NAPA Scanning Tour of Japan

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Presentation Outline

1. Background - compare & contrast U.S. & Japan business practices
2. Research and Technology
3. Recycling Practices - plant equipment and laboratory testing
Why Visit Japan?

- The National Asphalt Pavement Association (NAPA) learned that, on average, Japan recycles 45+ percent in their asphalt mixtures.

- NAPA promotes the increased use of recycled products here in the United States and therefore organized a scanning trip with Japanese counterparts to facilitate this technology transfer.
Scanning Trip Planned

- The trip was planned from December 1-10, 2014
- The US Delegation included 19 individuals representing NAPA contractor members, four (4) state DOT representatives, the National Center for Asphalt Technology (NCAT), NAPA staff, and a representative from the State Asphalt Pavement Associations
- Everyone arrived in Tokyo on December 2nd

- Special thanks go to Brian Wood from Kentucky APA
- Andy Welch from Maxam Equipment
US Delegation
TaiseiTotec Plant Visit
Full Schedule

- Asphalt Plant Tour and Paving Site Visit
- Seminar on Recycling
- Technical Tour of Expressway (porous)
- Sightseeing in Kyoto
- Bullet Train to Tokyo
- Asphalt Plant Tour and visit to the Public Works Research Institute (PWRI)
- Contractor lab visit
Industry Dynamics

Putting it all into context
Japan 101

- Island nation in East Asia with the worlds 10th largest population (over 126 million people)
- Greater Tokyo area and surrounding prefectures is the largest metropolitan area in the world with over 30 million residents
- Japan consists of 6,852 islands, has 108 volcanos, and experience earthquakes and tsunamis
- Average winter is 41.2F and summer is 77.4F
Size and scale

Japan’s land areas is 145,925 square miles - slightly smaller than the state of California at 163,696 square miles.
Size and scale compared to U.S.

- Japan has roughly half the population and only about 4% of the land area of the U.S.
  - Over 1,000 plants producing 50 million tons
  - Unites States production is 350 million tons with about 3,000 Plants

Average plant production 117,000

Average plant production 50,000
General Observations

- Japanese culture is an interesting blend of old traditions and new technology
  - That contrast between old and new extends into their asphalt paving operations as well
- In some specific areas – the Japanese would appear to be more advanced than the US but in many ways, they are decades behind
Asphalt in Japan Versus U.S.

**Advanced**
- Recycling over 45% and use of rejuvenators
- Performance-based specifications
- Workmanship & Safety

**Lagging Behind**
- Batch plants with low production
- Small projects with high unit costs
- Mix designs and materials
A few other things were more primitive
Seminar & Opening Reception

Information Exchange
Language Barriers

In case of emergency.
Break the door and get out here.
Recycling in Japan

- Government mandate
  - Legislation on recycling construction waste is stringent and fully implemented
  - Japanese concluded in 1992 that RAP mixtures were as good as virgin mixes
- Japan is a small country with large urban areas so waste disposal is an important issue
Japanese Asphalt Mix Products
Research and Technology
Public Works Research Institute
Japanese Name Plate
Presentations and discussions
Test Track with Driverless Trucks
Government Research
Similar to Turner Fairbanks and NCAT
Test Track @ 35 degree banking
Nippo Visit
Facility Tour
Research Laboratory @ Nippo
Innovation

Ice-breaking pavement using rubber aggregates
Visited Two Plants

Taisei Rotec

Maeda Road
High RAP Mixtures

Typical Asphalt Plant in Japan
HMA Plant control room = Office setting
Classroom Element
Cultural Differences
Plant Safety
Virgin Materials

- Handled and processed similar to the United States
- Mostly sandstone
- Covered cold feed bins to maintain low moisture content
Clean and Covered
Processing RAP

- Most of the RAP we saw was delivered in pieces (not milled)
- Delivered to the asphalt plant for processing
- Crushed, sized & screened
Indoor Processing Facility
Rap Processing

- RAP is fractionated much like it is here in the U.S.
- The RAP processing facility we visited was indoors (strict dust and pollution requirements)
RAP Processing Facility
Managing Materials

