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STATE OF THE ART:
CLASS I BICYCLE PATH PAVEMENTS

BY
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16. Abstract

This report presents the state-of-the-art of Class I bicycle path pavements. The review of the literature in this study covers the following items:

1. Defining the types of bikeway pavement systems
2. Determining bikeway pavement design criteria
3. Determining bikeway pavement design methods
4. Defining maintenance requirements
5. Determining the construction and maintenance costs
6. Obtaining data on field performance
7. Evaluating low-cost materials and waste materials that show promise for use in bikeway pavements.

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STATE OF THE ART:
CLASS I BICYCLE PATH PAVEMENTS

EXECUTIVE SUMMARY REPORT

I. INTRODUCTION

The bicycle is the second most widely used mode of transportation in the United States. In recent years, their sales have surpassed those of automobiles. The increased use of bicycles has caused accidents and fatalities in bicycle related accidents to skyrocket. One out of every three bicycle related accidents involve an automobile and the bicycle automobile accident accounts for almost all bicycle fatalities and serious injuries.

Recognizing this hazard, many states and municipalities have incorporated bikeways into their overall transportation system. Obviously, the best type of bicycle facility, from a safety standpoint, is one that physically separates the cyclist from other transportation modes; this being the Class I bikeway. And, as with anything that's the best, these facilities are the most expensive, averaging over $25,000 per mile. Governmental budgets are limited; this, together with the current economic situation, has retarded the implementation of Class I bikeways. If means could be found to reduce the high cost of these structures, more Class I bikeways could be constructed.

II. PROBLEM STUDIED

The objective of the research program is to develop design methods for Class I bikeway pavements of adequate strength and durability at the lowest possible cost. The development of low-cost bikeway pavements should permit the maximum mileage to be obtained from each appropriated bike path dollar.

III. RESULTS ACHIEVED

The first phase of the research program is to conduct a detailed review on the literature of all currently existing and experimental bikeway pavements. This report covers this phase of study. The items included in this review report are:

(1) Defining the types of bikeway pavement systems

(2) Determining bikeway pavement design criteria

(3) Determining bikeway pavement design method

(4) Defining maintenance requirements

(5) Determining the construction and maintenance costs

(6) Obtaining data on field performance

(7) Evaluating lost-cost materials and waste materials that show promise for use in bikeway pavements.

The following are the conclusions and recommendations from this study:

(1) The primary criteria governing the design of bikeway pavement section are to withstand the maintenance vehicles, construction vehicles and other vehicles which may have to ride on it. The average design load is almost two tons. It is strongly recommended that this design criteria be reassessed.

(2) About 90% of pavement surfaces are asphalt concrete or portland cement concrete.

(3) Most bikeway pavements are maintained using conventional highway maintenance equipment. Use of this relatively heavy equipment is a principal reason for the use of excessive design load. Use of

maintenance equipment specially designed for bikeway could substantially reduce the thickness of pavement structures.

(4) A more definitive performance criterion for bikeway pavement is lacking. Particularly, data relating the performance to the pavement structural section is not available.

(5) Many low-cost materials and waste materials have a great potential to be used for bikeway pavement materials.

IV. UTILIZATION OF RESULTS

This report provides a overview of the state-of-the-art of Class I bikeway pavement construction. Results from this phase of study has clearly pointed out the directions in which the future research and development program for the design and construction of Class I bikeway pavement should be taken such that a durable bikeway pavement can be constructed at the lowest possible cost.

V. CONCLUSION

Class I bikeway pavements are, at present, over designed and very costly. The present design criteria should be re-evaluated. Based on new design criteria, new pavement systems can be developed, and low cost materials and waste materials can be incorporated into the construction of the pavement system. This should result in a substantial reduction in construction cost.

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1. INTRODUCTION

The bicycle is the second most widely used mode of transportation in the United States. In recent years, their sales have surpassed those of automobiles. The increased use of bicycles has caused accidents and fatalities in bicycle related accidents to skyrocket. One our of every three bicycle related accidents involve an automobile and the bicycle-automobile accident accounts for almost all bicycle fatalities and serious injuries.

Recognizing this hazard, many states and municipalities have incorporated bikeways into their overall transportation system. Obviously, the best type of bicycle facility, from a safety standpoint, is one that physically separates the cyclist from other transportation modes; this being the Class I bikeway. And, as with anything that's the best, these facilities are the most expensive, averaging over $25,000 per mile. Governmental budgets are limited; this, together with the current economic situation, has retarded the implementation of Class I bikeways. If means could be found to reduce the high cost of these structures, more Class I bikeways could be constructed.

The objective of the research program undertaken at Georgia Institute of Technology is to develop designs for Class I bicycle path pavements of adequate strength and durability at the lowest possible cost. The development of low-cost bicycle path pavements should permit the maximum mileage to be obtained from each appropriated bicycle path dollar. It is hoped that reduction of pavement costs shall encourage the construction of Class I bicycle path bicycle paths on exclusive rights-of-way, a measure which considerably enhances the safety of this mode of transportation.

In the first phase of the program, the major effort has been to obtain and review all available published and unpublished information of all currently existing and experimental bikeway pavements to supplement information already available on hand. Emphasis has been placed on:

(1) Defining the types of bikeway pavement systems

(2) Determining bikeway pavement design criteria

(3) Determining bikeway pavement design methods

(4) Defining maintenance requirements

(5) Determining the construction and maintenance costs

(6) Obtaining data on field performance

(7) Categorizing and evaluating any new materials and methods used in related or allied technical fields that show promise for use in bike pavement systems.

2. TYPES OF BIKEWAY PAVEMENT SYSTEMS

The principal purpose of bicycle path is to provide the cyclist a safe, smooth and comfortable ride. In order to achieve this the bicycle paths must have an all-weather, smooth, wear-resistant and non-skid surface. Bicycle pavement structures are in many respects similar to that of highway pavements. Different materials have been used for bicycle pavements. According to a recent nationwide survey study on the Class I bicycle pavement [1,2], a typical bicycle pavement structure consists of a surface course and base course. Although, sometimes subbase course has also been included. Table 1 summarizes the results from the survey study [2] with respect to the pavement structure. The survey study indicated that a majority of bicycle pavement surfaces are asphalt concrete (79.13%), rock, crushed stone and limestone (12.51%) and portland cement concrete (8.33%). The survey study in 1973 conducted by the American Institute of Park Executives in which two questions were asked. One which surface material was used for Class I bikeways and which, in the respondee's mind, was the best suited for bikeway pavements. The results are shown in Table 2. Both survey results as shown in Table 1 and 2 showed similar findings.

Figures 1, 2 and 3 show the typical bicycle pavement systems recommended respectively in Guide for Bikeways by AASHTO [3], Bike Trail and Facilities by AIPE [4], and Bikeways, Design-Construction-Programs by NRPA [5]. In addition, typical bikeway pavement systems recommended by various states are shown in Appendix A. In the following, various bicycle pavement systems recommended by various agencies are summarized:

Table 1. Material Used for Class I Bikeway Pavement [2].

	Total	Mean	Stn. Dev.	Max.	Min.
Surface					
Asphalt Concrete					
Percent Using	79.17				
Depth, Inches		2.4	.72	4	1
Cement Concrete					
Percent Using	8.33				
Depth, Inches		3.7	1.37	6	2
Rock					
Percent Using	5.56				
Depth, Inches		2.5	1.00	4	2
Limestone Screenings					
Percent Using	5.56				
Depth, Inches		4.3	1.50	6	3
Base					
Aggregate					
Percent Using	37.84				
Depth, Inches		4.1	1.44	8	2
Crushed Stone					
Percent Using	27.03				
Depth, Inches		4.6	1.07	6	3
Gravel					
Percent Using	24.32				
Depth, Inches		4.4	3.24	12	1
Limestone					
Percent Using	2.70				
Depth, Inches		5.0	.00	5	5
Soil Cement					
Percent Using	8.11				
Depth, Inches		7.3	4.16	12	4
Subbase					
Sand					
Percent Used	2.52				
Depth, Inches		Mean = 2.8 Max. = 4.0 Min. = 0.			
Compacted Earth					
Percent Used	5.66				
Non Used					
Percent	91.82				

Table 2. Survey Study on Bikeway Pavement Surface by AIPE [4]

Surface	Percent Now Using	Percent Indicating Best
Asphalt	67.66%	72.20%
Dirt	24.44%	4.76%
Gravel	24.44%	4.76%
Concrete	20.00%	2.88%
Turf	8.88%	2.38%
Soil Cement	6.66%	4.76%
Blue Stone Dust	2.22%	2.38%
Calache	-	2.38%

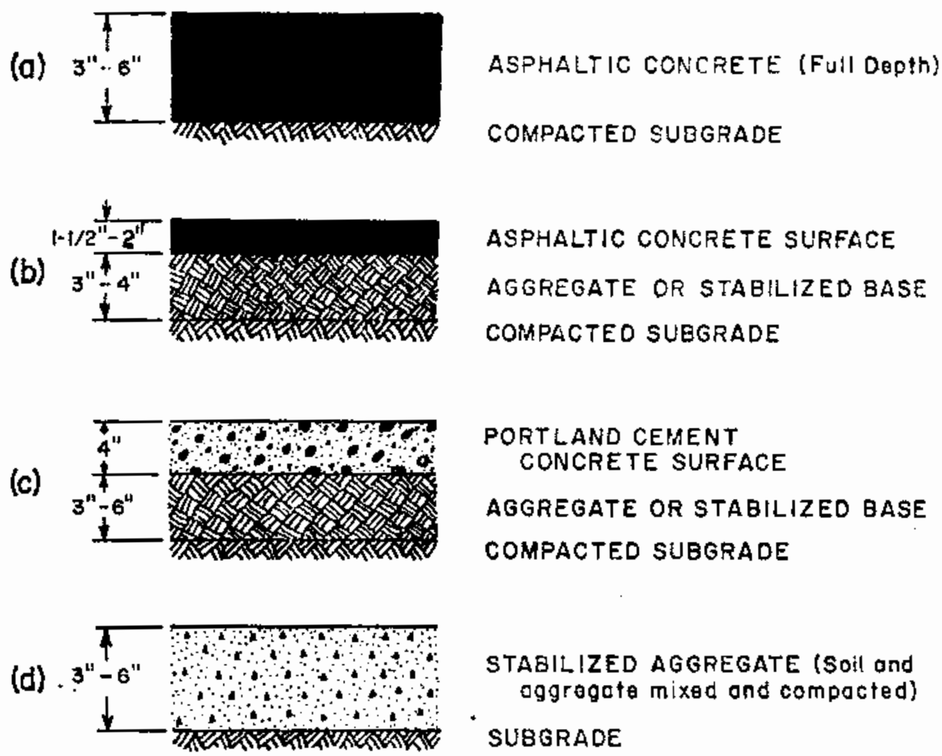
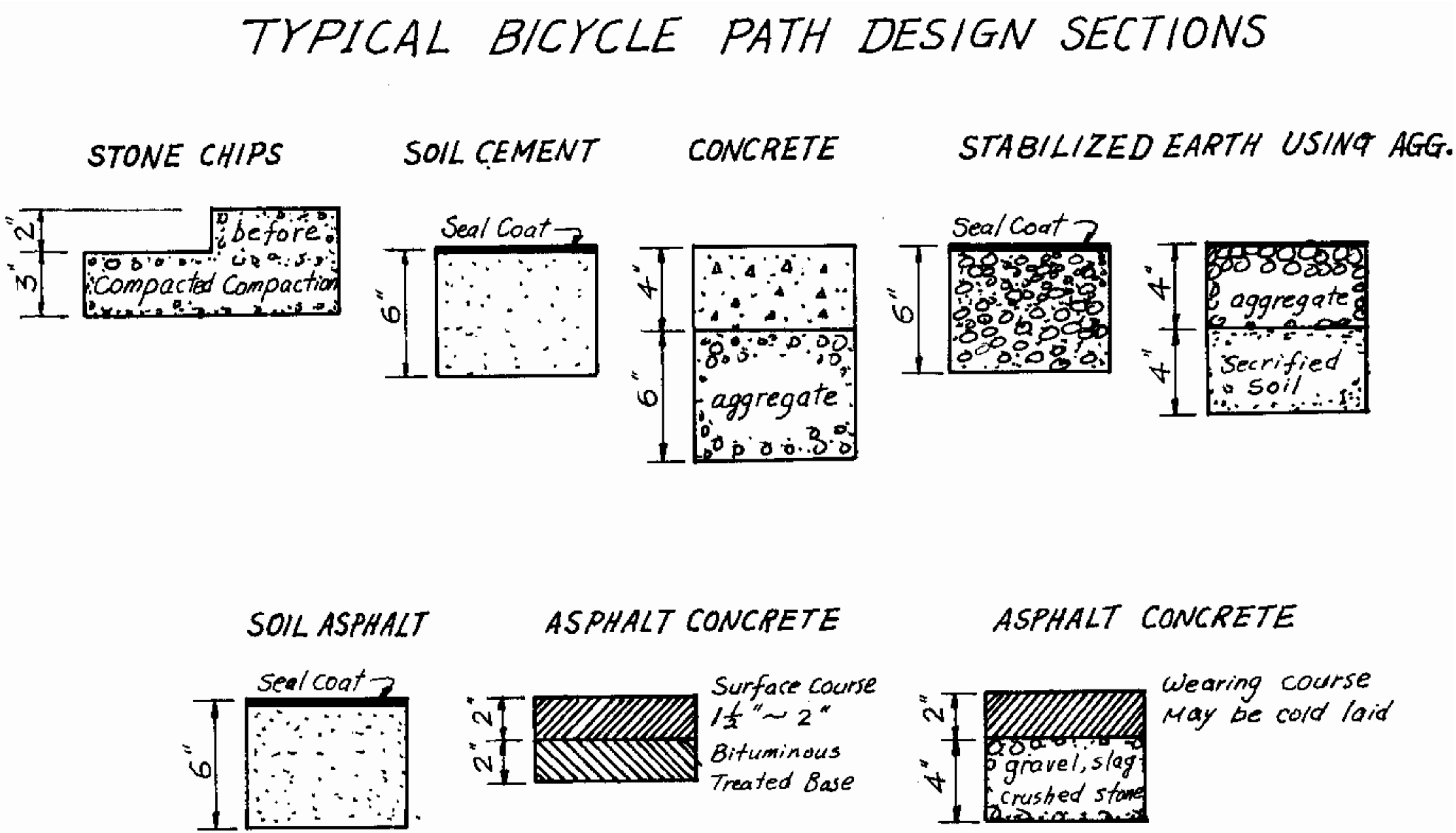


