[ESS26]

UNIVERSITY OF BOLTON

ENGINEERING, SPORTS AND SCIENCES

BEng (HONS) IN CIVIL ENGINEERING

SEMESTER TWO EXAMINATION 2018/2019

GROUND AND WATER STUDIES I

MODULE NO: CIE4009

Date: Monday 20th May 2019 **Time: 10:00 – 13:00**

INSTRUCTIONS TO CANDIDATES:

There are TWO Sections; A and B.

Answer Section A in ONE Answer Booklet, and Section B in the other.

Section A : Q1 to Q3 (Answer TWO Questions from three).

Section B : Q4 to Q7 (Answer THREE Questions from four).

Formulae and Definitions are provided.

Lined Graph Paper and Supplementary Answer Sheets are available for your use.

Ensure that you write your Candidate Number or Desk Number on each Figure, Supplementary Sheet or Sheet of Graph Paper you use to answer the selected questions.

All questions carry equal marks.

Marks for parts of questions are shown in brackets.

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SECTION A (Answer TWO Questions from three)

1a)

i. With the aid of sketches, explain what is meant by laminar and turbulent flow **(4 marks)**

ii. Define the 3 components of Bernoulli's equation. **(6 marks)**

b) A Pitch Fibre clay pipeline in normal condition delivers 4235litres/minute over a distance of 1.2km from a reservoir to a water distribution network. The water level in the reservoir is 100m AOD and the ground level at the distribution network 65m AOD. If the water main pressure is 210kPa determine the pipeline pipe diameter (HRS tables provided). **(10 marks)**

Total 20 marks

2a) With the aid of sketches, explain what is meant by 'minor energy losses' occur in pipelines. **(6 marks)**

b) Two tanks in a water treatment plant are connected by a pipeline which is 150mm in diameter for 11m and then changes abruptly to 225 mm in diameter for the remaining 18m of its length.

There are two 45° bends (each of $K_L = 0.5$) on the 150 mm diameter pipeline. The flowrate between the tanks is 21litres/sec. The Darcy friction coefficient λ is 0.024 for the 225 mm pipeline and 0.027 for the 150 mm pipeline. Taking account of all energy losses, determine the difference between the water levels in the tanks. **(14 marks)**

Total 20 marks

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3a) With the aid of sketches, explain how hydrostatic forces are determined.
(6 marks)

b) Water is drained from a storage tank through a 0.6m diameter circular flap valve shown in Figure Q3.

i) Determine the force on the gate when the water level is 0.4m above the hinge.
(6 marks)

ii) If the flap valve has a mass of 80kg, determine whether it remains closed.
(8 marks)

