FINAL REPORT

SIDEWALK UNDERMINING STUDIES

by

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Senior Research Scientist

(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

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SUMMARY

The report summarizes some five years of studies on the highly expensive sidewalk undermining problem which plagues the Northern Virginia area. Included are studies of sidewalk replacement techniques, of the soils and geometric conditions contributing to undermining, and of the methods of ensuring that newly constructed sidewalks will be free of undermining. A series of recommendations directed at the development of revised construction specifications and design standards are included.

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INTRODUCTION

Since mid-1974 the Research Council has been working with the Fairfax Residency on a severe sidewalk maintenance problem stemming from the erodibility of certain soils found in much of Fairfax County. While there are other problems associated with sidewalk maintenance in the area, the most difficult to handle are the many cases where sidewalks have been undermined through erosion of the immediately underlying soil layer. Undermining removes the support from under the sidewalks and results in faulting of the joints and the creation of peripheral drainage and siltation problems. More importantly, the faulted joints and other sidewalk distortions create hazardous conditions which need immediate repair. Because of the current policy of accepting sidewalks into the secondary system concurrent with acceptance of the adjacent subdivision pavements, the sidewalks become a maintenance responsibility of the Highway and Transportation Department. Maintenance costs of several million dollars per year are associated with the sidewalk undermining problem. The situation is aggravated by the fact that undermining occurs at a faster rate than maintenance can be programmed. Thus, a recent estimate places the cost of presently needed repairs at some \$30 to \$50 million.

The attention of the Research Council was first called to the problem through a memorandum dated March 22, 1974, from District Engineer D. B. Hope to Director of Program Management H. G. Blundon. Specifically requested in this memorandum was the Council's assistance in the development of solutions applicable at the time of initial construction to prevent the occurrence of undermining of sidewalks. During preliminary studies and discussions with Residency personnel it became evident, however, that any assistance with maintenance procedures, especially assistance directed at reducing costs, would also be welcomed.

Research efforts on the undermining problem proceeded in three distinct phases which have been reported earlier:

Phase I — Hydrology and Maintenance Studies(1)

Phase II — Soils Studies(2)

Phase III — Field and Model Studies(3)

Findings from all phases of the project have been incorporated as needed in the subsequent sections of this report to present, as concisely as possible, a description of the undermining problem, its mechanism and causative factors, and the actions recommended to minimize undermining of future sidewalks.

DESCRIPTION OF PROBLEM

Undermined sidewalks are generally located on longitudinal grades of 3% or more downgrade from drainage areas comprising one or more square blocks of subdivision development. Yards typically slope steeply upward from the sidewalks so that all water from roofs as well as the rest of the drainage area must travel over or along the sidewalks to reach storm drain systems located under the edge of the roadways.

Evidence of undermining is dislocation of joints and distortion (rotation) of slabs in either the transverse or longitudinal planes. Eroded material is usually deposited at the low point of vertical curves although it may break out intermittently at sidewalk joints or along the edges. After heavy rains these deposits are very evident although much of the material is carried away into the storm drain system. Voids under the walks range from negligible up to several feet, depending upon the severity of erosion. It is apparent that large volumes of water may flow under the sidewalks on occasion. Some evidence of the severity of undermining and the types of distortion encountered is indicated in Figures 1 and 2.

An approximate mechanism of erosion and undermining is as follows:

1. First stage erosion initiates a void at the interface between the sidewalk and the underlying soil. This condition may be aggravated by inadequate construction control and peculiarities of the subgrade soil. No base material is used between the sidewalk and the subgrade.

Figure 1. Severe sidewalk undermining.

