Environmental and Economic Benefits of the Full Depth Reclamation Process in the Urban Context

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**Paper prepared for presentation
At the Recycling Materials for Use in Highway Design Session
of the 2003 Annual Conference of the
Transportation Association of Canada
St. John's, Newfoundland and Labrador**

ABSTRACT

In 2000, The City of Lethbridge in partnership with the “Alliance for Lethbridge Infrastructure Services (ALIS)“ consulting team commenced planning and design for the upgrading of Mayor Magrath Drive from a four-lane to a six-lane divided urban cross-section. Consideration of several pavement reconstruction alternatives led to the selection of a Full Depth Reclamation (FDR) construction strategy for the project.

For this project it is estimated that approximately 25,000 cu.m. of “waste” material was reused. With conventional methods, this material would typically be removed from the site and potentially placed in a landfill. The FDR process reduced quantities of imported construction materials and resulted in an estimated 8000 less truck trips to, and from, the construction site.

The FDR strategy resulted in significant capital cost savings (in the order of 28% compared to conventional reconstruction), and allowed construction to occur on a key transportation corridor within the City of Lethbridge without major disruption to traffic flow and business access. The reduction in construction duration and the environmentally responsible re-use of a non-renewable resource, were added benefits.

This paper describes the process whereby the FDR alternative was selected, the steps taken to address the relative inexperience with this type of construction in Western Canada, as well as design and construction issues. The relative economics of the FDR strategy compared to conventional reconstruction alternatives are also discussed.

INTRODUCTION

The alignment that currently exists as Mayor Magrath Drive, in the City of Lethbridge, was originally a railroad grade for the CPR line travelling west to Fort Macleod. In 1909, the route was transformed to a roadway as a result of the construction of the High Level Bridge which served as a railway crossing over the Oldman River. The Mayor Magrath Drive route then began serving as a primary link to southern destinations, including the airport. In 1946 the roadway was hard surfaced, and in 1963 the roadway was upgraded to a four-lane divided collector.

Increased traffic on Mayor Magrath Drive due to community growth resulted in volumes exceeding the design capacity of 25,000 vehicles per day in the late 1990's. Efficient vehicle movement was negatively impacted at intersections and service roads, which in turn hampered access to the 150 businesses along the route.

In 2000, The City of Lethbridge in partnership with the "Alliance for Lethbridge Infrastructure Services (ALIS)" consulting team commenced planning and design for the upgrading of approximately three kilometres of Mayor Magrath Drive. The project included increasing capacity from a four-lane to a six-lane divided urban cross-section, and service road and intersection improvements. Ultimately a $17 million initiative, this upgrading represented the largest roadway infrastructure project in the City in over 15 years.

BACKROUND

Due to the size of the project, and other construction logistics, it was planned to undertake the project over a minimum two year period. In year one (2001) approximately one kilometre of the alignment was constructed, with the remaining section (approximately two kilometres) scheduled for 2002. The limits for each year were established as;

- Year 1 – Henderson Lake Boulevard to Scenic Drive (south portion of project) and,

- Year 2 – 7th Avenue South to Henderson Lake Boulevard (north portion of project).

In 2001, a detailed pavement evaluation was undertaken to provide the basis for developing pavement rehabilitation/reconstruction alternatives. This assessment included a geotechnical subsurface investigation, detailed condition survey, structural evaluation, using falling weight deflectometer (FWD) testing, and pavement structure thickness determination (using Road Radar ™ technology).

Originally, a “traditional” widening construction was considered feasible for the Year 1 section. In this case the ultimate profile and footprint of the upgraded facility enabled simply adding the additional two lanes to the outside of the existing roadway, This could potentially allow the majority of the existing pavement to be “salvaged”. A relatively simplistic life cycle cost analysis (LCCA) suggested that a reconstruction, versus rehabilitation and widening, was the favored strategy. This was primarily due to the relatively poor condition of the existing pavement, which required extensive rehabilitation in terms of surface condition (e.g. rutting, raveling, and localized fatigue cracking) and relatively severe transverse cracking.

Due to the potential salvage value of the existing pavement materials, several “recycling” options were considered for the reconstruction of the roadway. Full Depth Reclamation (FDR) appeared to be a potentially advantageous alternative. FDR is a construction technique in which the entire asphalt concrete pavement thickness and a portion of the underlying granular base is pulverized and reconstituted into a homogeneous pavement layer. Options to enhance the FDR material include mechanical, chemical and bituminous stabilization, or a combination of these. Typically, the material is pulverized, graded and shaped to the intended profile and cross-section, additives are incorporated when required, followed by stabilization, final grading and compaction. Detailed descriptions of the process are available in [1], and more recently [2].

