TRENDS IN THE USE OF ROLLER COMPACTED CONCRETE PAVEMENTS IN CANADA

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ABSTRACT

This paper covers the development and use of Roller Compacted Concrete (RCC) pavements in Canada since its inception in 1976. The application of RCC in the pavement market has undergone a major expansion and transition since its introduction to the forestry industry in Western Canada (1). Unlike other traditional paving materials, RCC has proven itself as a superior structural pavement in the first instance and is now gaining favour with roadway agencies in the more common municipal arena. Along with specialty applications such as RCC inlays for intersections (Fast-Track RCC!), designers have also used this innovative construction technique for subdivision residential and arterial roadways (2). Examples exist where RCC has been used exclusively for reconstruction of truck lanes (3) on major routes as well as alleys for garbage collection. The first RCC overlay of an existing deteriorated asphalt parking area was completed in 1996.

A brief review of RCC as a material will be presented. Construction methodology common to Canada will be covered and alternative construction equipment options will be suggested (4).
Example projects will form the main body of the paper. Early applications from the resource based industries in Canada such as forestry, pulp and paper and composting (5) are used to lead into the transition RCC pavement is experiencing. A broad cross-section of roadway applications and commercial uses of RCC are presented to effectively illustrate the emergence of RCC paving as a viable option for today and the future.

INTRODUCTION

The first use of RCC in Canada is credited to the construction of a log sorting yard (1), called Caycuse, on Vancouver Island, British Columbia, in 1976. Since that time it is generally accepted that the overall volume of RCC in Canada, for all paving applications, has grown to represent amounts defined by the following figures, TABLE 1, based on an equivalent 200 mm thickness of paving:

TABLE 1: Quick Canadian Facts (6)
March, 1997

* Total Area	3,000,000	m^2
* Single Lane Kilometres	860	km
* Tonne of RCC Placed	1,450,000	tonnes
*Cement Consumption	190,000	tonnes

Source: Canadian Portland Cement Association

As-built thickness of RCC pavements range from 100 mm to 600 mm. Thicker pavements, up to 1,200 mm of multi - lift construction are being proposed for very specific off-highway equipment with a mass in the order of 340 tonnes!

These figures are exclusively associated with RCC pavements. The use of RCC in water resource applications has been minimal to date in Canada, although, recent projects in Quebec and Newfoundland attest to the interest of RCC in this market segment.

The list of RCC pavement projects in Canada, over 200, now include the following applications:

* Log sorting yards
* Pulp storage warehouse floors
* Intermodal yards
* Haul roads - highway
* Alleys
* Overlays (whitetopping)
* Arterial roads
* Saw mill yards
* Chip storage sites
* Commercial truck stops
* General storage yards off-highway
* Truck lane inlays
* Intersection inlays
* 'Fast Track' RCC

Many advantages can be obtained from using RCC in addition to the structural capacity of the material. It has demonstrated its comparative economy to other systems and continues to perform well in the severe weather conditions of Canada, coast to coast. Users have increased productivity of their mobile yard equipment, reduced related maintenance costs and may even find that with a combination of these benefits they can minimize the number of extremely expensive units they need in the mobile fleet. Even one less machine could offset the cost of the RCC paving.

Two trends are evident in the reported applications of RCC. The first trend is the continued use of RCC as a paving material of choice for industrial and resource based facilities (7). This trend has been continuous for the past two decades. Most of the projects in this area represent larger volumes of RCC and receive a greater degree of awareness in the engineering community.

The second trend that has developed in the more recent history of the use of RCC has been in the urban paving arena. Subdivision residential streets and arterial roadways represent the more common applications. Other unique uses worthy of reference include inlays specific for truck routes, fast - track RCC, intersection approach lanes and exposed RCC overlays.

Both trends demonstrate an on-going acceptance of RCC as an engineered paving option.

ROLLER COMPACTED CONCRETE

Materials:

A RCC mixture is normally comprised of measured units of Type 10 Normal Portland Cement (Canadian Standards Association), water and market available aggregates (both fine and coarse or blended). The portland cement portion of the mixture (8 to 16 %, 190 to 400 kg/m3) can be varied by the use of high early cement and /or supplemental cementitious materials as fly ash. In 1995 the first use of silica - fume blended cement was recorded for an RCC mixture where high performance strengths were specified (8). A strength of 50 MPa in seven days was specified. Twenty-eight days strengths exceeded 65 MPa. Compressive strengths of 25 to 35 MPa in 28 days are more commonly specified (9).

Water requirements for the mixture are usually satisfied from locally available source of potable water.

Aggregate sources for early RCC projects were often site specific, had an acceptable gradation curve, with limits placed on the maximum top size aggregate and a degree of constraint on the percentage passing the 80 micron sieve. The maximum top size is now held between 12 mm and 20 mm which addresses the surface tightness requirements of most projects. The 80 um sieve quantity, the silts and clays component of the fines, is held to a figure not exceeding approximately 6% so as to not impact adversely on the strength development of the RCC mixture. TABLE 2 clarifies the characteristics and influence of the aggregates.

