The Benefits of Using Recycled Crushed Aggregates in Infrastructure Projects

March 24, 2023

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Project Objectives

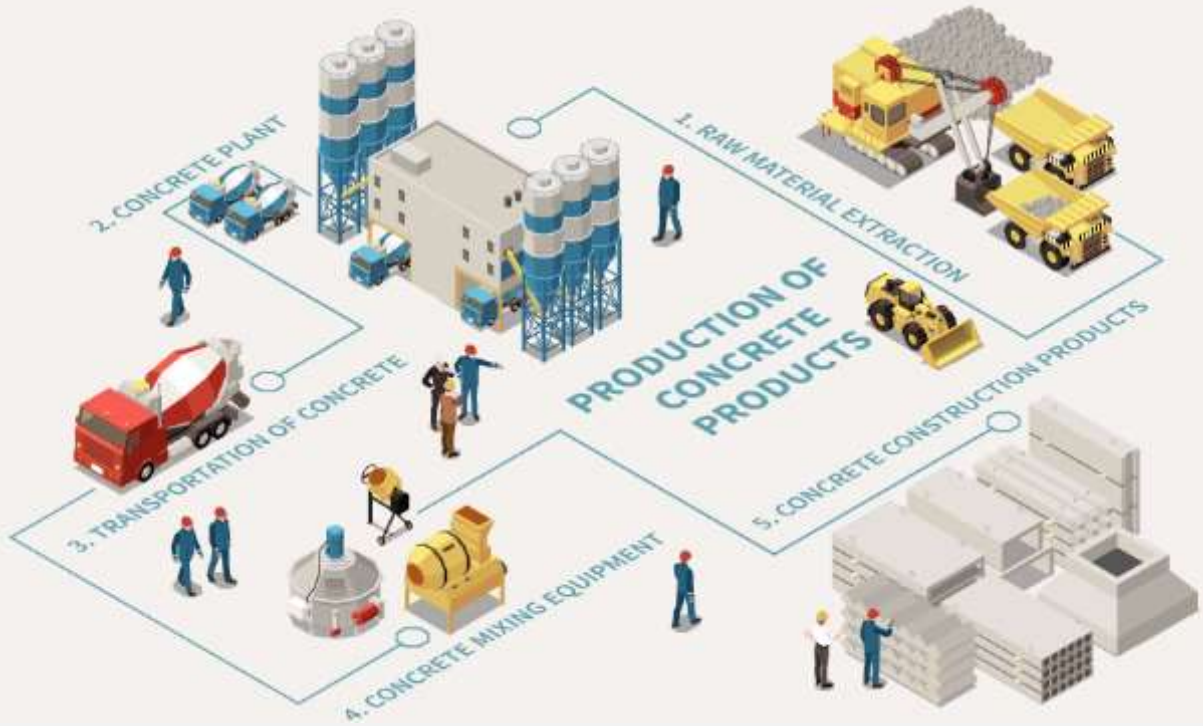
- To **support** municipalities in achieving the targeted goals with efficiencies, by furthering the use of Recycled Crushed Aggregates (RCA1010) more widely throughout Ontario.
- To **promote** economic, sustainable and more environmentally friendly practices.
- To **verify** the compliance of existing RCA1010 Product within the GTA with the applicable OPSS1010 Standard Specification.

Work Approach and Methodology

1. Work with Ontario Ministry of Transportation (MTO) and other Road Authorities.
2. Desktop review of historical records, including previous projects and case studies.
3. Collection of Gran A (RCA1010) samples from different crusher yards/stockpiles.
4. Perform laboratory testing in accordance with the current OPSS1010 for granular base materials.
5. Conclusions and next steps.