The AASHTO method of pavement design [3] was used to provide several “equivalent” pavement design alternatives for consideration. In developing a FDR design, a structural layer coefficient of 0.24 was utilized. This was assumed for the design based on typical ranges of values for bituminous stabilized materials provided in the pavement design guide [3], and other published information [4,5].

Ultimately FDR construction strategy was selected for the project. A preliminary cost comparison with other reconstruction alternatives indicated an initial cost saving, compared to conventional reconstruction, of approximately 15%.

Essentially FDR is an “at grade” construction which, in most cases, eliminates the requirement to remove and dispose of off-site, existing pavement materials. The strategy enables traffic to be maintained along the roadway being constructed (where three traffic lanes were made available), and intersecting roadways continue to function with minimal interruption to business access. This process does not require a significant sub-cut, which makes the construction site much less sensitive to inclement weather, and reduces the overall duration of construction in comparison to conventional reconstruction methods.

The lack of utility apparatuses and relatively uniform cross-section (in terms of layer thickness) of the existing pavement supported the FDR alternative.

In Year 2 the criteria for selection of the FDR construction strategy was significantly different that in Year 1. In this case, two circumstances governed the selection of the process;

1) The location of the existing pavement (in terms of footprint and profile) differed from the ultimate facility by approximately 80%, thereby essentially eliminating a rehabilitation / widening alternative even though the existing pavement was in relatively good condition, and,

2) The positive experience with the FDR construction process in Year 1, specifically with respect to the advantages described previously.

Figure 1 provides an illustration of the pavement structure design adopted for Years 1 and 2.

