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“Efficiency of the Soil Stabilisation in using the NTS(Renolit)-Technology”

Technical Report

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ISOTOP Ltd, Geotechnical Department

1. Introduction

The aim of this work was – to determine the optimal types and a ratio of components of soil – cement mixes whose properties can be efficiency modified by using renolit-technology up to level that must be achieved in accordance with designed projects (taking into account economical factors). This complex includes mechanical properties and their stability, flexibility, relaxation properties for long working time and, as result, increasing the cracking resistance; water resistance; weather (climate) durability and possibility of using in-situ soil for bottom construction (landfill, compost site, …) and waterproof construction (embankment, road shoulders, …).

According to product specification, renolit is the polymers based mixture of latex and cellulose dispersed in water and it is specially formulated to improve of mixes of in-situ soils with cement properties. The efficiency the renolit – technology use in practice is proportional to a quality of the preliminary obtained laboratory results.

This report constitutes the results of laboratory investigation that was carried out taking to account mention above and economical advisability of in-situ materials and low cost of additional materials variation that occurs on territory of Israel.

Staff:

G.Liskevich – supervising and discussing the results;
Dr.S.Shulov – methodology, design, executing and discussing the results;
Dr.A.Roslik – executing tests;
M.Naftaliev – executing tests;
A.Katkiv – executing tests.

2.Used materials and tests

2.1 The matrix of the test samples consists of the formulations comprising:

- A. Only in-situ based materials, having practical significance and distinguishing by a ratio of fine-grained / coarse-grained fraction and plasticity (sand, lean clay, fat clay;
- B. In-situ based materials as well quarry products (crushed stone, quarry sand, quarry waste);
- C. Materials according to categories A, B plus fly ash, that is frequently used to stabilize in-situ base materials.
- D. Materials according to categories A,B,C plus Portland-cement – soil-cement (SC) materials;
- E. Material according to categorie D plus Renolit – SC-Renolit formulations.

The formulations noted as categories A, B, C, D are used as comparative basis for estimation of renolit admixture effect for improving and stabilization of SC materials properties.

2.2. The list of tests, carried out in this investigation according under ASTM and whose results, introduced in this report, comprises:

- Indicative tests (sieve analysis, Atterberg limits, water content, density,…);
- Unconfined compressive strength;
- Modulus elasticity (Young’s modulus);
- CBR;
- Slake durability;
- Shrinkage;
- Permeability.

Requirements to preparation of the specimens, condition and expositions were variable, that determined especially for every group of samples.

3. Results and Conclusions

3.1. As can seen from the data in tables 1-2 the Renolit at least doesn't reduce the level of compressive strength achieved for SC-materials. For formulations on the base materials category C even at low dry density it is possible to safe compressive strength on the level 2-4MPa by variation of ratio in-situ materials / quarry materials / fly ash (Table 3, graph 1).

But in the same time it can be seen, that materials of category E (SC-Renolit) have more high resistivity with regard to water. It is true as well at evaporation (see picture 2, 3). Before inundation the SC and SC-Renolit materials had close values of compressive strength – approximately 5.5MPa. After 7 days inside water bath the compressive strength of SC reduced a three times, and for SC-Renolit it approached to stable value.

Table 5 and Graph 4 illustrate results of CBR test and results of the Young's modulus calculations. Cement-stabilization and as well Renolit admixture to lean clay, as base in-situ material, increase CBR more than three times and modulus elasticity 5-6 times.

Manipulating the ratio: lean clay / fly ash and cement / Renolit concentration of material category E gives us possibility to obtain materials of the durability properties as resistance to weathering and abrasive action close to properties of rock materials (Table 6).

The conclusion from our data obtained and noted in item 3.1 is as follows: It is possible, after preliminary carried out laboratory works with concrete in-situ material, to achieve significant economical affect in road and other construction by using Renolit-technology and thus reducing the material consumption (for construction layers) and rising working time of the objects.

3.2. The special group of samples was prepared for the permeability tests. The aim was to determine a potential possibility of Renolit-technology in reducing of coefficient permeability of in-situ sandy materials and close to those in composition up to level $< 5*10^{-7}$ cm/s. This is the requirement of many waterproof and environment protection objects construction. It is very important to note, that the result should be achieved at the mixture densities sufficient low for realization in field conditions.

