WHITE PAPER

Central Mix REAS (Rubberized Emulsion Aggregate Slurry)
An Eco-Friendly Preservation and Maintenance Treatment With a Proven Record of Performance

By

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Central Mix REAS (Rubberized Emulsion Aggregate Slurry): An Eco-Friendly Preservation and Maintenance Treatment with a Proven Record of Performance

Pavement Preservation is the idea of applying the right treatment on the right pavement at the right time to extend the pavement service life and delay or prevent costly rehabilitation. One of the most effective pavement preservation treatments is slurry seal. Slurry seals have been used as a preservation treatment on a large number of public roads, highways, and airports. Rubberized Emulsion Aggregate Slurry (REAS) material was invented in 1994 as an enhanced slurry seal with an effective recycling method for waste rubber tires. With REAS, the slurry mixture is improved through the use of rubber polymer modified emulsion (RPME), which uses crumb rubber from recycled waste tires. The main ingredients used in the production of REAS are: (1) asphalt emulsion, (2) aggregate, (3) crumb rubber, and (4) water.

REAS has become a widely accepted pavement preservation surface treatments over the last two decades; owing to the vast number of benefits and cost saving that this slurry offers over the life of the project. It has helped many agencies extend the life of existing pavements and stretch their available funds to cover more projects. The Central Mix production of REAS has further improved the REAS performance due to the enhanced quality of the mix that can be achieved in the Central Mix Plant. By mixing in a Central Mix Plant all aspects of manufacturing can be precisely controlled. At the Central Mix Plant all materials are rigorously tested before and after production to ensure only the highest quality REAS is produced. Central Mix REAS is delivered to the job site as a finished slurry mixture ready for placement using a Central Mix REAS distributer truck. The Central Mix REAS is available in four aggregate gradations that vary depending on aggregate size: Type Fine, Type I, Type II and Type III, with Type Fine being the finest and Type III the coarsest. The Type II REAS is the most commonly used, provides a medium-textured surface, and is mainly used on urban streets. Type III REAS is most suitable for heavy trafficked arterials streets and state highways.

The Central Mix plant production of REAS has proven to make possible the mass production of a highly engineered and superior quality product manufactured in a precisely controlled process and delivered to order to the jobsite for immediate application in cold form. Therefore, as superior pavement preservation Central Mix REAS outperforms many other surface treatments including other slurry seals, and has a proven record of performance in public works. It has been successfully used on residential and urban roadways, state highways, parking lots, and airport runways and taxiways. In all of these application areas, Central Mix REAS treatments offers many great benefits pertaining to pavement durability and long term performance, cost effectiveness, safety, environmental sustainability, and long-lasting aesthetically pleasing finish. In this regard, Central Mix REAS reduces the rate of deterioration by sealing the asphalt pavement from water, preventing further oxidation, correcting raveling, and improving the skid resistance and other surface conditions. One of the main environmental benefits of REAS is utilizing scrap rubber tires in which between 100-300 scrap tires are recycled (depending on REAS Type) for every lane mile of roadway treated. Therefore, besides being an effective pavement preservation treatment, REAS is an eco-friendly product that creates a new use of waste tire rubber; thus diverting significant number of scrap tires from traditional disposal at a landfill and putting them back into the road.

WHITE PAPER

Central Mix REAS (Rubberized Emulsion Aggregate Slurry):
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INTRODUCTION

Pavement preservation is a unique concept in pavement engineering and construction in which the basic idea is to apply the right treatment on the right pavement at the right time to extend the pavement service life and delay or prevent costly rehabilitation. The Federal Highway Administration (FHWA 2005) defines "pavement preservation" as a "*program employing a network level, long-term strategy that enhances pavement performance by using an integrated, cost-effective set of practices that extend pavement life, improve safety and meet motorist expectations*." In order for this program to be effective, it must address pavements while they are still in good condition and before the onset of serious deterioration, by selecting the most effective treatment for the pavement condition and applying it at the right time. This will ensure the pavement is restored to its original or reasonably high conditions; thus postponing or avoiding the substantially higher cost of rehabilitation and reconstruction.

A wide variety of pavement preservation treatments have been developed and applied to pavement throughout the country and worldwide to extend the pavement service life and delay the need for rehabilitation or reconstruction. Pavement preservation treatments offer a myriad of benefits including (i) cost saving where a typical treatment can roughly cost a fraction of the cost of rehabilitation or reconstruction, (ii) a green technology where preservation treatments produce fewer emission than that produced by rehabilitation treatments and reduce stress on the environment, and (iii) sustainability where some preservation treatments (primarily those including recycling options) save precious natural resources. Other benefits include (1) reduced user costs, (2) improved safety by reducing construction duration and minimizing duration of lane closure and disruption to normal traffic flow, and (3) improved overall network health by maintaining good pavement condition (Hicks and Stroup-Gardiner 2009).

