RESTORING STREETS WITH MECHANICALLY INSTALLED CBP

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SUMMARY

The use of concrete block pavements in the United States has accelerated from 500,000 square meters in 1980 to some 7 million square meters in 1987 (1). While residential and commercial applications compose of most of the market, there is increased demand for municipal installations. Mechanized installation offers cost and time reduction for successfully establishing concrete blocks as an alternative to conventional asphalt, concrete and brick streets.

This paper is about the first street installed mechanically in the U.S.A, by the City of Dayton, Ohio (2). The reasons why the City chose concrete block paving for street restoration, information on specifications, evaluation of mechanical installation, a performance evaluation of the street and tests conducted on the paving blocks. Design guidelines are presented for renovating streets with CBP, as well as for new applications.

1. INTRODUCTION

Concrete block paving is an emerging alternative to asphalt, concrete and clay brick pavements for municipal streets in the U.S. Mechanized installation has reduced the cost of CBP such that in some situations it is competitive with concrete initially, and competitive with both concrete and asphalt when life-cycle costs are considered. When compared to brick streets, CBP is a substantially cheaper choice when considering new construction or renovation of an existing one.

The City of Dayton, Ohio administration was introduced to CBP at the time of the author's employment with the municipality. See Figure 1 for the location of Dayton, Ohio. The City administration decided to install and evaluate a CBP street as an experlemental capital Improvement project. CBP was identified as a technology that could be added to the City’s menu of pavement technologies.

The street selected for improvement had an existing degraded asphalt surface and was scheduled for resurfacing and curb repairs in November 1985. Its sufficiently small dimensions (6.7m wide by 173m long) and straight geometry helped qualify it be to the project site. Furthermore, CBP would compliment the historic setting of the surrounding residential neighborhood which has many original brick streets.

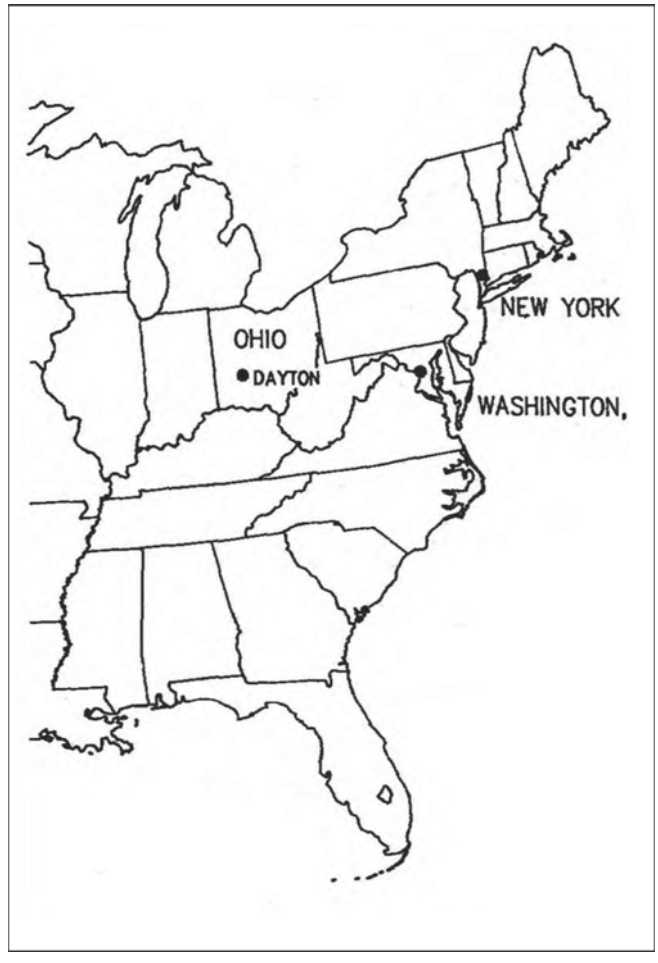


Figure 1 - Location of Dayton, Ohio

2. DESIGN

The consulting engineering firm Nigel Nixon, Knapton and Partners of London, England were commissioned to design the street. The primary design criteria for the street was maximum use of the residual strength of the existing pavement base. In order to assess its quality, core samples were taken. The cores were 600mm deep and showed an average of 25mm of asphalt

on 150mm of 70 to 80 year old concrete sub-base. The soil from the core samples was firm when dry but softened considerably as their moisture content increased. The soil and substantial amounts of clay and a soaked CBR of 3%.

