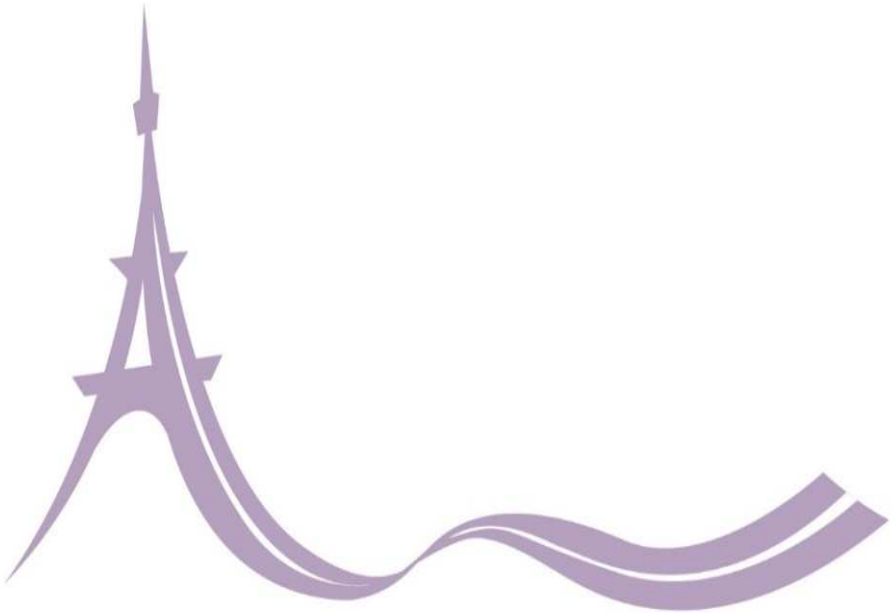
Utilization of demolition materials in concrete pavement



PAVEMENT PRESERVATION & RECYCLING SUMMIT

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François
de Larrard

Lafarge LCR,

Recybéton National
Project, France

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Summary

1. Introduction
2. Types of demolition materials
3. Incorporation of recycled concrete aggregate into concrete
4. Examples of recycled concrete in pavement
5. 100% recycled concrete in concrete wearing course: two recent cases
6. Concluding remarks

1. Introduction

› Contemporary trends:

- Increase of demolition
- Landfilling forbidden
- Need to decrease transportation distances
- In some areas, difficulties to open new quarries

=> Need to develop the reuse of Construction & Demolition materials (whatever the area: buildings, infrastructures …)

› Less new infrastructures => decrease of the market of materials for roads subbase/embankment

=> More recycling without functional degradation to envisage (circular economy)

2. Types of demolition materials

- Road deconstruction produces a mix of
  - Unbound granular materials
  - Reclaimed asphalt pavement (RAP)
  - Recycled concrete aggregates (RCA)
- Possibility of in-place treatment (with either hydraulic binders or bitumen emulsion)
- Possibility to incorporate road (or other constructions) demolition materials in new hydraulic concrete
- Effects on the material properties ? On the pavement behavior, functional properties and durability ?

3. Incorporation of RCA into concrete

Table 1. Effect of RCA on Mechanical Properties of Concrete		
Property	**Range of expected changes from similar mixtures using virgin aggregates. (ACI 555R)**	
	Coarse RCA only	**Coarse and Fine RCA**
Compressive Strength	5% to 24% less	15% to 40% less
Strength Variation	Slightly greater	Slightly greater
Modulus of Elasticity	10% to 33% less	25% to 40% less
Creep	30% to 60% greater	30% to 60% greater
Tensile Strength	10% less	10% to 20% less
Permeability	200% to 500% greater	200% to 500% greater
Thermal Expansion	Somewhat less than expected for coarse aggregate used	Somewhat less than expected for coarse aggregate used
Specific Gravity	5% to 10% lower	5% to 10% lower

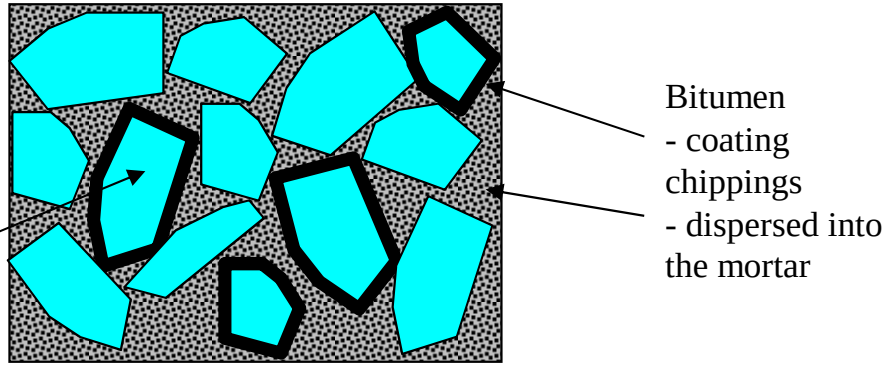
Table 2. Effect of RCA on Fresh Concrete Properties		
Property	**Range of expected changes from similar mixtures using virgin aggregates. (ACI 555R)**	
	Coarse RCA only	**Coarse and Fine RCA**
Water Demand	Greater	Much greater
Drying Shrinkage	20% to 50% more	70% to 100% more
Finishability	More difficult	More difficult

Table 3. Effect of RCA on Concrete Durability		
Property	**Range of expected changes from similar mixtures using virgin aggregates. (ACI 555R)**	
	Coarse RCA only	**Coarse and Fine RCA**
Corrosion Rate	May be faster	May be faster
Freeze-thaw Durability	Dependent on air void system	Dependent on air void system
Carbonization	65% greater	65% greater
Sulfate Resistance	Dependent on mixture	Dependent on mixture

From
FHWA - Technical Advisory
Use of Recycled Concrete Pavement as Aggregate in Hydraulic-Cement Concrete Pavement
T 5040.37 - July 3, 2007

RAP into concrete ?