TABLE 2: RCC General Aggregate Features and Related Influence

Item	Influence	Acceptance
Coarse Aggregate:		
.....Maximum Size	Affects Surface Tightness	12mm - 20mm
Mid-Range:	Affects Compactability	Local Specification
Fine Aggregate:		
.....% Passing 80 um	Affects Compressive Strength	<6%

Urban projects of the 1990's often call for the aggregate to be obtained from market available stockpiles such as may be specified for conventional concretes, bituminous mixtures or road crushed base course material. All three sources are common to the urban markets where RCC growth is evident and will in large measure satisfy the general criteria required for RCC. TABLE 3 provides a comparison of metric sieves and illustrates typical local specification.

COMPARISON OF METRIC SIEVES AND TYPICAL SPECIFICATIONS FOR LOCALLY AVAILABLE MATERIALS

SIEVES IN ACCORDANCE WITH: AASHTO DESIGNATION: M92 ASTM DESIGNATION: E11	METRIC SIEVES IN ACCORDANCE WITH: CGSB SPEC. 8-GP-2M	SPECIFICATION FOR TYPING LOCALLY AVAILABLE MATERIALS			
		PORTLAND CEMENT CONCRETE AGGREGATES	ASHALT CONCRETE AGGREGATES		ROAD BASE CRUSH COURSE
125.0 mm 5"	125000		#1	#2	
75.0 mm 3"	80000				
63.0 mm 2-1/2"	63000	CSA A231			
50.0 mm 2"	50000	SEC 5			
37.5 mm 1-1/2"	40000				
25.0 mm 1"	25000				
19.0 mm 3/4"	20000		100		100
16.0 mm 5/8"	16000	FINE		100	84 - 94
12.5 mm 1/2"	12500		85 – 95	80 - 92	
9.5 mm 3/8"	10000	100		70 - 84	63 - 86
4.75 mm # 4	5000	95 – 100	45 – 85	50 -65	40 - 67
2.36 mm # 8	2500	80 – 100			
2.00 mm #10	2000				
1.70 mm #12	1600				
1.18 mm #16	1250	50 - 90		26 - 45	20 - 43
0.850 mm #20	800				
0.600 mm #30	630	25 - 65		18 - 38	14 - 34
0.425 mm #40	400				
0.300 mm #50	315	10 - 35		12 - 30	
0.150 mm #100	160	2 - 10	7 - 12	8 - 20	5 - 18
0.075 mm #200	80		3 - 7	4 - 10	2 – 10
0.045 mm #325	45				

Construction Process:

The materials for RCC are fed uninterrupted from their respective storage areas into a horizontal mixing chamber. This continuous flow pugmill mixing plant blends the material with water to a slightly greater moisture content than optimum. The mix will look like damp gravel following mixing and little cement paste will be evident. Often the designated moisture content desired , optimum plus 1%, can be verified by the simple hand squeeze method.

Production rates vary from 200 to 600 tonnes / hour depending on the size of the plant. Most plants are highly mobile and can be ready for relocation and reassembly in hours. Standard conventional mobile mixers have been used on some projects with good RCC mix results. Volumes of RCC maybe somewhat lower. Batch plant RCC mixtures from conventional ready mix concrete plants also have also been utilized on occasion for smaller volume projects.

A generic RCC plant layout is shown in FIGURE 1.

The mixing chamber feeds a conveyor which in turn passes the RCC mixture through a surge or storage hopper to be received by open dump trucks. The surge hopper prevents segregation during loading as the trucks change and transport the mix to the laydown equipment.

The most common means of placing the RCC mixture is through an asphalt paving machine. Preference has developed for a European high density asphalt paver incorporating dual tamping bars. At last count nine such machines were at work in Canada. The main benefit of the high density pavers is the density achieved immediately behind the machine, in the order of 90 -95 % as compared to 75 - 85 % for standard North American equipment. Beyond the reduced final compaction effort to reach 100% density other benefits accrue with respect to achieving better riding quality, favorable surface friction and higher productivity with the use of a high-density paver.

