

**Application of Perpetual Asphalt Pavement Principles  
For  
The Design and Construction of the Kandahar to Herat Highway in Afghanistan**

A Paper  
By

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## ABSTRACT

The Louis Berger Group, Inc. (LBG) was retained by the United States Agency for International Development (USAID) in 2002 to serve as Program Manager for a multifaceted nation rebuilding program. This program involved management, design/build and construction in six separate sectors: irrigation, water & sanitation, schools & clinics, power & energy, urban roads, secondary roads, and primary roads. This paper focuses on the design and reconstruction of one of the major Ring Roads within Afghanistan.

The Kandahar to Herat (KH) highway was originally built by the Russians in the 1960's using Portland Cement Concrete (PCC). After nearly 40 years of neglect and war, the road had become nearly impassible in many locations and severely deteriorated for most of its length. Initial reconnaissance surveys determined that because of the existing pavement structure, geographic conditions, weather, traffic loadings and logistics for materials, a different approach to rehabilitation was necessary. Nearly 420km (260 mi) of the total 556km (345 mi) length of the road was determined to be in poor to very poor condition.

A detailed review of all the alternatives based on AASHTO Guide for Design of Pavement Structures, 1993 (1,2) principles, that included traffic counts, ESAL analysis, development of Structural Number (SN), Life Cycle Costing, time of construction and local materials availability was carried out. Three major alternatives utilizing both PCC and Asphalt pavements were analyzed and costed. The recommended pavement design resulting from this analysis was rubbilization of the PCC followed by overlay with Hot Mix Asphalt (HMA) layers: Asphalt Treated Base (ATB), Binder and Wearing Course (WC).

Design and construction was carried out on a Design-Bid-Build basis utilizing four international contractors who had previously worked with LBG on the design and construction of the Kabul to Kandahar highway in 2003-2004. Where ever possible, the PCC was rubbilized and compacted; a cushion layer of crushed aggregate base was added followed by the ATB, binder and WC. Because of the unknown characteristics of the subgrade, the local aggregates and even the imported bitumens, final job mix formulas proved daunting to the field staff and had to be constantly monitored to maintain specified requirements. Although the HMA layers do not fulfill all concepts of a Perpetual Asphalt Pavement (PAP), the pavement structures satisfy the strain threshold. This paper can be described as an experience in Afghanistan looking at the PAP concept.

The KH Road construction phase consisted of 327 Km (203 mi) of road rehabilitation and reconstruction funded by USAID and 115 Km ( 71 mi) funded by the Saudi Development Fund (SDF). The objectives of this phase were to provide a safe and effective economic corridor, built to international norms and standards while maximizing local participation for capacity building.

From initial design studies in the fall of 2003, construction has progressed well considering security conditions, importation of bitumen from various worldwide sources and the remoteness of the project, the road construction will be completed in July 2006 and final bridges by late 2006.

The paper concludes with a set of Lessons Learned that resulted from working in an environment like Afghanistan. Domestic construction projects in the developed world are far different than one would experience when security, logistics, local culture, environmental conditions and training of local staff are issues of consideration as was experienced in this project. Yet, a high quality road was built to serve the needs of the developing Afghan economy in a timely and cost effective manner.

## **BACKGROUND OF THE REFS PROJECT IN AFGHANISTAN**

The Louis Berger Group was retained by the United States Agency for International Development (USAID) in 2002 to serve as Program Manager for a multifaceted nation rebuilding program. This program, entitled “Rehabilitation of Economic Facilities and Services Infrastructure Rebuilding for Afghanistan” (REFS), involved management, design/build and construction in six separate sectors: irrigation, water & sanitation, schools & clinics, power & energy, urban roads, secondary roads, and primary roads. A major component of the entire program was the reconstruction of two primary highways, both part of the Ring Road National Corridor in Afghanistan, and nine Secondary roads throughout the country.

### **DESIGN AND CONSTRUCTION OF 389KM OF PAVED ROAD IN ONLY 207 DAYS – THE KABUL TO KANDAHAR HIGHWAY**

The first project undertaken was a 389km (241 mi) section of primary roadway between the capital city of Kabul and the city of Kandahar. The original road had been constructed in the early 1960’s by the US Army Corps of Engineers. But, 40 years of maintenance neglect coupled with 20 years of war in the country left the existing road nearly unusable. The journey between the two cities took about 19 hours. LBG was initially charged with delivering 49km (30 mi) of paved highway by December 2002. However, “Faster” became the buzzword in late 2002 and by April 2003 LBG was tasked with the delivery of 389km (241 mi) of paved road by 31 December 2003.

