Recycling Crushed Concrete in Pavements

Dr Bryan Pidwerbesky, CPEng, FIPENZ
General Manager – Technical
European view of recycled concrete

- Post World War 2 – demolition concrete & bricks were a major source of pavement construction material
- “Crushed Concrete from Building Demolition is a High Quality Material for Road Construction”
RECYCLING OF CONCRETE ROADS IN AUSTRIA

Recycling of worn concrete pavements into new concrete pavements

Acknowledgement: Michael Moffatt, ARRB Transport Research, Australia/NZ representative on PIARC technical committee 4.2 – Road Pavements
### Jointed Plain Concrete Pavement (JPCP)

#### Plan View

<table>
<thead>
<tr>
<th>L ≤ 5.0 m (motorway load classes S and I)</th>
<th>L &lt; 25 h</th>
</tr>
</thead>
<tbody>
<tr>
<td>transverse joint (sealed)</td>
<td>longitudinal joint (sealed)</td>
</tr>
</tbody>
</table>

**Detail: False joint**

- **Source:** Betonstraßen - Das Handbuch

#### Cross Section

- **Upper concrete layer (4 cm)**
- **Dowel bar (in longitud.: tie bars)**
- **Asphalt layer (5 cm)**
- **Unbound base course (45 cm)** or **Cement stabilised layer (20 cm)**

**Lower concrete layer**

- **22 cm (load class I)**
- **25 cm (load class S)**
Regulations – Construction

Grain Size Distribution (Lower Concrete Layer):

- Maximum aggregate size < 32 mm
- Grain size > 4 mm: recycling material in 3 particle size groups
Usage of the Recycling Material

Recycling – from old to new

**Old**

- (4 cm asphalt wearing course)
- 22 cm concrete layer (JPCP)
- 8 cm bituminous base course
- 40 cm unbound base course (frost protection layer)

- appr. 70% coarse aggregate 4/32 mm (max. 20% bitum. material)
- appr. 30% crushed sand/gravel 0/4 mm
- ascending fines
- subgrade

**New**

- min. 4 cm upper concrete layer (exposed aggregate surface)
- 21 cm recycling concrete layer (max. grain size 32 mm)
- 5 cm asphalt layer (base course)
- 20 cm cement stabilised layer

- subgrade

Source: Betonstraßen – Das Handbuch
Recycling Case Study
West Autobahn A 1

- construction started in 1930s
- new construction: 1955 – 1969
- total length: 292 km

Source: Archive of the former Upper Austrian Motorway Administration
Recycling Case Study
West Autobahn A 1

Main Steps
1. demolishing old pavement
2. removing & transport to recycling area
3. crushing & preparing for Reuse in new concrete
4. production of new concrete with re-used material
5. construction of base course and new concrete layer
Recycling Case Study
West Autobahn A 1

demolishing ("guillotine")

Source: Asamer Holding AG
Recycling Case Study

interim storage

Source: Asamer Holding AG
Recycling Case Study

West Autobahn A 1

Source: Asamer Holding AG
Recycling Case Study

Source: Betonstraßen - Das Handbuch
Recycling Case Study
West Autobahn A 1

Source: Asamer Holding AG
Recycling Case Study
West Autobahn A 1

Source: VÖZ/Österreichische Betondecken-ARGE
Summary
Case Study - West Autobahn A 1

• refurbishment in total:
  – 5,700,000 m²
  – 230 km

• costs in total:
  – 1.3 bn. € (appr. 50 % for Pavement)

• economical savings in construction:
  – approx. 1.85 €/m²

• ecological savings
  – 1,700,000 km of transport
  – 1,445 tonnes CO₂
RCC modulus in-service (Sweden)

Bearing capacity
Resilient modulus from FWD measurements. Road 109 at EKEBY. Sub-base layers.

Crushed concrete*
Crushed granite

* pure (> 95%) concrete from demolition waste

Resilient modulus (MPa)
Age after compaction (months)
North Dakota Rubblization of Concrete 2015
Challenges for Recycled Materials in NZ

- Recycled materials perceived as inferior to natural materials
- Quality control & contamination
- Alkaline runoff & leachate concerns
- Cost
Ohakea Runway 2003
Crushing existing Runway
RCC trials at CAPTIF

RCC was demolition concrete from Auckland buildings. All other pavements consisted of natural aggregates.

Canterbury Accelerated Pavement Testing Indoor Facility

Rutting Progression at CAPTIF under 10 Tonne Axles
(Linear Extrapolation - 90th Percentile Values)

AP40 TNZ M/4
Wards RCC
Conclusion

- Pavement segment constructed with recycled crushed concrete was best performer, achieved almost twice the life achieved with other pavements of same depth.
- This research & subsequent field trials gave Transit (NZTA) confidence to put RCC in M/4.
CLIENT: CHRISTCHURCH CITY COUNCIL

CONTRACT: GOLF LINKS RD RECONSTRUCTION

CONTRACTOR: Fulton Hogan Canterbury

100% RECYCLED ROAD

Start Date: 7th June 2005
Completion: 24th July 2005
Subbase Construction
Project Summary

