Lecture 4 보충자료 #1

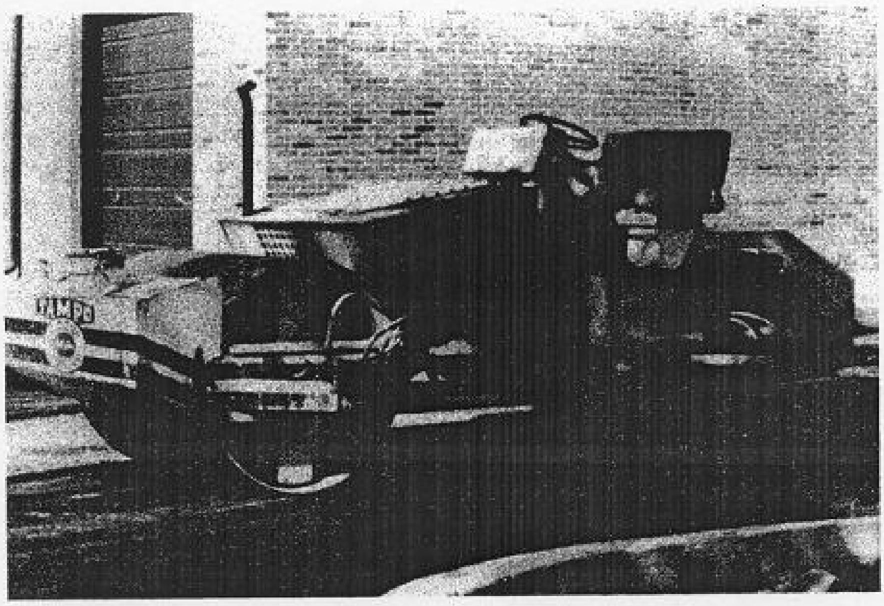
N-값, 상대밀도, 내부마찰각의 관계 (Peck and Meyerhof, 1956)

N 값	상대밀도	D_r	내부마찰각 (φ)	
			Peck	Meyerhof
0~4	very loose	0.0~0.2	< 28.5	< 30
4~10	loose	0.2~0.4	28.5~30	30~35
10~30	medium	0.4~0.6	30~36	35~40
30~50	dense	0.6~0.8	36~41	40~45
50 <	very dense	0.8~1.0	41 <	45 <

TABLE 7.6. COMPACTION EQUIPMENT AND METHODS (NAVDOCKS DM-7).

