The use of reclaimed asphalt in the production of asphalt
July 2021

Based on Manual 36: 2019

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Admin/ logistics

From	To	Description
0830	0845	Welcome and introductions
0845	0930	Definition and introduction, asphalt recycling,
0945	1030	Quality and quantity of RA, investigation of RA sources
1045	1130	Reclaiming, processing and stockpiling RA
1145	1230	Mix designs
1330	1415	Mixing plant requirements and quality control
1430	1515	Economic and environmental benefits, OHS
1530	1615	Contract documentation
1615	1630	New advancements, questions

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Introduction / context

History of TRH 21

- Draft TRH 21: 1996 - HOT MIX RECYCLING
- TRH 21 : 2009 - HOT MIX RECYCLED ASPHALT
- TRH 21: 2017 - Use of reclaimed asphalt in the production of asphalt
- Manual 36: 2019 - Use of reclaimed asphalt in the production of asphalt

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Introduction / context

- Manual 36 should be read in conjunction with Sabita Manual 35 / TRH 8 – February 2020 - Design and Use of Asphalt in Road Pavements which describes methods for designing asphalt

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Introduction / context

- Asphalt recycling
  - Combining new aggregate and binder with reclaimed asphalt (RA) in a mixing plant
  - Based on SA and international experience
- Manual 36 should be read in conjunction with Sabita Manual 35 / TRH 8 which describes the standard methods of designing conventional and special asphalts

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Terminology

- In SA term ***reclaimed asphalt (RA)***, is used
  - ***"fragments of asphalt that have been obtained from road pavements or plant returns and tailings"***
- In USA term RAP is used to differentiate between asphalt reclaimed from **p**avements as opposed to e.g. shingles

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RA defined

- Obtained from
  - milling or excavation of existing bituminous pavement layers
  - stockpiles (at plants) of asphalt production overruns, returned material

Milled unprocessed RA

Processed RA that has been crushed & screened into coarse, medium & fine fractions

- Stockpiled and loaded in such a manner as will enhance the uniformity of the material
- Processed – crushed, screened into fractions, stockpiled
- RA contains approximately 95% of high quality aggregate and 5% of aged bitumen, both ***valuable non-renewable resources***

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RA defined

Milled unprocessed RA

Processed RA (crushed)

Processed RA (screened)

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RA defined

Milling machine

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RA defined

Crushing and screening plant

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RA defined

Asphalt plant

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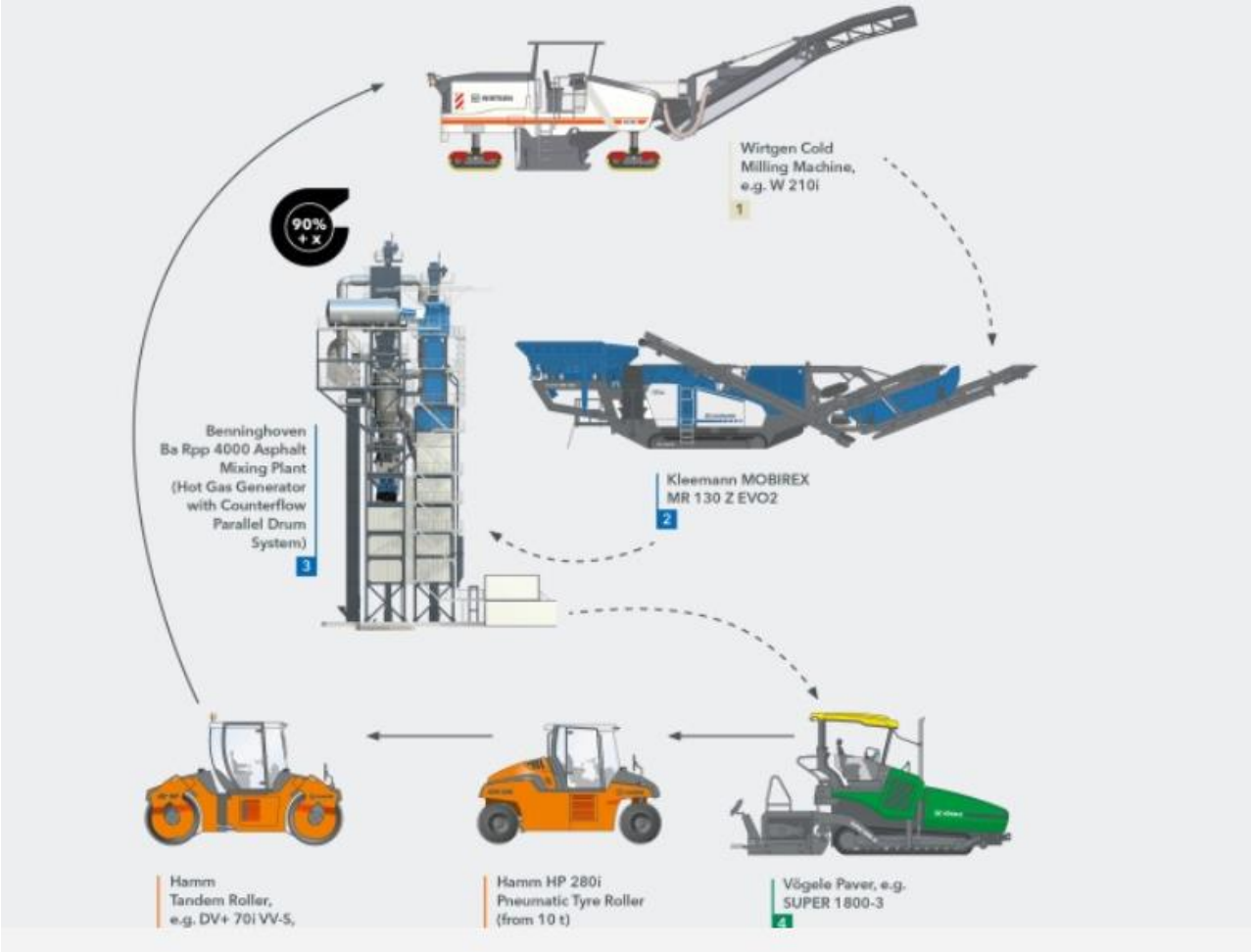
RA defined



Process chain

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Precautions with RA

- A fundamental principle - asphalt containing RA should deliver ***at least the same performance qualities*** as mixes containing new bituminous binder and aggregates
- Free of foreign material e.g.:
  - unbound granular base
  - broken concrete or other contaminants
- RA containing ***coal tar shall not be used***

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Numerical terminology

- **RA content**

  Proportion of the total RA material (binder and aggregates) expressed as a percentage of the total mass of the recycled mix

- **RA binder replacement**

  Amount of ***binder yielded by the RA*** as a proportion of the ***total binder content of the mix*** (the binder in the RA plus the new binder) to meet the target binder content.

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RA content (%)

$$RA\ content\ (\%) = \frac{Total\ mass\ of\ RA}{Total\ mass\ of\ mix}$$

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Terminology

RA aggregate
RA binder
New binder
New aggregate

$$RA\ binder\ replacement\ (\%) = \frac{Total\ RA\ binder\ in\ mix\ (\%)}{Total\ binder\ in\ mix\ (\%)}$$

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Proportion of RA in a mix

- New terminology adopted
  - no longer uses ***only*** mass ratio of RA / Total
  - the amount of ***reclaimed binder*** is dependent on aggregate size (surface area)
  - finer material will yield more binder and vice versa
- New term adopted is ***RA binder replacement***
  - amount of binder yielded by the RA as a proportion of the total binder content of the mix
  - total binder = binder in the RA plus new binder – to meet the target binder content

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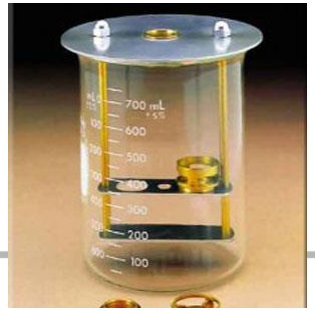
Proportion of RA in a mix

- New terms are used ***separately*** to define:
  - Tests required on aggregates (RA content)

  - Tests required on binder (RA binder replacement)



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Recycled asphalt defined

- Recycled asphalt - proportion of ***RA binder replacement > 10%***
- Reference is often made to *virgin materials*, (e.g. virgin binder or virgin aggregate)
  - Term "virgin" implies that the material has not been used beforehand in any bituminous product application
  - "Virgin mix" is composed wholly of materials not previously used in the manufacture of asphalt

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Use of RA world wide

- Use of recycled hot mix asphalt - grown steadily in many countries around the world
- Increasingly higher proportions of RA in asphalt - now standard practice
- USA
  - In 2014 the estimated usage of RA -72 million tons (20% of the total estimated quantity of asphalt produced in that year)
  - 2014 - 37 states reported usage in this range, with 4 states reporting RA percentage of more than 30%
- Japan
  - 99% of available RA is used
  - Percentages of RA: 47 – 51%
- Europe (2014)
  - 65% of the 39 million tons of RA available in Europe is used in asphalt production
  - Some countries (Germany, Finland, Slovakia and Spain) use > 80% of available RA in asphalt mixes

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Use of RA in SA

- Annual production of asphalt in South Africa ≈ 3.5 m tons
- 2014 usage of RA ≈10% of annual asphalt production (350 000 tons)
- Should specifications permit higher proportions of RA in asphalt, 90% of reclaimed material at fixed plants can be utilised to this end
- Considerable scope in South Africa
  - higher proportions of RA in asphalt
  - significant financial savings through a decrease in virgin material input
  - reducing the pressure on non-renewable resources and the carbon footprint of the asphalt industry
- Since 2009 use of higher proportions (up to 40%) in asphalt mixes on major road contracts
- Expertise gained - industry is now in a position to exploit the benefits of use of RA in new road layers

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Process options

- Cold in-place recycling
- Cold in-plant recycling
- Hot in-place recycling
- Hot in-plant recycling

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Cold in-place recycling

- Specialised equipment used
- Bitumen ***emulsion or foamed bitumen*** is added in predetermined quantities during the process
- Recycled layer is then shaped and compacted as a layer in the upper part of the pavement
- Generally overlaid with a wearing course

Cold in-plant recycling

- RA is transported to a specialised cold mixing plant
- Mixed with ***bitumen emulsion or foamed bitumen*** in a continuous mixing operation
- Mix is paved, or spread with a motor grader, shaped and compacted

- Suited to labour intensive construction methods within limited areas (Sabita Manual 12: *Labour absorptive methods in road construction using bituminous materials*)
- The recycled layer is then surfaced with a wearing course

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Hot in-place recycling

- The existing asphalt surfacing layer heated using specially designed radiant heaters
- Heated asphalt is scarified, transferred into a continuous-mix pug mill and mixed with new aggregate, bitumen and rejuvenating agents
- Paved and compacted as with conventional asphalt.
- More appropriate for fairly thick asphalt layers
- Limited application in South Africa

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Hot in-plant recycling

- RA is transported to a ***specially equipped and configured*** mixing plant
- Combined with new aggregate, new binder and, where appropriate, rejuvenating agents to meet specifications
- ***This course covers this processes***
- More information on cold recycling processes - TG 2: : Bitumen Stabilised Materials

Components of recycling process

- Obtaining RA
  - Milling
  - Excavated asphalt slabs
  - Reuse of returns and tailings at asphalt mixing plants
- Transporting the RA to the mixing plant site
- Fractionating
  - Crushing the RA (impact crusher)
  - Screening into the various fractions
  - Stockpiling
- Mix design using properties of reclaimed and virgin materials
- Mixing the RA in prescribed proportions with new aggregates and bitumen in an asphalt mixing plant
- Transporting the recycled asphalt to site where it is paved

