalt sampling adjacent to the expansion joints.

The investigation of asphalt drains that could be inspected (several asphalt drains were located within secure areas of NAC) disclosed that 4 of 11 drains were clogged with salt, debris and/or asphalt. The consultant recommended clean-out of the four asphalt drains and inspection by the City of the drains located within secure areas of the NAC.

Expansion joints observations indicated that infiltration occurred at the transverse expansion joints; along the longitudinal expansion joints no leakage was observed, although there was evidence of past leakage. The seals were water tested and no leakage was observed. The bond between the waterproofing, asphalt, armouring and concrete deck was determined using sawn asphalt samples; in general the bond was found to be good, with the bond being partially compromised in some locations, but intact above the construction joint between the deck and the expansion joint dam.

Inspection of the deck drains located over the existing roof slab and the sidewalks constructed in 1998 disclosed standing water in the two drains that could be inspected. The City flushed out the drains. The report indicates that four drains were plugged in the north sidewalk; three drains were cleaned, but the fourth one was found capped, so it does not drain.

The caulking between the north sidewalk and the NAC building was found to be badly deteriorated. NAC recaulked the areas in October 2005.

At the Elgin Street entrance to the NAC parking garage, the sidewalk and decorative planters built in 1998 were considered a potential source of water, in particular at the transverse beam at the entrance to the parking garage. Water leaked through the vertical construction joint on the south side of the entrance. Remedial work was carried out in October 2005, and it appears that the leakage was reduced substantially.

The report concluded that most of the leakage had been occurring due to lack of maintenance by NAC. The report recommended that the caulking between the bridge and the NAC building be inspected and repaired as required. The report recommended that the waterproofing over the expansion joint dam and deck construction joint be replaced before 2008.

C) Mackenzie King Bridge NAC Parking Garage Ceiling, Investigation Report, LG Building Group Inc., November 2008 (for the National Arts Centre)

The report documents a detailed site investigation of the MKB NAC parking garage building envelope, commissioned by the NAC Operations Group. The report contains a photographic record of leakage from the MKB into the NAC parking garage and makes the following points:

1. The total area of the NAC parking garage is 374,800 square feet (34,820 m²), of which 111,800 sq. ft. (10,387 m²) are located immediately beneath roadways or sidewalks maintained by the City of Ottawa. This includes a large portion of Garage Level 1, Trucking Lane, Main Transformer Vault, Emergency Generator Room, Archive Storage, Mechanical Rooms, and General Storage Rooms.
2. In February 2007 the structure above the main hydro vault was found leaking significantly, following roadwork on the MKB. Other areas affected include the Archive storage room and the slab in Garage 2. The NAC installed a temporary waterproofing structure over the electrical transformers. LG indicates that at the time the roadway waterproofing had not been repaired by the City.
3. Leakage problems have occurred for many years. Some areas that had been repaired have failed again.
4. The impact of leakage through the MKB into the building has affected the lowest level of the parking garage.
5. Sheet metal drain pans and gutters have been installed to prevent closure of affected parking spaces.

Audit of the Mackenzie King Bridge Rehabilitation

6. Expansion joints are a particular area of concern due to the volume of water that discharges through them.
7. The leakage has affected fire protection piping, electrical conduits, natural gas piping and duct work. Public Works and Government Services Canada central plant steam and chilled water piping system is routed via the NAC.
8. The report notes that the Bridge Transfer Agreement 1996 states that the responsibility for maintaining the roadways above the NAC parking garage structure rests with the City of Ottawa.

D) Mackenzie King Bridge (Structure No. 012200) NAC Structure Condition Assessment, McCormick Rankin Corporation, May 2009

The report indicates that the entire structure underwent a major rehabilitation in 1996, which included repair of the deck surface, installation of new expansion joints, and installation of waterproofing and paving of the wearing surface. The report states that the wearing surface was rehabilitated in 2006.

The report states that the structure is generally in good condition, but some locations have advanced deterioration. The report provides a list of these locations.

The report recommended the following repairs: Repair the deteriorated concrete soffit; patch, waterproof, and pave the Slater and Albert Street ramps; grout and seal abandoned utility ducts; repair deteriorated columns; repair the beam at the north end of Elgin Street sidewalk; repair deteriorated end dams at the north expansion joint; remove and replace the sealant at the sidewalk/building interface of the north sidewalk; route and seal with hot poured rubberized asphalt full depth the asphalt adjacent to the expansion joint dams and sidewalk curb interfaces at specified locations; and inspect and clean the sidewalk deck drains and asphalt drains.

In addition to the recommended repairs, the report recommended a number of investigations to confirm the extent of deterioration, possible structural deficiencies, construction constraints, and temporary support requirements for the repairs.

E) Mackenzie King Bridge Steel Viaduct Structure (Structure No. 012200-3) Deck Underside and Expansion Joint Investigations Report, McCormick Rankin Corporation, October 2010

The report addresses the Steel Viaduct structure over the Rideau Centre. The scope of the report addressed the deck underside, the longitudinal and transverse expansion joints at locations of reported leakage within the Rideau Centre and the entrance to the DND.

The report presents three alternatives, based on different timing for the bridge renewal work. The report indicates that the major structure renewal is scheduled by the City for the period 2017 to 2020.

F) Forensic Evaluation Rosphalt (Asphalt) Mix on Mackenzie King Bridge, AME
Materials Engineering, January 2010

The report was commissioned to conduct a forensic evaluation of the August 2008 resurfacing with RMHMA, to determine the likely cause or causes for the premature failure of the RMHMA, and to provide documentation for a potential claim against the contractor and the supplier.

The principal findings of the report are:

1. The RMHMA mix design diverged from the specified mix in several aspects:
 - a) The City specified a 12.5mm Stone Mastic Asphalt (SMA) with PG 70-34 asphalt cement, modified with Rosphalt. The Contractor proposed a 12.5mm dense-graded surface HMA mix, which was the one placed.
 - b) The number of gyrations used for the design is lower than the 125 gyrations specified in OPSS 1151 for a Level E mixture.
 - c) The asphalt cement was specified as PG 70-34, but the mix design used was 58-34. There was no documentation for the change.
2. The hydraulic conductivity of the mix was a factor of 100 times too high in relation to that for the adjacent pavement, and over 10,000 times higher than the advertised value.
3. The RMHMA was not bonded to the concrete deck and the samples could be removed readily. Examination of the samples in the lab showed little to no bituminous coating within the bottom of the sample.
4. The distress observed in the form of alligator cracking within the bus wheel paths is most likely the result of loss of bond between the RMHMA and the concrete deck.
5. The lack of bond could be the result of one or more of the following: overheating of the tack coat during construction; the concrete surface was not properly prepared prior to placing the tack coat; and moisture susceptibility of the RMHMA may have increased through overheating as the asphalt cement may have been over-oxidized.
6. Investigations subsequent to this report disclosed that the silt found at the base of the RMHMA has the characteristics of Portland cement.

1.2.3 Rosphalt 50 Technical Information

Rosphalt is a polymeric asphalt additive, manufactured by Royston Industries, a division of Chase Construction Products. The Rosphalt asphalt additive is applied to the hot mix asphalt (HMA) during the production of the asphalt concrete. In this audit, Rosphalt modified hot mix asphalt will be referred to as RMHMA.

According to Royston's marketing and product information, Rosphalt 50 is a dry mix asphalt additive that provides a waterproof wearing surface that will not rut or shove. The product information states that RMHMA is used as a single-system waterproofing and wearing course for bridge decks, in contrast with conventional asphalt and waterproofing installations, which consist of a waterproofing membrane placed on the bridge deck, covered with backer-board protection, covered with hot mix asphalt. The Rosphalt additive is intended to reduce the permeability of the HMA, eliminating the need to place a waterproofing membrane and protection board.

1.2.4 Resurfacing Contracts

This audit addresses two related resurfacing contracts for the Mackenzie King Bridge: The first one is a 2007 contract which was constructed in 2008; the second one was a resurfacing contract done in 2009 that also included emergency repairs to the bridge.

In 2007, in an attempt to control the extent of shoving and rutting of the asphalt pavement on the MKB, the City decided to place Rosphalt modified hot mix asphalt (RMHMA) directly on the MKB concrete deck, without a waterproofing membrane.

The resurfacing of the MKB with RMHMA was added in October 2007 to Contract ISB07-5010, but due to a number of factors the City postponed construction of the MKB resurfacing until the summer of 2008. Construction was done the weekends of August 17 and September 11, 2008.

Leakage into the National Arts Center garage reportedly started right after the RMHMA was placed, and the RMHMA started showing distress in the form of rutting, shoving and potholes by December 2008. The contractor repaired the potholes as part of the contract warranty.

Given the poor condition of the RMHMA and the extent of leakage to the facilities located under the bridge, in particular the National Arts Center parking garage in July 2009, the City decided to remove the RMHMA and replace it completely. The 2009 contract comprised resurfacing of the bus lanes on the bridge and emergency repairs to the segment of the bridge located over the NAC parking garage. The 2009 contract was completed in the fall of 2009.

At the time of the two contracts in 2007 and 2009, the City organization structure was different than at present. The Infrastructure Services Branch was divided into

Infrastructure Management and Construction Services (West, East and Development). The responsibility for assessing the road resurfacing and structure renewal needs was part of Infrastructure Management. Infrastructure Assessment & Program Development - Transportation had responsibility for road rehabilitation needs, while structure renewal needs was the responsibility of Infrastructure Assessment & Program Development - Structures. Construction Services became involved for implementation of the required works, based on the scope defined by Infrastructure Management.

2007 Contract

In 2007 the City had issued Contract No. ISB07-5010 for Asphaltic Overlay on the Transitway System. This contract included several segments of the West, Central, East, and Southeast Transitway, as well as the Lower Billings Bridge Station, Maintenance Access Road, Greenboro Park and Ride Lot, Eagleson Park and Ride East, and the Upper Queensway Woodroffe Station. The contract included patching on the Mackenzie King Bridge, but did not include resurfacing of the bridge.

The City believes that the most probable reason the asphalt on the MKB deteriorates more rapidly than in other applications is that the asphalt and waterproofing interface allows the asphalt to slide, thereby resulting in rutting and shoving of the asphalt. In 2006, the City had removed the waterproofing membrane and applied Stone Mastic Asphalt (SMA) directly on the bridge deck in some parts of the bridge near Elgin Street, but found that this allowed leakage to the areas below the bridge, specifically the NAC parking garage.

In September 2007, the Pavements Unit (part of Infrastructure Assessment & Program Development - Transportation) at the City started considering the use of Rosphalt, to improve the maintenance periods for the MKB. Initially the City intended to apply the Rosphalt-modified hot mix asphalt (RMHMA) in place of the standard hot-mix asphalt used by the City together with a waterproofing membrane. It is not clear why, but in the end, the City decided to place the RMHMA directly on the MKB concrete deck, without a waterproofing membrane.