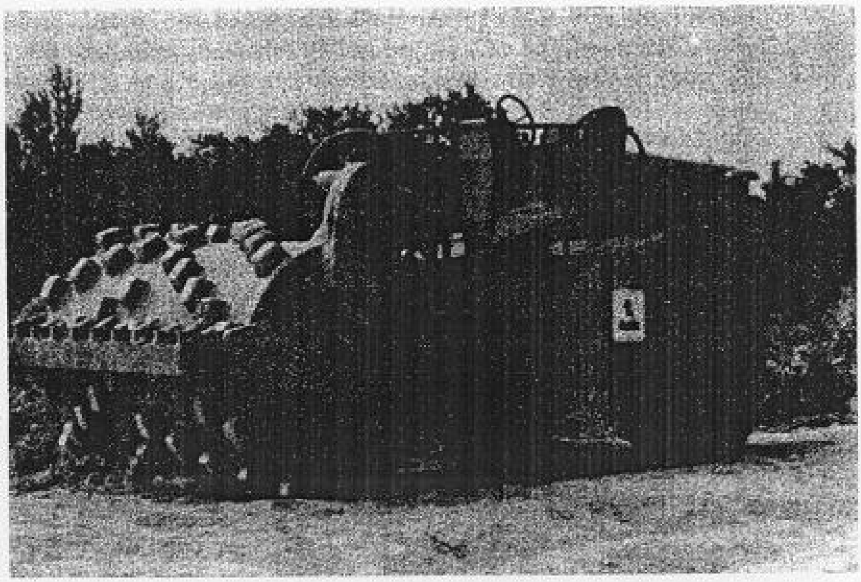
Equipment type	*Applicability*	*Requirements for Compaction of 95 to 100 Percent Standard Proctor Maximum Density*			*Possible variations in equipment*
		Compacted lift thickness, in	*Passes or coverages*	*Dimensions and weight of equipment*	
Sheepsfoot rollers	For fine-grained soils or dirty coarse-grained soils with more than 20 percent passing the No. 200 sieve. Not suitable for clean coarse-grained soils. Particularly appropriate for compaction of impervious zone for earth dam or linings where bonding of lifts is important.	6	4 to 6 passes for fine-grained soil; 6 to 8 passes for coarse-grained soil	Soil type / Foot contact area, in^2 / Foot contact pressures, psi: Fine-grained soil $PI > 30$ — 5 to 12 — 250 to 500 Fine-grained soil $PI < 30$ — 7 to 14 — 200 to 400 Coarse-grained soil — 10 to 14 — 150 to 250 Efficient compaction of soils wet of optimum requires less contact pressures than the same soils at lower moisture contents.	For earth dam, highway and airfield work, drum of 60-in dia., loaded to 1.5 to 3 tons per lineal foot of drum generally is utilized. For smaller projects 40-in dia. drum, loaded to 0.75 to 1.75 tons per lineal foot of drum is used. Foot contact pressure should be regulated so as to avoid shearing the soil on the third or fourth pass.
Rubber tire rollers	For clean, coarse-grained soils with 4 to 8 percent passing the No. 200 sieve.	10	3 to 5 coverages	Tire inflation pressures of 60 to 80 psi for clean granular material or base course and subgrade compaction. Wheel load 18,000 to 25,000 lb.	Wide variety of rubber tire compaction equipment is available. For cohesive soils, light-wheel loads, such as provided by wobble-wheel equipment, may be substituted for heavy-wheel load if lift thickness is decreased. For cohesionless soils, large-size tires are desirable to avoid shear and rutting.
Do	For fine-grained soils or well-graded, dirty coarse-grained soils with more than 8 percent passing the No. 200 sieve.	6 to 8	4 to 6 coverages	Tire inflation pressures in excess of 65 psi for fine-grained soils of high plasticity. For uniform clean sands or silty fine sands, use large size tires with pressures of 40 to 50 psi.	
Smooth wheel rollers	Appropriate for subgrade or base course compaction of well-graded sand-gravel mixtures.	8 to 12	4 coverages	Tandem type rollers for base course or subgrade compaction, 10 to 15 ton weight, 300 to 500 lb per lineal inch of width of rear roller.	3-wheel rollers obtainable in wide range of sizes. 2-wheel tandem rollers are available in the range of 1 to 20 ton weight. 3-axle tandem rollers are generally used in the range of 10 to 20 ton weight. Very heavy rollers are used for proof rolling of subgrade or base course.
Do . . .	May be used for fine-grained soils other than in earth dams. Not suitable for clean well-graded sands or silty uniform sands.	6 to 8	6 coverages	3-wheel roller for compaction of fine-grained soil; weights from 5 to 6 tons for materials of low plasticity to 10 tons for materials of high plasticity.	
Vibrating baseplate compactors	For coarse-grained soils with less than about 12 percent passing No. 200 sieve. Best suited for materials with 4 to 8 percent passing No. 200, placed thoroughly wet.	8 to 10	3 coverages	Single pads or plates should weigh no less than 200 lb. May be used in tandem where working space is available. For clean coarse-grained soil, vibration frequency should be no less than 1600 cycles per minute.	Vibrating pads or plates are available, hand-propelled or self-propelled, single or in gangs, with width of coverage from $1\frac{1}{2}$ to 15 ft. Various types of vibrating-drum equipment should be considered for compaction in large areas.
Crawler tractor	Best suited for coarse-grained soils with less than 4 to 8 percent passing No. 200 sieve, placed thoroughly wet.	10 to 12	3 to 4 coverages	No smaller than D8 tractor with blade, 34,500 lb weight, for high compaction.	Tractor weights up to 60,000 lb.
Power tamper or rammer	For difficult access, trench backfill. Suitable for all inorganic soils.	4 to 6 in for silt or clay, 6 in for coarse-grained soils.	2 coverages	30-lb minimum weight. Considerable range is tolerable, depending on materials and conditions.	Weights up to 250 lb, foot diameter 4 to 10 in.

