Improved Percolation Test for Septic Tank Leach Field Systems

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ABSTRACT

Septic tank systems are used at 50 percent of roadside rest areas in the United States for onsite disposal of wastewater generated from restrooms and from recreational vehicle waste holding-tank dump stations. The percolation test aids the sizing of septic tank leach fields by determining the percolation value for the soil, an index of the rate of seepage of water into the soil. The widely used Public Health Service percolation test procedure defines many aspects of the test, though some details are either discretionary or broadly defined. Comparative percolation tests were conducted to determine whether factors permitted to vary in the Public Health Service procedure could affect test results. Such factors investigated were: (a) test hole cross-sectional size; (b) method of excavation of test hole; (c) surface preparation of test hole; and (d) protection of interior surface of test hole. Based on findings of these comparative tests, certain precautions during testing are recommended to eliminate some causes of variation in test results, and a calculation is developed for adjusting raw data from percolation tests for the particular size of the test hole used. An improved percolation test method is proposed.

Figure 1 shows the distribution of waste disposal methods used at roadside rest areas in each Federal Highway Administration (FHWA) region and nationwide (1). Of 422 roadside rest areas surveyed nationwide, 50 percent were provided with septic tank systems, each treating waste flows up to 15,000 gallons per day (GPD). Although discharge of roadside rest area waste to municipal sewers is often favored where feasible, only in 6 percent of cases was this method actually employed, presumably because most roadside rest areas are in remote locations (1).

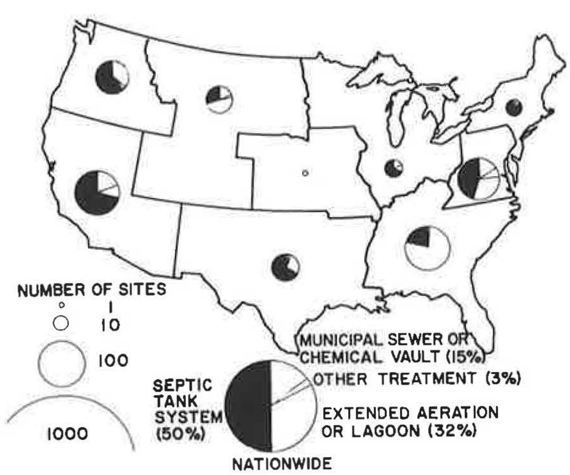

FIGURE 1 Roadside rest area wastewater disposal method methods according to FHWA region.

CHARACTERISTICS OF SEPTIC TANK SYSTEMS

Septic tank systems are relatively low in cost, easy to operate and maintain, and can tolerate fluctuations in loading and periods of nonuse. Where septic tank-leach field systems fail, failure is often manifested by surfacing of partially treated waste in the leach field. Common causes of such failure are:

1. Seepage following high precipitation;
2. Hydraulic overloading of the septic tank and leach field;
3. Failure to pump the septic tank with the result that septage overflows to clog the leach field;
4. Inadequate design of the leach field; and
5. Poor leach field construction.

PREDESIGN INVESTIGATIONS

The rate at which septic tank effluent will percolate into subsoil beneath the leach field is so site-specific that published or existing information can rarely be safely substituted for on-site investigations. Site investigations are made to evaluate the percolation characteristics of subsoil beneath the leach field trenches, and also to locate the maximum groundwater level under the leach field. A subsoil is considered suitable for a leach field if: (a) at the level of the leach field trench floor, the percolation value is between 5 and 30 min per in., and (b) groundwater remains at least 3 ft below the leach field trench floor (1). Where adverse subsoil or groundwater conditions exist, a sand filter might substitute for a leach field; sand filters are used in 15 percent of roadside rest area septic tank systems nationwide (1).

To assist in defining subsoil percolation characteristics, research was conducted by Van Kirk, Grottkau et al. (2) to develop a leach field percolation test procedure that appears more reputable than the Public Health Service procedure (3). The research concept was that some discretionary or broadly defined aspects of the Public Health Service percolation test procedure may affect test results. Based on findings of this research, a percolation test procedure was developed (2) that is consistent with, but more controlled than, Public Health Service and Environmental Protection Agency procedures (3,4).

EFFECT OF TEST HOLE BORE ON SOIL PERCOLATION VALUE

Existing Practice

The Public Health Service percolation test procedure (3) does not specify a particular cross-sectional

shape nor plan dimensions for the percolation test hole. The flexibility permitted by that procedure in selecting the plan dimensions of the test hole evidently resulted from findings of a series of comparative percolation tests that showed no statistically significant variation of percolation value with test-hole size (5). However, these tests were all conducted in tight soil with a percolation value > 60 min/in., outside the FHWA recommended range of 5 to 30 min/in. (1).