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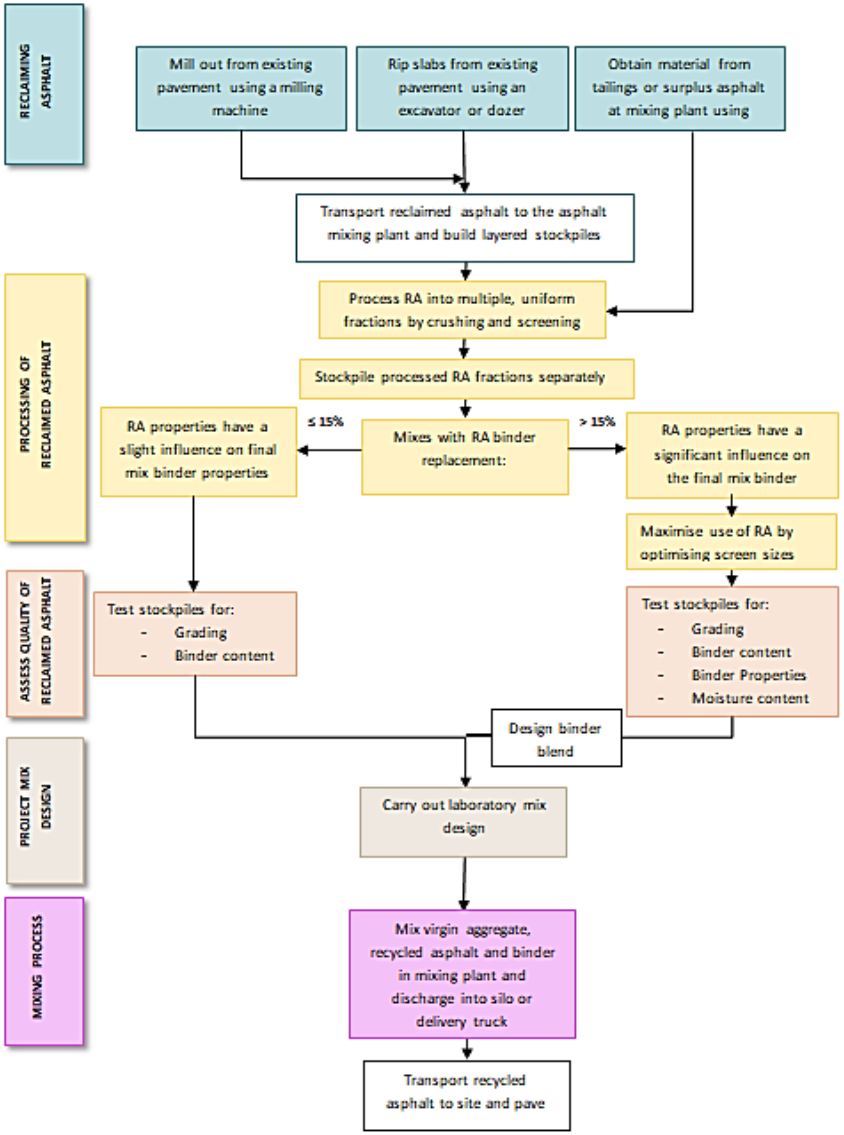
The recycling process



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Mixing plants

- Two basic types of plants (more details later)
  - Batch

  - Continuous drum

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Plant capabilities

- Handling the required proportion of RA
- Conforming to environmental regulations with regard to emissions, spillages, seepage and stockpiling
- Minimising binder ageing during the process
- Operating at acceptable production levels and
- Switching readily from recycled asphalt to conventional asphalt mix production and vice versa

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Factors influencing proportion of RA in mix

- Type and configuration of the mixing plant;
- Layer in which the mix is to be used, i.e. wearing course, base.
- Asphalt mix type e.g. sand or stone skeleton mix
- Number of stockpiles of fractions of RA for improved control
- Whether the RA derives from a single source or multiple sources;
- Quality of the RA, i.e. aggregate properties, binder content and properties;
- Uniformity and consistency of the RA material which may require:
  - uniform milling speed to promote particle size consistency in the resulting RA;
  - split milling of intermediate and surface asphalt layers where one of these may contain impurities;
  - proper crushing of asphalt slabs from full-layer pavement removal.
- Moisture content of the RA;
- Contamination of RA (coal tar, patching material or gravel)
- Need for the use of a rejuvenating agent

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Factors influencing availability and quality of RA

- Geographic distribution of asphalt pavements in South Africa
- Distribution of mix types in general use that would influence their use in recycled asphalt
- Constituent materials in terms of material types and quality

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Geographic distribution of asphalt pavements

- Proximity of asphalt pavements impacts positively on economics of recycling
- Major lengths of road in SA, built with thin chip seals
- Asphalt largely confined to:
  - provincial trunk roads
  - national routes
  - streets and motorways in the larger towns and cities
- Available quantities RA may limit RA proportions
- In general not enough asphalt available for recycling
- RA ***valuable resource material*** requiring care

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Distribution of mix types

- Pre 90's continuous and gap graded mixes used at various times in various regions
- Since then use of modified binders in mixes increased steadily
- Mid 90's SMAs with modified binders, cellular fibres or both
- 1999 introduction of UTFC with modified binders
- During last decade mixes with 40% RA

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Constituent materials of RA

- Presence of chip seals
- Coal tar
- Geosynthetic materials
- Aggregates
- Variability

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Presence of chip seals

- Before the introduction of UTFC, chip seals applied on top of the asphalt wearing course to improve surface friction
- Modified binders (SBS, bitumen-rubber) frequently used in these seals
- Many asphalt pavements will contain at least one layer of spray seal with a modified bitumen
- These types of seals can be effectively milled separately or together with asphalt layers processed and used in recycled asphalt

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Glue of black roads

TAR

BITUMEN

By-product:
distillation of
COAL

By-product:
distillation of
CRUDE PETROLEUM OIL

Carcinogenic compound:
Benz(a)anthracene

8 900 - 12 500 ppm

0.15 - 35 ppm

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Coal tar

- Coal tar is no longer used in South Africa,
- PVC modified coal tar regularly used in surfacing seals in KZN until the early 90's
- Coal tar can be detected by its pungent smell
- Its incorporation in recycled asphalt is strongly discouraged due to its carcinogenic nature

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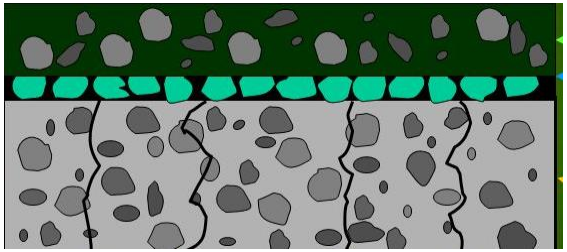
Geosynthetic materials

- Occasionally used to retard crack propagation
- Usually found at the bottom of the asphalt layer or sandwiched between asphalt layers



- May hinder milling operations, or contaminate RA stockpiles depending on location and type
- When detected during the investigation carry out a milling trial to assess severity of the problem to find solution
- Generally possible to screen out most of the geosynthetic fragments during RA fractionating

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Aggregates

- Coarse aggregates generally of a high standard; problems extremely rare
  - Basic igneous rock types (dolerite, basalt) prone to degradation over time
- When RA contains aggregates derived from these rock types in reported problem areas testing of intrinsic quality of the aggregates in the RA should be carried out to detect deleterious compounds e.g. smectite

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Variability of RA

- On extensively repaired road sections - consistency of RA compromised - both aggregate and binder properties
- Requires more attention to reduce the variability
- If significant variability still exists in the processed RA, it should be used in low proportions or in low risk applications
- Split milling may be required in certain situations e.g. UTFC, semi-gap graded and gap graded mixes

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Investigation of RA sources

- Desk study
- Field investigation

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Desk study

Investigations should determine the following:

- Quantities of RA available
- Haulage distance to the nearest suitable asphalt plant
- Alternatively, suitable area for stockpiling RA for future use
- Asphalt mix types in the existing pavement
- Uniformity of these asphalt pavement layers
- Visual condition of the pavement
- Ownership of the RA

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Field investigation

- Rehabilitation design dictates:
  - depth of asphalt removal
  - quantity of available RA
- Check quantities by coring and measurement
- Core sample frequency of the determined by:
  - comprehensiveness of all available information;
  - minimum of six (150 mm min) diameter cores

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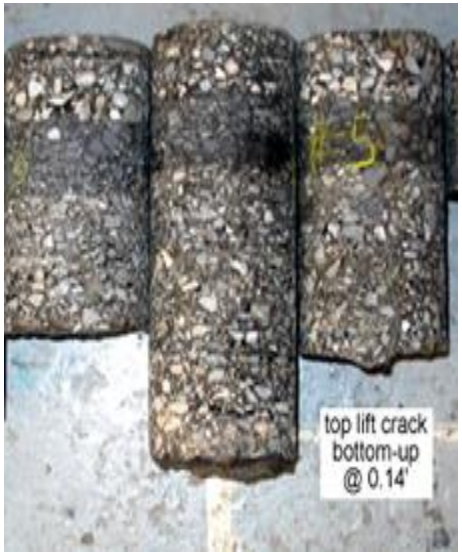
Field investigation / cont.

The cores should be carefully examined to check:

- The thickness of each asphalt layer in the core
- Asphalt mix types in single or multiple layers
- Determine presence of:
  - surfacing seals, particularly those containing highly modified binders
  - coal tar (pungent odour)
  - geosynthetic interlayers
- Signs of stripping of the binder from the aggregate

These examinations should be carried out by experienced personnel.



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Field investigation / cont.

- For large variations (e.g. layer thickness and mix types) ***intermediate cores*** recommended to identify ***uniform sections*** of potential RA
- Samples for further testing, depending on the proportion of RA in recycled asphalt
- Obtain characteristics of recovered binder e.g.:
  - binder content
  - penetration
  - softening point
- The presence of spray seals not necessarily problematic
- Presence of bitumen-rubber seals brought to the attention of the tenderer (additional methods may be required to assess their suitability and proportions as well as means of obtaining the RA)
- Presence of crumbed rubber in the cores may influence the recovered binder content test results

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Field investigation / cont.

- In cases where:
  - there is more than one asphalt layer in the pavement
  - complications exist (e.g. presence of modified seals)
- Cores will assist in determining most appropriate milling strategy e.g.:
  - whether to mill the asphalt layers separately, or
  - mill more than one layer at a time

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Field investigation / cont.

- Cursory visual inspection should be carried out to determine:
  - types and severity of distress;
  - frequency / type of patching;
  - any signs of poor aggregate / binder adhesion problems.

- Outcome will assist in decision on need for additional core sampling

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Field investigation / cont.

- Wide-ranging approach recommended – e.g. use of surplus RA on other projects (stockpiling)
- Variability in quality tend can be evened out in proper stockpiling and fractionating
- Alternatively the material could be set aside for use in such applications where the degree of variability would be acceptable, e.g. cycle tracks and sidewalks
- RA containing aged, hardened recovered binder should be considered as “black aggregate” and used accordingly where RA binder replacement < 15%
- RA at asphalt plants, (tailings and returns) should be considered for use in recycled mixes
- For preliminary mix design, RA can be sampled using either a small milling machine or extracting cores of at least 150 mm diameter

Reclaiming, processing, stockpiling RA

- Reclaiming
- Stockpiling unprocessed RA
- Moisture in RA
- Processing of RA
- Stockpiling processed RA
- Processing RA prior to recycling
- Optimising use of RA

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Reclaiming

- Most reclaiming in SA done by ***milling***
- Sometimes breaking out using excavators etc. and then crushed
- Discarded asphalt / tailings at mixing plants

Advantages of using milling machines

- fairly uniform grading;
- min. disruption of existing material
- precise - width, thickness
- selective removal in the design stage;
- reduced risk of contamination with substrates
- No special restrictions milling speed, drum/cutting tool configuration

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Reclaiming / cont.

Caution

- Problems can be expected when bitumen-rubber “SAM” or “SAMI” layers are milled together with an asphalt layer
- Bitumen-rubber layers tend to remain in large, resilient fragments which hinder the crushing and screening processes
- In these cases selective milling recommended and such material discarded

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Stockpiling unprocessed RA

- Stockpiles of *unprocessed* RA should be ramp shaped and lifted in layers

- When flattening tipped material, care should be taken not to push material over the edge that will cause excessive segregation

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Stockpiling unprocessed RA

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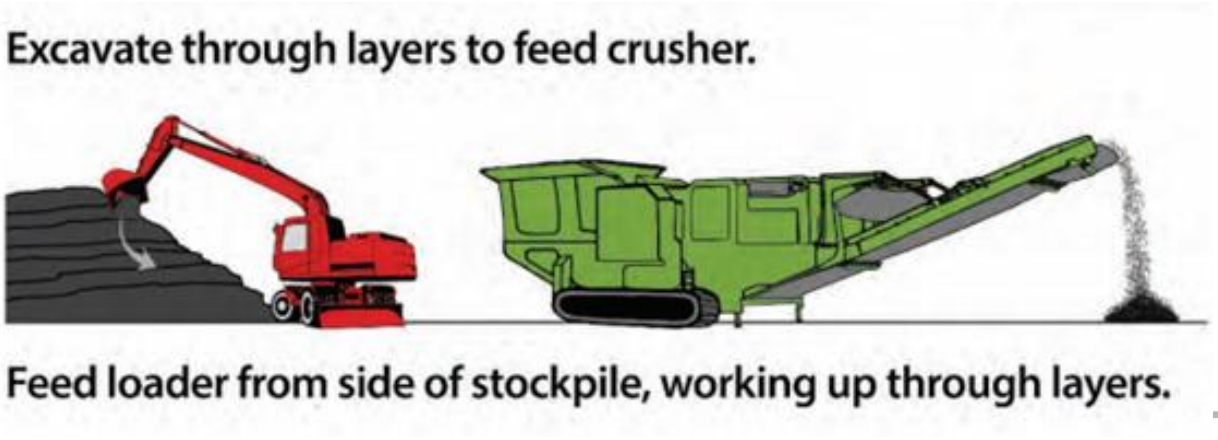
Stockpiling unprocessed RA / cont.

