

Highway Materials Research Laboratory
132 Graham Avenue, Lexington 29, Ky.
March 21, 1947

File: D-2-1

Memo. to Dean D. V. Terrell
Director of Research

Supplementing my memorandum of July 29, 1946, and the report on "Porous Backfill" by Mr. R. F. Baker, transmitted with it (copies of both are attached), there was some information summarized at the recent A.R.B.A. meeting in Chicago which emphasizes recommendations that were made in that report. We have obtained a copy of the A.R.B.A. summary and have analyzed it critically from the standpoint of gradation of backfill used by the different states. The results are worth bringing before a meeting of the Research Board for their consideration and possible recommendations for changes in specifications.

In the total of all highway practices the matter of porous backfill is relatively insignificant, yet, as Mr. Baker pointed out under Point 4 of his recommendations, graded filter material could be of consequence in the following Articles of our 1945 Specifications:

2.4.3(f)	Backfilling (Bridges); p. 66
2.5.2	Embankment Construction; p. 73
5.1.3-B-4(d)	Concrete Arches; p. 261
5.5.3-C-4	Culverts and Retaining Walls; p. 305
5.9.3-A-1	Stone Masonry Abutments, Wings and Walls; p. 347
5.10.3	Stone Masonry in Roadside Improvement (Weep Holes); p. 354
6.3.3(b)	Riprap (underdrains); p. 379
6.4.3	Concrete Slope Wall (underdrains); p. 381
6.8.3	Bin Type Retaining Wall (backfill); p. 392

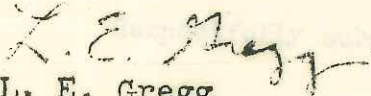
With regard to the comparative status of our present specifications (No. 6 Aggregate, as listed in the A.R.B.A. summary), those in a minimum of 26 states call for a finer or longer-graded material. Only five states definitely require backfill that is as coarse or coarser than ours; two states make no use of it or have no specification; and the information from 14 states was not specific enough for us to determine how their materials compared with ours.

Recommendations in the attached report designate our standard concrete sand (Article 7.3.2-D) as being the most practicable material that would serve the purpose reasonably well. In the northern part of the state such a material probably would be readily available and more economical than the crushed stone, if required. Undoubtedly the Jackson Purchase has an abundance of sand or gravel of equal or better gradation, and some sands in parts of eastern Kentucky may meet the requirement.

For that large portion of the state where sand and gravel do not occur locally, a 50-50 mixture of No. 9 and No. 10 stone would provide a satisfactory gradation and the cost for this would be little different from that of the No. 6 stone as specified at present, the difference being only in quantities. Of course the finer sized stone may be more scarce because of the usual demands for finer rather than coarse materials.

The important property of any material used is its gradation and not soundness or toughness as we usually apply them to aggregates. Thus, gravel or stone that are substandard for other purposes may serve this purpose very well, provided they do not approach the softness of shale which would disintegrate when exposed as backfill.

It is my recommendation that the Research Board consider this report, and that it be submitted to Mr. Oberwarth, and any others who may be concerned should a revision in specifications be contemplated. The A.R.B.A. summary will, of course, be published in the near future but in the interim I am having a copy of the preliminary tabulation of data from the several states circulated throughout the Central Office for the information of those who may be interested.


L. E. Gregg
Associate Research Engineer

LG:k

cc: Research Board Members:

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Highway Materials Research Laboratory
132 Graham Avenue, Lexington 29, Ky.

July 29, 1946

File: D-2-1

Memorandum to Professor Torrell
Director, Highway Research Laboratory

Early this year the Research Board considered materials and specifications for bituminous coated metal pipe, and a limited investigation by the Laboratory was proposed when equipment for that purpose became available. During his initial work on that matter, Mr. R. F. Baker became interested in the related subject of porous backfill because of its connection with soil.

As a result of a review of various articles and publications supplemented by inquiries concerning practices in other states, Mr. Baker arrived at some conclusions and recommendations which are sound. Fundamentally, he states this as a requirement, that backfill be coarse enough to permit sufficient flow of water into the drain yet fine enough to prevent flow of fine soil particles into the voids of the backfill or the drain.

When viewed logically, the old practice of using very coarse material is obviously unsound. Soils that need drainage are invariably fine grained, hence their permeability is not great at best. That being the case, the amount of water that can possibly reach the porous backfill is only a fraction of that which the backfill is capable of transmitting to the drain. Thus, the coarse material is not only too large from the standpoint of requirements for flow, but it is so large that fine soil washes into the voids and defeats the purpose of the drain.

Only a few copies of this report have been prepared with the intent of calling the matter to attention, mainly from the standpoint of specifications. Additional copies can be issued if this is found to be desirable.

Respectfully submitted,

L. E. Gregg
Associate Research Engineer

LG:k

Highway Materials Research Laboratory
132 Graham Avenue, Lexington 29, Ky.