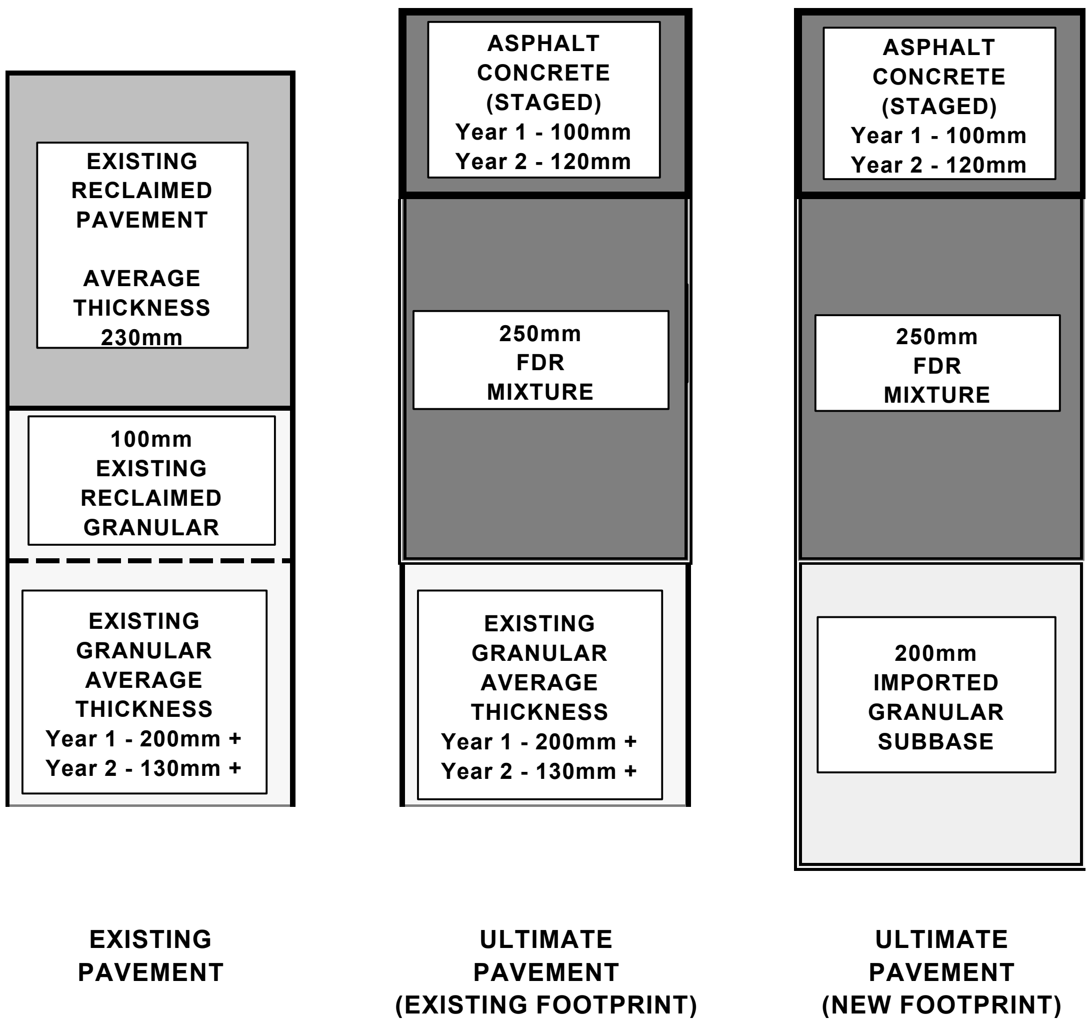

Figure 1: Design Pavement Structure (Years 1 and 2)

PROJECT ISSUES

It was evident that although the FDR strategy was perceived as appropriate, with respect to the Mayor Magrath Drive upgrading, several issues had to be addressed. The majority of the issues identified focused on a primary deficiency; that being the lack of experience with FDR technology in, not only Lethbridge but Western Canada. At that time FDR projects in Western Canada primarily had taken the form of demonstration or trial projects, using a range of stabilizers and applications in the pavement system. This combined with little, if any, urban application experience was significant to undertaking the process for this project.

The lack of experience with the process applied not only to the Owner (City of Lethbridge) but also, to the consulting team and the local and regional contracting industry. In addressing this hurdle, several aspects were considered:

1) A “shared risk” approach,
2) Technology transfer initiatives, and,
3) A partnering process

The “shared risk’ approach recognizes that for an Owner there is additional risk associated with utilizing a process with which limited experience exists in the construction community (i.e. consultants and contractors). This risk must be weighed with the potential advantages, both with respect to the project under consideration and future applications.

Recognizing this, a technology transfer with other jurisdictions, practitioners and contractors was initiated both before and after project tendering. Prior to the tender, pavements specialists began research into the pavement design aspects of FDR materials, and drew on contractor and supplier experience from other jurisdictions. This information was then provided to the Owner and the project design and construction consulting team, through informal presentations and meetings. A dialogue was also initiated with the local contracting industry, to advise them as to the intended course of action with respect to the project construction. They then gained familiarity with the FDR process by networking with, and seeking input from, contractors in other jurisdictions. A formal presentation outlining the pavement design aspects, FDR materials evaluation and mixture design methodology, and construction equipment and process requirements was provided at the mandatory pre-tender meeting.

The FDR specifications used for the project were developed using the guideline specifications published by the equipment manufacturer, Wirtgen [6]. The “shared risk” concept was used in the preparation of the tender. The objective was to reduce the risk of unknowns to the contracting sector. The tender provided comprehensive Road Radar™ pavement thickness information for the existing roadway and it was stipulated that all costs associated with materials evaluation and FDR mixture design would be borne by the Owner. In addition, separate pay items were established for;

- pulverization of existing asphalt concrete and granular base (sq.m.)
- provision of supplement aggregate, if required (tonne)
- provision of emulsified binder (tonne)
- relocation of pulverized material, if required
- stabilization and compaction of the FDR material (sq.m.)

It is noted that a cationic slow setting emulsion product (CSS-1) was specified for the project. This product was selected on the basis of the design layer thickness, and the anticipated gradation of the material in terms of fines content (i.e. percent passing the 80μm sieve size). It was acknowledged that alternative products would be considered if a benefit could be demonstrated.

Tenders were received from both of the primary road-building contractors in the Lethbridge area. Each demonstrated a genuine commitment to invest in the process in terms of the necessary equipment and other process requirements.

The technology transfer process continued after the contract tender closing. A delegation comprising a representative from the City, from the construction management team, a pavements specialist, and two principals of the successful contracting firm traveled to Ontario shortly after award of the contract. Here they met with a contractor experienced in the FDR process, and were provided with a presentation and tours of both completed projects and construction in progress. This initiative was considered of significant value in not only “educating” the project team, but also gaining a level of confidence that was primary to successfully undertaking the project at hand.

