NATIONAL ASPHALT PAVEMENT ASSOCIATION

AGENCIES & CONTRACTORS SURVEYS ON BARRIERS TO HIGHER RAP USAGE IN ASPHALT MIXTURES

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SUMMARY

In 2021, Reclaimed Asphalt Pavement (RAP) usage had significant environmental and economic impacts, saving 4.7 million tons of asphalt binder and nearly 90 million tons of aggregate, valued at over $3.4 billion. This contributed to a reduction of 2.3 million metric tons of CO2e emissions, enabling cost-effective maintenance and construction activities in line with lower embodied carbon construction materials guidelines. Despite an initial increase from 2009 to 2014, recent data indicate that RAP usage has plateaued above 20%. Two surveys conducted in 2023, involving 81 companies with 635 plants for contractors, along with agencies in 43 US states and two Canadian provinces, aimed to identify barriers to increasing RAP usage in asphalt mix production.

Agencies categorize "High RAP" mixes based on the percentage by weight or asphalt binder replacement ratio, falling into three groups: Conservative (15-25%), Moderate (25-35%), and Progressive (35% or more). RAP limits increase from surface to base layers, shoulders, or for lower traffic roads. However, achieved RAP percentages tend to be lower than specification limits, influenced in part by RAP availability or plant limitations or by additional provisions like minimum virgin asphalt content and restrictions in specific designs, all of which limit RAP use.

Factors limiting RAP use, as identified by agencies, include concerns about reduced service life attributed to raveling and cracking; inconsistency in binder content, gradation, or aggregate specific gravity; and the impact of high RAP content on Polymer-Modified Binder (PMB) mixes. Plant limitations, outdated specifications, and sourcing constraints are also recognized. Mirroring agencies' concerns, contractors perceive specifications and availability as being the two main obstacles to greater RAP utilization. Both agencies and contractors agree on the necessity for plant technology evolution to better accommodate increased RAP usage.

Agencies employ diverse strategies to maintain and increase RAP usage. Adjusting the virgin binder grade and using Warm Mix Asphalt (WMA) technologies as a compaction aid at conventional production temperatures are common practices. Although some states have experimented with recycling agents, use remains very limited. Approximately 60% of states implement various methods to increase virgin binder content. RAP processing and handling requirements, including dedicated piles, gradation controls, and fractionation, are used to ensure consistency. The deployment of Balanced Mix Design (BMD) faces technical and management challenges. Financial incentives, such as separate payment items or sharing savings linked to RAP use, have proven effective in increasing RAP utilization with adequate asphalt binder content.

The primary identified research needs are (1) BMD and index-based performance tests, focusing on correlating cracking tests with field performance; (2) quantifying economic and environmental benefits of high RAP mixes; and (3) emphasizing the use of recycling agents. These priorities are coupled with a demand for training programs for agencies' personnel.

Table 1 Demographics of Responses to Contractor Survey

Region	All	South Central	South	Midwest	Mountain States	Mid-Atlantic	West Coast	Northeast	Plain States
Responses	81	19	18	16	9	8	5	3	3
Plants	635	143	153	155	34	80	18	33	19
Urban Plants	42%	47%	56%	50%	44%	38%	100%	33%	67%
Rural Plants	58%	53%	44%	50%	56%	63%	0%	67%	33%

1. BACKGROUND

The reuse of Reclaimed Asphalt Pavement (RAP) in asphalt pavements offers substantial benefits in cost savings and environmental impact for State Departments of Transportation (DOTs). RAP usage reduces the demand for virgin mineral aggregates and asphalt binders, preserving resources and mitigating upstream emissions associated with raw material extraction and processing. In 2021 alone, the utilization of RAP is estimated to have saved 4.7 million tons of asphalt binder and nearly 90 million tons of aggregate, valued at over $3.4 billion, and resulting in a reduction of more than 2.3 million metric tons of CO2e emissions. Reusing RAP allows road owners to conduct more maintenance and construction activities within constrained budgets, while aligning with current State and Federal objectives for lower embodied carbon construction materials.

Despite a steady increase in average RAP use from 2009 to 2014, recent data from the NAPA IS-138 national annual survey show that it has plateaued above 20% since then. Recognizing this trend, NAPA conducted two parallel surveys in 2023 with agencies and contractors to identify their respective views on barriers to increased RAP usage in asphalt mix production. Only the responses about RAP usage are presented and analyzed here; questions pertaining to reducing production temperatures are addressed in a separate document.

2. SURVEY DEMOGRAPHICS

The contractor survey was accessible to the industry on NAPA ActionNews for 6 weeks, from mid-March to the last week of May. Demographics presented in Table 1 show that a few regions lack sufficient data to be representative. Fifty-eight percent of the plants are in rural areas, 42% in urban areas. Hauling range limiting their market footprint, more plants are needed to cover the large swaths of the rural market.

The Agency survey was circulated through the AASHTO committee on Material and Pavements (COMP) from August to September with 43 US States, Ontario and Quebec participating (Figure 1).

