KTMR-32 PARTICLE SIZE ANALYSIS (Kansas central lab test KTMR-32)

a. SCOPE

This method of test covers the quantitative determination of the distribution of the particle sizes in soils.

b. REFERENCED DOCUMENTS

b.1. AASHTO M 231: Weighing devices used in the Testing of Materials

b.2. AASHTO T 248: Reducing Samples of Aggregate to Testing Size

b.3. ASTM D 422: Standard Test Method for Particle-Size Analysis of Soils

b.4. ASTM E 100: Specification for ASTM Hydrometers

c. APPARATUS

c.1. Stirring apparatus as provided for in ASTM D 422 Section 3.2.2 Note 4

c.2. Hydrometer 151H or 152H conforming to ASTM E 100

c.3. Glass Sedimentation Cylinder 457 mm in height and 63.5 mm in diameter and marked for a volume of 1000 mL

c.4. Thermometer accurate to $0.5^{o}C$ ($1^{o}F$)

c.5. Sieves conforming to AASHTO M 92 as follows:
850 µm (No. 20)
425 µm (No. 40)
250 µm (No. 60)
150 µm (No. 100)
75 µm (No. 200)

c.6. Water bath capable of maintaining the suspension at $20^{o}C$ ($68^{o}F$)

c.7. Beaker of 250 mL capacity

c.8. Timing device with a second hand

d. DISPERSING AGENT

d.1. A solution of sodium hexametaphosphate shall be used in distilled or demineralized water, at the rate of 40 g of sodium hexametaphosphate/litre of solution.[a]

NOTE a: Solution should be made frequently or adjusted to pH 8 or 9 by means of sodium carbonate. Bottles containing solution should be dated.

d.2. All water used shall be either distilled or demineralized water. The water shall be brought to the test temperature before use.

e. SAMPLE PREPARATION

e.1. The size of the portion passing the 2.0 mm (No. 10) sieve for sandy soils shall be 115 g and 65 g for silt and clay soils.

f. COMPOSITE CORRECTION FOR HYDROMETER READING

f.1. Equations for percentages of soil remaining in suspension are based on the use of distilled or demineralized water. A dispersing agent is used in the water, and the specific gravity of the resulting liquid is appreciably greater than that of distilled or demineralized water.

f.1.a. Both soil hydrometers are calibrated at 20^{o}C (68^{o}F), any variation from this temperature produces inaccuracies in the hydrometer readings. The inaccuracies increase as the variance from the standard temperature increases.

f.1.b. Hydrometers are graduated by the manufacturer to be read at the bottom of the meniscus formed by the liquid on the stem. Since it is not possible to take soil suspension readings at the bottom of the meniscus, readings must be taken at the top and corrected.

f.1.c. The net amount for all three corrections is called the composite correction, and may be determined experimentally.

f.2. A chart or graph of composite corrections for a series of 1^{o} temperature differences for the range of expected test temperatures may be prepared. Measurement of the composite corrections may be made at two temperatures spanning the range of expected temperatures, and corrections for the intermediate temperatures calculated assuming a straight line relationship between the two observed values.

f.3. Prepare 1000 mL of liquid composed of distilled or demineralized water and dispersing agent in the same proportions as prevails in the sedimentation test. Place the liquid in a sedimentation cylinder and the cylinder in the constant-temperature bath, set for one of the two temperatures to be used. When the temperature of the liquid becomes constant, insert the hydrometer, and after a short interval to permit the hydrometer to come to temperature, red the

hydrometer at the top of the meniscus formed on the stem. For hydrometer 151H the composite correction is the difference between this reading and one: for hydrometer 152H it is the difference between the reading and zero. Bring the liquid and the hydrometer to the other temperature to be used, and obtain the readings as before.

g. HYGROSCOPIC MOISTURE

g.1 When the sample is being weighed out for the hydrometer test, weigh out an additional 10 to 15 g in a small metal or glass container, dry the sample to constant mass in an oven at 110 ± 5°C (230 ± 9°F), and weigh again. Record the masses.