- Covered processing and bin storage
  - They keep RAP dry... reported at 1.5%-2.0% moisture
- RAP is tested for penetration grade
RAP Parameters

- Liquid in RAP must have a penetration of 20 or more or it will be discarded
- Fractionated into 2 or 3 sizes to develop proper blend
Rejuvenators

- The key to using high RAP mixtures is the introduction of a rejuvenating agent to condition the RAP.
- It softens the hardened binder and activates the liquid.
Recycling Methods in Asphalt Plants

Plant Types

- Parallel Heat: 68.8%
- In Direction: 17.7%
- Dram Mixing: 13.5%
“In Direction” Heat System

- Appears most similar to a U.S. style batch plant utilizing superheated virgin aggregate to transfer to heat and dry the RAP

- Approximately 17.7% of the plants utilize this method but we did not visit one while there
“Dram Mixing” System

- RAP is added into a parallel flow dryer away from the flame. Not very common in Japan (13.5% of plants) and did not visit on our tour.
Parallel Heat System

- Most common plant type (68.8%) and the type we visited while on our tour
- Parallel dryers... one for recycle and one for virgin materials
TaiseiRotec Plant
Maeda Road Plant

- Parallel Heat System
- Batch plant producing 180 tons/hour
  - 270,000 tons/year
- 32 employees with dorm so that mix available 24 hours
Inside the Plant
RAP Dryer/Drum
Material Flow

- RAP to dryer, pugmill with rejuvenator, and to surge bin (3 hours)
- Virgin materials dried and moved over screens (typical)
- RAP mixed with virgin aggregates and AC in the mixer
Phase 1
Phase 2
Phase 3
Rejuvenators

- Proprietary!
- One plant we visited indicated that their product was generally classified as a paraffinic oil
Parallel Heating

- Heating and isolating the RAP with the rejuvenator makes a lot of sense
- Adaptations would be required in US for drum plants and for higher production (Estimated cost 25mm)
- Foaming the rejuvenator may be more feasible to minimize or eliminate conditioning times
- Potential for mixtures with higher RAP that demonstrate equivalent or better quality and performance
Plant Controls
Loading Operations
"Portable" Plant – No Recycle ability
Japan has established simple mix tests to evaluate mix designs:

- Those tests are the indirect tensile modulus (peak stress/deformation) and a wheel tracking test (dynamic stability)

This allows the mix designer (contractor) to be innovative in developing combinations of materials (e.g. RAP, softer virgin binders, and rejuvenators) to meet the mix design criteria.
Mix Types

- They keep mix types to a minimum and simple descriptions
- Batched a virgin mix along with 45% and 60% RAP mixes for our inspection
I got tired of hanging out with Abdul
I was pretty popular over there.
I’ll Pass this over to Abdul now for the technical portion..
History of RAP Pavement Technology in Japan

1982: Ministry of Construction started investigations on RAP mixture and conducted trial RAP pavement

1984: RAP pavement was paved, following the tentative RAP pavement guide

1992: It was confirmed that performance of RAP mixture is identical to virgin asphalt mixture

1992: RAP pavement guide was published and used in practice

2004: RAP pavement Handbook was published

2010: The handbook was revised for the purpose of increase in recycle rate and improvement in RAP quality
RAP Pavement Survey
1982-1984
By Ministry of Construction
Virgin Asphalt Pavement vs RAP Pavement
- Rut depth -

**Virgin Asphalt Pavement**

![Graph showing rut depth vs cumulative commercial vehicles volume for Virgin Asphalt Pavement.](image)

**RAP Pavement**

![Graph showing rut depth vs cumulative commercial vehicles volume for RAP Pavement.](image)
Virgin Asphalt Pavement vs RAP Pavement
- Cracking ratio -

**Virgin Asphalt Pavement**

Cracking ratio (%)

Cumulative commercial vehicles volume

**RAP Pavement**

Cracking ratio (%)