The City requested quotations for the work on the MKB from three contractors, including the contractor who was undertaking the work for contract No. ISB07-5010. The City received two quotations, the lowest of which was from the contractor for Contract No. ISB07-5010. The MKB resurfacing was carried out as a Purchase Order to this contract, authorized as emergency work. However, due to the time of the year and the weather (late November 2007), the City postponed construction until the summer of 2008.

According to the Guideline for Rosphalt 50 System, the mix design is done by Royston. Based on information provided in the City files, Royston prepared the mix design. The

Audit of the Mackenzie King Bridge Rehabilitation

contractor did design trials for the Rosphalt 50 mix design and submitted them to the City for acceptance of the mix design.

Construction was done the weekends of August 17 and September 11, 2008. According to City information, Royston had an inspector on site full-time during construction and another inspector at the asphalt plant. The City also provided full-time inspection.

The NAC reported leakage into their parking garage right after the RMHMA was placed (according to NAC, the seepage was black leakage). The Rosphalt-modified hot mix asphalt started showing distress in the form of rutting, shoving and potholes by December 2008. The City informed the contractor that potholes and other defects were to be fixed and corrected by the contractor as part of the contract warranty. The contractor requested representatives of Royston to help investigate the possible reasons for the premature failure of the Rosphalt modified hot mix asphalt.

The contractor repaired the potholes as part of the contract warranty during 2009; however, by the late summer the number of potholes was over 40, necessitating that the bridge be repaired in its entirety. It is noted that at one point the contractor abandoned the contract, but returned to the site shortly thereafter.

2009 Contract

Investigation work done by a consultant on behalf of the City in July 2009 showed that the RMHMA placed in late summer 2008 had a number of serious defects, including that the RMHMA was not bonded to the bridge's concrete deck and that the permeability of the RMHMA, marketed to be over 10,000 times less than that of normal HMA, was in fact about 100 times greater. There were over 40 potholes on the bus lanes by the end of the summer of 2009.

Given the poor condition of the RMHMA and the extent of leakage to the facilities located under the bridge, in particular the National Arts Center parking garage, the City decided to remove the RMHMA and replace it completely.

Infrastructure Management (now Asset Management) was involved in the investigation of options to repair the asphalt on the MKB, and noted during the investigations that the bridge was scheduled for renewal in the next five years. (It is noted that this has changed now to renewal in 5 to 10 years, with 2020 the expected renewal year). IM considered moving the bridge renewal to coincide with the asphalt rehabilitation. IM suggested that they would like to examine other options, including the use of a concrete overlay. In any case, IM requested Construction Services that the bridge be provided with a waterproofing membrane.

The design assignment was given to a consultant who was already carrying out design of a temporary leakage collection system to prevent leakage to the NAC parking garage and utility room (Report C in Section 1.2.2).

The 2009 contract was carried out as emergency repairs, and was completed in the fall of 2009.

1.3 Audit Scope

The scope of the audit comprised the maintenance procedure for the Mackenzie King Bridge, including the resurfacing and superstructure maintenance. The audit examined the scheduling of asphalt rehabilitation contracts for the bridge, the alternative solutions examined and the procedures used for selection of asphalt rehabilitation methods, including coordination with the structure renewal procedures.

The audit examined the investigations done by the City to resolve the problem of rutting and shoving of the asphalt and leakage into the NAC garage resulting in a need for a strategy that could deal with both; and the use of Rosphalt modified hot mix asphalt placed directly on the bridge concrete deck, including an assessment of this practice as a reasonable practice.

The audit encompassed the following tasks:

- Obtain and review all files for the project, as provided by the City
- Review background data on the bridge and Rosphalt
- Review the City's policies, procedures, standards and practices
- Review industry procedures, standards and practices
- Conduct interviews with individuals involved in the 2007 and 2009 contracts and those responsible for inspection and maintenance of the bridge
- Conduct a site visit

1.3.1 Review Project Files

The audit began by reviewing the files and reports for the project, provided by the City. Collection and review of the background information were undertaken in light of the Audit Objectives and Criteria.

1.3.2 Review Background Data

Background data available from the City was collected and reviewed. In general terms this included the structure inspection sheets, condition reports, reports, preliminary and detailed design, tender documents, construction administration files, construction inspection data and quality assurance data.

Audit of the Mackenzie King Bridge Rehabilitation

Data on the hot mix design procedures, testing, verification, quality assurance procedures, and inspection was examined in detail.

Information on asphalt and waterproofing systems used in the Province of Ontario was searched and reviewed, including the use of Rosphalt by the Ministry of Transportation and municipalities. Information on the use of Rosphalt additive and waterproofing protection methods was also obtained and reviewed.

Information on the forensic investigation carried out by the City in 2009, including testing data done by the contractor was also reviewed.

1.3.3 Review City Standards and Practices

Pertinent City's policies, procedures, standards, and practices were examined and reviewed, including:

- Guidelines for Infrastructure Renewal Options Analysis, December 2007;
- Project Manager's Procedures Manual, 2006;
- Inspection Manual for City's Construction Contracts, May 2003;
- Standard Tender Documents for Unit Price Contracts, Volumes No. 1 and 2; and,
- Ontario Provincial Standard Specifications, included by reference in the Standard Tender Documents.

1.3.4 Interviews

Interviews were held with City staff involved in the Mackenzie King Bridge resurfacing contracts, including department managers, program managers, project managers, and quality assurance engineers.

1.3.5 Site Visit

A site visit was conducted to become familiar with the bridge and its surroundings. It is important to note that the audit did not include a physical inspection of the structure and the condition of the structure was not confirmed during the audit.

This section can list each objective of the audit in a paragraph form, followed by the criteria in a bulleted list.

1.4 Audit Objectives

On the basis of the information gathered during the preliminary assessment, and the corresponding analysis of that information, the scope of the audit was synthesized in the Audit Objectives. The Criteria attached to each Audit Objective explain the scope of the review. The Audit Objectives and Criteria were presented in the Audit Plan, which was reviewed by management.

Audit Objective No. 1:

Examine the asphalt rehabilitation procedures used by the City for the Mackenzie King Bridge.

Criteria:

- Coordination of asphalt contracts with other structure renewal planning
- Input by Infrastructure Management structure specialists
- Asphalt rehabilitation procedures used in other structures, as background for procedures used in this bridge
- Use of waterproofing membrane in Ontario
- Comparison with other jurisdictions

Audit Objective No. 2

Examine and evaluate the studies, processes and methodologies used by the City to select the asphalt rehabilitation methods, including the selection of Rosphalt modified hot mix asphalt placed without waterproofing membrane.

Criteria:

- Pavement design criteria and procedures
- Mix design specifications, including selection of asphalt cement
- Mix design testing and verification, including inspection and testing
- Comparison with other methodologies
- Checking of Rosphalt references
- Testing

Audit Objective No. 3

Examine the scheduling of contracts for pavement rehabilitation, including coordination of work with structure renewal requirements.

Criteria:

- Program coordination with Infrastructure Management
- Timing of contract preparation in light of inspection results
- Frequency of resurfacing required
- Scheduling of design meetings

Audit Objective No. 4

Examine the qualifications of City staff and testing laboratory, and the use of consultants used to provide advice on the pavement rehabilitation.

Criteria:

- Review City staff qualifications in relation to complexity of decisions required
- Capabilities and certifications of City materials testing laboratory
- Review methodology used to decide between in-house vs. consultant design
- Review the involvement of pavement specialists on the project

1.5 Findings

This section of the audit report has been organized to address the Audit Objectives and Criteria, which are repeated here for convenience of the reader.

1.5.1 Audit Objective No. 1:

Examine the asphalt rehabilitation procedures used by the City for the Mackenzie King Bridge.

Criteria:

- Coordination of asphalt contracts with other structure renewal planning
- Input by Infrastructure Management structure specialists
- Asphalt rehabilitation procedures used in other structures, as background for procedures used in this bridge
- Use of waterproofing membrane in Ontario
- Comparison with other jurisdictions

1.5.1.1 Coordination of Asphalt Contracts and Structure Renewal Planning

The original 2007 contract ISB07-5010 Construction of Asphaltic Overlay on Transitway System was prepared in May 2007 or earlier. Review of the Tender documents indicates that the City envisioned work in the Central Transitway from Bronson Avenue to Waller Street. The work covered the MKB and Albert Street and Slater Street from Bronson Avenue to Elgin Street, a distance of about 3.8 km. The contract work for the Central Transitway comprised dry grinding of 4000 m² of asphalt (non-continuous), and resurfacing using 500 t of Performance Graded Superpave 12.5mm FC2 Level D (PG 70-28) hot mix asphalt, machined laid and also non-continuous. The City issued the Order to Commence work on July 19, 2007, for work to start on July 30, 2007 over 30 working days.

The City has indicated that the asphaltic overlay contracts are normally based on inspections carried out in the fall of the previous year, when the Roadway Rehabilitation Section, Asset Management Branch, Infrastructure Services Department, determines what roadways required rehabilitation. Tender documents are normally prepared over

the winter and the tender is issued in the late winter (March). The contract is awarded in the spring, for construction in the summer.

The asphalt overlay projects are scoped by the Roadway Rehabilitation Section, Asset Management, who provides Design and Construction Municipal the contract requirements; DCM prepares the contract documents. The project scoping is done by patrolling during the year to identify areas of concern for repair during the following year. The list of road pavement renewals are circulated to Structures during the preliminary needs circulation. If there are no structural renewal needs anticipated for the next five years and repaving of the structure is warranted, the resurfacing of the structure will be included in the scope of the Roads resurfacing project.

Where the structure requires repairs or is scheduled for renewal, the Structures Section manages the project scoping and provides it to DCM for implementation.

During the audit, the City provided a document titled "*Coordination of Resurfacing of Bridge Decks between AMB - Structures and Roads*", which summarizes the current practice within Asset Management Branch. The document states that structure resurfacing renewal needs are identified during routine inspections of the pavements by the Transportation Unit of AMB.

1. Structure Resurfacing Triggered by Structural Renewal Needs

The document states that when a structural renewal is required that involves resurfacing of a bridge deck; the resurfacing is included in the Structures section of the annual Capital Budget. Coordination involves sharing the list of structures proposed for renewal with Roads during preliminary Needs Circulation and during Budget preparation; checking the structures projects vs. other planned capital works projects; ensuring that the Structures' Scoping Document that is sent to Design and Construction staff requires the Project Manager to coordinate current and future Roads needs; circulating the project (project circulation process); assisting DCM Project Manager during design and tendering phase.