lecture #4 보충자료 2

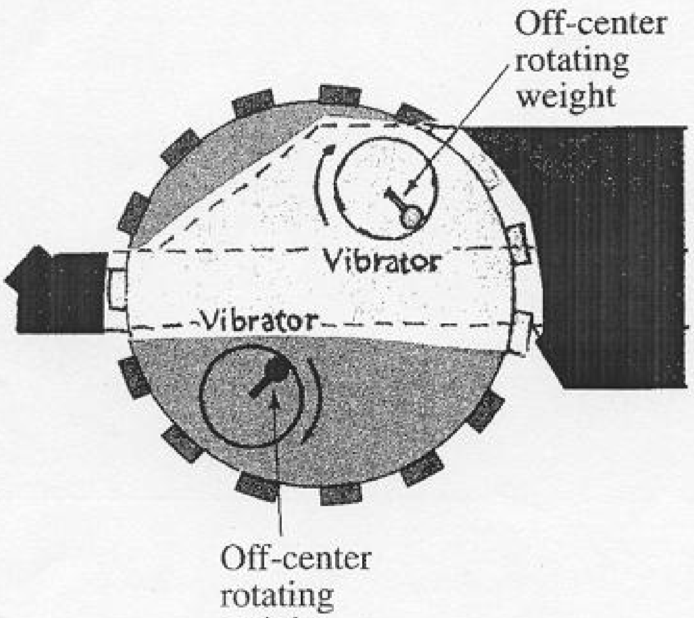


▼ **FIGURE 4.17** Smooth-wheel roller (courtesy of David A. Carroll, Austin, Texas)

▼ **FIGURE 4.18** Pneumatic rubber-tired roller (courtesy of David A. Carroll, Austin, Texas)



▼ **FIGURE 4.19** Sheepsfoot roller (courtesy of David A. Carroll, Austin, Texas)



▼ **FIGURE 4.20** Principles of vibratory rollers *lecture #4 보충자료 3*

- ASTM standard for compaction test

Document Summary

D698-00ae1 Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft^3 (600 kN-m/m^3))

Developed by Subcommittee: D18.03**See** Related Work**by this SubcommitteeAdoptions:** Building Codes; **Book of Standards Volume:** 04.08

1. Scope

1.1 These test methods covers laboratory compaction methods used to determine the relationship between water contentand dry unit weight of soils (compaction curve) compacted in a 4 or 6-in. (101.6 or 152.4-mm) diameter mold with a 5.5-lbf (24.4-N) rammer dropped from a height of 12 in. (305 mm) producing a compactive effort of 12,400 ft-lbf/ft^3 (600 kN-m/m^3).

Note 1—The equipment and procedures are similar as those proposed by R. R. Proctor (Engineering News Record-September 7, 1933) with this one major exception: his rammer blows were applied as "12 inch firm strokes" instead of free fall, producing variable compactive effort depending on the operator, but probably in the range 15,000 to 25,000 ft-lbf/ft^3 (700 to 1,200 kN-m/m^3). The standard effort test (see 3.2.2) is sometimes referred to as the Proctor Test.

Note 2—Soils and soil-aggregate mixtures should be regardedas natural occurring fine- or coarse-grained soils or composites or mixtures of natural soils, or mixtures of natural and processed soils or aggregates such as silt, gravel, or crushed rock.

1.2 These test methods apply only to soils (materials) that have 30 % or less by mass of particles retained on the 3/4-inch (19.0-mm) sieve.

Note 3—For relationships between unit weights and water contents of soils with 30 % or less by mass of material retained on the 3/4-in. (19.0-mm) sieve to unit weights and water contents of the fraction passing 3/4-in. (19.0-mm) sieve, see Practice D 4718.

1.3 Three alternative methods are provided. The method used shall be as indicated in the specification for the material being tested. If no method is specified, the choice should be based on the material gradation.

