Summary of SHRP Research and Economic Benefits of CONCRETE and STRUCTURES

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16. Abstract

In 1995, a project was initiated to assess the costs versus benefits of the Strategic Highway Research Program (SHRP). Information was collected from State and local highway agencies on their experiences with the SHRP products, and this information was used as the basis for an economic analysis of the costs and benefits of the program and its products.

This report summarizes the preliminary findings of an economic analysis conducted by the Texas Transportation Institute of the SHRP products for portland cement concrete and structures. It also describes the products for portland cement concrete and structures developed under SHRP and the experiences of highway agencies that have used them. In addition, it summarizes the objectives of the research conducted under SHRP on concrete and structures, and outlines the work by the Federal Highway Administration to refine the products and encourage their adoption.

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INTRODUCTION

The 1984 Strategic Transportation Research Study identified portland cement concrete and structures* as one of six priority areas for research and development.[1] As a result, concrete and structures became one of the key areas in the Strategic Highway Research Program (SHRP).[2] Established by Congress in 1987, SHRP had a mission to increase the durability and safety of our Nation's roads and bridges.

Research conducted under SHRP targeted six areas: concrete and structures, long-term pavement performance, pavement maintenance, asphalt, work zone safety, and snow and ice control. One hundred and thirty products, including new specifications, tests, equipment, and reports, resulted from SHRP research contracts, which expired in March 1993.

In 1995, shortly after SHRP concluded and during the early stages of the Federal Highway Administration's (FHWA) national program to encourage implementation of the SHRP products, the Transportation Research Board (TRB) SHRP Committee suggested that an objective assessment of the program and its products be conducted. The study, which was conducted during 1996 and 1997, was launched and funded by FHWA. Overall direction for the study was provided by FHWA with the help of the SHRP Assessment Steering Group. The assessment project was managed by the transportation technology transfer center at the University of Nevada-Reno (UNR). The technology transfer centers in Florida, Indiana, Minnesota, Pennsylvania, and Texas assisted UNR in collecting information on how State and local highway agencies were using SHRP products. This information was turned over to a team of engineers and economists at the Texas Transportation Institute (TTI) for use in an economic analysis of the costs versus benefits of SHRP and the SHRP products.

This report presents the preliminary findings of the economic analysis conducted by TTI. It describes the objectives and accomplishments of the research conducted under SHRP on concrete and structures, as well as the products developed from that research. It also summarizes how State and local governments are using those products.

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* Initially, the concrete and structures research was defined as two separate studies—"Cement and Concrete in Highway Pavements and Structures" and "Protection of Concrete Bridge Components." The SHRP research was conducted under the single title, "Cement and Concrete in Highway Pavements and Structures."

Four other summary reports, describing the results of the benefits-versus-costs analysis of SHRP's asphalt, pavement maintenance, snow and ice control, and work zone safety products, are also available.[3-6,*]

BACKGROUND

The $150 million spent on SHRP over 5 years is the largest single expenditure ever devoted to transportation infrastructure research. Product refinements and implementation continue with the support of FHWA, State highway agencies, and industry.

The Intermodal Surface Transportation Efficiency Act of 1991 authorized an additional $108 million for SHRP implementation and for continuation of the long-term pavement performance (LTPP) program. Funding for SHRP came from a set-aside of one-quarter of 1 percent of Federal-aid highway funds apportioned to the States.

SHRP was administered by the National Research Council in cooperation with FHWA and the American Association of State Highway and Transportation Officials (AASHTO). FHWA has taken the lead in helping State and local highway agencies make effective use of SHRP products.

CONCRETE AND STRUCTURES RESEARCH

The highway industry consumes about 16 percent of the portland cement used for construction in the United States.[2] Despite the widespread use of concrete, research is needed to improve its performance and to better understand the chemistry associated with the hydration and hardening of portland cement. The durability of portland cement concrete remains a problem, and a more complete understanding of the effects of additives on concrete.