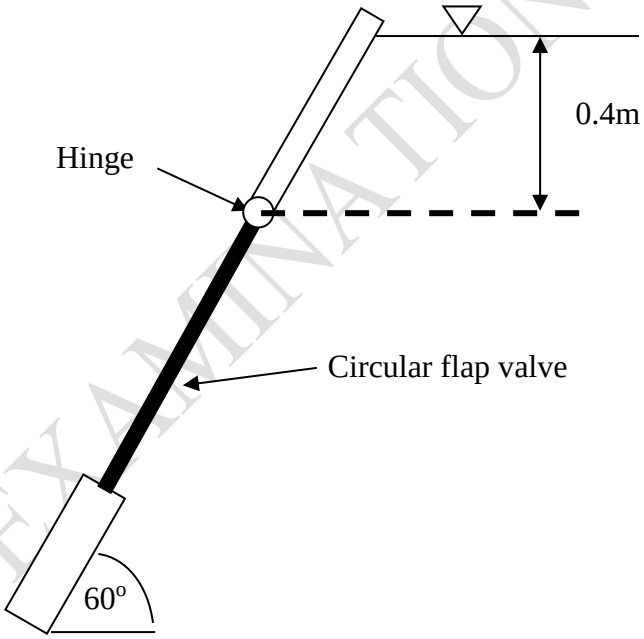

Fig Q3

Total 20 marks

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Classification (assumed clean and new unless otherwise stated)	Suitable values of k_s (mm) Good	Normal	Poor
Smooth materials			
Drawn non-ferrous pipes of aluminium, brass, copper lead etc, and non-metallic pipes of Alkathene, glass, perspex etc	—	0.003	—
Asbestos-cement	0.015	0.03	—
Metal			
Spun bitumen or concrete lined	—	0.03	—
Wrought iron	0.03	0.06	0.15
Rusty wrought iron	0.15	0.6	3.0
Uncoated steel	0.015	0.03	0.06
Coated steel	0.03	0.06	0.15
Galvanised iron, coated cast iron	0.06	0.15	0.3
Uncoated cast iron	0.15	0.3	0.6
Tate relined pipes	0.15	0.3	0.6
Old tuberculated water mains with the following degrees of attack:			
ght	0.6	1.5	3.0
Moderate	1.5	3.0	6.0
Appreciable	6.0	15	30
Severe	15	30	60
(Good: Up to 20 years use, Normal: 40 to 50 years use, Poor: 80 to 100 years use)			
Wood			
Wood stave pipes, planed plank conduits	0.3	0.6	1.5
Concrete			
Precast concrete pipes with 'O' ring joints	0.06	0.15	0.6
Spun precast concrete pipes with 'O' ring joints	0.06	0.15	0.3
Monolithic construction against steel forms	0.3	0.6	1.5
Monolithic construction against rough forms	0.6	1.5	—
Clayware			
G ed or unglazed pipe:			
with sleeve joints	0.03	0.06	0.15
With spigot and socket joints and 'O' ring seals — dia < 150mm	—	0.03	—
With spigot and socket joints and 'O' ring seals — dia > 150mm	—	0.06	—
Pitch fibre (lower value refers to full bore flow)	0.003	0.03	—
Glass fibre	—	0.06	—
uPVC			
With chemically cemented joints	—	0.03	—
With spigot and socket joints, 'O' ring seals at 6 to 9 metre intervals	—	0.06	—

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3 continued

ks = 0·030 mm
i = 0·004 to 0·1
ie hydraulic gradient = 1 in 250 to 1 in 10

Water (or sewage) at 15° C full bore conditions.
velocities in m/s
discharges in l/s