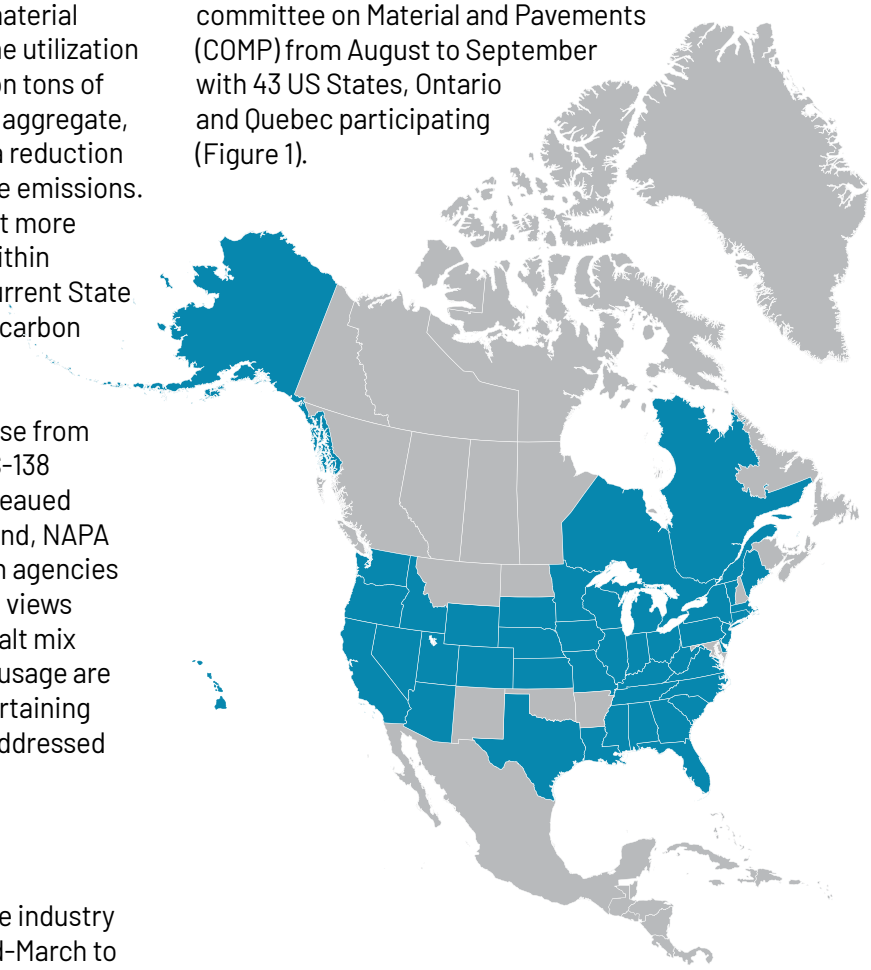

Figure 1 Participating US States and Canadian Provinces.

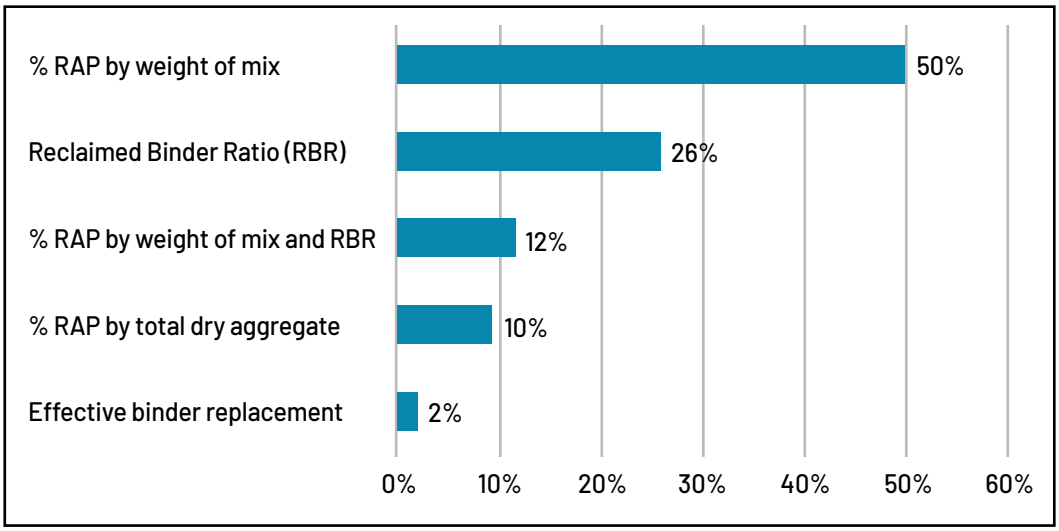

Figure 2 **Parameter used to define RAP content.**

3. AGENCIES: WHAT IS DEFINED AS HIGH RAP CONTENT MIX IN YOUR STATE, AND WHAT IS THE PARAMETER USED?

In half of the states, RAP content is quantified as a percentage of the total mix, while approximately a quarter use the asphalt binder replacement ratio (RBR), recognized as a better measure of RAP binder contribution. Some agencies employ a combination of both approaches, while others reference dry aggregates mass (Figure 2). Concerning 'High RAP' mixes, states generally fall into three categories: 'Conservative States' imposing maximum limits at around 15-25% (e.g., AZ, AR, NV); 'Progressive States' permitting 35% or more (e.g., FL, SC, GA); and 'Moderate States', ranging from 25% to 35%, falling in between. Many states base their specifications on NCHRP 9-12 research, though tier limits may vary. For instance, the trigger point for blending charts may still be the original 25%, but some states have reduced it to 15%. Across most states, RAP limits increase from surface to base layers and shoulders, or for lower traffic roads. Progressive States tie higher RAP limits with tighter gradation control, often involving fractionation, and adjust virgin binder content for improved performance.

4. AGENCIES: WHAT ARE THE CURRENT AVERAGE RAP PERCENTAGES BY LAYER IN YOUR UNMODIFIED MIXTURES IN YOUR STATE, AND HOW DO THESE COMPARE WITH THE RAP PERCENTAGE SPECIFICATION LIMITS IN YOUR UNMODIFIED MIXTURES BY LAYER?

› The box plots in Figure 3 present a layer-by-layer comparison of States' RAP % limits and announced averages. Some averages were not communicated