Cumulative commercial vehicles volume
Factors affecting the crack generation

- Cracking ratio exceeded 10% when cumulative commercial vehicle volume reached 5 millions
- Cracks were seen in the section paved by RAP mixture in three years
- Following factors were considered as causes of the cracks:
  - Pen grade: less than 20
  - Substandard RAP binder
  - Higher RAP percentage in indirect heating system
### Developing RAP Quality Standard:

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Content of RAP Binder</td>
<td>3.8 % Min</td>
</tr>
<tr>
<td>Properties of RAP:</td>
<td></td>
</tr>
<tr>
<td>RAP binder Penetration</td>
<td>20 Min</td>
</tr>
<tr>
<td>RAP Indirect tensile modulus</td>
<td>1.70 Max</td>
</tr>
<tr>
<td>Amount of RAP fines contributed to RAP mixture</td>
<td>5.0 % Max</td>
</tr>
</tbody>
</table>
Indirect Tensile Test

- **Test condition**

  - Curing time: More than 5 hours
  - Test temperature: 20 degrees Celsius
  - Loading speed: 50 mm/min
Indirect Tensile Modulus

Indirect tensile modulus (MPa/mm) = \( \frac{\sigma_t}{x} \)

Indirect tensile strength: \( \sigma_t (MPa) = \frac{2 \times P}{\pi \times d \times L} \)

- \( x \): Amount of displacement
- \( P \): Maximum load at break
- \( d \): Thickness of the specimen
- \( L \): Specimen of diameter
Indirect Tensile Modulus of RAP Aggregates

Acceptable range
Quality of Blended Binder

Blended Binder: RAP binder with virgin binder and/or rejuvenator
Evaluation of RAP Binder

- RAP binder is extracted to confirm its penetration
- Penetration of RAP binder is recovered by blending rejuvenator and/or virgin binder
## Quality Standard of Blended Binder

<table>
<thead>
<tr>
<th>Grade</th>
<th>Penetration 25°C (1/10mm)</th>
<th>Softening point (°C)</th>
<th>Ductility 15°C (cm)</th>
<th>Flash point (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 - 60</td>
<td>40 - 60</td>
<td>47.0 - 55.0</td>
<td>10 ≤</td>
<td>260 ≤</td>
</tr>
<tr>
<td>60 - 80</td>
<td>60 - 80</td>
<td>44.0 - 52.0</td>
<td>100 ≤</td>
<td>260 ≤</td>
</tr>
<tr>
<td>80 - 100</td>
<td>80 - 100</td>
<td>42.0 - 50.0</td>
<td>100 ≤</td>
<td>260 ≤</td>
</tr>
</tbody>
</table>
RAP Mix Design

Adjustments to the designed penetration or indirect tensile modulus
## Use of RAP Mixture in Different Regions

<table>
<thead>
<tr>
<th>Areas</th>
<th>Penetration grade (1/10mm)</th>
<th>Indirect tensile modulus (MPa/mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>General use</td>
<td>40 ～ 60</td>
<td>0.60 ～ 0.90</td>
</tr>
<tr>
<td>Cold and snowy Regions</td>
<td>60 ～ 80</td>
<td>0.40 ～ 0.60</td>
</tr>
</tbody>
</table>
Penetration and Indirect Tensile Modulus of RAP Mixture

- Virgin mixture
- Oven-aged RAP mixture
- Round-robin test using RAP mixture
- RAP mixture using RAP aggregates at PWRI
- Master curve

- General use
- Cold and snowy

Desired Indirect Tensile Modulus (MPa/mm)

Penetration of RAP Binder (%)
RAP Mix Design Procedure

Sample Collection

Material Evaluation

- Evaluation of RAP binder
  Penetration $\geq 20$ (1/10mm)
  
  - No
    - Unsuitable
  
  - Yes
    - Adjustment to meet Designed Penetration

Blending Design

- Evaluation of RAP Aggregates
  Indirect Tensile Modulus $\geq 1.7$ (MPa/mm)
  