Other Observations of Percolation Value Versus Test Hole Size

Other results indicate that for percolation tests in holes of differing sizes in a given soil, percolation value varies approximately directly with the bore of the hole. At Tempe, Arizona, percolation values were determined in three 3.3-in. bore holes and three 13-in. bore holes. Mean percolation rates were found to be 1.9 min/in. in the 3.3-in. holes, and 6.0 min/in. in the 13-in. bore holes (6). The ratio of these percolation values is 6.0/1.9=3.2, which compares to the diameter ratio of 13/3.3=3.9. At Portola, California, the percolation value measured in twenty 5-in. bore holes averaged 2.0 times the percolation value measured in paired 12-in. bore holes (7). Again, the diameter ratio of 12/5=2.4 only slightly exceeds the 2.0 ratio of percolation values. This pattern of observations can be explained theoretically.

Theoretical Effect of Test Hole Geometry on Test Results

Consider a vertical cylindrical test hole of a horizontal cross-section denoted A, and sectional perimeter C, so that the cross-sectional hydraulic radius is R=A/C. For a circular-section hole, the hydraulic radius is one-quarter of the diameter, that is, R=D/4. Water seeps through the wall and floor soil interface of the test hole at a particular interfacial velocity, v. This velocity is assumed to depend on the depth of submergence of the point in question, h, according to a power law, $v=kh^n$, where k is the constant and n is the exponent. Exponent values of 0.0, 0.5, and 1.0 are considered here, recognizing that the velocity of flow through porous media is commonly written as proportional to hydraulic gradient raised to an exponent that ranges from 0.5 for turbulent flow to 1.0 for laminar flow (8).

The decrease rate of the water volume stored in the test hole equals the total rate of water seepage through the floor and walls of the hole, as represented by:

$$Ae'dH/dt = k(AH^n + \int_0^H Ch^n dh) = kAH^n\{1+H/[R(n+1)]\} \quad (1)$$

where

- e' = hole porosity (presently taken as unity);
- H = depth of water in hole;
- t = time; and
- h = depth of submergence of an elemental annular slice of the hole wall surface.

By integrating Equation 1 (9), expressions for the time variation of water level can be obtained for n = 0.0, 0.5, and 1.0, respectively, by:

$$H_t = (R + H_0)[(R + H_T)/(R + H_0)]^{t/T} - R$$

$$H_t = 1.5R \tan^2\{(t/T)[\mathrm{arctg}\sqrt{H_T/(1.5R)} - \mathrm{arctg}\sqrt{H_0/(1.5R)}] + \mathrm{arctg}\sqrt{H_0/(1.5R)}\}$$

$$H_t = 2R/\{(1+2R/H_0)[(1+2R/H_T)/(1+2R/H_0)]^{t/T} - 1\} \quad (2)$$

where H_t equals water depth at time t. Profiles of water level versus time computed by Equations 2-4 are reasonably linear and independent of exponent n for small changes in water level, as Figure 2 shows.

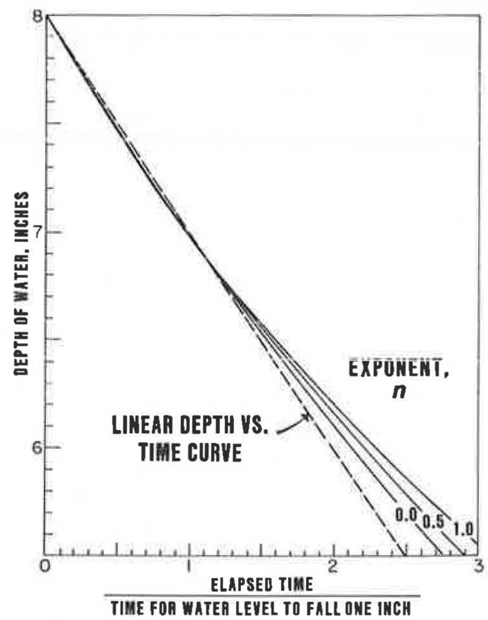

FIGURE 2 Example test hole depth versus time profiles by Equation 2.

However, percolation value will vary between tests in holes of differing cross-sectional size, that is, differing R. Given two holes of hydraulic radii, R_1 and R_2, with common initial water depths H_0, the respective water depths at any time during simultaneous percolation tests, H_1 and H_2, are related by:

$$H_2 = (R_2 + H_0)[(R_1 + H_1)/(R_1 + H_0)]^{R_1/R_2} - R_2$$

$$H_2 = 1.5R_2 \tan^2\{\sqrt{(R_1/R_2)}[\mathrm{arctg}\sqrt{H_T/(1.5R_1)} - \mathrm{arctg}\sqrt{H_0/(1.5R_1)}] + \mathrm{arctg}\sqrt{H_0/(1.5R_2)}\}$$

$$H_2 = 2R_2/\{(1+2R_1/H_1)[(1+2R_2/H_0)/(1+2R_1/H_0)]^{R_1/R_2} - 1\} \quad (3)$$

For n = 0, 0.5, and 1.0, respectively.