Table 7 illustrates results of our laboratory work for SC and SC-Renolit materials. It can be seen, on the samples of series no.1-2, that with Renolit addition coefficient permeability of the sand and sands mix reduces almost to require level. As result of manipulation with a ration: lean clay / fly ash and cement / Renolit concentration of material category E, we succeeded in reducing permeability coefficient up to $1*10^{-7}$ - $5*10^{-8}$ cm/s. It can be seen from graph 5, that, obtained on lean clay (at its dry density >1900 kg/m3) permeability coefficient $3\text{-}4*10^{-7}$ cm/s, the same result achieves at dry density SC-Renolit material <1750 kg/m3.

Conclusion from data of 3.2 – Now we are sure, that the Renolit-technology can be successful in the object constructions noted above.

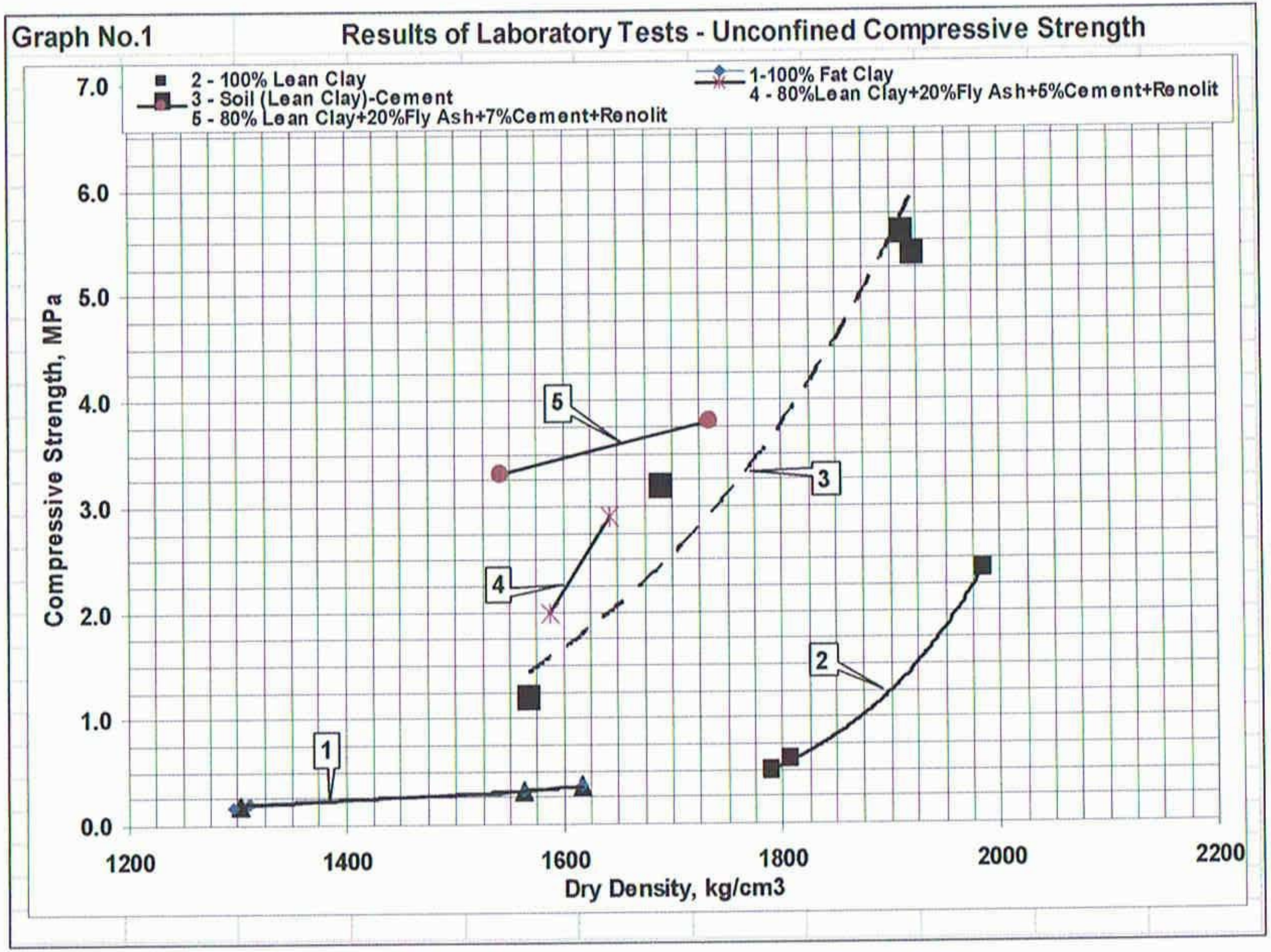
Table No.1 Soil / Soil-Cement (SC). Results of Laboratory Tests - Unconfined Compressive Strength

