Granular Base Stabilization with Emulsion in Las Vegas, Nevada

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ABSTRACT

Washington Avenue in the City of Las Vegas was distressed such that reconstruction was needed. However, reconstruction is a timely and costly process, especially on a busy city street. An alternate method, base stabilization with asphalt emulsion, was evaluated and chosen for its structural capacity and its ability to save time and money. The pavement was evaluated using ground penetrating radar (GPR) and falling weight deflectometer (FWD). Trenches were cut for obtaining samples for mix design. The mix design evaluated an asphalt emulsion designed specifically for granular base stabilization (GBS). The pavement design and FWD testing determined that the stabilization process with an overlay met the load requirements of the project. The project proceeded by milling off the existing four or six inches (100-mm or 150-mm) of asphalt pavement, lowering utilities, grading the remaining aggregate base, blending water to the recommended moisture content from the mix design with a reclaimer, and injecting asphalt emulsion with the same reclaimer. After compaction and fine grading, the stabilized base was allowed to cure for four to eleven days, and a 5-inch (125-mm) hot mix asphalt (HMA) overlay was placed in two lifts. The city saved an estimated $322,661 by using GBS, approximately 30 percent savings, which allowed additional network rehabilitation to be constructed. Furthermore, construction time was shortened from 120 days to 40 days, 3000 fewer loads were trucked on and off the project, and 23,432 square yards (19,592 square meters) of waste were not generated. The impact on nearby businesses was reduced.

INTRODUCTION

Background

A street in the condition of Washington Avenue in Las Vegas is typically a candidate for reconstruction. The pavement had severe block cracking, fatigue cracking in the wheel paths, longitudinal cracking, patches, and minor rutting in the intersection areas. The asphalt surface thickness varied from 4 to 6 inches (100 to 150 mm). It was 30 years old and had been rehabilitated 14 years previous. It also had a low Pavement Quality Index (PQI), and a low AASHTO Structural Number. Washington Avenue was classified by the City as being in poor condition. Figure 1 shows the condition of a general section of the street. Reconstruction would reduce the variability of the roadway structure and provide options for the future maintenance. In the typical reconstruction process in Las Vegas, the existing asphalt and 18 inches (455 mm) of aggregate and subgrade is removed, and the utilities are temporarily lowered. Then 18 inches (455 mm) of Clark County (Nevada) Type II aggregate base is installed, and 6 inches (150 mm) of HMA is placed over the base.

FIGURE 1 Washington Avenue before rehabilitation.

The city of Las Vegas decided to try a different approach for Washington Avenue. The alternative to reconstruction was Granular Base Stabilization (GBS) with asphalt emulsion. GBS provides a much improved base that is strong enough for traffic before surfacing and improves crack resistance and reduces susceptibility to moisture damage. Granular base stabilization is a rehabilitation technique in which the existing base rock is uniformly pulverized and blended with asphalt emulsion to provide a structurally upgraded, homogeneous base layer. GBS consists of reclamation of the existing materials, adding more materials (when necessary), mixing, initial shaping of the resultant mix, compaction, final shaping, and application of a bituminous surface treatment or wearing course (*1*). Emulsion-stabilized bases provide flexible, fatigue resistant, and lower cracking-prone pavements (*2*). Asphalt emulsion is best suited for granular materials rather than for soils, and it binds the materials for improved cohesion and strength. GBS improves the pavement structure of bituminous and granular roadways. GBS is especially useful in areas that need to support higher traffic loads or to correct base problems while maintaining roadway geometrics. The GBS process has the advantages of building structure down into the pavement, re-using existing materials, and saving time and money. The process had little impact on existing utilities located within the roadway, therefore decreasing costs and potential cost over-runs.

