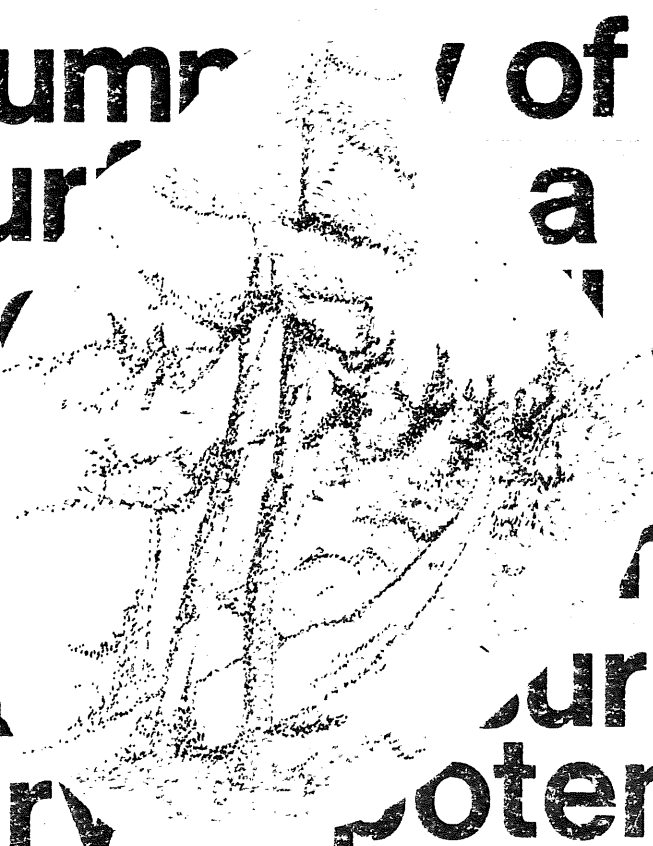


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SURFACE	COSTS ¹	AVAILABILITY	MAINTENANCE REQUIREMENTS		
			TYPE	FREQUENCY	COSTS
LIMESTONE	5,500.00 ²	SOUTH PART OF STATE	HERBICIDE	YEARLY	-----
ASPHALT (HOTMIX)	8,525.00	THROUGHOUT STATE	ASPHALT SEAL COAT	3-5 YEARS	2,464.00
CLAY-CALCIUM CHLORIDE BINDER	1,860.00	TWIN CITIES METRO AREA	CALCIUM CHLORIDE APPLICATION	YEARLY	660.00
SOIL CEMENT WITH ASPHALT SEAL COAT	7,744.00	THROUGHOUT STATE	ASPHALT SEAL COAT	3-5 YEARS	2,464.00
SOIL ASPHALT WITH ASPHALT SEAL COAT	4,752.00	THROUGHOUT STATE	ASPHALT SEAL COAT	3-5 YEARS	2,464.00
GRASS	96.00 ³	TWIN CITIES METRO AREA ⁴	NO INFORMATION		
LIGNUM	3,958.00	WISCONSIN PAPER MILLS	ASPHALT SEAL COAT	3-5 YEARS	2,464.00
CONCRETE	47,520.00	THROUGHOUT STATE	NO INFORMATION		
TACONITE TAILINGS/LEAN ORE ⁵	-----	-----	-----	-----	-----
BRICK PAVERS	29,253.00 ⁶	TWIN CITIES METRO AREA	NO INFORMATION		
3M ROCK BINDER	25,759.00 ⁷	TWIN CITIES METRO AREA	REAPPLICATION OF BINDER	3-7 YEARS	4,519.00

1. Approximate cost per mile for 6' wide trail
2. Cost for 8' wide trail
3. Cost of seed only
4. Information was not obtained for rest of state
5. Material not proven as a trail surface
6. Brick costs only
7. Does not include labor

*NOTE - Cost are just a general guideline. Individual jobs may be bid higher or lower depending on a number of factors.

INTRODUCTION

The following is a compilation of information on potential trail surfacing materials. This information is intended as a general guide to help the planner in choosing a material which best meets the cost and design requirements for each trail. Various sources contributed to this information with the intent being to gather only the basics: the most typical methods of using the materials, the general costs of using the materials, the availability of the materials, and the basic requirements for maintenance of the materials. The accuracy of this information reflects this general guideline approach, with numbers being rounded off and in one or two cases knowledgeable guesses from the sources being used. The sources of this information are listed for each material so that if a question of accuracy does arise, they may be contacted for clarification. Some of the things which can be obtained from this information are:

1. The cost relationships of the different materials.
2. Trail type recommendations.
3. Parts of state different materials can be found.
4. Maintenance considerations.
5. Possible new combinations of materials.
6. Problem associated with the materials.

LIMESTONE

Possible Trail Uses - snowmobiling, cross-country skiing, snowshoeing, walking, biking, trail bikes, four-wheeled vehicles.

Typical Process of Application

1. Shape and compact subgrade with vibratory compactors, sheep foot rollers or grid rollers.
2. Apply 3" Class 5 gravel base if unstable soils are present. Compact with steel wheeled or pneumatic tired rollers.
3. Apply lifts of crushed limestone (3-6 inches). The recommended crushed

rock mixture is:	Sieve (U.S. Standard)	Percent Passing
	3/8 inch	100%
	No. 4	70-100
	No. 40	20-50
	No. 200	10-30
	Plasticity Index	0-3
	Liquid Limit	Max. 25
	Los Angeles Rattler Loss	Max. 40

Limestone, when crushed, forms a natural blend meeting the above specifications. (Source - Mn. DNR Bicycle Trails Manual)

4. Compact to hard surface with steel-wheeled or pneumatic tired rollers.

Availability

Primarily available in Twin Cities metro area.

Costs (Source - Roger Liska - DNR Engineering)

1977 figures for a 3" compacted surface
8 feet wide \$5,500 per mile
4 feet wide \$3,600 per mile

Quotes for recent trail contracts

Moose Lake - Jay Cooke area

Gravel base (Class 5)	\$10 per cubic yard
Limestone surface	\$10 per cubic yard
Cost per trail mile (8' wide)	\$21,876.00

Bemidji-Itasca

Gravel base (Class 5)	\$10 per cubic yard
Limestone surface	\$33 per cubic yard
Cost per trail mile (8' wide)	\$14,000.00

Maintenance

Relatively maintenance free material. Problems of soft-spots and erosion damage can occur if a poor base is used and where adjacent soil is allowed to wash over surface. Yearly spraying of a herbicide may be required to prevent plant materials. Gophers may be a problem because of burrowing into the trail surface.

MINNESOTA DEPARTMENT OF NATURAL RESOURCES

Robert L. Herbst, Commissioner
Centennial Office Building
St. Paul, Minnesota 55155

SPECIFICATIONS FOR:

Douglas Trail Development
Olmsted and Goodhue Counties
Pine Island - Douglas - Rochester

OWNER:

Division of Parks and Recreation
Don D. Davison, Director

PREPARED BY:

Bureau of Engineering
Wayland K. Porter, Acting Administrator

DATE April 19, 1974
REVISED _____
FILE R.012.00.00.09
REQN 74-126
DEPT. CODE 327643

4/10/74

4-15 COMPACTING AND ROLLING SUBGRADE: The shaped subgrade shall be compacted with vibratory compactors, sheep foot rollers and/or grid rollers as required to thoroughly compact the subgrade to 90% of standard proctor density (ASTM 698 Testing Standard). Moisture shall be controlled to within 5% (on the dry side) of the standard proctor optimum moisture content. For example, if the test laboratory reports an optimum moisture content of 15%, the moisture shall be controlled within the range of 10% to 15%.

During the course of the work, the Engineer will perform such tests as are required to identify materials, to determine compaction characteristics, to determine moisture content, and to determine density of fill in place. These tests performed by the Engineer will be used to verify that the fills conform to the requirements of the specifications. Such tests are not intended to provide the Contractor with the information required by him for the proper execution of the work and their performance shall not relieve the Contractor of the necessity to perform tests for that purpose.

Under the direction of the Engineer, the Contractor shall prepare twenty (20) fifty (50) pound representative samples for testing at a qualified soil testing laboratory to determine the optimum density and optimum moisture content by the standard proctor test procedure in conformance with ASTM Designation D698-64T. The testing laboratory shall submit at least two copies of each test to the Engineer. All costs for testing shall be borne by the Contractor.

In the event compaction cannot be accomplished due to unsuitable subgrade material or weather conditions, the Contractor shall cease operations until the engineer allows progress to continue.

4-16 FINISH GRADING: Shall include work necessary to provide a smooth uniform surface after crushed limestone surfacing for the bicycle treadway and the Class 5 gravel for the Douglas parking area and entrance road has been placed.

4-17 GRAVEL AREAS: The bicycle treadway (Plan A) shall be surfaced with crushed limestone with a uniform gradation from 3/8 in. sieve down to the 200 sieve (U.S. Standard sieve sizes).

The Contractor shall submit a 20 lb. minimum weight sample from each source 10 days prior to placing for testing purposes. The surfacing shall be placed 8 ft. wide and 3 in. thick at the rate of 7.5 cu. yd. per 100 lin. ft. of trail.

The Douglas parking area and entrance shall be surfaced with Class 5 gravel 6 in. thick which shall meet the requirements for Class 5 material Sec. 3138 AGGREGATES for surface and base course of the Minnesota Highway Department Standard Specifications for Highway Construction, latest edition.

Volumes shall be measured by the basis of vehicular measure as specified by the Minnesota Highway Department Standard Specifications for Highway Construction, latest edition.

4/10/74

4-18 FINAL COMPACTION AND ROLLING OF CRUSHED LIMESTONE SURFACING
AND CLASS 5 SURFACING:

The lift of crushed limestone and class 5 shall be thoroughly compacted with steel wheeled rollers and/or pneumatic tired rollers. All rolling equipment shall be capable of delivering at least 200 pounds per lineal inch of rolling width. Rolling equipment shall make a minimum of 6 passes to accomplish compaction.

4-19 BITUMINOUS SURFACING: The bicycle treadway (Plan B) shall be surfaced with a 1 1/4 in. thick bituminous mat 8 ft. wide.

Following preparation of the subgrade, a prime coat shall be applied prior to the bituminous mat.

The prime coat materials and application shall conform to the requirements of Sec. 2358 bituminous prime coat of the above described specifications.

The mat consists of a plant mixed bituminous surface wearing course that shall conform to the requirements of Sec 2331 plant mixed bituminous surface of the above described specifications.

4-20 FINISHED SURFACE: The finished surface (Plan A or Plan B) shall be cross-sloped as necessary to ensure drainage. The cross-slope shall not exceed 1/4" per foot. Depressions capable of collecting water will not be permitted. The finished surface shall present a smooth continuous line to the eye. Humps and bumps shall be shaved off in a manner acceptable to the Engineer.

4-21 RANDOM RIPRAP: Shall be placed as noted on plans. The riprap shall consist of durable field or quarry stone, free from seams, cracks, or other structural defects and shall range in size from 6 inch diameter to 24 inch diameter. Approximately 40% of riprap shall be 6" to 12" and approximately 60% shall be 12" to 24". Stones shall be blended to yield a uniform mixture of sizes.

The riprap in the vicinity of bridge 127.12 shall be placed on a 1 ft. thick well graded coarse gravel bedding consisting of type 2 filter blanket material as outlined in Sec. 3601 riprap materials of the Minnesota Highway Department Standard Specifications for Highway Construction, latest edition.

The riprap for the south abutment of bridge 132.11 shall be placed along the upstream wingwall for a distance of 18 ft. and having a triangular shaped area 18 ft. wide at the bottom and 9 ft. high.

All riprap shall be dumped into position and spread evenly in such a manner so that the smaller stones will be uniformly distributed throughout. Sufficient handwork shall be done to produce a neat uniform surface.

ASPHALT (HOT MIX)

Possible Trail Uses - snowmobiling, cross-country skiing, snowshoeing, walking, biking, trail bikes, four-wheeled vehicles.

Typical Process of Application

1. Remove all trees, bursh, stumps (to at least 2' below surface) and debris from area to be paved.
2. Grade to desired surface.
3. Compact subbase with a sheep foot or pad-type roller (clay soils), pneumatic-tired or vibrating roller (granular soils), or pneumatic-tired or smooth-wheeled roller (silty soils). (Source Construction Leaflet No. 1, The Asphalt Institute)
4. Apply asphalt. Note - there are various methods of application. (Source - Bike Trails And Facilities, A Guide To Their Design, Construction, And Operation, Am. Institute of Park Executives)

$1\frac{1}{2}$ inches placed in one lift on a 4 inch base
of Class 5 aggregate.

OR A total of $3\frac{1}{2}$ inches placed in two lifts, the
first of 2 inches placed on the compacted
subbase then another lift of $1\frac{1}{2}$ inches added
on top of this.

(Source - Construction Leaflet No. 3, The Asphalt Institute)

A single lift of 4 inches thick placed directly
on compacted subbase.

5. Compact asphalt with a steel-wheeled or pneumatic-tired roller.

Availability

Permanent asphalt batch plants are set up in the Twin Cities, Rochester, St. Cloud and Duluth so availability in these areas is good. If jobs are large enough, a company may set up a plant as near to the site as possible.

Costs (Source - Bituminous Roadways)

Approximately \$9-10. per ton with one ton covering $4\frac{1}{2}$ square yards at 4 inches thick.

Installed the cost is approximately \$4.50-4.75 per yard at 4 inches thick.

Cost per trail mile is approximately \$23,760 for a 6 foot wide trail depending on transportation costs.

A very rough estimate of transportation costs was given at 15¢ per ton per mile.

(Source - Roger Liska, DNR Engineering)

3 inch base with $1\frac{1}{2}$ inch asphalt lift.

6 foot wide trail installed \$8,525 per mile

4 foot wide trail installed 3,600 per mile

Maintenance

This is a relative low maintenance material. A seal coat of liquid asphalt and aggregate is recommended at 3 - 5 year intervals. Cost of seal coat is .60 - .70 per square yard. (Source - Bituminous Roadways)

AUGUST 1973

CL-1

CONSTRUCTION LEAFLET NO. 1
THE ASPHALT INSTITUTE
ASPHALT INSTITUTE BUILDING
COLLEGE PARK, MARYLAND 20740

SUBGRADE PREPARATION FOR FULL-DEPTH ASPHALT PAVEMENT

DEFINITIONS OF TERMS USED

Subgrade: The uppermost material placed in embankments or unmoved from cuts in the normal grading of the roadbed. It is the foundation for the asphalt pavement structure.

Properly Prepared Subgrade: Subgrade prepared by whatever means necessary to enable it to act as a working platform to support construction equipment and as a foundation for a pavement structure.

Improved Subgrade: Subgrade improved to permit it to perform as a working platform by incorporation of stabilizers such as asphalt, lime or granular materials, to support a pavement structure.

PROPERLY PREPARED SUBGRADE

Effective subgrade preparation depends on careful execution of all prior operations: clearing and grubbing, grading, and construction of drainage facilities. The subgrade is considered prepared only when it has been processed and uniformly compacted to specified density and strength requirements established by appropriate laboratory tests, such as California Bearing Ratio (CBR), AASHTO T 193 (ASTM D 1883) or Resistance (R-) value, AASHTO T 190 (ASTM D 2844) methods. Therefore, proper preparation is essential to ensure that the subgrade's strength will equal or exceed the laboratory, or design, strength value.

Subgrade preparation may include the incorporation of selected materials, the blending of in-place soil materials, adjustment of moisture content for effective compaction, or the addition of stabilizers to improve strength characteristics. It is desirable to reserve the strongest and most uniform soils from the grading operation for the upper layer of the subgrade. In all cases, preparation must include sufficient compaction to ensure attainment of the design strength value.

CLEARING AND GRUBBING

Trees and shrubs within the clearing area that are to be preserved must be designated and the contractor so advised before work begins. After clearing and grubbing have been completed, the area should be inspected to make sure that sod, other vegetation, and surface debris have been removed.

In embankment areas, all stumps, whether sound, unsound or decayed, should be cleared away to a minimum depth of 2 ft. (0.6 m) below the original ground level.

*Full-Depth[®] Asphalt Pavement – The term Full-Depth (registered by The Asphalt Institute with the U.S. Patent Office) certifies that the pavement is one in which asphalt mixtures are employed for all courses above the subgrade or improved subgrade. A Full-Depth asphalt pavement is laid directly on the prepared subgrade.

GRADING

Grading should not begin until all clearing and grubbing have been completed. Because the subgrade soil actually carries the imposed loads, the better soils should be reserved, by selective grading, for the upper layers.

Excavation:

As excavation, or grading, nears the subgrade elevation the engineer should check for any unusual movement or displacement. If displacement exists and is caused by unstable material, the material should be removed. If the movement is caused by excessive moisture, and time, material type, and environment permit, the soil should be aerated and dried. Otherwise, it is advantageous to remove the unstable material and backfill with asphalt-aggregate mixture. This latter method is especially appropriate when paving must be accomplished quickly.

Embankments:

Generally, embankments can be constructed on existing foundations without problems. However, if soft or saturated soil pockets are encountered, they should be removed and replaced with the embankment material.

The areas where the subgrade changes from cut to fill frequently are points of failure. These failures can be minimized by digging shallow trenches along the lines of contact, removing loose material, and backfilling with embankment material.

When construction is on a hillside or against an existing embankment, benches should be cut into the slope to assure a firm bearing for the embankment.

DRAINAGE

It is most important to keep water away from the subgrade soil. If the soil becomes saturated it will lose strength and stability and make the overlying pavement structure susceptible to breakup under imposed loads.

Both surface and subsurface drainage must be considered. Generally, however, subsurface drainage is not needed if a Full-Depth asphalt concrete pavement structure is used. All drainage must be carefully designed and should be installed in the construction process as early as is practicable.

FORMATION AND COMPACTION

For earthwork construction, layers of uniform thickness should be used. Often, a compacted layer of 6 in. (15 cm) is used, although lifts of greater thickness can be considered if proper compaction equipment and density testing are available.

Compaction of soils consists of compressing particles into a dense mass. The type of soil to be compacted will determine the type of roller used. Clay soils require sheepsfoot or pad-type rollers. Granular materials can be compacted by pneumatic-tired or vibrating rollers, with pneumatic-tired or smooth-wheeled rollers used on silty soils. Weights of the rollers or, additionally, tire pressures on pneumatic-tired rollers, can be varied to change the compactive effort required.

Care should be taken that the materials are compacted at or near the optimum moisture content. The correct moisture for compaction of some soils can be estimated by molding the soil in the hand. Extreme dryness or wetness will be readily apparent. The subgrade should be compacted at the lowest moisture content at which the soil can be molded by a firm closing of the hand.

During compaction, required surface grade should be maintained so that a smooth surface of uniform density will result. Density tests of the in-place subgrade soil should be made using the sandcone method AASHTO T 191 (ASTM D 1556) or the rubber balloon method AASHTO T 205 (ASTM D 2167) to ensure attainment of specified density. If available, a nuclear method such as ASTM D 2922 may be used.

If density tests cannot be made, a heavily loaded truck (a 10-wheeled tandem axle truck loaded to at least 30,000 lb (13,000 kg) is recommended) can be used as a field expedient test by driving over the subgrade and noting any rutting or deflections. If any movement is readily discernible to the eye it means that either the subgrade has not been rolled sufficiently or an unstable condition exists because of high soil-moisture content. If additional rolling does not correct an unstable condition, the subgrade should be scarified to a depth of at least 6 in. (15 cm), aerated, recompact, and retested. If instability persists, it may be necessary to remove the upper portion of the subgrade and replace it with imported select material.

SURFACE TOLERANCES

The subgrade should be constructed to required grade and cross section and should not deviate more than 0.05 ft. (1.5 cm) from the plan elevation. Any depression that could collect water should be corrected by leveling.

SOIL STERILANT

For all off-street paving, to prevent the growth of weeds, it is good practice to sterilize the subgrade soil before placement of the layers of asphalt pavement. Available are commercial sterilants that will prevent the germination of weed seeds in the subgrade. Care should be taken to follow the manufacturer's recommendations for handling and application, and to comply with any laws, ordinances, or regulations governing the use of such chemicals.

IMPROVED SUBGRADE

When unusual conditions such as micaceous soils, heavy clays, or a very friable material are encountered, it may be worthwhile to consider stabilization.

Hydrated lime can be used to reduce the plasticity index of a clay. Coarse aggregate can be used to stabilize a micaceous material. Granular materials may be stabilized with asphalt. Friable subgrades that are subject to dislocation by traffic but are otherwise stable can be treated with repeated applications of a dilute emulsified asphalt.

AREAS SUBJECT TO FROST ACTION

Some soils, when dry, may appear to be relatively stable at the time of construction. However, if there is a suspicion that they may permit free water to enter the subgrade, making them subject to frost action, they should be removed and replaced with nonfrost-susceptible materials, or reworked to make uniform the upper portion of the subgrade.

NOTE: When unusually heavy loadings or drainage, compaction, backfill, or stabilization problems are encountered, it is advisable to consult the nearest Asphalt Institute engineer. His office address is listed below.

CL-2

CONSTRUCTION LEAFLET NO. 2
 THE ASPHALT INSTITUTE
 ASPHALT INSTITUTE BUILDING
 COLLEGE PARK, MARYLAND 20740

MINIMUM SPECIFICATIONS FOR FULL DEPTH PAVING JOBS

SPECIFICATIONS FOR PAVING

A _____ WITH FULL-DEPTH ASPHALT CONCRETE *

1. **Scope:** Furnish and construct a Full-Depth ¹ asphalt pavement structure for a _____ as specified.

A. GENERAL REQUIREMENTS

2. **Establishment of Grades:*** Grades shall be (will be) established by the contractor (owner) and the grade stakes shall be (will be) set to the desired section by the contractor (owner). In establishing the grades due allowances shall be (will be) made for existing improvements, proper drainage, adjoining property rights and good appearance.
3. **Preparation of Subgrade:*** All debris, vegetation, or other perishable materials shall be removed from the job site, except for trees or shrubs designated for preservation. The site to be paved shall be graded to the required section and all excess material removed from the location of the work. Material in soft spots shall be removed to the depth required to provide a firm foundation and shall be replaced with a material equal to, or better than, the best subgrade material on the site. The entire subgrade area shall be thoroughly compacted at the lowest moisture content at which a handful of the soil can be molded by a firm closing of the hand. The surface of the subgrade after compaction shall be hard, uniform, smooth, and true to grade and cross-section. If specified by the owner or his engineer prior to placing the base course, designated subgrade areas shall be treated with a soil sterilant at the rate specified by the manufacturer to prevent the growth of weeds. If specified, the subgrade shall be primed.
4. **Thickness of Structure:** On the prepared subgrade a plant-mixed asphalt base shall be laid in _____ course(s) to a compacted thickness of _____ inches. (_____ cm). Placing of the plant-mixed asphalt surface course shall follow and be laid in a single course to a compacted thickness of _____ inches (_____ cm).

¹ Full-Depth® Asphalt Pavement—The term Full-Depth (registered by The Asphalt Institute with the U. S. Patent Office) certifies that the pavement is one in which asphalt mixtures are employed for all courses above the subgrade or improved subgrade. A Full-Depth asphalt pavement is laid directly on the prepared subgrade.

* See Notes to the Owner (Engineer).

5. **Tack Coat:*** If specified by the owner (engineer), a tack coat shall be applied on each layer of the base course. The tack coat shall be _____ asphalt applied at the rate of _____ gallon per square yard (_____ 1/m²).
6. **Equipment, Materials and Labor:*** The contractor shall provide the necessary equipment, materials, and labor to complete the job acceptable to the owner. Variations in the size and amount of equipment will depend on the size of the area being paved.
7. **Sampling and Testing:** If specified by the owner (engineer) the contractor shall furnish for test and analysis representative samples of the materials to be used in the work. Alternatively, if specified by the owner (engineer), the contractor shall provide certification that material furnished is in accordance with the contract. Sampling and testing shall be in accordance with the latest revisions of the American Association of State Highway Officials (AASHO) or the American Society for Testing and Materials (ASTM) Standard procedures for sampling and testing the materials being used in the project.
8. **Smoothness:** The surface of the completed work, when tested with a ten- (10) foot (3m) straightedge, shall not contain irregularities in excess of ¼ inch (6mm).

B. MATERIALS

9. **Asphalt:** The asphalt for the plant mix shall be (*type and grade*) as specified by the owner (engineer) prior to the letting of the contract. The asphalt material for priming the subgrade shall be (*type and grade*) as specified prior to the letting of the contract. The asphalt material selected shall meet the requirements of the applicable table in *Specifications for Asphalt Cements and Liquid Asphalts*, Specification Series No. 2, The Asphalt Institute. A certificate of compliance with the specifications of the asphalt will be acceptable.
10. **Mineral Aggregate: Asphalt Plant Mix Base and Surface**
 - (1) The mineral aggregate for asphalt plant mix shall consist of coarse aggregate, fine aggregate, and, if needed, mineral filler. The coarse aggregate shall be sound, angular crushed stone, crushed gravel, or crushed slag. Uncrushed coarse aggregate may be used in base course mixtures if the mixture meets all design criteria. The fine aggregate shall be well graded, moderately sharp to sharp sands.
 - (2) The mineral aggregate and asphalt shall be combined in a mixing plant to meet the following gradations for asphalt concrete base and surface, as specified by the engineer prior to the letting of the contract.

* See Notes to the Owner (Engineer).