2. Structure Resurfacing Triggered by Road Resurfacing Needs

The document states that when road pavement renewal is identified independently of the structure renewal, the proposed list of road sections for resurfacing and reconstruction is provided to Structures and other staff in the preliminary Needs circulation and during Budget preparation. Roads and Structures discuss the need of resurfacing bridge decks; generally if there are no structure renewal needs and repaving is warranted, the resurfacing is included in the Roads resurfacing project. The Roads Scoping Document sent to DCM identifies the structures that require resurfacing, and identifies the pavement rehabilitation strategy, with input from Structures.

3. Structure Resurfacing on Transitway System

The document states that resurfacing needs on the Transitway are determined by the transit operational needs. Generally pavements on the Transitway last less than on other roads. Minor pavement surface repairs (e.g., spot patching or asphalt padding) are done by Public Works, until maintenance is no longer feasible and resurfacing is required.

In our opinion, the process for coordination is reasonable. However, we consider that all work on structures, including resurfacing of the structure's deck when no structure renewal, should be under the direction of a Project Manager with the appropriate bridge structure knowledge to oversee the delivery of the project. Resurfacing methods should be approved by the Structures Section of Asset Management.

The basis for this opinion, as described in the sections that follow, is that the decisions made by the former pavement engineer responsible for designing the bridge resurfacing in 2006 and 2007 appear to have been focussed on obtaining a pavement surface that did not rut or shove; these were not necessarily in the best interest of the structure.

Management has indicated that the decisions made regarding the resurfacing of the MKB were done in a consultative manner with all affected parties involved, including the Structures section. The fact that documentation is not extensive should not imply that decisions were made unilaterally and without due regard for the City's infrastructure. In fact, Section 1.5.1.2 acknowledges the collaborative work done in trying to find a solution to both the rutting and leakage problems.

In addition, we found that the selection of the resurfacing in 2007 did not follow a process similar to that in the Guidelines for Structure Renewal Analysis (which were issued in December 2007) prepared by Infrastructure Services, although the anticipated cost was nearly \$500,000 and the resurfacing methodology proposed was completely new to the City, and diverged very far from the standard procedures used by the City for protection of its structures.

1.5.1.2 Input by Infrastructure Management Structure Specialists

Review of the email and other correspondence provided by the City indicates that the leakage problems in the bridge have been occurring since at least early 2004, and that the Structures Specialists were involved in the assessments of the possible causes. Correspondence up to March 2006 show that both Pavements and Structures were involved in trying to resolve the leakage problems under the bridge, and the rutting and shoving problem of the pavement on the bridge.

In 2004, the Structures section retained a consultant to undertake an investigation of Pavement Rehabilitation and to recommend a rehabilitation strategy. The study report

recommended that the City continue with annual milling and repaving for the next 20 years, as it is the most economical pavement maintenance solution. It is not clear whether the Pavement Section took this report into account in the eventual selection of the RMHMA in 2007, but it would appear that it did not, likely because they were not aware of the report.

Management has indicated that the Structures section was aware of the 2004 report. The Structures section was also involved in discussions with the pavement engineer on options related to the pavement rehabilitation strategy for MKB. Therefore, management is of the opinion that the Pavement Section was aware of the report.

During the summer of 2005 a consultant retained by the Structures section investigated the leakage problems of the MKB section over the NAC parking garage. There are no communications in the files regarding this report addressed from Structures to Pavements.

Communication in October 2005 as a result of patching done earlier that month indicates that the patches done by the Operations Group used a hot mix that was not appropriate for the bus loads. The email is the first time that the waterproofing membrane acting as a slip plane is mentioned as the primary reason for the shoving and rutting of the pavement on the bridge, and it is mentioned by the former pavement engineer.

In November and December 2006 the City milled and repaved the eastbound and westbound bus lanes at Elgin Street; during this work the waterproofing membrane was removed from the deck in the vicinity of Elgin Street, in a segment of the bridge located above the NAC parking garage. The correspondence indicates that the City envisioned the removal of the bridge deck waterproofing as a temporary measure to address the severe rutting on the bridge. The available correspondence does not include any information on this decision, but it would appear to have been driven by the Pavements unit, without approval by the Structures Section of Infrastructure Assessment. Leakage through the deck appeared as a problem almost immediately after the work was completed.

Communications between the Pavement and Structures Sections to address possible ways of resolving the shoving and rutting problem and the leakage problem began in February 2007. The correspondence indicates that there was communication between Pavement and Structures during the review of the possible solutions for the rutting and shoving of the asphalt on the bridge in 2007 in the early part of the year (February 2007) and after August 2007, but there is no record of any communications in the interim.

Audit of the Mackenzie King Bridge Rehabilitation

During September 2007, the Design and Construction group recommended to the former pavement engineer that the resurfacing of the MKB be managed by the Structures Rehabilitation group in Construction Services. The Pavement Section referred the project to the Construction Services Structures Rehabilitation group, who agreed with the Pavement Section to use the Rosphalt modifier without waterproofing membrane for resurfacing the bridge. There is no documentation on file to indicate that these decisions were discussed with Infrastructure Assessment - Structures within the Infrastructure Management group. Management has indicated that in determining the recommended course of action, all affected groups were consulted and at no point did one group escalate a concern that they could not support the proposed direction.

In communications between Pavement Section and the Construction Services Structure Rehabilitation section the Pavement Section explains that they continue to struggle with keeping asphalt on MKB with existing waterproofing system, that in 2006 removed waterproofing in worst areas right to concrete deck and paved using SMA; that the approach worked, the asphalt remained stable, but there is leakage in the NAC electrical room that Structures attribute to the removal of the waterproofing; that assuming that this is true, it is necessary to use a different waterproofing that does not need protection board; that they believe that the protection board is slipping and taking the asphalt with it; that the resurfacing in 2006 confirmed this, but need waterproofing to prevent leakage. Options include the Eliminator System (spray on system) which does not require protection board and an additive that can reduce permeability of the mix [Rosphalt]. The Pavement Section indicates that using both systems is appropriate given importance of project. There is no further discussion of options.

By September 19, 2007, the Structure Rehabilitation section of Construction Services agreed with Pavement Section to remove the existing waterproofing and asphalt, and place Rosphalt modified hot mix asphalt directly on the MKB concrete deck, without a waterproofing membrane. We did not find correspondence to indicate that this decision was discussed with the Structures Section in Infrastructure Management (now Asset Management). It is not clear how it was determined that removing the waterproofing membrane was the best option.

On September 26, 2007 the Design and Construction Road Rehabilitation section asked for a quotation from the contractor who was undertaking the Transitway Resurfacing contract. Upon receipt of the quotation, the Road Rehabilitation section suggested that tenders should be called, given the estimated cost of \$493,000 plus taxes. However, thereafter the City requested quotations from this contractor and two others, and received two quotations.

Management indicated that Article 23 of the Purchasing By-law, Special Circumstance Purchases, delegates authority to the Director, or Deputy City Manager, as appropriate,

to authorize the purchase of construction as is considered necessary to remedy the special circumstance without regards to the requirement for a bid solicitation. In this instance, the Department opted to solicit quotations and award the contract to the lowest responsive bidder. This is considered preferable to a non-competitive contract award, which is permitted under Article 23, as pricing was provided in a competitive, although informal, environment. Moreover, the award to the lowest responsive bidder was approved in accordance with the Purchasing By-Law.

A concern that we have with this is that the delay in deciding on the course of action necessitated that the project be undertaken as emergency work. However, it would appear that it could have followed the normal tendering procedures.

An email dated October 18, 2007 from Infrastructure Assessment - Structures to Pavements regarding the life expectancy of waterproofing membranes states that *the Life Expectancy in Transitway Structures with high number of bus movements appears to be 15-20 years to replacing. In less demanding locations, LE is 25-30 years. MKB is noticeable exception, where the waterproofing has failed at the transit stops and at Elgin Street on the WBL at the traffic lights, and the LE is 10 years. The down grade and heavy vehicle braking have significant impact on LE. Poor maintenance of and plugged sub-asphalt drains appear to have negative impact on waterproofing. Because drains are typically located near joint armouring, it could be the standing water or the wheel loads that cause the membrane to fail first near the joints. Curbs are also an early failure zone, possibly as a result of poor details or the installation of the membrane termination, combined with the supply of water and de-icing chemicals.* [Paraphrased from original.]

In October 19, 2007, the Pavement Section wrote to the Infrastructure Assessment - Structures indicating that they have concluded that *the standard waterproofing system does not provide sufficient rutting resistance in areas where considerable bus traffic is experienced. The standard waterproofing system does not provide sufficient rutting resistance in areas with considerable bus traffic as it provides a slip plane between the asphalt and the concrete deck. In an attempt to provide both effective waterproofing as well as rut resistance to the Mackenzie King Bridge the existing asphalt and waterproofing system will be removed and be replaced with SMA (Stone Mastic Asphalt) asphalt modified with Rosphalt rubber additive. Success of the project will be measured by monitoring the amount of infiltration into the NAC electrical room.* [Paraphrased from original.] It is noted that by this time the decision to remove the waterproofing was already made.

An April 2008 email interchange between Design and Construction and Infrastructure Assessment - Structures, in response to emails regarding calls from NAC about water percolating through the bridge deck into the NAC parking garage, indicates that Design

Audit of the Mackenzie King Bridge Rehabilitation

and Construction recommended a spray on waterproofing membrane system with high performance asphalt, but the Pavement Section wanted to try the Rosphalt as a quick fix since this could address the waterproofing and rutting problems. The email notes that the Rosphalt may not solve the leakage problem as leakage may be coming from catch basins, construction joints, cracking or expansion joints. However, this email was not sent to Pavement Section. There is no other correspondence from Infrastructure Assessment - Structures section to the Pavements section to indicate this recommendation was given to Pavement Section.

Based on our review of the correspondence we have concluded that the selection of the Rosphalt additive and the decision to remove the waterproofing membrane was made by the Pavement Section, rather than a decision made by consensus of the Structures and Pavement Sections of Infrastructure Management. However, Management has indicated that the decision was a collective decision made in light of the available information, and that had there been serious reservations with the approach, the issue would have been escalated to management.

Recommendation 1

That the City modify its procedures to ensure that pavement work on structures be scoped with the specific agreement and approval by the Structures Section of Asset Management.

Management Response

Management agrees with this recommendation, and it has been implemented.

The Asset Management branch has documented procedures related to resurfacing on structures and associated approval processes. This information was provided to the auditor during the audit review process.