Benefits to using RCA

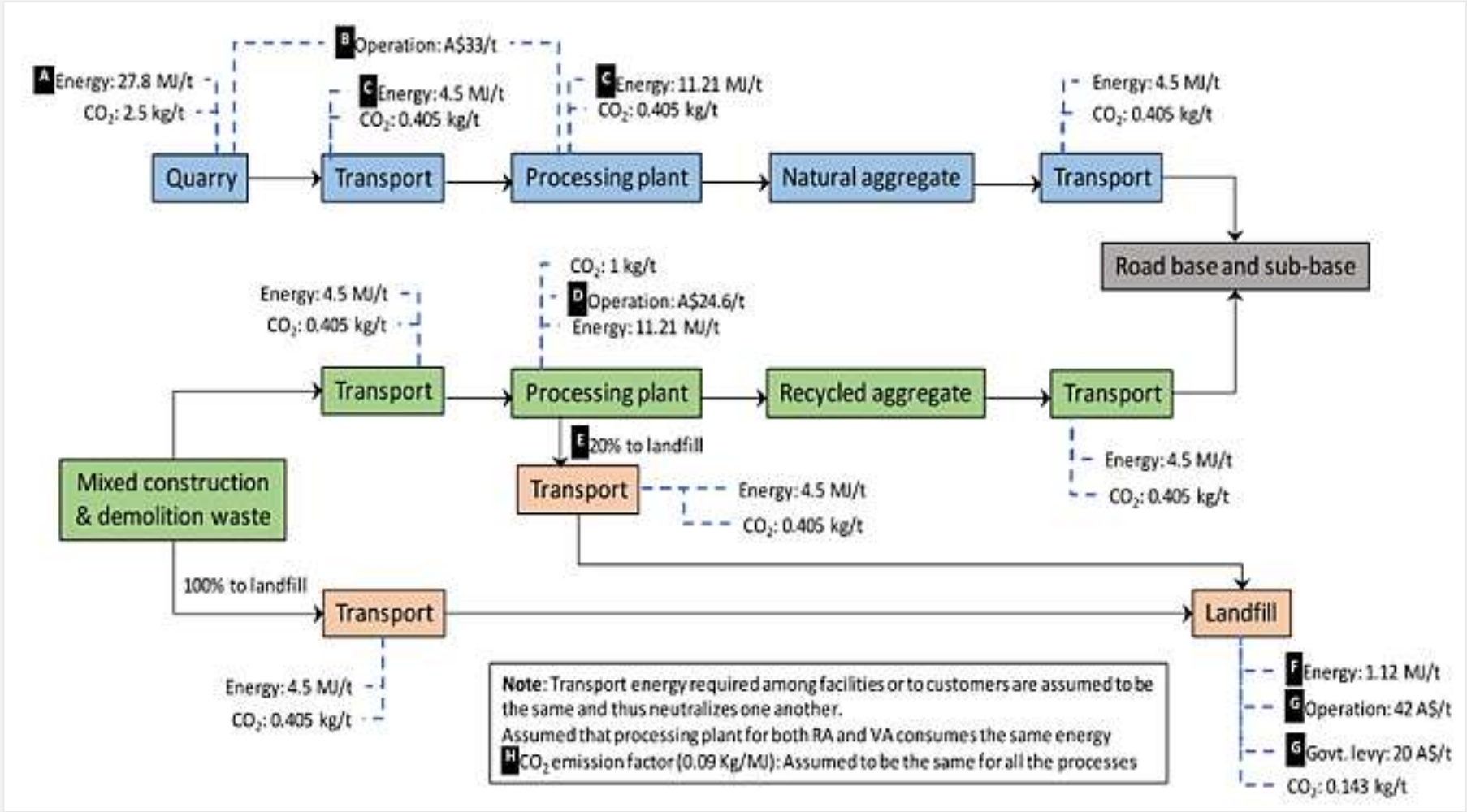
- **Expands** life of existing pits and quarries
- **Lowers** the cost of hauling virgin aggregate to project sites
- **Diverts** aggregates from landfill
- **Reduces** GHG emissions from the extraction and hauling processes