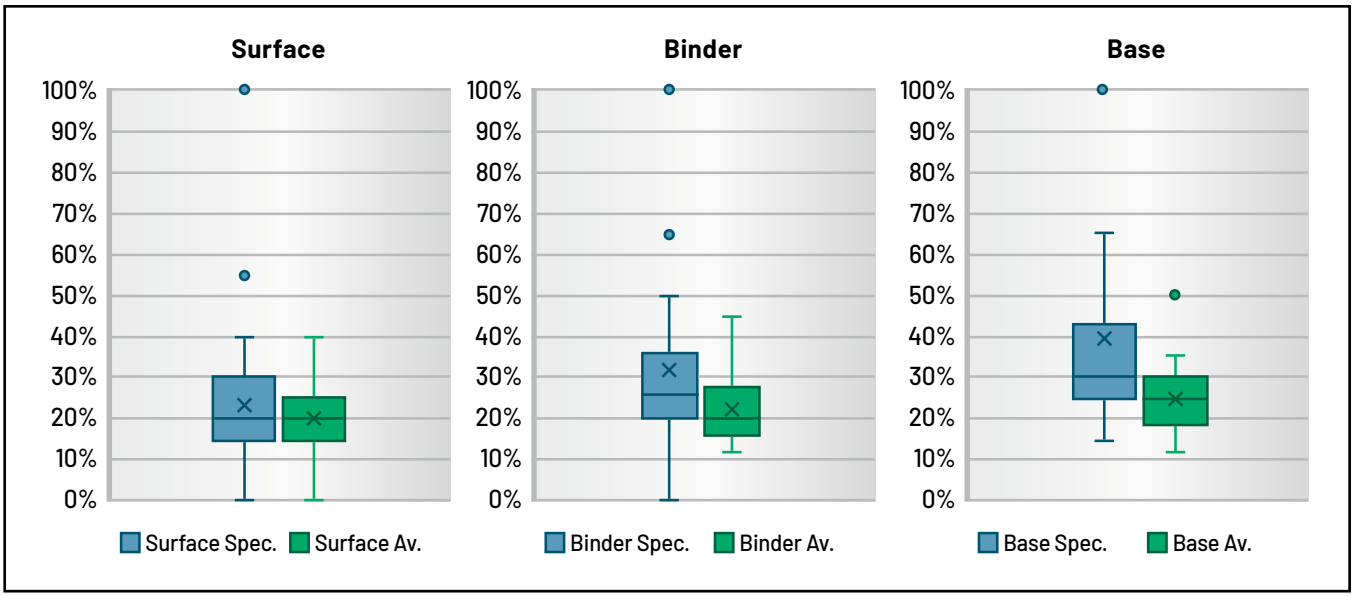

Figure 3 **Specifications RAP% limits vs. RAP% Averages by layer**

and others are estimations. The distributions of specifications are more spread than RAP% averages, indicating greater variation among states compared to RAP% actually achieved.

- Surface specifications and averages distributions are centered, skewed toward higher values in specifications. Moving from Binder to Base, specification limits shift upward. Generally, RAP% averages are lower than the corresponding layer specification limits.

- In conservative states, specifications limit RAP%, but the boxplots show that only a few States achieve averages exceeding 30% RAP, even with more permissive binder and base layers specifications. This can be attributed to various factors. As reported both by agencies and contractors, as more RAP is allowed, availability may become a concern. Plant limitations may also play a role: while some plants can handle high RAP mixes, many struggle to eliminate moisture while maintaining temperature and production rates over the 30% to 40% RAP range.

- However, specification RAP% limits alone don't provide the full picture. Specifications can indirectly restrict RAP content by mandating minimum virgin asphalt content, prohibiting, or limiting RAP in specific designs (e.g., SMA, OGFC, polymer-modified mixes), or imposing RAP aggregate specifications (e.g., aggregate skid resistance or microdeval value). Furthermore, specifications may influence pay adjustments, inciting contractors to limit RAP contents to ensure positive pay adjustments, particularly in terms of compaction.

5. FACTORS CONTRIBUTING TO LIMIT RAP USE.

5.1. Agencies: what are the RAP sourcing factors contributing to limit RAP use in your Sate?

- RAP sourcing varies locally, influenced by transport constraints and disparities between rural and urban areas within states. While some states utilize all available RAP, excess is generated in others due to increased paving programs. However, three-quarters of respondents highlight contractors' limited access to RAP as a key obstacle. This limitation may arise from local availability issues, particularly in rural areas, or the state retaining RAP for other applications like base layers, shoulders, or road programs implementing FDR and CIR.

- For some respondents, concerns about RAP source quality hinder increased use. Issues such as RAP binder stiffness or contamination could be mitigated with improved RAP pile management practices. Consequently, certain states mandate captive stockpiles for RAP sourced from state roads or requiring separation of RAP of varying quality.

- Only 13% of respondents reported no sourcing issues. In such cases, the RAP generated on a project typically becomes the property of the contractor.

5.2. Agencies: what are the RAP-related factors contributingto limit RAP use in your Sate?

About three-quarters of the limitations associated with RAP characteristics include binder stiffness and inconsistency, whether of binder content, gradation,