July 10, 1946

File: B-2-1

Memorandum to Mr. L. E. Gregg

Attached hereto is a report covering: (a) the type of material to be used as porous backfill in drainage construction; (b) the effect on any earth construction of placing a large grained soil adjacent to a fine grained soil.

It consists of a summary of theoretical studies and general practices of neighboring states. In brief, I have concluded: (a) the gradation of the backfill for sub-drainage is dependent upon the gradation of the surrounding soil, and will normally call for a material similar in gradation to the finest concrete sands; (b) serious failures may develop in completed earthwork if there is indiscriminate use of large grained soils adjacent to small grained soils.

The present Kentucky specifications do not specifically outline the correct procedure to eliminate the two cited problems and I have included recommendations for their revision.

I have not lost sight of the economic consideration as it affects these problems. In many instances, the recommended changes will mean a savings in initial cost, due to material locally available, and less costly than the cleaner, larger sized aggregate. The availability of river sand, pit-run gravel, and soft sandstones which can be crushed to desired size, will reduce considerably the number of areas where special concrete sands will be required.

Even if the recommended material constituted a higher initial cost, the fact still remains that a drain incorporated in the design should be constructed with the finer material. For if too porous a material is used, the entire initial cost will have been wasted. Silting and subsequent clogging of the drain can be anticipated within two to three years.

Likewise, the cost of the most suitably graded materials for earthwork must be balanced against the cost of possible damage due to the use of improperly graded material.

Further study in this problem of backfill selection could be correlated with our soil study. The gradation and availability of the best backfill material for each parent material could be determined.

Very truly yours,

R. F. Baker
Materials Engineer

RFB:mr

attach.

POROUS BACKFILL

INTRODUCTION

Until the late 1930's, the accepted practice for the construction of drainage installation included the use of a large, approximately No. 2 size, aggregate as porous backfill. However, a large number of drains ceased to function as result of clogging or "silting"*, and many highway departments practically eliminated sub-surface and intercepting drainage.

The following report summarizes some of the more important studies that have dealt with "filter" (backfill material) to be used in drainage construction. The scope of it is limited, dealing primarily with the question of proper gradation.

At present Kentucky Specifications (1) require that the gradation of the aggregate for backfill over pipe underdrains be as "specified for Class 'A' concrete", (page 462), that is No. 6 size coarse aggregate (No. 8 to 1-1/2"). For stone underdrains, it is required (page 408) that a No. 2 coarse aggregate be used (1-1/2" to 3").

BACKGROUND

One of the fundamental studies of filters was completed in Austria by Terzaghi nearly 25 years ago (2)**. His results were applied to filter requirements for earth dam construction, and subsequently to water treatment problems. Basically, the problem faced by Terzaghi is the same as is encountered in highway construction: that is; (a) the filter material must be many times more pervious than the base (adjacent) material, and (b) the filter must be fine enough to prevent base particles from washing into the filter. Terzaghi concluded that:

- a. The 15 percent size*** of the filter material should be at least four times that of the 15 percent size of the base (in order to insure flow).
- b. The 15 percent size of the filter material should be less than four times that of the 85 percent size of the base (in order to prevent "silting").

* "Silting" is the process whereby water-borne soil particles from adjacent soils are deposited in the pipe or voids in the drain.

** Numbers in parentheses refer to bibliography at end of report.

*** The 15 percent size is taken from the gradation curve of a soil or aggregate, and is the size (normally in millimeters) at that point on the curve where 15 percent by weight of the grains is finer.

Mr. G. E. Bertram (3) confirmed this work of Terzaghi's, but he placed different values on the "critical ratios". According to Bertram, the 15 percent filter - 15 percent base size ratio, should be greater than 6; while for the 15 percent filter - 85 percent base sizes, the ratio should be less than 9.

In 1941, the Vicksburg Experiment Station (2) reported on filter requirements. The results of their studies were similar to those previously mentioned. The Vicksburg Report states "a fine material will not wash through a filter material if the 15 percent size of the filter material is less than five times as large as the 85 percent size of the fine base material"; and "the grain size curves for filter and base materials should be approximately parallel in order to minimize washing of the fine base material into the filter material."

Mr. H. E. Cotton in 1945 (4) prepared a report of highway sub-drainage practice in which he reviewed various mistakes commonly made, and gave his recommendation for the proper procedures. According to Mr. Cotton, "Experience has proved that coarse backfill is definitely not a proper material to be used in subdrain trenches. Numerous uncovered drains have revealed a completely clogged condition." In order to circumvent this problem, Mr. Cotton suggested: "While it is theoretically advisable to test the soils and specify filters for the particular soils encountered along the proposed drain, it is to a certain extent impractical and will not usually be done. Therefore, if possible it is more practical to select a filter gradation which will perform satisfactorily for all soils, or nearly all soils." For this type gradation, Mr. Cotton recommended: "The coarse size limits of the 15 percent size is identical with that of concrete sand as specified by the American Association of State Highway Officials".