Aggregate Supply Chain

The Long Haul: Examining the Implications of Far-From-Market Aggregates

Calculating the Energy and Emissions Savings



Transportation of Aggregate: Fuel Consumption and GHG Emissions

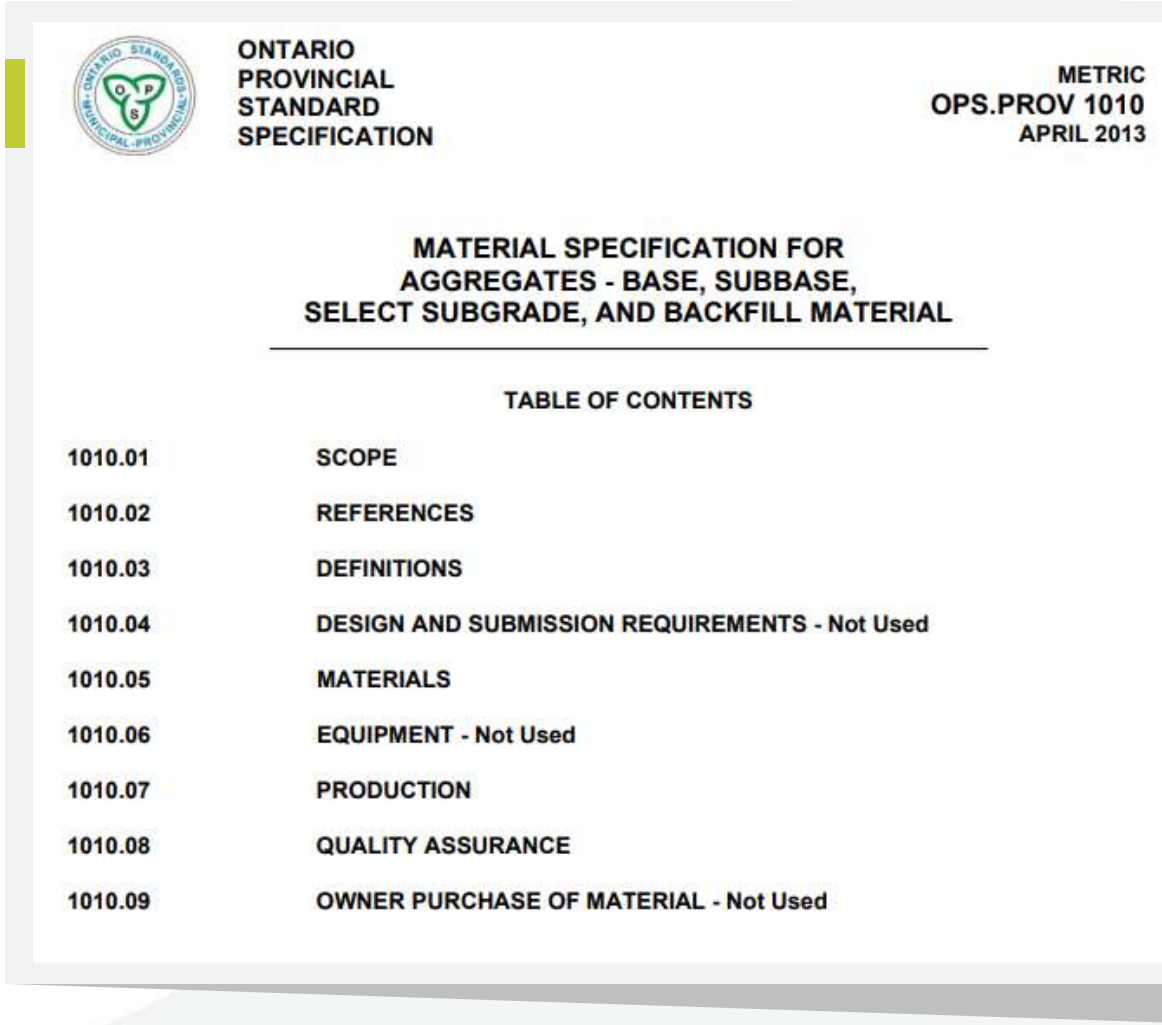
Daily and Annual Fuel Consumption and GHG Emissions by Distance*

	Distance	Per Year (All Truckloads)	Per Day (All Truckloads)
Fuel Consumption (Litres of Diesel Fuel)	Per km	437,500	1,989
	35 km	15,312,500	69,602
	75 km	32,812,500	148,148
	110 km	48,125,000	218,750
	Distance	**Per Year (All Truckloads)**	**Per Day (All Truckloads)**
Greenhouse Gas Emissions (Metric Tonnes of CO2)	Per km	1,189	5
	35 km	41,344	188
	75 km	88,594	403
	110 km	129,938	591

*Based on 25M tonnes

RCA: Applicable Standard Specifications

- Gran A aggregate (roadway base course)
  - shall be according to **Ontario Provincial Standard Specification OPSS 1010**
  - and shall conform to the requirements of gradation and physical properties as specified
- OPSS.PROV or OPSS.MUNI 1010



ONTARIO
PROVINCIAL
STANDARD
SPECIFICATION

METRIC
OPS.PROV 1010
APRIL 2013

**MATERIAL SPECIFICATION FOR
AGGREGATES - BASE, SUBBASE,
SELECT SUBGRADE, AND BACKFILL MATERIAL**

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Allowable Limits of RCA and RAP in Different Types of Granular Materials

Standard Specifications	Material	Allowable Percentage of Recycled Material (%) by mass	
		RCA	RAP
OPSS.MUNI 1010 (November 2013)	Granular A	Up to 100 %	Up to 30 %
	Granular B Type I and Type III	Up to 100 %	Up to 30 %
	Granular B Type II	0 % (Recycled materials shall not be permitted)	
OPSS.PROV 1010 (April 2013)	Granular A	Not specified	Up to 30 %
	Granular B Type I and Type III	Not specified	Up to 30 %
	Granular B Type II	0 % (Recycled materials shall not be permitted)	