1.5.1.3 Asphalt Rehabilitation Procedures Used In Other Structures

The City currently follows the procedures described in Sub-section 4.1.3 for the coordination of pavement rehabilitation on structures. For structure renewal decisions, the City uses the processes designed for the Bridge Maintenance procedures, including the Guidelines for Structure Renewal Options Analysis.

Information provided by the City is that they use the standard waterproofing membrane with the protection board and asphalt. The selection of the asphalt mix is based on the City's standard specifications, based on Superpave mix design procedures.

During the course of the audit we learned that Rosphalt was applied to a second structure in 2008, namely the Heron Road overpass over the O-Train line, located about 140m west of the Airport Parkway (see **Figure 4.1**).

According to the City, the RMHMA on this structure has broken up severely on the eastbound lanes but not on the westbound bus lane. The main difference between the two lanes is the existence of a bus stop a few meters east of the bridge (see **Figure 4.2**), a bus-only lane, and traffic lights only 60m east of the bridge on the eastbound lanes; the westbound traffic does not stop on or near the bridge and there is no westbound bus lane.

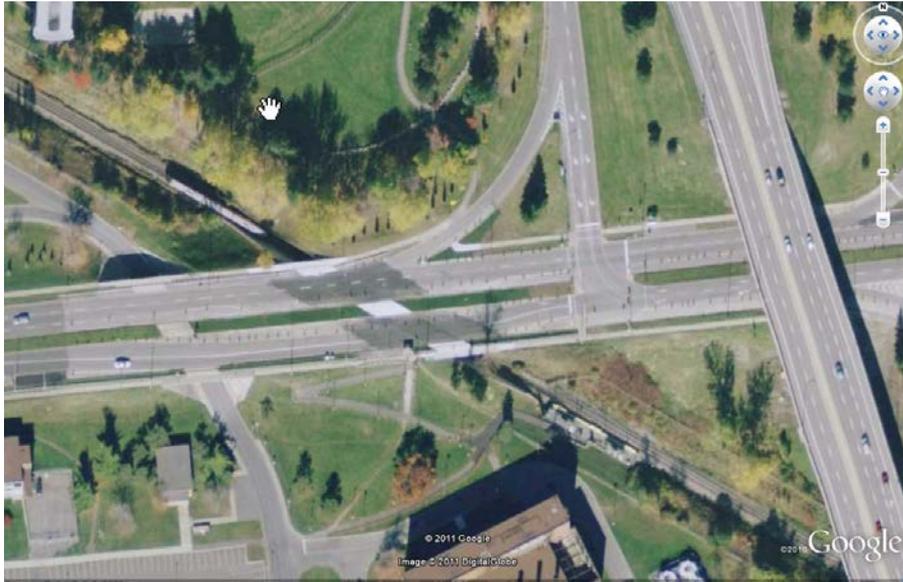


Figure 4.1 - Heron Road Overpass LRT (dark pavement)

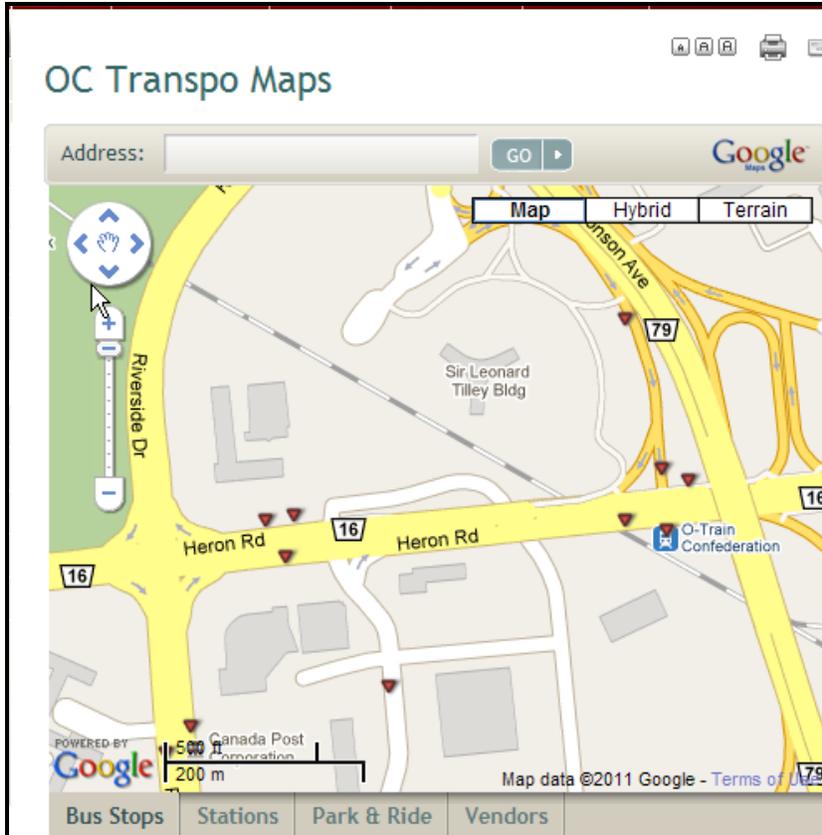


Figure 4.2 - Location of Bus Stops near the Heron Road Overpass LRT

The Heron Road Overpass at the Light Rail Transit bridge is a rigid frame bridge with a span of 7.5 m. The bridge was resurfaced with Rosphalt 50 modified HMA, placed directly over the concrete deck. As in the case of the MKB, the contractor sent aggregate samples to Royston, who did the mix design. Royston representatives were in Ottawa to review the construction process, the asphalt plant, and the site. The entire process followed Royston's guidelines.

The pavement on the bridge failed in less than 1 ½ years after project completion. Rosphalt was placed on the entire bridge deck. The bridge is situated such that there is a bus stop east of the bridge on the eastbound lanes; traffic on the westbound lanes does not stop. The RMHMA failed on the bridge in the EBL, but not the WBL.

The contractor in charge of the pavement was the same contractor as for the MKB resurfacing contract; the only difference was that they acted as sub-contractor to the contractor for the Heron Road reconstruction project.

We believe that this structure could have been used as a test structure for the Rosphalt application, rather than proceeding without testing to use the RMHMA in a much larger and important structure such as the MKB.

1.5.1.4 Use of Waterproofing Membrane in Ontario

We contacted the Ministry of Transportation to determine their use of waterproofing membranes and Rosphalt in Ontario. Information provided by the Structural Section of the MTO's Head Office in St. Catharine's, Ontario is as follows:

- The MTO generally uses waterproofing membrane and hot mix asphalt on bridge concrete decks.
- The MTO has used Rosphalt 50 additive on a trial basis in three recent contracts, in situations where the MTO cannot use their normal waterproofing system. Rosphalt is being used temporarily until the bridge deck can be completely rehabilitated.
- MTO structural staff is responsible for making the waterproofing decision. Normal waterproofing system is a hot applied rubberized asphalt waterproofing membrane, which cannot be used when the deck surface is rough.
- The MTO contact indicated that the paving company had some problems with getting the correct aggregate gradation. Rosphalt in the US kept sending it back. If gradation is not right then asphalt will not have the correct density and will not be waterproof.

Municipalities in Ontario generally use waterproofing and asphalt on concrete decks. In some applications bridge decks are provided with a concrete overlay as the wearing surface, but this is not a common practice.

We contacted the Ontario Good Roads Association to enquire whether they are aware of municipalities in Ontario who may have used the Rosphalt additive, but they were not aware of the use of the product.

This audit contacted the City of Guelph Engineering Department, as the City of Guelph's Edinburgh Street Bridge is listed in the reference provided by Royston for projects where the Rosphalt additive has been used, which is on a road used by buses. The City advised us that they do not have the files for this contract, as it was done in 1986.

It is notable that the product has not been used in either the City of Toronto or the City of Montreal, two cities with routes with significant bus loads.

1.5.1.5 Practices of Other Jurisdictions

Rosphalt 50 has been used in the Province of New Brunswick since 1988. Information provided to the City in 2007 by the New Brunswick Department of Transportation (NBDOT) is that NBDOT has been using Rosphalt on bridge decks usually for deck rehabilitation where there is a restriction on the amount of dead load that can be applied to the structure. NBDOT stated that they have had better performance "over the last 3 years" (2004-2007) because they are adding Rosphalt rubber to the highway mix to reduce air voids and make the mix impermeable. Prior to 2004 NBDOT was using a

Audit of the Mackenzie King Bridge Rehabilitation

mix just made of asphalt sand and then adding the Rosphalt rubber additive. These sand mixes tended to rut under heavy traffic loadings. Overall, NBDOT is happy with Rosphalt mix performance.

According to the Rosphalt Project Reference, the product has been used also by the City of Calgary, Alberta and the Nova Scotia Ministry of Transport.

1.5.2 Audit Objective No. 2

Examine and evaluate the studies, processes and methodologies used by the City to select the asphalt rehabilitation methods, including the selection of Rosphalt modified hot mix asphalt placed without waterproofing membrane.

Criteria:

- Pavement design criteria and procedures
- Mix design specifications, including selection of asphalt cement
- Mix design testing and verification, including inspection and testing
- Comparison with other methodologies
- Checking of Rosphalt references
- Testing

1.5.2.1 Pavement Design Criteria and Procedures

The City uses the Superpave system for its asphalt mixes. The City issued a Technical Information Bulletin in July 2006 titled "Superpave Asphalt Mix Selection". The bulletin explains in general terms what is Superpave, the Standard Specifications to be used, and the steps to select the appropriate Superpave for a given road. The document allows the designer to make allowances in the design for different mix design requirements in a single contract, including upgrading or downgrading mixes to achieve reasonable economies, and recognizes that in some cases there may be premature failure of the asphalt.

The 2007 RFQ specified asphalt mixture of Stone Mastic Asphalt (SMA) 12.5 mm with PG 70-34 asphalt cement, which is considered to be appropriate asphalt material for the specifics of this site. Application of the City's standard specifications and the Ontario Provincial Standard Specification to the selection of the hot mix for the bridge leads to selection of PG70-34 asphalt cement for the traffic and loading conditions on the bridge.

The Royston literature indicates that they will use the PG grade specified by the Owner. The substitution to the dense graded Superpave 12.5 mm mixture with PG 58-34 asphalt does not satisfy the requirements for mixture selection for this site. The addition of the Rosphalt additive to the parent asphalt mixture modifies the properties of the mixture, but it is unclear if the Rosphalt additive would compensate for the structural

difference between the specified asphalt mix (with PG70-34) and the Rosphalt mix, which is two grades lower than the specifications would allow.

Management has stated that the City recognized that it was dealing with a proprietary product and wanted to ensure that the responsibility for the warranty remained with Royston. Without knowing the proprietary composition of the Rosphalt additive, staff followed Royston's recommendation regarding the PG grade since staff could not confirm the reaction between the Rosphalt additive and the polymer in the PG 70-34.