Washington Avenue is an arterial five-lane city street in Las Vegas located near downtown. The project limits are between Rancho Drive on the west and Martin L. King Boulevard on the east, or approximately 0.8 miles (1.3 kilometers) long. There are two travel lanes in each direction, a center turn lane, and other turn lanes and bus stops scattered throughout the project. The street has a mix of residential housing, small businesses, a school, and a fire station. It consisted of curbs and gutters, four to six inches (100 to 150 mm), by design, of asphalt pavement and approximately 13 to 17 inches (330 to 430 mm) of aggregate base. Traffic is 15,500 average annual daily traffic (AADT) and approximately three percent trucks (primarily small trucks and buses), which results in a California Traffic Index (TI) of 9.

Objective

The objective of this project was to provide the City of Las Vegas with a stable, improved roadway while saving time and money relative to total reconstruction. The intent of this paper is to highlight the Washington Avenue project and illustrate the technical merits of in-place stabilization in a high traffic urban setting.

Scope

This paper describes the methods and equipment used on Washington Avenue in Las Vegas, NV to upgrade the roadway surface. There were five response variables/parameters used to quantify the improvements made through this rehabilitation procedure. These include: maximum normalized deflection, subgrade resilient modulus, effective granular modulus, effective pavement modulus, and effective structural number.

PROJECT

Pavement Evaluation

Before construction, the street was evaluated to determine its composition and to determine any weak areas that may need to be addressed. Stantec Consulting completed the detailed pavement investigation which included ground penetrating radar (GPR) to identify layer thickness, and falling weight deflectometer (FWD) testing to determine existing structural capacity (3).

Soil borings were taken at three different locations. Aggregate base and soil materials were classified according to ASTM D 2487 (4). Aggregate base thickness ranged from 13.5 inches to 19.5 inches (340 to 480 mm). The aggregate base material was found to be yellow-brown poorly graded sand with silty clay and gravel (SP-SC, GP-GC, and SP-SC); this was the material eventually stabilized. It had PI values of 7, 6, and 8. The soil under the aggregate base classified as GC, SM, or CL-ML with PI values of 28, 9, and 7, respectively. It had R-value strengths of 18, 35, and 13. Sixteen separate asphalt cores found the existing asphalt pavement ranged in thickness from 3.9 to 7.6 inches (100 to 190 mm).

GPR testing was conducted with equipment manufactured by Geophysical Survey Systems Inc (GSSI). Data was collected along the outer lane in the eastbound and westbound lanes in one-foot increments. Along the eastbound direction, there were three zones with an average asphalt thickness of 4.5 inches (115 mm), which was the predominant thickness in this lane. There were two zones at a thickness of 6.5 inches (165 mm). In the westbound lane, the predominant asphalt thickness was 4.5 to 4.75 inches (115 to 120 mm), with two zones between 6 and 7 inches (150 to 175 mm).

FWD testing was conducted using LTPP-SHRP calibrated equipment. Testing intervals were at 25 feet (7.6 meters). Four load drops were applied to the pavement at each location. The first drop was a seating drop of 9,000 pounds (4080 kilograms). The next three loads were 7000, 9000, and 12000 pounds (3175, 4080, 5440 kg). Nine geophones collected the deflection measurements. The offset values of the geophones from the center of the 12-inch (300-mm) plate were 0, 8, 12, 18, 24, 36, 48, 60, and -12 (inches). Pavement and air temperatures were recorded during FWD testing. Testing locations for FWD measurements are shown in Table 1. Results are compared to after-construction results as discussed below.

TABLE 1 FWD test locations

Test Section	Direction	Approximate station	Test Lane	Length, ft (meters)	Comments
LTP-1	West	55+50	Left (lane 2)	1,100 (335)	Start of section approximately 614.5 feet (187 m) east from center of Comstock Street
LTP-2	East	44+00	Right (lane 1)	225 (69)	Start of section approximately 260 feet (79 m) west from the center of Clarkway Street
LTP-3	East	30+00	Right	250 (76)	Start of section approximately 114.8 feet (35

			(lane 1)		m) east from the center of Carter Street
LTP-4	East	22+00	Left (lane 2)	150 (46)	Start of section approximately 21.7 feet (6.6 m) west from the center of Robin Street
RTL	East	54+67	Right (Lane 2)	300	Start of section approximately 532 feet (162 m) east from the center of Comstock Street. This section was thicker (approximately 6 inches or 150 mm))

