Use of Crushed Concrete by the City of Toronto Inspection, Testing and Design




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Introduction to the Project

- Concerns raised in 2013 about observed performance
  - May not be equivalent to natural sand and gravel sources
  - Lower apparent strength
  - Spongy appearance when used in wet conditions
  - Premature failure (heaving) noted
    - Both roadway and sewer use
  - Aggregate breakdown during handling
  - Low permeability
  - Consultants not comfortable designing and specifying these materials

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Introduction to the Project

Evaluate the performance issues in three phases

1. Desktop study of the current state-of-the-practice and city issues
2. Sampling and testing of typical RCM in City Projects
3. Update of City's field inspection and design guides

Provide training to City staff on the updates

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Desktop Study – Phase 1

- Typical sources and physical properties
- Recent City of Toronto experience with RCM
- Specifications review and recommendations


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Use of Crushed Concrete by the City of Toronto
Phase 1: Review of Current State-of-Practice

Construction Materials Engineering Report

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Hwy 427 north of Finch Ave

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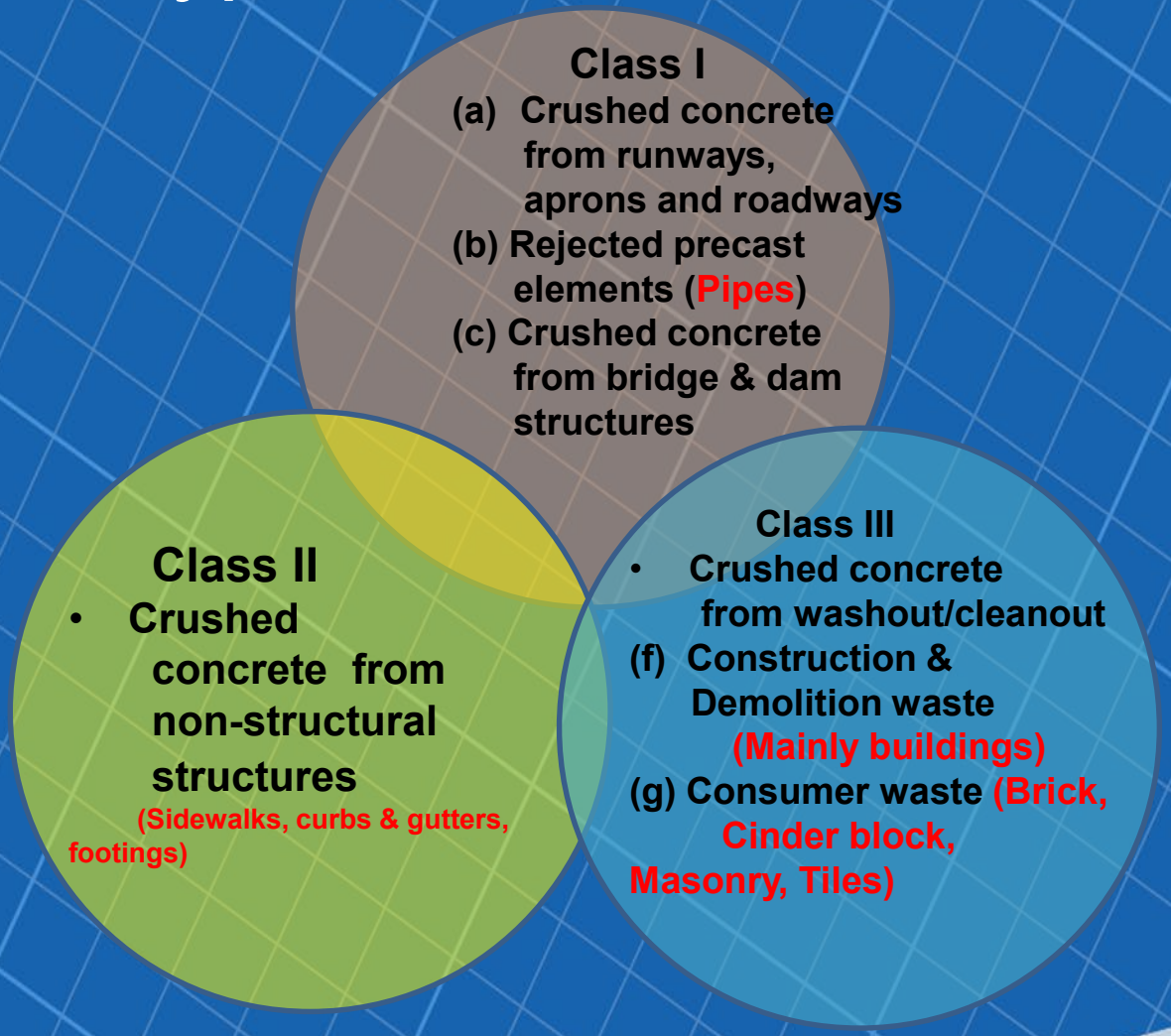
Phase 1 – Typical Sources