  - Yes
    - Adjustment to meet Designed Indirect Tensile Modulus
    
    - Yes
      - Marshall Test
    
    - No
      - Unsuitable

- No
  - Unsuitable

Determination of Design Mixture
Adjusting RAP Mix Designs:

**Adjustment Methods:**
- Rejuvenator
- Virgin binder

**Specification Criteria:**
- Penetration grade
- Indirect tensile coefficient
Adjustment to the Designed Penetration using Rejuvenator

![Graph showing the adjustment of designed penetration using rejuvenator. The x-axis represents the amount of rejuvenator (% by weight of Recovered RAP binder), and the y-axis represents penetration (1/10mm). The graph illustrates the relationship between the amount of rejuvenator and the penetration level, aiming to meet the designed penetration.]
Adjustment of the Designed Penetration using Virgin Binder

- Designed penetration

Blending ratio between virgin binder and RAP binder

Blending ratio of Virgin and RAP binders (%)
Adjustment to the Designed Indirect Tensile Modulus using Rejuvenator

- Designed Indirect tensile Modulus
- Amount of rejuvenator to meet designed Indirect tensile modulus

![Graph showing the relationship between amount of rejuvenator and designed indirect tensile modulus.](image)
Adjustment to the Designed Indirect Tensile Modulus using Virgin Binder

- Designed indirect tensile modulus (MPa/mm)
- RAP contents (%)

The graph shows the relationship between designed indirect tensile modulus and RAP contents. The design indirect tensile modulus is indicated by a dashed line. The RAP contents required to meet the designed indirect tensile modulus are shown by the intersection points on the graph.
Performance property for 3 years

Maintenance control index (MCI) = 10 - 1.48C^{0.3} - 0.29D^{0.7} - 0.47\sigma^{0.2}

※ C: Crack (%), D: Rutting (mm), \sigma: Smoothness (mm)

<table>
<thead>
<tr>
<th>Virgin Aggregate %</th>
<th>40</th>
<th>40</th>
<th>40</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAP including Straight asphalt %</td>
<td>0</td>
<td>20</td>
<td>40</td>
<td>0</td>
</tr>
<tr>
<td>RAP including PMA %</td>
<td>60</td>
<td>40</td>
<td>20</td>
<td>0</td>
</tr>
</tbody>
</table>

Chart showing MCI after three years for Up Lane and Down Lane.
In Summary:

✓ Established quality standard for RAP.
✓ Same standard must be achieved for any binder, virgin mix or RAP mix.

✓ Pre heat the RAP Material.
✓ Combine with a rejuvenating agent & condition.
✓ Conditioning will activate the RAP AC & enable it to regain original properties.

✓ Virgin aggregate is heated & dried to a max of 400 F.
✓ Combine the conditioned RAP with virgin aggregate and new AC.

✓ Mix discharge temperature is kept around 325 F.
✓ Properties of new AC are not compromised, **NO** premature long term aging.
Questions?
Field Operations

Asphalt Paving Project
Trucking Operations
Compaction
Attention to Detail

Workmanship and Quality
Field Inspection

Abdul felt like he was 20 years younger running around the job site.

Abdul was know as that guy who always has a question ????
Protecting the unconfined edge
Formed longitudinal joints

Formed the base, paving the surface in echelon
Tacking the longitudinal joint
Tight Joints
Excellent workmanship
Clear Sound Walls
Clean and precise operations
Finished Product
“Porous” Pavements = OGFC
Double Layer Porous
From roads to high speed rail...

Bullet Train
165 mph by train
Vehicles

- New and used cars are expensive, car ownership fees and fuel levies are used to promote energy efficiency
- Parking
Closing Dinner & Reception
Gifts and Business Cards
Observations

- Performance based specifications
- Emphasis on quality workmanship
- Use of rejuvenators to increase RAP percentage
Final hours before flying home...
Observations

- Performance based specifications
- Emphasis on quality workmanship
- Use of rejuvenators to increase RAP percentage
Questions?
Vehicles & Loading
Widescreen Test Pattern (16:9)

Aspect Ratio Test

(Should appear circular)