Base and Surface Sieve Size	* Percent Passing by Weight
1 in. (25.0mm)	_____
¾ in. (19.0mm)	_____
⅜ in. (9.5mm)	_____
No. 4	_____
No. 8	_____
No. 30	_____
No. 50	_____
No. 100	_____
No. 200	_____
Asphalt	_____

(Percent by weight of total mix)

* Figures to be filled in. See Item 7, Notes to the Owner (Engineer).

C. CONSTRUCTION

11. Spreading Base and Surface Courses: Asphalt Base and Surface

(1) For all areas of more than 1,000 sq. yds., (approximately 850m²) asphalt base and surface courses shall be spread and struck off with a paver. Any irregularities in the surface of the pavement course shall be corrected directly behind the paver. Excess material forming high spots shall be removed with a shovel or a lute. Indented areas shall be filled with hot mix and smoothed with a lute or the edge of a shovel being pulled over the surface. Casting of mix over such areas shall not be permitted.

(2) If it is impractical to use a paver or spread box in areas of 1,000 sq. yds. (approximately 850m²) or less, asphalt base and surface courses may be spread and finished by hand. Wood or steel forms, rigidly supported to assure correct grade and cross-section, may be used. Placing by hand shall be performed carefully to avoid segregation of the mix. Broadcasting of the material shall not be permitted. Any lumps that do not break down readily shall be removed.

12. Compaction, Asphalt Base and Surface: Rolling shall start as soon as the hot mix material can be compacted without displacement. Rolling shall continue until thoroughly compacted and all roller marks have disappeared.

In areas too small for the roller a vibrating plate compactor or hand tamper shall be used to achieve thorough compaction.

13. Method of Measurement: The quantities to be paid for will be as follows:

(1) *Preparation of Subgrade*—Total number of square yards of subgrade actually prepared for covering with base material.

(2) *Asphalt Mixture*—Total number of tons of asphalt mixture actually incorporated into the work.

14. Basis of Payment: The quantities enumerated in Section 13 will be paid for at the contract unit price bid for each item or at a lump sum price bid for the job. Payment will be in full compensation for furnishing, hauling and placing materials, for rolling, and for all labor and use of equipment, tools, and incidentals necessary to complete the work in accordance with these specifications.

15. Performance Guarantee: The contractor shall guarantee in writing the satisfactory performance of the completed pavement for a period of _____ years.

NOTES TO THE OWNER (ENGINEER):

1. This specification is applicable for such small paving jobs as
Parking Areas (5,000 sq. yds. [approximately 4200m²] or less)
Driveways
Service Stations
Bicycle Paths
Golf Cart Paths
Sidewalks
2. Full-Depth asphalt pavements are recommended for greatest strength and durability.
3. **Article 2. Establishment of Grades**—If the contractor is to establish the grades delete “will be” and “owner” wherever they appear in the first sentence. If the owner is to establish the grades delete “shall be” and “contractor.”
4. **Article 3. Preparation of Subgrade**—Commercial sterilants containing chemical compounds such as sodium chlorate, borate, or arsenate will prevent the germination of weed seeds in the subgrade.
5. **Article 5. Tack Coat**—From 0.05 to 0.15 gal/yd² (0.23 to 0.68 l/m² of diluted SS-1 or SS-1h asphalt emulsion is recommended. The asphalt emulsion should be diluted with equal parts of water.
6. **Article 6. Equipment**—If the job is under the supervision of an engineer, the engineer should approve those pieces of equipment applicable to the job to which the specification will apply.
7. **Article 10. Mineral Aggregate—Asphalt Plant-Mix Base and Surface**—Asphalt mixes meeting the requirements of ASTM Standard Specification D-1663 are recommended. Asphalt mixes specified by local public agencies may be used if they have a history of satisfactory performance. Contact an Asphalt Institute engineer for information on local mixes.

ASPHALT INSTITUTE ENGINEERING OFFICES (As of October 1, 1974)

EASTERN DIVISION

WASHINGTON, D.C. 20014—4733 Bethesda Ave., Connecticut, Delaware, District of Columbia, Kentucky, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Vermont, Virginia, West Virginia
NEW YORK, N.Y.—(Address: 20 Evergreen Place, East Orange, N.J. 07018), New York City, Westchester Co., Long Island, Delaware, New Jersey
ALBANY, N.Y. 12206—50 Colvin Ave., New York State (except New York City, Westchester Co. and Long Island)
SYRACUSE, N.Y. 13203—1054 James St., Northwestern Mutual Ins. Bldg., Western New York
BOSTON, MASS.—(Address: 599 North Ave., Wakefield 01880), Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont
HARRISBURG, PA. 17102—800 N. Second St., Pennsylvania
COLUMBUS, OHIO 43215—41 S. High St., Ohio
LOUISVILLE, KY. 40207—4050 Westport Rd., Kentucky, West Virginia
RICHMOND, VA. 23219—Travelers Bldg., District of Columbia, Maryland, Virginia

SOUTHERN DIVISION

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CL-3

CONSTRUCTION LEAFLET NO. 3
 THE ASPHALT INSTITUTE
 ASPHALT INSTITUTE BUILDING
 COLLEGE PARK, MARYLAND 20740

GENERAL INFORMATION

Correctly designed and constructed, asphalt pavements will give many years of service with little or no maintenance. Because asphalt is the most commonly used material for paving bicycle paths, golf cart paths, and walkways, this leaflet was prepared as a guide to the proper design and construction of asphalt pavements for these facilities.

Subgrade Preparation

The earth subgrade must serve both as a working platform to support construction equipment and as the foundation for the pavement structure. Therefore, it is most important for the architect or engineer to see that it is properly compacted and graded. ~~All topsoil should be removed and low-quality soils must be improved by adding asphalt or other suitable admixtures such as lime or granular materials.~~ Local soil areas that are highly susceptible to frost heaving and frost boils should be removed and replaced with better materials or reworked to make uniform the upper portion of the subgrade. ~~To prevent growth of weeds, the subgrade should be treated with an approved herbicide.~~ For additional information on subgrade preparation, the reader may refer to the Asphalt Institute's Construction Leaflet No. 1 (CL-1), Subgrade Preparation for Asphalt Pavements. Also available is Construction Leaflet No. 2 (CL-2), Model Specifications for Small Paving Jobs. Inquire at nearest Asphalt Institute office.

Surface Type

The Asphalt Institute recommends Full-Depth[®]* Asphalt Pavement construction. In this method, the paving mixture is placed directly on the prepared subgrade. Full-Depth pavements give smooth, durable and economical surfaces that resist high unit loads.

*Full-Depth[®] Asphalt Pavement – The term Full-Depth (registered by The Asphalt Institute with the U.S. Patent Office) certifies that the pavement is one in which asphalt mixtures are employed for all courses above the subgrade or improved subgrade. A Full-Depth asphalt pavement is laid directly on the prepared subgrade.

Composition of Mix

Asphalt mixes referred to in this publication are those specified in ASTM D 1663. See Table 1. Asphalt mixes specified by local agencies may be used in their place if they have a history of satisfactory performance. Contact an Asphalt Institute engineer for information on local mixes.

Compaction

Compaction of asphalt mixtures is one of the most important construction operations contributing to the proper performance of the completed pavement, regardless of the thickness of the course being placed. That is why it is so important to have a properly prepared subgrade against which to compact the overlying pavement.

Asphalt concrete placed and compacted in Deep Lifts[®] (4 inches thick or more) has several major advantages over thin-lift construction. Deep Lifts will retain heat much longer than thin lifts, permitting adequate time for compaction. Because of the longer heat retention of Deep Lifts, the construction season can be lengthened. Currently available compaction equipment of sufficient capacity can effectively compact Deep Lifts of asphalt concrete.

Initial compaction procedure is to roll the interior portion of the spread with three to four passes, then work to within 12 inches of the unsupported edge. The roller should advance toward the edge in approximately 4-inch increments with subsequent passes. This permits the bulk of the roller weight to be supported on partially compacted mix that has developed sufficient stability, thereby reducing the lateral thrust from the roller on the uncompacted mix. This pattern is applicable whether steel-wheel or pneumatic-tired rollers are used. Final compaction then is obtained by conventional rolling.

Drainage

Good drainage is important for pavement durability. The prospective builder should determine if a problem exists at the outset and make plans to correct any drainage deficiencies. It is desirable to blend the surface of the pavement to the contour of existing ground so that surface drainage runs over it or away from it in its natural course. Water should not be allowed to stand at the pavement's edge.

BICYCLE PATHS

PAVEMENT STRUCTURE — ~~The Full-Depth asphalt pavement for bicycle paths should be a minimum of 4 inches thick.~~ The Deep Lift technique can be employed to place the full asphalt layer in one pass of the paver. ASTM Standard D 1663, Asphalt Concrete Mix Designation 5A or 6A, is recommended. See Table 1.

PAVEMENT WIDTH — How wide to build an asphalt-paved bicycle path is a primary consideration. Generally, the recommended width is 8 ft. (2.4m). However, ready availability of conventional road construction equipment and maintenance vehicles may, when over-all cost is considered, govern ultimate width. There are small pavers available, but most asphalt paving machines in use today place widths ranging from 8 to 12 ft. (2.4 to 3.7m). The use of normal size equipment can offset the cost of hauling in mix and hand-laying. In remote areas or in difficult terrain, consideration should also be given to building the pavement wide enough for necessary maintenance and ambulances or rescue-squad vehicles to use during an emergency.

GOLF CART PATHS

GENERAL — Pavements for golf cart paths are normally built like bicycle paths, having a minimum width of 5 ft. (1.5m). However, to minimize golf shoe spike wear, the pavement should be designed and constructed in two layers.

PAVEMENT STRUCTURE — A minimum of 4 in. (10 cm) of asphalt concrete pavement is recommended. A 3 in. (7.5 cm) Full-Depth asphalt base should be placed first and topped by a 1 in. (2.5 cm) asphalt surface course. An open-graded mix, or a sand mix with an asphalt content higher than required for a normal highway paving mix, provides a good wearing course for players wearing golf shoes. If desired, a single 4 in. (10 cm) course may be placed. ASTM D 1663, Asphalt Concrete Mix Designation 5A or 6A, is suggested for the base course, while ASTM D 1663, Sand Asphalt Mix Designation 7A, is recommended for the surface course. See Table 1.

SIDEWALKS

GENERAL — Asphalt sidewalks are constructed like bicycle paths, except that they usually are not as wide. If desired, they can be given almost any surface color or texture by application of special materials.

PAVEMENT STRUCTURE — A minimum of 4 in. (10 cm) of Full-Depth asphalt concrete placed in a single layer is recommended. Asphalt concrete will resist high unit loads and provide a smooth, long-lasting pavement. ASTM D 1663, Asphalt Concrete Mix Designation 5A or 6A, is recommended. See Table 1.

Table 1. RECOMMENDED MIX DESIGNATIONS

Sieve Size	ASTM D 1663		
	Asphalt Concrete		Sand Asphalt
	Mix Designation and Nominal Maximum Size of Aggregate		
	1/2 in. (5A) (12.5 mm)	3/8 in. (6A) (9.5 mm)	No. 4 (7A) (4.75 mm)
	Grading of Total Aggregate (Coarse Plus Fine, Plus Filler if Required) Amounts Finer Than Each Laboratory Sieve (Square Opening), Weight Percent		
1 inch (25.0 mm)	---	---	---
3/4 inch (19.0 mm)	100	---	---
3/8 inch (9.5 mm)	---	90 to 100	100
No. 4 (4.75 mm)	45 to 70	60 to 80	80 to 100
No. 8 ^a (2.36 mm)	25 to 55	35 to 65	65 to 100
No. 16 (1.18 mm)	---	---	40 to 80
No. 30 (600 μ m)	---	---	20 to 65
No. 50 (300 μ m)	5 to 20	6 to 25	7 to 40
No. 100 (150 μ m)	---	---	3 to 20
No. 200 ^b (75 μ m)	2 to 9	2 to 10	2 to 10
Asphalt Cement, weight percent of total mixture	4½ to 9½	5 to 10	7 to 12

^a In considering the total grading characteristics of an asphalt paving mixture the amount passing the No. 8 (2.36 mm) sieve is a significant and convenient field control point between fine and coarse aggregate.

^b The material passing the No. 200 (75 mm) sieve may consist of fine particles of the aggregates or mineral filler, or both.

MAY 1974

CL-5

CONSTRUCTION LEAFLET NO. 5
THE ASPHALT INSTITUTE
ASPHALT INSTITUTE BUILDING
COLLEGE PARK, MARYLAND 20740

PAVEMENT REHABILITATION PREPARATION FOR ASPHALT OVERLAYS

ADVANTAGES OF OVERLAYS

Asphalt overlays, used for the protection of original investment in roads and streets, afford the following advantages:

1. More miles of modern pavement for less cost than new construction.
2. Considerable savings of energy products.
3. Use of the roadway while modernization is in progress.
4. Savings of construction time—an old road usually can be improved and put into full service more rapidly than a new road can be built.
5. A pavement overlaid in proper fashion is a pavement stronger than new, effecting a reduction of subsequent maintenance requirements.

PAVEMENT EVALUATION

The key to successful rehabilitation is careful planning and programming. Evaluation of the road's condition is the first essential in planning the improvement. If the road is found adequate for present service it should be reevaluated periodically to determine the trend of changes affecting its future adequacy. Such a program provides a continuous inventory, and in this way developing problems can be detected and proper corrective action planned on the most effective basis.

Evaluation, which should extend to all roads in the system, includes consideration of geometric adequacy, surface condition, and structural adequacy for current and future use.

Geometric adequacy is evaluated by studying the construction plans, by field inspection, or both. However, surface condition must be evaluated by field inspection. Structural adequacy is evaluated by studying both surface condition and pavement components, or by measuring pavement deflection.

PREPARATION OF PAVEMENTS FOR OVERLAYS

The thickness of the overlay is designed to improve a lower-than-average pavement condition, but not to provide the extra structural strength needed for localized weak areas. Should the overlay thickness be based on the weakest condition in the section it would be over-designed for the rest of the section, and thus needlessly costly. The proper procedure, therefore, is to correct the weaker areas in advance to provide, as nearly as practicable, a uniform foundation for the overlay. Careful and correct preparation of the existing pavement, prior to the construction of smoothing or strengthening overlays, is essential for good construction and maximal overlay performance.

Requirements for correct preparation of existing pavements for overlays varies with the pavement type and, for this reason, each is discussed separately.

ASPHALT PAVEMENTS

Local Repairs. All weak areas should be repaired with proper patches. Structural patches should be designed and constructed with Full-Depth asphalt concrete to ensure strength equal to or exceeding that of the surrounding pavement structure and economy of time and material. Carefully placed and adequately compacted patches will produce a uniform supporting layer for the overlay, ensuring good performance.

Leveling. When the surface is distorted, the construction of leveling courses and/or leveling wedges is required to restore proper line and cross-section. When thin surfacing courses are to be used it is especially important that prior correction of the surface contour be made. Heater-planing may be required in areas where maintenance of a minimum clearance and/or the matching of an existing elevation are necessary.

Leveling wedges are patches of asphalt plant mix used to level sags and depressions in an old pavement prior to the surfacing operation. The placing of leveling wedges is part of the leveling-course operation.

Leveling wedges should be placed in two layers if they are from 3 to 6 in. (7.5 to 15 cm) in thickness. Wedges thicker than 6 in. (15 cm) should be placed in compacted layers of not more than 3 in. (7.5 cm). In placing multiple layers the shortest length layer should be placed first, with the successive layer or layers extending over or covering the short ones. See Figure 1 for illustrations of the correct and incorrect ways of making leveling wedges. If the incorrect method were used, as shown in the lower illustration, there would be a tendency for a series of steps to develop at each joint because of the difficulty of feathering out asphalt mixtures at the beginning and end of a layer. A bump at these joints is apt to reflect through to the final surface.

Where wedging of dips requires multiple layers, sufficient levels should be taken to plot profiles and cross-sections accurately. From these, the grade of the proposed correction and the lineal limits of the successive layers should be determined so that the inspector and the contractor can be given definite stationing for starting and terminating the spreader or motor grader passes (Figure 2). Figure 3 illustrates the correct way to place leveling wedges for overcoming excessive crown.

Cleaning and Tack Coat. When repairs are completed, the surface to be overlaid must be thoroughly cleaned. A thin tack coat of asphalt is then applied to ensure uniform and complete adherence of the overlay. Lack of uniform thin-tack-coat coverage may result in slippage of the surface layer. Because they can be diluted safely with an equal amount of clean fresh water, asphalt emulsions SS-1, SS-1h, CSS-1, and CSS-1h are much used for tack coats. The diluted emulsion tack coat is applied at the rate of approximately 0.10 gal./yd² (0.45 l/m²).

Emulsion Slurry Seal. When the old pavement's surface has a large number of cracks and scaled areas, but the structure is sound, a slurry seal may be placed in preparation for the overlay. The slurry will fill the wide cracks and scaled areas and seal the surface to prevent moisture and air intrusion into the pavement. If the slurry seal is placed shortly before the overlay, and is clean, a tack coat may not be needed.



Figure 1—Correctly placed leveling wedges ensure smoother pavements

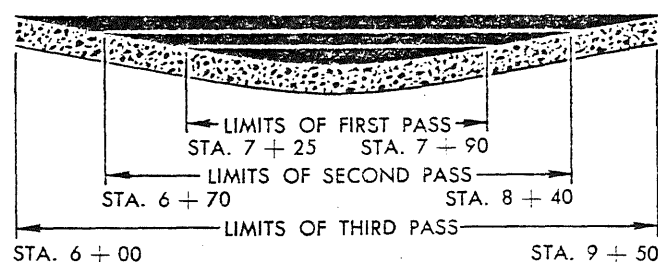


Figure 2—Limits for multiple-layer leveling wedges should be determined by level



Figure 3—Correctly placed leveling wedges for overcoming excessive crown

PORTLAND CEMENT CONCRETE PAVEMENTS

Careful Preparation Required. Preparation of rigid pavements for overlaying must be done carefully and thoroughly to obviate future distress in the overlay. Preparation may include one or more of the following:

- Reducing slabs to small pieces and seating with heavy rollers.
- Cracking and seating rocking slabs with heavy rollers.
- Removing and replacing faulted and blown-up areas.
- Undersealing to provide uniform support.
- Patching disintegrated and spalled areas.
- Scaling cracks to prevent subsurface water from reaching the overlay.

When the pavement has been rendered as uniformly stable as possible, it must be thoroughly cleaned and properly tacked with asphalt before the overlay is placed.

Reducing Reflection Cracking. Reflection cracks are caused by vertical or horizontal movement in the pavement beneath the overlay, brought on by traffic, earth movements, and by expansion and contraction with temperature or moisture changes. Employing one of the three methods of preparing rigid pavements for overlays, below, will reduce the probability and severity of reflection cracks appearing soon after construction. The first method is recommended as the most effective.

1. Breaking each slab into small pieces [average widest dimension about 2 ft. (0.6 m)] and seating them firmly on the subgrade or subbase with heavy [35-50 tons (32 - 45 tons metric)] pneumatic-tired rollers reduces the temperature effect and provides more uniform support for the overlay. Relatively thick overlays are required but reflection cracking is minimized, thus improving overlay performance and reducing future maintenance costs. This treatment is well adapted to planned stage construction. In Europe, reflection cracking has been virtually eliminated by reducing the rigid slabs to near rubble and treating it as granular base or subbase for the overlay. One problem with this method is the necessity to cut fabric or bars when breaking up reinforced pavement.
2. Breaking each slab into segments that can be firmly seated on the underlying course eliminates rocking, reduces deflection at joints and cracks, achieves some reduction in temperature effect, and improves support for the overlay. A leveling course should be placed, and the overlay thickness should be 4.5 in. (11.4 cm) or more, depending on traffic and subgrade conditions. This procedure may be used with planned stage construction.
3. Increasing overlay thickness without reduction of slab size will provide reasonably satisfactory service if the slabs are stable and are first undersealed to provide uniform support. Reflection cracking will be delayed but should be expected. Overlays of less than 4.5 in. (11.4 cm) thickness will develop reflection cracking rapidly. Thicknesses of 7 in. (18 cm) to 10 in. (25 cm) provide good service but some crack reflection might be anticipated.

The three methods described above are recommended as the best yet devised for alleviating the problem of reflection cracking. A number of other methods for preventing reflection cracking have been tried. None of them has been completely successful, although some have delayed crack appearance.

OVERLAY CONSTRUCTION

When the pavement has been prepared, placing the overlay to the predetermined thickness, whether for surface improvement or structural improvement, should proceed without delay. Usually, Mix Designations 4A through 6A (Table 1) or similar, are recommended for overlays, but some applications may call for Mix Designations 7A or 8A (Table 1) or similar. The specific mix should be selected to meet the requirements of thickness, aggregate availability and type of traffic.

Construction procedures for asphalt overlays are the same as for any other asphalt pavement construction.

For more detailed information on any of the subjects covered in this publication, please contact the nearest office of The Asphalt Institute.

TABLE 1. COMPOSITION OF ASPHALT PAVING MIXTURES

Asphalt Concrete				Sand Asphalt	Sheet Asphalt
Sieve Size	Mix Designation and Nominal Maximum Size of Aggregate				
	3/4 in. (4A) (19.0 mm)	1/2 in. (5A) (12.5 mm)	3/8 in. (6A) (9.5 mm)	No. 4 (7A) (4.75 mm)	No. 16 (8A) (1.18 mm)
Grading of Total Aggregate (Coarse Plus Fine, Plus Filler if Required) Amounts Finer than Each Laboratory Sieve (Square Opening), weight percent					
1 in. (25.0 mm)	100				
3/4 in. (19.0 mm)	90 to 100	100			
1/2 in. (12.5 mm)		90 to 100	100		
3/8 in. (9.5 mm)	60 to 80		90 to 100	100	
No. 4	35 to 65	45 to 70	60 to 80	80 to 100	100
No. 8	20 to 50	25 to 55	35 to 65	65 to 100	95 to 100
No. 16				40 to 80	85 to 100
No. 30				20 to 65	70 to 95
No. 50	3 to 20	5 to 20	6 to 25	7 to 40	45 to 75
No. 100				3 to 20	20 to 40
No. 200	2 to 8	2 to 9	2 to 10	2 to 10	9 to 20
Asphalt Cement, weight percent of Total Mixture					
	4 to 9	4½ to 9½	5 to 10	7 to 12	8½ to 12

From ASTM D 1663, Hot-mixed, Hot-laid Asphalt Paving Mixtures.
By permission of the American Society for Testing and Materials.

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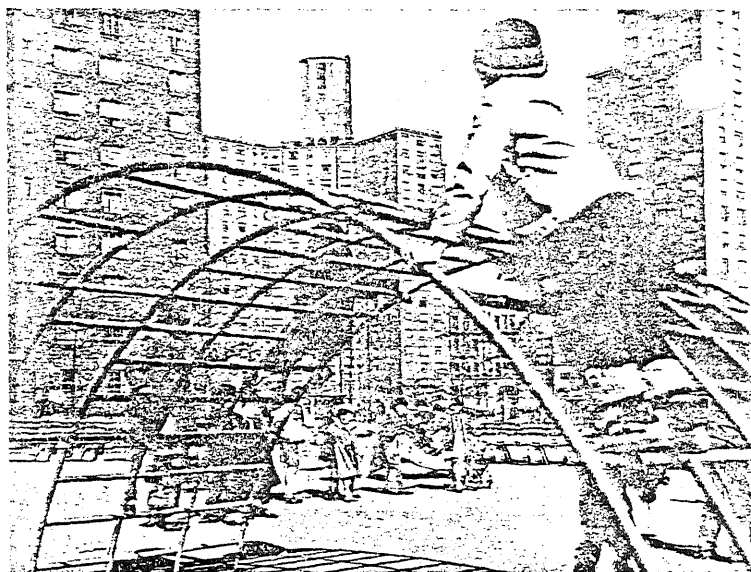
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factors affecting design



The three principal factors which affect the design of an asphalt pavement are:

- A. Traffic—Weight and Volume
- B. Subgrade Support
- C. Properties of Material in the Pavement Structure

Traffic

The design approach for asphalt pavements in recreation facilities necessarily varies according to the particular facility. The pavement thickness for a tennis court or playground probably would not be as thick as that required for an auto race track. Weight and volume of anticipated traffic is a determining factor.

Subgrade Support

~~Good or excellent subgrade soils provide better pavement support than poor subgrade soils and require thinner pavement designs.~~

Determining the quality of the subgrade is important. It is desirable to use laboratory tests to evaluate the load-supporting characteristics of subgrade soils, and if test equipment is available it should be used. However, if laboratory test equipment is not available, designs may be made on the basis of a careful field evaluation by an engineer who can assign the subgrade soils to one of the following categories.

1. ~~Good to excellent subgrade soils. Good~~ subgrade soils retain a substantial amount of their load-supporting capacity when wet. Included are the clean sands and sand-gravels and soils free of detrimental amounts of plastic materials. Excellent subgrade soils are unaffected by moisture or frost. They include clean and sharp sands and gravels, particularly those that are well graded.

2. ~~Medium subgrade soils which retain a moderate degree of firmness under adverse~~

~~moisture conditions.~~ Included are such soils as loams, silty sands, and sand-gravels containing moderate amounts of clay and fine silt.

3. ~~Poor subgrade soils which become quite soft and plastic when wet.~~ Included are those soils having appreciable amounts of clay and fine silt. The coarser silts and sandy loams also may exhibit poor bearing properties in areas where frost penetration into the subgrade is a factor.

See *Soils Manual for Design of Asphalt Pavement Structures* (MS-10), The Asphalt Institute, which describes in detail the more commonly used soil evaluation systems. Field evaluation of the soil involves visual inspection and simple field tests.