No.	Type of Soil and ASTM Classification	Cement w.%	Water w.%	Dry Den-ty kg/m3	LL/PI %	Exposure Time days	Conditions of curing period	Compressive Strength MPa
1.1	Fat Clay, CH	0	41	1296	84/54	-	-	0.17
1.2		0	41	1310	90/56	-	-	0.21
1.3		0	26	1563	61/37	-	-	0.31
1.4		0	24	1617	50/30	-	-	0.36
						-	-	
2.1	Lean Clay, CL	0	17	1790	39/20	-	-	0.5
2.2		0	17	1808	44/25	-	-	0.6
2.3		0	12.5	1985	33/12	7	Ambient	2.4
3	Quarry Sand (75w.%) + Lean Clay (25w.%), GP-GW	0	6.5	2220	31/15	14	Ambient	0.7
4.1	Lean Clay, CL	5.0	20	1688	39/20	14	Ambient	3.2
5.1	Quarry Waste, GP	5.0	19	1649	35/10	16	100% Humidity	1.0
5.2		6.0	20	1621	35/10			1.4
6.1	Crushed Stone (60w.%) + Quarry Sand (40w.%)	2.0	9	2135	NP	7	100% Humidity	0.7
6.2		2.5	8.7	2130				1.1
6.3		3.0	8.6	2145				1.5
6.4		3.5	8.2	2150				2.1

Table No.2 SC / SC-Renolit		Results of Laboratory Tests - Unconfined Compressive Strength							
No.	Type of Soil	Cement	Renolit	Water	Dry Den-ty	LL/PI	Exposure Time	Conditions of curing period	Compressive Strength
		w.%	w.% by Cement	w.%	kg/m3	%	days		MPa
1.1	Quarry Sand	3.0	5	15.0	1948	NP	10	Ambient	1.1
1.2		5.0	5	16.0	1957				1.6
2.1	Quarry Sand (20.3w.%)	5.4	0	16.2	1807	NP	44	Ambient (Including Permeability Tests after 14,28,44 days)	1.2
2.2			3		1790				1.2
2.3			5		1816				1.5
2.4	+ Sand (74.3w.%)		7		1833				1.5
3.1	Lean Clay	0	0	12.5	1985	33/12	7	Ambient	2.4
3.2		5	0	20.0	1688	39/20	14		3.2
3.3		6	0	13.5	1910	33/12	7		5.6
3.4		6	5	13.5	1920				5.4
3.5		7	5	24.5	1567	25/7	28 + 3	Ambient + 3 days inside water bath	1.2
4.1	Quarry Sand (20w.%) + Lean Clay (80w.%)	5	0	18	1836	31/15	14	Ambient	4.1
4.2		5	5	18	1808				3.0

Table No.3 Soil-Fly Ash-Cement-Renolit — Results of Laboratory Tests - Unconfined Compressive Strength

No.	Lean Clay	Quarry Sand	Fly Ash	Cement	Renolit	Water	Dry Den-ty	*LL/PI	Exposure Time	Conditions of curing period	Compressive Strength
	w.% by Soil				w.% by Cement	w.%	kg/m3	%	days		MPa
1.1	100	-	-	7	5	24.5	1528	25/7	28 + 3	Ambient + 3 days inside water bath	1.2
1.2	80	-	20	5	5	23	1587				2.0
1.3	80	-	20	7	5	25	1542				3.3
1.4	75	-	25	5	5	22	1561				2.5
1.5	75	-	25	7	5	22	1579				3.1
2.1	80	-	20	7	5	18	1735				3.8
3.1	80	-	20	5	-	23	1605	39/20	14	Ambient	2.3
3.1	80	-	20	5	5	23	1643				2.9
4.1	80	20	-	5	5	18	1808	39/20	14	Ambient	3.0
4.2	80	15	5	5	5	21	1718				2.9
4.3	80	10	10	5	-	22	1687				2.3
4.4	80	10	10	5	5	22	1698				2.2