1.3.1 *Method A*

1.3.1.1 Mold—4-in. (101.6-mm) diameter.

1.3.1.2 *Material*

Passing No. 4 (4.75-mm) sieve.
Layers

Three.

Blows per layer

25.

Use

May be used if 20 % or less by mass of the material is retained on the No. 4 (4.75-mm) sieve.

Other Use

If this method is not specified, materials that meet these gradation requirements may be tested using Methods B or C.

1.3.2 Method BMold4-in. (101.6-mm) diameter.

Material

Passing 3/8-in. (9.5-mm) sieve.

Layers

Three.

Blows per layer

25.

Use

Shall be used if more than 20 % by mass of the material is retained on the No. 4 (4.75-mm) sieve and 20 % or less by mass of the material is retained on the 3/8-in. (9.5-mm) sieve.

Other Use

If this method is not specified, materials that meet these gradation requirements may be tested using Method C.

1.3.3 Method CMold6-in. (152.4-mm) diameter.

Material

Passing 3/4-inch (19.0-mm) sieve.

Layers

Three.

Blows per layer

56.

Use

Shall be used if more than 20 % by mass of the material is retained on the 3/8-in. (9.5-mm) sieve and less than 30 % by mass of the material is retained on the 3/4-in. (19.0-mm) sieve.

1.3.4 The 6-in. (152.4-mm) diameter mold shall not be used with Method A or B. Note 4Results have been found to vary slightly when a material is tested at the same compactive effort in different size molds.

1.4 If the test specimen contains more than 5 % by mass of oversize fraction (coarse fraction) and the material will not be included in the test, corrections must be made to the unit mass and water content of the specimen or to the appropriate field in place density test specimen using Practice D 4718.

1.5 This test method will generally produce a well defined maximum dry unit weight for non-free draining soils. If this test method is used for free draining soils the maximum unit weight may not be well defined, and can be less than obtained using Test Methods D 4253.

1.6 The values in inch-pound units are to be regarded as the standard. The values stated in SI units are provided for information only.

1.6.1 In the engineering profession it is customary practice to use, interchangeably, units representing both mass and force, unless dynamic calculations (F = Ma) are involved. This implicitly combines two separate systems of units, that is, the absolute system and the gravimetric system. It is scientifically undesirable to combine the use of two separate systems within a single standard. This test method has been written using inch-pound units (gravimetric system) where the pound (lbf) represents a unit of force. The use of mass (lbm) is for convenience of units and is not intended to convey the use is scientifically correct. Conversions are given in the SI system in accordance with IEEE/ASTM SI 10. The use of balances or scales recording pounds of mass (lbm), or the recording of density in lbm/ft^3 should not be regarded as nonconformance with this standard.

1.7 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

Document Summary

D1557-02e1 Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft^3(2,700 kN-m/m^3))

Developed by Subcommittee: D18.03**See** Related Work**by this SubcommitteeAdoptions:** DOD Adopted; Building Codes; **Book of Standards Volume:** 04.08

1. Scope

1.1 These test methods cover laboratory compaction methods used to determine the relationship between water content and dry unit weight of soils (compaction curve) compacted in a 4- or 6-in. (101.6 or 152.4 mm) diameter mold with a 10-lbf. (44.5-N) rammer dropped from a height of 18 in. (457 mm) producing a compactive effort of 56,000 ft-lbf/ft^3 (2,700 kN-m/m^3).

Note 1—Soils and soil-aggregate mixtures should be regarded as natural occurring fine- or coarse-grained soils or composites or mixtures of natural soils, or mixtures of natural and processed soils or aggregates such as silt, gravel, or crushed rock.

Note 2—The equipment and procedures are the same as proposed by the U.S. Corps of Engineers in 1945. The modified effort test (see 3.2.2) is sometimes referred to as the Modified Proctor Compaction Test.

1.2 These test methods apply only to soils (materials) that have 30 % or less by mass of their particles retained on the 3/4-in. (19.0-mm) sieve.

Note 3—For relationships between unit weights and water contents of soils with 30 % or less by weight of material retained on the 3/4-in. (19.0-mm) sieve to unit weights and water contents of the fraction passing the 3/4-in. (19.0-mm) sieve, see Practice D 4718.