By engaging four international contractors, implementing an aggressive design/build program and through acceptance of a staged construction concept of applying only the asphalt treated base (ATB) in 2003, the project was opened to traffic on 16 December 2003 in a ribbon cutting ceremony led by interim Afghanistan president Hamed Karzi.

Completion of this rehabilitated and now paved road in only 207 days was considered nearly impossible in 2003 but was accomplished through the efforts of LBG staff and its subcontractor teams. Interim president Karzi at the opening ceremony stated that the opening of the road decreased travel time from 19 hours to 5 hours and created entire new industries along the corridor.

LBG received an award from the American Consulting Engineers Council for this project and was also honored by American Society of Civil Engineers (ASCE) as a finalist for their Outstanding Civil Engineering Achievement OCEA award in the spring of 2004. LBG also received a special humanitarian award from ASCE for the project.

### **DESIGN AND CONSTRUCTION OF 442KM OF PAVED ROAD - KANDAHAR TO HERAT HIGHWAY**

The second primary road, the Kandahar to Herat highway also part of the Ring Road system is 556km (345 mi) long and was constructed nearly 40 years ago by the help of the Russian government. LBG was tasked with the design and construction of 442km (274 mi) of this road with the remaining portion near Kandahar being built by the Japanese. It is the major transportation route for importing goods, especially from the Iranian port of Bandar Abbas. The existing road was paved with Portland Cement Concrete (PCC).

More than 20 years of neglect devastated the physical infrastructure of the country and with no available funding little emphasis had been given to maintenance of the road network. As a result, the existing pavement had generally severely deteriorated and required substantial rehabilitation works to restore it to its original condition.

The following sections describe the experience of the program managers regarding design and construction of the Herat to Kandahar highway.

## **EXISTING PAVEMENT CONDITIONS**

The existing pavement was a Portland Concrete Pavement (PCC) with gravel shoulders. Existing PCC slab depth varied from 20 to 25 cm (8-10 inches) and consisted of uncrushed screened river gravels as aggregate. PCC pavement at most places was plain un-dowelled concrete, relying on aggregate interlock to transfer the traffic loading. However, dowels 14 mm (0.6 inches) in diameter were found at a few locations at a distance of 8 cm and 28 cm (3.25-11 inches) from the edge on the concrete slab. At some locations a 6 mm (0.25 inches) diameter steel mesh was also found. No longitudinal tie bars were located in the existing pavement. The slab had been directly placed on the granular subbase.

Existing granular subbase varied from 20 to 40 cm (8-16 inches) and consisted of uncrushed river gravels with low field moisture content and relatively good density.

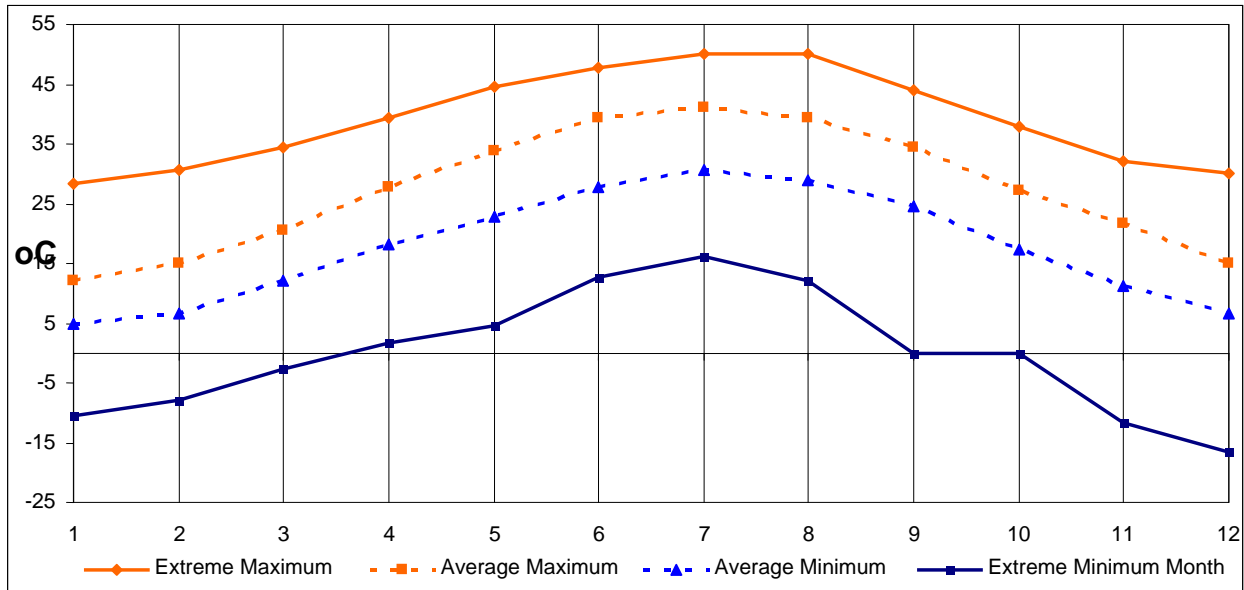
Subgrade soils were mainly silty sand or silty clay with low field moisture content and also relatively good density, with the amount of material passing No 200 sieve varying between 40 to 95%. Liquid Limit values ranged between 25 to 30% and Plasticity Index between 16 and 23%. Due to the low Field Moisture Content, the Consistency Index (CI) of the soils was above 1, showing a hard consistency, that agreed with in situ observations and analysis of Dynamic Cone Penetrometer (DCP) and Benkelman Beam tests.