h. DISPERSION OF SOIL SAMPLE

h.1. When the soil is mostly clay and silt sizes, weigh out a sample of air-dry soil of approximately 50 g. When the soil is mostly sand the sample should be approximately 100 g.

h.2. Place the sample in a sedimentation cylinder and cover with 125 mL of sodium hexametephosphate solution. Stir until the soil is thoroughly wetted. Allow to soak for at least 16 hours.

h.3. At the end of the soaking period, disperse the sample further, by using a dispersion tube as developed by Chu and Davidson at Iowa State College.

h.4. Add distilled or demineralized water, if necessary, so that the total volume in the cylinder is 250 mL, but no more.

h.5. Place the cover cap on the cylinder and open the air control valve until the gage pressure is 140 kPa (20 psi). Disperse the soil according to the following schedule:

Plasticity Index	Dispersion Period, Minutes
Under 5	5
6 to 20	10
Over 20	15

Soils containing large amounts of mica need be dispersed for only 1 min.

i. HYDROMETER TEST

i.1. Immediately after dispersion add distilled or demineralized water until the total volume is 1000 mL.

i.2. Using the palm of the over the open end of the cylinder (or a rubber stopper in the open end), turn the cylinder upside down and back for a period of 1 min. to complete the agitation of the slurry[b]. At the end of 1 min. set the cylinder in a convenient location and take hydrometer readings at the following intervals of time (measured from the beginning of sedimentation), or as many as may be needed, depending on the sample or the specification for the material under test: 2, 5, 15, 30, 60, 250, and 1440 min. If the controlled water bath is used, the sedimentation cylinder should be placed in the bath between the 2- and 5-min readings.

NOTE b: The number of turns during this minute should be approximately 60, counting the turn upside down and back as two turns. Any soil remaining in the bottom of the cylinder during the first few turns should be loosened by vigorous shaking of the cylinder while it is in the inverted position.

i.3. When taking a hydrometer reading, carefully insert the hydrometer about 20 to 25 seconds before the reading is due to approximately the depth it will have when the reading is taken. As soon as the reading is taken, carefully remove the hydrometer and place it with a spinning motion in a graduate of clean distilled or demineralized water.

i.4. After each reading, take the temperature of the suspension by inserting the thermometer into the suspension.

j. SIEVE ANAYLISIS

j.1. After taking the final hydrometer reading, transfer the suspension to a 75µm (No. 200) sieve and wash with tap water until the wash water is clear. Transfer the material on the sieve to a suitable container, dry in an oven at 110 ± 5°C (230 ± 9°F) and make a sieve analysis on the portion retained.

k. HYGROSCOPIC MOISTURE CORRECTION FACTOR

k.1. The hydroscopic moisture correction factor is the ratio between the mass of the oven-dried sample and the air-dry mass before drying. It is a number less than one, except when there is no hygroscopic moisture.

l. PERCENTAGES OF SOIL IN SUSPENSION

l.1. Calculate the oven-dry mass of soil used in the hydrometer analysis by multiplying the air-dry mass by the hygroscopic moisture correction factor.

l.2. Calculate the mass of a total sample represented by the mass of soil used in the hydrometer test, by dividing the oven-dry mass used by the percentage passing the 2.00 mm (No. 10) sieve, and multiplying the result by 100. This value is the weight W in the equation for percentage remaining in suspension/

l.3. The percentage of soil remaining in suspension at the level at which the hydrometer is measuring the density of the suspension may be calculated as follows:[c]

For hydrometer 151H:

$$P = [(100\ 000/W) \times G/(G - G_1)] (R - G_1)$$

NOTE c: The bracketed portion of the equation for hydrometer 151H is constant for a series of readings and may be calculated first and then multiplied by the portion in the parentheses.