Partnering, which has been used for some time on major projects in Lethbridge, was initiated by the City for this project. The partnering process focuses on relationships and how to “work together” towards a common goal. Partnering does not affect the contractual obligations or matters, but defines the lines of communication and dispute resolution. The partnering process fit well with this project, and was consistent with the “working together to make it work” atmosphere being nurtured.

MATERIALS EVALUATION AND FDR MIXTURE DESIGN

The contract required the contractor to pulverize the entire asphalt concrete pavement (ACP) layer (varying thickness) and the underlying 100mm of granular base or sub-base. As shown in Figure 1, the stabilized FDR layer thickness of 250mm was constant in both years. This was determined from the ACP thickness information provided by the Road Radar™ survey, the area to be pulverized and the area to be stabilized, while recognizing that an aggregate additive (mechanical modification) could be used to provide a modest supplement to the quantity if necessary.

As pulverization proceeded, samples of the material were characterized in terms of binder content, aggregate gradation and coarse aggregate fracture. Representative samples (pulverized material and potential aggregate additive) were provided to the Contractor's emulsion supplier for analysis. Compatibility of the aggregate / binder combination was assessed for coating ability with various emulsifiers, and the most appropriate formulation was established.

The mixture design phase proceeded, using what was considered the state-of-the-industry methodology. Generally, the mixture design process was as follows;

1) <u>Determine the need (and benefit) of an aggregate additive.</u> In this case, approximately 10% of a clear fractured rock was chosen. This was selected to reduce the fines content of the combined gradation, improve the physical properties of the mixture (e.g. strength), and marginally supplement the volume of stabilized material.
2) <u>Determine the optimum fluid content (OFC) for the mixture.</u> Using Standard Proctor methodology, the content of fluid (comprising a 50:50 blend of water and emulsion) was established which provided the highest compacted dry density.
3) <u>Determine the optimum emulsion content for the mixture.</u> Trial mixtures were prepared over a range of emulsion content, while altering the water content to maintain the OFC. Samples were cured for 1 hour at 60^{o}C and Marshall specimens were prepared with 50 blows per face, followed by a 24 hour conditioning at 60^{o}C, followed by 25 additional blows per face, and additional curing for 24 hours. The properties, including void content, strength (i.e. stability), and moisture susceptibility (i.e. tensile strength ratio and/or retained stability) are compared to the mixture design guidelines and the "optimum" emulsion content is selected.

Table 1 provides the FDR job mix formula (JMF) blend and properties for Years 1 and 2, and the mixture design guidelines. As shown, the aggregate additive dosage was increased in 2002. The primary reasons were to decrease the fines content (to below 10%), and to compensate for a projected shortage of pulverized material. It is noted that the 2002 JMF did not meet the design criteria for void content and dry indirect tensile strength. This was not considered critical, given the excellent resistance to strength loss due to moisture, and in fact the properties of the field-produced mixture were generally compliant with these criteria.

Table 1
Summary of FDR Design JMF Properties

Property	2001 JMF	2002 JMF	Design Criteria
Optimum Total Fluid Content (%)	5.5	5.0	-
Reclaimed Asphalt Concrete (%)	66	63	-
Reclaimed Granular (%)	26	25	-
Coarse Aggregate Additive (%)	8	12	-
Percent Passing 20mm	98	95	-
Percent Passing 5mm	51	46	-
Percent Passing 0.080mm	9.2	9.9	-
Emulsion Content (%, by mix)	2.7	2.9	-
Total Bitumen Content (%)	3.4	4.0	-
Bulk Specific Gravity	2.295	2.311	-
Maximum Specific Gravity	2.496	2.484	-
Void Content (%)	8.1	7.0	8 – 12
Dry Stability (kN)	22	14	8.9 min.
Marshall Flow (mm)	12	13	-
Wet Stability (kN)	16	13	-
Retained Stability (%)	73	93	50 min.
Dry Indirect Tensile Strength (kPa)	330	220	300 min.
Wet Indirect Tensile Strength (kPa)	239	180	100 min.
Tensile Strength Ratio (%)	72	82	50 min.

Note: Dry Stability, Flow and Indirect Tensile Strength at 25^{o}C
Wet Stability and Indirect Tensile Strength after 1 hour partial vacuum saturation at 20cm Hg (25^{o}C) followed by 1 hour soak at 25^{o}C

CONSTRUCTION

The construction sequence generally involved pulverizing the existing materials, moving the material (when required), and undertaking the necessary grade widening. Curb and gutter was installed to grade at the outside of the roadway, and the required materials were placed, graded and compacted. Final grading was done in preparation for FDR stabilization accounting for the layer of aggregate additive, which was then placed. A “pinned-on” curb was placed after paving to allow better access for construction equipment and enable more options for traffic accommodation. Although this roadway facility was relatively void of utility appurtenance, several manholes were located within the roadway. These were “dead-headed” at subgrade elevation. After paving the manholes were excavated and extended to surface elevation. The excavation was then backfilled with low-strength concrete and surfaced with asphalt concrete.

