Reconstruction and Widening of David to Boquete Highway in Panama using Foamed Asphalt

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The David to Boquete project involved the widening of an existing two lane road into a four lane highway between the city of David and the town of Boquete in western Panama, a distance of 38.8 Km (24.1 miles). The new four lane highway was built with the two southbound lanes constructed on new alignment and 32.8 Km (20.4 miles) of the two northbound lanes largely constructed using the existing two lane roadway.

The Ministry of Public Works of Panama (MOP) awarded a Design-Build contract to build the four lane roadway to Constructora Urbana S.A. (CUSA) in 2010. The original design build concept for the rehabilitation of the existing pavement was to mill and overlay the existing pavement, and widen the shoulders. During construction the original plan to mill and resurface the old roadway was changed to consider recycling the existing pavement in place as a bound base and surfacing with a hot mixed asphalt pavement.

A number of in-place recycling options were considered and a foamed asphalt reclaiming process was selected because of the extremely wet environment in which the project was situated.

The paper describes the site conditions, design approach and the construction procedures used in recycling the existing pavement in place to produce the bound base for a new pavement for a major four lane reconstruction project in Panama.

*Keywords: Recycling, Hot Mixed Asphalt, Foamed Asphalt Reclaiming.*
Introduction
The David to Boquete project involved the widening of an existing two lane road into a four lane highway between the city of David and the town of Boquete in western Panama, a distance of 38.8 Km (24.1 miles). The new four lane highway was built with the two southbound lanes constructed on new alignment and 32.8 Km (20.4 miles) of the two northbound lanes largely constructed using the existing two lane roadway. The first 6 Km (3.7 miles) of the northbound lanes was constructed on new alignment parallel to the southbound lanes.

![Figure 1. Project Location](image)

The Ministry of Public Works of Panama awarded a Design-Build contract to build the four lane roadway to Constructora Urbana S.A. (CUSA) in 2010. The original design build concept for the rehabilitation of the existing pavement was to mill and overlay the existing pavement, and widen the shoulders. However, CUSA wanted to explore reclaiming the existing pavement as a potential means of providing a more structurally competent and long lasting pavement while staying within the basic scope of the design build project. Also, there were cost considerations as savings were expected as the amount of base course production, transportation and placement was considerably reduced. Finally, as part of the contract, CUSA was required to provide maintenance services on the new road for a period of three years after completion. This paper describes the design considerations, construction processes and control used in reclaiming the existing pavement using foamed asphalt to build a new bound base which was then overlayed with Hot Mixed Asphalt (HMA) to reconstruct the existing roadway.

Overview
The first 6 Km of the project included the construction of the new four lane roadway on all new alignment west of the present roadway, and the reconstruction of the old existing two lane roadway which was required to serve local traffic only. Where the new roadway meets the old alignment at about station 6K+000 the two roadways come together and were constructed as a combined boulevard section through the town of Los Algarrobos. From there the alignment separates again with the northbound lanes constructed on the existing roadway and the southbound lanes constructed on new independent alignment. The new roadway continues to alternate between a boulevard section and separated alignment as it passes through different towns along the route terminating in a boulevard section as it approaches the town of Boquete.
The existing roadway consisted of about 10 cm to 20 cm (4 to 8 inches) of hot mixed asphalt (HMA) over 10 to 27 cm (4 to 11 in) of unbound base course. The thicker sections of base course are found in the middle section of the project. There are limited shoulders and little or no drainage of the pavement section. The following figures shows images of typical pavement conditions in the more urban areas and the rural sections along the project. There were occasional ditches but the material between the pavement and the ditches was made up of predominantly native soil.

![Figure 2 Photographs of typical, preconstruction roadway conditions.](image)

Existing Pavement Conditions
The existing pavement exhibited a range of pavement distress from short areas with little or no distress to fairly common longitudinal cracking in the wheel paths to areas of extensive alligator cracking in the wheel paths. Most of the longitudinal cracks had been sealed and in areas of extensive alligator cracking there can be extensive patching as seen in Figure 2.