- Loading of stockpiled materials with a loader proceeding from the front (high) face with the loading action proceeding through the entire height of the face
- This will ensure that loading scoop incorporates a number of layers, thereby enhancing uniformity



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Moisture in RA

- High moisture contents in the RA will result in:
  - decrease in the rate of production
  - increase in fuel energy costs
  - increased emissions and steam - stretch emission control systems
  - 1% change in moisture content typically results in a 10% change in heating fuel consumption
  - could result in high moisture in the final recycled asphalt mix and lead to adhesion problems
- ***Important issue – moisture should be limited***

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Stockpiling processed RA

RA tends to retain moisture - factors should be considered when stockpiling *processed* RA:

- stockpile base
  - sloped (6%) for drainage
  - hardened so that:
    - water does not soak into floor material
    - groundwater contamination is reduced
    - contamination of RA with underlying soil

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Stockpiling of processed RA / cont.

- ***Processed*** RA should be stockpiled in large conical shapes with steep sides. A surface crust will shed water and reduce consolidation of the rest of the stockpile
- Machines should be kept off stockpiles to avoid compaction

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Stockpiling of processed RAP / cont.

- Avoid covering RA stockpiles with tarpaulins or plastic sheets - condensation will increases its moisture content (except when rain is imminent - temporary cover beneficial
- Best measure - stockpile in an open sided shed
- Fractionating the material into fairly similar sized particles to reduce inevitable variability in grading (and hence binder content)
- Do not load the RA from one side of the stockpile to the other - rather in a staggered manner for homogeneity

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Processing RA

- Processing comprises:
- Crushing
- Screening
- Fractionating

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Crushing, screening and fractionating

- Important as larger proportions of RA are used
- Key factors for good quality recycled asphalt mixes are:
  - consistency
  - awareness of the properties of the aggregates and bitumen in the RA
- Contract documentation provide for this
- All RA for use in recycled asphalt should be fractionated to enhance control at the mixing plant
- For low RA content – (RA binder replacement < 15%) – remove oversize by scalping

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Crushing, screening and fractionating

- Where RA binder replacement >15% - screen and fractionate for consistency
- Common practice to crush the RA to ***top sieve size - one sieve size smaller*** than ***aggregate top size*** in mix
- Crushing and screening systems enables small quantities of consistent RA to be used straightaway
- Ideally sufficient RA should be processed to meet the daily needs - reducing consolidation in stockpiles

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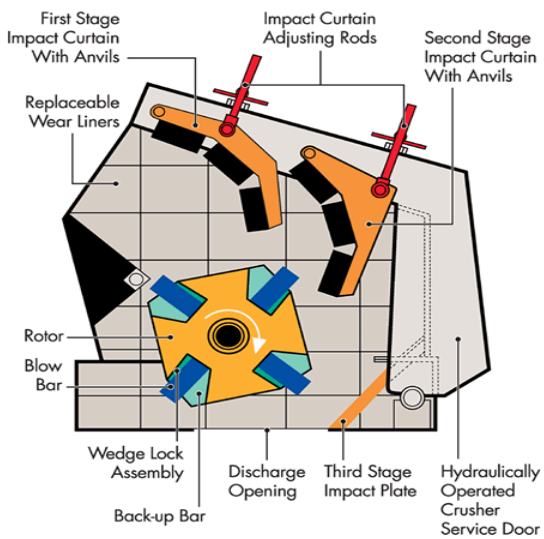
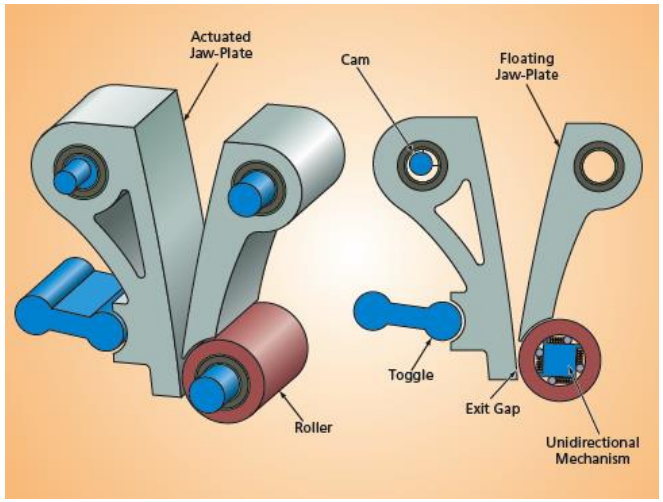
Crusher types for RA

- Two types of crushing plants are in general use, impact crushers and jaw/roller combination crushers.
- ***Crushers should be set to break up the lumps of RA and not to crush the aggregates***



Impact crusher



Jaw/roller crusher

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Optimisation of the use of RA

- ***Coarser RA fractions*** will ***yield lower binder volumes*** than finer fractions due to the difference in aggregate surface area
- Binder content of the fractionated RA tested in batches not greater than 200 tons
- RA fraction screen sizes coordinated with mix design to optimise the use
- Large quantities of RA from different sources should be kept separately and demarcated

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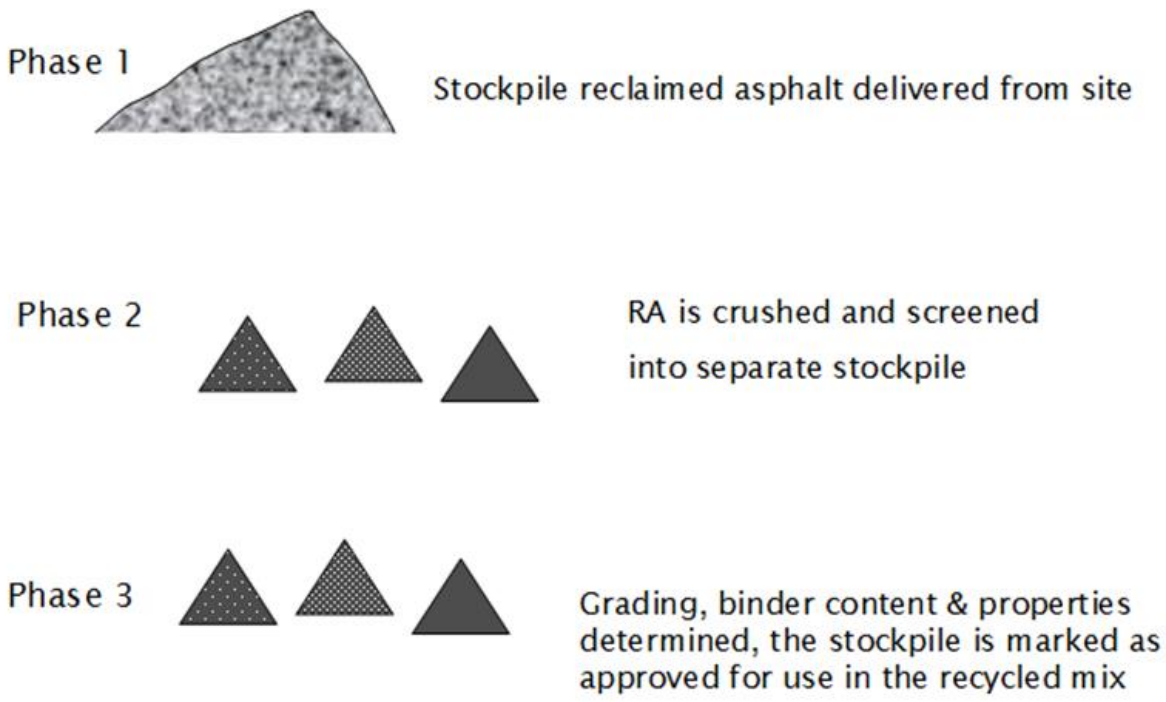
Optimisation of the use of RA / cont.

- RA should be handled in three distinct stockpiling phases



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Mix design

1. Proportion of RA in a recycled mix
2. Testing for RA quality
3. Preliminary design
4. Sampling of RA for the mix design
5. Procedure for different proportions of RA
6. Use of rejuvenators
7. Mix design testing
8. Plant mix trials

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Proportions of RA in mix

- RA content of mix (%) = $\frac{mass\ of\ RA}{total\ mass} \times 100$
  - e.g. for mix with a 20% RA content:
    - For every 1000 kg of asphalt
    - 200 kg is RA; 800 kg is new asphalt
- RA % determined by:
  - mix design requirements
  - NOT by;
    - plant capability
    - road authority perceptions / preferences
  - Limitations on amount of binder in RA as proportion of total binder content i.e. "***RA binder replacement***"

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RA binder replacement

Total binder in the mix B_{RA}

$$B_{RA} = \sum_{i=1}^{n} \left(\frac{(RA\ content)_i}{100} \times \frac{(RA\ binder\ content)_i}{100} \times 100 \right)_{fi}$$

Where:

$n = total\ number\ of\ processed\ RA\ fractions\ used$

$f_i = RA\ fraction\ number, eg\ f_1, f_2\ \ etc$

$B_T = Target\ (optimum) binder\ content\ of\ the\ mix$

$i.e. the\ sum\ of\ RA\ binder\ and\ virgin\ binder$

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RA binder replacement / cont.

RA binder replacement (B_R)

$$B_R = \frac{B_{RA}}{B_T} \times 100$$

Virgin binder required (B_V)

$$B_V = B_T - B_{RA}$$

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Worked example

- Total RA content – 22 %
- Total RA made up of two fractions:
  - RA fraction 1
    - Proportion used = 10%
    - Size: -A mm + B mm
    - Binder content = 4 %
  - RA fraction 2
    - Proportion used = 12%
    - Size: -B mm
    - Binder content = 6%
  - Target (optimum) binder content of mix B_T = 5.4%

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Worked example / cont.

Total RA binder in the mix:

$$B_{RA} = \left[\frac{10}{100} \times \frac{4.0}{100} \times 100\right] + \left[\frac{12}{100} \times \frac{6.0}{100} \times 100\right]$$

$$= \mathbf{1.1\%}$$

RA binder replacement

$$B_R = \frac{1.1}{5.4} \times 100$$

$$= \mathbf{20.4\%}$$

Virgin binder required

$$B_V = 5.4\% - 1.1\%$$

$$= \mathbf{4.3\%}$$

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Fraction size vs RA binder content

- Binder content and aggregate grading - differ from one RA fraction to the next
- Finer RA has ***more surface area*** than the coarser RA
- ***Higher RA binder content*** is expected for a ***finer RA fraction*** and vice versa
- RA binder replacement requirement may be satisfied by;
  - small content of fine RA
  - large content of coarse RA
  - or a combination of the fine and coarse RA fractions

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RA binder properties

- For a particular RA source, binder properties are independent of the processed fractions
- Properties of the RA binder from one fraction is the same as the RA binder properties recovered from another fraction or even the unprocessed RA

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Variability of RA

- ***RA should always be processed*** (i.e. crushed and screened) into specific fractions to limit the variability improve the consistency of this raw material
- Sieve sizes for the different RA fractions
  - should not be prescribed
  - left to the discretion of the asphalt manufacturer to allow for optimisation based on the RA binder replacement

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Number of RA fractions

To prevent the overuse of fine RA fractions in particular, a minimum number of RA fractions are recommended in Table 7.1 of Manual 36

RA Binder Replacement in Mix	Number of processed RA fractions
≤ 15%	One
> 15%	Two

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Mix design

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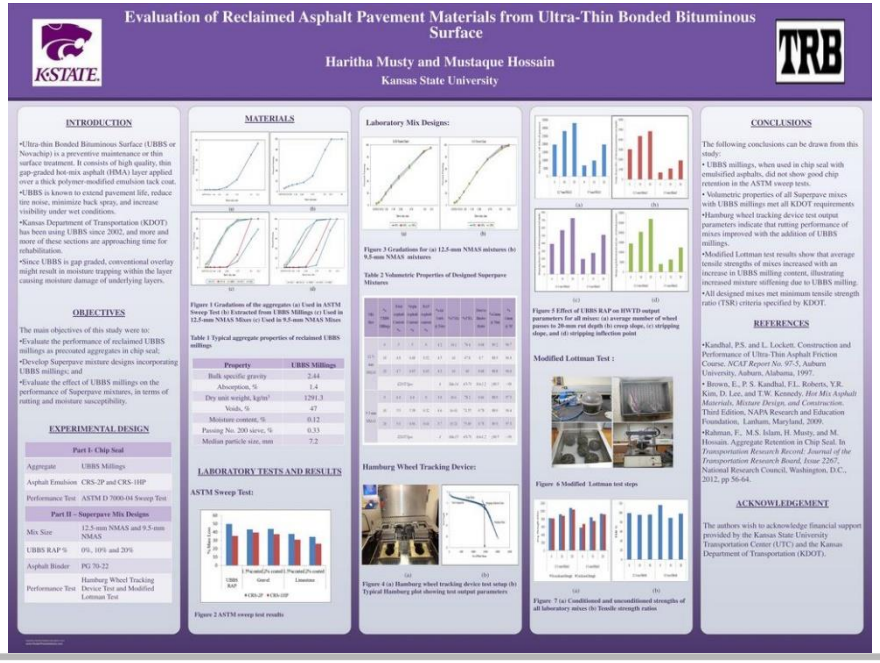
Testing for RA quality

- ***Processed RA fractions*** - evaluated for an RA mix design
- Basis for tests on aggregates and binder differs



Evaluation of Reclaimed Asphalt Pavement Materials from Ultra-Thin Bonded Bituminous Surface

Haritha Musty and Mustaque Hossain

Kansas State University

INTRODUCTION

•Ultra-thin Bonded Bituminous Surface (UBBS or Novachip) is a preventive maintenance or thin surface treatment. It consists of high quality, thin gap-graded hot-mix asphalt (HMA) layer applied over a thick polymer-modified emulsion tack coat.