Mix Design and Criteria

A mix design was completed from samples taken along various portions of the street. The design was performed in SemMaterials' Terre Haute, Indiana laboratory. The emulsion had an approximate asphalt residue of 65 percent, was cationic and formulated for the climate and to meet the specification requirements. It is designed for the GBS process in that less water is required in the existing base for dispersion and coating, and it cures faster for quicker return of traffic and quicker time for overlay compared to other asphalt emulsions.

The properties of the aggregate materials are shown in Table 2. The mix design results are shown in Table 3. Mixtures were compacted in a Superpave gyratory compactor at a 1.25° angle, 600kPa vertical pressure, and 30 gyrations. Afterward, they were cured in an oven at 40°C for 72 hours and then allowed to cool to 25°C. The criteria were established for this project but will be adjusted as the City gains more experience. The dashes in the table mean that there were no specific criteria for that particular material property.

TABLE 2 Aggregate properties.

Property	Criteria	Las Vegas Values
Maximum dry density, ASTM D 1557 Method C, lb/ft^3 (g/cm^3)	-	145.2 (2.326)
Optimum moisture content, ASTM D 1557 Method C, %	-	5.7
Optimum mixing water, %	50 – 75% of OMC	4.0
Sand equivalent, ASTM D 2419 Method B	-	27
Gradation (ASTM C 117 and C 136)	-	
1 inch (25 mm)	-	100
¾ inch (19 mm)	-	99
½ inch (12.5 mm)	-	95
3/8 inch (9.5 mm)	-	88
No. 4 (4.75 mm)	-	64
No. 8 (2.36 mm)	-	44
No. 16 (1.18 mm)	-	30
No. 30 (0.600 mm)	-	21
No. 50 (0.300 mm)	-	17
No. 100 (0.150 mm)	-	15
No. 200 (0.075 mm)	-	11.0

TABLE 3 Mix design results.

Emulsion content		4	5	6	7
Indirect tensile strength (ITS), ASTM D 4867 Part 8.11.1, 25°C, psi (kPa)	35 min. (240)	43 (296)	40 (275)	40 (275)	34 (234)
Conditioned ITS, ASTM D 4867, psi (kPa) (after 24-hour soak)	20 min. (135)	23 (159)	27 (186)	26 (180)	25 (172)
Resilient modulus, ASTM D 4123, 25°C, psi X 1000 (MPa)	120 min. (827)	441 (3041)	276 (1903)	224 (1544)	181 (1248)

Construction

The existing 4 and 6 inch (100-mm and 150 mm) sections of asphalt were removed by roto-milling so that the new overlay would match the existing curb line. Since the existing aggregate base was fairly dry, water was added using a Caterpillar R-350 reclaimer, which helped in obtaining an even dispersion of the emulsion. The target moisture content was within one percent of the mix design (four percent), which was below the OMC of 5.7 percent. Afterwards, the material was graded and compacted, and 5 percent emulsion was added. Emulsion was added over eight days, or four days for each half of the road. The reclaimer injecting emulsion is shown in Figure 2. The material in front of the reclaimer is the existing aggregate base.

A Caterpillar R-350 reclaimer with emulsion spray bar was used for emulsion injection and mixing to a depth of 6 inches (150 mm). The reclaimer had been calibrated off-site prior to the start of this project. The reclaimer pushed a distributor truck containing the emulsion. The reclaimer was followed by an Ingersoll-Rand DD-118 vibratory steel roller and an Ingram 9-wheel pneumatic-tired roller. A motor grader fine-trimmed the compacted stabilized material, and the material was rolled again with the steel roller.

The hot mix asphalt was a City of Las Vegas Traffic Category 1, Type 2, ¾ inch mixture made with AC-30. The design asphalt content was 4.1 percent and 4 percent air voids.