There are intermittent shoulders throughout the project and long areas with no shoulders or ditches. The more distressed areas of pavement are found where pavement drainage is nonexistent which also can be seen in the right photograph in Figure 2. One of the most significant design features that was incorporated into the planned reconstruction of the existing pavement was the construction of new shoulders. This called for excavating next to the existing paved roadway section and placing a thick section of unbound base that extends to the fill slope or in-slope of the ditch. Where this form of open drainage could not be provided then internal drainage using longitudinal drains was used instead.

The subgrade soils ranged from silty sandy gravels (AASHTO A-2-4) to clays (ASHTO A-7). Well over fifty Dynamic Cone Penetrometer (DCP) tests were taken along the project indicating CBR values ranging from 2 to 100 with an average CBR value of 27 and an average minimum CBR value of 8.5.

Traffic studies indicated that the current traffic volume was about 2,600 Average Annual Daily Traffic (AADT) with 11 percent trucks and an estimated truck loading of 300,000 Equivalent Single Axel Loads (ESALs) a year. With a 3 percent growth rate that would produce an estimated 12 year design loading of 4 million ESALs². The project specifications required a 12 year pavement design.
Pavement Recycling Options

There were three primary options considered for cold recycling the existing pavement. All three considered Full Depth Reclamation (FDR). In the FDR process a reclaimer is used to pulverize the existing pavement and base and mix in an asphalt emulsion, foamed asphalt, or Portland cement to construct a bound base. If asphalt materials are used they are blended within the reclaimer unit. When Portland cement is used it is spread on the surface of the pavement ahead of the reclaimer and then blended into the material as part of the pulverizing process.

The use of an emulsified asphalt was carefully considered. The advantage of the use of the emulsified asphalt was the long history of use in countries like the United States\(^1\). The primary issue with using the emulsified asphalt is the amount of water that comes with the process and the potential difficulty of getting the water out of the material in a very wet environment. Typical annual rainfall in the area is around 320 cm (126 inches) and the average humidity is around 85 percent. There is a dry period from January through March during which the rain fall decreases significantly, for the rest of the year rain is an almost daily event, particularly in the afternoons. Even during the dry period the relative humidity stays high so that evaporation of the water out of the emulsion mixture would be problematic. The use of asphalt emulsion was eliminated because of the climate in which it would be used.

The use of Portland cement as a binder was also considered. Its use fit the wet environment better but it also requires a cure period of up to 5 days before trucks can drive on the cement treated base. In scheduling the staging of the construction around the dry period for final paving the cure time requirement also became an issue.

The use of foamed asphalt fit the environmental and staging constraints of the project best. The use of the foaming process introduces a small amount of water into the process to create the foamed asphalt but significantly less than that which comes with the emulsified asphalt. A diagram of the process is shown below in figure 3.

![Figure 3 Diagram of foam injection process. (Wirtgen\(^3\)](image)

In this process a small amount of water is injected into hot asphalt as it is injected into the reclaiming chamber. The resulting foaming process causes the hot asphalt to expand and coat the millings coming from the cutting head. The process is similar to using asphalt emulsion except that the emulsion process uses much more water as the vehicle to coat the millings with asphalt. Though the foamed asphalt pavement remains tender for a short period after construction normal
traffic can be returned to the pavement within 1.5 and 2 hours. With all issues considered the foamed asphalt system was the clear choice for this project.

The final pavement design for the project was as follows.