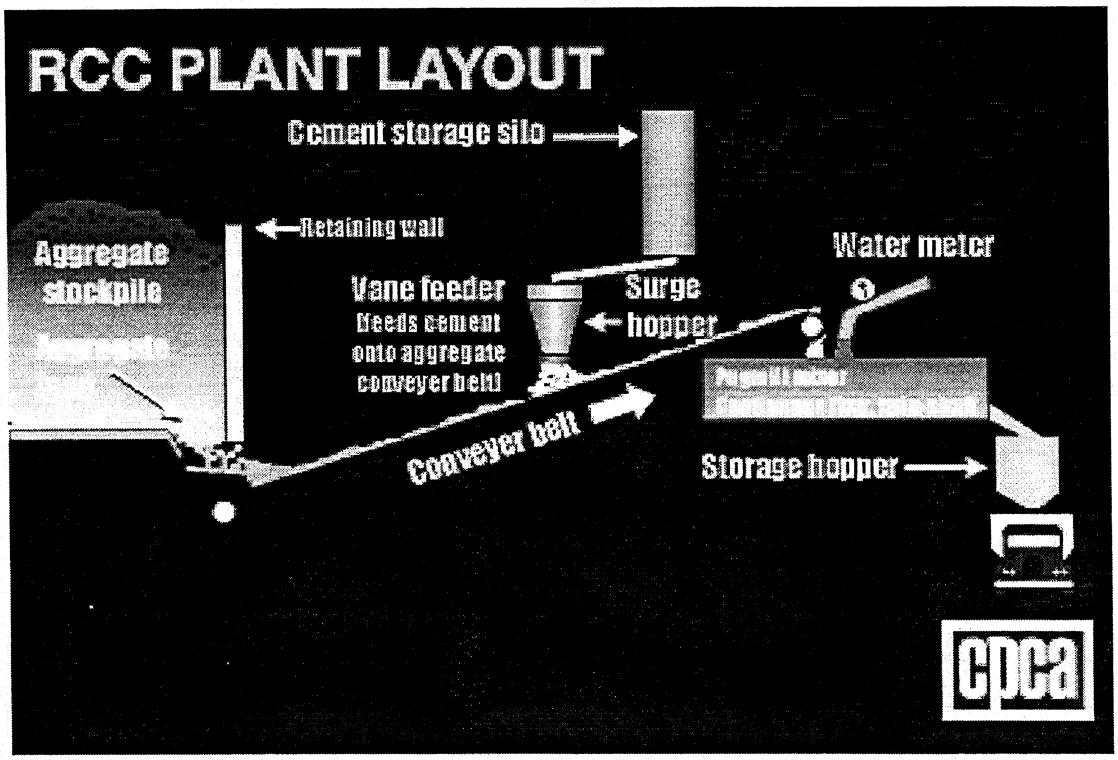


FIGURE 1: RCC plant layout for pugmill operation.

It follows that less preferred means of placing the RCC mixtures include standard asphalt pavers, Jersey spreaders (common to cement treated base construction), and dump and blade techniques. The equipment selected should provide the best arrangement to achieve the end result of acceptable thickness, surface texture, density and smoothness or riding quality. Each project should be evaluated for these factors and the economies arising from the equipment options available.

Regardless of equipment selected, compaction of the RCC lift should commence immediately behind the spreader. The required maximum density is achieved by the use of normally available steel wheeled vibratory rollers, usually 10 tonnes or greater. Rubber tired rollers may also be used for final passes to provide greater surface tightness. Caution must be taken to avoid surface delaminations which may develop from excessive rolling of the RCC. Experience and field testing will provide the minimum and most efficient rolling pattern to achieve maximum density and avoid surface delaminations.

Whether the RCC is left exposed in service or will receive a bituminous cap, curing of the pavement should begin immediately following final compaction. The preferred curing method is with the use of water directly applied by water trucks or sprinkler systems employed for larger areas. Other methods of curing that have been used include curing compound as used for conventional concretes, and sprayed applied asphalt emulsions. Project specifics will dictate the curing option best suited for the RCC.

Tests employed in monitoring the RCC pavements during construction include the fabrication of standard cylinders for laboratory cured compressive testing, nuclear densometer readings for measurement of densities, coring of in-place RCC, cutting of beams, etc. A final consensus on acceptable tests for RCC has yet to be adopted but some guidance is offered by reference to Canadian Standards Association A23-2 M95, Methods of Test For Concrete (National Standards of Canada).

DURABILITY AND MAINTENANCE

Freeze/Thaw

Durability of the exposed RCC pavements constructed since 1976 has not proven to be an issue relative to the end field performance of any of these facilities.

Maintenance on existing RCC installations has been minor and primarily related to the need to address random shrinkage cracking. Routing and sealing of these cracks is deemed necessary particularly in municipal paving. Other repairs which may arise are usually rectified with the ready mixed concrete used as a replacement material.

TRENDS IN THE USE OF RCC PAVEMENTS

Industrial and Resource Pavements:

The first trend evident in the use of RCC in Canada is the continuing application of RCC in heavy industrial and resources based industries. These applications are primarily characterized by the need of the pavement to support extremely heavy equipment such as log stackers (90,000 - 150,000 kg) , intermodal container equipment (100,000 - 150,000kg), off-highway trucks (200,000 - 360,000kg) and the more basic large front end loaders and fork lift trucks. The majority of these examples represent the 'first use' of heavy duty pavements as operators recognize the increased productivity achieved from paving.

All the examples of RCC pavements given within this paper should be noted as having been constructed and are operating in a climate that is noted for its extremes even by the residents! Temperatures range from + 35 C to - 40 C .