•UBBS is known to extend pavement life, reduce tire noise, minimize back spray, and increase visibility under wet conditions.

•Kansas Department of Transportation (KDOT) has been using UBBS since 2002, and more and more of these sections are approaching time for rehabilitation.

•Since UBBS is gap graded, conventional overlay might result in moisture trapping within the layer causing moisture damage of underlying layers.

OBJECTIVES

The main objectives of this study were to:

•Evaluate the performance of reclaimed UBBS millings as precoated aggregates in chip seal;

•Develop Superpave mixture designs incorporating UBBS millings; and

•Evaluate the effect of UBBS millings on the performance of Superpave mixtures, in terms of rutting and moisture susceptibility.

EXPERIMENTAL DESIGN

Part I- Chip Seal	
Aggregate	UBBS Millings
Asphalt Emulsion	CRS-2P and CRS -1HP
Performance Test	ASTM D 7000-04 Sweep Test
Part II – Superpave Mix Designs	
Mix Size	12.5-mm NMAS and 9.5-mm NMAS
UBBS RAP %	0%, 10% and 20%
Asphalt Binder	PG 70-22
Performance Test	Hamburg Wheel Tracking Device Test and Modified Lottman Test

MATERIALS

Figure 1 Gradations of the aggregates (a) Used in ASTM Sweep Test (b) Extracted from UBBS Millings (c) Used in 12.5-mm NMAS Mixes (c) Used in 9.5-mm NMAS Mixes

Table 1 Typical aggregate properties of reclaimed UBBS millings

Property	UBBS Millings
Bulk specific gravity	2.44
Absorption, %	1.4
Dry unit weight, kg/m³	1291.3
Voids, %	47
Moisture content, %	0.12
Passing No. 200 sieve, %	0.33
Median particle size, mm	7.2

LABORATORY TESTS AND RESULTS

ASTM Sweep Test:

Figure 2 ASTM sweep test results

Laboratory Mix Designs:

Figure 3 Gradations for (a) 12.5-mm NMAS mixtures (b) 9.5-mm NMAS mixtures

Table 2 Volumetric Properties of Designed Superpave Mixtures

Hamburg Wheel Tracking Device:

Figure 4 (a) Hamburg wheel tracking device test setup (b) Typical Hamburg plot showing test output parameters

Figure 5 Effect of UBBS RAP on HWTD output parameters for all mixes: (a) average number of wheel passes to 20-mm rut depth (b) creep slope, (c) stripping slope, and (d) stripping inflection point

Modified Lottman Test :

Figure 6 Modified Lottman test steps

Figure 7 (a) Conditioned and unconditioned strengths of all laboratory mixes (b) Tensile strength ratios

CONCLUSIONS

The following conclusions can be drawn from this study:

• UBBS millings, when used in chip seal with emulsified asphalts, did not show good chip retention in the ASTM sweep tests.

• Volumetric properties of all Superpave mixes with UBBS millings met all KDOT requirements

•Hamburg wheel tracking device test output parameters indicate that rutting performance of mixes improved with the addition of UBBS millings.

•Modified Lottman test results show that average tensile strengths of mixes increased with an increase in UBBS milling content, illustrating increased mixture stiffening due to UBBS milling.

•All designed mixes met minimum tensile strength ratio (TSR) criteria specified by KDOT.

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• Brown, E., P. S. Kandhal, F.L. Roberts, Y.R. Kim, D. Lee, and T.W. Kennedy. *Hot Mix Asphalt Materials, Mixture Design, and Construction*. Third Edition, NAPA Research and Education Foundation, Lanham, Maryland, 2009.

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ACKNOWLEDGEMENT

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Tests on aggregates

- Proportion of the RA aggregate to the total aggregate in the mix - ***related to the RA content***
- Therefore the guideline for tests on the quality of aggregate recovered from each RA fraction is ***based on the RA content***

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Tests on aggregate / cont.

Table 7.2 of Manual 36 21 gives guidelines

RA content in mix	Recovered RA Aggregate Tests[1]
≤ 15%	• Check intrinsic aggregate properties[2] • Aggregate grading
> 15%	• Check intrinsic aggregate properties[2] • Aggregate grading • Aggregate Crushing Value (ACV) • 10% Fines Aggregate Crushing Value (10% FACT) • Flakiness Index

Notes:

1. *Recovered in accordance with:*
   - *SANS 3001 AS-25 by solution of the binder; or*
   - *SANS 3001-AS21 using an ignition furnace.*
2. *Important if they consist of basic igneous rock types, such as dolerite or basalt*

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Tests on binder

- The ***RA binder replacement*** (proportion of the RA binder to the total binder in the mix) is the basis for the guideline for ***tests on the quality of binder recovered***

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Tests on binder / cont.

Table 7.3 of Manual 36 gives guidelines

RA binder replacement	Recovered RA Binder Tests[3]
≤ 15%	• Binder Content • Contaminants (presence of coal tar)
> 15%	• Binder Content • Contaminants (presence of coal tar) • Softening Point[4] • Penetration[4] • Performance grade parameters[4]: - G*, δ, Jnr, using the dynamic shear rheometer (DSR) - S and m value using the bending beam rheometer (BBR)

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Tests on binder / cont.

- Method used for both binder extraction and binder recovery - ***stated and agreed (SANS 3001-AS25)***

- Presence of coal tar and/ or contaminants checked
- Recovered RA binder
  - already aged in service
  - tests would reflect an RTFO and/or PAV aged binder

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Testing for quality

- Binder content and grading tests - on each of the samples
- Results should be scrutinised for variation
- Where large variations are encountered, precautions to improve the uniformity
  - mixing with a front-end loader before loading into the cold feed hopper
  - increasing the number of screened fractions of RA
- Again, ***moisture content*** of the RA should be kept ***as low as possible***
  - moisture content checks on the various RA stockpiles - part of the mix design testing programme

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Mix design

1. Proportion of RA in a recycled mix
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3. Preliminary design
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Preliminary design

- Feasibility study should be conducted to determine:
  - ***relative proportioning*** of the RA and new materials
  - ***nominal RA binder replacement*** value (important step to develop realistic tender documents)
  - whether there will be ***enough processed RA available*** by analysing layer thicknesses and the average percentage yield of each processed RA fraction
- 150 mm diameter core size is recommended
- When the type, quality and thickness of the asphalt, varies significantly, further samples should be taken to determine their influence on the use of the recycled mix

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Further analysis

- For guidance on steps in the RA mix design procedure carry out further analysis
  - aggregate grading
  - binder content
  - binder properties
  - determination of the RA binder replacement

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Procedure for further analysis

1. Mill the RA sample from the designated site
2. Process the RA into the minimum required fractions
3. Determine mean %age yield of each processed RA fraction
4. On each RA fraction determine:
   a. Binder content tests
   b. Aggregate grading tests
5. Calculate the (nominal) RA binder replacement to be specified
6. To gauge influence of RA on the final binder specification, determine the following properties of recovered binder:
   a. Softening Point
   b. Penetration
   c. PG Binder Tests (J_{NR}, G*, δ, etc.)

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Sampling RA

- Preferably use (small) milling machine
- Milling according to determine milling strategy
- Sufficient RA milled for the feasibility study (and/or for the laboratory mix design work)
  - 10m^3 tip truck for full scale crushing and screening exercise

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RA processing

- Milled RA is crushed, screened and fractioned (full scale processing exercise)
- Laboratory scale processed RA samples are ***not recommended*** (not be truly representative of the full scale processing)
- In milling process portions of existing asphalt pavement is ground up - more fines than original mix design and as-built data
- Finer RA fractions yield higher binder volumes (larger surface area)
  - recovering enough RA binder for testing from the finer RA fraction would require fewer extraction cycles – saving time and money
  - ***caution*** – careful filtering of the very fine RA aggregates is required during the extraction

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Sampling RA for mix design

- Source of the RA will come from:
  - specific project site (mill and replace projects)
  - an existing RA stockpile
  - or both
- Either 150 mm cores or stockpile samples

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Summary of tests conducted

- RA aggregate grading – indication of the possible RA fractions/ % yields of various fractions;
- RA binder content:
  - indication of how binder content varies with various fractions
  - allow for the determination of a maximum RA binder replacement
- Recovered RA binder properties – early indication of the need to consider using a softer binder and/or a rejuvenator

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Nominal mix proportions

- Max ***RA binder replacement*** limit for specification purposes determined using:
  - specified nominal mix binder content
  - RA binder content (as determined from field cores or RA stockpile samples)
  - nominal RA content
- ***Max. RA binder replacement*** determines ***minimum proportion of new binder*** to be added to the recycled asphalt mix

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Sampling requirements for mix design

- Mix design process requires more representative RA sampling
- If available in ***stockpiles*** the following can be readily determined:
  - yield of processed RA fractions
  - quality of the RA aggregate and binder etc.
  - RA mix design to be conducted before commencement of
- When the RA is to be ***sourced from a project site***
  - sufficient quantities of RA must first be milled, processed and stockpiled
  - may cause a slight delay before the RA mix design can be conducted

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Recommendations for RA from project

- Mix design carried out on RA milled and processed from site, (full-scale operations);
- Avoid cost of procuring milling and processing at investigation level;
- RA sample size equivalent to one laden $10m^3$ tip truck for the conducting a full scale crushing and screening exercise;
- For uniform quality of the processed RA, milling and processing operations should be consistent for the duration of the project;
- Processed RA stockpile(s) sampled with a front end loader, following the method described in TMH5 Sampling Method MB1;
- ***In the case of mill-and-replace projects that require immediate paving of a new mix (e.g. temporary lane closures), an alternative approved mix design may be required initially until the RA mix design approved.***

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Procedure for different proportions of RA

- Proportioning of aggregate and filler carried out in the same way as for mixes containing all new aggregates (using grading of RA)
- For mixes with multiple RA fractions, determine most effective blend to achieve required composition
- ***Design binder blend*** to conform to the end binder specification of equivalent virgin mix
- Softer binder and/ or rejuvenator may be required

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Procedures for various proportions of RA

- More risk attached to compliance of binder properties than aggregate properties
- Procedures therefore based on ***RA binder replacement*** (Table 7.4 in Manual 36)
- Lab design carried out after RA has been crushed, screened and stockpiled
- Only processed RA fraction(s) used
- Briquettes for volumetric analysis – prepared as per SANS 3001-AS1

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Mix design framework

RA Binder replacement	Minimum no. of processed RA fractions	Tests on processed RA fractions	Recommendations for achieving the end binder specification	Determine blended binder properties
≤ 15 %	One	Binder - binder content - contaminants Aggregate - Grading - intrinsic properties	• None	• Not required
15 – 30%	Two	Binder - binder content - contaminants - Softening point & penetration - G*, δ, J_{NR}, S & m Aggregate - Grading - intrinsic properties - ACV, 10% FACT - Flakiness index	• Use softer binder grade; • Use rejuvenator	• Use blending charts to determine appropriate softer binder grade • Use blending charts to determine appropriate rejuvenator dosage rate • Report blended binder properties
30 – 60%	Two		• Use Rejuvenator	• Use blending charts to determine appropriate rejuvenator dosage rate • Report blended binder property tests

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Laboratory procedures

- New aggregate oven-dried at 105°C - 110°C to constant mass
- RA oven-dried at 60°C max. to a constant mass
- Fractions of new aggregate and RA oven-heated to mix temp + 25°C
- Mixing temperature is based on penetration of RA-binder/ new binder blend. (e.g. Tables 7.6 and 7.7)
- Required proportion of new binder mixed with aggregate and RA in a mechanical mixer for the period shown in Table 7.5
- Compaction temperature is based on penetration of RA-binder / new binder blend (e.g. Table 7.6 and Table 7.7)
- Mixed material oven-cured - 60 min at required compaction temperature
- Material compacted in Marshall moulds as per SANS 3001-AS1

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Laboratory mixing times

Table 7.5

RA Binder Replacement (%)	Mixing Time (min ± 5 sec)
< 15	5
15 – 30	7
30 – 50	8

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Blending chart

Table 7.6 for 50/70 pen new binder

RA Binder Replacement (%)	Recovered RA Binder Penetration (dmm)						
	5	10	15	20	25	30	35
30	28	35	40	43	46	49	51
25	32	38	42	46	48	50	52
20	37	42	45	48	50	52	54
15	41	46	49	51	53	54	55
10	47	50	52	54	55	56	57
5	53	55	56	57	57	58	58
0	60	60	60	60	60	60	60
Resultant Pen of 50/70 Pen bitumen mixed with RA							

New binder - 50/70 pen (assumed pen - 60 dmm)

RA binder pen - 5 dmm

The blended binder can be expected to pen ≈ 37 dmm.