For hydrometer 152H:

$$P = (Ra/W) \times 100$$

Where:

a = correction faction to be applied to the reading of hydrometer 152H. (Values shown on the scale are computed using a specific gravity of 2.65. Correction factors are given in Table 1),

P = percentage of soil remaining in suspension at the level at which the hydrometer measures the density of the suspension,

R = hydrometer reading with composite correction applied,

W = oven-dry mass of soil in a total test sample represented by mass of soil dispersed in g,

G = specific gravity of the soil particles, and

G_1 = specific gravity of the liquid in which soil particles are suspended. Use numerical value of one in both instances in the equation In the first instance any possible variation produces no significant effect, and in the second instance, the composite correction for R is based on a value of one for G_1.

m. DIAMETER OF SOIL PARTICLES

m.1. The diameter of a particle corresponding to the percentage indicated by a given hydrometer reading shall be calculated according to Stokes' law[d], on the basis that a particle of this diameter was at the surface of the suspension at the beginning of sedimentation and had settled to the level at which the hydrometer is measuring the density of the suspension. According to Stokes' law: see Table 2

$$D = \sqrt{[30n / 980(G - G_1)] \times L / T}$$

Where:

D = diameter of particle, mm,

n = Coefficient of viscosity of the suspending medium (in this case water) in poises (varies with changes in temperature of the suspending medium),

L = distance from the surface of the suspension to the level at which the density of the suspension is being measured, cm. (For a given hydrometer and sedimentation cylinder, values vary according to the hydrometer readings. This distance is known as effective depth), see Table 2,

T = interval of time from beginning of sedimentation to the taking of the reading, min,

G = specific gravity of soil particles, and

G_1 = specific gravity (relative density) of suspending medium (value may be used as 1.000 for all practical purposes).

NOTE d: Since Stokes' law considers the terminal velocity of a single sphere falling in an infinity of liquid, the sizes calculated represent the diameter of spheres that would fall at the same rate as the soil particles.

m.2. For convenience in calculations the above equation may be written as follows: see Table 3

$$D = K\sqrt{L / T}$$

Where:

K = constant depending on the temperature of the suspension and the specific gravity of the soil particles. Values of K for a range of temperatures and specific gravities are given in Table 3. The value of K does not change for a series of readings constituting a test, while values of L and T do vary.

TABLE 1 Values of Correction Factor,α, for Different Specific Gravities of Soil Particles

Specific Gravity	Correction Factor[a]
2.95	0.94
2.90	0.95
2.85	0.96
2.80	0.97
2.75	0.98
2.70	0.99
2.65	1.00
2.60	1.01
2.55	1.02
2.50	1.03
2.45	1.05

[a]For use in equation for percentage of soil remaining in suspension when using hydrometer 152H.

Table 2 Values of Effective Depth Based on Hydrometer and Sedimentation Cylinder of Specified Sizes

Hydrometer 151H		Hydrometer 152H			
Actual Hydrometer Reading	Effective Depth, L, cm	Actual Hydrometer Reading	Effective Depth, L, cm	Actual Hydrometer Reading	Effective Depth, L, cm
1.000	16.3	0	16.3	31	11.2
1.001	16.0	1	16.1	32	11.1
1.002	15.8	2	16.0	33	10.9
1.003	15.5	3	15.8	34	10.7
1.004	15.2	4	15.6	35	10.6
1.005	15.0	5	15.5		
1.006	14.7	6	15.3	36	10.4
1.007	14.4	7	15.2	37	10.2
1.008	14.2	8	15.0	38	10.1
1.009	13.9	9	14.8	39	9.9
1.010	13.7	10	14.7	40	9.7
1.011	13.4	11	14.5	41	9.6
1.012	13.1	12	14.3	42	9.4
1.013	12.9	13	14.2	43	9.2
1.014	12.6	14	14.0	44	9.1
1.015	12.3	15	13.8	45	8.9
1.016	12.1	16	13.7	46	8.8
1.017	11.8	17	13.5	47	8.6
1.018	11.5	18	13.3	48	8.4
1.019	11.3	19	13.2	49	8.3
1.020	11.0	20	13.0	50	8.1
1.021	10.7	21	12.9	51	7.9
1.022	10.5	22	12.7	52	7.8
1.023	10.2	23	12.5	53	7.6
1.024	10.0	24	12.4	54	7.4
1.025	9.7	25	12.2	55	7.3
1.026	9.4	26	12.0	56	7.1
1.027	9.2	27	11.9	57	7.0
1.028	8.9	28	11.7	58	6.8
1.029	8.6	29	11.5	59	6.6
1.030	8.4	30	11.4	60	6.5
1.031	8.1				
1.032	7.8				
1.033	7.6				
1.034	7.3				
1.035	7.0				
1.036	6.8				
1.037	6.5				
1.038	6.2				