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Phase 1 – Physical Properties

PROPERTY	RCM	SAND AND GRAVEL
Specific Gravity Coarse Particles Fine Particles	 2.2 to 2.5 2.0 to 2.3	 2.5 to 2.7 2.5 to 2.7
Absorption (%) Coarse Particles Fine Particles	 2 to 6 4 to 8*	 0.5 to 2.4 0.8 to 2.4
Magnesium Sulphate Soundness (%)	3.8	2.5 to 9.0
Micro-Deval Abrasion (%) Coarse Particles Fine Particles	 17.0 13.2	 10 to 15 10 to 15
Los Angeles Abrasion (%)	36.5	25 to 35
Standard Proctor Maximum Dry Density (kN/m3)	1900 to 1970	1950 to 2300
California Bearing Ratio, CBR	94 to 148	10 to 125
Permeability (cm/sec)	10^{-1} to 10^{-3}	10^{-2} to 10^{-4}
*Absorption values as high as 11.8 percent have been reported		

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Phase 1 – Staff Surveys

- Historically main issues were with excessive RAP and soil (silt and clay)
- More recently some projects noted excessively fine (sandy) RCM that met specs but had low bearing strength (construction vehicles) and poor drainage
- Post construction heaving
- Differential heaving
- Damage of Gaskets

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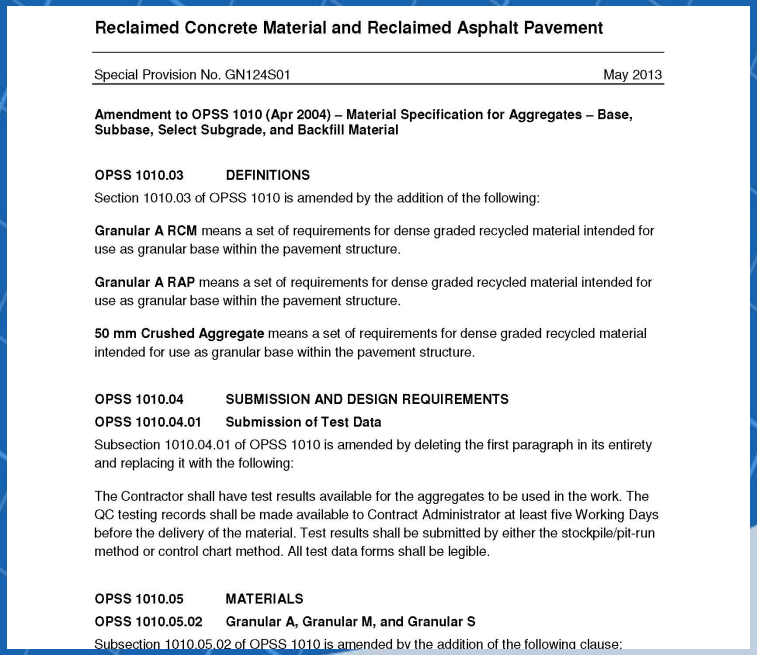
Phase 1 – Specification Review