1.3 Three alternative methods are provided. The method used shall be as indicated in the specification for the material being tested. If no method is specified, the choice should be based on the material gradation.

1.3.1 *Method A:*

1.3.1.1 *Mold*—4-in. (101.6-mm) diameter.

1.3.1.2 *Material*—Passing No. 4 (4.75-mm) sieve.

1.3.1.3 *Layers*—Five.

1.3.1.4 *Blows per layer*—25.

1.3.1.5 *Use*—May be used if 20 % or less by mass of the material is retained on the No. 4 (4.75-mm) sieve.

1.3.1.6 *Other Use*—If this method is not specified, materials that meet these gradation requirements may be tested using Methods B or C.

1.3.2 *Method B*

Mold—4-in. (101.6-mm) diameter.

Material—Passing 3/8-in. (9.5-mm) sieve.

Layers—Five.

1.3.2.4 *Blows per layer*—25.

1.3.2.5 *Use*—Shall be used if more than 20 % by mass of the material is retained on the No. 4 (4.75-mm) sieve and 20 % or less by mass of the material is retained on the 3/8-in. (9.5-mm) sieve.

1.3.2.6 *Other Use*—If this method is not specified, materials that meet these gradation requirements may be tested using Method C.

1.3.3 *Method C*

1.3.3.1 *Mold*—6-in. (152.4-mm) diameter.

1.3.3.2 *Material*—Passing 3/4-in. (19.0-mm) sieve.

1.3.3.3 *Layers*—Five.

1.3.3.4 *Blows per layer*—56.

1.3.3.5 *Use*—Shall be used if more than 20 % by mass of themateria1 is retained on the 3/8-in. (9.53-mm) sieve and less than 30 % by mass of the material is retained on the 3/4-in. (19.0-mm) sieve.

1.3.4 The 6-in. (152.4-mm) diameter mold shall not be used with Method A or B.

Note 4—Results have been found to vary slightly when a material is tested at the same compactive effort in different size molds.

1.4 If the test specimen contains more than 5 % by mass of oversize fraction (coarse fraction) and the material will not be included in the test, corrections must be made to the unit weight and water content of the test specimen or to the appropriate field in place density test specimen using Practice D 4718.

1.5 This test method will generally produce well defined maximum dry unit weight for non-free draining soils. If this test method is used for free draining soils the maximum unit weight may not be well defined, and can be less than obtained using Test Methods D 4253.

1.6 The values in inch-pound units are to be regarded as the standard. The values stated in SI units are provided for information only.

1.6.1 In the engineering profession it is customary practice to use, interchangeably, units representing both mass and force, unless dynamic calculations (F = Ma) are involved. This implicitly combines two separate systems of units, that is, the absolute system and the gravimetric system. It is scientifically undesirable to combine the use of two separate systems within a single standard. This test method has been written using inch-pound units (gravimetric system) where the pound (lbf) represents a unit of force. The use of mass (lbm) is for convenience of units and is not intended to convey the use is scientifically correct. Conversions are given in the SI system in accordance with IEEE/ASTM SI 10. The use of balances or scales recording pounds of mass (lbm), or the recording of density in lbm/ft^3 should not be regarded as nonconformance with this standard.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

한국공업규격(KS)에 따른 다짐 시험 방법 (KS F 2312)

(2001년 11월 15일 개정)

방 법	래머무게(kg)	낙하높이(cm)	각 층 당 타격회수	층 수	몰 드 치 수	허용최대 입경(mm)
A	2.5	30	25	3	100	19
B	2.5	30	25	3	150	37.5
C	4.5	45	25	5	100	19.0
D	4.5	45	55	5	150	19.0
E	4.5	45	92	3	150	37.5

*Field measurement

1. The core cutter method

This method is suitable for cohesive soils free of stones and consists of driving a steel cylinder, with a hardened cutting edge, into the ground using a specially designed steel rammer and protective dolly(Fig. 3.9). The cutter is then dug out and the soil trimmed-off flush at each end. Since the volume of the cutter is known and the contained mass of soil can be found by weighing, the bulk density may easily be determined. At the same time, small samples of soil are taken from either end from which the moisture content is determined.