Depths of water in the test hole at the start and end of the percolation test are H_0 at time 0 and H_T at time T, so the percolation value indicated by the test results is:

$$P = T/[e'(H_0 - H_T)] \quad (4)$$

Consequently, relative percolation values in test holes of different sizes are computed by substituting Equation 3 in Equation 4 written as:

$$P_2 = P_1[e'_1(H_0 - H_1)]/[e'_2(H_0 - H_2)] \quad (5)$$

where e'_1, e'_2, P_1, and P_2 are porosities and percolation values in test holes of hydraulic radii, R_1

and R_2, respectively. By combining Equations 3 and 5, a percolation value measured in a test hole of hydraulic radius R_1 may be adjusted to the equivalent value for a test hole of hydraulic radius R_2.

A simpler method of adjusting percolation test data for test-hole size uses the property that the depth versus time profile is fairly linear for small changes in water level as illustrated in Figure 2, so that Equations 1 and 4 can be combined to:

$$1/P \simeq e'dH/dt = kH^n \{1+H/[R(n+1)] \} \qquad (6)$$

Then for n = 0:

$$P_2/P_1 \simeq (1+H/R_1)/(1+H/R_2) \qquad (7)$$

If $H \approx H_0 = 8$ in. as recommended later herein, and P_2 is the percolation value for a 12-in.-bore test hole, then:

$$P_2/P_1 \simeq [1+8/(0.25D_1)]/[1+8/(0.25x12)] = 0.27+8.7/D_1 \qquad (8)$$

where P_1 is the percolation value as measured in a D_1-in. bore hole.

Table 1 contains ratios of the percolation value in a 12-in.-diameter test hole to the percolation value in a test hole of lesser bore, computed by the preceding equations. Leach field design criteria are based on percolation values as determined in 12-in. test holes (10), so determinations in smaller holes should be adjusted to values for a 12-in. hole. Equations 3-8 predict higher percolation values in 12-in. test holes than in smaller holes, so percolation value determinations from smaller holes that are used for design without adjustment will produce an underdesigned leach field.

Equation 8, the simplest of the adjustment equations, generally overadjusts the results of a small-bore-hole percolation test. Equation 8 thus produces a safer design than other equations, provided the actual depth of water in the hole at the beginning of the test does not exceed 8 in. For initial water depths other than 8 in., Equation 7 safely approximates the adjustment factor. The data in Table 1 demonstrate that variations in test conditions--such as the initial depth of water, and the fall in water level during the test--may explain some of the variability in field determinations of percolation value. Further significant effects might be demonstrated by exploring a more exact analytical framework than Equation 1 provides, coupled with field investigations.

MAINTAINING THE PERVIOUS SOIL STRUCTURE IN PERCOLATION TESTING

The continued ability of a leach field to remove wastewater that it receives depends on establishing and maintaining an adequate wastewater seepage rate from the leach field into the subsoil. Failure of this seepage process can be caused by (a) the inherent impermeability of the subsoil, (b) intrusion of groundwater into the leach field, (c) destruction of the pervious structure of the subsoil, or (d) clogging of the subsoil by waste solids or biological growths.

The first two of these factors are identified through routine site investigations that include percolation tests. During these percolation tests, care is needed to maintain the pervious structure of the soil. Similar care is needed during construction and operation of the leach field. Otherwise, in percolation testing as in construction of the leach field, an otherwise suitable subsoil can become impermeable by compaction or smearing of the infiltrative subsoil interfaces, or by erosion of fines to the floor of the open excavation.

Augering of Test Hole

Power augering of a percolation test hole compacts excavated soil into the walls of the hole to a greater extent than hand augering. Compaction of soil into the walls of a percolation test hole during power-augering reduces the water seepage rate, thus increasing the percolation value.