Materials in Pavement Structure

Given any combination of traffic and subgrade soil, how thick to design a pavement structure then depends upon the characteristics of materials in the structure. Because of uniform high strength, waterproofness, resistance to frost, and other factors, ~~Full-Depth* asphalt concrete construction permits design of a structure of minimum thickness.~~

Asphalt Concrete is a high-quality, thoroughly controlled hot mixture of asphalt cement and well-graded, high-quality aggregate, thoroughly compacted into a uniform dense mass typified by Asphalt Institute Type IV Mixes. See *Construction Specifications for Asphalt Concrete and Other Plant-Mix Types* (SS-1).

*A Full-Depth Asphalt Pavement is an asphalt pavement in which asphalt mixtures are employed for all courses above the subgrade or improved subgrade. A Full-Depth Asphalt Pavement is laid directly on the subgrade.

SPECIFICATIONS FOR PAVING WITH ASPHALT CONCRETE (Note 1) *

1. **Scope:** Furnish and construct a Full-Depth asphalt pavement structure for a _____ as specified. (Note 2)
2. **General Requirements**
3. **Establishment of Grades:** Grade stakes shall be (will be) set by the contractor (owner). (Note 3)
4. **Preparation of Subgrade:** All debris and vegetation, or other organic materials, shall be removed from the job site. The site to be paved shall be graded to the required section and all excess material removed from the location of the work. Material in soft spots shall be removed to the depth required in the plans to provide a firm foundation and shall be replaced with a material equal to the best subgrade material on the site. The entire subgrade area shall be compacted at the lowest moisture content at which a handful of the soil can be molded by a firm closing of the hand. The subgrade shall be compacted with at least 5 coverages of a pneumatic-tired roller. The surface of the subgrade after compaction shall be stable, uniform, smooth, and true to grade and cross section. Subgrade areas designated on the plans shall be treated with a soil sterilant, applied in conformance with the manufacturer's recommendations, to prevent the growth of weeds. (Note 4)
5. **Thickness of Structure:** On the prepared subgrade an asphalt concrete base shall be laid in one lift or more to a total compacted thickness of (Note 5) inches. Placing of the asphalt concrete surface course shall follow and be laid in a single course to a compacted thickness of (Note 5) inches.
6. **Tack Coat:** A tack coat shall be applied on each layer of the base course if directed by the owner (engineer). The tack coat shall be (Note 6) asphalt applied at the rate of (Note 6) gallon per square yard.
Equipment (Note 7): The contractor shall provide the necessary equipment to complete the job acceptable to the owner.
7. **Sampling and Testing:** If requested by the owner (engineer) the contractor shall furnish for test and analysis representative samples of the materials to be used in the work. Sampling and testing will be in accordance with the latest revisions

*See "Notes to the Owner (Engineer)" at the end of this specification.

of the American Association of State Highway Officials (AASHO) or the American Society for Testing and Materials (ASTM) Standard procedures for sampling and testing the materials being used in the project. The cost of all required tests will be paid by the owner.

8. **Smoothness:** The surface of the completed work, when tested with a ten-foot (10) straightedge, shall not contain irregularities in excess of one-quarter ($\frac{1}{4}$) inch.

3. Materials

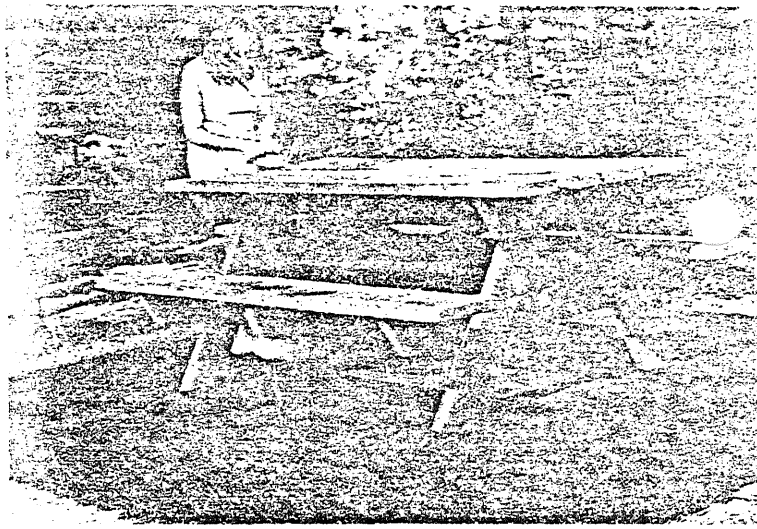
9. **Asphalt Materials:** The asphalt material for the asphalt concrete shall be (Note 8). The asphalt material selected shall meet the requirements of the applicable table in **Specifications for Asphalt Cements and Liquid Asphalts** (SS-2) The Asphalt Institute. A certificate of compliance with the specifications of the asphalt material will be acceptable.
10. **Mineral Aggregate: Asphalt Concrete Base and Surface**

(1) The mineral aggregate for asphalt concrete shall consist of coarse aggregate, fine aggregate, and, if needed, mineral filler. The coarse aggregate shall be sound, angular crushed stone, crushed gravel, or crushed slag. Uncrushed coarse aggregate may be used in base course mixtures if the mixture meets all design criteria. The fine aggregate shall be well graded, moderately sharp to sharp sands or screenings.

(2) The mineral aggregate and asphalt shall be combined to meet a job-mix formula within the following grading band.

Base and Surface Sieve Size	Percent Passing by Weight
$\frac{3}{4}$ in.	(Note 9)
$\frac{3}{8}$ in.	
No. 4	
No. 8	
No. 30	
No. 50	
No. 100	
No. 200	
Asphalt Cement	
(Percent by weight of total mix)	

A picnic table patio is another example of the many uses of asphalt in recreation areas. They are easy to construct and provide economical, long lasting service.



The asphalt-aggregate mixture shall meet the following test criteria (Note 10):

Stability: _____
 Flow (Marshall Method): _____
 Swell (Hveem Method): _____
 Air Voids: _____%
 Voids in Mineral Aggregate: _____%

C. Construction

11. Spreading Base and Surface Courses: Asphalt Base and Surface

(1) Paving shall not be done when it is raining or if the area to be paved has free water on the surface. Paving shall not be done on prior lifts of asphalt base unless the surface is clean, dry, and dust free.

(2) Asphalt base and surface courses shall be spread and struck off with a spreading device. Any irregularities in the surface of the pavement course shall be corrected directly behind the paver. Excess material forming high spots shall be removed with a shovel or a lute. Indented areas shall be filled with hot mix and smoothed with a lute or the edge of a shovel being pulled over the surface. Casting of mix over such areas will not be permitted.

(3) Base course shall be placed in one or more lifts. The maximum lift thickness shall be that which can be demonstrated to be laid in a single lift and compacted to required uniform density and smoothness.

(4) If it is impractical to use a paver or spreader box, asphalt base and surface courses may be spread and finished by hand. Wood or steel forms, rigidly supported to assure correct grade and cross section, shall be used. Placing by hand shall be performed carefully to avoid segregation of the mix. Broadcasting of the material will not be permitted. Any lumps that do not break down readily shall be removed.

(5) The surfaces of curbs, gutters, vertical faces of existing pavements and all structures in actual contact with the asphalt concrete shall be painted with a thin, complete coating of asphaltic material to provide a closely bonded, water-tight joint.

12. Compaction: Asphalt Base and Surface—Rolling shall start as soon as the asphalt concrete mate-

rial can be compacted without detrimental displacement. Rolling shall continue until thoroughly compacted and all roller marks are removed.

In areas too small for the roller a vibrating plate compactor or hand tamper shall be used to achieve thorough compaction.

13. Method of Measurement: The quantities to be paid for will be as follows:

(1) **Preparation of Subgrade**—Total number of square yards of subgrade actually prepared for covering with base material.

(2) **Asphalt Mixture**—Total number of tons of asphalt mixture actually incorporated into the work. (Note 11)

(3) **Asphalt Tack Coat**—Total number of gallons of asphalt tack coat material actually applied.

14. Basis of Payment: The quantities enumerated in Article 13 will be paid for at the contract unit price bid for each item or at a lump sum price bid for the job. Payment will be in full compensation for furnishing, hauling and placing materials, for rolling, and for all labor and use of equipment, tools, and incidentals necessary to complete the work in accordance with these specifications.

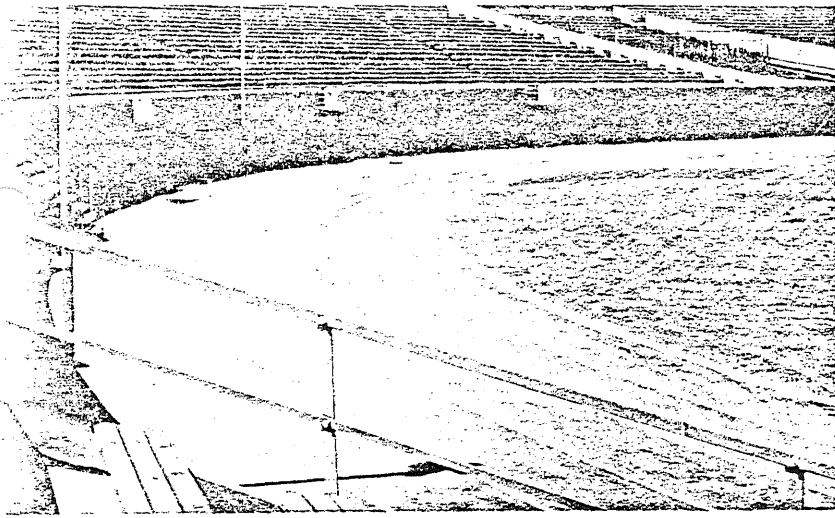
NOTES TO THE OWNER (ENGINEER)

Note 1: This specification applies to paving areas that are generally less than 5,000 square yards. For projects of larger area, specifications similar to those in **Construction Specifications for Asphalt Concrete and Other Plant Mix Types**, (SS-1) The Asphalt Institute, should be used.

Note 2: Full-Depth asphalt pavements are recommended for greatest strength and durability.

Note 3: If the contractor is to set the grade stakes delete "will be" and "owner." If the owner is to set the grade stakes delete "shall be" and "contractor." In establishing the grades due allowances must be made for existing improvements, proper drainage (2 percent slope recommended), adjoining property rights and good appearance.

Note 4: Delete this sentence if a soil sterilant is not required. Sterilant should be



The famous Rose Bowl in Pasadena, California, has a Full-Depth asphalt running track.

specified if the area has been exposed to an accumulation of weed seeds, or if weed growth can be expected to encroach from adjacent areas. Commercial sterilants containing chemical compounds such as sodium chlorate, borate, or arsenate will prevent the germination of weed seeds in the subgrade.

Note 5: Pavement thickness design information for different subgrade soil and traffic conditions can be obtained from any Asphalt Institute engineer.

Note 6: From 0.05 to 0.15 gallon of diluted SS-1 or SS-1h asphalt emulsion is recommended. The asphalt emulsion should be diluted with equal parts of water.

Note 7: Variations in the size and amount of equipment will depend on the size of the area being paved. If the job is under the supervision of an engineer, the engineer should approve those pieces of equipment applicable to the job to which the specification will apply. Good compaction is generally obtained by using three-wheeled or two-axle tandem steel rollers weighing not less than 10 tons, or pneumatic-tired rollers capable of exerting a pressure of up to 80 pounds per square inch. Vibratory steel-wheeled rollers may be used if it is demonstrated that the density requirements can be met.

Note 8: The type and grade of asphalt material generally used is 60-70 for hot and temperate climates, and 80-100 for colder climates.

Note 9: Asphalt Institute dense-graded Mix Types IVa or IVb are recommended gradations. See table below. Other satisfactory dense-graded mix types are tabulated in **Construction Specifications for Asphalt Concrete and Other Plant-Mix Types (SS-1)** The Asphalt Institute. Dense-graded asphalt mixes specified by local public agencies may be used if they have a history of satisfactory performance.

Composition of types IVa and IVb mixes
(Dense Graded)

Mix No. Use	IVa Surface	IVb Base, Surface
Recommended Minimum Compacted Depth for Individual Course	1 in.	1½ in.
Sieve Sizes (Square Openings)	Total Per Cent Passing (by weight)	
¾ in.		100
½ in.	100	80-100
⅜ in.	80-100	70-90
No. 4	55-75	50-70
No. 8	35-50	35-50
No. 30	18-29	18-29
No. 50	13-23	13-23
No. 100	8-16	8-16
No. 200	4-10	4-10

Normal asphalt cement content: 5.0-7.0 per cent by weight of total mix. Upper limit may be raised when using absorptive aggregate.

Aggregate required: Sound, angular crushed stone, crushed gravel, or crushed slag, and fine aggregate. Uncrushed coarse aggregate may be used in base course mixture if the mixture meets all design criteria.

Surface texture: Medium to fine.

Usual applications: Type IV mixes are recommended for all applications.

Traffic limitations: None.

Note 10: Enter the criteria for test limits for each mix in accordance with the method of mix design to be used. Suggested criteria for test limits are included in Chapter II, **Construction Specifications for Asphalt Concrete and Other Plant-Mix Types (SS-1)** The Asphalt Institute. In addition, state any special provisions necessary because of the type and quality of local aggregate or because of other local conditions. The test criteria not used should be deleted.

Note 11: If measurement is to be made on an area basis, delete this sentence and add the following: Total number of square yards of asphalt concrete mixture actually placed.

CLAY - With Calcium

(Source - Heartland Trail Plan Draft)

Chloride Binder

Possible Trail Use - snowmobiling, cross-country skiing, snow showing, walking, biking.

Typical Process of Application

1. With a disc harrow mix approximately $1\frac{1}{2}$ - 2 inches of clay into the top two to four inches of soil. More or less clay may be needed depending on the soil conditions present. Tests should be done to determine the correct amount.
2. Compact this mix with a pneumatic rubber tired roller.
3. Apply calcium chloride at a rate of 1 gallon per 36 square feet. The easiest method of application would be a spray truck.
4. Let dry.

Availability

The availability of clay will change from area to area which means that costs will vary. Liquid calcium chloride availability is limited, with the Van Waters and Rogers Company being the company to contact in the twin cities area.

Costs

These cost estimates are taken as they apply to the Heartland Trail. Estimates for other parts of the state may vary. The Heartland Trail is being put on an established railroad grade.

Calcium Chloride	\$660 per mile of trail, 6' wide
Clay	200 per mile of trail, 6' wide
Grading	1,000 per mile of trail, 6' wide
total	<u>\$1,860</u> per mile of trail, 6' wide

Maintenance

It is anticipated that repairs needed for this surface would be few. The process of application would be followed to fix repairs. Each year calcium chloride would be applied to the trail surface to bind the clay. The cost of this yearly application would be approximately \$660 per mile for a 6 foot wide path.

SOIL CEMENT - With
Asphalt Seal Coat

(Source - Bike Trails And Facilities A Guide To Their
Design, Construction, And Operation. American In-
stitute of Park Executives)

Possible Trail Uses - snowmobiling, cross-country skiing, snowshoeing, walk-
ing, biking, trail bikes, four-wheeled vehicles.

Typical Process of Application

1. Scarify soil.
2. Pulverize soil to be mixed. The depth depends on the specification of the individual trail. A minimum of 6" of pulverized soil is recommended. Shape into bed.
3. Spread dry cement over the pulverized soil. The exact amount of application should be determined by testing. (too much cement will not be harmful but too little will result in a poor base). As a guide, a 10% mixture of cement in a base of 6" will take approximately .45 of a bag per square yard.
4. Mix soil and cement thoroughly with a disc harrow or grader blade.
5. Add water at a rate of 8 gallons per square yard (for a 10% mixture) and mix with a disc harrow or grader blade. Water should be added in small increments and mixed after each addition. Too much water will result in a soggy mixture impossible to compact. Too little water will result in improper hydration.
6. Compact the mixture and let cure. The compaction should take place within six hours of the application of the water. A protective cover of moist straw or dirt should be put over the surface for 7 days.

7. Apply seal coat of liquid asphalt and small stones or pea gravel.

Note - this process works best on sandy or gravelly soils. Silt and clay soils can be used, but more cement will be needed with these soils.

Costs

\$1.50 per square yard excluding the seal coat.

Seal coat of liquid asphalt and pea gravel costs approximately .60 - .70 per square yard (Source - Bituminous Roadways). Cost per trail mile \$7,392-7,744 for a 6' wide trail.

Maintenance

No maintenance information was obtained but it could be assumed that, like asphalt, a seal coat should be added to this material approximately every three to five years.

SOIL ASPHALT - With
Asphalt Seal Coat

(Source - Bike Trails And Facilities A Guide
To Their Design, Construction, And Operation.
American Institute of Park Executives)

Possible Trail Uses - snowmobiling, cross-country skiing, snowshoeing, walking, biking.

Typical Process of Application

1. Establish good subbase - compact soil with sheeps foot roller, grid roller, or vibratory compactors.
2. Pulverize soil to be mixed. The depth depends on the specifications of the individual trail. A minimum of 6" of pulverized soil is recommended.
3. Apply liquid asphalt at a rate of 3 - 6% of the final volume of soil to be treated (3655 gal. - 7310 gal. per trail mile for a 6' wide trail). Emulsified asphalt can be used but a medium curing, solvent based asphalt is recommended. Soil should contain 4 - 9% water for best results.
4. Mix soil and asphalt with a disc harrow or grader blade.
5. Allow to cure so that approximately one-half the solvents evaporate before compacting.
6. Compact with a steel-wheeled or pneumatic tired roller.
7. Apply seal coat of liquid asphalt and small stones or pea gravel.

Costs

.40 - .65 per square yard for a 4 inch thick surface excluding seal coat.

Seal coat cost approximately .60 - .70 per square yard (Source - Bituminous

Roadways).

Cost per trail mile \$4,400 - \$4,752 for a 6' wide trail.

Maintenance

No maintenance information was obtained but it could be assumed that, like asphalt, a seal coat should be added to this material approximately every three to five years.

GRASS

Possible Trail Uses - snowmobiling, cross-country skiing, snowshoeing, walking.

Typical Process of Application

1. Remove trees, brush, stumps, and debris from area to be seeded.
2. Grade to desired surface - if top soil is needed apply after rough grading and final grade for seeding. 4 - 6 inch of topsoil should be present.
3. For high traffic areas in sunny locations, the following mixtures were recommended:

Athletic Mix (Source - Peterson Forage Seed Div.)
40% Kentucky 31 Tall Fescue
Formula A 20% Park Kentucky Bluegrass
10% Chewing Fescue
30% Perennial Ryegrass

(Source - U of M Extension Service)
Formula B 40% Red Fescue
60% Delfy Kentucky Blue or Pylking Kentucky Blue

For high traffic areas in shady locations, the following mixture was recommended:

(Source - U of M Extension Service)
Formula C 60 - 80% Red Fescue
20 - 40% Nugget Kentucky Bluegrass

The mixture to be used should be spread at the approximate rate of 400 square feet per pound of seed.

4. Areas susceptible to erosion should be mulched with a thin layer of straw.
5. Watering should take place often enough so as to keep area moist.

Availability

Special grass seed mixtures are available in the Twin City metro area. No information was obtained concerning availability outside the area.

Note - The DNR currently has a price contract with Peterson Forge Seed Div., Pioneer Hi Bred Int'l Inc., Savage, MN, for five grass seed formulas (see attached sheet). However, these mixtures do not meet the recommendations for high traffic areas.

Costs (Source - Peterson Forage Seed Div.)

The only costs available were for seed itself.

The actual costs of seeding will depend on grading requirements, topsoil needs, and labor costs.

Seed costs -	Formula A	\$75 per 100 pounds
	Formula B	120 per 100 pounds
	Formula C	121 per 100 pounds

Cost per trail mile for seed only (6' wide trail) approximately \$96.00

Maintenance

Maintenance requirements will vary from area to area. Reseeding should not be necessary unless excessive wear takes place. If this is necessary, shallow cultivation of the area and reseeding should be done.

REQUIREMENTS: The variety of seed, percent of each in the mixture, purity and germination shall be as stated below:

FORMULA No. 1 for shady mowed area: (60 lbs/acre)

92.22 per 100 lbs.

<u>Specie</u>	<u>% in mixture</u>	<u>Purity</u>	<u>Germination</u>
Creeping Red Fescue	50%	97%	80%
Perennial Ryegrass	13%	99%	92%
Red Top	15%	92%	87%
Park Kentucky Bluegrass	20%	95%	82%
Dutch White Clover	2%	99%	92%

FORMULA No. 2 standard mixture for normal soils, mowed or unmowed areas:
(50 lbs/acre)

89.66 per 100 lbs.

<u>Specie</u>	<u>% in mixture</u>	<u>Purity</u>	<u>Germination</u>
Park Kentucky Bluegrass	30%	95%	82%
Creeping Red Fescue	20%	97%	80%
Smooth Bromegrass	20%	90%	85%
Red Top	8%	92%	87%
Perennial Ryegrass	16%	99%	92%
Dutch White Clover	6%	99%	92%

FORMULA No. 3 for sandy soils, mainly unmowed areas, but can be mowed:
(45 lbs/acre)

136.95 per 100 lbs.

<u>Specie</u>	<u>% in mixture</u>	<u>Purity</u>	<u>Germination</u>
Perennial Ryegrass	13.3%	99%	92%
Park Kentucky Bluegrass	33.4%	95%	82%
Smooth Bromegrass	22.2%	90%	85%
Timothy	11.1%	99%	90%
Sand Dropseed	13.3%	98%	88%
Birdsfoot Trefoil, Empire	6.7%	97%	85%

FORMULA No. 4 for urban mowed areas: (70 lbs/acre)

116.23 per 100 lbs.

<u>Specie</u>	<u>% in mixture</u>	<u>Purity</u>	<u>Germination</u>
Park Kentucky Bluegrass	60%	95%	82%
Creeping Red Fescue	20%	97%	80%
Red Top	10%	92%	87%
Perennial Ryegrass	10%	99%	92%

FORMULA NO. 5 for unmowed, no maintenance areas: (40 lbs/acre)

309.88 per 100 lbs.

<u>Specie</u>	<u>% in mixture</u>	<u>Purity</u>	<u>Germination</u>
Crownvetch	50%	95%	77%
Perennial Ryegrass	20%	99%	92%
Creeping Alfalfa	20%	99%	92%
Birdsfoot Trefoil, Empire	10%	97%	85%

The lawn grass seed furnished shall comply in all respects with applicable laws and regulations of the State of Minnesota.

LIGNUN

(Source - Dave Wiley, Alexandria RCD Project
Coordinator)

Possible Trail Uses - snowmobiling, cross-country skiing, snowshoeing, walking, biking, trail bikes, four-wheeled vehicles.

Typical Process of Application

1. Form a raised soil bed. Road beds have been formed 1 - 2 feet high with good results. Trails with beds of only 8 inches high have been established but are relatively new so that any weather action on them is not known yet.
2. Apply lignun to soil at a rate of 1 gallon per square yard. Spray truck is the easiest method of application.
3. Till lignun into the soil to a minimum depth of 6 inches.
4. Compact the soil and lignun mixture with a steel wheeled or pneumatic tired roller.
5. Let cure for one week.
6. Add a seal coat of liquid asphalt and pea gravel.

Availability

The availability appears to be good with the best price and supply being obtained directly from Wisconsin paper mills. Previous contracting has been done with Ponderosa Contracting, Souix Falls, S.D. For the best price, however direct contact with the paper mills should be made.

Costs

Cost figures from 1975 are:

\$3,600 per trail mile, 8 - 10' wide. This includes labor and construction.

Cost figures from 1978 are:

The following costs are for the 3.3 mile Milan Bike Trail:

Right of Way		\$ 1,531.00
Grading - County paid for \$7,535. The state Highway		17,767.00
paid \$10,232 to backslope tow cuts to prevent drifting snow.		
Labor - Contractor		811.00
Labor - County employees		4,200.00
Equipment (County owned) Rent & operation		5,000.00
Culverts		1,348.00
Surfacing -Lignin	\$6,162.00	
Oil	2,462.00	
Sand seal	1,140.00	
County labor	2,000.00	
County equipment	1,300.00	
		<u>\$43,657.00</u>

Cost of lignun surfacing per trail mile \$3,958.00

Maintentance

Repairs in this surface are easy to accomplish. The damage area is removed, a new batch of lingnun and soil is mixed and the area is filled with this. The area is then compacted, allowed to cure and a seal coat applied. The biggest problem with this material is drainage. Standing water will cause soft spots. A seal coat should be applied every 3 - 5 years.

CONCRETE

Potential Trail Uses - snowmobiling, cross-country skiing, snow shoeing, walking, biking, trail bikes, four-wheeled vehicles.

Typical Process of Application

1. Remove all trees, brush, stumps (to at least 2' below surface) and debris from area to be paved.
2. Grade to desired surface.
3. Compact subbase with a sheep foot or pad-type roller (clay soils), pneumatic-tired or vibrating roller (granular soils, or pneumatic-tired or smooth-wheeled roller (silty soils).
4. Apply 4 - 6 inch of aggregate base and compact.
5. Place side forms and expansion material.
6. Apply a minimum of 4 inches of concrete and level with a straight edge.
Allow for proper drainage.
7. After it has begun to set finish for proper surface. (Source - Bike Trails And Facilities - A Guide To Their Design, Construction, And Operation. American Institute of Park Executives)

Availability

Appears that availability is good throughout the state. It may be harder to obtain concrete in some smaller northern towns.

Costs

Source - Arrigoni Brothers Contracting

\$1.50 per square foot in the metro area.

1.60 per square foot for exposed aggregate.