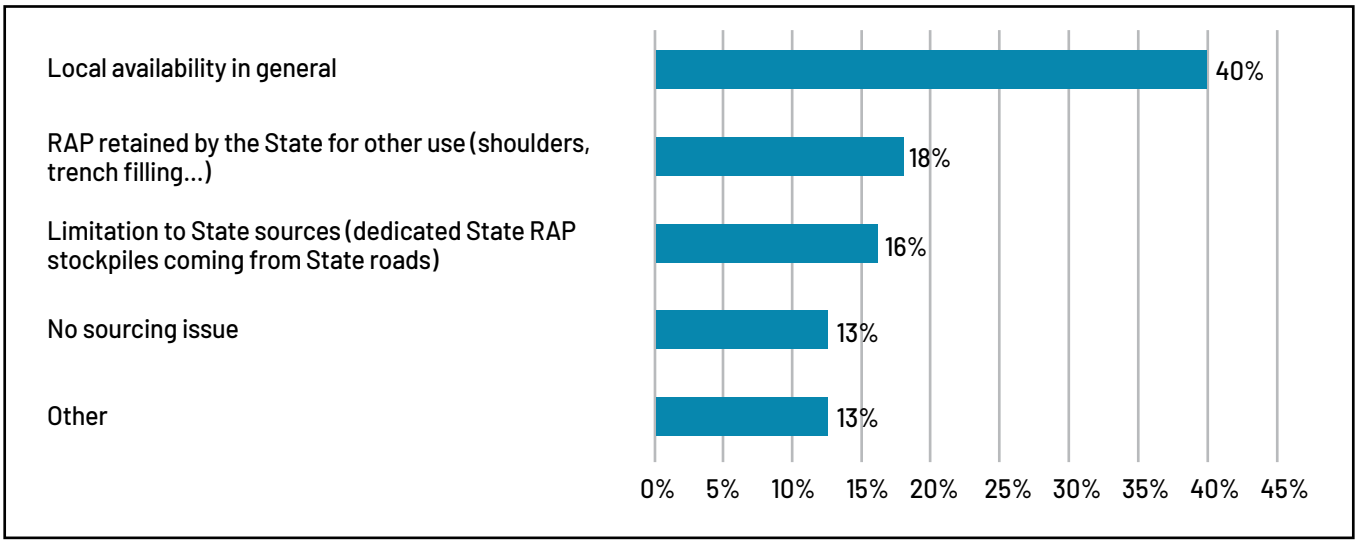

Figure 4 RAP Sourcing limiting factors according to State Agencies

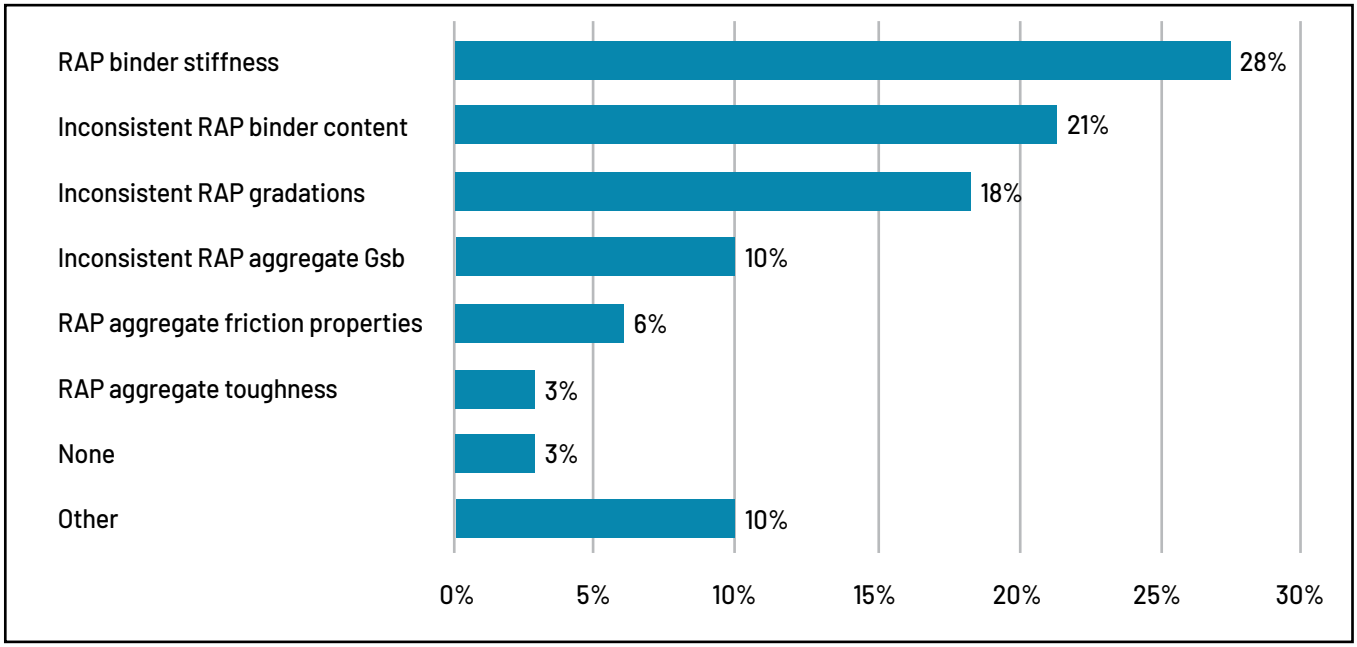

Figure 5 **RAP-related limiting factor according to State Agencies**

or aggregate specific gravity. These factors impact the cracking resistance and volumetrics of asphalt mixtures. Furthermore, challenges in meeting volumetric requirements may arise from RAP fines not recycled through the plant's dust control system. This is contingent on the plant's capabilities, including the presence of baghouse fines silos on weight-pods. Constraints related to RAP aggregate properties, such as friction or toughness, and their impact on the overall mineral blend are also mentioned.

5.3. Agencies: what are the production related factors contributing to limit RAP use in your State?

Plant-Related Factors:

- *Batch Plants:* In respondents' states, batch mix plants are typically limited to 20-25% RAP, while counter-flow drum mix plants can handle up to 40%. Batch plants are often located in urban areas, where RAP is more accessible.
- *Drum Mix Plants' Heat Transfer Capacity:* Only a limited number of plants are adapted for high RAP mixes. Managing moisture elimination, maintaining temperature, and production rates become challenging beyond 30% RAP, leading to increased energy consumption.
- *Dust Control and mineral blend processing capabilities:* Volumetric efficiency varies, with some plants performing better at 20% than 25%, or at 30% compared to 40%. Issues arise as RAP fines are not recycled through the dust control system, impacting volumetrics. Other limitations include insufficient RAP cold-feed bins, undersized screen decks, and dryer flighting.
- *RAP-Friendly Plant Designs:* There's a demand for more RAP-friendly plant designs including longer mixing zone drums, reflighting or VFDs.
- *Air Permits:* Limitations are imposed by Department of Natural Resources and Environmental Control air permits.

Accessibility to Softer PG Grades: Many plants store only two PG grades, limiting options for the softer grade needed in RAP mix production. Terminals, avoiding binders outside regional grades like PG64S-28 and PG58S-34, also hinder high RAP use. Proposed alternatives include technology like online recycling agent metering to soften binders.

RAP Processing and Stockpile Management: Implementing practices like separating RAP by quality (fractions, skid resistance, or binder stiffness) would alleviate variability issues, control contamination, and permit higher RAP contents. However, limited storage areas for stockpiles are common.