- Little effects on fresh concrete properties
- Similar effects as RCA on mechanical properties (decrease of strength and modulus, increase of shrinkage and creep)
- RAP cement concrete essentially behaves as a softer hydraulic concrete (limited visco-elastic behavior)



Mathias, 2005

Mix-design of concrete incorporating recycled materials

- Coarse aggregate first, some fine aggregate if necessary
- Low rate (e.g. less than 20 % of CA): simple substitution with little changes on general properties
- High rate (up to 100 %) and/or much fine RAC:
  - Account for water absorption by RAC
  - Need to increase cement and admixture dosages to maintain workability and final strength
  - Need to redesign the pavement (different ratio between tensile strength and E-modulus + account to shrinkage changes)

4. Examples of recycled concrete in pavement

Washington State Department of Transportation

WSDOT Research Report

Review by the Washington state DOT (Anderson et al., 2009)

- More than 100 interstate road sections identified where RCA was used in Portland Cement Concrete Pavement, between 1976 and 1994
- Mainly concrete slabs with dowels, little change in design (thicknesses, distances between joints)
- Mainly CA, sometimes FA used in the concrete mixes
- Summary of the American experience:
  - Pavements made with RCA aggregates may have problems with excessive midslab cracking, poor load transfer, but generally no problems with durability if proper steps are taken to combat D-cracking, freeze-thaw and ASR susceptibility
  - Recommendation for design are provided

Concrete Pavement Design Element	Design Recommendation
Pavement Type	JPCP with short joint spacing may be preferred to prevent transverse cracks and the reliance on aggregate interlock; JRCP or CRCP may be candidates if: • larger top-size aggregate used. • blend of RCA and virgin aggregate used. • greater amount of reinforcement used.
Slab Thickness	Thickness same as for conventional design, although the use of two-layer slabs (i.e., lower layer of recycled concrete with upper wearing layer of high-quality virgin aggregate) should be investigated.
Joint Spacing	Shorter joint spacing may be desirable to reduce the amount of crack opening.
Load Transfer	Dowels recommended for transverse joints; load transfer at cracks (for reinforced pavements) must consider factors listed in section on *Pavement Type*.
Joint Sealant Reservoir Design	New recommendations may be needed due to increased drying shrinkage.
Base Type	For JPCP, conventional base types appropriate. For reinforced pavements, consider the use of a strong, durable, non-erodible base.
Reinforcement	Increased longitudinal steel reinforcing may be required in JRCP and CRCP to hold the cracks tightly together so that aggregate interlock can be maintained.
Shoulder Type	Same as for conventional mix design.

Other reported recycled concrete pavement

- Highway in Germany (Hanover area, 2005)
- Built by Eurovia Beton
- Full use of demolished concrete from the old pavement
- Recycled sand mixed with soil and binder, in-place treatment to provide a stiff subbase
- Base course incorporating recycled coarse aggregate
- Wearing course (fresh-on-fresh) conaining only virgin aggregates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5. 100% recycled concrete in concrete wearing course: two recent examples

Airport recycled concrete application (Dao et al. 2014)

- Context
  - Many 40 year-old taxiway slabs need to be replaced in the Terminal 1 of Roissy-CdG airport
  - Need of 100% on-site recycling while the management of airport security leads to limit the transfer of incoming and outgoing materials
- Slab specification
  - At least 3.7 MPa of TSS@28 days
  - 100% made from RCA of demolished slabs
  - Good resistance to freeze-thaw cycles


HITACHI

The Chaponost experimental site (de Larrard et al., 2015)

- Aim: to demonstrate the feasibility of recycling up to 100 % in large parking areas
- 6 areas of more than 300 m^2
- Concrete slabs on grade, distance between joints 5 m
- Recycling rate from 0 to 100 %, concrete compositions adjusted to maintain slump and tensile strength at 28 days
- When the recycling rate increased,
  - Constant w/c
  - Increasing paste volume
  - Increasing admixture dosages (except AEA)
  - E-modulus from 30 to 20 GPa
  - Shrinkage from 400 to 840 10^{-6}

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No cracks between the joints after 1 year, in spite of the higher shrinkage in the 100 % recycled concrete

6. Concluding remarks

- Recycling demolitions materials into concrete: not new nor difficult
- Some precautions to be taken, some adjustments in pavement design
- Is it economical ? Depends on the cost of recycled aggregates
- Is it environmental friendly ?
  - Preserves virgin aggregate resource
  - Avoids landfilling
  - Energy and CO2 balances: depend mainly on the transportation distance
- Still some standards/regulations barriers to be overcome (one of the tasks of Recybéton French national project)

The Recybéton French national project (2012-2015)

- A joint initiative of the scientific/technical community to foster the use of recycled concrete into concrete
- Yes concrete is recyclable as much as its competing materials !
- A 4-year, 5M-€ R&D program, 2012-2016
- 44 partners
- Expected output
  - Scientific/Technical advances in aggregate & concrete processes, material and structures made up with recycled concrete, sustainable development issues
  - Textbooks, guides and good practice manuals
  - Proposals to French and European standards/codes
  - Experimental sites
- http://www.pnrecybeton.fr/en/

Thank you for your kind attention !