Annual bridge project obligations currently are about $3.5 billion, including $1.4 billion for bridge replacement, $0.7 billion for new bridges, $0.89 billion for major bridge rehabilitation, and $0.17 billion for minor bridge work.[7] These obligated levels are insufficient to satisfy future needs for bridge replacement, rehabilitation, and maintenance.

OBJECTIVES

The objectives of the SHRP portland cement and portland cement concrete research were to increase the service life of concrete through an improved understanding of the

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* The long-term pavement performance (LTPP) program is only at its midpoint, and thus it is too early to report on the economic benefits of its products.

chemistry of cement hydration, the properties of concrete, and the performance of concrete in the highway environment.

The objectives of the structures research program were to provide methods to protect and rehabilitate existing chloride-contaminated concrete bridge components and to develop a decision model that would identify the most appropriate treatment for any structure under an agency's jurisdiction.

RESEARCH PROJECTS

The proposed SHRP research on portland cement and portland cement concrete identified four projects:[2]

1. Chemistry and physics of cement and concrete.
2. Durability of concrete.
3. Quality control and condition analysis through nondestructive testing.
4. Mechanical behavior of concrete.

The results of these research projects were expected to improve portland cement properties such as strength gain and curing and to improve the durability of concrete in diverse climates using various additives.

SHRP research on structures identified four projects:[2]

1. Inspection and assessment of the physical condition of concrete structures.
2. Protection and rehabilitation by electrochemical methods.
3. Protection and rehabilitation by other than electrochemical methods.
4. Methodology for the protection and rehabilitation of bridges.

The results of these research projects were expected to determine how and when to protect bridges from corrosion to minimize life-cycle maintenance costs.

ACCOMPLISHMENTS

SHRP concrete and structures research and development produced 44 products that can be grouped into the 12 areas shown below.

Concrete

- Concrete performance.
- Alkali-silica reactivity.
- Freezing and thawing resistance.
- Nondestructive testing.
- High-performance concrete.

- Concrete strength tests.
- Optimum highway concrete technology.

Structures

- Diagnostic tools for concrete bridge physical condition assessment.
- Concrete permeability tests.
- Concrete sealers.
- Concrete bridge protection and rehabilitation—electrochemical techniques.
- Concrete bridge protection and rehabilitation—other than electrochemical techniques.

Table 1 lists the products available from each of the concrete and structures areas. Twenty-four products were developed for concrete, and 20 products were developed for structures.

Concrete Products

Portland cement and portland cement concrete products included a handbook for mixture design;[8] guidelines for thermal effects;[9] tests for recognition and mitigation of alkali-silica reactivity; tests and mitigation techniques for freeze-thaw cracking; nondestructive tests for strength, air content, and flaw detection; high-performance concrete; concrete strength tests; and procedures for optimizing the properties and performance of portland cement concrete.

Structures Products

Structures products included diagnostic tools, repair methods, and guidelines for selecting appropriate rehabilitation and maintenance treatments for bridges. Some of the diagnostic tools included the chloride content tester, permeability tests, and corrosion rate tests. Repair methods included guidelines on chloride removal,[10] a cathodic protection manual,[11] a manual on rapid concrete repair techniques,[12] a manual on protecting marine structures,[13] and a manual on concrete removal methods.[14] Guidelines for selecting appropriate rehabilitation and maintenance treatments were included in a manual[15] and in the Highway Concrete (HWYCON) Expert System computer program.[16]

POST-SHRP ACTIVITIES

Additional research, development, and implementation activities resulted from the SHRP research on concrete and structures. Research and development sponsored by

FHWA, States, and industry included electrochemical chloride extraction, concrete curing relationships (curing tables), and mix design aggregate packing.

The major implementation efforts currently under way are funded by FHWA and State highway agencies. They include the five showcase workshops listed below:

- Assessment of Physical Condition of Concrete Structures.
- Methodologies for Selection and Implementation of Bridge Protection and Rehabilitation Techniques.
- Alkali-Silica Reactivity.
- Concrete Durability.
- High-Performance Concrete.