The street normally received light automobile traffic, 200 vehicles per day, and occasional use by heavy vehicles such as waste collection trucks. An overlay appeared to be the best solution given the traffic load, the residual strength of the concrete base, and the project budget. A design method by knapton was used to decide on the overlay. It is described at the end of the paper and discussed at length elsewhere in these proceedings. In order to use the existing combined concrete curb and gutter, the new pavement required nearly the same level as the existing pavement at the gutter. Also, the new elevations had to match adjacent streets. The elevations at the center of the street were not considered as critical and were raised slightly co facilitate drainage.

3. CONSTRUCTION

The City of Dayton Division of Street Maintenance provided a grinding machine to remove (and sell) all of the asphalt and to grind a slight camber in the concrete base. The maximum depth of concrete removed next to the curbs was about 90mm. This left 15-25mm for the sand, 80mm for the concrete blocks, with an 8mm allowance for placing the blocks just slightly higher than the curb. A smaller grinding machine was used to remove concrete around utility covers. Concrete was removed from the center of the street and the entire street was cleaned to enable detailed inspection of the old concrete base.

Poor areas of concrete were removed to the sub-grade and replaced with new concrete. The sub-grade was compacted prior to placing the concrete. Some areas became totally saturated from rain and were replaced with suitable sub-base material. The new concrete covered about 20% of the entire street area. A 2.4mm length was completely removed at both ends of the street and new 175mm thick concrete bases were added. This was done for two reasons. First, both ends of the street had substantial degradation of the old concrete base. This was suggested by the core samples. Second, new bases were poured to strengthen the two ends of the street where loads were higher from stopping and starting vehicles.

After these two concrete bases were cured, two running courses of pavers were set in acrylic fortified, high-strength concrete at both ends of the street.

The two running courses provided a straight face from which to lay the blocks against and to act as an edge restraint for the blocks. Utility covers were raised to the proper finish elevations, concrete collars were formed and poured around them. The collars were air entrained and dosed with the same color pigment as in the concrete blocks. A blend of three colors in the pavers simulated the color of old clay bricks.

A mechanical installation machine, the Optimas Speedi-pave was used to install the pavers. One layer (1 square meter) taken directly from the pallet and placed on the screeded bedding sand (Figure 2). Table 1 shows the gradation for the bedding sand. Prior to starting, a few layers had to be placed manually in a diagonal patten so the machine could work from this laying face. The contractor set a line of pavers



Figure 2 - Placing the Layers

TABLE 1
SAND GRADATION SPECIFICATION

Metric Sieve Size	Percentage Passing
10mm	100
5mm	70 - 100
2.36mm	40 - 90
1.18mm	25 - 70
600µm	10 - 35
300µm	5 - 20
150µm	0 - 10

along one curb for use as a laying edge. The Optimas machine worked from this edge diagonally to the other side of the street. Figure 3 shows the pavers on the opposite side that were dropped on both the sand and excess pavers over the curb. These excess blocks were placed as edge pavers and others were cut and fitted by hand against them (See Figure 4). Edge pavers were also placed by hand around the utility covers (sewer and water) and blocks were cut to fit against them by the contractor.



Figure 3



Figure 4 - Edge pavers were cut to fit along curb. Layers were tightened by worker.

The Optimas was very maneuverable and had no difficulty working in the narrow street. The machine placed about 350 to 400 square meters in a day. Faster rates are possible, but many interruptions from the television news media, visitors, interested neighbors and City staff slowed the installation time. The machine's light weight allowed movement over the uncompacted blocks and sand. The Optimas machine ran for a total of 23 hours and consumed 49 liters of diesel fuel with its two-cylinder engine.

The pallets of blocks were located close to the Optimas machine to reduce the travel time and to and from the layirg face. The blocks came on the pallets in a 90 degree herringbone pattern 2mm thick with spacer bars. Two half blocks in each layer had to be removed by hand and replaced with whole blocks. A person at the laying face did them between the placement of each layer (Figure 5). He also straightened each layer while on the sand and tightened the joints between the blocks.

4. COSTS

The Job was bid as mechanically installed and manually installed to compare prices. Costs including placement of sand, edge pavers, supplying and placing the pavers mechanically was $27.16 per square meter. Manual installation was bid at $46.80 per square meter. This compares with approximately $22.00 per square meter for 150mm thick non-reinforced concrete and $11.00 per square meter for 80mm thick overlay of asphalt for a 1100 square meter area of street pavement of similar size to this project.