The recommendations advanced in the four studies are shown graphically, for a typical base, in Fig. 1.

APPLICATIONS

Specifications and correspondence pertinent to the use of porous backfill material were studied for the following states: Illinois (5), Pennsylvania (6), Ohio, West Virginia (7), Virginia (8), and Indiana (9). In Fig. 2, a comparison is made between their specification and the recommended gradations. The states of Virginia and Ohio have recently changed their specification as per letters shown in Annex 1. Indiana was not included, since various sized aggregates are used (Annex 1), but no indication was given as to the method used in selecting the aggregate.

The solutions shown in Fig. 2 represent the nearest that the State Highway Departments can approach the gradation recommended by the various investigations. However, with the exception of Virginia, Ohio, and Indiana, there is no certainty that there have not been recent changes in specifications and practices.

Gravel Sand Silt Clay

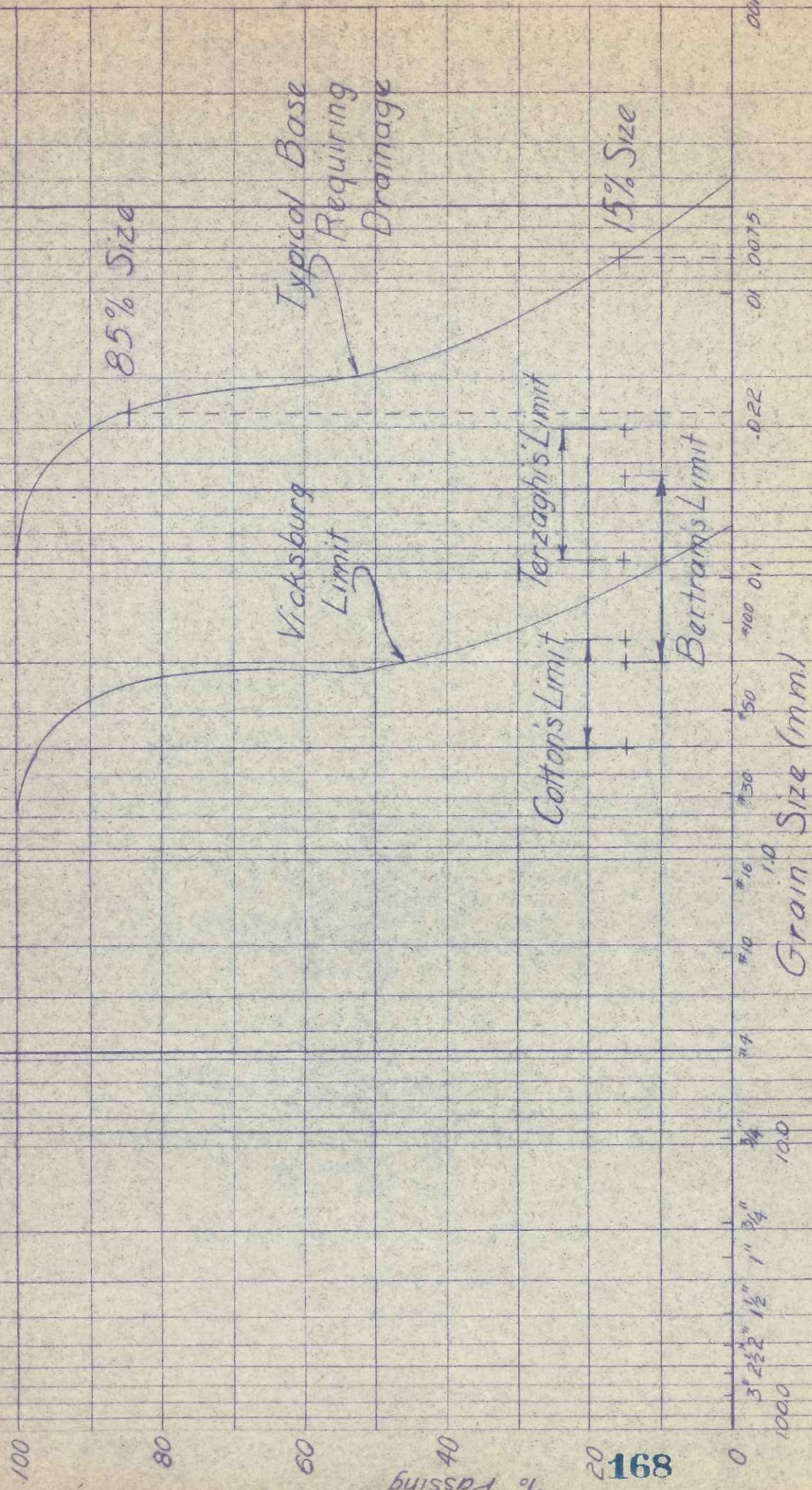


Fig. 1 - Filter Limits

JUNE 11, 1946

The "typical base" of Fig. 2, was selected at random as a gradation likely to require sub-surface drainage. It is a small grained soil, but not the smallest that could reasonably be expected in drainage construction.