Mixing and compaction temperature should be based on a 35/50 pen grade binder (i.e. higher mixing and compaction temperatures than a 50/70 pen grade)

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Rejuvenators

- Restore the original properties of aged binders - ***to some extent***
- Applied:
  - spray onto an existing wearing course, or
  - blending with a binder used in the manufacture of asphalt

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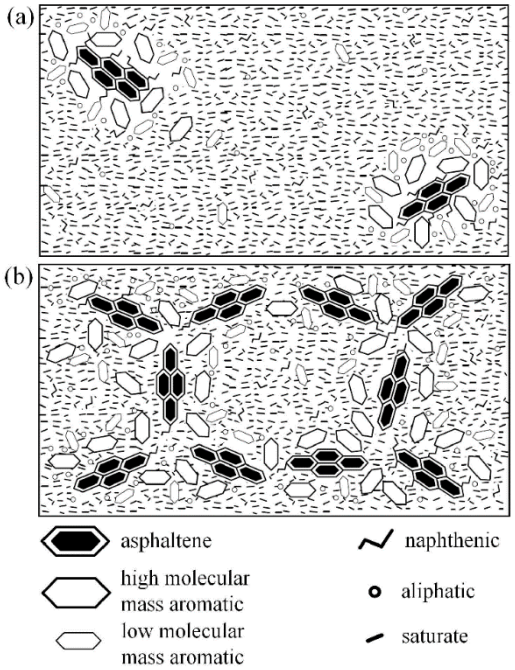
Colloidal model of bitumen

- Bituminous binder - complex colloid consisting of:
  - insoluble asphaltenes dispersed in:
  - soluble maltenes



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Effects of ageing

- When sufficient maltenes present asphaltene micelles can move smoothly with the binder
- As the bitumen ages maltenes are transformed into asphaltenes
- This process upsets the balance of the ratio of the two components leading to a hardened, brittle asphalt mix, as is the case with RA binders

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Function of rejuvenator

- Restore consistency of aged bitumen to a appropriate for both ***construction purposes*** and ***performance*** through:
  - dispersing the agglomeration of the asphaltene components over the years (binder hardening)
  - replenishing lost maltene phase due to oxidation
- Recondition the aged binder to optimal chemical characteristics for durability
- Provide a sufficient amount of additional, useful binder to coat aggregates and to meet design objectives

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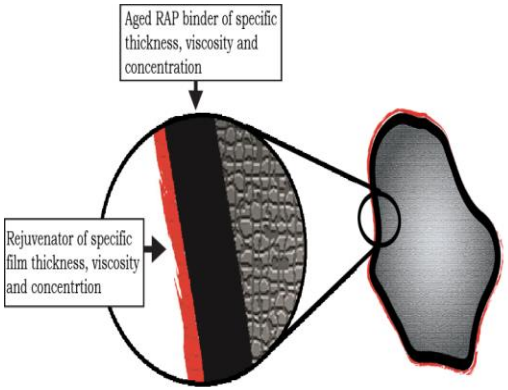
Rejuvenation mechanism

- Rejuvenator forms a very low viscosity layer surrounding the bitumen-coated aggregate where the binder layer is highly aged
- Rejuvenator penetrates into the aged binder layer
  - decreasing the amount of raw rejuvenator coating
  - softening the aged binder
- Penetration continues
  - decreasing viscosity of the inner layer of binder film
  - gradually increasing the viscosity of the outer layer
- After a certain period, equilibrium is approached over the recycled binder film



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Use of rejuvenators

- Variety of materials
  - aromatic oils
  - paraffinic oils
  - naphthenic oils
  - waste engine oils
  - waxes plus fatty acids and tall oils
- ***Some of these, due to environmental and health concerns, should not be used in asphalt recycling***
- Industry group - propose a protocol for accreditation by Agrèment SA for
  - surface application to aged wearing courses
  - use in recycled asphalt mixes
- The aim of accreditation is to:
  - facilitate the optimal selection
  - protect workers against the use of toxic substances

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Applications

- Softer binders and / or rejuvenators are used to obtain a binder blend that will conform to the final project requirement
- When RA binder replacement > 15% rejuvenator is recommended as softer grades of binder do not have enough ***co-mingling or diffusion*** capability
- For RA binder replacement > 25% always use rejuvenating agent

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Mix design testing

- Recycled asphalt - meet the usual requirements of a specification for equal or better performance than the equivalent mix with virgin materials
- RA mix design should follow the guidelines set out in Sabita Manual 35: *Design and use of Asphalt in Road Pavements*
  - tests on the recycled asphalt same as tests on conventional asphalt mixes
  - tests to evaluate moisture sensitivity included (Modified Lottman)

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Plant mix trials

- Laboratory mix design followed by plant mix trials:
  - small quantities at three different binder contents:
    - optimum binder content in the laboratory mix
    - at optimum binder contents + 0.5%
    - at optimum binder contents - 0.5%
- Results of tests on trial mixes examined for ***shift*** between lab mixes and those manufactured full-scale
- Final adjustments made accordingly
- Moisture content of the final product should be checked again to ensure that the mix complies with maximum moisture requirements

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Mixing plant requirements

1. Mixing plant types
   - Batch plants
   - Drum plants
2. Cold feed systems

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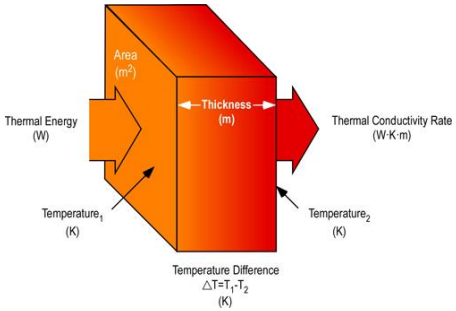
Mix plant essentials

1. Heat transfer from (super) heated virgin aggregate to RA
2. Provide opportunity for:
   - reclaimed binder viscosity to be reduced
   - proper blending of RA and virgin aggregates
3. Correct proportions of RA / virgin materials (aggregate and binder)
4. Reduce risk:
   - of steam explosion (moisture of RA)
   - exposure of bituminous materials to naked flame
5. Compliance with environmental legislation



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Plant modification

- Standard plants ***not*** used for asphalt with high RA content
- ***Modifications*** required to produce mixes of the same quality as those using all-virgin aggregates and binders
- For drum mixer type plants, retrofitting should be carried out to ***protect the RA from naked flame***
- Mixing plants must comply with the same emissions standards as for conventional asphalt mixes - National Environment Management Air Quality Act (Act No 39 of 2004)
- Guidelines regarding the various types of mixing plants can be found in SABITA Manual 5, as well as in NAPA Information Series 123 - *Processing and handling RAP*

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Caution

- Whatever the plant configuration
  - ***exposure of RA to a naked flame in the heating process should be avoided*** or at least limited

- Throughput of the plant should be adjusted to allow for sufficient lag time in the mixer for heating the RA to a temperature that will enable proper co-mingling

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Batch plant options (examples)

1. Pugmill recycling - separate RA weigh hopper
2. Introducing RA into bucket elevator

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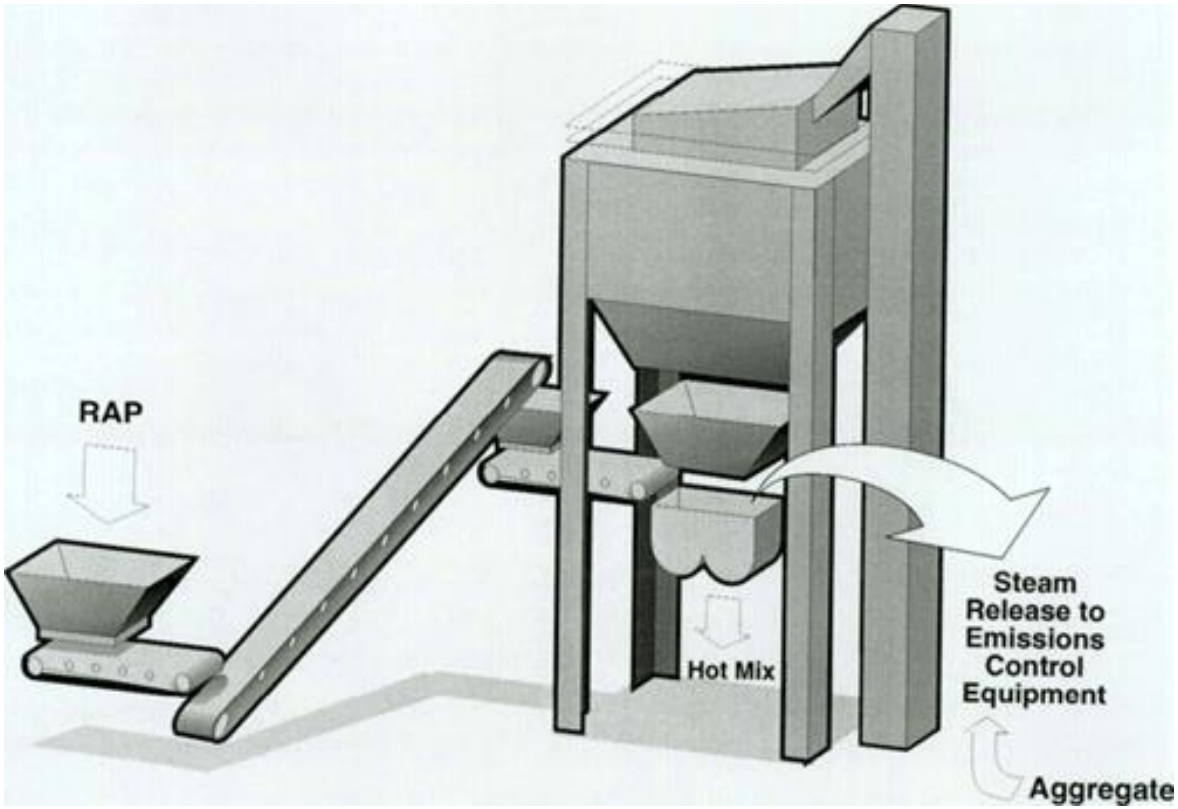
Separate RA weigh hopper



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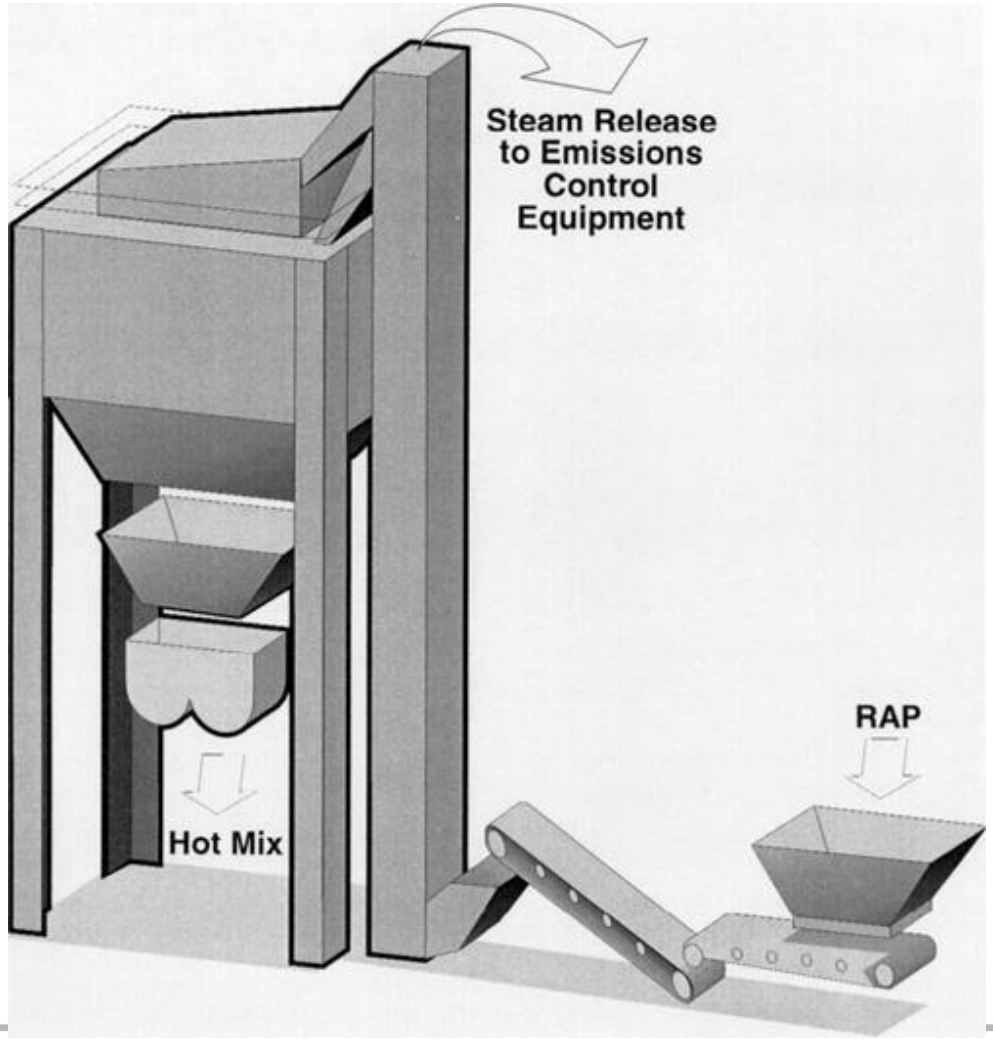
Description