MTO Central Region | 2020 Construction Year – 400 Series Projects

		Highway Number				
		401	**400**	**401**	**404**	**410**
Location		Between Credit River and 410/403 Interchange	HWY 400 1.0km north of King Rd northerly to 1.9km north of Lloydtown-Aurora Rd	Jane St to Allen Rd	Richmond Hill, ON	HWY 410 Brampton, ON
Granular A Unit Rate (Avg. 3 Low Bids)		$15.25	$18.89		$22.44	$ 24.20
Granular A Tender Quantity in tonnes		275,955	142,841	10,240	64,175	46,087
Total Qty of Natural + Recycled Aggregates Placed in 2020		25,459	47,366	1,121	21,185	22,680
Recycled Materials	**RCA – Quantity (t)**	**24,949**	**47,366**	**974**	**16,842**	**15,780**
Source Info	**Name of the Source**	D Crupi & Sons	Strada Aggregates	Furfari	D. Crupi	Gazzola
	Location of the Source	176 Bethridge	Vaughan Yard	1159 Tapscott Rd Scarborough	14th Ave, Markham	529 Carlingview Dr. Etobicoke

Highway 400 (MTO, Ontario)

- **Project Description:** Highway widening including Centre Barrier Wall replacement from Major Mackenzie Drive to King Road
- **Years of Construction:** 2017 – 2021
- **Pavement Layers:** Recycled aggregate was used to replace both Gran B and Gran A
- **Total Quantity:** 300,000 tonnes
- **Cost Savings:** $1.2M
- **Source of RCA (Distance to Site):** <10km from site

$1.2M
COST SAVINGS

300,000
TONNES

<10km
FROM SITE

1978 Edens Expressway (Chicago, IL)

- **Project Highlights**
  - First major US urban freeway completely reconstructed
  - Largest highway project using concrete recycling (1981)
  - The Illinois Department of Transportation permitted the use of RCA in base layers and fill applications on this project
- **Pavement Layers:** 350,000 tonnes of old pavement was crushed
- **Fuel savings:** 200,000 gallons (no removal from site)
- **Current Condition:** Excellent service for nearly 40 years under extremely heavy traffic

Concrete Recycling Operation Set up Inside of Edens Expressway Cloverleaf Interchange (Photo from NHI 1998)

#1	350,000	200,000
MAJOR US URBAN FREEWAY COMPLETELY RECONSTRUCTED	TONNES OF OLD PAVEMENT CRUSHED	GALLONS OF FUEL SAVINGS

Other Roadway Projects: USA

- The Illinois State Toll Highway Authority use of RCA in base materials between 2006 and 2016, resulting in savings of more than $61 million (2016)
- An 18-mile two-lane recycling project in Minnesota that saved 150,000 gallons of fuel and 27% of project costs (1981).
- A 1.5-mile Wisconsin Interstate that was projected to save more than $250,000 over the project life (2015).

I-90 Tollway Project: Concrete Recycling; International Society of Concrete Pavement

$61M	150,000	$250,000
COST SAVINGS	GALLONS OF FUEL SAVED	SAVED OVER PROJECT LIFE

Pearson International Airport, Old Terminal 1 – Decommissioning / Demo

- **Year of Demolition:** 2004 – 2006
- **Year of Construction New T1 Apron:** 2006
- **Total Quantity Recycled On Site:** 253,000 tonnes

Old Terminal One Located in the New Apron Development Between the New Pier E and the Constructed Pier F (2004)

