Semi-Annual Progress Report

Project Number and Title: *2.1 Asphalt Mixtures with Crumb Rubber Modifier (CRM) for Longevity and Environment*
Research Thrust: *New Materials for Longevity and Constructability*
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Overview:

Increasing loading and traffic volume leads to high demand of well performing pavements. There is also need of lots of rehabilitation of the pavement to maintain the old highway back onto work. In such cases, large number of waste asphalt mixtures was produced during rehabilitation and reconstruction, which would take lots of land and pollute the environment. Numbers of road maintenance and rehabilitation (M&R) were carried out which creates large amounts of reclaimed asphalt pavement (RAP) that can be potentially re-used for resurfacing of the same pavements and can be used for new constructions. On the other hand, lack of virgin materials becomes challenges to the civil engineers. In additions, there is dramatically increasing cost of asphalt binder, dwindling budgets, growing traffic and desire to find more sustainable strategies, e.g., maximizing the re-use of RAP. Therefore, researchers are focusing on developing new techniques and searching new materials that will maximize the re-use of RAP and bring better performance so that the pavement will be served in longer periods within less efforts and budget.

On the other side, there is rapidly increase in vehicles and generating millions of old waste tires every year, causing negative impacts on the environment. So, crumb rubber modifier (CRM) will be one of the alternative potential materials in asphalt mixtures for sustainable pavement. The University of Rhode Island (URI) team had performed a research on the feasibility of using CRM in 1996. They found that the paving asphalt mixtures incorporated CRM shows the equivalent performance in deformation and fatigue cracking resistance with conventional hot mix asphalt (HMA). The also learn that the addition of CRM to asphalt binders appeared to improve some of binder's properties such as reducing the inherent temperature susceptibility. The improvement of the properties of CRM binders largely depends on the interaction between CRM and asphalt binders where the CRM particles swell in the binders to form a viscous gel; resulting in an increase in the viscosity of the CRM binders. Fereidoon et al. researched on the bitumen containing CRM and concluded that G*, G*sin δ and G*/sin δ parameters were increased as the contents of CRM is increased at higher temperatures and lower frequencies and at lower temperature and higher frequencies vice-versa.

Xunhao Ding et al. (2019) studied on the performance of RAP with stable crumb rubber asphalt (SCRA). They used performance tests like wheel-tracking test and four-point bending beam test which examined the high-low temperature performance moisture stability and the fatigue resistance, respectively. They found that higher the RAP content better in high-temperature stability but worse in low-temperature property, moisture stability and fatigue life in both virgin asphalt and SCRA mixtures. Additionally, they concluded that mixtures with SCAR shows better performance than virgin asphalt mixtures, and that addition of rejuvenator in SCAR shows positive effect on the low-temperature performance, moisture stability and fatigue resistance.

Gallego et al. (2016) studied on the CRM with warm mix asphalt (WMA) additives. They used WMA organic additive "Sasobit" which is mixed with 15% and 20% CRM. They found that WMA additives significantly lowered the maximum deformation and increased the elastic recovery when compared to the control binders. Yu et al. (2018) investigated and found that Warm Asphalt Rubber (WAR) with chemical and foaming additives exhibited a poorer performance than asphalt rubber (AR), but their fatigue performance was still great in performance than conventional bitumen.

Evotherm with RAP

Many agencies including New England States used Evertherm to produce WMAs. Thus, some researches focused on studying the effect of Evotherm on short-term performance of asphalt binder in the laboratory, e.g., comparing with the traditional HMA binder. For instance, Howard et al. (2014) found that the effect of Evotherm on polymer-modified binder is different from unmodified binder. Xiao et al. (2013) found that Evotherm 3G improved the low temperature property. Evotherm mixtures showed better rutting resistance and had similar resilient modulus values as compared to HMA mixtures (Xiao et al. 2013). Xu Yang et al. (2017) found that Crumb rubber-WMA with Evotherm had a higher tensile strength and better low temperature performance than the control HMA. Furthermore, the production of the Evotherm mixtures required lower fuel consumption compared to HMA production (Hurley et al. 2006).

Foamed Asphalt with CRM

A Louisiana research team investigated the potential use of foamed asphalt (FA)-treated RAP as a base course material in lieu of a crushed-limestone base beneath a concrete pavement layer. They designed FA-treated RAP mixture, and carried out experimental study of FA base course using dynamic cone penetrometer (DCP), Humboldt stiffness geogauge (HSG), falling weight deflectometer (FWD), light FWD (LFWD), and Dynaflect in the laboratory. They found that FA-treated RAP materials showed better performance than traditional stone base. They also confirmed that FA-treated base with 100%RAP can be exchangeable with FA-treated base with 75% RAP+25%crushed limestone as there is no significant difference in measured field strength and stiffness (Mohammad et al.2003).
CIR with foamed asphalt can be used under some adverse weather compared with CIR with asphalt emulsion (Eller and Olson 2009).

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Yu et al. (2014) studied that foamed Crumb Rubber modified asphalt (F-CRMA) binders, and learn that it provided better low-temperature performance, temperature stability, and fatigue resistance, compared to regular CRMA binder. With the increase of foaming water content, the low-temperature performance of foamed CRMA binder first decreases and then increases, and the temperature stability and fatigue resistance of foamed CRMA binder keep increasing.

