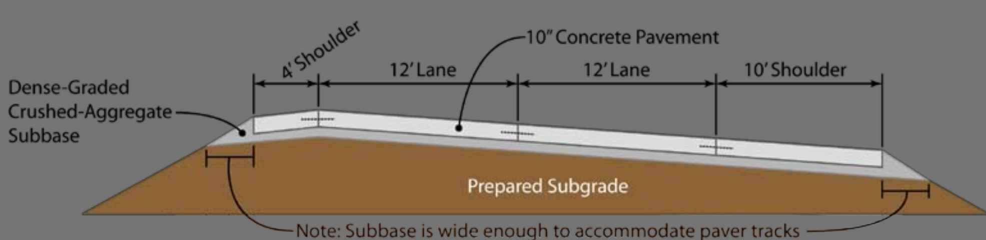
2010

Relative Cost of Concrete Highway Features

Final Report—12-27-10

In 2010 a survey of ACPA contractors was conducted to determine the relative cost of selected design features. Three different surveys were used; a General Survey evaluating nine design features, a Saw and Seal survey evaluating four sealant types and four reservoir widths, and a smoothness survey designed to establish the cost to attain lower and lower roughness levels. To complete all three surveys required 117 cost inputs to be developed by each contractor.



AMERICAN CONCRETE PAVEMENT ASSOCIATION

ACPA
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Introduction

The performance of concrete pavements is highly dependent upon the design, construction techniques and materials, project specifications and inspection, and maintenance activities. During the project development stage, owners select pavement design features based on their ability to balance cost and performance to establish what they believe is the best **value** or design optimization. The best value may be different than the lowest initial construction cost and can differ based on the category and function of the roadway. The expected level of performance depends, among other things, upon the desired level of service, facility type, traffic levels, speeds, etc. An urban freeway typically requires a higher performance level than a city street for example.

The owners of transportation facilities are faced with the challenge of balancing infrastructure needs with current and future budgets, designing for predicted future traffic levels, and procurement of construction contracts through a competitive low bid system. Many of these aspects make selecting the best value difficult to say the least.

To assist owners in determining the best value achieved from standard pavement design features, the ACPA conducted a survey in 1995 to establish the relative cost of concrete pavement design features[1]. The features evaluated consisted of pavement thickness, joint spacing, incorporation of a drainage system, sub-base type, subgrade modification, use of dowels, sealant type, shoulder design, and surface texture type.

The 1995 effort was executed by surveying contractors to obtain their estimates of the relative change in cost of a specific design feature when only that featured was varied. A standard or reference pavement design was used, indicated in Figure 1. The contractors were instructed to prepare their relative costs by estimating the actual cost of the construction of the "reference" section first. This section was considered to be a typical rural multilane divided highway with two 10" thick lanes, undoweled joints, with tied lanes using No. 4 bars on 30" centers. It was a plain jointed pavement with non-skewed, uniformly spaced, transverse joints on 20 ft. centers. All joints had single-width saw cuts to a depth of 3" with hot-poured sealant. The design used gravel shoulders 10 ft. wide on the right side and 4 ft. wide on the left side. The pavement was place on a dense graded crushed aggregate base compacted to a 6 inch thickness. The subgrade was prepared by scarifying to a depth of 6" and recompacting at optimum moisture content.

To establish the relative cost of a given design feature, each contractor estimated the actual cost of the reference pavement section. The actual cost of the reference pavement section was then determined to be equal to a cost of 100%. The design feature, such as thickness for example, would then be changed from 10" (e.g. reference design) to 12" (e.g. design change being investigated) and the contractor would estimate the cost of the new construction. The contractor would then determine the increase or decrease in cost as a percentage of the reference section cost. That is, is if the actual cost of the 12" thick pavement section increased the total cost 5%, the increase in thickness would be assigned a relative cost of 105%. The relative cost approach was used to allow comparisons

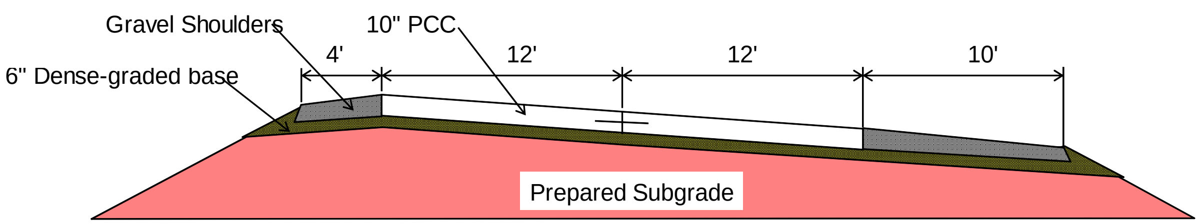

Figure 1 1995 Standard Reference Section

between design features without exposing actual costs. Each design feature was evaluated one increment at a time against a reference pavement section.

Fourteen contractors participated in this effort. The results of the 1995 survey are indicated in Table 1 below. For each design feature investigated, the average relative cost and range in relative cost

TABLE 1 RESULTS OF 1995 ACPA SURVEY

Design Feature Evaluated	Average Relative Cost (Percent)	Range in Relative Cost (Percent)
Pavement Thickness		
6’’ Thickness, 12ft joint spacing, 1 3/4” saw depth	81	70 - 93
8” Thickness, 15ft joint spacing, 2 ¼” saw depth	91	86 - 104
10” Thickness, 20 ft Joint Spacing 3” saw depth	100	
12’ Thickness, 20 ft joint spacing, 3 ½” saw depth	114	104 - 135
Transverse Joint Spacing & Sealants		
15 ft spacing, single cut joint, hot pour sealant	101	95 - 107
15 ft spacing, reservoir cut joint& backer rod, silicone sealant	104	101 - 107
20 ft Spacing, single cut joint, hot pour sealant	100	
Base Type		
Standard Subgrade, No Base Material	84	78 - 95
Lime Treated Subgrade(12”) , No Base Material	97	87 - 108
6” Dense Graded Aggregate Base	100	
4” LCB, 4” Aggregate Base,	122	96 - 144
4” Unstablized open-graded base, 6” granular drainage layer, trench drains with pipes	114	105 - 122
4” Asphalt stabilized base drainage layer, 6” dense graded aggregate base, trench edge drain with pipes	123	109 - 132
4” Cement stabilized open graded drainage layer, 6” dense graded aggregate base, trench edge drains w- pipes	124	110 - 135
Shoulder Type		
6” Asphalt Shoulder, 6” aggregate base	111	105 - 125
6” Partial Depth Tied Concrete Shoulder, 6” aggregate base	124	108 - 145
10” Aggregate Base Shoulder	100	
10” Full Depth Tied Concrete Shoulder, 6” aggregate base	132	115 - 160
14 ft widened traffic lane, 6” asphalt shoulder 8ft wide, 6” aggregate base	112	104 - 112
Load Transfer Options		
20 ft Joint Spacing, Undoweled	100	
20 ft. joint spacing, 1 ½” dowels @ 12” c-c,	108	105 - 115
15 ft. joint spacing, 1 ½” dowels @ 12” c-c	112	106 - 121
CRCP	134	118 - 190

Joint Sealant		
Unsealed	98	94 - 99
Single Saw Cut filled with hot pour sealant	100	
½”wide reservoir cut, silicone sealant	102	101 - 105
½” wide reservoir cut, silicone sealant, 15 ft joint spacing	104	101 - 107
½” wide compression sealed joint,	105	102 - 115

is indicated as a percentage of the cost of the reference pavement. For full details of the comparisons consult reference one.

Upon completion of the 1995 survey a TRB paper[1] was developed and presented at the 1997 annual meeting. The paper summarized the effort by stating: “This study has determined that the selection of various concrete pavement features has a significant effect on construction costs. Relative cost information has been presented for various features that will provide general information for use by pavement designers in concrete pavement features. This information, when used in conjunction with related pavement performance information, should enhance the life cycle costs of concrete pavement designs.”

As indicated in the TRB paper summary, users of the relative cost information need to recognize that the cost information pertains to initial construction costs and that the **value** of a design feature can only be determined when the initial cost is balanced with the associated impact on pavement performance. There typically is a law of diminishing returns in terms of performance for most improvements. That is, after improving a feature so much, any additional improvements may have very little effect or impact on pavement performance.

Since the 1995 survey, other authors have addressed the benefits and costs of concrete pavement design features [2]. Darter and Gharaibeh asserted that many design features evolved over time based on previous field performance experience, research, or adoption of other states practices [2]. Their paper presented a methodology for evaluating the costs and benefits of jointed plain concrete design features. This methodology employed both a means for assessing the impact on performance of the design feature as well as determining its value through life cycle cost analysis.

2010 Relative Cost of Highway Concrete Pavement Features Survey

In 2009 it was realized that there was a need to update the 1995 survey as the results were almost 15 years old at that time. In recent times there had been commodity price increases on various materials so the combined cost for labor and materials of some features may be different in the present day than in 1995. Therefore an updated survey was planned and executed in 2010.

The 2010 survey approached the relative cost issues in a similar manner as before but with some changes also. Like the 1995 survey, the 2010 survey developed a reference section, shown in Figure 2, which was very similar to the reference section in 1995 but with some modern updates. For example, concrete shoulders were included as the reference as well as dowels. It was felt that this better represented current designs. Products such as roller compacted concrete shoulders did not exist in 1995 so these new features were also included.

The 1995 process used one survey to collect all the data and was conducted using a mailed out and mailed in hard copy process. The results that were mailed in contained only percentage costs of the reference pavement section.

The 2010 process was designed around a main “General Survey”, two additional surveys, and two additional modules.

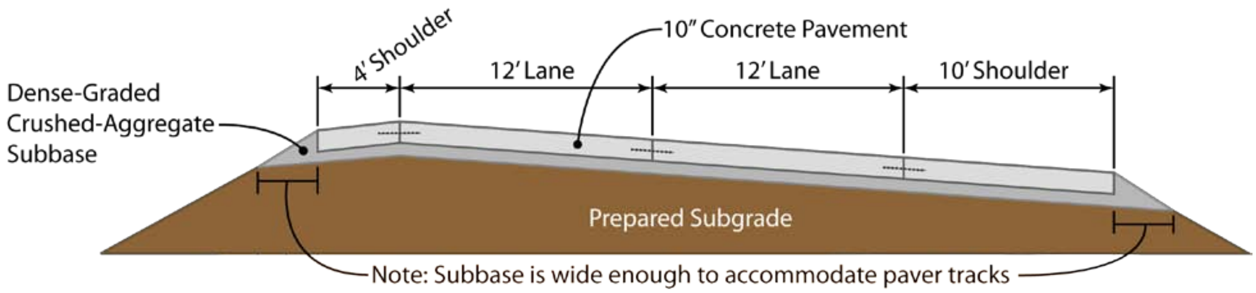

Figure 2 2010 Cross Section of "Reference" Construction Project

The two additional surveys consisted of a "Saw and Seal Survey" and a "Smoothness Survey". The additional surveys and processes were developed to provide more detailed information and also a process that could be more readily updated in the future. Details of these surveys and processes follow. The 2010 process distributed the surveys via email and provided a web-based application to input the results.

One major difference between the 1995 survey process and the 2010 survey process was that actual costs were collected. To accomplish this, attorneys needed to be included in the approach so that anti-trust issues did not arise. The result was a two level password security approach where each contractor had to enter a user ID and password to input "their" information into the web application. They could not access any other data. The passwords and user ID were randomly generated with alpha-numeric characters. The assignment of the user ID and password were done off site so that the data base operators managing the web application could not identify the origin of any of the data. Only one person had access to both the contractor names and the user IDs and passwords; and this individual did not have direct access to the database.

The 2010 process also differed in that the Chapter organizations identified the contractors in their territories to be contacted for participation. The concept was that the Chapters could provide a link at the local level and hopefully provide greater participation. While 30 solicitations for participation went out in 1995, 54 went out in 2010. For the 2010 survey, two agencies were solicited for input as to what should be included in the survey effort. This resulted in the inclusion of the smoothness survey in the 2010 update.

General Survey

The General Survey solicitation letter and survey form are shown in Appendix 1. As indicated in Appendix 1, nine features were evaluated and are indicated in Table 2. This resulted in 34 separate cost inputs to be developed by each contractor. The web based input screen resembled the Table indicated in Appendix 1.