Equipment loan programs were developed by FHWA for the impact echo device, alkali-silica reactivity field kit, AC impedance test, air-void analyzer, and several nondestructive testing devices. Five states—Nebraska, New Hampshire, Ohio, Texas, and Virginia—are designing or constructing bridges that contain high-performance concrete.[17]

As of August 1995, AASHTO had adopted 16 SHRP concrete and structures products as provisional standards. The adoption of these test methods and techniques will increase their rate of implementation. FHWA's Concrete Technical Working Group, which included representatives from highway agencies and industry, met in 1994 and 1995 to evaluate the products and their level of implementation.[17, 18]

Case Studies

For the purposes of the economic analysis, 18 case studies on concrete and structures products were obtained from 14 States.* Table 2 contains a State-by-State listing of these case studies. The following are brief summaries of the benefits of the products implemented or evaluated by the States.

Aggregate Durability Test

Cost savings from the test are expected to be significant based on the test equipment's reduced expense and the test's reduced operational time.

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* FHWA has published 104 RoadSavers case studies, many of which were based on case studies collected for the economic analysis. The RoadSavers case studies are available on the Internet at www.ota.fhwa.dot.gov/roadsvr.

Alkali-Silica Reactivity

The quick detection procedures extend the performance life of concrete pavements and structures, resulting in lower maintenance costs and fewer traffic delays.

Electrochemical Chloride Extraction

The process has two key benefits: It extends the life of bridges by 12 to 15 years, and bridges treated with it require less rehabilitation work that is expensive and disruptive to traffic.

Cathodic Protection

Cathodic protection of bridges costs $525/mi ($326/km) less than conventional corrosion control methods. Additionally, the service life provided by the technology is more than double that of other procedures.

Chloride Content Test

Significant savings are reported by two States. The $2,000 invested in the chloride content test kit has saved Alaska DOT $95,000 in 1 year of use. Although its evaluation of the test is not complete, Texas expects the device will save several hundred thousand dollars per year.

Impact Echo Test

Used most extensively in California, the test's accuracy has allowed Los Angeles County to pinpoint its repair needs. The result: Anticipated construction costs were reduced by nearly $100 million.

Surface Permeability Test

The test is less time-consuming and labor-intensive than other permeability tests. As a result, traffic disruption is minimal, and worker exposure to traffic is reduced.

ECONOMIC BENEFITS

Because many of the products of SHRP concrete and structures research have not been used extensively, economic benefits were based on the implementation of six concrete test methods and guidelines and on implementation of products that will extend the life of some portland cement concrete pavements.

Savings Related to Six Concrete Products

Cost savings associated with the six concrete test methods and guidelines are from extending the life of concrete structures (other than pavements) and from reducing the cost of testing and evaluating portland cement concrete. Table 3 contains an estimate of

the savings from using the six SHRP products. These estimates are based on engineering judgment and information available at this time.

Annual State highway agency savings are expected to be about $47 million over 20 years, assuming immediate full implementation[19] of the SHRP products. However, the implementation process will likely be gradual. Taking the annual maximum savings amount of $47 million, savings for slow, moderate, and fast implementation scenarios were calculated using a 5 percent discount rate (Tables 4, 5, and 6). Each scenario assumes that the pace of implementation is slow in the early years and gradually increases over time.

Slow Implementation

- Implementation reaches 25 percent after 20 years.
- Estimated State highway agency savings: $51 million.

Moderate Implementation

- Implementation reaches 50 percent after 20 years.
- Estimated State highway agency savings: $98 million.

Fast Implementation

- Implementation reaches 100 percent after 20 years
- Estimated State highway agency savings: $193 million.