Figure 1. Typical Bicycle Path Design Sections - AASHTO.

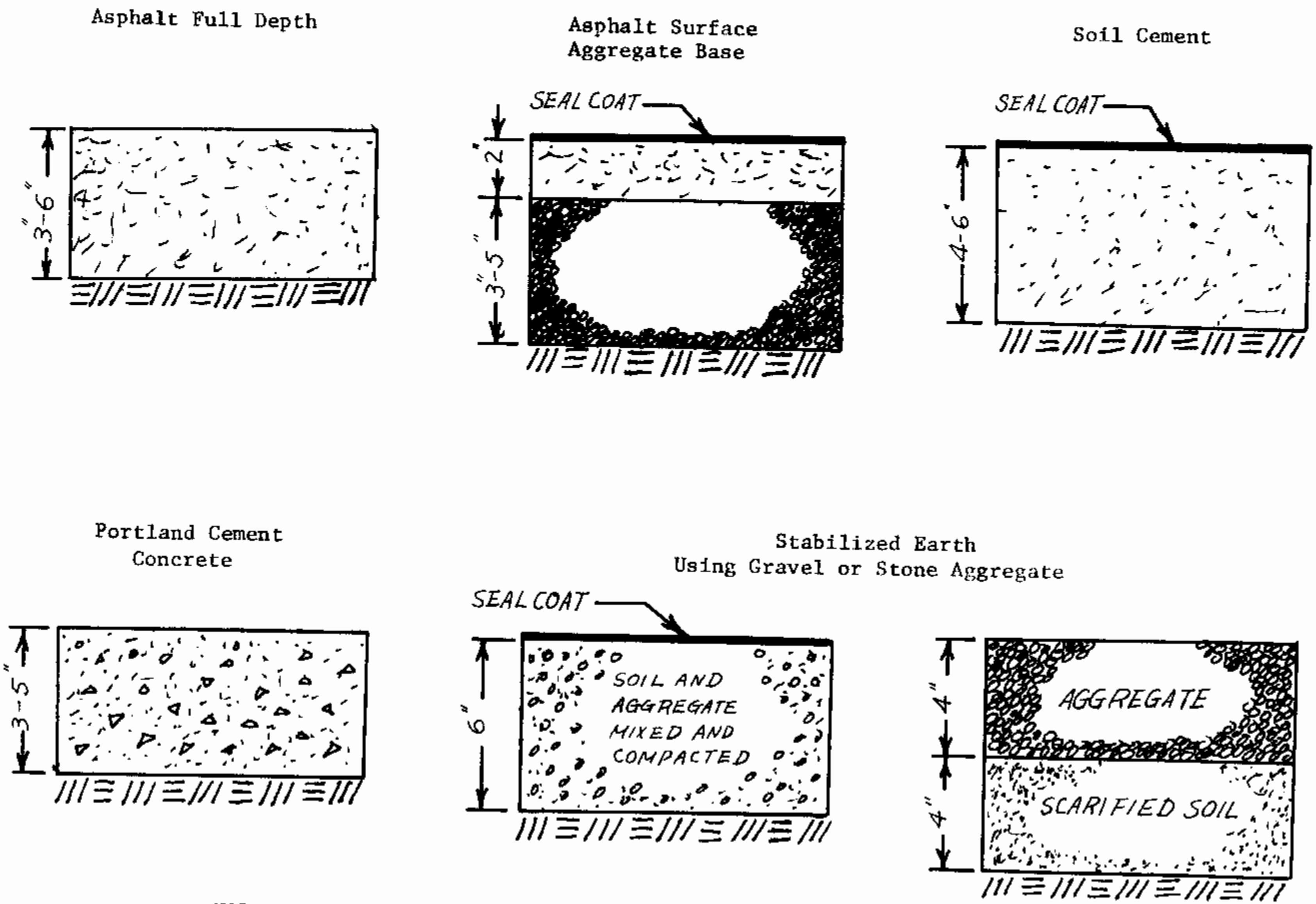
Source: AASHTO: Guide for Bike Routes [3].



NOTE: All of the above types of bicycle paths must be constructed on a well drained subgrade or subbase to prevent settling, or heaving through frost action.

Figure 2. Typical Bicycle Path Design Sections. (Generally the same as sidewalk design sections)

Source: American Institute of Park Executives [4].



NOTE: All of the above types of bicycle paths must be constructed on a well drained subgrade or subbase to prevent settling, or heaving through frost action.

Figure 3. Typical Bicycle Path Design Sections.

Source: National Recreation and Park Association, Bikeways, Design-Construction-Program [5].

Asphalt Concrete

Several combinations using asphalt concrete are possible and many have been used for bikeways. One that is used extensively consisted of three to six inches of full-depth hot mix asphalt concrete directly above a compacted subgrade. With this design, regular highway mixes can be used provided they are dense graded. As a rule, asphalt content should be one half to one percent higher than that used on a regular highway mix as the bikeway will be subject to lighter loads [6].

Another widely used section, consists of three to four inches of aggregate base of gravel, crushed stone or slag with 1-1/2 to 2 inch asphalt surface course. This method is preferable to the full-depth hot mix method in that it is more representative of the usual low-type highway practices and is more economical when the bikeway is placed on poor quality subgrade.

In all bikeway surfaces using asphalt concrete, AIPE recommends that the depth of the surface course be twice the thickness of the largest aggregate in the mix.

Portland Cement Concrete

Concrete is a very durable and, once in place, is relatively maintenance free. Successful concrete construction calls for the building of a good base to prevent settling, heaving and pumping. Unlike most other pavement systems, concrete is rigid. Any shifting occurring will cause the concrete surface to crack.

Design specifications for concrete are generally the same as for sidewalks. Generally, a good, well compacted subbase, is necessary. The surface should be four inches of concrete; no reinforcing is necessary.

When pouring, joints must be made to allow for expansion and contraction. When pouring, forms must be used in order to level the path and/or to provide proper drainage.

Soil Cement

Soil cement is a simple mixture of pulverized soil combined with measured amounts of portland cement and water compacted to a high density. Although the actual chemical reactions that lead to the increase of strength are not clearly known, it is believed that the strengthening comes from two processes. The primary process is the hydration of cement, whereby cement particles develop strong linkage to bind soil aggregates. The secondary process consists of reaction between soil particles and calcium hydroxide liberated during the hydration process (lime-clay interaction). This secondary process may contribute to strength for silt-clay soil mixtures and may account for the reduction in plasticity and expansive characteristics. Cement stabilization is generally not effective for organic salts and clays and alternative methods of stabilization such as lime stabilization should be considered.

Lime Stabilization

Lime stabilization works best for highly plastic, wet clay soils, the effective of lime is remarkable both as a soil modifier that decreases plasticity and increases workability, and as a stabilizer that increase strength and reduces swell potential as a result of pozzolanic reactions. Normally, lime content is about 2% to 6% by dry weight of soils, with each percent equivalent to about 5 lb/yd^2 for the usual 6 in. to 8 in. lift.

In soils where the amount of natural pozzolan available for lime stabilization is very low, such as silty and sandy soils, artificial pozzalan such as fly ash can be added.

Soil Aggregate

In construction, all top soils should be removed and a minimum of four inches of graded aggregate placed on top of subbase (when used). All material, earth and aggregate, in a proportion of 60% aggregates and 40% clay, should then be thoroughly mixed, usually with a scraper blade or road grader. After mixing, the surface should be crowned in the center at a rate of about 1/2 inch per foot and compacted. If aggregate is not available, crushed rock, or other suitable material may be used. In some circumstances, it may be necessary to haul in amounts of clay to bind aggregate together. The surface is then suitable for bicycle traffic; however, it may be sealed with an asphaltic material and stone chip to keep water off and provide a wearing surface. Where sandy soils are encountered, clay hardening may be necessary. This consists of bringing in clay materials for mixing with the sandy soil to form a subbase. Thickness of subbase will depend on the type of soil in the locality.

Stone Chip

Five inches of graded, incompacted, stone chip material is placed on subgrade and compacted to a thickness of three inches with a roller. The variation in size of the stone chips causes most of the voids to be filled to create a durable wearing surface, particularly after some use. Care must be taken to protect the edges of the stone course to prevent unravalling. Shoulders can be formed by scooping out the subbase to form a trench; this soil is later placed on the surface edge once the pavement is in place. Wood, metal, or additional stone chips can also be used to create shoulders.

The advantages and disadvantages for use of various materials for bikeway pavements are shown in Table 3.

Table 3

ADVANTAGES AND DISADVANTAGES OF SELECTED BIKEWAY SURFACING MATERIALS

MATERIAL	ADVANTAGES	DISADVANTAGES	TYPICAL APPLICATION
STABILIZED EARTH	LOCAL MATERIALS USUALLY ADEQUATE, LOW COST, GOOD BASE FOR FUTURE SURFACE MATERIALS, SMOOTH RIDING SURFACE IN DRY WEATHER	REQUIRES CONSIDERABLE MAINTENANCE TO MAINTAIN IN GOOD RIDING CONDITION, NOT A GOOD ALL-WEATHER SURFACE, MAINTENANCE DIFFICULT IN WET WEATHER, NOT SUITABLE FOR MOTOR VEHICLE TRAFFIC	LOW BICYCLE VOLUME, OFF-ROAD ROUTES, SUITABLE FOR MIXED PEDESTRIAN USE
CRUSHED STONE	LOW COST WHEN MATERIALS ARE AVAILABLE NEAR SITE, MAKES GOOD BASE FOR FUTURE MATERIALS	COULD CUT TIRES-ANGULAR PIECES, REQUIRES MORE MAINTENANCE THAN ASPHALTIC OR CONCRETE SURFACES, NEEDS LOCAL SUPPLY, NOT A GOOD ALL-WEATHER SURFACE, NOT SUITABLE FOR HEAVY MOTOR VEHICLE TRAFFIC	LOW BICYCLE VOLUME, OFF-ROAD ROUTES,SUITABLE FOR MIXED PEDESTRIAN USE
SOIL CEMENT	LOCAL MATERIALS USUALLY ADEQUATE, RELATIVELY SMOOTH RIDING SURFACE, EASY MAINTENANCE, GOOD BASE FOR FUTURE SURFACE MATERIALS	SURFACE IS PRONE TO EROSION, SURFACE CAN BECOME ROUGH, NOT SUITABLE FOR HEAVY MOTOR VEHICLE TRAFFIC	LOW BICYCLE VOLUME, OFF-ROAD ROUTES
HOT-MIX ASPHALTIC CONCRETE	LONG SERVICE LIFE, EASY TO MAINTAIN, ALL-WEATHER SURFACE, SMOOTH RIDING SURFACE, MOST DURABLE IN FREEZE-THAW SITUATIONS	HIGH COST, POSSIBLE FUTURE MATERIALS SHORTAGE	HIGH VOLUME, OFF-ROAD PATHS OR ON-STREET LANES
COLD-MIX ASPHALT	SAME ATTRIBUTES AS HOT-MIX PLUS ACCESS TO REMOTE PLACES, CAN STOCKPILE	SAME AS HOT-MIX BUT HIGHER CONSTRUCTION COSTS DUE TO MORE LABOR REQUIREMENTS	HIGH VOLUME OFF-ROAD PATHS OR ON-STREET LANES
CONCRETE	LONGEST SERVICE LIFE, LOW MAINTENANCE, SMOOTH RIDING SURFACE, TAKES HEAVY LOADS, ALL-WEATHER SURFACE	CONSTRUCTION JOINTS CAN BE BUMPY, HIGHEST CONSTRUCTION COST	HIGH VOLUME, OFF-ROAD PATHS

Low Cost Bikeway Pavement [8].