- Reviewed TS 1010 (2004)
- New Special Provision GN124S03 Developed "Reclaimed Concrete Material and Reclaimed Asphalt Pavement"
- Added requirements for Granular A RCM, Granular A RAP and 50 mm crushed aggregate



Reclaimed Concrete Material and Reclaimed Asphalt Pavement

Special Provision No. GN124S01 May 2013

Amendment to OPSS 1010 (Apr 2004) – Material Specification for Aggregates – Base, Subbase, Select Subgrade, and Backfill Material

OPSS 1010.03 DEFINITIONS

Section 1010.03 of OPSS 1010 is amended by the addition of the following:

Granular A RCM means a set of requirements for dense graded recycled material intended for use as granular base within the pavement structure.

Granular A RAP means a set of requirements for dense graded recycled material intended for use as granular base within the pavement structure.

50 mm Crushed Aggregate means a set of requirements for dense graded recycled material intended for use as granular base within the pavement structure.

OPSS 1010.04 SUBMISSION AND DESIGN REQUIREMENTS

OPSS 1010.04.01 Submission of Test Data

Subsection 1010.04.01 of OPSS 1010 is amended by deleting the first paragraph in its entirety and replacing it with the following:

The Contractor shall have test results available for the aggregates to be used in the work. The QC testing records shall be made available to Contract Administrator at least five Working Days before the delivery of the material. Test results shall be submitted by either the stockpile/pit-run method or control chart method. All test data forms shall be legible.

OPSS 1010.05 MATERIALS

OPSS 1010.05.02 Granular A, Granular M, and Granular S

Subsection 1010.05.02 of OPSS 1010 is amended by the addition of the following clause:

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Phase 1 – Specification Review

- May contain up to 100 Percent RCM and varying amounts of RAP
- No glass or ceramic material permitted
- Deleterious material (Max 0.5%) and added gypsum, gypsum plaster and wall board mix to list

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Phase 1 – Recommendations

- Supplemental testing for water-soluble sulphate concentration and comparison to risk assessment criteria
- Contractors to provide quality control plan for RCM sources
- Contractors to demonstrate control of sources
- Contractors to guarantee that no construction and demolition waste building materials used

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Phase 2 – Field Investigation

- Chose four City RCM projects from interviews
- Completed Visual Condition Survey (ASTM D6433-07 *Standard Practice for Roads and Parking Lots Pavement Condition Surveys*)
- Falling Weight Deflectometer Testing (ASTM D4694 *Standard Test Method for Deflections with a Falling-Weight-Type Impulse Load Device)*
- Test cuts to measure and sample RCM

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Phase 2 – FWD Results

SITE LOCATION	SURFACE MODULUS (MPa)	BACKCALCULATED RESILIENT MODULUS (MPa)
Greenwood Subdivision All Laneways	Average 821 (Very Good) Range 312 – 1504	N/A
Beecroft Road – Kempford Boulevard to Ellerslie Avenue	Average 1323 (Very Good) Range 538 – 2011	271
Ronald Avenue – Schell Avenue to Castlefield Avenue	Average 248 (Poor) Range 170 – 370	131
Lorraine Drive – Finch Avenue to Blakeley Road	Average 341 (Fair) Range 191 – 667	156

Backcalculated Resilient Modulus Values for Greenwood Subdivision not reliable due to pavement structural component thicknesses and as a result, they have been excluded

Surface Modulus > 400 MPa (Good to Very Good); > 300 MPa (Fair); >200 (Poor); < 200 (Very Poor)

Typical Design Resilient Modulus (MPa): Granular A (250); 50 mm Crushed Aggregate (200); Granular B Type I (150) [MTO, 2012]

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Phase 2 – Inspection of Stockpiles