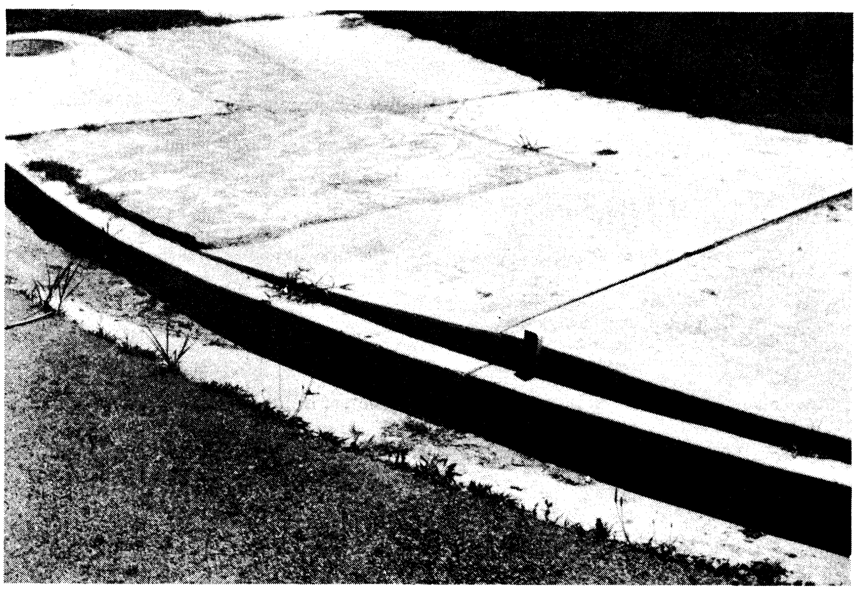


Figure 2. Sidewalk distortion due to undermining.

2. Water goes beneath the sidewalk at the "yard" side, enters the void, and proceeds downgrade causing further erosion and transportation of the subgrade soil as water volume and velocity increase.

3. In most cases, undermining is aggravated by the presence of a sodded utility strip from 1 to 12 feet (0.3 to 3.6 m) wide between the sidewalk and the roadway curb. Because of normal growth the sod in both the utility strip and the yards typically is higher in elevation than the sidewalk, and the sidewalks thus function as paved ditches to carry much of the drainage longitudinally. If voids are present under the walks, the water will flow under as well as over the concrete slabs. In an earlier study of the sidewalk maintenance problem, much of the undermining was attributed to excessive edge trimming of the walks by property owners.(1) Such trimming, sometimes to the depth of the 4-inch (100 mm) slabs, gives the water ready access to the subgrade soil.

4. The earlier observation that undermining is most often present where longitudinal grades are 3% or more is related to the fact that unless longitudinal grades are flat there will always be some longitudinal drainage, either on top of the sidewalks or beneath them. Although some of the problem sidewalks were constructed on flat ground, many have cross slopes of approximately 2%. When longitudinal grades exceed this 2% cross slope, the preponderance of drainage will be longitudinal.

5. One further complication to the undermining problem is provided by water flowing downgrade on the surface of walks which have been repaired or have never been undermined until it reaches an undermined section and enters the area beneath the walks. In such cases, the volume of water contributing to the undermining can greatly exceed the runoff attributable to the property directly adjoining the walk.

6. The tendency of certain soils to erode more than others was clearly identified in the soils studies where it was shown that a soil with 34% or more passing the No. 200 sieve and having a plasticity index (PI) of 13 or less is approximately 5 times as likely to contribute to undermining as a soil not meeting those criteria.(2)

In summary, then, it may be said that sidewalk undermining is a function of terrain and soil properties, and that undermining can be expected to occur in a relatively short time when the sidewalk longitudinal gradient is 3% or more and when the underlying soil has 34% or more passing the No. 200 sieve and has a PI of 13 or less.

PROVEN METHODS OF PREVENTING UNDERMINING

Upon even scant consideration it becomes apparent that at least three actions or combinations of actions can be taken to prevent undermining of sidewalks built on erodible soils. These are to —

1. stop the entry of water to the areas beneath the sidewalks;
2. protect the erodible soil through use of a cover material or through special handling of the subgrade; and
3. provide an effective means of removing infiltrated water from beneath the walks without damage to the subgrade soils.

Detailed study by others of several severe undermining situations led to the conclusion that it would be very difficult to prevent the infiltration of surface water into the area beneath the sidewalks.[4,5] Thus, for maintenance purposes, both the County of Fairfax and Fairfax Residency personnel early decided that it would be better to provide a combination of soil protection and improved drainage. Nothing in the subsequent research has changed this view and all later efforts to prevent undermining have been based on similar thinking. The approaches taken and the apparent results are summarized below.

Curtain Wall Approach

An early approach used by the Department for maintenance purposes involved the protection of erodible soil by the use of aggregate base and longitudinal curtain walls under the rebuilt sidewalks, combined with the removal of infiltrated water through the use of a drainage system constructed under the walks and draining into the existing storm sewer system.