3. BIKEWAY PAVEMENT DESIGN CRITERIA

Selection of a proper pavement system is a function of vehicle characteristics, design load, subgrade condition and environmental condition. The bicycle has a relatively small area in contact with the surface in proportion to the weight of the bicycle and rider. The pavement must be able to withstand this type of stress. Bicycle tires are also quite narrow and on soil surfaces, especially clayey soils when moist, rutting may occur. This indicates that some sort of binder material should be used. For proper riding during adverse weather, or in areas of excessive rainfall, a water-tight pavement material is needed.

The pavement must also be able to support the automotive vehicles that will be used. Most municipalities do not have specially made maintenance vehicles for bikeways and must, therefore, rely on small trucks. Police and security cars may on occasion patrol bikeways and the need may arise when ambulances or other emergency vehicles may have to use the facility. Although Class I bikeways are intended solely for use by the cyclist, the loads that these automotive vehicles exert must be considered in the pavement design. As a result, the weight of these vehicles may be a more critical factor in bikeway pavement design than the stresses caused by a bicycle's high tire pressure.

The design criteria mentioned above has been used by most of the agencies. These include AASHTO [3], AIPE [4], The Asphalt Institute [6] as well as many other agencies [8-12].

4. BIKEWAY PAVEMENT DESIGN METHODS

Although it is recognized by most of the agencies that the selection of a bikeway pavement system should be based upon the soils, climate, materials and construction practices in addition to the expected vehicular loads, no specific design method has been developed to guide the design and selection of bikeway pavement section from a given set of design parameters; e.g., soil support conditions, local weather conditions and drainage conditions. As a result, most of the design manuals provide only a general guide and recommend certain typical sections such as those shown in Figures 1, 2, 3 and the figures shown in Appendix A. These typical cross-sections for bikeway pavements are usually laid out to the same specifications as low volume roads, driveways and service roads or sidewalks. The range of variations in thickness in each suggested cross-section is provided to accommodate for the wide variations in soils, climatic conditions and construction practices. To properly select the type of pavement system and the thickness of each components will depend upon the experience and wisdom of the project engineer or designer. This situation is similar to the highway pavement design practice in the early days.

When the question of design load used for bikeway pavements was asked in the survey study [2], the following statistics were obtained: mean design load was 3712 pounds, maximum design load was 9000 pounds and minimum design load was 500 pounds. The vast majority of respondents specified that design load was based on maintenance and construction vehicles and not on bicycle loads.

5. MAINTENANCE REQUIREMENTS

The information with respect to the maintenance requirements for bikeway was reported in [1,2]. In that survey study it was reported that only 14% of those responding indicated that maintenance was required. Of those, 48% was for sweeping, 20% was for cleaning of refuse, 32% was for repairing and repaving rutts. The problems of rutts, pot holes, and extensive cracks which need repairing and repaving were caused by flooding and wash-outs of non water-tight surfaces. Rutting problems occurred mainly with limestone and crushed stone surfaces.

Only four agencies from those responding indicated that specially designed maintenance vehicles for bikeways were being used. The others indicated no special designed maintenance vehicles were being used. Among those agencies, 55.33% were using light maintenance vehicles, 17.7% were using street sweepers.

Among those agencies where specially designed maintenance vehicles were being used, the pavement system was generally much lighter. For example, 2 inches of asphalt concrete was paved directly on clay (Georgia clay) on 50 miles of Class I bikeway pavement at Peachtree City, Georgia [13]. In this case, golf-cart type of specially designed maintenance vehicle was used for the bikeways maintenance.

6. CONSTRUCTION AND MAINTENANCE COSTS

The cost of providing the various physical facilities and improvements is of critical importance in planning the network. The factors that determine these costs are complex and subject to rapid change. Furthermore costs of various items depend widely on local conditions. The best approach is to obtain the latest price information from local contractors and suppliers. The handbook prepared for the North Carolina Department of Transportation Highway Safety by Barton-Aschman Associates, Inc. [9] provides a very complete cost information for the various physical facilities for bikeway pavements in the State of North Carolina.

In the survey study [1,2] the cost information on construction of various facilities were also reported. These statistics are shown in Table 4. In addition, construction cost information from several agencies as reported in [2] are included in Appendix B. In the following the cost of several major items are discussed briefly.

Materials. As shown in Table 4, the highest percentage of total cost (the mean percentage as well as the maximum percentage) went for materials. This indicates the quality of materials being used, as well as the quantities of materials being used.

Right-of-Way Acquisition. It is difficult to say if right-of-way acquisition could be significantly reduced. One alternative is to construct bikeway facilities on public lands. This, however, limits the type and purpose of bikeways to being recreational. One conceivable alternative is to share right-of-way with other publicly owned facilities. Class II

Table 4. Cost of Construction of Class I Bikeway.

	Mean	Stn. Dev.	Max.	Min.
Cost of Construction $/Mile[1]	$26,429.7	8,159.28	80,000	1,000
Allocation of Cost- Percent of Total Cost[2]				
(1) Right of Way Acquisition	30.03	23.71	50	8
(2) Leveling & Grading	16.1	7.68	33	5
(3) Materials	38.8	16.85	87	20
(4) Construction Costs	28.7	16.67	80	1
(5) Labor Costs	28.1	12.02	65	1
(6) Signing, Lighting, Landscaping	9.9	7.76	25	1

---

(1) Mean width of the path 7.7 ft.

(2) In answering this part of the questionnaire, many respondents did not include all six categories in their respective percentage breakdown. Hence, the total of the mean percentage is greater than 100 percent.

and III bikeways do this through joint use of street right-of-way. Class I could share utility right-of-ways.

The Rural Electric Administration (REA) specifies that electric membership cooperatives, publicly owned utilities, provide sideways clearance for transmission lines. The side clearance varies from twenty-five to seventy-five feet from the transmission pole centerline to right-of-way edge. Vertical clearance of transmission lines exceeds the eight to ten feet recommended for bikeways. Further, REA makes no specification as to joint use of transmission line right-of-way, but does recommend that some access be provided. Transmission lines are susceptible to snapping only under the most severe of weather conditions, conditions worse than those normally prohibiting bicycle travel. Electric Membership Cooperative transmission line right-of-way is public domain, though use is controlled. Bikeway right-of-way acquisition could be very inexpensive. Despite the aethestical value of travelling in the vicinity of transmission lines, such right-of-way is usually the shortest and straightest distance between two points, and generally removed from roadways.

Construction and Labor Costs. Construction costs are related to labor costs, and vice versa, that both should be considered together. In light of current pavement techniques, it is inconceivable that these costs will be reduced. The alternatives are to use pavement systems that are more labor oriented; but, in light of present labor costs, that may not be the proper direction to go.

Leveling, Grading and Signing, Lighting and Landscaping. Leveling and grading costs are a function of both topography and cost of labor. As labor costs rise, so will leveling and grading costs. Selection of the flattest routes will minimize these costs. This is more a planning problem than a construction problem.

Signing, lighting and landscaping costs are minor in Class I bikeways. The highest percentage reported (80%) was from Wichita Bikeway Plan, which added bikeways after linear parks had been planned. The cost of landscaping was included in the bikeway project, but it should have been the other way around. Wichita also had the highest cost per mile constructed ($80,000).

While not necessary for Class I bikeways, landscaping gives them a more esthetical appearance in urban and suburban areas. It is not needed in areas where nature trails are constructed. Lighting is used in urban and suburban areas as a crime deterrant and seldom used in rural areas. Signs are used mainly at traffic intersections.

Very little information is available with respect to the cost for the maintenance of bikeways.

7. FIELD PERFORMANCE

Most of the agencies responsible for bikeway maintenance indicated good to satisfactory performance from their pavements. Only those pavements constructed with non water-tight surface had less than satisfactory performance. In general the performance of the pavements are rated by the existance and severity of pot holes, extensive cracks, rutts and other minor defects.

The fact that most of the pavements using asphalt and portland cement concrete surfaces receiving good and satisfactory performance may be attributed to the fact that most of the Class I bikeways are less than four years in age [1,2] and that many pavements may be overdesigned.

It appears that a more definitive pavement performance criteria other than just good, satisfactory, fair and poor is needed.

8. USE OF NEW MATERIALS

With cost of bikeway construction running between $20,000 and $30,000 per mile, agencies implementing Class I bikeway facilities are finding it difficult to build them. State and local governments are hard pressed to come up with the funds needed, especially in view of the needs of other governmental agencies. If inflationary trends continue, the cost for Class I bikeways may be too expensive to warrant their construction. One way to overcome this problem is to develop low-cost pavements through the use of low-cost materials and "waste materials". The development of low-cost materials and utilization of waste materials in order to reduce the use of petroleum-based products (such as asphalt), energy intensive materials (such as portland cement)* and also to solve the waste materials disposal problem, have been undertaken vigorously, particularly, by the highway agencies. In addition to the soil cement and soil stabilization using lime and cement many of the low-cost materials and waste materials have been developed as a promising substitution for paving materials and can be used readily on bikeway pavements. Some other materials are still in research and development stage. The first catagory includes fuel ash and fly ash from electric power plants and municipal incinerators [7], glass from non-returnable bottles [14], use of rubber reclaimed from discarded automobile tires [15,16], recycled scrap bituminous concrete [17,18]. The second catagory includes the use of sulfur and wood lignin to replace asphalt or use as the asphalt extender. Various materials which show the potential as bikeway pavement materials are reviewed in the following.

---

* It is estimated that three-fourths of the cost of the manufactured materials is represented by energy costs.

Marginal Materials

These are materials which do not meet specifications for highway systems but that may be suited for bikeway construction. For example, low cost stabilized sand and/or gravel certainly deserves serious consideration for bikeway pavements. Many state highway departments are currently re-evaluating their specifications to permit use of lower quality materials which have previously been excluded.

Many European cities use bricks with a sand mortar. The surface is acceptable when bricks are closely spaced and the surface offers no discomfort to the cyclist. Such brick bikeways appear in linear parks with overhanging trees to minimize rainfall problems. Where rainfall is a problem, conventional mortar is used and performs well. Maintenance is performed by manual labor and consists of sweeping, garbage removal and brick rotation. In most of Western Europe, material costs are substantially higher than labor costs. This warrants the use of more maintenance prone systems, such as bricks in sand. In areas where bikeways are covered (either by trees or structurally) compacted clay and even sand enjoy satisfactory performance [19].

Waste Materials

Materials such as fuel ash from electric power plants and municipal incinerators are being used as replacements for conventional materials. New York State is investigating the possible use of lime fly ash as a pavement aggregate [7]. Lime fly ash is a byproduct of electric power generation and is readily available in large quantities in most, if not all states. In the Southeast alone, more than nine million tons of power plant fuel ash year year. Less than ten percent of it is used in highway construction. Results of tests indicate this material holds promise both as a soil stabilizer with or without additional admistures. For economic reasons, use of fly ash would probably have to be restricted to areas close to its source.

Another waste material that holds promise is glass. The University of Missouri at Rolla is constructing a bikeway system using glassphalt: asphalt mixed with crushed glass. Glass in the form of non-returnable bottles has created refuse problems despite efforts at recycling. Like fuel ash, glass is available in enormous quantities and can be readily mixed with asphalt [14].