Gradient	Pipe diameters in mm: 50	75	80	100	125	150	175	200	225	250	275	300
0.00400	0.372	0.494	0.516	0.601	0.699	0.790	0.874	0.955	1.031	1.104	1.175	1.243
1/ 250	0.730	2.181	2.595	4.722	8.578	13.952	21.033	29.995	41.003	54.216	69.782	87.847
0.00420	0.382	0.507	0.530	0.618	0.718	0.811	0.898	0.980	1.059	1.134	1.206	1.276
1/ 238	0.750	2.241	2.666	4.851	8.811	14.329	21.598	30.798	42.099	55.661	71.639	90.179
0.00440	0.392	0.521	0.544	0.634	0.736	0.832	0.921	1.005	1.086	1.163	1.237	1.308
1/ 227	0.770	2.300	2.736	4.977	9.038	14.697	22.151	31.584	43.170	57.074	73.454	92.460
0.00460	0.402	0.534	0.558	0.649	0.755	0.852	0.943	1.030	1.112	1.191	1.267	1.340
1/ 217	0.790	2.357	2.804	5.100	9.260	15.057	22.692	32.353	44.219	58.457	75.230	94.692
0.00480	0.412	0.546	0.571	0.665	0.772	0.872	0.965	1.054	1.138	1.218	1.296	1.371
1/ 208	0.809	2.414	2.870	5.221	9.478	15.410	23.222	33.107	45.246	59.812	76.970	96.878
0.00500	0.421	0.559	0.584	0.680	0.790	0.892	0.987	1.077	1.163	1.246	1.325	1.401
1/ 200	0.828	2.469	2.936	5.339	9.692	15.756	23.742	33.845	46.253	61.140	78.675	99.020
0.00550	0.445	0.589	0.616	0.716	0.832	0.939	1.039	1.134	1.225	1.311	1.394	1.474
1/ 182	0.873	2.602	3.095	5.626	10.210	16.594	24.999	35.633	48.689	64.353	82.802	104.205
0.00600	0.467	0.618	0.646	0.751	0.872	0.984	1.089	1.189	1.283	1.374	1.461	1.544
1/ 167	0.916	2.731	3.247	5.901	10.706	17.397	26.204	37.345	51.023	67.431	86.753	109.169
0.00650	0.488	0.646	0.675	0.785	0.911	1.028	1.138	1.241	1.340	1.434	1.525	1.612
1/ 154	0.958	2.854	3.393	6.165	11.183	18.168	27.363	38.991	53.265	70.388	90.550	113.938
0.00700	0.509	0.673	0.703	0.817	0.949	1.070	1.184	1.292	1.394	1.492	1.586	1.677
1/ 143	0.999	2.973	3.534	6.420	11.643	18.913	28.479	40.578	55.427	73.238	94.210	118.534
0.00750	0.529	0.699	0.730	0.849	0.985	1.111	1.229	1.340	1.447	1.548	1.646	1.740
1/ 133	1.038	3.088	3.671	6.667	12.088	19.632	29.559	42.111	57.517	75.992	97.746	122.975
0.00800	0.548	0.724	0.757	0.879	1.020	1.150	1.272	1.388	1.497	1.602	1.703	1.801
1/ 125	1.076	3.200	3.803	6.906	12.519	20.329	30.605	43.596	59.540	78.660	101.170	127.276
0.00850	0.567	0.749	0.782	0.909	1.054	1.189	1.315	1.434	1.547	1.655	1.759	1.860
1/ 118	1.113	3.308	3.932	7.138	12.938	21.006	31.620	45.038	61.504	81.249	104.493	131.449