- RA is fed into the pug mill direct via separate weigh hopper
- Virgin aggregate superheated to accommodate “cold” RA
- Dry mix cycle adjusted for better heat transfer
- Care to ensure that the steam (generated when RA fed into the pug mill) is properly vented into dust extraction system
- A mini-explosion when moisture in the RA makes contact with the superheated aggregate
- After initial burst, steam is released relatively slowly – typically within a period of 30 seconds – by the vigorous mixing process in the pug mill
- Possible to increase the RA content if dried prior to mixing

RA into bucket elevator



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Description

- RA via cold feed bin directly into hot elevator where virgin aggregate discharged from drying drum
- RA mixes with the hot virgin aggregate in the bucket elevator - steam released more gradually
- Blend of RA and virgin aggregate weigh batched into pug mill and mixed with new binder
- Longer contact between RA and virgin aggregate facilitates good heat transfer
- Eliminates the violent release of steam (as in direct pug-mill method)

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Drum plants (examples)

- Two basic configurations available:
  - parallel flow
  - counter flow

Operational aspects

- Feeding RA into drum type plant is easier as the generation and venting of steam managed more easily through the (larger volume) drum,
- However, the risk of generating “blue smoke” is greater, as in some instances the burner flame makes direct contact with the RA as it is being fed into the drum

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Parallel flow

- ***Basic*** - RA metered in cold feed bin and fed into the drier drum with virgin aggregate:
  - potential for ***blue smoke*** emissions
  - limit RA proportion to ***10%***
- ***With central ring***.
  - Metered RA fed through central ring
  - Away from high temperature zone at burner end
  - ***reduced risk of blue smoke***
  - RA proportion typically ***25%***

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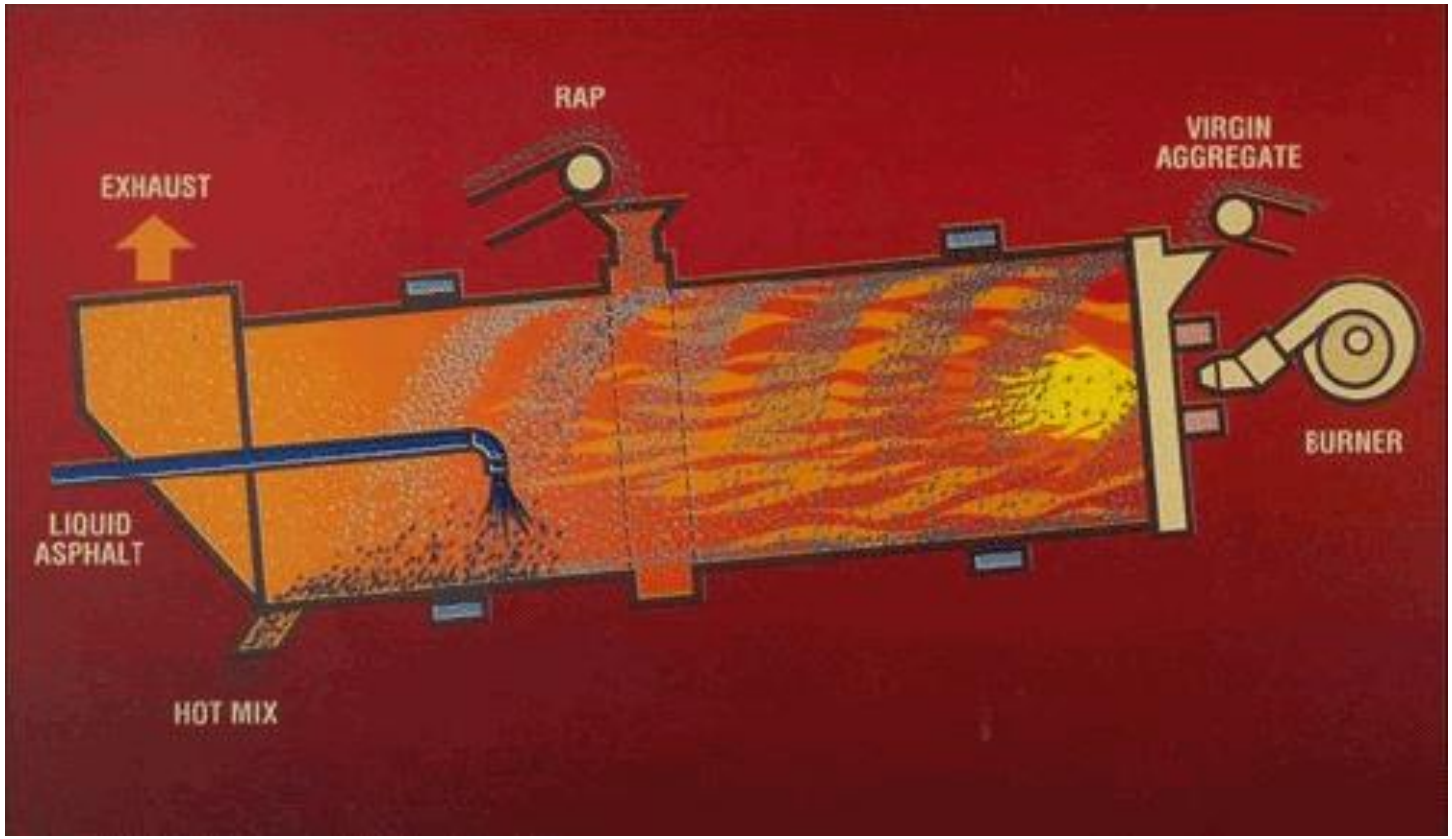
Parallel flow drum with central inlet



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Parallel flow / cont.

- ***With after-mixer***
  - separate rotating mixing drum (coater)
  - heated mixture of ***virgin aggregate and RA*** mixed with the ***binder***
  - hot gasses from the mixing drum do not come into direct contact with the binder
  - reduces emissions - RA content can consequently be increased to at least ***30%***

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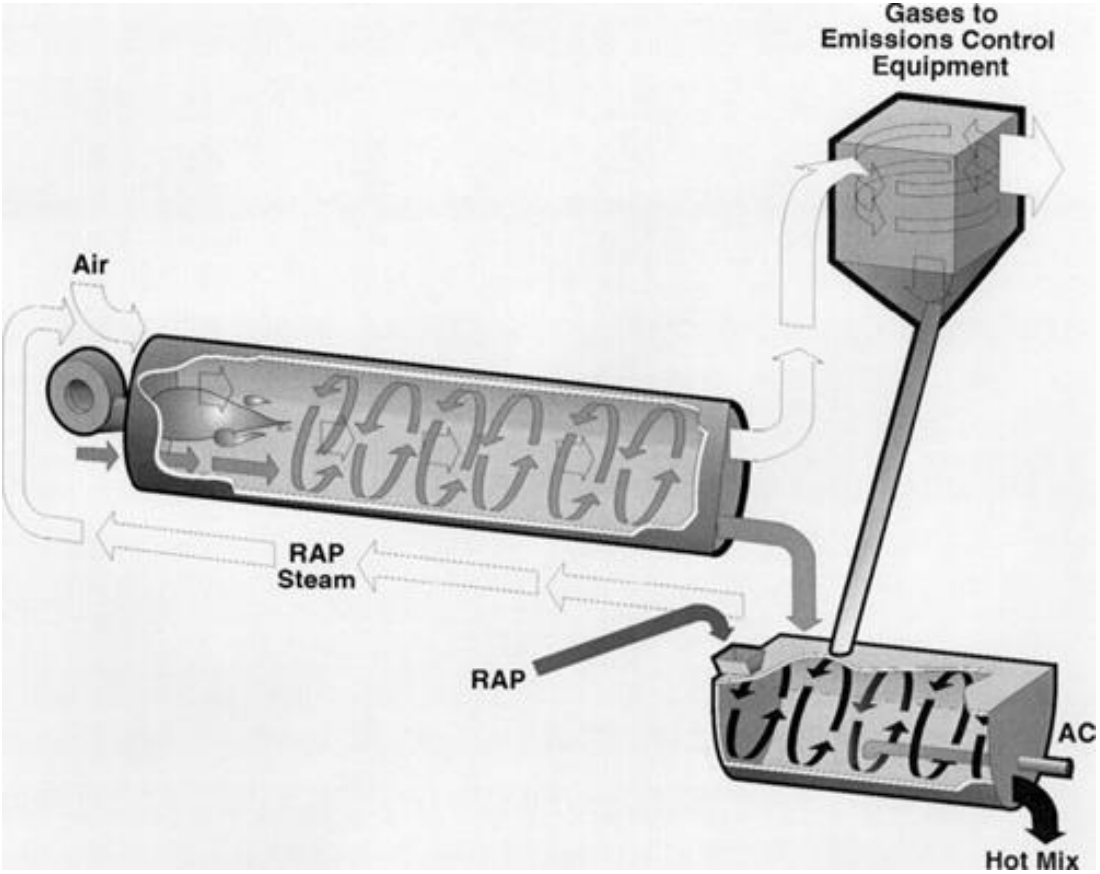
Parallel flow drum with coater



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Parallel flow: limitations of RA content

- Parallel flow with RA ring – 25% max;
- Parallel flow with after-mixer/coater – 30% max;
- Parallel flow with RA ring and after-mixer/coater – 40% max

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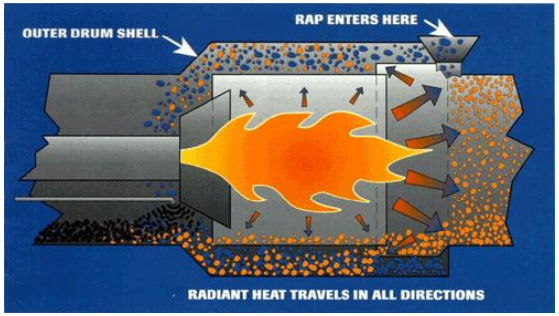
Counter flow drum mixers

- Burner is located opposite to aggregate feed point
- Excessively high process gas temperatures reduced by cooler, moist aggregate as the gasses evacuate the dryer
- Steam exhausted at the burner end of the dryer while hydrocarbons carried in the air stream are destroyed by the high temperatures that prevail in this part of the drum



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Types of counter flow drum mixers

- With RA ring - mixing takes place in the drum on the burner side of the RA ring;
- With an after-mixer (coater) where mixing takes place;
- With RA ring and after mixer/coater
- Twin drums, which consist of:
  - a counter-flow drum where drying and heating of the virgin material takes place
  - second drum (or in certain instances a barrel wrapped around the first drum) where mixing takes place
  - Typically, % RA that can be used is substantially higher when double/twin drum mixers are used, up to 70% RA

