ADDITIONAL DATA TO BE GIVEN ALONG WITH EXAMINATION QUESTION PAPER CIE4020

SECTION A - SOIL MECHANICS

TERMINOLOGY, SYMBOLS AND UNITS

Term	Symbol	Units
Volume	V	m^3
Litre	l	Litre (= 1 x 10^{-3} m^3)
Mass	M	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
Weight of water	W_W	kN
Weight of solids	W_S	kN
Total weight	W	kN
Specific gravity	G_s	None
Density of water	ρ_W	1000 kg/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
Air void content	A_v	None
Bulk density	ρ_b	kg/m^3
Dry density	ρ_d	kg/m^3
Saturated density	ρ_{sat}	kg/m^3
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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FORMULAE

Density $\mathbf{kg/m^3}$	Unit weight $\mathbf{kN/m^3}$
1. $\rho_b = \frac{\rho_w\,(G+es)}{1+e}$	$\gamma_b = \frac{\gamma_w\,(G+es)}{1+e}$
2. $\rho_b = \frac{\rho_w\,G(1+w)}{1+e}$	$\gamma_b = \frac{\gamma_w\,G(1+w)}{1+e}$
3. $\rho_d = \frac{\rho_w\,G}{1+e}$	$\gamma_d = \frac{\gamma_w\,G}{1+e}$
4. $\rho_{sat} = \frac{\rho_w\,(G+e)}{1+e}$	$\gamma_{sat} = \frac{\gamma_w\,(G+e)}{1+e}$
5. w G= eS	

Transposing the above expressions:

From 3 above	From 3 above
6. $e = \frac{\rho_w\,G}{\rho_d} - 1$	$e = \frac{\gamma_w\,G}{\gamma_d} - 1$
7. $\rho_{d\,max} = \frac{\rho_w G(1-A_v)}{1+wG}$	$\gamma_{d\,max} = \frac{\gamma_w G(1-A_v)}{1+wG}$

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DEFINITIONS

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	$\frac{\text{density of solids}}{\text{density of water}}$	$\frac{\rho_s}{\rho_w}$
Moisture 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	$\frac{\text{volume of voids}}{\text{total volume}}$	$\frac{V_v}{V}$
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}	$\frac{\text{total saturated mass}}{\text{total volume}}$	$\frac{M}{V}$
Bulk unit weight, γ_b	$\frac{\text{total weight}}{\text{total volume}}$	$\frac{W}{V}$
Dry unit weight, γ_d	$\frac{\text{weight of solids}}{\text{total volume}}$	$\frac{W_s}{V}$

PLEASE TURN THE PAGE FOR HYDRAULICS DATA

SECTION B – HYDRAULICS

. Recommended Roughness values

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:			
Slight	0.6	1.5	3.0
Moderate	1.5	3.0	6.0
Appreciable	6.0	15	30
Severe (Good:Up to 20 years use:Normal: 40to50 Years use, Poor:80 to 100 years use)	15	30	60
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			
Glazed or unglazed pipe:			
With sleeve joints	0.03	0.06	0.15
With spigot and socket joints and 'O' ring seals - dia <150 mm	-	0.03	-
With spigot and socket joints and 'O' ring seals – dia > 150 mm	0.003	0.03	-

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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 m^3/s