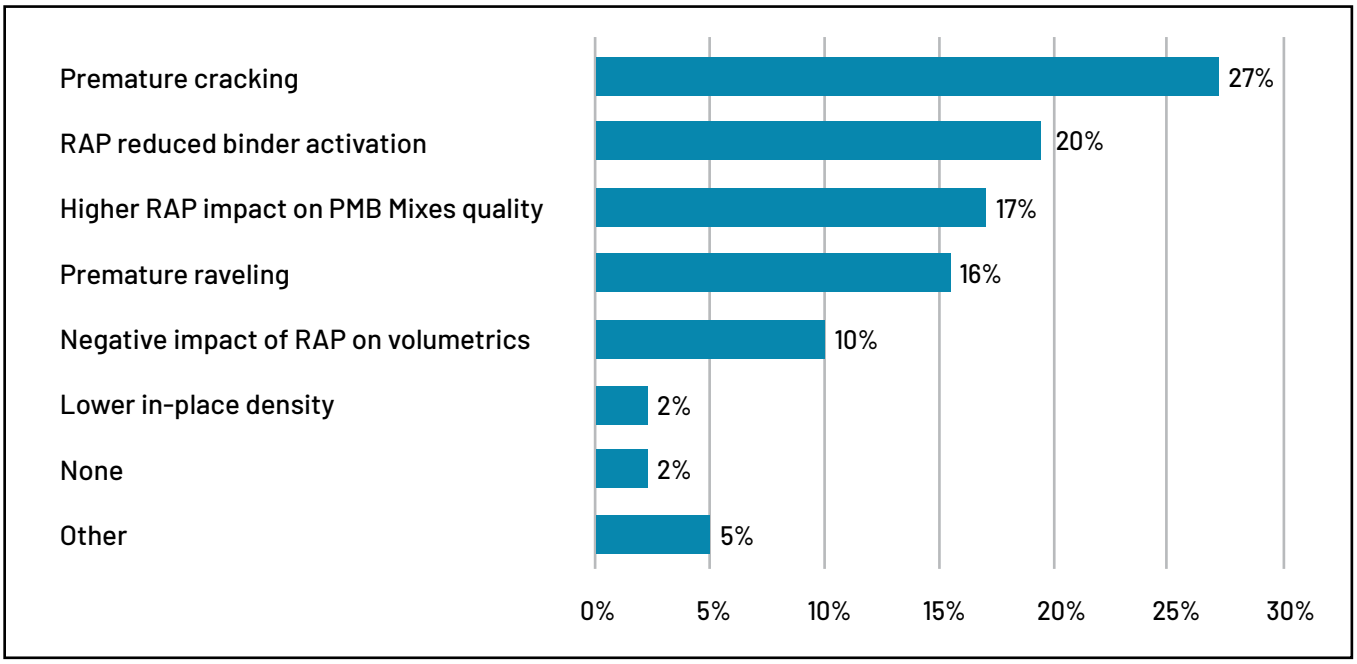

Figure 6 **Performance concerns limiting RAP use according to State Agencies**

5.4. Agencies: performance Concerns Limiting RAP Use

- *Reduced Service Life Concerns:* about two-thirds of responses express concerns related to reduced service life, particularly regarding raveling and cracking. This is attributed to the stiffening effect of the RAP binder and the overestimation of RAP binder availability, leading to dry mixes. To address this, some agencies have implemented measures such as mandating minimum virgin binder contents or introducing specifications that require additional virgin binder content through reduced gyrations, regressed design air voids, increased minimum VMA, or use of RAP Gsb and corrected optimum asphalt content (COAC).

- *Impact on PMB Mixes:* Another concern is the negative impact of higher RAP content on PMB mixes as the contribution of the polymer-modified virgin binder decreases. Some agencies question whether cost savings justify allowing higher RAP in highly modified surface courses.

- *Outdated specifications:* Other agencies recognize that outdated specifications, such as viscosity-based blend chart specifications and volumetrics-only mix specifications, inadequately address risks of premature cracking and raveling. To address this, a shift toward performance-based specifications is recommended, including PG-based blending charts and Balanced Mix Design. Additionally, it is advised to implement the use of recycling agents and/or softer binders, even at lower RAP percentage.

5.5. Contractors: what are the factors that inhibit increasing the use of RAP in your mixes

Owner agency specifications emerge as the primary obstacle, particularly in urban areas (90%). This is linked to the prevalence of mill-and-fill operations, leading to surplus RAP stocks and incentivizing contractors to exceed current specifications. Agency specifications are also a significant barrier in rural areas (77%), aligning with availability concerns (72%). Even though rural RAP stocks may not allow for maximum tolerances, specifications limits are perceived as too restrictive. Customer desires, including commercial and FOB preferences, are cited one-third of the time, hinting at potential flexibility in the private market for higher RAP usage. Plant technology limitations are noted by 33% of urban and 18% of rural respondents, a factor that may evolve with increased RAP use tolerances. Additional considerations include agency promotion of in-place recycling, RAP retention for base or shouldering, RAP variability impacting volumetrics and performance test results, and customer preferences for virgin mixes at higher costs.