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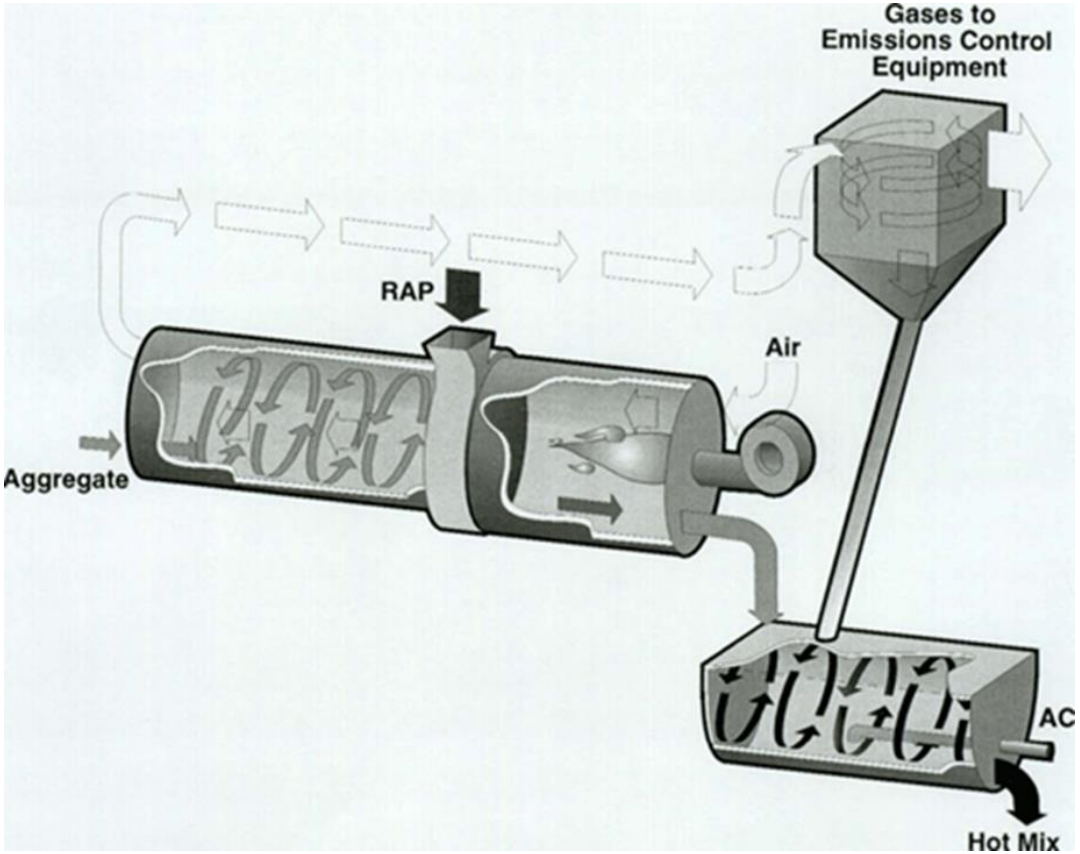
Counter-flow drum mixer with coater



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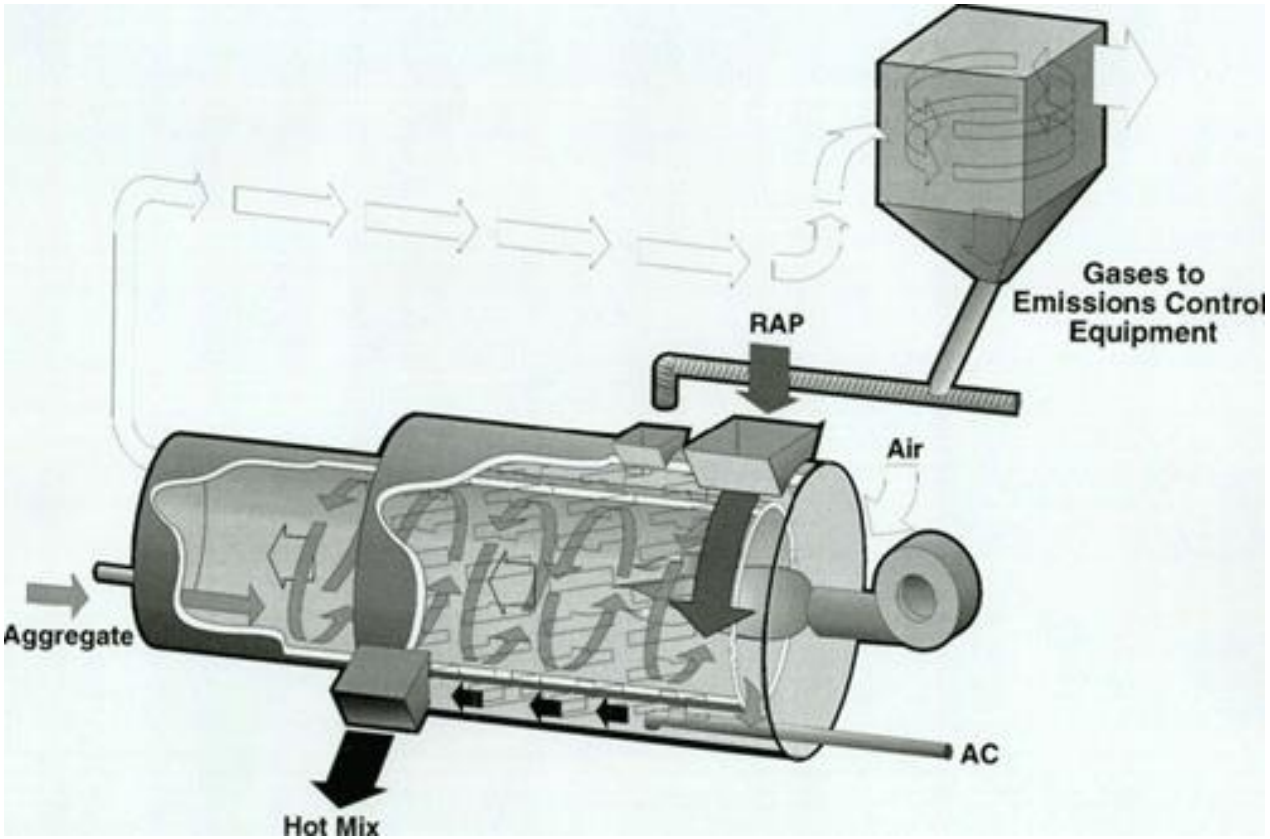
Double barrel drum



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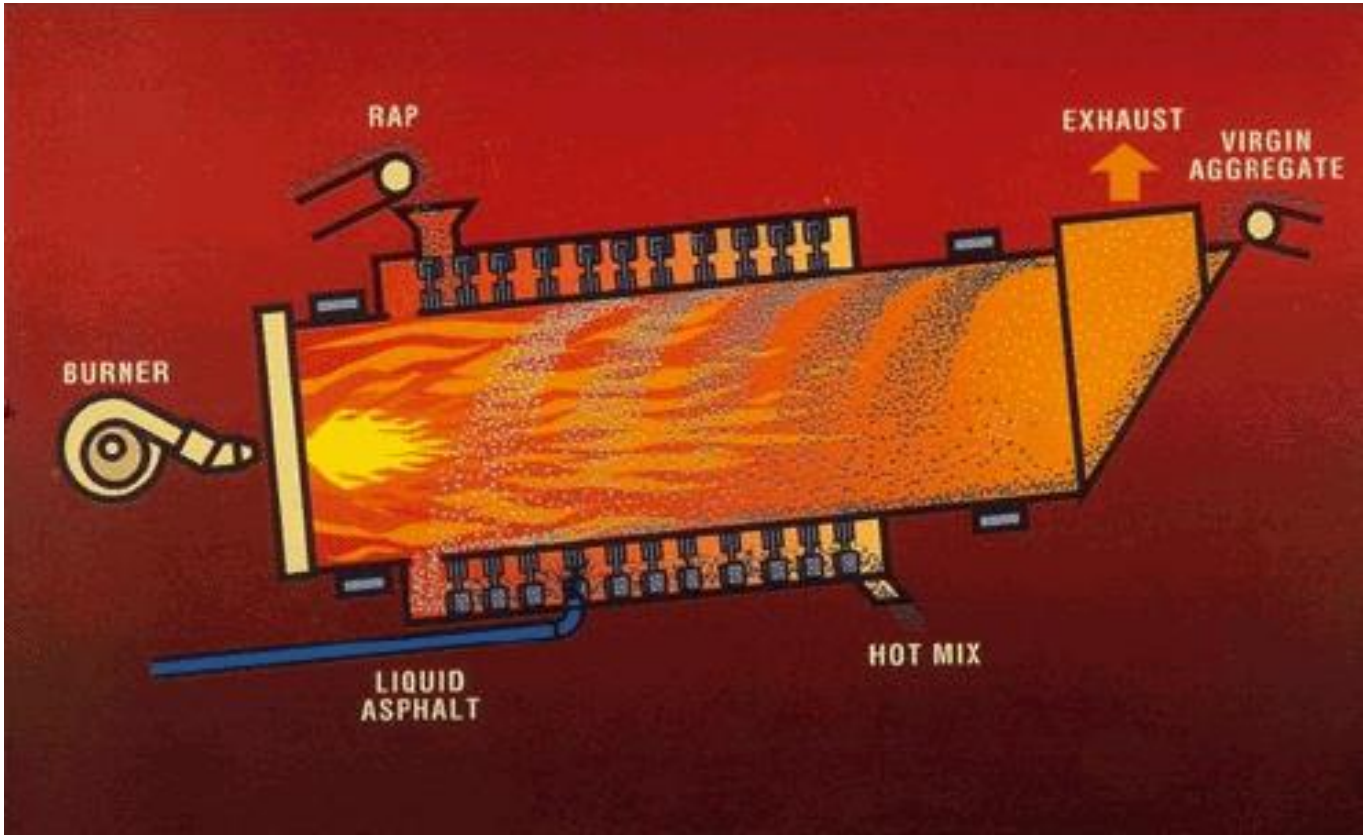
Counter-flow double drum



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Batch vs Drum

- **Batch** ⬇ - Virgin aggregate superheated to accommodate the “cold” RA (increased energy)
- **Batch** ⬇ A mini explosion when moisture in the RA makes contact with the superheated aggregate (venting of steam)
- **Drum** ⬆ Feeding RA into drum type plant is easier as the generation and venting of steam can be managed more easily through the drum, which has a larger volume
- **Drum** ⬇ Risk of generating “blue smoke” is greater- burner flame can make direct contact with the RA

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Typical suggested max. RA capabilities

Type of mixing plant	Maximum % RA[1]
Batch mix	
• Pug mill only	15
• Pug mill and hot elevator	30
Drum mix	
• Parallel flow feed with aggregate	10
• Parallel flow with centre ring	25
• Counter flow with RA ring	30
• Counter flow with after-mixer	30
• Counter flow with RA ring & coater	40
Twin dryer drum	40
Double barrel drum	70

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Cold feed systems

- Separate cold feed bins for each RA fraction
- For even, consistent feed:
  - sides of the bins steeper than for virgin aggregates;
  - openings of bins onto the feed belts lengthened;
  - longer feed belts required;
  - RA trickle-fed into bins to prevent packing;
  - vibrators should be avoided;
  - RA with a high binder content not left in bins overnight; and
  - sensors installed of to detect blockages in RA feed

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Plant requirements in relation to RA content

RA Content	Mixing plant requirements		Binder adjustments
	Cold feed	Mixing	
<15%	One cold feed bin is required for the RA	Batch plants with separate RA weight hoppers are suitable. Exhaust system modification required for mixes with >10% RA. Parallel-flow and counter-flow drum mixers with RA collars at mid-point of drier drum are suitable	Mix design using normally specified bitumen grade. Change in bitumen grade normally not necessary Could be changed after reviewing the mix properties
15% to 30%	Cold feed bin required for each RA fraction	Batch plant, with modified exhaust systems, are suitable up to 20% RA. Counter-flow drum mixers with RA collars at mid-point of drier drum are suitable. Parallel-flow drum mixers require separate continuous mixer where the binder is added	Mix design using one grade softer than normally specified bitumen grade. Review binder grade based on the mix properties obtained in the design.
>30%		Parallel-flow mixers require a separate continuous mixer where the binder is added Exhaust system to be modified. Specialised plants, such as double drum or twin drum mixing plants are required when >40% RA is used in the mix	Determine properties of RA binder Mix design with bitumen grade based on combined binder properties and, where applicable, rejuvenators

Quality control

- Systematic QC process - similar to that of conventional asphalt
  - Chapter 7 of Sabita Manual 35 / TRH 8: *Design and Use of Asphalt in Road Pavements*
  - COTO specifications or other project specifications

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Items requiring special attention

- RA stockpiles
- RA moisture control

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RA stockpiles

- RA - ***controlled input component*** of any recycled asphalt mix
- Additional quality control aspects should be considered:
  - RA binder content
  - Gradation of RA aggregate
  - RA moisture content
  - Bulk density of the RA aggregate
  - Agreed properties of RA aggregate
  - RA binder properties (for mixes with RA binder replacement values > 15%)

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Moisture content

- MC of RA checked daily to ensure it does not exceed 0.5%
- RA with MC > 0.5% problematic for many mixing plants not capable of removing moisture during heating process
- Special consideration in selecting mixing plant or conversions required for mixes:
  - with binder replacement percentages >15%
  - large percentages of fine fractioned RA need to be used, (Refer to Chapter 8)
  - mixing plant capable of pre-drying the RA
- A large drop of mix temperature between plant and paving site - indication of a high RA MC resulting in:
  - non-homogeneous mix
  - poor workability
  - compaction problems

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Benefits of RA in asphalt

- RA makes sense for ***environmenta***l and ***economic*** reasons
- Established practice internationally and nationally
- Reduces demand for materials from non-renewable resources
- Upholds two principles of the National Environmental Management: Waste Act (Act 59 of 2008):
  - Minimising the consumption of natural resources; and
  - Avoiding and minimising the generation of waste