TABLE 1 Factors to Adjust Percolation Values to Equivalent 12-Inch Bore Test Hole Percolation Values[a]

Initial depth of water in test hole, inches	Diameter of test hole, inches	Approximate solution for P_1/P_2 by Eq. 5c	Fall in water level during percolation test: One inch — More exact solution for P_1/P_2 for assumed n: n = 0.0 Eq. 3a	One inch: n = 0.5 Eq. 3b	One inch: n = 1.0 Eq. 3c	Four inches: n = 0.0 Eq. 3a	Four inches: n = 0.5 Eq. 3b	Four inches: n = 1.0 Eq. 3c
8	2	4.62	4.40	3.90	3.50	3.62	2.93	2.43
	4	2.45	2.36	2.16	2.00	2.04	1.77	1.57
	6	1.72	1.68	1.58	1.50	1.52	1.38	1.29
	8	1.36	1.34	1.29	1.25	1.26	1.19	1.14
	10	1.14	1.14	1.12	1.10	1.10	1.08	1.06
	12	1.00	1.00	1.00	1.00	1.00	1.00	1.00
24	2	4.62	5.35	5.08	4.83	5.06	4.68	4.33
	4	2.45	2.74	2.63	2.53	2.62	2.47	2.33
	6	1.72	1.87	1.82	1.77	1.81	1.74	1.67
	8	1.36	1.44	1.41	1.38	1.41	1.37	1.33
	10	1.14	1.17	1.16	1.15	1.16	1.15	1.13
	12	1.00	1.00	1.00	1.00	1.00	1.00	1.00

[a] Multiply tabulated P_1/P_2 value by measured percolation value to obtain equivalent 12-inch bore test hole percolation value.

TABLE 2 Effect of Augering Method on Percolation Rate (2)

Test location	Soil analysis, percent by weight			Percolation value, minutes per inch		Ratio of power auger percolation rate to hand auger percolation rate
	Sand	Silt	Clay	Power auger	Hand auger	
Transportation Laboratory,	39	39	22	46,53	0.3	38 (mean)
California Department				61,61	1.0	
of Transportation,				61,92	2.9	
Sacramento, California				122,122	3.8	
				122,122	4.4	
				122,182,375	6.1	
Dean Creek	33	52	15	14	0.7	43 (mean)
proposed roadside rest,				17	0.7	
near Garberville, Calif.				24	0.9	
				80	1.0	
Auburn Lake	--	--	--	>60	2.4	25
trails development,				80	0.8	100
near Cool, California				120	4.3	28
				240	10	24
				240	50	5

Table 2 summarizes results of tests at three locations to compare percolation values between power-augered holes and hand-augered holes. Percolation values measured in holes that were power-augered for their full depth averaged about 30 times higher than percolation values measured at the same sites in holes that were hand-augered for the final foot or more of depth. To minimize compaction of soil in the walls of the lower portion of a percolation test hole where the test is conducted, it is recommended that the final foot or more of hole depth be hand-augered.

Interior Surface Preparation of Test Hole

As mentioned earlier, the permeability of a cohesive subsoil can be sharply reduced as a result of smearing of tooled surfaces during excavation, or due to erosion of fines that can clog soil pores particularly on the floor of a ponded excavation. To minimize these possible effects before conducting a percolation test, hand-augered surfaces should first be scraped to roughen possibly smeared soil surfaces, and loose soil should be removed from the test hole.

Armoring of Test Hole

Protection is usually needed to avoid water scour or structural collapse of the carefully prepared surfaces of the percolation test hole during testing. The best way to accomplish this is by armoring the bottom of the test hole with a 2-in.-deep layer of 0.25-in.-sized pea gravel, and the walls with an approximately 0.75-in.-thick annular layer of pea gravel retained by a vertical length of perforated pipe. A piece of perforated pipe about 6 in. longer than the depth of the test hole should be centrally set on end on the bed of pea gravel, and more pea gravel should be placed between the pipe and walls of the hole.

Percolation values were compared between armored and unarmored test holes. The data in Table 3 indicate that in a cohesive soil (clay loam) the mean percolation value in 12 unarmored test holes was about 16 times the mean percolation in 6 armored test holes. Evidently, armoring of test holes protected their interior surfaces from scouring or collapse. Water added to an unarmored hole in clay loam produced a suspension of clay that appeared responsible for clogging soil pores. The data in Table 3 indicate an opposite trend, however, for granular soil, of a slightly higher percolation value in armored holes than unarmored holes; but this trend was statistically insignificant.

Gravel and perforated pipe occupy space in an armored test hole, so voids space (as measured by the volume of water needed to fill the hole) is less than if armoring materials were removed. Voids occupy the entire capacity of an unarmored hole so the porosity is unity. The porosity of an armored test hole is the voids fraction of the portion of capacity of the same hole without armoring that lies within the range of water level of the percolation test, which for a circular-section hole reduces to:

$$e' = e[1-(O/D)^2] + (I/D)^2 \quad (9)$$

where

- e' = hole porosity;
- e = pea gravel porosity;
- D = test hole diameter; and
- O and I = outside and inside diameters of perforated pipe, respectively.