- Inspected and photographed the RCM source stockpiles
- Noted types of materials present and any deleterious materials
- Wide variability of material types
- Wide variability in source material sizes

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Phase 2 – Inspection of Stockpiles

- Inspected and photographed the RCM product stockpiles
- Noted types of materials present and any deleterious materials (negligible)
- Metal appropriately separated during processing
- High angle of friction

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Phase 2 – Stockpile Samples

- Sampled in accordance with MTO LS-625
- Sampling pad is created by 3 bucket loads from a front end loader
- Thoroughly mixed and back bladed to make a pad 0.3 to 0.5 m thick
- Material is sampled from 3 separate locations from the pad using an approved spade

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Phase 2 – Laboratory Testing

- Road and stockpile samples were tested in accordance with TS 1010 (2014) in the Lab
- Full physical suite of tests completed for compliance check
- Additional water soluble sulphate risk assessment criteria assessed by CAEAL certified third part lab
- Results compared against typical virgin aggregates

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Phase 2 – Laboratory Testing

- Stockpile samples met TS 1010 gradation requirements
- Roadway samples did not meet TS 1010 gradation requirements*
- Roadway samples did not exhibit any obvious signs of breakdown over time or during construction
- Samples generally pose a low risk for sulphate induced heave

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PROPERTY	RCM	SAND AND GRAVEL	SPECIFICATION GRANULAR A
Sieve Size (Particle Gradation) 26.5 mm	100	100	100
19.0 mm	93.6 – 97.6	87.8 – 94.3	85 – 100
13.2 mm	82.2 – 85.4	78.4 – 81.7	65 – 90
9.5 mm	68.8 – 71.2	59.2 – 67.3	50 – 73
4.75 mm	49.3 – 51.7	35.7 – 47.7	35 – 55
1.18 mm	32.9 – 33.9	28.6 – 33.7	15 – 40
300 μm	13.8 – 18.9	10.5 – 17.4	5 – 22
75 μm	4.7 – 7.9	6.3 – 7.8	2 - 8
Coarse Aggregate Petrographic			
Crushed Glass/Ceramic Material	0 to 0.1	0 to 6.8	15% MAX
Fine Particles	0.1 to 3.2	0 to 0	1.0% MAX
Micro-Deval Abrasion (%)			
Coarse Particles	14.6 to 21.4	10 to 15	25% MAX
Fine Particles	9.3 to 15.6	10 to 15	30% MAX
Percent Crushed Particles	92.6 to 95.1	62.4 to 97.8	50% MIN
Asphalt Coated Particles	5.7 to 24.5	0 to 33.4	30% MAX

Phase 2 – Laboratory Results

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Phase 2 – Laboratory Results

- Roadway and stockpile materials were found to pose a low risk of sulphate induced heave
- Results ranged from 720 – 1100 μg/g
- Once sample tested 4,400 μg/g – moderate risk
- Importance of demonstrating control of stockpile

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Phase 2 – RCM in Trenches Concerns

- Concerns raised regarding RCM use as pipe bedding and trench backfill
- PHCs and PAHs present in RAP could leach and damage rubber pipe gaskets
- Tufa precipitates could reduce the permeability or clog drains
- pH of leachate could affect some water resources and fish habitat

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Phase 2 – RCM in Trenches

- RAP considered to be chemically stable
- Tufa not an issue in the City based on research to date
- pH still requires more research
  - Some research shows an initial spike in pH (first couple of hours) followed by a fairly rapid normalization
- Can be corrosive to some metals (galvanized and aluminum piping)

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Phase 2 – Contractor/Supplier QC Plan

- Key Elements
  - Describe the processes to ensure control, acceptance and documentation of sources of old concrete
  - Identify how the sources are controlled during delivery to ensure they are from a suitable source
  - Detailed description of process including how deleterious materials are identified and removed and how gypsum and plaster are kept out

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Phase 2 – Conclusions

- RCM involved in case studies generally meets City specification requirements
- Similar to the properties of virgin materials
- Physical and mechanical properties were observed to vary, sometimes considerably between projects
- Confirms the need for contractor ‘Control’ and City QA

Is this being done?