TABLE 2 2010 GENERAL SURVEY FEATURES EVALUATED

Design Feature Evaluated	Options Evaluated for Each Feature
PCCP Thickness	8", 10", 12", 14"
Shoulder Thickness/Material Design	10" PCCP, 6" PCCP, 4" PCCP, 10" RCC,, 10" AC, 6"AC, 10"AB
Aggregate Base Thickness	2" , 4", 10", and 15" Aggregate Base
Base Material Type	6" Free draining aggregate base, 6" Cement stabilized base, 6" bituminous stabilized base, 4" Cement Stabilized base,4" Bituminous Stabilized Base, 4" AC, 2" AC
Subgrade Improvement	6" Untreated Subgrade, 6" Cement Stabilized, 6" Lime Treated
Surface Texture Category	Astro turf, Diamond Ground, Transverse Tined, Longitudinally Tined
Curing Method Used	AASHTO M148 Type 2 Class B, MnDOT Poly Alpha Methylstyrene,

	Water cure/polyethylene covering
Dowel Bar Inserter	Reduction in Sq Yd Cost of 10” Pavement if DBI Used
Widened Lane Category	13 ft Travel Lane, 9 ft shoulder, dowels in travel lanes only not in shoulders

The instructions provided to the contractors included the typical sections show in Figures 2 and 3 and the project assumptions listed as follows:

- The project is a five mile long, rural, four-lane interstate to be constructed within 50 miles of your home office.
- The concrete design features are as follows:
  - Two 12 ft. wide travel lanes in each direction (paving width restricted to a maximum of 30 ft.)
  - 10 inch thick concrete pavement for the entire roadway width
  - 4 ft. and 10 ft. tied, full-depth concrete shoulders
  - Transverse joint spacing is 15 ft. o-c with non-skewed joints
  - 1-1/2” by 18” long epoxy coated dowels placed in baskets on 12 inch centers in the traffic lanes only (i.e. no dowels in shoulders)
  - 30” long, No. 5 deformed tie bars on 30” centers for all longitudinal joints
  - 3/8” wide transverse joints filled with recessed silicone sealant and backer rod
  - The surface texture was constructed using a burlap drag and ¾” o-c longitudinal tining which is 1/8” deep. The curing compound used is AASHTO M148
  - A 43 ft. wide dense-graded crushed-aggregate base layer compacted to 6" thickness and wide enough to accommodate paver tracks.
  - Subgrade prepared by scarifying to a depth of 6" and re-compacting at optimum moisture content
- Typical materials specified by the State Department’s of Transportation and construction methods used in your area should be assumed
- The existing grade alignment is assumed adequate, with no earth work required
- The total quantities for the five mile project are as follows:

  24 ft. Mainline Paving: 70,400 sq. yds. (Note this is one direction)
  10 ft. Shoulder Paving: 29,333 sq. yds. (Note this is one direction)
  4 ft. Shoulder Paving: 11,733 sq. yds. (Note this is one direction)
  Longitudinal Joints: 158,400 Lineal Feet
  Transverse Joints: 133,760 Lineal Feet
  All Joints: 292,160 Lineal Feet

Figure 2 was the reference section used for all features. Figure 3 was included to depict the widened lane option for added clarification.

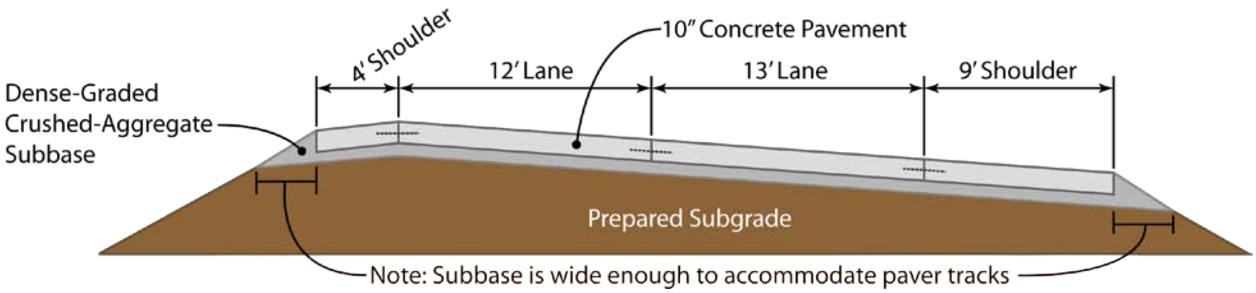

Figure 3 2010 Widened Lane Category- Note 13 Dowels in Widened Lane

Saw and Seal Survey

A separate Saw and Seal Survey was conducted to provide additional information without having to have each contractor complete all the many different items. It was realized that oftentimes subcontractors provide the sawing and sealing and this could reduce the burden of the survey on the general paving contractors. It also allowed more detailed information on sawing and sealing costs to be developed.

The Saw and Seal Survey and instruction are included in Appendix 2. As indicated in Table 1 of Appendix 2, four features were evaluated. This resulted in 22 separate cost inputs to be developed by each contractor. The web-based input screen resembled Table 1 in Appendix 2.

TABLE 3 2010 SAW AND SEAL SURVEY FEATURES EVALUATED

Design Feature Evaluated	Options Evaluated for Each Feature
Initial Saw Cut Depth	1/8" wide by 2.75" deep, 1/8" Wide by 3.7" deep
Reservoir Cut Width	¼" wide by 1-¼" deep, 3/8" wide by 1-¼" deep, ½" wide by 1-1/4" deep
Cleaning Joints (all 1-¼" deep)	1/8" wide no sealant, 1/8" wide sealant, ¼" wide sealant, 3/8" wide sealant, ½" wide sealant
Furnish and Install Sealant (all 1- ¼" deep reservoir)	
〈 1/8" wide	Hot pour
〈 ¼" wide	Hot pour, silicone, preformed compression seal
〈 3/8" wide	Hot pour, silicone non-sag, silicone self-leveling, preformed compression seal
〈 ½" wide	Hot pour, silicone non-sag, silicone, self-leveling, preformed compression seal

The additional detail provided by the saw and seal survey allows better extrapolation of the data to other possible sawing and sealing combinations in the future.

Smoothness Survey

The purpose of the smoothness survey was twofold: First, to determine the cost, if any, to achieve various ranges of specified smoothness levels; and, second, to determine what additional effort is needed to meet a given level of smoothness and what that effort may consist of. The basis for the additional cost or effort was what is necessary to achieve the specified smoothness beyond the normal construction effort. The normal construction effort was defined as the effort necessary to attain a smoothness level achieving a profilograph specification of 7 inches per mile based on a two tenths blanking band.

A major difference in the smoothness survey approach was that in addition to indicating an associated cost for a feature, the contractor was asked to provide commentary regarding what additional tasks or effort was associated with a given increase in cost. This was done to better understand how the costs were developed as well as ways to improve overall smoothness in general which could be valuable for future efforts.

The smoothness survey and instructions are included in Appendix 3. As indicated in Table 1 of Appendix 3, three "features" were evaluated. This resulted in 15 separate cost inputs to be developed by each contractor. The web-based input screen resembled Table 1 in Appendix 3.

TABLE 4 2010 SMOOTHNESS SURVEY FEATURES EVALUATED

Design Feature Evaluated	Smoothness Levels Evaluated for Each Option (in/mi)
IRI	< 35, <50, <60, <70, <90
Profilograph PI (0.2" BB)	<2, <5, <7, <9
Profilograph PI (0.0" BB)	<10, <15, <18, <30, <35

Dowel and Tie Bar Module

In lieu of including dowel bar and tie bar options as variables in the general survey, Mr. Glen Eder of Block Heavy and Highway Products Company proposed an alternative approach. This approach was based on defining the steel costs in terms of the typical local sq. yd. cost of concrete pavement. That is, instead of this cost being established by a contractor in the general survey, the final product could have the "user" input their current overall sq. yd. pavement price. The user would then be able to select different steel options and then see how the relative cost was impacted based on their own local conditions. This allows transport cost to be roughly considered by the prevailing local in-place concrete price. That way, only the steel costs need to be considered. This is also true of the labor cost, as these also were not directly considered in the module, but again assumed to be at least partially accounted for in the prevailing local price.

The original format of the approach for both the dowel bar and tie bar modules is indicated in Tables 1 and 2 in Appendix 4. The features that were evaluated in Mr. Eder's original proposed approach are indicated in Tables 5 and 6. The true value of this approach is that it can readily be updated in the future if steel prices change significantly. It also allows for considerable more options to be considered.

TABLE 5 2010 TIE BAR MODULE FEATURES EVALUATED

Design Feature Evaluated	Option Evaluated
Tie Bar Spacing	Variable
Tie Bar Length	Variable
Tie Bar Size	Variable

TABLE 6 2010 DOWEL BAR MODULE FEATURES EVALUATED

Design Feature Evaluated	Options Evaluated
Dowel Bar Diameter	1-¼", 1-½"

It should be noted however, that the General Survey has an option for the reduction in cost resulting from using a dowel bar inserter in lieu of baskets for dowel placement. This approach was used to augment the dowel module so that this comparison can still be made.

2010 Survey Results

Prior to discussing the results, the reader is reminded that, the performance of concrete pavements is highly dependent upon the design, construction techniques and materials, project specifications and inspection, and maintenance activities. When considering the relative cost of concrete pavement features it should be noted that the best value may be different than the lowest initial construction cost and the value can differ based on the category and function of the roadway and design feature. There may also be interaction between the performances of different design features that cannot adequately be accounted for by cost alone.

To determine the best value requires consideration of the initial construction cost, assessment of the performance attributable to the design feature, and the impact on life cycle costs for the evaluation period. Gharaibeh and Darter previously proposed a methodology for conducting benefit-cost analysis[2]. Their approach used Life Cycle Cost analysis combined with pavement performance prediction models to determine the cost effectiveness of selected design features. This methodology can also be used to determine the optimum combination of features. That is, the features which produce the lowest life-cycle cost for a given set of project conditions and performance period. The methodology, developed in approximately 2000, used: (1) performance models from PaveSpec 3.0 software to predict distresses and smoothness, (2) a performance based M&R policy, and (3) the computed life-cycle analysis of the design for the performance period.

With the introduction of the ME Pavement Design Guide, the prediction of distress and smoothness is more readily attainable by agencies for their design situations. Thus a methodology such as previously proposed by Gharaibeh and Darter can be more readily applied by highway designers today. If such an analysis is pursued, it is best to use agency specific data when ever possible.

The 2010 survey was set up so that average cost and the standard deviation of those costs were tabulated. This allows assessment of the variability of the data and also allows for probabilistic life cycle cost determinations in addition to the conventional deterministic evaluations.

The purpose of this survey is to provide general direction regarding the relative cost of highway pavement concrete features. It should be emphasized that these cost comparisons are based on national data and do not represent conditions for any location or project. As such, this data should not be used for estimating projects, or direct cost preparations. The data is intended to provide for relative comparisons using national data.

General Survey Results

As described previously, the General Survey consisted of evaluating nine different categories of features. Each category is discussed separately in the subsequent sections. The results presented in this report represent the responses obtained through 11/8/2010.

Pavement Thickness Category

The pavement thickness category evaluated four thicknesses; 8”, 10”, 12”, and 14”. Only the thickness was varied. Eight contractors provided responses to this category with the results indicated in Table 7 and graphically by the solid blue line in Figure 4. The relationship between thickness and in-place cost is linear and predictable over the range investigated. It would appear appropriate to use this relationship to establish estimates outside the range evaluated. The coefficient of variability for the in-place cost ranged between 13% and 16% for the pavement thickness.

Table 7 Survey Results of Pavement Thickness

PCCP Thickness	Number of Responses	Relative Cost (%)	Coefficient of Variation
8”	8	87	16
10”	8	100	14

12"	8	112	13
14"	8	128	14

Shoulder Design Category

The shoulder design category evaluated seven designs as indicated in Table 8 with 8 contractors participating in the effort. For each option considered the mainline consisted of 10" of PCCP. The results are indicated in Figure 5. As evident the AC shoulder option is the most expensive.

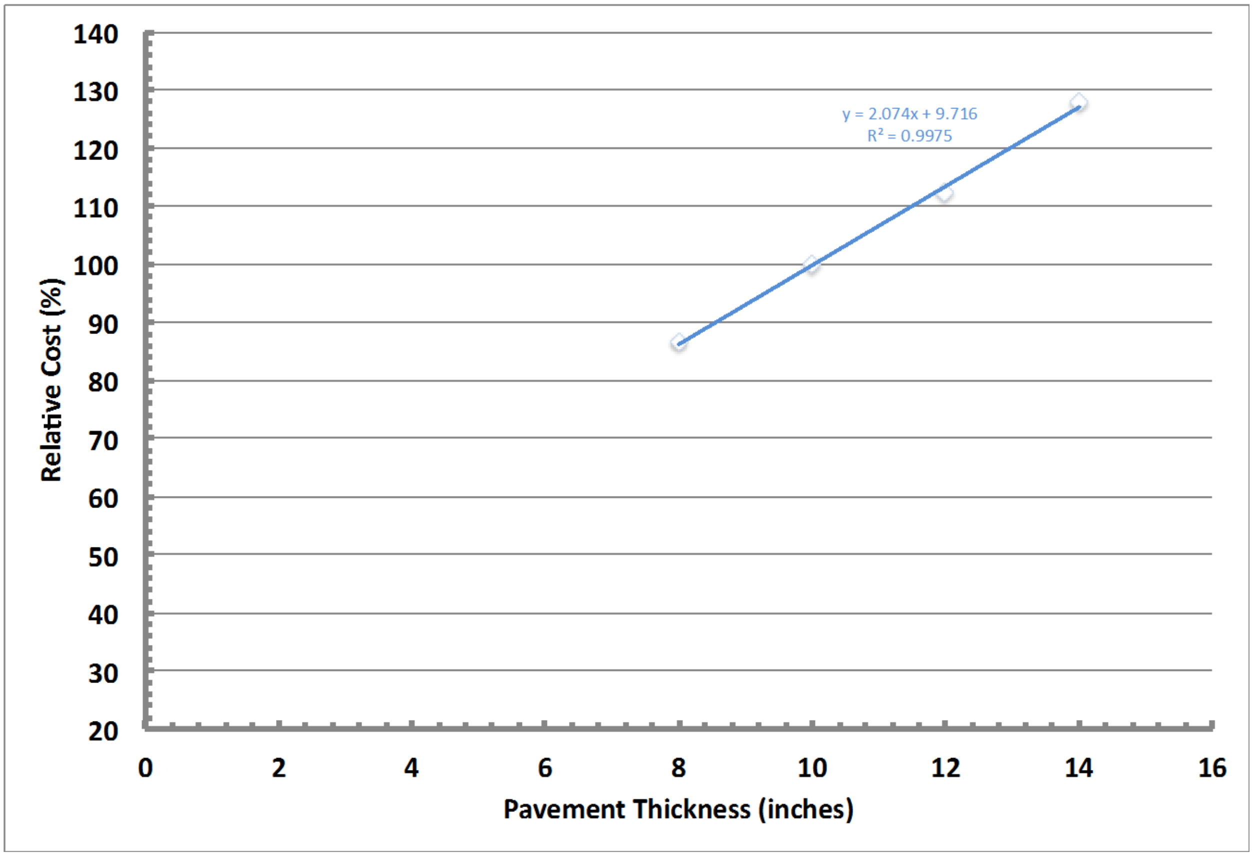

Figure 4 PCCP Thickness Versus In-Place Construction Costs

Table 8 Shoulder Design Category Responses

Thickness/Material Type	No. of Responses	Relative Cost (%)	Coefficient of Variation (%)
10" PCCP	8	100	16
6" PCCP	8	91	16
4" PCCP	8	86	18
10" RCC	2	91	18
10" AC	3	110	12
6" AC	3	94	10
10" AB	5	80	53

Figure 5 Survey Results for Shoulder Thickness/Material Type Features

Aggregate Base Thickness Category

The aggregate base thickness design category evaluated four designs as indicated in Table 9 with 5 contractors participating in the effort. For each option considered, the mainline consisted of 10" of PCCP. The results are indicated in Figure 6. As with the PCCP thickness the results are linear and very predictable over the range of evaluation (2" to 15"). This relationship should be adequate to predict over a larger range of base thicknesses. However, these costs do not consider excavation costs only furnishing and placing costs. It should also be noted that the cost of the standard reference section was determined from the regression indicated in Figure 6 and used to establish the relative cost for each of the other four thicknesses.