The visual inventory had shown that PCC slabs were in poor to very poor condition and about 95 % of the area was cracked to some degree. The joint seals had long since disappeared. The edges of the joints had spalled quite severely to depths of about 50 to 100 mm (2-4 inches) and some had become filled with debris. In some places, pavement blowups were observed. Possible causes of the poor pavement condition were related to traffic overloads and lack of maintenance for a road originally constructed around the 1960's.

## **Environmental Conditions**

Climate conditions in the project had been gathered for a period between 1972 and 1992 from National Oceanic and Atmospheric Association (NOAA). Along the Kandahar – Herat road, extreme air temperatures can vary between 50° C (122° F) and -20° C (-8° F). Daily changes on air temperature often range greatly within a single day between 20 and 30° C (68 to 86° F) down to freezing conditions at dawn. Most precipitation occurs between the months of October and April with mean annual precipitation range between 175 and 275 mm (7-11 inches) and a maximum annual precipitation around 750 mm (29.5 inches) between December and April, when also some snow is observed (below 10 cm). Frontal winds sweeping in from the west bring large sandstorms or dust storms. The road is located at elevations from 800 to 1500 m (2,400-4,650 ft.). Variations of air temperature are shown in Table 1.

**TABLE 1 Monthly Air Temperatures - Farah**



**TRAFFIC ANALYSIS**

Seven Day Traffic Counts were conducted for 24 hours in 2003 yielding an Average Annual Daily Traffic (AADT) of 1,827. Additionally a load axle study was conducted leading to the Load Spectra for pavement design purposes as shown in Table 2 and indicating a high axle overload condition typical of countries in the region (3).

**TABLE 2 AADT Load Spectra - Number of Axle Types (2003)**

| Range of Axle Loads<br>Metric Tons (MT) |    | Range of Axle Loads (Kips) |    | Axles |        |        |
|---|----|----------------------------|----|-------|--------|--------|
|   |    |                            |    | Steer | Single | Tandem |
| 0                                       | 1  | 0                          | 2  | 1,852 |        |        |
| 1                                       | 2  | 2                          | 4  | 60    |        |        |
| 2                                       | 3  | 4                          | 6  | 76    |        |        |
| 5                                       | 6  | 12                         | 14 | 12    |        |        |
| 6                                       | 7  | 14                         | 16 | 330   |        |        |
| 7                                       | 8  | 16                         | 18 |       |        | 50     |
| 8                                       | 9  | 18                         | 20 |       | 12     |        |
| 9                                       | 10 | 20                         | 22 | 454   |        | 51     |
| 11                                      | 12 | 24                         | 26 |       | 104    |        |
| 17                                      | 18 | 38                         | 40 |       |        | 301    |
| 23                                      | 24 | 50                         | 52 |       |        | 602    |

## **REHABILITATION OPTIONS**

Considering that it was possible to keep the actual horizontal and vertical alignment in the main portion of the complete road, the general criteria for rehabilitation was to take advantage of the existing pavement structure; thus, the following alternatives (4) were considered for the pavement rehabilitation:

- Hot Mix Asphalt (HMA) Overlay on Crack and Seat PCC
- HMA Overlay on Rubblized PCC
- PCC Overlay over Rubblized PCC

To select the most advantageous alternative a Life Cycle Costs (LCC) analysis was conducted. The net present value (NPV) of HMA overlay was substantially lower than Rigid Pavement overlay, mainly because of the PCC high initial cost. NPV of HMA overlay on crack and seat PCC and HMA overlay on Rubblized PCC were comparable. Taking into account construction constrains, joint distresses, possibility of reflection cracks, occurrence of reinforcement at some places in the pavement and timely completion of project, the HMA overlay on Rubblized PCC was adopted.