Gradient	Pipe diameters in mm: 350	375	400	450	500	525	600	675	700	750	800	825
0.00400	1.372	1.434	1.494	1.611	1.722	1.776	1.931	2.079	2.127	2.220	2.311	2.356
1/ 250	0.132	0.158	0.188	0.256	0.338	0.384	0.546	0.744	0.819	0.981	1.162	1.259
0.00420	1.409	1.472	1.534	1.653	1.767	1.822	1.982	2.133	2.182	2.278	2.372	2.417
1/ 238	0.136	0.163	0.193	0.263	0.347	0.394	0.560	0.763	0.840	1.007	1.192	1.292
0.00440	1.444	1.509	1.572	1.694	1.811	1.868	2.031	2.187	2.237	2.335	2.431	2.477
1/ 227	0.139	0.167	0.198	0.269	0.356	0.404	0.574	0.782	0.861	1.032	1.222	1.324
0.00460	1.479	1.545	1.610	1.735	1.854	1.912	2.080	2.239	2.290	2.390	2.488	2.536
1/ 217	0.142	0.171	0.202	0.276	0.364	0.414	0.588	0.801	0.881	1.056	1.251	1.356
0.00480	1.513	1.581	1.647	1.775	1.897	1.956	2.127	2.289	2.342	2.445	2.545	2.594
1/ 208	0.146	0.175	0.207	0.282	0.372	0.423	0.601	0.819	0.901	1.080	1.279	1.386
0.00500	1.546	1.616	1.683	1.814	1.938	1.999	2.173	2.339	2.393	2.498	2.600	2.650
1/ 200	0.149	0.178	0.212	0.288	0.381	0.433	0.615	0.837	0.921	1.103	1.307	1.416
0.00550	1.627	1.700	1.771	1.908	2.039	2.102	2.286	2.460	2.516	2.626	2.733	2.786
1/ 182	0.157	0.188	0.223	0.303	0.400	0.455	0.646	0.880	0.968	1.160	1.374	1.489
0.00600	1.704	1.780	1.855	1.998	2.135	2.201	2.393	2.575	2.634	2.749	2.861	2.916
1/ 167	0.164	0.197	0.233	0.318	0.419	0.477	0.677	0.922	1.014	1.215	1.438	1.559
0.00650	1.778	1.858	1.935	2.085	2.227	2.296	2.496	2.686	2.747	2.867	2.984	3.041
1/ 154	0.171	0.205	0.243	0.332	0.437	0.497	0.706	0.961	1.057	1.267	1.500	1.626
0.00700	1.850	1.933	2.013	2.168	2.316	2.388	2.596	2.793	2.856	2.981	3.102	3.162
1/ 143	0.178	0.213	0.253	0.345	0.455	0.517	0.734	0.999	1.099	1.317	1.559	1.690
0.00750	1.919	2.005	2.088	2.249	2.402	2.477	2.692	2.896	2.962	3.091	3.216	3.278
1/ 133	0.185	0.221	0.262	0.358	0.472	0.536	0.761	1.036	1.140	1.365	1.617	1.752
0.00800	1.986	2.074	2.161	2.327	2.485	2.562	2.785	2.996	3.064	3.197	3.327	3.390
1/ 125	0.191	0.229	0.272	0.370	0.488	0.555	0.787	1.072	1.179	1.412	1.672	1.812
0.00850	2.051	2.142	2.231	2.402	2.566	2.645	2.875	3.092	3.163	3.300	3.434	3.499
1/ 118	0.197	0.237	0.280	0.382	0.504	0.573	0.813	1.107	1.217	1.458	1.726	1.871
0.00900	2.114	2.208	2.300	2.476	2.645	2.726	2.962	3.186	3.259	3.400	3.538	3.605
1/ 111	0.203	0.244	0.289	0.394	0.519	0.590	0.838	1.140	1.254	1.502	1.778	1.927
0.00950	2.175	2.272	2.366	2.548	2.721	2.805	3.047	3.278	3.352	3.498	3.639	3.709
1/ 105	0.209	0.251	0.297	0.405	0.534	0.607	0.862	1.173	1.290	1.545	1.829	1.983
0.01000	2.235	2.334	2.431	2.617	2.795	2.882	3.131	3.367	3.443	3.593	3.738	3.809
1/ 100	0.215	0.258	0.306	0.416	0.549	0.624	0.885	1.205	1.325	1.587	1.879	2.036
0.01100	2.351	2.455	2.556	2.752	2.939	3.029	3.291	3.539	3.619	3.776	3.928	4.003
1/ 91	0.226	0.271	0.321	0.438	0.577	0.656	0.930	1.266	1.393	1.668	1.975	2.140
0.01200	2.461	2.570	2.676	2.881	3.076	3.171	3.444	3.703	3.787	3.951	4.111	4.189
1/ 83	0.237	0.284	0.336	0.458	0.604	0.686	0.974	1.325	1.458	1.746	2.066	2.239
0.01300	2.567	2.681	2.792	3.005	3.208	3.307	3.591	3.861	3.949	4.119	4.285	4.367
1/ 77	0.247	0.296	0.351	0.478	0.630	0.716	1.015	1.382	1.520	1.820	2.154	2.334
0.01400	2.670	2.788	2.903	3.124	3.335	3.437	3.733	4.013	4.104	4.281	4.454	4.538
1/ 71	0.257	0.308	0.365	0.497	0.655	0.744	1.055	1.436	1.579	1.891	2.239	2.426
0.01500	2.768	2.891	3.010	3.239	3.458	3.564	3.870	4.160	4.254	4.438	4.616	4.704
1/ 67	0.266	0.319	0.378	0.515	0.679	0.771	1.094	1.489	1.637	1.961	2.320	2.514
0.01600	2.864	2.990	3.113	3.350	3.576	3.686	4.002	4.302	4.399	4.589	4.773	4.864
1/ 62	0.276	0.330	0.391	0.533	0.702	0.798	1.132	1.540	1.693	2.027	2.399	2.600
0.01700	2.957	3.087	3.214	3.458	3.691	3.804	4.131	4.440	4.540	4.736	4.926	5.019
1/ 59	0.284	0.341	0.404	0.550	0.725	0.824	1.168	1.589	1.747	2.092	2.476	2.683
0.01800	3.047	3.181	3.312	3.563	3.803	3.919	4.255	4.574	4.677	4.878	5.074	5.170
1/ 56	0.293	0.351	0.416	0.567	0.747	0.848	1.203	1.637	1.800	2.155	2.550	2.764
0.01900	3.135	3.273	3.407	3.665	3.912	4.032	4.377	4.704	4.810	5.017	5.218	5.317
1/ 53	0.302	0.361	0.428	0.583	0.768	0.873	1.237	1.683	1.851	2.216	2.623	2.842
	Coefficient for part-full pipes:											
	250	250	300	350	350	400	450	500	500	550	600	600