Key Findings from Literature Review

- Mixtures containing RAP with CRM need improvement in thermal cracking, moisture stability and Fatigue life
- WMA mixtures containing RAP perform better compared to the virgin mixtures with respect to rutting resistance at high temperature due to the incorporation of aged binder.
- Addition of WMA additives on CRM lowers the deformation and increase the elastic recovery
- Addition of WMA additives in mixtures containing RAP with CRM shows positive effects on the low temperature performance, moisture stability and fatigue resistance.
- Scarcity of standard mix design procedure for WMA containing CRM and RAP

The University of Rhode Island (URI) team will investigate a new generation of asphalt mixtures with CRM for longevity of the pavement. Figure 1 will show the flowchart of the research of WMA containing tire rubber modified asphalt mixtures and RAP to improve durability and to extend the life of transportation infrastructure

Figure 1: *Flowchart of the Research Project*

Participants and Collaborators:

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Changes

The URI research team originally planned to make cold-recycled RAP mixtures with CRM. However, there is change, i.e., studying WMA before the cold mixed mixtures. So, first we will prepare CRM-WMA with two types of additives i.e., Evotherm (and LEADCAP) and foamed Bitumen. It may be noted that Evetherm has been used in RI and LEADCAP is an eco-friendly organic additive manufactured by a collaboration between Kumho Petrochemical and the Korea Institute of Construction Technology (KICT) that is

specifically for WMA pavements. In addition we will conduct a series of experimental study in the laboratory in order to select the best WMA mixture containing RAP and CRM. Therefore, a new apparatus "Laboratory foamed bitumen WLB10S" is needed to develop the foamed bitumen so that URI research team can develop the foamed asphalt mixtures with CRM and RAP. This will help to develop the better WMA containing CRM and RAP, which will eventually compare its performance with the HMA and cold treated mixtures.

Planned Activities:

Evotherm with RAP

The URI Research Team plan to develop the CRM mixtures with Evotherm and RAP. They have already started their study on Evotherm with RAP first and after that they will produce CRM mixtures with Evotherm and RAP. They are using findings from NCHRP 9-43 Report to prepare the WMA mix design and also will follow the procedure for additives dosage rates including water, mixing temperatures and compaction temperatures.

We will conduct the performance test of asphalt binders on various content of RAP along with/without CRM & Evotherm. Modified Asphalt is a composite material that exhibits complex behavior; its modulus is highly dependent on temperature and rate of loading. For this reason, a cyclic loading test will be used to characterize how the properties of a given mix are affected by loading. Dynamic modulus is a useful parameter for pavement design because it characterizes the time and temperature dependency of asphalt mixtures. It is also one of the primary material inputs for designing flexible pavements using the Mechanistic-Empirical Pavement Design Guide (MEPDG) or ASHTOWare Pavement ME Design (PavementME), while flow number testing can be used as an indicator of rutting resistance.

After getting familiar with the RAP mixtures containing Evotherm, we will study RAP mixtures containing CRM and Evotherm with same procedure. The above activities will allow predicting the nature and relationship of RAP with Evotherm and CRM. If feasible, balanced mix design (BMD) for WMA will be developed and used for the present study.

Foamed Asphalt with CRM

The next steps would be developing the foamed asphalt mixtures containing RAP and CRM. The objectives of this study are: (a) to evaluate the field performance of foaming WMA pavement as compared with HMA control pavement in terms of rutting and cracking distresses; and (b) to investigate the volumetric properties (asphalt content, in-place density, and aggregate gradation) for both foaming WMA and HMA mixtures in the field in relation to field distresses.

The water foamed asphalt mix with CRM will be developed, and it will be evaluated with different promising tests to obtain the optimum proportions of CRM content and additives considering performance improvements, emissions reduction, and cost effectiveness. After calculating optimum moisture content (OWC), optimum foamed asphalt bitumen at targeted air voids will be determined. Then the developed mixture will be used for further performance test.

Asphalt Mixtures Performance Test (AMPT) will be used to find out the properties of asphalt mixtures at different temperatures and different frequencies at different loading like dynamic modulus, flow number and flow time. Dynamic modulus testing is primarily used to characterize asphalt materials for pavement structural design using the MEPDG or PavcementME, while flow number testing can be used as an indicator of rutting resistance. The dynamic modulus is a measure of material stiffness at different temperatures and loading frequencies. The flow number is the point at which the material goes from a low rate of deformation. We will also develop master curve so that future prediction of the longevity can be done.

The response of the asphalt mixtures will help to predict the performance of mixtures against rutting, fatigue and thermal cracking. The generated data will be used as an input in the PavementME software. This study will help predicting the performance of asphalt mixtures containing CRM at different temperature under different loading. Several performance tests including the Semi-Circular Bend will be performed for regular HMA and Water Foamed Asphalt Mix with CRM.

After the performance test, we will explore the potential of applying CRM foamed asphalt for pavement preservation, e.g., asphalt emulsion chip seals etc. A comparative study of different asphalt mixtures (with and without) CRM on different proportions will result the feasibility of using various mixtures with CRM for implementation in the field. A life cycle cost analysis (LCCA) will be also performed. A comprehensive Guide will be developed for selecting optimum proportions of CRM and additives in the mixture for pavement longevity.