From the perspective of the asphalt pavement performance, the removal of the bituminous waterproofing system could have improved the horizontal shear and slippage resistance of the asphalt pavement when subjected to extensive bus traffic with repeated start and stops. However, we note that this comment is not based on any tests of standard waterproofing and asphalt combinations.

Review of the documentation on the asphalt stability problems on the bridge indicates that more advanced examination of the reasons for the instability of the hot mix were warranted. Tests that could have provided additional insight into the rutting, shoving, and shear forces between the asphalt mix and the waterproofing membrane, such as the Asphalt Pavement Analyzer, the Repeated Load Permanent Deformation test, Fatigue testing and the Superpave Shear Tester (SST), appear to have been warranted. There is no documentation on file attesting that any of these tests were conducted.

In addition, there is no documentation to indicate that the pavement selection process was based on a formal evaluation process, including the absence of any financial projections to confirm the validity of the assumption that the change in approach, from annual repairs at localized spots to complete resurfacing of the structure, was valid.

In summary, the expenditure of more than \$500,000 was not properly justified in terms of analyses and tests, and was contracted without preparation of tender documents.

The 2009 resurfacing contract was necessitated by the failure of the RMHMA. Our review of this contract indicates that the City followed its procedures in the design of the resurfacing, including re-instating the waterproofing membrane and the asphalt used for repaving. It is noted that the failure of the 2008 RMHMA and the effects of this failure on the leakage and infiltration into the NAC parking garage and other uses under the bridge made it necessary for the City to proceed with a standard design.

1.5.2.2 Mix Design Specifications

The asphalt mix design process utilized for this project was led by Rosphalt's technical department. Based on the mix design documents available for review, the mix design process utilized appeared to be a modified process from the standard Superpave criteria for Ontario. The mix design process carried out by Rosphalt selected the design

Audit of the Mackenzie King Bridge Rehabilitation

number of gyrations as 50, whereas this site would require 125 gyrations based on OPSS 1151 specifications. The concern with this difference is whether the asphalt mixture is evaluated in the laboratory at an appropriate compactive level. The addition of the Rosphalt additive to the parent asphalt mixture modifies the properties of the mixture, but there were no other tests to confirm that the Rosphalt additive would compensate for the differing compactive efforts.

The asphalt cement grade selected by Rosphalt for this mixture was a PG 58-34. OPS specification identify that a PG 58-34 is the appropriate asphalt cement based on the base climatic data, however given the traffic composition at this site, the asphalt cement grade must be "bumped" to compensate for the elevated traffic loadings. OPS 1101 requires the asphalt cement to be at least a PG 64-34, however recommends to consider utilizing a PG 70-34 when very high truck and bus traffic at low operating speeds is present. The addition of the Rosphalt additive to the parent asphalt mixture modifies the properties of the asphalt cement, but it is unclear if the Rosphalt additive would compensate for the structural difference between the utilized and OPS recommend asphalt cement products. The Rosphalt 50 technical guide does recommend that the asphalt cement shall conform to the Authority requirements. The final blend will be in accordance with the Royston's requirements and approved by the engineer. In summary, we conclude that Royston should have used the originally specified asphalt cement (PG 70-34).

Other references indicate that in Superpave design methodology, the design pavement temperature calculations are based on HMA pavements subjected to fast moving traffic. Pavements subject to significantly slower (or stopped) traffic such as intersections, toll booth lines and bus stops should contain a stiffer asphalt binder than that which would be used for fast-moving traffic. Superpave allows the high temperature grade to be increased by one grade for slow transient loads and by two grades for stationary loads. Additionally, the high temperature grade should be increased by one grade for anticipated 20-year loading in excess of 30 million Equivalent Standard Axle Loads (ESAL). For pavements with multiple conditions that require grade increases only the largest grade increase should be used. For a pavement intended to experience slow loads (a potential one grade increase) and greater than 30 million ESALs (a potential one grade increase), the asphalt binder high temperature grade should be increased by only one grade. This design high temperature adjustment is often called "binder bumping". The highest possible pavement temperature in North America is about 70°C but two more high temperature grades were necessary to accommodate transient and stationary loads, and could require grades as high as PG 76-22.

It is unclear based on the documents reviewed, the process in which the original contract specified mix type was modified to the actual placed mix and who reviewed and accepted this. Information provided by the City during the interviews for this audit

disclosed that the City essentially left it up to Royston, the Rosphalt 50 supplier, and the contractor, to arrive at the mix design for the site. This procedure is unusual. As noted previously, Royston literature indicates that they work with the owner's specifications. This was not done here.

Management has indicated that it is not unusual for the City to ensure that actions are not taken that would void the contractor's warranty. It is recognized that this was a challenging situation, and the intent was to have Royston assume all responsibilities for the product and its performance.

Standard documentation provided by Royston in their website and found in the files for the project indicate that Royston Technical Services Department will work with the contractor, in conjunction with agency engineering representative, to provide a recommended specialized mix design using local aggregate and asphalt cement, to control the limits to obtain the desired Rosphalt physical characteristics. The Royston documentation states that the suggested mix design developed by Royston will be used by the contractor to produce the Job Mix Formula to be approved by the contractor and agency; and that Rosphalt specifications are controlled to tighter limits than most state asphalt designs, due to the fact that the polymer modifier is typically outside specification limits listed in most state documents, thereby requiring a specification be developed for the application of Rosphalt.

However, based on the documentation found and the interviews, the City relied completely on the work done by Royston and the contractor. There was no specification developed by the City for use in the 2007 Contract.

The 2009 Contract was designed using Superpave methods, and in accordance with the City's and Ontario Provincial Standard specifications. The waterproofing was reinstated on the bridge.

Recommendation 2

That the City modify its procedures to ensure that application of new technologies be preceded by a sufficiently detailed, tested and documented investigation of alternatives and costs, and that application receives specific management approval.

Management Response

Management agrees with this recommendation.

Audit of the Mackenzie King Bridge Rehabilitation

In May 2011, the General Manager, Infrastructure Services issued a departmental directive outlining requirements to be followed when piloting new technologies. Management will monitor amendments that may be required to further clarify the directive. The audit recommendation will be reflected in the next amendment, which is expected in Q4 2011.

1.5.2.3 Mix Design Testing and Verification

The mix design was carried out by Rosphalt. The technical criteria used for developing the mix design were selected by Rosphalt. Given the specialized nature of the product, conventional municipal specifications do not cover this type of product.

The mix design documentation does not indicate that any checks for moisture susceptibility or stripping were performed. The submitted mix design indicates that 1% lime was incorporated into the mix. Depending on the aggregate type utilized in the asphalt mixture, hydrated lime can be an appropriate anti-stripping additive. The submitted mix design does not indicate that source of the aggregate or the parent rock material. Moisture susceptibility testing determines the required dosage rate of the anti-stripping additive.

The mix design developed by Royston and the contractor was submitted to the City of Ottawa. The City of Ottawa expressed some concern with the properties of the proposed mix and identified their lack of experience with this type of material. The City requested additional information. No additional information was available in the file for review to identify how these concerns were resolved.

The City reviewed the Rosphalt mix design information and trials performed in the contractor's lab. City did not have experience with Rosphalt and there were technical issues that the City did not completely understand. However, the City recommended to the contractor that they consider the following aspects:

- The mix was locking up at very low gyrations, which could mean that the AC and not the aggregates are filling the air voids;
- Recommended tests with lower AC to determine how aggregate skeleton resists loadings; and,
- Run conventional Superpave mix design without Rosphalt to investigate aggregate performance.

The number of gyrations in the lab is an important parameter that reflects the quality of the mix. The various measurements give an indication of the stability and resistance to deformation of the mix when subject to traffic. For this reason, we consider that the QA Section's concerns were valid. However, these were not resolved by the City before construction.

The City explained during meetings for this audit the following points:

- The Rosphalt mix design is proprietary and not a conventional asphalt mix covered by Ontario Provincial Standards.
- There was no mix design or product specification for the Rosphalt modified hot mix asphalt in the contract and as such no approval or “acceptance” could be provided by the QA Section.
- The QA Section provides mix design approvals based on conformance to contract specifications and standards; given that there was no specification for the RMHMA, the QA Section was not in a position to provide “acceptance” of the Rosphalt mix despite attempts from the contractor to initiate such an approval.

The City indicated during this audit that the concerns expressed above were not pursued further for the reasons enumerated below:

- They considered that the typical Superpave mix design approach is not fully compatible with the Rosphalt modified hot mix asphalt.
- The concerns noted were documented because Rosphalt shares similar volumetric principles as conventional asphalt (despite being designed differently).
- Although the City had questions, concerns and opinions regarding how the product is designed, it was not considered that the Rosphalt design was improper and the proprietary Rosphalt product had been used by many other road authorities.
- The use of the material was considered a value for money decision which was previously assessed and authorized by Infrastructure Management scoping group.

Based on information provided by the City during this audit, throughout the involvement of the QA Section in this project, it was their ongoing understanding from Construction Services that the concept of maintaining warranty expectations for the Rosphalt product was a priority for the City. The City indicated that previous conventional asphalt pavements at this site were only lasting approximately one year and the City did not have warranty expectations for the previous projects, and that contractors had not been held accountable for the failure of conventional pavements (Superpave Level D, E and SMAs) at this site. The QA Section indicated that it was their ongoing understanding that Construction Services had an expectation that warranty was applicable to the Rosphalt product placement in 2008.

We note with respect to the above that the resurfacing of the MKB was covered by the same warranty clause included in the contract documents for Contract No. ISB07-5010, since it was carried out as extra work added to that contract.

The QA Section indicated that requiring the contractor to pursue a mix design methodology by the City would have resulted in nullification of the City’s warranty expectations regarding the proprietary Rosphalt product. The concerns expressed by

Audit of the Mackenzie King Bridge Rehabilitation

the QA Section were resolved through the decision by the QA Section to not impose a specified mix design methodology for this proprietary product, which was deemed consistent with the known objective of Construction Services to rely on product warranty with regards to the Rosphalt product placement.

There is no documentation to support the above assertion.

The QA Section indicated that this decision was consistent with the other decisions made on the project with regards to warranty preservation. The QA Section noted that the contractor had insisted that the warranty would not apply if the Rosphalt was placed in one 80mm lift as was specified in the contract and that warranty would only apply if the mix was placed in two 40 mm lifts, and Construction Services authorized the placement of the material in two 40mm lifts to prevent nullification of the warranty and had no objections to this decision from a quality perspective.