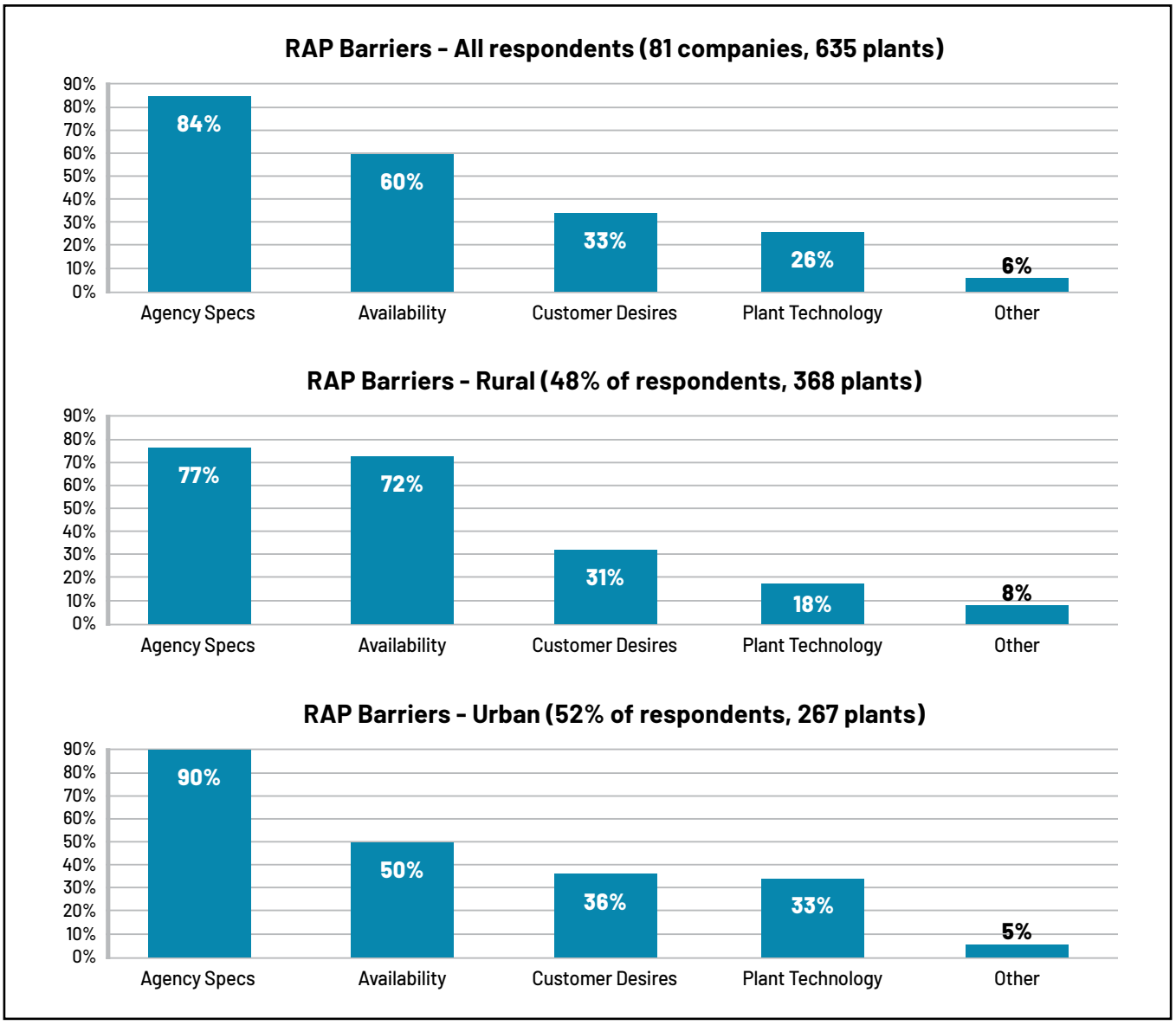

Figure 7 **Contractors perceived barriers**

Comparing Agencies' and contractors' perspectives on RAP use limiting factors:

Both survey findings on RAP use limiting factors are consistent and describe two sides of the same reality:

- Agencies' main concerns about reduced service life due to RAP binder characteristics and availability, as well as material inconsistency, are reflected in stringent specifications. Contractors consider these specifications as the primary obstacle to increasing RAP use.
- Sourcing is identified as a significant local constraint by both agencies and contractors, particularly in rural areas or when RAP is retained for other uses.
- Both agencies and contractors agree that plant technology must evolve to accommodate more RAP.

6. AGENCIES: WHAT INNOVATIONS/ BEST MANAGEMENT PRACTICES HAVE BEEN IMPLEMENTED IN YOUR STATE TO INCREASE RAP USE?

All states have some form of adjustment of the binder grade with RAP, specifying softer binders with increased RAP usage. Originally based on the NCHRP 9-12 tier specification system, methods have been simplified by removing blending chart requirements or maintaining only two tiers (no PG change or blending chart).

Additives: WMA technologies are predominantly used to facilitate compaction at conventional production temperatures and less frequently at lower production temperatures to reduce binder aging. Recycling agents have been used in a few states, but their use is not widespread.

Additional Asphalt Content: 60% of States have reported implementing various methods such as minimum virgin asphalt content, reducing gyrations numbers or design air voids, increasing minimum VMA, application of corrected optimum asphalt content (COAC), and using RAP aggregate Gsb in VMA calculation.

RAP Processing, Handling, and QC: Practices vary across states, including RAP fractionation, QC plans and dedicated stockpiles. For instance, the South Carolina DOT and Georgia DOT link increased RAP allowances to improved gradation control, implementing RAP fractionation or tighter RAP gradation tolerances respectively. Other states utilize captive stockpiles sourced from controlled state routes to manage RAP materials more effectively.

Balanced Mix Design (BMD) Testing: "performance-index tests" for mixture design, test strips, and production acceptance are being deployed in many States. Examples include the use of APA, HWT, SCB tests, and IDEAL-CT. However, agencies are facing technical challenges (aging protocol, benchmarking) and management challenges (integration in specifications).

Contractual provisions: Several states (NE, OR, SC, IA) offer financial incentives for higher RAP content, such as separate payment items for RAP and virgin binders at contract prices, or sharing savings linked to RAP use. Those initiatives have been successful in maximizing RAP use with adequate asphalt binder content.