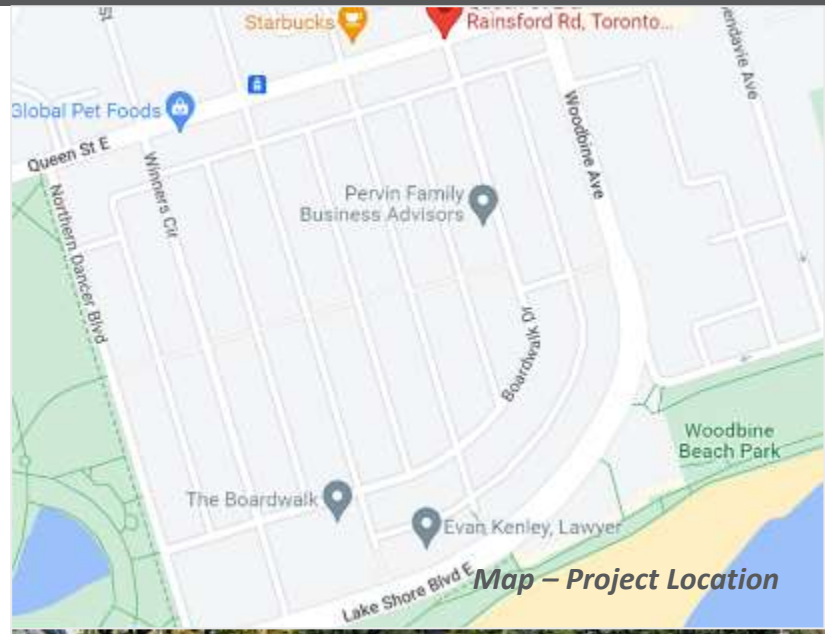
On Site Concrete Crushing Plant and Processed Concrete Backfill (2004)

Source of Information: *Lester B. Pearson Airport Greater Toronto Airports Authority, "Old Terminal 1 Decommissioning and Demolition", Paper prepared for presentation at the "Innovations in Bridge Engineering (A)" Section of the 2005 Annual Conference of the, Transportation Association of Canada, Calgary, Alberta.*

253,000
TONNES Recycled On Site

Greenwood Racetrack Development

- **Project Location:** East half of the former Greenwood Racetrack at Queen / Woodbine / Lakeshore (Toronto)
- **Key Highlights:** First use of RCA as road base material in Toronto's history
- **Years of Construction:** 1996 – 2009
- **Pavement Layers:** 150 mm HMA, over 150 mm Gran A (RCA – 19 mm max size), over 300 mm Gran B (RCA – 50 mm max size)
- **Pavement Condition:** EXP reviewed the conditions in Sept. 2022. Pavement is in good condition, without any structural failures.



Map – Project Location

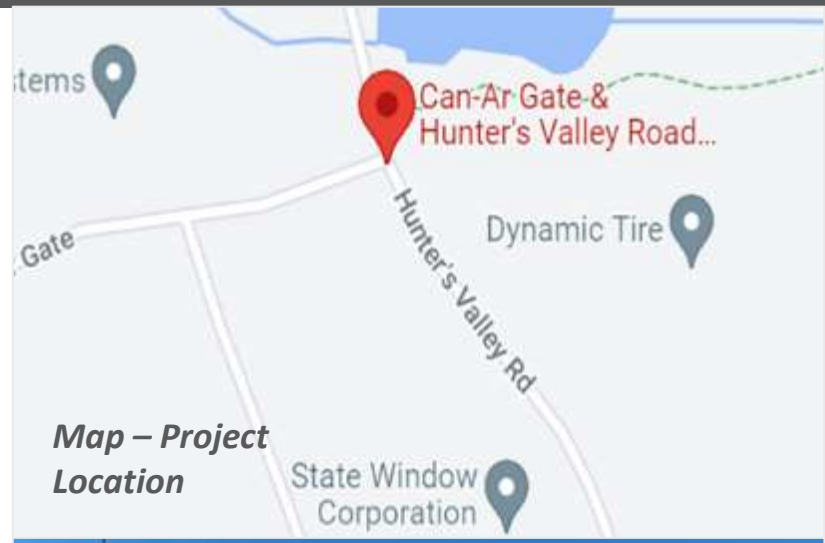

Photo – Current Conditions

#1
USE OF RCA AS ROAD BASE IN TORONTO

Zero
PAVEMENT STRUCTURAL FAILURES

Huntington Glen

- **Project Details:** Phase 2 of an industrial subdivision (Boca East Investment Ltd.)
- **Project Location:** East of Highway 50 (Vaughan); Hunter's Valley Road and Can-Ar Gate
- **Years of Construction:** 2012 – 2016
- **Pavement Layers:** 125 mm HMA, over 125 mm Granular Base (19 mm diameter RCA), over 405 mm Granular Subbase (50 mm diameter RCA)
- **Test Results (2012):** EXP concluded that the 19 mm and 50 mm RCA samples are in conformance with Gran A and Gran B Type 1 requirements outlined by OPSS 1010.



Map – Project Location

Photo – Completed Project

19mm and 50mm
RCA SAMPLES IN CONFORMANCE

Queensville Subdivision Phase 6 (Queensville Development Inc.)

- **Project Location:** Town of East Gwillimbury – John Candy Dr. / Ben Sinclair Ave.
- **Year of Construction:** July 2021
- **Quantity RCA (Gran A and Gran B):** 13,230 tonnes
- **Cost Savings:** $152,145 ($11.5/t).