In our opinion, the QA Section was correct in raising their valid concerns, and should have pursued for clarification by Royston and the contractor. We do not agree that having Royston clearly justify their results would have voided the contract warranty. As noted previously, the way the contract was set up the warranty conditions were not changed when the MKB resurfacing extra work was added.

Management indicated that the documentation provided clearly demonstrates that annual repairs using the conventional resurfacing methods over the existing waterproofing was expected, therefore the City could not hold the contractor responsible. The difference with Rosphalt is that it was installed under the understanding that it would provide a greater level of resistance while providing an impermeable surface.

However, we found that the contract used had the same warranty requirement as used for the resurfacing of the MKB. In fact, the resurfacing work was carried out as part of the 2007 contract and therefore it had the same warranty provisions as for a standard resurfacing project.

A trial batch of the proposed Rosphalt modified asphalt product was performed prior to the main paving. The City of Ottawa and Tomlinson staff members were present. Field testing and sampling was performed by both parties. The results of the testing indicate that the test batch material was generally consistent with the Rosphalt mixture and placement criteria.

Recommendation 3

That the City ensure that the specifications for application of new technologies be vetted by management in the same or more strict manner than the production of standard specifications.

Management Response

Management agrees with this recommendation.

In May 2011, the General Manager, Infrastructure Services issued a departmental directive outlining requirements to be followed when piloting new technologies. Management will monitor amendments that may be required to further clarify the directive. The audit recommendation will be reflected in the next amendment, which is expected in Q4 2011.

Recommendation 4

That the City modify its procedures when applying a new technology to ensure that all departments who will be involved in the implementation have proper training on the new technology.

Management Response

Management agrees with this recommendation.

In May 2011, the General Manager, Infrastructure Services issued a departmental directive outlining requirements to be followed when piloting new technologies. Management will monitor amendments that may be required to further clarify the directive. The audit recommendation will be reflected in the next amendment, which is expected in Q4 2011.

1.5.2.4 Comparison with Other Methodologies

The justification for applying RMHMA instead of the conventional waterproofing and asphalt pavement was based on the following assumptions:

- a) The interface between the waterproofing membrane and the hot mix asphalt was considered to provide a slip plane which prevented the hot mix from adhering to the concrete deck, and permitted it to shove and rut.
- b) The RMHMA would provide sufficient waterproofing to permit removal of the standard waterproofing membrane without adverse effect to the concrete deck.

We noted that there were no tests at all, by the City, to confirm either of these assumptions, although tests are available to examine the potential performance of the asphalt and waterproofing membrane combination, or that of the RMHMA. For example, the Superpave Shear Tester (SST) could have been used for testing whether assumption (a) above was correct or if other waterproofing membranes would provide better performance than the standard waterproofing membrane with protection board. As well, we noted that the RMHMA was not tested to determine whether it could withstand the load conditions expected at the bridge, using methods such as the Asphalt Pavement Analyzer or other similar methods.

Audit of the Mackenzie King Bridge Rehabilitation

In this sub-section we examine other options to removal of the waterproofing, available at the time of the selection of the RMHMA by the Pavements section, which could have been considered by the City.

The traditional bridge deck waterproofing system uses a protection board between the waterproof membrane and the asphalt wearing surface. Through this audit it was determined that other types of bridge deck waterproofing systems exist, that do not require a protection board:

1. Spray on Waterproofing Membranes,
2. Thermofusible Waterproofing Membranes.

Spray on Waterproofing Membranes

The spray on waterproofing membrane systems generally consist of a concrete primer, a one or two coat waterproofing membrane, and a tack coat. The asphalt is then placed on top of the tack coat.

Two different products were found in this category. The Eliminator Bridge Deck Waterproofing System by Stirling Lloyd North America and the Britdex MDP Bridge Deck Waterproofing System by USL BridgeCare. Each company states that their product is 100% waterproof and that all layers bond 100%.

The Eliminator product was installed in the year 2000 on the A. Murray Mackay Bridge in Halifax, Nova Scotia. In speaking with the Halifax-Dartmouth Bridge Commission it was found that they are very happy with the application of the Eliminator product. The product has withstood the movement of the orthotropic steel deck, without issue, for approximately 10 years. The asphalt has cracked in a few locations because of wear/age; however, all of the asphalt remains bonded to the membrane and does not move.

It was noted in the correspondence prior to the 2007 contract that the Eliminator system was suggested by Construction Services Bridge Rehabilitation to the Pavement Section, but there is no indication that the system was considered. As noted at the beginning of this sub-section, no tests appear to have been done at all.

Management indicated that staff have confirmed that this was considered and discussed but not retained. One of the main concerns was that if not successful, further grinding of the bridge deck would be required to remove the waterproofing further reducing the deck and reducing the cover over the rebars.

Thermofusible Waterproofing Membranes

Thermofusible waterproofing membrane systems generally consist of a single layer bitumen membrane that is torched on over a primed surface. The asphalt is then placed directly on the bitumen membrane.

Two different products were found in this category. Force Point 5000 has been distributed in Canada by ACP Applied Products and Antirock is sold by Soprema. Both products claim to provide a 100% bonded and waterproof surface that is driveable even before the placement of asphalt. This type of product has been available in Canada since before 2007. Based on our queries we found no specific instances of product use with the same loading condition as the Mackenzie King Bridge.

1.5.2.5 Checking Of Rosphalt References

Rosphalt provided the City with a list of references, which include the Province of New Brunswick Department of Transportation (NBDOT), the City of Calgary, Alberta, the City of Guelph in Ontario, and the Nova Scotia Ministry of Transport. Information contained in the files shows that the City contacted the NBDOT, but there is no documentation of checking of references with the other Canadian references.

The information provided by NBDOT pertained to highway bridges, but none of these bridges had the loading characteristics of the MKB, which are a very severe combination of bus wheel loads and stop-and-go traffic.

The City of Calgary site, done in 1985, is the Memorial Drive Bridge; the City of Guelph site, done in 1986, is the Edinburgh Road Bridge. Both bridges are in urban roads; Edinburgh Road is part of the bus network of the City of Guelph. It could be that these two sites are more representative of the conditions found in the MKB than the highway bridges in New Brunswick, but no data was found for Edinburgh Road Bridge.

Recommendation 5

That the City ensure that the application of new technologies be preceded by a documented investigation of references, including an assessment of whether the referenced applications had similar conditions as those known or anticipated in the City's site.

Management Response

Management agrees with this recommendation.

Audit of the Mackenzie King Bridge Rehabilitation

In May 2011, the General Manager, Infrastructure Services issued a departmental directive outlining requirements to be followed when piloting new technologies. Management will monitor amendments that may be required to further clarify the directive. The audit recommendation will be reflected in the next amendment, which is expected in Q4 2011.

1.5.2.6 Inspection and Testing

The City has indicated that they provided full-time inspection during construction, by the City Road Rehabilitation section within Design and Construction.

The lack of bonding of the asphalt pavement to the overall concrete bridge deck in the outer lanes is believed to be a significant cause of the premature failure of this pavement. The presence of the thin layer of cemented particles below that asphalt pavement that was delaminated from the underlying concrete deck is very uncommon. No reviewed documentation indicated awareness that the delaminated cemented layer was present. However, the City has stated that the Royston representative required that the concrete deck be power swept twice before applying the tack coat, which was also applied twice at the direction of the same representative.

The City has prepared the Inspection Manual for City Construction Contracts, dated May 2003, which contains inspection requirements for Bridge Deck Waterproofing and Hot or Cold Mix Paving Operations. The requirements include provision for sampling and testing. The Ontario Provincial Standard Specifications 313 and 1151, as modified by the City's specifications, applied to the contract. Testing during construction consisted of compaction tests done by the contractor for quality control. There is no record of Quality Assurance testing by the City.

The 2009 Resurfacing contract followed procedures used by the City.

1.5.3 Audit Objective No. 3

Examine the scheduling of contracts for pavement rehabilitation, including coordination of work with structure renewal requirements.

Criteria:

- Program coordination with Infrastructure Management
- Timing of contract preparation in light of inspection results
- Frequency of resurfacing required
- Scheduling of design meetings

1.5.3.1 Program Coordination with Infrastructure Management

At the time of the two contracts in 2007 and 2009, the City's organizational structure was different then at present. The Infrastructure Services Branch was divided into

Infrastructure Management and Construction Services (West, East and Development). The responsibility for assessing the road resurfacing and structure renewal needs was part of Infrastructure Management. Infrastructure Assessment & Program Development - Transportation had responsibility for road rehabilitation needs, while structure renewal needs was the responsibility of Infrastructure Assessment & Program Development, - Structures.

Construction Services would become involved for implementation of the required works, based on the scope defined by Infrastructure Management.

Infrastructure Assessment & Program Development - Transportation was responsible for the inventory and assessment of linear infrastructure, such as roads, sidewalks, transitway, and pavements. The section prepares the annual rehabilitation program, using in-house and consultant resources. The process is to carry site inspections twice per year, in spring and fall. Documentation provided by the City and staff statements indicate that the needs are identified a year in advance. However, management indicates that the needs are typically identified four years in advance. If the repairs are necessary, they are included in the budget for the following year. As needs are identified one year in advance, they are circulated to other departments, by the end of June, for comment and coordination. Structures are usually stand-alone projects, coordinated with structures. In the case of the 2007 contract, the Transportation unit was not aware of any structural needs that would prevent proceeding with spot patching. If there are no structural needs, the resurfacing is done as an individual project.

In 2007, the former pavement engineer reported to the Program Manager, Infrastructure Assessment & Program Development - Transportation. As it has been discussed in sub-sections 4.1.1 and 4.1.2, there is a process in place for coordination between the Structures and Roads sections. However, in this particular case of resurfacing over an important structure, it appears that the input from the Structures group was not the determining factor in the manner in which the work was carried out. The 2009 resurfacing contract was managed in accordance with the coordination procedures established by the City.

1.5.3.2 Timing of Contract Preparation

As noted previously, the process is to carry site inspections twice per year, in spring and fall. The needs are identified a year in advance. If pavement repairs are necessary, they are included in the budget for the following year. Normally the contract for the year's work is prepared near March of the current year, based on the site inspection data from the previous year.

Audit of the Mackenzie King Bridge Rehabilitation

In the case of the 2007 resurfacing contract it is apparent from the correspondence that the need to resurface the bridge was known within the City since at least December 2006. Construction services included repairs on the bridge within the 2007 contract, in line with the work that had been done in previous years; the work consisted of milling and paving at different locations. This work was consistent with the recommendations of the 2004 Rehabilitation Options study, previously discussed.

The issue of leakage from the MKB to the NAC parking garage was discussed in February 2007 and earlier; however, it appears that no work was done to determine the preferred course of action until August 2007. The decision to resurface the bridge using RMHMA was made in September 2007.