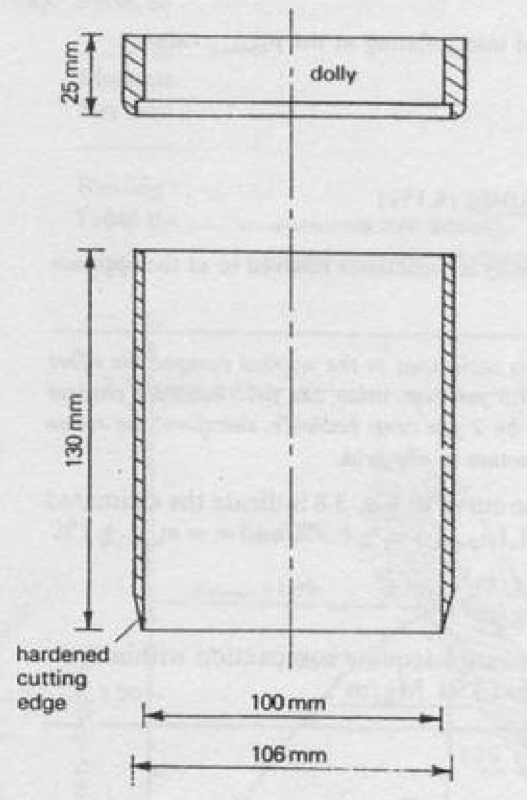


Fig. 3.9 Core cutter and dolly

2. The sand replacement method

This method is suitable for granular soils and involves the use of a sand-pouring cylinder as shown in Fig. 3.10. Firstly, a small hole is dug about 100 mm in diameter and not more than 150 mm in depth and the soil removed carefully weighed. The volume of the hole is then determined by pouring sand into it from the pouring cylinder. The sand-pouring cylinder is weighed before and after this operation, and the mass of sand filling the hole determined. Since the density of the sand is known, the volume of the hole can be determined, and hence the bulk density of the *in-situ* soil. Two sizes of sand-pouring cylinder are recommended: a small version suitable for fine- and medium-grained soils and a large version for fine-, medium- and coarse-grained soils.

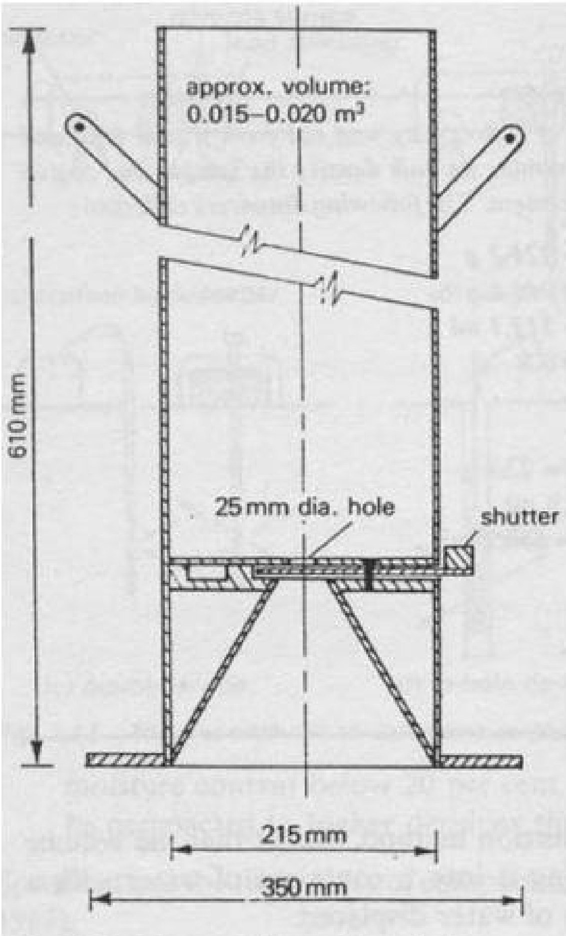


Fig. 3.10 Large sand-pouring cylinder

3. Nuclear methods

Both the bulk density and the moisture content of *in-situ* soil can be measured using controlled gamma radiation techniques. The apparatus generally consists of a small shielded radiation source and a detector. Several methods have been devised using surface back-scatter, single and double probes and in-hole devices(Fig. 3.11). The intensity of transmitted or back-scattered radiation varies with density and moisture content. Calibration charts are used which relate detected radiation intensity to values recorded from soils of known intensity(ASSHTO, 1986; ASTM, 1986)