Graph No.1
Results of Laboratory Tests - Unconfined Compressive Strength
2 - 100% Lean Clay
3 - Soil (Lean Clay)-Cement
5 - 80% Lean Clay+20%Fly Ash+7%Cement+Renolit
1-100% Fat Clay
4 - 80%Lean Clay+20%Fly Ash+5%Cement+Renolit
Compressive Strength, MPa
Dry Density, kg/cm3
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
1200
1400
1600
1800
2000
2200
1
2
3
4
5

Picture No.2 Laboratory Srinkage Test

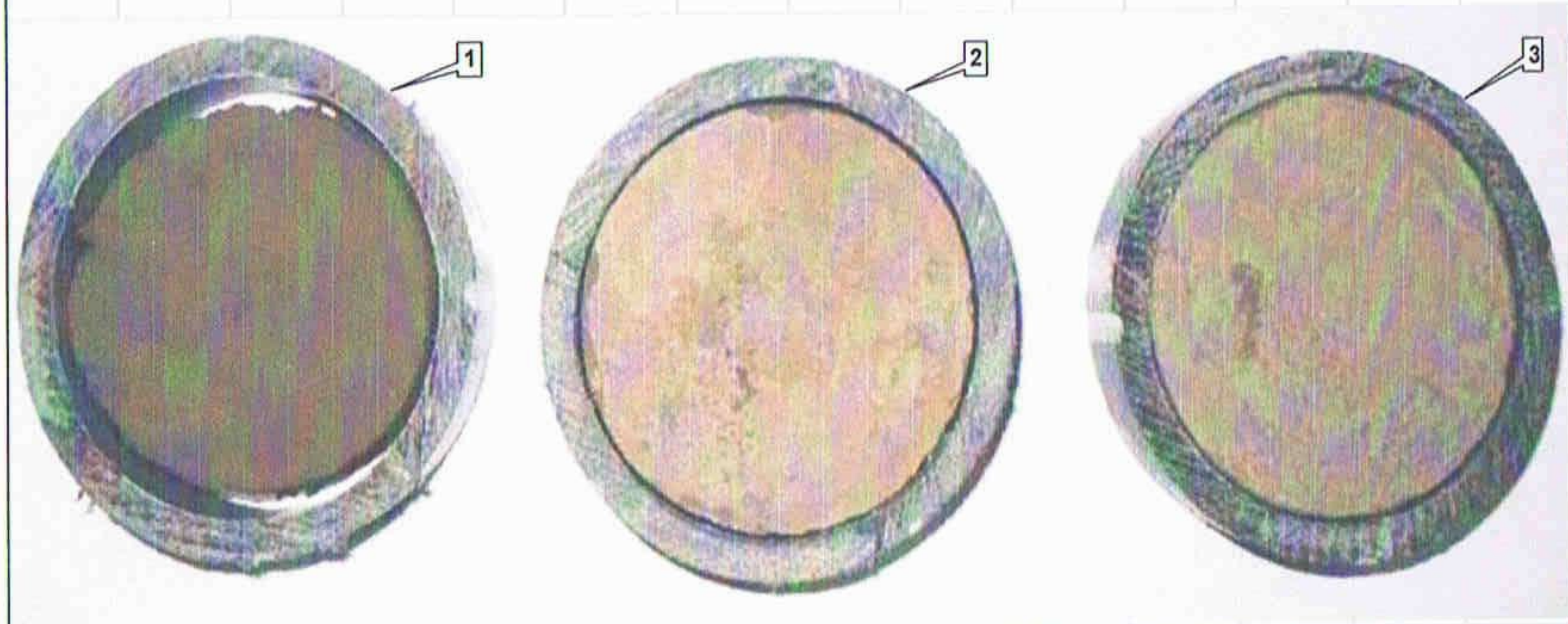
Exposure Time, days : 3

Conditions : ambient

1. 100%Lean Clay (LL/PI - 39/20)