Once this decision was made, the project was carried out as emergency contract. However, there was no reason why the project could not have followed standard project procedures for project scoping, contract preparation, and tendering. There is no documentation in the file to account for the delay. In particular, there is no documentation in the file about the process followed to confirm that removal of the waterproofing and resurfacing with RMHMA was the preferred course of action. The files do not contain any data on analysis of alternatives, cost estimates, life cycle financial projections, testing, or any other calculations that would confirm the premises on which this decision was based.

The 2009 resurfacing contract, on the other hand, was designed within a relatively short period of time, and was managed by the City in accordance with its procedures, including the issue of tendering in accordance with the City's Purchasing By-law.

1.5.3.3 Frequency of Resurfacing Required

The 2004 Pavement Rehabilitation report commissioned by the City as a result of the deterioration of the asphalt wearing surface of the bridge examined several alternatives, from maintaining the existing waterproofing and milling and paving annually to replacing the wearing surface with a concrete overlay, and combinations thereof. The report recommended continuing to mill and repave the damaged areas on an annual basis. As noted before, the conclusions were based on the premise that the existing waterproofing would last 30 years, which is a reasonable premise given that it was placed in 1998, and had been in serviced for only 6 years at the time.

Based on the 2004 pavement rehabilitation study and the rehabilitation work done from 2004 to 2007, both inclusive, the City could have continued to spend up to \$33,000 annually for another 15 years before milling and repaving the entire bus lanes. Instead, the City spent \$625,000 in a pavement rehabilitation scheme that was unsupported by adequate investigations, testing, and financial analysis.

Management has indicated as follows: The bridge was renewed in 1998 and it would be unreasonable to expect that it would be another 15 years beyond 2004 before resurfacing would be required. Because of the frequent repairs and the fact that shortly after the repairs were done the pavement started showing signs of failure, staff worked collaboratively to find an innovative solution. Based on the history of the bridge, its unique challenges and the premature pavement failures, staff concluded that the 2004 plan warranted a different approach.

Management informed us that the 2004 report was reviewed and accepted by senior engineering staff within the City. On this basis, it is our opinion that it would be expected that the assumptions in the report were vetted by them. Management has now stated that those assumptions are unreasonable. If the City was not in agreement with the assumptions made in the 2004 report, further discussion should have taken place to ensure that the report's assumptions were correct. If there was disagreement with the report, it should have been modified to address the revised assumptions regarding the useful life of the asphalt and waterproofing.

Audit of the Mackenzie King Bridge Rehabilitation



Table 5.1 provides a summary of the pavement rehabilitation done on the MKB, based on information provided by the City:

Table 5.1 Mackenzie King Bridge Pavement Rehabilitation Work

Year	Rehabilitation Description	Approximate Area (m2)	Approximate Cost	Asphalt Mix Details	Comments
2001	No work identified on MKB	n/a	n/a	n/a	n/a
2002	No work identified on MKB	n/a	n/a	n/a	n/a
2003	No work identified on MKB	n/a	n/a	n/a	n/a
2004	Eastbound and Westbound lanes	n/a	n/a	50mm HL1 PG64-34	No details available
2005	Spot locations eastbound lane at QE Driveway overpass	720	\$16,000	50mm HL1 PG64-28 ^a	Cost based on 6 areas of 4 m x 30 m

Year	Rehabilitation Description	Approximate Area (m ²)	Approximate Cost	Asphalt Mix Details	Comments
2006	Spot locations, Elgin Street to Waller	720	\$35,000	50mm Superpave 12.5mm FC2 Level D (PG64-28) ^b	Strategy by former pavement engineer, cost based on 6 areas of 4 m x 30 m Removed waterproofing membrane at areas of repaving.
2007	Spot locations, eastbound and westbound, west of Nicholas overpass	700	\$23,000	50mm Superpave 12.5mm FC2 Level D (PG64-28)	Cost based on 6 areas of 4 m x 30 m
Jan. 2008	n/a	n/a	n/a	n/a	Former pavement engineer left the City's employment
Aug. 2008	Remove waterproofing, Elgin to Waller, EB and WB transit lanes	4,000	\$625,000	90mm Superpave 12.5mm SMA PG70-34	Mix used was PG58-34, modified with Rosphalt 50

Year	Rehabilitation Description	Approximate Area (m2)	Approximate Cost	Asphalt Mix Details	Comments
Jul. 2009	n/a	n/a	n/a	n/a	Former pavement engineer, now working for consultant, retained by the City to advise on the problems with the RMHMA on the MKB.
Sept.20 2009	Remove RMHMA, waterproofing and paving, Elgin to Waller, EB and WB Transit lanes	4,000	\$718,000 Approximately \$80,000 to \$100,000 of this amount was for coordinated structural work and not resurfacing.	80mm Superpave 12.5mm FC2 Level E PG70-34	Contract to repair work done in 2008; included bridge structural work coordinated within the same contract.
2010	No resurfacing required	n/a	n/a	n/a	n/a

- a) Information provided by Construction Services indicates that patching was done twice this year.
- b) Information provided by Construction Services indicates that the asphalt was SMA PG70-28, and that the waterproofing membrane was removed in those spots.
- c) As noted in this report, this is the asphalt mix specified; subsequently changed to Superpave 12.5mm FC2 PG58-34

From the information provided in Table 5.1 it is possible to observe that the pavement rehabilitation work being done was in accordance with the 2004 Pavement Rehabilitation report until 2007. In 2006, the City carried out milling and paving of the problem areas only, but removed the waterproofing membrane, as discussed previously in this report.

Information in correspondence provided by the City indicates that until 2006 the waterproofing on the bridge was working, although indications are that it had moved with load, and that the 2005 work possibly had resulted in some overmilling in spots, causing thinning of the waterproofing membrane, but not perforation of the same.

In 2005 the Pavement Section of Infrastructure Assessment - Transportation was asked to provide input regarding the pavement design.

The removal of the waterproofing in 2006 during the pavement rehabilitation work for that year was done at the direction of the former pavement engineer, with the intention of increasing the stability of the pavement on the bridge. As noted elsewhere in this report, this decision was not shared with the Structures engineer in Infrastructure Management.

In correspondence interchanges in October 2007, Construction Services asked Infrastructure Management-Structures if the City should be concerned with water infiltration if the waterproofing does not perform adequately during its service life. Construction Services also asked for information on the service life of the hot applied waterproofing membrane used by the City, and how often it is replaced.

Infrastructure Management-Structures responded that the Life Expectancy in Transitway Structures with high number of bus movements appears to be 15-20 years to replacing. In less demanding locations, LE is 25-30 years. MKB is a noticeable exception, where the waterproofing has failed at the transit stops and at Elgin Street on the WBL at the traffic lights, and the LE is 10 years. The down grade and heavy vehicle braking have significant impact on LE. Poor maintenance of and plugged sub-asphalt drains appear to have negative impact on waterproofing. Because drains are typically located near joint armoring, it could be the standing water or the wheel loads that cause the membrane to fail first near the joints. Curbs are also an early failure zone, possibly as a result of poor details or the installation of the waterproofing membrane termination, combined with the supply of water and de-icing chemicals.

Based on the fact that leakage to the NAC parking garage was occurring from a variety of sources, including the section of deck where the waterproofing membrane had been removed in 2006, and that the City had retained a consultant at the time to assist in developing possible solutions, we consider that the City should have completed the investigation before investing over \$600,000 on the bridge resurfacing in 2008.

However, at this stage (in October 2007) the City had already decided to remove the waterproofing on the transit lanes of the MKB and resurfacing them with the RMHMA without waterproofing.

Audit of the Mackenzie King Bridge Rehabilitation

It is noted that the resurfacing done in 2009 has been found to be working properly in 2010 and so far in 2011. However, management has informed us that it is premature to draw conclusions with respect to 2011. The pavement is showing signs of rutting that will require further investigation before determining if repairs will be required in 2011.

Recommendation 6

That the City modify its procedures to include all major rehabilitation work on structures, including major resurfacing work, in its guidelines for renewal options.

Management Response

Management agrees with this recommendation, and it has been implemented.

This requirement has already been reflected in the Asset Management branch's Structures Best Practice Guide.

1.5.3.4 Scheduling of Design Meetings

Based on the correspondence and files reviewed, we concluded that there were no design meetings recorded for the 2007 contract or for those in prior years. On the basis of the correspondence reviewed, it appears that all issues were handled via email. Unfortunately, it also appears that not all the persons who should have been involved in the decisions about the bridge were. For example, there is no indication that the Program Manager, Infrastructure Management was aware that the Former pavement engineer and Construction Services were working on a project that would remove the waterproofing membrane on the bridge, even though at the same time there were discussions regarding leakage problems to the NAC parking garage.

There are records of meetings held by Infrastructure Management - Structures from 2008 onward, and involving the staff from IM-Structures and Construction Services.

1.5.4 Audit Objective No. 4

Examine the qualifications of City staff and testing laboratory, and the use of consultants used to provide advice on the pavement rehabilitation.

Criteria:

- Review City staff qualifications in relation to complexity of decisions required
- Capabilities and certifications of City materials testing laboratory
- Review methodology used to decide between in-house vs. consultant design
- Review the involvement of pavement specialists on the project.

1.5.4.1 City Staff Qualifications

In assessing the City staff qualifications we found that all the staff involved in evaluating the problem, developing alternative solutions and implementing them were professional engineers with several years of experience. In 2007, the years of experience since graduation ranged from 10 years to 39, with an average of 26 years of experience.

The former pavement engineer responsible for selection of the Rosphalt additive is a professional engineer, who at the time had 10 years of experience since graduation and 7 years since receiving his professional license from Professional Engineers Ontario. He had graduated from a Masters program in pavement engineering. He reported to the Program Manager. From our review of the relevant correspondence made available by the City, it appears that the former pavement engineer had significant influence on the approach to defining the problem with the pavement, examining alternative solutions, and selection of the use of Rosphalt as the solution.

The Quality Assurance staff are engineers with substantial experience in testing of materials, but are not certified either by the Canadian Standards Association (CSA) or the Canadian Council of Independent Laboratories (CCIL).

1.5.4.2 City Materials Testing Laboratory

The Ontario Provincial Standard Specifications for asphalt specify that testing of asphalt and its components be tested in laboratories certified by the Canadian Council of Independent Laboratories.

CCIL certification is voluntary, but the certification program ensures that materials testing labs meet correlation and proficiency requirements. The Ontario Provincial Standard Specifications for Municipal and Provincial contracts require that testing of materials be done in CCIL-certified labs. MTO requires that all their testing be done in CCIL (or equivalent) certified labs.