0.00900	0.585	0.773	0.807	0.938	1.087	1.226	1.356	1.478	1.595	1.706	1.814	1.917
1/ 111	1.149	3.413	4.057	7.364	13.345	21.664	32.607	46.440	63.414	83.766	107.724	135.506
0.00950	0.603	0.796	0.831	0.966	1.120	1.262	1.396	1.522	1.642	1.756	1.867	1.973
1/ 105	1.184	3.516	4.179	7.584	13.741	22.305	33.568	47.805	65.273	86.217	110.869	139.455
0.01000	0.620	0.819	0.855	0.993	1.151	1.298	1.435	1.564	1.687	1.805	1.918	2.027
1/ 100	1.218	3.616	4.298	7.799	14.128	22.930	34.506	49.136	67.086	88.606	113.936	143.306
0.01100	0.654	0.862	0.901	1.046	1.212	1.366	1.510	1.646	1.775	1.899	2.018	2.132
1/ 91	1.284	3.810	4.528	8.214	14.875	24.137	36.316	51.706	70.586	93.218	119.855	150.737
0.01200	0.686	0.904	0.945	1.096	1.270	1.431	1.582	1.724	1.860	1.989	2.113	2.233
1/ 83	1.347	3.996	4.748	8.611	15.590	25.293	38.049	54.166	73.935	97.632	125.519	157.849
0.01300	0.717	0.945	0.987	1.145	1.326	1.494	1.651	1.799	1.940	2.075	2.205	2.330
1/ 77	1.408	4.174	4.960	8.993	16.278	26.403	39.714	56.529	77.153	101.872	130.959	164.678
0.01400	0.747	0.984	1.027	1.192	1.380	1.555	1.718	1.872	2.018	2.159	2.293	2.423
1/ 71	1.467	4.346	5.164	9.361	16.940	27.474	41.318	58.807	80.254	105.957	136.201	171.258
0.01500	0.776	1.022	1.067	1.237	1.433	1.613	1.782	1.942	2.094	2.239	2.378	2.513
1/ 67	1.523	4.513	5.361	9.717	17.581	28.508	42.869	61.007	83.249	109.903	141.264	177.613
0.01600	0.804	1.058	1.105	1.281	1.483	1.670	1.845	2.010	2.167	2.317	2.461	2.600
1/ 62	1.578	4.674	5.553	10.061	18.201	29.510	44.370	63.138	86.149	113.724	146.165	183.766
0.01700	0.831	1.093	1.142	1.324	1.532	1.725	1.905	2.076	2.237	2.392	2.541	2.684
1/ 59	1.632	4.831	5.738	10.396	18.804	30.483	45.827	65.205	88.963	117.430	150.920	189.734
0.01800	0.858	1.128	1.178	1.365	1.580	1.778	1.964	2.140	2.306	2.466	2.619	2.766
1/ 56	1.684	4.983	5.919	10.721	19.389	31.428	47.243	67.214	91.698	121.033	155.541	195.534
0.01900	0.883	1.162	1.213	1.405	1.626	1.831	2.021	2.202	2.373	2.537	2.694	2.846
1/ 53	1.735	5.131	6.095	11.038	19.959	32.348	48.622	69.171	94.360	124.539	160.039	201.179
	Coefficient for part-full pipes:											
	35	50	60	70	90	110	130	150	150	200	200	200

ks = 0·030 mm i < 0·1

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ks = 0·600mm
i = 0·004 to 0·1
ie hydraulic gradient = 1 in 250 to 1 in 10