Table 9 Survey Results for Aggregate Base Thickness Design Costs

Aggregate Base Thickness (In.)	No. of Responses	Relative Cost (%)	Coefficient of Variation (%)
2	5	87	46
4	5	93	46
6	N.A.	100	N.A.
10	5	113	54
15	5	128	52

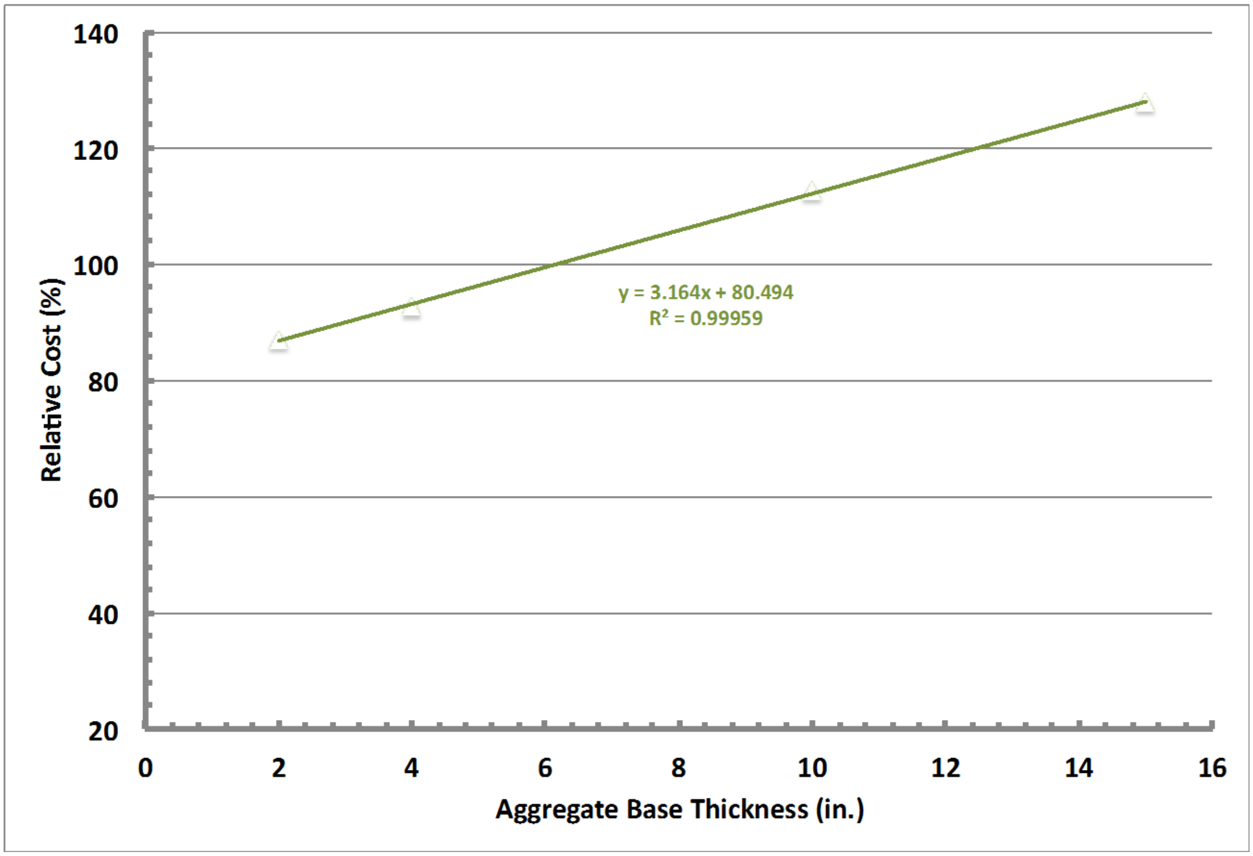

Figure 6 Aggregate Base Thickness Versus Costs

Base Material Type Category

The base type/thickness design evaluated seven designs as indicated in Table 10. As before each option considered the mainline consisted of 10" of PCCP. The survey results are indicated in Figure 7. The bituminous stabilized base was the most expensive and the unstabilized, free-draining aggregate the least expensive. The AC option was similar in cost to the bituminous stabilized option

Table 10 Survey Results for Base Material Type Design Costs

Material Type And Thickness	No. of Responses	Relative Cost (%)	Coefficient of Variation (%)
6" Unstabilized Free Draining Aggregate	5	100	46
6" Cement Stabilized	4	113	45
6" Bituminous Stabilized	2	143	15
4" Cement Stabilized	4	105	47
4" Bituminous Stabilized	2	127	1
4" AC	3	129	14
2" AC	3	109	34

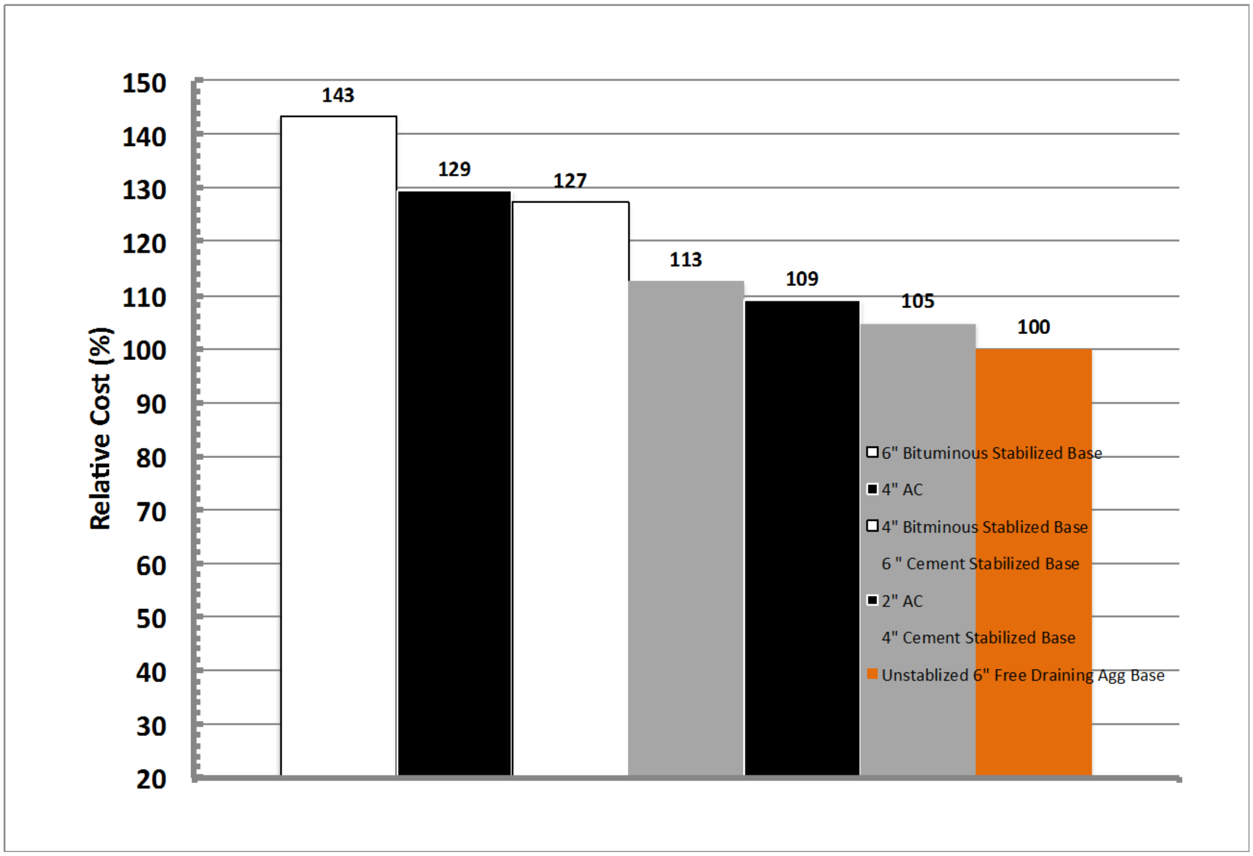

Figure 7 Base Type and Thickness Features Option Results

with the AC option being slightly higher in cost. The standard deviation for some of the base materials was larger than for some of the other design feature options evaluated.

Subgrade Improvement Category

The subgrade improvement design evaluated three subgrade conditions: untreated subgrade; cement stabilized, and lime treated with a maximum of five contractors. Table 11 and Figure 8 indicate the survey results. As indicated the cement-stabilized subgrade was the most costly option.

Table 11 Survey Results for Subgrade Improvement Costs

Material Type (6"in. thickness)	No. of Responses	Relative Cost (%)	Coefficient of Variation (%)
Untreated Subgrade	5	100	33
Cement Stabilized	4	122	56
Lime Treated	4	118	54

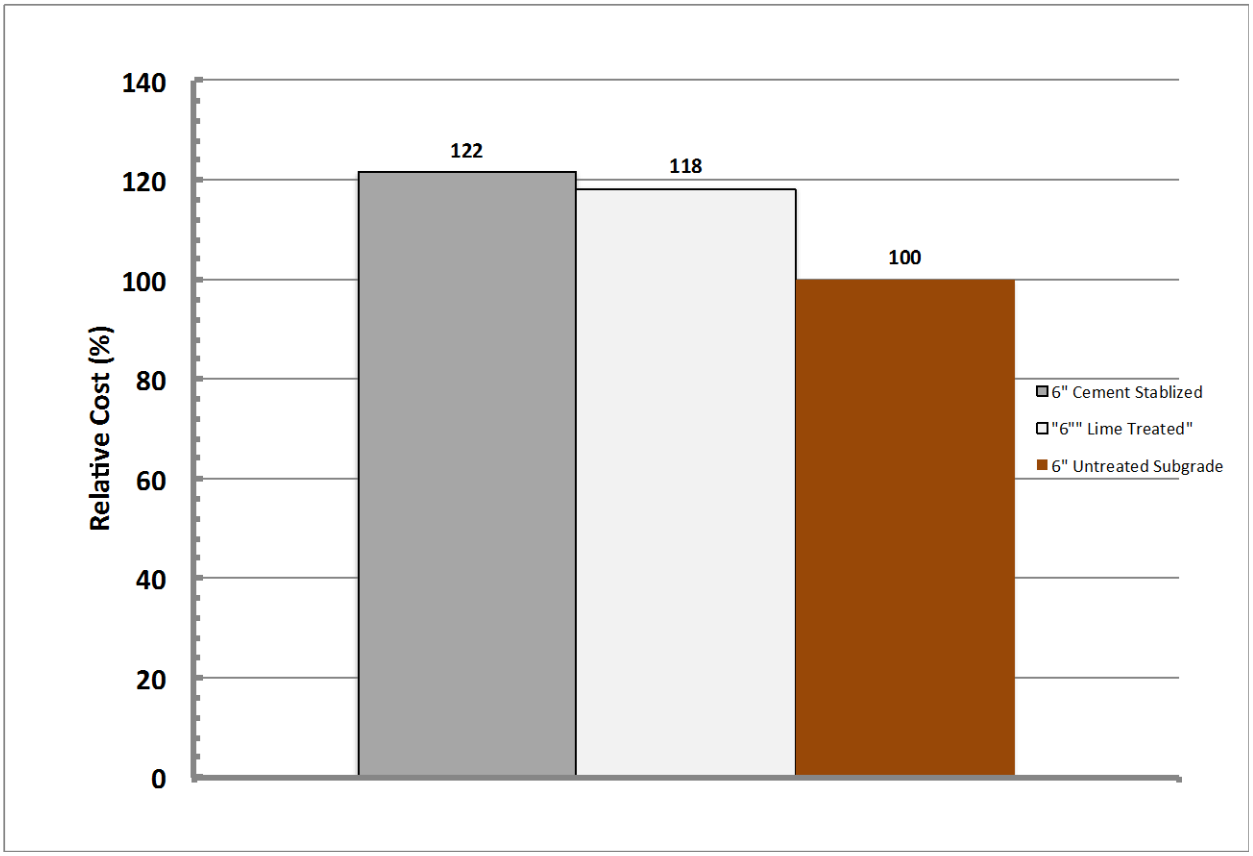

Figure 8 Results of Subgrade Improvement Design Options

Surface Texture Category

The surface texture design options considered four texture types; astro turf drag texture, conventional diamond grinding, ¾” uniform transverse tining, and ¾” uniform longitudinal tining. Table 12 and Figure 9 indicate the survey results. The surface textures were considered to be applied to the full roadway width including shoulders. As indicated, the conventional diamond ground surface was considerably more expensive than the formed in-place textures. The astro-turf texture was the least expensive followed by the longitudinal tined, and then transverse tined.