Example No. 1 - PHOTO 1

Caycuse,Vancouver Island, British Columbia.

The RCC pavement for this log sorting operation has been referenced (1) on many occasions as the first in Canada. The "mother of necessity" switched the original surface from asphalt to soil-cement, similar to the base, when the asphalt plant became unavailable. The one exception to the soil-cement mix used to replace the asphalt was the addition of double the cement content to meet the abrasion resistance needed for the exposed surface. RCC was born in Canada! The log sorting yard operated for a dozen years before closing. It was subjected to a total of more than 30 freeze thaw cycles per year without evidence of surface deterioration. This project was completed in 1976. The facility was abandoned in the late 1980's.



PHOTO 1: Caycuse, British Columbia log sorting operation in British Columbia.

Example No. 2 - PHOTO 2

Vancouver, British Columbia.

The Port Authority of Vancouver has been constructing a major addition to its Roberts Bank Terminal south of Vancouver, British Columbia. A significant portion of this expansion has been to handle increased global container traffic for the port. The railroad interface to the intermodal yard was paved with RCC to a depth of 425 mm. Approximately 17,000 m^2 of exposed RCC was placed. Quality 35 mm aggregate controlled the cement content to 6% and the RCC easily reached its seven day compressive strength of 10 MPa . On this project compaction was enhanced by the use of an 18 tonne steel wheeled vibratory roller. The project was completed in 1996.

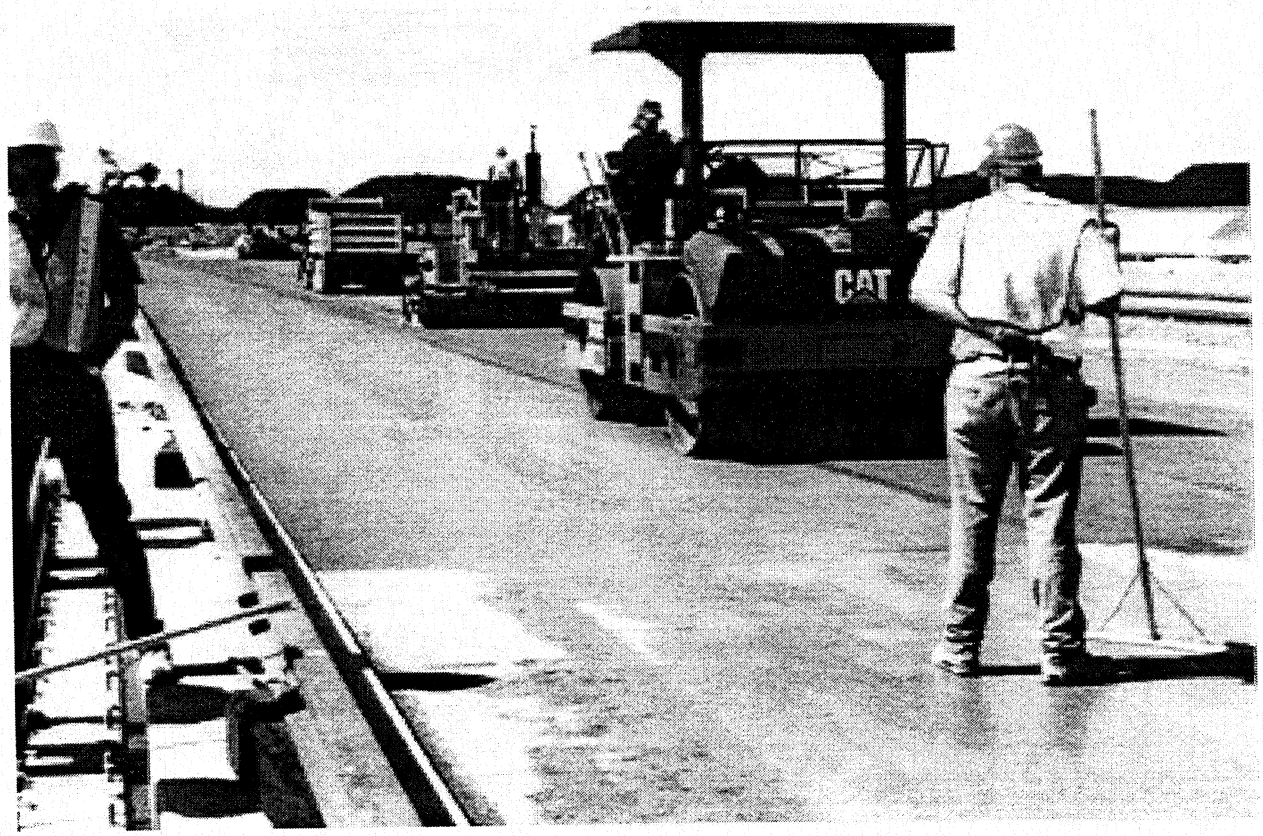


PHOTO 2: Deltaport intermodal terminal, Vancouver , British Columbia, used RCC for railroad interface area.