A new pavement structure was considered and adopted in some sections due to the highly deteriorated condition of existing PCC slabs, poor subgrade conditions for rubbilization, presence of drainage structures and to match the existing alignment with the new one.

## **PAVEMENT DESIGN**

The pavement structure was designed following the AASHTO Guide for Design of Pavement Structures, (1993). Taking into consideration subgrade soils conditions, the lack of water table and environmental conditions and loss of serviceability was not considered due to the low probability of frost heave and/or subgrade swelling due to expansive soils.

HMA layers were considered as dense graded asphalt concrete and designed to fulfill the Marshall Design Criteria in accordance to Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects FP-03, (2003) and the Asphalt Institute (5, 6). To improve the rutting resistance, large stone mixes (100% passing 1.5 inches (37.5mm)) was adopted for all HMA layers (7, 8, 9, and 10).

Asphalt cement was imported from several countries and was mainly classified by penetration grade (60/70). To minimize fatigue cracks, low temperature cracks and rutting in HMA, a study of Performance Grade asphalt cement was conducted (11). Table 3 shows the criteria for the selection of asphalt cement, considering PG classification for the three types of HMA that were considered: Wearing Course (WC), Binder Course (Binder) and Asphalt Treated Base (ATB).

**TABLE 3 Selection of Asphalt Cement – Performance Grade (PG)**

| Course | Reliability | 50%   | 85%   | 90%   | 98%   |
|--------|-------------|-------|-------|-------|-------|
| WC     | Kandahar    |       | 70-10 | 70-10 | 70-10 |
|        | Farah       | 64-10 |       |       | 70-16 |
|        | Herat       |       | 70-16 | 70-16 | 70-22 |
| Binder | Kandahar    |       | 64-10 | 64-10 | 64-10 |
|        | Farah       | 58-10 |       |       |       |
|        | Herat       | 58-16 | 58-16 | 58-16 | 64-22 |
| ATB    | Kandahar    |       | 58-10 | 58-10 | 64-10 |
|        | Farah       | 58-10 |       |       | 64-16 |
|        | Herat       | 58-16 | 58-16 | 58-16 | 64-22 |

Based on Table 3, PG 58-16 and PG 76-22 were considered for the ATB-Binder and WC respectively. The 60/70 asphalt cement sources, in most cases, were classified as Performance Grade (PG) 58-16, therefore Asphalt Cement Penetration 60/70 was adopted for all HMA layers, except for the WC, where 4 to 5% of Styrene-Butadiene-Styrene (SBS) was added to achieve a PG 76-22 (12).

Table 4 shows the main inputs for the AASHTO design procedure.

**TABLE 4 AASHTO 1993 Design of Pavement Structures - Input Data**

|  |            |
|--|------------|
| Reliability (Rural, 75 to 90%)   | 90%        |
| Standard Deviation (Flexible, Variance of Projected Traffic)             | 0.49       |
| Initial Servicability (Flexible=4.2)                                     | 4.2        |
| Terminal Serviceability (People Stating Unacceptable, 85%=2, 55%=2.5.)   | 2.5        |
| Traffic in the Design Lane (Do=0.5, DI=1)                                | 50%        |
| Analysis Period (Years)  | 15         |
| Design Period (Years)  | 15         |
| Annual Traffic Growth Rate   | 4%         |
| ESAL Design Period for the Design Lane                                   | 33,400,000 |
| Subgrade Reaction Modulus (In Situ Conditions)                           | 7,550      |
| (a)WC (1/in) – HMA Dense-Graded (Wearing Courses). With PMB              | 0.42       |
| (a)B (1/in) - HMA Dense-Graded (Binder Course). Large Stone Mix          | 0.40       |
| (a)ATB (1/in) – HMA Dense-Graded (Asphalt Treated Base). Large Stone Mix | 0.39       |
| (a)RPCC (1/in) - Rubblized PCC   | 0.20       |
| (a)CAB (1/in) - Crushed Aggregate Base                                   | 0.14       |
| (a)ESB (1/in) - Existing Aggregate Sub Base                              | 0.10       |
| Minimum AC Layer on Top CAB CBR $\geq$ 100% (cm) – Layered Analysis      | 23         |
| Thickness of Existing PCC (cm)   | 20         |
| Thickness of Existing Aggregate Subbase (cm)                             | 20         |

(a) – structural coefficients

Table 5 shows the selected pavement structures for rubblized PPC as well as new sections. An HMA thickness of 25 cm has been defined when HMA is laid on a crushed aggregate base (Minimum 23 cm was required in accordance to AASHTO’s layer design).