With an armored test hole porosity of e' and unit porosity for an unarmored standard 12-in. test hole, then the joint correction for the hole size and armoring of the test hole results from combining Equations 8 and 9 by:

$$P_2/P_1 \simeq K = (0.27+8.7/D)/\{e[1-(O/D)^2] + (I/D)^2\} \quad (10)$$

TABLE 3 Effect of Pea Gravel Armoring of Test Hole on Percolation Rate

Test location and soil classification	Soil analysis, percent by weight				Percolation value, minutes per inch				Ratio of unarmored hole percolation value to armored hole percolation value
					Without armoring		With armoring		
	Gravel	Sand	Silt	Clay	Values	Mean (CV%)	Values	Mean (CV%)	
Transportation Laboratory, California Department of Transportation, Sacramento, California (clay loam)	0	39	39	22	20,24	50	0.3	3.1	16
					27,30	(57)	1.0	(70)	
					34,40		2.9		
					48,60		3.8		
					60,60		4.4		
					80,120		6.1		
Camp Roberts, northbound roadside rest area, near Paso Robles, California (sandy gravel)	25	57	6	8	2.0,4.0	4.1	3.3	9.3	0.4
					4.1,4.3	(27)	4.8	(71)	
					5.0,5.1		11.4		
							17.8		

where

K = correction factor;
P_2 = percolation value corrected to a 12-in.-diameter unarmored test hole, min/in.; and
P_1 = percolation value observed in a D-in. diameter armored test hole with an initial water depth of 8 in., min/in.

Presoaking and Adding Water To the Test Hole

Overnight presoaking of a percolation test hole before starting the test will allow cohesive soils to swell, and it will establish pseudo-steady-state seepage from the hole as during operation of a leach field at the site.

A domestic toilet-type float valve can be adapted to maintain a steady depth of water in the test hole during the presoaking period, provided water pressure at the site is adequate to operate the valve. Water should be introduced gently and to the bottom of the hole to avoid scouring the soil. For manual filling of the hole, the water supply hose can be connected to a valved section of 3/8-in.-diameter soft copper tubing long enough for a gentle stream to be directed to the bottom of the hole.

Water Level Measurement

Percolation testing involves measuring the fall in water level in a prepared test hole during a timed interval. The Public Health Service procedure (3) recommends measuring the fall in water level with the aid of two stakes: a movable vertical pointed stake, and a fixed horizontal reference stake fastened above the test hole to posts on either side of the hole. At the start and end of the timed test interval the vertical stake is supported with its point in contact with the water surface and scribed against the horizontal reference stake. The fall in water level over the timed interval is then measured as the distance between the marks scribed on the vertical stake.

This method was found to be rather awkward in practice and gave slightly variable results with discrepancies between replicate readings by different observers averaging 3/16 in. (6). A float gauge was found easier to use and was judged more accurate for indicating water level changes in the test hole. Such a gauge was fabricated from a plastic bottle, small enough to fit inside the perforated pipe, with a rod calibrated in inches (increasing downwards) fastened into the neck of the bottle. The gauge floats in the test hole, rising and falling with varying water level in the hole. Changes in water level in the test hole are read as differences between readings on the calibrated rod against an adjacent fixed reference point.

This float gauge may also be used as an aid to adjustment of the depth of water over the pea gravel surface to a specified value (6 in.) at the start of each timed interval in the percolation test. This is accomplished by reading the gauge first when depressed to rest on the pea gravel, then again when released to float on the water. Water is added to, or removed from, the hole until the reading with the floating gauge exceeds that for the depressed gauge by an amount equal to the specified depth of water over the pea gravel (6 in.) minus the draft of the gauge. (The draft of the gauge is the minimum depth of water needed to float the gauge, measured one time for a particular gauge. To measure its draft, the gauge is placed in an empty bucket and water is trickled in until the gauge begins to float, whereupon the draft is measured as the depth of water in the bucket without removing the gauge.)

Percolation Test Procedure and Results

A test procedure is proposed in the following section of this paper, based on the preceding considerations. In this procedure, the time for the test-hole water level to fall a measured amount ($\leq$ 1 in.) is recorded and adjusted by Equation 10 according to specific details of construction of the test hole. This simulates test conditions in a 12-in.-bore open

test pit similar to that used by Ryon (10), upon whose work leach-field design criteria are based (3).

As was indicated in Tables 2 and 3, water seeps more rapidly from test holes into subsoil if precautions are taken to reduce compaction of soil into the test hole walls during excavation of the hole, and if the interior surfaces of the test hole are roughened, loose material removed, and the prepared surfaces protected by armoring. A higher rate of seepage translates into economy in leach field design, provided precautions to maintain the pervious structure of the soil are as stringent during construction of the leach field as during percolation testing. Otherwise, the ability of a cohesive subsoil to accept water or wastewater can be seriously impaired.