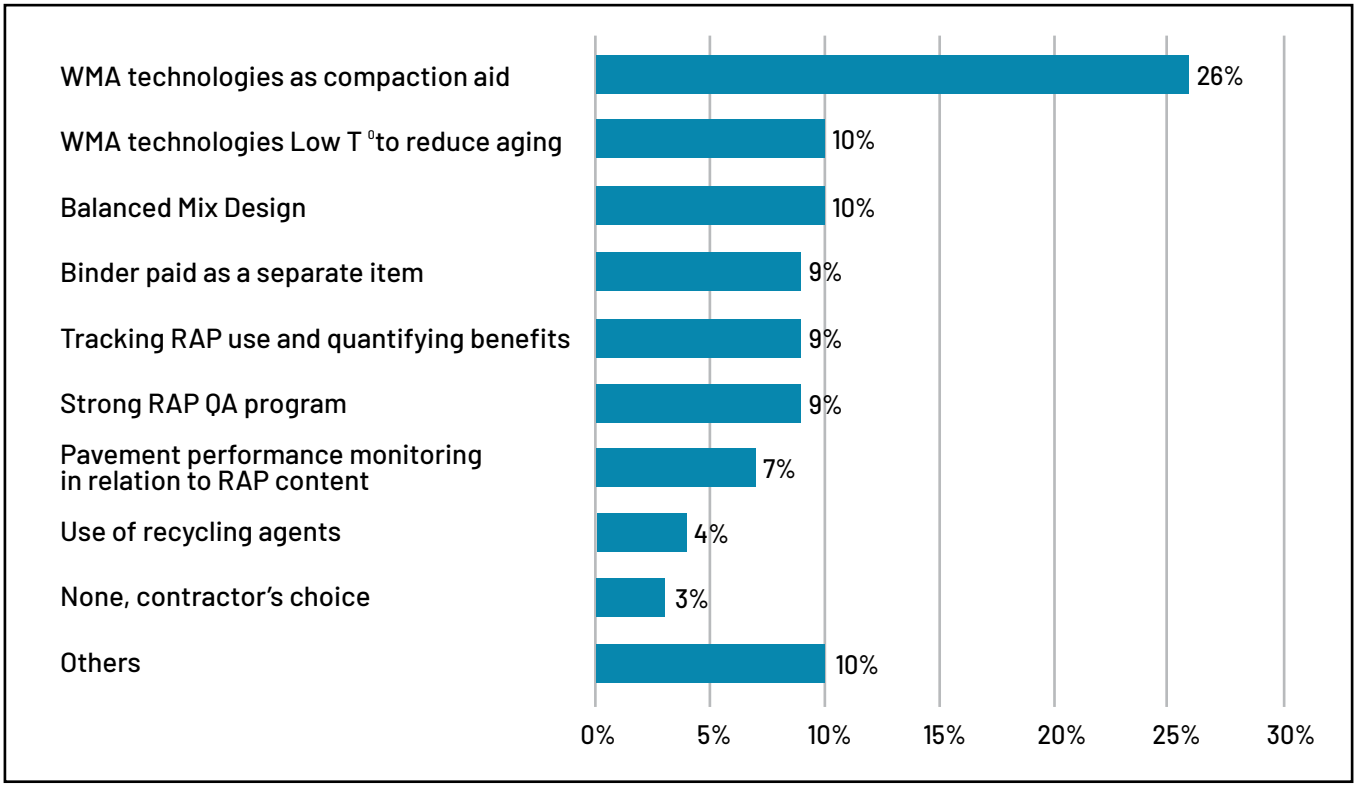

Figure 8 **Agencies Innovations & Best Practices to Increase RAP use.**

7. AGENCIES: WHAT WOULD GIVE YOUR AGENCY MORE CONFIDENCE REGARDING THE PERFORMANCE OF MIXTURES WITH HIGHER LEVELS OF RECYCLED MATERIALS?

The primary research needs revolve around Balanced Mix Design (BMD) and index-based performance tests, focusing on (1) correlating cracking tests with field performance; (2) quantifying economic and environmental benefits of high RAP mixes; (3) emphasizing the use of recycling agents. These priorities are coupled with a demand for training programs for contractors and local agencies' personnel.

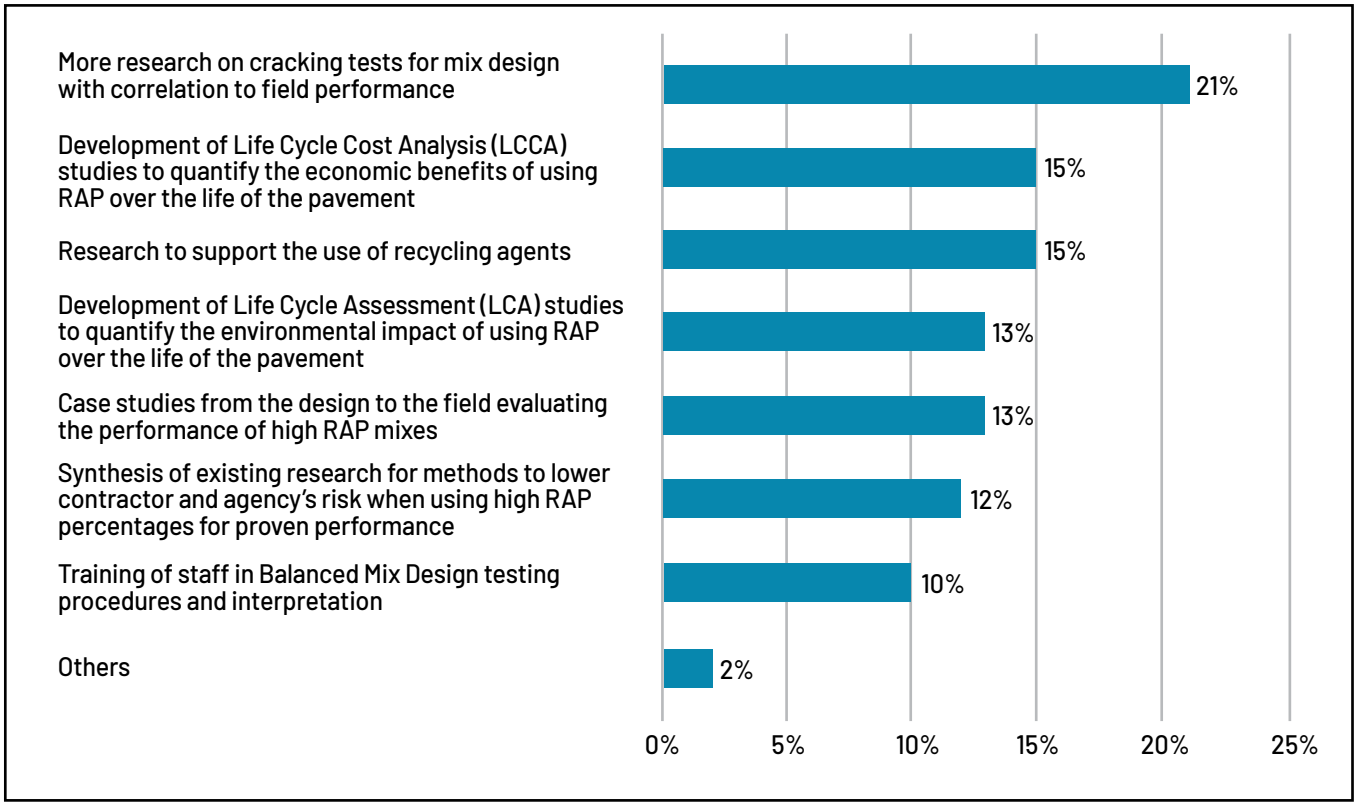

Figure 9 **Agencies identified Research and Training Needs**

APPENDIX A

AGENCIES SURVEY QUESTIONNAIRE

Barriers to adopting Technology and Specifications to increase RAP in Asphalt Mix Production