5. EVALUATIONS

A performance evaluation was conducted over the first six months of life of the street, December 1985 to June 1986. The evaluation included a monthly elevation survey and comments on the condition of the street. Elevations were measured at the two sides, one fourth and three fourths across the street width. These were taken every 15m along the entire length of the street. Monthly measurements were taken to an accuracy of 0.3mm from December 1985 to May 1986 by a local engineering company. Settlement varied from zero to 1.8am. Most of 1092 elevations taken showed settling between 0.9mm and 1.2mm. Some measurements indicated rising or settling between 0.6mm to 0.9mm beyond this range. This was due to expansion and contraction of the street, compaction of the sand, and slight settlement of ths pavement which is necessary for interlock. Minor unevenness will not effect the structural performance of durability of the pavement.

Concrete blocks produced by the manufacturer were tested for compressive strength and moisture absorbtlon. The average compressive strength was 76 Mpa exceeding the 55 Mpa standard set by under ASTM C-936 (3). The maximum water absorbtlon allowed by this standard is 5% for the average of three sample blocks. The average absorption was 3.8%.

Two samples of blocks were taken directly from the pallets on the job underwent two different freeze-thaw tests of 50 cycles each. One was U.S. test, ASTM C67-83 (4), and the other was a Canadian test, CAN 3-231.2-M85 (5), that includes immersion of the blocks in 3% saline solution of water. The Canadian test is designed to simulate the effect of deicing salts. Both tests require no more than 1% of the dry weight of the block to be lost after the 50 freeze thaw cycles. The blocks passed both tests. While the Canadian test has not been adopted as an American standard, blocks exposed to any deicing salts should be tested prior to installation to ensure their resistance to salt arid freeze-thaw.

6. CONCLUSION

1) Concrete block paving appears to be an economical substitute for clay brick concrete streets when initial costs are compared and especially when pavers are installed mechancially. CBP costs less than brick, as brick is 55 to 65 U.S. dollars per square meter. There are thousands of brick streets in the U.S., many of them in need of major repair or replacement. CBP offers a less expensive alternative while maintaining the visual character and durability of brick.

2) Mechanically installed CBP is cost-competitive with poured-in-place concrete in many situations. Generally, the larger the area of CBP, the more cost competitive it is with concrete. CBP potentially has lower life-cycle maintenance costs. This is because their is little or no new material used when the pavement is removed and replaced for utility repair.

3) The initial cost of CBP is higher than asphalt, but CBP life cycle costs may be lower, especially in heavy loading situations. Life cycle-costs should be compared for each situation. Asphalt streets are typically resurfaced every 7 to 15 years depending on climate and traffic. CBP streets can be virtually maintenance free for over 30 years.

4) Low maintenance street pavement systems are increasingly important to municipal officials, as street maintenance budgets have high personnel costs. CBP offers a sufface that has substantially lower maintenance costs. City officials are increasingly willing to spend more money to construct CBP streets in order to decrease the personnel costs tied to street maintenance, and are willing to spend more money to improve the visual quality of neighborhoods and business districts.

5) When an old pavement base has structural life remaining, but the surface is worn, CBP makes an excellent overlay surface. Mechanical installation can reduce these initial costs and time for construction. Asphalt and concrete grinding and pavement removal technology enables CBP to match elevations of existing pavements.

6) Construction time with CBP was seven days shorter than with poured concrete. This reduces the time the street is not open to emergency and service vehicles, as well as reducing the inconvenience to the residents. As the street was installed, it was ready for traffic, so residents could park on the completed portion in the evenings between construction days. Emergency and service vehicles could also use the finished portions of the street during construction.

7) While 20 years time will be the ultimate judge, the pavers are very durable and are resistant to the eroding effects of deicing salt. Based on the long term experience of Canadian and European cites, the pavement endures deicing salt. Snow removal was not a problem, especially as rubber-edge plow blades were used in Dayton.

8) Construction time would have been shortened further if there was a fork lift truck on the site to move the pallets of the blocks next to the Optimas machine. While the pallets were close to the machine, travel time to and from the pallets could have been reduced to zero with a fork lift, perhaps shortening the Installation time to two days.

9) Mechanical installation requires that each layer of the blocks on every pallet are perfect. If there are any reject blocks, they must be removed by hand. The time taken to

do this slows the installation time and works against the efficiencies of mechanical installation.