Approximately \$47,520 per mile for a 6' wide trail.

Transportation costs 20-25% increase for over 50 miles
 30% increase for over 200 miles

Source - Shiely Concrete

Average cost of concrete throughout the state is approximately \$35 per cubic yard delivered.

Source - Roger Liska, DNR Engineering

\$2 per square foot

Approximately \$46,000 per mile for a 4' wide trail.

Bominate (Patterned and colored concrete) costs approximately \$3 per square foot.

Maintenance

Virtually a maintenance free material.

TACONITE TAILINGS AND LEAN ORE

(Source - Godfrey Zakula, Mineral Engineer, Hibbing)

There are basically four types of tailings which are processed out:

Jig Tailings	3/8 - 1 1/4 inches
Cyclone tailings	48 mesh - 3/8 inch
Course tailings	200 - 100 mesh
Fine tailings	325 - 200 mesh

Jig tailings are the most applicable to trail use. It contains some fines so it is a dirty material. Compaction is not very good because of the sameness of size.

Available from U.S. Steel and Eveleth Taconite.

Currently used as a subbase and fill material for tailing dykes, and in company parking areas and roads.

It may be possible to obtain this jig tailing material for .10 - .20 per cubic yard.

(Source - George Meadows, Trails)

Stated that compaction was good which contradicts what the other had said.

The biggest problem according to George was that of erosion. Trails need to be crowned to promote drainage.

This material should be able to be used for biking and walking trails.

(Source John Pawlak, District Director of Transportation, Duluth)

No tailings can be used at present without covering them with some form of sealer.

Compaction of these materials is poor because of the uniformity of size.

Suggested mixing gravel with it to act as a binder.

Has been used as the aggregated in an asphalt seal coat.

BRICK PAVERS

Potential Trail Uses - snowmobiling, cross-country skiing, snowshoeing, walking, biking.

Typical Process of Application

There are many ways to construct a brick surface so the specific specifications for this type of construction are not dealt with. The most common methods of laying brick include placing the brick on a concrete or asphalt base. The brick is usually mortared together. The other common method is that of dry laying brick on a base of sand. Sand is also placed in the joints between the bricks. The edge of this type of construction is unstable and an immovable edge should be used to hold the brick.

Costs (Source - Corning Donohue, Inc.)

The costs obtained were for the brick only and do not include any items or labor costs associated with installing brick.

20,000 or more brick ordered - \$205 per 1000 bricks

Transportation costs are \$1.25 per mile for a load of 6000-7000 bricks.

Cost per mile of trail for brick only is \$29,253 for a 6' wide trail.

Availability

Brick are primarily available in the metro area but it was indicated that they could be shipped throughout the state.



Technical Notes on Brick Construction

Brick Institute of America 1750 Old Meadow Road, McLean, Virginia 22101

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REVISED

Mar/Apr

1976

BRICK IN LANDSCAPE ARCHITECTURE TERRACES AND WALKS

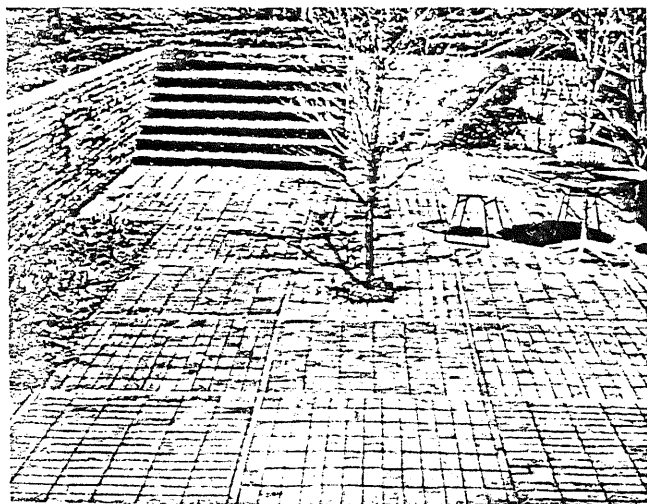


FIG. 1
Brick Terrace



FIG. 2
Brick Walk

INTRODUCTION

Landscape architecture has been defined as the planning of the site of a home, estate or public building. It also extends to parks, playgrounds, highways and cemeteries. Landscape architecture dates back to the early Egyptian civilization and has only been recently recognized as a branch of art to be practiced by specialists. Since it is an art, it must conform to certain rules of perspective, color, mass, light and shadow.

Brick is playing an ever growing role in landscape architecture. Brick is an ideal material for it is made of natural earth materials, clay and shale, fired to permanence and color. Popular brick colors of red, brown, buff and gray, to name a few, are harmonious with nature.

This *Technical Notes* issue, one of three in a series, discusses the application of brick for paving walks, terraces and patios. Other issues in this series discuss elements of landscaping, such as garden walls, brick screens, tree wells and miscellaneous applications.

TERRACES

One of the most widely used features of landscape design to which brick are adapted is the terrace. The terrace in all periods of gardening, and whether called patio, atrium, promenade or lanai, has been an obviously man-made part of the garden.

A terrace is generally defined as a raised level or platform of earth supported on one or more sides by a wall or bank of turf. There can be a series of terraces arranged one above the other. Today's terraces and patios are quite often adjacent to dining, living, family or recreation rooms. They are outdoor extensions of these living spaces and supplement the activities of the occupants.

WALKS

A walk of brick can often be effectively used to provide an interesting and inviting entrance path to a garden or home. Walkways are generally desirable where foot traffic is anticipated or occurs frequently and are used to define precise geometric patterns in formal garden layouts or simply to provide a path through a natural garden setting. Paved walkways, properly installed, have an important utilitarian function, as well as being decorative, of providing a clean, hard, stable path of travel.

APPEARANCE

The appearance of the terrace or walk can play an important part in determining the character of the site. It may allude to a friendly, inviting atmosphere or a staid, formal environment.

Color and Texture

Brick pavers are available in many colors and textures. Red is the most popular and is available in several ranges. Other colors include buff, gray and brown shades. Textured units are more suitable where slip resistance is desirable.

Sizes and Patterns

Brick offer variations of color, pattern, texture and shape which lend themselves to almost unlimited ef-

fects. Some effective pattern bonds in which brick might be laid are shown in Fig. 3. The patterns shown are developed with brick units having exposed faces of either nominal or actual sizes of 4 in. by 8 in. Other sizes and shapes are also available, including 6 in. by 6 in. and 8 in. by 8 in., and hexagonal units. The designer should ascertain the local availability of unit sizes and colors prior to final pattern selection.

Any of the patterns shown can be constructed with 4-in. by 8-in. actual dimension units laid dry and tight,

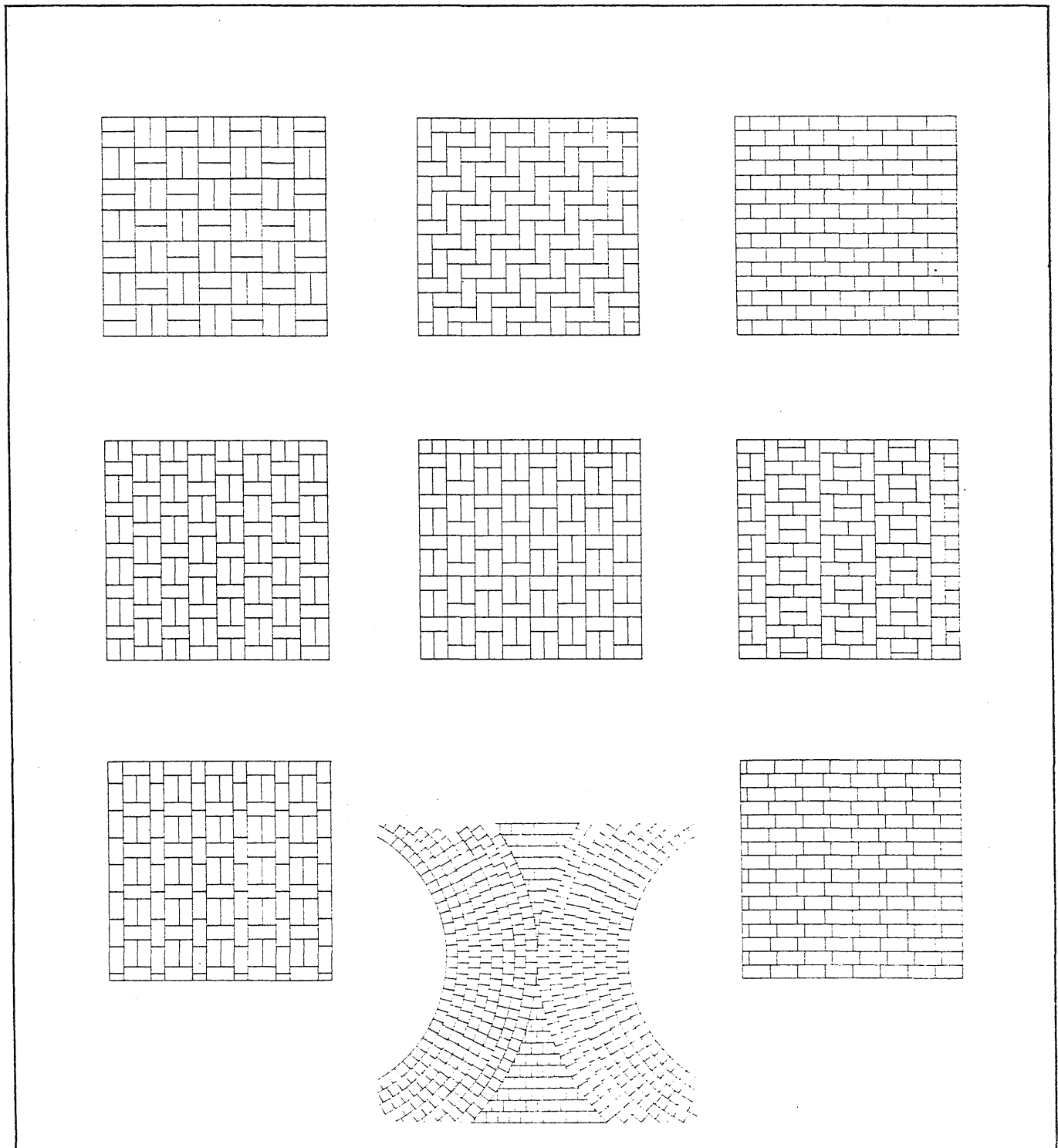


FIG. 3
Pattern Bonds

or 4-in. by 8-in. nominal dimension units ($3\frac{5}{8}$ -in. by $7\frac{5}{8}$ -in. or $3\frac{1}{2}$ -in. by $7\frac{1}{2}$ -in. actual dimensions) placed with mortar or sand in the joints. Patterns which require the width of the unit to be $\frac{1}{2}$ the length may not be laid dry and tight with nominal dimension units designed for a mortar joint, nor with mortar and actual dimension units of 4 in. by 8 in. normally designed for use without mortar. Table 1 shows several of the popular sizes available.

TABLE 1^a
Brick Paver Units

Face Dimensions (actual size in inches)			Thickness
w	x	l	
4	8		The unit thickness of brick pavers varies. The most popular thicknesses are $2\frac{1}{4}$ in. and $1\frac{5}{8}$ in. The range of thickness is generally from $\frac{3}{4}$ in. to $2\frac{1}{2}$ in.
$3\frac{3}{4}$	8		
$3\frac{3}{4}$	$7\frac{1}{2}$		
$3\frac{5}{8}$	$7\frac{5}{8}$		
$3\frac{1}{2}$	$7\frac{1}{2}$		
6	6		
8	8		
6	6	Hexagon	
8	8	Hexagon	

^aTable 1 is based on BIA survey conducted in 1973. According to the survey approximately 38 sizes are manufactured.

TYPES OF BRICK PAVING

There are two general types of brick paving, mortared and mortarless. Mortared brick paving is usually installed over a rigid base such as a concrete slab. Mortarless brick paving may be installed over either a rigid or flexible base, such as asphalt or well compacted gravel. Generally, it is placed over the more economical flexible type base.

Mortared Brick Paving

Mortared brick paving is traditional. It can be quite durable and pleasing in appearance. A proper installation usually requires a brick mason or tile setter. It is permanent and possesses excellent weathering properties with relatively low maintenance.

Mortared brick paving requires a very stable base, such as a slab, and a short initial curing period before being placed into service. Unless special precautions are taken during installation, cleaning may be difficult.

Mortarless Brick Paving

Mortarless brick paving has become very popular because of its economy, durability and excellent performance. This type of paving combines the desirable characteristics of low initial cost and excellent aesthetic values. Inexpensive, flexible base material can be used and the installation may be executed with semi-skilled or unskilled workers. After being placed into service, brick units can be removed or replaced if damaged. Easy access to underground utilities is possible with mortarless brick paving.

Rigid edging around the paved area is usually required to restrict the movement of units.

SELECTION OF MATERIALS

Material selection for brick terraces or walks, whether mortared or mortarless, requires thought and judgment. The following sections are to assist in this process but are not all encompassing.

Brick

Several considerations affecting the selection of brick are: (1) traffic to which the paving is subjected, (2) exposure to moisture and freezing cycles, and (3) the desired appearance.

Resistance to Abrasion. Resistance to wear and tear is generally associated with dense, hard-burned brick. However, brick paving units, suitable from a weathering standpoint, should perform satisfactorily as far as abrasion is concerned. Resistance to abrasion is usually not a problem unless brick units are subjected to extremely abrasive traffic in special types of installations; i.e., industrial locations.

Resistance to Weathering. For exterior pavement, resistance to freezing and thawing in the presence of moisture cannot be emphasized too strongly. Paving is one of the most severe exposure applications for brick. Resistance to weathering should be a prime consideration.

In general, dark colored units are associated with durability and good performance. This generalization, however, can be misleading, since modern brickmaking technology permits the manufacture of many units that are both light in color and extremely durable in use.

For best results, it is suggested that the selection of brick units for paving be based on the knowledge of satisfactory performance of units in a similar application and exposure. This type of performance information can usually be obtained from the manufacturer or his agent.

Lacking performance information, the following physical properties of each type of extruded or molded brick units may be considered minimum:

For Extruded Brick—Minimum average compressive strength of 8000 psi, maximum average cold water absorption of 8 percent, and maximum saturation coefficient of 0.78, or satisfactorily pass 50 cycles of freezing and thawing as set forth in ASTM C 67, "Standard Methods of Sampling and Testing Brick and Structural Clay Tile."

For Molded Brick—Minimum average compressive strength of 4500 psi, maximum average cold weather absorption of 8 percent, and maximum saturation coefficient of 0.78, or satisfactorily pass 50 cycles of freezing and thawing as set forth in ASTM C 67, "Standard Methods of Sampling and Testing Brick and Structural Clay Tile."

The above physical properties are purposely conservative. There are undoubtedly units that will not conform to these minimums but will perform very satisfactorily. It is, therefore, most important that performance data be used whenever possible.

Used Brick. The use of salvaged brick for brick paving is *not* recommended. The durability of masonry depends upon the uniform quality of materials. Used brick are *not* uniformly durable when exposed to weathering. They may spall, flake, pit and crack, due to freezing in the presence of moisture (see *Technical Notes* 15, "Salvaged Brick").

Mortar

For exterior mortared paving, a type M, portland cement-lime mortar is recommended. It has high durability, good bonding characteristics and is particularly suitable for masonry in contact with the earth. Proportions by volume for type M mortar are: 1 part portland cement, $\frac{1}{4}$ part hydrated lime and 3 parts sand.

Bases, Cushions and Membranes

Flexible bases may consist of washed gravel, unwashed gravel or sand. Rigid and semi-rigid bases are of concrete, asphalt or bituminous concrete. Cushions may be of sand, sand and cement mixtures, chat, pea gravel or stone screenings. Membrane materials for landscaping pavement usually consist of asphaltic roofing felt or polyethylene plastic film. *Technical Notes* 14A Revised contains a thorough discussion on the various aspects of these materials.

CONSTRUCTION

Properly designed and constructed terraces and walks will provide years of nearly carefree service. When planning or building a brick terrace or walk, considerations should be given to the installation of the base, drainage, edging, mortar bed and the type of joint and expansion joints.

Edging

Some type of rigid edging around the perimeter of a paved area is generally desirable for both mortared and mortarless paving (see Figs. 4 and 5). Mortarless brick paving is especially susceptible to spreading or shifting at the edges under normal use. Edging may be constructed from a soldier course of brick laid in concrete or mortar.

Drainage

Exterior brick paving is exposed to diverse climatic conditions, thus requiring special attention to drainage design. When subjected to excessive moisture, the paving may be susceptible to efflorescence, growth of fungi or moss, or disintegration by freezing and thawing. Pavement surfaces should be sloped $\frac{1}{8}$ to $\frac{1}{4}$ in. per ft for walks and patios. Use the greater slope for large areas. Generally, pavement surfaces should be sloped to direct water away from buildings, walls or other places where water may collect. Gutters at pavement edges are also effective ways of removing water.

In areas susceptible to high water tables, a porous base and cushion material of gravel may be necessary to

serve as a capillary break to prevent the upward flow of moisture. Localities with relatively impervious soils and high water retentivity may require subsurface drainage (see Fig. 6).

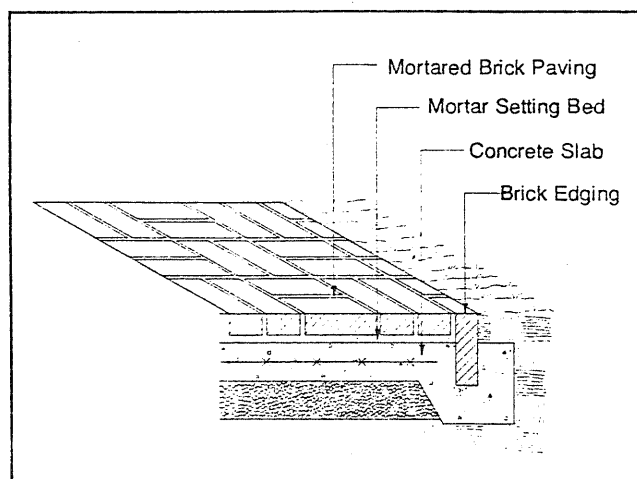


FIG. 4

Mortared Brick Terrace—Concrete Base

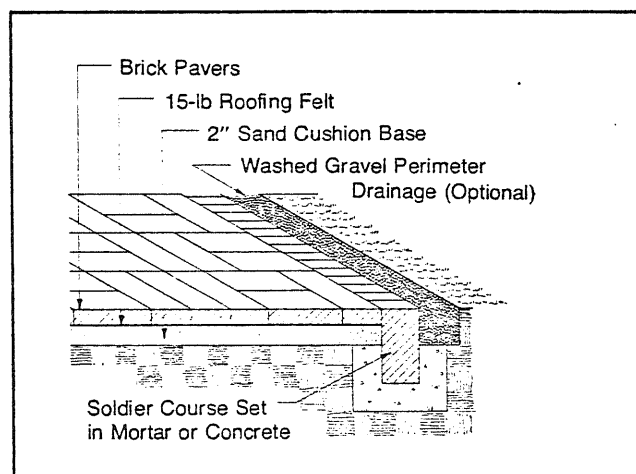


FIG. 5

Mortarless Brick Terrace—Sand Base

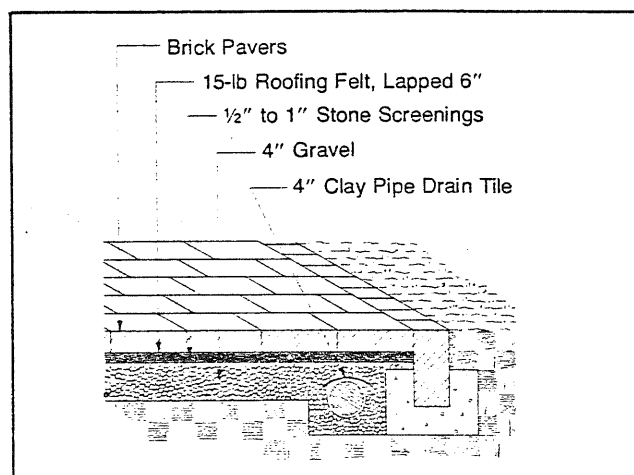


FIG. 6

Mortarless Brick Terrace—Gravel Base

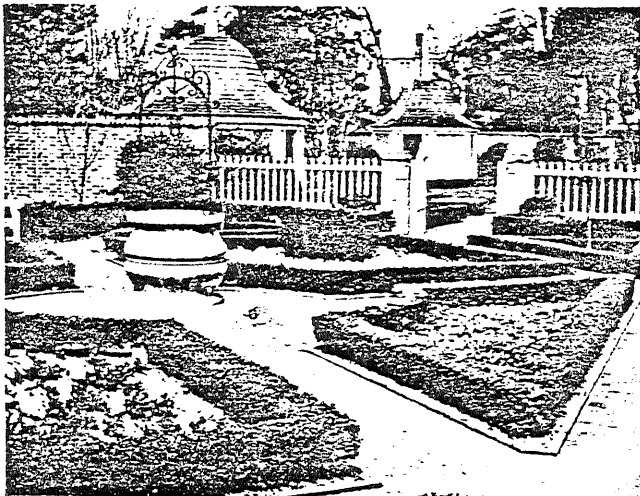


FIG. 7
Brick Walkways—Formal Garden

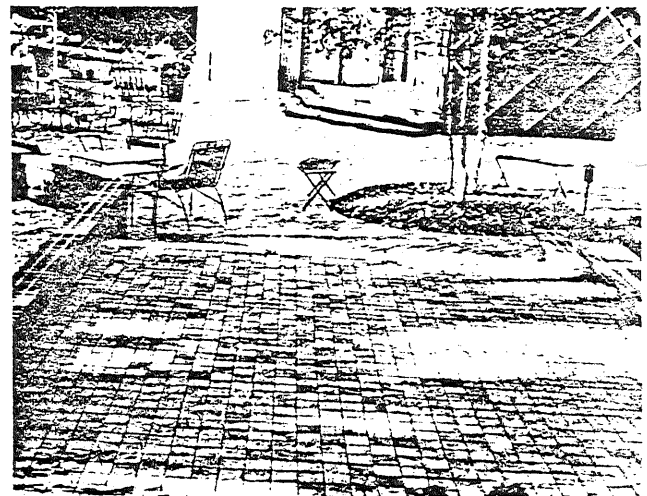


FIG. 8
Brick Patio

Installation

The method of installation of mortared or mortarless paving will vary, depending upon the design and size of the project.

It is recommended that rigid or mortared paving be placed on a rigid base installed in a conventional manner. The thickness of a mortar setting bed may vary from $\frac{1}{2}$ to 1 in. Mortar joints are generally placed in a conventional manner but may be poured as grout mixture, or dry-mixed and swept into place. The dry mixture is then sprayed with a fine mist of water. Mortared paving should be allowed to cure undisturbed for at least 3 days. Afterwards light pedestrian traffic is permissible, provided the pavement is protected. Approximately 28 days should be allowed for full cure.

Among the most important aspects of installing mortarless brick paving is the proper placement of the base and edging. Various base and cushion assemblies of gravel and/or sand may require both hand and equipment placement and compaction. Usually, a mortarless installation can be used immediately upon completion, requiring little or no cure or cleaning.

Movement

Consideration should be given to the potential for movement due to thermal and moisture changes. The following expansion joint location guidelines are suggested for large areas: (1) parallel and adjacent to curbs and edgings, (2) at right angle turns, (3) around interruptions, and (4) between paving and other construction.

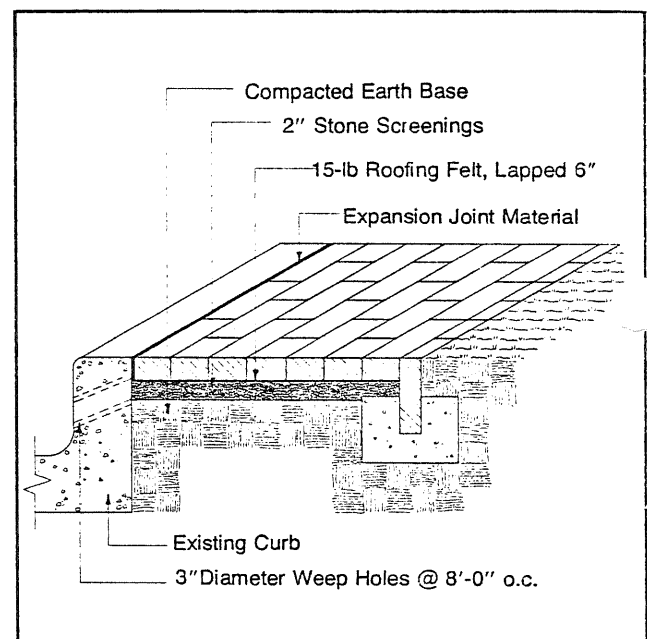


FIG. 9
Mortarless Brick Walk—Gravel Base

Mortarless brick paving will usually have the ability to accommodate these movements without the need for expansion joints. However, it is suggested that expansion joint material be placed adjacent to and around fixed objects, such as curbs, walls and planters.

SUMMARY

This issue of *Technical Notes* has discussed brick paving related to walks and terraces in landscape architecture. No effort is made or implied that this is a total discussion of the subject matter, since conditions may vary widely. It is, however, a basis from which a designer may develop successful brick walks and terraces.

The following publications contain additional information on brick paving:

1. "Brick Floors and Pavements", *Technical Notes* 14 Series.
2. "Differential Movement—Expansion Joints, Part II", *Technical Notes* 18.
3. "Portland Cement—Lime Mortar for Brick Masonry", *Technical Notes* 8 Series.
4. "Salvaged Brick", *Technical Notes* 15.
5. *Good Practice for Construction of Mortarless Brick Paving and Flooring*, Brick Association of North Carolina.



