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Hot Mix Asphalt with RAP (and/or Other Materials)

Project 56

- **Analysis of Dynamic Modulus and Binder Data for High RAP**

  A substantial amount of material is collected and tested during individual High RAP (HMA and WMA) projects, but there is little analysis that is being done on the overall body of test results. The goal of this project is to take a broad view of the available data to evaluate the amount of blending that is occurring between the virgin and RAP materials. This will be done by back calculating the asphalt properties based on the collected dynamic modulus and binder test data. Dr. Jo Daniel at UNH is conducting this project, with $32,798 of funding from the RMRC Pooled Fund. Only $500 has been spent to date as efforts have focused on collecting the data from various sources. The detailed analysis is to begin this summer.

Recycled Materials in Unbound Base/Subbase Applications

Project 45

- **Modulus and CBR Values for Construction and Demolition Debris**

This project will address the need for engineering data on coarse and fine aggregate obtained from mixed stream C&D debris. More than 45 State Transportation Agencies (STAs) allow the use of crushed concrete in base applications, however, in practice only concrete from STA infrastructure is used. Only a handful of states allow the use of building derived concrete (BDC) or mixed stream concrete in STA projects. A major barrier to the use of BDC in transportation project seems to be the presence of crushed brick, porcelain and cement-based masonry units in the material. The current AASHTO standard on crushed concrete in base applications (M 319) allows up to 5% brick by mass, and more with the approval of the engineer. However, there seems to be a perception that BDC does not perform as well as RCA due to the presence of these non-concrete materials.

This is a significant barrier since brick alone can exceed 10% by mass of BDC, depending on the region.

- The first task will be to evaluate the performance of BDC compared to natural aggregates using the CBR test, resilient modulus test, and using a "light" falling weight deflectometer.
- The second task will be to evaluate the variability in the results obtained by the different test methods.
- In the third task the gathered data will be evaluated as level 1 and level 2 inputs in the Mechanistic Empirical Pavement Design Guide and MnPAVE, to see the sensitivity of rutting with respect to the variability of materials.
- The final task will be to evaluate how different materials (brick, pavers, etc.) affect the results.
- Dr. Jeffrey S. Melton at UNH is conducting this project.
- To date, $20,167 has been provided by the RMRC base funds in the form of tuition and a stipend. A graduate student has been supported for three semesters by UNH, worth $30,251.
- The RMRC Pooled Fund has provided an additional $97,055 of which $66,232.70 has been spent.

<u>Work completed to date:</u>

- NH Department of Transportation is widening a major state highway (Route 16) near the University. This project site was used to test the in-situ properties of the natural sand and gravel that was being used by NH DOT

(standard base material). The light falling weight deflectomers (LFWD) were used to measure the in-situ stiffness of the sand subbase and gravel base layers. Seventy-five LFWD drops were done on the subbase, and 75 on the base. Sand cone and nuclear density tests were also conducted, along with moisture contents.

- Once the field-testing was completed, laboratory testing was started. The same sand used in the Route 16 project was brought into the laboratory and placed into the 4ft X 4ft X 2ft test pit and compacted as close as possible to the in-situ density that was determined in the field. LWFD testing using the same instruments was then conducted in the same manner as the field testing. Pit density was determined using sand cone tests. Seventy-five LWD drops were conducted in random spots on the surface of the pit. Once pit testing was completed CBR and resilient modulus testing (RMT) were conducted on the sand. CBR testing was conducted first so that the vibratory hammer used for compaction could be properly calibrated for this particular material. Over 15 CBR tests were conducted to obtain a complete data set that would be used when correlating the results to RMT testing. RMT testing was started once the machine was properly setup and calibrated. As with the CBR testing over 15 tests were conducted for a complete data set.

- At the completion of sand testing in November 2009 the NHDOT was beginning to place the base material for the Route 16 project. The base material was placed in a 1 foot of 6" minus crushed stone, overlaid with 1 foot of 2" minus crushed stone. The 2" material was collected and brought to UNH for laboratory testing. Due to the material size constraints when performing CBR and RMT testing, only the 2" minus material was tested. The same setup used for sand field-testing was also used for testing of the 2" minus material. The material, like the sand, was then placed in the pit and tested. The aggregate was then scalped to remove particle greater than 1" so that RMT and CBR testing could be conducted. The same amounts of tests run on the sand were also run on the 2 in minus to compile a complete data set.