DISCUSSION

Both theory and practice tend to verify the fact that a coarse material should not arbitrarily be used as porous backfill in drainage installations. Fig. 3 indicates the various failures that can and do develop if the filter material is too large. However, the fact remains that in many cases it does not appear economically feasible to use a fine grained material. Naturally, in such cases, reconstruction, maintenance, and initial costs of the project will have to be considered. In the event that a drain is absolutely necessary, it is most desirable that the filter material selected meet the requirements of (a) sufficient flow, and (b) sufficient imperviousness to soil flow.

OTHER APPLICATIONS

The principle that fine grained soils will be carried by water to the voids of larger grained soil, has many important applications in highway engineering. In Fig. 4, various illustrations of this fact are shown.

In the case of embankment construction, the settlement that would result from the movement of soil downward is apparent. Whether this instability would be serious would depend upon the height of the fill, depth of the porous layer, and the quantity of water percolating from the fine grained soil.

In side hill construction, it is common practice to place a porous layer over the stripped hillside, in order to intercept water. It is important that this water be kept out of the fill, both for protection against slides and for stability of the highway. Therefore, the porous layer must be fine enough to prevent silting and the subsequent trapping of water. For this type construction, however, an intercepting drain, similar to the one illustrated in Figure 4B, would also be necessary.

Weep holes in bridge abutments are normally "protected" by a porous layer between the end of the abutment and the backfill. These weep holes are designed to drain water from the fill, but they are also the entrance into the fill when the outside water level rises. As the water recedes it tends to carry soil with it. In both actions, the possibility for silting exists if the porous layer is not fine enough. Subsequent failures could include sliding, settlement, or both.