10) When some of the layers of pavers were picked up by the Optimas machine, a few blocks from the layer beneath would occasionally stick to them. These had to be knocked off of the layer that was being clamped by the Optimas. The sticking is due to insufficient sand between each layer of blocks when manufactured by multi–layer equipment. This can be overcome by better control of the layering process when the blocks are being produced. Installation time could have been decreased without the time taken to remove sticking blocks. As the use of single layer manufacturing machines grows, the sticking problem will be eliminated.

11) One of the best features of CBP is its visual appeal. The residents along the street were thrilled with the character it adds to the street and the value it adds to their hones. This was demonstrated by a recent repair made in the street by the local natural gas company. Residents intensely questioned crews as they began removing the pavement and sought assurances that the pavement would be replaced properly after the repair was made. The pavement was replaced properly so that evidence of a repair is nonexistent.

7. DESIGN METHOD

Three tables follow that can be used for street pavement design and rehabilitation of streets. Table 2 and 3 should be selected depending on the level of water table below a base of at least 80% CBR. The thickness of the sub-base can be determined for any situation. For heavier trafficked situations over softer ground, a 12N/mm² strength concrete base is recommended over the compacted gravel base.

Table 4 is used for rehabilitating existing pavements. The thickness of each existing layer is multiplied by a conversion factor, depending on the condition of the materials. This gives the equivalent thickness of gravel base material. The sum of the equivalent thicknesses gives a dimension that can be compared to Table 2 and 3 (depending on the level of the water table). This comparison can be adjusted with respect to the traffic load. If the existing pavement is adequate, it can be directly overlaid with concrete blocks and 25mm of sand. If the pavement is inadequate, then the defective material should be removed and replaced, or an additional layer of asphalt or concrete should be applied to the street before overlaying the sand and blocks.

The design of the Dayton street is presented as an example. In this instance removal of the top of the pavement is required in order to provide depth for construction of the overlay. Table 4 is used to determine where the underlying concrete is satisfactory or where it should be replaced.



Figure 5 - 80 Year Old Brick Street Adjoins the New CBP



Figure 6

Table 2

Sub-base Design Chart

Water Table Is More Than 600mm Below The Base

SUB GRADE	HEAVY CLAY				SILT	SILTY CLAY	SANDY CLAY		SAND POORLY GRADED	SAND WELL GRADED	SAND GRAVEL WELL GRADED
Plasticity %	70	60	50	40	-	30	20	10	-	-	-
CBR %	2	2	2.5	3	2	5	7	5	20	40	60
APPLICATION											
Pedestrian use only 60mm thick blocks	100	100	100	100	100	75	50	75	50	On grade	On grade
Pedestrian and light vehicles 60mm thick blocks	150	150	150	150	150	75	75	75	75	On grade	On grade
Parking lot - light vehicles 60mm thick blocks	225	225	215	200	225	115	100	100	75	75	75
Parking lot - occasional heavy vehicles 80mm thick blocks	300	300	275	250	300	140	100	140	75	75	75
Minor Residential Street 80mm thick blocks	375	375	340	300	375	190	100	190	75	75	75
12N/mm² Concrete	175	175	165	140	140	100	100	100	-	-	-
Granular	150	150	150	150	150	150	150	150	150	150	150
Major thoroughfare 60mm thick blocks											
12N/mm² Concrete	190	190	175	165	190	115	115	115	-	-	-
Granular	150	150	150	150	150	150	150	150	200	200	200

Table 3

Sub-base Design Chart

Water Table Is Less Than 600mm Below The Base

SUB GRADE	HEAVY CLAY				SILT	SILTY CLAY	SANDY CLAY		SAND POORLY GRADED	SAND WELL GRADED	SAND GRAVEL WELL GRADED
Plasticity %	70	60	50	40	-	30	20	10	-	-	-
CBR %	1	1.5	2	2	1	3	6	4	10	15	20
APPLICATION											
Pedestrian use only 60mm thick blocks	100	100	100	100	100	100	75	75	50	On grade	On grade
Pedestrian and light vehicles 60mm thick blocks	190	150	150	150	190	150	75	75	75	On grade	On grade
Parking lot - light vehicles 60mm thick blocks	250	240	225	225	250	200	100	125	75	75	75
Parking lot - occasional heavy vehicles 80mm thick blocks	350	325	300	300	350	250	175	190	75	75	75
Minor Residential Street 80mm thick blocks	400	400	375	375	400	300	140	225	75	75	75
Collector Street 80mm thick blocks											
12N/м² Concrete	190	190	175	175	190	140	100	115	-	-	-
Granular	150	150	150	150	150	150	150	150	150	150	150
Major thoroughfare 60mm thick blocks											
12N/м² Concrete	200	200	190	190	200	150	115	140	-	-	-
Granular	150	150	150	150	150	150	150	150	200	200	200