One of the most effective pavement preservation treatments is slurry seal. Slurry seal has been in use as a maintenance (preservation) treatment in a large number of application areas pertaining to paved surfaces of public roads, highways, and airports. The main ingredients used in the production of slurry seal mixture are: (1) asphalt emulsion, (2) aggregate, (3) water, (4) mineral filler, and (5) additives. As a maintenance treatment, a slurry seal effectively provides several benefits to an existing pavement by improving the functional characteristics of the pavement surface. These benefits include (MTAG 2007):

(1) Sealing sound and oxidized pavements,
(2) Restoring surface texture by providing a skid-resistant wearing surface,
(3) Improving waterproofing characteristics of the pavement,
(4) Correcting raveling of affected asphalt pavements, and

(5) Providing a new surface where weight restrictions preclude the use of heavier overlays (e.g., bridge decks), or where height restrictions are a problem (e.g., overcrossings).

Some pavement problems that cannot be addressed with a slurry seal include surface profile, potholes, and cracking. Additionally, slurry seals do not improve the structural capacity of the existing pavement.

Slurry materials mixture must have free-flowing characteristics with such consistency to allow it to spread easily over and bond securely (adhesively) to the existing pavement surface. Slurry seals are typically placed at ambient temperature as a relatively thin surface treatment of a thickness that is usually 1 ½ time the largest size of its component aggregate. As the water evaporates, a product is formed with surface characteristics resembling those of hot mix asphalt. In order to achieve these benefits, slurry seals have undergone significant improvement over the years in areas pertaining to component materials ingredients, production, and placement methods. Some of these are discussed in the following:

a. Some improvements in component materials included the introduction of improved emulsifiers (Caltrans 2004) and the use of polymers and special additives added to the asphalt emulsion to improve mixture properties. Rubber polymer modified emulsion (RPME) has also been recently introduced into the production of slurry seals to enhance their properties. RPME is composed of emulsified asphalt, recycled crumb rubber, and other additives (in lieu of the standard asphalt emulsion) that provide additional advantages to both the slurry seal and the environment.

b. Further improvements aimed at ensuring consistent and uniform quality of slurry through the highly-controlled precise production of Central Mix slurry and field construction using innovative placement pavers.

RUBBERIZED EMULSION AGGREGATE SLURRY (REAS)

The Rubberized Emulsion Aggregate Slurry (REAS) material was invented and patented in 1994 as an effective scrap rubber tire-consuming preservation and maintenance surface treatment technology. The REAS mixture is improved through the use of rubber polymer modified emulsion (RPME), crushed graded aggregate, water and set control chemical additives and stabilizers. The formulation and chemistry of the REAS is complex and covered by a number of patents (CalRecycle 2009). It should be noted here that the terms of these patents have expired and that REAS is now a public domain technology.

REAS Components

In the following, a brief description of the main components of the REAS (Rubberized Emulsion Aggregate Slurry) is provided.

Asphalt emulsion. The asphalt emulsion in REAS is composed of emulsified asphalt and crumb rubber. The emulsified asphalt is the bituminous material uniformly emulsified with water and an emulsifying or stabilizing agent. The asphalt emulsion breaks onto the

pavement surface through heterogeneous or homogenous flocculation and the asphalt particles coalesce into films, creating a cohesive mixture (MTAG 2007). When the mixture is totally cured by losing its water, it transforms into a hardwearing dense-graded asphalt/aggregate mixture that strongly bonds to the existing pavement.

The granulated crumb rubber mixed with the asphalt emulsion is recycled from scrap tires. For a high-quality REAS product, the crumb rubber must be free from fabric, wires and other contaminants, dry and free flowing, and have a specific gravity between 1.15 and 1.20. The granulated crumb rubber gradation must meet the following requirements:

- 100% passing the No.16 (1.18 mm) sieve,
- 95% passing the No. 20 (900 µm) sieve, and
- Maximum of 1% passing the No. 200 (75 µm) sieve.

In order to prevent rubber particles from sticking together, calcium carbonate or talc may be added to the crumb rubber up to 4% by weight of rubber. The RPME must contain between 0.55-0.65 lb. of crumb rubber per one gallon of RPME. For high-performance and long lasting product, the rubber polymer modified emulsion (RPME) used in REAS must meet the requirements given in Table 1.

Table 1. Requirements for polymer modified emulsion (RPME) used in the production of Central Mix REAS.

Property	Test method	REAS Emulsion Requirements	
		Minimum	Maximum
Viscosity@25°C, Brookfield, Model RVT #6 Spindle@10 RPM (Centipoise)@60 sec	ASTM D2196	2,000	–
Weight, lbs./gallon@25°C ± 5°C	ASTM D1475	8.4	–
Residue by Evaporation, w%	ASTM D6934	50	–
Test on Residue	–	–	–
Softening Point, °F	ASTM D36	160	–

The percent of RPME in REAS depends on the four REAS types (will be discussed below) and must meet the values shown in Table 2.

Table 2. Typical percent of RPME in central plant-mixed REAS slurry.