ks = 0·030 mm i < 0·1

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ks = 1·500mm
i = 0·00015 to 0·004

ie hydraulic gradient =
1 in 6667 to 1 in 250

Water (or sewage) at 15° C
full bore conditions.

velocities in m/s
discharges in m^3/s

Gradient	Pipe diameters in mm: 350	375	400	450	500	525	600	675	700	750	800	825
0.00075	0.416	0.435	0.454	0.490	0.524	0.541	0.590	0.636	0.651	0.681	0.709	0.723
1/ 1333	0.040	0.048	0.057	0.078	0.103	0.117	0.167	0.228	0.251	0.301	0.356	0.387
0.00080	0.429	0.449	0.469	0.506	0.542	0.559	0.609	0.657	0.673	0.703	0.733	0.747
1/ 1250	0.041	0.050	0.059	0.080	0.106	0.121	0.172	0.235	0.259	0.311	0.368	0.399
0.00085	0.443	0.463	0.483	0.522	0.559	0.577	0.628	0.678	0.694	0.725	0.755	0.770
1/ 1176	0.043	0.051	0.061	0.083	0.110	0.125	0.178	0.242	0.267	0.320	0.380	0.412
0.00090	0.456	0.477	0.497	0.537	0.575	0.593	0.647	0.697	0.714	0.746	0.777	0.793
1/ 1111	0.044	0.053	0.063	0.085	0.113	0.128	0.183	0.250	0.275	0.330	0.391	0.424
0.00095	0.468	0.490	0.511	0.552	0.591	0.610	0.665	0.717	0.734	0.767	0.799	0.815
1/ 1053	0.045	0.054	0.064	0.088	0.116	0.132	0.188	0.256	0.282	0.339	0.402	0.435
0.00100	0.481	0.503	0.525	0.566	0.606	0.626	0.682	0.735	0.753	0.787	0.820	0.836
1/ 1000	0.046	0.056	0.066	0.090	0.119	0.135	0.193	0.263	0.290	0.348	0.412	0.447
0.00110	0.504	0.528	0.550	0.594	0.636	0.657	0.716	0.772	0.790	0.825	0.860	0.877
1/ 909	0.049	0.058	0.069	0.095	0.125	0.142	0.202	0.276	0.304	0.365	0.432	0.469
0.00120	0.527	0.552	0.575	0.621	0.665	0.686	0.748	0.806	0.825	0.862	0.898	0.916
1/ 833	0.051	0.061	0.072	0.099	0.131	0.149	0.211	0.289	0.318	0.381	0.452	0.490
0.00130	0.549	0.574	0.599	0.647	0.692	0.714	0.778	0.839	0.859	0.898	0.935	0.954
1/ 769	0.053	0.063	0.075	0.103	0.136	0.155	0.220	0.300	0.331	0.397	0.470	0.510
0.00140	0.570	0.596	0.622	0.671	0.719	0.742	0.808	0.871	0.892	0.932	0.971	0.990
1/ 714	0.055	0.066	0.078	0.107	0.141	0.161	0.228	0.312	0.343	0.412	0.488	0.529
0.00150	0.590	0.617	0.644	0.695	0.744	0.768	0.837	0.902	0.923	0.965	1.005	1.025
1/ 667	0.057	0.068	0.081	0.111	0.146	0.166	0.237	0.323	0.355	0.426	0.505	0.548
0.00160	0.610	0.638	0.665	0.718	0.769	0.793	0.864	0.932	0.954	0.997	1.038	1.059
1/ 625	0.059	0.070	0.084	0.114	0.151	0.172	0.244	0.333	0.367	0.440	0.522	0.566