2. 100%Lean Clay + 5%Cement

3. 100%Lean Clay + 5%Cement + 5%Renolit



Results of unconfined compressive strength tests

after variable conditions and duration of samples exposure

Table No.4

Mix Number	Mix Components	Dry Density, kg/m3	Initial Water Content, %	Compression Strength after Exposition 1	2	3	4
				MPa			
1	100%Lean clay	1985	12.5	1.9	2.4	0.0	0.0
2	100%Lean clay + 6%Cement	1910	13.5	5.1	5.6	3.1	1.8
3	100%Lean clay + 6%Cement + 5%Renolit	1920	13.5	4.2	5.4	3.8	3.3

1. 4 days - ambient conditions
2. 7 days - ambient conditions
3. 7 days - ambient conditions + 4 days - inside water bath
4. 7 days - ambient conditions + 7 days - inside water bath

Graph No.4

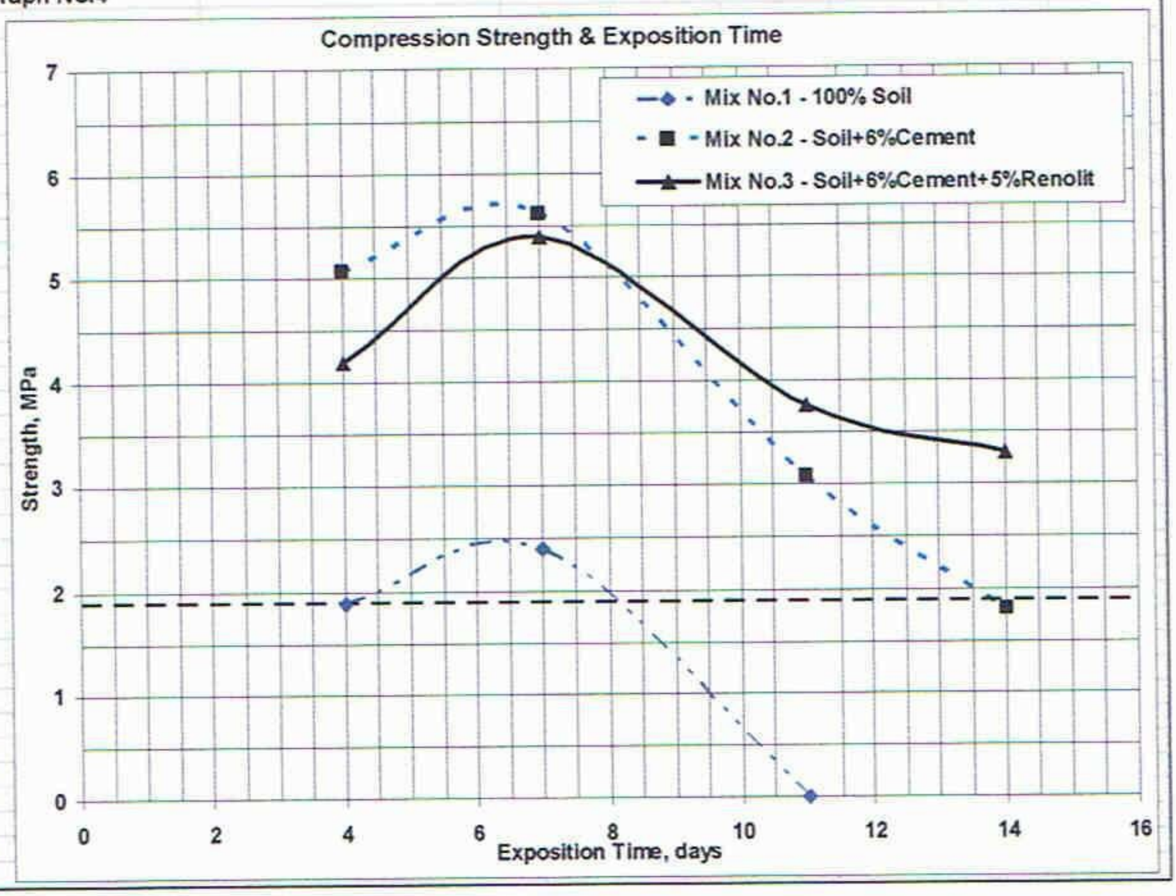


Table No.5 Results of Laboratory CBR test and Young Modulus Measurements

No.	Type of Mixture	CBR (56 blows)	Young Modulus
		%	MPa
1	Lean Clay - 100%	33	*50*
2	100% Lean Clay + 6% Cement	285	*770*
3	100% Lean Clay + 6% Cement + 5% Renolit	290	*880*