	Type Fine	Type I	Type II	Type III
Pounds per gallon of REAS	11.0	13.0	13.5	14.0

Aggregates. The aggregate used in the slurry seal must be of such physical characteristics suitable for use in slurry seal mixes. This includes the compatibility of the aggregate with the emulsion to ensure long term adhesive and cohesive properties. The aggregates must be 100% crushed rocks that have fractured faces in order to provide for a stable interlocked matrix. The surface of aggregate must be rough to ensure a strong bond with emulsions. Freshly crushed aggregates have a higher surface charge than aged (weathered) aggregates which improves bonding and reaction rates between the emulsion and aggregate surfaces.

REAS Types

There are four basic types of REAS varying in their aggregate gradations, primarily the aggregate top size (maximum aggregate size), and percentage of the rock in other sizes. The four types are designated as Type Fine, Type I, Type II, and Type III; where Type Fine is finest and Type III is the coarsest.

Table 3 shows the aggregate gradations used in the four types of REAS. The selection between the four types depends on the surface condition of the pavement, the required target thickness of the slurry, the preferred texture of the finished surface (e.g., more texture is for roads with higher speed to provide a better skid resistance), and project economics.

Table 3. Caltrans Slurry Seal Aggregate Gradations (from Greenbook 2012).

Sieve Sizes	Percentage Range Passing Sieves			
	Type Fine	Type I	Type II	Type III
3/8 inch (9.5 mm)	100	100	100	100
No. 4 (4.75 mm)	100	100	90-100	70-90
No. 8 (2.36 mm)	95-100	90-100	65-90	45-70
No. 16 (1.18 mm)	75-92	65-90	45-70	28-50
No. 30 (600 µm)	50-75	40-60	30-50	19-34
No. 50 (300 µm)	35-50	25-42	18-36	12-25
No. 100 (150 µm)	15-30	15-30	10-24	7-18
No. 200 (75 µm)	10-20	10-20	5-15	5-15

The fines fraction (passing No. 200 sieve) in the four types of slurry seal mixes is essential in forming a mortar with the residual asphalt to bind the larger stones in place; thus creating a cohesive stable hardwearing mix. The four types of REAS seals are classified by the amount of residual asphalt required by the mixture and the areas of application that the REAS type is most effective:

1. *Type Fine REAS (very fine):* This type of REAS is the finest type of all REAS types with aggregate mostly passing No. 16 sieve (1.18 mm). Type Fine REAS is used for maximum crack penetration and sealing pavement surfaces of low volume traffic areas subjected to low wear damage.

2. *Type I REAS (fine):* It is a fine type of slurry with most of the aggregate smaller than the No. 8 sieve (2.38 mm), but not as fine as the Type Fine REAS. It provides a fine textured surface. Type I REAS is generally limited to lightly trafficked areas such as minor roads and parking lots. It is also used on urban and residential neighborhood streets with low traffic and light aircraft airfields including runways. This type of REAS is basically used to fill small surface cracks to maximum penetration and provide a thin surfacing for the existing pavement. Sometimes, Type I REAS is used as a final treatment for asphalt concrete overlays, chip seals, or other surface treatments, and especially characterized by its high color retention capability.

3. *Type II REAS (general):* This is the most commonly used type of gradation in slurry seals. This type of slurry is coarser than both the Type Fine and Type I slurry types with a maximum aggregate size of 9.5 mm with some aggregate (up to 6%) retained

on No. 4 sieve (4.76 mm). Type II REAS provides a medium-textured surface. It is generally effective for asphalt concrete roadways and surfaces with moderate to heavy traffic such as arterials and surfaces exhibiting moderate to severe raveling and loss of matrix due to aging and oxidation. Type II REAS is mainly used on most urban streets. Type II is very effective in improving skid resistance of existing asphalt pavement.

4. *Type III REAS (coarse):* This type is the coarsest of the four types of REAS with an appreciable amount (up to 30%) of aggregate retained on No. 4 sieve (4.76 mm). Type III REAS provide rough-textured surface, and is most suitable for heavy trafficked arterials streets and state highways. This type of slurry is most effective for filling minor surface irregularities and defects, correcting raveling and oxidation, and restoring surface friction (MTAG 2007). Because of its coarser gradation, Type III REAS is also effective in filling slight depressions to prevent water accumulation that causes vehicle hydroplaning. Type III REAS is also used for temporary fix for a bad situation such as damage caused by heavy traffic loads, as well as to improve such roadways' aesthetics.

The general requirements for the aggregate used for the various types of REAS are listed in Table 4. The sand equivalent (SE) test determines the amount of claylike materials or clay size fines in the aggregate mix. A minimum SE value is specified to limit the permissible quantity of claylike or clay size fines in the aggregate. The soundness test (also called durability test) determines the resistance of the aggregate against repetitive exposure to wet and drying cycles.

Table 4. Aggregate requirements for the various slurry seal types (from Greenbook 2012)

Test	ASTM Test Method	Requirements	
		Minimum	Maximum
Sand Equivalent	D2419	55	–
Soundness (5 Cycles), %[1]	C88	–	15
[1] To be run on the material retained on the No. 4 (4.75 mm) sieve graded from the source.			