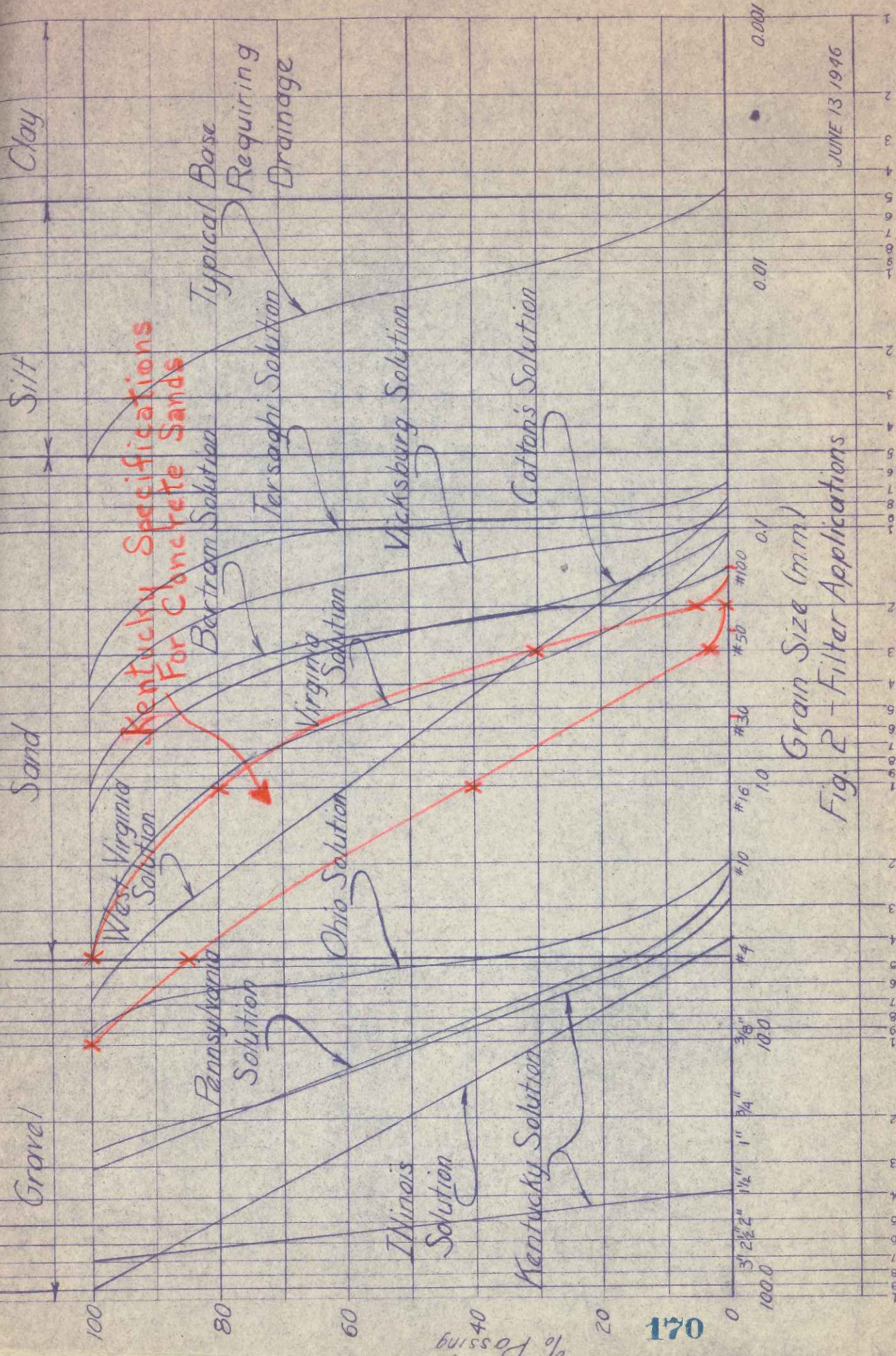
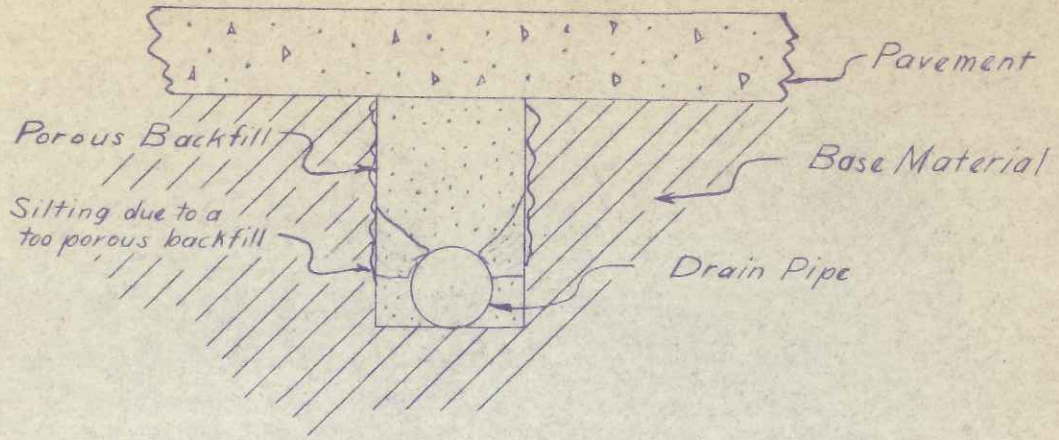


Fig. 2 - Filter Applications

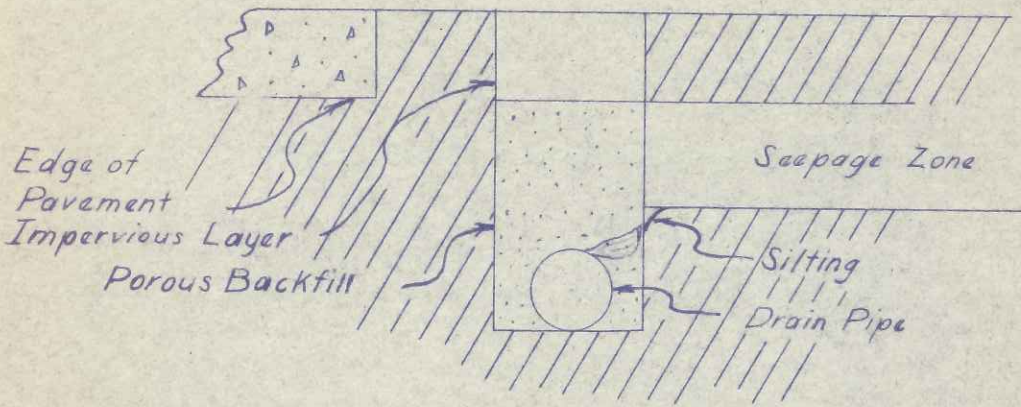
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A. Under Drains