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Phase 3 – City Standard Updates

- Reviewed Design Criteria for Sewers and Watermains (First Edition, November 2009)
- Reviewed City of Toronto Field Services Manual (Second Edition, May 2009)
- Reviewed Engineering & Construction Services Division Standards
  - Specifications
  - Drawings
- Reviewed Special Provisions

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Phase 3 – City Standard Updates

- Focus on five main areas identified during first two phases
  - RCM without RAP used for pipe bedding and backfill
  - Aluminum and galvanized pipes and fittings not used in conjunction with RCM materials
  - Begin completing water soluble sulphate testing in new projects
  - Begin requesting contractor material testing data to confirm ‘Control’
  - Complete physical testing in accordance with TS 1010

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Design with RCM – TS 1010

- Start with selecting the most appropriate RCM material for the infrastructure being designed
  - **Granular A Native** – dense graded aggregates intended for use as granular base within the pavement structure, granular shouldering and backfill. Granular A is also intended for use as embedment material for flexible pipes, bedding and cover for rigid pipes and backfill material for all pipes
  - **Granular A RCM** – dense graded recycled concrete material intended for use as bedding, embedment material and trench backfill round underground infrastructure
  - **Granular A RAP** – dense graded recycled asphaltic material intended for use as granular base within the pavement structure and/or road allowance
  - **50 mm Crushed Aggregate** – dense graded recycled material intended for use as granular base within the pavement structure

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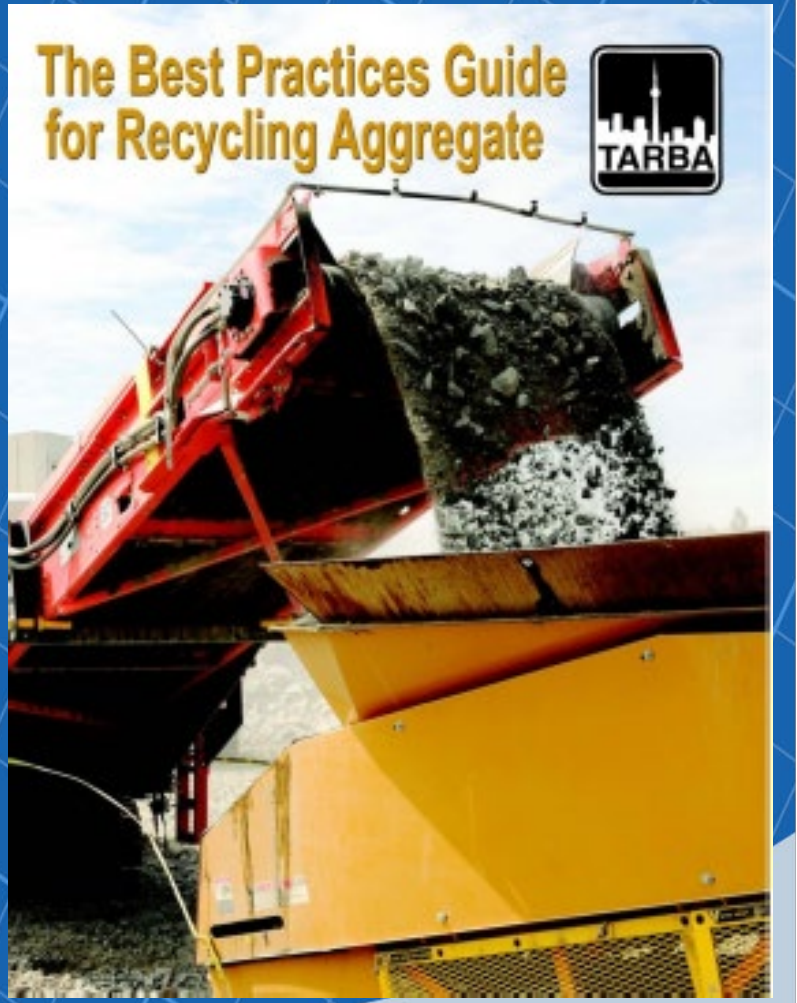
RCM Production - ARO