The advantages of the FDR process with respect to traffic accommodation became evident early in the construction process. As no significant widening construction was necessary at primary intersections, traffic disruption was limited to very limited periods (i.e. in the order of 10 minutes) during pulverization and stabilization activities. In the case of business access, alternative routes were provided during the period when widening or relocation of the roadway footprint where undertaken.

The FDR process also provided some benefit with respect to minimizing traffic disruption on the Mayor Magrath Drive route. When required, traffic was opened on the stabilized FDR while work proceeded on adjacent lanes. The FDR surface remained intact, with minimal raveling, and traffic markings were effectively applied and maintained. The nature of the construction also significantly reduced the amount of construction traffic to, from and within the construction site. This had a positive impact on the volume of traffic to be accommodated during construction.

Figure 2: Traffic Accommodation during FDR Stabilization

Figure 3: Continuous Transit Bus Service during Construction

Comprehensive QC/QA was provided during all phases of the construction. Initially, characterization of pulverized material was undertaken to evaluate the materials and validate the mixture design. Investigation, using trenching or test-holes, was undertaken following placement of the pulverized material to the required grade. This investigation served to assure the required thickness of pulverized material was in place and that granular material, as necessary, was present below the pulverized FDR layer. The moisture content of pulverized material was determined from collected samples and, when required, corrective action was taken to attain a total fluid content (i.e. in-situ moisture and emulsion) as near to optimum as practical. When a deficiency in water content was identified, provision was made for pre-wetting the material prior to stabilization. In some cases, the area was re-pulverized to assist in reducing the moisture content prior to stabilization. The moisture content samples, after heating, also provided an indication of the material composition (i.e. if the material generally had the 2/3 asphalt concrete, 1/3 granular composition). Although subjective in nature this, in at least one case, required removal and replacement of material prior to stabilization.

Grading control for all pavement layers was important. This is more critical in the urban context, as opposed to rural applications, in that the final surface elevation is closely fixed. This required tight survey control throughout the process. Due to the relatively thin asphalt concrete design thickness, the underlying FDR layer was compacted prior to stabilization and "overbuilt" to enable precise grading during finishing of the stabilized layer, and removal of the excess material.

Figure 4: FDR Grading Operations

Continuous QC/QA monitoring and testing was provided during the FDR stabilization process. This effort responded to the experience of others; that being "that the design JMF is only a starting-point and you must react to the prevailing conditions (i.e. material moisture content and climatic conditions)"[7]. Moisture content samples were acquired from behind the stabilizing equipment, and tested on-site. This provided a continuous measure, and trend, of the material moisture content. If considered significantly less than optimum, pre-wetting of the material ahead of the stabilizing was considered. Some reduction in emulsion addition rate was an option if the moisture was above the optimum.

In response to the influence of climatic conditions, the consistency of the stabilized material was monitored continuously, immediately behind the stabilizing unit. A type of "snow-ball test" was done, where the material is considered "optimum" when a snow-ball can be made (the material has acceptable cohesion), and a mottled staining of the hands is noted (as compared to a heavy staining which would indicate excessive binder). This and other observations of the material (e.g. adherence to the equipment tires and appearance after initial compaction) were used as the basis for minor adjustments to the emulsion addition. Such adjustments were typically the result of collective agreement between the QC/QA and Contractor personnel.

Generally, an increase in emulsion addition would be considered in response to hot, dry weather and/or a less than desirable moisture content in the stabilized material. If the material was below the optimum moisture content range pre-wetting was typically used, but if the weather was cooler (particularly with a high humidity) a decrease in emulsion addition was considered.

Random samples of the stabilized FDR material were acquired for laboratory testing. The samples were tested for total binder content, aggregate gradation, compacted density (which formed the standard for compaction), Marshall stability, air void content and moisture susceptibility (retained stability or tensile strength ratio).

The emulsion addition rate was checked periodically based on the total mass of emulsion applied (using delivery truck weigh-bills) and the area, or volume, stabilized. The microprocessor controlled additive system on the stabilizing equipment proved to be reliable. Proper positioning of the mixing chamber front and rear gates, and regular checking of the spray bar nozzles for blockage assured adequate mixing.