Table 3 Values of K for Use in Equation for Computing
Diameter of Particle in Hydrometer Analysis

Temp °C	Specific Gravity of Soil Particles								
	2.45	2.50	2.55	2.60	2.65	2.70	2.75	2.80	2.85
16	0.01510	0.01505	0.01481	0.01457	0.01435	0.01414	0.01394	0.01374	0.01356
17	0.01511	0.01486	0.01462	0.01439	0.01417	0.01396	0.01376	0.01356	0.01338
18	0.01492	0.01467	0.01443	0.01421	0.01399	0.01378	0.01359	0.01339	0.01321
19	0.01474	0.01449	0.01425	0.01403	0.01382	0.01361	0.01342	0.01323	0.01305
20	0.01456	0.01431	0.01408	0.01386	0.01365	0.01344	0.01325	0.01307	0.01289
21	0.01438	0.01414	0.01391	0.01369	0.01348	0.01328	0.01309	0.01291	0.01273
22	0.01421	0.01397	0.01374	0.01353	0.01332	0.01312	0.01294	0.01276	0.01258
23	0.01404	0.01381	0.01358	0.01337	0.01317	0.01297	0.01279	0.01261	0.01243
24	0.01388	0.01365	0.01342	0.01321	0.01301	0.01282	0.01264	0.01246	0.01229
25	0.01372	0.01349	0.01327	0.01306	0.01286	0.01267	0.01249	0.01232	0.01215
26	0.01357	0.01334	0.01312	0.01291	0.01272	0.01253	0.01235	0.01218	0.01201
27	0.01342	0.01319	0.01297	0.01277	0.01258	0.01239	0.01221	0.01204	0.01188
28	0.01327	0.01304	0.01283	0.01264	0.01244	0.01255	0.01208	0.01191	0.01175
29	0.01312	0.01290	0.01269	0.01249	0.01230	0.01212	0.01195	0.01178	0.01162
30	0.01298	0.01276	0.01256	0.01236	0.01217	0.01199	0.01182	0.01165	0.01149

n. SIEVE ANALYSIS VALUES FOR PORTION FINER THAN 2.00 mm (NO.10) SIEVE

n.1. Calculation of percentages passing the various sieves used in sieving the portion of the sample from the hydrometer test involves several steps. The first step is to calculate the mass of the fraction that would have been retained on the 2.00 mm (No. 10) sieve had it not been removed. This mass is equal to the total percentage retained in the 2.00 mm (No. 10) sieve (100 minus total percentage passing) times the mass of the total sample represented by the mass of soil used (as calculated in **l.2.**), and the result divided by 100.

n.2. Calculate next the total mass passing the 75 µm (No. 200) sieve. Add together the fractional masses retained on all the sieves, including the 2.00 mm (No. 10) sieve, and subtract this sum from the mass of the total sample (as calculated in **l.2.**).

n.3 Calculate next the total masses passing each of the other sieves.

n.4. Calculate last the total percentages passing by dividing the total mass passing (as calculated in **n.3.**) by the total mass of the sample (as calculated in **l.2.**), and multiply the result by 100.

o. GRAPH

o.1. When the hydrometer analysis is performed, a graph of the test results shall be made, plotting the diameters of the particles on a logarithmic scale as the abscissa and the percentages smaller than the corresponding diameters to an arithmetic scale as the ordinate.