REAS PRODUCTION AND APPLICATION

The success of REAS treatment relies on a number of factors and activities that are considered key to a successful construction project. These include: (i) proper surface preparation, (ii) project selection where the REAS is most effective when placed on structurally sound pavements, (iii) successful mix design, (iv) spreading equipment performs properly and calibrated, (v) mix produced accurately and according to the desired proportions and aggregate gradation at the central plant, (vi) proper workmanship and application technique, (vii) weather conditions are favorable, (viii) specifications precisely followed, and (ix) traffic kept off until seal has cured to avoid tracking.

Central Mix REAS is delivered to order to the job site in finished slurry mixture previously prepared at a central plant and ready for placement continuously on the pavement using a REAS distributer truck. A spreader box is attached to the rear of the truck so that the slurry mix can be deposited from the tank for spreading onto the pavement. A water tank and spray

bar are also built into the truck, at both the front and rear, to dampen the pavement before application of the material. The material is spread directly behind the truck using a mechanical-type squeegee distributor. Figure 1 shows the simple operation of placement of Central Mix REAS on pavement.

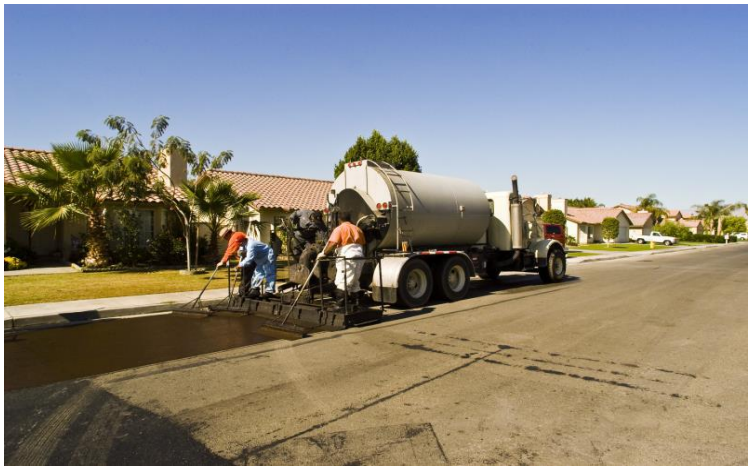


Figure 1. The simple operation of spreading Central Mix REAS on residential street

Central Mix REAS is placed at ambient temperature (or slightly above) on the prepared surface of the existing pavement in relatively thin layer. For ideal application, the ambient temperature must be at least 50°F and rising. The existing pavement must be cleaned by sweepers immediately ahead of the spreader truck. If needed, the pavement surface can be wetted with water prior to the application of REAS material. The slurry spreader box must be equipped with flexible material in continuous contact with the existing pavement and capable of controlling the rate of flow of the slurry. The application rate is dependent on the surface texture of the existing pavement (e.g., existing pavement with a high degree of distressed areas requires more slurry than a pavement with lesser distressed areas). The spreader box must have adjustable width and strike-off height, and be capable of controlling and providing uniform spreading. In areas inaccessible to the spreader box, hand squeegees and other equipment are normally used for spreading the slurry and removal of accidental spillage. As the water evaporates, the REAS quickly develops surface characteristics similar to those of structural asphalt concrete.

For most projects, the agency typically provides sweeping, traffic control, and traffic striping and contractor provides all materials, equipment, and labor. Special trucks carrying Central Mix REAS are dispatched, at order, from plant locations to various job sites.

PROJECT SELECTION

Central Mix REAS is a high quality performance preservation treatment and is used for a wide range of application areas. Since 1994, Central Mix REAS has been successfully used on residential and city streets and parking areas, state highways, as well as on airport runways and taxiways. For an ideal performance, however, it is crucial that this pavement preservation treatment be applied on the right project at the right time (MTAG 2007). Emphasis on project selection is crucial to success of surface treatment, and therefore, it is

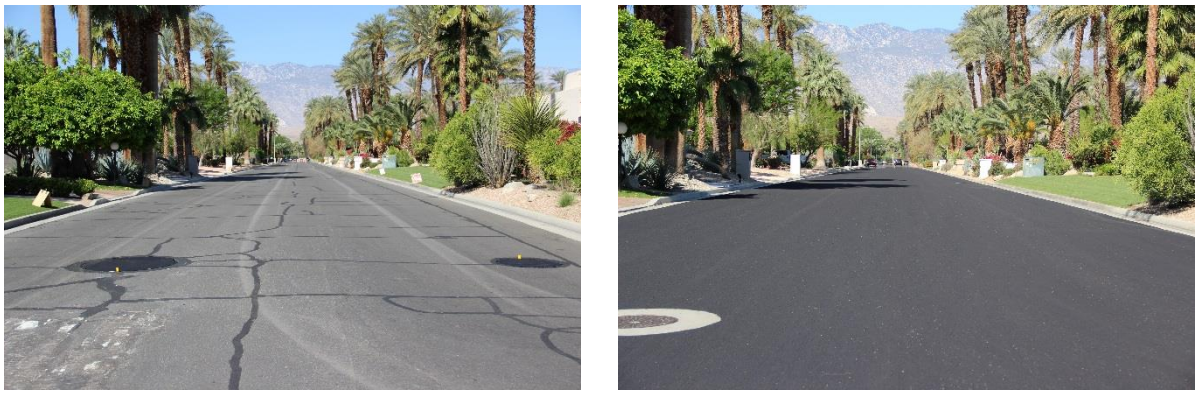
also important for REAS application. Pavements that are most suitable to receive Central Mix REAS are those free of serious distresses including potholes and significant cracking. Therefore, Central Mix REAS must be better instituted as preservation (preventive) treatment before any significant deterioration had occurred on the pavement. Besides it's superiority as a preventive treatment, Central Mix REAS may be used as a corrective maintenance treatment of asphalt pavement surfaces with minor distresses. For pavements exhibiting potholes and cracks, pre-treatments such as patching, digouts, and crack sealing are effective to improve structurally weak localized areas prior to application of Central Mix REAS. Additionally, surface irregularities that adversely affect ride quality such as ruts, waves, humps, and crown deficiencies must be repaired before placement of Central Mix REAS.