**TABLE 5 Pavement Structures – AASHTO 1993**

|             | Pavement Layer                      | Rubblized   | New  |      |
|-------------|-------------------------------------|-------------|------|------|
| AASHTO 1993 | WC (HMA Wearing) – cm               | 7.5         | 7.5  |      |
|             | BINDER (HMA Binder) – cm            | 7.5         | 7.5  |      |
|             | ATB (HMA Asphalt Treated Base) – cm | 10          | 10   |      |
|             | CAB (Crushed Aggregate Base) – cm   | 5 to12 (a)  | 35   |      |
|             | Rubblized PCC – cm.                 | 20          |      |      |
|             | Existing Subbase – cm.              | 20          |      |      |
|             |                                     | SN Obtained | 6.44 | 6.08 |
|             |                                     | SN Required | 6.03 |      |

(a) To achieve the design cross section

The pavement structures obtained with AASHTO93 were verified using Perpetual Asphalt Pavement (PAP) design criteria (13). The flexibility criterion of the bottom HMA layer (ATB) was sacrificed, because it would require more asphalt cement and would be more prone to rutting during construction, due to elevated air temperatures. . It is noted that for all HMA, the total asphalt cement content varied between 3.8 to 4.2% (by weight), with an asphalt film thickness between 8 to 10 micron. Losses of adhesion between asphalt cement and aggregates were not detected.

Pavement structures were also evaluated using PerRoad 3.1 software (14). Tables 6 and 2 show the structural/seasonal and the load spectra input data respectively. A summary of outputs is presented in Table 7. It is to be noted that strain criteria are fulfilled but not the maximum vertical deflection criteria, which is considered not as critical as the tensile strain criteria.

**TABLE 6 PerRoad 3.01 Analysis – Structural and Seasonal Input Data**

**TABLE 7 PerRoad 3.01 Analysis – Results**

| Layer    | Position | Criteria            | Threshold       | % Below Critical Obtained | % Below Critical Minimum |
|----------|----------|---------------------|-----------------|---------------------------|--------------------------|
| WC       | Top      | Vertical Deflection | 20 milli-in     | 80                        | 90                       |
| ATB      | Bottom   | Horizontal Strain   | -70 microstrain | 100                       |                          |
| Subgrade | Top      | Vertical Strain     | 200 microstrain | 100                       |                          |

**CONSTRUCTION CHALLENGES**

The construction phase of the KH Road project was organized in four road sections with five individual subcontracts as shown in Table 8.

**TABLE 8 KH Road Contract Sections**

| <b>SECTION</b> | <b>LENGTH<br/>(Km)</b> | <b>CONTRACTOR</b>  | <b>HOME</b>      |
|----------------|------------------------|--------------------|------------------|
| 2              | 115                    | KoINat JV          | Istanbul, Turkey |
| 3              | 124                    | KoINat JV          | Istanbul, Turkey |
| 4A             | 50                     | Gulsan-Cukurova JV | Istanbul, Turkey |
| 4B             | 50                     | Gulsan-Cukurova JV | Istanbul, Turkey |
| 5              | 101                    | BSC C&C            | Gurgaon, India   |

Due to the remote location and lack of economic development, the local area provided no construction resources other than raw material sources for aggregate and water supply, independent truck operators, stone masons and unskilled labor. Following the necessary land use agreements, four campsites of approximately 30 ha were established complete with plants, storage and maintenance facilities, offices, cafeteria and dormitory. De-mining was required for the campsites and the 47 M construction right-of-way. Plants and equipment from previous work on the Kabul-Kandahar Road with supplemental imports from India, Turkey, Italy, U.A.E, U.K. and the United States were mobilized to the campsites to include 8 asphalt plants, 4 aggregate crusher plants, 4 aggregate screening plants, 12 paving machines, 20 compactors, and over 300 pieces of other equipment. The project staff numbered over 3,000 personnel with Afghan engineers from Kabul and Herat and expatriates from Australia, Bangladesh, India, Netherlands, Pakistan, Peru, Philippines, South Africa, Thailand, Turkey, United Kingdom and the United States.

All campsites, construction worksites and vehicular movements were supported on a full-time basis by a U.S. security contractor in cooperation with the Afghan Ministry of Interior police forces. This implied an additional coordination measure for construction managers and required detailed planning to maintain a 2,000-3,000 MT daily paving schedule.

Bitumen supply for the HMA placement required 90,000 MT of PG 60-70 bitumen imported from Egypt, Bahrain and the United Arab Emirates. The supply chain consisted of sea transport from the port of Dubai, U.A.E to the port of Karachi, Pakistan followed by overland trucking from Pakistan to Kandahar, Afghanistan for final distribution to the various construction campsites.

