Recent Advancements in the Application of Foamed Asphalt Technology for In-Place Recycling of Highly Degraded Pavements over Poor Quality Aggregates and Subgrade Materials

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Ron Skaggs, PE, GE, General Contractor Lic. 732026-A, Condor Earth Technologies, Inc.

INTRODUCTION

Cold foam in-place recycled asphaltic concrete (CFA) is now a well established methodology for in-place recycling of distressed pavements with a successful track record of completed projects throughout California. This track record includes many general engineering and specialty subcontractors with experience in conventional uses of CFA. Initially, projects in California were most commonly applied to rural applications, with Caltrans using CFA successfully on numerous rural highways in northern and southern California. While the application of CFA in California is still not common, successful projects can now be shown by example to interested parties, both private and public agencies, where CFA has successfully been implemented. For those readers that are not familiar with the basic procedure, it consists of grinding and pulverizing the existing pavement section and addition of "foam" bituminous materials, followed by compaction using conventional compaction equipment (sheepfoot compactor, steel drum roller, pneumatic rollers) to construct a new stabilized pavement subgrade over which an asphaltic concrete (AC) overlay is typically applied. Typical treatment depths vary from 6 to 12 inches, with typically 2 to 4 inches of AC overlay to complete the project.

This paper will discuss several case studies that are good examples of innovative applications of CFA in urban and rural areas using pavements which conventionally would not be considered as good candidates for CFA treatment due to their existing pavement and/or aggregate base (AB) thickness, and/or the quality of the underlying subgrade.

CASE STUDIES

City of Stockton, San Joaquin County – Stagecoach Road

The City of Stockton desired to provide an improved roadway surface and increase the existing traffic index (TI) from the original design of 5 to a minimum of at least 8. The existing 4-inch thick AC was highly degraded, but overlaid a deep aggregate base and aggregate sub-base layer (23 to 26 inches) that was part of the original construction. The aggregate base and aggregate sub-base layer overlaid a weak subgrade with an R-Value of 10. In order to minimize off-haul and maintain grade at the existing curb and gutter, Condor proposed that CFA consist of the following steps:

1. Pre-pulverize the entire width of the roadway to a depth of 12 inches, gutter pan to gutter pan after the lowering of existing utility covers.
2. Re-grading the pulverized material to form a new crown at a higher center elevation in order to provide a minimum of 3½ inches of cut for the AC overlay at the gutter pan.
3. Re-compaction of the entire pulverized depth to the full depth of the pulverized material to a minimum specified compaction of 93 percent.
4. Foam treatment of the upper 9 inches of the new pulverized material for the entire width of the roadway followed by fine grading and compacting of the stabilized subgrade.

5. Placement of 3 inches of AC overlay to match existing gutter elevation on each side of the roadway.
6. Re-placement of the utility covers at the new grade elevations.

The project was successfully implemented and allowed the City to eliminate off-hauling of all materials, eliminate import of new aggregates, and limit import of new material to the new AC overlay. In addition, the re-crowned roadway provides enhanced drainage, yet did not raise the grades so significantly that it inhibits traffic or appears visually unacceptable.

City of Chico, Butte County – East Avenue Road Improvement

The City of Chico had a good track record of successfully using CFA for several projects throughout the city in areas that did not require grade control (i.e. were not tied to existing elevations of curbs and/or gutters). The City wished to expand their application of CFA to projects where existing grades had to be met either at the parking lane curb and gutter pan or at the center median while maintaining the existing cross fall, or in some cases, eliminating two different cross falls to form a uniform cross fall. In addition, several streets had thin sections of AC and AB which would not facilitate the conventional use of CFA and yield the final desired TI while maintaining the grade restrictions. Condor worked with the City and the contractor to develop a system where the subgrade was incorporated into the CFA design to facilitate maintaining the grade elevations. A good example of this technique was applied to East Avenue, which was an existing four lane arterial street, heavily used by regional and local traffic. Typical existing conditions included, 2½ to 4½ inches of AC over 7 to 9 inches of AB over native soils with a R-Value ranging from 11 to 32. In addition, the City wished to have a final TI of 9.5, a relatively high index to be achieved by these restrictions. Condor developed a CFA design that incorporated 22 percent AC grindings, 45 percent AB, and 33 percent subgrade soil treated with 2 percent Quicklime to eliminate reaction to clay size particles and provide a stable lime treated base beneath the CFA section. The final construction steps consisted of the following:

1. Spread 2 percent Quicklime on the road surface at a rate of 4 ± 0.2 pounds per square foot across the entire work area.
2. Grind and mix 18 inches of the existing pavement section. Provide mellowing time to allow chemical reaction of the Quicklime of at least 24 hours. Process and compact the lime treated material to develop lime treated base (LTB). The bottom 6 inches should be compacted to 95 percent relative compaction, using the CAL 216 method.
3. Mill and remove the upper 3½ inches of mixed material (LTB) or sufficient material to account for the final AC pavement thickness.
4. CFA treat the top 9 inches of the remaining mixed material with 3.0 percent (2.9 lb/sq ft) PG 64-16 asphalt oil mixed in accordance with project specifications and compacted to a minimum of 98 percent relative compaction, using the CAL 216 method. The CFA should be full width of the existing roadway, one direction at a time, followed by compaction of the material to allow traffic on the roadway at the completion of the CFA process.
5. Re-crown and re-grade as necessary to shape the road for final grading. This can be done one direction at a time to allow for single-direction traffic through the project site during the construction period.
6. Perform final rubber-tired compaction and “slushing” of the finished surface.
7. Overlay the CFA with 3-inch minimum AC, placed in accordance with current Caltrans standards and compacted to a minimum of 95 percent relative compaction.

This methodology provided a final section that consisted of a 3-inch AC overlay, 9-inch CFA section, 6-inches of LTB consisting of a mixture of lime treated native soils, grindings, and AB, underlain by the native soils. Using this three-layered-section approach, the design was able to achieve the desired TI of 9.5. All of the work was performed at night and each day the road was open to traffic with minimal impact to businesses and residences adjacent to the roadway. Based on scheduling, the drivers traveled on LTB, or CFA prior to the final placement of the AC overlay. In addition to the road being available to the traffic during daylight hours, traffic was allowed to continue in adjacent lanes during the nighttime, and traffic was allowed to cross on cross streets while construction operations proceeded.

City of Chico, Butte County – Fifth Avenue

A similar mix design was prepared for the Fifth Avenue, City of Chico project for essentially the same grade and material restrictions sited above in the East Avenue project. Typical existing sections consisted of 3½ to 5 inches of AC over 0 to 7 inches of AB. The thinnest section included a section with 3½ inches of AC over 0 inches of AB. Condor prepared a CFA design based on 22 percent AC grindings, 28 percent AB, and 50 percent subgrade soils with the addition of 3 percent Quicklime added prior to the addition of PG 64-16 asphalt oil. The lime treated mixture to be foamed was provided a mellowing time of 24 hours in the laboratory prior to treatment. The construction sequence consisted of the following:

1. Spread 3 percent Quicklime on the road surface at a rate of 6 pounds per square foot across the entire work area.
2. Pulverize and mix 18 inches of existing pavement section.
3. Mill and remove the upper 3½ inches of material.
4. CFA treat the top 9 inches with 2.5 percent PG 64-16, compacted to 98 percent relative compaction.
5. Re-crown and re-grade roadway as necessary.
6. Perform rubber-tired compaction and "slushing".
7. Overlay the CFA with a minimum of 3-inch minimum AC.

Several other projects have been performed within the City of Chico using similar techniques where the existing roadway geometry constrained the final elevations either at the gutter line or the median or both. On a variety of projects, similar techniques as described above were used. In some cases, the AC was initially ground and removed from the project site prior to pulverizing because the grindings had a higher value than the subsequent CFA mixture. Once the initial thickness was removed through grinding, the subgrade was stabilized using CFA with the addition of either lime or in some cases fly ash and cement, and then overlaid with a final AC thickness. With the techniques described in these two projects and others, a final section can be designed that incorporates some percentage of the existing subgrade materials when lime treatment or other treatment is used to help stabilize the subgrade material, especially when the subgrade material is primarily a sandy material.

County of Yolo, Woodland – County Road 99

The County of Yolo, northwest of Sacramento, has used CFA successfully on numerous projects throughout the county over the past 10 years. With their comfortable track records, the County wished to apply CFA technology to their County Road 99 project. County Road 99 had a unique set of constraints associated with it due to its past use. This included a long history as a county rural roadway, the recent improvement of a bridge crossing, and recent addition of a bike lane with a new pavement section and one edge of the northbound lane. As a result of these conditions, the existing pavement conditions varied widely and included 1½ to 4½ inches of AC, underlain by 1½ to 3 inches of AB/oiled (historical aggregate placed on roadways and oiled through numerous applications), and AB/non-oiled from 0 to 9 inches. As a result, the total thickness of potential material that could be used in a CFA mix design varied from 4 inches to 11½ inches, depending on the location. These materials were underlain by dark brown sandy silt classified as ML. Condor recommended preparing a design that included the addition of new Class II AB (ABII) on the existing roadway surface prior to CFA treatment, in order to provide sufficient aggregate to develop a good quality CFA mix. The amount of aggregate to be added to the roadway was developed based on the results of laboratory testing with various proportions of existing site materials mixed with cement and the addition of AB materials using a TI of 7.0 for design. These mixtures were then tested in the field through two test strips at various locations along the roadway to verify that the CFA mixes would perform adequately in the various road locations. Based on these results, the following recommendations were provided for the addition of AB:

1. Between CR29 and Dry Slough, place 6 inches (compacted thickness) of ABII on the existing pavement section.
2. Between Dry Slough and Willow Slough, place 2 inches (compacted thickness) of ABII on the existing pavement section.
3. Between Willow Slough and CR27, place 4 inches (compacted thickness) of ABII on the existing pavement section.

The construction sequencing consisted of the following steps:

1. Place ABII layer on the road surface as stated above.
2. Spread 1.5 percent by weight cement Type II on the ABII surface at rate of 1.8 ± 0.2 pounds per square foot across the entire work area.
3. CFA treat the top 11 inches of the existing pavement section and the added ABII layer with 3.0 percent by weight (3.6 ± 0.2 pounds per square foot) PG 64-16 asphalt oil mixed in accordance with project specifications and compacted to a minimum of 98 percent relative compaction, using CAL 216 method.
4. Re-crown and re-grade as necessary to shape the road for final grading.
5. Perform final rubber-tired compaction and "slushing" of the finished surface.
6. Overlay the CFA with 3-inch minimum AC, placed in accordance with project specifications and current Caltrans standards and compacted to a minimum of 95 percent relative compaction.

The project was successfully completed and has exceeded the County's requirements. The County felt the design was appropriate because it eliminated off-hauling of any materials, utilized the existing materials, and augmented the materials based on the actual conditions in the field.

County of Yolo, Woodland – County Road 27

The County of Yolo desired to improve County Road 27 to accommodate additional traffic for the future using a design TI of 8.5. The native soils underlying this site are silty clay with an R-value of 5. Working with the County, Condor developed an innovative “high fines” CFA mix design in order to minimize the addition of new materials, such as aggregate base or AC grindings. The existing roadway section consisted of 2½ to 4 inches of AC over 1¾ to 6½ inches of AB/oiled over 0 to 10 inches of AB/non-oiled, for a total thickness range of 6½ to 17 inches. Two mix designs were generated with the following proportions:

- Mix No. 1 contained 19 percent AC, 8 percent oiled AB, 6 percent non-oiled AB, and 67 percent subgrade, with the addition of 4 percent Quicklime added to the mixture prior to CFA treatment; and
- Mix No. 2 consisted of 17 percent AC, 17 percent oiled AB, 44 percent non-oiled AB, and 22 percent subgrade, with 4 percent Quicklime added prior to CFA treatment.

The results of the indirect tensile strength (ITS) laboratory tests for Mix No. 1 were 82 psi dry and 40 psi soaked with 3 percent oil, and for Mix No. 2 80 psi dry and 71 psi soaked with 3 percent PG 64-16 asphalt oil. The significant difference between the soak strength for the two designs can be accounted for based on the difference of percentage fines between the two mixes. Based on the results of the ITS testing, Condor recommended that a test strip be conducted using the following:

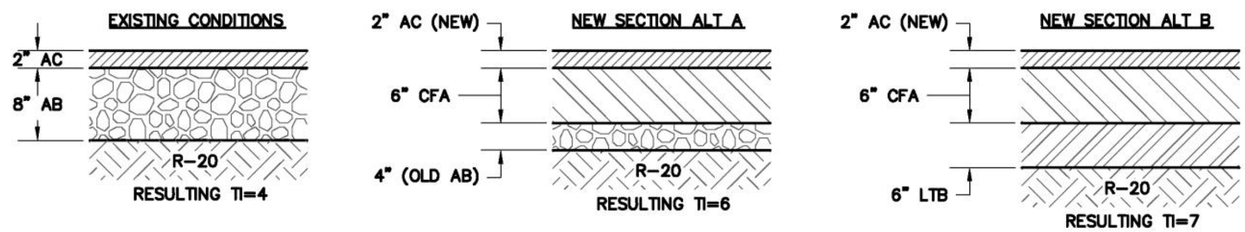
1. Spread 4 percent Quicklime on the road surface at a rate of 7.5 pounds per square foot across the entire work area.
2. Pulverize 18 inches of the existing pavement of the subgrade section, and provide a mellowing time of at least 36 hours to allow chemical reaction of the Quicklime. Remix, process, and compact the material. The bottom 7 inches was recommended to be compacted at 95 percent relative compaction using the CAL 216 Method.
3. CFA treat the top 11 inches of the remaining mixed materials of the existing treated road section with 3 percent PG 64-16 asphalt oil.
4. Re-crown and re-grade as necessary to shape the road for final grading.
5. Perform final rubber-tired compaction and “slushing” of the finished surface.
6. Overlay the CFA with 4 inch minimum AC, compacted to 95 percent relative compaction.