CCIL provides certification programs for asphalt and aggregate testing laboratories and laboratory technicians. The certification programs are overseen by Certification Program Administration Committees (CPAC). The CPAC is comprised of representatives from industry stakeholder organizations. The mandate of the CPAC is to establish and direct the technical elements of the programs. The operations and management of the certification programs are administered by the CCIL Program Manager and technical staff.

The CCIL Laboratory Certification Programs have four mandatory components: satisfactory participation in an annual inter-laboratory correlation program; CCIL laboratory inspection; CCIL certified laboratory technicians; and, a laboratory quality manual / quality system.

Audit of the Mackenzie King Bridge Rehabilitation

CCIL has implemented a Petrographic Analyst certification program, in response to industry needs. The program requires that a minimum level of experience as a Petrographic Analyst is demonstrated, and that a demonstrated proficiency in petrographic examination of aggregates through a correlation program is achieved.

In 2009, CCIL acquired the former CSA Concrete Laboratory Qualification Program. CCIL's twenty-seven year history of running successful laboratory certification programs was a strong incentive for CSA to turn the program over to CCIL.

The City's Quality Assurance lab has a total of 7.98 FTEs, a 2011 budget of \$871,594, and anticipates recovering \$803,022 from the Capital Works program by way of services. The QA lab currently outsources up to 80% of the City's bulk asphalt testing and 100% of the structural concrete testing to certified laboratories.

The City Materials Testing Laboratory is not presently certified and was not certified in 2007. The lab management has been outsourcing testing to private CCIL certified laboratories, as follows:

- In 2008, 5% of bulk asphalt samples (i.e., AC, gradation, air voids) were tested at certified consultant labs.
- In 2009, 62% of bulk asphalt samples were tested at certified consultant labs.
- In 2010, 80% of bulk asphalt samples are expected to be tested at certified consultant labs.
- As of April 2009 all QA acceptance testing of structural concrete is conducted at a certified consultant laboratory.

The City's lab currently tests most granular, non structural concrete (sidewalks) and asphalt cores.

The QA Section is transitioning much of the testing work to outsourced labs but some testing still currently occurs at the City's lab. The certification status of the City's lab is well known by ISD management, local contractors and local consultants.

The lack of CCIL or equivalent certification places the City's lab at a disadvantage in relation to labs that are CCIL-certified, particularly in cases of disputes.

Recommendation 7

That the City review its requirement for a Quality Assurance lab, including staff requirements.

Management Response

Management agrees with this recommendation.

The services provided by the Quality Assurance section have been previously reviewed with a change in focus from a high dependence on materials testing towards specialty services. A further review will be conducted regarding the lab testing services. This review will be completed by Q3 2012.

1.5.4.3 In-House vs. Consultant Selection Methodology

The City has a Purchasing By-law which includes the methods and procedures necessary for engagement of consultants. This is not the topic of this section and will not be discussed here. The criterion being examined here is how the City decided in this particular case to undertake the design or parts of the design using in-house engineers; and how the City used consultants to assist.

The Structures section retained a consultant to carry out the studies listed in Section 1.3 - Bridge Investigations, among which was an investigation of Pavement Rehabilitation done in 2004 and an investigation of leakage in the NAC parking garage completed in early 2006. From the information that we have available, it would appear that these reports were not shared with the Pavements section.

The former pavement engineer joined the City in 2002. At the time of the 2006 resurfacing contracts he had nine years of experience, most of them in pavement related activities. We believe that he was qualified for pavement design, but not necessarily qualified to make decisions regarding bridge deck protection.

Road rehabilitation contracts are put out every year. They use the City's standard specifications and drawings. Pavement design is done by the Asset Management section (formerly Infrastructure Management), and the information is given to Design and Construction for tendering and construction. Normally no consulting input is required for resurfacing contracts.

No consultant was used for pavement design. The City's former pavement engineer was involved in the selection of the pavement to be applied to the bridge in 2006 and 2007. Because the former pavement engineer had 10 years of experience in pavement design and a masters degree, it can be concluded that the work was essentially under the direction of a pavement specialist. Therefore, it can be concluded that there was no need to retain consultants at the time for the pavement design.

The staff former pavement engineer left the City's employment in early 2008, when the decision to use Rosphalt had been made and the purchase order for the work had been issued. When the staff former pavement engineer left, the City did not have another person on staff with the same or higher level of expertise in pavement design.

Based on the above, it may have been helpful that a pavement specialist be involved in the implementation of the RMHMA. Given that there was no one in-house with the

required expertise, it would have been useful to retain a consultant to provide that expertise. However, as far as we could determine, the City has no guidelines for retaining consultants to assist in construction projects if they consultant has not been involved in the design.

Recommendation 8

That the City develop guidelines for the engagement of consultants to assist with unusual or new situations in construction projects where the required expertise or experience is not available within the City.

Management Response

Management agrees with this recommendation.

This is consistent with the procurement processes already in place through the Standing Offer, Request for Qualification and Request for Proposal processes.

1.5.4.4 Involvement of Pavement Specialists

As discussed above, the selection of the asphalt was made by the staff former pavement engineer, who left the City's employ before construction. During construction, the City did not have a pavement specialist on staff, and therefore, relied completely on the work of the Rosphalt manufacturer and supplier and the contractor.

The result of the lack of expertise within the City, and that the City did not retain in that case an experienced consultant to assist in the evaluation and testing of Rosphalt, was that the City relied completely on the expertise of Royston and the contractor. As previously discussed in this report, the City did not have a proper specification, was not completely aware of testing procedures for acceptance or quality assurance of the Rosphalt modified hot mix asphalt, and accepted changes made to the specified asphalt cement, although the Rosphalt procedure is to use the asphalt specification by the City. In addition, the asphalt cement was changed without formal approval by the City.

Following the failure of the RMHMA, the City retained a consulting firm to provide assistance with the evaluation of the reasons for the failure. The firm's principal engineer is the former staff pavement engineer. Although enquiries made would indicate that he is recognized as an expert in pavements, we are of the opinion that the City should, if possible, not have the same engineer who designed the project being hired to advise on problems within the same project. City staff indicated that the reason this consultant was engaged is that they could not find a suitable pavement engineer consultant in Ottawa or vicinity.

We had previously made a recommendation to the effect that the City should not retain the design engineer for review in cases where problems with the design have occurred. The review engineer must be arms length from designer.

Work done by the original consultant was reviewed by another consultant. In our opinion, the Peer Review engineer should have been retained to be the main investigator, rather than the other way around.

The City indicated that they attempted to retain a Rosphalt specialist to assist in the assessment of the pavement placed in 2008, and was directed to a New Brunswick (NB) engineer with experience in RMHMA. However, the City found that this individual had experience with construction of RMHMA, but not in design or evaluation. Furthermore, from information provided during the interviews, it appears that the NB engineer was not prepared to get involved in a case which eventually could become a court case.

Recommendation 9

That the City modify its procedures for situations in which projects have presented to problems to ensure that the reviewing engineer is different from the design engineer; and that this procedure applies to both individual engineers and engineering firms.

Management Response

Management agrees with this recommendation.

For future projects that require further review or investigation after project completion, the engineering firm and engineer assigned for review will be different than the firm/engineer who originally undertook the work. This will be reflected in a departmental directive by Q4 2011.

Recommendation 10

That the City modify its procedures so that in cases where a project is found to have a design problem, the City retain an engineer different from the one responsible for the original design to provide advice on the possible solutions to the problem.

Management Response

Management agrees with this recommendation.

For future projects that require further review or investigation after project completion, the engineering firm and engineer assigned for review will be different than the firm/engineer who originally undertook the work. This will be reflected in a departmental directive by Q4 2011.

Recommendation 11

That the City request Legal Services to consider recovering the costs associated with both the 2008 and 2009 resurfacing contracts.

Management Response

Management agrees with this recommendation, and it has been implemented.

As acknowledged in the audit report, this has already been initiated. The contract information was submitted to Legal Service prior to the date the audit was initiated. Management considers that no further action by Infrastructure Services is required.

1.6 Conclusion

The Mackenzie King Bridge is part of the OC Transpo Central Transitway, with large volume of bus traffic, operating at slow speeds and making frequent starts and stops. The MKB is also part of the NAC parking garage where leakage has been a chronic problem. These are onerous conditions on the pavement, and the City has had to mill and repave portions of the bridge annually due to deformation such as rutting and shoving in the most severe portions. A 2004 study of options for pavement rehabilitation concluded that annual pavement repairs were the most economical solution: spend an average of \$33,000 (2004\$) annually for 30 years, mill and repave the entire surface course every 15 years at an estimated cost of \$169,400, including engineering (2004\$), and replace the waterproofing and asphalt every 30 years at an estimated cost of \$621,500, including engineering (2004\$). The City could have continued to spend \$33,000 until 2019. It is noted that the assumptions in the 2004 report were vetted by the City.

Although the 2004 report was vetted by senior engineers, management now states that the bridge was renewed in 1998 and that it would be unreasonable to expect that it would be another 15 years beyond 2004 before resurfacing would be required. Management indicates that because of the frequent repairs and the fact that shortly after the repairs were done the pavement started showing signs of failure, staff worked collaboratively to find an innovative solution; based on the history of the bridge, its unique challenges, and the premature pavement failures, staff concluded that the 2004 plan warranted a different approach.

The decision to remove the waterproofing and asphalt, and repave using Rosphalt modified hot mix asphalt did not heed the previous study result, was made without proper design and testing, and without following alternative evaluation methods that were formalized in the guidelines for structure renewal. Management indicates that the decision was made in consultation with affected parties, including the Structures section, and recognizing the complexities of this structure to address both rutting and leakage issues. The total cost of removing the waterproofing on the bus lanes for the

entire length of the bridge and repaving using Rosphalt 50 modified hot mix asphalt was \$625,000 in 2008.

The decision to remove the badly damaged Rosphalt modified hot mix asphalt and repaving using conventional waterproofing and asphalt appears to be justified based on the amount of damage to the RMHMA and the leakage to the NAC parking garage. The cost of this work was \$718,000 in 2009, including approximately \$100,000 in structural bridge work that was coordinated with the resurfacing contract.

A portion of the cost of the 2008 and 2009 repaving contracts (a total of \$1,243,000) could have been avoided if the City had continued with the program of milling and repaving only those sections of the bridge pavement requiring repair in accordance with the recommendations of the 2004 Pavement Rehabilitation Report. It is expected that the annual spot milling and repaving will need to resume within a few years, as the asphalt placed in 2009 will require maintenance. This strategy did not address the leakage concerns in the NAC parking garage, which the 2005 report concluded originated from sources other than infiltration through the bridge deck.

1.7 Acknowledgement

We wish to acknowledge our appreciation for the cooperation and assistance afforded the audit team by management.