Besides pavement condition, traffic volume affects the Central Mix REAS type selection. Table 5 shows criteria in terms of annual average daily traffic (AADT) and depending on the amount and type of repair needed for selecting gradation type of slurry seals for the project (MTAG 2007). Table 5 can also be used as the criteria for selecting Central Mix REAS type that will be most effective for the project (note that Type I in Table 5 can also be used for Type Fine).

Table 5. Selection criteria for REAS type (from MATG 2007).

APPLICATIONS	AGGREGATE TYPE		
	I	II	III
Void Filling	●	●	
Wearing Course (AADT) < 100	●	●	
Wearing Course (AADT) 100 – 1,000		●	●
Wearing Course (AADT) 1,000 – 20,000			●
Minor Shape Correction (0.4-0.8 in [10-20mm])			●
Application Rates in pounds of dry aggregate per square yard	8 - 12	10 - 15	20 - 25

Figure 2 shows photos of pavement condition before and after application of Central Mix REAS has been placed.



Before treatment **After treatment with REAS**

Figure 2. Before and After of Central Mix REAS

As a preservation treatment, Central Mix REAS application is most effective for pavements in good structural condition exhibiting only low severity surface distresses. However, for structurally sound pavements with moderately severe surface distresses (such as cracks, moisture damage, rough texture, oxidation and raveling), a double Central Mix REAS system has been found to be especially effective. In this double Central Mix REAS system, Type III Central Mix REAS (3/8" minus gradation) is placed first on the existing pavement, and after it has fully cured, it is capped with a Central Mix Type II REAS (1/4" minus gradation). The double REAS treatment system is considerably less costly than employing conventional hot mix overlays, and offers an ideal solution for strained budget to repair pavements, whether on residential streets or heavily trafficked highways, before further deterioration forces agencies into more costly rehabilitation or reconstruction.

BENEFITS OF CENTRAL MIX REAS

Rubber Emulsion Aggregate Slurry (REAS) has become widely accepted pavement preservation surface treatments over the last two decades, owing to the vast number of benefits and cost saving that this slurry offers over the life of project. Central Mix production of REAS has further improved the REAS seal performance due to the enhanced quality of the mix that can be achieved in the central plant. As a result of the successful use of REAS in various application areas, its specification was incorporated in 1998 into the Standards Specifications for Public Works Construction (also known as the Greenbook) where to date more than 200 cities, counties, and agencies in the State of California have adopted the Greenbook as their standard. REAS has received numerous awards as a green technology; among which are:

- The Los Angeles County Quality and Productivity Committee Award, Special Presentation for Creativity and Innovation for the El Monte Airport Rubberized Slurry Seal-1995 Award.
- The National Association of Counties, 1995 Achievement Award Winner, Los Angeles County, California.
- 1995 Award Program for Excellence in Transportation, County of Los Angeles, Department of Public Works.
- Caltrans Excellence in Transportation, 1996 Awards Program, Category 6-System Operations, Project-Rubberized Asphalt Slurry Seal.
- The 2001 City of Los Angeles, Bureau of Street Services Productivity Program Award.

The benefits that Central Mix REAS can offer are grouped into various categories related to the pavement performance, environment, cost to agency and tax payer, construction, and others. These benefits include:

1. **Pavement durability benefits**:
    - Central Mix REAS restores the pavement wearing surface, protects the asphalt surface from oxidation, renews oxidized (age-hardened) asphalt, and reduces potential of raveling and loss of matrix; thus securing the pavement structure against structural deterioration and extending the roadway service life.
    - Central Mix REAS seals off the pavement structure against moisture and air intrusion; thus protecting the structural asphalt surface from deterioration

caused by the environment (air/water) and the structural base, subbase and subgrade layers from softening due to water intrusion.