Water (or sewage) at 15° C
full bore conditions.
velocities in m/s
discharges in l/s

Gradient	Pipe diameters in mm: 50	75	80	100	125	150	175	200	225	250	275	300
0.00400	0.298	0.395	0.413	0.480	0.558	0.629	0.697	0.760	0.821	0.879	0.934	0.988
1/ 250	0.586	1.746	2.076	3.773	6.845	11.123	16.756	23.882	32.632	43.131	55.498	69.846
0.00420	0.306	0.405	0.423	0.493	0.572	0.645	0.714	0.779	0.841	0.901	0.958	1.013
1/ 238	0.601	1.790	2.129	3.868	7.018	11.404	17.178	24.482	33.451	44.213	56.888	71.595
0.00440	0.313	0.415	0.434	0.504	0.586	0.661	0.731	0.798	0.861	0.922	0.981	1.037
1/ 227	0.616	1.834	2.180	3.962	7.187	11.678	17.589	25.068	34.251	45.269	58.246	73.303
0.00460	0.321	0.425	0.444	0.516	0.599	0.676	0.748	0.816	0.881	0.943	1.003	1.061
1/ 217	0.630	1.876	2.231	4.053	7.352	11.945	17.992	25.641	35.033	46.301	59.574	74.973
0.00480	0.328	0.434	0.454	0.527	0.612	0.691	0.764	0.834	0.900	0.964	1.025	1.084
1/ 208	0.644	1.918	2.280	4.142	7.514	12.207	18.386	26.202	35.798	47.312	60.873	76.606
0.00500	0.335	0.443	0.463	0.539	0.625	0.705	0.780	0.852	0.919	0.984	1.046	1.106
1/ 200	0.658	1.958	2.328	4.230	7.672	12.464	18.772	26.751	36.548	48.301	62.145	78.206
0.00550	0.352	0.466	0.486	0.566	0.656	0.740	0.819	0.894	0.965	1.033	1.098	1.161
1/ 182	0.691	2.057	2.445	4.441	8.054	13.084	19.704	28.078	38.358	50.692	65.218	82.071
0.00600	0.368	0.487	0.509	0.591	0.686	0.774	0.856	0.934	1.008	1.079	1.147	1.213
1/ 167	0.723	2.151	2.557	4.644	8.420	13.676	20.595	29.345	40.088	52.976	68.155	85.765
0.00650	0.384	0.507	0.530	0.616	0.715	0.806	0.892	0.973	1.050	1.124	1.195	1.263
1/ 154	0.753	2.241	2.664	4.837	8.770	14.244	21.449	30.561	41.748	55.167	70.972	89.307
0.00700	0.399	0.527	0.550	0.640	0.742	0.837	0.926	1.010	1.090	1.167	1.241	1.312
1/ 143	0.783	2.328	2.767	5.024	9.108	14.791	22.271	31.731	43.344	57.276	73.682	92.716
0.00750	0.413	0.546	0.570	0.663	0.769	0.867	0.959	1.046	1.129	1.208	1.285	1.358
1/ 133	0.811	2.411	2.866	5.204	9.433	15.319	23.064	32.860	44.885	59.310	76.298	96.005
0.00800	0.427	0.564	0.589	0.685	0.794	0.896	0.991	1.081	1.166	1.248	1.327	1.403
1/ 125	0.838	2.492	2.962	5.378	9.748	15.829	23.832	33.952	46.375	61.278	78.828	99.187
0.00850	0.441	0.582	0.608	0.706	0.819	0.924	1.022	1.114	1.203	1.287	1.368	1.447
1/ 118	0.865	2.571	3.056	5.547	10.053	16.324	24.576	35.011	47.820	63.185	81.280	102.270
0.00900	0.454	0.599	0.626	0.727	0.843	0.951	1.052	1.147	1.238	1.325	1.409	1.489
1/ 111	0.891	2.647	3.146	5.711	10.349	16.804	25.298	36.038	49.223	65.037	83.660	105.264
0.00950	0.466	0.616	0.643	0.747	0.867	0.977	1.081	1.179	1.272	1.362	1.448	1.530
1/ 105	0.916	2.721	3.234	5.870	10.638	17.271	26.000	37.038	50.587	66.838	85.976	108.176
0.01000	0.479	0.632	0.660	0.767	0.890	1.003	1.109	1.210	1.306	1.397	1.485	1.571
1/ 100	0.940	2.793	3.320	6.025	10.918	17.726	26.684	38.012	51.915	68.593	88.231	111.013
0.01100	0.503	0.664	0.693	0.805	0.934	1.053	1.164	1.270	1.370	1.466	1.559	1.648
1/ 91	0.988	2.933	3.485	6.325	11.459	18.604	28.003	39.889	54.477	71.975	92.579	116.480
0.01200	0.526	0.694	0.725	0.842	0.976	1.100	1.217	1.327	1.432	1.532	1.629	1.722
1/ 83	1.033	3.066	3.643	6.611	11.977	19.442	29.263	41.682	56.924	75.206	96.734	121.705
0.01300	0.548	0.723	0.755	0.877	1.016	1.146	1.267	1.382	1.491	1.595	1.696	1.793
1/ 77	1.076	3.193	3.795	6.885	12.473	20.246	30.472	43.402	59.272	78.306	100.718	126.716
0.01400	0.569	0.751	0.784	0.910	1.055	1.189	1.315	1.434	1.548	1.656	1.760	1.861
1/ 71	1.117	3.316	3.941	7.149	12.950	21.019	31.635	45.057	61.531	81.288	104.553	131.538
0.01500	0.590	0.777	0.812	0.943	1.093	1.232	1.362	1.485	1.602	1.715	1.823	1.927
1/ 67	1.158	3.435	4.081	7.404	13.410	21.766	32.758	46.655	63.710	84.166	108.252	136.191
0.01600	0.609	0.803	0.839	0.974	1.129	1.273	1.407	1.534	1.655	1.771	1.883	1.990
1/ 62	1.196	3.549	4.218	7.650	13.856	22.488	33.843	48.199	65.819	86.950	111.831	140.691
0.01700	0.628	0.829	0.865	1.004	1.164	1.312	1.451	1.582	1.707	1.826	1.941	2.052
1/ 59	1.234	3.660	4.349	7.889	14.288	23.188	34.895	49.697	67.862	89.647	115.299	145.052
0.01800	0.647	0.853	0.891	1.034	1.198	1.351	1.493	1.628	1.757	1.880	1.998	2.112
1/ 56	1.271	3.768	4.478	8.121	14.707	23.867	35.917	51.151	69.846	92.267	118.667	149.287
0.01900	0.665	0.877	0.916	1.063	1.232	1.388	1.535	1.673	1.805	1.932	2.053	2.170
1/ 53	1.306	3.873	4.602	8.347	15.115	24.528	36.911	52.565	71.776	94.815	121.942	153.406
	Coefficient for part-full pipes:											
	25	40	40	50	60	80	90	100	120	130	140	150