The costs of SHRP-related concrete and structures research, development, and implementation were estimated at $55 million over 20 years.[19] If annual net savings are derived only from the use of the six products based on the implementation scenarios given above, benefit-cost ratios of about 1 to 3 are expected. One dollar spent will return $1 to $3 to State highway agencies (Table 7).

Savings Related to Portland Cement Concrete Pavements

Implementation of the SHRP research is expected to increase the performance life of portland cement concrete pavements by providing improved test methods and tools to help mitigate the effects of D-cracking and alkali-silica reactivity.

For the purposes of this economic analysis, the research team at Texas Transportation Institute assumed that portland cement concrete pavements exhibiting D-cracking and alkali-silica reactivity have a remaining service life of 10 years. They also assumed that using SHRP products to mitigate D-cracking and alkali-silica reactivity would extend the life of the portland cement concrete pavements from 10 years to 17 years.[19] Ap-

proximately 12,900 mi (20,800 km), or 10 percent, of the portland cement concrete pavements in the United States are affected by D-cracking and alkali-silica reactivity.

Annual nationwide State highway agency savings and user savings of about $578 million ($145 million for public highway agencies and $432 million for users) were determined using the MicroBENCOST computer program[20] to estimate savings for various types of roadways in urban and rural areas (Table 8). A 40-year analysis period and a traffic growth rate of 2.1 percent were used in the analysis.[19]

Technology to extend the life of portland cement concrete pavements will not be implemented immediately by all public highway agencies. Taking the annual maximum savings amount of $578 million, savings for slow, moderate, and fast implementation scenarios were calculated using a 5 percent discount rate (Tables 9, 10 and 11). Each scenario assumes that implementation is slow in the early years and gradually increases over time.

Slow Implementation

- Implementation reaches 25 percent after 20 years.
- Estimated State highway agency savings: $160 million.
- Estimated user savings: $476 million.
- Estimated State highway agency and user savings: $636 million.

Moderate Implementation

- Implementation reaches 50 percent after 20 years.
- Estimated State highway agency savings: $307 million.
- Estimated user savings: $913 million.
- Estimated State highway agency and user savings: $1.2 billion.

Fast Implementation

- Implementation reaches 100 percent after 20 years.
- Estimated State highway agency savings: $611 million.
- Estimated user savings: $1,786 million.
- Estimated State highway agency and user savings: $2.4 billion.

The costs of SHRP-related concrete and structures research, development, and implementation were estimated at $55 million over 20 years.[19] If annual net savings are derived only from extending the life of portland cement concrete pavements based on the

implementation scenarios given above, expected benefit-cost ratios range from about 3 to 11 for public highway agencies and range from about 9 to 33 for highway users (Table 7). One dollar spent will return between $3 to $11 to State highway agencies and between $9 to $33 to users.

SUMMARY

New concrete and structures guidelines and tests developed under SHRP are helping State and local highway agencies improve the durability of the Nation's roads and bridges. These methods save taxpayers money by helping highway engineers identify problem materials, select appropriate materials for longer-lasting concrete pavements and structures, and make more efficient use of crews and equipment.

Benefit-cost ratios will increase substantially with the implementation of more SHRP concrete and structures products.

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10. *Chloride Removal Implementation Guide.* Publication No. SHRP-S-347. Washington, D.C., Strategic Highway Research Program, National Research Council, 1993.

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13. *Sprayed-Zinc Galvanic Anodes for Concrete Marine Bridge Substructures.* Publication No. SHRP-C-334. Washington, D.C., Strategic Highway Research Program, National Research Council, 1993.