A typical installation of this type is shown under construction in Figure 3 and schematically in Figure 4. Note that the drainage system is installed on the high side of the walk to intercept lateral drainage from yards or longitudinal drainage along the sidewalk and direct it into the storm sewer system. The concrete curtain wall prevents the flow of infiltrated water laterally and directs it into the perforated plastic drain pipe. The subgrade soil to the right of the curtain wall, see Figure 4(b), is protected by a layer of densely graded crushed stone. While the curtain wall method proved relatively successful in that only one case of subsequent undermining was found, its high cost led to the consideration of other methods.

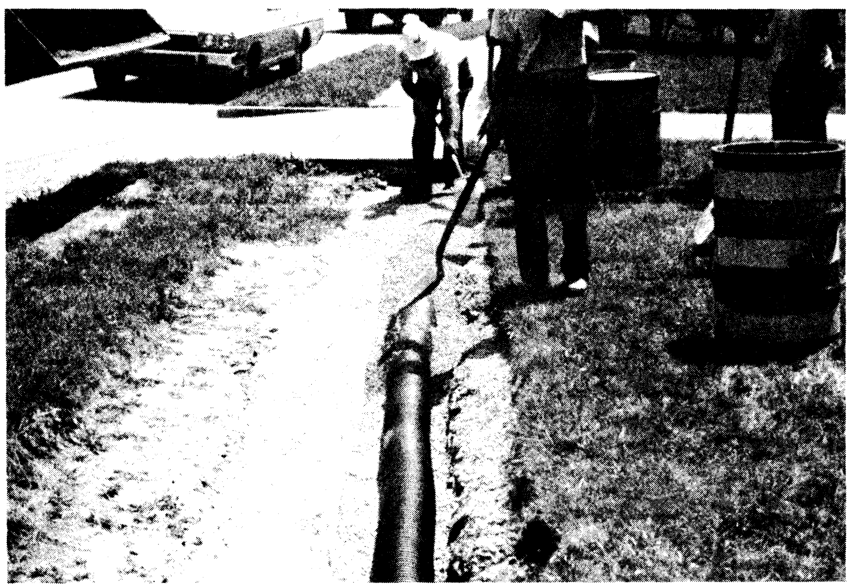
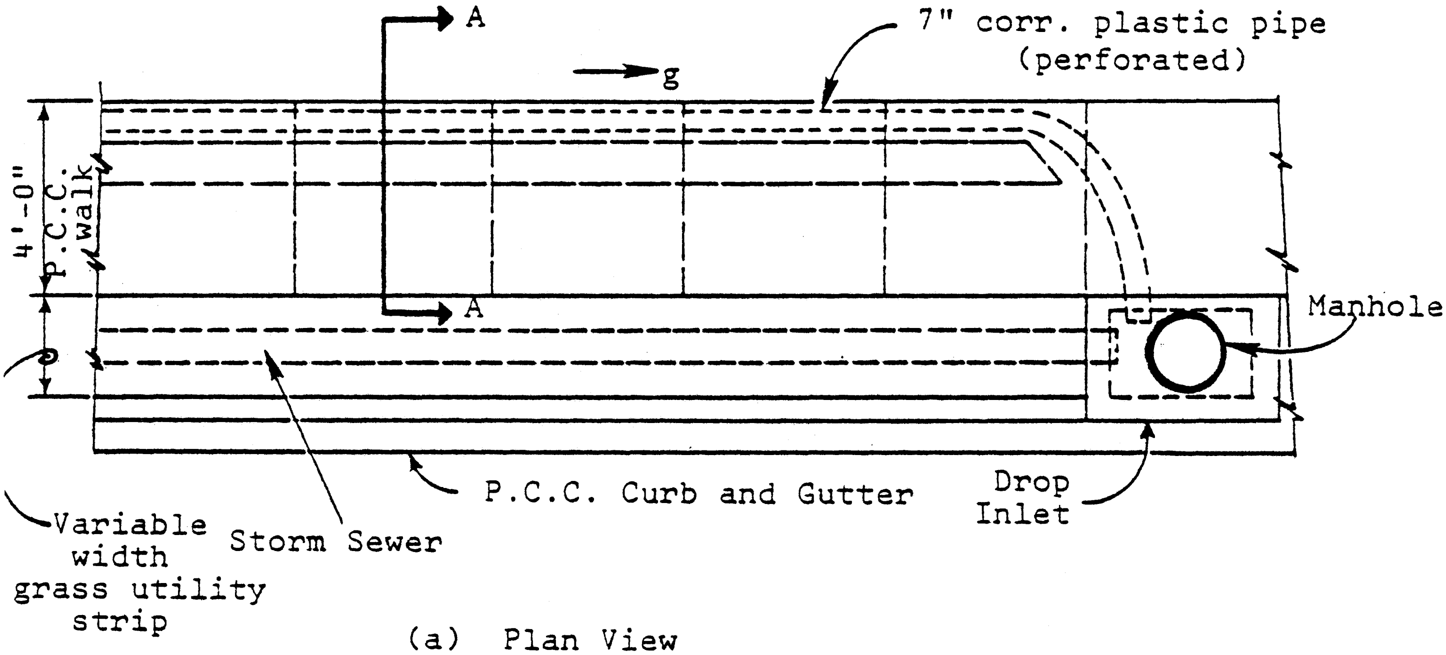
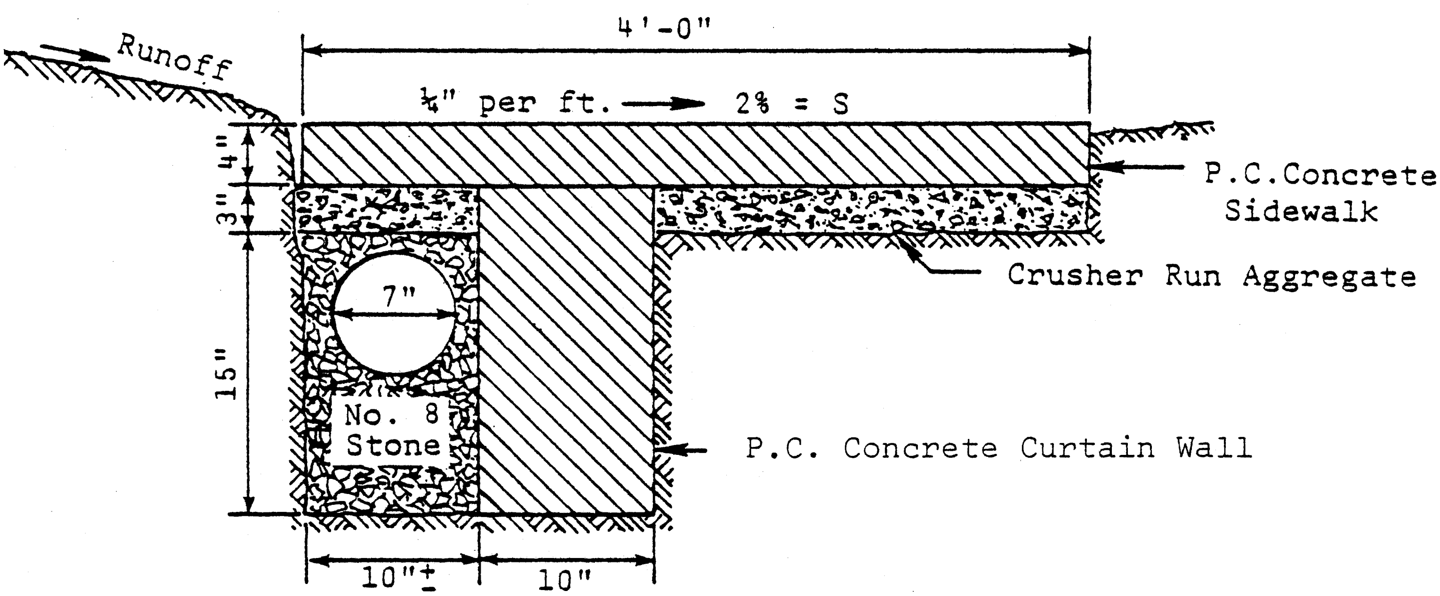