Rubber reclaimed from discarded automobile tires is grounded to size between #16 and #25 sieve size. The rubber particles (25% to 30%) were mixed with hot asphalt to form a tough and elastic binder. It has been used very successfully in seal coat construction for maintenance operations in the city of Phoenix, Arizona for several years and has been especially successful in overlaying pavements that exhibit severe fatigue cracking [15,16].

Spray on Applications of Penetrating Liquids

Several types of spray-on applications have been employed as expedient surfaces in highway and airfield applications. These materials penetrate the natural soil to provide a stable erosion-resistant surface. The use of these often properietary materials or modifications of them hold considerable promise for bikeway pavements [20,21].

In-Situ Soil Stabilization

To date, little use has been made of admixture stabilization of local materials. Conversion of existing soils into a suitable material with lime, cement, fly ash asphalt emulsions or other chemicals should be considered. The stabilized local material may require a surface course or it could be left in a natural state. This would be especially pleasing in rural surroundings and nature trails [22].

Recycled Construction Materials

Recycled bituminous concrete has been used for base course and surface course materials. Marek [17] indicated that in 1967 the Texas Highway Department initiated reconstruction of a 15 mile section of highway using recycled bituminous concrete as stabilized based course material as well as for surface course material. This has also been done recently on a one mile section of Interstate I-15 near Sloan, Nevada [18].

Experiments using "scrap" asphalt concrete available from a parking lot resurfacing on a test section of a bikeway have been carried out by the East Point, Georgia chapter of the Southern Bicycle League. Waste asphalt concrete was placed using low heat and compacted with a hand roller. The bikeway was surfaced with a thin layer of portland cement mortar mix. This facility has been in place for two years and has shown excellent performance. Additional studies should be carried out regarding the use of other recycled construction materials.

9. CONCLUSIONS AND RECOMMENDATIONS

The construction cost for Class I bikeway at the present time is too expensive. The development of low-cost pavements will increase the mileage obtained from each appropriated bikeway dollar and help meet the increasing demands and numbers of cyclists. The following are the conclusions and recommendations from this state-of-the-art study:

1. The primary criteria governing the design of bikeway pavement section are to withstand the maintenance vehicles, construction vehicles and other vehicles which may have to ride on it. The average design load is almost two tons. It is strongly recommended that this design criteria be reassessed.
2. About 90% of pavement surfaces are asphalt concrete or portland cement concrete.
3. Most bikeway pavements are maintained using conventional highway maintenance equipment. Use of this relatively heavy equipment is a principal reason for the excessive design load. Use of maintenance equipment specially designed for bikeway could substantially reduce the thickness of pavement structures.
4. A more definitive performance criterion for bikeway pavement is lacking. Particularly, data relating the performance to the pavement structural section is not available.
5. Many low-cost materials and waste materials have a great potential for use in bikeway pavement construction.

ACKNOWLEDGMENTS

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The author is indebted to many organizations and individuals who have generously provided the information. This work includes information from many sources, and the author has endeavored to give credit where it is due. Special acknowledgment is given to Tom Crawford of Southern Engineering Company of Georgia, former graduate student of Georgia Institute of Technology for permission to use material from his publication. Thanks also to R. Gary Hicks, and James J. Berryhill for providing many valuable information and suggestions.

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APPENDIX A

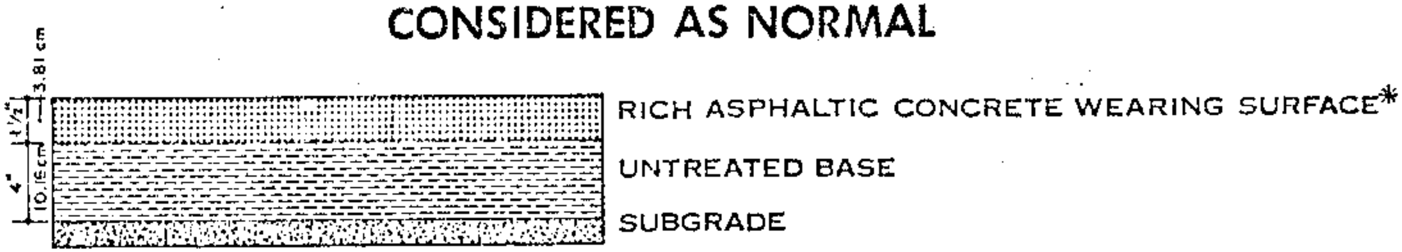
PAVEMENT CRITERIA

Listing of selected pavement criteria received through Bikeway Survey [2]. Information appears alphabetically by agency.

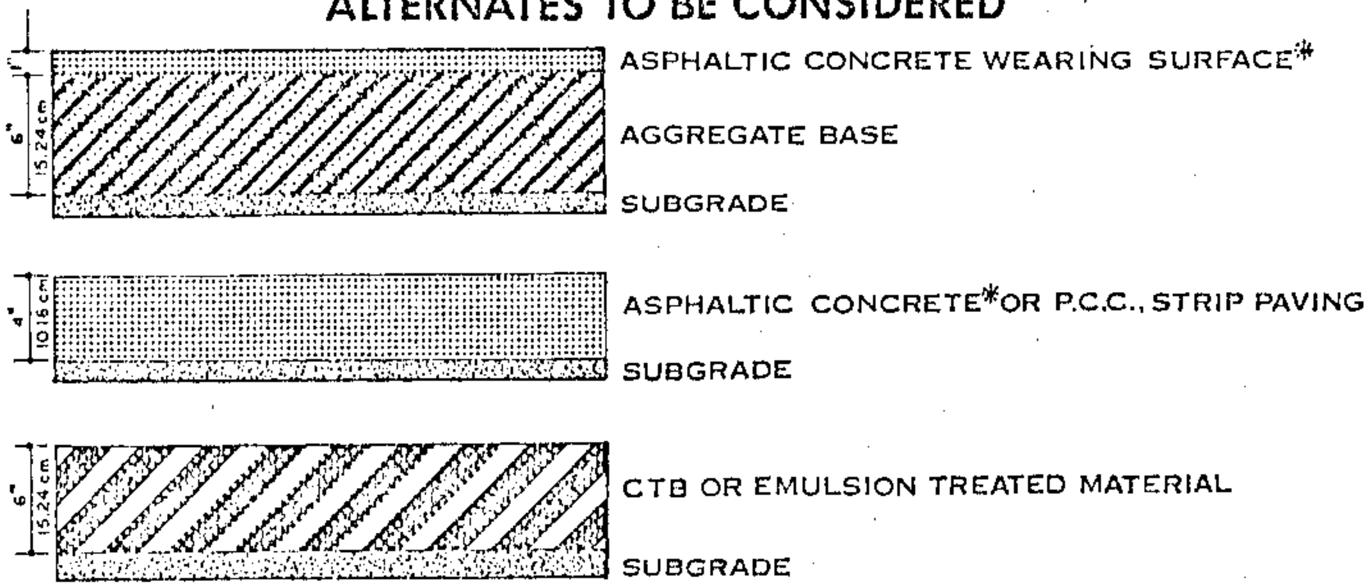
The information from the following agencies is included:

City of Las Cruces
Connecticut Department of Transportation
Louisiana Department of Transportation
National Crushed Stone Association
National Asphalt Paving Association
Pennsylvania Department of Transportation
Professional Engineering Consultants
Sacramento City-County Bikeway Task Force
Tennessee Department of Transportation
Vermont Department of Highways
Wisconsin Department of Transportation

SUGGESTED
TYPICAL SECTIONS-BASE DESIGN CONSIDERED AS NORMAL



SUGGESTED
ALTERNATES TO BE CONSIDERED



*A DILUTED EMULSION FOG SEAL IS RECOMMENDED ON ALL ASPHALTIC CONCRETE SURFACES EVERY TWO YEARS, AS A REJUVENATION AND MAINTENANCE PROCESS.

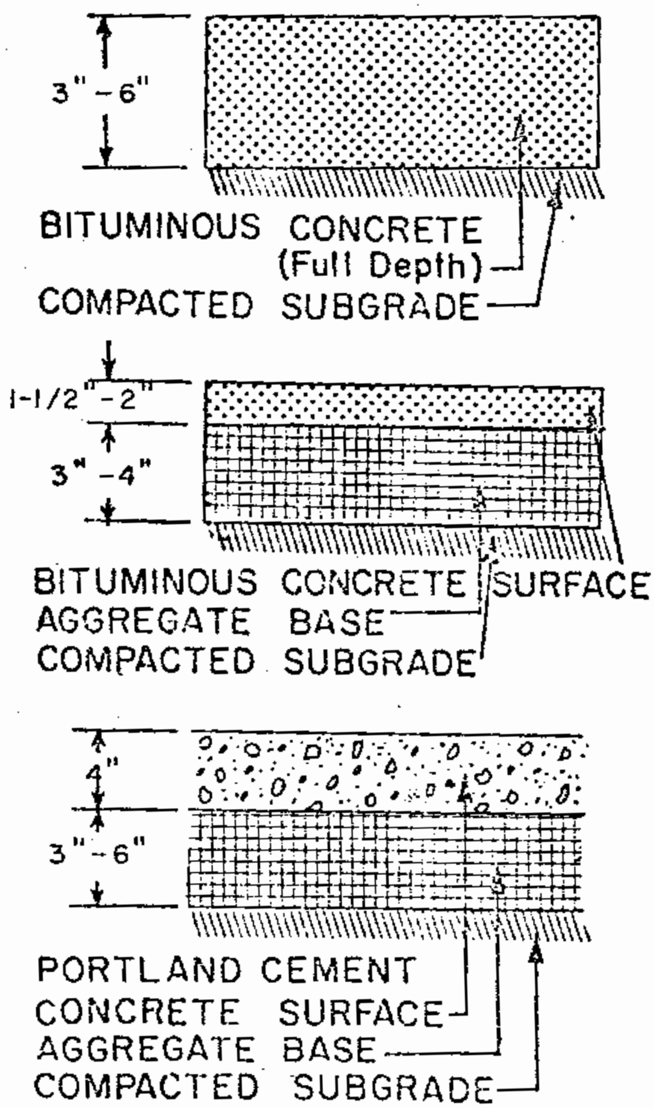
Source: [illegible] es, New Mexico, Guidelines for Bridle Paths and Bike Lanes

Surface and Structural Section

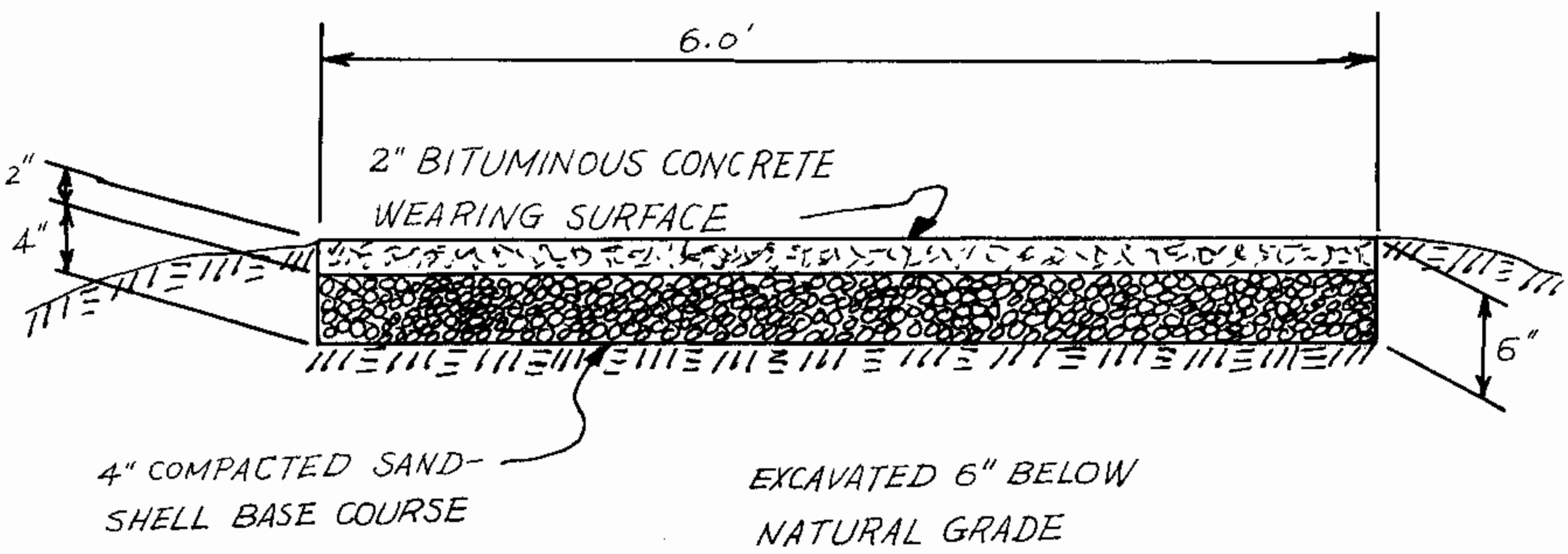
The primary criteria governing a bikeway structural section are its own stability and the ability to support anticipated wheel loads. This is determined primarily by the construction or maintenance equipment and other motorized vehicles that must use or cross the facility, rather than by the bicycles themselves.