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Socio-economic benefits

- Reduced energy consumption and greenhouse gas emissions
- Recovery of non-renewable raw materials (bitumen, aggregate)
- Cost savings:
  - same quality at a lower cost
  - reduced disposal costs
- RA is a valuable resource (not a waste material)
- Waste produced by road construction is minimised
- Diversion of waste stream from landfills, by stockpiling RA for use when and where required

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Direct cost savings

- Lower virgin aggregate consumption
  - RA reduces quantity of virgin aggregate required
  - if haulage for RA not excessive, unit cost of RA < unit cost virgin aggregate
- Lower bitumen consumption
  - For ***10% of RA*** used, bitumen content reduced by 0.3 - 0.5%.
  - Price of (petroleum-based) bitumen expected to increase over time; cost reduction will become significant
  - Reduced bitumen requires less energy for heating bitumen during mixing, storage and transport
- Bitumen transport costs
  - Reduction in the quantity of bitumen reduces transport costs from source
- Disposal charges
  - Charges related to the disposal of asphalt at landfill sites are potentially eliminated / greatly reduced
- ***Offset against the additional costs incurred in handling and processing of the RA in recycling process***

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Key economic factors

- Location of source materials
  - RA
  - Suitable quality crushed stone
  - Bitumen
- Associated transport costs
- Siting of static or mobile asphalt plants with recycling capability in relation to:
  - Raw materials
  - Jobsite where the RA is available
  - Project site

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Ownership and disposal of RA

- Aspects of current legislation will impact on decisions on the use and disposal of RA
- The ownership and disposal of assets of all state-owned enterprises governed by:
  - Section 19.6 of the Treasury Regulations 2005 promulgated in terms of Section 90 of PFMA, MFMA
  - Section 10 - Annexure A SIPDM

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Ownership

- In terms of above legislation:
- Ownership of RA, by default, vests with the road owner, who may transfer such ownership to
  - another organ of state
  - contractor in terms of the conditions of contract
- The road owner should declare his intentions of transfer / disposal prior to going to tender

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Contractual issues

- RA has a value to be reflected in any contract let by public tender as well as arrangements regarding the transfer or disposal of the asset
- Consequently, if it is required that the contractor take ownership of the RA, a ***payment item*** must be included in the bill of quantities in which a ***saving to the contract is tendered***

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Factors influencing transfer/disposal of RA

- Decisions regarding the use, transfer or disposal of RA to take account of:
  - Location of a project
  - Area required for temporary or permanent storage and stockpiling
  - Potential use of stockpiled / excess processed RA, not required for the project
  - Responsibility for current / future handling, transport costs
  - Costs of securing the RA asset, e.g. fencing
  - Environmental requirements – storage, disposal
  - Asset auditing obligations

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OHSE specific to RA

- To optimise major environmental benefits of recycling of asphalt:
  - imperative that worker safety not compromised
  - due consideration given to the environmental aspects during mixing operations

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Potential health and safety hazards

- Exposure to:
  - coal tar
  - dust
  - toxic vapours and fumes
- Elevated temperatures
- Combustible nature of bitumen

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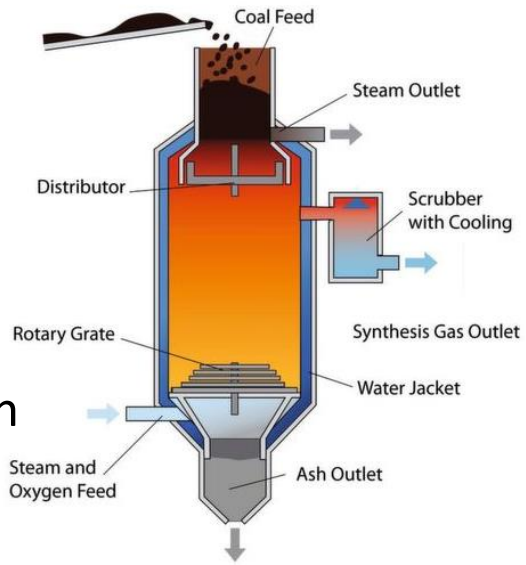
Exposure to coal tar

- Coal tar is a known carcinogen
- Determine presence prior to milling (white spray paint turns brown when in contact with coal tar - indicator test for its presence)
- RA containing it should therefore be regarded as ***hazardous*** and ***health risk to workers***
- Workers involved in reclaiming materials that contain tar should be equipped with appropriate protective clothing and breathing apparatus, and the reclaimed material should be ***removed to a registered hazardous waste site***.
- If no coal tar present in RA, it is inert and handled like virgin aggregate



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Exposure to dust

- During milling operations workers must be protected against inhalation of dust generated
- Suitable respiratory protection should be provided and used

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Toxic vapours and fumes

- Caution where aromatic oils used to rejuvenate the aged binder in the RA
- Some of these aromatic oils contain high concentrations of harmful Polycyclic Aromatic Hydrocarbons (PAHs)
- Hazardous concentrations of PAHs may be present in fumes liberated when bitumen is heated
- Every precaution taken to reduce the exposure of workers to fumes or skin contact

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Elevated temperatures

- Contact with liquid bitumen during the manufacture of the recycled asphalt, will cause severe burns and shock - can be fatal
- Contact with storage tanks and pipelines containing hot bitumen will also cause severe skin burns.
- All workers involved with handling of the hot binder must be issued with appropriate PPE and its use must be strictly enforced

Combustible nature of bitumen

- Paving grade bitumen is combustible and under ideal conditions can ignite
- Recommended that effect of rejuvenator agents be considered in this respect
- In asphalt blending operations ideal conditions for ignition may exist under

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Conditions for ignition

- Elevated temperatures increases release flammable vapours
- Small quantities of the vapours of hydrocarbons in air can form a flammable mixture which can be ignited in the vapour space of storage if e.g. tanks, road tankers by:
  - Flame
  - Hot surface or heating element
  - Spark or other source of ignition

- Bitumen at temperature above its flashpoint; contact with an ignition source (flame) can ignite the flammable vapour released from the surface of the bitumen;
- Presence of small quantities of water forms foam that will ***expand rapidly*** causing tank to overflow
- This expanding foam can quickly reach hot objects or burners, and cause the bitumen (flammable vapours) to ignite

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Rules for minimising risk of ignition

- Control the maximum temperature at which bitumen is stored and handled
- ***Bitumen should be stored and handled at the lowest appropriate temperature***
- ***Eliminate sources of ignition*** in potentially dangerous atmospheres in the blending operations

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Environmental aspects

- Excessive fume emissions during mixing
- Spillage or leaching into aquatic environment

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Excessive fuming

- Excessive fuming can occur if the ***RA is exposed to the burner flame*** in the drum mixer
- ***This contact should be avoided at all costs***, even if it imposes a restriction on %^{age} of RA that can be recycled
- Usual baghouse emission control systems may not be adequate when high %^{ages} of RA are used
- Supplementary / other types of emissions control systems may be necessary

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Spillage

- Because of viscous nature of road bitumen, it is extremely unlikely that spillage could pollute water
- Studies conducted world-wide show that the leaching behaviour of asphalt containing RA *(free of coal tar)* is not different from conventional asphalt
- In Europe, asphalt with or without RA**,** does meet the most onerous requirements with regard to leaching *(EAPA, 2008)*
- Notwithstanding, any spillage into the environment must be cleaned up as soon as possible

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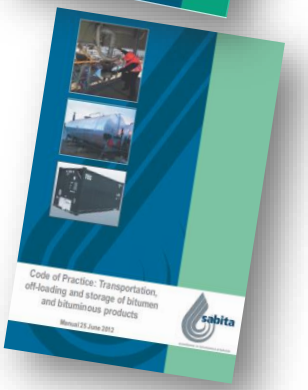
Guidance

- SABITA Manual 8: *Guidelines for the safe and responsible handling of bituminous products*
- SABITA Manual 25 Code of Practice: *Transportation, off-loading and storage of bitumen and bituminous products*
- Best practice guide: *An industry best practice guide for the storage of reclaimed asphalt (RA) at asphalt plants*
- Bitumen spill protocol – Version 1, August 2013: *An industry protocol for responding to bitumen spills on land and/or adjacent water environments*



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Contract documentation

- Comprehensively dealt with in Manual 36
- For this course a few matters are singled out:
  - Mix selection
  - Mixing plants
  - Milling
  - Contract information
  - Mix design
  - Construction programme
  - Quality assurance

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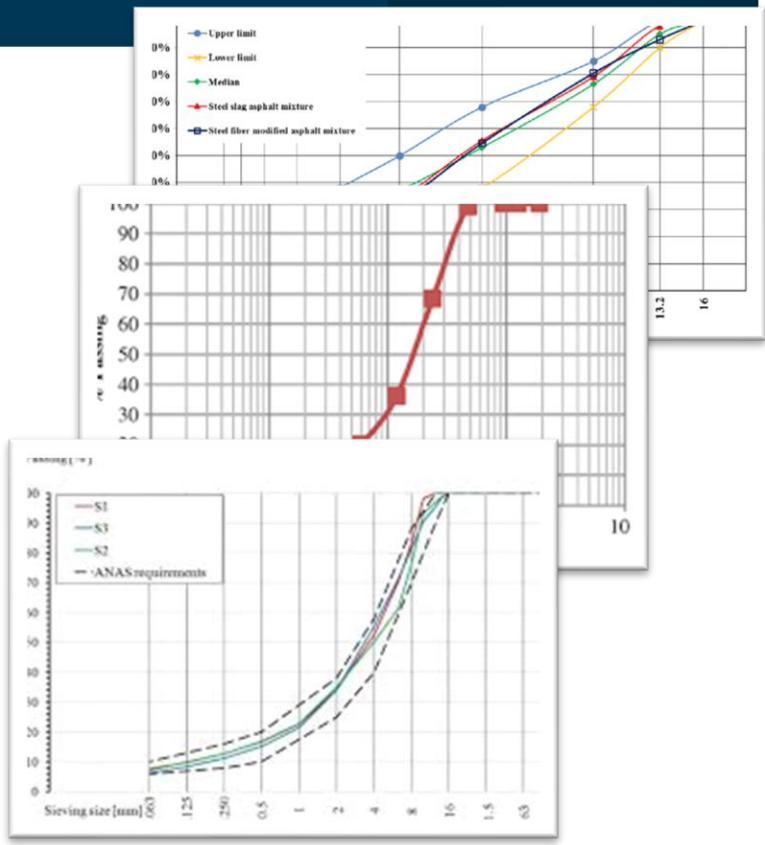
Mix selection

- Prescribed RA proportion must be appropriate in terms of RA properties and final mix requirements
- E.g. inappropriate to specify 40% sand skeleton RA for new SMA



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Mixing plants

- Static major plants likely to be properly configured for RA
- Investigate availability of suitable mobile plants in remote areas to ensure equitable tendering process

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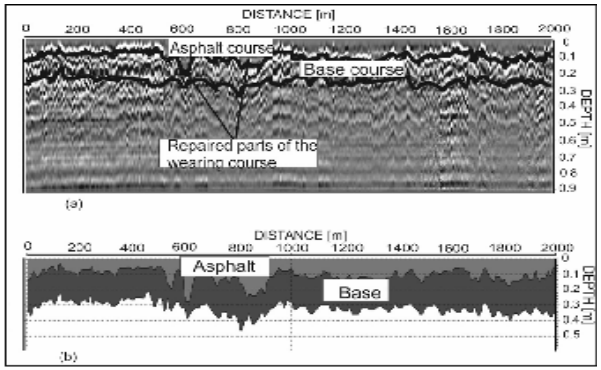
Milling

- Existing asphalt pavement layers may vary:
  - Mix types
  - Longitudinally
  - Transversely
  - In depth
  - Subsequent seals



- Adequate pre-tender investigation to identify variations and relative quantities with certainty
- Use of as-built information and coring survey
- Split milling and stockpiling may have to be provided for in contract documentation

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Contract information

- Provide sufficient information at tender stage:
  - various bituminous material types, location and quantities
  - aggregate type, grading and shape
  - binder type and recovered binder properties
- Requires either:
  - selective milling
  - large diameter cores

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Mix design

- Mix design carried out as per the standard method (Sabita Manual 35)
- Major differences where % RA prescribed:
  - Changes to nominal proportions listed in specifications
  - Delays in obtaining RA for mix design – affect construction programme
  - Need for and appropriate type of rejuvenator and dosage – ***this should not be specifically prescribed***

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Construction programme

- Asphalt design periods for various levels may impact significantly on programmes
- Sufficient time should be provided
- Current experience suggests that the following periods be accommodated:
  - Level I design: 4 – 6 weeks
  - Level II design: 6 – 8 weeks
  - Level III design: 8 – 12 weeks
- In certain instances e.g. rural situations or where client nominates project as source – provide for rate for 100% virgin mix to avoid delays especially for “mill-and-fill” situations

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Quality assurance

- Recovery and assessment of RA quality and properties relatively expensive
- Pre-empt compromising quality of finished product by:
  - Allowance in pricing schedule (prov. sum)
  - Cover cost of specialised testing additionally required

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