Table 12 Survey Results for Surface Texture Costs

Surface Texture Type	No. of Responses	Relative Cost (%)	Coefficient of Variation (%)
Astro Turf	7	99.9	100
Conventional Diamond Grinding	7	106.3	46
¾” Uniformly Transverse Tined	7	100.3	58
¾” Longitudinally Tined	7	100	71

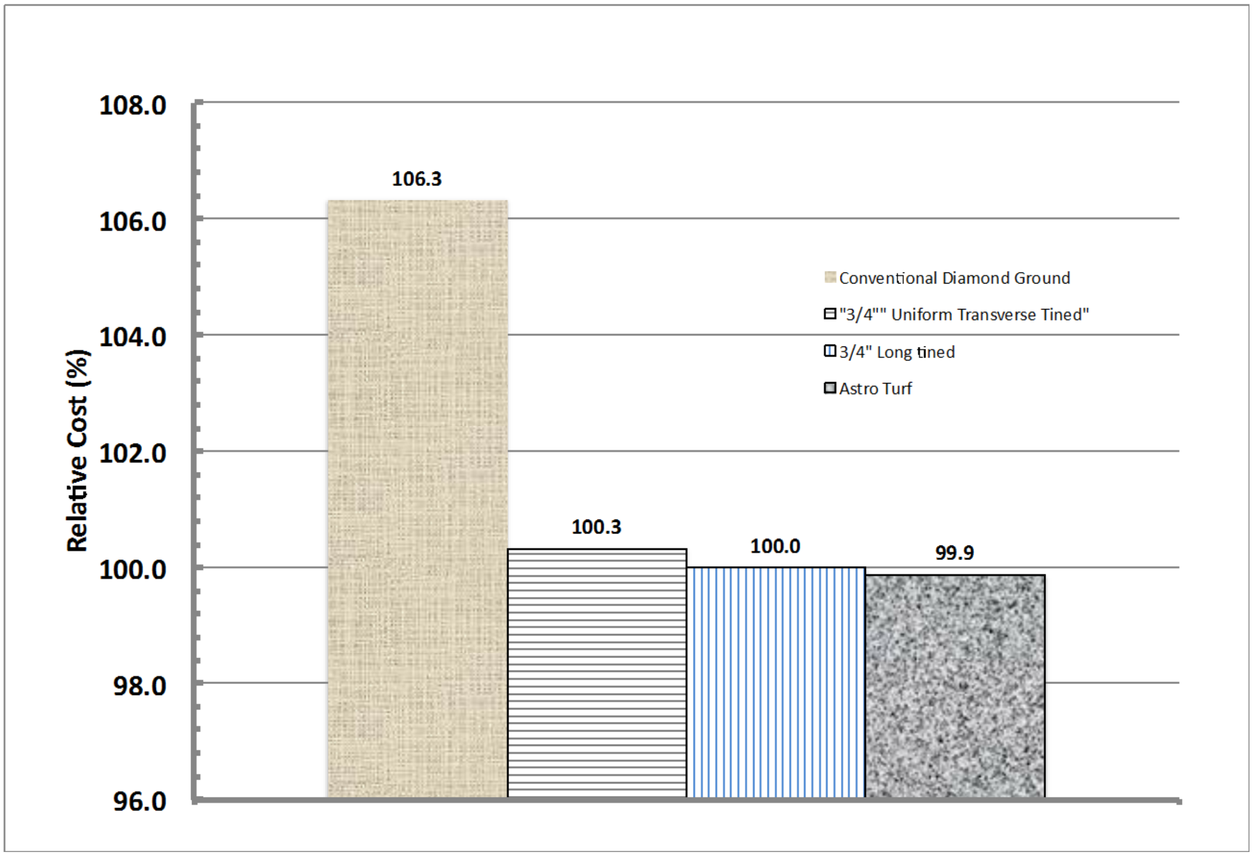

Figure 9 Results of Surface Texture Options Cost

Curing Method Category

Three different PCCP curing options were evaluated; conventional curing using AASHTO M148, Type 2, Class B, a Poly Alpha Methylstyrene product specified by MnDOT, and a water cure/polyethelyne covering system. Table 13 and Figure 10 indicate the survey results. As indicated, the typical curing method (e.g. AASHTO) was the least expensive of the options and the water cure the most expensive. It should be noted however that the coefficient of variation of the water cure method exceeded 100 %. It is not known whether this large variability was due to lack of experience in bidding this option since it is not specified or some other factor.

Table 13 Survey Results for Curing Method Costs

Curing Method	No. of Responses	Relative Costs (%)	Coefficient of Variation (%)
AASHTO M148 Type 2, Class B	7	100	66
MnDOT Poly Alpha Methylstyrene	3	101	45
Water Cure/ Polyethylene Covering	4	109	131

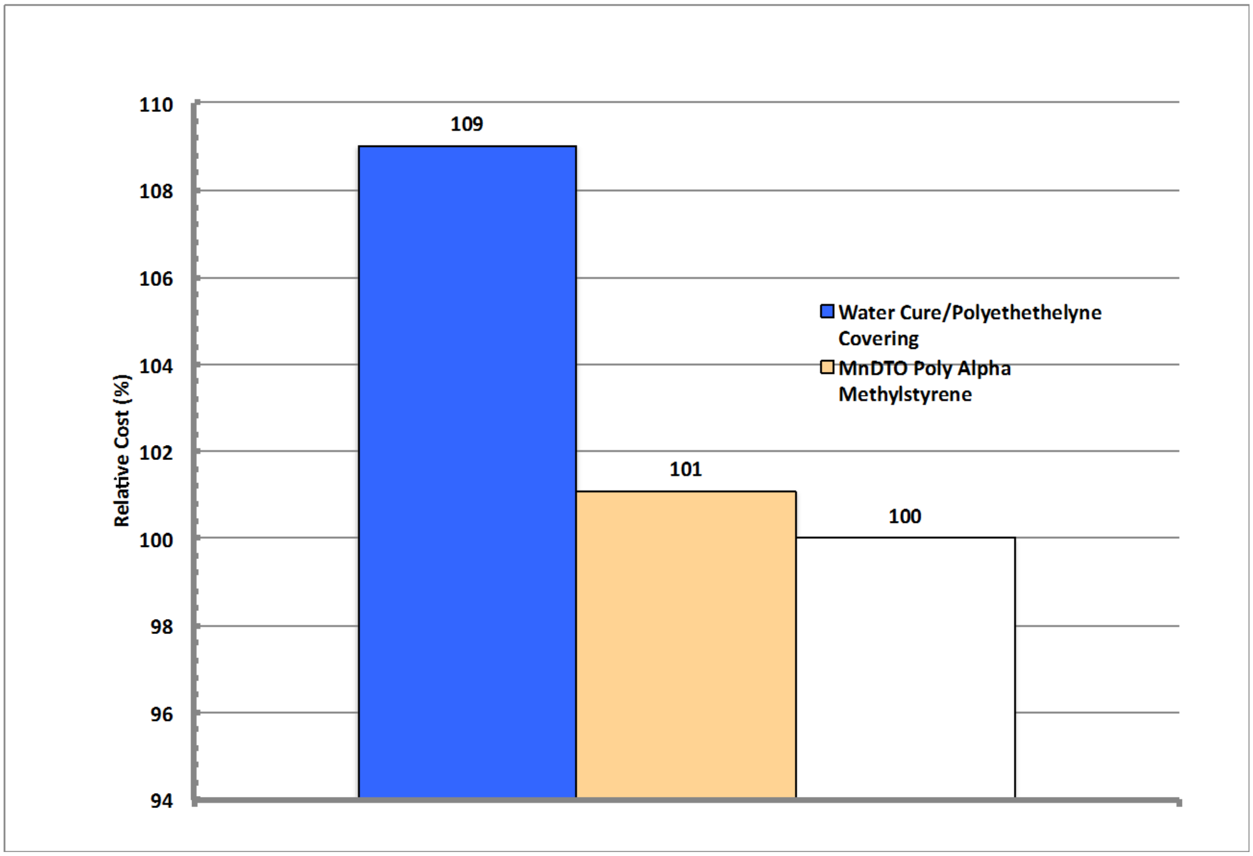

Figure 10 Survey Results for PCCP Curing Method Options

Dowel Bar Inserter Category

The use of a dowel bar inserter was considered as an option to determine the reduction in cost associated by this method when compared to the standard project design for the survey which was: 10" PCCP with 1-1/2" dowels @ 12" centers with baskets. Based on the response from six contractors, the relative cost of this feature was 95% with a coefficient of variation 55 %.

Widen Lane Category

A widen lane design option was also included to evaluate the costs associated with this design feature as research has indicated added performance based on this option[2]. The results, from seven contractors indicated a relative cost of 99.5% with a coefficient of variation of 18 %. At this time this difference is not understood as it would seem that the widened lane would slightly increase cost due to the added dowel bar.

Saw and Seal Survey Results

The Saw and Seal survey was separated from the general survey so that more options could be explored which could be helpful in future applications. It was also felt that it could be more readily updated in the future as a separate survey. The number of responses at the time of this report ranged from 1 to 6 contractor responses for each of the 44 inputs requested, with 5 to 6 responses per item the most common.

The quantities of longitudinal and transverse joints were provided with the typical cross section in the survey so that each contractor would be estimating the same lineal footage of joint/sealant installation. It should be noted that the quantities for joints shown in the original survey is for both roadway directions while the paving quantities are for one direction; this was an error in the original survey.

Four sealant types were evaluated; non-sag silicone (ASTM D5893), self-leveling silicone (ASTM D5893), hot pour sealant (ASTM D6690), and preformed compression seal (ASTM D2628). A 1/8" saw cut was used for the unsealed condition. The results of the longitudinal joints were almost identical to the transverse joints so only the transverse joint results are presented in the graphs and discussed in subsequent sections. The longitudinal joints were typically within 1-2 cents of the costs for the transverse joints with the exception of cleaning the joints. For this work element the longitudinal joints were typically 33% to 50% less. The average cost, complete-in-place, for the longitudinal joints was approximately 4% less than for the transverse joints.

The control for the sealant comparisons was based upon a 3/8" reservoir filled with self- leveling silicone sealant for both the transverse and longitudinal joints. All relative costs are compared back to this standard reference condition. Similarly, all comparisons are made using the same reservoir opening width for all joints. In actual practice the longitudinal and transverse reservoir cuts could be different and even different products used. This condition was not evaluated for this report.

Figure 11 indicates the percent of total installation cost of each of the steps of joint sealing installation. Specifically, initial saw-cut construction, reservoir saw-cut construction, joint cleaning prior to sealant installation, and furnishing and installing the sealant and backer rod (if necessary). The percentage of cost for each work item relative to the total in-place cost for each product are shown for hot pour, non-sag silicone, self-leveling silicone, and preformed compression seals. The unsealed condition can be evaluated by comparing only the initial saw cut data percentage for each application. As indicated the pre-formed compression seal and the non-sag silicone have the largest percentage of cost associated with the furnishing and installation step. This is due to the additional labor necessary to tool the recess into the silicone and the material cost for the compression seal.