- Central Mix REAS technology provides an exceptional bond between the emulsion and aggregate in the mix, which results in a durable product under traffic and environment stresses.
- Central Mix REAS offers an excellent surface texture for paint striping.
- Central Mix REAS extends the pavement service life. Serviceability life expectancy of REAS has been reported to range from 5 to 7 years when the seal is placed as true preventive maintenance treatments on suitable roads.
- Because of the high amount of asphalt emulsion of the Central Mix REAS's [typically 2-3 times that used in other slurry seals; Sandwick (1998)], REAS provides for a longer life in the field compared to many other types of treatments.
- Because Central Mix REAS contains more than double the amount of recycled rubber compared to other rubber based slurry systems, it provides for additional performance benefits besides those related to scrap tire recycling. The increased rubber content in the asphalt binder improves its rheological properties including those affecting the slurry's permanent deformation and fatigue cracking at high temperature and cracking at low-temperature. Additionally, the antioxidants and other anti-aging components in the crumb rubber help reduce aging of the asphalt binder.
- The Central Mix REAS specifications require a minimum of 15.0 % to 26% asphalt residue content (asphalt binder content after evaporation of water from the emulsion). The asphalt residue content in REAS is more than double the amount of residue required for other systems and other rubber modified slurry seal systems. The higher asphalt residue in REAS provides for a thicker film of asphalt binder to protect the aggregates which provides for higher resistance of the asphalt binder against oxidative aging in warm climates, against moisture damage in wet climates, and against raveling under traffic action. In turn, these benefits result in a long-lasting field performance of REAS compared to other slurry seals.
- Central Mix REAS is effective in addressing a number of minor asphalt pavement distresses such as asphalt raveling, aging, and oxidation, and also reduced skid resistance. Unlike other slurry seals, some more serious distresses can be addressed with the use of double Central Mix REAS systems (Type II over Type III).

2. Safety benefits:

- Central Mix REAS provides a superior macro-texture to the pavement which increases its surface friction and enhances its skid resistance especially at higher traffic speeds.
- Central Mix REAS provides a uniform texture and an extremely long-lasting deep black color, and an improved pavement appearance due to the carbon black that is added to the rubber tires when they are manufactured. REAS retains its black color much longer than many other surface treatments due to

the recycled tires and longer than other rubberized slurry seals because it contains high amount of emulsion. REAS has a superior resistance to fading, with color retention reported to exceed five years after application (Sandwick 1998). The long-lasting color contrast is important for (i) painted traffic striping and markings that remain sharp and bright; thus providing a long term enhanced visibility and safety for motorists, and (ii) color contrast offers an enhanced aesthetic finish value for the property or the roadway.

- Central Mix REAS is transported and applied at ambient (or slightly higher) temperature and produces no fumes or particulates; making it a lot safer for workers and the public than many other preservation treatments.

3. Environmental benefits:

- Central Mix REAS is considered a scrap rubber tire-consuming strategy that provides for environmental sustainability by utilizing waste tires in the mix. About 290 million scrap rubber tires are discarded annually in the U.S. and disposed of traditionally at landfills; posing a great concern on the environment (EPA 2014). Figure 3 shows waste tries at a landfill. In California alone, over 40 million waste tires are generated each year (CalRecycle 2014).

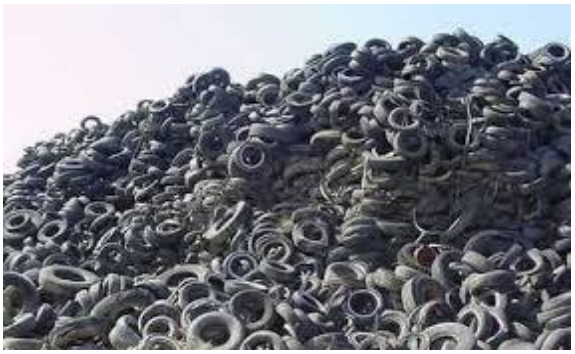


Figure 3. Waste tires disposed of at landfills.

Annually, several hundred thousands of discarded tires are used in the annual production of REAS. One gallon of REAS contains over one half pound of recycled tire rubber. In terms of number of tires diverted from traditional disposal in landfills, one mile of pavement (12 ft wide) treated with central mix REAS utilizes between 100 to 250 scrap tires depending on REAS Type (Fine, I, II, III), with the double REAS system utilizing 395 scrap tires (PMI 2014). Since 1996, REAS treatments have recycled over 15 million pounds of used tires (ISSA 2009); a significant amount of waste tires that could have ended in already crowded landfills or worse illegally burned. Table 6 below shows the approximate number of tires recycled (or diverted from traditional landfill disposal) for the various REAS types.

Table 6. Approximate Number of scrap tires recycled in each REAS type (PMI 2014)

REAS Type	Number of recycled tires per lane mile (12 ft wide)

Type Fine	100
Type I	123
Type II	162
Type III	233
Double REAS (Type II over Type III)	395

- Besides reducing the stress on the environment and demand on landfills, the added recycled crumb rubber in REAS replaces a portion of valuable natural aggregates; thus preserving this valuable non-reneawable natural resource.
- Unlike some other slurry seals, Central Mix REAS is a true green ecologically-responsible product and an environmentally friendly treatment. This is because the REAS product is water-based and no fumes produced during its manufacturing or application; thus generating less pollution to the environment. REAS is also transported and applied at ambient temperature therefore saving energy as no heat would be required to keep the asphalt at high temperature before and during its application.