Leach Field Construction Considerations

Precautions necessary during construction of a leach field to protect the pervious structure of the subsoil include: (a) working only in dry weather and above groundwater; (b) closing a leach field trench overnight; (c) hand removal after machine excavation of any smearing or consolidation of the trench walls; (d) removing loose material from the trench floor before placing gravel; and (e) using only clean, uniformly graded gravel protected from contamination by fines before use and during use.

TEST METHOD FOR DETERMINING SOIL PERCOLATION VALUE

Scope

This test is an aid to sizing septic tank leach field systems. The test determines the percolation value of a soil, an inverse index of the tendency for water to seep into the soil. Percolation value is determined from measurements of the fall in water level in a prepared hole in the soil over a timed interval.

Apparatus

Some of the following items are illustrated in Figure 3:

- Six-in. diameter hand auger,
- Hole scraper (Figure 3a),
- Hole cleanout tool (Figure 3b),
- Stopwatch,
- Supply of water, for example, tanker truck,
- One per test hole of each of the following items:
  - Float valve (perhaps adapted from a toilet cistern valve as in Figure 3c), to be operable at pressure of available water supply;
  - Perforated PVC pipe, 4-1/2-in. outer diameter, about 6 in. longer than depth of hole (Figure 3d);

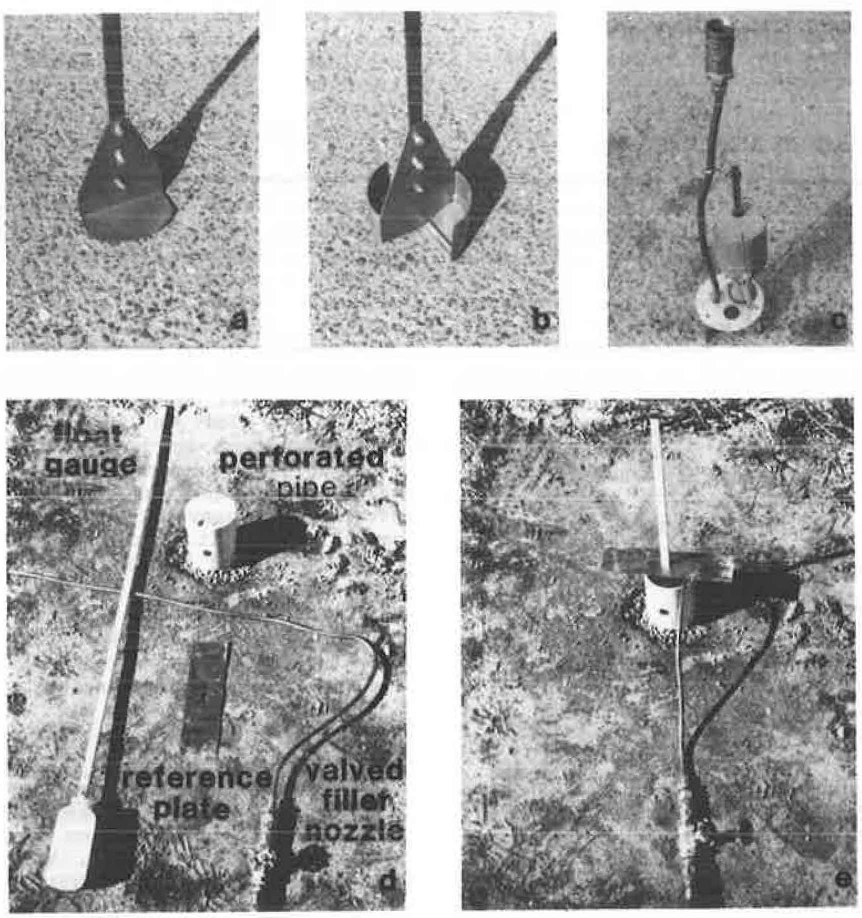

FIGURE 3 Some items of equipment for percolation testing: (a) scraper tool; (b) hole cleanout tool; (c) float value; (d) unassembled test apparatus; (e) assembled test apparatus.

- Float gauge fabricated from plastic bottle, with rod calibrated in inches (increasing downwards) fastened into the neck (Figure 3d);
- Reference plate, for example, 12 in. x 6 in. x 16g steel, slotted slightly larger than float gauge rod (Figure 3d);
- Valved filler nozzle of 3/8-in. soft copper tubing about 2 ft longer than the perforated pipe, connected through a gate valve and hoses to the water supply (Figure 3d); and
- Pea gravel, sized approximately 1/4 in., about 1/6 ft^3.

Determine the porosity of the pea gravel, and measure the inside and outside diameters of the perforated pipe, and the draft of each float gauge. Compute the correction factor by Equation 10.