Figure 12 indicates the relative cost of each of the sealant grouped by product type and joint opening width. As indicated, the unsealed joint is approximately seven percent less than the silicone sealed joint. The preformed compression seals, except for the ¼" reservoir are the most expensive

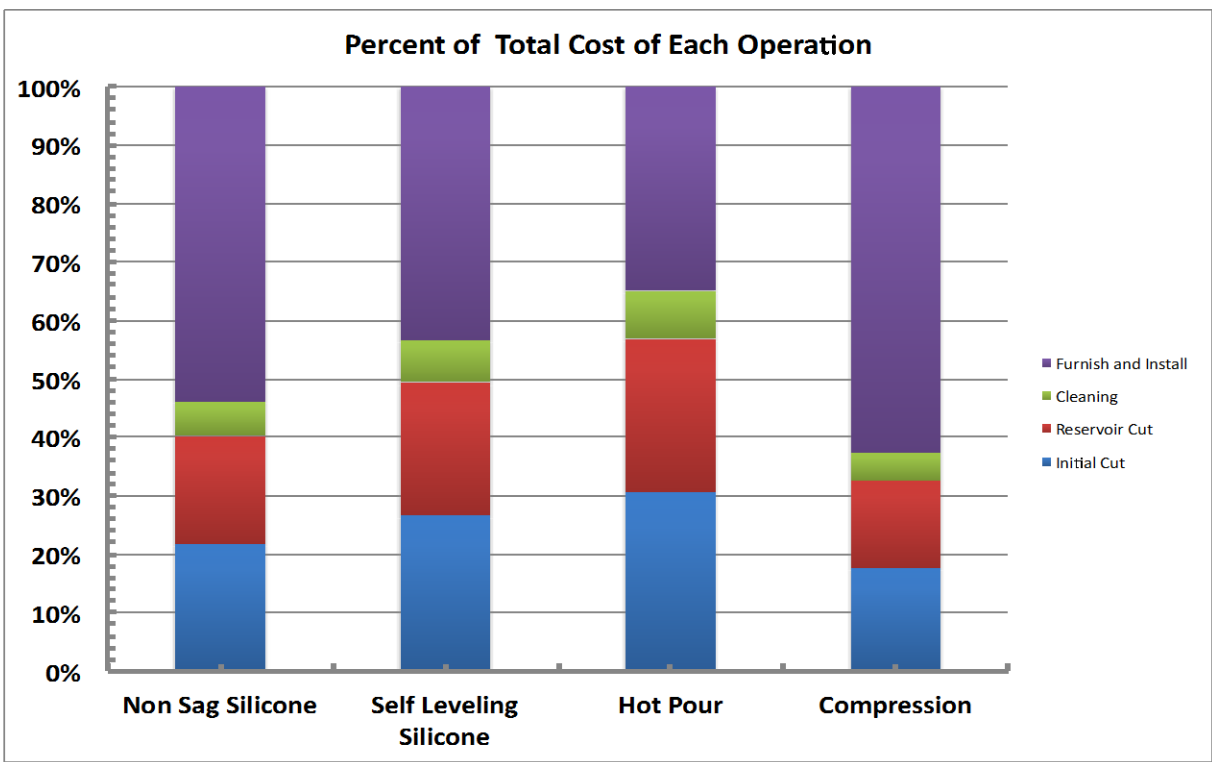

Figure 11 Percent of Total Installation Cost of Each Sealant Construction Phase

product type. The hot pour sealant is the least expensive of the sealed options. The ¼" compression seal and the ¼" self-leveling silicone are the least explainable results. It could be that the ¼" silicone is more expensive than the 3/8" because of the greater difficulty in cleaning the joint. It is also possible that the ¼" compression seal is more competitive due to less material consumed. However, this option is not widely used so additional data would be valuable.

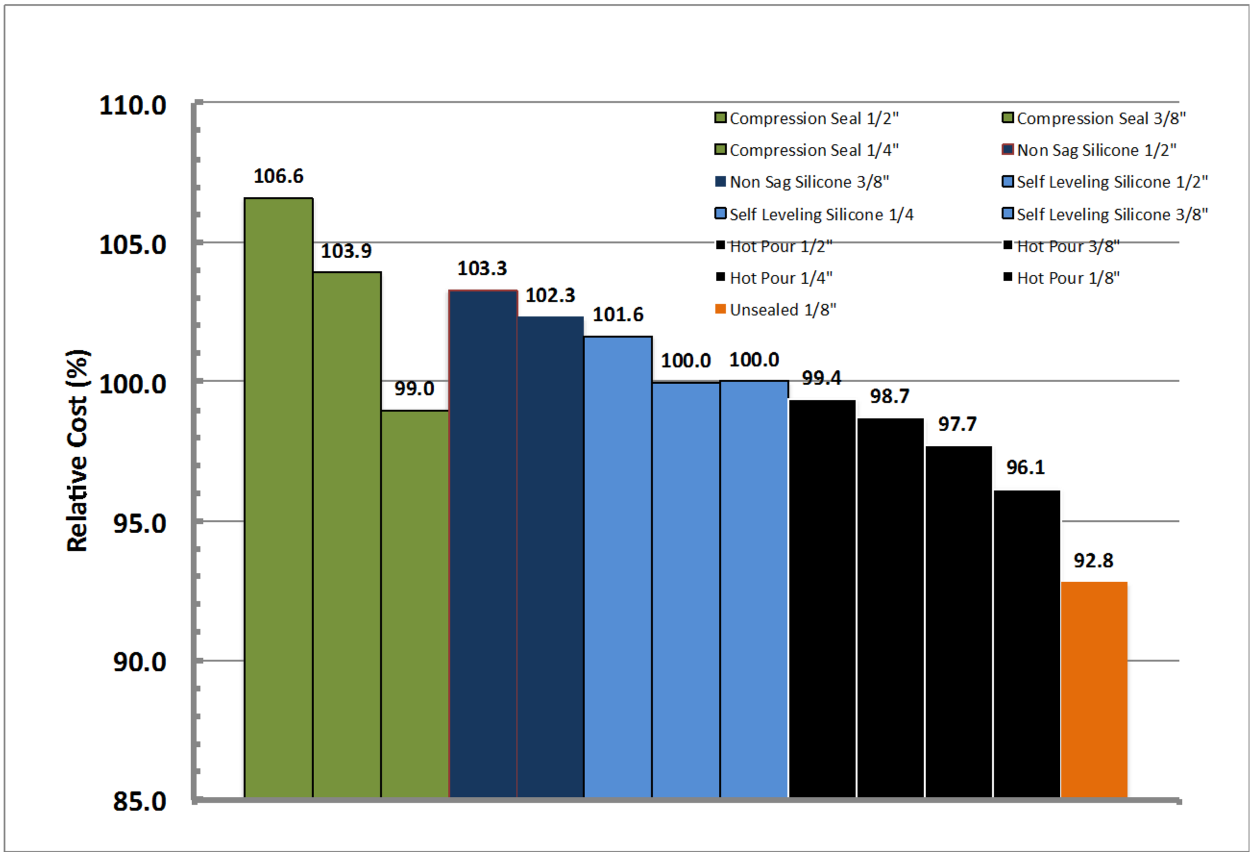

Figure 12 Relative Cost of Sealant Installations by Product Type

Smoothness Survey Results

The purpose of this survey was twofold: First, to determine the cost, if any, to achieve various ranges of specified smoothness levels; and, second, to determine what additional effort is needed to meet a given level of smoothness and what that effort may consist of. The basis for the additional cost or effort should be what is necessary to achieve the specified smoothness beyond the normal construction effort: the normal construction effort was considered as meeting a profilograph specification of 7 inches per mile based on a two tenths blanking band.

As described, the smoothness survey was conducted to establish the cost of achieving lower smoothness/roughness levels during the construction phase. Historically, the value (incentive/disincentive) of concrete pavement smoothness/roughness was established by the specifying agencies. Little information exists regarding the actual construction costs incurred to achieve these requirements.

With interest by some agencies to shift to the International Roughness Index (IRI), it was decided to approach the cost of attaining smoothness/roughness in terms of three scales of measure: (1) Profile Index with 0.2" blanking band, (2) Profile Index with 0.0" blanking band, and (3) International Roughness Index (IRI).

To accomplish this, a smoothness level of 7 in./mi. on a 0.2" blanking band for the California Profilograph was selected as the "Control" roughness by which all improvements would be compared. This standard was first established by the California Highway Department in 1960 after conducting a statewide survey of their road network between 1956 to 1958. The objective ride measurements obtained (e.g. profilograph results) were then related to consumer satisfaction by conducting jury (e.g. consumer) ride comfort evaluations of these same sections. This formed the basis for the California profilograph specification, which continues in use today.

This roughness specification has served the industry well for the past half century but many agencies have gone to a 0.0" blanking band or are converting to IRI. Therefore it was felt that the survey results should include the legacy measurement (e.g. 0.2" blanking band), the current measurement (e.g. the 0" blanking band) and the future measurement (e.g. IRI). The 0.1" blanking band was not considered as it was felt that states would not be commonly using that option in the future.

Table 14 indicates the additional sq. yd. cost to achieve the various smoothness/roughness levels over that necessary to achieve a 7 in./mi. result on a 0.2" blanking band. The Table indicates the roughness levels, average cost, standard deviation, and number of responses for each level. Each contractor was requested to provide 13 different roughness level cost assessments.

TABLE 14 2010 SMOOTHNESS SURVEY RESULTS

Smoothness Requirements	Average Bid Item Cost ($/sq. yd.)	Standard Deviation of Responses ($/sq. yd.)	Number of Responses Received
IRI (in./mi.)			
< 35	2.28	0.89	4
< 50	1.22	0.76	4
< 60	0.77	0.64	3
< 70	0.47	0.29	3
< 90	0.24	0.33	3
Profilograph Index (0.2 in. blanking band)			
< 2	0.92	0.89	4
< 5	0.40	0.49	4
< 7	0	--	--
< 9	0	--	4
Profilograph Index (0.0 in. blanking band)			
< 10	1.93	0.41	4
< 15	1.25	0.64	4
< 18	0.94	0.84	4
< 30	0.25	0.43	4
< 35	0.15	0.26	4

At this time, too few responses have been received to provide a comprehensive evaluation of the results. However, Figure 13 indicates the preliminary IRI results in graphical form. As evident, the cost to achieve lower and lower levels increases at an ever-increasing rate and is essentially an exponential curve. The costs indicated in Figure 13 are a result of diamond grinding the surface to achieve the lower IRI values. Diamond grinding was indicated for values below an IRI of 70 to 90 with the cost determined by the percent of surface ground. For low IRI values, blanket grinding was indicated, and an additional cost of approximately $2.25 per sq. yd. incurred to achieve an IRI of 35 or less.

Figure 14 indicates the preliminary PI results for a 0" blanking band in graphical form. As with the IRI results, the cost to achieve lower and lower levels increases at an ever-increasing rate and is essentially an exponential curve. The costs again, are the result of diamond grinding the surface with a cost of approximately $2 sq. yd. to attain a PI of 10 in./mi. with a 0" blanking band requirement.

Figure 15 indicates the preliminary PI results for the 0.2" blanking band in graphical form. The curve indicated in the Figure is essentially linear and attains a maximum cost of approximately $0.92 to achieve a level of 2 inches per mile or less. The values for the 0.2" blanking band are fairly consistent with many agency incentive/disincentive specifications using the original profilograph requirements.

As described previously, the Smoothness Survey differed from the General and Saw and Seal Surveys in that it asked not only for cost information but also an explanation regarding what additional effort or tasks were needed to warrant the cost increase. Initially, it was felt that there would be additional construction methods employed to improve smoothness. One example would be a dense graded mix or widened track line. The project template included a widened track line so this aspect could not be evaluated. Similarly, the original concept for the general survey was to require a gap graded mixture for the standard mix. Then, if contractors were using dense graded mixes as a means to improve smoothness that cost could be evaluated.

However, the General Survey allowed the use of local mixes so a correspondence to the gap graded and dense graded mixes was lost. The result of this is that the only changes which were proposed to improve smoothness were varying percentages of diamond grinding coverage, ranging from approximately 5% to full surface grinding.

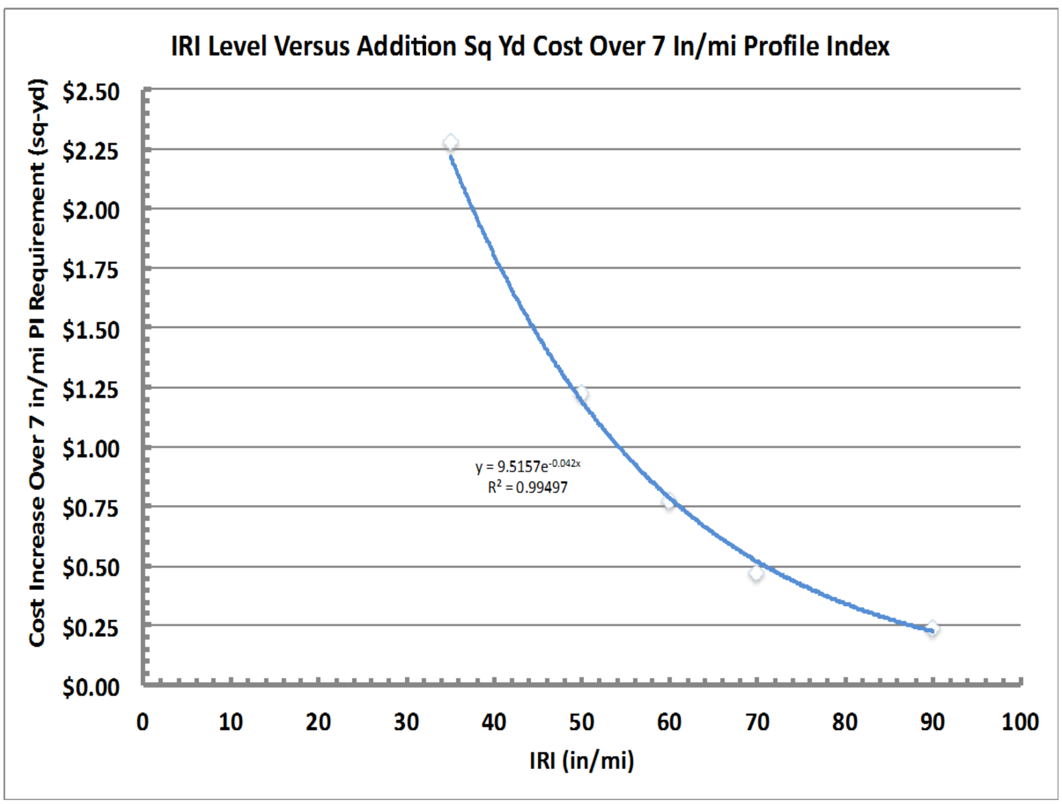

Figure 13 IRI Level Versus Additional Cost to Achieve the Specified Roughness Compared to the Cost to Achieve 7 in./mi. PI with 0.0" Blanking Band