4. Cost benefits:

- Central Mix REAS develops very few to no scuff marks on the slurry seal typically caused by tires reacting to power steering (Sandwick 1998). Therefore, the use of REAS does eliminate the need to frequently return to the project site for frequent application of new slurry seals in areas affected by tire scuffing and the resulting raveling.
- The long term performance of Central Mix REAS considerably reduces the frequency of maintenance activities and helps the agency and tax payer utilize scarce roadways funds on other projects.

5. Construction benefits:

- Central Mix REAS offers a preservation treatment that is applied quickly, and the newly resurfaced pavement can be reopened to traffic in typically 2-4 hours after application.
- Central Mix REAS is manufactured and applied at ambient temperature; therefore no smell or hydrocarbon emissions commonly produced with heated asphalts is noticed. This makes REAS application neighborhood-friendly.
- Because Central Mix REAS can be produced with as fine aggregate as 1/8-inch, it can be applied very thin on the pavement surface. This allows REAS to set in the same amount of time as the non-rubber product without the addition of an accelerator or retarder often necessary with non-rubber seal products (Sandwick 1998).

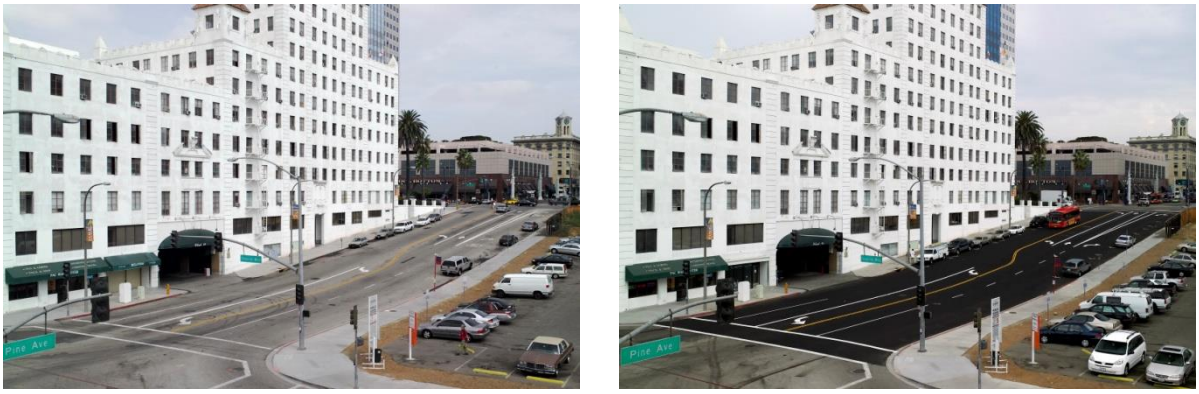
6. Other benefits:

- Neighborhood surveys show that 94% of homeowners believe that an improved pavement appearance through the blacker surface offered by

Central Mix REAS increases neighborhood pride (PMI 2014) and improves property value.

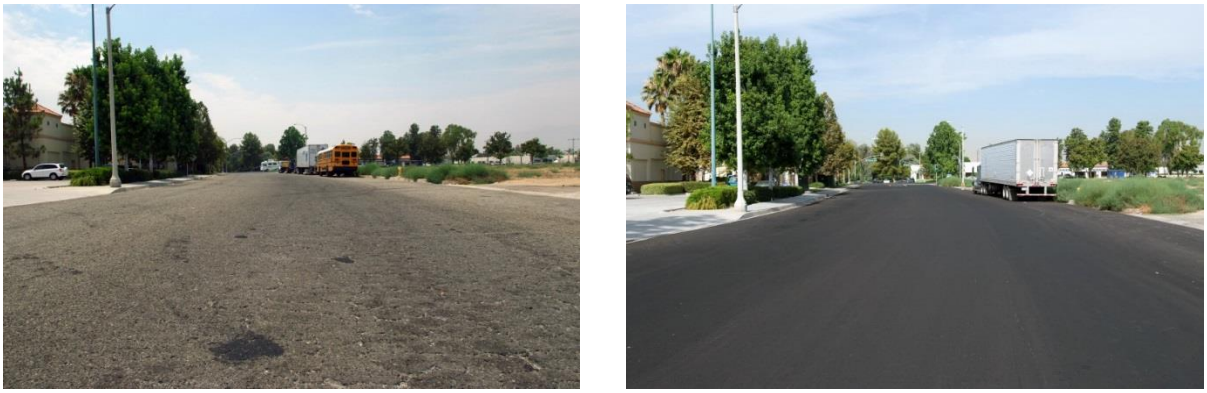
- Because Central Mix REAS is applied in thin layers it offers a minimum loss of curb height compared to other types of surface applications. Also, manhole and other structure adjustments are typically not required.
- Using recycled tires in Central Mix REAS in quantities that exceed those used in other surface treatments is environmentally a more effective way to use tax payers' money.
- Central Mix REAS does not "track" in hot weather.

Figure 4 shows before and after photos of busy streets carrying heavy trucks treated with Central Mix REAS. Also, Figure 5 shows a close up of a high traffic pavement treated with Central Mix REAS.