Technical Notes on Brick Construction

Brick Institute of America 1750 Old Meadow Road, McLean, Virginia 22101

14
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BRICK FLOORS AND PAVEMENTS PART I OF III

INTRODUCTION

This *Technical Notes* is Part I of a series on the state of the art of brick paving for residential, commercial and institutional construction. Recommended materials and design considerations are the main topics of discussion. Factors such as site conditions, drainage, edging, traffic loading, bases and cushions, membrane layers and appearances also are included.

The paving assemblies discussed in this series of *Technical Notes* are principally for applications such as shopping plazas, building entrances, walkways, patios, etc. These recommendations are not applicable to streets for heavy vehicular traffic nor for industrial floors which have special requirements, such as chemical resistance and impact resistance. These recommendations can, however, be applied with care to residential driveways and to residential parking areas.

Future *Technical Notes* in this series will cover paving assemblies for various types of design conditions and also suggested methods of surface maintenance for interior brick flooring.

CLASSIFICATION OF PAVING ASSEMBLIES

Paving assemblies under discussion will be basically classified in accordance with the type of base supporting rigid or flexible brick paving. Rigid brick paving, as defined in this issue of *Technical Notes*, consists of units laid in a bed of mortar with subsequent mortar joints between the units. Conversely, flexible brick paving contains no mortar below or between the units.

Rigid Base Diaphragm. A rigid base diaphragm is defined as a reinforced concrete slab on grade. Rigid or flexible brick paving may be placed over this type of base.

Semi-rigid Continuous Base. This type of base usually consists of continuous asphalt or bituminous concrete road pavement. Flexible brick paving is suitable over this type base.

Flexible Base. A flexible base consists of compacted gravel or a damp, loose, sand-cement mixture tamped in place. Only flexible brick paving should be placed over this type of base.

Suspended Diaphragm. Suspended diaphragm bases are structural roof or floor deck assemblies; the composition of which will vary depending upon design. Either flexible or rigid brick paving is suitable for this type of base.

DESIGN CONSIDERATIONS

Traffic. Generally, the first design consideration is to assess applicable traffic loadings. Heavy vehicular loadings on grade will generally require rigid base diaphragms or semi-rigid continuous bases. Lighter vehicular traffic, such as for residential driveways, may be supported on flexible bases and flexible paving. Pedestrian traffic can be accommodated over any of the previously mentioned assemblies. Traffic patterns dictating the geometry and size of a paved area may directly influence the selection of base and cushion material.

Site. A site may involve anything from a small residential patio to a major urban renewal project, encompassing several city blocks. During the planning stages of large projects, consideration should be given to the location of underground utilities, storm drainage and user convenience.

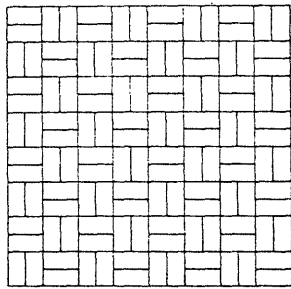
Successful installations will also depend upon proper subgrade preparation. All vegetation and organic materials should be removed from the area to be paved. Soft spots containing poor subbase material should be removed and refilled with suitable material properly compacted.

Drainage. Surface and subsurface drainage are of major importance. Generally, exterior brick paving should be sloped $\frac{1}{8}$ to $\frac{1}{4}$ in. per ft. Large paved areas for malls and vehicular parking lots require the larger value. All paving should be sloped away from buildings, retaining walls and other elements capable of collecting surface water. In areas susceptible to high water tables, a porous base and cushion material of gravel may be used. This type of base serves as a capillary break, preventing the upward flow of moisture due to capillary action. Localities with relatively impervious soils, capable of surface water retention, may require subsurface drainage systems.

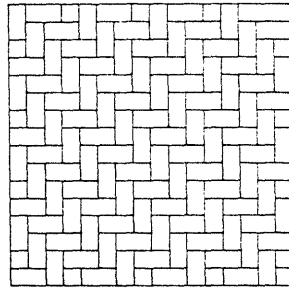
Edging. To prevent horizontal movement of mortarless brick paving units, a method of containment must be provided around the entire perimeter of the paved area. This may be a curb of brick soldier coursing set in concrete or mortar. An existing concrete curb, building or retaining wall will also suffice. New edging should be constructed prior to placement of the paving units.

Joints. There are three basic methods for installing brick paving with mortar joints.

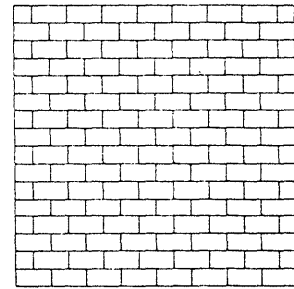
The first method is by the conventional use of mortar



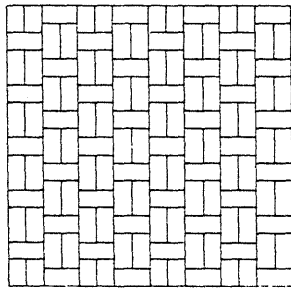
Basket Weave



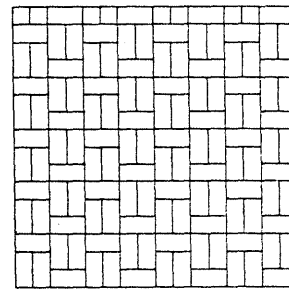
Herringbone



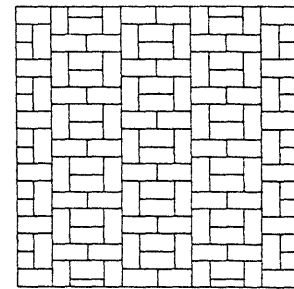
Running Bond



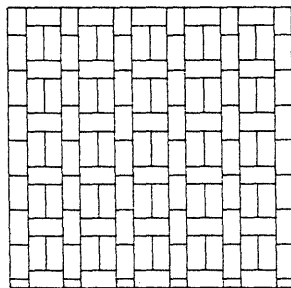
Variation of Basket Weave



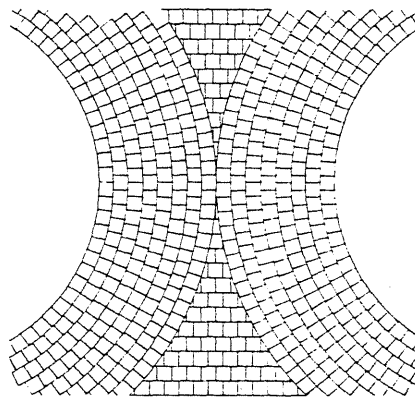
Variation of Basket Weave



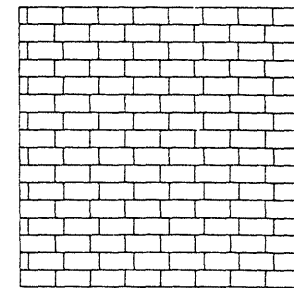
Variation of Basket Weave



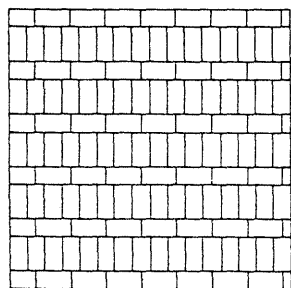
Variation of Basket Weave



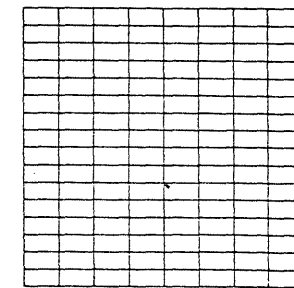
Circular and Running Bond Mixed



$\frac{1}{4}$ Running Bond



Running and Stack Bond Mixed



Stack Bond

FIG. 1
Brick Paving Patterns

and a trowel. Brick pavers are buttered with mortar and shoved into a leveling bed of mortar.

A second method involves placing each brick unit on a mortar leveling bed with $\frac{3}{8}$ to $\frac{1}{2}$ in. of space provided between the units, followed by pouring a grout mixture between the units. Generally, grout proportions of portland cement and sand are the same as for mortar with the exception that hydrated lime may be omitted. When grout is poured into the joints, special care must be taken or the units must be protected to facilitate cleaning.

A third method involves a dry mixture of portland cement and sand, using the same proportions as for grout. Brick pavers are installed on a damp cushion comprised of this mixture, followed by the same mixture between the paving units. After cleaning excess material from the paving surface, the paving is sprayed with a fine mist of water until the joints are saturated. The pavement should be maintained in a damp condition for a period of two or three days.

Brick paving without mortar joints may be swept with plain dry sand or a mixture of portland cement and sand. For the proper proportions of portland cement and sand, refer to the discussion on dry mixed and grout type mortars.

Expansion Joints. Consideration should be given to the potentials for thermal and moisture movements, and expansion joints provided to accommodate these movements. A single specific spacing or expansion joint size recommendation is not feasible for all types of installations. However, the following location guidelines are offered for large areas. General locations for expansion joints are: (1) parallel to curbs and edgings, (2) at 90-deg or right angle turns, and (3) around interruptions.

Mortarless brick paving usually has the ability to move slightly and accommodate these changes. Consequently, expansion joints in mortarless brick paving are not generally required. It is suggested, however, that expansion joint material be placed along fixed objects, such as curbs and walls.

For information on expansion joint size and spacing, see *Technical Notes 18 Series*, "Differential Movement". In addition to expansion joints in the mortared brick surface paving, consideration should be given to movement joints in the supporting base, which may also be affected by moisture and temperature changes.

Membrane Materials. Membranes are installed for several purposes: (1) to control or reduce the passage of moisture, (2) to discourage weed growth, and (3) as a separating layer to accommodate differential movement. To accomplish these tasks, membranes should be resistant to moisture and capable of resisting rot and decay. Generally, they are of sheet and liquid materials. Examples of the sheet form are: asphaltic roofing felt, polyethylene film, vinyl, neoprene and rubber. Liquid types are usually asphaltic, modified urethane or polyurethane bitumen. Installed properly, fluid types have some advantages over sheet membranes mainly because they are seamless and will conform to irregular surfaces.

Care should be exercised during construction to avoid membrane damage. Although some membranes resist abrasion better than others, protection should be considered especially for roof deck construction where resistance to moisture penetration is of primary importance.

Appearance and Esthetics. The visual impact of brick paving units results from the interplay of many factors; i.e., shape, size, color, texture and pattern. Most brick paving consists of solid, uncured units placed flat. However, cored or uncured brick placed on edge are also used as paving.

Bond Patterns. An endless variety of pattern effects can be achieved with brick paving. Therefore, it is important to specify the proper size of the unit, especially for pattern bonds. Two examples of pattern bonds are the "herringbone" and "basket weave" shown in Fig. 1. Before attempting a paving layout, the designer should be familiar with the availability of various types of brick paving units. A recent survey of members of the Brick Institute of America indicates about 38 sizes and shapes of brick paving units are available. These include rectangular, square and hexagonal units. In addition, a few manufacturers make special and molded shapes. The three most common types of paving units are shown in Fig. 2.

Color and Texture. Brick pavers are available in many colors and textures. Red is the most popular color and is available in several color ranges. Other colors available include buff, gray and brown shades.

The texture of a unit will affect its performance, installation and maintenance. Therefore, a few basic factors should be considered. Slip resistance is related

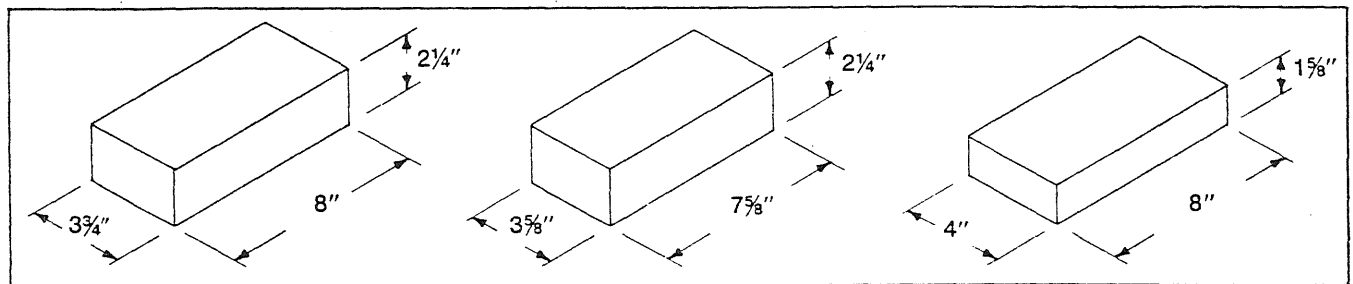


FIG. 2
Popular Brick Pavers

to the texture of the unit; the coarser the texture, the better the slip resistance. For interior use, smooth units are more responsive to the application of sealers, coatings and waxes and, thus, are easier to maintain or clean. Generally, low maintenance, smooth units are more desirable in high traffic areas of buildings, such as lobbies and foyers. Coarse textured units may be ground smooth in a fashion similar to terrazzo floors. Rough units are generally more suitable for exterior use where good slip resistance is desirable.

MATERIAL SELECTION

Brick. Several considerations affecting the selection of brick are: (1) traffic to which the floor or paving is subjected, (2) exposure to moisture and freezing cycles, and (3) the desired appearance. Resistance to chemicals and acids are often a major criterion for industrial paving. For information on chemical-resistant brick masonry, see *Technical Notes* 32.¹

Resistance to Abrasion. Resistance to wear and tear is generally associated with dense, hard burned brick. For floors not subject to heavy wear; e.g., residential and most non-industrial floors; a low absorption, dense brick meeting or exceeding the requirements of ASTM Specification C 62, grade SW should prove satisfactory. In addition, the denser the brick and the lower its absorption, the more resistant it is to discoloring and staining. Consequently, floors of dense, low-absorption brick are more easily cleaned and maintained.

Resistance to Weathering. For exterior pavement, resistance to freezing and thawing in the presence of moisture is perhaps more important than resistance to abrasive wear.

At the present time there do not exist any widely accepted standard specifications for brick units for floors and pavements. Therefore, care must be exercised in the selection and specification of brick units for this purpose.

In general, dark colored, hard burned brick units are associated with durability and good performance. This generalization, however, can be misleading, since modern brickmaking technology permits the manufacture of many units that are both light in color and extremely durable in use.

For best results, it is suggested that the selection of a brick for paving application be based on the knowledge of satisfactory performance of the units in a similar application. This type of information can usually be obtained from the manufacturer or his agent.

Lacking the specific knowledge of performance, it is suggested that the following physical properties of each, extruded brick units and molded brick units, be considered minimum.

For Extruded Brick: Minimum average compressive strength of 8000 psi, maximum average cold water absorption of 8 percent, and maximum saturation coefficient of 0.78.

¹For special purpose paving installations see the following specifications: ASTM C 7, Paving Brick; ASTM C 410, Industrial Floor Brick; and ASTM C 279, Chemical-Resistant Masonry Units.

For Molded Brick: Minimum average compressive strength of 4500 psi, maximum average cold water absorption of 8 percent, and maximum saturation coefficient of 0.78.

The above physical properties are purposely conservative. There are undoubtedly units that will not conform to these minimums that will perform very satisfactorily. It is therefore most important that performance data be used whenever possible.

Used Brick. The use of salvaged brick for brick paving is not recommended. The durability of masonry depends upon the uniform quality of materials and, generally speaking, used brick are not uniformly durable when exposed to weathering. They may spall, flake, pit and crack, due to freezing in the presence of moisture. For further discussion on used brick, refer to *Technical Notes* 15, "Salvaged Brick".

Base Material. Base materials generally have one or more purposes: (1) support, (2) drainage, and (3) ground swell protection. Cushion materials function as the term implies. They also serve to establish fine grading requirements.

Gravel Bases. For maximum drainage efficiency and the prevention of the upward flow of moisture due to capillary action, a clean, washed gravel should be specified. The size of the stones will depend upon the installation. Pea gravel is self-compacting and can be easily screeded to a finished grade. Where a thick base build-up is desired for drainage purposes, a larger stone size may be more economical.

Bases consisting of unwashed gravel mixed with fine clay and stone dust are popular because they are economical. Referred to as "stone screenings", "bank run", or "bluestone", this material compacts well and is readily available. However, it does present a few problems, such as a loss of porosity and drainage characteristics due to hardening from moisture. Brick in direct contact with this material may be susceptible to efflorescence, since moisture in combination with the stone dust particles can deposit water-soluble salts on the face of the brick paver.

Concrete Bases. Both existing and new concrete bases may be used for brick paving. New concrete should be installed following recommended concrete practices. If a mortar leveling bed is used, the slab surface should have a raked or float finish to facilitate good bond. If non-cementitious types of leveling beds or cushions are used, the surface need only be screeded, eliminating the need for further finishing.

If brick paving is placed over existing concrete, the concrete should be sound with any major cracks properly filled.

Asphalt Base. New or existing asphalt paving bases may be used to support brick paving. Mortar leveling beds are acceptable with asphalt bases; however, there will be little, if any, bond between the mortar and asphalt. Avoid placing mortar leveling beds on hot asphalt as flash setting of the mortar may occur. Major

defects in existing asphalt pavement should be repaired prior to installation of brick paving.

Cushion Material. Cushion material, placed between the base and the paver, functions as a leveling layer to help refine the finished grade and compensate for irregularities of surface and of units. It may be a 1 or 2-in. layer of sand, chat, pea gravel or stone screenings, or even several layers of roofing felt. Under extremely wet conditions, fine particle cushions, such as sand or stone screenings, should be avoided since drainage of moisture may be too slow.

Sand. It is recommended that sand for cushions, bases, joints and mortar be specified in accordance with ASTM C 144, Aggregate for Masonry Mortar. Sand should be free of clay to avoid "scumming" when swept over the face of brick units.

Sand and Cement Mixtures. Dry mixtures of sand and cement may be used as bases or cushions. One part portland cement may be mixed with three to six parts damp, loose sand. Bond is not usually achieved between the brick unit and the leveling bed when high sand ratio mixtures are used.

Roofing Felt. Roofing felt, generally of 15 to 30-lb weight, may serve as a cushion between brick pavers and concrete or asphalt paving. This type cushion can be installed rapidly and provides some compensation for minor irregularities between the surface of the base and the brick pavers. Roofing felt may also impart some resilience to the paving.

Setting Beds.

Mortar. Mortar setting or leveling beds may be used in conjunction with concrete and asphalt bases. A mortar bed for exterior paving should be a type M portland cement and lime mortar. For interior applications, type S or N is suitable. The thickness of the bed may vary from $\frac{1}{2}$ to 1 in.

Other mortars using high-bond additives or latex modified portland cement mortars are also available. These mortars should be mixed and used in strict accordance with the manufacturers' recommendations and only after suitable testing or performance documentation. One important advantage of high-bond mortar is its bonding ability to certain brick. Since high-bond mortar does not perform well with all brick, caution should be exercised. It is recommended that pre-project testing be used to assure the compatibility of the brick and mortar combination.

According to the Tile Council of America, latex mortars are somewhat more flexible than conventional mortars and have excellent water resistance and cleanability characteristics prior to setting up. This type of mortar is useful for mortared paving supported by a flexible structural system, such as a wood joist floor assembly.

Bituminous. Bituminous setting or leveling beds composed of aggregate and asphaltic cement may be used to support brick paving units. The mix is usually heated at an asphalt plant before being delivered to the

job. Typical bases supporting bituminous setting beds are usually concrete slabs or asphalt pavements. Proportions of asphalt and aggregate are generally determined by the specialty contractor and are beyond the scope of this *Technical Notes*.

Portland Cement-Lime Mortars. For exterior mortared paving on grade, type M (1:¼:3) portland cement-lime mortar is recommended. It has high durability and is specifically recommended for masonry in contact with earth. For interior mortared paving, type S (1:½:4½) or type N (1:1:6) portland cement-lime mortars are suitable. Type S mortar is recommended for both reinforced and unreinforced masonry where maximum tensile bond strength is required. It is also suitable for outdoor use, provided the brick slab is not in contact with the ground. Type N is a medium strength mortar suitable for interior use. Masonry cement mortars are not recommended. For further discussion on portland cement-lime mortars, refer to *Technical Notes* 8 Revised and 8A.

Colored Mortars. Colored mortars may be used in paving installations. Tinted aggregates, metallic oxide pigments, mixing and physical requirements of colored mortars are beyond the scope of this issue. Therefore, for information on colored mortars, refer to *Technical Notes* 8 Revised and 8A.

Dry-mixed or Grout Type Mortar. Sand and cement may be mixed dry and swept between the brick pavers laid without mortar joints. The pavement is then fogged down with water to set the mixture. Dry mixtures for exterior use should follow type M mortar proportions. For interior use, type S or N mortar is recommended.

Some installers prefer a soupy, grout-type mixture and pour the mortar joints. The basic difference between the grout and mortar ingredients is the omission of hydrated lime in the grout. To facilitate cleanup, the brick units may be coated with melted paraffin prior to laying. Thus, grout pours spilling on the face of the coated units will not stain the surface. Caution should be exercised to make sure that the paraffin does not coat the joint side of the brick where grout bond is desirable. After all grouting has been completed, a steam jenny may be used to clean off the paraffin coating. Hot water hosing or cold water under pressure are other ways to remove the paraffin coating.

Latex-Portland Cement Mortars. Latexes for cement mortar vary among manufacturers. Therefore, the manufacturer's directions should be carefully followed. Material and installation specifications are contained in ANSI A119.4-1973, "Specifications for Latex-Portland Cement Mortar".

High-Bond Mortar. SARABOND® high-bond mortar additive is a liquid saran polymer that greatly enhances the bonding, compressive and tensile strength characteristics of the resultant mortar. It permits a designer to take advantage of the higher tensile strength of brick masonry. For further information and discussion on high-bond mortar, refer to *Technical Notes* 38, "Brick Masonry with High-Bond Mortar".

REFERENCES

Future *Technical Notes* in this series will discuss and illustrate various types of installations suggested for patios, driveways, shopping center malls, suspended plaza decks and parking lots. For further information on related topics, the following publications are recommended:

1. *Technical Notes* 8 Revised, "Portland Cement-Lime Mortars".
2. *Technical Notes* 8A, "Standard Specifications for Portland Cement-Lime Mortar for Brick Masonry".
3. *Technical Notes* 15, "Salvaged Brick".
4. *Technical Notes* 18, "Differential Movement—Cause and Effect—Part I of III".
5. *Technical Notes* 18A, "Differential Movement—Expansion Joints—Part II of III".
6. *Technical Notes* 20 Revised, "Cleaning Clay Masonry Products".
7. *Technical Notes* 38, "Brick Masonry with High-Bond Mortar".
8. *1974 Handbook for Ceramic Tile Installation*, by Tile Council of America.



Technical Notes on Brick Construction

Brick Institute of America 1750 Old Meadow Road, McLean, Virginia 22101

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BRICK FLOORS AND PAVEMENTS PART II OF III

INTRODUCTION

This issue of *Technical Notes* expands upon the subject of brick paving as it pertains to non-industrial and residential applications. *Technical Notes* 14 Revised, Part I of III in this series discusses recommendations for materials and basic design considerations. This issue will discuss the basic types of brick paving and illustrate various on grade brick paving assemblies applicable to residential, commercial, institutional and urban usages.

Estimating tables for both mortared and mortarless paving are also included for the convenience of the designer.

General. There are two types of brick paving, mortared and mortarless. Mortared brick paving traditionally has been one of the most popular forms of installation. The use of mortarless brick paving, in the past several years, has become very popular and continues to be in great demand.

As in Part I, mortared brick paving will be referred to as rigid pavement and mortarless brick paving as flexible paving. Rigid paving is normally installed over a rigid base in order to maintain the integrity of the mortar joints. Flexible paving can be installed over either a rigid or flexible base.

Ecological Impact of Flexible Brick Pavement. The Franklin Institute Research Laboratories of Philadelphia, Pennsylvania, recently conducted a study for the Environmental Protection Agency on porous pavements. Although flexible brick paving was not included in this study, information contained in it is applicable to mortarless brick paving. The following discussion, based on conclusions of the final report, may be considered before designing a mortarless brick paving installation.

Flexible brick paving possesses the ability to return surface water to the subgrade through infiltration of the paving assembly and percolation of the subgrade. A summary of the objectives of the 1972 EPA study by the Franklin Institute Research Laboratories is as follows:

1. Primary objective—Alleviation of combined sewer overflow pollution.
2. Water supply—Return of rain water to the ground by percolation to reduce water supply problems.
3. Flash flooding—Return of most of the surface water to the ground to alleviate flash flooding and protect streams from erosion.

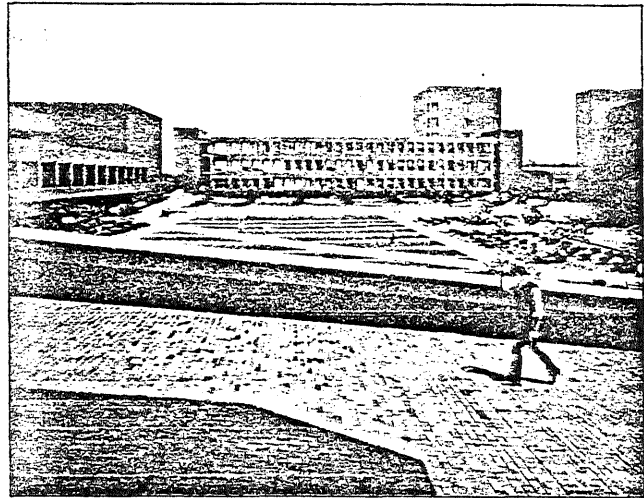


FIG. 1

Rochester Institute of Technology

4. Vegetation and natural drainage preservation to alleviate soil conditions beneath impervious paving, directly affecting vegetation and plant life of surrounding areas.
5. Puddling—To avoid the presence of water puddles in parking lots and other pedestrian areas.
6. Temperature and storm control—Meteorologists suspect that large expanses of very dark paved areas cause heated air to develop in populated urban areas on summer afternoons. Lighter colored pavement would provide a cooling effect.