During construction, half of the road was closed for construction while traffic used the other half. Once the overlay was placed over the stabilized base, traffic was diverted to the new section, and the other section was constructed. The traffic did not drive directly on the emulsion-treated material. Emulsion was added over four days on the south side (east bound) of the road, from April 24, 2006 to April 27. The bottom lift of hot mix asphalt (HMA) was placed in one day on April 28, and the top lift was placed on April 29. Once traffic was diverted to the east bound lanes, the north side (west bound lanes) was constructed. Emulsion was added May 16 to 17 and May 24 to 25. The bottom and top lifts of HMA were placed on May 26, May 31, and June 1.

Station 11+50 was at the west end of the project. Dates, locations, and quantities of emulsion injection and HMA paving are shown in Table 4.

FIGURE 2 Washington Avenue during rehabilitation.

TABLE 4 Dates, locations, and quantities for project.

Date	Locations (stations)	Square yards (square meters) of emulsion injection	Emulsion, gallons (liters)	HMA, tons (metric tons)
April 24	11+50 to 29+50	6407 (5357)	22,225 (84,131)	
April 25	29+50 to 36+60	2700 (2258)	11,307 (42,802)	
April 26	36+60 to 49+00	4888 (4087)	20,011 (75,750)	
April 27	49+00 to 62+00	4000 (3345)	17,050 (64,541)	
April 28	11+50 to 62+00			3095 (2808) (bottom lift)
April 29	11+50 to 62+00			2197 (1993) (top lift)
May 16	62+00 to 47+37	5204 (4351)	22,350 (84,604)	
May 17	47+37 to 35+87	4092 (3421)	16,950 (64,163)	

May 24	35+87 to 20+37	5510 (4607)	21,997 (83,268)	
May 25	20+37 to 11+50	3222 (2778)	13,743 (52,023)	
May 25	62+00 to 36+50			1380 (1252) (bottom lift)
May 26	62+00 to 36+50			1412 (1281) (top lift)
May 31	36+50 to 11+50			1462 (1326) (bottom lift)
June 1	36+50 to 11+50			1371 (1244) (top lift)

Quality Control

Moisture Content

Moisture content was determined by a calcium carbide gas pressure tester, ASTM D 4944 (*4*). Target moisture content before emulsion addition was determined by the mix design to be 4.0 percent. A field tolerance of ± 1 percent was desired. Moisture contents measured from April 24 to May 16 ranged from 4.3 to 5.0 percent. Moisture measurements were not taken for the duration of the project but the base material was processed in the same way and was expected to be in this same range.

Emulsion Content

Emulsion content target was 6.0 percent, or 4.7 gallons per square yard (21 liters per square meters) by the laboratory design. The actual placed emulsion content, based on daily yields, was an average of 4.04 gallons per square yard (18.5 liters per square meter), or approximately 5.16 percent. The lower emulsion content was chosen since the mixture properties were not much different at 5.0 percent compared to 6.0 percent.

Density

Compaction testing was performed with a nuclear density gauge. The density from the gauge (direct transmission) was calibrated to the sand cone measurements, ASTM D 1556 (*4*). Samples for direct moisture measurements were taken for calibrating the gauge. Thereafter, the nuclear density gauge was used for measuring in-place density after finish rolling. A modified Proctor density test, ASTM D 1557 Method C (*4*), was established as the target dry density on each day of the project. Seventy-five nuclear density measurements were taken throughout the project, and the average was 98.3 percent of the dry density from the modified Proctor density results.

HMA Tests

HMA thickness and density values were verified by cores taken on June 2. The average thickness was 5.1 inches (130 mm) with a target of 5 inches (125 mm) (two lifts). The average density was 92 percent (percent of maximum theoretical specific gravity).

IMPROVEMENTS TO THE PAVEMENT

Five comparisons were made using FWD data from before the GBS procedure and after. These comparisons were used to determine the success of the rehabilitation (*6*). This testing was performed five to six months after the HMA overlay was completed.