Graph No.4

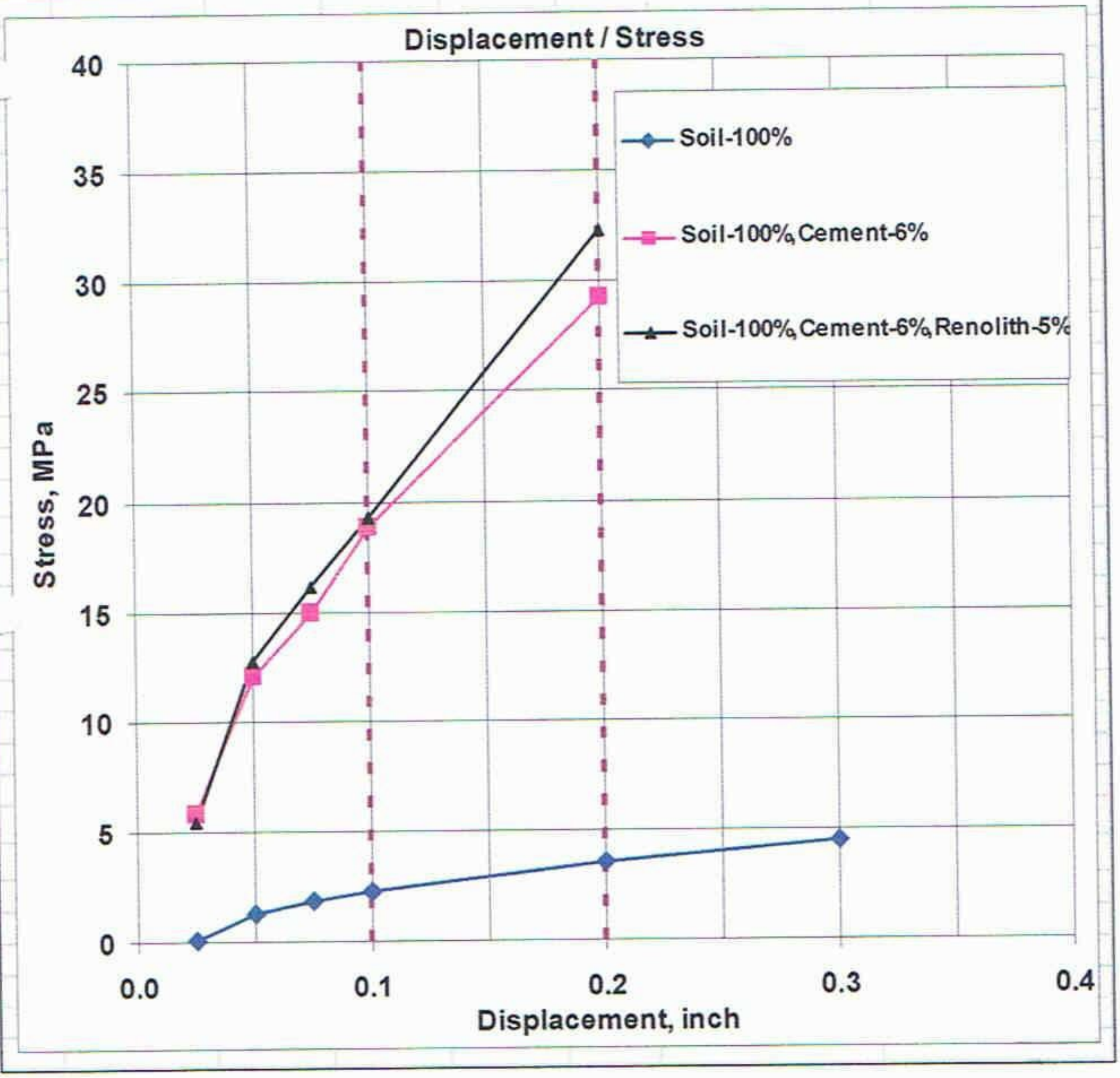


Table No.6 Results of Laboratory Slake Durability Tests

Initial Data

Spec.No	Lean Clay	Fly Ash	Cement	*Renolit	Water	Dry Den-ty	LL/PI
	w.%			w.% by Cement	w.%	kg/m3	%
1.1	100	-	7	5	24.5	1528	25/7
1.2	75	25	5	5	22	1561	
1.3	75	25	7	5	22	1579	
1.4	80	20	5	5	23	1587	
1.5	80	20	7	5	25	1542	
2.1	80	20	7	5	18	1735	25/8