Before treatment **After Type II Central Mix REAS**

Figure 4. Before and After treatment with Type II Central Mix REAS



Before treatment **After treatment with Central Mix REAS**

Figure 5. Street Before and After application of Type II Central Mix REAS

PERFORMANCE

As a high performance slurry surface treatment, REAS has been successfully used in the last 20 years for the preservation and maintenance of asphalt pavements on streets, highways, parking lots and airport runways and taxiways. Central Mix REAS is an engineered product produced with high quality in a precisely controlled process at a central mix plant. This is done by blending polymer modified asphalt binder emulsion containing graded recycled tire

crumb rubber with crushed and properly graded aggregates, along with other stabilizers and performance additives, all proportioned to provide a long lasting performance under effect of traffic and environment for the surface treatment. Besides being an eco-friendly product, Central Mix REAS uses high amounts of asphalt binder, polymer and recycled tire rubber resulting in better looking and longer lasting roadways. This section presents some details on the use and performance of Central Mix REAS in California.

Cities and Counties

Since its release in 1994, REAS has been well received by cities and counties throughout the state of California and has demonstrated excellent results as an efficient method to extend pavement life and reducing life cycle costs in maintaining pavements. As discussed previously, REAS offers many benefits to the agency, public users, and the environment that far outweigh those achieved using other surface treatments. In Southern California, REAS has been successfully applied to pavements to protect the asphalt of streets, highways, parking lots, and airports. The City of San Diego and the Los Angeles County Public Works Department have applied extensive amounts of REAS to streets and highways (Construction 2005). The Los Angeles County Department of Public Works has been applying REAS on their pavements for many years, and their test results indicated that REAS "*has the potential to decrease the maintenance frequency for recoating asphalt surfaces while providing a highly skid-resistant surface*" (Construction 2005). The Central Mix REAS is continuing to provide uniform coverage and maintain its dark color.

At the El Monte Airport in Los Angeles county, all the paved surfaces including runways, taxiways, airplane tie-down areas, and parking lots (Figure 6) were treated with REAS in year 1994 and has shown no wear even though after 4 ½ years after application (date of the study), and the slurry seal continued to provide uniform coverage and maintain its dark color (Construction 2005). The Los Angeles County Public Works placed this coat of REAS on the pavement surfaces at El Monte Airport after the original REAS treatment, then eight years old, was still dark and the asphalt paved surfaces were still well sealed (Construction 2005). At the time of the second treatment in 2001, the Los Angeles County Public Works indicated that other products used to sealcoat the airport pavements did not perform as well as Central Mix REAS over a comparable time period.

Figure 6. El Monte airport in Los Angeles county treated with REAS in 1994

CENTRAL MIX REAS SPECIFICATION

In order to achieve high performance REAS, specifications that control the quality of materials needed in the production of REAS and placement method are essential. REAS specifications exist in California and the most commonly employed include:

1. 2012 Standard Specifications for Public Works Construction (Greenbook) Section 203-5.5 titled "Rubberized Emulsion Aggregate Slurry" (Greenbook 2012), and
2. Caltrans nSSP titled "37-2 Rubberized Emulsion Aggregate Slurry" (Caltrans 2014).

Currently, Central Mix REAS is only produced to order at Central Mix Plants and delivered to the job sites ready for placement. The specifications and Materials Safety Data Sheet (MSDS) for Central Mix REAS are available upon request.

CONCLUDING REMARKS

This paper presented an effective preservation/maintenance technology employing Central Mix Rubber Emulsion Aggregate Slurry (REAS) for sealing existing pavements and improving their surface condition. Central Mix REAS reduces the rate of deterioration by sealing the pavement from water, preventing further oxidation, correcting raveling, and improving skid resistance. REAS has been around for many years and has helped many agencies extend the life of existing pavements and stretch their available funds to cover more projects. REAS is cold mix blend produced by mixing high quality crushed graded aggregate, specialized asphalt emulsion, SBR latex polymer, graded ground tire rubber, break control additives and stabilizers according to a pre-determined mix design prepared in the laboratory. Mass production of REAS is performed in central mix plants for achieving maximum quality and many other benefits, and delivered to order to the jobsite for immediate application in cold form to existing pavement surfaces. Central Mix REAS is available in four aggregate gradations (Type Fine, Type I, Type II, and Type III); each is most effective for surface and traffic conditions. Central Mix REAS was found to outperform many other surface treatments including conventional slurry seals, has a proven record of performance in public works, and has been successfully used on residential and urban roadways, state highways, parking lots, and airport runways and taxiways. The application of Central Mix REAS treatments offers many great benefits mainly pertaining to pavement durability and long term performance, cost effectiveness, safety, environmental sustainability, and offers a long-lasting aesthetically pleasing finish. One of the main environmental benefits of using REAS is utilizing scrap rubber tires. For every lane mile of roadway treated with REAS, between 100-300 scrap tires are recycled (depending on REAS gradation). Therefore, besides being an effective pavement preservation treatment, REAS creates a new use of waste tire rubber that diverts significant number of scrap tires from traditional disposal at landfills and putting these recycled tires back on the road.

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