Example No.3 - PHOTO 3

Athabasca, Alberta.

The Alberta Pacific Pulp and Paper Company included RCC pavement for their new $1.2 billion (Cdn) plant in north central Alberta. Over 95,000 m² of 250 mm to 300 mm thick RCC was constructed for the five large chip storage and recovery pads. This project remains the largest single tender RCC project in Canada to this date. The project was successfully completed in 1992 and has been in continuous operation since that date.



PHOTO 3: RCC pavement covered 95,000 m² for the chip storage and recovery area at Alberta Pacific Pulp and Paper .

Example No. 4 - PHOTO 4

Vancouver, British Columbia. (4)

Following extensive engineering review, the City of Vancouver awarded a contract for the construction of a 1.8 hectares RCC pavement for their first major composting facility. The 200 mm to 250 mm thick pavement was constructed in four days. This continues the use of RCC for composting yards. Previous composting projects were built in Ontario and throughout the Prairie Provinces. The project was completed in 1995.

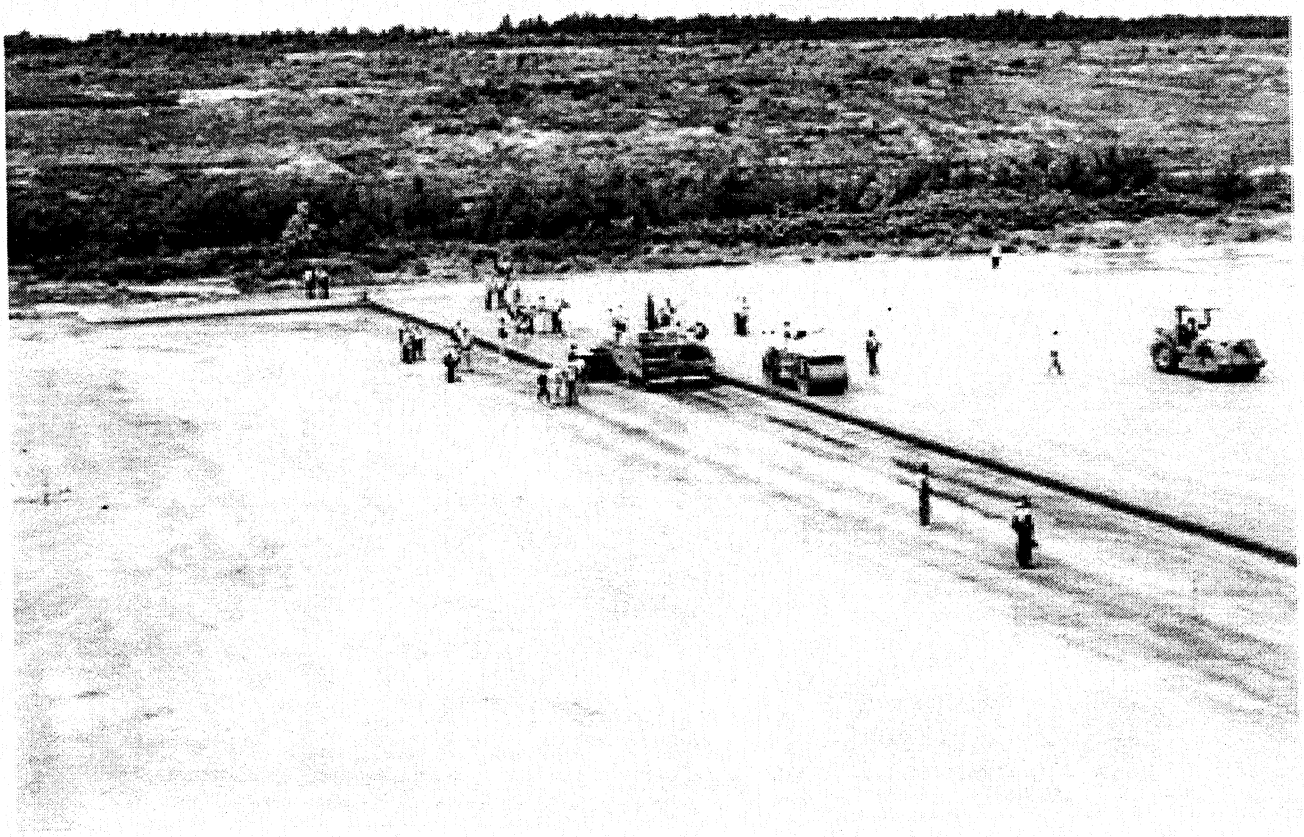


PHOTO 4: The 1.8 Ha composting facility under construction for the City of Vancouver.

Example No. 5 - PHOTO 5

Manning, Alberta.