13,230
TONNES

$152,145
COST SAVINGS

Highway 400 (MTO, Ontario)

- **Project Description:** Constructing Light Rail Transit on Finch Avenue (Humber College Rd to Keel Street)
- **Year of Construction:** 2019 – 2023 (projected)
- **RCA Applications:** RCM with no asphalt particles will replace Gran A (pipe bedding)
- **Total Estimated Quantity:** 85,000 tonnes
- **Cost Saving:** $510,000 (saving $6.0/t)
- **Distance from Crusher Yard to Project:** <10 km

$510,000
COST SAVINGS

85,000
TONNES

<10km
FROM SITE

Toronto Pearson Airport's Runway Rehabilitation Project

- **Project Description:** Rehabilitation of Runway 06L/24R, Pearson's second-busiest runway. Project will extend the life of the runway.
- **Use of RCA:** Crushed concrete from the runway pavement removal will be used as the sub-base and base materials and recycled milling asphalt materials on approach roads in the vicinity of the runway.
- **Year of Construction:** Fall 2022

Source: ReNew Canada – Infrastructure Magazine, July/August 2022

Project will extend the life of Pearson Airport's second busiest runway.

Details of Collected Samples

Sample No.	Yard Address (Producer/Suppliers)	Sample Collection Date
1P/1C/1E (Gran A-RCA1010)	1667 Creditstone Rd, Concord (Strada Aggregate)	8/8/2022
2P/2C/2E (Gran A-RCA1010)	176 Bethridge Rd, Etobicoke (D. Crupi & Sons Ltd)	30/8/2022
3P/3C/3E (Gran A-RCA1010)	2777 14th Ave, Markham (D. Crupi & Sons Ltd)	8/8/2022
4P/4C/4E (Gran A-RCA1010)	85 Passmore Ave, Scarborough (D. Crupi & Sons Ltd)	30/8/2022
5P/5C/5E (Gran A-RCA1010)	120 Wentworth Crt, Brampton (Strada Aggregate)	7/9/2022
6P/6C/6E (Gran A-RCA1010)	10 Leslie St, Toronto (Strada Aggregate)	8/9/2022
1E - Gran A Native	437159 4 Line, Shelbourne (Strada Aggregate)	9/9/2022
2E - Gran A Native (CRL)	Breckon East	16/9/2022
3E - Gran A Native (CRL)	Dundas West	16/9/2022

Samples (1P-6P) for Gradation and Physical Properties Tests(Pavement)
Samples (1C-6C) for Freeze/Thaw Cycle and Magnesium Sulphate Soundness(Concrete)
Samples (1E-6E) for Environmental Tests
Note: Samples of RCA1010 with same number are collected from same stockpile (e.g., 1P/1C/1E)

Lab Testing: Gradation

- All tested samples of Gran A (RCA1010) met requirements

Item	% Passing by Mass – Granular A (OPSS.PROV 1010)							
Sieve No	**26.5 mm**	**19 mm**	**13.2 mm**	**9.5 mm**	**4.75 mm**	**1.18 mm**	**300um**	**75 um**
Acceptable Limits	100 - 100	85 - 100 (87-100) (1)	65 - 90 (75-95) (1)	50 - 73 (60-83) (1)	35 - 55 (40- 60) (1)	15 - 40	5 - 22	2 - 8 (2-10) (2)
Sample No.	**Results – Total % Passing (Gran A RCA1010)**							
1P	100	96.1	81.8	65.8	40.9	25.2	12.7	5.2
2P	100	95.0	82.3	68.6	51.6	31.3	16.1	7.9
3P	100	91.7	76.6	64.5	46.8	31.3	15.9	5.0
4P	100	96.3	84.3	66.7	43.1	21.0	9.9	4.6
5P	100	93.0	74.2	61.4	45.2	32.3	18.1	6.5
6P	100	94.0	81.4	70.1	53.5	33.4	19.0	8.0
Minimum	100	91.7	74.2	61.4	40.9	21.0	9.9	4.6
Maximum	100	96.3	84.3	70.1	53.5	33.4	19.0	8.0
Average	100	94.3	80.1	66.1	46.8	29.0	15.2	6.2

(1) Where aggregate is obtained from an iron blast furnace slag source.
(2) Where aggregate obtained from a quarry or slag source.