The stabilizing unit made successive passes beginning at the outside curb. The length of passes was typically in the 300m to 400m range. The compaction operation was generally a three phased approach. Initial compaction was by two relatively large vibratory pad-foot rollers directly behind the stabilizing unit. This served to seat the material and initiate the compaction process from the bottom of the FDR layer, upwards. When sufficient area was stabilized, the upper 100mm to 150mm was graded off, and compaction of the lower portion of the layer was accomplished with a combination of relatively large steel vibratory rollers, and pneumatic tire rollers. This compaction equipment was also used as the previously removed material was graded back into position. The final phase of the compaction process was with lighter combination rollers and pneumatic tire rollers during final grading.

The grade control consisted of accomplishing the correct elevation at the curb line with physical measurements, then utilizing the grade control equipment on the motor-grader for the remained of the roadway width. A light application of water was made on the completed FDR layer, which with pneumatic tire rolling flushed the uppermost fine material upward to seal the surface.

The specified density requirement for the stabilized FDR material was 97% of the 75 blow Marshall determined from representative mixture samples acquired during construction. Testing was done using a nuclear densometer, using the “wet density” mode. This was considered necessary to eliminate inconsistencies with the instrument’s measurement of both bitumen and water as “mois Attempts to acquire full depth cores of the stabilized FDR material (even after curing) were unsuccessful.

Figure 5: FDR Compaction Operations

It was envisioned that, depending on the weather conditions, the curing period requirement for the FDR stabilized with emulsion would be in the order of two weeks. This curing period is required to enable the mixture to gain sufficient strength prior to overlaying the surface with the asphalt concrete layer. For emulsion stabilized mixtures, some agencies require that the material cure until the moisture content is at, or below 2%. Another requirement used by some is that if a core can be extracted from the stabilized layer, it is acceptable to overlay the material. Having said this, it is generally recognized that these materials typically achieve their ultimate strength within a time frame anywhere from one month to over a year. Therefore, the decision to enable the placement of the overlying asphalt concrete layer is based on whether the stabilized material has gained sufficient strength to satisfy the pavement design, while recognizing that some additional strength gain will occur after the overlay.

The 2% moisture criteria were adopted for the Year 1 construction, and generally this was the case, particularly for the upper 2/3 of the stabilized layer. In Year 2 the prevalent climatic conditions (i.e. wet, humid weather) resulted in extended curing periods to reach the 2% moisture content level. It became obvious early in the 2002 construction that this requirement would necessitate extended curing periods far in excess of two weeks. This would have serious implications on the project schedule and as a result alternatives to the 2% moisture content requirement were considered. An approach was taken were the strength gain was monitored by deflection analysis using Benkelman beam methodology. The concept adopted was that if the deflection of the FDR layer was less than that which would indicate little or no overlay requirement for the anticipated traffic, it was acceptable to overlay the material. For this project, and estimated traffic, a deflection of 1.0mm was selected as the requirement for strength gain prior to paving. Figure 6 illustrates the deflection analysis for selected sections of FDR construction. In one case (SBL Sept. 25, outside lane), the deflection was above the 1.0mm criteria and areas were milled and inlayed prior to paving. These areas were selected on the basis of the deflection results. Figure 7 presents the average moisture content results for the same four sections, based on three test holes per section.