The EPA study is basically concerned with the problem of conserving run-off rainfall and attempts to show where it is wasted and how it can be controlled. Mortarless brick paving over a porous base should perform well in this regard.

DESIGN FACTORS

There are certain design factors or considerations discussed in Part I that will be expanded into more detail in this issue. Those design considerations are as follows:

Traffic. It may be desirable to arrange the bond pattern so that anticipated paths of vehicular traffic are across brick coursing rather than parallel to the brick units. If traffic lanes are such that the travel path is perpendicular to the long dimension of the unit, it is more likely that the unit will transmit the load through uniform bearing pressure to the supporting base.

Drainage. Bond pattern orientation may differ for rigid and flexible pavement drainage considerations.

For example, in rigid pavement it may be desirable to have long mortar joints running in the direction of surface flow. Since mortar joints are generally less durable than brick units, concentrations of standing water should be avoided.

Brick walkways should be sloped to one side or crowned. Large areas may be sloped to special surface channels or main drains of a subsurface drainage system. The utilization of edge gutters on walkways adjacent to buildings may be a solution for some conditions.

Expansion Joints. The need for expansion joints and their spacing is discussed in *Technical Notes 14 Revised*, Part I of this series. Fillers for these joints must be compressible and of materials not subject to rot or vermin attack. Generally speaking, pavement joint fillers are made either solid or preformed out of materials such as polyvinylchloride, butyl rubber, silicone rubber, polychloroprene (neoprene) and other elastomeric compounds. Figures 2(a) and 2(b) show typical expansion joints of preformed and solid type fillers. Separation of paving layers may be accomplished with sand cushions or sheet membranes.

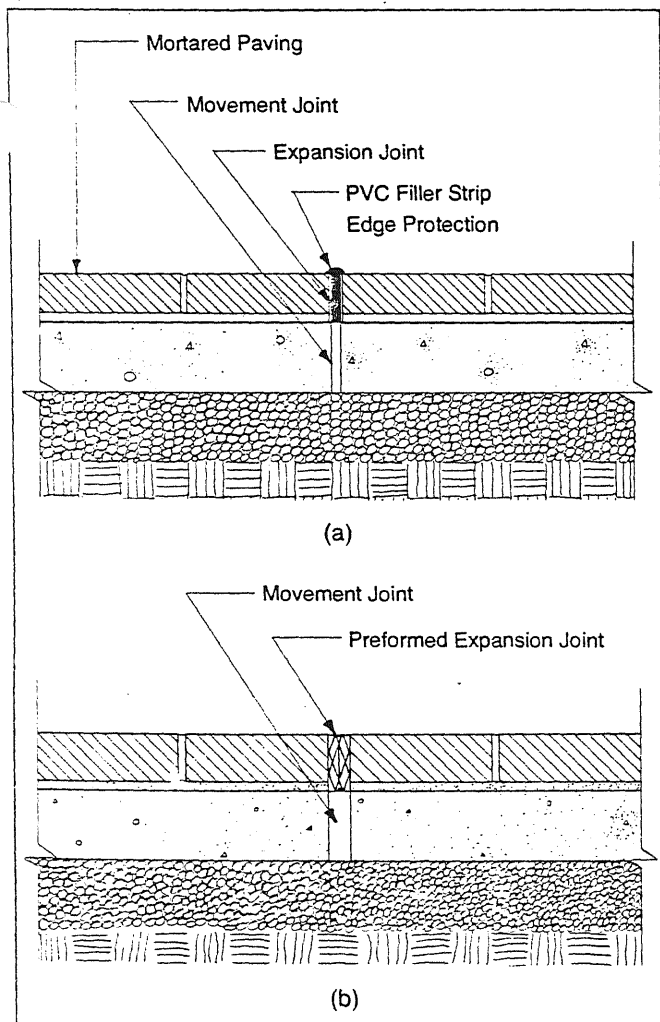


FIG. 2
Expansion Joints

Bond Pattern. The most popular paving patterns are shown in Fig. 1 of Part I of this *Technical Notes* series. These may be laid either with or without mortar joints. Patterns to be laid without mortar joints, such as the basket weave, herringbone, all the variations of the basket weave, and the running and stack bond mixed, will require brick pavers with length dimensions exactly twice that of the width, such as a 4-in. by 8-in. or 3¾-in. by 7½-in. unit. The remaining patterns using rectangular pavers can be laid without mortar joints using nominal size units. For rigid or mortared paving, the designer should keep in mind that a nominal unit, such as a 4 by 8-in. unit, includes the mortar joint thickness. For layout on a pattern with mortar joints, use nominal dimensions.

Patterns that best resist movement in flexible pavements are the herringbone and running bond. However, the selection of a pattern should not be limited to this factor alone since restraint may be frequently provided by the presence of walls, curbs, and planters. Due to the number of shapes, sizes, and pattern variations possible, all the possibilities can not be explored in this *Technical Notes*. The designer is therefore encouraged to develop other variations or original designs.

Efflorescence. In order to reduce or eliminate the occurrence of efflorescence on brick paving, an understanding of the nature and mechanisms is an essential requirement.

Technical Notes 23 and 23A discuss the sources of soluble salts, moisture, and nature of efflorescence, and it is suggested that the designer become familiar with these issues.

Brick units which will not contribute to efflorescence are readily available in all parts of the United States. The details of a pavement assembly should include provisions for separating base and cushion material, suspected of containing soluble salts, from contact with brick pavers. Proper drainage of the pavement is required to aid in reducing the source of moisture.

SUGGESTED BRICK PAVING DESIGN ASSEMBLIES

The supporting base for an on grade brick paving assembly may be one of three types as discussed in Part I of this series: (1) rigid, (2) semi-rigid, and (3) flexible. The paving assemblies included herein are suggested methods, based on experience, for various types of usages. The following suggested assemblies make use of all three bases.

Figure 3—Mortared Brick Paving. Mortared brick pavers may be used for virtually any type of design condition for both interior and exterior applications.

Figure 4—Concrete or Asphalt Base. Flexible brick paving may be installed on these bases as shown for pedestrian malls or slow vehicular traffic as discussed in Part I of this series.

Figure 5—Existing Concrete or Asphalt Bases. Flexible brick pavers can be installed as shown on an

existing rigid or semi-rigid base of a residential driveway.

Figure 6—New or Existing Concrete Base. Mortarless pavers may be installed as shown on a new or existing rigid base of a residential patio.

Figure 7—Concrete Base For Interior Flooring. Interior brick flooring may be installed on a rigid base similar to an outdoor residential driveway. The depressed slab eliminates an abrupt level change from one floor finish to another.

Figure 8—Gravel Base. This type of flexible base is suitable for a residential patio in areas that experience severe precipitation, subsurface drainage problems, and high ground water tables.

Figure 9—Gravel Base. This flexible paving assembly is suitable for a residential driveway.

Figure 10—Gravel Base. This is another type of flexible brick paving suitable for residential driveway use.

Figure 11—Gravel Base. This assembly is intended to accommodate light pedestrian traffic of walkways.

Figure 12—Sand-Portland Cement Base. This type of base is suitable for pedestrian mall traffic.

Figure 13—Sand Base. This flexible paving installation is suitable for residential patios in areas subject to low ground water tables and slight to moderate precipitation.

INSTALLATION AND WORKMANSHIP

There are certain factors that the pavement designer should be aware of before a final design is determined. These factors will be discussed in relation to Figs. 2 through 13.

Mortared Pavement. It is suggested that this type of installation be executed by a skilled mason or tile setter. A discussion on the various types of mortar available is contained in Part I of this series.

Bituminous Setting Bed. Bituminous setting beds are usually placed on rigid or semi-rigid bases as noted in Fig. 4. The thickness of the base is a matter of design and should be sized to accommodate the traffic loading and dead weight of the brick pavers and other materials. Design of the supporting bases are beyond the scope of this *Technical Notes*, but generally are 4 to 6 in. in thickness. Brick pavers are installed hand tight, on a bituminous setting and leveling bed. A tack coat of 2 percent neoprene oxidized asphalt is applied to the setting bed prior to laying brick pavers. The porous bituminous setting bed may consist of approximately 7 percent asphalt and 93 percent graded sand. Delivered hot from the plant, the bitumen material is rolled to a $\frac{3}{4}$ -in. depth. To accommodate light vehicular traffic, one installer recommends an application of a primer coat of rapid curing cut-back asphalt to the concrete slab or asphalt pavement.

Roofing Felt Cushion. Where regular flat brick pavers are used, two layers of 15-lb roofing felt over a rigid or semi-rigid base can suffice as a cushion.

Depressed concrete slabs should be considered in order to avoid an abrupt change in floor finishes (Fig. 7). An exaggerated vertical projection of one unit above the other can occur as a result of overlapping of felt paper. However, this can be avoided by abutting the edges before the pavers are laid.

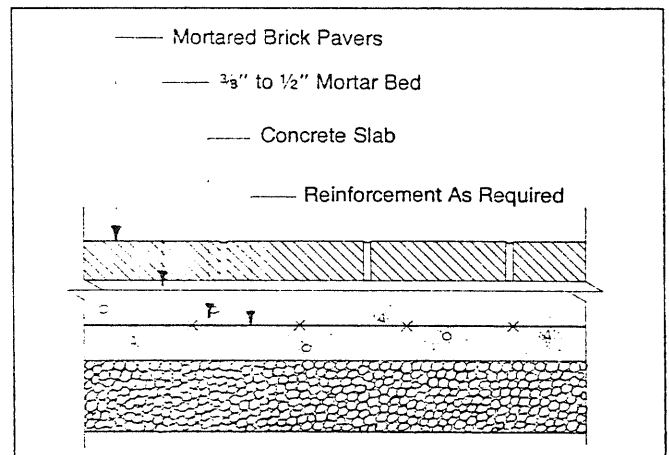


FIG. 3
Mortared Brick Paving

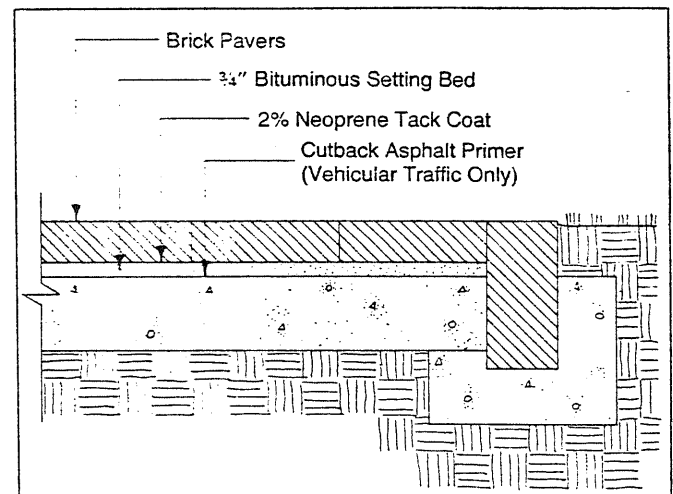


FIG. 4
Concrete or Asphalt Base

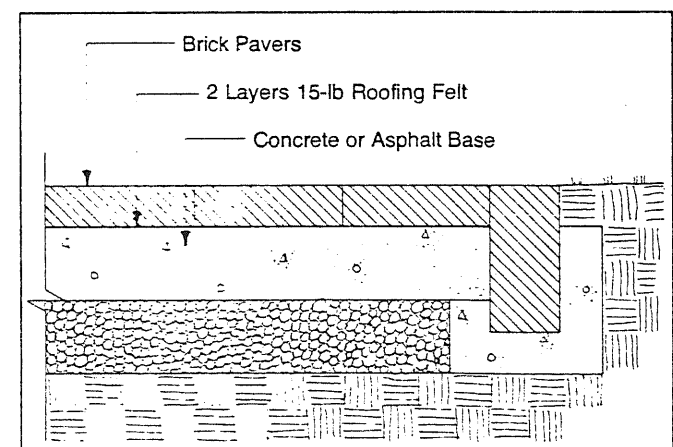


FIG. 5
Existing Concrete or Asphalt Base

Flexible Bases. Only flexible paving should be placed over flexible bases. Generally, flexible bases are the most economical type of base to install. They usually consist of layers of gravel, damp loose sand or mixtures of sand and cement.

Porous gravel bases may be of either graded or ungraded stone. Ungraded gravel or stone has the general advantage of a better interlocking quality, whereby graded gravel has a tendency to roll under foot. Stone screenings containing finer particles generally compact better than pea gravel. However, pea gravel has better subsurface drainage characteristics. In Fig. 8, a ½-in. sand cushion is recommended because it will accomplish two basic purposes. The brick pavers can be laid more efficiently to the desired grade, and the sand cushion lends better stability to the brick paver. In this assembly it is mandatory that a membrane be used or the sand will eventually settle through the pea gravel.

Gravel for the base in Fig. 9 should contain stones ranging from 1 in. to screenings size. This type is often referred to in many localities as "crusher-run" stone.

The assembly shown in Fig. 10 contains a 2-in. stone base, approximately half of the base thickness shown in Fig. 9. This reduced base is adequate provided the brick paver thickness is increased, and is easily accomplished by placing the units on edge. In this installation brick units may be cored instead of 100 percent solid. Road construction equipment (Fig. 9) is generally required to make a smooth, hard, well bonded support base prior to placement of the thin stone screenings layer. Compaction of the 2-in. stone screenings base (Fig. 10) may be accomplished with less elaborate equipment. It is more suitable for compaction with hand tools. Experience has shown that the assembly in Fig. 10 will accommodate residential driveway traffic as well as the assembly shown in Fig. 9.

For walkways (Fig. 11), screenings are spread uniformly in place after grading and edging have been completed. Then the screenings may be moistened and thoroughly compacted with hand or mechanical equipment. Rescreeding and more compaction may be necessary to accomplish the desired grade as specified. A membrane layer of asphalt impregnated roofing felt or polyethylene plastic sheeting is placed over the screenings to prevent efflorescence and for other purposes as previously discussed.

In special cases, it may be advantageous to add portland cement to stone screenings to provide stabilization where surface drainage slopes are critical. One part portland cement is added to 6 parts stone screenings by volume and mixed with only enough water to form a ball. This mixture is screeded into place and allowed to set up. A stable base results and will permit some drainage through the screenings.

For large paved areas, such as a pedestrian mall, Fig. 12 shows an installation which lends itself to soils with generally good subsurface drainage characteristics. A grid system of earth trenches is excavated to accommodate reinforced concrete grade beams. After the con-

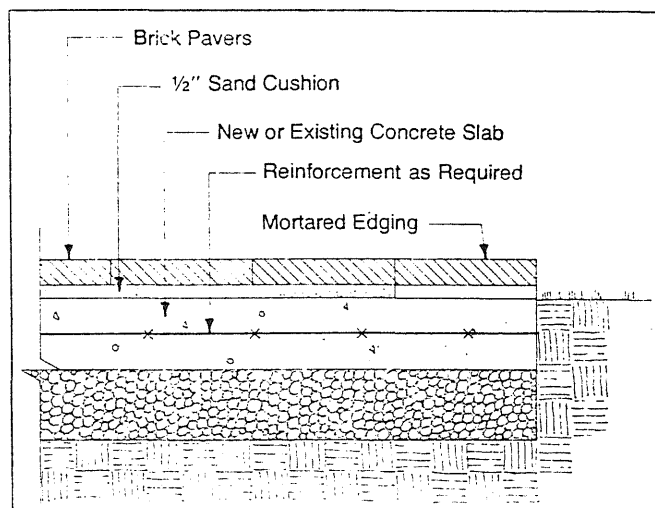


FIG. 6
New or Existing Concrete Base

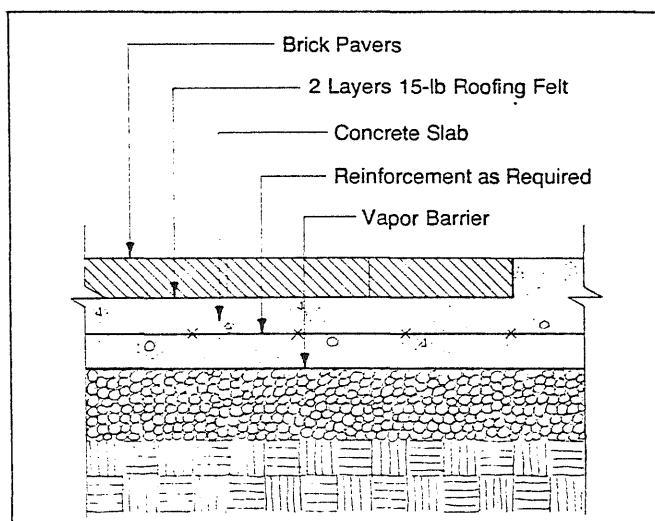


FIG. 7
Concrete Base for Interior Flooring

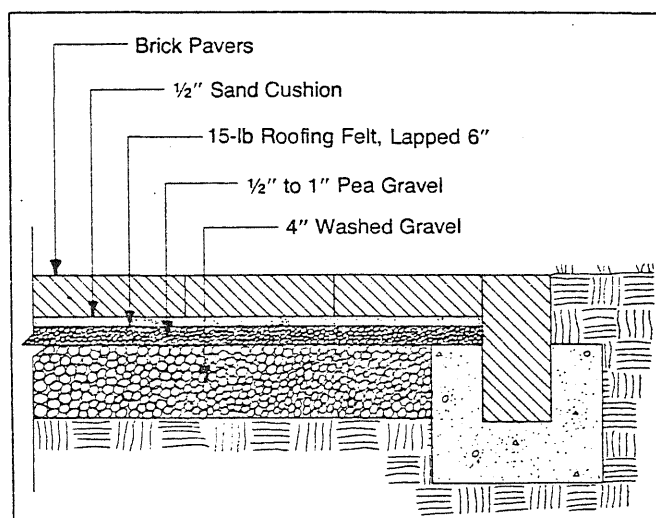


FIG. 8
Gravel Base

crete has cured, the subgrade is stripped away and replaced with a sand-cement base (3 to 6 parts sand to one part portland cement). A 1-in. sand cushion is spread over the compacted base to facilitate laying the pavers and to separate the pavers from the base.

Figure 13 shows the most economical type of installation for a residential patio. It is recommended only over soils that have good subsurface drainage characteristics.

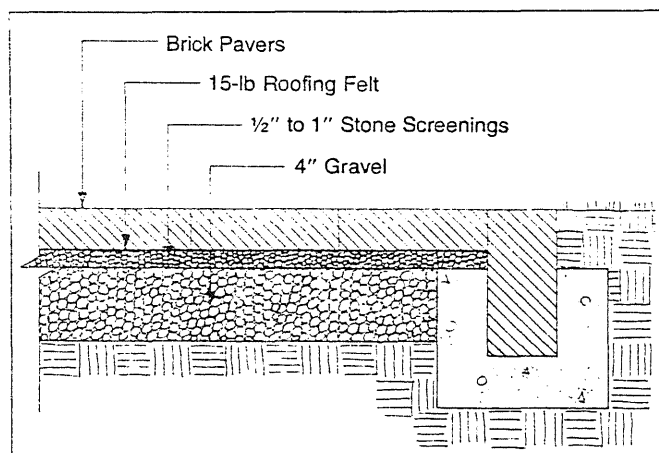


FIG. 9
Gravel Base

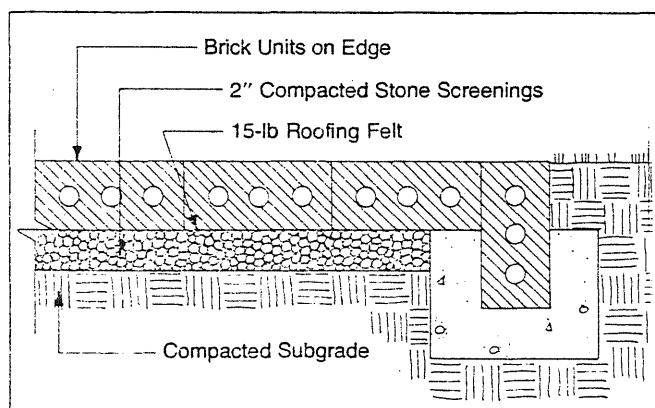


FIG. 10
Gravel Base

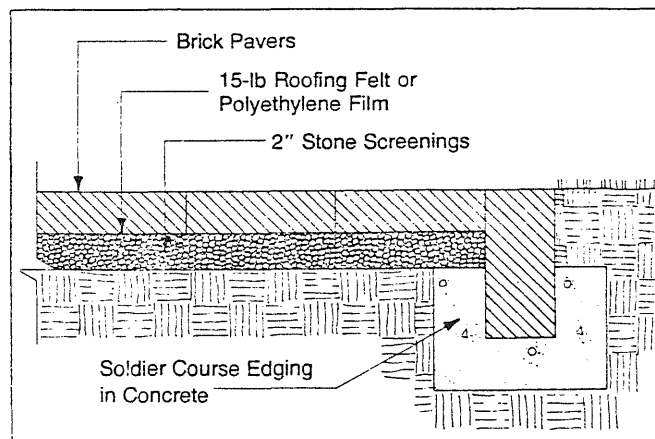


FIG. 11
Gravel Base

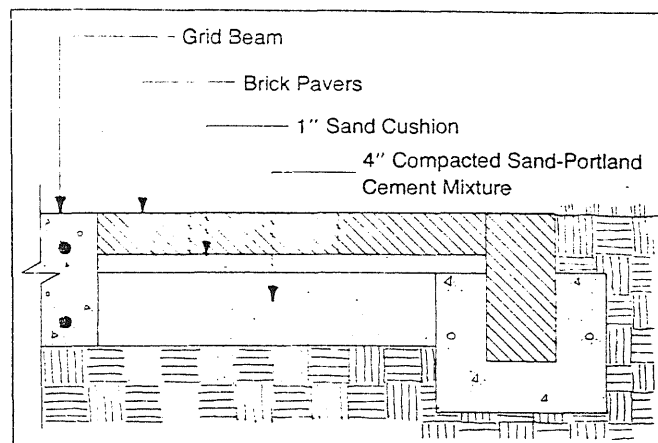


FIG. 12
Sand-Portland Cement Base

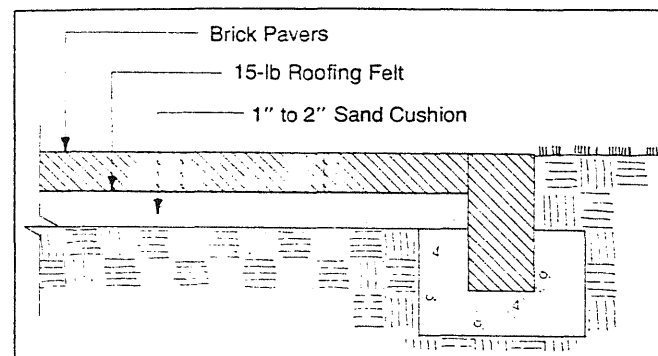


FIG. 13
Sand Base

SUMMARY

This issue of *Technical Notes*, the second in a series of three, has discussed brick paving installations, materials, and considerations based on existing knowledge and experience. No effort is made or implied that this is a total discussion of the subject matter, since conditions vary widely throughout the country. However, it is a basis from which a designer can develop successful brick paving installations.

Part III of this series will continue the discussion on paving assemblies and include suspended diaphragm bases, reinforced brick structural slabs and the use of high-bond mortared pavement. Suggested ways of cleaning and maintaining both interior and exterior brick pavements will also be covered.

REFERENCES:

1. "Efflorescence. Causes", *Technical Notes* 23 Revised, December 1969. Brick Institute of America.
2. "Efflorescence. Prevention and Control", *Technical Notes* 23A, January 1970. Brick Institute of America.
3. "Good Practice for Construction of Mortarless Brick Paving and Flooring", Brick Association of North Carolina, Greensboro, North Carolina.
4. "Brick Floors and Brick Paving", BDA Technical Note, May 1973. Brick Development Association, London, England.
5. "Investigation of Porous Pavements for Urban Runoff Control", March 1972. Franklin Institute Research Laboratories, Philadelphia, Pennsylvania, sponsored by the Environmental Protection Agency.

Estimating Table 1^{a, b}
Brick Paver Units
for Mortarless Paving

Face Dimensions (actual size in inches) w × l		Paver Face Area (in sq in.)	Paver Units (per sq ft)
4	8	32.0	4.5
3¾	8	30.0	4.8
3¾	7¾	27.6	5.2
3¾	8¼	32.0	4.5
3¾	7¾	30.0	4.8
3¾	7½	28.2	5.1
3¾	7¾	29.1	5.0
3¾	11¾	42.1	3.4
3¾	8	29.0	5.0
3¾	11¼	42.6	3.4
3¾	8	28.5	5.1
3½	7¾	27.1	5.3
3½	7½	26.3	5.5
3¾	7½	25.3	5.7
4	4	16.0	9.0
6	6	36.0	4.0
7¾	7¾	58.1	2.5
7¾	7¾	60.1	2.4
8	8	64.0	2.3
8	16	128.0	1.1
12	12	144.0	1.0
16	16	256.0	0.6
6	6 Hexagon	31.2	4.6
8	8 Hexagon	55.4	2.6
12	12 Hexagon	124.7	1.2

^aTable is based on BIA survey conducted in 1973. According to the survey approximately 38 sizes are currently manufactured.