ks = 0·600mm i < 0·1

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END OF SECTION A

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SECTION B (Answer THREE Questions from four)

4a) Sketch a "soil model" diagram clearly showing the solids, water and air components annotated with conventional symbols to allow development of 'soil property' equations.

(5 marks)

b) The total volume of a soil specimen is 80,000 mm3 and it weighs 150 grams. The dry weight of the specimen is 130 grams and the density of the soil solids is 2680 Kg/m3.

Find the following (use either the equations provided in the formulae sheet at the end of the exam paper or the ones you derived in part a):

(i) The water content.
(ii) Void Ratio.
(iii) Porosity.
(iv) Bulk unit weight.
(v) Dry unit weight.

(15 marks)

Total 20 marks

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5. The following results are obtained from a standard compaction test:

Moisture Content (%)	11	12.1	12.8	13.6	14.6	16.3
Mass of Soil (g)	1920.5	2051.5	2138.5	2147	2120	2081.5

The specific gravity of the solids is 2.7 and the volume of the compaction mould is 1000cm^3.

a) Plot the compaction curve and obtain the maximum dry density and optimum moisture content.

(10 marks)

b) At the maximum dry density, calculate the corresponding air content (A_v), void ratio (e) and degree of saturation (S_r).

(10 marks)

Total 20 marks

6. The table given below shows the mass of a soil sample retained on each sieve in a sieve analysis experiment. The total mass of a soil sample is 650gram.

Sieve number	Diameter (mm)	Mass of soil retained on each sieve	Percent retained on each sieve (%)	Cumulative retained on each sieve (%)	Percent finer (%)
4	4.750	30			
10	2.000	44			
20	0.850	50			
40	0.425	132			
60	0.250	228			
100	0.150	88			
200	0.075	46			
Pan		32			

a) Determine the percent finer (%)

(5 marks)

b) Draw the particle-size distribution curve (PDC)

(10 marks)

Question 6 continues over the page….

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Question 6 continued….

c) Obtain the Coefficient of Uniformity (C_u) and the Coefficient of Curvature (C_c). Indicate whether the soil sample is well or poorly graded.

(5 marks)

Total 20 marks

7a) Use the soil texture triangle to name the correct textural class for the following percentages:

(i) Clay 25%; Silt 25%, and Sand 50%. Circle the correct texture:

a. Clay loam
b. Silty clay
c. Sandy clay loam
d. Clay

(5 marks)

(ii) Clay 35%; Silt 40%, and Sand 25%. Circle the correct texture:

e. Clay loam
f. Silty clay
g. Sandy clay loam
h. Clay

(5 marks)

b) A soil sample has a water content of 15%, a porosity of 45%, and a specific gravity of 2.68. Determine the void ratio and the degree of saturation.

(10 marks)

Total 20 marks

END OF QUESTIONS

Formulae and definitions over the page….

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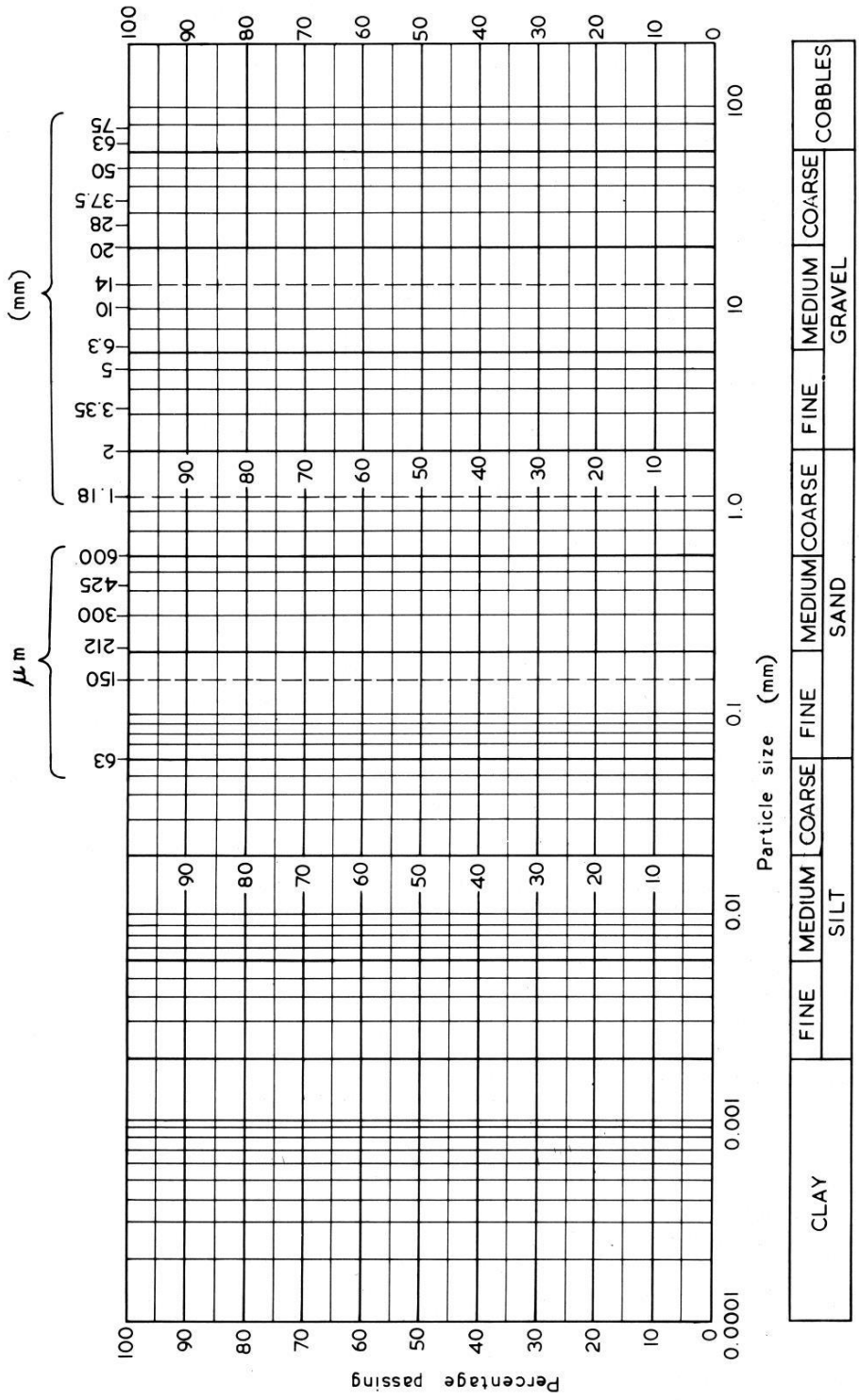