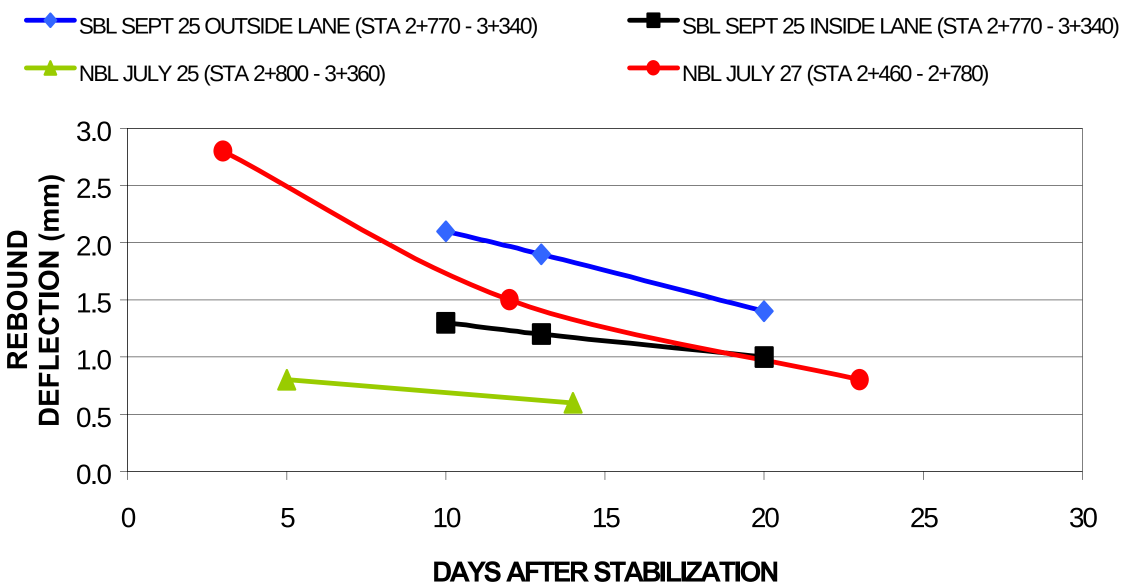

Figure 6
Deflection vs. Time After Stabilization
(Selected FDR Sections)

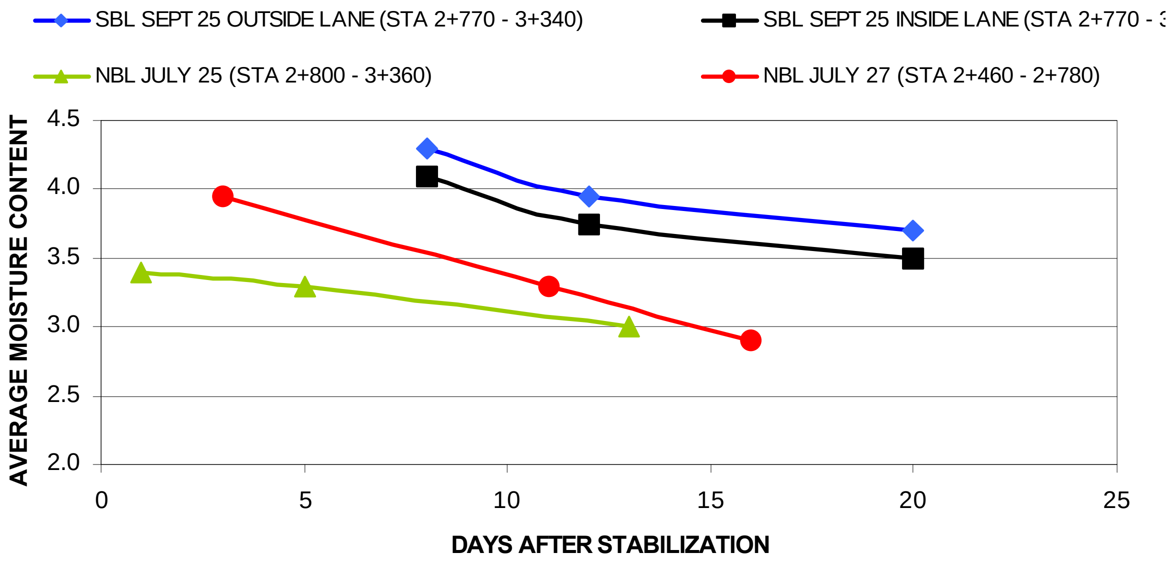

Figure 7
Moisture Content vs. Time After Stabilization
(Selected FDR Sections)

As shown, the deflection criteria adopted supported enabling paving to proceed, when it would not have been allowed if the 2% moisture content requirement was enforced. In fact, it is unlikely that any of the sections constructed in 2002 would have reached this moisture content for an extended period, if at all. It is recognized that the sections that had lower moisture content after stabilization generally had the shortest curing period until the 1.0mm deflection level was reached. This reinforces the importance of proper moisture conditioning, and the resultant advantages with respect to reducing the curing period.

ECONOMIC AND ENVIRONMENTAL BENEFITS

As previously discussed, a potential initial cost savings in the order of 15% for the FDR alternative, compared to conventional reconstruction, was identified during the preliminary design phase for the project. Based on an estimated design traffic loading of 3 million Equivalent Single Axle Loadings and an assumed subgrade modulus of 32 Mpa, the required Structural Number (SN) for the pavement design was 124. The pavement structures specified for 2001 and 2002, with the equivalent conventional structure, are presented in Table 2.