Bituminous and portland cement concretes satisfy both structural and surface criteria, and are required for state bikeways. Bituminous concrete is more commonly used than portland cement concrete. In either case, a fine-graded aggregate should be used to insure a smooth surface texture.

The surface of a bikeway of any type must be smooth, hard, and durable. A smooth surface is required for the safety and comfort of the cyclist. Rough surfaces can result in a lack of control and, due to the poor ride quality of modern bicycles, a very bumpy, uncomfortable ride. The ridability of a facility partially depends on the surface hardness because the energy requirements of the cyclist are least when the surface is smooth and hard. Durability of a bikeway surface is important because it will prolong the life of the facility and reduce maintenance costs and effort.



Source: Connecticut Department of Transportation, Connecticut Bikeways



CROSS SECTION

BIKEWAY

Source: Louisiana Department of Transportation.

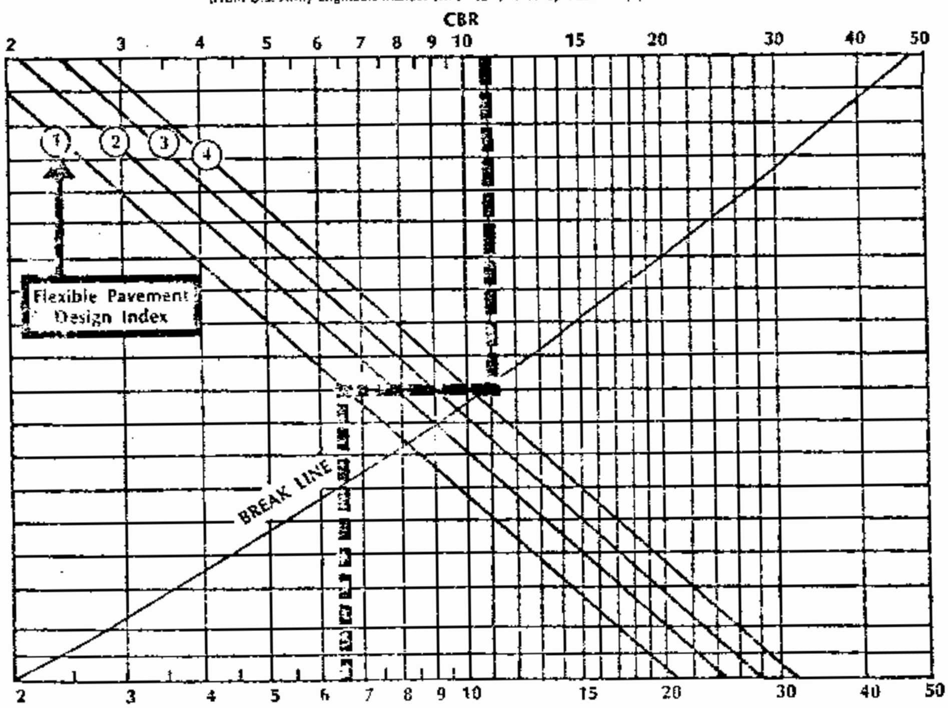
The following table provides general definition of four soil groups in ascending order of frost susceptibility:

Frost Group	Percentage Finer than 0.02 mm	Unified Soil Classifications*	Frost Susceptibility
F-1			
(a) Gravelly Soils	3-10	GW, GP, GW-GM, or GP-GM	Low
F-2			
(a) Gravelly Soils	10-20	GM, GW-GM, or GP-GM	Low to Medium
(b) Sands, Sand Clays	3-15	SW, SP, SM, SW-SM, or SP-SM	
F-3			
(a) Gravelly Soils	over 20	GM or GC	High
(b) Sands, coarse to medium	over 15	SM or SC	
(c) Clays, PI > 12	—	CL or CH	
F-4			
All silts, very fine silty sands, clays w/PI < 12, etc.	over 15	ML, MH, SM, CL, CL-ML, CH and alternately banded deposits	Very High

* Reference ASTM Standard D 2487.

Thickness Design Chart

(From U.S. Army Engineers Manual TM 5-822-5, 1965, reproduced by permission)



Total Design Thickness in Inches

Source: National Crushed Stone Association, Design Guide for Low Volume Rural Roads

Table 1-2

Simplified Practice Recommendations (SPR)

for

Standard Sizes of Coarse Aggregate

Amounts Finer than Each Laboratory Sieve (Square Openings), weight percent

	SIZE NUMBER (SPR)																		
	1	2	24	3	357	4	467	5	56	57	6	67	68	7	78	8	89	9	10
4 in.	100	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3½ in.	90-100	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3 in.	—	100	100	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2½ in.	25-60	90-100	90-100	100	100	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2 in.	—	35-70	—	90-100	95-100	100	100	—	—	—	—	—	—	—	—	—	—	—	—
1½ in.	0-15	0-15	25-60	35-70	—	90-100	95-100	100	100	100	—	—	—	—	—	—	—	—	—
1 in.	—	—	—	0-15	35-70	20-55	—	90-100	90-100	95-100	100	100	100	—	—	—	—	—	—
¾ in.	0-5	0-5	0-10	—	—	0-15	35-70	20-55	40-75	—	90-100	90-100	90-100	100	100	—	—	—	—
½ in.	—	—	0-5	0-5	10-30	—	—	0-10	15-35	25-60	20-55	—	—	90-100	90-100	100	100	—	—
⅜ in.	—	—	—	—	—	0-5	10-30	0-5	0-15	—	0-15	20-55	30-65	40-70	40-75	85-100	90-100	100	100
No. 4	—	—	—	—	0-5	—	0-5	—	0-5	0-10	0-5	0-10	5-25	0-15	5-25	10-30	20-55	85-100	85-100
No. 8	—	—	—	—	—	—	—	—	—	0-5	—	0-5	0-10	0-5	0-10	0-10	5-30	10-40	—
No. 16	—	—	—	—	—	—	—	—	—	—	—	—	0-5	—	0-5	0-5	0-10	0-10	—
No. 50	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0-5	0-5	—
No. 100	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	10-30

(Adopted from American Society for Testing & Materials, D 448)

Source: National Crushed Stone Association, Design Guide for Low Volume Rural Roads

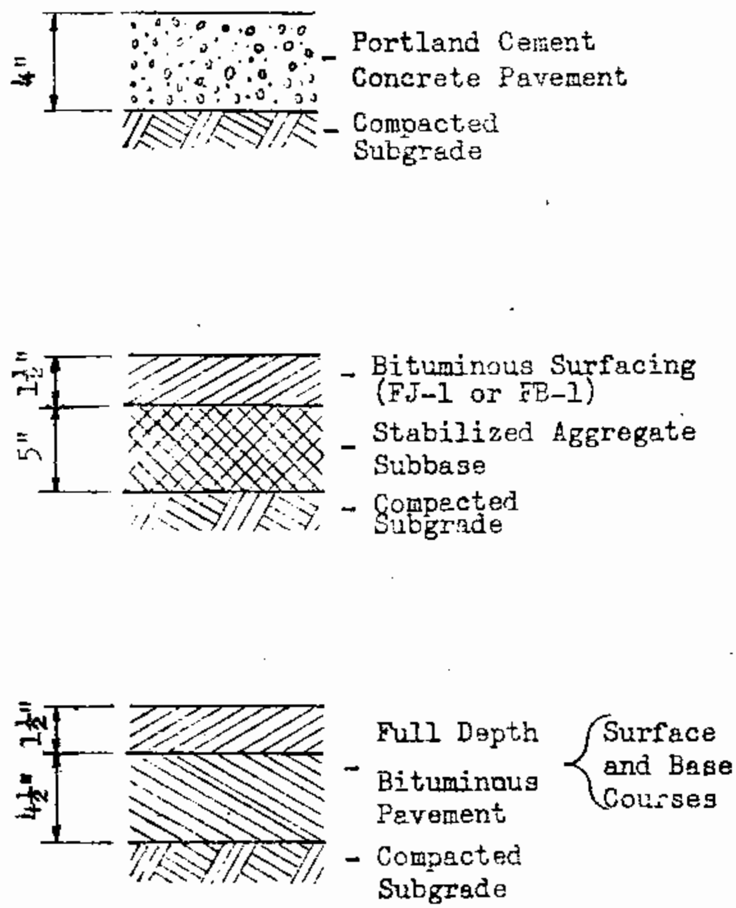
RECOMMENDED BIKEWAY THICKNESS FOR FULL-DEPTH HOT-MIX A.C. ON VARIOUS SUB-GRADES; (FROM "EFFECTIVE DESIGN FOR BICYCLE PATHS", PAVING FORUM, APRIL 1966, P. 7: NATIONAL ASPHALT PAVING ASSOCIATION).[1]

QUALITY OF EXISTING SUB-GRADE	MATERIAL (AASHO SYSTEM)	TOTAL THICKNESS (INCHES)
Very good	Gravels and sandy gravels: A-1, A-2-4, A-2-5, A-2-6	3
Good	Slits and clays: A-4, A-5, A-6, A-7-5, A-7-6	4
Poor*	Slits and clays: A-4, A-5, A-6, A-7-5, A-7-6	6

*Slits and clays rate poor only under the following conditions:

1. When they occur in low lying areas with poor natural drainage.
2. Where conditions of the water table and climate are such that severe frost heave can be expected.
3. Where high percentages of mica-like fragments or diatamaceous particles produce a highly elastic condition.
4. Where it is desired to "bury" highly expansive soils deeper in the section to limit the effects of seasonal variations in moisture.

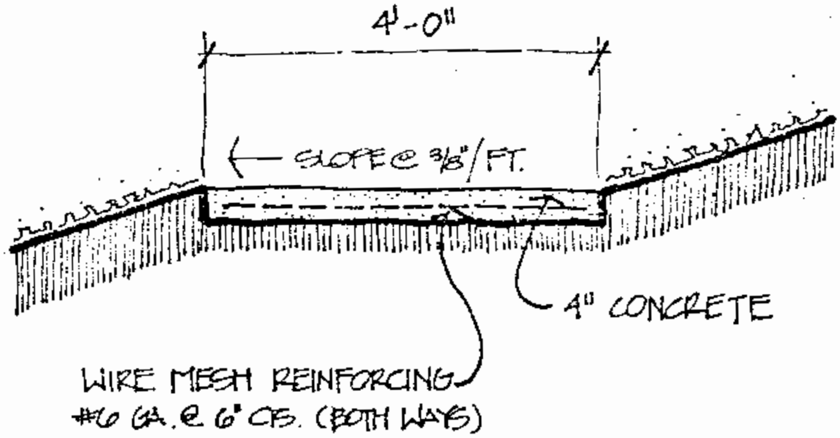
1/ Bikeway Planning
Criteria & Guidelines:
UCLA



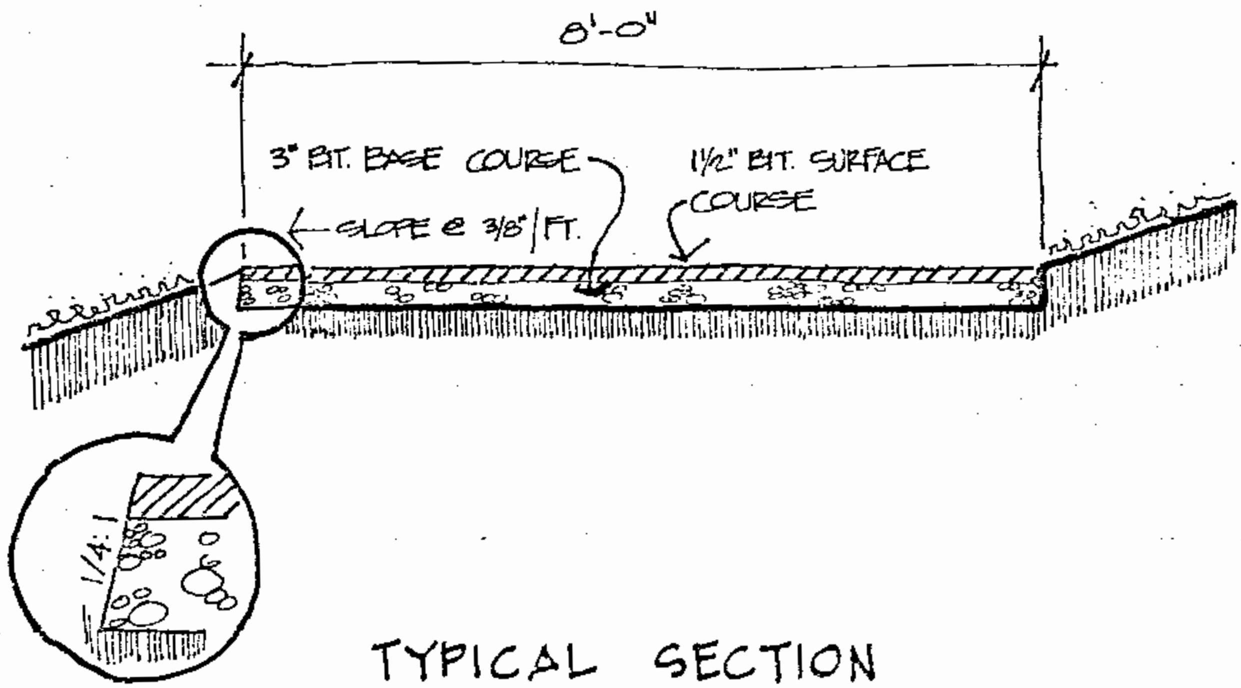
NOTE: Actual Pavement Depths Should be Determined
For the Soil Conditions Encountered.