Lab Testing: Results of Physical Properties vs. OPSS.PROV.1010

Physical Property	OPSS.PROV 1010 (April 2013)	Results of Tested Sample of Gran A (RCA1010)		
		Minimum	Maximum	% Pass
Coarse Aggregate Petrographic Requirement (LS-609)	Test is Not Specified	0	1.0	100 %
Fine Aggregate Petrographic Requirement (LS-616)	Test is Not Specified	No Deleterious Materials		100 %
Micro-Deval abrasion coarse aggregate loss, % maximum (LS-618)	25 %	16.5	22.2	100 %
Micro-Deval abrasion fine aggregate loss, % maximum (LS-619)	30 %	7.9	19.4	100 %
Plasticity Index, maximum (LS-703/704)	NP (Non-Plastic)	NP	NP	100 %
Percent crushed, minimum (LS-607)	60 %	96	99.7	100 %
Asphalt Coated Particles, % maximum (LS-621)	30 %	1.4	33	83 %
Recycled Concrete Materials, % maximum	100 %	100	100	100 %
Amount of Contamination, % maximum (LS-630)	<= 1 % (total, combined) <= 0.1 % (wood only)	0.02 % (Wood) 0.1 (Ceramic)		100 %
Sulphate Concentration (µg/g)	Not Specified	650	870	100 %
Determination of Permeability, k (LS-709)	k > 1.0 x 10^-4 cm/s	6.9X 10^-4	1.3 X 10^-2	100 %

Lifecycle Analysis: Cost of RCA and Estimated Savings

Pit/Quarry Locations	Average Distance from Pit/Quarry to Project Location (km)	Average Distance from Closest Crusher of Gran A RAP to Project Location (km)	Total Tonnes per Project (approx.)	Unit Rate ($/ton)		Savings (Gran A – RAP Vs. Gran A – Native)	
				Gran A - Native	Gran A - RCA	$/tonne Average	$/Project
				Average	Average		
Brechin	80.5	18 (Mt. Albert)	11,000	$22	$15	$7	77,000
Orillia	115	6 (Vaughan)	100,000	$23	$14	$9	900,000
Milton	52	10 (Brampton)	7,000	$22.5	$14	$8.5	59,500
Flamboro	70	14 (Mississauga)	50,000	$24	$16	$8	400,000
						Total Savings for four Projects $	**1,436,500**

Unit Rates of Gran A RAP Vs. Gran A Native and Estimated Savings Based on Project Location

Assumptions and Metrics

Product	Energy (MJ/t)
Continuous reinforced concrete	29
30 % reclaimed material	37
Untreated Granular Material	40

Product	GHG Emissions (kg/t)
Continuous reinforced concrete	5.1
30 % reclaimed material	8.25
Untreated Granular Material	9.6

Product	Energy Savings (%)	GHG Emissions Savings (%)
Virgin/Natural Aggregate	–	–
30 % RAP with 70 % Natural	7 %	14 %
100 % RAM	25 %	46 %

Emissions from RCA and Estimated Savings

GHG Emissions (MTCO2e)												
Location	Extraction		Transportation of unfinished product to processing plant		Processing		Transportation of finished product to Site [1]		Total		Savings by using RCA	Equivalent passenger vehicles of avoided emissions
	Gran A - Native	Gran A - RCA	Gran A - Native	Gran A - RCA	Gran A - Native	Gran A - RCA	Gran A - Native	Gran A - RCA	Gran A - Native	Gran A - RCA		
	** impacts from quarry only*		** assumed equal*		** additional emissions in RCA for sorting*		** using distances from each location*		**cumulative results for each product type*			
Brechin	27.50	0.00	4.46	4.46	4.46	16.50	38.74	8.66	75.15	29.62	**45.53**	**9.8**
Orillia	250.00	0.00	40.50	40.5	40.50	150.00	503.13	26.25	834.13	216.75	**617.38**	**133.0**
Milton	17.50	0.00	2.84	2.84	2.84	10.50	15.93	3.06	39.10	16.40	**22.70**	**4.9**
Flamboro	125.00	0.00	20.25	20.25	20.25	75.00	153.13	30.63	318.63	125.88	**192.75**	**41.5**
											Total Equivalent Passenger Vehicles of the Avoided Emissions (Four Projects)	**189.3**

Note: Each trip assumes one truck carrying 32 tonnes

Industry QC Plan and Best Practices Guide (TARBA)