- Aggregate Recycling Ontario created in order to set standard for producing quality aggregates for project use
- Indicate commitment to produce quality materials
- Maintain process control to achieve desired result
- Instill confidence in end user



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RCM Inspection and Testing

- Raw Material Quality – Acceptance Criteria - TARBA
  - Concrete and asphalt separated at jobsite. Well bonded asphalt to concrete is the exception.
  - Concrete and asphalt free of deleterious materials such as wood, plastic, and organics. Zero tolerance to exceptions!
  - Cinder blocks, bricks, tiles or any clay based material not allowed
  - Concrete containing reinforcing or mesh must be pre-approved for delivery and all loads subject to inspection and rejection
  - Solid concrete demolition materials such as footings, floor slabs and poured concrete walls must be pre-approved.

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RCM Inspection and Testing

- Product Quality Control - TARBA
  - Materials delivered to the crushing facility should be sorted into properly identified stockpiles
  - Production control gradations, including percentage of ACP are to be conducted every 1,000 tonnes of production. The producer will record the results in a control chart log book and provide the results to pavement owners and their agents upon request
  - Physical aggregate testing will be performed every 25,000 tonnes of production compared to OPSS 1010
  - CCIL sampling procedures will be used to take samples and CCIL laboratories will be used for testing

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RCM Production for City Projects

- TS 1010 Supplemental Requirements
  - Contractors shall submit a detailed QC plan covering RCM production and placement
  - Contractor shall provide a written certificate to the CA expressly stating that no building demolition wastes have been used in the production of RCM
  - Contractor shall include water soluble sulphate testing and ensure concentrations less than 5000 µg/g
    - Testing frequency for sulphate testing is one every 1000 tonnes (same frequency as gradations) or until control is established, and then every 5000 tonnes thereafter

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RCM Inspection and Testing

- Review of Contractor supplied materials
  - Verification of Ticket
    - Source
    - Stockpile
  - If does not meet QC documentation provided, corrective action required
    - Document where load was placed
    - Reject load?
    - Halt work until new documentation can be reviewed?
    - Provisionally accept material based on additional QA testing (Cost?)

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RCM Inspection and Testing

- Complete a quick inspection of each load delivered to site for consistency
  - Segregation
  - Oversize particles
  - Deleterious (visual check)
  - Clumping
  - Friability of RCM particles
  - Fines content (permeability)
  - Relative moisture content

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RCM Inspection and Testing

- QA Sampling and Testing Frequency
  - Verify Contractor is following their proposed site QC plan and the standard
  - Review Contractor QC on a regular basis to confirm Control
  - Critical to follow TS 1010 testing frequencies for QA for verification

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Field Experience - 2022

There are two advantages to using RCM and RAP;

1. They are cheaper than native granular material, as they are sourced at either concrete or asphalt plants.
2. They are environmentally conscious.

Disadvantages of RCM and RAP;

1. RCM, RAP are given the same weight and are paid at the same rate as native. If not specified in the contract tender, bidding may not be equitable to bidders. The City may pay a premium for a cheaper delivered product.

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Field Experience – 2022 cont'd

1. RCM and RAP become segregated the more they are handled and may contain high amounts of deleterious material if the supply of material is not consistent.
2. If RCM is not provided optimum moisture content and is saturated then it becomes unworkable. The rule was to ensure that the RCM was rolled at the end of the day and graded, as loose material would require scrapping off if it rained over-night. It is a good construction practice for native material also, but not as important as native is more forgiving.
3. There is a belief quality control measures (gradation) are more closely followed at the pits then the plants that supply the recycled material.

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Questions and Answers

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