^bThe above table does not include provisions for waste. Allow at least 5% for waste and breakage.

Estimating Table 2^a
Brick Paver Units
for Mortared Paving

Brick Paver Units w × l × t	Paver Units per sq ft	Cubic Feet of Mortar Joints per 1000 Units	
		¾-in. Joint	½-in. Joint
3¾ × 8 × 2¼ ^b	4.3	5.86	—
3¾ × 7¾ × 2¼	4.5	5.68	—
3¾ × 8 × 2¼	4.0	—	8.0
3¾ × 7¾ × 1¼	4.5	3.15	—
3¾ × 8 × 1¼	4.0	—	4.0

^aThe table does not include provisions for waste. Allow at least 5% for brick and 10% to 25% for mortar.

^bRunning bond pattern only.

Estimating Table 3
Material Quantities
for ½-in. Mortar
Setting Beds^a

Mortar Type and Material	Cubic Feet ^b per 100 sq ft	Material Weight per cu ft in lb
Type N (1:1:6) portland cement hydrated lime sand	4.17	15.67 6.67 80.00
Type S (1:½:4½) portland cement hydrated lime sand	4.17	20.89 4.44 80.00
Type M (1:¼:3) portland cement hydrated lime sand	4.17	31.33 3.33 80.00

^aThese quantities are only for setting bed. For mortar joint quantities see Table 2.

^bThe table does not include provisions for waste. Allow 10% to 25% for waste.



Technical Notes on Brick Construction

14B

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Brick Institute of America 1750 Old Meadow Road, McLean, Virginia 22101

BRICK FLOORS AND PAVEMENTS PART III OF III

INTRODUCTION

Technical Notes 14 Revised and 14A Revised, Parts I and II of this three part series deal with general considerations, classifications, materials selection, design factors, types of installations and suggested paving design assemblies. This issue of *Technical Notes* will discuss assemblies and installation techniques pertaining to special paving applications.

Brick paving may be adapted to suspended diaphragm bases, reinforced brick structural slabs with conventional mortars and installations using high-bond latex modified mortars. This issue of *Technical Notes* will discuss these applications and suggest ways of cleaning and maintaining brick floors.

SUSPENDED DIAPHRAGM BASES

To assure long term performance on a roof deck or suspended plaza, certain special design factors must be considered to minimize the risk of deterioration. A roof deck plaza application generally must be structurally sound, esthetically appealing, durable and economical to install. Consequently, there are special moisture, thermal and structural considerations inherent in this type of application.

Moisture. To insure an effective waterproofing system, it becomes necessary to give proper attention to base and counter flashing details of parapet walls as well as to the selection of the proper type of horizontal membrane.

For mortarless paving, adequate drainage is very important to prevent damage to or displacement of pavers due to water and/or frost action. Sloping membranes in conjunction with porous base layers will permit water to percolate or run freely to roof drains. Special all-level roof drains are available which will handle both pavement surface and subsurface water (see Fig. 1).

Consideration should be given to horizontal differential movement between structural concrete slabs and the waterproofing membrane. Built-up bituminous membranes generally have non-elastic properties. Seamless liquid waterproofing and rubber sheet membranes are usually elastic in behavior and are capable of adjusting to horizontal differential movement that may occur in the supporting base.

Thermal Considerations. The thermal aspects of roof terraces are similar to those of normal roofs. The position of roof insulation is important with respect to the temperature variation of each element in a paved roof assembly. Under many conditions it is advantageous to place insulation directly over membrane waterproofing when considering thermal and condensation effects.

Generally speaking, roof deck insulation should be of a non-rotting, moisture resistant, closed-cell type of material capable of retaining its thermal resistance in the presence of water. Traffic loadings may be supported on insulation materials in a deck assembly provided the insulation material is structurally adequate.

Brick pavers like all materials change dimensionally with changes in temperature. A slip plane between pavers and a waterproofing membrane is recommended to avoid disruption of the membrane. For example, it may consist of a porous gravel cushion, asphalt impregnated protection board or other materials capable of withstanding both horizontal abrasive movement and vertical traffic loadings.

Structural Considerations. The structural design of a suspended base should follow normal accepted design procedures. The dead weight of brick pavers combined with other materials and design conditions, such as live loads, vibration and impact from traffic, should be considered. For structural design purposes, the dead weight of mortared or mortarless brick pavers may be taken at approximately 10 psf per inch of thickness. Since brick pavers are available in various thicknesses, their total weight will vary. The most popular pavers mentioned in Part I are 1½ in. to 2¼ in. thick, weighing approximately 16 to 22 psf, respectively.

In residential wood joist design, consideration must be given to the additional weight of brick pavers. It will be necessary to consult a structural design loading table for wood joists and select a suitable grade and joist size. A good reference manual is "Wood Structural Design Data" by the National Forest Products Association (NFPA). The subfloor thickness and grade should also be checked for structural adequacy for supporting brick pavers.

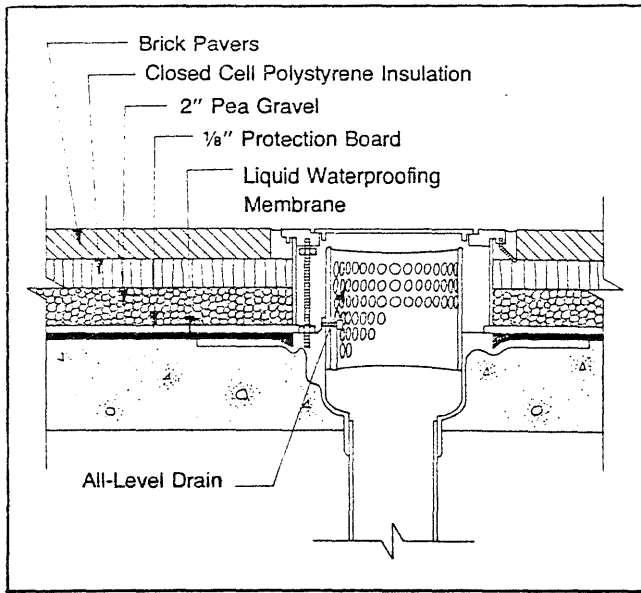


FIG. 1
Reinforced Structural Concrete Slab

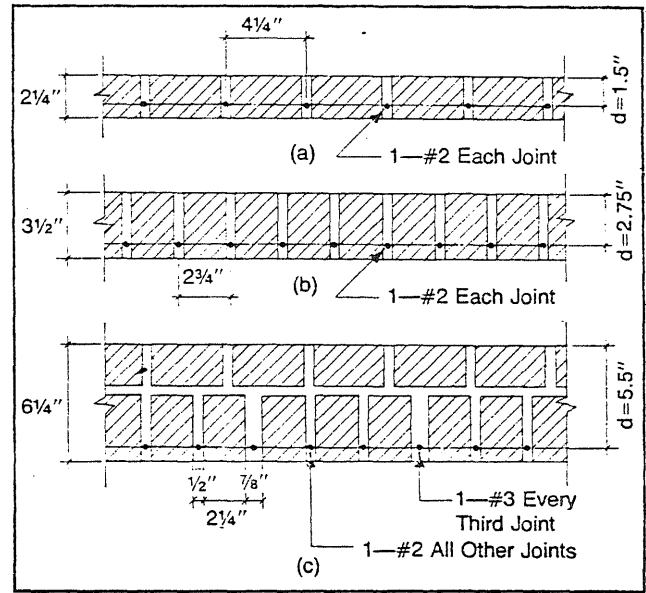


FIG. 2
Reinforced Brick Masonry

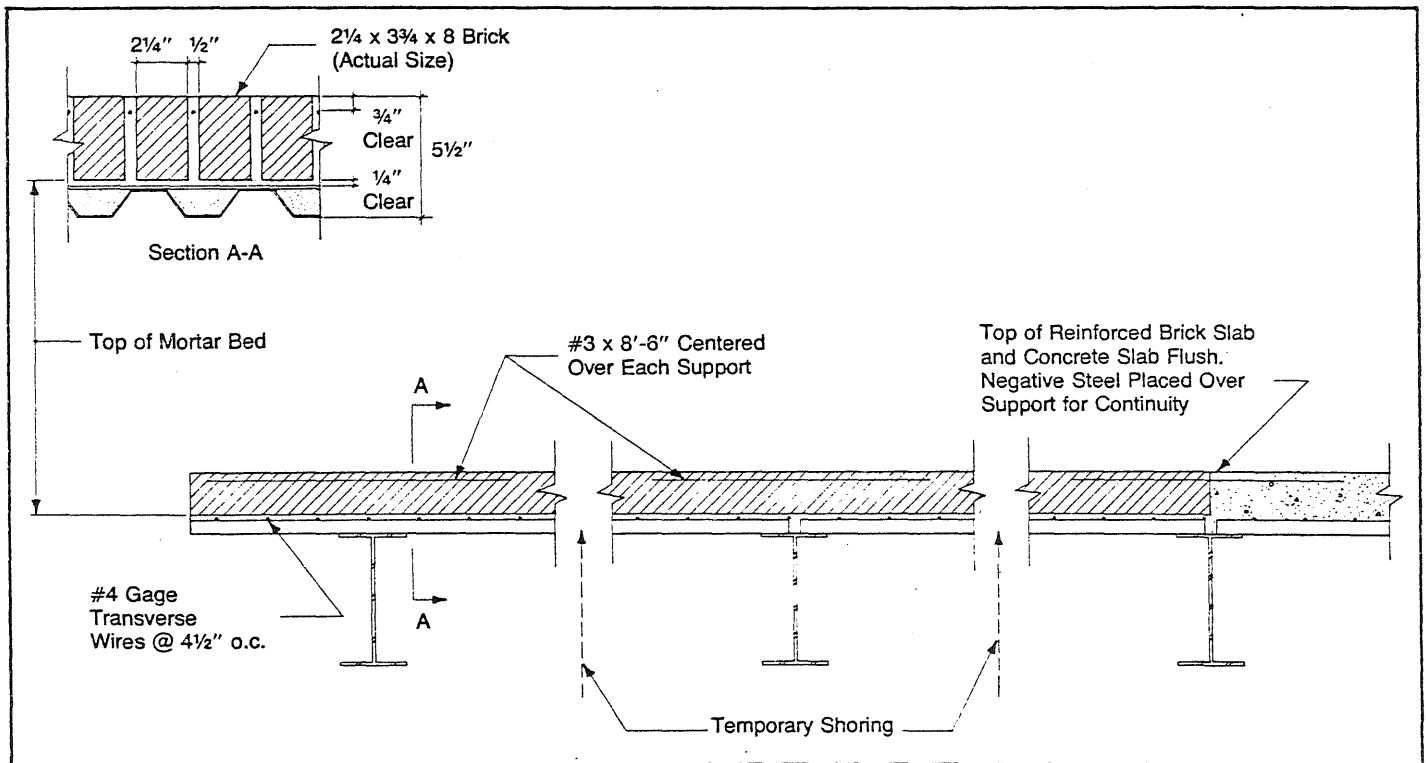


FIG. 3
Corrugated Sheet Steel—Reinforced Brick Masonry Slab Assembly

For mortared paving, diaphragm action becomes important in order to maintain the integrity of mortar joints. Deflection should be limited to $1/600$ of the span for mortared paving and $1/360$ for flexible paving.

REINFORCED CONSTRUCTION

Reinforced brick paving can be used to span an open space or for use over a fill which may tend toward uneven settlement. Reinforcement of the masonry can

eliminate the necessity for a separate reinforced concrete slab or other rigid base.

Reinforced brick masonry slabs are practical, especially over relatively short spans. They are capable of satisfying design loadings for pedestrian and vehicular traffic. Model building codes stipulate live loads ranging from 50 to 250 psf. A $2\frac{1}{4}$ -in. thick brick slab may be designed to support a 50 psf live load, spanning almost 6 ft [Fig. 2(a)]. Also, using the same strength

TABLE 1^a
Reinforced Brick Masonry Slabs

Live Load (psf)	Maximum Clear Span		
	t = 2¼"	t = 3½"	t = 6¼"
	1 #2 each joint [Fig. 2(a)]	1 #2 each joint [Fig. 2(b)]	1 #3 every 3rd joint 1 #2 remaining joints [Fig. 2(c)]
30	6'-10"	10'-5"	14'-5"
40	6'-3"	9'-9"	13'-8"
50	5'-10"	9'-2"	13'-1"
100	4'-6"	7'-3"	10'-11"
250	1'-10"	5'-0"	7'-10"

^aNote: Design parameters for the above Table 1 are as follows: The brick compressive strength average is 8000 psi. The mortar is type M (1:¼:3), portland cement-lime and sand. Reinforcement steel is ASTM A 82-66, $f_s = 20,000$ psi. A simple span loading condition was assumed

$$\left(M = \frac{wl^2}{8} \right)$$

All mortar joints are ½ in. thick for the slabs shown, except as noted.

brick and mortar, but by simply turning a unit on edge to increase the slab's thickness, the design load capacity can be doubled (100 psf) and the span increased to over 7 ft [Fig. 2(b)].

The design of reinforced brick masonry slabs, as shown in Table 1, is based on a rational analysis and the Standard, *Building Code Requirements for Engineered Brick Masonry*, BIA(SCPI), August 1969. For additional information on the design of reinforced brick masonry slabs, the 17 Series of BIA *Technical Notes* on Brick Construction contain design examples and calculation procedures.

Brick on Sheet Steel Forms. A variation of reinforced brick construction utilizes corrugated sheet steel as a base. The steel serves as combined form and reinforcing and can provide an economical solution to the problem of constructing brick floors over open spans. For continuous spans, negative steel is placed in grouted mortar joints. Brick are placed on a bed of mortar and vertical joints are filled with mortar or grout (Fig. 3).

A number of years ago, the Research and Development Department, Granco Steel Products Co., tested this method of construction to "determine the feasibility of using 24-gauge Cofar¹ on 14-ft spans, using bricks, mortar and steel acting compositely to give a structurally sound floor slab."

Brick were standard size, dry-press, red brick with an average compressive strength of 7800 psi. The mortar was ASTM C 270, type M, of portland cement and hydrated lime. The steel form was of 24 gage corrugated sheet steel (4.25-in. pitch, 1.2-in. depth) with positive reinforcement.

The test specimen was approximately 17 in. wide and 5½ in. deep over two continuous 14-ft spans. Test loads consisted of various increments of uniform and concentrated loads on combinations of one and two

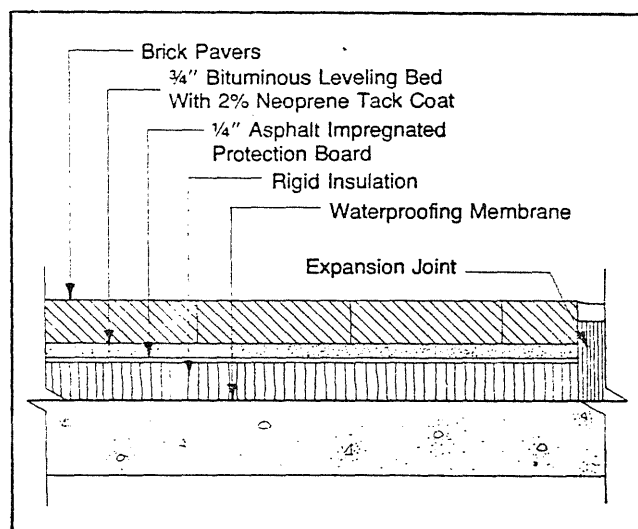


FIG. 4
Reinforced Structural Concrete Slab

spans at a time. Repeated concentrated loads were applied and relieved for as many as 500,000 cycles.

Conclusions to the test report emphasized three pertinent points:

1. The brick slab had adequate stiffness and minimal deflections.
2. Fatigue failure did not occur.
3. Failure occurred only when the actual uniform load exceeded 7 times the design load.²

HIGH-BOND MORTARED PAVEMENT

General. Rigid brick paving installed with high-bond mortar may be generally more resistant to water penetration than paving with conventional mortars. This advantage is primarily the result of higher bonding characteristics between the mortar and brick unit.

SUGGESTED BRICK PAVING DESIGN ASSEMBLIES

The following assemblies illustrate how brick paving can be adapted to suspended diaphragm bases of various types. These support bases may consist of reinforced brick masonry slabs, reinforced concrete slabs, steel decking, and wood framing.

Figure 1—Reinforced Structural Concrete Slab. This assembly is suitable for exterior pedestrian traffic. The pea gravel percolation layer will permit rapid drainage to occur, thus preventing possible damage from freeze-thaw cycles of trapped water. The protection board should be at least ¼ in. in thickness and of asphalt impregnated material.

¹Cofar is the trade name for combined form and reinforcing corrugated sheet steel produced by the Granite City Steel Corp., Granite City, Illinois.

²Granco engineers designed for 50 psf superimposed loads. When this specimen was tested, allowable design stresses were lower than now permitted. This perhaps explains why such a large factor of safety was exhibited.

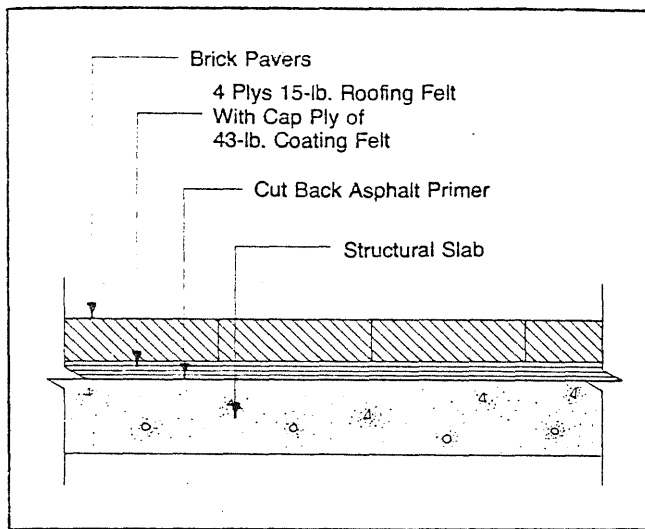


FIG. 5
Reinforced Structural Concrete Slab

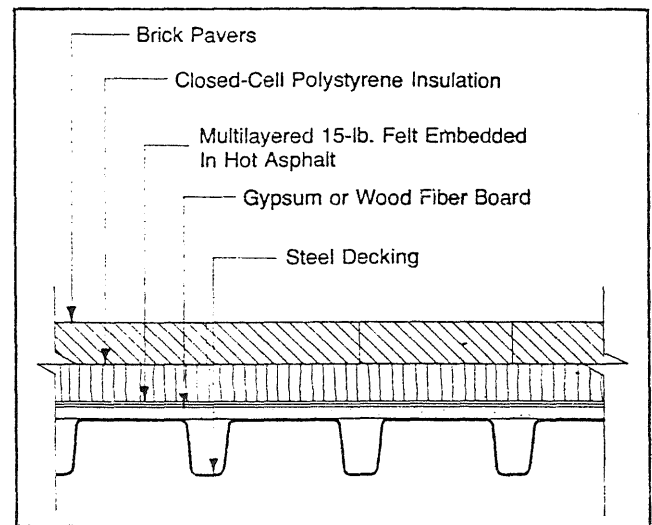


FIG. 6
Steel Decking Base

Figure 2—Reinforced Brick Masonry Slab. The various types of reinforced brick masonry slabs, as illustrated, can support a wide range of live load conditions as shown in Table 1. Reinforced brick masonry slabs eliminate the need for other types of support bases.

Figure 3—Corrugated Sheet Steel—Reinforced Brick Masonry Slab Assembly. This assembly combines both reinforced brick masonry and steel decking, constructed with positive and negative reinforcing steel for continuous span applications.

Figure 4—Reinforced Structural Concrete Slab. This assembly is suitable for exterior pedestrian traffic and utilizes a bituminous leveling bed.

Figure 5—Reinforced Structural Concrete Slab. This assembly, utilizing conventional build-up roofing, can be easily adapted to flexible brick paving suitable for outdoor pedestrian traffic.

Figure 6—Steel Deck Base. This type of construction may be designed as a non-rated or rated fire resistive assembly. Figure 6 illustrates only the general material composition. For specific types of fire resistive assemblies consult Factory Mutual and Underwriters' Laboratories.

Figure 7—Wood Framing Assembly. This assembly is suitable for mortarless paving used in residential frame construction.

Figure 8—Wood Framing Assembly. This assembly is suitable for mortared paving used in residential frame construction.

INSTALLATION AND WORKMANSHIP

There are certain factors that the designer should be aware of before a final design is selected. These factors will be discussed in relation to Figs. 1 through 8.

Drains and Waterproofing. For suspended decks where control of surface drainage is important, all level

drains and waterproofing membranes (Fig. 1) should be installed in strict accordance with the manufacturers' instructions and specifications.

Insulation. In Fig. 4, the insulation is required to support a specific design live load and also must be capable of withstanding the temperatures transferred through the protection board from the application of hot bitumen. Consequently, one installer of this system suggests that the insulation be capable of withstanding a minimum temperature of 300 F (149 C).

In Fig. 6, the insulation is usually installed in steep asphalt. If the roofing assembly's wearing surface is temporary in nature, the insulation may be laid loose and removed later for reuse. If a temporary installation is desired, the possibility of uplift due to high winds should be considered.

Mortar. High-bond and latex modified portland cement mortars vary among manufacturers. Therefore, instructions for their installation should be carefully followed. When mortar joints are thumb-print hard, they should be properly tooled. Various types of conventional portland cement-lime mortars are discussed in Part I.

Reinforced Brick Masonry Slabs. Brick masonry slabs spanning open spaces are constructed on forms with brick units spaced accordingly, to allow for proper joint thickness. Mortar is used to seal the bottom of the joint and also to serve as a support for reinforcing steel. After the steel is placed, all the joints are grouted. To insure complete filling of the joints, the grout should be carefully puddled. More detailed suggestions for constructing RBM soffits are given in *Technical Notes* 36A, "Design and Construction of Brick Soffits."

CLEANING

To facilitate cleanup of high-bond mortar or grouted installations, brick pavers may be prewaxed on the

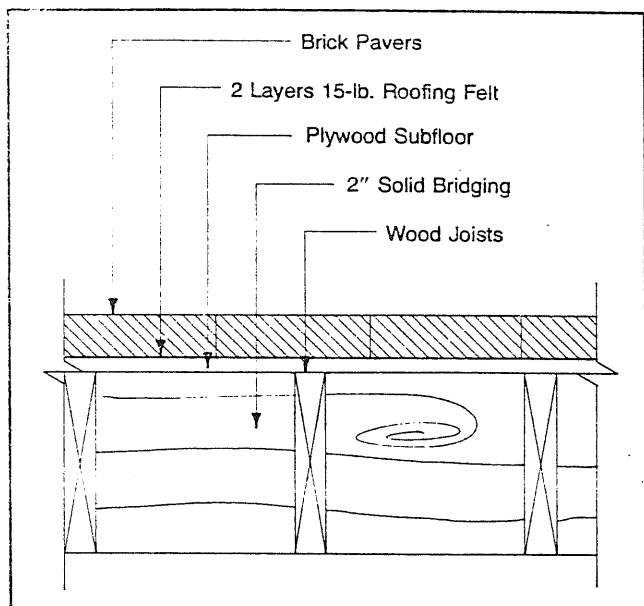


FIG. 7
Wood Framing Assembly

exposed face with a good grade of paraffin. The paraffin should have a melting range between 150 F (66 C) and 170 F (77 C). Experience has shown that paraffins with lower melting points are often affected by hot sunlight, while those with higher melting points are difficult to remove. Prewaxed pavers utilized in conjunction with conventionally grouted joints will also be easier to clean. While waxing the pavers, care must be exerted to prevent the edges or joint surfaces from becoming smeared with paraffin. The edges must remain clean for proper bond.

When cleaning high-bond mortared pavement, it is recommended that cleaning be executed as soon as possible after the mortar joints have been allowed to cure. Due to high bond characteristics of this mortar, the pavement surface should not be left uncleaned for longer than three weeks.

Steam cleaning is effective in melting the paraffin coating and lifting excess mortar. Drains should be protected from clogging by floating wax. A visual inspection after cleaning may reveal problem areas requiring scraping or light brushing with a wire brush.

Generally speaking, if care is exercised during mortar application, cleaning can be avoided or held to a minimum. Mortarless installations should require little or a minimum amount of attention. On conventionally mortared installations, wet sand swept over the surface will often remove mortar droppings. Burlap bags may also be used to remove excess mortar as the mason progresses. If dry cleaning or hosing with water fails to flush the surface clean, use a cleaning solution and the procedures in *Technical Notes 20*, "Cleaning Clay Products Masonry." Avoid the use of strong acid solutions where possible. Strong acids can dissolve mortar from the joints and kill grass and shrubbery. They may also cause "acid burn" discolorations on the brick

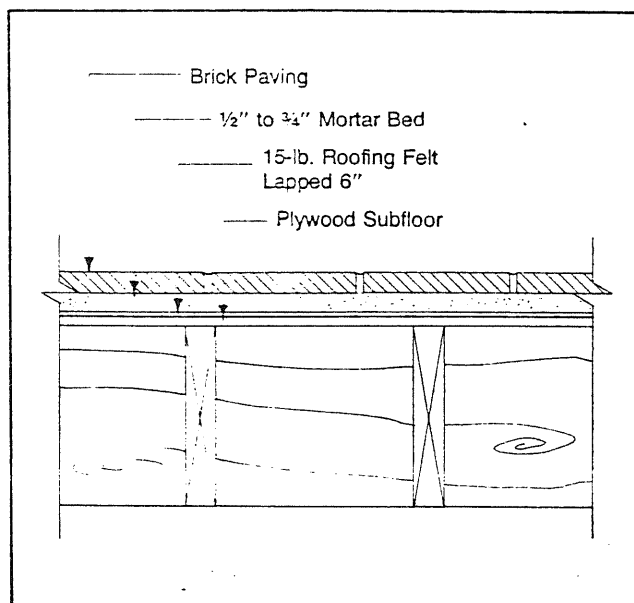


FIG. 8
Wood Framing Assembly

paving. When applied in confined spaces, provide sufficient ventilation to dilute the harmful effects of acid fumes.