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Table 1. Concrete and Structures Products

Product Area	Product Number and Title
Concrete Performance	2005 Handbook for Mix Design
	2006 Guide to Thermal Effects
	2008 Fluorescent Microscopy Manual
Alkali-Silica Reactivity	2009 Screening Reactive Aggregate Tests
	2010 Manual for ASR Detection
	2011 ASR Mitigation in Existing Concrete
	2013 Chemical Test for ASR Detection
	2017 ASR-Safe Mix Designs
Freeze-Thaw Resistance	2002 Aggregate Durability Test
	2004 Mitigation of D-Cracking
	2018 Modified Freeze-Thaw Test
	2019 Soundness Test for Concrete
	2020 Air Entrained Specifications
	2021 PCC Aggregate Specifications
Nondestructive Testing	2012 Flaw Detection by Impact-Echo Method
	2022 Guide to Strength/Maturity
	4001 Measuring Air Entrainment
High-Performance Concrete	2014 High Performance Concrete Specifications
Concrete Strength Tests	2023 Flexural Strength Test
	2024 Compressive Strength Test
	2025 Interfacial Bond Test
Optimum Highway Concrete Technology	2027 Fresh Concrete Water Content Test
	2028 Test for Consolidation
	239 HWYCON-Concrete Expert System
Diagnostic Tools for Concrete Bridge Physical Condition Assessment	2001 Corrosion Rate Method
	2015 Radar Method for Asphalt Decks
	2016 Membrane Integrity Survey Method
	2030 Chloride Content Test
	2032 Bridge Condition Evaluation Method
	4003 Monitoring Cathodic Protection
Concrete Permeability Tests	2007 Permeability Laboratory Test
	2026 Permeability Test—Electrical Resistance
	2031 Permeability Test—Surface Air Flow Method

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Product Area	Product Number and Title
Concrete Seals	2029a Electrical Resistance Test
	2029b Water Absorption Test
Concrete Bridge Protection and Rehabilitation—Electrochemical Techniques	2033 Manual on Chloride Removal
	2034 Cathodic Protection Manual
	2040 Guidelines for Cathodic Protection
Concrete Bridge Protection and Rehabilitation—Other than Electrochemical Techniques	2003 Concrete Removal Manual
	2035 Manual for Rapid Repair of Bridge Decks
	2036 Field Guide on Bridge Rehabilitation and Protection
	2037 Manual for Selecting Bridge Rehabilitation and Protection Options
	2038 Computer Programs for Bridge Rehabilitation and Protection Options
	4009 Repairing Marine Structures

Table 2. Concrete and Structures Case Studies

State	Case Study Title
Alaska	Concrete "Test-It-Yourself" Kit Helps Save Alaska's Bridges
Arkansas	Chloride Test Saves Money
	Permeability Device Offers Economic Benefits
California	Saving the Seawall
	Concrete Testing Puts Subway Riders at Ease
Florida	Zinc Anode Coating Protects Coastal Bridges
	New Corrosion Control Methods Save Tax Dollars
Idaho	New Tests Mean More Durable Concrete Pavements and Structures in Idaho
Kentucky	Simpler and Less Expensive Method to Test Aggregates
Nebraska	Test Critical to Longer-Lasting Concrete
Nevada	A Better Way to Evaluate Concrete Permeability
New Mexico	New Test Provides Quick Assessment of Bridge Conditions
	New Cure for Old Problem
North Carolina	The Fight Against Internal Chemical Attack
Oregon	Innovative Technology Saves Landmark
South Dakota	Impact-Echo Device Gives Quick Reliable Information
Virginia	New Technology Adds Years to Bridges' Lives
Texas	Big Savings Expected with Concrete Testing Methods

Table 3. Estimated Agency Cost Savings from SHRP Concrete Products

Product	Total Savings (Million $)	Implementation Cost (Million $)	Net Savings (Million $)
Guide to Strength/Maturity[1]	20.00	1.00	19.00
Aggregate Durability Test[1]	20.00	1.50	18.50
Modified Freeze-Thaw Test[1]	200.00	0.01	199.99
Mitigation of D-Cracking[1]	50.00	0.10	49.90
Permeability Test—Surface Air Flow Method[1]	200.00	5.00	195.00
ASR Mitigation in Existing Concrete[1]	100.00	1.50	98.50
20-Year Total[1]	590.00	9.11	580.89
Annual Total[2]	47.34	0.73	46.61

[1] Numbers represent the 20-year present worth of savings and costs assuming full implementation over that period.