The first comparison was made between the maximum deflection measured at the center of the load plate. This deflection is a function of the overall pavement layer stiffness and is also an indicator of the support capacity of the subgrade. A decrease in deflection is expected after rehabilitation. The percent decrease for each of the five sections tested was as follows: 57%, 53%, 58%, 54%, and 28% respectively. See Figure 3.

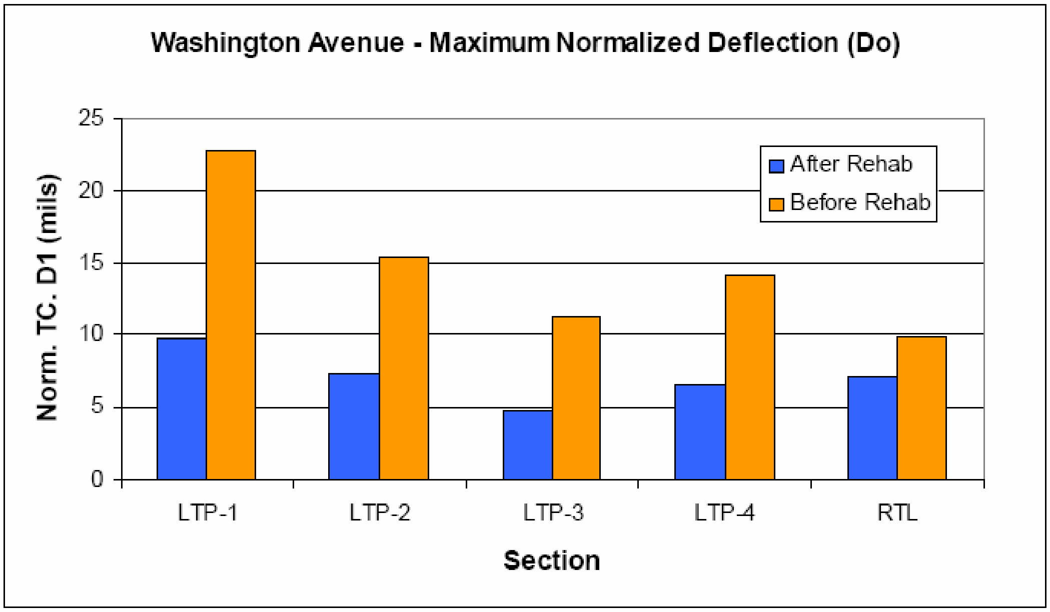

FIGURE 3 Comparison of maximum normalized deflection.

The second comparison made was the subgrade resilient modulus (M_r). There was no treatment carried out on the subgrade; therefore, change in subgrade resilient modulus was not expected. However, Figure 4 shows that there was an increase in the subgrade resilient modulus in each section tested. This was attributed to compaction by construction equipment. The percent increases were as follows: 45%, 19%, 17%, 27%, 45% respectively.