Pavements (Minimum Depths)

Source: Pennsylvania Department of Transportation, <u>Guidelines for the Development of Bikeways</u>.



TYPICAL SECTION
CONCRETE HIKE PATH



TYPICAL SECTION
BITUMINOUS BIKE PATH

PROPOSED PATH SURFACE SECTIONS

Prepared by
Professional Engineering Consultants
in Association with
Oblinger-Smith Corporation
Wichita, Kansas

Surface Material

Class I structural development criteria must be adequate to support the wheel loads of bicycles and those of maintenance vehicles that may require access to the facility.

Acceptable surface materials are asphalt concrete and portland cement concrete. Aggregate base material is acceptable for the base.

The surface material selected will depend on whether or not an all weather surface is desired. Asphalt is generally favored, since it is the least expensive and provides an excellent surface.

The surface should be resistant to abrasion and indentation, clear of loose dirt and gravel, and because of high tire inflation pressures, possess tough and stable composition.

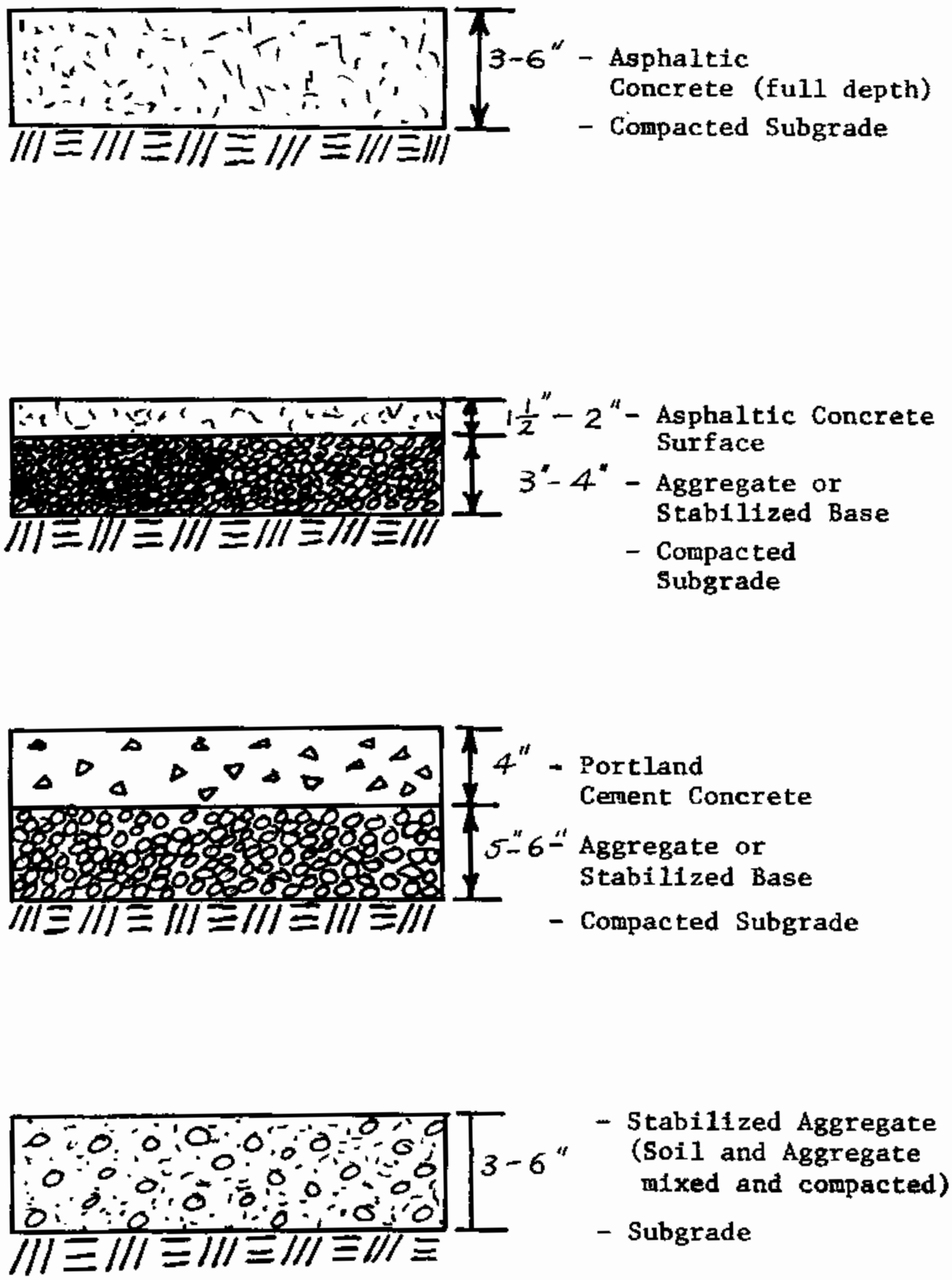
The thickness of the surfacing material depends upon the quality of the subgrade, the surface of the earth or rock leveled off to receive the foundation of a bikeway. Although it is generally satisfactory to lay full depth hot-mix asphalt directly onto the subgrade, it may be necessary to improve the quality of the subgrade first. An acceptable way of accomplishing this is to place a three to four inch aggregate base of gravel or crushed stone on the subgrade and to lay one and one-half to three inches of asphalt over this base.

In general, asphalt concrete should be used due to its low cost, long life, smooth surface and ease of maintenance. An open graded mixture of three-eighths inch maximum aggregate and paving asphalt grade AR 4000 placed with an asphalt paver is recommended for general use. It is suggested that the asphalt content be from one-half to one percent higher than that normally used on highway paving projects.

For all but the poorest quality basement soils (R-value less than 5), 0.25-foot thick asphalt concrete placed directly on prepared subgrade of basement soil is considered adequate.

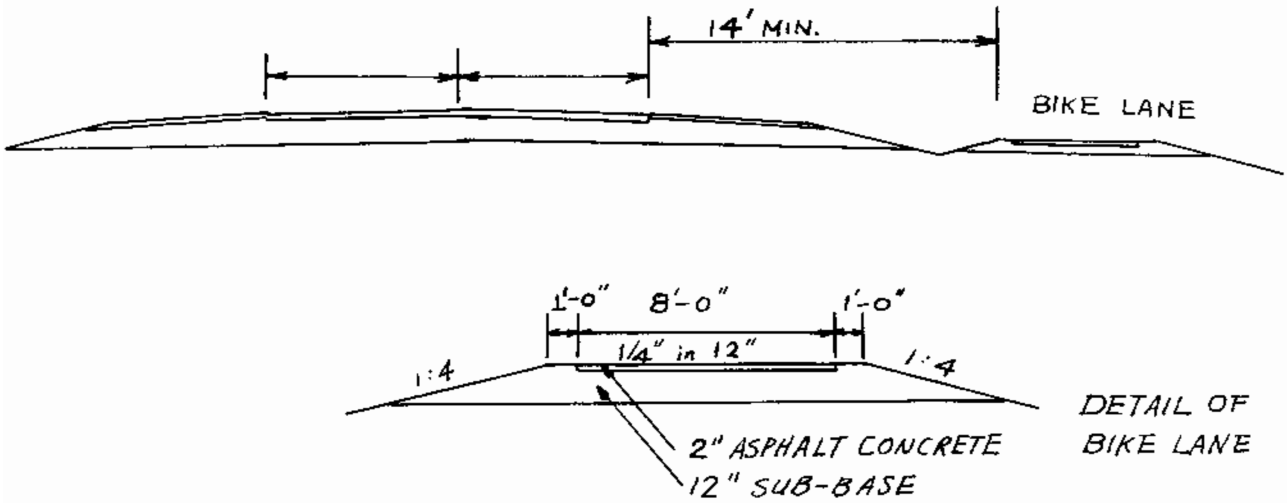
In order to protect the surface material from damage by vegetation, it is necessary to apply a long-lasting pre-emergence herbicide. This sterilization of the soil is necessary when a bike trail or path is constructed on bare soils. If trees are removed, it is important to remove all surface roots.

Source: Sacramento City-County Bikeway Task Force, Sacramento Bikeways, Master Plan

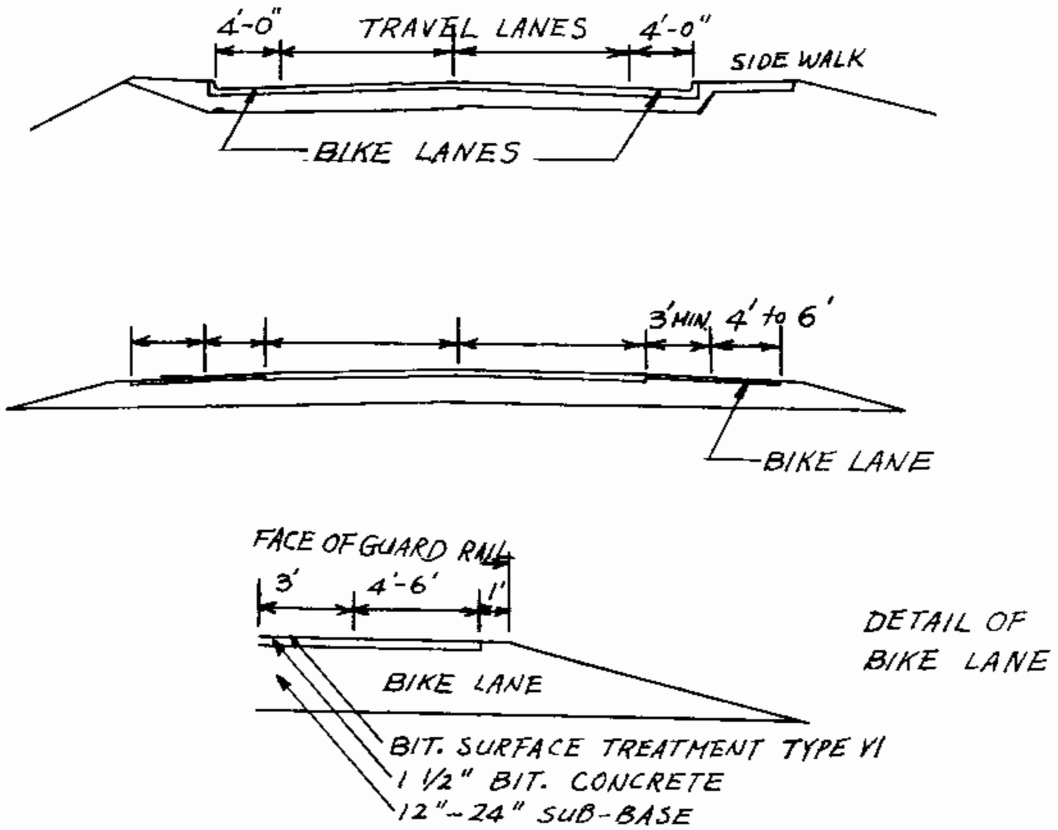


TYPICAL PAVEMENT CROSS SECTIONS

Source: Tennessee Department of Transportation



TYPICAL SECTION — RURAL "C"



TYPICAL SECTION — RURAL "B"

Source: Vermont Department of Highway: Standard A-77.