Manning Diversified Forest Products Ltd. chose RCC for approximately 60,000 m² of 200 mm pavement at their sawmill operation in northern Alberta. Previous to the contract, the handling and storage of raw logs and finished dimensional lumber was restricted by axle-deep debris and mud. Productivity and general mobile operations noticeably improved immediately following the RCC paving. The project was completed in 1995.

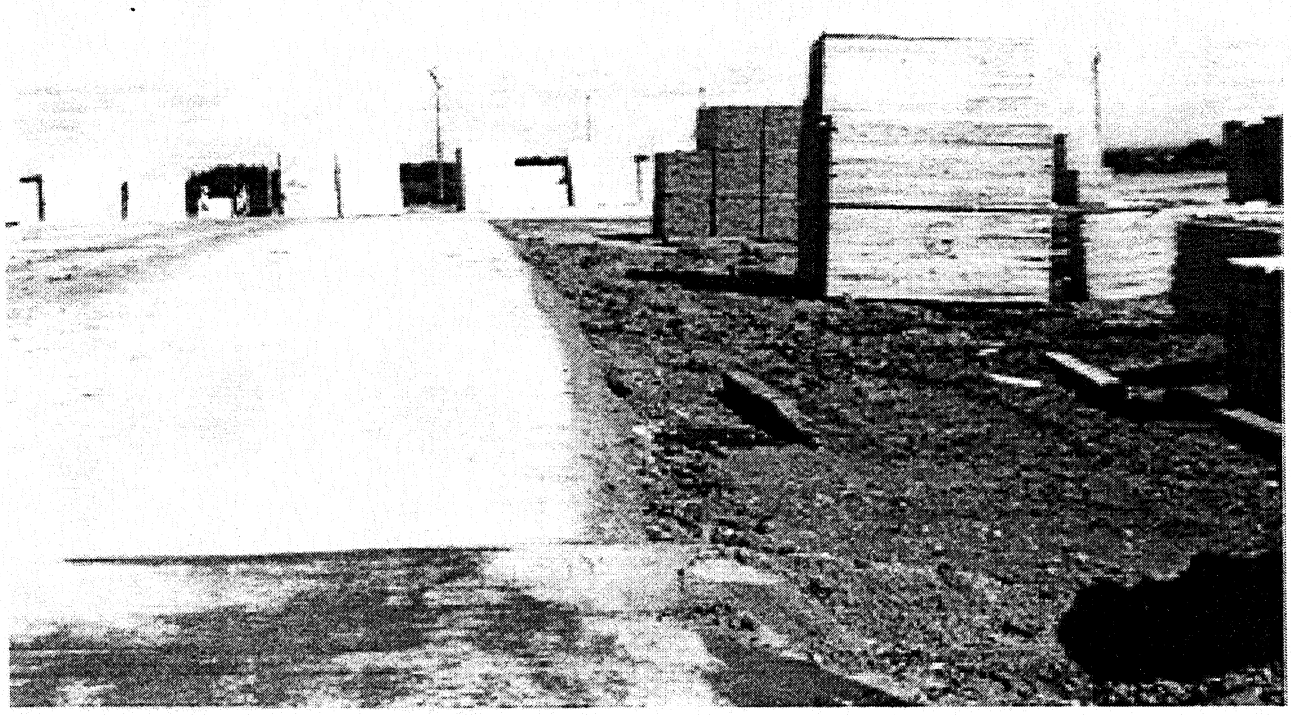


PHOTO 5: The new RCC pavement is ready for the relocation of finished product at this large sawmill.

Example No. 6 - PHOTO 6

Rouyn - Noranda, Quebec (7).

The project for Metallurgy Noranda Inc. at the nickel and copper mining smelter in western Quebec has a number of elements that make it the most unique RCC project in Canada. The 25,000 m^2 of 350 mm to 425 mm thick RCC pavement was built to handle 50 tonne ingots of "cooled" slag. The large slag pots imposed not only a heavy load on the slab but some thermal shock from molted interior slag when the ingots are broken on the pavement. This operation provides for the recovery of residual copper minerals from the ingots. The mix design for the RCC specified a compressive strength of 55 MPa in seven days. This was achieved with the first use of silica-fume (8%) blended cement for a project of this size. The project was completed in 1995.



PHOTO 6: Cooling 50 tonne ingots wait for the RCC pavement completion at Rouyn- Noranda.

II - Municipal Pavements(2)

The second trend to be readily identified in Canada for the use of RCC pavements is in the urban transportation system. Selected projects attest to the growing acceptance of RCC for municipal uses and also illustrate some advanced applications such as "Fast-Track" and overlay RCC pavements. As Public Works engineers and consultants become more familiar with RCC, its acceptance will continue to mature. Six projects are herein referenced for this second trend. All the projects were capped with an asphaltic riding surface immediately or prior to the conclusion of the two-year final acceptance as specified by the owner. In all cases the RCC was allowed to develop joints by natural shrinkage without sawing.