0.00170	0.629	0.658	0.686	0.740	0.792	0.818	0.891	0.961	0.983	1.027	1.071	1.092
1/ 588	0.060	0.073	0.086	0.118	0.156	0.177	0.252	0.344	0.378	0.454	0.538	0.584
0.00180	0.647	0.677	0.706	0.762	0.816	0.842	0.917	0.989	1.012	1.057	1.102	1.123
1/ 556	0.062	0.075	0.089	0.121	0.160	0.182	0.259	0.354	0.389	0.467	0.554	0.601
0.00190	0.665	0.695	0.725	0.783	0.838	0.865	0.942	1.016	1.040	1.087	1.132	1.154
1/ 526	0.064	0.077	0.091	0.125	0.165	0.187	0.266	0.364	0.400	0.480	0.569	0.617
0.00200	0.682	0.714	0.744	0.803	0.860	0.887	0.967	1.043	1.067	1.115	1.162	1.185
1/ 500	0.066	0.079	0.094	0.128	0.169	0.192	0.273	0.373	0.411	0.493	0.584	0.633
0.00220	0.716	0.749	0.781	0.843	0.902	0.931	1.014	1.094	1.119	1.170	1.219	1.243
1/ 455	0.069	0.083	0.098	0.134	0.177	0.202	0.287	0.391	0.431	0.517	0.613	0.664
0.00240	0.748	0.782	0.816	0.881	0.943	0.973	1.060	1.143	1.169	1.222	1.273	1.298
1/ 417	0.072	0.086	0.103	0.140	0.185	0.211	0.300	0.409	0.450	0.540	0.640	0.694
0.00260	0.779	0.815	0.849	0.917	0.981	1.013	1.103	1.190	1.217	1.272	1.325	1.351
1/ 385	0.075	0.090	0.107	0.146	0.193	0.219	0.312	0.426	0.469	0.562	0.666	0.722
0.00280	0.808	0.845	0.882	0.952	1.019	1.051	1.145	1.235	1.264	1.320	1.376	1.403
1/ 357	0.078	0.093	0.111	0.151	0.200	0.228	0.324	0.442	0.486	0.583	0.691	0.750
0.00300	0.837	0.875	0.913	0.985	1.055	1.088	1.186	1.278	1.308	1.367	1.424	1.452
1/ 333	0.081	0.097	0.115	0.157	0.207	0.236	0.335	0.457	0.503	0.604	0.716	0.776
0.00320	0.865	0.904	0.943	1.018	1.089	1.124	1.225	1.320	1.351	1.412	1.471	1.500
1/ 313	0.083	0.100	0.118	0.162	0.214	0.243	0.346	0.472	0.520	0.624	0.739	0.802
0.00340	0.891	0.932	0.972	1.049	1.123	1.159	1.262	1.361	1.393	1.456	1.516	1.546
1/ 294	0.086	0.103	0.122	0.167	0.221	0.251	0.357	0.487	0.536	0.643	0.762	0.827
0.00360	0.917	0.959	1.001	1.080	1.156	1.193	1.299	1.401	1.434	1.498	1.561	1.591
1/ 278	0.088	0.106	0.126	0.172	0.227	0.258	0.367	0.501	0.552	0.662	0.784	0.851
0.00380	0.943	0.986	1.028	1.110	1.188	1.225	1.335	1.439	1.473	1.539	1.603	1.635
1/ 263	0.091	0.109	0.129	0.176	0.233	0.265	0.377	0.515	0.567	0.680	0.806	0.874
Coefficient for part-full pipes:	90	100	110	120	130	140	150	200	200	200	200	200

ks = 1·500mm i < 0·004

END OF DATA