[2] Annual totals are calculated using a percent worth factor of 12.4622, to convert the 20-year totals into equivalent annual values.

Table 4. Total Concrete Cost Savings with a Slow Implementation Scenario

Year	Implementation Rate (Percent)	Discounted Agency Savings (Million $)
1	1.0	0.47
2	1.3	0.58
3	1.8	0.76
4	2.4	0.97
5	3.1	1.19
6	4.0	1.46
7	4.9	1.70
8	5.9	1.95
9	7.1	2.24
10	8.3	2.49
11	9.6	2.75
12	11.0	3.00
13	12.5	3.24
14	14.0	3.46
15	15.7	3.70
16	17.4	3.90
17	19.2	4.10
18	21.0	4.27
19	23.0	4.45
20	25.0	4.61
20-Year Total		51.29
Equiv. Ann. Total		4.12

Table 5. Total Concrete Cost Savings with a Moderate Implementation Scenario

Year	Implementation Rate (Percent)	Discounted Agency Savings (Million $)
1	1.0	0.47
2	1.7	0.75
3	2.7	1.14
4	3.9	1.57
5	5.4	2.07
6	7.1	2.59
7	9.0	3.13
8	11.1	3.68
9	13.4	4.23
10	15.9	4.78
11	18.5	5.29
12	21.4	5.83
13	24.4	6.33
14	27.6	6.82
15	30.9	7.27
16	34.4	7.71
17	38.1	8.14
18	41.9	8.52
19	45.9	8.89
20	50.0	9.22
20-Year Total		98.43
Equiv. Ann. Total		7.90

Table 6. Total Concrete Cost Savings with a Fast Implementation Scenario

Year	Implementation Rate (Percent)	Discounted Agency Savings (Million $)
1	1.0	0.47
2	2.4	1.07
3	4.3	1.82
4	6.8	2.74
5	9.8	3.76
6	13.3	4.86
7	17.1	5.95
8	21.4	7.09
9	26.0	8.20
10	31.0	9.31
11	36.4	10.42
12	42.2	11.50
13	48.3	12.54
14	54.7	13.52
15	61.5	14.48
16	68.6	15.38
17	76.0	16.23
18	83.7	17.02
19	91.7	17.76
20	100.0	18.45
20-Year Total		192.57
Equiv. Ann. Total		15.45

Table 7. Twenty-Year Cost Savings (Million $) and Benefit-Cost Ratio* for SHRP Concrete and Structures Research

Basis of Cost		Implementation Rate					
		Slow		Moderate		Fast	
		Savings (Million $)	Ratio†	Savings (Million $)	Ratio†	Savings (Million $)	Ratio†
Agency	Test Methods	51	0.93	98	1.8	192	3.5
	Pavements	160	2.9	307	5.6	600	11
	Subtotal	211	3.8	405	7.4	792	14
User	Pavements	476	8.7	913	17	1,790	33
Agency and User	Test Methods	51	0.93	98	1.8	192	3.5
	Pavements	636	12	1,220	22	2,390	43
	Subtotal	687	13	1,318	24	2,582	47

* Based on an estimated 20-year research, development, and implementation cost of $55 million.

† Totals may not add up because of rounding.

Table 8. Total Annual Cost Savings (Million $)

	Urban			Rural			Total
	Freeway	4-Lane Divided	2-Lane Undivided	Freeway	4-Lane Divided	2-Lane Undivided	
Agency Cost Savings	58.81	19.14	19.47	28.14	3.64	16.24	145.44
Motorist Cost Savings							
Delay	56.67	7.94	25.32	12.63	0.79	6.08	109.43
VOC*	192.15	26.51	28.20	59.91	2.85	13.39	323.01
Subtotal	248.82	34.45	53.52	72.54	3.64	19.47	432.44
Total	307.68	53.59	72.99	100.68	7.28	35.71	577.88