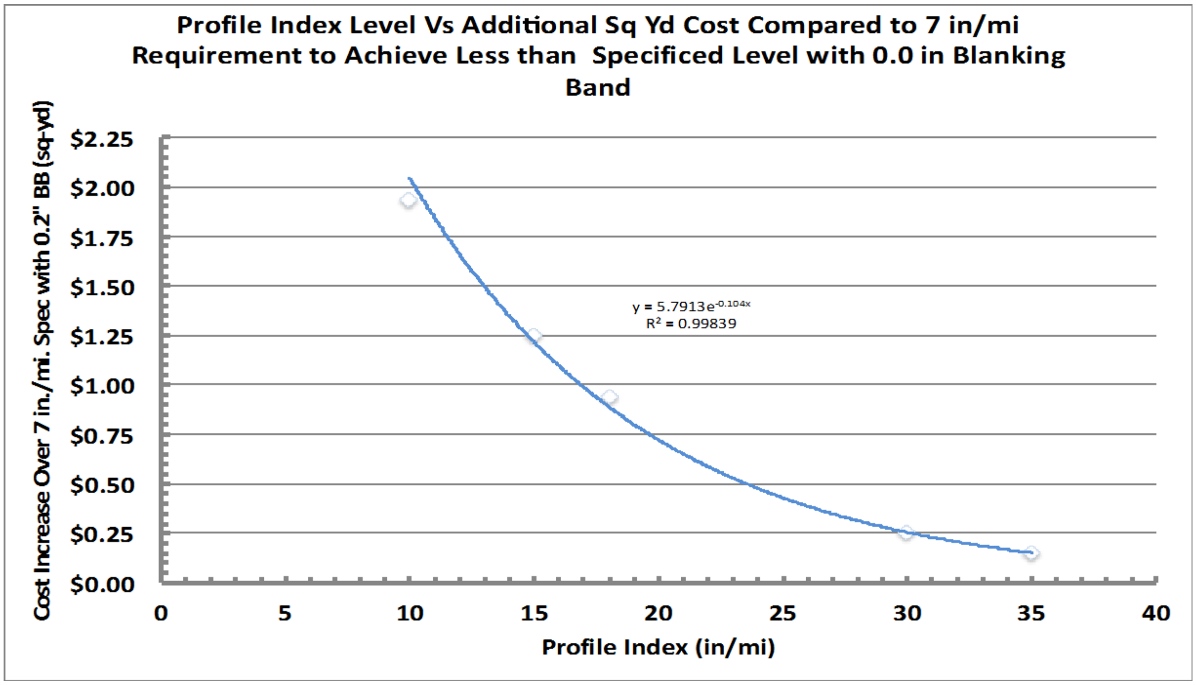

Figure 14 PI with 0" Blanking Band Versus Additional Cost to Achieve the Specified Roughness Compared to the Cost to Achieve 7 in./mi. PI with 0.2" Blanking Band

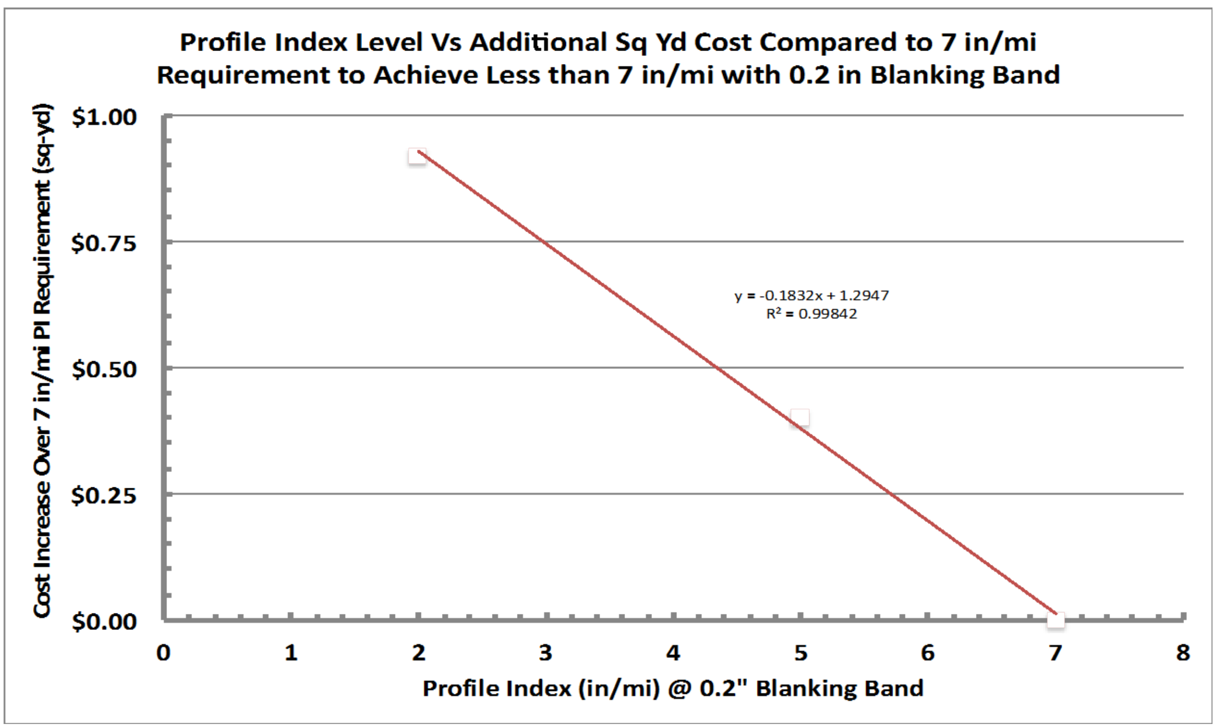

Figure 15 Additional Cost to Achieve the Specified Roughness Compared to Cost to Achieve 7 in./mi. PI with 0.2" Blanking Band

Steel Module Results

In addition to the three surveys, a tie bar and dowel bar analysis module was developed as previously described. The format or screen layout of these modules is indicated in Appendix 4. These tools allow the user to evaluate the impact of reducing or increasing steel components as a percentage of the total in-place cost of the PCCP. Figure 16 indicates an example of how the dowel bar tool can be used. Although only dowel sizes of 1-¼" and 1-½" are indicated here the tool will also evaluate dowels sizes of 7/8" and 1".

A similar analysis could be conducted for varying the size and spacing of tie bars.

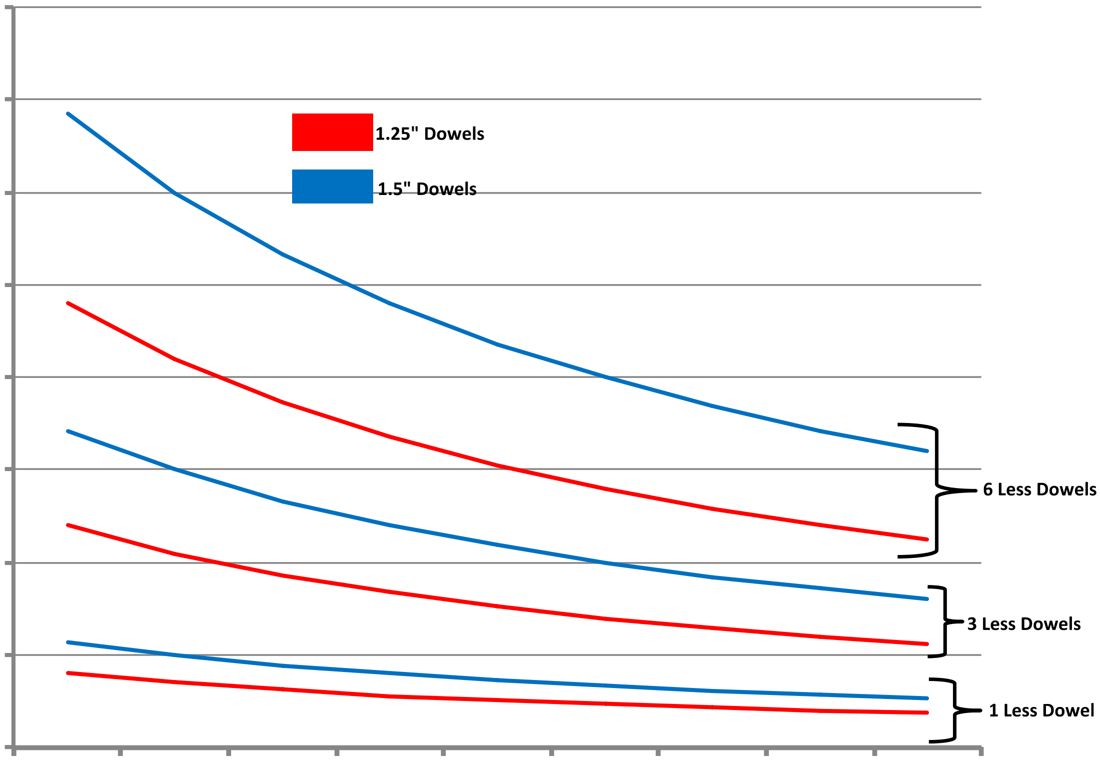

Figure 16 Change in Cost of Modifying Number of Dowel Bars as a Percentage of the In-Place Cost of the Concrete Pavement (sq. yd.)

Summary

The 2010 survey consisted of a general survey which considers several different design features, a saw and seal survey which adds additional capability regarding hybrid alternatives and an ability to easily update the results in the future, and a smoothness survey designed to address the cost of attaining additional smoothness. The cost to attain additional smoothness could then be compared to prevailing smoothness incentives.

In addition a steel module was developed, which provides the capability to evaluate increasing and decreasing the number of steel units and configurations and the attendant impact on overall relative costs. This module also allows a mechanism for conveniently updating the cost component for future updates.

Although it would seem desirable to compare the 2010 survey results with the 1995 survey results this is not recommended. Although similar approaches were used, the 1995 survey represented pavement designs of that era and the 2010 survey current designs. As such the relationship between features can be different. For example, the 1995 survey used gravel shoulders while the 2010 survey used concrete shoulders. The impact on this change is that the 2010 standard had significantly more sawing and sealing included, as there were now three longitudinal joints instead of just one. Additionally, the 2010 survey used a 15 ft. spacing of transverse joints instead of the 20 ft. spacing used in the 1995 survey. This would again increase the amount of sawing and sealing for the project.

Therefore it is recommended that if comparisons between the surveys are made that the conditions upon which the costs were determined are clearly understood.

When viewing the survey results it is important to remember that the data represents initial construction cost only. As such, the "value" of a given design feature needs to be assessed based on the initial construction cost, the impact on pavement performance, and its life cycle cost over the evaluation period. It should also be noted that there can be interaction between the design features and that this is not accounted for in this survey approach. For example, it may be possible to reduce the thickness when using dowels and this could change the value of this feature. Therefore it is important for the value of a design feature to be established considering all aspects.

It is also important to note that these costs represent "national" costs for generalized conditions and are intended only to provide relative comparisons. They should not be used as actual construction costs nor as representing local bid conditions.

References

1. L.W. Cole, M.J. Hall, "Relative Costs of Various Concrete Pavement Features", Transportation Research Record 1574,1997, pgs 99-102
2. Gharaibeh, N.G., Darter, M.I., "Benefits and Costs of Jointed Plain Concrete Pavement Design Features

Appendix 1 General Survey Form

July 10, 2010
XXX Construction, V.P Engineering & QC
XXX - XXX, Inc.
XXX XXXX
PO Box XXXX
Skokie, IL 60077

Re: General Survey on Relative Cost of Concrete Design Features

Dear XXX:

Enclosed you will find a survey we have developed to assess the relative cost of specific design features commonly found in concrete pavement construction. This survey is part of a process updating an ACPA survey conducted in 1995. We intend to use the results of this effort to convey the message that concrete pavement is cost competitive when compared to equivalent asphalt designs. We will educate design engineers on the importance of including only the features necessary and the consequence of adding “bells and whistles” that drive up initial costs. If an engineer wants all the bells and whistles to improve performance, the result of this effort will show the implications of that decision. This survey is one of four surveys that comprise the entire survey process.

We would greatly appreciate your assistance in this effort. Your expertise, and that of your contractor colleagues around the country, represents our best source of “real world” information. Each individual confidential response will be collected and averaged with those of other contractors to help us develop clear information showing the relative costs and benefits of a range of design features.

We will not share or disclose your information with anyone. All data received will be held in strict confidence by the Association. Your response will be averaged with the responses from other survey respondents and the composite results provided in relative terms as a percentage of total pavement cost and NOT in direct cost terms. A PowerPoint presentation that was prepared for the results of the 1995 survey is attached for your review to indicate how this information was presented previously.

We expect that it will require about two to three hours to complete the survey. We encourage you to involve one of your estimators for this effort. We want your best estimate of the cost for the design features presented.

We would appreciate your response on or before XXXX . Thanks for your cooperation.

Sincerely,
Gerald F. Voigt, P.E.
President and CEO

Appendix 1 General Survey Form

Survey Instructions

The survey is based upon using a typical roadway design for a rural interstate as the "standard" project, and then varying one design feature at a time to establish the impact on the in-place sq yd pavement cost due to that particular feature change. Each time a new feature is evaluated, all the other features are those shown for the standard project in Figure 1 and described in the bullets under project assumptions. Once a feature has been evaluated, that feature reverts back to the standard project assumption so that a new feature can be evaluated. Again, only one feature is evaluated at a time (except for pavement thickness) with all other features held constant to the standard project design assumption. For the pavement thickness category, the shoulders and mainline are always the same thickness. This will not be the case for the shoulder design category.