Exposure Time, days : 28 + 3

Conditions of Curing Period : Ambient + 3 days Inside Water Bath

Results

Spec.No	Slake Durability Index I_d, %		***Rock Resistance
	After 1-st cycle	After 2 cycle	
1.1	54.6	-	Very Low
1.2	74.8	60.4	Low
1.3	89.9	83.3	Average
1.4	88.7	66.3	
1.5	85.0	72.1	
2.1	94.2	83.8	

*Gamble's Classification Scale of Rock Resistance Based on Slake Durability Tests Results :

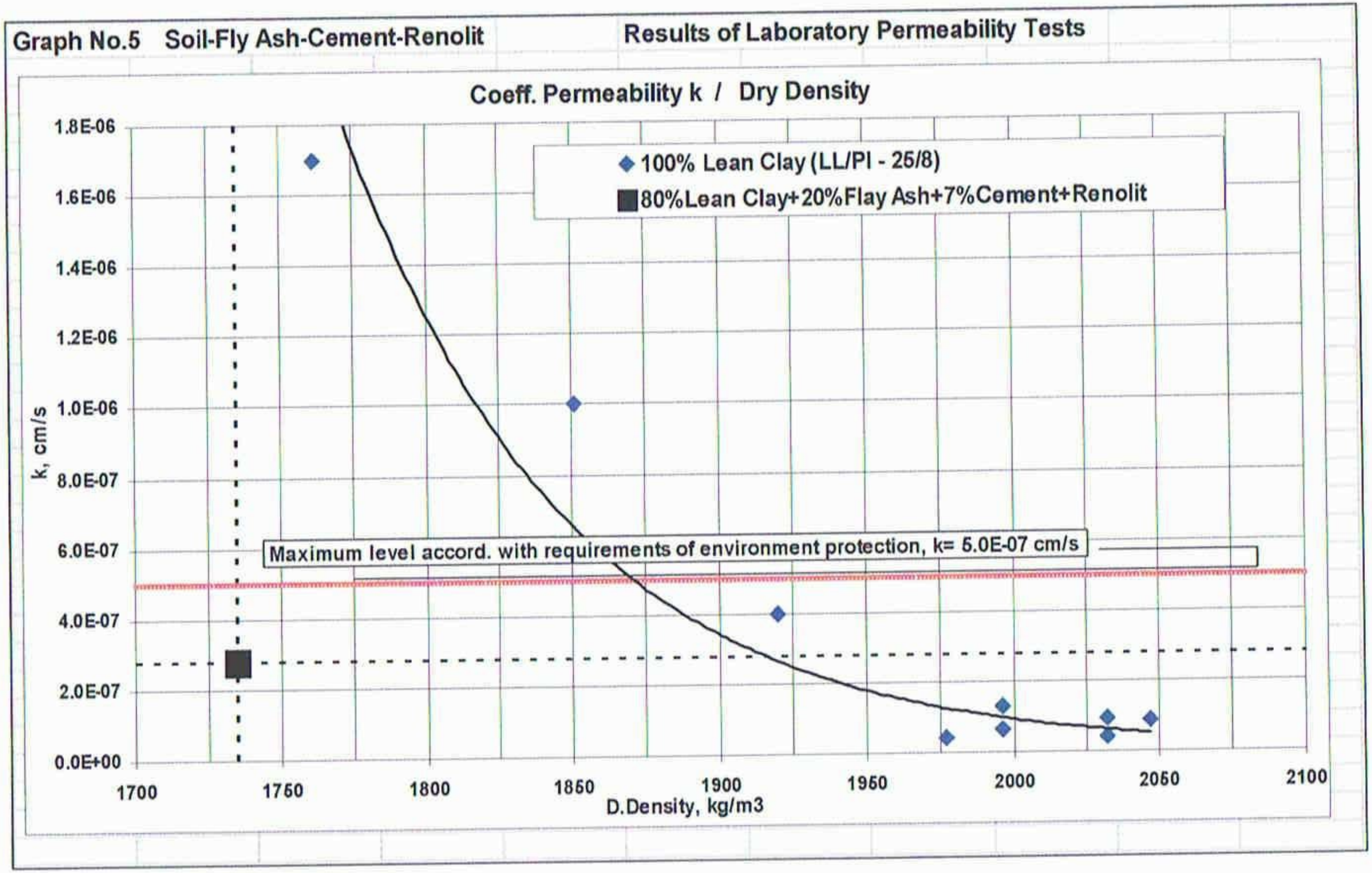
Class of rock resistance	Values of I_d [%]	
	After 1-st cycle	*After 2-nd cycle*
Extremely high	>99	>98
High	98 - 99	95 - 98
Relatively high	95 - 98	85 - 95
Average	85 - 95	60 - 85
Low	60 - 85	20 - 60
Very low	<60	<20