CURING AND PROTECTION OF BRICK MASONRY PAVING

It is suggested that rigid or mortared paving be allowed to set in an undisturbed condition for a period of at least 3 days. Afterwards, light pedestrian traffic is permissible with protection afforded to the paving as required. Protect from staining and light impact loads through the use of large sheets of plywood or hardboard. Full service of the pavement should be avoided until the masonry has cured a minimum of 28 days.

For guide lines on cold weather protection, refer to the *Technical Notes 1 Series*, "Cold Weather Masonry Construction" and *Technical Notes 11A Revised*, "Guide Specifications for Brick Masonry," Section 1.05.C.

Flexible brick pavement requires no curing time. However, before sweeping sand into the joints, spread damp sand in thin layers and permit it to dry. Sand must be clean and free of clay to avoid surface "scumming" of the finished paving.

MAINTENANCE

Brick floors and pavements are usually abrasion resistant and hard wearing. Therefore, they normally do not require coatings to maintain surface appearance. However, coatings and waxes are often desirable on interior brick floors to enhance their appearance and make the surfaces easier to clean. Coatings on exterior brick pavement are not recommended. For interior brick there are a few aspects to be considered before applying any type of coating.

In the past it has been recommended that a sealer be

applied before waxing. In many cases this has proven satisfactory. However, sealer and wax compatibility should be checked prior to final application.

Sealers generally have two purposes: (1) to lock loose sand in the cracks, and (2) provide an impervious finish. If a sealer is to be used, it should be tried on a small area and evaluated before full application. A compatible wax should be selected, preferably a water emulsion type recommended for brick floors.

Before a coating is applied, the floor surface should be dry. Each maintenance situation, whether it be with a sealer and wax or a synthetic sealer-finish material (spray-buffing process), must be judged on its own merits to determine the most economical means for maintaining a brick floor.

Snow removal on large or small areas of brick pavement should not present any particular problem. However, there are precautionary measures that can be taken to preserve the character of the brick. Avoid the use of chemicals and "rock" salt to aid in melting ice. Use of these materials will introduce soluble salts to the masonry and may, in turn, be a source of efflorescence. To render icy surfaces passable, use clean sand on the affected area.

For snow plowing efficiency, it is suggested that, where a metal plow blade is used, the edge should be rubber tipped, or mounted on small rollers. The blade edge should be adjusted to a clearance height suitable to the pavement surface. Regardless of the method used, needless chipping of the edges of the brick should be avoided.

CONCLUSION

The Brick Institute of America has attempted to discuss the many factors involved in the design and installation of brick paving. The suggestions offered should be utilized under the close direction of a competent professional. Their use does not preclude nor supplant professional judgment, but merely provides general and detailed information on which this judgment can be based. The designer, anticipating the use of suggested paving details shown, should analyze his design conditions in conjunction with the factors discussed in this series of *Technical Notes*.

The Brick Institute of America can *not* assume responsibility for results or designs obtained from suggestions and recommendations discussed. It is beyond the scope of the Institute to anticipate every design situation that may arise, and the designer is urged to consider all of the factors.

REFERENCES:

1. Building Code Requirements for Engineered Brick Masonry, 1969, BIA Standard.
2. "Design and Construction of Brick Soffits," *Technical Notes* 36A, April 1970, Brick Institute of America.
3. "Brick Masonry with High-Bond Mortar" *Technical Notes* 38 Revised, May/June 1975, Brick Institute of America.
4. "Good Practice for Construction of Mortarless Brick Paving and Flooring," Brick Association of North Carolina, Greensboro, North Carolina.
5. "Brick Floors and Brick Paving," BDA Technical Note, May 1973, Brick Development Association, London, England.

3M ROCK BINDER/GRAVEL COSTS

Potential Trail Uses - cross-country skiing, snowshoeing, walking, biking.

Typical Process of Application (Source - Product Data Sheet)

1. Excavate and compact the soil as a subbase.
2. Lay down a minimum of 4 inches of a crushed aggregate base material.
3. Add a course of smaller aggregate. Depth depends on the size of the aggregate used.

Recommended stone depth based on stone diameter:

Stone diameter	Stone depth
1/8"	1/2 - 3/4"
1/4"	3/4 - 1"
1/2 - 5/8"	1" - 1 1/2"

4. Level the surface and roll.
5. Spray apply rock binder at an application rate of 15 - 20 square feet per gallon. Approximately 1.5 square yards per gallon.
6. Allow to dry.

Availability

Rock Binder is available in 5 gallon or 55 gallon quantities from the St. Paul area. Gravel availability good in southern 3/4 of state.

Costs

The costs obtained were for materials only.

Costs of rock binder is \$10.70 per gallon.

Applied at a rate of approximately 1 gallon per 12 square feet. Cost per trail mile is \$25,109 for a 6' wide trail.

Gravel costs - (Source - Shiely Concrete)

Class 2 \$3.50-4.00 per ton 1 1/2 tons per cubic yard placed 1" deep
for a 6' wide trail needs 65 tons per mile. Costs are \$227.50-260
per mile.

Class 5 \$2 per ton 2 tons per cubic yard
placed 4" deep for a 6' wide trail needs 195 tons per mile.
Costs are \$390 per mile.

Transportation Costs - .08 per ton mile over 50 miles
.12 per ton mile under 50 miles

(Source - Roger Liska, DNR Engineering)

\$10 per cubic yard for class 5 gravel installed.

Total Costs of materials per trail mile \$25,759 for 6' wide trail.

Maintenance

Within 3 - 7 years the rock binder surface should be sprayed with a coat at the rate of 1 gallon per 50 - 75 square feet. Repairs are done by removing the damaged area, replacing it with the identical stone and respraying the area.

Groundskeeper

BRAND

ROCK BINDER

Product Data Sheet

JUNE 1, 1975

REVISED MARCH 1, 1976

PRODUCT DESCRIPTION

Groundskeeper Brand Rock Binder is a one-component, liquid, polyurethane binder that is spray applied or admixed with landscape aggregate. It reacts with the soil or air moisture to form a unified load bearing surface and is designed to be sprayed on or mixed with stones to form a unitized surface for pedestrian walkways, or to stabilize decorative rock mulches. Highlights the natural beauty of stone, is tough and durable yet water permeable, easy to keep clean.

PRODUCT USES

Groundskeeper Brand Rock Binder is excellent for use in constructing sidewalks, patios, nature trails, traffic medians, courtyards around pools, and for stabilizing rock mulches around trees and plantings. In pedestrian traffic areas, used in conjunction with a suitable aggregate, it can replace concrete, asphalt, paving bricks, wood chips, grass, or loose stones. Provides functional landscaping for residential, commercial, or industrial applications.

Rock Binder has further application for resurfacing old, cracked, spalled, worn concrete or asphalt.

ROCK BINDER INSTALLATION

	<u>PEDESTRIAN AREAS</u>	<u>DECORATIVE, NON-PEDESTRIAN TRAFFIC AREAS</u>
<u>PREPARATORY WORK:</u>	Excavate and compact to secure a solid base in the installation area. Lay down a minimum of 4" of a crushed aggregate base material. It is recommended the base material conform to standard specifications for highway construction. Compact the base material to 98-100% of modified proctor density, (AASHTO T-180), according to the specified density method.	Remove any undesirable vegetation from the area where Rock Binder is to be used. Firmly compact the base of the excavated area. No further preparation is necessary.
<u>FORMS & EXPANSION JOINTS:</u>	Forms are required only where a sharp delineation of a walkway is desired. Forms should be made of rot resistant wood, concrete, or metal. Bury forms in the crushed aggregate base so that 1/2" — 1 1/2" is left exposed above the surface of the prepared base. Expansion joints or dividers may be used to aid in preparing the stone surface or for aesthetic purposes. When forms and expansion joints are used, they must remain in place.	If desired, the area can be formed using either wood or metal stripping. Forms can either be left in place or removed after the Rock Binder has cured. If the forms are to be removed, they should be wrapped with polyethylene or treated with a suitable release agent, such as 3M Brand Spray Silicone.

Adhesives, Coatings and Sealers Division



3M CENTER, ST. PAUL, MINN. 55101

PHONE: 733-1110 AREA CODE 612

ROCK BINDER INSTALLATION (NOSE)

	PEDESTRIAN AREAS	DECORATIVE NON-PEDESTRIAN TRAFFIC AREAS
STONE SELECTION:	Use a stone gradation between 1/8" and 5/8"; stones must be sound, not porous, nor susceptible to air slaking. White stones should not be used, because they will turn somewhat yellow upon exposure to sunlight. (A relatively clean, smooth river-washed gravel is ideal to insure a smooth surface).	Either smooth or crushed stones with a gradation between 1/8" and 3" can be unified with Rock Binder. White stones should not be used.

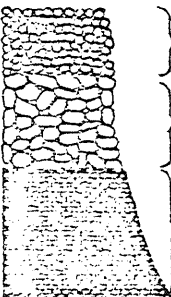
	STONE GRADATION	STONE DEPTH	STONE GRADATION	STONE DEPTH
RECOMMENDED	1/8"	1/2" — 3/4"	#6 mesh ceramic	1/8" — 1/4"
STONE DEPTH	1/4"	3/4" — 1"	coated chips	
BASED ON	1/2" — 5/8"	1" — 1 1/2"	1/8"	1/2" — 3/4"
STONE			1/4"	3/4" — 1"
DIAMETER:			1/2" — 5/8"	1" — 1 1/2"
			3/4"	1 1/4" — 1 3/4"
			1"	1 1/2" — 2"
			1 1/2" — 2"	2" — 3"
			2 1/2" — 3"	3" — 4"

OPTION 1: Screed and Spray

STONE PLACEMENT:	Place the specified depth of stone into the formed area. Screed the stone surface until the upper surface is level, then roll with a roller to insure a smooth surface.	Place the specified depth of stone into the area. Level the stones and roll with a roller to orientate any sharp points in the stones downward.
ROCK BINDER APPLICATION:	Spray apply Rock Binder to the prepared stone surface at a rate of 15-20 square feet per gallon.	Spray apply Rock Binder to the prepared stone surface at the rate of 20-30 square feet per gallon.

OPTION 2: Admix and Trowel

	Add Rock Binder to the surface aggregate at a rate of 2/3 gallons per 100 lbs. of rock. Mix thoroughly and dump into place. Finish surface to desired smoothness by hand troweling.	Add Rock Binder to the surface aggregate at a rate of 2/3 gallons per 100 lbs. of rock. Mix thoroughly and dump into place. Finish surface to desired smoothness by hand troweling.
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	PEDESTRIAN AREAS	DECORATIVE, NON-PEDESTRIAN TRAFFIC AREAS
CROSS SECTIONAL SKETCH:	 Stone layer 1/2" — 1 1/2" dependent on stone size. Base 4" — 8" of compacted crushed graded aggregate containing fines. Sub-Base Original soil well compacted.	 Stone layer 1/8" — 4" dependent on stone size. Sub-Base Original soil well compacted.

INSTALLATION OVER CONCRETE OR ASPHALT

Remove all loose material from the old surface. Firmly anchor wood forms to the periphery of the entire area. Use forms ranging between ½" and 1" thick. Apply aggregate and material in accordance with installation instructions for pedestrian areas (Option 1 or Option 2). If sprayed, care should be taken to minimize stone depth differences as they will require different coverages.

APPLICATION EQUIPMENT

Groundskeeper Brand Rock Binder can be spray applied through Rock Binder Applicator Model No. 9960, available from the 3M Company. Assistance in the design and modification of conventional airless spray equipment for applying Rock Binder can be obtained from the Adhesives, Coatings & Sealers Division; Application and Equipment Group; Building 209; 3M Center; St. Paul, Minnesota 55101.

CONDITIONS OF APPLICATION

Be sure the surface aggregate is dry throughout, before spraying. The sprayed surface must be protected from rain for at least six hours after application. Apply Rock Binder only when the air temperature is between 40°F and 100°F, (5°C—38°C). All pedestrian traffic must be kept from the treated surface for 16 hours after application.

SOIL PROTECTION

Vegetation and structures adjacent to the area should be covered or masked with polyethylene sheeting to protect against overspray during the spraying operation. Wooden forms should be covered with masking tape during application. For easy removal, the tape should be removed as soon as possible after spraying.

MAINTENANCE

Cleaning: The cured Rock Binder surface can be cleaned by any of several methods: washing with a stream of water, blown clean with air pressure, vacuumed, or swept clean.

WEED CONTROL

Rock Binder presents a physical restriction to weed growth but is not a complete weed barrier. Either liquid or granular herbicides can be used in conjunction with Rock Binder. The herbicides can be placed under the surface aggregate during construction or applied over the cured Rock Binder surface.

In decorative, non-pedestrian traffic areas where there is existing vegetation that would be adversely affected by herbicides, use polyethylene sheeting for weed control. Place the polyethylene sheeting over the base, then put the surface aggregate over the polyethylene. To permit water percolation necessary for plant growth, cut one inch diameter holes in the polyethylene at the rate of one hole every two square feet.

LONG TERM MAINTENANCE

After exposure to the environment, the Rock Binder surface will gradually change in appearance to a non-glossy surface. If desired, the gloss can be restored by respraying the surface at the rate of 80-100 square feet per gallon.

Within three to seven years, the Rock Binder surface should be sprayed with a maintenance coat at the rate of 50-75 square feet per gallon to revitalize the upper surface.

REPAIR OF DAMAGED AREAS

The Rock Binder bound surface is easy to repair if accidentally broken. Remove any weak or damaged sections and reinstall with stone identical to that removed. A sufficient area of the original surface should be lightly resprayed so the repaired area is not distinguishable.

For general "looseness" of a section, which is intact on the surface, respray the section with Rock Binder at 25-35 square feet per gallon.

AVAILABILITY AND STORAGE

GroundsKeeper Brand Rock Binder is available in 5 gallon pails and 55 gallon tighthead drums.

Rock Binder must be stored in a cool, dry area and in full compliance with regulations concerning the storage of flammable materials. Rock Binder has a shelf life in excess of one year.

FLAMMABILITY

Rock Binder in its liquid condition is extremely flammable. Precautions for handling flammable materials should be strictly followed. In the cured form, Rock Binder bound aggregate is self-extinguishing according to the "Tablet Test", Federal Specifications DDD-D-95.

TOXICOLOGICAL INFORMATION

Human: The application of Rock Binder as outlined in the GroundsKeeper Brand Rock Binder training manual should not present a health hazard to exposed workers. However, due to the possibility of varying environmental conditions during the application operation, it is required that all persons in the immediate area wear an approved organic vapor respirator and safety glasses. It is recommended that in the event of eye contact with Rock Binder, they should be immediately flushed with plenty of water.

An industrial hygiene study was conducted to determine the degree of exposure to the applicator to solvent and trace amounts of diisocyanate present in the product during application. Results from breathing zone sample analysis indicate that the exposure levels were below the allowable Threshold Limit Values (TLV). Less than 40 ppm of acetone, (TLV of 1,000 ppm), and less than 4 ppm of toluene, (TLV of 100 ppm), were detected. For diisocyanate, less than 0.004 ppm were detected compared to the TLV of 0.02 ppm. Within 24 hours after application there is no detectable solvent or diisocyanate present.

Animal: The hazards to animals coming into contact with the liquid Rock Binder should be quite low. Cured Rock Binder is completely inert and does not present a health hazard to animal life. These statements are based on results of tests conducted on albino rabbits and rats to assess acute oral toxicity, primary skin irritation, and eye irritation of both the liquid and cured Rock Binder.

Aquatic: Based on an evaluation of the test data in normal use situations, Rock Binder is not expected to cause any adverse environmental effects in either unexpected spills of uncured material or in applications for normal use. It is concluded that the cured Rock Binder is an inert, non-hazardous substance.

An acute fish toxicological study was conducted by an independent testing laboratory to assess the effect on marine life of drift or direct spraying Rock Binder in ponds, lakes, or streams. These tests were conducted to determine the 96 hour Threshold Limit 50 (TL₅₀) for liquid Rock Binder. Results follow:

SPECIES	TL ₅₀
Bluegill	256 ppm
Rainbow Trout	160-210 ppm
Channel Catfish	370-560 ppm

These TL₅₀'s indicate that under the conditions tested, Rock Binder is low in toxicity to the three species tested.

BULK PHYSICAL PROPERTIES

Property	Measuring Standard And Conditions	Results
Specific Gravity	ASTM D 70-52 (1968) Fisher #3-247 Pyconometer	0.99 ± 0.1
Weight	ASTM E 201-67	8.20 lbs./gal. ± 0.3 (0.98 kg./l)
Non-Volatile Content	ASTM D 1353-64 3 hrs. @ 200°F (93°C)	61% ± 3%
Drying Time	ASTM D 1640-65 10 mil. (0.010") (.25 mm film) 77°F (25°C) 50% RH	Dry to touch: 9 hr. max. Dry to complete: 24 hr. max.
Flash Point	ASTM D 1310-67	0°F (-17.8°C) minimum
Solvent		Acetone/Toluene Complies with Rule 66
Color	Visual	Light Amber

PROPERTIES OF THE CURED ROCK BINDER FILM

Property	Measure Standard And Conditions	Results
Tensile Strength	ASTM D 412* DIE "C" pulled at 2 ipm	3000 psi minimum (21090 kgf/mm ²)
Elongation	ASTM D 412* DIE "C" pulled at 2 ipm	150% minimum
Tear Resistance	ASTM D 1004*	275 pounds per linear inch minimum (490.0 kgf/mm)
Heat Resistance	ASTM D 573* 28 days at 160°F (71°C) DIE "C", 2 ipm	Tensile 3000 psi minimum Elongation 120% minimum
Salt Spray Resistance	ASTM B 117* 28 days at 100°F (37.8°C) 5% NaCl, DIE "C", 2 ipm	Tensile 3000 psi minimum Elongation 120% minimum

*Test conducted on deaerated, 10 mil. (0.010", 0.25 mm) dry film. Cured for seven days at 77°F (25°C) and 50% RH.

PAUL DE NUCHIO

3M BRAND ADHESIVE PRODUCTS ARE CLASSIFIED AS DANGEROUS BY THE U.S. DEPARTMENT OF TRANSPORTATION

Property	Measure Standard And Conditions	Rock Binder	Results	
			Asphalt*	Concrete*
Compressive Strength	ASTM D 1632-63 (modified) Using #9 coarse aggregate Meeting ASTM D 448	750 psi minimum	450 psi	4,500 psi
Flexural Strength	ASTM D 1632-63 (modified) Using #9 coarse aggregate Meeting ASTM D 448	500 psi minimum	150 psi	1,200 psi
Weathering Resistance	As above for compressive strength — per ASTM G23 type D, 500 hours weatherometer	750 psi minimum		
Freeze-Thaw Resistance	ASTM D 560 (modified) Using #9 coarse aggregate Meeting ASTM D 448	No cracking, raveling, or loss of adhesion after 250 freeze-thaw cycles		

Deflection prior to failure—A Rock Binder bound aggregate exhibits deflection readings five times greater than either asphalt or concrete prior to breaking.

*Typical Values

DANGER: EXTREMELY FLAMMABLE ... HAZARDOUS VAPOR. Contains T.D.I.

(toluene diisocyanate), toluene and acetone. Keep product and its vapors away from heat, sparks and open flames. The vapors given off from this product will burn. Avoid breathing vapor. This product system is intended for outside use. Use only in well ventilated areas. Wear an approved respirator with chemical cartridge for organic vapors during application. Avoid contact with eyes, skin or clothing. Suggested first aid for eye or skin contact; Immediately flush with plenty of water. For eye or respiratory difficulty, obtain medical attention. For inhalation exposure remove individual to a non-contaminated area, get medical attention. If swallowed, do not induce vomiting, call physician immediately. Remove and wash contaminated clothing before reuse. Keep out of reach of children. Keep container closed when not in use.

SAFETY PRECAUTIONS

The specified product is a liquid spray applied, moisture curing, one component polyurethane binder. The binder is designed to be sprayed on stones for use as a surfacing for pedestrian traffic or for stabilizing decorative rock mulches.

The performance information contained in this data sheet can be used for performance specifications.

FREIGHT CLASSIFICATION: CHEMICALS, N.O.S., FLAMMABLE LIQUID, Red Label Required

IMPORTANT NOTICE TO PURCHASER

This product is intended for sale to and use by qualified applicators only. 3M makes or gives no warranties or guarantees whatsoever in connection with the product other than is set forth in its qualified applicator manual and that warranty is made in lieu of all other warranties, either expressed or implied. In no event shall 3M be liable for any injury, loss, or damage either direct, incidental, special, or consequential arising in connection with the use of or the inability to use this product. No warranties are made on defects or failures in material other than as specified in the qualified applicator manual.

Adhesives, Coatings and Sealers Division



3M CENTER, ST. PAUL, MINN. 55101

PHONE: 733-1110 AREA CODE 612

Spray Unit = \$495
FOB ST Paul

GROUNDKEEPER BRAND

ROCK BINDER 2391

3M ADHESIVES, COATINGS & SEALERS

DISCOUNT SCHEDULE

Date: March 1, 1976

Container Size	5-99 Gals.	100-499 Gals.	500-999 Gals.	1000+ Gals.
PER GALLON				
5 Gallon Pail	13.34	12.30	11.51	11.00
Drum	13.04	12.00	11.21	10.70

F.O.B.: Springfield, Missouri

TERMS AND CONDITIONS OF SALE

TERMS: Net 30 days. Each order is considered firm, non-cancellable, and subject to immediate shipment unless specific future shipping dates are shown.

PRICES: Prices are F.O.B. nearest stocking location. Order for immediate shipment will be billed at the price in effect on the date order is received. Orders specifying future dated shipments will be billed at the price in effect on date of shipment. Stocking locations and containers are subject to change without notice.

Prices shown are for standard packaging and labeling only. Prices covering non-standard containers or container sizes, special markings, government and/or customer specification requirements are available upon request.

TECHNICAL INFORMATION: We believe you have technical information sheets covering each of these products. If not, please advise and we will forward the required copies to your attention as it is important that you have this information so that you can evaluate and determine if the product is suitable for your particular purpose.

IMPORTANT NOTICE TO BUYER

The following is made in lieu of all warranties, express or implied. Seller's and manufacturer's only obligation shall be to replace such quantity of the product proved to be defective. Neither seller nor manufacturer shall be liable for any injury, loss or damage, direct or consequential, arising out of the use of or the inability to use the product. Before using, user shall determine the suitability of the product for his intended use, and user assumes all risk and liability whatsoever in connection therewith.

No statement or recommendation not contained herein shall have any force or effect unless in an agreement signed by officers of seller and manufacturer.

Adhesives, Coatings and Sealers Division



3M CENTER, ST. PAUL, MINN. 55101

Application rate of Rock Binder (in square feet per gallon)

Traffic Areas

Stone Depth

Stone Size	Stone Depth				
	1/2"-3/4"	3/4"-1"	1"-1 1/2"	1 1/2"-2"	2"-2 1/2"
	1/8" 20	17	14	10	
	1/4" 20	20	17	12	
	1/2"	20	20	15	12
	5/8"	20	20	15	12

APPLICATION RATE OF ROCK BINDER (in square feet per gallon)

Page 8.

STONE DEPTH INSTALLED

	1/8"- 1/4"	1/4"- 1/2"	1/2"- 3/4"	3/4"- 1"	1"- 1 1/2"	1 1/2"- 2"	2"- 2 1/2"	2 1/2"- 3"	3"- 3 1/2"	3 1/2"- 4"	4"- 4 1/2"	4 1/2"- 5"
#6 Chips	25	20	15	10								
1/8"	25	25	25	20	15	10						
1/4"	25	25	25	25	20	15	10					
1/2"		30	30	30	25	20	15	10				
5/8"			30	30	25	20	15	10				
3/4"			30	30	25	25	20	15	10			
1"				30	30	25	20	15	10			
1 1/2"					30	30	25	20	15	10		
2"						30	30	25	20	15	10	
2 1/2"							30	30	25	20	15	10
3"								30	30	25	20	15

NOTE: Applicable only for areas receiving no foot traffic.

Soil Sterilants

Many of the materials considered are porous which could cause problems arising out of vegetation coming through them. To prevent this, a soil sterilant should be applied before surfacing is accomplished. Materials with which a soil sterilant should be used are limestone, 3M Rock Binder, soil cement, soil asphalt, clay, and lignun. Depending on the specifications used in constructing asphalt or brick trails, a soil sterilant may also be necessary.

Permatal was recommended as being the best herbicide for trail application.

(Source R.L. Gould and Co. and Castle Chemical Co., Inc.)

This product comes in 5 gallon containers.

Cost - \$39.75 per 5 gallons.

Coverage - 5 - 7 1/2 gallons mixed with 50 - 100 gallons of water treats one acre.

Trail coverage 5 gallons (39.75) covers 1 1/3 miles.