Example A - PHOTO A

Edmonton, Alberta

The first use of RCC for "Fast-Track" pavements occurred on the Yellowhead Trail in Edmonton, Alberta. This six lane freeway carries 65,000 ADT and all major intersections exhibited severe rutting. Westbound approaches to 122nd Street and the Yellowhead Trail were milled out to a depth of 250mm and reconstructed with 200mm of RCC and an immediate bituminous 50mm cap over a 48 hour period. One day strengths of the RCC approached 25 MPa. The project was completed in 1993.

Example B - PHOTO B

Ft. McMurray, Alberta

Ft. McMurray was concerned about the rutted truck/bus lane climbing the 8% grade southbound from the city centre. The 1.6 km, 200 mm RCC inlay of the lane was constructed in one day. This roadway serves the multi-billion dollar oil sands operations 35 km from the city. The project was completed in 1995.

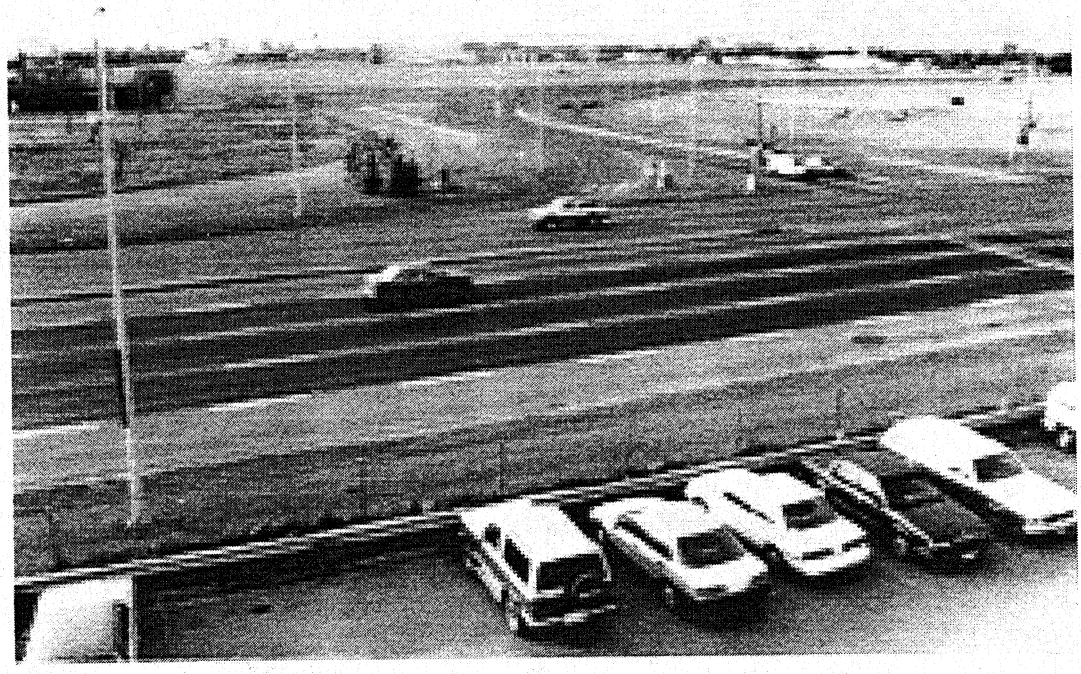


PHOTO A: "Fast Track" RCC inlay in service in 48 hours.



PHOTO B: Rutted truck/bus lane receives RCC inlay reconstruction.
(Courtesy of ISL Infrastructure Systems Ltd.)

Example C - PHOTO C

Terrace, British Columbia

The provincial Ministry of Transportation and Highways selected RCC as a 200mm inlay for reconstruction treatment for five major intersections serving Terrace. Four of these rutted intersections were "mainstreet" locations (two abutting the downtown bridge over multi-lane railroad tracks), and the remaining location was at a "T" highway intersection. Traffic control was maintained during the construction period. The project was completed in 1996.