Figure 3. Sidewalk replacement utilizing curtain wall and subsurface drainage.



(a) Plan View
(Not to Scale)



(b) Section A-A
(Not to Scale)

Figure 4. Sidewalk reconstruction with curtain wall and drainage system. (Metric conversion 1 in. = 25.4 mm).

Polyethylene — Fabric Method

The major maintenance effort to prevent the reoccurrence of undermining involved the use of the system indicated in Figure 5. This system captures all infiltrated water and delivers it to the storm sewer system. The actual cross section is variable in shape, depending upon the nature of the erosion channel. After cleaning and shaping of the subgrade soil, approximately 6 inches (150 mm) of crusher run aggregate are placed in the lower portion of the trench. Polyethylene sheeting is then placed to cover the entire excavated area. A 7-inch (178 mm) diameter corrugated, perforated plastic pipe is laid in the trench and covered to the elevation of the bottom of the sidewalk with No. 8 stone. The No. 8 stone is open-graded to permit entry of infiltrated water to the drain pipe. After the 4-foot (1.2 m) wide sidewalk is placed and the forms removed, the 1-foot (0.3 m) width on either side of the walk is filled with top soil and seeded. Several of these operations are indicated in Figure 6.

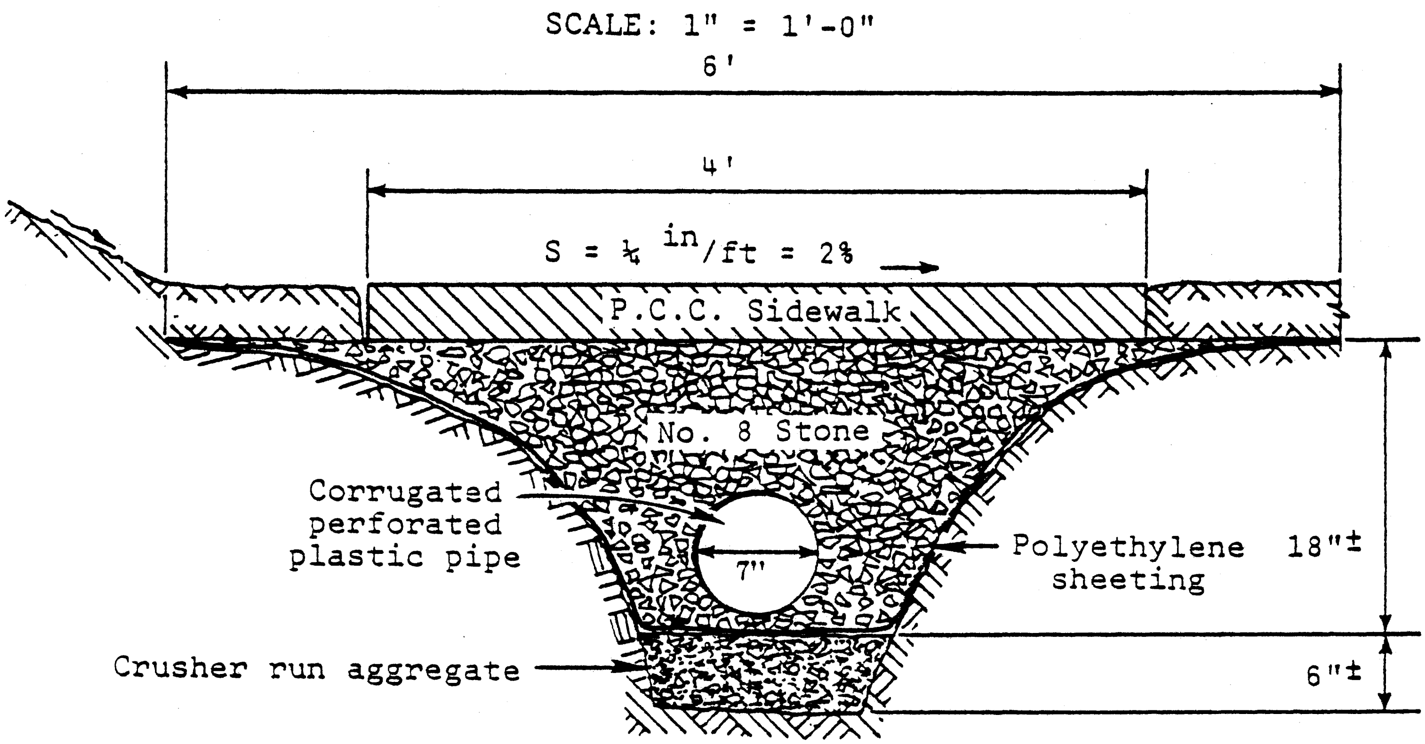


Figure 5. Cross section of experimental sidewalk installation. (Metric conversion 1 ft. = 0.3 m).

Figure 6. Test site showing installation of polyethylene, pipe, and No. 8 stone.