For the widened lane Category, Figure 2 indicates the standard cross section to be evaluated. Only the 10" travel lanes and 10" shoulders are to be evaluated for the widened lane category.

To complete the survey online go to acpa.org/survey. The information necessary to complete the survey is provided in Table 1 on page 4 and is set up just like the online input screen. Table 1 is organized in sections to identify the different variables under investigation. Within each section, the various features to be considered are listed. For example, the first category is pavement thickness. Within this category there are four thickness "features" that will be evaluated. The first feature is a thickness of 8 inches. To conduct the evaluation you replace the Standard Thickness shown in Figure 1 (e.g. 10 inches) with the feature under evaluation (e.g. 8 inch thickness--note the shoulder also changes to 8 inches) and determine the complete in-place sq yd cost of the standard pavement section with all the features included. You then repeat the process for the three remaining thickness substituting a different thickness each time and re-evaluating the in-place costs. Upon completion of the thickness feature, the thickness reverts back to the standard thickness (e.g. 10 in.) and you go to the next category. The process starts over again by replacing the standard feature for the new category with each of the features indicated in the category. The only difference for the remaining features is that you are not estimating the in-place cost of the completed pavement section as with thickness, but rather the complete in-place cost of that particular feature. The exception to this is the widened lane category that requires the in-place cost of the total pavement section again.

When completing the survey if you encounter a feature that you are not comfortable estimating, it is ok to leave that feature blank. An example may be RCC shoulders. However, it is very desirable to have you estimate as many features as possible.

Project Assumptions:

- The project is a five mile long, rural, four-lane interstate to be constructed within 50 miles of your home office.
- The concrete design features are as follows:
    - Two 12 ft wide travel lanes in each direction (paving width restricted to a maximum of 30 ft)
    - 10 inch thick concrete pavement for the entire roadway width
    - 4 ft and 10 ft tied, full-depth concrete shoulders
    - Transverse joint spacing is 15 ft o-c with non-skewed joints
    - 1 1/2" by 18" long epoxy coated dowels placed in baskets on 12 inch centers in the traffic lanes only (i.e. no dowels in shoulders)
    - 30 inch long, No. 5 deformed tie bars on 30" centers for all longitudinal joints
    - 3/8" wide transverse joints filled with recessed silicone sealant and backer rod

Appendix 1 General Survey Form

- o The surface texture was constructed using a burlap drag and ¾" oc longitudinal tining which is 1/8" deep. The curing compound used is AASHTO M148
- o A 43 ft wide dense-graded crushed-aggregate base layer compacted to 6" in thickness and wide enough to accommodate paver tracks.
- o Subgrade prepared by scarifying to a depth of 6" and re-compacting at optimum moisture content

〈 Typical materials specified by the State Department's of Transportation and construction methods used in your area should be assumed

〈 The existing grade alignment is assumed adequate, with no earth work required

The total quantities for the five mile project are as follows:
24 ft. Mainline Paving: 70,400 sq yds.
10 ft. Shoulder Paving: 29,333 sq yds.
4 ft. Shoulder Paving: 11,733 sq yds.
Longitudinal Joints: 158,400 Lineal Feet
Transverse Joints: 133,760 Lineal Feet
All Joints: 292,160 Lineal Feet

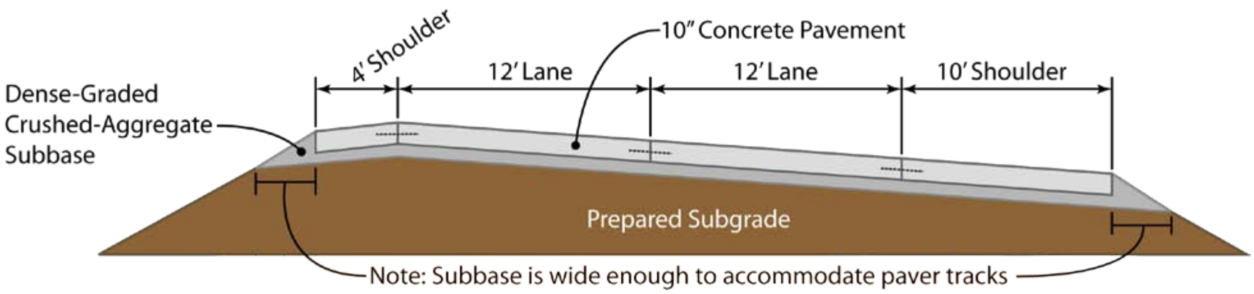

Figure 1 Cross Section of "Standard" Construction Project

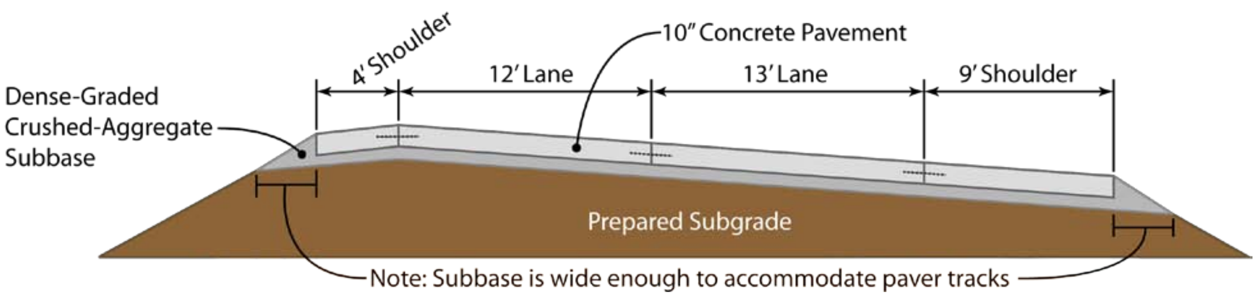

Figure 2 for Use With Widened Lane Category- Note 13 Dowels in Widened Lane

Appendix 1 General Survey Form

Thickness Design Category		
Feature	**Pavement Thickness**	**In-Place Pavement Cost (sq yd)**
G-1A	8” PCCP and 8” Shoulders	
G-1B	10’ PCCP and 10” Shoulders	
G-1C	12” PCCP and 12” Shoulders	
G-1D	14” PCCP and 14” Shoulders	
Shoulder Design Category		
Feature	**Shoulder Thickness/Material Design**	**In-Place Shoulder Cost (sq yd)**
G-2A	10” PCCP	
G-2B	6” PCCP	
G-2C	4” PCCP	
G-2D	10” Roller Compacted Concrete	
G-2E	10” Asphalt Concrete	
G-2F	6” Asphalt Concrete	
G-2G	10” Aggregate Base	
Aggregate Base Thickness Category		
Feature	**Aggregate Base Thickness Design**	**In-Place Base Cost (sq yd)**
G-3A	2” Aggregate Base	
G-3B	4” Aggregate Base	
G-3C	10” Aggregate Base	
G-3D	15” Aggregate Base	
Base Material Type Category		
Feature	**Base Material Type Design**	**In-Place Base Cost (sq yd)**
G-4A	Un-stabilized Free Draining 6” Aggregate	
G-4B	6” Cement Stabilized Base	
G-4C	6” Bituminous Stabilized Base	
G-4D	4” Cement Stabilized Base	
G-4E	4” Bituminous Stabilized Base	
G-4F	4” Asphalt Concrete	
G-4G	2” Asphalt Concrete	
Subgrade Improvement Category		
Feature	**Subgrade Improvement Type**	**In-Place Subgrade Cost (sq yd)**
G-5A	6” Untreated Subgrade	
G-5B	6” Cement Stabilized	
G-5C	6” Lime Treated	
Surface Texture Category		
Feature	**Finished Surface Texture Type**	**In-Place Texture Cost (sq yd)**
G-6A	Astro Turf (1 mm MTD) (Full Width)	
G-6B	Diamond Ground Texture (Traffic Lanes Only)	
G-6C	¾” oc Uniformly Transverse Tined Texture(Full Width)	
G-7D	¾” oc Longitudinally Tined Texture (Full Width)	
Curing Method Category		
Feature	**Curing Method Used**	**In-Place Cure Cost (sq yd)**
G-7A	AASHTO M148 Type 2 Class B	
G-7B	MnDOT Poly Alpha Methylstyrene	
G-7C	Water Cure/Polyethylene Covering	

Appendix 1 General Survey Form

Dowel Bar Inserter Category		
Feature	**Impact of Using A Dowel Bar Inserter**	**Cost Reduction of In-Place Pavement (sq yd)**
G-8A	Reduction in Sq Yd Cost of 10" Pavement if DBI Used	
Widened Lane Category		
Feature	**Widened 13 ft Travel Lane**	**In-Place Pavement Cost (sq yd)**
G-9A	13 ft Wide Travel Lane, 9 ft Shoulder, dowels@ 1 ft centers in 12 ft and 13 ft travel lanes only.	

Appendix 2 Saw and Seal Survey

July 10, 2010
XXX Construction, V.P Engineering & QC
XXX - XXX, Inc.
XXX XXXX
PO Box XXXX
Skokie, IL 60077

Re: Survey on Saw and Seal Features
Dear XXX:
Enclosed you will find a survey we have developed to assess the relative cost of sawing and sealing features commonly found in concrete pavement designs. This survey is part of a process updating an ACPA survey conducted in 1995. We intend to use the results of this effort to convey the message that concrete pavement is cost competitive when compared to equivalent asphalt designs. We will educate design engineers on the importance of including only the features necessary and the consequence of adding “bells and whistles” that drive up initial costs. If an engineer wants all the bells and whistles to improve performance, the result of this effort will show the implications of that decision. This survey is one of four surveys that comprise the entire survey process.
We would greatly appreciate your assistance in this effort. Your expertise, and that of your contractor colleagues around the country, represents our best source of “real world” information. Each individual confidential response will be collected and averaged with those of other contractors to help us develop clear information showing the relative costs and benefits of a range of design features. This particular survey is concerned only with the sawing and sealing activities.
We will not share or disclose your information with anyone. All data received will be held in strict confidence by the Association. Your response will be averaged with the responses from other survey respondents and the composite results provided in relative terms as a percentage of total pavement cost and NOT in direct cost terms. A PowerPoint presentation that was prepared for the 1995 survey is attached for your review to indicate how this information was presented previously.
We expect that it will require about 30-60 minutes to complete the survey. We encourage you to involve one of your estimators for this effort. We want your best estimate of the cost for the sawing and sealing features presented.
We would appreciate your response on or before XXXX 1. Thanks for your cooperation.
Sincerely,

Gerald F. Voigt, P.E.
President and CEO

Survey Instructions

The overall survey process is based upon using a typical roadway design (see Figure 1) for a rural interstate as the “standard” project, and then varying one design feature at a time to establish the impact on the in-place sq yd pavement cost due to a given feature change. The Saw and Seal Survey is different from the other three surveys in that the pavement structure remains the same and only the joint width, saw depth, and sealant conditions are varied. The hypothetical project remains the same however, and is described under the heading “Project Assumptions”. Use the project assumptions as the basis for your estimates in conjunction with the information presented in Table 1 and Figure 1.

Table 1 is organized into sections (categories) to identify the different work activities under investigation. Within each category, the various “features” to be considered are listed. For example, the first category is initial saw cut. Within this category there are two saw depths or “features” that will be evaluated. The first feature is an initial saw cut to T/4 and the second to T/3. To conduct the evaluation, estimate the cost per lineal foot of the activity for the specified conditions for the both the longitudinal and transverse joints. It should be noted that the same conditions apply to both the longitudinal and transverse joints. Once both features in the first category are estimated proceed to the second category and so on. The shaded areas in Table 1 do not contain information and should not be filled in; they are only provided to complete the Table format.

The actual survey to be completed will be online and available at acpa.org/survey. You just fill in the respective sections. The online survey is similar in layout to Table 1.

The work activities pertaining to each category are indicated below and hopefully provide sufficient detail to enable estimates of the work. The total joint quantities are indicated in the project assumption section and should be used for preparation of the estimates.

Initial Saw Cut Activities:

Consists of sawing to specified depth and width; no clean up or power wash included.

Reservoir Cut Activities:

Consists of sawing to specified depth and width; no clean up, but power wash included if normally done.

Clean Joint in Preparation of Sealant Installation:

Consists of all preparation activities such as power wash (if not included in reservoir cut), media blast, air blast, etc. necessary to provide a proper surface for installation of the specified sealant strategy. Note that for item SS-3A which receives no sealant, if no cleaning would normally be done insert a cost of $0.