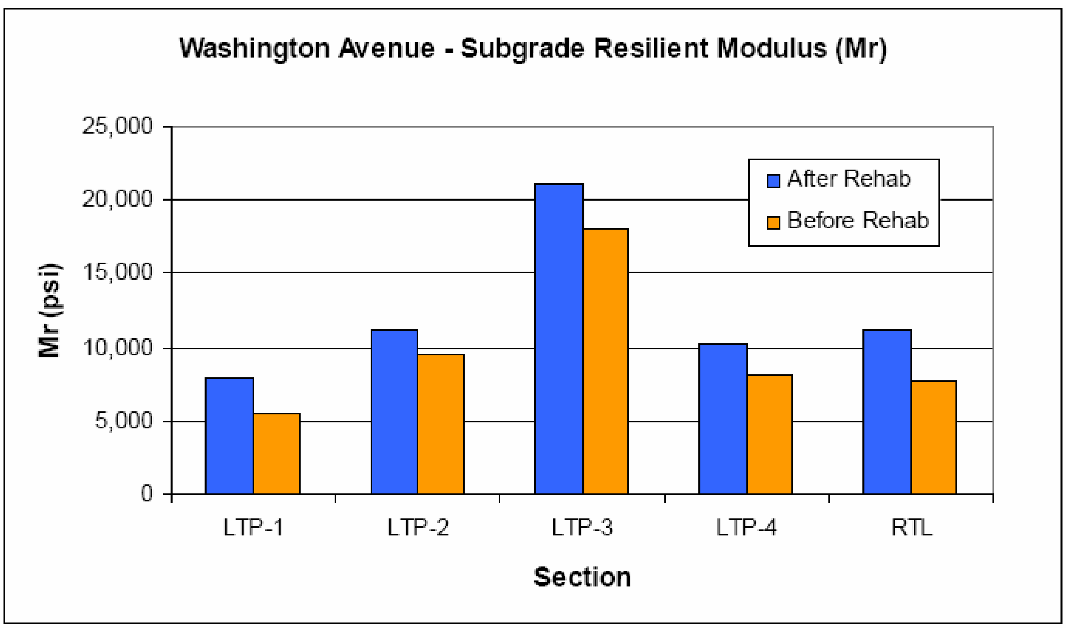

FIGURE 4 Comparison of the subgrade resilient modulus.

The effective granular modulus (E_{agg}), the third measure of comparison, was evaluated in order to determine the effects of stabilizing the granular base. The effective granular modulus increased in every section as can be seen in Figure 5.

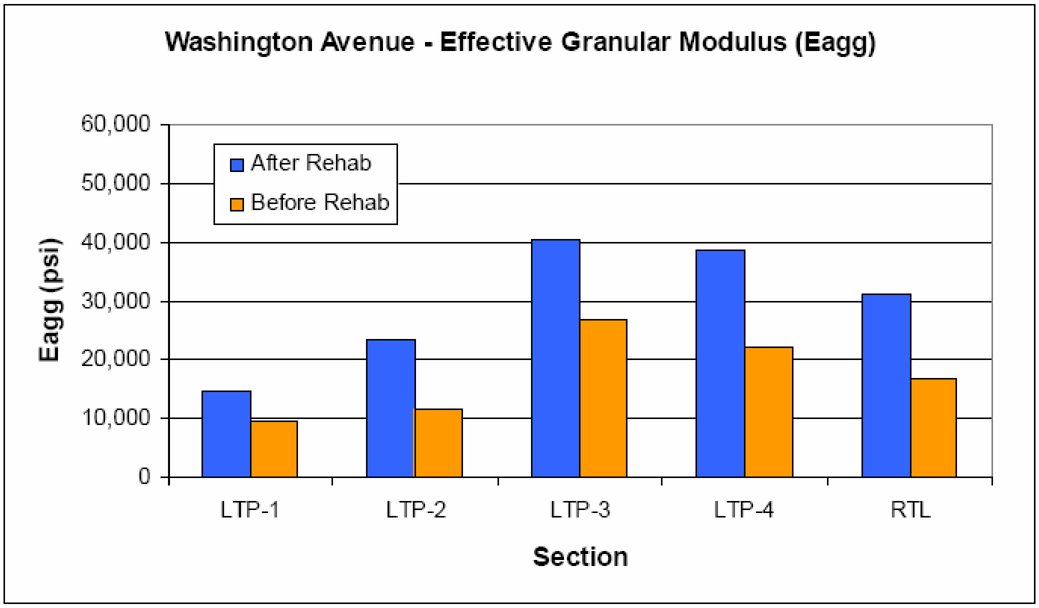

FIGURE 5 Comparison of the effective granular modulus.

A good measure of the structural capacity of the pavement structure is the effective pavement modulus (E_p). This is dependent on both the pavement thickness and integrity. The percent increase in effective pavement modulus in each section indicates overall improvement in the structural capacity. The percent increase was as follows: 76%, 152%, 168%, 182%, and 34% respectively. These values are shown in Figure 6.