REQUIRED SPECIFICATIONS FOR BICYCLE TRAIL DESIGN, CONSTRUCTION AND MAINTENANCE

1.) DESIGN: Off-Road Path

a. Surface width minimum of 8-feet for two-way traffic.
b. Shoulder width minimum of 2-feet on each side.
c. Surface depth minimum of 2" bituminous or limestone or soil cement or any combination.
d. Base minimum of 3", class 2 material.
e. Signs and symbols approved or supplied by the Department of Natural Resources.
f. Bike racks, locks and parking areas located at a point on the trail.

2.) DESIGN: On-Road Lane

a. Surface minimum width 6-feet for one-way traffic. Auto traffic and parking prohibited within the lane.
b. Striping minimum width 6" of white or yellow paint.
c. Signs and symbols approved or supplied by the Department of Natural Resources.
d. Bike racks and parking areas located at a point on the trail.

3.) USES

a. Bicycle only for summer use.
b. Snowmobiles may be permitted during the winter.

Source: Wisconsin Department of Transportation, Guidelines for Developing Rural Bike Routes

APPENDIX B

COST INFORMATION

Listing of selected cost information received through Bikeway Survey [2]. Information appears alphabetically by agency.

The information from the following agencies is included:

Arlington County Department of Environmental Affairs
Connecticut Department of Transportation
Honolulu Department of Public Works
City of Las Cruces, New Mexico
North Carolina Department of Transportation
Ohio Department of Transportation
City of Mesa, Arizona
Minnesota Department of Natural Resources
Professional Engineering Consultants
Sacramento City County Bikeway Task Force
Virginia Department of Highways and Transportation
Wisconsin Department of Natural Resources

COST BREAKDOWN ESTIMATES

Construction of Total Project		$200,000
Cost per lineal foot	$8.2338	
Estimated Length	24,290 feet	

Construction of trail surface, including tree removal, grading, drainage, base and surface material	$150,740
Construction of six (6) fords	12,500
Construction of three (3) rain shelters, one (1) rain-control station-shelter	14,500
Landscaping, sod, tree and shrub replacement	5,000
Trash receptacles (50 estimated)	1,500
Control gates (33 estimated)	6,600
Signs (62 estimated)	1,860
Drinking Fountains (10 estimated)	3,000
Safety Fence (3,000' estimated)	4,300
	$200,000

No contingency provided. Ancillary facilities are estimated and shall be revised if funding adjustments are needed for basic trail construction.

Source: Arlington County Department of Environmental Affairs

CURRENT BIKEWAY CONSTRUCTION COSTS— AVERAGE VALUES

As with other transportation facilities, bikeway construction costs vary over a considerable range. The price of an individual facility is determined by the bikeway type, extent and type of construction required, availability and suitability of construction materials, and numerous other factors. This chapter's purpose is to give a general indication of the cost of bicycle facilities. Presented below are approximate costs for typical construction items involved in bikeway development. These estimates were obtained from appropriate units within the Department of Transportation.

1. Two lane bicycle trail (8′ wide–2″–3″ bituminous concrete surface. 4″–6″ aggregate base) exclusive of utility relocation or right-of-way acquisition. $65,000-75,000/mile
2. One lane bicycle trail (4′ wide–2″–3″ bituminous concrete surface, 4″–6″ aggregate base) exclusive of utility relocation or right-of-way acquisition. $25,000-30,000/mile
3. Roadway shoulder widening (4′ addition to both sides) exclusive of right-of-way acquisiton. $80,000-100,000/mile
4. Pavement Stripes (6″ wide–white) $100–mile
5. Signs (installed) $ 25 each
6. Structures (short span or outrigger on existing structure) $25-30/square foot
7. Temporary, half-face New Jersey barrier $264,000/mile
8. Chain link fencing $ 32,000/mile

These figures show that bicycle facilities can be more expensive than many people realize. Basic bicycle trails serving two directional traffic may cost between $51,000 and $76,000 per mile to construct. with appropriate signs and pavement markings. Any additional construction work, such as protective barriers, structures, or utility relocation, or right-of-way acquisition will raise the cost.

Source: Connecticut Department of Transportation, Connecticut Bikeways

Item No.	Estimated Quan.	UNIT DESCRIPTION	Unit Price
1.	L.S.	Clearing and grubbing for necessary site clearance, sight distance including all labor, material and equipment	4,000.00
2.	3,050	Cu. Yds., Unclassified roadway excavation	9.50
3.	2,478	Tons, asphaltic concrete pavement, 2" finished thickness, including prime coat of liquid asphalt	21.00
4.	15,414	Sq. Yds., 4" thick base course	1.50
5.	L.S.	Scarify and reshape exist base between Sta. 0+00 to 6+00 including additional base material	1,000.00
6.	L.S.	Repair chuck holes between Sta. 6+00 to 24+00	800.00
7.	300	Gallons of Quick Setting Emulsified Asphalt Tack Coat, including cleaning of surface	0.40
8.	110	Tons, asphaltic concrete overlay 1" thick	21.00
9.	1	Ea., Drainage structure at Sta. 71+90+	1,500.00
10.	300	Lin. Ft. chain link fence, 6' high along HECO easement	11.25
11.	L.S.	Bridge railing and fence at Sta. 28+80+ including incidentals and all appurtenances, in place complete	2,500.00

Source: Honolulu Department of Public Works

Item No.	Estimated Quan.	UNIT	DESCRIPTION	Unit Price
12.	L.S.		Bridge railing and fence at Sta. 32+20+ including incidentals and all appurtenances, in place complete	2,000.00
13.	L.S.		Bridge railing and fence at Sta. 93+45± including incidentals and all appurtenances, in place complete	1,900.00
14.	L.S.		Bridge railing and fence at Sta. 101+00± including wood curb, incidentals and all appurtenances, in place complete	3,100.00
15.	L.S.		Bridge railing and fence at Sta. 103+20± including wood curb, incidentals and all appurtenances, in place complete	7,000.00
16.	10		Ea., chain gates, including reflectors, chains, posts, and incidentals, in place complete	175.00
17.	1		Ea., adjust guy line	1,500.00
18.	Allowance Contingency			
			Allowance	15,000.00
			TOTAL SUM BID (Items 1 through 18, inclusive)	

Source: Honolulu Department of Public Works

CONSTRUCTION COSTS

For Class I & II Bike Paths and Bike Lanes

	Cost per mile
Asphalt concrete surface 1 1/2"	$ 4,000
4" untreated base	4,000
8' wide	
Asphalt - 8' wide, 4" depth	10,600
with subgrade blading, soil) treatment and compaction)	2,000
ADD:	
Signing, striping and stencilling	1,500
Curbing barrier	xxx
Total	---

For Class III Bike Routes

Basically the cost would be the difference between the proposed roadway section and the modified roadway section including the Bikeway	$ 1,200
Plus	
Signing, stencilling and striping	1,500
Total	$ 2,700

MAINTENANCE

Types I & II per year per mile	$ 325

Type III - Since Type III Bikeways share the paved surface of roadways and streets with motor vehicles, it is assumed that the surface maintenance would be part and parcel of the roadway maintenance costs.

BARRIER

		Cost per mile
Single metal beam	$ 6.50 Lin. Ft.	$ 34,320
Asphalt dike 0.5'h	0.70 Lin. Ft.	3,700
Curbing barrier	1.25 Lin. Ft. (to be designed)	6,600
Concrete median barrier	12.00 Lin. Ft. (N.J.)	63,360
72" Chain link fence	6.50 Lin. Ft.	34,320
48" Chain link fence	4.50 Lin. Ft.	23,760

CONCRETE BIKEWAY RAMP

4' wide	4' long	4" depth	$25.00 each
8' wide	4' long	4" depth	$50.00 each

Source: City of Las Cruces, New Mexico

Class	Length (Miles)	Construction Cost	Signing Cost	Striping Cost	Total Cost
I	9.8	$ 138,180.00	$ 1,662.00	$ ---	$ 149,842.00
II	23.1	$ ---	$ 27,489.00	$ 9,702.00	$ 37,191.00
III	10.7	$ ---	$ 12,733.00	$ ---	$ 12,733.00
				Grand Total	$ 199,766.00

Annual Maintenance Cost $21,000 ($480.00/mile)

As will be noted, the largest portion of the costs are within Class I, which will be financed in the large majority by the State Highway Commission during construction of their upcoming projects on State Road 292, Amador Avenue, and University Avenue. We expect to receive funding from the Bureau of Outdoor Recreation on the bicycle lanes adjacent to the outflow channel from the Government Dam and along the Las Cruces Arroyo. Most costs for Class II and Class III as shown above would be borne by the City. Yearly priorities on these projects have not been established due to funding requirements. It is felt by the departments concerned that it is possible to complete the network within a five year time span.

Source: City of Las Cruces, New Mexico

Table 6.13
PAVEMENT SURFACE COSTS (per 100 linear feet)

	Structural Cross Section			
Bikeway Surface Widths (feet)	Full Depth Asphaltic Concrete	Asphaltic Concrete Surface with Stabilized Base	Cement Surface with Stabilized Base	Stabilized Aggregate
3.5	$200 - 290	$175 - 200	$470 - 500	$140 - 180
4.0	$230 - 320	$200 - 240	$540 - 580	$170 - 220
7.0	$390 - 570	$350 - 400	$950 - 1,010	$290 - 370
8.0	$410 - 590	$355 - 455	$1,070 - 1,150	$330 - 430
10.5	$520 - 730	$450 - 540	$1,300 - 1,390	$430 - 550
12.5	$620 - 870	$560 - 690	$1,540 - 1,670	$510 - 650
14.0	$700 - 990	$610 - 760	$1,730 - 1,860	$570 - 740
17.0	$840 - 1,180	$740 - 950	$2,120 - 2,260	$690 - 880

NOTE: Costs reflect: average 2 feet excavation throughout; incidental clearing and grubbing; reduced material cost allowances for increased quantities

Source: North Carolina Department of Transportation and Highway Safety "The North Carolina Bicycle Facility and Program".

ESTIMATED COSTS PER MILE

Bike Facility	Degree Safety	Signing	Striping	Barrier	Pavement and Base	R-O-W	Total
Bike Route	Low	$120.00	N/A	N/A	N/A	N/A	
Unprotected Bike Lane	Medium	$120.00	N/A $2,957.00	N/A	N/A $42,240	N/A	
Protected Bike Lane	High except Xing	$120.00	N/A	N/A	N/A $42,240 Complete	N/A	
Bike Track	High except Xing	$120.00	N/A	N/A	$42,240 Complete	*	
Bike Path	High	$100.00	N/A	N/A	$42,240 Complete	*	

* R-O-W cost for a 10 ft. wide strip of land valued at $10,000/acre would be $12,100/mile.

Source: <u>Winston-Salem, North Carolina Bikeways</u>

GENERAL COST, PER MILE, OF CLASS I BIKEPATH*	
2" Asphalt Concrete Surface	$ 5,700
4" Aggregate Base and Excavation	2,500
Drainage Ditch Regrading and Finishing	500
Striping and Pavement Marking at Intersections	150
Curb Ramps	75
6" Underdrain	500
Signs, 5 per mile	200
Pole Bridge, 20'x 8' (one per 7 miles)	100
	$ 9,725

GENERAL COST, PER MILE, OF CLASS II BIKELANE*	
Lane and Intersection Marking and Striping	$ 1,000
Signs, 15 per mile	600
Curb Ramps, 20 per mile	1,500
	$ 3,100

GENERAL COST, PER MILE, OF CLASS III BIKEROUTE*	
Signs, 10 per mile	$ 400
	$ 400

*Means Building Construction Data, 1973

Source: Ohio Department of Transportation

ARIZONA BIKEWAY CONSTRUCTION COSTS

Bikepaths	Cost/Mile (one side)	(both sides)
1. Enzymatic treated 5½" base (peneprime & chips) rolled and compacted.	$4,000.00	$ 8,000
2. Full-depth asphaltic concrete, 8 feet wide, 4" deep with sub-grade blading, soil treatment and compaction.	9,700.00	19,400
3. Enzymatic treated 5½" base and 2" A.C. surface (8' wide).	11,000.00	22,000
4. Portland cement concrete, 8' wide, 3" deep, strip paving	12,000.00	24,000
5. Asphalt concrete surface, 8' wide, 4" A.B., 2" A.C.	15,400.00	30,800
6. Portland cement concrete, 8' wide, 4" deep, 4" A.B., formed.	$27,500.00	*55,000

*Computed @ $.65/S.F.