Aggregate supply for the HMA placement required 4 quarries and over 100 borrow pits to provide 4 million MT of raw material for crushing and screening in the campsite plants. Four aggregate stockpiles were maintained in each campsite at the 37.5-19.0mm (1 ½ -3/4 inch), 19.0-12.5mm (3/4-1/2 inch), 12.5-7.0mm (1/2-1/4 inch) and 7.0mm-0.0mm (1/4 inch -) sizes.

Finally, the roadway reconstruction was performed in two major steps: Rubbilization followed by HMA placement.

### **Rubbilization**

In September 2003 LBG, Inc. began investigating the process of cracking and seating the PCC prior to placing a flexible overlay. Inquiries were made to obtain information regarding costs, production rates, availability and suitability of crack and seat machines in the USA. LBG also investigated the two types of rubbilization equipment, the resonance breaker and the guillotine breaker. Following an internet search and after talking with several contractors and

Departments of Transportation (DOT) representatives in the USA there appeared to be only two types of machines that are built in the USA to perform rubbilization. Both types were self-contained, self-propelled units. Both types of rubbilization machines are used by contractors throughout the USA in pavement reconstruction and have been used in a number of states. Both machines have relatively the same daily production rate of about 1 lane mile (1.6km) per 10 hour working day.

Based upon initial information that had been gathered, LBG engineers believed the road had failed due to poor subgrade support and initially concluded that the crack and seat method was feasible and that the rubbilizing method was questionable. However, following a site visit by a contractor familiar with the rubbilization process it became obvious that the pavement had been built on a stable natural gravel base, contrary to what had been expected. Almost all slabs had transverse cracks, often every few feet apart as well as serious longitudinal cracks. It was not unusual to see the top 4 inches (100mm) of pavement literally gone leaving serious potholes. By far the most surprising condition was the 3 to 4 inches (75-100mm) of pavement which had eroded from the transverse joints. This was rarely seen according to the contractor's experience—"it is unusual to see a pavement wear out to this extent from the top down". These conditions changed his and LBG's opinion regarding crack and seat versus rubbilization.

Due to the irregular spacing between transverse cracks, the depth of the eroded joints, the irregular pavement profile from centerline to shoulder due to longitudinal cracks, surface potholes and some sign of reinforcing steel, LBG concluded that the crack and seat method could not effectively fracture this pavement into consistently sized pieces nor would it have much effect on smoothing the existing pavement. Typically impact within 2 feet (0.6m) of a joint is not done because it results in a significant percentage of the joints reflecting through an asphalt overlay within 3 to 5 years.

Following this analysis, the three on-site subcontractors chose the multiple head drop hammer equipment and entered into agreements for its use as the most cost effective and most adaptable piece of equipment for the work. Rubbilization was accomplished using 5 MHB (multi-headed) Badger Breakers for rubbilizing the 300 mm PCC slab in-place with accompanying 3 Z-grid vibratory steel wheel rollers for setting and compacting the rubbilized aggregate. The specifications called for a maximum of 75 mm nominal size aggregate at the top of the existing PCC slab with a corresponding maximum of 300 mm nominal size at the bottom of the slab. Slabs not meeting the size specification were removed and replaced with crushed aggregate base.

The rubbilization of the PCC slab was followed with a crushed aggregate base course to build-up the cross-section template. Engineers considered this aggregate layer significantly less expensive than asphalt to build the correct cross-sectional template not to mention a lot easier to 'fine-grade'.

Two situations requiring special field engineering were slabs overlying existing drainage structures and several isolated areas of pumping of subgrade soils. In the first situation, field engineers assessed the kinetic energy delivered by the multi-head breakers as a risk to damaging underlying drainage structures. This risk was mitigated by implementing construction controls by not rubbilizing the overlying PCC slab for a distance of 20 M on either side of the drainage centerline. Instead, a full depth removal and replacement with crushed aggregate base was performed.

The pumping subgrade situation was observed in several isolated areas during the proof rolling of the rubbilized PCC slabs. Field investigations discovered high moisture contents and

low CBR in the underlying soils. Further, the subgrade pumping was observed more frequently in the winter months as the ground water table was elevated due to an unusually high rain and snowfall season. It was also observed by field engineers that the original construction did not allow for subgrade drainage due to the impermeability of the shoulder material. To maintain schedule, the pumping subgrade was replaced with selected borrow material. Field engineers implemented construction controls on the existing subgrade with a minimum CBR of 5 to support construction traffic loading and for final HMA pavement performance.