What is defined as high RAP content mix in your State? (Please specify)

_____

_____

_____

_____

What is the parameter used to define RAP content in asphalt mixtures in your State?

☐ % RAP by weight of mix
☐ Reclaimed Binder Ratio (RBR)
☐ Other (Please specify)

_____

_____

What are the current RAP % specifications limits in your non-modified mixtures?

In surface courses: _____

In binder courses: _____

In base courses: _____

What is the current average RAP % in your non-modified mixtures?

In surface courses: _____

In binder courses: _____

In base courses: _____

Please provide a web link to your agency's RAP specification(s) or email an electronic copy (*.pdf) of the specification(s) to engineering@asphaltpavement.org.

_____

_____

What are the RAP Sourcing factors contributing to limit RAP use in your State? (Please check all that apply)

☐ Local availability in general
☐ Limitation to State sources (dedicated State RAP stockpiles coming from State roads)
☐ RAP retained by the State for other use (shoulders, trench filling…)
☐ Other (please specify)

_____

_____

_____

What are the RAP related factors contributing to limit RAP use in your State? (Please check all that apply)

☐ inconsistent RAP gradations
☐ inconsistent RAP binder content
☐ RAP binder stiffness
☐ inconsistent RAP aggregate Gsb
☐ RAP aggregate toughness
☐ RAP aggregate friction properties
☐ Other (please specify):

_____

_____

_____

What are the production related factors contributing to limit RAP use in your State? (Please specify)

Type of production plants available in your state (batch, continuous parallel flow…)

_____

_____

Accessibility to softer PG grades (availability, plants storage capacities…)

_____

_____

Other production related reasons

_____

_____

What are the Performance concerns, if any, contributing to limit RAP in your State? (Please check all that apply)

- ☐ None
- ☐ Negative impact of RAP on mixture volumetrics (added mixture inconsistency)
- ☐ RAP reduced binder availability: concern with too little activation in general and at lower production temperatures.
- ☐ Poor surface texture and ride quality.
- ☐ Lower in-place density
- ☐ Higher RAP reduces the quality of polymer-modified binders asphalt mixes.
- ☐ Premature cracking.
- ☐ Premature raveling or stripping.
- ☐ Others (please specify):

_____

_____

_____

What innovations/ best management practices have been implemented in your State to increase RAP use? (Please check all that apply)

- ☐ Strong RAP Quality Assurance program. D Tracking RAP use and quantifying benefits. D Binder paid as a separate item.
- ☐ Pavement performance monitoring in relation to RAP content.
- ☐ Introduction/ deployment of Balanced Mix Design.
- ☐ Use of recycling agents
- ☐ Use of WMA technologies to reduce production temperature (reduced aging)
- ☐ Use of WMA technologies as compaction aid only (without temperature reduction).
- ☐ Others (please specify)

_____

_____

_____

If your State has been allowing increased RAP use through additional binder content, could you specify the applied method? (Please check all that apply).

- ☐ n/a
- ☐ through reduced gyrations
- ☐ minimum AC%
- ☐ lower air voids
- ☐ higher MA
- ☐ Corrected Optimum Asphalt Content (COAC)
- ☐ Use of RAP Gsb in VMA calculation
- ☐ Others (please specify):

_____

_____

_____

What would give your agency more confidence regarding the performance of mixtures with higher levels of recycled materials

- ☐ Synthesis of existing research for methods to lower contractor and agency risk when using high RAP percentages for proven performance.
- ☐ Case studies from the design to the field evaluating the performance of high RAP mixes.
- ☐ More research on cracking tests for mix design with correlation to field performance
- ☐ Training of Staff in Balanced Mix Design testing procedures and interpretation.
- ☐ Research to support the use of recycling agents.
- ☐ Development of Life Cycle Cost Analysis (LCCA) studies to quantify the economic benefîts of using RAP over the life of the pavement.
- ☐ Development of Life Cycle Assessment (LCA) studies to quantify the environmental impact of using RAP over the life of the pavement.
- ☐ Others (please specify):

_____

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APPENDIX B

CONTRACTORS' SURVEY QUESTIONNAIRE

Please take a few moments to answer the following questions. There will be a space at the end of the survey where you can write a free-form response and offer any additional input you feel is valuable.

Name and Company

_____

_____

# of Asphalt Plants

_____

What geographical region of the United States does this plant operate in?

☐ Northeast (ME, VT, NH, MA, RI, CT)
☐ Mid-Atlantic (NY, NJ, PA)
☐ South Central (MD, VA, WV, NC, KY, TN)
☐ South (SC, GA, FL, AL, MS, LA, AR)
☐ Midwest (OH, IN, MI, IL, IA, WS, MN,)
☐ Plains States (OK, KS, NE, SD, ND)
☐ Southwest (TX, NM, AZ)
☐ Mountain States (CO, WY, UT, MT, ID)
☐ West Coast (CA, NV, OR, WA)
☐ Alaska Hawaii

This survey attempts to identify market factors, market dynamics, or other externalities that inhibit RAP utilization in mix production.

What are the factors that inhibit increasing the use of RAP in your mixes? (check all that apply)

☐ Plant Technology
☐ Owner Agency Specifications RAP Availability
☐ Customer Desires (Commercial, FOB, etc.)
☐ Other (please specify)

_____

_____

_____