Bikeroutes		
1. Striping (4" white) and signing ("Bikeroute" and "No Parking").	675.00	1,350
2. Extruded 6" concrete curb	5,300.00	10,600

Bikelanes		
1. Signing only ("Bikeroute")	175.00	350
2. Grate modification	150.00	300

Note: Costs used for Bikeroutes and Bikelanes are based on current estimates by the City of Mesa.

Source: City of Mesa, Arizona

Department of Natural Resources
Division of Parks and Recreation

MINNESOTA BICYCLE TRAIL ASSISTANCE PROGRAM

Summary of 1975 Grants-in-Aid
Bicycle Trail Applications

LOCAL UNIT OF GOVERNMENT	MILES	TOTAL COST	STATE COST
1. Blue Earth County	5.20	97,520.00	63,388.00
2. Roseville	5.00	62,000.00	40,300.00
3. St. Paul	5.00	118,800.00	77,220.00
4. Becker County	1.50	13,433.00	8,731.45
5. Fairmont	0.75	14,000.00	9,100.00
6. Marshall	0.57	12,620.00	8,203.00
7. Washington Co.	7.50	123,610.00	80,346.50
8. Owatonna	0.65	13,500.00	8,775.00
9. Rochester	7.40	25,805.00	16,773.25
10. Eagan	4.00	47,000.00	30,550.00
11. Golden Valley	4.86	36,323.69	23,610.40
12. Benson	2.25	4,877.00	3,170.05
13. Apple Valley	1.00	10,500.00	6,825.00
14. St. Cloud	1.00	151,000.00	98,150.00
15. Woodbury	1.30	63,826.00	41,486.90
16. Red Wing	1.00	17,511.00	11,382.15
17. Bloomington	3.00	30,000.00	19,500.00
18. St. Croix	3.50	118,000.00	76,700.00
19. Edina	0.75	11,125.00	7,231.25
20. Edina	4.50	111,000.00	72,150.00
21. White Bear Lake	1.40	10,000.00	6,500.00
22. Islands of Peace	0.80	24,425.00	15,876.25
23. Minnetonka	2.00	43,000.00	27,950.00
24. Marine	14.00	77,730.00	50,524.50
25. Minneapolis	1.00	22,765.00	14,797.25
26. St. Louis Park	4.01	34,518.00	22,436.70
27. Koochichiching Co.	3.00	28,965.00	18,827.25
Total	86.94 miles	1,323,853.60	860,504.90

*Not entirely funded.

Source: Minnesota Department of Natural Resources

Department of Natural Resources
Division of Parks and Recreation

MINNESOTA BICYCLE TRAIL ASSISTANCE PROGRAM

Summary of 1974 Grants-in-Aid Bicycle Trail Applications

LOCAL UNIT OF GOVERNMENT	MILES	TOTAL COST	STATE COST
1. Minneapolis - C/R	1.0	$ 51,500.00	$ 33,475.00
2. Hopkins	1.5	22,336.80	14,518.92
3. Golden Valley	8.25	75,020.86	48,763.56
4. Edina	1.0	39,800.00	25,870.00
5. Bloomington	5.2	128,547.00	83,555.55
6. Minnetonka	2.0	59,680.00	39,792.00
7. Woodbury	2.5	20,000.00	13,000.00
8. Red Wing	7.0	26,469.45	17,205.14
9. Crystal	7.0	7,175.25	4,663.91
10. Islands of Peace	0.8	27,500.00	17,875.00
11. Blue Earth County	5.2	97,520.00	63,388.00
TOTALS	41.45	555,549.36	361,107.08*

* Not entirely funded.

Source: Minnesota Department of Natural Resources

PRELIMINARY
CONSTRUCTION COST ESTIMATE SUMMARY

Item	Segment A.1	Segment A.2	Segment A.3	Segment B.1	Segment B.2	Area C	Sub-Total	Contingency (67%)	Total
Plant Material	$ 79,161	$ 39,570	$ 44,334	$ 199,174	$ 367,751	$ 220,891	$ 950,881	$ 637,090	$1,587,971
Earth Mounding	1,256	6,211	12,485	1,754	17,298	964	39,968	26,779	66,747
Paths	22,295	58,075	45,734	36,692	57,722	71,653	292,171	195,755	487,926
Bridges	182,050	–	–	21,840	21,840	194,510	420,240	281,561	701,801
Underpasses	–	–	–	127,200	127,200	55,320	309,720	207,512	517,232
Lighting	72,180	162,394	99,014	91,933	193,099	125,696	744,316	498,692	1,243,008
Irrigation	108,839	34,916	32,305	179,652	301,881	267,397	924,990	619.743	1,544,733
Fencing	41,681	12,150	12,900	63,375	103,350	59,250	292,706	196,113	488,819
Chain Barrier	–	–	1,950	38,250	46,050	–	86,250	57,788	144,038
Signing	1,650	4,700	3,450	7,150	5,150	3,900	26,000	17,420	43,420
Recreation & Rest Areas	17,925	12,300	15,410	55,314	16,950	15,110	133,009	89,116	222,125
Sub-Total	$527,037	$330,316	$267,582	$ 822,334	$1,258,291	$1,014,691	$4,220,251		
Contingency (67%)	353,115	221,312	179,280	550,964	843,055	679,843		$2,827,569	
Total	$880,152	$551,628	$446,862	$1,373,298	$2,101,346	$1,694,534			$7,047,820

Source: Professional Engineering Consultants, P.A., A Preliminary Plan Report on Improvements to the I-35 Canal Route Corridor Through the City of Wichita, Sedgwick County, Kansas

Surface Construction Types

1) Asphalt-Concrete Bike Path

Costs for construction of an eight feet wide asphalt-concrete bike path were obtained for two different types of base and surface. These costs currently run approximately $20,000 per mile for 4" asphalt concrete and $15,000 per mile for a four inch aggregate base with a two inch asphalt concrete surfacing. The four inch full-depth asphaltic concrete pavement structure is recommended since it is easy to construct and durable, requiring minimum maintenance.

2) Concrete

Costs for construction of concrete pavement bike paths, eight feet wide, were obtained from the city on a recent contract at approximately $40,000 per mile for 3½ inch thick strip paving. The 3½ inch thick concrete paving is considered desirable from a maintenance and durability standpoint.

Table 3

It should be noted from Table 3 that a wide range of bike path costs exists. The cost of a specific bike path will depend, to a great extent, upon the selection of the type of surface desired.

Class I Bike Paths	Cost Per Mile
Portland cement concrete surface 8 feet wide, 3½ inch deep strip paving, including grading	$40,000
Full-depth asphaltic concrete 8 feet wide, 4 inch depth with subgrade blading, soil treatment and compaction	20,000
Asphalt concrete surface, 8 feet wide, 4 inch aggregated base with 2 inch surface	15,000
Signing, striping, legends	2,000
Landscape barriers (irrigated hedge)	24,000
(not irrigated)	8,000
Barrier (chain link or rail fencing one side only)	27,000

Source: Sacramento City County Bikeway Task Force, Sacramento Bikeways, Master Plan

VIRGINIA DEPARTMENT OF HIGHWAYS AND TRANSPORTATION
UNIT COST ESTIMATES FOR
TYPICAL BICYCLE TRAILS, LANES AND SHARED ROADWAYS

Description	Cost Per Mile
Bicycle Trail Two-Way (Separate from Roadway)	$38,250
Bicycle Trail Two-Way (Adjacent to Roadway)	$38,250
Bicycle Lanes (Between Parking Lane & Travel Lane)	$ 2,280
Bicycle Lanes (Between Travel Lane & Edge of Road)	$ 1,420
Bicycle Lanes (Elevated Above Roadway with Curb & Gutter & Drainage Structures)	$72,350
Bicycle Lanes (Overlayed on Roadway Shoulder)	$12,180
Shared Roadway	$ 950

COMMONWEALTH OF VIRGINIA
TOTAL BIKEWAY MILES AND CONSTRUCTION COSTS

Type Bikeway	Cost Per Mile	1972 Miles - Cost	1980 Miles - Cost
Trail	$38,250	1,250 mi. $47,812,500	1,596 mi. $61,047,000
Lanes	$10,000	1,250 mi. $12,500,000	1,596 mi. $15,960,000
Shared Roadway	$ 950	1,070 mi. $ 1,016,500	1,368 mi. $ 1,300,000
TOTALS:		3,570 mi. $61,329,000	4,560 mi. $78,307,000
WEIGHTED COST:	$17,200		

Source: Virginia Department of Highways and Transportation, Bikeway Development

State Park Trail	Year Established	Acquired From	Length (Miles)	Location	Acquisition Costs**	Development Costs**	Recreational Activities Provided	Open For Public Use in 1974
Elroy-Sparta*	1965	Chicago Northwestern	32	West Central Wis. Monroe & Juneau Counties	Original Cost = $ 12,000 Total Cost = $ 37,800	$317,181	Hiking Bicycling Snowmobiling	Entire 32 Miles
Tuscobia-Park Falls	1966	Chicago Northwestern	72	Northwestern Wis. Price, Sawyer, Washburn & Barron Counties	Original Cost = $ 20,000 Total Cost = $ 52,000	$152,482	Hiking Snowmobiling	The West 30 Miles Tuscobia-Couderay River
Ahnapee	1970	Ahnapee & Western	15	East Central Wis. Door & Kewaunee Counties	Original Cost = $ 20,000 Total Cost = $ 25,000	$ 57,753	Hiking Snowmobiling	Entire 15 Miles
Sugar River*	1972	Milwaukee Rd.	23	Southern Wis. Green County	Original Cost = $ 74,000 Total Cost = $ 83,000	$ 80,226	Hiking Snowmobiling	Entire 23 Miles
Hafford Junction - Minocqua	1973	Milwaukee Rd.	25	North Central Wis. Oneida County	Original Cost = $150,000 Total Cost = $150,000	$ 16,860	½ of trail open for snowmobiling. Purchase approved - August, 1973	
Menomonie - Red Cedar Junction	1973	Milwaukee Rd.	13	West Central Wis. Dunn County	Original Cost = $ 60,000 Total Cost = $ 60,000	$ 2,100	Not open for public use. Purchase approved - Sept., 1973	
TOTALS			180 Miles		Original Cost = $336,000 Total Cost = $407,800	$626,602		

* Designated by the Federal Government as a national recreation trail under 1968 National Trails Act.
** Acquisition and development costs from the establishment of project up through June 30, 1974.

12-12-74
djl

Source: Wisconsin Department of Natural Resources

DEVELOPMENT COSTS OF MULTI-USE RECREATIONAL TRAILS (FORMERLY ABANDONED RAILROAD GRADES)

DEVELOPMENT TYPICAL OF ALL MULTI-USE TRAILS	ELROY-SPARTA	SUGAR RIVER	AHNAPEE	TUSCOBIA-PARK FALLS	TOTALS
ACQUISITION	37,824.00	74,000.00	25,350.00	53,900.00	191,074.00
LENGTH OF TRAIL (in miles)	32	23	15	74	144
SURFACING (grading, tie removal, landscaping)	20,020.66	56,827.90*	41,040.25	57,191.71*	175,080.52
PLANKING & RAILING, TRAIL STREAM CROSSINGS, BRIDGES, CULVERTS	28,471.29	21,801.00*		94,694.50*	144,966.79
SIGNING	1,743.14	400.00*	228.50	11,971.69	14,343.33
TOTALS	88,059.09	153,028.90	66,618.75	217,757.90	525,464.64
COST PER MILE	2,751.85	6,653.43	4,441.25	2,942.67	3,649.06

MISCELLANEOUS DEVELOPMENT (not required, but contributory to overall cost of development	ELROY-SPARTA	SUGAR RIVER	AHNAPEE	TUSCOBIA-PARK FALLS	TOTALS
FENCING	40,168.19*	5,490.18*	*	16,663.34	62,321.71
REST STOP DEVELOPMENT (depots, toilets, parking, tunnel work, campgrounds)	198,071.07*	11,514.71*	1,282.78*	*	210,868.56
OTHER (specialized signing, monumentation, etc.)	4,370.63	3,716.96	5,561.73	347.19	13,996.51
TOTALS	242,609.89	20,721.85	6,844.51	17,010.53	287,186.78
GRAND TOTALS	330,668.98	173,750.75	73,463.26	234,768.43	812,651.42
GRAND TOTAL COST PER MILE	10,333.40	7,554.38	4,897.55	3,172.54	5,643.41

* Incomplete as of this date

Source: Wisconsin Department of Natural Resources

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