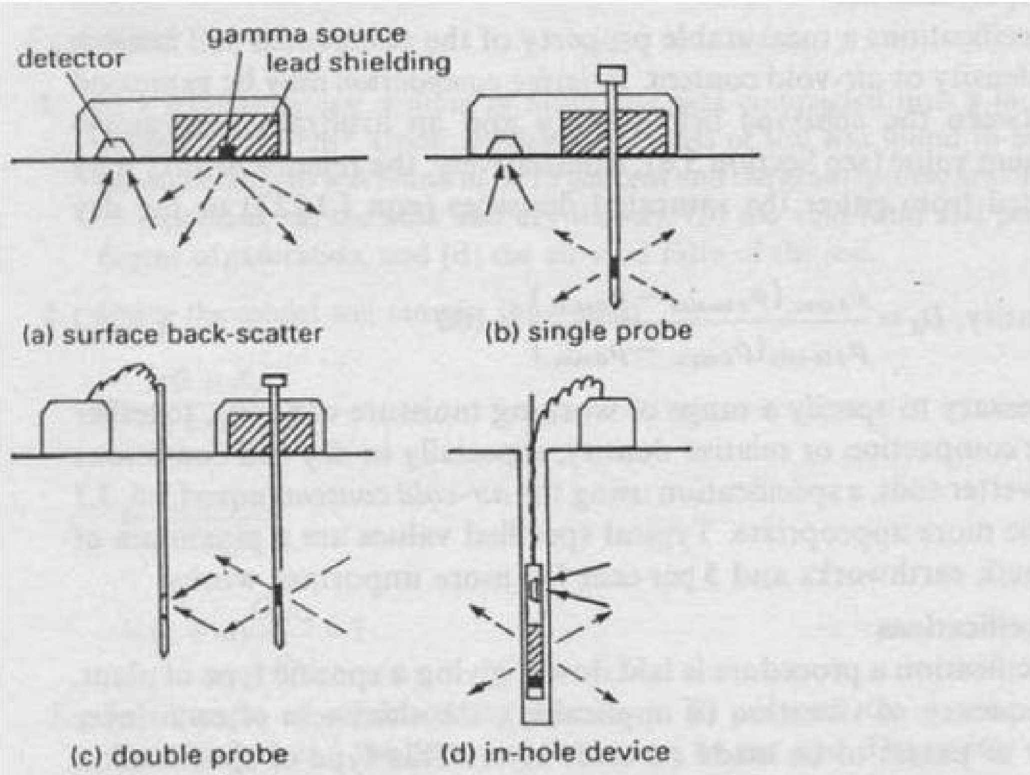


Fig. 3.11 . Nuclear methods to determine *in-situ* density and moisture content

TABLE 7.3. COMPACTIBILITY (*F*) OF COHESIONLESS SOILS (where $F = (e_{max} - e_{min})/e_{min}$).