- While testing of the sand and 2" minus material were being conducted, the C&D debris was being prepared for testing. During July 2009 approximately 2 cubic yards of C&D material was obtained at ERRCO in Epping, NH. In

order for this material to be tested properly it needed to be crushed to an appropriate size. A small jaw crusher was used for this task and the crushed material was then screened to resemble a 1" minus material. By visual inspection it seemed that the material was mainly comprised of concrete, rock and brick. At the completion of testing the 2" minus material from the C&D material was placed into the 4ft X 4ft X 2ft pit for LWFD testing. Following the same procedure as performed on the sand and 2" minus mixed material. The C&D was tested numerous times to obtain a good data set. Since the material was not tested in a field setting the material was compacted with a water content that produced the highest density possible. The material was then modified for CBR testing (due to it being 1" minus no modifications were needed for RMT tests) and both tests were run with the same water content and densities as the LWFD pit testing.

- The CBR and resilient modulus results showed that the C&D material meets the requirements for use as base course aggregate. There was good correlation between the LFWD and the resilient modulus (for all materials), but not between the CBR and resilient modulus (for all materials).

- It was also noted that the C&D debris did harden with time.

- Current work is focused on evaluating the results using the MEPDG and MnPAVE, looking at the predicted rutting behavior.

- This summer a short project will evaluate how the C&D hardens with time, and how the corresponding CBR values and stiffness values change with time.

- Additional work will be done using dynamic finite element analysis to develop a finite element model for the C&D debris.

- Research paper on the findings will be final output of the study.

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PROGRESS ON RMRC POOLED FUND PROJECTS:
University of Wisconsin-Madison

Engineering Properties of Recycled Asphalt Pavement and Recycled Concrete Aggregate for Unbound Applications - This study focuses on characterizing the engineering properties of RAP and RCA used as subbase, base, and structural fill. The objective is to indentify properties for design.

Completed:

- Collected RAP and RCA samples from 8 states in US
- Conducted index tests, compaction tests, resilient modulus tests on all samples
- Conducted large-scale prototype pavement tests using RAP and RCA from field test sections

Current Work:

- Evaluating how compaction condition affects resilient modulus of RAP and RCA
- Evaluating how deleterious material content affects RAP and RCA
- Evaluating how resilient modulus can be predicted from index properties
- Evaluating hydraulic properties of RAP and RCA

Notable Findings to Date:

- Similar properties of RAP (or RCA) regardless of source/geographic location
- RAP and RCA have higher resilient modulus than conventional base course
- Scaling from bench scale to prototype scale follows accepted principles based on stress level and strain level.
- Rutting in RAP is higher than RCA or conventional aggregate

Upcoming Work:

- Evaluate how freeze-thaw cycling affects resilient modulus of RAP and RCA
- Evaluate how temperature affects resilient modulus of RAP
- Compare lab-measured properties to field-measured properties for field sections

Project Completion: 60%

Budget Expended: 40% of RMRC Pooled Fund (remainder on base)

Recycled Asphalt Shingles as Structural Fill - This study is evaluating the use of shredded recycled asphalt shingles (RAS) as structural fill.

Completed:

- Collected three RAS samples
- Conducted index tests and compaction tests on all samples
- Conducted compression tests on one RAS
- Conducted shear strength test on one RAS
- Conducted hydraulic conductivity tests on one RAS

Current Work:

- Evaluating properties of RAS blended with foundry sand
- Evaluating properties of RAS blended with bottom ash
- Evaluating properties of RAS blended with cementitous fly ash
- Evaluating creep properties of RAS and RAS blended with byproducts

Notable Findings to Date:

- RAS is too compressible to be used as structural fill alone
- RAS has high shear strength, and strain hardens appreciably
- Blends with 50% bottom ash have adequate compressibility for modest (< 15 m) embankments
- RAS is very permeable and will drain well.

Upcoming Work:

- Continue testing with other RAS materials
- Expand evaluation of blended materials to identify optimal blends
- Consider RCA-foundry sand blends

Project Completion: 70%

Budget Expended: 60% of RMRC Pooled Fund (remainder on base)

Stabilizing Recycled Pavement Materials Using Coal Combustion Products and Cement Kiln Dust - This study will focus on improving the engineering properties of recycled pavement materials (RPM) by blending them with cementitous industrial byproducts.

Completed:

- Collected RPM samples
- Conducted bench-scale and prototype-scale tests on RPM blended with and without cementitous materials
- Evaluated resilient modulus of field test section with FWD
- Conducted back-analysis and scaling to compare bench-scale and prototype-scale resilient modulus
- Developed recommendations for design

Current Work:

- Evaluating fatigue cracking of cement-stabilized layers

Notable Findings to Date:

- RPM blended with cementitous fly ash or CKD is a stiff but not brittle base course
- Adding cementitous binder greatly reduces rutting in RPM
- Using RPM blended with cementitous materials can extend life cycle of pavement layers.

Upcoming Work:

- Fatigue cracking assessment

Project Completion: 90%

Budget Expended: 80% of RMRC Pooled Fund (remainder on base)