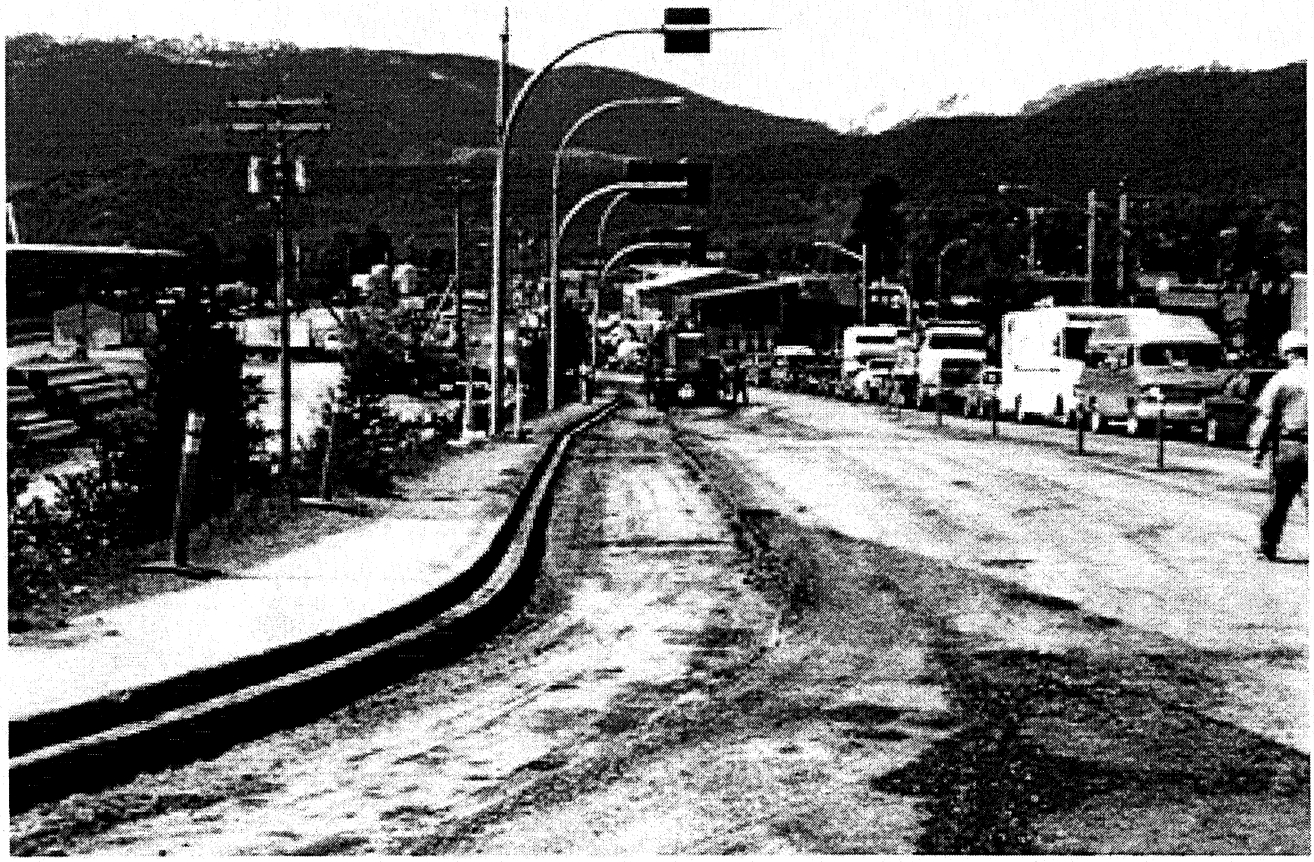


PHOTO C: Turning lane milled in preparation for RCC inlay at Terrace, BC.

Case D - PHOTO D

St. Albert, Alberta

In 1993, several subdivisions were constructed using RCC. Kingswood in St. Albert was one of these which saw RCC replace soil-cement (150-200mm) as the base for the residential roadways. The stronger RCC was placed in a thinner lift (125mm-165mm) and remained exposed for two years handling all the construction traffic. This construction sequence eliminated the normal bituminous cap immediately required for the traditional soil cement base. Prior to final acceptance by the city, a thin bituminous cap was placed on the RCC. The project was completed in 1992.



PHOTO D: Exposed RCC pavement carried first two year construction traffic in St. Albert.

Example E - PHOTO E

Richmond, British Columbia

Built on the delta of the Fraser River, this rapidly growing city chose to use RCC (165mm) for the widening/reconstruction of Williams Avenue, a four-lane residential arterial roadway. An extension to this project will be similarly constructed in 1997. RCC was chosen to minimize the cross-sectional thickness of the roadway. The project was completed in 1996.



PHOTO E: RCC spreader builds two lanes in one pass on Williams Avenue.

Case F - PHOTO F

Fort St. John, British Columbia

Fully satisfied with the use of RCC road construction of the previous year, the City of Fort St. John, in northeast British Columbia, chose to build an exposed 125mm RCC pavement to rejuvenate the parking lot for their recreation centre. This 7500m2 project became the largest RCC overlay of deteriorated asphalt ever placed in Canada! This project was completed in 1996.



PHOTO F: First exposed RCC overlay parking area in Canada at Fort St. John,BC.
(Courtesy of Urban Systems Ltd.)

SUMMARY

The use of RCC pavements in Canada has grown since its inception in 1976. It is estimated over 3,000,000 m^2 of equivalent 200 mm thick pavement has now been constructed. The original use of RCC in the heavy industrial and resource based industries continues and is cited as one of two significant trends for RCC pavements in Canada. The second significant trend is for the use of RCC in roadways within municipal jurisdiction to overcome existing rutting problems and provide enhanced base courses in the system.

Various projects have been selected to illustrate the two trends that are synonymous with RCC pavements in Canada.

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