<table>
<thead>
<tr>
<th>Hot Mixed Asphalt</th>
<th>7.50 cm</th>
<th>(3 inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foamed Asphalt Base</td>
<td>12.5 to 22.5 cm</td>
<td>(5 to 9 inches)</td>
</tr>
<tr>
<td>Existing Agg. Base</td>
<td>10 to 20 cm</td>
<td>(4 to 8 inches)</td>
</tr>
<tr>
<td>Total</td>
<td>35 cm min.</td>
<td>(14 inches)</td>
</tr>
</tbody>
</table>

It should be noted that this design satisfied 1993 AASHTO Guide for the Design of Pavement Structures for traffic loadings ranging from 5 million to 12 million ESALs\(^2\). The reason for the higher possible loading values is that the reclaiming process requires cutting thru the existing asphalt pavement so that the resulting bound base is thicker which increases the potential design life. There were some sections where that asphalt pavement thickness was thinner so the reclaiming process incorporated more of the underlying base rock to make the bound base.

The typical roadway section for the northbound roadway, where it was on independent alignment, is shown in Figure 4 below. Note that the shoulder section was reconstructed first to drain the pavement before the reclaiming operation.

![Figure 4 Typical roadway sections showing general pavement configuration](image)

**CONSTRUCTION PROCESS**

**Mix Design**

The mix design for the foamed asphalt base was developed by Consultant Gustavo Matallana I.C MSc;\(^2\) AllConsult S.A. and Wirtgen - Resansil. CUSA and AllConsult did a site investigation that included 56 DCP tests, 78 Benkelman Beam tests, 30 cores of in situ asphalt concrete samples and 60 in situ samples of base/subbase. Also over 150 locations along the road were sampled in order to determine the existing thicknesses and depths of different materials in the existing pavement.

As the existing conditions in both soils and existing pavements varied along the road, several tests were conducted in order to determine the optimum thicknesses of recycled pavement; asphalt percentage to be included and the addition of Portland cement. Testing included:
• Different proportions of existing materials: RAP + base (50% & 50%), (75% & 25%); RAP + base + sub-base (50%, 25% & 25%).
• Different proportions of asphalt cement AC-30: The following quantities were tested; 2.0%, 2.4%, 2.6%, 2.8%.
• Addition of Portland cement: Certain areas along the roadway indicated a lack of fine material. A proportion of Portland cement was added to aid in obtaining the proper gradation.
• Mixture sample testing: Mixture samples were prepared with a Marshall Hammer and cured as follows; 3 cores were submerged in water for 24 hours at ambient temperature and 3 cores were put in the oven for 72 hours at 40 C.
• Test Results: Final results ITS results were obtained using the Marshall equipment.

Table 1 indicates the final thicknesses of recycled pavement, % of asphalt; addition of Portland cement and proportion of RAP + base:

<table>
<thead>
<tr>
<th>Road Section</th>
<th>Subsections</th>
<th>Recycled thickness (mm)</th>
<th>AC 30 (%)</th>
<th>Portland cement (%)</th>
<th>Average RAP (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.1 0k+000 4k+600</td>
<td>125</td>
<td>2.2</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.2 6k+000 6k+000</td>
<td>200</td>
<td>2.2</td>
<td>1</td>
<td>75</td>
</tr>
<tr>
<td>2</td>
<td>2.1 6k+000 8k+550</td>
<td>225</td>
<td>2.2</td>
<td>1</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>2.2 8k+550 14k+500</td>
<td>125</td>
<td>2.2</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>3 14k+500 24k+250</td>
<td>125</td>
<td>2.2</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>4.1 24k+250 24k+850</td>
<td>125</td>
<td>2.8</td>
<td>1</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>4.2 24k+850 25k+450</td>
<td>125</td>
<td>2.2</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.3 25k+450 25k+550</td>
<td>125</td>
<td>2.8</td>
<td>1</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>4.4 25k+550 25k+750</td>
<td>125</td>
<td>2.2</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.5 25k+750 25k+850</td>
<td>125</td>
<td>2.8</td>
<td>1</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>4.6 25k+850 26k+050</td>
<td>125</td>
<td>2.2</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4.7 26k+050 26k+150</td>
<td>125</td>
<td>2.4</td>
<td>1</td>
<td>75</td>
</tr>
<tr>
<td>5</td>
<td>5 26k+150 38k+800</td>
<td>125</td>
<td>2.2</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