B. Intercepting Drains



C. Longitudinal Drains

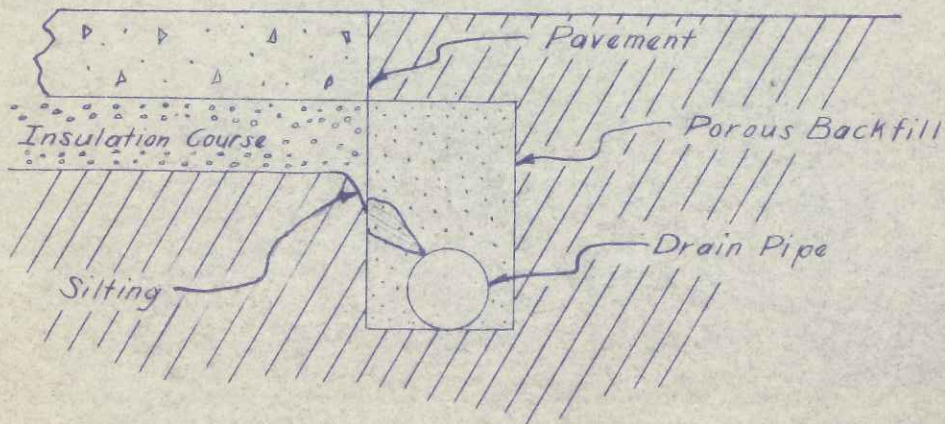
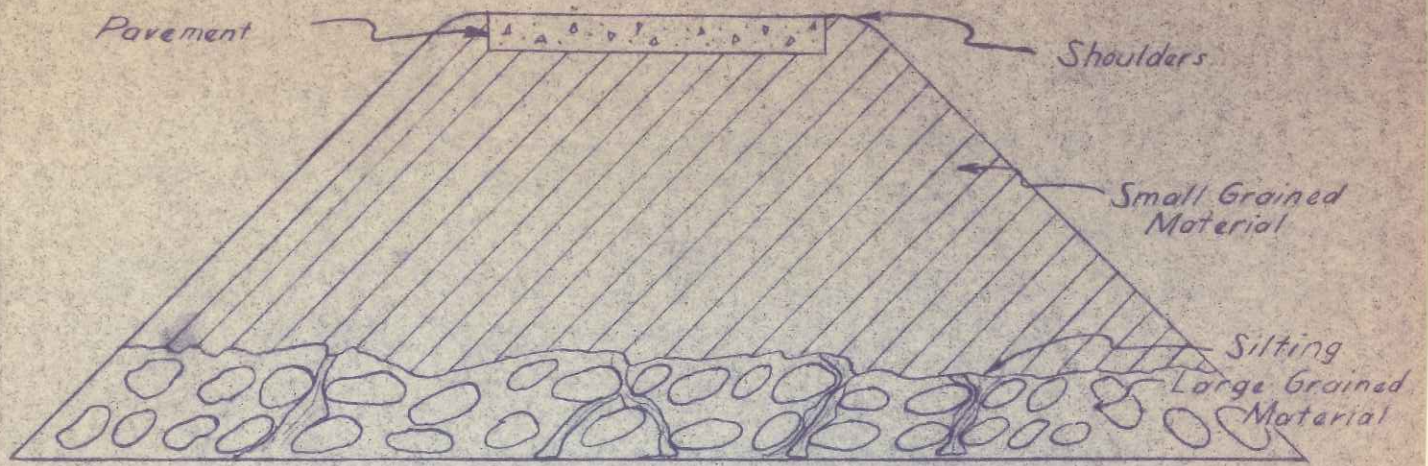
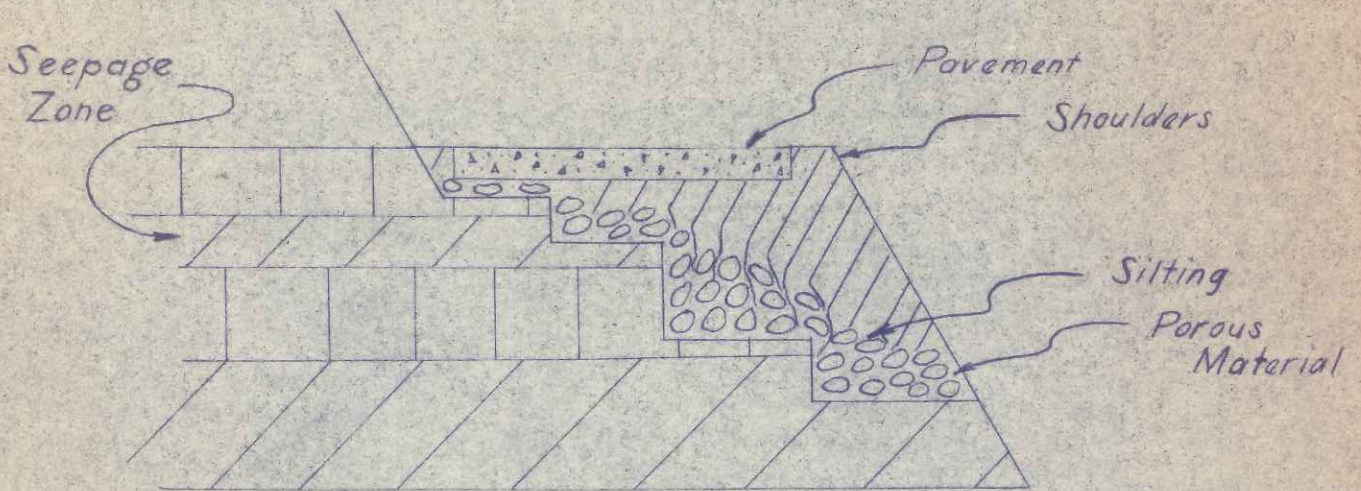