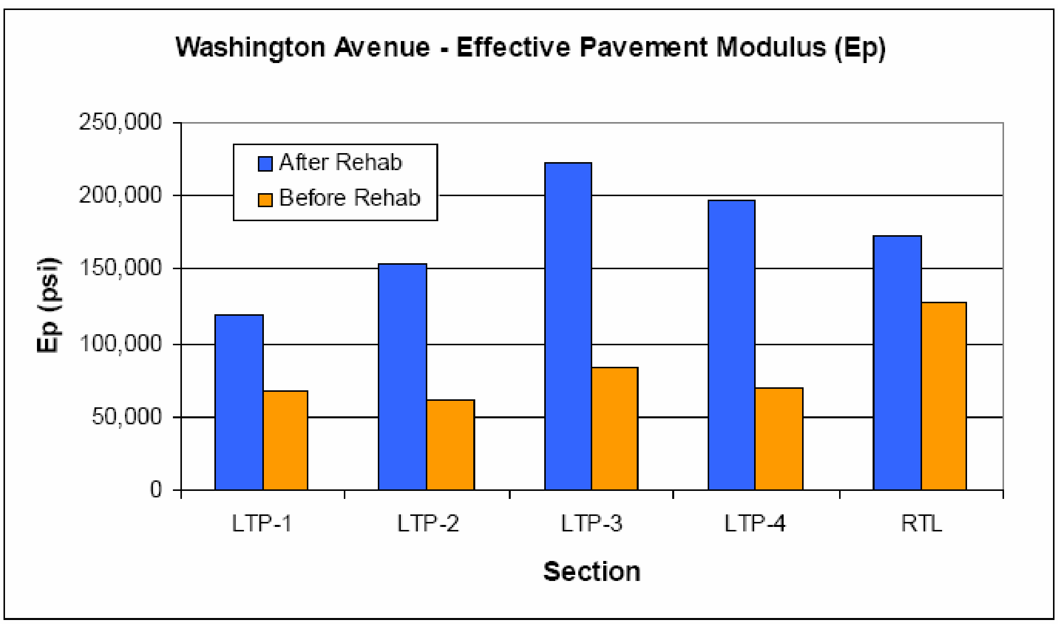

FIGURE 6 Comparison of effective pavement modulus.

The final comparison is the effective structural number. An increase in effective structural number is expected after rehabilitation as was the case in every section. The percent increase is as follows: 40%, 49%, 76%, 38%, and 23% respectively, as shown in Figure 7.

The design structural number (SN) was 4.35, based on the AASHTO pavement design process and a 20-year life (*7*). This value was generally achieved. Section LTP-1 had a value of 4.31, which was slightly below the target. This was likely due to the lower subgrade modulus in this area.

A structural coefficient was calculated for the stabilized base layer. Based on 84 FWD measurements, the coefficient was calculated as follows:

a_{GBS} = (SN_{eff} – (HMA thickness x a_{HMA}) – (aggregate thickness x a_{agg}))/thickness GBS

Using an average HMA thickness of 5.1 inches, an HMA structural coefficient of 0.42, a remaining aggregate thickness of 9 inches, an aggregate coefficient of 0.10, and 6 inches thickness for the GBS layer, the average GBS structural coefficient is 0.282, and the 50th percentile value is 0.253. The City of Las Vegas uses an HMA structural coefficient of 0.35, but the 0.42 value appeared more representative for this analysis method.

It appears that there is some trend of the FWD-determined properties with the subgrade modulus. There is a wide variation in this property that had an effect on the final pavement structure (i.e. SN_{eff}).