Table 1 – Summary of thicknesses; % asphalt; additions and % RAP per sections

Construction Sequence
Prior to the startup of construction, the proper selection of equipment was made to fit the project and site requirements. As this was the first time CUSA was performing this type of work, new or almost new low hour equipment was used. CUSA selected the following fleet to perform the works:

- Recycling Machine Wirtgen WR2400.
- Motor grader CAT 120M
- Sheep foot compactor CAT CP56
- Smooth wheel compactor CAT CS74
- Smooth wheel compactor CAT CS533E
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- Pneumatic compactor CAT PS150
- Water tanker – 3,000 Gals
- Asphalt Tanker – 10,000 Gals

Once daily operations started and the “paving train” was set in motion, in order to assure a proper execution of the works, it was important to keep track of:

- Depth of recycling on both sides of the recycling equipment.
- Optimum mixing speed of 6 to 12 m/min; depending on depth, type of materials being recycled and addition of Portland cement.
- Alignment of equipment.
- Temperature of asphalt cement not to be below 160\(^0\) C (320\(^0\) F).

The resulting paving train can be seen in Figure 5.

Figure 5. Photograph of paving train during construction. (CUSA)

Traffic Management
The roadway being rehabilitated was in continuous operation so the management of traffic was a key component in the execution of the project. The contractor faced several scenarios which are described as follows:

1. Rural Areas: For these areas, rehabilitation took place after then new alignment had been completed. This way, traffic would be moved from the lanes under rehabilitation, to the new lanes. Construction operations then took place with a minimum traffic interference.

2. Urban Areas: In urban and town areas, alternate roadways and detours were used. CUSA made sure that some of these local roads were rehabilitated in order to
accommodate a larger volume of traffic. Traffic going thru the urban areas was then managed using the alternate roads and detours, avoiding traffic inside the work areas.

3. Local Traffic within both Rural and Urban Areas: Especially in urban areas (and in some cases rural areas), it was impossible to keep traffic out of the construction areas as the work may take place right in front of commercial and residential areas on which access had to be maintained. For this reason CUSA always rehabilitated one lane at a time instead of the entire width of the road. Flagmen were stationed at both ends of the stretch under construction to manage local traffic moving in the lane not being worked on. Additional safety personnel was placed inside the stretch in order to assist both, local traffic and equipment operators.

As part of the reclaiming process the paving crew was continually assisted by a Quality Control team responsible for performing all required testing to meet project specifications. Materials for testing were collected at the site from immediately behind the recycling machine as it was produced. A total of twelve samples were prepared for every 500 linear meters (140 ft.) of roadway recycled. Six samples were prepared at the site with a manual hammer and six were prepared at the laboratory with mechanical equipment. The samples were then tested for Indirect Tensile Strength under both wet and dry conditions.

During construction, the Quality Control team was responsible for performing the following tests on site:

- Moisture content on the foam mix. Test at the beginning of the works and every 500 linear meters (1640 ft.).
- Compaction with Nuclear Densometer. Minimum compaction was set at 98% of modified Proctor (AASHTO T180). Three tests every 500 linear meters. (1640 ft.)
- Compaction with sand cone equipment: This test was performed in order to correlate results obtained with the Nuclear Densometer. One test for every kilometer (0.62 mile).
- Standard Proctor: One test every 500 linear meters. (1640 ft.)

The following figure shows a summary of number of test results obtained during construction.
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Since the Indirect Tensile Strength (ITS) is a good indicator of the quality of the base material a large number of samples were taken and tested during production. The following figure shows the average dry and wet ITS values for each month of production.

The minimum average ITS values targeted during production was 250 kPa (36.3 psi) for the dry samples and 175 kPa (25.4 psi) for the wet samples.