Table No.7 SC / SC-Renolit — Results of Laboratory Permeability Tests

No.	Type of Soil	Cement	Renolit	Water	Dry Den-ty	*LL/PI	Exposure Time	Conditions of Curing Period	Permeability,k
		w.%	w.% by Cement	w.%	kg/m3	%	days		cm/s
1.1	Quarry Sand	3	5	15.0	1948	NP	10	Ambient	3.2E-06
1.2		5	5	16.0	1957				6.5E-07
2.1	Quarry Sand (20.3w.%) + Sand (74.3w.%)	5.4	0	16.2	1807	NP	44	Ambient (Including Permeability Tests after 14,28 days)	1.9E-06
2.2			3		1790				1.0E-06
2.3			5		1816				7.7E-07
2.4			7		1833				8.2E-07
3.1	Quarry Sand (20w.%) + Lean Clay	5	0	18.0	1836	31/15	14	Ambient	5.0E-06
3.2		5	5	18.0	1808				1.5E-06
4.1	Lean Clay	0	0	12.5	1910	33/12	4	100% moisture	4.7E-08
4.2		6	0	13.5	1892				5.5E-06
4.3		6	5	13.5	1902				3.4E-06
4.4		7	5	24.5	1567	25/7	28 + 3	Ambient + 3 days inside water bath	4.5E-06

Table No.8 Soil-Fly Ash-Cement-Renolit **Results of Laboratory Permeability Tests**

No.	Lean Clay	Quarry Sand	Fly Ash	Cement	Renolit	Water	Dry Den-ty	*LL/PI	Exposure Time	Conditions of Curing Period	Permeability,k
	w.%				w.% by Cement	w.%	kg/m3	%	days		cm/s
1.1	100	-	-	7	5	24.5	1528	25/7	28 + 3	Ambient + 3 days inside water bath	4.5E-06
1.2	80	-	20	5	5	23	1587				3.6E-08
1.3	80	-	20	7	5	25	1542				1.2E-07
1.4	75	-	25	5	5	22	1561				5.2E-08
1.5	75	-	25	7	5	22	1579				6.1E-07
2.1	100	-	-	-	-	10	1762	25/8	-		1.7E-06
2.2	80	-	20	7	5	18	1735		28 + 3		2.8E-07
3.1	80	-	20	5	-	23	1605	39/20	14	Ambient	1.4E-06
3.1	80	-	20	5	5	23	1643				1.4E-07
4.1	80	20	-	5	5	18	1808	39/20	14	Ambient	5.0E-06
4.2	80	15	5	5	-	21	1716				4.9E-06
4.3	80	15	5	5	5	21	1718				1.6E-07
4.4	80	10	10	5	-	22	1687				2.7E-06
4.5	80	10	10	5	5	22	1698				1.2E-07


Graph No.5 Soil-Fly Ash-Cement-Renolit
Results of Laboratory Permeability Tests
Coeff. Permeability k / Dry Density
100% Lean Clay (LL/PI - 25/8)
80%Lean Clay+20%Flay Ash+7%Cement+Renolit
Maximum level accord. with requirements of environment protection, k= 5.0E-07 cm/s
k, cm/s
1.8E-06
1.6E-06
1.4E-06
1.2E-06
1.0E-06
8.0E-07
6.0E-07
4.0E-07
2.0E-07
0.0E+00
1700
1750
1800
1850
1900
1950
2000
2050
2100
D.Density, kg/m3