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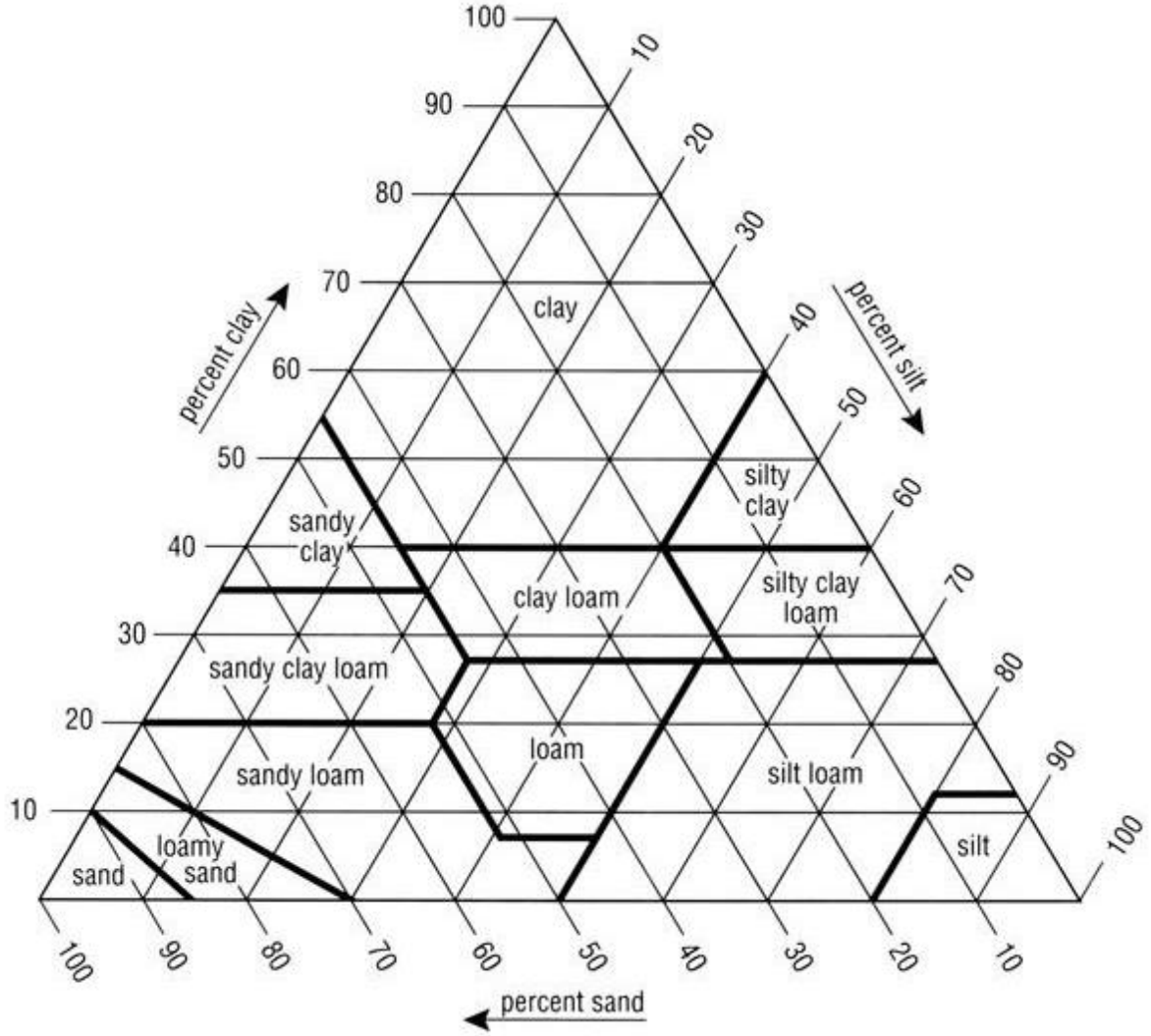