The first installations by this method were constructed in August 1974 and have been inspected periodically since that time. No evidence of renewed undermining has been detected with the result that for the past several years all undermining repair contracts have required that this method be used. Minor modifications from the design given in Figure 5 include (a) variations in pipe size (b) the use of concrete pipe on occasions, (c) the occasional use of porous construction fabrics in lieu of the polyethylene, and (d) an increase in the depth of the No. 8 stone to 4 inches (100 mm) for 1 foot (0.3 m) on either side of the sidewalk. While modifications (a) through (c) have had no apparent effect on the serviceability of the system, modification (d) is helpful in reestablishing sod on the sidewalk edges.

Design Without Drain Pipe

As pointed out in the Phase I report no drain pipe is necessary where the drainage area is less than about 0.1 acre (0.04 ha). In most such cases an effective underdrain system cannot be used because a storm drainage system is not available. Where these conditions have occurred the system indicated in Figure 7 has been used successfully over the past several years.

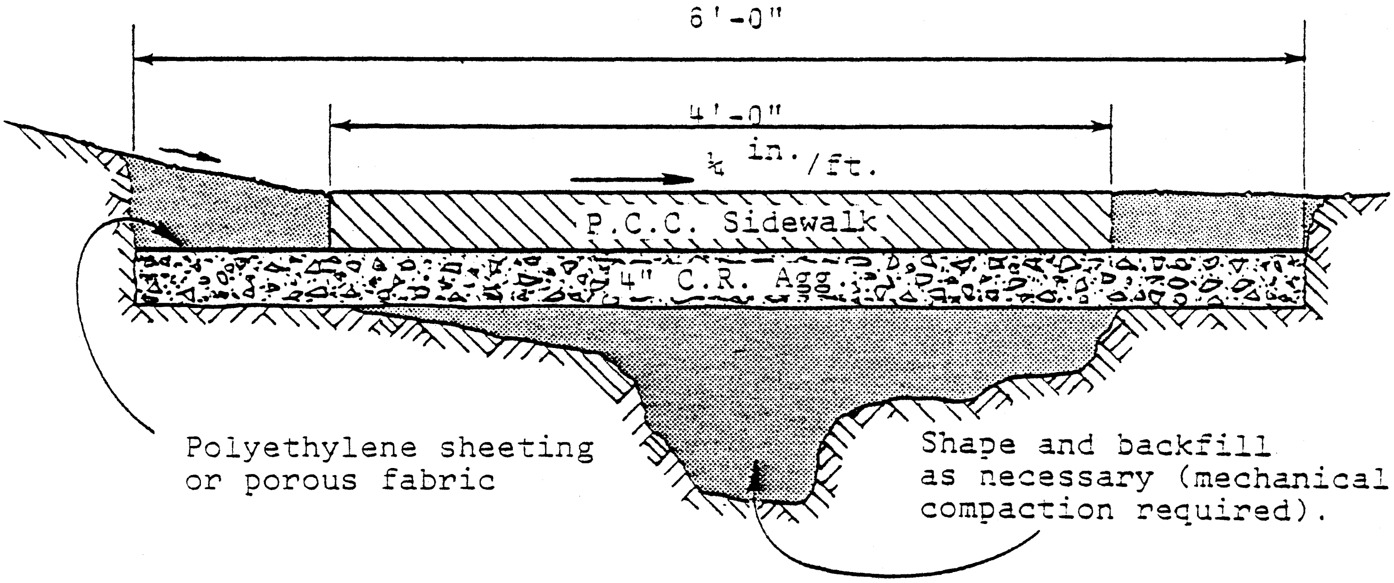


Figure 7. Sidewalk replacement without underdrains.
(Metric conversion 1 ft. = 0.3 m.)

This system apparently is successful because of the small volumes of water resulting from the small drainage area and the positive protection of the underlying erodible soil by the combination of the polyethylene or fabric and the 4-inch (100 mm) aggregate base.

MODEL STUDIES OF UNDERMINING — PREVENTIVE MEASURES

Model studies of several undermining preventive measures have been reported in a comprehensive study by Plott.[3] In these studies a prototype sidewalk foundation was built on an inclined plane containing as subgrade a large volume of highly erodible soil transported from the Fairfax area and extensively tested for the erosion potential criteria discussed earlier.

Plexiglass plates were used to simulate a sidewalk built over several different subgrade treatments and, in one case, an aggregate base material. Simulated rainfalls of a known intensity were provided by a sprinkler system while the rate of soil erosion was determined through retention and testing of all runoff. The findings from these studies are summarized briefly below.