Furnish and Install Backer Rod (if needed) and Sealant Material:

Consists of furnishing all materials, equipment, labor, and incidentals necessary for the proper installation of designated sealant strategy. No sawing or cleaning is included in this item. For the compression seals use the following requirements:

- For the ¼” wide joint use a nominal width seal of 7/16”
- For the 3/8” wide joint use a nominal width seal of 11/16”
- For the ½” wide joint use a nominal width seal of 13/16”

Project Assumptions:

- The project is a five mile long, rural, four-lane interstate to be constructed within 50 miles of your home office.
- The concrete design features are as follows:
  - Two 12 ft wide travel lanes in each direction (paving width restricted to a maximum of 24 ft)
  - 10 inch thick concrete pavement for the entire roadway width
  - 4 ft and 10 ft tied, full-depth concrete shoulders
  - Transverse joint spacing is 15 ft o-c with non-skewed joints
  - 1 1/2” by 18” long epoxy coated dowels placed in baskets on 12 inch centers in the traffic lanes only
  - 30 inch long, No. 5 deformed tie bars on 30” centers for all longitudinal joints
  - 3/8” wide transverse joints filled with recessed silicone sealant and backer rod

Appendix 2 Saw and Seal Survey

  - The surface texture was constructed using a burlap drag and ¾” oc longitudinal tining which is 1/8” deep. The curing compound used is AASHTO M148
  - A 43 ft wide dense-graded crushed-aggregate base layer compacted to 6" in thickness and wide enough to accommodate paver tracks.
  - Subgrade prepared by scarifying to a depth of 6" and re-compacting at optimum moisture content
- Typical materials specified by the State Department’s of Transportation and construction methods used in your area should be assumed
- The existing grade alignment is assumed adequate, with no earth work required

The total quantities for the five mile project are as follows:
24 ft. Mainline Paving: 70,400 sq yds.
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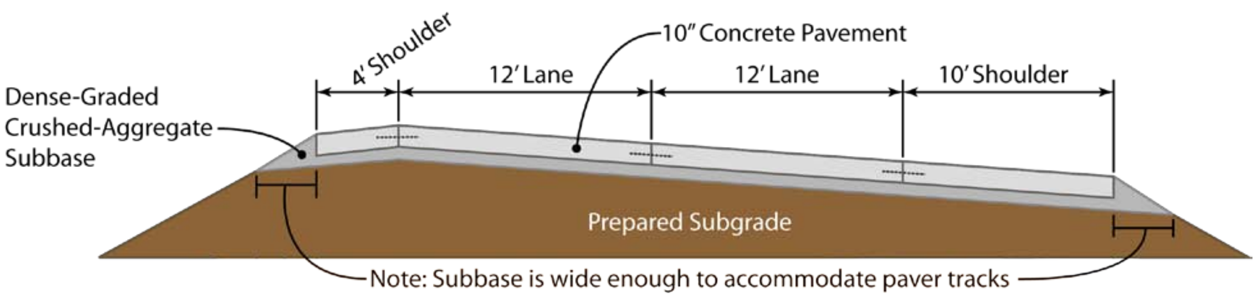


Figure 1 Cross Section of “Standard” Construction Project

Appendix 2 Saw and Seal Survey Form

Table 1 Survey Form

Feature	Initial Saw Cut	Reservoir Saw Cut	Sealant Type	Backer Rod	Transverse Joint Cost per Lineal Ft	Longitudinal Joint Cost per Lineal Ft
Initial Saw Cut Category						
SS-1A	1/8" Wide 2.75" Deep	None				
SS-1B	1/8" Wide 3.7" Deep	None				
Reservoir Cut Category						
SS-2A		¼" Wide by 1 1/4" Deep				
SS-2B		3/8" Wide by 1 1/4" Deep				
SS-2C		1/2" Wide by 1 1/4" Deep				
Clean Joint in Preparation of Sealant Installation Category						
SS-3A		1/8" Wide by 1 1/4" Deep	No Sealant to be Installed (Note if cleaning is not normally done include a cost of $0			
SS-3B		1/8" Wide by 1 1/4" Deep				
SS-3C		¼" Wide by 1 1/4" Deep				
SS-3D		3/8" Wide by 1 1/4" Deep				
SS-3E		1/2" Wide by 1 1/4" Deep				
Furnish and Install Backer Rod (if needed) And Sealant Category						
SS-4A		1/8" Wide by 1 1/4" Deep	Hot Pour Sealant (ASTM D6690)	No		
SS-5A		1/4" Wide by 1 1/4" Deep	Hot Pour Sealant (ASTM D6690)	Yes		
SS-5B		1/4" Wide	Preformed	No		

Appendix 2 Saw and Seal Survey

		by 1 1/4" Deep	Compression Seal (ASTM D2628)			
SS-5C		1/4" Wide by 1 1/4" Deep	Silicone Sealant (ASTM D5893) Self Leveling	Yes		
SS-6A		3/8" Wide by 1 1/4" Deep	Hot Pour Sealant (ASTM D6690)	Yes		
SS-6B		3/8" Wide by 1 1/4" Deep	Preformed Compression Seal (ASTM D2628)	No		
SS-6C		3/8" Wide by 1 1/4" Deep	Silicone Sealant (ASTM D5893) Non Sag	Yes		
SS-6D		3/8" Wide by 1 1/4" Deep	Silicone Sealant (ASTM D5893) Self Leveling	Yes		
SS-7A		1/2" Wide by 1 1/4" Deep	Hot Pour Sealant (ASTM D6690)	Yes		
SS-7B		1/2" Wide by 1 1/4" Deep	Silicone Sealant (ASTM D5893) Non Sag	Yes		
SS-7C		1/2" Wide by 1 1/4" Deep	Silicone Sealant (ASTM D5893) Self Leveling	Yes		
SS-7D		1/2" Wide by 1 1/4" Deep	Preformed Compression Seal (ASTM D2628)	No		

Appendix 3 Smoothness Survey

Survey Instructions

The purpose of this survey is twofold: First, to determine the cost, if any, to achieve various ranges of specified smoothness levels; and, second, to determine what additional effort is needed to meet a given level of smoothness and what that effort may consist of. The basis for the additional cost or effort should be what is necessary to achieve the specified smoothness beyond the normal construction effort: the normal construction effort should be considered as meeting a profilograph specification of 7 inches per mile based on a two tenths blanking band.

It is important that as a respondent, you only complete the sections in which you have reasonable experience in achieving the reported levels of smoothness. For example, if you have not worked under an IRI specification, leave that section blank. It is desirable that you only complete sections for which you have constructed at least 2-3 projects under similar smoothness requirements.

The survey is based upon using a typical roadway design for a rural interstate as the "standard" project. The project assumptions and typical cross section (see Figure 1) are shown below.

Table 1, on page 3, indicates the various smoothness levels to be considered. The bid item cost column is set up to capture the increased cost due to each specific smoothness level (e.g. feature) that requires additional effort beyond the normal construction. The cost is determined as though it were a bid item for smoothness alone. That is, it does not include the construction costs of the pavement, just the additional cost incurred to achieve the specified smoothness ranges. The additional cost should be considered any cost beyond what would be necessary to achieve a smoothness of 7 inches per mile with a profilograph using a 0.2 inch blanking band. If no additional costs would be necessary, all the unit prices would be $0. The only reason the costs should increase is if additional effort/expense is necessary.

The comment section is provided to describe what changes in your process would be necessary to achieve the required smoothness that result in higher costs. For example, is there a smoothness threshold when it becomes necessary to do additional tasks to accomplish a given level of smoothness?

The actual survey to be completed will be online and available at XXXXX. You just fill in the respective sections. The online survey is similar in layout to Table 1.

Project Assumptions:

- The project is a five mile long, rural, four-lane interstate to be constructed within 50 miles of your home office.
- The concrete design features are as follows:
  - Two 12 ft wide travel lanes in each direction (paving width restricted to a maximum of 24 ft)
  - 10 inch thick concrete pavement for the entire roadway width
  - 4 ft and 10 ft tied, full-depth concrete shoulders
  - Transverse joint spacing is 15 ft o-c with non-skewed joints
  - 1 1/2" by 18" long epoxy coated dowels placed in baskets on 12 inch centers in the traffic lanes only
  - 30 inch long, No. 5 deformed tie bars on 30" centers for all longitudinal joints
  - 3/8" wide transverse joints filled with recessed silicone sealant and backer rod
  - The surface texture was constructed using a burlap drag and ¾" oc longitudinal tining which is 1/8" deep. The curing compound used is AASHTO M148
  - A 43 ft wide dense-graded crushed-aggregate base layer compacted to 6" in thickness and wide enough to accommodate paver tracks.

Appendix 3 Smoothness Survey

  - Subgrade prepared by scarifying to a depth of 6" and re-compacting at optimum moisture content
- Typical materials specified by the State Department’s of Transportation and construction methods used in your area should be assumed
- The existing grade alignment is assumed adequate, with no earth work required

The total quantities for the five mile project are as follows:
24 ft. Mainline Paving: 70,400 sq yds.
10 ft. Shoulder Paving: 29,333 sq yds.
4 ft. Shoulder Paving: 11,733 sq yds.
Longitudinal Joints: 158,400 Lineal Feet
Transverse Joints: 133,760 Lineal Feet
All Joints: 292,160 Lineal Feet

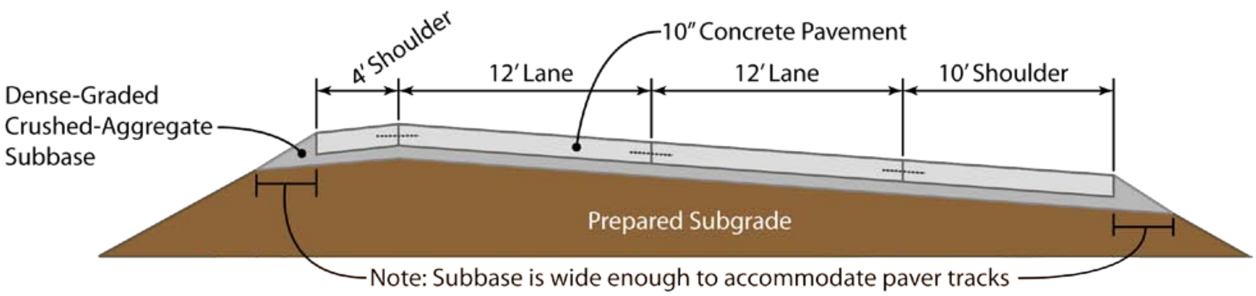


Figure 1 Cross Section of “Standard” Construction Project

TABLE 1 SMOOTHNESS SURVEY

Smoothness Requirement	Bid Item Cost ($/sq yd)	Comments
IRI (in/mi)		
< 35		
< 50		
< 60		
< 70		
<90		
Profilograph		
P.I. 0.2” BB		
<2		
<5		
<7	**$0**	
<9		
P.I. 0.0” BB		
<10		
<15		
<18		
<30		
<35		

Appendix 4 Dowel Bar and Tie Bar Module

Table 1 Dowel Bar Model

Relative Cost Anaylsis

Assumptions:

14,080 SY 10" P.C.C. Pavement
Doweled, Joints @ 15'-0" o.c.
2 - `12'-0" wide lanes poured at 24'-0" wide x 5,280 LF (1 mile) with a slip form paver
Municiple type job relatively clean but not production paving
Poured with ready mix trucks
40 Paving Hours

Cost per Square Yard
Includes: Concrete, Steel, Labor, Sawing & Sealing, Overhead & Profit

$ 52.00 SY ← **Plug in any per square yard price you feel appropiate**
All other values will recalculate

Difference using Dowel Baskets with:

1-1/2 dia x 18" long Epoxy Coated Dowels @ 12" Contraction Baskets
versus
1-1/4 dia x 18" @ 12" o.c. Epoxy Coated Dowels Contraction Baskets

$ 0.60 SY or 1.1538% of the Total cost per square yard.

Once it is decided whether 1-1/2" dia or 1-1/4" dia baskets will be used here is a relative comparison on the impact to the square yard price per number of dowels reduced from using 12 dowel in a 12' wide lane.

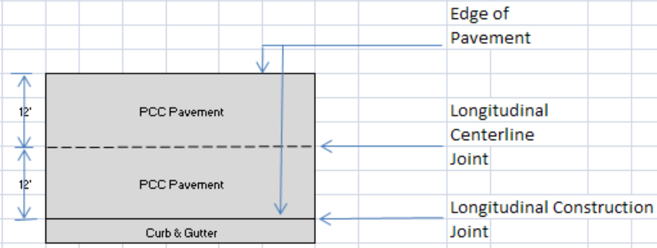
		# of Dowels	Saving		% of Total SY Cost
1-1/2 dia	12'-0" lane width using	12			
		11	$ 0.20	SY	0.3846%
		10	$ 0.40	SY	0.7692%
		9	$ 0.60	SY	1.1538%
		8	$ 0.80	SY	1.5385%
		7	$ 1.00	SY	1.9231%
		6	$ 1.20	SY	2.3077%

		# of Dowels	Saving		% of Total SY Cost
1-1/4 dia	12'-0" lane width using	12			
		11	$ 0.14	SY	0.2692%
		10	$ 0.28	SY	0.5385%
		9	$ 0.42	SY	0.8077%
		8	$ 0.56	SY	1.0769%
		7	$ 0.70	SY	1.3462%
		6	$ 0.84	SY	1.6154%

I think it is important to look at the total relative savings impact with each separate change
It appears that that altering the steel does not present that much of the impact on the square cost .

Appendix 4 Dowel Bar and Tie Bar Module

TABLE 2 RELATIVE COST ANALYSIS FOR TIE BARS FOR LONGITUDINAL JOINTS



Total Square Yards of Pavement	14,080 SY
Cost per SY of Pavt	$ 52.50 SY
Total Quantity in Lineal Feet Longitudinal Centerline Jt Required	10,560 LF
Cost Per Pound for Tie Bars	$ 0.50 LBS

	Size of Tie Bars		Length of Tie Bars in Inches	On Center Spacing of Tie Bars In Inches	Total Quantity of Tie Bars Required in Pieces	Total Weight of Tie Bars in Pounds	Total Cost for Tie Bars Selected	Percentage of Square Yard Cost
Specified	# 8	x	24 "	24 "	5,280 PCS	28,195 LBS	$ 14,097.60	1.9071%
Alternate	# 6	x	24 "	24 "	5,280 PCS	15,861 LBS	$ 7,930.56	1.0729%
Difference + / -							$ 6,167.04	0.8343%