# Improve Material Inputs into Mechanistic Design Properties for Reclaimed HMA & Recycled Concrete Aggregate (RCA) Roadways

**Executive Summary Report**

**July 2020**


**Investigators:**

**Bora Cetin** – Principal Investigator

**Tuncer B. Edil –** Principal Investigator

**Mustafa Hatipoglu** – Investigator

**Ida Gheibi –** Graduate Research Assistant

**SUMMARY REPORT for Q2 for 2020**

The research team has continued to collect more data on recycled concrete aggregates (RCA), recycled asphalt pavements (RAP) that are used as a base/subbase material in pavement foundation systems. Draft Task 2 report is almost ready to be submitted to the Technical Advisory Panel (TAP). This report will cover summary of the results from approximately 60 research articles and technical reports. Properties of RCA and RAP materials for the available data were captured for the following states: Minnesota, Colorado, Michigan, California, Texas, Ohio, New Jersey, Wisconsin, Illinois, Montana, Virginia, Florida, Tennessee, Maryland, New Mexico, Washington, Utah and Rhode Island. The laboratory data of more than 40 different recycled samples were collected in terms of mechanical and index properties. Most of the samples used in the studies were 100% recycled materials, while there were also some blended samples of natural aggregates with RCA and RAP at different mixture ratios.

Overall summary shows that the index properties of RAP and RCA materials are highly affected by the following factors: aggregate source, aggregate type, and crushing operations. Database was summarized in five categories: (1) index properties, (2) compaction characteristics, (3) hydraulic conductivity, (4) strength, and (5) stiffness.

**(1) Index Properties:** The first material characteristics for this database are the gradation properties of RCA and RAP materials which were studied in the past. Gradation characteristics include gravel, sand, silt and clay fractions, grain size distribution curves, effective diameter sizes ($D_{60}$, $D_{30}$ and $D_{10}$), and coefficient of uniformity ($C_u$) and curvature ($C_c$). Even though most of the samples used in the studies were coarse-grained soils, the consistency properties were also examined. Approximately 190 different samples including natural aggregate-recycled aggregate blends were used in the gradation database. Gravel contents of RCA materials varied between 94.1% to 4% which is wide range. Fines contents of the collected RCA materials were at the range from 12.8% to 2%. It was observed that sand content was the highest in RAP materials while there were RAP materials with almost 0% percent fines.

Asphalt content (about 4.5%- 6%) and trapped air between asphalt coating and aggregate particles cause lower specific gravity values for RAP than that of natural aggregates. RCA also has a relatively lower specific gravity than specific gravities of natural aggregates due to the presence of mortar bounds in RCA matrix. This is well shown in the collected database.

Most of the plasticity index of RAP and RCA were reported as none-plastic (NP).

**Compaction Characteristics:** The general trend shows that RAP and RCA have lower maximum dry unit weight than natural aggregates. While using more RAP content in the RAP-natural aggregate blends decreases the optimum water content, while the use of a higher amount of RCA in the RCA-natural aggregate blends increases the optimum water content.

**Hydraulic Conductivity:** One of the main functions of aggregate base layers is to provide adequate drainage and prevent capillary action to increase the service life of pavements. Due to the hydrophobicity of RAP, it tends to have higher $k_{sat}$ than RCA and natural aggregate. Based on the collected database, RAP tends to provide a better drainage layer than RCA.

$D_{10}$ and percent fines seemed to have major influence on hydraulic conductivity of RCA and RAP materials. Low $D_{10}$ yielded higher fine particles which resulted in clogging the pores and reducing air voids that finally caused lower permeability.

**Strength:** Database showed that in general, RAP materials had lower California Bearing Ratio (CBR) than that of natural aggregates. In addition, increasing the RAP content in the RAP-natural aggregate mixtures reduced the CBR. Majority of the previous studies showed that the CBR values of 100 % RAP ranged from 18 to 35. However, depending on the physical, chemical and morphological characteristics of RAP or different moisture content used for blends different trends could be observed in different studies. There was not a discernible trend for CBR versus RCA content according to the data collected. CBR of 100% RCAs ranged from 60 to 150.

**Stiffness:** $k_1$, $k_2$, $k_3$, $k_6$ and $k_7$ model coefficients obtained from $M_r$ tests were included to the database and the summary resilient moduli ($SM_R$) were reported at a bulk stress of 208 kPa and octahedral stress of 48.6 kPa. Results showed that an increase in RAP content increased the $M_r$ of RAP-natural aggregate mixtures. RCA content and $SM_r$ relationship was not very straight forward like those observed for RAP content in RAP-natural aggregate mixtures. More than 400 $M_r$ data about RAP, RCA or blends were collected for the database.

Results showed that moisture contents of RAP and RCAs have a negative influence on summary resilient modulus of these materials. The available data indicated that $SM_r$ of RCAs were lower than $SM_r$ of RAPs.

The $SM_r$ of RAP reduces as temperature increases while it was observed that $SM_r$ of RCA was independent from the changes in temperature.

$SM_r$ of RAP tended to be higher when gravel to sand ratio was than one according to the database. The same trend was also observed for $SM_r$ of RCAs.

$SM_r$ of RAP materials were higher for the ones that have higher $D_{30}$ and/or higher $D_{60}$ values. However, the database showed that $D_{30}$ and $D_{60}$ did not affect the $SM_r$ of RCAs.