A nominal 25mm (1 inch) layer of CAB was placed above the compacted rubbilization layer and prior to the ATB because of its lower cost.

### **HMA Placement**

Asphalt treated base construction consisted of batching, loading, transporting, placement and compaction of 753,000 MT of asphalt material. Batch plants controlled the volumetric proportioning via mechanical and computerized systems. Weigh scales were mobilized and calibrated to provide controls on hauling and payment quantities. Standard U.S. paving practices were followed and a high quality construction was achieved in lift thickness, density and smoothness.

HMA binder course consisted of batching, loading, transporting, placement and compaction of 570,000 MT of asphalt material. The binder course was completed in similar fashion to the base course albeit different mix designs.

HMA wearing course with polymer modified bitumen (PMB) construction consisted of batching, loading, transporting, placement and compaction of 554,000 MT of asphalt material, and three Massenza bitumen plants were mobilized to produce the 4.8% Kraton SBS polymer modified bitumen.

### **Quality Assurance/Quality Control**

A central materials testing laboratory was mobilized equipped and staffed at the main construction camp to provide quality assurance (QA) testing which allowed for timely information to confirm quality of construction and payment verification. The central laboratory was capable of testing aggregates, bitumen, polymer modified bitumen, asphalt and concrete.

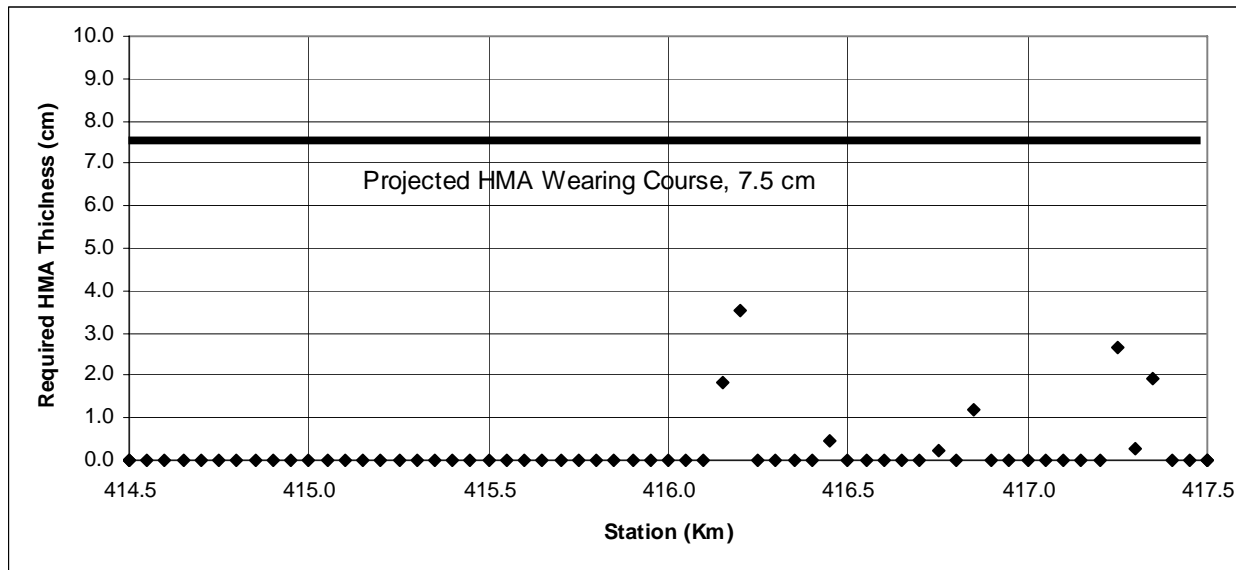
Each construction subcontractor prepared and submitted a comprehensive quality control (QC) plan conforming to FP-03, ASTM and AASHTO. A materials testing laboratory was mobilized, equipped and operated at the construction campsite for complete QC testing of aggregates, bitumen, asphalt and concrete. In addition to the laboratory operations, field testing was performed for compaction density, temperature control, and sampling.

Each construction subcontractor prepared and submitted a construction methodology prior to asphalt placement. Afghan site engineers and surveyors under expatriate management and supervision were assigned at each plant and work site for quality assurance inspection and testing, performance measurement and field engineering.

A Dynatest heavy-weight falling deflectometer (HWD) was utilized to conduct in-service performance assessments on the HMA binder course. The binder course was being heavily utilized by local overland haul trucks circumventing the established traffic control plan. Although visual inspection could find no rutting, cracking or damage on the partially completed pavement, engineers decided to investigate the binder course with the HWD for additional assurance.