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TERMINOLOGY, SYMBOLS AND UNITS

Term	Symbol	Units
Volume		m^3
Mass		kg
Gravity	g	9.81 m/sec^2
Weight		kN = (kg x 9.81)/1000
Total volume	V	m^3
Volume of air	V_A	m^3
Volume of water	V_W	m^3
Volume of voids	V_V	m^3
Volume of Solids	V_S	m^3
Mass of water	M_W	kg
Mass of solids	M_S	kg
Total mass	M	kN
Specific gravity	G_s	None
Density of water	ρ_w	$1000kg/m^3$
Unit weight of water	γ_w	9.81 kN/m^3
Void ratio	e	None
Degree of saturation	S_r	None
Moisture content	w	None
Porosity	n	None
Soil Bulk density	ρ_b	kg/m^3
Dry density	ρ_d	kg/m^3
Saturated density	ρ_{sat}	kg/m^3
Soil Bulk unit weight	γ_b	kN/m^3
Dry unit weight	γ_d	kN/m^3
Saturated unit weight	γ_{sat}	kN/m^3

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DEFINITIONS

Term	Expression
Density of water, ρ_w	$\frac{\text{mass of water}}{\text{volume of water}} = \frac{M_w}{V_w}$
Unit weight of water, γ_w	$\frac{\text{weight of water}}{\text{volume of water}} = \frac{W_w}{V_w}$
Specific gravity, G_s	$\frac{\text{density of solids}}{\text{density of water}} = \frac{\rho_s}{\rho_w}$
Water content, w	$\frac{\text{mass of water}}{\text{mass of solids}} = \frac{M_w}{M_s}$
Void ratio, e	$\frac{\text{volume of voids}}{\text{volume of solids}} = \frac{V_v}{V_s}$
Degree of saturation, S_r	$\frac{\text{volume of water}}{\text{volume of voids}} = \frac{V_w}{V_v}$
Porosity, n	$\frac{\text{volume of voids}}{\text{total volume}} = \frac{V_v}{V}$
Soil Bulk density, ρ_b	$\frac{\text{total mass}}{\text{total volume}} = \frac{M}{V}$
Dry density, ρ_d	$\frac{\text{mass of solids}}{\text{total volume}} = \frac{M_s}{V}$
Saturated density, ρ_{sat}	$\frac{\text{total saturated mass}}{\text{total volume}} = \frac{M}{V}$
Soil Bulk unit weight, γ_b	$\frac{\text{total weight}}{\text{total volume}} = \frac{W}{V}$
Dry unit weight, γ_d	$\frac{\text{weight of solids}}{\text{total volume}} = \frac{W_s}{V}$
Saturated unit weight, γ_{sat}	$\frac{\text{total saturated weight}}{\text{total volume}} = \frac{W}{V}$

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BASIC PROPERTIES Formulae:

Void space relationship from soil model $w G_s = S_r e$

$$\rho_b = \frac{(G_s + S_r e)\rho_w}{1 + e}$$

Bulk Density

$$\rho_b = \frac{\rho_W G_s(1 + w)}{1 + e}$$

Dry Density

$$\rho_d = \frac{\rho_W G_s}{1 + e}$$

$$\rho_d = \frac{\rho_b}{1 + w}$$

Theoretical Dry Density

$$\rho_d = \frac{\rho_W G_s (1 - A_v)}{1 + w G_s}$$

Porosity

$$n = \frac{e}{1 + e}$$

Soil Coefficient of Uniformity

$$C_u = \frac{D_{60}}{D_{10}}$$

END OF PAPER