Classification	γ_{min}	γ_{max}	e_{min}	e_{max}	Max. size	D_{10}	C_u	C_c	F
SP-SM	90	108	0.54	0.84	#16	.058	6.0	2.2	.555
SM	75	97	0.83	1.36	3/4"	.0065	31	5.5	.638
SP	92	112	0.48	0.80	#4	.15	3.0	.93	.667
SP	93	113	0.46	0.77	1 1/2"	.16	2.4	.92	.674
SP	95	116	0.43	0.74	#4	.30	3.7	1.0	.721
SP-SM	92	113	0.46	0.80	3/4"	.08	3.0	.88	.739
SP	85	107	0.54	0.94	#30	.10	2.3	1.3	.740
SP	97	118	0.40	0.70	1 1/2"	.11	3.2	1.2	.750
SP	99	120	0.38	0.67	1 1/2"	1.8	4.4	.76	.763
SM-ML	83	108	0.62	1.11	#4	.012	8.3	1.5	.790
SP-SM	79	103	0.60	1.08	#30	.09	2.4	1.5	.800
SP	103	124	0.33	0.60	3/8"	.17	5.0	.75	.818
SM	105	126	0.31	0.57	5"	.02	350	.30	.838
SP-SM	87	112	0.48	0.90	#4	.08	3.0	1.3	.875
SM	82	108	0.54	1.02	#16	.023	6.5	1.4	.889
SW-SM	95	119	0.39	0.74	3"	.05	10	1.4	.897
SP	98	122	0.36	0.69	#4	.37	5.1	1.2	.917
SW-SM	98	125	0.34	0.71	3"	.07	6.8	1.0	1.088
SP-SM	97	124	0.33	0.70	3/4"	.10	5.0	1.4	1.121
SP-SM	84	115	0.44	0.97	1 1/2"	.085	4.7	1.4	1.205
SP-SM	94	123	0.34	0.76	1 1/2"	.12	4.4	1.3	1.235
SM	99	128	0.31	0.70	3"	.02	240	1.8	1.258
SP-SM	80	114	0.44	1.06	#16	.07	3.7	1.6	1.409
SW-SM	80	116	0.42	1.07	1 1/2"	.074	6.6	2.4	1.547
SM	83	120	0.38	0.99	#4	.015	26	6.1	1.605
SM	102	134	0.23	0.62	3/4"	.01	120	1.9	1.695
GN-GM	113	127	0.31	0.47	3"	.14	86	1.2	.517
GP-GM	112	129	0.32	0.52	3"	.03	200	.50	.625
GW-GM	116	133	0.26	0.44	5"	.17	171	2.2	.692
GP-GM	110	128	0.30	0.51	3"	.11	191	15	.700
GP-GM	117	133	0.24	0.41	5"	.125	160	4.0	.708
GW-GP	111	130	0.27	0.49	3"	.20	105	7.5	.815
GP	116	134	0.23	0.43	5"	.27	111	6.2	.870
GW	119	139	0.24	0.45	3"	.51	45	2.2	.875
GW	120	139	0.20	0.39	3"	.45	51	1.6	.960
GW	119	139	0.21	0.41	3"	.18	94	1.1	.952
GW	111	132	0.25	0.49	3"	2.9	9.7	1.8	.960
GP	115	136	0.22	0.44	5"	.38	29	.61	1.000
GP	114	135	0.22	0.45	3"	2.0	11	.77	1.045
GW-GM	121	141	0.19	0.39	3"	.30	77	2.3	1.052
GM	122	141	0.17	0.36	1 1/2"	.025	381	3.0	1.118
GW-GM	114	137	0.21	0.45	3"	.60	16	1.2	1.143
GW	112	138	0.20	0.48	3"	2.0	12	1.3	1.400
GW	109	137	0.21	0.52	3"	2.0	14	2.6	1.476
GP	114	140	0.18	0.45	3"	1.7	10	.76	1.500
GM	101	132	0.25	0.64	1 1/2"	.03	260	12	1.560
GW-GM	111	139	0.19	0.49	3"	1.8	13	2.3	1.578
GP	115	142	0.17	0.44	3"	.31	87	8.2	1.588
GW	123	146	0.13	0.34	3"	.21	124	1.1	1.615
GW-GM	110	139	0.19	0.50	5"	.42	43	2.1	1.631
GW-GM	115	142	0.17	0.45	3"	.15	133	1.1	1.647
GP-GM	112	140	0.18	0.48	3"	.42	26	4.2	1.667
GW-GM	112	140	0.18	0.48	5"	.25	56	1.0	1.667
GW-GM	114	142	0.16	0.45	3"	1.2	15	1.7	1.812
GP	112	141	0.17	0.48	3"	1.4	7.1	.73	1.823
GW-GM	118	147	0.12	0.40	3"	1.3	19	1.1	2.333