The AASHTO 1993 design procedure for NDT pavement evaluation was adopted in order to verify the designed pavement structures. Table 9 shows the HMA requirements at binder level. It is noted that the required HMA thicknesses tested at the binder level changed below the subsequent wearing course layer of 7.5 cm (3 inches). Thus, the binder course was considered adequate to support temporary traffic with the final wearing course providing more than the requirements for long-term performance.

**TABLE 9 HMA Requirements at Binder Course Level.**



**Lessons Learned**

The following lessons learned are offered for asphalt paving construction in remote and hostile project environments such as Afghanistan:

- Qualified and experienced staff – Project staff require unique qualifications and abilities to handle the security and cultural environment, as well as substantial technical experience to troubleshoot problems and adapt standard practices to local conditions.
- Supply chain – The supply chain is marked with long lead times and requires a global coordination effort making inventory management a key success factor.
- Quality control/Quality assurance – Road construction performed in developing countries, with little to no in-house maintenance capability, should be considered as a one time opportunity requiring the highest quality of material and construction methods to ensure a long performance lifecycle.
- Cultural awareness – The local societal as well as the construction industry culture must be considered and incorporated into the project implementation plan to ensure that local participation, cooperation and support are maximized.
- Security – Security operations are challenged to secure a long, linear area such as a road, particularly when cost controls are important. Proactive techniques are required to provide a cost-efficient solution. Passive techniques such as local hiring, public relations, low-key presence and cultural awareness by the construction staff are paramount.
- External environment – The objectives of donor organizations must be recognized and supported during the construction phases with timely information on project

performance, open communications, and adherence to budget, time and quality constraints.

- Subgrade foundation – The underlying subgrade must be able to support follow-on construction traffic and final roadway performance. A CBR of 5 for the underlying and existing subgrade soil was implemented as a control measure with success.
- Drainage – Proper drainage via a V-shape ditch, pipe, open graded base, and free-draining-base trenches should be considered to minimize subgrade pumping and seasonal frost heaving.
- Polymer modified bitumen – Field engineers need to ensure that temperature requirements and mixing to prevent phase separation are met for polymer modified bitumen in storage to maintain physical properties and to guarantee proper density can be achieved during placement.

## **SUMMARY AND CONCLUSIONS**

This experience shows that Perpetual Asphalt Pavement technology can be applied in different scenarios around the world.

PCC rubbilization with HMA overlays is a cost efficient alternative for rehabilitation of PCC pavements that allows the possibility to build a Perpetual Asphalt Pavement.

High axle overload conditions increase the possibility of early pavement failures when inappropriate HMA thickness were adopted. PAP technology can improve this situation, especially when no structural maintenance is expected at the proper time,

PAP technology is an efficient candidate for the rehabilitation of thin HMA pavements, where asphalt recycling technique is considered.

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## REFERENCES

1. American Association of State Highway and Transportation Officials. *AASHTO Guide for Design of Pavement Structures*, Washington D.C. 1993.
2. NCHRP. *Pavement Structural Design Practices*, Synthesis 189, TRB, 1993.
3. Croney D.; Croney P. *The Design and Performance of Roads Pavements*, Her Majesty Stationary Office. 2<sup>nd</sup> Edition, London, 1991.
4. The Asphalt Institute. *Asphalt Overlays for Highway and Street Rehabilitation*, MS 17, AI, USA, 1999.
5. FP-03 *Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects*, USA, 2003.
6. The Asphalt Institute. *Model Construction Specifications for Asphalt Concrete and Other plant-Mix Types*, SS-1, AI, USA, 1981.
7. National Asphalt Pavement Association. *HMA Pavement Mix Type Selection Guide*, IS128, USA, 2001.
8. The Asphalt Institute. *Mix Design Methods for Asphalt Concrete and Other Hot-Mix Types*, MS-02, AI, USA, 1985.
9. National Asphalt Pavement Association, *Hot Mix Asphalt Materials, Mixture Design, and Construction*. NAPA TB001, USA, 1996
10. National Asphalt Pavement Association, *Design, Construction, and Performance of Heavy Duty Mixes* NAPA QIP123, USA, 2003.
11. Transportation Research Board. *Unmodified and Modified Asphalt Binders* No 1488, USA, 1995.
12. The Asphalt Institute. *Polymer-Modified Asphalt for the Paving Industry*, IS 200, AI, USA, 1999.
13. Transportation Research Circular. *Perpetual Bituminous Pavements*, Circular 503, USA, December 2001.
14. Timm D. *PerRoad Perpetual Pavement Software*. The Asphalt Pavement Alliance, USA, 2004.