Visual Inspection of Soil Profile

Excavate by backhoe or borings and document the vertical profile of soil strata at the site, noting particularly conditions that may impede drainage from the leach field, such as hardpan (4). Confirm that groundwater levels remain at least 3 ft below the leach field invert level. If monitoring of the maximum groundwater level is necessary, simple ways to record the high water mark in a test pit are: (a) sprinkle a conspicuous floatable powder in the pit, for example, cork dust; or (b) place in the pit a stake with a water-soluble coating, for example, blackboard chalk.

Preparation of Test Holes

Usually six or more test holes are dug and distributed to represent conditions over the entire leach field. More test holes may be needed later if some are found to have percolation values outside the FHWA-recommended range of 5 to 30 min/in. (1). The following procedure applies for each test hole and is illustrated in Figure 4:

- Machine augering is permissible to within 12 in. from the bottom of the test hole (Figure 4a);
- Hand-auger for the final 12 in. or more of depth (Figure 4b);
- Scrape the lowest 12 in. of sidewall and remove loose soil from the hole (Figure 4c);
- Place a 2-in. depth of pea gravel in the hole (Figure 4d);
- Centrally set a perforated pipe on end in the hole (Figure 4e);
- Backfill the annular space between the perforated pipe and the hole walls with pea gravel for 12 in. of depth (Figure 4f);
- Install float valve and connect to water supply (Figure 4g);
- Presoak hole by maintaining constant water level in hole at least 6 in. above pea gravel at bottom of hole, for 18 hr or more (Figure 4h);
- Adjust depth of water over pea gravel to 6 in. with float gauge in place (Figure 4i);
- Repeat the following procedure at least three times until a stable percolation value is obtained:
  - Adjust the water level to 6 in. above the surface of the layer of pea gravel in the bottom of the hole, and start the stopwatch at zero (Figure 4j);
  - Record the time in minutes for the water level to fall an inch or measured fraction of an inch (Figure 4k); and
- Calculate (Figure 4l):

Percolation value = correction factor x time, in minutes/fall in water level, in inches.

Table 4 contains an example of data collection and reduction. A stabilized percolation value in the range 5 to 30 min/in. is considered suitable for a leach field, provided groundwater does not rise closer than 3 ft below the invert of the leach field trenches (1).

TABLE 4 Example Percolation Test Data

Parameter	Value		
Test location	Translab, Sacramento		
Test date	September 11, 1982		
Test made by	J. Van Kirk		
Weather	Clear, sunny, 70-75 F		
Type of soil	Silty loam		
Presoaking period, hr	24		
Test hole diameter, D, in.	6		
Perforated pipe OD, O, in.	4 1/2		
Perforated pipe ID, I, in.	4 1/4		
Pea gravel porosity, e	0.4		
Test hole number	1	2	3
Test hole depth, in.	43	40	42
Initial gauge reading, in.[a]	13 3/8	12 1/4	13
Interval of test readings	1 in.	10 min	30 min
Test reading #1	2m 39s	13 in.	13 3/4 in.
#2	2m 50s	13 1/8 in.	13 5/8 in.
#3	2m 55s	13 in.	13 7/8 in.
#4	2m 53s	13 in.	13 7/8 in.
#5	2m 54s	13 in.	13 7/8 in.
Raw percolation value, min/in.	2.9	10/(13-12 1/4) = 13.3	30/(13 7/8 -13) = 34.3
Correction factor[b]	x 2.54	x 2.54	x 2.54
Percolation value, min/in.	= 7.4	= 34	= 87

[a] Water added to give this gauge reading before each test interval.

[b] $K = (0.27 + 8.7/D)/\{e[1-(O/D)^2] + (I/D)^2\}$

$= (0.27+8.7/6)/\{0.4[1-(4.5/6)^2]+(4.25/6)^2\} = 2.54$

CONCLUSIONS

The percolation test aids the sizing of septic tank leach fields by determining the percolation value for the soil, an index of the rate of seepage of water into the soil. The widely used Public Health Service percolation test procedure defines many aspects of the test, though some details are discretionary or broadly defined. Comparative percolation tests were conducted to determine whether factors permitted to vary in the Public Health

FIGURE 4 Steps of proposed method for percolation test: (a) machine-auger except for final foot of depth; (b) hand-auger final foot of depth of test hole; (c) scrape lowest foot of sidewall and remove loose soil; (d) place two inches of pea gravel on bottom of hole; (e) install perforated pipe; (f) backfill between pipe and hole walls with pea gravel; (g) install and connect float valve; (h) presoak test hole for at least 18 hours; (i) float gauge indicates depth of water over gravel; (j) adjust depth of water over gravel at start of test; (k) record time for water level to fall measured distance; (l) compute percolation value.