During the initial test strip, the contractor was unable to achieve the desired 95 percent compaction on the lower 7 inches of the lime treated section (LTB). The contractor achieved an average of 92 percent compaction, and then proceeded to perform the CFA treatment at the prescribed rate. The CFA portion of the test strip was then compacted, and the compaction again did not achieve the desired specification of 98 percent, but an average 95 percent. ITS tests performed on the materials collected during the test strip indicated that the strength was achieving approximately 90 percent of the desired strength specified in the contract. As a result, the contractor performed a second test strip, and the compaction of the LTB was monitored as compaction passes were counted. Again, the desired 95 percent compaction could not be achieved due to the wet condition of the underlying subgrade which was not providing the necessary to support needed to achieve the desired compaction. An average compaction of 94 percent was achieved in the best areas, and typical values ranged from 92-93 percent. The CFA treatment of the second test section included an area that received an additional 2 inches of aggregate base added to the surface. This area achieved 95 percent compaction, but typical values of the CFA were 92-94 percent. Again, the ITS laboratory results were achieving approximately 90 percent of the desired strength originally specified for the project. As a result of these construction difficulties and other contract restrictions, the project was converted to a cement treated subgrade project and completed as such with the original treatment depths left at their original thicknesses followed by a 4-inch overlay. While this project provided an excellent opportunity to see the difficulties involved in such a design with the existing soft subgrade condition, it also indicated that when performing a CFA design outside the conventional norms, a degree of flexibility needs to be provided in the contract specifications for adjustments under these conditions. In part because this flexibility was not provided in the contract, the contractor and County did not feel it was appropriate to continue to the completion of the project with the original CFA design.

TYPICAL DESIGN FOR RECENT ADVANCEMENTS IN CFA DESIGN

Based on the above case studies sited, a successful record has been established for CFA design where some portion of the CFA mix includes underlying subgrade material that is in a sandy condition. Figure 1 illustrates what a typical design might be for existing materials of 2 inches AC, over 8 inches of AB, over native subgrade with an R-Value of 20, yielding a TI of 4 when newly constructed. Two alternative CFA designs are provided in Figure 1 which show 2 inches of AC, over 6 inches CFA, over 4 inches of the old AB (see Alternate A), and 2 inches AC, over 6 inches CFA, over 6 inches of LTB (see Alternate B). These two alternates provide a new TI of 6 and 7, respectively. Therefore, this type of design application can be used to enhance existing roadways with relatively thin existing sections, and increase the traffic index significantly to accommodate new traffic loading of high truck loads and greater commuter traffic. Several types of sections can be developed in a preliminary design prior to the laboratory CFA mixture to confirm the initial design concept.

Figure 1



CONCLUSION

Based on the case studies provided, recent advancements have been made in the application of CFA projects in California for in-place recycling of highly degraded pavements over poor quality aggregates and subgrade materials. As additional projects are performed that utilize these new designs, new lessons will be learned and additional designs can be developed and verified in the field through test strips. Flexibility in the specifications needs to be included when new design concepts are being verified in the field.

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THE AUTHOR

Ron Skaggs holds a Bachelor of Civil Engineering from Fresno State, and a Masters in Engineering from UC Davis, 1985. He is a licensed Civil and Geotechnical Engineer in California, and holds a California General Engineering Contractor Class A license with a Hazardous Materials Certificate. His responsibilities at Condor Earth Technologies, Inc. include Division Manager of the Stockton office and Jamestown cold foam asphalt (CFA) and construction materials laboratory. He has been with Condor 15 years and is currently serving on the Board of Directors. His professional activities include Past President of the Central Valley Chapter of the American Society of Civil Engineers, President of the San Joaquin Engineers Council, and Co-Chair of the Stockton Chamber of Commerce Manufacturing and Industrial Subcommittee. Ron is married to his wife, Karen, of 26 years and has six children. They make their home in Stockton and Ron is a Little League baseball umpire in his spare time.

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