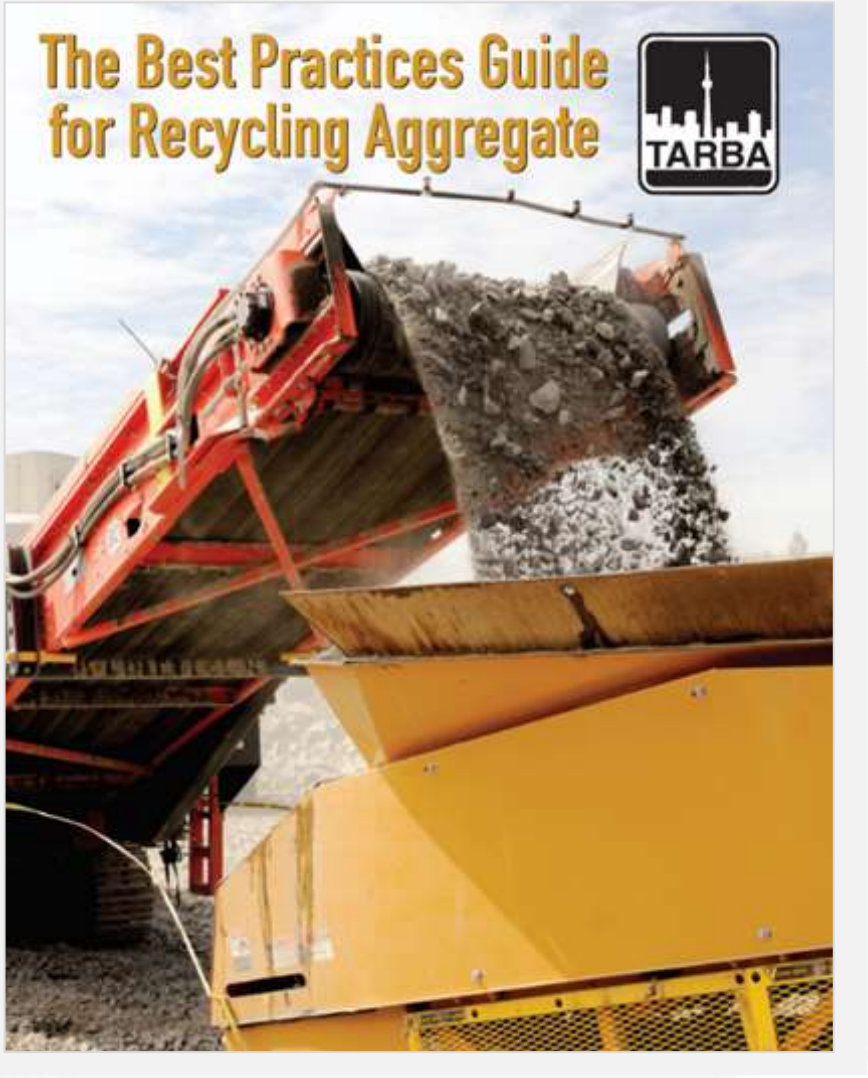

Project Name: Quality Control Plan
Date: October 27, 2022

TARBA

QUALITY CONTROL PLAN
Production of Recycled Crushed Aggregates
TARBA – Product Producers

Date: October 27, 2022
Revision: 1

QC Plan for Production of Recycled Crushed Aggregates



Conclusions

- The existing Gran A RCA1010 produced within the Greater Toronto Region can achieve/pass all the required standard specifications for Gran A – Native for gradation, physical properties, sulphate concentration, and Soundness of Aggregate using Magnesium Sulphate mentioned in related OPSS1010, OPSS 1002, and TS1010, without any issues or concerns.
- With the implemented QC/QA plans and programs, the use of RCA in infrastructure projects within the GTA and Ontario should be encouraged.
- Greater use of RCA materials in municipal roads and other infrastructure projects represents an opportunity for Ontario municipalities to demonstrate their environmental commitment.
- Most of the previously undertaken research and studies (within Canada, United States, and other countries) confirmed the importance of encouraging the use of RCA due to the proven acceptable pavement performance, valuable financial savings, and environmental and sustainable benefits.
- The measured sulphate concentrations are insignificant (much lower than the maximum allowable value of 5000 µg/g, from 650 µg/g to 870 µg/g with average value of 770 µg/g), with low risks of heaving.
- The produced recycled crushed aggregate materials (Gran A base and Gran B subbase) are available in large quantities at different yards/depots across this region with lower unit rates when compared with native granular materials.

Next steps

1. Hosting workshops and site visits
2. Circulating TARBA's QC template plan
3. Incorporating financial and environmental objectives into municipal documents; adopting KPIs relating to the use of recycled crushed aggregates
4. Involving third-party consultants
5. Updating municipal standard specifications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