* VOC: Volatile organic compounds

Table 9. Total Concrete Pavements Cost Savings with a Slow Implementation Scenario

Year	Implementation Rate (Percent)	Discounted Agency Savings (Million $)	Discounted Motorist Savings (Million $)	Total Discounted Savings (Million $)
1	1.0	1.45	4.32	5.77
2	1.3	1.80	5.35	7.15
3	1.8	2.38	7.06	9.44
4	2.4	3.02	8.97	11.99
5	3.1	3.71	11.03	14.74
6	4.0	4.56	13.55	18.11
7	4.9	5.23	15.81	21.04
8	5.9	6.10	18.13	24.23
9	7.1	6.99	20.78	27.77
10	8.3	7.78	23.14	30.92
11	9.6	8.57	25.49	34.06
12	11.0	9.36	27.81	37.17
13	12.5	10.13	30.10	40.23
14	14.0	10.80	32.11	42.91
15	15.7	11.54	34.29	45.83
16	17.4	12.18	36.19	48.37
17	19.2	12.80	38.04	50.84
18	21.0	13.33	39.62	52.95
19	23.0	13.90	41.33	55.23
20	25.0	14.39	42.78	57.17
20-Year Total		160.02	475.90	635.92
Equiv. Ann. Total		12.85	38.19	51.04

Table 10. Total Concrete Pavements Cost Savings with a Moderate Implementation Scenario

Year	Implementation Rate (Percent)	Discounted Agency Savings (Million $)	Discounted Motorist Savings (Million $)	Total Discounted Savings (Million $)
1	1.0	1.45	4.32	5.77
2	1.7	2.36	7.00	9.36
3	2.7	3.56	10.59	14.15
4	3.9	4.90	14.57	19.47
5	5.4	6.46	19.21	25.67
6	7.1	8.09	24.06	32.15
7	9.0	9.77	29.04	38.81
8	11.1	11.48	34.11	45.59
9	13.4	13.20	39.22	52.42
10	15.9	14.91	44.32	59.23
11	18.5	16.52	49.11	65.63
12	21.4	18.20	54.11	72.31
13	24.4	19.77	58.75	78.52
14	27.6	21.30	63.29	84.59
15	30.9	22.71	67.49	90.2
16	34.4	24.07	71.55	95.62
17	38.1	25.39	75.48	100.87
18	41.9	26.60	79.05	105.65
19	45.9	27.75	82.47	110.22
20	50.0	28.79	85.56	114.35
20-Year Total		307.28	913.30	1,220.58
Equiv. Ann. Total		24.66	73.29	97.95

Table 11. Total Concrete Pavements Cost Savings with a Fast Implementation Scenario

Year	Implementation Rate (Percent)	Discounted Agency Savings (Million $)	Discounted Motorist Savings (Million $)	Total Discounted Savings (Million $)
1	1.0	1.45	4.32	5.77
2	2.4	3.33	9.88	13.21
3	4.3	5.67	16.87	22.54
4	6.8	8.55	25.40	33.95
5	9.8	11.73	34.86	46.59
6	13.3	15.16	45.06	60.22
7	17.1	18.57	55.18	73.75
8	21.4	22.13	65.77	87.90
9	26.0	25.60	76.10	101.70
10	31.0	39.07	86.41	125.48
11	36.4	32.51	96.63	129.14
12	42.2	35.90	106.70	142.60
13	48.3	39.13	116.30	155.43
14	54.7	42.21	125.44	167.65
15	61.5	45.19	134.32	179.51
16	68.6	48.01	142.69	190.70
17	76.0	50.66	150.56	201.22
18	83.7	53.13	157.92	211.05
19	81.7	55.44	164.77	220.21
20	100.0	57.58	171.13	228.71
20-Year Total		611.02	1,786.31	2,397.33
Equiv. Ann. Total		48.23	143.34	191.57

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