Table 2
Comparison of Pavement Structures

	2001 Structure	2002 Structure	Conventional Structure
Asphalt Concrete (mm)	100	120	180
Stabilized FDR (mm)	250	250	-
Granular Base (mm)	-	-	200
Granular Sub Base (mm)	200	130	200
Resulting Structural Number (SN)	124	124	124

The design called for a staged asphalt concrete pavement, where a 40mm final lift would be placed over the entire project. Therefore, the 2001 and 2002 construction was a single lift application of 60mm and 80mm, respectively.

Based on an ultimate pavement area of 25,000 sq.m. in 2001 and 45,000 sq.m. in 2002, the pavement construction costs are provided in Table 3. The cost associated with a conventional pavement structure is provided for comparison. The costs for the FDR structures are based on actual project costs. The cost for the conventional structure is based on recent capital works projects in the City of Lethbridge.

Table 3
Comparison of Pavement Structure Costs

	2001 Construction (25,00 sq.m.)		2002 Construction (45,000 sq.m.)	
	FDR Structure	Conventional Structure	FDR Structure	Conventional Structure
Total Cost ($)	675,600	1,037,750	1,305,000	1,703,250
Difference ($)	362,150		398,250	
Difference (%)	35%		23%	

Note: All costs exclude 40mm final lift paving

Assuming the same service life for each alternative, the initial cost savings for the project were in excess of $750,000. The primary reason for lower cost savings in 2002 was the increased quantity of pulverized material which had to be moved from one location to another. In fact almost the entire existing pavement was moved after pulverization and stockpiled on site. This suggests that significant cost savings can still be achieved even when the upgrading requires total relocation of the roadway footprint and/or profile. The magnitude of the savings (28% for this project) indicates that the FDR alternative may, in some cases, be more cost-effective than rehabilitation of a pavement with significant cracking distress.

Although more difficult to quantify, another economic benefit was the reduced construction period. Due to the limited construction window in 2001 (August to November), and the record-setting rainfall during the 2002 construction season (June to November), it was likely that construction completion would have been seriously jeopardized in both years. The shorter duration of construction also had a positive impact on the costs associated with traffic accommodation.

For the business community effected by this construction, this was a “make, or break” project. The reduced disruption to business, and the perception that everything that could be done, was being done, resulted in no claims for loss of business as a result of the construction.

Environmental benefits were also significant. The most obvious is the reduction in waste material. It is estimated that, with conventional reconstruction, approximately 25,000 cubic metres of material would have been removed from the site and potentially placed in a landfill. With the FDR process this material was reused, which not only eliminated waste of material but also significantly reduced the amount of haulage. This, along with the reduced quantities of imported construction materials, resulted in an estimated 8000 less truck trips to, and from, the construction site. Not only did this reduce traffic congestion at the site; the reduction in truck travel (estimated to be 38,000 km) both reduced wear and tear on existing infrastructure and resulted in fuel savings.

Preservation of non-renewable aggregate resources is both an economic and environmental benefit. Generally, substantial quantities of aggregate, at reasonable cost, are available in the Lethbridge region. Therefore, it could be expected that the economic benefits of the FDR strategy could be more significant in areas were aggregates are less plentiful.

Finally, the social perception of this type of process is consistent with the public’s support, and preference to reclaim/recycle/reuse.

CONCLUSIONS

The FDR strategy offered a number of advantages relative to the primary objectives of the upgrading construction; namely to minimize the impact on traffic, both on Mayor Magrath Drive and the surrounding roadway network, and to minimize the disruption in access to the adjacent businesses.

The FDR strategy resulted in significant capital cost savings, and allowed construction to occur on a key transportation corridor within the City of Lethbridge without major disruption to traffic flow and business access. The reduction in construction duration and the environmentally responsible re-use of a non-renewable resource, were added benefits.

Based on the experience gained from this project, FDR is considered a viable alternative to traditional reconstruction / rehabilitation strategies in the urban environment. This positive experience with the FDR application will be supplemented by performance monitoring (visual condition, IRI, FWD) over the longer term.

CLOSURE

A key component of the functional planning for the project was an extensive public consultation process. Principals, or key issues, were developed by the consulting team in association with a focus group made up of business and community stakeholders. These issues, among others, included improving (and maintaining during construction) business access, value for money, safety, and implementing opportunities for environmental stewardship. The FDR construction process successfully responded to these stakeholder priorities.

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