Fig. 3

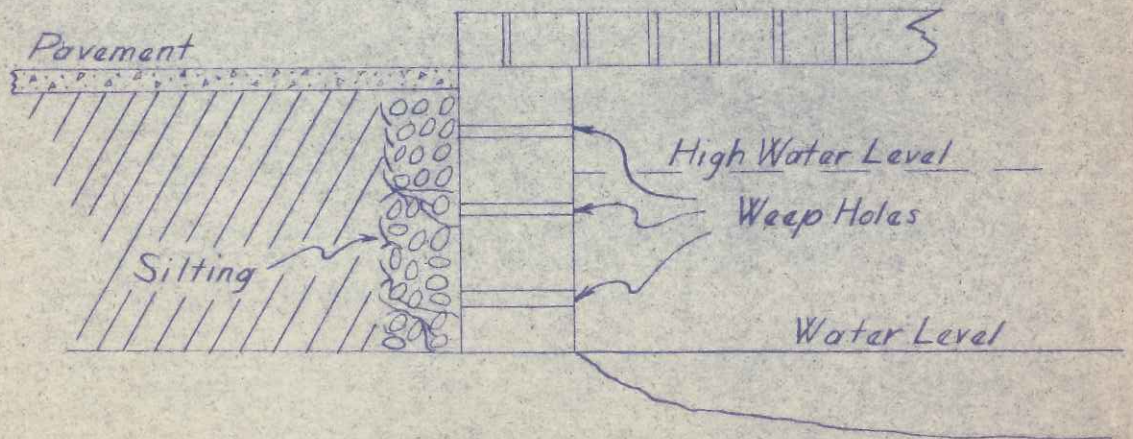
A. Embankment Construction



B. Sidehill Construction



C. Bridge Approaches



CONCLUSIONS

- 1. Coarse grained aggregates should not arbitrarily be used as porous backfill.
- 2. The gradation for porous backfill should be determined by the gradation of surrounding (or base) material.
- 3. To prevent silting, the 15 percent size of the filter should be between four and nine times the 85 percent size of the base material.
- 4. To insure flow, the 15 percent size of the filter should be four to six times the 15 percent size of the base.
- 5. In general construction, where flow of water may exist through adjacent soils, the principle of paragraphs 3 and 4 above, should be considered.

RECOMMENDATIONS

It is recommended that the 1945 Kentucky specifications be changed in the following ways:

- 1. That a section be added to "Division VII, Material Details" for the 1945 Kentucky Specifications to include backfill material. The gradation of this backfill material should be as follows:

"The gradation of all backfill material will be in accordance with standard concrete sand (par. 7.3.2 D). Locally available material may be used if 10-30% passes No. 50 sieve, 0-20% passes the No. 100 sieve, and 0-5% passes the No. 200 sieve.

- 2. For underdrain, page 406, par. 6.14.3 and page 408, par. 6.15.2. Gradation for backfill will be in accordance with par. 1 above.
- 3. For earthwork backfilling, page 65, par. 2.4.3-(f). A granular or rock material (as defined in par. 2.5.2) shall not be placed adjacent to a water-bearing finer grained soil, where settlement or interrupted drainage would be detrimental. The material to be used in such cases will conform with par. 1 above, or be similar in gradation to adjacent soil.
- 4. For porous backfilling. The gradation of the material will be in accordance with par. 1, above. This is applicable in the following instances:
 - a. Construction Methods: Weep Holes, page 66
 - b. Side Hill Embankments, page 72

- c. Concrete Arches: Weep Holes, page 261
- d. Culverts: Weep Holes, French Drains, and Underdrains, page 305
- e. Stone Masonry: Weep Holes, page 347
- f. Stone Masonry: Weep Holes, page 354
- g. Riprap: Underdrains, page 379
- h. Concrete Slope Walls: Underdrains, page 381
- i. Bin Type Retaining Wall: Weep Holes, page 392
- j. Curb Openings: Drains, page 413, page 416, page 417

BIBLIOGRAPHY

1. Kentucky Department of Highways, "Standard Specifications for State and Federal Road and Bridge Construction," February 10, 1945.
2. "An Investigation of Filter Requirements for Underdrains", Technical Memorandum #183-1, U.S. Waterways Experiment Station, Vicksburg, Mississippi, November 1, 1941.
3. G. E. Bertram, "An Experimental Investigation of Protective Filters", Soil Mechanics Series #7, Graduate School of Engineering, Harvard University, Cambridge, Massachusetts, 1939.
4. H. E. Cotton, "Highway Subdrainage and Base Drainage", ARMOO Drainage Products Association, Middletown, Ohio.
5. Illinois Division of Highways, "Standard Specifications for Road and Bridge Construction", July 1, 1942.
6. Pennsylvania Department of Highways, "Specifications", January, 1941.
7. West Virginia State Road Commission, "Standard Specifications - Roads", January, 1943.
8. Virginia Department of Highways, "Road Specifications", January 1, 1938.
9. Indiana State Highway Commission, "Standard Specifications for Road Construction", October, 1939.