Subgrade Compaction Studies

A model sidewalk built on subgrade compacted to 78% and to 95% of AASHTO T-99 maximum theoretical density showed conclusively that greater subgrade density served only to slightly delay the onset of soil erosion and undermining. The higher subgrade density was almost totally ineffective in reducing undermining once erosion started.

Lime Treatment of Subgrade Soils

A model sidewalk built on a subgrade containing 2% agricultural hydrated lime by dry weight and cured for 72 hours before the application of simulated rainfall was totally free of undermining after numerous rainfalls.

Provision of Aggregate Base

A model sidewalk built on a base material of 4-inches (100 mm) of Virginia specification No. 21A crushed aggregate compacted to 95% of AASHTO T-99 (Method C) density was totally free of undermining after numerous simulated rainfalls.

Discussion of Model Studies

While both lime subgrade stabilization and the provision of an aggregate base material were highly effective in preventing sidewalk undermining in the model studies, there is at least one area of concern when using these methods. It has been observed several times in the course of the undermining study that when sidewalk undermining is prevented or corrected by a system which prevents water access to the subgrade soil, the undermining can be transferred from the sidewalk to the curb and gutter area or even out into the street itself. It is for this reason that if either stabilization or the aggregate base approach is chosen for new sidewalk construction on erosion prone soils, it will be necessary to protect the entire right-of-way with the prevention method chosen. This approach may be very costly but could be considered as an alternative to providing a drainage system under new sidewalks.

RECOMMENDATIONS

The following recommendations have been derived from the results of studies reported herein and in the three phase reports, and are intended to provide the basis for sidewalk construction specifications and design standards.

Sidewalks Subject to Undermining

The recommendations given under this subheading are intended to apply to sidewalks constructed or accepted by the Department of Highways and Transportation where —

A. the longitudinal grade is as much as 3%, and

B. the subgrade soil has 34 or more percent passing the No. 200 sieve and has a PI of less than 13.

1. All sidewalks should be constructed to a minimum cross slope of 2%. The area between the sidewalk and the curb and gutter section should be constructed to slope downward to the curb at a minimum grade of 4%.

2. All sidewalks should be constructed with an internal drainage system similar to that given in Figure 5 of this report. The pipe size and composition, the depth of No. 8 stone, and the type of waterproofing material (polyethylene or porous fabric) should be approved by the Engineer.

3. As an alternate construction method, all sidewalks may be constructed such that the specified aggregate base material Type I or II shall extend the full width of the right-of-way and shall be no less than 4 inches (100 mm) thick under the sidewalk and grass utility strip.

4. As an additional alternate construction method, all sidewalks may be constructed such that lime or portland cement stabilized subgrade shall extend the full width of the right-of-way. The type and amount of stabilization must be approved by the Engineer.

All Other Sidewalks

The following two recommendations are intended to apply to all sidewalks constructed or accepted by the Department of Highways and Transportation in areas not meeting the criteria for undermining potential cited above.

1. All sidewalks should be constructed on an approved waterproofing material and on a base course of a minimum of 2 inches (50 mm) of aggregate base material Type I or II to conform to Section 209 of the Virginia Department of Highways and Transportation Road and Bridge Specifications (1978). The base material should extend a minimum of 6 inches (150 mm) on each side of the sidewalk. This action is intended to provide a stable platform for sidewalk construction and to provide some protection against undermining in variable soil areas where the undermining criteria outlined below may have questionable application.

2. All sidewalks should be constructed to a minimum cross slope of 2%. The area between the sidewalk and the curb and gutter sections should be constructed to slope downward to the curb at a grade of not less than 4%.

ACKNOWLEDGEMENTS

The author acknowledges the contributions of R. W. Gunn, technician supervisor, and H. W. Plott, former bridge design engineer, of the Council staff, without whose efforts the research reported herein would not have been possible. Appreciation is also expressed to the personnel in the Fairfax Residency and to D. S. Roosevelt, resident engineer in Charlottesville (formerly in Fairfax) whose ideas and efforts on the field studies were of great value.

The work was conducted under the general direction of Jack H. Dillard, state research engineer, and was financed from state research funds.

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5. Memorandum from R. F. Gilbert, Assistant Chief, Public Utilities Inspection Branch, Fairfax County to S. T. Terrett, Director, Division of Design Review, Fairfax County, February 15, 1974.