Figure 8 shows the same information by Km of roadway.
Figure 8. Summary average ITS Test, and Compaction by kilometer

There were some locations where the wet and dry ITS values did not meet the target values but those were quickly corrected by the contractor. The average ITS values for the project was 300 kPa (43.5 psi) dry and 242 kPa (35 psi) wet which clearly exceed the target values.

The construction of the foamed asphalt phase of the project was planned to be executed during the 2012 dry season in Panama, which runs from December until May in order to maximize production by avoiding stoppages due to rains and also to keep water off the recycling process. Because of the dry conditions experienced, CUSA was able to achieve average production rates of 2,500 m$^2$ (2,990 yd$^2$) per day, with peak production rates of 4,500 m$^2$ (5,383 yd$^2$) of completed foamed asphalt base. Total production over the course of the project was 235,371 m$^2$ (281,544 yd$^2$) of foamed asphalt base. The pavement design estimate for total asphalt quantity to be used was 378,925 gal, and the actual total quantity of asphalt used was 392,243 gal.

It is much too soon to confirm that the actual service life of the pavement will meet the design criteria of 12 years. However, the overall quality of the finished product and the performance of a portion of the foamed asphalt base exposed to traffic during the wet season indicates the pavement should provide very good service, maybe as much as 20 or more years with occasional surface renewal. It should be noted that the design traffic was for 12 years was 4 million ESALs, which set the minimum foamed base thickness. The actual base thickness constructed varied but was sufficient to carry from 5 million ESALs to 12 million ESALs.

The contractor tried to make sure that all of the foamed asphalt base was covered with one lift of HMA before the wet season started. There was one section of base however that was not covered with HMA during the wet season. No damage was experienced in that section over the rainy season. The following figure 9 shows a photograph of that section and the completed project. This also tends to indicate the bound base as constructed should perform very well and provide long service.
The construction went smoothly largely due to the excellent guidance provided by the equipment supplier and their consultant who helped get the project started with very detailed guidance. The continued testing and monitoring of the process insured that there was no surprises and the occasional changes in the material being processed were accommodated in the process.

CUSA successfully completed the project in August 2013. Some delays occurred during the execution of the project but these can be attributed to issues related to land acquisition and utilities relocation, all the responsibility of the Ministry of Public Works. It is important to point out that most of the reconstructed roadway had to be opened to traffic during the construction period, therefore the pavement has been subjected to traffic for a period of over 2 years at this time and appears to be in excellent condition.

SUMMARY AND CONCLUSION

CUSA the contractor on the David to Boquete highway reconstruction project chose to reclaim the existing HMA rather than milling off the material and using it either as fill or base material. A foamed asphalt reclaiming process was selected as the best option considering the wet environment and staging the construction around the limited dry season. This required putting traffic back on the reclaimed base as soon as possible and placing at least the first lift of the HMA wearing course during the dry season.

The contractor performed extensive testing of the existing pavement to develop the mix design and followed with detailed and continuous quality control testing to insure the production of a uniform and high quality foamed asphalt base.

The effort to build a high quality base and HMA surfacing is evident in the resulting pavement. Admittedly the new pavement has only been in place and in use for two years but there is no sign of any premature distress and the test results during construction indicates that the resulting pavement should provide a very long lasting pavement. The total thickness of bound material constructed on this project ranges from 20 cm to 30 cm. This thickness has the potential of producing a long life pavement which should provide 20 years of service and could provide 30 or more years of service with occasional renewal of the surface by milling and overlaying.

Figure 9 Photograph of Foamed Asphalt Base before paving resumed and when project was completed
Since this was the first foamed asphalt reclaiming project in Panama, CUSA and the Ministry of Public Works looked at other similar projects in Central America, to confirm that it could be used successfully in Panama. Based on the review of other projects and the successful outcome of this project CUSA, their consultant, and the Ministry of Public Works are working together to develop standard specifications for foamed asphalt reclaiming in Panama.

REFERENCES