Service procedure could affect test results. Such factors investigated were:

- Test hole cross-sectional size,
- Method of excavation of test hole,
- Surface preparation of test hole, and
- Protection of interior surface of test hole.

Based on findings of these comparative tests, precautions during testing are recommended to eliminate some causes of variation in test results, and a calculation is developed for adjusting raw data from percolation tests for the particular size of the test hole used. An improved percolation test method is proposed.

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REFERENCES

1. N.R. Francingues, Jr., G.W. Hughes, D.E. Averett, and J.L. Mahloch. Rest Area Sewage Treatment Methods State of the Practice; Current Technology, Interm Design Criteria and Regulations, Phase I. Report FHWA-RD-76-64. FHWA, U.S. Department of Transportation, Dec. 1975, 126 pp.

2. J.L. Van Kirk, W.A. Grottkau, R.B. Howell, and E.C. Shirley. Percolation Testing for Septic Tank Leach Fields at Roadside Rests. Report FHWA/CA/TL-81/05. Transportation Laboratory, California Department of Transportation, Sacramento, 81 pp.
3. Manual of Septic Tank Practice. Public Health Service, U.S. Department of Health and Human Services, 1967 (Rev.), 92 pp.
4. C.V. Clements et al. Design Manual: Onsite Wastewater Treatment and Disposal Systems. EPA 625/1-80-012, Office of Water Program Operations, Office of Research and Development, Municipal Environmental Research Laboratory, Environmental Protection Agency, Oct. 1980, 412 pp.
5. T.W. Bendixen, M. Berk, J.P. Sheehy, and S.R. Weibel. Studies on Household Sewage Disposal Problems, Part II. NTIS Report PB-216-128, Environmental Health Center, Public Health Service, Cincinnati, Ohio, 1950, 96 pp.
6. J.T. Winneberger. Septic Tank Practices, Part II. Arizona State University, Tempe, Nov. 1972.
7. J.T. Winneberger. Studies of the Feasibility of Subsurface Disposal of Wastewaters at Corte Madera Ranch, Portola Valley, California. Report I, Redwood City, Aries Enterprise, Nov. 1979.
8. L.G. Rich. Unit Operations of Sanitary Engineering. Wiley and Sons, New York, 1961, 308 pp.
9. I.S. Gradshteyn and I.M. Ryzhik. Table of Integrals, Series, and Products, (A. Jeffrey, ed.), Academic Press, New York, 1980.
10. H. Ryon. Notes on the Design of Sewage Disposal Works, with Special Reference to Small Installations. Unpublished paper, Albany, N.Y., 1928.

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Onsite Disposal of Restroom and Recreational Vehicle Wastes

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ABSTRACT

Septic tank systems are used at 50 percent of roadside rest areas in the United States for onsite disposal of wastewater generated from restrooms and from recreational vehicle waste holding tank dump stations. Survey results are presented from 28 California roadside rest areas of the use of rest areas, and of the volume and strength of wastewater generated at restrooms and dump stations. Traffic densities in peak months averaged 24 percent higher than the annual mean, while peak holiday weekend densities averaged 86 percent higher for facilities serving one direction of traffic. A mean of 12 percent of mainline traffic used the rest areas, and of the traffic using rest areas that provided dump stations, 2 percent were recreational vehicles that actually dumped. Restrooms generated 5.5 gal of waste per vehicle, and dump stations generated 12 gal of wastewater plus 9 gal of washdown water per dump. Restroom wastewater is comparable in strength to domestic wastewater, but dump station wastewater (diluted by washdown water) produces about 20 times the quantity of sludge as the same volume of domestic wastewater. Depending on the proportion of dump station waste and the frequency of pumping the septic tank, rest area septic tanks should be sized to provide 1.5 to 30 days detention of diluted dump station wastewater, compared to 1.5 days for a domestic septic tank. Septic tank-leach field system design procedures consider the risk of overload for a particular design, or permit design to a selected acceptably low risk of overload.

Restroom toilets so predominate among roadside rest area amenities that a rest area may have to be closed if its waste disposal system fails. Being distant from city sewers, most rest areas must dispose of the wastewater they generate onsite. One-half of the roadside rest areas surveyed in the United States used septic tank systems for wastewater disposal (1). The design of onsite wastewater disposal systems for roadside rest areas are addressed in this paper, with emphasis on septic tank systems.

EFFLUENT QUALITY REQUIREMENT

Section 301b of the 1972 Amendments to the Federal Water Pollution Control Act (P.L. 92-500) requires a level of effluent quality of point waste discharges equivalent to secondary treatment (2) (i.e., that level generally specified for municipal discharges). Section 402 of this Act requires monitoring of the quality of effluent discharges greater than 50,000 gal per day. For lesser discharges (as from most roadside rest areas) the question of whether ef-