ANNEX I

Part A

Excerpt of letter from Charles W. Allen, Acting Chief Engineer, Tests and Research, Ohio Department of Highways, dated March 13, 1946.

"The 1939 Ohio Specification for porous backfill for underdrains specified material of our No. 3 or No. 3a size. These materials as shown in the table below are quite coarse for backfill for drains. This fact was recognized by our design engineers at least as far back as 1941 and as a consequence finer textured materials were specified by special notes on the plans. On a number of projects the same material permitted for use in the granular subbase was also specified for backfill over the drains. This subbase material nearly always contained a large sand fraction and on several jobs some clogging of the drains resulted from the sand filtering into the drain tile at the joints. On subsequent projects it has been the practice to specify our No. 6 size aggregate around the pipe and for the first 6 inches above it. Usually the No. 6 size aggregate is used for the full depth of the backfill over the pipe. On a few projects, however, the material used as a subbase under the pavement has also been used as backfill down to the top of the No. 6 aggregate immediately around the pipe.

Our new specification will require No. 6 or No. 6a size for porous backfill over pipe underdrains.

Specification gradations for the various sized aggregates mentioned above are given in the following table:"

Standard Size	Total Per cent Passing (Square Openings)							
	2"	1-1/2"	1"	3/4"	1/2"	3/8"	#4	#8
3	100	80 - 95	20 - 55	0 - 15				
3a		100	30 - 65	0 - 20				
6					100	90 - 100	10-35	0-5
6a				100	90 - 100	40 - 70	0-15	0-5

Part B

Excerpt of letter from Tilton E. Shelburne, Director of Research, Virginia Department of Highways, dated February 11, 1946.

"In regards to your question concerning backfill material, I presume that you have reference to porous backfill material for drains. I have been unable to find anything in the 1938 Specifications covering this item. I understand, however, that in the past this has been taken care of on standard sheets and that a No. 1 stone (3-1/2" - 2") has been used. In checking with Mr. T. F. Loughborough, our Construction Engineer, he informs me that a much finer material is specified

in our new Specifications, namely, a No. 14 or 15 sand (see page 36 of the 1938 Specifications). Some difficulty has been encountered in the past in the use of underdrains, and we have been requested to make a study of current practices. As yet we have had little opportunity to work on this particular project."

Part C

Excerpt of letter from the State Highway Commission of Indiana, dated March 14, 1946, signed by F. F. Havey, Engineer of Tests, per W. T. Spencer, Soils Engineer.

"The aggregate for backfilling shall be Class A, B, or C, Size No. 7, except that the amount retained on the No. 4 sieve shall be 85-100 per cent instead of 70-100 per cent and that the loss by decantation shall not exceed three (3) per cent by weight.

We realize that this gradation has large voids that could permit the infiltration of fines if improperly used. However, since most of our normal subsurface drainage is used to remove water from granular water-bearing strata we feel that in most cases this material fits our needs and does a satisfactory job. If conditions are such that this material is not satisfactory for a localized area we feel that we can alter the gradation sufficiently to meet the special conditions encountered, or if these conditions are known in advance of the contract letting a special backfill can be set up to fit the local condition.

Generally our subsurface drainage installations are more or less local varying from four (4) to nine (9) hundred feet in length. Where long or extensive installations are involved more attention is given to exact needs and the type backfill best suited for the particular soil condition is specified. In some special cases, particularly the edge drain used to control pavement pumping, the standard backfill (size #7) was used in the bottom eleven (11) inches of the trench and the remainder of the trench backfilled with #14 sand. In other cases we have specified a minimum permeability coefficient with a maximum of 5% passing the #200 sieve.

Based on our past experience we have found it advisable to select one of our standard aggregate sizes as our standard backfill. If a standard size is specified the contractor, producer, and engineer know what is desired and in most cases the producer has such material in stock. However, if there is sufficient material involved to justify specifying a particular gradation then it is advisable to do so. We found it very difficult to advise the contractor and the producer what was meant and what was needed when permeability coefficient were specified.

Although the specification as quoted is our standard backfill for sub-surface drains we believe the backfill should be changed where conditions warrant. Generally these standard backfill specifications are satisfactory.