Table 4
Existing Pavement Material Conversion Factors

SUB GRADE	MATERIAL DESCRIPTION	CONVERSION FACTOR
A	Natural subgrade	0.00
B	Improved subgrade (predominately granular material) containing some silt and clay but with a plasticity index of less than 10.	0.00-0.50
C	Lime modified subgrade made with soils with a plasticity index of greater than 10.	0.00-0.50
SUB BASE		
A	Granular sub-base with a well graded, hard aggregates and some plastic fines, CBR not less than 20 and plasticity index not more than K.	0.50-0.60
B	Granular sub-base with well graded, hard aggregates and some plastic fines, CBR not less than 20 and plasticity index less than 6.	0.60-0.75
C	Cement modified sub-base made with soils with a plasticity index less than 10.	0.50-0.75
BASE		
A	Granular base with nonplastic granular material and conforming to established standards for a high quality aggregate base.	0.90-1.25
B	Soil cement base having devel oped extensive cracking shown by reflective cracks. May show some pumping or instability.	0.75-1.25
C	Soil cement base showing little cracking and in a stable condition.	1.25-1.75
D	Asphalt base having developed extensive cracking shown by reflective cracks and in a stable condition.	1.25-1.75
E	Asphalt base shows only slight cracking and little deformation.	1.75-2.25
F	Portland cement concrete base having developed extensive cracking shown by reflective cracks but in a stable condition.	1.50-1.75

Table 4 Continued

BASE		
G	Portland cement concrete base showing only slight cracking and no deformation.	2.25-2.50
ASPHALT SURFACE		
A	Asphalt surface mixtures having large well defined crack patterns, spalling along the cracks and noticeable deformation in the wheel tracks.	0.75-1.25
B	Asphalt surface mixtures having well defined crack patterns but no spalling and little deformation in the wheel tracks.	1.25-1.75
C	Asphalt surface with some fine cracking and little deformation in the wheel tracks and in stable condition.	1.75-2.25
D	Asphalt surface is not cracked with no deformation.	2.25-2.50
CONCRETE PAVEMENT		
A	Portland cement concrete pavement that has broken pieces measuring 600mm or less.	0.75-1.25
B	Concrete pavement that is substantially cracked with all pieces less than 5m² that can be well seated by rolling.	1.25-1.50
C	Concrete pavement which is stable and undersealed with slight cracking but no pieces less than 1m².	1.75-2.25
D	Concrete pavement that is stable, undersealed and not cracked.	2.25-2.50

Design Example for Dayton Street:

Existing Construction

25mm Asphaltic surface showing extensive signs of wear.

150mm concrete showing signs of cracking and crumbling.

425mn granular sub-base material con taminated with clay.

sub-grade CBR 3% (clay)

New Construction

From Table 2 using:

3% CBR, heavy clay with water table more than 600mm below formation

Residential street with 8Qom thick concrete blocks on 35mm of sand.

Required sub-base (Table 2) thickness = 300mm

Equivalent Thickness

Conversion factors (Table 4)

Portland cement concrete with extensive cracking in stable condition

Base F = 1.50

Weak and crumbly Portland cement concrete, minor instability and some pumping.

Base B = 1.00

Granular sub-base with some plastic fines.

Base A = 0.50

Granular sub-base contaminated with silt and clay.

Subgrade B = 0.35

Remaining thickness:

Center of street = 125mm concrete

Edge of street = 90mm concrete

Poor condition at center:

125mm x 1.00 = 125mm
425mm x 0.35 = 150mm
275mm

Less than 300mm, therefore replace.

Good condition at center:

125mm x 1.50 = 185nn
425mm x 0.50 = 210mm
395mm

Greater than 300mm, therefore acceptable.

Poor condition at curb:

90mm x 1.0 = 90mm
425mm x 0.35 = 150mm
240mm

Less than 300mm, therefore replace.

Good condition at curb:

90mm x 1.5 = 125mm
425mm x 0.5 = 210mm
445mm

Greater than 300mm, therefore acceptable.

Mark unacceptable areas on pavement and re place with 12N/mm² or stronger.

8. REFERENCES

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(2) Smith, David R. and Smallridge, Mark Tecumseh Street Concrete Block Paving City of Dayton, Department of Planning Dayton, Ohio, U.S.A., 1986.

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