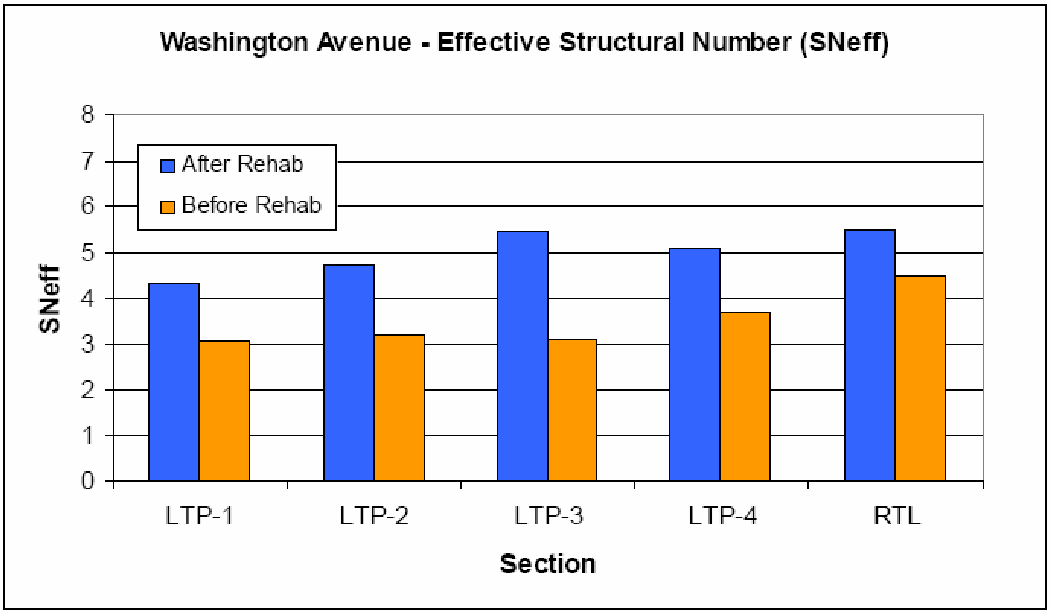

FIGURE 7 Comparison of the effective structural number.

A picture of the street with the asphalt overlay is shown in Figure 8.

FIGURE 8 Washington Avenue after GBS with final overlay.

CONCLUSIONS

Washington Avenue, near downtown Las Vegas, Nevada, was rehabilitated using the GBS procedure in April and May of 2006. This rehabilitation included stabilization of the first 6 inch (150 mm) lift of the granular base and placement of a new 5 inch (125 mm) lift of hot mix asphalt. FWD testing was performed both prior to and following the rehabilitation. The following is a summary of the effectiveness of the rehabilitation treatment.

The results of the FWD backcalculation analysis indicated:

- The average maximum normalized deflection range from 4.72 mils to 9.84 mils. Deflection decreased for all sections from 28% to as high as 58% indicating higher strength and improved structural capacity.
- The average subgrade resilient modulus range from 7,988 psi to 21,084 psi (55 to 145 MPa). An increase for all sections ranging from 19% to 45% was observed.
- The effective granular modulus ranged from 14,682 psi to 40,490 psi (101 to 279 MPa). Effective granular modulus increased for all the sections and ranged from 52% to as high as 101%.
- The effective pavement modulus ranged from 119,115 to 222,675 psi (821 to 1535 MPa). Effective pavement modulus increased for all sections from 34% to as high as 182% indicating a significant improvement in the overall pavement strength.
- The effective structural number ranged from 4.31 to 5.49. Effective structural number increased for all sections from 23% to as high as 76% indicating a significant improvement in the effective strength of the pavement structure.
- A structural coefficient for the GBS of 0.282 can be achieved, based on the results of the FWD analysis.

The benefits of the rehabilitation included:

- Granular base stabilization with asphalt emulsion is an effective method for rehabilitating busy city streets. The simplicity of the approach should encourage more recycling to be performed.
- The stabilization of part of the granular base and placement of the new hot mix asphalt layer was determined to have a significant improvement on the overall structural capacity relative to the previous pavement structure.
- The city saved an estimated $322,661 by using GBS, which allowed additional network rehabilitation to be scheduled and constructed. This was approximately a 30 percent savings.
- Construction time was shortened from 120 days to 40 days.
- 3000 fewer loads of material were trucked on and off the project.
- 23,432 square yards (19,592 square meters) of waste were not generated.
- The impact on businesses and residents was reduced.

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