• Excellent technical properties
• Performing well after 9 years
• Savings obtained when whole of life costs are considered
• Encourages sustainability of natural resources
• No environmental risks
• Replacing asphalt layer but NOT RCC subbase & base
M/4:2006 RCC Basecourse specification

- Same requirements as for natural aggregate
- RCC is Recycled Crushed Concrete composed of rock fragments coated with cement with or without sands and/or filler, produced in a controlled manner to close tolerances of grading and minimum foreign material content
- RCC fragments shall consist of clean, hard, durable, angular fragments of concrete
- It must be approved for use by the appropriate Regional Council
M/4:2006 RCC Basecourse specification

% of foreign materials shall be determined by RTA Test Method T276. % of foreign materials shall not exceed the following percentages by mass:

Type 1 Materials: Glass, brick, stone, ceramics and asphalt < 3%
Type II Materials: Plaster, clay lumps and other friable material: < 1%
Type III Materials: Rubber, Plastic, Bitumen, Paper, Wood and other vegetable or decomposable matter: < 0.5%

No Type II or III materials may be retained on 37.5mm or above sieves for RCC Basecourse materials
Christchurch Southern Motorway

Divided into three distinct sections

ZONE A

ZONE B

ZONE C
Overview

Zone A – Cement modified granular pavement

Zone B – Foamed bitumen stabilised granular / unbound RCC pavement

Zone C – Structural asphalt / heavily cemented RCC pavement
# CSM Stage 1 Pavements

<table>
<thead>
<tr>
<th>Greenfields Section</th>
<th>Thickness (mm)</th>
<th>Duplication Section</th>
<th>Thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 coat seal/OGPA</td>
<td>40</td>
<td>SMA</td>
<td>40</td>
</tr>
<tr>
<td>AP 40 Foamed bitumen stabilised</td>
<td>150-200</td>
<td>Asphalt Mix 20</td>
<td>125</td>
</tr>
<tr>
<td>RCC 65 mm</td>
<td>150 - 300</td>
<td>Polymer-modified membrane seal</td>
<td></td>
</tr>
<tr>
<td>Granular fill</td>
<td>0 - 450</td>
<td>RCC 65 mm, 3.5% cement, microcracked</td>
<td>200</td>
</tr>
<tr>
<td>Subgrade</td>
<td>CBR = 7-10</td>
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</table>
Greenfields – RCC Subbase – Zone B

Typical Design

1 coat 2nd Seal
2 coat 1st Seal
150 FB
200 RCC

Subgrade
CBR = 10%

Traffic: 2.1 x 10^7 ESA
Design CBR: 7 - 10
Pavement: Foamed Bitumen
Methodology

- Prepare subgrade
- Subgrade trim
- Grader lay RCC subbase (AP65, unmodified)
- High water demand – RCC is very thirsty
- Excellent for winter construction!
- Checking compaction – allow for hydrogen in RCC have to determined offsets with lab mc% tests
Structural Asphalt – Zone C

Typical Design

Traffic: $4 \times 10^7$ ESA
Design CBR: 10
Pavement: Structural Asphalt

Curletts - Collins
Chainage 7700 - 10300
4.00E+07

- 40 OGPA
- 125 SAC

Membrane Seal

- 200 RCC+3.5% Cem

Subgrade
CBR = 10%
Materials & Design

- Maximised use of RCC
  - Trials to confirm optimum maximum size for stabilising
  - Tests confirmed optimum cement content to add for cemented subbase
- Maximised use of RAP
  - RAP sorting & storage methodology
  - 30% RAP in asphalt mix
- Maximised sustainable use of virgin aggregates
  - Maximised use of existing aggregate in Halswell Junction Rd
  - Broken faces as per B/5 spec in Zone B
- Trials of aggregate from 3 different quarries - Zone B
  - PSD vs moisture susceptibility
Case Study: RCC in Henry Rose Place, North Shore City

• Footpath concrete from North Shore & Waitakere City
  Maintenance contracts crushed by Fulton Hogan in April 2009 to produce GAP65 aggregate

• Virgin aggregate control section & RCC test section

• Test section
  – Basecourse: Recycled crushed concrete aggregate
  – Surfacing: AC14 Asphalt with 30% recycled concrete aggregate
Compaction issues

- Extra work required to develop offsets for Nuclear Density Meter (NDM) due to hydrogen in crushed concrete significantly affecting readings.

- Benkleman Beam results on Crushed Concrete met design deflections in CIRCLY pavement design.
Production issues

- AC14 CC30: difficult to dry RCC due to high moisture content (10.3%)
- Drying aggregate achieved by slowing hot mix plant to below normal production levels to ensure bag house temperature was not exceeded
- Adhesion agent also added
Findings/conclusions

• RCC suitable as a pavement construction aggregate
• NDM offsets must be determined specifically for RCC being used
• AC14 Crushed Concrete met design criteria but slowed Asphalt Plant (& therefore paving crew) significantly due to high moisture content
• Overall job came in on budget & has met all expectations to date
Conclusion

• Recycled crushed concrete is an excellent material for pavement basecourse & subbase layers – performance is equal to or better than natural aggregates
• Requires quality processing
• Don’t waste high quality product like RCC in footpaths
• Sustainability can be incorporated into pavements without adverse effects
Questions / Comments / Discussion